Web Words

An anthology of Web Works articles and columns written by

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***** Note to the User**

This document consists of articles and columns written by David R. Roisum Ph.D. for the Converting Magazine that are in various stages of edits. The Feb 1994 – May 1999 columns articles were later copy edited by David Bentley for TAPPI PRESS based on the original drafts here occasionally referring to the final published version in the Converting Magazine. Subsequent issues, after May 1999, are primarily the original drafts supplied to Converting Magazine. This means they are also minus the copy-editing (i.e., gramer and speling and etc) and most of the figures. The final published versions can be found on the magazine's website for free for those issues dating since November 2000. Earlier issues, text only, can be found through pay-per-use archiving services. The internet searcher will undoubtedly find copies or derivatives of some of these articles and columns elsewhere.

Even though this document is limited in that some corrections and figures are missing, it has something that no other document has: all of Dr Roisum's articles and columns written for the Converting Magazine. Being a simple document, it is easy to use and very rapid when searching for any specific title, date or keywords.

***Preface

**[NOTE: this following introduction and following table of contents were written for the Web Words book and this document, they did not appear in Converting Magazine.]

I love to write. My first 'short story' was written while I was in the second grade. This first work of fiction was lost. (Discarded would be more accurate). My first 'books' were on wound roll stresses and winder vibration, and were written when I was manager of R&D at Beloit. These non-fiction works were reincarnated in part in my Mechanics trilogy published by TAPPI PRESS in the latter half of the 1990's. I doubt, however, that I am a natural at writing. Rather, it required both passion and practice to enable the effort to bear some fruit. And practice I did. I have begun a second trilogy of books on industrial problem solving, the first of which should be available early 2001. I have now published well over 100 columns, papers, and articles. I have also written nearly 1,000 internal memos and reports.

Of all my work, however, the most popular are the Web Works columns published by Converting Magazine. In some sense this began as a monthly internal technical newsletter entitled Web Watch, and was written when I was as a senior research scientist at Kimberly-Clark. With this newsletter, I learned how to communicate technical information in a short, direct, informal and often entertaining style. I am still learning.

In the fall of 1992, I gave up conventional employment to become a consultant. I thought this would be easy. There were five winder consultants in the paper industry, and all were nearing retirement. I would simply pick up their work. I would also be made easy because I was better known, through publications, and better educated than the other consultants. Wrong.

My timing couldn't have been worse. The paper industry entered a serious slump from which it still has not emerged even today. Paper companies were 'right sizing' their people by the thousands. My potential clients were in no mood for hiring an outsider when they were firing their own. My target customers were hunkered down in a survival mode. In my first year of consulting I did feed my family and put a roof over their heads, but little else. I needed to reinvent myself for a changing market and economy.

The breakthrough came in the fall of 1993 when I approached Yolanda Simonsis of Converting Magazine to write a column. I showed her samples of my work. She had the sense of opportunity to risk introducing a column on a subject that had never been covered regularly before, namely web handling. I began writing the monthly Web Works column in January of 1994 and continue to this day. This column was a marriage made in heaven. It was to become the most popularly read page in the magazine. I was introduced to a much wider market of potential customers. I survived and even thrived as a consultant.

These columns as well as other longer technical reports are included in entirety here much as they were published in Converting Magazine. The differences are minor changes in formatting, figures and grammar that editors are wont to tinker with, usually to the improvement of the work. This anthology is being published because we found that many readers were already clipping and filing the columns. However, few had access to a complete set. TAPPI PRESS has added utility to the Converting Magazine columns by collecting, binding and indexing them for you.

**** Table of Contents – Feature Articles

**** Table of Contents - Web Works Columns

How do I set up a Shear Slitter?	30	Jul	1997
How do I get rid of Edge Trim	30	Aug	1997
Why does my web move sideways during speed changes?	32	Sep	1997
Why is my roll’s edge rough?	28	Oct	1997
What Causes a roll to telescope?	30	Nov	1997
What causes a roll corrugation?	30	Dec	1997
What causes a roll to star or buckle?	22	Jan	1998
How can I keep air out of my wound roll?	32	Feb	1998
How can I keep my wound roll round?	34	Mar	1998
What does percentage means on my control benchboard?	34	Apr	1998
Are my controls ergonomic?	38	May	1998
Are my pneumatic controls healthy?	30	Jun	1998
What converting project should I work on?	38	Aug	1998
How should I define the goals of my project?	38	Sep	1998
What does it take to become a good problem solver?	38	Oct	1998
What is your favorite problem solving techniques?	26	Nov	1998
Why doesn’t my machine start and stop gracefully?	20	Dec	1998
What type of foundation is best for my machine?	32	Jan	1999
Why are my web’s edges baggy?	30	Feb	1999
Why does my wound roll have ridges?	44	Mar	1999
Are my machine operators operating proficiently?	52	Apr	1999
Are my mechanics masterful?	32	May	1999
Are my electricians energized?	36	Jun	1999
How can I keep rollers from marking my web?	24	Aug	1999
Why is my calender roll wrinkling my web?	34	Sep	1999
Why are my rolls telescoping during storage?		Oct	1999
Why do my rolls dish during winding?	30	Nov	1999
What is the master speed reference?	46	Dec	1999
Are there different ways of stopping a machine?	30	Jan	2000
Are there dangers with draw control?		Feb	2000
Are there dangers with dancer control?		Mar	2000
How are load cells properly used?		Apr	2000
Can there be too much bow on a spreader?		May	2000
When should crowned rollers be used?		Jun	2000
When should reverse crown rollers be used?		Jul	2000
When should I use spiral grooved rollers?		Aug	2000
What makes a good converting team?		Sep	2000
Why is plant lighting so important?		Oct	2000
Why is neatness so important?		Nov	2000
Why are my defects worse in summer or winter?		Dec	2000
How can I change the amount of spreading?		Jan	2001
What are the Pros and Cons of Cantilevered Machinery?		Feb	2001

What are Some Considerations for Pilot Machines?	Mar	2001
How do I know if winding caused my defect?	Apr	2001
What is the most serious oversight in the web business?	May	2001
What is the most serious oversight in working with customers?	Jun	2001
Is there more than one type of curl?	Jul	2001
How can I decurl a web?	Aug	2001
When is traction desirable?	Sep	2001
When is sliding desirable?	Oct	2001
What causes laminate tunneling?	Nov	2001
What causes wound roll tin-canning?	Dec	2001
What is the optimum core size?	Jan	2002
What is the optimum roll size?	Feb	2002
Why isn't my web flat?	Mar	2002
How can I prevent wrinkling?	Apr	2002
Why does my wound roll have flared ends?	May	2002
How do I know if my process is level?	Jun	2002
What is the best winding tension?	Jul	2002
What is the best winding curve or taper?	Aug	2002
Can a bowed roller cause bagginess?	Sep	2002
Can a spreader treat bagginess?	Oct	2002
How can I map defects?	Nov	2002
What are Plant Biorythyms?	Dec	2002
How can I speed up my machine?	Jan	2003
How do I know if my tension control is working well?	Feb	2003
What are the challenges of width?	Mar	2003
What is the best type of guide?	Apr	2003
What is the best nip control?	May	2003
How do caliper variations affect winding?	Jun	2003
How does differential or slip-core winding work?	Jul	2003
What are the best splicing techniques?	Aug	2003
How do I prevent wrinkles from forming?	Sep	2003
Can a spreader treat bagginess?	Oct	2003
How can I troubleshoot and reat winding defects?	Nov	2003
Can I hide defects by winding loose?	Dec	2003
Are we having more drive difficulties?	Jan	2004
Why we are having more drive difficulties - My opinion	Feb	2004
Why do guides work so well?	Mar	2004
What can we do to improve tension control?	Apr	2004
How can I adjust tension to improve winding?	May	2004
How would I adjust nip load on my winder?	Jun	2004
How does gage profile affect winding?	Jul	2004
How can I measure Gage profile?	Aug	2004
Do dancers absorb tension variations?	Sep	2004

How big should my rollers be?	Nov	2004
How important is wound roll edge quality?	Dec	2004
How can you read roll edges?	Jan	2005
How do you define machine quality?	Feb	2005
How do you define machine reliability?	Mar	2005
How can I measure footage?	Apr	2005
How trustworthy is that measurement?	May	2005
Why should I use slip core winding?	Jun	2005
Why should I NOT use slip core winding?	Jul	2005
When should I use gap winding?	Aug	2005
When should I use center-wind assist?	Sep	2005
What are good sources of web handling knowledge?	Nov	2005
What are good sources of web handling data?	Dec	2005
What is the best surface for my roller?	Jan	2006
Why are rollers grooved?	Feb	2006
Must I endure baggy webs?	Mar	2006
Why can't I spread out a baggy web?	May	2006
What is the best type of grooving for my rollers?	Jun	2006
Is flat always the best profile?	Jul	2006
What is the best way to tape rollers?	Aug	2006
Why would I want to skew rollers?	Sep	2006
Why should I spread near sitters?	Oct	2006
What is the best way to float a web?	Nov	2006
Why does my web shift at roll change?	Dec	2006
Is it hard to speed up a line?	Jan	2007
What can I do about wrinkling?	Feb	2007
What is the most important web handling sensor?	Mar	2007
What is your favorite management program?	Apr	2007
What is your favorite troubleshooting method?	May	2007
How can I take away trim?	Jun	2007
What should I expect of pneumatic trim removal systems?	Jul	2007
How can I calibrate load cells?	Aug	2007
How can I calibrate dancers?	Sep	2007
What is the best instrument to measure wound roll quality?	Oct	2007
What is the best taper to run on my winder?	Nov	2007
How can I wind material with bad gage profile	Dec	2007
Can you apply DFM to winding?	Jan	2008
How closely do I need to align my machine?	Feb	2008
When do I need to align my machine?	Mar	2008
What do you mean by process and product quality?	Apr	2008
What do you mean by machine quality?	May	2008
What is draw control?	Jun	2008

What are the drawbacks to draw control?	Jul	2008
What is gap winding?	Aug	2008
What is the best winding curve?	Sep	2008
What do I need to know about accumulators	Oct	2008
Looking back and looking forward	Nov	2008
What is the best tension for laminators?	Dec	2008
How can I measure web and roll length?	Jan	2009
How can I measure wound-roll diameter?	Feb	2009
What is the master-speed reference?	Mar	2009
What is a helper drive?	Apr	2009
How can I improve roller traction?	May	2009
How can I improve roller release?	Jun	2009
What causes a wound roll to telescope? Part 1	Jul	2009
What causes a wound roll to telescope? Part 2	Aug	2009
How should I combat core crush?	Sep	2009
Why are accumulators so troublesome?	Oct	2009

**** Feature Articles ****

***1994.06 Jun 1994
The Profile of a Nip

A nip, as described by the dictionary, is a pinching force between two surfaces. However, in converting the term refers more specifically to rollers that are forced together. Nips are ubiquitous in web manufacturing and converting. So much so, that they are often overlooked until problems arise. Table 1 lists a few of the more common nips found in converting. We will first discuss a few specific applications. Then we will show how all nips are the same in key respects, despite the wide variety of materials and applications.

One common application for nipped rollers is to step the web strain or tension up or down between sections of a process. This equipment goes by a number of names such as pull rollers, draw rollers, pinch rolls and so on. As seen in Figure 1, the components usually consist of an undriven metal roller nipped against a driven covered roller. (It is not a good idea to drive both rollers because of difficulties in precisely matching the surface speeds).

While the pull rollers do provide a useful function, they can easily cause wrinkles and creases if the web or nip is not uniform across the width. A more gentle alternative is the ÔS' wrap which is two identical metal rollers with textured surfaces that are often tied together by a timing belt or other drive connection. The only significant application difference between the arrangements is that the pull rollers may provide a bit more traction than the S-wrap, and thus can sustain a larger draw/tension difference. In any case, every drive section must be justified if for no other reasons than to reduce equipment cost and complexity.

Nips are also used in surface winding as seen in Figure 2. Here, the nip provides additional winding tightness or hardness than could be achieved by web tension alone. Also, the nip helps exclude air from the wound roll when winding nonporous materials. Unfortunately, the winding nip can also cause several types of web and roll defects. This is the subject of a TAPPI publication later this year.

While pull rollers and winding nips are not intended to modify the web, other nips are in converting are. These include calendering and laminating, coating, embossing, and printing. Regardless of the process however, the goal is the same. That is to control the nip to a target level that is both uniform across the width as well as along the length of the web.

The target, or setpoint, is best expressed as the nip force between the rollers per unit width of the web. The units for this in the English system are pounds per lineal inch, which is commonly abbreviated as PLI. Table 1 Nips in Converting

Calendering Nipped Pull Rollers Coating Printing Embossing Winding Laminating
etc.

**[INSERT Figure 1 Pull and S-Wrap Drive Rollers]

**[INSERT Figure 2 Winding Nips]

**[INSERT Figure 3 A Nip Loading System]

A typical nip load control system is shown in Figure 3. Here, the pivoting bottom roller is loaded against the top roller by a pneumatic or hydraulic cylinder. A portion of the cylinder pressure is used to lift the weight of the bottom roll, with the remainder used to load the nip. This pressure is commonly displayed as PSI (pounds per square inch) on a pressure gage on a control panel. However, the web cares about PLI, not PSI. Thus, a calibration curve between loading pressure and resulting nip load is required. This is easily calculated from engineering statics from cylinder areas, geometries as well as roller and arm weight. In the case where roller weight is unknown, it can be 'weighed' by the pressure gage readout. This is calculated from the average of the lifting and lowering pressures considering cylinder and other geometries.

One problem that is common on many loading systems is excessive friction, particularly for rollers mounted on slides instead of pivots. I've seen a particularly bad situation where a converter wanted to run a 2 PLI load, but the system had nearly 30 PLI of friction. The result was an out-of-control process where adjustments in the setpoint pressure did not result in predictable and significant changes in the actual nip loading.

An estimate of the system friction is easily calculated from the difference of lifting and lowering pressures. Systems with excessive friction can't hold nip loads closely, thus cause a variation in the product along the length or with time. Friction also affects how low the nip load can be controlled. The minimum nip is half of the friction deadband plus a small margin for safety to make sure that the rolls remain in contact during run.

Nip loads can also vary across the width because of several types of geometrical errors. Figure 4 shows two nip rollers that are not parallel. Here, the nip is high on the left side and may not even contact on the right side. Also, all rollers will deflect and bow away from the nip, which causes a pinching at the ends. This is particularly a problem with slender rollers (length more than 8-10 times the diameter).

If both of the rollers are (uncovered) metal, one can be crowned to even out the nip. The amount of crown (barrel shape) is calculated from the beam deflection formula and is good for only one nip load. However, cutting an accurate crown is very difficult. Also, crowns can cause other problems due to surface speed variations across the width.

Finally, no roller is a perfect cylinder as seen in Figure 5. It will vary in radius with rotation but at a given CD (cross direction) position. This is measured with a dial indicator and is called TIR (Total Indicated Runout). If the runout is excessive, periodic marking and roller vibration can result. Also, the diameter can vary across the width as measured with a caliper. These variations can cause bands or streaks in the product.

Metal rollers can be cut to within a few ten thousandths of an inch accuracy, while covered rollers can only be cut to within a few thousandths. Roller geometrical tolerances should be appropriately specified whenever manufacturing or buying nipped rollers.

It is important note that the softer the cover, the less geometrical errors will affect nip and product uniformity. Indeed, metal-metal nips are so touchy that they should be avoided except for very thick products. Unfortunately, soft covered rollers may not provide the nip intensity needed for some applications. Also, soft covers are often less durable than harder covers. Cover hardness, measured by handheld indentors, is a very important roller and process specification.

Variations of nip pressure across the width can be measured with nip impression papers. These are, in simple terms, something like carbon paper. They are carefully run through a nip at thread speeds. High pressure areas will show up as darker areas, and lower pressure areas as light. These are carefully documented and kept in maintenance files for that roller set.

**[INSERT Figure 4 Misalignment and Deflection]

**[INSERT Figure 5 Cylindricity Errors]

Choosing among the wide variety of nip impression papers first involves a balance between cost and performance. However, even more important is to choose one that is activated by the pressure range anticipated in a particular nip. If the nip pressure is too low to activate the paper anywhere, it remains uncolored and nothing is learned at all. Conversely, if the nip pressure is so high that the paper is completely colored, nothing is learned about uniformity.

Figure 6 shows two rollers nipped with a nip force of ÔN’ PLI. Where these rollers are in contact, there is a stress in the Z direction of the material which varies from zero at each end of the contact to a maximum at the center. The width of the contact is often called a footprint. The area under the ZD stress curve is exactly equal to the nip force ÔN’. However, the width will be wider and the maximum will be lower for softer covers and vice versa. The effect of the nip on a product is related primarily to the nip load, and to a lesser extent the peak stress and the web line speed.

Nipped rollers influence product consistency and quality more than most others. Therefore we want to hold the nip accurately and uniformly. To do this we need to know and control:

1. Nip load in PLI
2. Loading friction in PLI
3. Alignment tolerance and deflection
4. Roller TIR and diameter variation tolerance
5. Cover thickness, composition and hardness

Only then do we have control over our process and product.

For Further Information

1. D. R. Roisum. Nip Induced Defects. To be published in TAPPI late 1993.

2. T. M. Spielbauer and T. J. Walker. Theory and Application of Draw Control for Elastic Webs with Nipped Pull Rollers. Proc. of the 2nd Int'l Conf. on Web Handling, Oklahoma State Univ., June 6-9, 1993.

3. W. B. Kennedy. Nip Impressions. Tappi J., May 1991. Figure 6 Anatomy of a Nip

***1995.03 Mar 1995
A Guide to Roller Sizing and Selection

Rollers are the foundation of all web manufacturing and converting processes. They allow us to economically manufacture our products continuously instead of in batches. Despite their ubiquitousness, however, rollers are poorly understood and appreciated. They are often dismissed as trivial and uninteresting components because of their deceptively simple appearance.

However, rollers are neither simple nor unimportant. Their complexity is such that an entire handbook can (and is) being written to describe their behavior. They are so vital that they can be the most important aspect of web processes. While raw materials are also important, the material's interaction with rollers can largely affect quality and productivity. With few exceptions, webs are formed, converted and transported principally on rollers and related elements. In this article, we will merely highlight some of the most important roller considerations. The guidelines given will be good for most applications.

Do Not Use Even a Single Roller More Than Necessary

The best machines often have the fewest parts, and rollers are no exception. The more obvious reasons to reduce roller counts are to reduce initial costs, maintenance, machine floorspace, as well as threading and cleanup time. However, as will become more apparent shortly, rollers can damage webs.

Rollers serve one of two primary functions. Transport rollers merely carry the web through the machine as opposed to modify the web, and are often supplied in excess. Indeed, you can often judge the skill of a machine designer by how few transport rollers are used. Process rollers, on the other hand, are usually required by the application and are seldom supplied in excess. You can often improve existing processes merely by threading around rollers that don't serve an essential function.

Do Not Allow a Roller to Deflect Excessively

The most common design error is to select a roller that is too slender. Rollers with undersized diameters will deflect excessively under the combined forces of gravity, tension and nips. Some of the numerous problems that can result are: machine direction trough wrinkles, wrinkling through a nip, process variations in a nip (Converting Magazine, June Ô94), and general tension profile variations. Slender rollers also are susceptible to being bent and are difficult to balance. Roller deflection can be quite serious. In one case I've seen, a single undersized $1K lay-on roller cause $1M in waste.

Specifically, one should allow no more than about 0.00015 x face as a maximum deflection for most rollers. The deflection of a simply supported roller, shown in Figure 1, can be calculated from beam bending equations. As a very rough rule of thumb, however, properly sized rollers will typically have slenderness ratios (length/diameter) between 10 and 15, and are relatively insensitive to shell material or wall thickness.

Cantilevered machines, common in narrow web converting, also must abide by deflection standards. Unfortunately, cantilevers have two handicaps not shared by their larger machine cousins. First, the roller component that resists deflection is the shaft of the dead shaft roller, which is much smaller than the shell. Second, mounting and framework compliance add to the misalignment.

Never Allow a Web to Slip on Roller

Traction can sometimes be lost on rollers so that the web slides across part or all of its width. Factors that aggravate slippage are lightly wrapped rollers, slippery web and roller surfaces, air/fluid entrainment and high inertial or drive torques. If an idler roller can't be configured to avoid slippage, it must be driven.

The obvious result of slipping is roller surface wear and web marking (of some grades). However, a more serious universal result is the loss of web control. When a web transitions between floating, sliding or traction, there will be a tension and edge position upset. This becomes particularly debilitating with processes that require registration, or have those with tight tolerances for length, width or thickness.

**[INSERT Figure 1 Roller Deflection]

Avoid High Tension Differentials Across Rollers

There is a tension difference across every roller determined by three components. The first is drag caused by bearing friction, windage, and nip rolling resistance (if present). A simple test of bearing friction is to make sure an idler roller will coast for at least 10 seconds after a sharp hand spin. The second component, only seen on speed changes, is roller inertia because the torque to accelerate or decelerate the roller's mass is supplied by a tension difference across the roller. The largest factors in inertial tension are the roller's diameter (machine width) and the machine's acceleration rate. Though some relief can be obtained by using Ôlow inertia rollers', reducing roller counts should be the first step. The last component, only seen with driven rollers, is the torque applied by the drive mechanism.

There are a few situations where a high tension differential across rollers is needed, and will generally be across a driven roller. One is where the web undergoes a large change in strength, and thus requires a different tension setpoint in that zone (Converting Magazine, November Ô94). Another is where tension must be stepped up or down from zero, such as on a threading or sheeting operation. As a general rule, however, tension should not vary more than about 10% through a tension zone. This effectively determines how many non-driven rollers can be used. Figure 2 illustrates this concept with a simple tension control section.

**[INSERT Figure 2 Tension Variations in a Control Zone]

Reduce Clearance and Compliance

Rollers and the mountings can have excessive clearance and compliance. The resulting problems include machine vibration and alignment difficulties. Bearings can have more clearance than the few ten thousandths of an inch needed for proper operation. An extreme example is some self-aligning bearing styles which may have many mils (0.001Ó) of clearance, even when new. More often, it is a pivoting or sliding roller mounting that has excessive clearance. However, even a tight bearing and mounting can be compromised if it is attached to a flimsy framework, such as a cantilevered beam. In general, the total system clearance and framework compliance under applied loads should be much smaller than values for allowable deflection or misalignment.

Rollers Must Be Aligned

Misaligned rollers can easily wrinkle lightweight webs (Converting Magazine, June Ô94), and can contribute to a loss of traction on stiff webs. Furthermore, a misaligned roller will always skew the tension distribution as seen in Figure 3. It is not unusual for misalignment to cause the web to go baggy on the loose side, and yet be so tight on the other side as to damage or break to web. The only cure for these problems is to periodically re-align every roller in a line. In most cases, alignment must be done by optical transit in order to get the roller close enough to avoid a significant (10%) disruption of the tension profile across the width. Unfortunately, the cost of optical realignment can exceed the costs of some rollers, giving yet more impetus to reduce roller counts.

**[INSERT Figure 3 Tension Variations Upstream of a Misaligned Roller]

Rollers Must Have Tight Cylindricity Tolerances

Webs will steer toward the high diameter portions of a roller. Thus, a bulge on one end will cause a web edge offset. More seriously, a bulge in the middle can cause a light web to gather or wrinkle there, especially if the roller is in nip. To avoid these roller induced disruptions of web stress, the roller must be machined and maintained to tight tolerances.

Figure 4 shows the common measures of roller cylindricity errors. Radial runout is the deviation from circularity in a particular plane (CD position) and is often referred to as TIR (Total Indicated Runout). Maximum diametral variation, and equally important, station-to-station diametral variation are the other two important measures. In general, most rollers should be machined to about 0.002Ó tolerance by those measures. However, hard process rollers, particularly those in nip, may need tighter tolerances of about 0.0002-5Ó. Covered rollers, on the other hand, can and need only be machined to about 0.005Ó tolerance. After a period of time, rollers may wear and will need to be reground when their outgoing tolerances reach about 2-4x the ingoing tolerances.

**[INSERT Figure 4 Roller Cylindricity Errors]

Most Rollers Need to Be Balanced

Roller imbalance is the primary cause of machine vibration, and can be a major contributor to web tension surges. Thus, nearly all rollers need to be balanced after machining, and in some cases after re-machining. Only applications with very heavy webs running at very low speeds may not need roller balancing. At low speeds (10-100 FPM), a simple static balance may be adequate. Static imbalance can be checked on some rollers with very free bearings as the tendency pendulum to the heavy spot. Intermediate speed (100-1,000 FPM) applications will require a 6.3 class balance, while a 2.5 class may be desirable for very high speeds (1,000-10,000 FPM).

Roller Surfaces

The previous roller design and maintenance criteria are fundamental to all rollers, webs and applications. Only after these are taken care of do we need to look at application dependent considerations. Of these, we will merely note a few common roller surface options.

Some rollers are coated with a thin metal such as anodize, chrome or tungsten carbide. This additional treatment is often for one of two principle reasons. First, coatings are much harder than the base metal, making the roller more resistant to abrasion or other damage. Second, coatings allow a greater control over surface roughness, which can vary from mirror smooth polished chrome to a very gritty tungsten carbide. Smoothness may be desirable to avoid web marking or enhance web or material release from a roller. Roughness may be desirable to increase roller traction. An interesting recent development is teflon impregnated tungsten carbide which can grip the web while being resistant to fouling.

Some rollers are covered with one of a dozen or more common polymer options. The most common motivation for covering is to reduce the intensity and improve the uniformity of a nip. Also, covered rollers usually have a higher web traction than smooth metal.

Whether plain, coated or covered, rollers are sometimes grooved or machined with a bewildering variety of patterns. Sometimes these patterns are given near mystical attributes. The most common fallacy of which is the ability to spread webs. Unfortunately, the reality is that grooving or raised topology tends to contract rather than spread the web.

The principle reason to groove a roller is to allow a fluid (air or liquid) to pass around the roller, instead of lifting the web which will reduce traction. Thus, grooving should be considered for light nonporous webs traveling at moderate or higher speeds. Unfortunately, many of the grooving patterns used are not well engineered for this purpose. In general, the groove pitch is far far too large, and the groove width and depth greater than needed or desirable.

***1995.09 Sep 1995

Easy Ways to Keep Static Under Control

Static Concerns

Static generation and discharge is common in many processes because most web materials are non-conductors and some rubbing of the web is inevitable. The severity of static concerns can vary from a benign nuisance to a life threatening hazard. At the nuisance level, operators may not work as effectively because static discharges are unpleasant and even painful. If the potential is further increased, static can be a safety issue. Static discharges have caused many injuries directly, such as an arc into the eye, or more often indirectly, such a startling an operator into a hazardous position. Static discharges can cause explosions and fires when volatile solvents are involved.

Static may not be desirable for the process either. Though the the forces are weak, static can cause a web to cling to a surface. On light webs this may cause the web to leave a wound roll or roller erratically and with tension surges. Laminating of light materials such as tissue may become more difficult because the plies may cling to each other or separate during transport. Also, static may interfere with the proper stacking and destacking of sheeted material. Finally, a statically charged web will attract dust and lint.

However, static electricity can useful on occasion. Static can be used to pin a web tail to a core during an automated turnup on a winder. Similarly, static can be used to pin a tail to a roller during sheeting. Finally, some web cleaners are statically assisted.

Static Electricity

Static electricity begins with an electrostatic charge generation where there is sliding or other relative motion between materials. A common example of static charge generation is to walk (scuff) across carpet in a very dry room. This can lead to a static discharge when one then touches a lightswitch, register or other grounded object. Common demonstrations of static are to rub a balloon on one’s hair, or rub a wool cloth against a glass rod. In all of these cases, electrons were peeled off one material and deposited on the other. This leaves a potential (voltage difference) between the objects. If the potential is high enough, the electrons will cross a small air gap as an arc. Though dependent on humidity and electrode shape, it takes about 50,000 volts to jump an inch of air. There is, however, very little current or power to the arc. Generating Static Charges

The amount of static generation is roughly proportional to the speed of relative motion between two objects, such as between a web and roller. Sliding is one type of relative motion which is always present, even on rollers in full traction. This occurs prior to the exit tangent where the web transitions by the band-brake equation from the upstream to downstream tensions. Thus, one way to reduce static generation might be to reduce the tension differential across rollers. However, static can still be generated at the departure of a roll(er) as the web is peeled away from it. Another large source of relative motion are process nips and wound roll nips. While static might dissipate on a web in a matter of minutes or at most hours, wound rolls can store a static charge for months or years.

The Triboelectric Series

Another factor for static generation is the separation on the triboelectric series of the two rubbing materials. As seen in Table 1, for example, paper will generate more static running across a polyurethane roller than across a steel roller. Also note how air flowing across any other material can generate a charge (which is why you can get a shock from a vacuum cleaner hose). To minimize static generation, we might choose our roller surfaces to be close to our web on the triboelectric series.

Table 1 - Triboelectric Series

+ Positive +
Air
Hands
Glass
Nylon
Aluminum
Paper
Cotton
Steel
Hard Rubber
Copper
Polyester
Polyurethane
Teflon
Silicon
Rubber
- Negative -

Static Dissipation

While a static charge can be generated by rubbing, this charge can quickly drain away through several mechanisms. If the web is even slightly conductive, the charge will quickly bleed off by traveling to ground through rollers and framework. Thus, one way to reduce the dangers of static is to embed or coat the web with a conductor if it can be done economically and without compromise to product attributes. Similarly, rollers can dissipate their charge to ground through their bearings and supporting framework. In most cases, the contact pressures in a bearing are enough to yield enough metal-metal contact through the bearings. If not, graphite additives can be specified to increase lubricant conductivity. Only in rare cases is a grounding brush to the roller surface needed. However, the larger problem with charges on rollers are covers which are, for the most part, non-conductive.

Static can be bled off of the web and into the air, provided that the humidity is high enough. This is the reason why static is much less noticeable in our homes and plants in the humid summer months. Static is easily dissipated and rarely a problem when the relative humidity is 50% or more. However, there seems to be a great reluctance by most plants to humidify their air. The usual reason given is that the cost is prohibitive. However, humidification is much cheaper than the heating or cooling systems that most plants enjoy, and may well be cheaper than some static removal systems. A side benefit to maintaining a 50% RH is that it is more comfortable to plant personnel.

The Wand

One way to help operators to work more comfortably in a static prone line is to provide them with grounded wands. These are useful to discharge a web or wound roll that must be handled or worked around. The wand is a rod with a insulating handle that is connected to a grounded frame via a conducting chain or braided wire. An alternative is to use a hand held anti-static blower.

Passive Static Elimination

Of the three methods of continuous static elimination, the passive means is the least expensive. This is nothing more than conductive tinsel, garland or brushes which lies on or just above the web. The tinsel should have sharp needle tips, much like lightning rods, to be most effective. Finally, the tinsel must be well grounded.

There are three primary disadvantages to tinsel. First, it is only able to bring down potentials to about 5kV. While this is more than enough to eliminate nuisance static, it may not be sufficient to eliminate the threat of solvent explosions. Second, the tinsel can come loose if it is not securely mounted. Third, the tinsel might scratch some exceptionally soft coatings.

Electrical Ionizing Bars

Air can be ionized by bars powered by a high voltage AC or DC supply. Ionizing the air makes it a better conductor so that static can be bled off the web and onto the bar's numerous tiny needles. Electrical ionizing bars are most suitable for reducing the potential of solvent ignition because they can reduce static potentials more than passive eliminators. Disadvantages of electrical ionizing bars are higher cost, bulkiness and the potential for electrical shock on some designs. Also, they can produce ozone and nitric acid vapors.

Nuclear Ionizing Bars

Low grade radioactive material generates alpha particles which ionizes the air close to the web, and thus operate similar to electrical bars. Nuclear bars may be used on photographic film where other methods may fog the film. Disadvantages of nuclear bars are that they need to be exchanged (renewed) about once a year, and the negative perceptions about nuclear materials.

Where to Locate Static Eliminators

Static can build up on a web when it passes any other element in a process line, and thus several eliminators may needed. Their location is determined when the measured static potential exceeds a desired maximum. Static potentials may need to be as little as 1 kV in an explosive environment or less than 5-10 kV for operator comfort. Static potentials of 30 kV or more could be considered dangerous (the startle factor) in the proximity of operators.

The level of static potential can be easily measured with inexpensive hand held electrostatic field meters. These can be used to survey the line while running different grades, speeds and at different relative humidities. They can also be used to evaluate the efficacy of static eliminators and treatments.

Static bars and tinsel should not be placed directly over idler or other rollers as it will impair their effectiveness. Rather, the bars must be much closer to the web than to any other metal or grounded object.

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***1995.11 Nov 1995

The Well-Proven Principles of Web Spreading

Why Spread?

In a perfect world there would be little need for spreading. In this world, the web would be manufactured uniformly flat and would remain so through subsequent handling. The realities are, however, quite different. Spreaders are required on many web manufacturing and converting processes to prevent or remove wrinkles, to widen a web, or to separate slits during winding. They are used on most light grades of materials including film, foil, nonwovens, paper and textiles.

In this article, we will briefly discuss the application of all spreader systems including: the concave roller, the bowed roller, the D-bar, dual element spreaders and expander rollers. Before we begin, however, it would be good to define the term spreading. Spreading is a converting process that widens the web on or near the spreading element. Using this definition, much of the mystique of the benefits of spreading is removed. If the web is widened at a spreader, it will widen or open up the gaps between individual strips so that rolls don't intertwine during winding. If the web is widened, some types of wrinkles can be alleviated. However, spreaders do not effectively correct baggy webs as is commonly believed. In fact, spreading only rarely leaves any permanent effects on the web. Rather, the effects tend to be very local and temporary, often lasting only for a span or so after the spreading unit.

Concave Spreader Roller

The simplest and least expensive spreader is the concave roller (sometimes called a bowtie roller). As seen in Figure 1, this spreader is a conventional roller whose diameter at the ends is slightly greater than at the center. In its ideal configuration, the diameter profile of the roller is cut as an arc of a circle. However, a simpler version can be made for unslit webs by cutting a roller with conical ends and a cylindrical center. A rough starting point for a diameter reduction at the center would be 10-25% of the MD strain induced by web line tension or draw control.

A crude but sometimes effective way to make a concave spreader is to add a couple of wraps of tape to the ends of a straight roller. However, this useful trick for flattening unslit webs is all too often misapplied. I've seen rollers so full of tape you couldn't see the shell, or where tape was applied well inside the edges of the web. Finally, this spreader requires traction because slippage can compromise spreading or even turn it into a wrinkle maker.

**[INSERT Figure 1 - The Concave Spreader Roller]

**[INSERT Figure 2 - Bowed Roller]

**[INSERT Figure 3 - Bowed Roller Setup]

Bowed Spreader Roller

The bowed roller, as seen in Figure 2, has a curved stationary axle upon which a rotating sleeve(s) is mounted over numerous bearing sets. The axle may have either a fixed or variable bow. The sleeve is typically a one-piece flexible tube of a soft synthetic composite, or may consist of numerous narrow metal shells.

The amount of bow is very important because too little will reduce the effectiveness of the spreader, while too much will also reduce spreading and may even generate wrinkles. Unfortunately, the historical tendency has been to over-bow. As a rule of thumb, most bowed rollers should have a 1/8% bow, unless the material is slit, very flexible or very troughed where the bow might be increased to as much as 1/2-1% of roller width. Since traction is vital for the spreading function, the bowed roller should be wrapped about 15-45 degrees and the cover must be grippy. Similarly, the cover may need grooving for high speed applications and the roller may need to be driven when used on light or weak webs.

The setup of a bowed roller is straightforward. First, the bow should be pointed downstream in a direction perpendicular to the bisector of the wrap as seen in Figure 3. However, the bow can be rotated into the sheet slightly to accommodate a web with a baggy center and turned away from the sheet slightly to accommodate baggy edges. Second, the entering/exiting span length ratio is desirably about 2:1, but will work acceptably at quite different ratios.

Bent Pipe and D-Bar Spreaders

The popularity of the bent pipe spreader lies with its simple construction. Unfortunately, this simplicity often leads to crude manufacturing practices and dubious spreading qualities. A D-bar spreader takes its name from the characteristic 'D' cross-section of the bar. The only functional difference between a D-bar and bent pipe spreader is that the D-bar's shape can be adjusted by intermediate jacks. With this adjustment, the operator can spread a local baggy or wrinkled spot, or open up a particular slit position. The bow of the bent pipe or D-bar is pointed directly into the web.

One application limitation of pipe, D-bar and other sliding spreaders is that web scratching may be unacceptable for many grades, particularly those that are coated. Indeed, even a hardened steel bar may wear out prematurely on paper grades which can be so abrasive that they generate sparks on the bar. Dual Spreaders

There are several types of dual element spreaders used for the spreading of narrow slit webs. The dual bowed roller, as seen in Figure 4, consists of two bowed rollers pointing perpendicular to the ingoing and outgoing web runs. The amount of spread may be adjusted by pivoting the spreaders or by changing bow magnitudes. The Pos-Z^{a}, as seen in Figure 5, consists of two air float bars pointed upstream. Finally, another version is a bowed spreader followed by a D-bar. The dual spreaders operate by entirely different principles than their single element counterparts.

**[INSERT Figure 4 - Dual Bowed Roller Spreader]

**[INSERT Figure 5 - The Pos-Z^a Spreader]

Expander Rollers

Expander rollers, as seen in Figure 6, have shells that stretch outward from the centerline as the web transits from the ingoing to outgoing tangents. In one version, cam operated half-width slats slide at their junction in the middle. Another version has numerous elastomeric bands connecting across the width to adjustable cams on each end. Finally, another variant has a very flexible cover attached to the end cams and supported elsewhere by bristles mounted on a central shaft. One very unusual characteristic of these spreaders is that they operate successfully in traction, sliding or even transitions between traction and sliding. However, these spreaders are geometrically crude. Edge Pull Web Stretchers

Edge pull stretchers are the most powerful spreaders, and are sometimes capable of increasing web width by hundreds of percent. Obviously, strains this large are limited to very stretchy materials such as films, nonwovens and textiles. Indeed, the intent may be to draw the web permanently wider.

Edge pull stretcher rollers are a pair of narrow, soft covered nipping rollers on each edge of the web which are canted outward, as seen in Figure 7. Unfortunately, these spreaders are often finicky to set up. Another edge pull spreader is the tenter used in the manufacture of some films and textiles. This spreader has an endless track which guides a chain with numerous clips which pull the web outward following the shape of the tenter track, and release it on the downstream side. A disadvantage of edge pull stretchers are severe stress gradients.

Common Spreading Fallacies

It is widely believed that grooving, such as spiral or herringbone, can spread a web. The reality, however, is quite opposite. Grooving tends to contract because the web is pulled into the grooves which may pull the web's edges inward. Also, there is no strong evidence that the popular compliant cover rollers provide any spreading function.

Another common fallacy is that spreaders can fix a baggy web. First, spreading is short lived because the effects are lost after the web progresses only one or two rollers downstream. Second, spreading is elastic (temporary) in all but rare applications.

Where to Locate Spreaders

The temporary nature of spreading has three practical implications. First, spreaders should be located just upstream of critical processes so that the maximum benefit is retained. Example processes that demand a flat web include embossing, calendering, laminating, printing, slitting and winding. Note that many of these processes involve nips because nips are very intolerant of webs that are not flat. Second, spreaders may be needed after expansive processes such as heating, moisturizing or solvent addition. Third, spreaders may be required elsewhere just to keep the web from getting too troughed as it proceeds down the machine. These locations can't usually be predicted initially, but can be easily seen once a process is running. Starting at the upstream end, follow the web until troughing gets to the point where it might cross a roller (as a foldover, crease etc), and add a spreader there. Then continue downstream in the same fashion.

**[INSERT Figure 6 - Expander Roller Spreader]

**[INSERT Figure 7 - Edge Pull Web Stretchers]

Is My Spreader Operating?

All of the spreaders discussed here are based on sound and well proven principles. However, spreading can be compromised by improper application or setup. Perhaps the most common problem is web slippage on spreaders that require traction everywhere, such as the concave rollers and bowed rollers. Slippage may occur because the spreader is lightly wrapped, has a low coefficient of friction or is oversized. Slippage may well turn these spreaders into wrinkle-makers.

The effectiveness of a spreader is easy to determine in most applications. On a slitter, for example, the individual webs should be uniformly and adequately separated. On extensible materials, such as stretch film, nonwovens and tissue, the web should be measurably wider at the spreader than it is upstream. On many materials, such as thin films, the web should be visibly flatter at or just after the spreader. However, no spreader should be expected to remove a crease, foldover, severe trough or bagginess. These insults must be prevented rather than treated after the fact.

Further Information

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***1996.07 Jul 1996
The Marvel of On-Line Web Inspection

One industry trend has most impressed me from the half dozen conferences and exhibitions I have attended in as many months. That is, the proliferation of many new products for online web measurement and inspection. These tools merit serious consideration as weapons in the war against waste, delay and less-than-perfect product.

New products include improvements in sensors for basis weight, caliper, moisture and the like. It is also now possible to measure web bagginess with several commercial devices that have 'load cells' that can profile tension across the width. The recent thrust has been to hook sensors such as these into closed loop web process controls. Advanced software can learn or correlate the relationship between process adjustments and web properties. This allows process corrections to be made quickly and surely, but without overshoot or instability. The goal is to make the web as uniform as possible both along its length as well as across its width.

From a web handling perspective, the traditional load cell tension and edge position controllers have added several features that go beyond mere control. These features include grade setup tables, trending, alarms and integration into plant-wide networks. New diagnostic tools include laser velocimeters that can be used to accurately measure the speed of solids, liquids and sometimes even gasses without touching the target. Also, more web lines are now including built in vibration detectors that will alert operators and shut down machinery if necessary to protect against jams, roll wraps and other accidents.

Revolutionary changes are seen with CCD, camera and/or laser web inspection systems. Some are now able to do 100% inspection if speeds and widths are modest. Their incredible software is able to detect edges for adjusting complex pick-and-place registrations. Now we can add edge cracks, dirt specks and print variations to the list of defects that can be seen and detected by optical systems.

Also, there are as many changes in the supervisory end as there is on the sensor end of the control spectrum. For example, the entire manufacturing history of a web product can be logged and analyzed with plant-wide information systems. In most systems, the independent variable is the time of manufacture, grade, lot or roll number. However, some are imprinting visible or invisible bar codes right on the web instead of relying on printed labels which may be lost in handling or after the product is opened.

Automatic flagging and tagging of defects will greatly reduce the defects passed on to the customer in the event the operator doesn't open the waste gate soon enough. It will also reduce waste to an absolute minimum compared to an operator who might turn on the gate too soon and/or leave it open too long. While flagging has always been available for webs, we now see more rolls being automatically flagged. Some roll systems are tied into the winder drive so that it can be slowed and stopped right at the defect that needs to be edited out.

There are many new options to consider as we’ve seen with this brief tour of new measurement and control products. Many have been due in large part to the ever-increasing power and sophistication of the CPU’s that serve as the brains of the measurement and control systems. Like computers, unfortunately, the price tag for controls is as steep as ever. The upside, however, is that the choices, performance and utility has often greatly improved. This tips the scale of the cost-benefit ratio so that an ever-increasing portion of the machines will be equipped with these modern marvels.

***1996.09 Sep 1996
Progressive Web-Machine Controls Provide Options

More than any other area of converting, machine controls are becoming more sophisticated. This revolution has caused many changes in how we specify, design, maintain and operate machines. It has also made more challenging the successful integration of old and new machinery under the same plant roof. However, we need not fear these changes because they do not fundamentally change our business, they only give us more options. In this brief article, I will attempt to give a layman's introduction to the jargon and options for machine controls.

Only a couple of decades ago, most machines were controlled by relays and timers. A relay is nothing more than a fancy switch. Sometimes it would allow a low voltage pushbutton on an operators panel or benchboard to turn on a large motor or other device whose wiring would be unsafe or impractical to route directly to the panel. Sometimes relays were used as safety permissives. For example; Do not allow the main drive to start unless the nip is loaded and safety gate is closed. Relays, timers and other controls are usually centrally located in a cabinet. Centrally located controls are easier to troubleshoot and maintain, and the metal cabinet protects contents from the hazards of the plant environment, and casual personnel from electrical danger.

Today, however, few relays and timers are still in service because they've largely been replaced by PLC's. PLC stands for Programmable Logic Device. A PLC is a specialized computer used for industrial controls. While it is nowhere near as sophisticated as your desktop PC, which could also be used, it tends to be faster for machine control and is far more reliable because it is hardened for harsh environments.

A PLC is composed of one or more CPU's, analog and digital I/O cards as well as other specialized cards plugged into a common backplane. The CPU is the main brains of the control, though there is certainly some intelligence in all of the cards. Analog cards monitor sensors that vary continuously, such as temperature, and control continuously varying actuators such as a regulated air pressure to a nip control cylinder. Digital cards monitor switches and control devices that have only an on or off state, such as a indicator light. A common example of a switch is a proximity switch that looks something like a bolt and can detect the presence or absence of a metal target. I/O stands for input/output. The backplane provides a common power supply and communication between the cards.

The 'program' in a PLC is custom written for virtually every machine application by the machine builder or in some cases the plant electrical engineer or technician. The most common 'language' that is used is called ladder logic because the circuit diagram includes rungs that connect power to an output when certain conditions are met. Some of the elements in the ladder logic diagram are real such as pushbuttons and indicator lights, while other are virtual and only exist as a programming convenience. Sometimes a PLC may run other languages such as Basic, and may have communication cards that allow connection to foreign devices.

Similar revolutions have also been seen with web machine drives. A drive is a device or system used to turn or resist the turning of rollers. (While we most commonly think of electric motors for the term drive, mechanical drives include pneumatic brakes, belts, shafting and transmissions.) Three decades ago, most web drives were MG sets (Motor-Generator) for analog control of DC motors. Two decades ago, SCR (Silicon Controlled Rectifier) drives were commercialized as a more flexible and precise means of analog DC motor control. Though there are a few MG sets and even more analog DC drives, they are becoming difficult to obtain parts and service for.

In the past decade, most new drives were digital. In the case of the DC drive, the firing of the SCR thyristors is controlled by a computer rather than finicky analog circuits. This digital revolution has also made maintenance easy: replace the board if the red light comes on. Tuning usually needed to be done only once because the digital devices did not tend to drift. The digital revolution also gave much more flexibility to drive control. For example, switching between draw, dancer or load cell control became mostly a matter of reprogramming (Web Watch, Nov. Ô94 to Feb Ô95).

The digital revolution also made it easy to connect drives to other computers, PLC’s and the like. Also, some drive builders can run control block (drive), ladder logic (PLC), and Basic (communication etc) languages simultaneously. The latest revolutions in computer drives has also made AC vector, brushless DC and servo drives strong contenders to unseat the DC motor as the motor of choice for web machines.

The last element in a full blown control system is the data highway or network which connects many of the digital devices in the plant together. These devices can include PLC’s and drives used for machine control, scanners used for quality control and measurement, supervisory and production computers, desktop PC’s and the like. Thus, one can select the most appropriate device for each task, yet have them communicate and share information between each other.

In most cases there are several different types, brands and vintages of electronic device on a network. They merely need to have two things in common to be connected: an electronic protocol and a data protocol. An example of an electronic protocol is Ethernet which can be used to connect PC’s together in an office environment. An electronic protocol primarily specifies the signals carried on a wire, but says nothing about how the contents of the message are coded. ‘standards’ for electronic and data protocols are constantly changing.

While connectivity certainly has its desirable features, it is fraught with some severe difficulties as well. First, networking has some fairly steep hardware costs. Second, there are even greater labor costs to integrate all of the various devices into a common system. Often times, this might need to be done by a third party as few builders enjoy working with foreign devices. Finally, the half life of this equipment is frighteningly short. For example, the mechanicals of a machine might need modest parts replacement or rework every decade, and the useful life of the mechanical machine could be as much as a half century. In contrast, control hardware changes so quickly that it can be difficult to find parts and service in far less than a decade.

In the article, we've touched on a number of different ways that web machines can be controlled. We will illustrate them by showing a schematic example of how they might be found in a multi-machine plant. Notice here the combination of separate single point control, such as guiding and tension, with PLC's, drives and supervisory computers.

**[INSERT figure - you need to recreate from scratch]

***1997.05 May 1997

Process Automation Equals a Quality Web Product

Automation is the use of a machine or machine component to do what would have been done manually. Automation has changed the way we design products, processes and production, and thus has changed the way we do business. We automate for a variety of reasons including increased process consistency, productivity and safety.

Automation can improve process consistency that will result in higher quality products and reduced waste. In previous generations of machinery, process control may have had a one-hour or longer delay between the making of material and the making of process adjustments. First, a complete wound roll had to be made. Next, samples were taken from the top of the roll and tested in the lab. Only then could the operator finally make a set of trial adjustments to correct the process. In contrast, the feedback loop on automatic systems can be as little as milliseconds. New machines equipped with gaging, scanners or other measurement systems that run the profile controls have greatly increased the quality of web products.

Automation can also improve productivity that can reduce per unit labor costs. An automated machine may produce more for the same workforce, reduce the required crewing, or both. Similar benefits are also obtained by increasing machine width or speed. However, one must continually feed our machines with orders to achieve the economics of automation, width or speed. One does not want to find themselves, as one company did, with a brand new 200Ó wide 5000 ft/min machine that ran only a few days a week to fill its orders.

Finally, automation can often increase safety. At first glance this might seem improbable because automation which includes self initiated movements could catch someone off guard and in a hazardous location. However, this can be overcome by guarding off the entire section to bar access during operation. In the past, the operator was responsible to keep personnel clear while movements were made. Now, everyone is clear as the machine more or less runs itself.

Web process automation may begin at or before the raw material mixing stage. More impressive, however, is the profiling controls which control the die (film) or slice (paper) opening. Here gaging systems downstream measure the weight, thickness or other attribute of the web. If the product is consistently low in an area, the die or slice will open minutely to compensate, and if high will close down. The profile control task is more complex than it might first appear. The controller must assemble a three-dimensional picture of the web from the zig-zag path of the scanning head sensor. Next, the controller must filter the noisy data so that meaningful trends will stand out. Finally, the controller must determine how aggressively it will attempt to make corrections. If the gain is too high, the process will continually hunt. If the gain is too low, needed corrections will be sluggish.

Profile controls are a complex example of continuous automation. A simpler example is the use of closed loop dancer or load cell control of drives or unwind brakes. Here, the controller can maintain precise tension by compensating for changing roll diameters, inertial demands during speed changes, and other process upsets far quicker and more accurately than even the most dedicated and skillful operator. Additionally, this controller needs only be trained once and may run years before it needs to take its first break.

Obviously, there are many more process settings to manufacture a web than merely thickness and tension. Furthermore, each grade will require its own settings. Again, automation can help by storing the setpoints for each grade in a recipe that can be called up for every new order. Whether there be five or five hundred settings, the controller will never forget how to make a grade, even if it has been years since it was last run.

Even with our best efforts and controls, portions of the web may contain defects. Here, lasers, cameras or other sensors will watch the web without ever blinking. If a spot is found, it will be flagged for MD (machine direction) and CD (cross direction) position, as well as size. In some mills, the MD position is passed on to a rewinder that can automatically stop at the spot, almost to the nearest wrap. If the problem is recurrent, the process technician will be able to search the database for defect position trends so that maintenance efforts can be more closely directed.

In most cases, we will also have to test the web in the lab to verify important features or specifications that are not measured on the machine. Lab measurements may be required because in process measurements are too expensive or are not as sensitive. In most cases, however, we test in the lab because online versions of the test are not available. Nonetheless, we can still automate some aspects of testing. First, samples can be transported via pneumatic tubes or cart rather than by human courier. Next, common tests such as basis weight, tensile strength, brightness and so on can be all performed on a single robotic tester not much bigger than an office copier. Here, the only thing the operator needs to do is to load the samples into the front end of the machine. Finally, the test instruments can be wired directly into data acquisition systems which transfer the test values automatically into a database.

Sometimes the defect or troubles may be so severe as to cause the web to break. A simple example of discrete automation is the control logic of a web break detector. Here, a photoeye senses the presence of the web. If the web is not detected and the machine is in run, then the machine will go into an emergency stop and nips may open. Here, the web break and drive controls can react faster and surer than the human to protect the machine from further damage after a web break. If a single photoeye is prone to false alarms, two or more may be used. Here, a disagreement of sensors flags maintenance, whereas a majority or consensus will shut down the machine.

Some truly impressive automation can be found on the modern winder. For example, a production computer downloads new order widths to a computer positioned slitter. Here, the computer will move some slitters into the correct cut positions and park the others which are disabled or not needed. In as little as 30 seconds, a dozen or more slitters can be moved to a new setup to an accuracy of better than 0.005Ó. In conjunction, the slitter positioner may be linked with an automated core cutter which provides the correct core diameter, lengths and sequence. Finally, a label printer will print a barcode ID and lettering to identify the customer, grade and roll geometry and other product information.

Automation has also allowed use different machine design techniques. We often have to synchronize the two ends of accumulators, dancers, nip loading systems and layon rollers so that they move together. In the past, this would have been done by chains, gear racks or torque tubes. However, mechanical complexity can be reduced by synchronizing the ends of the equipment with servo motors (displacement or position control) or servo hydraulics (cylinder force control). Here, the 'electronic cross shaft' maintains registration to tight tolerances, and does so without the mechanical friction of its mechanical counterparts that can destroy their sensitivity. Similarly, 'electronic line shafts' will reduce the mechanical complexity of drives, and at the same time can allow faster grade changes and more precise adjustment than variable speed mechanical transmissions.

The high production winder may have automatic set change equipment as well. For example, a two drum winder is first automatically brought to a stop to meet exact preset diameter or length requirements. Then, the core chucks are extracted and the rider roll raised to allow the ejector to cut the tail and push out the finished roll set. Next, a core injector drops cores into the pocket that have been automatically taped or glued to catch the tails. Finally, the chucks engage and rider roll lowers so that the winder can begin its climb to the stratospheric speeds found in the paper and other industries. In less than 60 seconds, the winder has discharged as many as a couple dozen finished rolls and restarted itself with minimal operator involvement.

After winding, the rolls may move via automatic conveying systems to sheeting, wrapping or other processing. Again, these processes are highly automated. Also, it is not unusual now to see robotic carts carrying raw materials or finished products to and fro. They will usually be following an invisible magnetic or other tracked embedded in the walkway which may be shared by other traffic. While it is disconcerting at first to see driverless carts, collisions are rare and usually innocuous. First, they move much slower than even the most cautious (if there is such a thing) fork lift driver. Second, they may be able to Ôsee' obstacles via ultrasonics or other means. Finally, they are surrounded by a bumper switch that will stop them quickly, much like an elevator door will re-open if some gets caught trying.

Automation is not limited to the large web makers. Indeed, converting has abundant examples where automation has allowed products to be made so fast as they are visible only as a streak or blur. For example, stamping, cutting and packaging have been performed at rates exceeding 1,000 units per minute, which by comparison makes a machine gun look like its standing still. At these converting rates, the operator does not run the machine. Rather, the operator merely monitors the process through computer displays. Sometimes, one will visit a plant where the machines seem to run themselves as one is hard pressed to see the workers that tend them.

Thus, automation certainly offers us many ways of making our products better, faster and cheaper. However, this technology comes at a cost. First, it must pay for itself by reducing waste, increasing quality so that a premium can be commanded, or by allowing operators to make more products during their shift. It also demands much higher technical skills of everyone from operators, to maintenance and to engineering. Training and retraining must be continuous. Finally, it makes us even more dependent on our suppliers in two ways. First, automation has become so intertwined with our processes that they may not even operate if the controller becomes disabled. What was a luxury has now become a necessity. Second, the technology may be so complex that a plant may no longer have the expertise to service many aspects of the new technology. This can be mitigated, to an extent, if the builder can hook into the controller via a phone line. Here, some problems can be diagnosed without the time and expense of bringing in a service engineer from the supplier.

***1997.07 Sep 1997
How to Develop Contacts and Rate Machine Builders

Conferences and tradeshows, such as the CMM, are a good way to renew acquaintances and make new ones. Attendees may well include your suppliers and customers, as well as industry experts who will frequent these events more than most. Obviously, you should try to meet up with colleagues from other divisions of your own company who may also be there. However, you should also at least consider acquaintanceship with your competitors.

Contacts can be invaluable when you need information about products and services, or when you have questions about field performance. You may also receive advice on where to turn or how to proceed when faced with process troubles. (Free advice may not always be bad if it is obtained from someone with integrity and expertise.) Contacts might also help locate potential hires if you have a position that needs filling. Perhaps you may even find yourself in need of a new situation, in which case an extensive network of acquaintances could shorten the search.

Several things should be considered when developing contacts. First, the contact must truly have expertise or knowledge, else any information garnered is suspect. Second, the contact must have integrity so that proprietary information is protected, else you may find that your business plans and trade secrets have become public. On the other hand, a two way dialogue and communication must be present to some degree. A supplier, for example, will need a minimum amount of information in order to suggest equipment that is most appropriate. Also, some people resent being pumped indefinitely for information without a return of some type. A supplier, for example, will want to be considered for future business, and a colleague may expect similar help later if needed.

Here is where corporate cultures vary enormously. Some forbid contacts that are not absolutely necessary, protected by confidentiality agreements and sanitized by a lengthy list of procedures. On the other end of the scale, many companies will allow you to help a competitor in modest ways to find public domain information which could be a net gain for society. They note how our founding fathers had the wisdom to make sure that the exclusive rights of a patent would not be granted without the responsibilities to teach. An example of this ‘coopertition’ is the many paper mills that allow their competitors in to see a particular model of machine they are considering for purchase

In addition to meeting people, tradeshows are good way to find out what products are available. Here, it matters not whether the product is truly new or just new to you. In either case the knowledge is useful. If you are shopping for a particular product, you can focus your efforts on specific suppliers. Even if you are merely window shopping, the tradeshows are a good place to collect invaluable directories and useful catalogues for future reference.

Finally, tradeshows are a good means to evaluate the technical savvy of the component suppliers and machine builders. It is not all that hard to make a machine. All it takes is a concept, drawings and shops tools. What you should seek out is the subset of suppliers who actually understand the mechanics of their product, its application and its limitations. It is their experience and understanding that will most strongly affect the ultimate performance of your machine.

Builder experience is easiest to evaluate. The simplest approach is to compare sales volume. With each new machine, the builder has the opportunity to learn more about his product, and to further hone the design. However, mere opportunity does not necessarily guarantee knowledge. Another measure is the scope of webs and applications the builder has worked on. A wide experience base may indicate that the builder has the resources and confidence to solve problems as they occur. Lastly, we would desire that the builder have successful applications running at our sister plants and competitors

Builder understanding is more difficult to evaluate. To do this we must query their technical people. While one might tempted to ask questions which are most troubling to us, the best questions are often those for which we already know the answers. The expectation here is that the builder be at least as proficient as we are. Following is a sampling of questions which might indicate that the builder has succumbed to common problems or misperceptions.

Brakes
Question: What is the minimum pneumatic pressure I should run on my brake (or cylinder)?
Good Answer: Try to stay above 10 psi so that you might maintain tension (or force) closely.
Bad Answer: 1-2 psi.
Question: Can a single unwind brake cover all of my applications?
Good Answer: We can use a single brake provided that the calipers (or equivalent) be valved off as necessary to maintain a minimum pressure on light products at core diameter and that the brake have sufficient torque and horsepower for heavy products at full roll diameter and full speed.
Bad Answer: You only need one brake per unwind.

Rollers
Question: What class of deflection would you recommend for my application?
Good Answer: A class B deflection of 0.00015xface is suggested for many applications.
Bad Answer: Someone wrote a book on rollers?
Question: Why should I groove rollers?
Good Answer: To maintain traction in spite of air entrainment at higher speeds.
Bad Answer: Spiral grooving helps spread the web.

Slitters (Shear)
Question: What sideload should I run?
Good Answer: You should run a sideload force just enough to cut the current grade with sharp blades. For your product, this will be about x pounds of force as measured by a force gauge, which is about y psi of pressure on the gage.

Bad Answer: y psi.

Speed

Question: How fast can your machine go?
Good Answer: Most machines could be designed to operate at most any speed you could imagine. For example, the paper industry is pushing speeds of 3000 FPM for printing, 5000 FPM for coating and 10,000 FPM for winding. However, our market does not usually ask for speeds faster than x.
Bad Answer: x FPM

Spreaders

Question: How does a bowed roller work?
Good Answer: By the normal entry law for traction, the web must enter the bowed roller at a right angle to the axis everywhere which causes a widening of the web at the spreader.
Bad Answer: It spreads outward over the hump.
Question: How much bow should the spreader have?
Good Answer: Bows will typically range from 1/8% to 1% of machine width depending on the web's cross direction stiffness and other considerations.
Bad Answer: We recommend a 1-3 inch bow for most applications.

Tension Control

Question: Which is better, dancers or load cells?
Good Answer: In most cases, dancers or load cells can be equally effective if properly designed. For example, the dancer must have minimum friction and the load cell must be mechanically overload protected. While the load cell is an excellent process indicator, some drives may not be sufficiently responsive to use a load cell for control.
Bad Answer: Dancers are better than load cells.

Whether we buy a car or converting machine, we consider many factors such as price, performance, features, delivery and so on. However, converting machinery requires yet an additional consideration because what we are really buying is expertise rather than metal. Conferences and tradeshow are a good place to get to know your machine partners.

***1997.08 Aug 1997

Waste is Not a Dirty Word

Waste (September 1994) and delay (July and Aug 1994) are important concerns for any converter. Delay is the more ambiguous of the two because it may depend on targets selected for times to change grades, perform routine service, and planned maintenance. In some plants efficiency is the measure trended for the convenience of management. Efficiency is relative to the output potential of a machine or plant which again may be somewhat arbitrary. Efficiency numbers are not particularly helpful for troubleshooting because they shed no light on the individual sources of the waste and delay, and thus give us no direction in which to proceed.

Waste is less subjectively defined as differences in the quantity of raw material in and saleable product out of a plant. The quantity may be either defined as weight (producers) or area (converters). Thus, at the end of a period one could do a simple mass (or area) balance to infer how much waste was generated. While this is a useful check of more direct measures, there are complexities. First, one must account for changes in inventory of raw materials, in process, finished and returned goods. Second, some raw materials change weight or area during processing, such as moisture content in paper, or widths of extensible nonwovens. Third, the mass balance technique doesn't return feedback quickly enough for responsive process corrections. Most importantly, however, is we still have no breakdown of the individual sources of waste using the overall mass balance technique.

A better way to tabulate waste is to measure it at its points of creation. Locations where material is lost might be categorized broadly as trim, breakdown, top & bottom of wound rolls, rejected product and returned product. Each of these may be further divided as appropriate. One would like enough categories so that opportunities are not buried in the 'other' category, nor so many categories that some are rare or unimportant. We also should avoid euphemisms for waste such as 'shrinkage or 'trim' which do not convey sufficiently grave connotations.

Since trim waste can be taken in several places in the process, each should be separately identified.. One example of trim is the weed resulting from a round product punched from a square sheet. The amount of weed loss in this example can be calculated and will be reduced if the pattern is on a staggered rather than square grid. We also might redesign the product to a rounded square for even less waste.

An example of process trim is the outside edges of the web which do not meet specification for some reason. In some cases, such as the edge of coating, the boundary between web and trim is clearly defined. In other cases, such as paper manufacturing, the web gradually deteriorates beginning several feet in from the edges. Here, a judgment must be made as to where how far out the web is still good. The wise converter will shop around to find the center cuts from machines as they will make better product with less trouble. Standard numbering in the paper industry allows us to read a roll ID# to tell whether it is an end roll (A or Z position). Even if one can't cherry pick the rolls, one can, for example, match A’s with A’s instead of Z’s to avoid chiral curl in laminated products.

Additional trim must be carried to allow for poor web handling which causes variations in raw material width (July 1995). If the web width varies by 1/4Ó, for example, we will probably have to carry an extra 1/4Ó of trim. Similar allowances must be made for CD position variations (camber, guiding, tracking or weave problems). Finally, trim must be wide enough to provide sufficient strength against the pull of trim systems without breaking.

Nesting trim results when the widths of orders do not match up with the machine width. For example, one will have 1’ of waste when cutting 3’ wide products from a maker which can only produce 10’ wide web. Nesting trim is greatest when cutting large width orders from a narrow machine. Nesting trim increases with JIT (Just In Time) or FIF (First In First Out) schedules as there is less flexibility in selecting orders which fill the machine’s width.

Actual lengths that are greater than the specified length are also waste for the supplier. Many will pad the length of a 100 yard roll by a yard or so to counter uncertainties in the cutoff process or length measurement. Similarly, any roll lengths longer than the least in a set are waste for both the supplier and the consumer on synchronized unwinding processes. Synchronized unwinding processes are common in laminating and sheeting.

Breakdown waste occurs whenever the web breaks, jams or fouls so that the machine must be stopped, cleaned up and rethreaded. Waste here usually includes some of the last of the finished product, all the material in the web path, some of the raw material on the upstream end, and any product that is made out of spec when the machine is coming back online. Breakdowns are especially costly because they engender delay as well as waste. Breakdowns must be carefully recorded as to date, time, grade, order, crew, machine, break cause, location in the machine, lost production time and waste.

Roll waste occurs, as mentioned earlier, if the lengths are longer than specified. The problem here may be one of definition as much as measurement (June Ô95). However, we can also lose material at the top of the roll as the operator slabs off layers to get to fresh and clean web. You may be surprised at how even the shallowest roll cut can cost more than one percent of material. Similarly, we can lose material near the core as people fear losing the tail by cutting it too close. While some can unwind almost down to the last wrap, automated flying splice unwinds may require leaving 1/8Ó or more of wraps on the core due to uncertainties in timing. We also know that the wound roll may be prone to defects near the core, such as bursts and wrinkles on paper. Roll waste can also occur due to damage in storage or handling (cuts and dents). However, the worst roll waste is the telescope or cone where the entire roll may be lost due to the roll shifting sideways during unwinding. The telescope can be prevented by increasing core diameter, reducing roll diameter, or in some cases, by using proper winding tensions.

The waste that often gets the most attention is rejected or out of spec product. Setting rejection criteria must be done with great care. First, we would desire that rejectable specifications are relevant to processing or end use rather than customary. For example, many plants reject based on strength, even though the material rarely breaks in processing or end use. Second, the rejection should be quantitative rather than qualitative wherever reliable tests are available. Qualitative measurements can be improved merely by setting up a series of photographs varying from worst to best against which to compare the product. Third, the sample frequency must be selected which strikes an appropriate balance between consumer, and producer risk as well as economics. Finally, the tests must be based on sound instrumentation (January 97). Our rejectable variation allowance must be within the capability of the test or measure to resolve.

Losses due to each defect must be carefully accounted for and entered into a computer database for routine reports. The database should also be able to export selectable portions of the data into standard files for analysis by PC's. Dedicated mainframes (accounting) or PLC computers (process control) are usually not as nimble and flexible as the desktop PC for custom analysis of trends and cause/effect relationships.

Lastly, we need to troubleshoot the causes of defects. An excellent starting point is 'Web and Roll Defect Terminology by TAPPI PRESS 1995 [current edition is 2008]. This encyclopedia of defects is often used as the basis for quality control systems in many mills and plants. It also is useful to standardize the communications between suppliers and customers who may give the same defect different names. Some people use coning for telescoping, roping for corrugations and spoking for starring, and this is just for common wound roll troubles. Web defects, especially in coating, may have dozens of names for the same or similar defect.

We need to recognize that some types of waste are more costly than others depending their recycle value or disposal costs. Some waste, such as single species thermoformed plastics, can be recycled internally without process compromise and may cost little more than lost profit. Other trim waste, such as paper, may not be as good as virgin material. At the extreme end of the spectrum, some types of waste must be disposed of in landfills or may even be hazardous.

Also, some types of waste are more costly than others depending on where in the process they occur. For example, one has not put much effort into raw material which falls on the floor on the input side of a machine and thus may only cost half as much as product that is rejected at the end of the line. However, the most expensive waste of all is that that is returned by the customer. Again one has paid for the raw materials and manufacturing costs. Additionally, however, one also pays for transportation to the customer, return transportation from the customer, plus trucking and tipping fees to the landfill. Finally, one must reimburse the customer and even then may lose their future business. When analyzing customer returns, always remember that for every customer who complains there may be tens or even hundreds of customers who were dissatisfied in some way but registered no complaint.

Finally, we must track waste as a function of individual product or grade. Some grades could be much more troublesome than others. If so, one has four choices. First, one can accept a loss of profit on a product if there is some strategic motive to do so. Second, one can raise prices to account for higher waste or delay on certain grades which are more difficult to run (Flex-Pack Mgmt 1/1/96). Third, one can invest labor and capital in hopes of reducing waste on a difficult grade. (A halo effect often improves all grades even though the target was merely the known troubled ones.) Finally, one might choose not to offer the grade as the purpose of business is to make a profit rather than sell product.

As we can see, the best ranking of waste problems is not one simply of weight, but rather of cost. It is worth the extra effort to put a value on different waste streams so that one works on those which are most important. We must know first where and then why waste occurs before we can begin to reduce it. This requires a multi-disciplinary effort involving including machine operators, maintenance, quality control, sales, accounting, as well as industrial and process engineering. We should also not expect to get good breakdowns of waste ready for the next team meeting. Rather, we must also allow months and sometimes even years to refine the data gathering process and have sufficient samples to given meaningful conclusions on a wide variety of grades and setups.

Waste is not a dirty word. Rather, it is an opportunity to improve the competitiveness of our machines, processes or companies. We should be continually aware of the sources of waste and their costs. Reducing waste through innovation and perspiration should consume a noticeable part of our daily efforts.

***1998.07 Jul 1998
Plant-Wide Information Systems are the Future

Web machinery just gets better every year through design innovation and improved mechanical precision. However, instrumentation and controls again steals the limelight this year. Substantial advances are fueled, in part, by the ever faster and more powerful microprocessors which are the brains of process controls. In the past, microprocessors were reserved strictly for use by controllers and supervisory systems due to their expense. Now even the humblest of sensors and actuators can be equipped with smarts to help them do their job better, or to carry on a dialogue with a variety of controllers through one of several standard communication protocols.

However, the real show stoppers are the plant wide information systems. To see what is on the near horizon for converters, we can take a peak at what the paper industry is already doing today. Even the most basic paper mill is a rich and complex mixture of computers, PLC's (programmable logic controllers), drives, scanners and other types of components. A challenge is integrating these multiple individual devices which are made by different vendors, but integration is necessary because no single source of information can provide a good picture of the whole.

Some paper mills are now trending more than 10,000 data points for process variables such as speed, flow rates, temperatures, pressures and so on. While most data originates on the paper machines themselves, other sources such as order entry, production, shipping, quality control testing and maintenance feed information to and draw information from these plant wide information systems.

Some applications require fast sampling rates, often exceeding 1,000 samples per second. One example is when there are a large number of sensors that must be checked many times a minute. Another example is drives which require fewer sensors, but each must be sampled every few seconds, if not considerably faster, in order to be useful for tuning and troubleshooting. Similarly, permanently installed FFT (fast fourier transform) systems monitor the spectral content of key bearings, fluid pressure pulses and other dynamic sensors to watch bearing condition as well as help diagnose cyclic problems such as vibration. Finally, a single sensor used for scanning the web may require extremely high rates to provide fine x and y resolutions. Commonly scanned variables include basis weight, caliper, moisture, and optical density.

Sensor and actuator data are stored for periods ranging from days to years depending on the variable's priority and storage space. Current and stored data is available from many locations and is used for many purposes. Most systems can be accessed either by dedicated terminals, or by portable pc's equipped with modems and special software.

Salesman may call up production, scheduling or shipping information to determine the latest status for a customer he or she is visiting. Alternatively, the salesman may doublecheck the compliance of a lot to specifications, or look up its manufacturing conditions. A process engineer may use the system to troubleshoot connections between waste and delay and process measurements. Additionally, the engineer can check the status of the machine without leaving the office. In all of these cases, it is vital that the data have a stored and searchable lot stamp (roll, box, pallet etc) in addition to the more common time stamp.

Maintenance may use use PLC alerts and faults to determine what part has failed or is preventing operation. Finally, modern controls offer exciting new possibilities for training. For example, operators can learn to run the machines offline with the control terminals set in a simulation mode. These have the same advantages that aircraft simulators have for training pilots: unusual situations can be safely mimicked, and mistakes are cheaper.

Admittedly, these modern systems are not inexpensive. They are costly to begin with, and tend to have a short technological half-life. Also, even the most user friendly require initial and recurrent training. Nonetheless, as systems get better and cheaper we expect that converters and others outside of paper mills will find them a strategic advantage.

***1999.05 May 1999

Pushing Web Handling to the Limit

Many would have you believe their grades, processes or equipment are uniquely difficult. However, process troubles can be anticipated to some extent by knowing key web material or physical properties. For example, slippery materials are difficult to wind without telescoping. This challenge is shared by materials as diverse as low COF films and glossy magazine paper. Conversely, materials with a high web-to-web friction may be difficult to wind without vibration or out-round-rolls. This winding challenge is shared by materials as diverse as tissue paper, kraft sack and nonwovens. Other predictive material properties and associated problems include: web breaks and low MD tensile strength, web flatness and low MD modulus, speed/draw control and high MD modulus, wrinkling and moisture/temperature expansion coefficients and so on.

There is one web property, however, that is continually being pushed to the limits and beyond. That is the drive to ever thinner materials. There are large economic incentives to make thin gages, provided that they can serve the same duty as thicker grades do. First, raw material costs are reduced. Second, storage, handling and transportation costs are reduced. Finally, the insult to our environment is reduced. While many associate the drive to thin with packaging grades of web, you will find that everywhere customers and suppliers alike are requesting and designing ever thinner versions. Cardboard, car body panels, clothing, newspaper, and roofing are just a few examples of webs that have seen significant weight reductions in recent years.

Unfortunately, many companies have found themselves in trouble when they tried to make thinner grades. While the details vary considerably with the situation, the roots are often the same. Product developers designed grades for end use, but without regard to processing or handling. Similarly, process developers felt their job was done when they successfully extruded, coated or otherwise manufactured the new grade, but failed to fully consider downstream handling and converting issues. In short, neglect of web handling has caused many novel grades to struggle and even fail due to high waste or other inefficiencies.

Tension Control

The most basic task of any machine's drive is to control tension. However, thin materials present an extra challenge for the drive system in two ways. First, the absolute tension is lower. Second, the tension range and tolerances are tighter. A general guideline for many typical materials is that tension should be between 10% and 25% of the MD tensile strength that is readily available in test labs. However, the appropriate tension for very light materials may be between 5% and 10% of strength. Note how both the value and range are reduced. Now imagine holding these low tensions to within a tolerance of 10% of the setpoint. You will quickly appreciate that a drive may have to effectively hold tension excursions to less than 1% of an already low tensile strength. This may be just a couple of pounds on a wide machine, to just a few ounces on a narrow machine.

Many older machines and even some new ones do not have the mechanical and control finesse to be able to hold low tensions consistently. These tension control shortcomings may be the result of conscious design choices for an originally specified purpose. Sometimes, however, the shortcomings stem from lack attention to detail during the design process. An example here is oversized pneumatic devices, such as unwind brakes which result in low control pressures, or oversized motors which result in low armature currents. Another example would be to incorporate an excessive number of overly large idler rollers which would cause large inertial tension upsets during speed changes. Unfortunately, it can be difficult, often to the point of impracticality, to rebuild a machine to handle low tensions properly. At the very least the drive controls may need rework or upgrading, if not the mechanicals as well.

The results of running a thin web on a brutish machine depends on the circumstances. If the web is brittle, such as paper, expect an increase in web breaks. However, even a ductile material will break if the drive allows the web to momentarily go slack. If the material is stretchy, an increase in tension wrinkling may result. If the process involves lamination, expect that curl and flatness may be inconsistent. If the process involves printing, expect registrations to vary. Tension control is vital for web processing and handling, and no where is tension control more challenged than on thin grades.

Wrinkling

Thin webs are also prone to wrinkling because the buckling resistance goes down with the cube of caliper. Thus, a 40 gage film is not twice as wrinkle prone as a 80 gage film. Rather, it is 10 times as wrinkle prone! Few process engineers and even fewer product developers, marketing directors or managers appreciate just how much harder it will be to handle even a slightly thinner material without wrinkling. Thus, the expectations and excitement of a new grade can be replaced by disappointment and frustration as waste rates remain stubbornly high.

Sometimes the wrinkles are generated by the web manufacturing process itself. For example, coating or printing on paper; oven drying, curing or metalizing of film are just a few examples of expansive processes which can generate MD trough wrinkling. I have seen many process that were not able to run thinner materials without wrinkling them because of the insult of water, solvents or heat addition. This often leads to finger pointing at the raw material supplier and/or machine designer when the largest factor was the very design of the product or process itself

Thin materials are also more demanding of many aspects of mechanical maintenance. In particular, roller alignment and diametral precisions become much more important. For example, a thick material may take a 20 mil bulge or groove on a roller without wrinkling, while a thin material may only allow a 2 mil diametral variation. I have seen many materials that were so fussy that tails could not be conventionally taped to the cores without starting a wrinkle at the tape patches. I have seen more than a couple materials that were so fussy that the gaps or overlaps in the seams in the fiber core were enough to trigger a defect.

Thin materials are also more demanding of web uniformity. Tiny absolute variations in manufacturing become relatively larger with thin materials. The result is that profile variations of caliper, formation, moisture, temperature and many other factors can result in webs that have baggy lanes or patches which become more vivid as caliper is reduced. Further troubles are seen in winding when gage bands, sometimes below our threshold of simple measurement and control, build to cause ridges and other difficulties on the wound roll.

Figure 1 shows examples of wrinkles caused by expansion, roller alignment and roller diametral variations. A generic treatment of many types of wrinkling is to use spreading devices such as concave, bowed or expander rollers. However, thin materials not only need more spreading attention because they are more wrinkle prone, they are more difficult to apply spreading to. The reason is that most spreaders require traction to operate, which in turn requires tension, which is minimal on thin materials. Without tension, spreaders can't grab onto the web very effectively.

Air Entrainment

If the above challenges weren't enough, we have even more if we try to run thin materials at high speeds. Since many of our formers can run thin materials faster, we will try to run thin faster for the economics of productivity. The two challenges of high speed handling are air entrainment between the web and roller and in the winding process. Though both shares many similarities, the resulting problems and treatments are somewhat different.

As a machine is sped up, more and more air is brought in between the web and roller as seen in Figure 2. The amount of air brought in depends on several factors including speed, web tension, web bagginess and roller diameter. The result is that the web will lift off of the roller given enough speed. Obviously, control of tension, position and many other factors is then lost. The treatment is to either roughen (moderate speeds) or groove (very high speeds) the roller surface. The catch-22 is that while thin materials need more air handling treatment because their tensions are less, wider grooves will tend to make wrinkles on thin materials. (Spiral grooving does not spread as widely believed.) A starting point for maximum grooving width is no more than 10-20 times the minimum web caliper. This makes the grooves so narrow on thin grades that they are more like scratches. Not only are micro-grooves more costly to machine, they are also harder to maintain, especially in the presence of adhesives, coatings and paper dust.

Similar challenges are also found when winding thin materials. Here, however, air is brought into the wound roll which can cause several difficulties. First, air causes loose winding. Second, the air can outgas during storage causing the roll to buckle and collapse. Third, air can cause the outer layer to lift off of the roll so that control of edge position, tension and other web handling factors are lost. The most common treatment for air entrainment during winding is to use a layon or nip roller as shown in Figure 3. Unfortunately, some air will still be brought into the roll. It is then possible for the air between the layers to collect behind a nip and even burp through the nip as a wrinkle.

Thus, the nip roll which provides the beneficial reduction of air entrainment is also responsible for the undesirable bubble behind the nip. Sometimes this can be alleviated with strategic application of wide but shallow grooving of the drum or layon roller.

Go For It

Changes, whether they be of lifestyle or web process, can be desirable in the long term. We must recognize, however, that these changes may well be difficult in the short term. To improve our chances of success we should arm ourselves with as much knowledge as possible. We should expect a period of difficulty where new problems must be solved before the benefits are accrued. Losing a few pounds of web basis weight or a few points of gage can be just difficult as taking a few pounds or inches off of one’s middle. However, the result can be as rewarding.

***1999.07 Jul 1999
Has the novelty of modern displays outworn their welcome?

In past columns, I have lauded and applauded the advances in sensors, instrumentation and controls. Indeed, many of the recent machinery advances have been electrical rather than mechanical. However, in good conscious I must caution that this new technology is a two-edged sword. In many cases, our controls have now become so intricate and confusing that programming a VCR looks easy by comparison.

Perhaps an analogy may help. To learn to drive a car, it takes about one-half semester of classroom and about 40 hours of dual experience to pass the tests. Once you've learned to drive one car, transitioning to another make or model would take less than an hour if the vehicle was not substantially different such as having a manual transmission or was a commercial vehicle such as a semi-truck. Part of the reason for the ease of transitioning is that the controls on vehicles are standardized far more than is apparent. Steering wheels are always centered, the left foot is the brake, while the right foot is the gas. Even though there is some creativity with switches, the turn signal lever and headlights are on the left and the radio is on the right, though the dome light, could be found on the left or overhead. Transitioning from a car to a motorcycle takes only about 10 hours of classroom and about 10 hours of road work. Transitioning between bikes is but an hour or so because controls are few and very standardized.

To learn to fly an airplane, on the other hand, takes about one semester of classroom instruction and about 80 hours of dual experience to pass the tests. Obviously, learning to fly takes longer because airplanes are more complicated than cars. However, once you've learned to fly one airplane, transitioning to another takes about 5-50 hours depending on the situation. One of the reasons for this steep transitioning time is because only the wheel and six instrument cluster is even close to standardized. The placement and operation of other devices differs greatly between aircraft.

How does this relate to converting machinery? Simple, all of these examples are machines which require an initial learning curve which depends on complexity, and a transitioning time that depends on complexity and standardization. Surprisingly, a full-featured coater , printer, laminator or winder will have more controls than simple airplanes! Furthermore, there has NO standards for industrial controls except the shape and color of only one button: the E-stop. Thus, it should not be surprising that learning to operate some converting machines could literally take years and transitioning could take months.

Benchboards, control panels and CRT screens are the link between man and machine and are vital for the health of the system. Yet, not enough attention has been given to how the human uses the interface because the awareness of industrial ergonomics has not penetrated much beyond carpal tunnel and back injuries. It is a shameful industry secret that many of our controls have been laid out by designers who have never operated a converting machine in their life, and may not have studied operators or ergonomics. Thus, some panels are so disorganized so that it almost seems that the required inputs and outputs were put in a bushel basket and thrown at a blank panel. Wherever the device landed is where it was placed. Even the basic shape of the benchboard can lack attention to human engineering. A well-designed benchboard is something like a tilted desk with a 'knee hole', for a swiveling armless stool, and has a blank writing surface. Instead, we find panels that one can't sit next to without a long reach because it lacks the knee hole. Auxiliary furniture must be cobbled up to give the operator a place to handle the paperwork which is inevitable in even the most modern environments. In many cases, the control panel is so tall or poorly positioned that the operator loses visual connection to the machine.

Labeling on panels and screens can also be so cryptic that I often can't tell what a fair fraction of the knobs, dials and meters actually represent. While pictograms are a nice supplement, they should never be a substitute for word labels because pictograms are even less standardized. Obviously, all analog inputs and outputs should be in standard engineering units (nip pressure in PLI instead of psi of cylinder pressure, for example). In extreme cases, I have had my clients employ an engineering co-op student for an entire summer to calibrate or reverse engineer some winder nip curve or other control as even the builder's documentation does not reveal precisely what physical forces are imparted to the product for a given benchboard setting.

We now see the ubiquitous use of numerical readouts, though we long knew that they compared poorly to an analog needle or bar. For example, a gage with a thick needle or bar can be read from 10 feet away for average and variation. However, a readout requires reading proximity and mental averaging of a flickering number. (Consider the numerical speedometers that first appeared on cars in the '70's. How long did the utility/novelty of these 'modern' displays last?). Also, the response time of a gage can be much faster than a display and thus is helpful for reading things like motor loads and web tension variations. The most useful screen design for analog inputs and outputs may include both a number and a bar. While computer screens offered many possibilities for improving the ease of use, in many cases poor layouts contributed to the problem. A illustrative example is controlling speed which was, in more practical times, input by a user friendly dial. Now, some operators must change screens, type in a new number, verify and enter just to bump up the speed, tension or other value. Worse yet, I've seen systems that require creating a new recipe to get a new speed.

How do we more effectively use rather than abuse modern control technology. First, the controls must be viewed from a different perspective. Rather than 'controlling' a machine, controls are an interface or conduit between a man's brain and machine's brawn. From this viewpoint, the goal is to improve the interface or conduit rather than extend the list of things that can be read and adjusted. It is not unlike word processors. While I have personally used more than a score of writing programs, my most capable and favorite were written in the late 1980's for a computer whose survival is often in doubt. Now, the processors on all machines are feature-0laden bloatware as the designers are programmers rather than general users. (Word processor instruction manuals can now exceed 1,000 pages so that one can learn to play sounds and Internet sites from your memo). Second, the education of designers needs to be well rounded and include actual machine operating experience, time/motion studies of operators and schooling in ergonomics. Third, the sharpest and most creative operators should be employed to suggest design features and to evaluate prototypes of control layouts in a simulation mode. Fourth, the industry should try to emulate the most successful interface layouts, much as software writers have copied the GUI's of innovators such as Apple and Commodore.

In some broad sense, controls are like colors. It costs no more for green than it does for blue or red, except a bit more time for study and shopping. Yet it can make all the difference in the world when your effectively coordinate colors in clothing, gardens and interiors. In a more serious vein, you can save product and even a life by carefully considering control placement. This was made most evident to me one day when flying a different plane when I reached without looking to throttle back in the landing pattern and accidentally pulled the mixture to full lean (off) on a non-standard control.

***2001.05 May 2001

What do we do with all this data?

Does more process data automatically mean more process knowledge? Not necessarily.

Many mechanical designs are on the mature end of their design life cycle. While there are certainly innovations in the details, the changes are often evolutionary than revolutionary. The evolution comes from field-testing and refinement, emulating successful approaches used elsewhere and, most importantly, the application of sound engineering and science. Even with such refinements, the types of guides we use now; unwind, winder, displacement and steering, are the same types as used decades ago. The same is true of other machines such as winders. We have center winds, centerwinds with layon rollers and center-surface winders, just as in the past. We have reels, turrets and two-drums, just as in the past.

In stark contrast, however, most process automation is still on the "adolescent" end of its design life cycle. Process automation can be likened to a teenager, who outgrows clothes or tires of the style in less than a year. Like a teenager, process controls are quite capable of doing useful work. Like a teenager, however, they sometimes lack direction and motivation, and can even be obstinate and troublesome. It is not uncommon for them to be self-centered rather than benevolent.

For better or worse, however, our future is in the hands of automation—and teenagers. They give us the certainty of change, if not the promise of better ways. It is our responsibility to understand these changes and guide them to their maximum potential.

Data, data everywhere

To know where we are going, we must first know where we came from. The evolution of process automation begins with sensors and actuators. A sensor might be a load cell for tension, or a beta gage for basis weight or caliper, or a camera for defect detection. An actuator might be a drive motor, or a CD profile thermal jack on a die lip, or a web-marking system.

Even though sensors and actuators are generally more mature than their supervisory controls, they are still evolving. Onboard computer chips can do local data manipulation and simple control, as well as manage two-way communication with the outside world. Local digital control is generally faster than supervisory control but, surprisingly, still not always as fast as analog circuits are. Local intelligence also allows sensors and actuators to be more precise because they can compensate for certain complications of the real world such as ambient temperature changes, profile imperfections and so on.

The digital revolution has on occasion radically changed mechanical design. For example, the new servo drives on printers, packaging and other machinery give us an 'electronic line shaft' option with many advantages.

First, we can exchange inflexible mechanical complexity for flexible control complexity.

Second, we can do things that are difficult to do mechanically, such as change registration and repeat length on the fly.
Third, the drives can report on their status and health in much more detail than can a mechanical drive.

Another example is the 'smart' layon roller, dancer or other pivoting device. The control system 'knows' where in the stroke the device is and can compensate for varying gravity, mechanical advantage, friction, interaction with other variables and so on. The result is better precision and more mechanical and control flexibility.

However, the biggest trend may not be the mere digitization of sensors and actuators. Rather, it is in the number of sensors. Machines built only just a couple of decades ago may have been equipped with not much more than a speed meter and a few motor ammeters. Even web makers may have had only a few pressure gages and temperature readouts to guide the process developer and the machine operator. As recently as three years ago, the most abundantly sensored paper mill had 10,000 sensors. These days, many paper mills have more than 20,000 sensors that report to data acquisition systems. Obviously, most of us do not have that many sensors, much less log them all into a computer, but the trend is still the same.

Not just data—knowledge

As computer automation began to have an impact on American manufacturing, it was assumed that knowledge is power and that data was the key to knowledge. Thus, we bought sensors and data acquisition technology with the expectation that our processes, and thus our products, would somehow improve. However, the results have been variable. In some cases, the sensors allowed closed-loop control that made the machine, and thus the product, much more consistent. In not a few cases, however, either the sensor, the actuator, or the control algorithm was not trustworthy enough to be allowed to control a process. In other words, the process was more stable when the automatic controls were turned off. Managers assumed that technology would make a better product, but the potential benefits are not always realized due to oversight of a few key details.

The most serious limitation we are now running into is the lack of process knowledge. For example, a new winder can program 'curves' for each of the tension, nip and torque functions. Yet few operators or managers know how to select a curve to minimize a single defect, much less minimize the sum of several defects.

The result is an infinite number of potential curves without guidance on how to make use of the capabilities. In fact, the computer controls sometimes get in the way of learning about our processes because one can't just go in and 'twist a knob' because of the many interlocks and other control restrictions.

The same is true of sensors. So what if the sensor shows a process variation? The real question is whether this variation does (as opposed to can) contribute significantly to product variability. Next, whether that specific variability of the product causes a real or a perceptual issue with the customer. All variations are not equally important, yet the control system makes no distinction. We human operators must make that distinction based on our knowledge of our process, product and customer.

Sometimes technology is not used the way we think it is. I recall a recent visit to a client whose engineer insisted that they were using taper on the winder. I discovered that the operators had not used taper for years. The engineer knew what should be done but did not know what was being done. The operator knew what was being done, but did not know what should be done. The sad thing here is that the client wanted to buy a new winder just because it had more knobs and thus might give them a better product. They did not effectively use the one knob they already had. In order to use new technology, we must go to school—both in the classroom and in our plant.

Sometimes technology forces us to learn more about our plant systems. Consider scheduling software that takes customer orders as inputs and then outputs a schedule for a machine. The simplest scheme and most attractive for just-in-time (JIT) is first-in-first-out (FIFO). However, some customers don't need as quick a turnover as others. Also, to run this type of schedule raises waste and delay because it requires machine changes from one grade to another and then back again.

An improvement might be to weight scheduling so that it groups similar chemistries together, so personnel don't have to clean the machine and vats as often. In contrast, changing thickness or speed can be done more gracefully and is thus weighted less for scheduling priority. On top of all of this, it gets really complicated when one tries to nest various individual smaller wound-roll widths to fill out the width of a machine with minimum trim waste. Scheduling software forces us to decide what is important. For example, is a day quicker turnaround on an order worth more than a 5 percent loss of throughput and a 2 percent increase in waste?

Payback

Every investment must provide an economic payback. The easiest payback for process automation may be reduced delay. Control systems can report the time cycle or heartbeat of the machine. If it skips a beat during the night shift, you will know right away when you sign on. You can look at the control data before the event so see if there were any precursors for the trouble. If a new crew is struggling, it will show up. Obviously, this will not replace the need to go down to the floor and talk with the operator, only that it will make the dialog more meaningful. Process automation can also reduce the time to make grade changes and other setups, especially if the recipe has been preloaded. Though not new, defect mapping is becoming much more common and useful. One example is a high-speed camera that inspects the entire web for variations in brightness and passes the data to a computer. The computer is taught how to classify different patterns of brightness variations as an indication of a certain type of defect such as, for example, a streak, thin spot or hole. These defects are color-coded by type and displayed on a plot for the width and length of a roll.

In some cases, the mapping is used merely for troubleshooting. In more sophisticated installations, the defect map is downloaded to the rewinder, which automatically stops at each location for visual inspection by the operator. Manual inspection is often required, as the system may generate false positives and inappropriate classifications.

Other important returns for process automation are reduced waste and customer complaints. However, a subtle limitation on data systems used in plants can cripple its utility here. The difficulty begins because process information is acquired on time-based intervals while lab test, waste and customer complaints are acquired on lot-based intervals such as wound rolls or boxes. Also, the time the data is acquired is different. Process data is available immediately, test data is delayed by minutes to hours, and customer feedback is delayed by weeks or months. To stitch the data together from the various sources requires a lot of effort.

First, you must get the roll number from the customer and then look up what time interval that roll was produced. Hopefully, both you and the customer are absolutely consistent in what you mean when referring to a defective roll.
Then you must go to the process system and download the data for the interval when the roll was produced.

Finally, you may need to attach the lab data for that roll or the closest roll to it that was tested. While this is doable for a single roll, a single roll rarely gives you insight into a problem. Rather, you must statistically compare sets of rolls that are good with sets of rolls that are bad for a particular reason on the same grade.

In the real world, the data is obtainable, but is almost unusable for problem solving because few of us want to take the time for data synthesis. More often, we make use of only what is convenient.

It is imperative that the next generation of software allows us to simply and artfully sieve the wealth of data just sitting in the computers. We don't need more data and more graphs. What we need is more insight—the kind of insight that can truly help us improve the process and the product.

If you found this article helpful, ENTER 240 or Inquire Online.

Try it online

Telephone help can be frustrating for the user and expensive for the provider. While not every problem can be solved without a physical visit, the net is fast becoming our first stop. Recently I asked for drawings and manuals for a small printing machine. I was pleasantly surprised to find that these documents were online and, more importantly, almost as easy to use as their paper counterparts. The online version might be more accessible than the paper version that is locked in Joe's office or, more likely, lost. The online version is also the most complete and the most up-to-date.

Other encounters with online instructions were not as smooth. Some formats require you to scroll up and down to use, like reading a book through a magnifying glass. Sometimes an instruction manual download takes many minutes. Do not hesitate to ask for a paper version of the help manual if it better meets your needs.

Online help allows the supplier to provide more with what may be already strained resources. They can more efficiently work on a problem once they have background information such as customer, model number, web products and problem category. Astute suppliers track online help as a form of customer feedback so that they can improve the next revision of products. Also, many suppliers have a searchable FAQ section. It is unlikely that you are the first to have any particular difficulty. Finally, some control systems can be connected, via phone line, back to the builder's facility so that they can see real-time status. Working in conjunction with the onsite technician, an expert can guide the troubleshooting and repair process. The products that have these remote diagnostic capabilities are obviously high-end, but are neither unusual nor unusually expensive. Online services are often provided as part of an optional maintenance package. To take advantage of these opportunities, we will see more web-enabled computers on the plant floor.

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To control costs: Work smarter

Want to really control your costs? You must first identify them—down to the smallest bit of scrap.

Come month's end, bills burn the better part of our paycheck and then some. Making more money doesn't necessarily solve the problem, because all we do is spend more. Investments for the future are deferred to the future. Today we struggle just to keep our heads above water. We can't seem to get ahead.

This scenario may apply to personal finances, but business finance is no different. In order to control our destiny, we need to control our costs with just as much vigor as we demonstrate in making our product and pursuing customers.

However, before we can control our costs, we must first know where the money is going. In our personal life, a financial advisor would counsel us to keep track of how we spend our money, even pocket change. Expenditures would be grouped into categories such as housing, utilities, food, transportation, recreation, investments and so on. The categories in business are different—such as raw materials, direct and indirect labor, utilities, and so on—but the principle is the same.

Raw materials

The largest cost category in most manufacturing businesses is raw materials. To reduce costs we might look at less costly materials. Perhaps we may sandwich cheaper materials in the core of a product where they are not so vital, and save the better stuff for the outside. We can also expect that gage to be thinner every year, taxing our tension and wrinkling-control prowess. In order to capitalize on these opportunities, we may need to spend capital on equipment. Examples would be more versatile extruders, better drives, and spreaders.

However, upgrading equipment may not necessarily reduce raw material costs. Even if it does, it may not pay for itself in the year or so that most companies expect for payback on capital expenditures. We must also factor in additional startup labor and inefficiencies that seem all but inevitable. Reducing per-unit raw material costs is not always straightforward because the process/product must be redesigned.

In the excitement of new products and machinery, we often forget that it may take months or years before the new stuff runs as good as the old stuff did. In order to improve our prospects for success and speed up the payback, we must have a staff of product and process developers who know their business. They and their supervisors must exercise good judgment in where they apply their efforts, as well as their company's money.
Another way to reduce material costs is to reduce waste. We first begin by auditing our processes to find out how many pounds are lost per year in different parts of the process. This audit may be as simple as weighing the "piles" that didn't make it through the process and out the door to the customer on the first pass.

However, the cost of waste varies depending on the position in the process. Waste on the upstream end is less expensive than on the downstream end because less effort has been invested in added value. Also, waste on the upstream end may have a greater recyclable worth before other materials are mixed in. Sometimes all it takes is a thin coating to degrade the worth from half of what the finished product is worth, to having to pay to have it hauled to the landfill. Waste rates and costs will vary with grade, so you must weight the audit by the relative sales of each grade to come up with a yearly average.

Is it trim or waste?

I am surprised by the naiveté of many people in the plant who think that trim is not waste because it is recycled. Waste is any material that does not make it all the way through the system to the customer on the first pass. It does not matter whether it is on the ends or in the middle as bleed. It does not matter what the reason, such as bad edges or the differences between product and manufactured widths or failure to meet spec. It is all waste just the same. Its value is, at best, only half of what it would have been had it been manufactured successfully.

The analogy I like to give is tap water. If you look at the big picture, tap water is recycled. First, the water goes from our drain to the wastewater treatment facility and then to the lake (or ground). Then we pump water out of the lake (or ground) and purify it in a water-treatment facility. Using this logic, water is recycled—so we shouldn't concern ourselves with closing the faucets when we are done.

The most expensive waste you can make, by far, is customer returns. Here, you've invested all of your raw materials, labor and energy into the product with the expectation that it is good. Your customer, however, thinks otherwise. Trying to meet customer needs, you will send your salesman and engineers to the customer to determine what the problem is and how to fix it. If you are unsuccessful, you—and your product—will come back home. You may lose the next order or even the customer. The costs of a pound of returned product are harder to estimate, but could be 10 times more than a pound of internal waste in a plant.

Once you know where the waste is going, you can brainstorm ideas on how to reduce it. For example, if the waste is produced during grade changes, you could charge more or even refuse small or JIT (Just in Time) orders. You may also try to make the procedure more efficient through an industrial engineering time study of the changeover or by order nesting.

If the problem is breakdowns or jams, you might assemble a multi-disciplined technical team to first determine the causes and then brainstorm ideas to fix them. Again, reducing raw material costs by reducing waste might require an equipment upgrade. However, it certainly requires an application of process knowledge above what had been practiced previously.

Labor costs

The second-largest cost category is usually labor. The simplistic approach to reducing costs here is to cut wages and lay people off. While wage cuts are not common, staffing cuts are. Thus, librarians, receptionists, secretaries and QA testers are now almost extinct. Instead, the higher paid professional staff must find things, make copies and perform the innumerable other tasks that were previously done by support staff. Operators must do double duty as testers and mechanics.

The question is not whether others can do these more mundane tasks. Rather, it is who does them best, most efficiently and at the least cost. If you examine these tasks with this viewpoint, you may conclude that the most efficient workers for many tasks are the librarians, receptionists, secretaries and testers that were just laid off.
Indirect labor also includes technical positions such as maintenance and engineering. Sometimes it does make sense to contract maintenance out if it is sporadic or requires special skills or tools. However, this doesn't help much in the middle of the night when the line goes down and there is no one to even answer the phone at the service shop. Engineering is also being downsized. Corporate staffs are being dissolved, with some being sent to the plants. Sometimes it is the plants that relinquish their engineers in order to consolidate the last few at corporate. Doing more with less has left the technical people overworked to the point of exhaustion. More and more, we rely on vendors and equipment suppliers to do what was previously done in-house.

The danger here is the "fox guarding the henhouse." It is beguiling to believe that an upgrade will make things better. However, as in the case of computers, an upgrade is just an upgrade. Despite a dozen 'upgrades', my word processor is no faster despite a 100-fold increase in clock speed, and is actually less capable than it was 15 years ago.

Direct labor can also be reduced by eliminating or grouping positions. However, this may not always produce the intended results. I recall a story of a new paper mill manager taking his first tour of his plant. He noticed three workers sitting at a bench and asked the foreman "Why aren't these people working?" The foreman walked over to the paper machine and broke the web. The three workers—and everyone else in the area—jumped up to clear the jam and rethread. The foreman told the new manager, "Now they are working."

His point was that when these people are working it probably is because the machine is not making paper. For operating personnel, the most important consideration is to reduce downtime. There is nothing worse than paying someone to run a machine that is not running. Again, we must audit our processes against downtime codes and causes. Then we use our application knowledge and brainstorming for innovative fixes. It also means making people more efficient by reducing the turnover and, most importantly, training. Indeed, there is no lack of opportunities in our plants. Rather, we have so many opportunities that we must pick our battles so that we can achieve the most savings with the least effort. This is especially important if time and talent are our limiting factors, as they usually are.

The answer is the same whether the cost problem is waste, delay, energy or some other category. The answer is the same for paper, film, foil, nonwovens or textiles. The answer is to work smarter. We need to first know what the costs are so that we can prioritize our efforts. Then we need highly trained people to cover the variety of skills needed to run a plant. Finally, we need innovation and willingness to change. Otherwise, the costs will be the same tomorrow as they are today.

***2002.06 Jun 2002
Process Automation: Kudos and Cautions

I have been involved in converting machinery controls for almost a quarter century. I have seen controls perform miracles that would have been undreamed of just a couple of years prior. I have also seen controls misbehave so badly that they kept brand new machines down for months until they were bypassed or replaced. Because of these extremes of performance, my views on automation, computers and controls have swung from techno-nerd to Luddite and back again so often that I get dizzy just thinking about it.

At first blush it seems that there is no predictable formula for success. Some modern drives can literally sing songs, while others perform more poorly than their mechanical brake, chain and flat belt predecessors. Some gage profile controls improve product consistency while others must be shut off because they destabilize controls. Sometimes automation pays off. In other cases, reduction of operating labor is more than offset by the need for increased technical support labor at a net loss for the company. However, upon closer examination of projects, there does seem to be a factor that correlates with success. Those that do their homework fare much better than those that just buy or build stuff. This homework begins with an understanding of the economics that underlie a particular situation. What realistic savings in waste, delay, maintenance or safety are expected for upgrading controls? What are the incremental costs? What additional support is needed? Finally, what are the risks? Some projects fail to live up to expectations.

In this brief treatment, I can only share with you some generalizations I have found from experience. You must judge for yourself what is best for your particular situation. Each process has an optimum level of controls beyond which there is no incremental payback. A different response may even be needed for nominally identical side-by-side machines running different grades. A different response may be needed for the second of two nominally identical machines running the same grades, but coming on line but a few months later.

Drives

Kudos. AC vector drives have reduced mechanical maintenance because they do not have brushes that the venerable DC drives do. They also have better control finesse that can be helpful in some unusual applications. AC vector drive technology has matured considerably since its introduction to high speed paper rewinders in the mid 1980’s. Teething pains of obsolescence of early models and difficulty taming the response of these hot engines is long past. AC are no longer much more expensive than DC, they are similar depending on the horsepower rating.

Kudos. Servo drives can literally sing. Applications such a printing press registration and packaging machinery have been revolutionized by this technology. Inshafts and gears are getting scarcer every year as we trade mechanical complexity for control complexity.

Cautions. AC drives and servo drives have no practical performance advantage over DC drives in most applications. In fact, I have seen more gruesome drive startups in the last two years than I have in the last two decades. The problem is obviously not with the hardware or software that is much more capable than when I started in the industry. The problem is wetware. Very few people understand what a drive is supposed to do (web handling) AND know how to do it (drive programming). To make matters worse, the new software is so beguiling that ordinary human beings think they can program drives. This is rarely the case. Only a fraction of those who tune web drives most days of the week, year after year, can tune web drives well for difficult positions like unwinds and centerwinds. The operative word here is WEB drives. You could commission a drive and drive engineer famous for robotic or machine tool motion control finesse and have them fail miserably on a web application.

Scanners and Gauging Controls

Kudos. Scanners have been around for several decades on paper machinery. Measurement of basis weight, caliper and moisture is standard equipment on the thousands of paper machines throughout the world. This has revolutionized troubleshooting of process variation problems. In the past two decades, the measurements have improved to the point where they are (often) trustworthy enough to be given responsibility for profiling controls. Gage controls have made paper ever more uniform and more runnable at their customers. Waste and delay have been clearly reduced in most cases and payback has been achieved in many cases.

Cautions. Paper scanners cost millions of dollars. The associated gage controls are even more expensive. They are so complex that they often demand the full time, onsite support service of the equipment manufacturer. However, even with the paper industry's breadth and depth of engineering resources, problems are common. It is not unusual for gauging controls to be shut off or manually overridden because they degrade performance and destabilize control. These challenges are even more severe in other industries that do no have the resources the paper people have. Also, it is more difficult to accurately measure thin materials, like film, than thicker materials like paperboard. Insufficient measurement sensitivity is usually the limiting factor with profile controls. Sensors are not good enough to 'see' gage related problems that show up in winding. If they can't see them, they obviously can't correct them. It should go without saying, but I need to anyway, that do-it-yourself gauging projects do not work. Every one I've seen on thin webs has failed so miserably that not a minute of production was made under their direction.

Process Controls

Kudos. Process controls have made our processes more responsive, more flexible while at the same time more consistent. What was a series of grade adjustments made by an operator who may have varying experience and knowledge is now made by the (hopefully) best practices of process knowledgeable people. At the very least, every shift produces the same as the last because the operator is given less direct discretion on process changes. Grade changes are faster as a new recipe is called up within seconds.

Cautions. Control screen ergonomics are universally abysmal. They look like they were programmed by a computer programmer, electrical engineer or technician who has never operated a machine before. In fact, this is almost certainly the case. It is also almost certain that control designer never studied ergonomics. In rare cases, the programmers consult operators during the design phase of the project. In even rarer cases, they study the new operator's difficulties after startup to revise their first effort.

Defect Detection

Kudos. Defect detection has been made possible by the increase in computer processing speeds. 100% scanning can be done even at paper machine speeds of thousands of feet per minute. At first I was highly dubious, but I've seen a couple of paper machine installations that could flag coin-sized defects without too many false alarms. Slower and narrower machines should be easier or less expensive.

Cautions. Low contrast defects are more difficult to see with a camera than with your eyes. Also, the correct camera for this application is a 1-D linescan, not a 2-D camera. Again, don't do-it-yourself. Finally, picking up defects does nothing in itself to save money. You must either reject that material (are you prepared for the costs?) or diagnose and fix the root cause (do you have the resources to do so?).

Roll Handling

Kudos. Operators in many companies never touch the rolls they make. They are wound, discharged, wrapped, labeled and stacked in the warehouse by hard automation. (Robotics are sometimes used but are not usually not the best choice because the forte of robotics is reprogrammability not repeatability). Automation can eliminate one or two operating positions at a machine.

Cautions. Obviously, the reduction in operating manpower must be great enough to pay back the difference between fully automatic and fully manual roll handling stations. However, the real issue is reliability. Any component failure not only brings the roll handling down, it can sometimes take the producing machine down with it. Older manual systems have fewer parts and thus tend to fail less frequently and are simpler to repair. In fact, repair is not the right way to think of reliability. If a mission-critical component fails in the first year (where recovery takes an hour) or first decade (where recovery takes the better part of a shift), the component should be redesigned. If it failed once it will likely do so again. The problem is not so much this particular failed part. It is that this part is but one of the hundreds of mission critical pieces. Each and every one must have extraordinary reliability in order to keep the entire system up and running.

Administrative or Supervisory Controls

Kudos. Systems now keep track of nearly every aspect of manufacturing from order entry, to scheduling, production, label printing, inventory and shipping. Waste and delay are tracked and reported. Online diagnostics, training and help are available for operators and maintenance. We can do more with less.

Cautions. Supervisory controls are even more difficult to calculate payback because the benefits are not so directly tied to waste, delay and labor reduction. It is not unlike office automation. Will an upgrade in computer hardware or software make a person more productive or will they eat up any potential gains in equipment costs and the installation and retraining time?

Training

Kudos. With operating turnover sometimes as short as month, initial training and recurrent training is imperative. A few high-end systems offer online training or simulator training to assist other more traditional routes.

Cautions. Practical online training is almost unavailable. Builders are often exhausted by merely making systems that operate. Instruction manuals, documentation and training are the last parts of the project and thus the first to be dropped if they run short on resources.

Safety

Kudos. Automation can increase safety by having multiple levels of barriers, interlocks and permissive to keep operators away from hazardous situations. Automation can do things that were previously done manually, thus freeing the operator from hazards of repetitive motion disorders or the risks of close man-machine interaction.

Cautions. Automatic operations, such as in wound roll changes and roll handling, can catch people off guard. A robot has such a nasty backhand that it is best to never enter the rink with it unless multiple levels of lockout-tagout have been put in place.

Conclusion

Successful control upgrades mean that money has been returned to the company's stakeholders' in any number of ways such as: reduced injuries, increased speed, reduced waste or reduced downtime. Alternatively, quality can be improved such that new orders fill the machines and price increases can be passed on to those customers who demand the best. Success is not guaranteed and not every outcome is predictable. However, chance favors the prepared mind. The ones who tend to do best have done their homework instead of just making or buying stuff.

It is the responsibility for the supplier to make things work smoothly and reliably. Reliability is easily measured and can be specified as a minimum acceptable MTBR (mean time between repairs), MTTR (mean time to repair) or % uptime. It is the responsibility of the consumer to make sure they buy the right things from the right people. They must also have the resources to support and make use of the new technology. The right things are those which return the most to the economic shareholders of the company. It is the responsibility of all to do their homework before the project begins, even if the project must be put on hold to get better answers.

***2007.07 Jul 2007
Upgrade Your Web Line

A well built web machine may have a useful life of decades. This does not mean that all you need to do is to change the filter and add oil. Machines often need to be upgraded at least once in their lives. This may be done to merely maintain functionality, such as when components wear and direct replacements become unavailable. More often we will try to increase functionality such as to run new products, improve quality or increase speed.

The path to an upgrade always begins in the same place; economic justification. Some situations require very little formal justification; such as if safety equipment is lacking or severe breakdowns threatens production. More often you will be required to justify capital expenditures based on requirements which vary with companies and circumstances. A common requirement may be something like a payback of 1-2 years. [THE FOLLOWING MIGHT BE DELETED IF YOU NEED THE SPACE: People often wonder why such a high bar. The reason is high risk. If you invested in a bank, the risk is negligible and a payback of a half dozen years would be fine. The stock market is even riskier, but usually pays off more quickly. Capital expenditures have a much greater risk and thus the stockholders are going to want even more return.]]

Payback is almost a given for adding capacity when existing machines are fully utilized and comfortably profitable. Here the only barrier may be the availability of capital and market outlook. Payback is much more difficult to justify with improvements in waste or delay. This is a major disappointment to many in a plant who would like to improve their process or product. Even such worthy goals of continuous improvement are still subject to the harsh laws of economics.

The next step is to carefully define what it is you want to do. This involves careful specification to meet the economic justification. Padding here is a big temptation and more than a bit disingenuous. Just because you may be getting capital does not excuse going on a binge. Also beware of over specifying what the rebuild is to look like. Define what you want to do, not how you want it done. This is where you want the builder’s experience and ideas to add to your own rather than fit into your own. Most important of all is to include lead operators in all major steps in the process. They, more than any others, will keep you out of trouble with devil in the details oversights. Major specifications are documented in an RFQ or Request For Quote.

Where do you send these RFQs to? Look to suppliers in directories such as the Converting Magazine’s Buyer’s Guide. Send out at least a half dozen requests because a good purchasing department will require at least three quotes from which to make a decision. You may have to meet with the suppliers once or maybe several times to make sure that everyone understands what is needed and what is being offered. Selecting the proposal and writing a contract are very important but beyond the scope of this article.

[THE FOLLOWING MIGHT BE DELETED IF YOU NEED THE SPACE: Briefly, going with either the best or the cheapest are not always the best strategies. The best may not be needed for undemanding and straightforward applications. However, the cheapest may not have the breadth and depth of coverage should things become difficult during the startup.]

What upgrades are more common? Probably drives for three reasons. First, many machines have a mechanical speed limits beyond or well beyond the current drive speed. Most old paper machines are operating well in excess of their original design. If you can increase capacity, you can usually get easy payback. Of course, you may have to upgrade coaters, dryers and other speed dependent processes, but we usually know how to do this as well. Another reason to upgrade drives is to improve performance of its duties such as tension control. Beware that good hardware and software is necessary but not sufficient. The programming of the drives is now the weak link. Finally, drive obsolescence means that you may have to upgrade simply because you might not be able to get parts or service for even an otherwise well performing drive.

Component upgrades are also popular and easy to do, especially if the machine was modularly designed. If so, replacing an old unwind, brake or slitter section with a new one is not quite just a drop in, but almost. A new coater or dryer is more involved but also not that hard with modular designs. Here we might justify capital by improved quality or productivity. We should not be shy about getting quotes from the OEM’s competitors; many are quite willing and even happy to upgrade someone else’s machine.

Some rebuilds are a bit more complicated. Rebuilding just about anything in the windup station tends to fall into that category. Most winders are mechanically busy and thus a small change in one area often affects many other things nearby. Even adding a simple safety barrier requires a lot of thought on how to keep clear of roll building, removal and winder operator movements. Most winder rebuilds are done by the OEM. One exception is modern control of the TNT’s (torque, nip, tension) and operation of the winder which tend to be more of a drop in.

Modern controls are common upgrades. Recipes can make setups consistent when returning to a grade. Trending helps troubleshoot problems during running and may help resolve the source of customer complaints. Alarms help speed up troubleshooting and may improve productivity. Scanners, profile controls, defect detection are much more expensive, but are more trustworthy, capable and affordable than ever.

It is very important to have realistic timetables, especially when economic impatience is high. You can not simultaneously have good, fast and cheap. While haste does not always imply waste, it always increases the risk. This generous timetable not only includes the time between order placement and startup, but also the startup process itself. The time constant of a successful startup may be as long as a year. There are always a few bugs to smooth out and new operation to get used to.

It is wise to consider penalty clauses in the contract. These must be objective and quantifiable. Late delivery may be one to consider if that is important to you. Uptime may be another. A machine that breaks down frequently after the startup is everyone's worst nightmare. MTBF (Mean Time Between Failures) is quantitative. Penalty clauses are like insurance; they increase overall costs on the average but decrease the costs of catastrophe. Quality is not easy to define and few builders will agree to it because many variables are out of their control. The standard procedure is to hold back the last of four payments until the quantitative objectives have been met.

Upgrading is an exciting time. However, don't let the excitement carry you away. You want to foresee possible difficulties and avoid them at the earliest stages. Upgrading is also a busy time. These project duties are usually on top of everything else. Don't let it overwhelm you. Get a good night's sleep and spend time with the family.

***2008.05 May 2008
Slitter/Rewinder Tech: Web Works

Consulting technical editor David Roisum provides answers to three key slitting and winding questions.

Why should I spread near slitters?

The gold standard of slitting design is spread > slit > spread > wind. In this ideal, we use two different spreaders. The first is called the pre-slitter spreader, and the second the post-slitter spreader. Each has a separate and vital function for optimum converting health. The venerable paper industry has known this for decades, but the message has been slow to reach converters. Let me try to explain why spreading should (almost always) be paired with slitting.

The pre-slitter spreader has two functions. The first is to make the web dead flat going through the slitter section. Even the slightest of puckers, barely visible to the eye, will be enough to destroy tight width tolerances of the slit product. The reason is simple—the width of the web with a pucker is slightly wider than the distance between the slitter blades. This is not a problem with a constant pucker size, but this is also not usually the case.

The second function of a pre-slitter spreader is to provide a small amount of CD tension. This can assist the other stresses at the slitter blade(s) to boost cut quality. Beware, however, that there is a near epidemic of oversizing of almost all spreaders, resulting in web instability, wrinkles and loss of spreading.

The post-slitter spreader has just one function—to provide a tiny separation between the slit lanes. This keeps the individual strands from tangling each other. Some of this separation is the result of a possible slight tension increase at the slitting span with respect to the one just upstream.

No more yanking If we are merely edge-trimming, rather than cutting a wider web into narrower webs, we do not use a “spreader” in the conventional sense. Rather, the trim chute pulls the trim at a very tiny angle away from the main web. Converting operators who yank the web sideways in the belief that cutting will be improved find the result is actually the opposite. Cutting is greatly degraded when the trim is directed at even a small angle because it forces a shear pucker in front of the blade.

Just as good slitting requires a rock-steady web in that area, so too does good edge trimming require a rock-steady trim. This can be done several ways. One is to use a trim pan at the slitter instead of a trim opening some distance away. If the opening is away from the cut point, the trim can be stabilized by running it over the next roller. Some pull their trim at a ZD angle instead of a CD angle, which is more benign to cut quality, but the above principles apply there as well.

We now see the reasons for the two spreaders. We also see these reasons are different. Thus, if we equip our slitters with two spreaders, they would be sized differently. Using a bowed roller on paper, for example, the pre-slitter bow may be about 0.125% and the post-slitter bow about 0.5%. The after-slitter bow has more (separation) work to do and the individual lanes are easier to move than increasing the width of an unslit web; thus two reasons for the difference in size.

How can I adjust tension to improve winding?

Every winder is equipped with an adjustable tension. Most winders can taper this tension automatically as the roll diameter builds. Some winders can even program a curve. Whether we have a simple setpoint, linear taper or arbitrary curve, we must choose how to set the tension. The best setting is determined the same way here as with any other adjustment: economics. Specifically, we choose a tension which avoids the most, but not necessarily all, defects.

We can group defects into the following categories: low tension, high tension, taper tension or independent of tension. Examples of low-tension defects are out-of-round rolls, some rough roll edges and loose cores. Examples of high-tension defects would include blocking, gage bands and some crushed cores. Some defects are independent of tension, such as wrong diameter rolls due to an operator setup error. A couple of defects, namely subsets of starring and tension, are very sensitive to a lack of taper.

If you had customer complaints of out-of-round rolls, you would look into roll handling practices as well as tighten up the tension. If you had loose cores, you would also consider increasing the tension. You also must check to make sure you don't have wet cores. Increasing tension may not be strong enough to counter shrinking cores.
If, on the other hand, you had gage bands you would look into manufacturing. Obviously, you would also decrease winding tension as much as possible. However, if the gage bands are severe enough you will not eliminate the problem solely by tension changes.
Go for the break So how far do you move the tension in response to a defect? The answer is always the same: until you break something. In other words, if you have a high-tension defect you will reduce the tension until you clearly have a low-tension problem of some sort. Once you are clear what and where the limits on both ends are, try running half way between. If you are lucky, you will find a sweet spot where both high- and low-tension defects are absent. If not, you may well have both high- and low-tension defects at the same time. Next steps may be to redesign the process or do economic optimization as described in my Critical Thinking book.

We use the same approach for the taper-sensitive defects—starring and telescoping. We make sure that a particular case is amenable to tension treatment. For example, starring on one side of a wound roll is not treatable by tension because it is probably caused by a gage variation. Gage variations may be unintentional, due to profile variations in manufacturing, or intentional such as printed patterns. If your case is amenable to tension, the appropriate amount of taper is maximum. You would start the roll at maximum, just short of breaking something. You would finish the roll at minimum, again just short of breaking something.

This tension strategy outlined here makes sense for several reasons. First, it is based solidly on economics rather than theory. Second, it adapts to any particular situation rather than conforming to a “one size fits all” guideline that probably fits very few very well. Third, anyone can get the answers if they are willing to spend the effort and ruin a few rolls finding the limits.

Notice that we have not promised complete relief from defects. Expecting any single knob to make the hurt go away completely is often unrealistic. Product/process design always offers alternative solutions, and they should also be considered. Sometimes design is so much more powerful that continuing to think about tension is distracting. Even so, tension is always the right place to start.

How do caliper variations affect winding?

Caliper is never truly level across the width of a web. However tiny these variations might be, they may still be large enough to cause the winder to complain. In fact, the winder is often the most fussy customer for gauge uniformity. If you can get the caliper-varying web through the winder without defect, the purchaser of your web may have no further cause for complaint in this regard.

Listen closely to the language the customer uses to complain. They do not usually talk about poor web caliper uniformity. Instead, they talk about poor roll quality. Not only is the winder the most fussy customer, the winder may also be the most sensitive measure for gauge uniformity. Wound roll variations may develop where the corresponding web variations cannot be picked up by conventional lab tests or online scanners. This situation is difficult for manufacturers because they can't tell for sure whether the web is good enough until after the roll is wound. Sometimes, such as with some films, it takes days for the air to escape, leaving ridges to bloom after the roll has been shipped to the customer.

First, which wound roll defects are commonly the result of winding a web with caliper variations?

Baggy lanes
Blocking
Corrugations
Crushed core
Out of round
Ridges
Starring
Telescoping
Wrinkling on a roll

Second, how can you tell if caliper variations have an influence on the severity of a winding defect? Some of these, such as corrugations and ridges, are almost certainly the result of caliper profile problems. Others are often exaggerated by poor profile. One way to differentiate is if one of these defects favors a certain CD position. For instance, if a baggy lane coincides with a ridge in the wound roll, you can be pretty sure it was made worse by profile.

If the defect position moves around with time, you can be almost certain that profile had a role, though not necessarily caliper profile.

Caliper variations cause the window of defect-free operating tensions to be narrowed. However, tension sensitivity by itself only indicates winding is involved, not necessarily the winding of gauge-varying web.

Third, what do you do when you have one of these “winding” defects? The first thing to do is to reduce the tightness of the wind by lowering web tension and especially nip load. Tightness should be reduced to the point where it becomes obvious that going any farther would be counterproductive because loose defects would then outnumber the tight defects. After that, you may get relief by replacing the winder with a more tolerant arrangement, such as duplex with individual stations or duplex with differential shafts. Ultimately, however, you will get the most benefit from eliminating the root cause, which is caliper variations. You must identify which specific manufacturing or converting element is responsible for a particular feature (there may be more than one source). Then you must identify what variation on the element is responsible.

For example, on an extruder it may be temperature or gap variations that cause a particular problem. Finally, you must change the design or maintenance of the offending element so that it is more uniform across the width than anything you've ever done or ever seen to date. If you want to know if it is good enough, don't ask extrusion, coating or QA. Ask the winder operator.

**** Web Works Columns

***1994.01 Jan 1994

Introducing “Web Works” - for all your web handling questions

There is a converting crisis breaking out in the paper, film, foil, nonwovens and textile industries. Our web handling technologies are not always keeping up with our web processing technologies. We are becoming quite adept at designing new and innovative materials, only to find that they don’t always make it through our converting machines without damage. Our machines are becoming larger and faster, only to find we’ve lost control of the web.

It is not unusual to find more waste in converting than in manufacturing, sometimes exceeding 20% due to a single cause. This obviously represents an enormous economic opportunity to those converters who can capitalize on web handling technologies. It also reduces the burden to the environment because converting waste has a higher energy investment and a much lower (if any) recycle value than manufacturing waste.

While the sources of this converting crisis are many, there are several recurring themes.

Materials are becoming thinner to reduce raw material costs, without increasing the converting machine tension, alignment and other precisions required to keep the more fragile web from wrinkling or breaking.

Materials are being laminated without regard to how the individual stress-strain properties will dictate process settings required to keep the laminate from curling. Similar issues result when embossing, printing, or otherwise modifying the web on selective portions instead of over the entire web.

Wound rolls are getting larger without considering how the increased internal stresses may damage the product or reduce its uniformity.

Materials are being redesigned for end use based on marketing input, but without considering whether the new material will be compatible with the old machine.

Machines are running faster without considering whether the web will remain in traction with rollers, instead of skidding and slipping out of control.

Machines are getting wider without establishing mechanics based standards for roller deflection.

Machines are being rebuilt with an increase in the number of rollers, instead of the decrease in roller count demanded by good web handling design.

Fortunately, we are experiencing a revolution in web handling and finishing technologies. What used to be cut-and-try, is now a design methodology. What was an art, is now a science. What was a problem, is now an opportunity. Because of this new understanding we can now run even more delicate webs, in widths in excess of 400Ó, at speeds in excess of 10,000 ft/min, and at higher efficiencies than ever before.

In the coming months, I will answer questions on web handling and converting in subject areas such as roller design; calendering, embossing and laminating; slitting; spreading; winding and unwinding; as well as drive, nip and draw/tension controls. First we will explain the underlying mechanics, then we will draw conclusions from the mechanics as to what options are available for improved performance. Our objectives will be improved productivity and reduced product damage.

We are pleased that Dave Roisum has joined our staff as a regular Consulting Editor. Dave has fifteen years of experience in the design, development and troubleshooting of converting machinery. He is a frequent author in the TAPPI Journal and other technical magazines, and is a recipient of the TAPPI Finishing & Converting Division Award and the Thomas W. Busch Prize. He received his Ph.D. from the Web Handling Research Center for a thesis in winding, and later became an Industrial Advisory Board member. He is now a principal of Finishing Technologies Inc., providing consulting services to manufacturers and converters of paper, film, nonwovens and other materials.

***1994.02 Feb 1994
Why is my web wrinkled?

A web wrinkles because it has buckled in compression. This is similar to a yardstick that will bow outward if too much axial load is applied. Unlike the yardstick that was loaded only in one direction however, a web can be loaded in three. One direction is the line tension, and the other two directions are what cause wrinkling.

To understand the wrinkled web, lets look at Mohr's Circle for the simpler case of an unwrinkled web in pure MD (machine direction) tension. As seen in Case 1, the right side of the circle is the MD face which is under line tension. The left side of the circle, or CD (cross direction) face, has no stresses and thus sits at the origin. Just to the left of the circle and under slight compression is the wrinkling boundary. While the figure shows a large separation between the circle and the boundary for illustration purposes, in real life the separation is a hairsbreadth for thin materials.

If we add just a touch of CD compression to the MD web tension, we push Mohr's circle past the wrinkling boundary as seen in Case 2. One way this can happen is when a web wants to get wider going through a process such as due to a tension drop, or due to a moisture or temperature increase. Since the web can't push itself outward, it buckles out of plane instead. Another way is when the web gathers because a slender roller deflects too much, or at a spreader that doesn't. The distinctive feature of CD compression is that the wrinkles run exactly in the MD.

If we add just a touch of shear stress to the MD web tension, we again push Mohr's circle into the wrinkling boundary as seen in Case 3. The causes for shear stress share a common theme, either a web and/or roller is crooked. The distinctive feature of shear wrinkles is their diagonal direction.

Mohr's Circle is more than just a painful academic memory. Rather, it is a powerful tool for diagnosing wrinkles. First, you can cut troubleshooting time in half by merely noting the angle of the wrinkle. Second, you can gage shear stress severity by the angle of the wrinkle. Third, you can pull out shear wrinkles with enough tension (left as an exercise for the reader). However, they will return when the product is cut or sheeted if its source was the material itself. Finally, it shows just how close to trouble we run even under the best of conditions.

**[INSERT three figures]

***1994.03 Mar 1994
What causes machine-direction trough wrinkles?

In many web processes the web is asked to get wider. One way might be thermal expansion in a dryer or hot calender. However, moisture or solvent addition in a coater or printer will act similarly due to hygroscopic expansion. Finally, web width will tend to increase if tension is decreased due to Poisson necking.

Rollers can also cause MD trough wrinkling for two related reasons. First, if a roller deflects excessively the web will tend to gather or bunch up at the center. Second, a roller with excessively wide grooving may draw a thin web into the grooves slightly, causing the edges to pull in. Finally, a Ôspreader’ which is not properly set up may actually cause the web to contract.

Unfortunately, it is very difficult for the web to push itself outward to become flat. Rather it will often tend to buckle out of plane to accommodate the extra width. This results in MD trough wrinkles that resemble the shape of a curtain: nearly uniform across the length and width, and evenly spaced. If the wrinkles are not evenly spaced, you have a baggy web which will be discussed next month.

Given a troughed web, the first step would be to identify the specific cause(s) and perhaps reduce their effect. Mild cases of trough wrinkles can often be cured with a spreader. Severe cases might require sliding or floating the web over a stationary bar.

Symptoms

1. Wrinkles are oriented in the machine direction
2. Wrinkled area covers most or all of the web.
3. Wrinkles are uniformly spaced across the width with a pitch given by:

**[INSERT equation and nomenclature]
**[INSERT figure of MD Trough Wrinkle Appearance]

Causes	**Cures**
Tension drop in a span	Increase tension
Temperature increase	Decrease temperature
Moisture/solvent increase	Decrease moisture/solvent add on
Slender roller deflection	Increase roller diameter
Excessive roller grooving width	Decrease roller grooving width
Improper spreading	Apply correct spreading
	Slide or float web over a stationary bar

***1994.04 Apr 1994
What causes a baggy web?

The baggy web has two distinct visual differences from the MD troughs discussed last month. First, the tight and loose bands are irregularly spaced across the width. Second, the product will not lay flat and straight on a table. Furthermore, while the MD trough is caused by web handling, baggy webs are caused by web processing.

A baggy web is one where the ‘natural length’ of the material is different across its width. The easiest way to show this is to measure the length differences by cutting free long strips so that they can each find their own preferred length. Surprisingly, a web where lengths vary by only 0.1% (1 part in 1,000) will result in severe bagginess on almost any material or product. The baggy lane is a position that is just a smidgen longer than the rest. It buckles out of the plane of the web to accommodate the extra length because it can’t push and stretch the adjacent tight bands. While the measurement technique is too involved to use for routine quality control, it demonstrates the mechanics involved. On narrow webs this same mechanics may result in a web that lays flat, but on an arc instead of a straight line. This is called camber and is quite easy to measure.

The specific causes for baggy lanes are as diverse as the names given to the defect. However, the are some universal trouble shooting techniques. First, the source of the defect must be where the material has sufficient mobility such as the point of manufacture, or later in processing where there are high stresses, moistures, temperatures and the like. Second, the deckle position and width will correspond to its source. This source must be identified and corrected as there is usually little that can be done after the fact. In general, the source will be a profile precision problem.

Symptoms
1. Wrinkles are oriented in the machine direction.
2. Irregular spacing of tight and loose bands across width.
3. Product does not run flat in machine or lay flat on a table.

**[INSERT three figures]

***1994.06 Jun 1994
What causes diagonal shear wrinkles?

As a class, shear wrinkles are easy to identify: they are oriented at a slight angle to the MD (machine direction). However, pinpointing the specific cause can be a little trickier. Sometimes they are caused by web handling problems such as at winding nips and at nipped rollers. Other times they are caused by the material itself. For example, the principle axes of some materials such as paper and extruded film are not necessarily oriented in the MD. Instead, the material's stiffest direction is slightly outward on the manufactured edges. You can demonstrate a material skew problem to yourself by pulling a piece of fabric slightly off axis and note the diagonal wrinkles that result. To avoid material skew, avoid buying supply rolls from the AZ edge positions of manufacture.

However, the most common source of shear wrinkles is roller misalignment. Builders of large paper converting machinery have known for a long time that precision alignment is crucial to keeping a web flat. This required precision is literally much less than the thickness of a human hair. However, this knowledge has not always been practiced by other builders and other industries.

It makes me cringe when I see installation manuals refer to alignment using a tape measure because the results will be quite predictable. It is simply not possible to adequately align converting machinery with shop tools such as tapes, levels and even dial indicators. These methods are, at best, only able to detect gross misalignment errors. Adequate machine alignment can only be done with optical transits or lasers.

Alignment precisions necessary to avoid wrinkling can be calculated with an equation, which shows that tolerances must be tighter for thin, stiff materials with close roller spacing. However, in lieu of a calculation the following square and level guidelines may suffice as a starting point:

Further Information

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2. Benson, Richard C et al. Simulation of Wrinkling Patterns in Webs. 2nd Int'l Conf. on Web Handling, Oklahoma State Univ, June 6-9 1993.
3. Boggs, R.E. Rotating Machine Misalignment: The Silent Disease but not the Symptom. Tappi J., vol 73, no 12, Dec 1990.

**[INSERT figure of Diagonal Shear Wrinkle Appearance]
**[DELETE chart/table]

***1994.07 Jul 1994
How can I improve productivity? - Part I

Improving productivity means increasing the saleable output from an existing line. Sometimes this can be done by merely changing operating procedures. Other times equipment changes may be required. Increasing the number of operating personnel, however, can seldom be economically justified because labor already accounts for about 25% of the cost to produce most web products.

To improve productivity, we must first know what activities take place on the converting line. Then, we must determine how much time is spent on each of these activities. While every converting plant keeps production records of some type, these are at best only the overall time it took to produce a roll, box, skid or other unit. They do not detail the time cycle elements within that overall time.

A simplified time cycle, typical of many roll-to-roll converting operations, is shown in Figure 1. This example is chosen because it is more complex than continuous converting operations. However, the principles of productivity analysis are the same for all web manufacturing and converting processes.

The roll-to-roll cycle starts as the winder accelerates to speed, which is followed by a longer time at running speed, and finally a deceleration to a stop. The area under the speed versus time curve is the length of the product. After the winder has stopped, the roll or set of rolls are discharged, new cores are inserted, the tails are taped to the cores, and the winder is readied for the next run. Following this set change may be other nominally identical run/stop cycles before either a new supply roll must be put in the unwind, or a grade change is made.

However, there are many other activities that are not considered in this idealized cycle. These include machine breakdowns and maintenance, scheduled downs and web breaks. Also, the machine may not always run at the same speed on all grades, or slowdowns may be required because of occasional process difficulties. Finally, the machine might be runnable, but can’t because it is blocked or starved. Blocked means there is no room to put the output because the downstream operation is stopped or full. Starved means a required input material is missing. These and other typical time cycle elements are listed below.

Blocked (no place to put the output): wrappers, palletizers, etc. are down or full; conveyors or other transport is down ;storage is full
Starved (an input is missing): supply rolls or cores are missing; all product orders are filled
Down (periodic): roll/set change
Down (aperiodic planned): grade change, maintenance
Down (aperiodic unplanned): machine breaks, web breaks, jams

Running (out-of-spec): unsalable cull or waste, degraded but salable
Running (in spec): accelerate or decelerate, run at reduced speed, run at full speed

Whenever the machine is not running an in-spec product we have an opportunity to increase productivity. We could also improve throughput even when the machine is running, however, by increasing the operating speeds. Next month we will show how to measure time cycle elements and how to prioritize the options.

**[INSERT figure of An Idealized Time Cycle]

***1994.08 Aug 1994
How can I improve productivity? - Part II

Last month we showed how measuring productivity means a lot more than knowing how long it took to produce a roll, box or skid. It means making a detailed list of converting machine activities, and then determining how much time is spent on each item.

The most sophisticated means is to time and log activities automatically with a PLC (Programmable Logic Controller) or a PC (Personal Computer) equipped with data acquisition. This has two distinct disadvantages, however. First, it requires expensive equipment and extensive development time. Second, it is often difficult for the computer to know why the machine isn't running unless the operator manually logs the cause. The problem here is that they might not take the time to log the cause, or may list it inappropriately.

A simpler alternative is to use automatic clocks or timers to record how many minutes per day the machine is not running. The balance of the time is running, from which speed can be obtained if the number and length of units produced that day is also known. The important details of the down time, however, must then be determined by other means. A variation on the timer is to use a 24 hour circular speed chart. While this gives a very visible record that can be annotated by hand, getting times from the chart can be difficult and inaccurate.

The traditional productivity analysis, as first refined by industrial engineers, is the stop watch and clip board. There are two problems with this approach, however. First, one has to spend many days sitting at the machine to get a representative sample, especially for aperiodic events. Second, operators may speed up or slow down when they know they are being measured. Another behavior, called buffer pacing, happens when operators adjust their output to just keep up with the upstream manufacturing line. A better measure of the potential for manual operations is when crews are pushed by the upstream supply or motivated by a productivity contest.

My favorite method is what I call TCBWA (Time Cycles By Walking Around). Here, someone who regularly visits the machine merely records the type of event first observed as a tick mark in the appropriate category. This approach has a couple of advantages. First, the operators don't know they are being observed because the recording is done after leaving the machine area. Second, it takes very little effort. There are two disadvantages, however. First, it takes months to accumulate a sufficiently large sample. Second, you must be careful not to bias the data. This could happen, for example, if visits disproportionately coincide with shift changes or during process problems.

No matter how time cycle data is obtained, the next steps are the same. The time data is first summed, ranked and charted on a Pareto diagram as shown in Figure 1. (Obviously he individual times must add up appropriately.) Then, options, costs and anticipated time savings are determined and another Pareto diagram is made.

In this example, most of the time is spent at running speed. Thus, increasing the speed would be a good candidate for a throughput increase. Next comes roll change and grade change times. Both might be reduced by some type of automation. However, a SMED (Single Machine Exchange of Dies) program should probably be done first. This determines whether parts of the roll or grade change cycle could be shortened, done while the machine is running, or performed in parallel. The next category in this example was starved, which can vary in effect from disabling (such as on a web manufacturing line) to innocuous (such as on a rewinder following that line).

What are the best options for improving productivity? Start by listing options for each of the largest time categories. Costs and time savings for each option must then be estimated. These options are finally ranked and plotted on a Pareto diagram as minutes saved (per month) per amortized dollar spent. You do as many of these most cost effective options as needed to reach a required productivity or other economic goal.

***1994.09 Sep 1994
How can I reduce waste?

Waste and rejects have a large effect on the economics of a converting plant. Small changes here can easily mean the difference between profit and loss. To reduce waste and rejects, we must have a very good understanding where they are coming from. While every plant keeps records of this type, it is not always done as carefully as it should be.

The initial accounting of waste and rejects is by a mass balance. Waste is the difference in weight between the raw materials coming in and the saleable product going out. Salable product has a couple of subtleties, however. First, it could be salable but at a reduced price because it doesn't meet premium specifications. Second, it could be considered salable but might be later rejected and returned by the customer after receipt.

Just as with productivity, we must first list of the kinds of waste and rejects. While the list will vary depending on the products and activities at any particular plant, there are several desirable characteristics:

1. The items must be inclusive.
2. The items must be unique.
3. If a lot is rejected for more than one reason, the sources must be proportionally distributed.
4. Rejects should be unambiguous. Measurements are usually better than subjective interpretation, such as visual defects compared against a set of photographs or samples.
5. The categories must be fine enough, so that information isn't lost.
6. Codes should be used instead of free form words for waste and rejects.

It is very important that the items on the list only refer to kinds of waste and rejects instead of causes, even if the cause is (believed to be) well known. First, causes are not so clear as are kinds. If they were, you should have already solved them because cause implies solution. Second, rarely is there only a single cause (or solution) to any kind of waste or reject. Most are complex process, machinery or system issues.

While the initial accounting of waste and rejects is by weight, we don't always need to weigh every source. For example, trim waste can be calculated from length, width and basis weight. Also, regular waste at the top and bottom of wound rolls can be weighed a few times to establish a reference if habits are consistent, and then checked periodically to make sure it hasn't changed. Finally, don't forget startup waste as the machine and product comes into spec. This can be calculated from time, speed, and basis weight.

Just as with productivity, waste and reject items are summed and ranked on a Pareto diagram as total weight for each category. It will normally take as least a month to establish a good sample for any converting line. While daily production records are useful for firefighting, we need better data to justify the more sustained and long- term solutions.

The next step is to assign a cost for each of the waste items. For example, raw material waste will typically cost about 50% of the cost to produce a product, while rejects at the end of the process are assigned full product value. Trim or other waste in between has some intermediate cost depending in part on whether the material has a recycle value, or if you must pay to haul it away. Finally, product returned by the customer will have more than full product value for two reasons. First, you may need to pay for a roundtrip ticket for both the product and some of your people. Second, you may risk the loss of that customer, which must be made up by increased marketing and other efforts.

After the costs for the items are determined and multiplied by weights, the results are again ranked on a Pareto diagram. The most costly sources are places to begin problem solving in earnest.

***1994.10 Oct 1994
How can I improve my workforce?

Machine operators and plant floor personnel are a significant investment in any converting operation. Typically, their labor costs account for about 15-20% of the cost to produce a product. You want to make sure that you get your money's worth.

Often, operating personnel lack training. True, they usually know what buttons to push and when, but they seldom know why. Multi-million dollar machines are typically crewed with people who have had less training than you would get in a driver's ed class. At best, the machine builder will provide initial training on startup. Eventually those operators will train their successors and move on. More and more of the initial knowledge is lost with each succeeding generation until operators don't even know the names of the parts of the machine, or what some of the knobs and dials do.

Opportunities and product are lost when operators and plant floor personnel are not able to recognize the causes and cures of various process problems. While a process may have been in good health at one time, it may end up as Ôits been like that since I've been here'. Also, we now know more about converting processes than was known only 10 years ago. Only those with current knowledge can take advantage of this new understanding.

The solution to these and many other related problems is simple: relevant, regular and recurrent training. It needs to be easy enough so that most parts are mastered so that confidence, pride and eventually processes are improved. However, it should be demanding enough so that everyone appreciates that converting processes are complicated enough to suggest a lifetime of continuous learning and improvement.

However, sometimes operators know why their process is ailing, but won't tell anyone. For example, engineers from both a mill and the machine builder struggled for two years to determine why a component wouldn't move. I turned to the operator and mentioned my frustration in finding the cause, who calmly pointed to where the part had been binding. He had known since startup, but wouldn't tell anyone because they never listened. In another case, I found a dial that had penciled labels for A thru D. I asked him whether this was for four different grade settings. He laughed, and said it was the settings favored by four different shift supervisors. While he knew what the best setting was, he had to conform to varying directions from management.

Operators should be given a formal mechanism for requesting maintenance or other modifications to their machines (such as on a work request form). Morale can hurt, however, if their request disappears into a system without receiving feedback. Another excellent practice is to use a logbook on each machine so that crews can communicate between shifts. It also serves nicely to document a history of process troubles that can be invaluable for troubleshooting.

Other neglected areas are operator access, visibility and comfort. The machine should not be unnecessarily hard to get around because of obstructions. Sometimes this can be done by merely staging materials differently. Other times the machine aisleways can be opened up by moving pipes, cables, sensors etc. Simple housekeeping items such as these can also make the machine safer to operate.

Finally, crew duties should consume 50-75% of their time. More, and they may not have time to catch their breath during process troubles. Less, and they can become bored or inattentive. Sometimes duties can be rebalanced by using a Ôfloating hand’ between one or more machines in close proximity.

Operators are an investment that must be maintained by formal recurrent training. They are the eyes and ears of the process. Finally, they are people whose morale and performance is a reflection of their environment.

***1994.11 Nov 1994

What tension should I run?

Tension is a most important web manufacturing and converting process setting. If the tension is too low: the web will tend to flop and flutter, will tend to shift and wander sideways going through the machine, and may loose traction on rollers. Conversely, if the tension is too high: portions of the web may be damaged due to local yielding, or web breaks may increase if the material is brittle.

However, web tension is also important for sizing rollers and drives. First, rollers must be large enough so that the combined effects of web tension, roller weight and nips do not deflect them excessively. Second, web tension (as well as wrap angle and coefficient of web/roller friction) determines how much torque can be transmitted into the roller to overcome bearing drag, windage and inertia for web driven idler rollers or how much torque can be applied by an externally driven roller before the web breaks loose from its roller. Third, web tension (as well as roller diameter and speed) determines how much air is pumped in between the web and roller which causes a loss of web/roller traction.

An estimate of a good running tension would be based on previous successful experience with a similar web material. If the new material is of a different caliper, the tension will be scaled appropriately by the ratio of their thicknesses.

Tension2 = Tension1 x Caliper2 / Caliper 1

Lacking any previous experience with a similar material, one can turn to guidelines suggested by machine builders, technical organizations (such as the TAPPI for paper), or published in the literature. These guidelines will typically be a chart or family of curves of tensions versus thickness/weight for several nominal classes of materials.

However, even lacking any other tension guidelines, a good range can be constructed based on the strength of the web. The figure shows a typical tension versus stretch (stress-strain) curve for a material which can be easily obtained from tensile testing machines. As seen here, you would run a web tension at 10-25% of its breaking (or better yet yield) strength. In draw control, you would need no more than 10-25% of the material’s yield strain (similar to stretch for brittle materials) as a total draw through the machine.

Note the universality of the rule. First, it works well for most webs and web thicknesses. This means that the web handling mechanics are the same for paper, film, foil, nonwovens and so on. Second, it works well for most processes. In other words, a desirable web tension will be similar for calendering, embossing, slitting, winding and so on. Applying the rule is quite simple. Rollers and drives are sized based on 25% of the strongest material anticipated to be run in the lifetime of the machine. Then, the precision and finesse of the rollers and drives is sized based on 10% of the weakest material ever anticipated. Running tensions are set as a compromise between floppy and taut web problems.

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**[INSERT figure - must be recreated from scratch]

***1994.12 Dec 1994
How do I measure web tension?

The most direct measurement of web tension is by the use of rollers mounted on load cells. A load cell is scale which measures a force component produced when a web wraps a roller under tension. Most commonly, the load cell is an electronic strain gage. However, LVDT’s (linear variable displacement transformer), spring loaded pneumatic regulators and other force sensors have been used.

In addition to the web tension force, the load cell also must bear the weight of the roller, bearings and mountings. Thus, the first rule of load cell sizing is that the gross load (vector sum of web tension and roller weight) must not exceed the capacity of the cell. Note that some cells have different ratings in the sensing and cross sensing directions. The second rule of load cell sizing is that the tare weight (tension component in the direction of the sensing) should be at least 10 times the accuracy of the cell for the lowest tension product to be run.

To avoid the proverbial problem of trying to Ôweigh a pea in a dump truck’, the following steps will give an improved sensitivity by increasing the ratio of tare to load cell capacity.

1. Select the smallest load cell capacity that meets the first rule of gross weight sizing.
2. Wrap the load cell roller as much as possible.
3. Orient the wrap (or cell) to create a tension force acting closely to the sensing direction of the cell.
4. For cells with a vertical sensing direction, orient the wrap so that it pulls upward to relieve roll weight.
5. Use light rollers and mountings. Composites can be very helpful here.
6. The load cell roller should be an undriven idler so that drive forces and torques are not superposed onto the tension signal.

In addition to sizing, there are several other application considerations.

1. The cells should have mechanical overload protection to avoid inevitable damage in plant environments. The first sign of overload damage is an unexplained shift of the zero.
2. Load cells should be periodically zeroed and recalibrated by stringing a weighted rope through the web run.
3. Load cell rollers should be balanced to a G6.3 class or better.
4. A good amplifier will be able to selectively display and output: front, back, sum and difference signals. Also, the display will have an adjustable gain for calibrating in tension units of lbs/in (PLI) that is independent of the output (0-5V or 4-20mA).

However, there are other less common ways of measuring tension besides load cells. Some alternative sensors are based on the propagation of ultrasonic waves. Others are based on the indentation of a probe into the web. Both principles have been used in both handheld and scanning applications. Finally, tension can also be calculated from drive motor readings or web sag.

While every machine should have load cell tension measurement, controlling the drives via tension feedback is not always a good choice. First, very stretchy webs such as tissue, nonwovens and some stretch or food wrap films are better controlled by draw. Second, not all drives are precise and responsive enough to keep up with load cell feedbacks.

Much more detail about tension control and related topics can be found in my books The Mechanics of Winding (1994) and The Mechanics of Rollers (1995) which are published through the TAPPI PRESS. In the next couple of months, we will cover alternative methods such as dancer and draw control.

***1995.01 Jan 1995
How do dancers work?

The dancer, as most commonly designed, is shown in the figure below. The dancer roller is connected to a pivoting arm whose position is measured by a rotary or linear pot (potentiometer). If the tension is high, the dancer is pulled upward and the pot sends a signal to the downstream drive to slow down or the upstream drive to speed up. If the tension drops, so does the dancer roller.

A minimum tension is provided by the weight of the roller and a portion of the arm. To run a higher tension, a pneumatic cylinder is pressurized or weights are added to the arm.

Dancers are one of the oldest web tension sensors, and are still commonly used today. Their primary advantage is that they can accommodate drives that are sloppy (as were most before digital drives) or for applications which have extremely fast tension transients (such as on flying splices). This tolerance is due to the length of stored material in the loop that can be drawn from or fed into. A less common arrangement of dancer is a festoon which provides even more stored material and is used for zero speed splicing of unwinding or winding rolls.

However, there are several disadvantages and misconceptions with dancers. The first disadvantage is that while it does respond to changes in tension, it does not display tension as does a load cell. Thus, there is no output of average or instantaneous tension to be used for process design, quality control or troubleshooting. The best that can be done is to calculate the (average) tension as a function of cylinder pressure or arm counterweight. Even then however, one would not be able to determine tension excursions to gage the health of the drive control system.

Another disadvantage of the dancer is the ubiquitous use of pots (variable potentiometers) for position sensing. An example of a pot is the volume knob on a radio. It is not durable to continuous turning. Also, the pot fails in the worst manner possible as occasional and erratic control glitches as the slider gets worn and dirty.

However, the best judge of dancer performance is to measure tension excursions after the dancer with a load cell. Typically, dancer tension is very poorly held. It is not unusual to see tension excursions exceeding 50% during speed changes. Much of the poor performance of dancers is excessive mechanical friction of the pivot and cylinder assembly which should be <<1/10th of the force of the lightest tension to be run. If a shock absorber function is desired, it must be done without spring or friction (e.g., a viscous damper).

A final common misconception with dancers is that they provide a damping or attenuation of tension disturbances as might be generated by an out-of-round supply roll, unstable drive, or vibrating roller. While this can happen, the realities show much more mixed results. To simplify a complex topic, dancers tend to have no effect at very low frequencies, exaggerate tension disturbances at intermediate frequencies and only provide a desirable attenuation at high frequencies. Thus, the dynamic performance of dancers has the same character as a high inertia idler roller.

Dancers do have applications for sloppy drives and flying splices. However, even dancer controlled machines should have load cells to set a consistent process tension and to monitor dancer/drive performance.

**[INSERT figure of a Pivoting Dancer]

***1995.02 Feb 1995
How does draw control work?

Draw control is the speed regulation of several driven rollers in a process line. While the equipment and controls are quite simple, draw or speed control is limited to very stretchy materials such a tissue paper, stretch film, nonwovens and some textiles.

The figure below shows an example of draw control on a roll-to-roll converting line. Here, the unwind, a converting process (calender, emboss, print, slit, etc.), and the windup are all driven at a controlled surface speed. However, the tach or encoder connected on the back end of a motor measures RPM (revolutions per minute), and must calculate surface speed from the equation for rigid body motion,

$V = w r$

that can be given in more conventional units as:

Metric: $V = 0.031416 \times D \times RPM$

English: $V = 0.26180 \times D \times RPM$

where the speed V is in MPM (m/min) in the metric system and in FPM (ft/min) in the English system, and while D is the outer diameter of the roll(er) in (cm) for the metric system and (inches) for the English system. The diameter of rollers will be measured by a caliper, while the changing diameter of unwinding and rewinding rolls may be measured by a variety means such as by the ratio of tach pulses or ultrasonically.

The draw between any two rollers is expressed as a percent speed change with respect to some reference which should be stated. For example if the converting unit were the speed reference for the system, the windup draw would be

$\%Draw3/2 = 100 \times (V3-V2) / V2$

Web strains (elongations) can be calculated from speeds or draws provided that a strain is known somewhere. For example,

$e2 = e1 + \%Draw2/1 / 100$

Notice, however, that in the roll-to-roll converting line we would generally not know the strain present in the unwind (e1). Similarly, in a manufacturing line we would generally not know the strain coming out of the maker. Thus, draw control is not closed loop because there is no web sensor. This means draw is, by itself, unable to measure or compensate for upstream web fluctuations. Indeed, the web only cares about stresses (tension) and strain, not dancer position or roller speed.

Draw control precision needs to be appropriately sized. If for example, a typical quality speed control can achieve a 0.1% accuracy, then we should run no less than 1% draws, which means the MD stretch (or better yet, yield) must be greater than 10%.

Finally, an important web process design consideration is to determine the optimum number of independent draw or drive sections in a machine. The answer is the fewest possible, and most often just one (unless yield strengths change through the line). This reduces cost and complexity. While other rollers may be driven, they are slaved to a master or are merely helper drives to assist in overcoming drag and inertial resistance.

**[INSERT figure - Draw Control in Roll-to-Roll Converting]

***1995.3 Mar 1995
How can I reduce laminator curl?

With few exceptions, the product coming out of a laminater is desirably flat and free of curl. Controlling curl requires that the ingoing webs are matched in both MD (machine direction) and CD (cross direction) strains. This laminater design principle of strain matching is based on the observation that if the webs are evenly stretched in both directions, they will contract evenly when process tension is removed.

However, if the MD strains are not balanced, then the product will curl into a trough that is oriented in the CD. In the absence of gravity or support stresses, the trough will be an arc of a circle. The requirement of MD strain matching can be converted to process tension settings for the uniaxial tension case (of no CD stresses) as:

**[INSERT equation]

where T is the unit tension (lb/in), t is the web thickness (in), E is the MD modulus (lb/in^2) and the subscripts A and B refer to the two constituent webs. A practical difficulty results when laminating webs that have widely different moduli. An everyday example of this an elastic wasteband, where the cloth is much stiffer than the elastic and may wrinkle when bonded together.

A similar curl problem can result if the CD strains are not matched, but now the trough is oriented in the MD. However, in this case the CD strains are the result of Poisson contraction. The requirement of CD strain matching can be converted to process tension settings for the uniaxial tension case (of no CD stresses) as:

**[INSERT equation]

where n21 is the anisotropic Poisson contraction in the CD resulting from a MD stress. Comparing the two tension design equations shows that an exact MD and CD strain match can only occur when the two material’s Poisson ratios are identical!

Two other laminating constraints result from the general web handling principles of web tensions being tight enough to avoid floppy problems and loose enough to avoid damage (Web Works, Nov Ô94).

**[INSERT two equations]

If strains can’t be matched, then the resulting radius of curvature of the product curl can be calculated. The method is based on elementary composite beam theory (the classic reinforced concrete beam or bimetallic strip problems).

It is important to observe whether the curl has any nonuniformities (varying radius) across the width or length. If so, then there may be other contributing factors such as baggy webs (Web Works, April Ô94) or nonuniform nips (Profile of a Nip, June Ô94). A common example of nonuniformity is curl that occurs just on the edges of the web.

Once curl is formed into a web or laminate, the material must be yielded and reset to flatten it out. On paper, this might be done by moisturizing in a steambox under line tension. On film, this might be done by sending it through an oven. The role of moisture, temperature (and solvents) is to temporarily reduce the yield strength. A final purely mechanical method is to run the web over a sharp radiused or small diameter bar. Often, you may need several alternating bar in series to accomplish the task.

Ultimately however, curl is much easier prevented than cured. This means the four laminator design rules must be obeyed. It also means running a uniform product through a uniform, precise and well maintained machine.

***1995.04 Apr 1995
How can I fix a crooked web?

Sometimes webs aren't as straight and flat as desired. Examples include wrinkles (March and June 94), baggy webs (April 94), curl (March 95) and almost uncountable other variations on this theme.

First, we must determine if the web is naturally crooked, or is elastically (temporarily) forced that way through the machine. If it lays flat on a table but not through the machine, then the web isn't being handled properly through the machine due to causes such as excessive roller misalignment or deflection, poor control of tension or traction, lack of proper spreading and so on. If the web doesn't lay straight and flat on a table, then you've got a bonifide case of residual stresses.

A web that doesn't lay flat on a table has uneven stresses built into it during manufacturing, and in some cases, brutish handling after manufacturing. Obviously the best course would be to find the source and correct it. In some cases however, the original cause may be difficult to find and/or correct. Then we are faced with the last resort of attempting to fix a crooked web after the fact.

Before we begin, however, it would be helpful to understand what residual stresses are and how they cause the web to be crooked. Figure 1 shows a stress-strain curve for a material laying on a table under no external stress. On this sample are two points labeled A and B. Note how one is compressive and the other is tensile. Residual stresses mean that the web has non-zero stresses inside it, even though no external stresses are imposed on it.

The effect of the residual stresses might be made clear by two examples. If A and B were at the same (x,y) point, but one was on the top and the other on the bottom, it will have a curl in the MD or CD. If the points had the same MD position but were on different edges of the web, it would be baggy or cambered. Of course, there are many other combinations of MD, CD and shear stresses that can cause crookedness in a web.

To fix the web, it must be stressed so that all points are brought into yield, which usually occurs at the knee in the curve. This will cause the points A and B to be strained to A' and B'. Finally, the tension is relaxed to a more conventional level or released as shown by A'' and B''. Note that the strains are nonzero because the shortest parts were permanently stretched longer than the other parts of the web were stretched. However, the stresses are now equal so that the web can lay flat.

To assist in the yielding process, moistures, solvents or temperatures may be increased. This lowers the yield point and extends the yielding region (horizontal part of the stress-strain curve) enough to provide some working room. Since paper responds readily to moisture, it might be steamed. Film responds better to temperature, and may be reheated in an oven to near the glass transition temperature. Finally, this treatment is best done under draw (strain) control to avoid having it run away under tension (stress) control, much like two kids fighting over a piece of taffy.

Yielding is not a panacea for curing crooked web problems, however. If it is done unevenly, it may produce the same kind of effects that prompted the treatment in the first place.

**[INSERT figure of Stress-Strain during Web Yielding]

***1995.06 Jun 1995
What is the best way to measure length?

Length is a common advertised or specified feature of a web product. While length is easily measured, it is more difficult to define. This has led to numerous disagreements between suppliers and their customers.

Length is almost invariably measured by counting revolutions of a wheel or roller traveling at web speed. When in traction, every revolution of the roller means that (Pi X Diameter) of web has passed. All that needs to be done is to reset (zero) the counter prior to run, and read it after the run is completed.

The wheel mounted footage counter is perhaps the least expensive option and is ubiquitous on older machines. However, it suffers from many accuracy problems. First, the rubber surface of the wheel will wear to smaller diameters, making the resulting length measurements erroneously larger. Second, the rubber compresses so that the footage will read lower with higher nip loadings. Third, the edge of the wheel needs to be ground to a special arc to reduce the effect of camber alignment errors. Finally, there will be a reduction of footage with toe-in alignment errors. More pragmatically, however, the wheel mounted footage counter can be a nuisance. It tends to get in the way of operator access and threading, and doesn’t always hold up well in plant environments.

The alternative is to count revolutions of a roller in traction. Revolutions can be counted by (direct) drive motors or an incremental encoder if the live shaft roller is so equipped. However, any roller can be fitted with a metallic (for inductive proximity switches) or optical (for photoeyes) target. These small sensors are best mounted on the edge of a roller to minimize interference. The only issue with roller footage counters is to make sure that the web is always in traction on that roll.

Defining length is a bit trickier however. With most products, dimensions are specified under no stress. A common example is a 3Ó rubber band which is the advertised length when laying on the table under no load, but is capable of expanding to at least twice that during use. However, suppliers of roll products will usually measure length under web line tension, while their customers may measure it under a different tension, or under no tension at all. This difference in length definition, as well as errors in the measurements themselves, contribute to discrepancies between suppliers and their customers.

However, there are two other factors that change length elastically. The first is temperature changes. A length measurement coming out of an oven will be longer than the on the same product when cooled. The second is moisture/solvent differences between shipped and received products. Paper and some polymers will swell significantly with increasing moisture/solvents.

All of these factors can be calculated by the following equation which accounts for elastic strain (length) changes due to tension, temperature and moisture. These correction terms can, in some cases, be as much as several percent. In order to use this equation, however, we need to know the material’s modulus and coefficients of hygrothermal expansion.

**[INSERT equation]

Thus, accurate measurements of length necessarily requires accurate sensors. However, this may not be sufficient for tight tolerance specifications. We may have to accurately control and factor out changes in tension, temperature and moisture.

***1995.07 Jul 1995
How can I control width accurately?

Width is another common product specification that shares similar issues to length as was discussed in last month's column. However, in many cases width is more important and/or requires tighter tolerances. It is not uncommon for allowances for width specifications to be only 1/32Ó or 1 mm.

The first step to controlling width is to accurately set the distance between slitters. These distances will need to be slightly different than the width specification as defined by the equation which accounts for tension induced Poisson necking, temperature and moisture changes.

The next step is to make sure that the slitter-to-slitter distances are measured accurately. The most common method is with a hardware variety tape measure. Unfortunately, these are seldom accurate enough for tight tolerance products. First, the hook is not always machined and mounted accurately, giving a zero offset. Second, the rule printing may well have a noticeable (gain) error over wide widths. The solution: select instrument quality tape measures and issue them to all of the operators and inspectors. Closer slitter tolerances may benefit from automated measurement and/or positioning systems which can reach accuracies of as little as a couple of mils (0.001Ó).

We must also make sure that the slitter mountings are very stiff and tight. Similarly, the slitters (blades or bands) must have a minimal axial runout, else the edges will have a slight scallop. This will show up as slitter rings on the sides of wound rolls roughly corresponding the integral multiples of bottom shear band or top score blade diameter.

Next, we must make sure that the web is flat and evenly tautened in both the MD and CD as it goes through the slitter section. This will require precise tension control and perhaps a modest spreader upstream. Wrinkles going through the slitter section are a common way of cutting overly long widths.

Finally, a caution about measuring width on wound rolls. Even if roll widths are specified and are most easily measured, they are not an accurate measure of product width. As seen in the figure, all wound rolls will tend to have radially varying widths. Notice how the outside, where one would place the rule, is narrower than the rest of the roll. These radially varying widths result from pressures and tensions inside wound rolls and the immutable laws of physics.

I am continually awed by how web handling principles can take what is deceptively simple in appearance, such as length and width, and make it more complicated (but predictable). Conversely, web handling can make clear what appears complicated.

**[INSERT Width Equation]

**[INSERT figure Widths in a Wound Roll]

***1995.08 Aug 1995
Why are my rollers grooved?

Rollers should be grooved solely for one purpose: to maintain web/roller traction at speed by allowing air or liquid to pass around a roller instead of lifting a web. Grooving does not, as widely believed, provide any spreading or wrinkle removal function. In fact, the tendency is always to contraction or wrinkle generation.

To understand the need for grooving, we must understand the mechanics of fluid entrainment on a roller or wound roll. As seen in the figures, fluid is carried or pumped by both the web and roller into the gap between the two. The fluid thickness, H, can be calculated for simple systems by the equation shown (be careful of units).

**[INSERT equation]

As an order of magnitude approximation, air film thickness is about 1 mil per 1,000 FPM (ft/min) for light nonporous webs. However, liquids have such a large viscosity that webs may float off rollers at just a few FPM.

With this calculation, we can truly design grooving to match the application. First, we note that the total area of the grooves or texture must be a safety factor times the film height times web width. Then we select a grooving width so that it is no more than 10-20 times the thinnest caliper web so that the web doesn’t pull into the grooves and cause contraction and wrinkling. The pitch should be as narrow as practical and the depth makes up the difference.

Going through this type of exercise, one finds that the optimum grooving, for all but very high speeds, is not much coarser than the texture of the scratches on a phonograph record. Knowing this, we see that most of the grooving used in the web industries is like using a tractor tires on an automobile; not a good match.

**[INSERT figure of Air/Fluid Entrainment]

**[INSERT figure of Grooving Geometry]

***1995.09 Sep 1995
Do I need a nip for traction?

In most cases, no. However, since in general it is not a good idea to let webs slip on rollers, we need to compare the required traction with the available traction.

The required traction for a simple (unnipped) roller is determined by the tension difference which exists across any roller. This tension difference is composed of one or more of three possible elements. First, all rollers have bearing drag and sometimes have significant windage from rotating in a fluid (air at very high speeds, liquid at any speed). This will tend to make the upstream tension, T2, greater than the downstream tension, T1.

The second element is the inertial tension present whenever there is a speed change. This will tend to make T2 > T1 during acceleration and vice versa during deceleration. The inertial element can be quite high for large diameter process rollers, or when acceleration rates are high such as on a winder.

The last element is only present on driven rollers. Here we use driven in a broad context to include belts, pneumatic brakes, electric motors and so on. A positive motor torque will tend to compensate for the above elements, while braking will increase the tension rise going over a roller.

The sum of the torques from these three elements divided by the roller radius and width gives the total required tension difference. There is a limit, however. That is, the tension difference can't be so large as to cause the web to break loose from the roller. Here, the limit is expressed as a tension ratio and is known as the band-brake law. If the required tension difference is greater than the limit ratio, then the web will simply break loose from the roller and both will travel at different speeds.

**[INSERT figure of Tension Difference Across a Roller]

**[INSERT Band Brake Equation]

However, this does not imply that we need a nip to provide traction. In fact, a light 45 degree wrap and a very slippery 0.1 friction coefficient will be able to sustain a 8% tension difference without slippage. While this may sound small, it is way more than enough for any appropriately designed idler roller. On the other hand, a 180 degree wrap with a more typical 0.5 friction coefficient is able to sustain a nearly 5:1 ratio of tensions across a roller. Thus, a nip should rarely be needed on a pull roll unless one of the tensions is near zero such as on sheeters and some accumulators during roll change. Since nipped rollers require such precision maintenance to avoid wrinkling or otherwise damaging a web, why not try and run without?

Thus, no rules of thumb can be given for wrap angles because it depends greatly on the application. However, it is no mystery, its a calculation.

***1995.10
When should I use composite low inertia rollers?

Composite rollers have shells which are made of carbon fiber and epoxy or similar space age materials. They are more structurally efficient than steel and aluminum because their strength/weight and stiffness/weight ratios can be superior. However, they also cost 1.5-2 times as much as the more conventional alternatives.

Unfortunately, builders have not always given solid justifications for using composite rollers. For example, it is true that composites are lighter than metal. However, only coreshafts are routinely handled manually without crane or other lifting aids. Thus, for most rollers the weight is truly unimportant. Also, composites require less energy to accelerate (and if the bearings are equivalent, to run). However, drive motor energy costs are decimal dust when looking at the cost to manufacture webs. Also, composites are resistant to some chemicals which can attack metals. However, this is very much a niche application.

Perhaps the reasoning that comes closest to the mark is that composites can reduce tension variations because of their lower inertia. However, tissue is transported on cast metal drums exceeding 15 feet in diameter and length without significant tension disturbances. Thus, something is missing from the inertia justification.

Here, we will show how to justify composite rollers as an economic recipe rather than as a judgment call. First, you need to decide how much tension disturbance you will tolerate during speed changes, which is the only time when inertia comes into play. My suggestion is no more than 15% of the minimum web tension as a total inertial tension rise due to all idlers in a drive section. Next, we need to know the acceleration/deceleration rates as well as the number of idlers in a section. If the inertial tension exceeds our standard considerably, we will need to drive the roller(s) to get an appropriate tension control. However, if we are just a little short of our goal, then composites may give us that modest difference because they are structurally more efficient than metal.

The role of composite rollers is summarized in the figure below. On the Y axis we plot web strength, because it along with our allowable tension deviation percentage tells us how much we have left to accelerate rollers. On the X axis we plot length because it is the primary factor in inertia for rollers obeying a deflection criteria. On the lower right of the plot, we have very wide (large diameter) rollers which can’t be safely turned by a weak web, and thus will require an external drive. On the upper left we have narrow machines running stout webs which are quite capable of turning rolls without assistance and without significant tension upset.

Composites give us a new choice because of their structural efficiency which is a thin band between undriven and driven roller applications. Thus, composites are not an alternative to metal rollers. Rather, they are an alternative to drives and are always more economical. In this band, drives would be required to run light webs or wide rollers within some tension quality tolerance if it were not for the composite alternative. Thus, the decision whether to use a metal or composite roller is not a judgment call, is an economic recipe.

**[INSERT figure of Application Range for Low-Inertia rollers]

***1995.11 Nov 1995

How can I align my machine?

Roller alignment is perhaps the single most overlooked maintenance item on web machinery. Indeed, even many of the builders do not know that rollers must be optically aligned during installation and then periodically every few years. Roller misalignment can cause a variety of web problems including stretching, breaking, wrinkling, and registration difficulties.

The simplest indicator of misalignment on light webs is the walking diagonal wrinkle (crossing a roller) or mild diagonal troughing (in the open web span). Do not be deceived by the deceptively benign appearance of the slight diagonal, it is an indicator of a very severe web stress distribution. Other evidence of misalignment is a web that is consistently tight or loose on one side of one span.

Rollers which are grossly out of level can be detected with very accurate machinist's (or better yet master) levels. The accuracy is usually written on the level or case as something like 0.001Ó/ft which means that one mark off center is out of level by 1 mil per foot (truly gross). Before you use the level, however, the bubble needs to be calibrated to center. This is done by setting it on a very level surface and flipping it 180 degrees and making sure the bubble gives the same reading. Levels should be placed at the center of simply supported rollers and at the ends of cantilevered rollers. If the roller surface is uneven, several readings should be taken across the width and an average reported.

Rollers that are even mildly misaligned in parallelism, which is the most important direction, can be diagnosed with a tramming stick or vernier PI tape The tramming stick is easy to make up with a piece of angle iron, a threaded rod and dial indicator. The angle iron base is held tightly against one roller and rotated so that the dial indicator sweeps against the other. The maximum reading during the sweep is recorded. The parallelism error is the difference in readings between the front and back of the roller. If this difference is more than 0.010Ó (0.3 mm), the roller is almost certainly out of align.

If a roller is out of alignment, do not attempt to correct it manually. First, there are no manual methods of alignment, only of misalignment detection. Second, moving a single roller is likely to just move the wrinkle or other problem into an adjacent span. Only in desperation because product is being destroyed in an area might one attempt to realign a roller manually. Even then, one could as easily make the situation worse as better.

The only cure for misalignment is to optically (laser or transit) align all (process and transport) rollers in a section. Optical alignment can be obtained from a number of qualified builders, contractors or engineering firms. Unfortunately, alignment is an expensive proposition and can be quite difficult to sell to management. However, I consider it to be the first step in solving registration, wrinkling, web break and many other process problems.

There is quite a bit of work need to prepare for an alignment. Briefly, one should first eliminate as many nonessential rollers as possible with the help of a web handling knowledgeable process engineer. It is quite common to have 10-50% of the rollers in a line perform no useful function. Next, all clearances and play (such as on slides, pivots and bearings) must be reduced to an absolute minimum. This is because one can’t align rollers to tolerances less than the slop in a machine part. Finally, all roller surfaces must be checked for cylindricity and reworked as necessary. This is because the roller surface is what the optical target sets on. Finally, allow some time to align a machine, perhaps something on the order of one hour per roller.

**[INSERT table of Optical Alignment Preparation]

***1995.12 Dec 1995
Where can I learn about Web Handling?

By some estimates, the web industry is the largest industry, surpassing other giants such as chemical and automotive. The reason its size has not been readily apparent is that there is such a diversity of components and products that are made from web materials such as paper, film, foil, nonwovens, textiles and so on. Despite the size of the industry, unfortunately, there is a somewhat limited number of web handling and converting information resources. Here, I briefly describe a few of which I am familiar and use regularly.

The most widely accessible web handling resources are magazines which everyone should follow regularly. My favorite, of course, is the Converting Magazine (708-635-8800). In all fairness, however, the Paper, Film Foil Convertor (312-726-2802) also has similar fare. A slightly more technical though still readable source is Tappi Journal (404-446-1400), which requires a membership for a subscription. While there are great many other trade magazines, most do not cover web handling at all and seldom web converting in any depth.

There are only a few books on web handling or converting. First, there is a series of 4 books written by the late Herbert Weiss and published by his company (414-352-6750). Second, there is an excellent overview of many types of converting machines by Donatas Satas which is published by Von Nostrand Reinhold (New York, NY, ISBN 0-442-28177-3). Finally, I have a book on winding (0101 R-236), another in the works on rollers, and co-authored one on roll and web defects (0101 R-234) which are all published by TAPPI PRESS (404-446-1400).

There are several organizations worth following. Perhaps the most important is the CMM (Converting Material and Materials) which has a trade fair every two years. I am like a kid at a candy shop there because of the enormous scope of products and technology. On a more technical level, the WHRC (Web Handling Research Center) at Oklahoma State University provides research funded by consortium companies, seminars about twice a year and an international web handling conference every two years (Pat Netherton, 405-744-5714). Occasionally web handling and converting research is also performed at other universities in support of the paper or printing industries. Finally, CEMA (Converting Equipment Mfg. Assoc.), IOPP (Institute of Packaging Professionals) and TAPPI (Technical Association of the Pulp and Paper Industry) also provide conferences and seminars.

Another source of web handling and converting expertise is machine builders. They are usually the first place to turn when difficult process problems arise. However, the results can sometimes be a little spotty. Many builders are quite small and thus may have only a couple of experts in the entire company. What you should be able to count on from a builder to be able to bring a machine to a like new condition and performance. However, if the problem you face has been present from the beginning, chances are they builder has yet to find the solution.

As a last resort, one can turn to consultants. It is important to find one who has significant experience and true expertise in the area of your need. Consultants and their areas of expertise can be found in directories such as the Converting Magazine's annual Buyer's Guide and computerized databases maintained by organizations such as TAPPI. In addition to problem solving, many consultants share their expertise by teaching seminars, writing or speaking at conferences.

The amount of information available on a particular topic varies enormously. For example, calendering, printing and winding each have several thousand articles. On the other hand, most topics have only a handful of articles or maybe only a few brief paragraphs. If you have trouble finding information on a web handling or converting topic, give me a call. I'd be happy to help.

***1996.01 Jan 1996

How big should my rollers be?

Length is sized first for rollers. Length must be sufficient so that the web will never overhang the roller’s edge despite variations of web width and web path. A common allowance for many applications would be a roller face which is 2-4Ó wider than the widest web. It may be economical to have the same roller width throughout the machine even when edge trim is taken off at an intermediate position or when deckle (web width) changes due to an intermediate process step. However, oversizing length can be undesirable because it increases roller costs and decreases roller performance. Similarly, it is very important to minimize roller journal or shaft stickout on the ends.

Nominal diameter is then determined in most cases by a deflection criteria. The deflection criteria can be thought of as a class of precision. As seen in the table, the deflection grade is expressed as a ratio of roller deflection to roller width. Roller deflection is induced by roller weight, web tension, nip and other forces. Roller deflection is very sensitive to face width as well as live shaft journal stickout. Roller deflection is resisted strongly by diameter and to a much lesser degree wall thickness and shell material modulus.

Roller deflection should be calculated by the machine builder and/or roller supplier from simple beam bending equations. However, a rough rule of thumb can be used as a sanity check. Many rollers will have a slenderness ratio (length/diameter) of about 10 for nipped applications and about 15 for unnipped applications. The reason this rule of thumb works as well as it does is because deflection is so strongly determined by diameter (4th power) and length (3rd power), that other parameters are quite minor by comparison (1st power).

Rollers should never be undersized for deflection because numerous subtle and not so subtle process problems and web defects can result. On the other hand, rollers should not be unnecessarily oversized because it increases machine costs. Also, increasing roller diameter may require adding a drive to minimize inertial tension upsets during speed changes.

However, there are several cases where rollers need to be larger than determined by deflection criteria. First, heated and cooled process rollers need sufficient dwell time (diameter, wrap angle, 1/speed) to bring a web to temperature. Second, very thick materials have a minimum bend radius to avoid overstressing the outside surface. Third, high speed rollers may require larger diameters to increase the critical speed. Finally, specialized rollers need to have a circumference sufficient to contain one or more repeats. Examples here include rotary diecutters, embossers and printing rollers.

**[INSERT figure of Deflection Geometry]

Deflection Class (Deflection Ö Roller Face Length)

A - Precision - 0.00008	precision process or nipped rollers
B - Normal - 0.00015	most rollers
C - Utility - 0.00030	very extensible or thick materials
D - Special - 0.00060+	conveyors, spreaders, shafts, cores

***1996.02 Feb 1996

How much wrap do I need on my rollers?

The answer to this common question is ÔThe wrap angle must be at least sufficient to avoid web/roller slippage.’ Web/roller traction should be maintained because slippage incurs the very real risks and dangers of web marking, roller wear and general loss of web control. The next question that inevitably follows is ÔCan you give me a rule of thumb for wrap angle to ensure traction.’ Unfortunately, there is no rule of thumb for any web or application that would be safe but not overly conservative. However, we can offer solid design recipes.

The traction on an idler roller must be sufficient to overcome bearing drag and acceleration inertia without slippage. The torque to turn the bearings and accelerate the roller come from a tension difference (Tupstream - Tdownstream) across the roller. However, the tension ratio (Tupstream/Tdownstream) across the roller is limited by traction as calculated by the band-brake equation (Converting Magazine, September 1995). Traction is improved by increasing wrap angle, tension and web/roller friction. The idler traction demands are increased with increasing bearing drag, acceleration rate and roller inertia.

The minimum wrap on a driven but unnipped roller is also calculated by the band-brake equation. Here, however, the wrap needs to be sufficient to create the maximum anticipated tension difference between the zones separated by the drive roller.

For nipped drive rollers, the total traction or tension difference capability is the sum of the wrap and nip contributions. In most cases, however, the nip is dominant and sufficient in itself so that no wrap is required at all. Thus, calendering, embossing, laminating and printing stations often have little or no wrap on either roller.

The minimum wrap angle for traction should be a little more than calculated to allow for a safety factor. However, one may use minimal wrap (and use a large diameter roller) to avoid wrinkles crossing rollers in a specific and strategic position. Many spreaders require more than a minimum wrap to allow for spreading forces. Heavier wrap angles are seldom a problem except as to increase deflection on slender rollers.

There are certain rollers that have wrap constraints above and beyond those of ensuring traction. For example, the load cell must be wrapped sufficiently to be able to resolve much better than 10% of the lowest web tension. Similarly, the dancer should be well wrapped to best utilize its accumulation feature. Finally, edge guides work better if wraps are 90 degrees and oriented appropriately.

Note that the wrap angle has no influence on bending stresses of a thick web, as is sometimes believed. The bending strains are determined merely by the ratio of web thickness to roller diameter and are completely independent of wrap angle. Thus, it is no more damaging to the web to wrap 180 degrees than it is to wrap 10 degrees.

Some rollers will work just fine with 1 degree of wrap while others may need more than 180 degrees. Thus, no rules of thumb are appropriate. However, with Ôfaith in physics’ we can and should always use web handling calculations to design our processes.

***1996.03 Mar 1996
What is the best spacing between rollers?

**[NOTE - no hardcopy available]

A common perception is that there exists an ‘optimum’ spacing between rollers for web control. However, as we will see, there is no optimum and few limits. Rather, there are issues that can arise when rollers are placed very close together or very far apart.

Web spans between rollers might be as little as a couple of inches or as much as a couple hundred feet. However, the better measure of roller spacing is often span ratio rather than absolute span length. Span ratio is the length of the span (distance between rollers) divided by web (or roller) width. The span ratios on most equipment is between 0.1 and 100.

Some of shortest span ratios are found in paper mill winders where a 300Ó wide web might have a 30Ó span. Short spans are also found on many web machines at s-wrapped drive rollers. The primary advantage of short spans is that equipment can be made more compact. If compactness is carried too far, however, access for operation, cleanup and maintenance might be compromised.

The primary difficulty with short spans is that alignment precision must increase in order to run with a relatively flat crossweb tension profile and in order to run without wrinkling. This is why the paper industry was the first to use routine optical realignment of all rollers. Alignments had to be closer than the thickness of a human hair in order to run a inextensible material (dry paper) over short span ratios. While other machines and materials may be more tolerant, the principle is the same. The closer the rollers, the closer the alignment must be to avoid web distress. Also note that web guides and oscillators will require a certain minimum span length (because they are ‘misaligned’) .

Long span ratios are most common on tapes or ribbons. For example, it would be trivial to run a 1 inch wide ribbon over 10 feet without support. The primary advantage of long span ratios is that the web can be run a given distance without adding the cost and insult of additional support rollers.

There are two issues that will result if span ratios are increased sufficiently. First, you may have to notch the floor to allow clearance for web sag if you send the web to an adjacent building without intermediate support. Second, the end of the span may require a guide to bring the web back to the center of the machine. Long spans or paths, contrary to common belief, do not alter web tension and thus do not need an intermediate drive points to Ôhelp the web along.’

While most webs can be run enormous distances without support, there are exceptions. One is to avoid web flutter of lightly tension webs exposed to strong air drafts or extremely high speeds (e.g. tissue paper). More commonly, webs that are exceptionally baggy, curled or otherwise ugly will misbehave if spans get too long. I am aware of the wet end of one paper machine where the limp edge curled down so bad that it couldn’t be safely carried more than a couple of inches without folding over.

In short, I wouldn’t be overly concerned about web span lengths because it is seldom an issue. Instead, I would be careful to regularly optically align my machines so that even the shortest of spans can be run safely. Long spans are even less of an issue because many machine builders believe that they are undesirable. The opportunity there is to remove those extra rollers which were neither needed nor helpful.

***1996.04 Apr 1996

How can I reduce web flutter?

Desirably, a web should run flat, stable and flutter free at all times and through all sections of a machine. Excessive flutter can cause web breaks, cause the web to contact air flotation bars in an oven, cause problems entering nips and so on. However, in most cases flutter is a symptom of a web or web handling problem rather than a problem in itself.

Perhaps the most common cause of web flutter is a problem with the web itself. In other words, if the web is baggy in spots, how can it be expected to run flat through a machine? (See Converting Magazine April 1994 and April 1995). For example, a web with baggy or loose edges will appear to flutter at the ends where it is most visible. A baggy or cambered web can be diagnosed by how straight and flat it lies on a table or floor. While increasing the web tension may give a little relief, a better approach is to fix the web.

Another common cause of web flutter is when the web is slack on one side due to roller misalignment or cantilevered roller deflection. These causes of flutter can be diagnosed because the flutter is limited and relatively consistent to certain sides and spans of the machine. If the cause is roller misalignment, the machine must be optically realigned. Cantilevered roller deflection causes the web path to be shorter on the tending side than on the frame side and thus gives the appearance of baggy front edge. If this is the case, the machine will need to be gutted and rebuilt.

Sometimes web flutter is caused by tension oscillations. A change in tension will cause a change the amount of web sag in horizontal spans, which will make the web appear to bounce or flutter. A common example here is an unwinding roll with a flat spot which causes tension surges on every revolution. If this is the case, the parent roll must be more carefully handled and stored. Another example is the spans surrounding a rotary die cutter, cross cut knife, or similar component. Tension oscillations are diagnosed as flutter which decreases as one progresses away from the source. Indeed, just a couple of rollers is enough to damp out many tension surges.

It is also possible that a drive (electrical or mechanical) point is unstable and causing tension oscillations. However, drives are not usually fast enough to make the web appear to flutter and excessive gain is easy to diagnose. In simple terms, the oscillations become temporarily worse when there is a transient such as at the top and bottom of a speed change.

Finally, air currents in the area can cause a light web to billow and blow, especially at the edges of long spans. Air currents can come from external sources such as blowers and fans for ovens, trim systems and HVAC, or even from open doors. The worst air current is one that moves in the cross machine direction. However, the web and rollers by virtue of their speed can also induce their own air currents. Air currents can be seen using a light tissue streamer suspended from a probe.

One universal means of reducing web flutter is to increase web tension. In most cases, the web should be tautened to at least 10% of its strength in order to be handled well. Increasing tension much beyond this can mask the underlying problems and may induce web breaks or other damage. Finally, one can reduce the unsupported span length by adding a roller, or better yet, a pan or shoe. Again, however, we may mask the underlying problem.

***1996.06 Jun 1996
What type of drive should I use?

Before we decide what type of drive is best for our web line, we must understand what the goal of a drive should be. Simply stated, the role of a drive is to supply torque to rollers so that web tension (or strain) is maintained at all times, positions and conditions. Thus, from the web's perspective, it doesn't know if a roller is driven by a squirrel cage motor or by a squirrel in a cage. Similarly, it doesn't care about armature amps or pneumatic brake pressure, as long as its tension is maintained.

The primary electric drives used for webs include scalar and vector AC, brush and brushless DC, and servo drives. The least expensive drive is a plain (scaler or inverter) AC drive. However, the AC drive has trouble holding loads or speeds to sufficiently close tolerances. Thus, the AC drive is not suitable for driving most rollers and is relegated to duties such as turning slitters, fans, pumps and similar auxiliary components.

The next step in control finesse is the brush type DC drive, which is the workhorse of the web industry. In decades past, the DC drive was an MG (motor-generator) set. Now, many DC drives are computer programmable and digitally controlled. The only significant disadvantages of the DC drive is that the maintenance is higher due to brush and commutator wear and some difficulty holding settings at very low speeds.

Recent advances in computer control has now allowed the AC drive to leapfrog the DC drive in terms of control finesse. This advanced type of AC drive is referred to as a vector rather than the scalar drive discussed earlier. The AC drive requires less maintenance than the DC because there are no brushes. Since the prices of vector AC are now similar to DC, the only reason to buy DC is for compatibility with existing equipment and expertise in the plant.

At the very high end of drives, brushless DC, servo-motor and stepper motor drives. These drives are so responsive that they can literally be made so sing. However, this technology comes at a cost and thus these drives are reserved for high end positioning applications.

It is important to remember that the drive is composed of both a motor and a controller. Often, one will find motor controllers purchased based on low price that are not suited to the application. Indeed, most drive controllers are not suitable for web machines. Web drive controllers should be capable of open-loop speed and torque modes as well as closed-loop dancer or load cell modes of control. Also, web drives need to have a programmable acceleration and deceleration speed ramps with adjustable rounding on each end. Finally, motors connected to winders or unwinds must have inertia compensation to change the gain automatically as diameter changes.

However, even the best motor and controller can be crippled if it is applied incorrectly, or if it is attached to mechanicals that are compromised. Common examples of incorrect applications include running stiff (most) webs under draw control, or giving the drive a signal from a friction bound dancer or undersized load cell with insufficient resolution. Examples of mechanical compromises include excessive drive friction when using torque (or amperage) control and not driving rollers when high drag or inertia indicates the need.

Finally, we must not forget mechanical drives such as pneumatic or magnetic particle brakes and clutches, lineshaft drives, variable speed mechanical transmissions and the like. Invariably, these will be initially less expensive than electric drives. In some cases, such as unwind brakes, they may be entirely adequate. In other cases, however, the mechanical drive may not have the resolution or range to hold web tensions accurately at all conditions.

***1996.07 Jul 1996
When and where do I need a drive?

You will notice that some rollers have drives connected to them and others do not. Process rollers, for example, are almost always driven while transport rollers are seldom driven except on very wide and/or fast machines. Previously, the decision whether to drive a roller or not was often based on list of cases or experiences such as this.

Now, however, we can provide four quantitative design rules based on web handling principles that justify the extra expense of a drive point. This objective recipe based approach should be more satisfying than the previous experience based judgment. First, it avoids adding a drive point when it wouldn't noticeably improve performance. Second, it avoids leaving out a drive point when it would substantially impair the quality of tension control. Finally, in addition to avoiding these two potential errors of judgment, it allows us to design new systems for which no previous experience exists.

First, a drive is required on each end of a process line to establish tension. On a roll-to-roll converting line, the unwind will be a brake and/or motor while the windup will be a motor. While it is true that some nonwovens or textile machines pull loose material from a box, they have essentially no means to control tension and thus violate good design principles. If a maker is on the upstream end, the drive might be a pump. If a sheeter is on the downstream side, the drive will be a motor driven nip roller set.

Second, a drive point is required to create a new tension zone in a machine. In most cases this is where there is a substantial change in web strength such as heating (strength reduction) or laminating (strength increase). Sometimes a new tension zone is needed in speed control to counter hygro-thermal expansivity. Another example is to isolate taper tensioned winding from the upstream process.

Third, a drive is required to avoid web/roller slippage. Some lightly wrapped rollers do not have enough traction to be turned solely by the web. In this case, the drive is used merely to counter drag and inertia so that the web does not slip on the roller which would cause roller wear, possible sheet marking and a general loss of web handling control. Web/roller traction is calculated via the band-brake equation. In unusual cases, such as some types of coaters, the drive is actually used to control a specified overspeed or underspeed of web/roller slippage.

Finally, a drive is required to avoid large tension differences across a roller or section due to drag and inertia. This is by far the most common drive point requisite and why most process rollers are driven. For example, a nipped roller usually has so much drag and possibly inertia that the web would break trying to turn it without help. A quantitative guideline might limit tension rises through all undriven rollers in a drive section (bounded by two drive points) to less than 10% of the minimum tension setpoint in that section during steady state. During transients, such as speed changes, the guideline might open up to allow no more than a 25% tension deviation range anywhere in the section and at any time. The tension difference across a roller is calculated by the rotational equivalent of Newton’s Third Law.

Thus, as we have seen, a quantitative and unambiguous set of design rules will tell us whether a point in our process line should be motor driven or web driven. The only judgment required is how close do we want to hold process tension. Once this machine quality standard is chosen, the web machine mechanicals and controls will almost design themselves.

***1996.08 Aug 1996
Should I consider a wider or faster machine?

The reader has probably noticed that there is a tremendous range of widths and speeds of web machines. Webs can be as narrow as 1/8Ó wide (pinstriping tape) to more than 400Ó wide (paper machines). Similarly, web converting speeds can be as slow as 10 FPM (feet per minute) (specialty coating) to more than 10,000 FPM (newsprint rewinding).

Why are some machines so much wider and/or faster than others? To understand the impetus, we must first look at a simplified but typical breakdown of the cost to produce/convert a web product:

50% - raw materials 25% - labor 25% - other

The per unit raw material costs might even drop slightly on wider/faster machines because they almost force reduced waste rate. On the other hand, the per unit Ôother' category might increase slightly as wider/faster machines are more capital intensive. However, the overriding reason that wider/faster/automated machines can be more economical is that the per unit labor charges are significantly reduced. Simply put, one operator can make more material than before.

However, the caveat is that reduced per unit production costs are only achieved if we can sell enough material to keep this machine running nearly continuously. While small machines are run as needed to fill orders, wide/fast machines will only stop a few times a year for scheduled maintenance or unscheduled breakdowns. Thus, the challenge and justification for wide/fast machines is solely one of marketing their capacities. Wide and fast will not, as we will see, pose any particular technological difficulties.

Increasing machine width has two principle economical advantages. First, as already mentioned, is that the per unit labor costs are reduced more than the per unit machine cost increase when the machine is run near capacity. Second, increasing machine width provides a greater range of product widths that can be offered and increases the flexibility of nesting multiple wide products with less trim waste. However, obtaining increased productivity by width is much more expensive than obtaining it by speed.

There are three primary technical considerations with increasing width. The first is that roller diameter and crossbeam section must increase so that deflection is not excessive. As discussed earlier (March 1995 and January 96), an appropriate deflection limit for most rollers is 0.00015xwidth. This will result in slenderness ratios (length/diameter) of between 10 and 20. Obviously, framework and foundation must be also increase in heft to handle these heavier components.

The second affect of increasing width is that the increased roller diameters will require ever more rollers to be driven to overcome increasing bearing drag with heavier rollers and increasing inertia with larger diameter rollers. Though one can buy a little relief by keeping down roller counts, reducing acceleration rates or using composite rollers, motors will be eventually needed on light wide webs even for mere transport rollers.

The third affect of increasing width is that system vibrational resonances become more numerous. Though some roller manufacturers and machine builders calculate critical speed of their rollers, the calculations are usually meaningless and always nonconservative. This is because these simplistic formulae assume a infinitely rigid roller support, which is simply not achieved by any real framework. The net result is that resonances are ubiquitous (but fortunately most often benign) on machinery that is both wide and fast.

The only real limitation for width is economics. Currently, the widest machines are just over 400 inches. However, they require rollers that are 2-3 feet in diameter to keep deflection at bay. Obviously, wider machines will become impractically expensive due to the massive amounts of metal required to span such distances.

Machine speed also has several technical considerations. First, higher speeds mean more potential resonances and increased demands for precision roller balancing. At low speeds, one might get away with a simple static balance. However, beyond 100 FPM, a 6.3 balance class might be specified and beyond 1000 FPM a tighter 2.5 balance class might be indicated. These imbalance loads also contribute noticeably to bearing failures if one is not careful. Also, one may have to shop around more for drive component with sufficient RPM ratings to handle the higher speeds.

Second, higher speeds may increase the machine’s length to provide sufficient ‘dwell time’. For example, it may take a certain number of seconds to dry a material on a heated roller at a certain speed. If speed is doubled, it still takes the same amount of time so that the area in contact with a heated roller must double. This can be achieved either by doubling the diameter or by doubling the number of heated rollers. Many high speed paper machines are nearly 1/4 mile long, mainly because of the scores of dryer cans needed to get the dwell time.

Third, proportionally more of the drives capacity is used to accelerate the machine than to create tension. This is because high productivity machines may accelerate 10x as quickly (100 versus 10 FPM/sec). These machines then require drives that are more accurate and responsive. Finally, higher speed machines may require special provisions for trim handling (pneumatic), threading (pneumatic or rope) or other considerations.

There are two physical limitations to speed. First, air entrainment into wound rolls of light grades becomes a problem at speeds around 1000 FPM for film and around 10,000 FPM for paper. Second, centrifugal force will tend to lift webs off of rollers in the 10,000-20,000 FPM range. For these reasons, I do not expect much of an increase in design speeds beyond the current 8,500-10,000 FPM for light web grades.

No matter what your product and process, you will continue to see ever increasing design speeds of new machines. Initially, new machines will make high volume grades. As they age, they will later be relegated to high dollar / low volume niche products as they fail to be competitive against even newer and faster machines. This second life is only obtainable, however, if the machines were robustly designed and were well maintained. Though the design life of good machinery is 40 years, it is not uncommon to find some that is the better part of a century old.

Thus, as we've seen, there are no new principles involved when increasing machine width and speed. We merely need to do the same design sizing as always, but with slightly different numbers. We can take comfort in the fact that the theory has been well proven by the paper industry who has been operating wider than 100 inches and faster than 1000 FPM for the better part of a century.

Our main challenges for high productivity machines will be in marketing. First, as mentioned previously, we need to sell the produce of the higher output machine. If we don't, the economics will not be friendly. Second, we need to make marketing aware that higher widths and speeds will require adjustments in some product specifications. For example, while a 3Ó core might be adequate for a 50Ó wide wound roll, a 6Ó core might be required for a 100Ó wide roll. Similarly, a wound roll on a 3Ó core might be safely unwound at 1000 FPM, but might explode when unwound at 2000 FPM.

In conclusion, to reach your next machine productivity plateau you merely need to have your marketing and engineering departments put in a little creative overtime.

***1996.09 Sept 1996
Is my drive healthy?

A healthy drive system is essential for a healthy web process. An unhealthy drive can cause a bewildering variety of different symptoms such as variations in product geometries of length, width, thickness or weight. If the drive allows tension to drop too low, web edge position may be compromised and wrinkling may result. If the drive causes excessive tension, the web may be deformed or even break.

The drive system includes components such as all rollers and shafts, the electric motors which drive them, and the motor controllers. Many drive systems will also include mechanical brakes, clutches, gearboxes, belts and the like as well as electrical sensors such as load cells. Obviously, each component must do its job in order for the whole to perform acceptably. However, even good components can be assembled improperly into a drive system that fails to work well. In this article we will describe how drive system health can be evaluated.

To understand drive health, we must first observe that the only purpose of a drive is to turn the rollers while maintaining tension within some bounds everywhere. Tension is the common denominator for measuring and defining drive health, even if the drive is actually operated under dancer, speed or other type of control Tension errors include a nominal tension range which doesn’t cover the required needs, as well as variations of tension with respect to time, MD position or CD position.

First, the drive must have the range to cover tensions from as little as 10% of strength of the weakest product to as much as 25% of the strongest product (Web Works, Nov. Ô94). This tension range is most difficult to achieve on unwinds and centerwinders where the radius ratio (outside to core) multiplies tensions to an even larger required torque range. In the case of true drawing, the tension range is the strength range of the products.

Second, the drive must be responsive so that tension errors are dealt width quickly, but without overshoot or instability. Examples of sluggish drives include older controllers, pneumatic devices and winder/unwinds without inertia compensation. Similarly, the drive must be sensitive and accurate so that steady state tension errors are small. Examples of insensitive drives are those whose sensors are high friction dancers or oversized load cells. As a quality guideline, we would expect a drive to hold tension variations to less than 5% (of minimum setpoint) during steady state and 10% during transients (speed changes) as read by responsive load cells. Since there is no substitute to evaluate a line by this rule, all good machines should have load cell tension monitoring.

Third, the drive system should not allow tensions to climb by more than 10% in a section during steady state nor vary by more than 25% during transient extremes. Conformance to this rule is a calculation based on roller drags and inertias (Web Works, July 1996).

Finally, web tensions should not vary across the width. Tension variations with respect to the CD are caused in part by web bagginess (Web Works, April Ô94) and in part by roller misalignment and cylindricity errors (Rollers, March Ô95). While this may not seem like a drive issue, the web does not know the source of tension errors.

Without these quantitative measures of drive health, one can only estimate conditions. First, we expect the master speed reference to hold speeds within 1:1000 or better. Second, the drive should accelerate/decelerate at a controlled rate (10-100 FPM/sec is typical) with a second or two of rounding at each end. Third, we expect ammeters and other gages to move smoothly to new setpoints and remain there without quiver. Finally, we expect the web to behave essentially the same during all conditions of acceleration, run and deceleration.

***1996.10 Oct 1996
How much vibration is too much?

Machine vibration can cause excessive wear and premature failure of components such as bearings, couplings, pivots, slides and so on. In fact, one study indicates that more than one half of all bearing failures were substantially aggravated by machine vibration. While most converting machine components should live more than a decade, those that are under distress may not celebrate their first birthday

Vibration can also cause process and product troubles. For example, a vibrating nip roller can cause barring in the product. Similarly, vibrating coater components can cause skips and light spots. Finally, vibration can increase the frequency of web breaks on brittle materials such as paper, cellophane and so on.

However, the most serious aspect of vibration is that it may pose a safety threat. One example is the fatigue failure of a roller journal or shaft. Another example is the escape or throwout of winding rolls from a winder. To get an idea of the energies involved, simply compare the weight of the roll or roller with an automobile or truck traveling at similar speeds.

In an ideal world, we would not generally want any vibration on a machine. However, this is simply not practical. So we must tolerate a bit of shake as a part of doing business. In a few cases, such as the affects of roller imbalance on bearing life, we can calculate appropriate vibration levels. In most cases, however, we usually establish criteria based on what is typical for machines that are well designed and maintained.

The first aspect of a vibration criteria, which is the easiest, is to determine how and where vibration levels are to be measured. Vibration severity is usually measured with hand held vibrometers or FFT vibration analyzers with remote sensors. The points and directions of greatest concern are often where the magnitude and direction of the vibration are maximum. An exception to this is nonstructural components, such as panels or guarding, which might vibrate considerably without debilitating the process. The severity is also defined as the peak or worst vibration level seen during a run. Thus, as we’ve seen, vibration mapping is a 7 dimensional problem (3D position, 3D direction and time). However, causal non-instrumented observation will usually limit the search to a few key areas.

The next aspect of a vibration acceptance criteria is to define the units of measure. The three choices are displacement, velocity or acceleration. Being of a mechanical background, I tend to work in displacement as it seems intuitive to compare the amount of movement with other machine tolerances. However, most work in velocity because it best captures severity which is independent of machine operating speed. Finally, acceleration units are related closest to machine forces. Bear in mind, however, that the choice of units is for reporting purposes only because the vibration instrument can display or convert between any of the three units.

Finally, the tough part. That is defining an acceptable magnitude of vibration. I will leave you with the following table from my roller book that gives a starting point for establishing your own standards

Class	Accel g pk	Velocity in/sec pk	Displacement mil pk-pk
Poor	1.0	1.0	10.0
Good	0.1	0.1	1.0
Excellent	0.01	0.01	0.1

***1996.11 Nov 1996

How can I reduce vibration?

The first step to reduce vibration is to determine what is driving or forcing the vibration. In almost all cases it will be rollers. The problem roller(s) is most easily identified with an FFT (Fast Fourier Transform) vibration analyzer because the frequency of the worst spike is an integral number times the offending roller’s rotational frequency. If there are several rollers of the same diameter, the vibration will be weighted toward the closest, most out of balance, or most flimsily mounted.

The first thing to check for is roller balance. Most rollers should be balanced to an ISO G6.3 grade, though a few slower or nonprecision rollers might be adequate at a G16. High speed rollers and/or precision rollers may need a G2.5, or in exceptional situations, a G1.0 balance. At these balance standards, one can calculate that the magnitude of the unbalance forcing function is only a small fraction of roller weight.

The next thing to check for is excessive roller runout, especially for wound rolls or rollers in nip. Out-of-round rollers in nip will vibrate much like a follower on a camshaft. Establishing runout standards depends on the application. Some hard high speed calender rollers may vibrate excessively with less than 1 mil (0.001Ó) of runout while wound rolls might be processed adequately with over 100 mils of runout.

The next two things to check for are for roller misalignment and roller mounting looseness, especially if the FFT shows harmonics of roll rotational speed. As a practical matter, however, misalignment or mounting looseness would have to be far greater than the few mil tolerances required by web handling considerations in order to cause excessive vibration.

If the rollers are true and excessive vibration still results, it may be quite likely due to poor structural integrity of the framework and foundation. While this is usually easy to avoid at the design stage, it is often impractical to fix after the fact. The three ways to ensure structural integrity at the design stage are by: experience, finite element analysis or by design overkill. Making structures very beefy is often the cheapest and surest because metal is only a buck a pound and concrete is even cheaper.

The foundation or footings necessary to ensure machine stability vary considerably between applications. High speed, wide, paper calendering or winding machines may need continuous footings three feet thick and running the length of the machine. However, even the most modest converting machines should have footings no less than 1 foot wide by 1 foot deep and continuous the length of the machine. In general, it is not a good idea to simply bolt a machine to a slab floor, even if it is a 6Ó thick industrial floor. The slab floor is simply not adequate to hold long term alignment with seasonal swelling and compaction of the earth. Neither is it sufficient to withstand much in the way of vibration forces.

Machine framework design considerations are even more difficult to state succinctly for a wide variety of applications. However, the gravest and most common sins are excessive journal length, mounting to thin plates, and cantilevered mountings. The journal or dead shaft stickout beyond the roller face to the bearing or mounting should be an absolute minimum. Structural mounting surfaces should be either very thick (> 1Ó) plates or should be backed up with gussets to reduce flexure. Finally, cantilevering of any kind must be kept to an absolute minimum. Cantilevers, such as a flagpole, are mounted to ground on only one end.

Even after all of these things are done, one still may be left with excessive vibration in a few rare instances. An example is the vibration of surface wound rolls which, despite our best efforts. can be inevitable in some cases.

***1996.12 Dec 1996
Is my spreader roller working?

Spreaders are one of the most common of all converting elements. They are found on most machines. Many spreaders are intended to flatten a web prior to some critical process. Spreaders are also used to widen a web or to increase the separation between slit lanes. There are many types of spreaders (Converting Magazine, Nov. Ô95) to fill almost all application niches. However, they all operate on the same fundamental level by inducing a small amount of CD tension and thus minutely moving the web’s edges apart, i.e., spreading.

Unfortunately, many spreaders serve no useful purpose and some are even damaging. The problem is not one of principle, but rather one of application. In other words, all of the spreaders can serve a useful and identifiable purpose if they are applied properly. Conversely, if they are placed in locations where no spreading is required, or if they are not set up properly, the results will be nonexistent at best and damaging at worst.

The first thing to do is to determine specifically why a spreader would be useful in a certain location. For the most common application of web flattening, a spreader is required immediately in front of critical processes for preventative reasons, even if the web is generally flat. Critical processes include calendering, coating, embossing, laminating, printing, slitting, winding and so on. A spreader may also be required to keep web troughs from crossing a roller as wrinkles.

However, if the web is already flat in an area, a spreader will not make it any flatter. If a spreader is located too far forward of a critical process, the temporary benefits of spreading may be lost before they are most needed. Finally, a spreader should not be expected to be able to pull out a crease or foldover.

One way to tell if a spreader is working is to use the definition of spreading which is, namely, to make a web wider at the spreading unit. Extensible materials such as tissue, many nonwovens and stretch film will widen by 1% or more at a strong spreading unit. In these cases, spreading action can be verified merely with a tape measure. While all material will widen at a spreader, the width increase on inextensible materials, such as paper, is very difficult to measure without special sensors.

If a spreader is used to separate slit webs, the gap between the lanes should increase slightly as they move from the slitter to the spreader. However, do not expect more than about 1/16Ó separation on wide inextensible materials as the web does tend to resist moving out of its path. Also, it is best to use average instead if minimum separation because baggy webs and other profile problems may cause the paths and thus the distributions of spreading to be erratic.

Another way to tell if a spreader is needed and working is to observe a visible flattening of the web. In other words: ugly in, flatter out. There could be several possibilities why he web might not be visibly flatter over the spreading unit. First, the web may already be flat and thus can’t benefit from spreading. Second, the web can be so baggy and distorted that the weak forces of spreading are not able to do much with it. Finally, the spreader may not be working properly.

A sizable share of all spreaders are not functioning. In some cases, it is because the so called ‘spreader’ is not based on any known spreading principle. The most common example here is the ubiquitous spiral grooving that is thought to provide spreading (Web Watch, Aug. Ô95). Many times the spreader doesn’t work because it is set up wrong, such as by pointing the bow in the wrong direction. Finally, many spreader types require traction to operate, and will fail to do so if traction is lost.

***1997.01 Jan 1997
Should I question the value of process controls?

**[NOTE this article is formatted for two pages]

Measurement is the foundation of process control. Since control of our processes and products can be no better than the quality of the measurements we make, our products can be no better than our measures of them. If our measurements are noisy and uncertain, our products and processes can't help but vary, perhaps exceeding contract or customer expectations.

Though measurements are vital, how often do we question their goodness? If you are like most, you will observe the process reading or record the quality lab test measurement without a second thought about its goodness. If the meter was provided by the builder, must it not be relevant? If the test has long been used to qualify material, must it not be discriminating. If the reading is from a calibrated and traceable gauge in an ISO environment, must not the value be accurate and consistent?

Unfortunately, experience has taught us that the machine's knobs and dials are not always relevant to those things that matter most. For example, many wound roll defects are not influenced strongly by any of the knobs or settings on the winder, nor are their propensity or intensity strongly predicted by any of the dials and meters displayed on the benchboard. Similarly, without a responsive load cell tension readout, we have difficulty troubleshooting many drive and web handling problems. However, web breaks are almost never correlated to any measurement on the machine or in the lab.

Lab testing is also not always relevant. For example, strength is measured ubiquitously, even when the product never fails in tension during converting or end use. Caliper is also measured on most products. Unfortunately, while we know that caliper variations are responsible for wound roll defects such as ridges and corrugations, our instrumentation is not usually fine or sensitive enough to pick them up. Sometimes measurements are so inaccurate or uncertain as to render their use and interpretation more harmful than good. I once worked on a project to test the sensitivity of a half dozen commercial wound roll hardness testers to detect a step change in winding tension as well as a web break and splice. As seen in the figure below, the best of the methods was barely able to detect even violent changes in the roll, while most yielded little but measurement noise. Curiously, the worst was the only one recognized as an official test method. It is unfortunate that these devices have been used for decades without anyone ever Ôtesting the tester'. It is no more difficult to do than to put a large known step change in the system, measuring response, and using the Z-test for significance. Many now suspect that roller cover hardness tests may be similarly flawed.

**[INSERT Fig 1. - Lab Test Instrument Sensitivity Comparison]

The integrity of machine controls can also be suspect. For example, dancers and nips are simple devices which are usually controlled by pneumatic cylinders. We should expect that a constant cylinder pressure would therefore cause a constant nip or tension. However, as shown below, a load cell readout installed to monitor nip load on a machine shows exceptionally poor quality. Similarly, a load cell tension readout of a dancer shows tension variations exceeding 50%.

In both cases, the readings were obtained on commercial units which have been installed in thousands of locations. In both cases, no one thought to question whether the pressure settings on the machine were a good indicator of vital process control variables. In both cases, the root cause was excessive mechanical friction. In both cases, the solution is a complete mechanical redesign because control fixes to counter the variabilities of friction are not especially effective.

**[INSERT Fig 2 - Nip Load Control]

**[INSERT Fig 3 - Tension Control with a Dancer]

Finally, the reader should bear in mind that almost all measurements are derived rather than direct. For example, load cells do not measure tension but rather resistance changes due to a displacement of the cell. Here, the load cell will respond equally well to roll weight, roller imbalance, tension and amplifier adjustments. Thus, we must be sure of all of the assumptions and conditions that are made when converting a measurement from its raw sensor input to its engineering value output.

Similarly, we have no direct means of measuring temperature, which is a vital process parameter for heated rollers, chilled rollers, ovens, extruders and the like. Furthermore, the most important temperatures can be the most difficult to obtain. These temperatures are of the machine points that are in direct contact with the web (usually rollers) and the web itself. Both the contacting bimetallic thermometer and the optical infrared gun can have trouble with accuracy and consistency. The bimetallic device is subject to vagaries of conduction and frictional heating. The infrared gun must be calibrated to each substrate and even then changes in surface emissivity can cause erroneous temperature readings.

The only measurement I am aware of that directly measures what it advertises to is the ruler. All other measures are converted. However, even this simple device is subject to manufacturing errors, thermal expansion, distortion, parallax errors and plain old misreading. If such a simple instrument such as this has subtleties, how much more so the more complicated instruments used for process control and lab test measurements.

In basic installations, none of the knobs and dials may be connected to a particular problem of interest. In instrument rich environments, we can get buried in data so that the relevant connection is missed. In any case, however, I hope the reader is left with a measure of distrust of measurements. Too often we accept the readings at face value and without question.

***1997.02 Feb 1997

Why isn’t my bowed roller spreading the web?

From last month’s column, we would now expect to see a visible flattening of the web and/or a measurable width increase over a spreader. If not, the spreader may not be needed or may not be working properly. Unfortunately, it is very common to find the ubiquitous bowed roller falling in the latter category.

It is important to recognize that the bowed roller spreader requires traction to function. Even an imperceptibly small amount of slippage between the web and roller can compromise spreading, destroy it, or even turn it into a wrinkle making device. As seen in the figure, a loss of traction causes a portion of the web to break loose and run into adjacent neighbors which are still in traction.

The potential causes of a traction loss on a bowed roller are many. Perhaps the most common is to overbow the spreader so that the web will refuse to conform to a perpendicular entry on the ends. An appropriate bow magnitude would be between 0.15% of face for a flat, unslit and inextensible web (the most common situation) to as much as 1% for special circumstances. Unfortunately, most bowed spreaders, especially on narrow converting machinery, are bowed much more than this.

Another common way to destroy the effectiveness of the spreader is to allow the covers to become glazed, worn and slippery. The surface of a cover which is in good condition will feel grippy like a tire to the touch, while one that is in need of rework will feel slippery like plastic pipe. Cover diameter profile should be measured regularly and the cover replaced when the variation across the width exceeds 10 mils.

The web may also slip over the spreader if the roller isn’t wrapped sufficiently. Try to get at least a 30 degree wrap for most applications. Finally, the spreader may not operate well if there is so much bearing drag that the cover tends to travel slower than the web or if a drive tends to turn it at speed different than web speed.

There are several symptoms of an overbowed or ailing spreader. First, spreading appears good at the center. Second, spreading appears poor at the ends and the web may even become wrinkled. Third, the operators have found that the best orientation of the bow is up into the sheet more than 10 degrees from the nominal. As seen in the figure, the nominal bow direction is halfway between the direction of the web ingoing and outgoing the spreader.

**[INSERT figure of Bowed Roller Streamlines]

**[INSERT figure of Bow Orientations]

***1997.03 Mar 1997
What is the best slitting method?

Slitting is such an ubiquitous converting operation that most webs are slit at least twice. The first slit is usually the edge trim taken on the manufacturing machine. The second slit is often on a rewinder to cut the web to end use widths. The most common slitting methods and applications are given in Table 1. Unfortunately, slitting is more of an art than a science so that the best method is determined by experience rather than calculation. One simply needs to run the target material through several slitter types on a pilot machine or at a contract convertor to compare performance. Sometimes more than one method will be acceptable by criteria given below. Some applications may have trouble using any or all methods of slitting. Red flag slitting situations are given in the Table 2.

The purpose of a slitter is to severe the web completely along its length. Thus, the cut line must be straight along the machine direction, and continuous without skips. If other cutting shapes are required, sheeting (cross-direction), die cutting (odd shapes), perforating, waterjets or other means are employed.

Additionally, the slitter must severe the web cleanly. The cut edge is desirably sharp rather than ragged or hairy. The cut quality can be quantitatively measured by putting the edge into a micro-fiche reader. The median position of the cut is aligned with a center mark on the screen, and fuzz extending beyond the correction or rejection limits can be quickly and easily seen.
If paper is not cut cleanly, the edge will be fuzzy with wood fibers that are torn loose rather than severed. Also, the slitter will probably be generating a great deal of dust which can be objectionable for processes such as printing. This dust may need to be vacuumed off or otherwise removed. If film is not cut cleanly, long strands of angel hair can be extruded through the cutter. Also, the very edge of the film is prone to a thicker caliper bead which can cause difficulties in winding.

The slitter should also cut with minimal attention and for a long time. Slitter life is often a compromise with cuttability. In other words, the harder you try to cut, the shorter the life. Thus, many setup adjustments are engaged just enough to cut a particular product. Bearing any harder will not cut any better, but rather will only shorten life. The life between regrinds of blades, for example, can vary from hours to years depending on the application.

Slitter life depends on a number of factors beyond the web. First, the operators must be taught how to make adjustments quickly, consistently and optimally. Second, maintenance and grinding must be uncompromised. Third, blade metallurgy options can affect life by almost an order of magnitude.

Finally, the slitting process must be safe. Slitters can cut fingers as easily as webs. Thus, the slitter heads should be guarded to prevent fingers from reaching blades during operation. If this is not possible, a light curtain might be used to shut the machine down if entry is attempted during running. Similarly, knives and blades should be handled with gloves. A particularly dangerous practice to avoid is cutting a moving web or roll with a handheld knife.

Table 1 - Slitting Scenarios

1. Laser - laser perfed paper, plug wrap
2. Razor - thin film
3. Saw - small rolls
4. Score - adhesive tapes and tissue
5. Shear - most materials
6. Waterjet - thick or difficult materials

Table 2 - Slitting Situations.

1. Abrasive materials - high wear rates
2. Brittle materials - web breaks
3. Bulky (thick) material
4. Bulky (1/r) materials
5. Gummy materials - foul blades
6. High speeds - high wear rates
7. Thin film - edge bead
8. Narrow cuts or trim

***1997.04 Apr 1997
How are laser and razor slitters used?

As a cutting tool, lasers are more often used by science fiction writers than they are by other technologists. The reason is that it is very difficult to design lasers with enough power to economically remove material at high enough rates for most cutting applications. Thus, cutting lasers are most common in applications such as medical surgery where material removal is small and slow.

Nonetheless, lasers are used in web cutting applications. One consumer products example is the laser perf cross cut on premium fan-fold computer paper. Another example is the holes drilled in the paper which makes up part of a cigarette filter. These examples illustrate the niche use of a laser to cut fine patterns in materials that may not hold up well to more traditional mechanical cutting or patterning methods.

The first limitation of laser slitting is that the material must be thin and/or running slowly so that the laser has time to Ôburn’ away the material. The second limitation is that the material must be opaque, but not reflective. The material must absorb the energy of the beam in order for it to heat up to melting, burning or vaporizing temperatures. Finally, the edge will have a different appearance than if it were cut mechanically.

The laser also has several installation considerations. First, it tends to be more bulky than other cutting systems. Second, it has more plumbing and wiring. For example, each cutting head may need to be supplied with a vacuum duct to remove the gases produced at the cut point. Finally, it has a unique set of safety considerations. For example, the laser must be turned off when the web comes to a stop or it might catch fire! Though the laser is more unusual and more expensive than other cutting or patterning methods, it has been used on webs for some time and offers some unique capabilities.

Razor slitting is quite simple, because it can consist of as little as a utility knife blade held in the web’s path. Consequently, it is one of the least expensive cutting methods. Also, it is most simply repositioned, and blades can be changed on the run. Unfortunately, razors can only be used effectively only on a few materials, such a thin films.

The ability of the razor to cut is determined by many factors as given in the table. Of these, sharpness, web tension and web support are most important. Sharpness is the radius of curvature of the blade’s edge. The most effective web support is to cut over grooves in the wrapped portion of a roller. However, the grooves may limit cut widths to pitch increments, and grooving of any kind increases the propensity to MD trough wrinkling.

The ability of the razor to cut for a long time is determined by factors similar to those given in the table. However, life can be extended by oscillating or repositioning the blade. Also, ceramics will last much longer than tungsten carbide, which lasts longer the high carbon steel.

Finally, common sense dictates that all blades be changed out at the same time prior to dulling because blades are much less expensive than lost production. Similarly, dual blade holders should always be considered.

Razor Cuttability Factors

1. sharpness - increase
2. web MD tension - increase
3. web CD tension - increase
4. web support - increase
5. blade grinding angle - decrease
6. blade attack angle - decrease
7. blade thickness - decrease
8. blade/web friction - decrease
9. material - thin, not gummy

***1997.05 May 1997

How can I improve the performance of a score slitter?

A score slitter is a rotating blade nipped against an anvil roller that is driven very close to web speed. The score slitter is also known as a crush cut slitter because it is the web's compression under the blade rather than shear that causes the material to fail. Unfortunately, the score cut can be more ragged than with a shear blade. Also, the cut can be skippy or incomplete so that a stationary following blade may be required to completely separate the lanes. Finally, the score slitter is speed limited to 1,000-3,000 FPM depending on the precision of the blade and anvil roll runouts as well as the dynamics of the mounting.

The most common application for the score slitter may be adhesive tape and similarly gummy webs. Here, the score slitter provides adequate cut quality without the fouling of the blades that can accompany the shear slitter. Also, the shear slitter is used on many older tissue converting machines as well as a few specialty web products.

The ability of the score slitter to cut depends on many factors. Of these, the engagement force and the sharpness of the blade tip are the most important controllable parameters. The engagement force should be just enough to sever a particular grade with new blades. Increasing the force beyond this value is counterproductive because it simply wears out the blades and anvils quicker. Engagement force should not be increased to compensate for worn blades because this is also counterproductive. Instead, the blades should be reground.

The ability to cut is also increased with increasing sharpness of the blade. Sharpness is defined as the radius of curvature of the tip. A blade which is new has a small radius which will then increase as the blade dulls. However, the radius can't be too small (too sharp) else the blade may fail catastrophically due to compression, chipping and/or spalling, or the anvil roller may be marked. Tip radius, which is a most vital blade geometry factor, is not ground with precision. Rather, it is the result of a final dressing step of the grinderman using a handheld stone. The grinding angle is typically about 90 degrees but is not of such vital importance.
As given in the table, the factors which extend blade life include those which affect cuttability, but are in the opposite direction. In other words, increasing force and sharpness will increase cuttability, but will decrease blade life. However, there are variables that can increase life without affecting initial cuttability. For example, one can increase the hardness of the anvil roller, the blade or both to increase acceptable cutting life without hurting initial cuttability.

However, there are several caveats. First, the harder the material, the more expensive it is. Second, the material must not be so hard that ductility is lost else spalling or chipping may result. Third, one of the members must be softer so that it becomes the sacrificial element. In most machinery, the blades are slightly softer and thus sacrificial. However, it may make more sense to make the blades harder because they are more numerous and complicated of shape. Perhaps the historical reason for the hard anvil roller is that the machine builders have not made them easy to change them out.

Score Slitting Life Factors

1. material
2. engagement force - decrease
3. sharpness - decrease
4. anvil & blade hardness - increase
5. grinding precision - increase
6. speed - decrease
7. anvil roller oscillation
8. cutting zone lubrication

***1997.06 Jun 1997

What is the best type of shear slitter?

Shear slitters are two circular blade which are loaded against each other. As suggested by the name, shear slitting is analogous to cutting with a scissors. Shear slitters are used on a wide variety of materials and at speeds in excess of 10,000 FPM. Shear slitters come in a variety of styles including individual mount (wide and/or high productivity machines) or twin shaft (narrow cuts or heavy materials), tangent or wrap. Also, shear slitters have many setup parameters as will be seen. This versatility allows the shear slitter a wide application range, but at a cost of increased complexity.

The first shear slitter selection decision is whether zero, one or two shafts are used to mount the slitters as seen in Figure 1. In general, the individual mounts tend to be found on a web maker or a wide converting machine while the twin shaft is more common on smaller converting machinery. The individual mounts, while more expensive, are easier and faster to set up. Indeed, some are computer positioned to set up automatically to widths downloaded from a production schedule. Twin shaft, on the other hand, are very time consuming to set up or even to change blades. However, they do offer economy and the ability to cut the narrowest widths.

The second shear slitter selection decision is whether to use the tangent or wrap shear configurations. Since, as seen in Figure 2, the cut point is on the wrapped portion of the bottom band even on the tangent shear, thus cutting action is very similar. Probably the biggest difference is how each must handle the vital sheet support issue. Rollers immediately adjacent the tangent slitter provide the necessary support against web flutter. The support on the wrap shear comes from spacers or unused bands between the cutting bands. Beware, however, that the grooves or spacings between cutting bands will cause wrinkles on light products. On the other hand, trim handling is simplified a little with the wrap shear because the band tends to pull the trim along. Tangent shear is common with individual mounts while wrap shear is common with single or twin shaft mounts.

**[INSERT figure of Shear Slitter Mounting Styles]

***1997.07 Jul 1997
How do I set up a shear slitter?

How well a shear slitter cuts a given web depends on just a few key parameters. How long a shear blade will cut before it dulls and requires regrinding also depends on those same parameters. However, there may be tradeoffs between cuttability and life. If you try to cut more aggressively, you will regrind blades more often.

Some of the shear slitting parameters are built in by the machine designer. Examples here are slitter penetration, toe-in and camber angle. Penetration is the distance that the (tangent slitter) bottom band is projected up into the web run, and is typically about 50 mils. This is used to ensure web stability at the cut point. The toe-in angle is typically about 1 degree, while camber angle is often 0 degrees. Toe-in and camber are usually machined in by the builder. Nonetheless, maintenance should check that the slitter holders are not loose or bent else these angles will be compromised. Also, maintenance should verify that the shear band is driven at (wrap shear) or over (tangent shear) speed as appropriate.

Other adjustments, such as slitter position, overlap and sideload may be made by the operator. Obviously, the operator will set slitter positions to obtain specific cut widths using a tape measure spanning from one band to the next. The only caution here is that hardware store quality tapes may not have accuracies sufficient for tight width tolerances. Slitter blade changes or setup may take as little as one minute for individual mount slitters to several hours for shaft mounted slitters.

Blade to band overlap must be set every time a new blade is installed. Most operators merely eyeball the overlap or chord distance. However, this setting is so important to cuttability and life that it should always be set by measuring overlap with a gauge or chord with a ruler. Similarly, the sideload force between the blade and band should be set via air pressure, but verified occasionally by measurement with a force gauge.

Finally, blade grinding angles must be selected as appropriate for each substrate. Shallow angles (nearly square) make for a sturdier and more durable edge, but may distort the web at the cutpoint. To cut at higher speeds, the axial and radial runout of the blades must be maintained within a few mils to keep the blades from bouncing apart or chattering.

Though many of the slitter parameters are a tradeoff between cuttability and life, we can increase life independently by using harder band and blade materials. In order of increasing life we may move from tool steels to tungsten carbide and finally to ceramics.

**[INSERT figure of Shear Slitter Geometry]

***1997.08 Aug 1997
How do I get rid of edge trim?

Edge trim may be removed at the web maker as the edges may not be straight or uniform. For example, an edge that wanders 1Ó will require an even greater trim width to avoid ‘losing the trim’. Similarly, if one can’t coat to within 1/2Ó of the edge of the web, then that width will be lost. Trim waste will also result when the ordered width(s) do not equal the manufactured widths. A wide machine has the dual advantages of better nesting flexibility as well as proportionally less waste.

Trim widths are usually on the order of 1Ó, but may be as little as 1/8Ó or as much as 8Ó. Unfortunately, trim seems to cause much more problems than its mere size might indicate. If it isn’t getting tangled into and ruining its saleable neighbor, then it will be plugging something up. Much of this is preventable, however, so that we should expect that a trim disappear so reliably that few give it any thought as to where it goes.

First, we must tension the trim, which ideally would be equal to the web tension to avoid any distortion at the slitter cut point. However, a lesser pull from a pneumatic system or even gravity might be adequate. Second, we must pull the trim away in the proper direction, which is initially in the direction it would have traveled had it not been slit. In other words, the trim should not be pulled sideways or out of the plane of the web at the cut point. Finally, we must take the trim away to some other location.

At low speeds, say less than 10 FPM, we might merely let the web fall on the floor or into a basket. If we are fortunate enough to have a basement underneath, we can run the trim into a compactor or dumpster at somewhat greater speeds. Occasionally, we may need to steer the web a bit with trim pans or air.

With a winder we will have other options. We may wind the trim into a butt roll (on axis) or a weed roll (off axis). Though a weed roll requires a separate winder (often a spool), it reduces the possibility of trim intertwining into a neighboring roll and eliminates the difficulty in handling the often unstable cookie shaped butt roll. Small diameter rolls such as tape or tissue can be cut with a single blade saw and thus allows the trim to be sawed off. The only issue here is that the end cut tends to be scalloped due to roll deformation caused by saw blade forces.

At higher speeds, one will most often use a pneumatic trim system. If properly designed, trims of varying widths can be reliably carried away at speeds up to 10,000 FPM and for distances of several hundred yards. Pneumatic trim systems can be assembled in one of the following configurations: All Negative, In-Line Fan, Eductor and Ejector.

Many of the problems with pneumatic systems occur on the inlet or outlet. Obviously, the inlet must pull the web straight away and with a proper force. Secondly, it should be ‘self-priming’ so that the trim enters the opening without operator intervention. To be self priming the opening should be located close to and under the trim slitter. As speeds increase, the shape and design of this inlet become more intricate and vital to the health of the system.

The trim piping should have very generous minimum bend radii as well as have smooth interiors to reduce blower requirements. The piping material should not generate static nor foul with coatings or other components. Finally, the exit of the system must get rid of the air and slow the trim down in a controlled fashion.

***1997.09 Sep 1997
Why does my web move sideways during speed changes?

A troublesome edge position excursion, known variously as the acceleration or ramp offset, is where the web moves sideways when machine speed is increased or decreased. The cause of most ramp offsets is illustrated by the various web tracks through a machine given in the figure. Here we show the path of the web through a machine where one of the rollers is misaligned. In the case of traction, the web will conform to the Normal Entry law on all rollers, including the one that is misaligned. Note how the web moves over as the result of this misalignment. In the case of pure flotation, however, the web is not steered by the Ôroller’ and, thus passes straight through the machine. The case of sliding is intermediate in that there is a small offsetting of the web.

Every roller or element that touches the web also steers the web. If the state of traction is constant, however, the path of the web will remain constant, though not necessarily straight. The web will snake through the crooked machine elements in conformance to web handling laws. However, if the web changes from full to partial tracking, the path of the web will change slightly in response. Though the change in traction may be subtle and not easily picked up by conventional observations and measurements, the web will move to a slightly different path in response.

While there are many ways the state of traction can change, the most common is due to a tension change on a lightly wrapped roller. This means that if our drive system allows tension variations, the web might shift slightly on some of the rollers. Furthermore, the condition where it is most difficult to hold tensions is during a speed change.

As we now see, the acceleration offset may not be directly caused by the speed change itself, but rather is due to the tension variations that will accompany the speed change. Our first efforts should then be to tune the drive so that tension is held well at sensors (load cells) as well as elsewhere where there are no sensors. Sometimes tension is held well only at the drive points or sensors, but not elsewhere because the web might be pulling against excessive roller inertia or drag, or against errant ‘helper’ drives.

We can also expect to reduce the severity of the offset if we reduce roller misalignment or other geometrical problems. The surest way to do this is through optical alignment of every roller in the line because even the lowly idler is as capable of shifting the web as any of the major process rollers. However, sometimes it is not a roller but rather an airfloat oven that is steering the web. Here, the first step is to balance the ovens to uniform clearances and airflow. However, the web will be the ultimate judge of balance as its position should not vary objectionably during tension changes or even dryer engagement/disengagement (for those that can open).

Finally, you want to keep your web as uniform, flat and baggy free as possible. This is because the web with profile troubles will merely exaggerate the difficulties discussed here. Only when material and machine are made true will edges run consistent.

**[INSERT figure of Web Paths Through a Crooked Machine]

***1997.10 Oct 1997
Why is my roll’s edge rough?

Desirably, a wound roll should have edges that are flat and uniform of width. However, winding physics guarantees that the nominal shape will be such that the interior of the roll will be wider than the outside due to Poisson swelling caused by winding pressures. Superposed onto this nominal roll shape are subtle edge variations that can be read like the rings of a tree to diagnose the process.

First, we must determine if the edge disturbance is a width variation or an offset. Though they may look similar on one side, there is almost nothing in common with their causes. An ‘outsie’ on one side and an ‘insie’ on the other is an offset. Any other combination involves a width change. The width change may be caused by a tension variations during or after slitting (Web Works July Ô95). The width change could also result from a slitter blade which moved, or by a wrinkle or trough in the slitter area.

An offset wrap will result if either the web or roll moves sideways during winding. To improve the tracking of the web, the web and rollers should be uniform. Also, it is extremely important to have a short distance between the slitter and the windup to give the web less chance to wander sideways.

The roll itself can also move sideways in a variety of ways. Perhaps the most common is due to poor maintenance of the winding machine which allows axial play in the shaft or core system. Other causes include axial thrust loading on surface winders which can swage the ends of cores up onto the corechucks, slip on coreshafts and even deform the winder frame. Finally, interlayer slippage inside the roll can allow a sideways movement. The most common example here is the telescope where the layers broke free in the MD and then allow a possible sideways shift.

**[INSERT figure of Nominal Roll Shape]
**[INSERT figure of Width Variations and Offsets]

***1997.11 Nov 1997
What causes a roll to telescope?

The telescope is a sideways or axial movement of a wound roll. Strictly speaking, the term telescope is for reserved for unwinding, though many also use it for related problems during winding (dishing) or handling (plating). Aliases for the telescope include scoping, coning and many more that are unprintable. The telescoped roll is especially troublesome because it will cause considerable waste (usually the entire roll) and delay (sometimes the roll must be slabbed down to get it out of the machine).

To understand the telescope, one must understand the stresses inside the wound roll. The most important of these stresses is the pressure between the layers that serves as the glue that holds the roll together. If this pressure combined with web-web friction is insufficient to withstand process stresses, then the layers will slip upon each other.

There is a tendency to note the sideways shift of the telescoped roll and then look for axial forces. However, a better analogy is locking up the brakes of an automobile on an icy road. If one is very lucky, the car will slide straight ahead. If one is very unlucky, the car will slide into the oncoming lane. The most likely direction is the ditch because of the crown in the road. However, a car in the ditch is the result of a loss of traction rather than a crowned road. The telescope is similar because it is most often accompanied or preceded by machine direction interlayer slippage. This is why many operators draw a radial line on the side of the roll as an early warning detector.

There are two primary forces that the wound roll must withstand as seen in the figure. The first and most easy to visualize is the braking torque at the core required to develop web tension at the roll's outside. The second but no less important is the gravity support internal nip force between the outside of the core and the inside of the roll.

Torque induced slippage is most common with dense and slippery materials while nip induced slippage is more common with bulky webs. Though there are subtle distinctions, the cures are similar:

1. decrease the roll's outside diameter
2. increase the core diameter (to the bend in the J'line)
3. wind the roll tighter
4. increase web-web friction (torque) or increase web density (nip)
5. decrease unwinding tension (torque) or relieve roll weight (nip)

**[INSERT figures of Nip and Torque, Interlayer Slippage]

***1997.12 Dec 1997
What causes a roll corrugation?

A corrugation is a wound roll defect caused by caliper or basis weight variations of the incoming raw material. As seen in the figure, it appears as a narrow band which runs about the circumference of the roll. In contrast to a ridge or valley, which can also be caused by caliper variations, the corrugated band has rungs which may be on a diagonal. The corrugation is also known by the aliases ‘rope marks’ and ‘chain marks’ because of its appearance.

The corrugation forms at a position where there is a sufficiently abrupt change in web caliper. The worst caliper profile is a high-low-medium pattern 1-2Ó wide, though others may also trigger the fault. The diametral variation of the building roll will mirror the incoming web profile. Thus, thicker areas of the web will cause the roll to build larger there than at the thinner areas as seen in the figure.

With pure centerwinders, caliper variations may not cause corrugations as the large diameter will simply stretch tighter there than elsewhere. The real problem begins when the roll is wound with a nip. Since the wound roll is a solid body, it wants to turn at the same rotational speed (RPM), which causes the surface speed to vary from slower at the low points to faster at the high points. However, the nip roller (layon roller, drum, etc) wants the roll to turn at a constant surface speed (FPM) across the width. This fight between the winding roll and nip roller causes the web to advance less at the high diameter area and thus get behind the low diameter area. The transition between the high and low diameter, if sufficiently great and close, will display the telltale diagonal of in-plane shear stresses.

The most effective cure for corrugations is to reduce caliper and basis weight variations. A practical problem results, however, in that the caliper variations responsible for the defect are often too small to be resolved by many online scanners and even lab test instruments. Furthermore, the variations may be too closely spaced to be resolved by some online scanners or controlled by some adjustable headbox slices or die lips. Often one will trace the source of a persistent caliper variation to inadequate attention to housekeeping or maintenance of some process element.

In addition to leveling the web, one can also work with the winder to make it as tolerant as possible. The roll should be wound as loose as the machinery and handling considerations will allow. Most particularly, however, the nip load should be reduced as much as possible.

**[INSERT figure of Cause of a Corrugation]

***1998.01 Jan 1998
What causes a roll to star or buckle?

Last month we discussed beneficial stresses inside a wound roll, namely the pressure between the layers that hold the roll together. In the other direction, the MD or machine direction, the stresses are tensile on the outside of the roll but compressive elsewhere. It can be disconcerting at first to think about MD compression because we’ve all heard that Ôyou can’t push a rope’. However, we know that much of the roll is ready to buckle in compression because of models, measurements and defects. If it were not for beneficial interlayer pressures, we would see a lot more buckles.

The two most common MD compression defects are the star and the buckle. The star is a faint radial pattern on the side of a wound roll spanning from the core to near the outer diameter. Often the pattern is very symmetrical giving the appearance and alias of ‘spoking’. Sometimes the star is a single spoke which arose due to a bump or other handling forces. The most common cause of starring is winding tight over loose. This is one of the motivations for ‘taper’ tension controls. In most cases, however, the star is more cosmetic than damaging to webs.

The buckle, on the other hand, is a wavy series of layers in the bottom half of the roll. The buckle results from a loss of interlayer pressure support caused by one of several mechanisms. First, the roll might overhang the core. Second, the core can collapse or shrink. Core problems can be verified by monitoring the ID of the core before, during and after winding.. Third, material can be extruded out the side of the rolls (plasticity or creep). This might occur, for example, with tape where the adhesive is prone to creep. Fourth, air can be forced out the edges of the rolls of nonporous webs.

The last case is most common with film that is wound at higher speeds. Here, air is entrained into the roll during winding. Later during storage, the interlayer pressure causes the air to weep out the edges. This loss of air causes the roll to collapse much like removing enough bricks from a wall. The air buckle is best prevented by winding slow or by using a layon roller at higher speeds. The layon roll must be sufficiently loaded and conform to the surface to best prevent the entry of air.

**[INSERT figures of starring, buckles]

***1998.02 Feb 1998
How can I keep air out of my wound roll?

Air is dragged into wound rolls by the moving web and rotating roll as seen in the figure. This can cause many problems with the wound roll such as a loss of edge position as the top layer skates around on the air cushion. More often, the problems show up later as the air weeps out of the edge of the roll causing it to collapse. The collapse may result in the blooming of annular ridges on the roll's exterior, or buckles in the interior. Surprisingly, some film materials need a metering of a small amount of air into the roll to keep the layers from blocking together.

For simple cases, the amount of air (thickness) brought into the roll increases with 2/3 power of speed and diameter, and decreases with web tension. Other factors include surface roughness of the web, cylindricity deviations of the wound roll, and the layon roller if so equipped. It is also possible to measure the amount of air in rolls of smooth and stiff materials, such as film and metals, by comparing roll density with material density.

The mechanism for pumping air into the roll is quite weak. As a consequence, the thickness of the air is on the order of the thickness of a human hair (plus or minus one order of magnitude) for many operations. The thinness of the air layer means that innovative ideas for air removal such as doctoring, damming or otherwise blocking the inlet will be ineffective because the air layer will reestablish itself quickly. Without a layon roller, the only effective remedy (aside from winding in a vacuum) is to reduce speed. The speed at which air becomes a problem can be from 100 to 10,000 ft/min depending primarily on the nature of the material rather than the winding machine itself.

If air entrainment is a potential problem, the winder should be equipped with a nipped layon roller. The roller should be located at the winding inlet to block air off rather than after the ingoing tangent when the air is already brought in. The roller should be capable of loading up to 5 lb/in, beyond which no further reduction in air is likely. The roll and roller should be extremely stiff in bending, but radially conformable to block air from the valleys in the roll caused by low caliper.

Layon rollers do, however, have limitations. First, roll deflection and web caliper variations can cause tunnels for the air to enter. Second, air that does pass through the nip (and some always will), can be blocked on the second pass as a bubble which may cause wrinkling. Finally, layon rolls can mark or stretch delicate materials. Nonetheless, the layon roller is the most powerful defense against excessive air entrainment into the roll and its resulting problems.

**[INSERT figures of layon rollers]

***1998.03 Mar 1998

How can I keep my wound roll round?

Rolls should be wound round so that they can be run at high speeds without excessive vibration and web bounce. Rolls should be kept round during storage and handling so that they can be reliably processed by your customers. Rolls that are not round will cause cyclic tension surges as the roll rotates in the unwind, which can then contribute to increased web breaks, loss of registration and a host of other problems. The only thing a customer might do to salvage a misshaped roll is to limit speed. Dancers provide only minimal protection against these tension surges, and then only if located very close to the unwind.

The out-of-roundness of a roll in an unwind has three distinct components. First, the surface can be wavy or bumpy. Second, the core may be eccentric with respect to the centroid of the surface. Finally, the core may be chucked or shafted eccentrically with respect to the core. The first two components result from winding and/or handling. The third component is a system issue caused by excessive core to corechuck (or coreshaft) clearances.

The first two components are lumped together by a single easy to measure parameter of maximum TIR (total indicator runout). The simplest way to measure this is to find the maximum difference in radii from the core to the surface of a roll. A more elaborate means to measure runout is as a peak-to-peak excursion of a dial indicator riding against the surface of the roll turned slowly in tight fitting chucks. Finally, an invention can record the polar shape of the roll using a pantograph fitted into the core. Maximum allowable TIR can vary from less than 1/8Ó for high speed printing applications to over an inch for nonwovens and textiles. The core to shaft clearance can be minimized by ordering the tightest fitting core inside diameters such that the shafts can just be withdrawn. The desirable core clearance might vary from 5-50 mils depending on the application.

Rolls can be wound misshaped. In some cases, the roundness can be improved by winding the roll tighter, or winding at different speeds. However, some materials are prone to eccentric winding and resulting vibration. These materials often have high layer-to-layer friction and low ZD modulus. Example include tissue, kraft paper, nonwovens and textiles.

Rolls can be bent out of shape by brutish handling. The classic example is the clamp truck with excessive clamping pressure which squeezes a roll into a peanut shape. Other examples include roll stops on conveying equipment, dropping or tipping over rolls. Finally, rolls can be bent out of shape merely by their own weight during storage. The storage options ranked from worst to best include: on its side on the floor, by its core in a rack, cradled by a conforming sling, and finally, on end. While winding tighter can sometimes cut handling and storage deformation by half, reducing loads often results in more substantial improvements. Reducing storage time has little practical effect unless one compares weeks to minutes.

Measurement is the key to determining where to focus roundness improving efforts. First, the magnitude of the unroundness should be sampled at important winding, handling, storage and unwinding locations. The location with the largest increase in unroundness is the component that most needs attention. Second, the shape of the unroundness provides clues as to the source much like fingerprints at the scene of a crime. For example, a single full width flat spot may be caused by floor storage, while opposing partial flat spots may be caused by clamp trucks. Diagnostic efforts such as these are important because your customers have every right to expect cylindrical and blemish free rolls.

***1998.04 Mar 1998
What does Percent mean on my control benchboard?

Web machine operating panels can be poorly laid out and very difficult to interpret. While this may not be a hindrance for a veteran operator of a simple machine, it may be for most others. However, even the veteran operator will need retraining when he moves to another machine of the same type, but built by a different supplier, or to one built in a different era by the same supplier. For the rest of us, determining what an adjustment actually does may not be straightforward.

As a simple example, a knob may be rotated to provide a process adjustment. The exact parameter being adjusted may not be clear, even if the knob has a label. Furthermore, what does its range of rotation signify? Is the counterclockwise limit zero, minimum or some other value for that parameter? Similar questions can be made of the clockwise limit of the knob. Furthermore, some knobs rotate just less than one revolution while others, such as multi-turn pots and regulators, rotate several turns.

In cases where a readout has been provided, we can turn to a meter to determine what affect our adjustment has had on the process. But what if the meter display is in %, or has no labeled units? Even the ubiquitous gage displaying pressure in psi may not be what it seems. For example, nip load could be adjusted by varying a cylinder pressure. However, the universal web units for nip load are PLI (pounds of nip load per linear inch of width) rather than the machine units of psi (pounds of pressure per unit area of cylinder cross section). Indeed, all of the universal web force units are in PLI whether we talk about tensile strength, machine tension, nip load or motor torque. Yet in the plants, we have a hodgepodge of lbs of force (across an unspecified specimen width), psi of dancer pressure, psi of cylinder load and armature amps respectively for those values.

Ironically, the biggest problem with machine units is that they do not take into account differences in machinery. For example, 50 psi may be a small force on a 2Ó diameter cylinder, but a crushing force when applied over a 4Ó diameter cylinder. Similarly, 50 psi may be a small force on a 40Ó wide machine but a crushing force on a 10Ó wide machine. Thus, our concept of what is a big or little number must be relearned for every machine we work on. Note that this discussion is not one of what system of units to use, English or Metric, rather that the units provided are not proper in any system.

The group that should most appreciate this discussion are the machine builders because they are often scientists and engineers by training. Yet they are the same group that gives us the cryptic labels of % and psi, and usually without conversion tables or formulae. One might argue that it would be cost prohibitive to provide custom displays for each order. However, blank gage scale overlays can be purchased for less than a dollar, and a scale drawn in a few minutes. Modern PLC displays can be calibrated in proper units for the cost of a mere line of program.

If the weatherman gave use the current temperature in ‘inches of mercury on his foot long thermometer’, we would be quite confused. If an automobile provided a speedometer reading as ‘wheel revolutions per minute’, we probably wouldn’t purchase it. Why then, do we accept machine controls with nonstandard units for settings and displays?

***1998.05 May 1998
Are my controls ergonomic?

Control panels should be as easy as possible to learn and operate. The most obvious reason would be so that the process run most smoothly. Defective product can result from the turn of the wrong knob, the right knob in the wrong direction, or even a hesitation in adjusting the right knob in the right direction. The most important reason for ergonomic control design, however, is that the equipment can be operated most safely. One should not have to search for the button to stop the machine or open up a nip. In the first case, codes suggest a big red mushroom head pushbutton switch. In the second case, no codes or standards exist to guide the control designer on panel layout and labeling.

I have spent all of my professional life designing and troubleshooting web machinery. Yet seldom can I figure out just what all of the knobs and buttons do without some serious study. While some of this may be attributable to my lack of familiarity with a certain make and model of equipment, I believe the shortcoming is more extensive. The reasons is that the process engineers and operators, when queried, can also have only a cloudy concept of what some of the inputs and outputs represent. Incredibly, even equipment designers when queried do not always have the answers to questions as basic as what are the tension and nip values produced by a certain setting. I have seen more than engineering co-op student spending a summer to reverse engineer what the winder ‘curves’ were actually providing for a nip load.

I am certain that the control confusion of many web machines far exceeds that of the often used example of programming a VCR. What I am not certain, is exactly what to do about it. The first challenge is that different web machines, such as a coater and winder, have different functions. Second, there are ambiguities of terminology that vary between industries and even companies. Third, control hardware is different. For example, older machines tend toward knobs, dials and gauges, while new machines tend towards computer screen or PLC control. Fourth, the people who design the controls tend to be well educated and electrically inclined, while those that operate them are less educated and more mechanically inclined. Furthermore, it is rare that the control designer has ever operated a machine in a production environment.

Despite these challenges, there are key features of ergonomically designed control panels that should be considered when selecting or designing equipment:

1. The inputs and outputs are calibrated in standard web units (last months web works).
2. The layout of the controls follows the flow of the web, the arrangement of the machine, or the sequence of operation.
3. Seldom used controls are placed on the periphery of the benchboard.
4. Controls are color coded into groups. The color red is reserved strictly for safety or emergency functions. On benchboards, color can be provided by printing a laminated background on the panel.

5. The controls are labeled with short but descriptive words which are supplemented by pictograms. Labels for inputs are never below the device.
6. If digital (number) readouts are used, they are accompanied by analog (bar or meter) displays.
7. The benchboard or screen is designed using the fewest number and type of devices possible.
8. Permissives that aren't being met are flagged by light or display.
9. Computer screen layouts are such that the operator seldom needs to change screen pages.
10. The machine is accompanied by separate maintenance, operation, troubleshooting and training sections to describe the operation of the controls. Translations of foreign languages should be checked by native speaking engineers.

***1998.06 Jun 1998
Are my pneumatic controls healthy?

Pneumatic controls are widely used in web manufacturing and converting machinery. Common examples include pneumatic cylinders for nip load control, guiding, brakes and clutches. Air is simple, cost effective, and can perform without practical compromise for many applications. The secret for success, however, lies in attention to certain aspects in the application, design and maintenance areas of machine concerns.

First, the limitations of air must be recognized so that it is not applied where other means would be more appropriate. For example, pneumatics are good for position control on the ends of a cylinder’s stroke, but not for stopping midway. Also, pneumatics should not be used when high precision forces are required. Finally, air is slower than electrons so that responses much faster than one second are not reasonable. Even given these restrictions, however, air can perform wonderfully for many common machine applications.

Second, the major design mistake with pneumatics is so common as to be epidemic. That is, sizing the system so that operating pressures fall below 10 psi. A simple example and analogy should suffice. Given that common regulators can only hold pressures to about 1 psi, a system running a 10 psi operating load would have an uncertainty of 10% due to a single cause, the regulator. Imagine having a cruise control in your new car that could only hold speeds to ± 6 mph at a highway speed of 60 mph!

This low pressure problem is most common on unwind brakes because of the large torque range required by the roll diameter build down, tension requirements of various grades, and roll width variations. Indeed, it is difficult to use a single brake configuration to meet the needs of even various grades and widths yet stay within a 10-60 psi range, much less the needs of the roll diameter build down. The solution to this problem is to use as many calipers of a multiple caliper brake as necessary to keep it within a proper working pressure range. This can be done manually, or preferably, by automatic valves or controls.

A related design problem is excessive system hysteresis which causes load uncertainties, especially for nip controls. Hysteresis prevents precision loading and can come from the regulator, but is more often the result of mechanical friction of slides, pivots, cylinder seals and other moving parts. Fortunately, hysteresis is easy to measure. One need only take the difference between the load and unload breakaway pressures. If this difference is more than 10 psi or 10% of your working load, expect poor quality control.

For example, if a nip were found to open at 40 psi, close at 50 psi and operate at 60 psi, we should be disappointed. First, the working pressure is only 10 psi (60-50). Second, there is the equivalent of 10 psi of hysteresis (50-40) so that we can expect nearly ±100% force variations on our machine.

Finally, for long term reliability, attention must be paid to keeping the air clean. This starts during the design stage by using a separate ‘instrument’ air line for delicate components. The air from the supply is filtered, dried (after the compressor and again in front of components), and oil lubricated as needed for certain devices. These components require regular attention and care. During installation, air lines must be kept free of construction debris such as thread cuttings, Teflon tape and so on. Lastly, maintenance must make sure that the lowest parts of all runs are equipped with drains which are checked periodically.

You should now be able to judge the skill of the designers of your machinery by merely observing pressure gages. Similarly, maintenance can be evaluated by merely opening a water trap or oiler. I hope, for the sake of our client, the web, that it passes.

***1998.08 Aug 1998
What converting project should I work on?

In any converting plant there are so many opportunities vying for our attention that picking our battles is almost as important as fighting them. We simply do not have enough time or resources to do everything. We begin by making a thorough list of things we might be able to help with. Then we choose only a few items from that list to actually work on at any time.

Lists of opportunities can come from a variety of sources, many of which are obvious. Sometimes we are told what to work on by our boss. It would be prudent to consider those requests even though Rule #1 does not so universally apply as the maxim indicates. Sometimes customer needs and complaints monopolize our consciousness because ÔThe Customer is Always Right’ mania replaces the more coolheaded ÔThe Customer is Always the Customer’ approach to honest and fair dealings with a business partner. Another source for project ideas is the most costly waste (Converting Magazine, August 97) and delay (Converting Magazine, July and August 1994) items.

Operator squawks are an often-overlooked source of ideas. (The term ‘squawk’ is used by pilots and mechanics to indicate items that need tuning or fixing on an airplane). Operators will tell you much if you earn their trust, ask them for ideas, and listen carefully. Pay most attention to the seemingly small and unimportant ‘nuisance’ items which can have handsome returns. Often clients ask me how to spend earmarked money to rebuild their equipment so that it runs better. On more than one occasion, I said that installing good lighting will pay back sooner than any other upgrade. In other words, the lights will pay for themselves if only one (mill) roll is saved because the operator didn’t misread his tape measure while setting slitters in the dark recesses of the winder.

Another source for projects is your own passions and hunches. If you really want to work on something badly, you will succeed where others less interested would fail. If you have a hunch that something will pay back, listen to that sixth sense. Take care, however, that you don’t work on things that are fun and amusing, but which are not largely helpful to the bottom line.

After the list of project ideas is drawn up, it must be prioritized or ranked. If you are truly mired in problems, you must perform triage. (War wounded are separated into three groups: those that will probably survive without attention, those that need immediate attention to survive, and those that probably won’t survive. You work on middle group first).

If you have more sedate conditions, you can rank the opportunities by potential savings in waste and delay and then select your projects from the top few. There are shortcomings with this common approach, however. The top few problems are likely to be difficult or costly else they would have been solved long ago. It is also possible that some of the top problems are (currently) insoluble for a variety of reasons including technology that is insufficient, or conditions that are over constrained. For example, we currently don’t have the technology to treat, much less cure, the rabies disease no matter how much we would wish otherwise.

A flip side methodology is to work on the easiest problems even if they aren’t the attention getters. There is much to be said about improving something in a straightforward, low cost, low risk manner. If you really want to make a science of it, however, you rank opportunities in order of greatest cost-benefit ratios. Only then can you be most certain that your efforts will be most helpful to your company.

***1998.09 Sep 1998
How should I define the goals of my project?

Last month we discussed picking priority projects selected from a list of requests, costly waste and delay factors, and the sure and simple. Before diving into our ameliorative efforts, however, it would be time well spent to think about goals and formulate a good problem statement. Even if the project is already defined and assigned, a critical examination is still indicated.

For example, did you know that there are always three aspects to a problem statement? These are: what they say it is, what they think it is, and what it really is. Differences between these aspects may not be subtle and unimportant, especially between customer-supplier relationships. In most cases, technologists will seek to resolve the underlying physical problem. Nonetheless, how the solution will be received by the customer or boss must be considered for maximum success.

A good problem or goal statement has several important characteristics. First, it’s foundations are solidly built upon the business economics of reducing costs, increasing manufacturing efficiency, increasing product quality, increasing the scope and flexibility of manufacturing processes and so on. Second, progress should be reasonable and realistic. It does no good, for example, to assign goals which may require nonexistent resources of time and/or money. Third, progress should be quantifiable. It does little good to try to reduce customer complaints, for example, if defects are not measured and complaints are not tabulated to begin with.

Unfortunately, poor problem statements abound. For example, I have been on many occasions asked to reduce the tightness of wound rolls. Yet tight rolls are rarely a defect. The assignment should have been posed as reducing the incidences of rejects due to baggy webs, blocking or whatever. This definition allows additional solutions such as reducing caliper variation, redesigning the surface chemistry and so on which are usually much stronger and often overpowering influences. It is all to easy to let someone turn a symptom or observation into problem if you aren’t careful.

Another example of a poor problem definition is the assignment to reduce the costs of the converting department. Here, the client often hasn’t done the homework to see first if the costs and efficiencies are comparable with contract converters or competitors. If they are, one can expect that significant progress will be either unlikely, or could require significant efforts. Another reason that this goal is poor is that one can easily reduce converting department costs by shutting down machines and laying off operators, but that may not be in the companies best long term interests. When given these type of assignments, I will often try to find quick and easy things for them to work on. This has the dual benefits of first determining whether they can apply minimal resources and sustain efforts for a few months, and if so, confidences and experiences are improved prior to tackling more substantial issues.

One pitfall to avoid is the arbitrary target. Too often one receives a commission to reduce defects by x%, increase speed by y% and so on. This numerical target can be camouflage to make a poorly researched problem appear to be precisely defined. The law of diminishing returns teaches us that the cost-benefit ratios will quickly become unfavorable after a certain level of improvement. However, where this lies is very seldom known at the initial problem definition portion of the project.

Most importantly, however, you never want to try to fight physics with your problem statement. As an example, I've been asked to reduce core crush without the leeway to change key variables such as the material (this is the product we make), winding tensions (if we wind looser the material telescopes) or the core (too expensive to increase wall thickness). In this case, all you can do is to offer one last piece of advise: find another project to work on.

***1998.10 Nov 1998

What does it take to be a good problem solver?

Good problem solving skills are essential for working in a manufacturing plant. Even though knowledge and experience are invaluable, they can sometimes be insufficient to completely resolve the complex problems that face us regularly. In other words, even the most grizzled and travel-weary expert will find many situations that are new to his or her experience. He then must rely on wide ranging set of problem solving skills to determine options for improving a manufacturing or converting process.

Problem solving skills range from the quick-and-dirty to the formal. For example, the street-smart problem solver will know how to do accelerated testing by moving a setting to both extremes of its range to observe changes in problem severity or incidence. Alternatively, the problem solver may elect to use more involved techniques such as design of experiments, Duncker and fishbone diagrams, or Kepner-Tregoe meetings.

Without a doubt, the most important aspect of problem solving is to make a complete list of options, all of which will significantly reduce the problem severity or incidence. If the list is not complete, opportunities may be lost. If the list has nonfunctional ÒsolutionsÓ, which is often the case, energy and resources may be expended to no avail. To illustrate the importance of the options step, consider this: if a good set of options is generated, even the poorest of decision making processes, such as throwing darts, will yield results; but the converse is not necessarily true. Unfortunately, determining options is the most difficult and the most often-neglected step of problem solving.

Homework is a requisite for a successful list of options. Obviously, one should gather information, observations and data about the extent, timing, character etcetera of the problem. However, data gathering is necessary but not sufficient. One should also perform a database search of literature and possibly patents to see if the industry has already found hints or possibly a solution to your problem. To paraphrase a Bell Laboratories maxim: Òfour weeks in the lab will save four hours in the library.Ó It is unfortunate that many people are unaware of the many basic troubleshooting guides that are available such as TAPPI’s Roll and Web Defect Terminology.

After a search of written material is completed, you may want to contact industry experts. These experts may be from suppliers of equipment or materials, competitors or consultants. Suppliers, for example, are very good at suggesting how a machine or process can be brought to state of the art condition by maintenance, rebuilds or replacement. Beware, however, that new isn’t necessarily better and often doesn’t solve the problem. Competitors can be a resource if the two companies’ cultures allow dialogue on non-proprietary subjects. Consultants and their areas of expertise can be found from computer databases such as maintained by organizations such as IPST and Teltech.

If the problem is simple and well known, then the search should reveal a good list of options. Unfortunately, this not always the case because lists vary between sources. One might look at the options that are most common to all of the sources and judge those options to be accurate. However, this is a fallacy of logic which goes by various names including Òscience by consensus.Ó While it is prudent to consider frequency of mention as evidence of truth, it is not by any means irrefutable.

If options are uncertain, one is faced with a dilemma. If one implements the options, success is not guaranteed because the list may contain non-functional solutions. Alternatively, one could expend more effort to better determine a-priori whether a factor will budge a problem as will be discussed in next month’s column. However, while more homework and effort should improve the quality of the options list, it is by no means guaranteed. Such is the nature of real-world problem-solving.

***1998.11 Nov 1998
What are your favorite problem solving techniques?

At some point, you will be well immersed in a true problem solving situation. That is where the solutions and perhaps even the problem is not known for certain. Since it beyond the scope of this article to teach problem solving, all I will do at this point is to outline steps and tools that can be used to proceed along the best path when a map is not available.

To be a good problem solver, you must first arm yourself with a depth of knowledge on the subjects or areas in which you work most commonly. Equally important is to expand the breadth of your knowledge to interrelated areas because most process problems are not so simply compartmented into chemical, electrical or mechanical categories for example. To quote, ‘Chance favors the prepared mind. ‘Knowledge is obtained most simply obtained by extensive reading of trade journals, technical journals, books and reports. However, regularly attending conferences, shortcourses and seminars is also important. The trait that is most helpful here is a burning curiosity to know how things work.

To be a good problem solver, you must also be creative, imaginative and often daring. You should be able to look at common machinery and processes from various angles and with fresh eyes. You should be able to consider and eschew conventional wisdom when it doesn’t seem to be leading in fruitful directions. Unfortunately, there is a tendency to lose creativity as we get older and more learned. In other words, knowledge can get in the way of seeing other possibilities. This is not to say, however, that ignorance is an advantage for problem solving because both creativity and knowledge are useful in equal measures. The most useful trait here is the ability to brainstorm as an individual or in a group.

Finally, a good problem solver has and uses a variety of problem solving skills. It is important to avoid the most common trap of regularly using a preferred tool or technique to solve problems. Examples of tool fixation is the statistician who can’t see beyond mathematical correlations or the process engineer beyond his/her new data gathering instrument. Similar problems occur when a group has been taught one of the several formal problem solving strategies which channels the group to constrain their thought processes to that particular technique. In all of these cases, one is handicapped much like a mechanic with only a adjustable wrench and a pliers in his toolbox, or a surgeon with only a single scalpel and scissors on her instrument tray. Table 1 lists just a few of the tools and techniques useful for problem solving.

Bounding and Bracketing
Design of Experiments
Divide and Conquer (Binary Search)
Duncker Diagram
Envisioning
Exaggeration (Accelerated Testing)

Fishbone Diagram
FMEA and FTA
First and Worst
Kepner-Tregoe
Logic
Process Knobs Listing
Science
Shape of Cause Matches Problem
Statistics
Toggling
Truth Tables

However, if I had to pick a technique that I favor, it would have to be that ÒThe shape of the cause must match the shape of the problemÓ. I like this tool because it is very quick and very adaptable to a variety of problems. This tool is most useful as an initial screen for the scores of ideas that people generate when confronted with serious problems. Very little junk will pass this screen so that one can focus subsequent efforts in more productive directions. Next I might employ exaggeration to determine which of the remaining ideas is strong enough to budge the problem.

***1998.12 Dec 1998
Why doesn’t my machine start and stop gracefully?

Our web machine should speed up and slow down smoothly and gracefully just as our family car does. The engine should not cough, hesitate or backfire when we depress the accelerator. Similarly, the brakes should slow us predictably with all four brakes performing in unison.

The web can show symptoms of poor machine dynamics. First, the width or registration of the product may vary during speed changes if tension is allowed to vary. Second, the path of the web through the machine may change when tension variations act on roller misalignment (Web Works, September 97). In both cases, the wound roll would record the resulting edge disturbances as a defect known as an ‘acceleration offset’. Third, the web may break more frequently. It is not unusual for paper coaters to have one or two orders of magnitude greater web breaks during a minute of speed change when compared with a minute of steady state. In extreme cases, the web may go slack and/or drum tight during the speed ramp.

The machine also gives symptoms of poor machine dynamics. The best measure of drive health is a steady load cell tension reading. Lacking that, one can look at motor ammeters to make sure they move in concert during the inertial demands of speed changes. Also, the ammeter should move quickly to its new location, but without overshoot. Unfortunately, the ubiquitous dancer can’t be read for dynamic health.

To achieve graceful speed changes, the designer must pay attention to details. To begin with, the speed reference from the operator must be modified to an Ôs’ shape composed of three parts before the drive can use it. First, the speed rounds from the current speed onto the linear ramp over the course of several seconds. Second, the linear acceleration ramp should be programmed to be appropriate for the duty. Third, the speed rounds from the linear ramp onto the new speed over the course of several seconds.

The accel/decel rate may be less than 10 ft/min/second for complex machines and/or those with poor drives, excessive roller inertia or other compromises. It is very important not to push acceleration rates on machines which nominally run continuously as control quality will suffer. However, some machines, such as rewinders, must accelerate quickly for productivity reasons, sometimes at rates in excess of 100 ft/min/second. Higher rates, such as 1,000 ft/min/sec are used only on discontinuous processes, such as packaging machinery, and require the use of servo-drives.

Next, all other drives must follow an appropriate target, be responsive, and be accurate. Briefly, the error (difference between the setpoint and feedback) should be small always. In order to do this, the drive must be tuned for maximum stable gain. Unwind and rewind drives thus require ‘inertia compensation’ to vary the gain so that the drive is aggressive with errors at large roll diameters (because the inertia resists changes) and moderate with errors at small roll diameters (to avoid instability). Feedforward is helpful to alert drives to changes in speed or other conditions.

Always keep in mind that machines are an electro-mechanical system so that the mechanicals must also be in good health. In particular, the machine must not have excessive roller counts or inertia. Sensors such as dancers must be low friction and load cells must be sized appropriately so that one doesn’t try to ‘weigh a pea in a dump truck’. Finally, actuators must be sized so that drives are not idling. In other words, pneumatic brakes should be kept above 10 psi pressure and electric motors should be loaded to a fair fraction of their capacity.

***1999.01 Jan 1999

What type of foundation is best for my machine?

Foundations vary considerably depending on the size, speed and precision of the machine to be supported. At one extreme, many small commercial printers are mounted on wheels which allow the machine to be rolled into position, often on uneven 4" concrete slab flooring. At the other extreme, wide, high-speed paper calenders and winders may be mounted over a 1/4 million pound foundation consisting of baseplates, epoxy grout and enormous reinforced concrete footings. In any case, however, the foundation must meet several criteria.

First, the foundation must be strong enough to support the machine loads without yielding or breaking. However, designing a framework or a foundation merely for loads would almost surely be inadequate. Second, the foundation must be stiff enough to resist deflection due to static or slowly changing loads. For example, the changing weight of a wound roll or the passage of a fork lift in the area should not elastically deform the foundation by even 1 mil, else alignments and other precisions be lost. Third, the foundation must be substantial enough to resist movement due to dynamic loads. For example, roller imbalances, wound roll vibration and other cyclic loads should not cause the foundation to move even so much as 0.1 mils on high speed machines else the pounding would take a toll on man and machine alike.

The foundation may also have other challenges. It must be constructed to resist local motion due to changing water content of the underlying soil due to seasonal variations in rainfall or daily fluctuations of tides, and/or temperature. Yet, at the same time it must yield to those same forces over large distances by inclusion of expansion joints. Second and higher floors must resist all of the above forces, plus wind loads on the building.

I am usually very uncomfortable about mounting even small equipment on the ubiquitous 6" industrial slab floor. Thus, I would usually recommend either a continuous footing or baseframe be added for rigidity. A footing can be constructed by trenching a slot in the floor underneath where the frame will mount. On modest machines, the concrete footing need only be about 1-1.5 ft tall and wide, but should span the length of the machine. Narrow or cantilevered machines only require one footing 'rail' while wider machines require two. Next, metal baseplate pads are epoxy grouted into the footing wherever the machine's feet will be mounted. These baseplates are leveled by studs prior to grouting. A baseframe is a steel I or box frame version of the concrete footing.

These footing and baseframe systems are not as involved or expensive as they might seem at first sight. Neither are they unusual because many web and non-web machines alike are thus mounted. However, they do require planning well in advance of delivery of a machine. Also, they can be a little inflexible if later one wants to move a machine, especially sideways.

Unfortunately, there are no standards and very little published on the special needs of web machine foundations. Thus, the reader is on his or her own to determine the best course. Obviously, the machine builder should be consulted for recommendations. Also, a civil engineer specializing in foundations should also be consulted, but only after they be made aware that hairsbreadth deflections are an order of magnitude too much for web machinery.

When mounting machinery, I believe it is prudent to err on the side of caution. The penalties for overdesign are merely a small increase in installation costs. The penalties for underdesign may be vibrating machinery, more frequent maintenance, damaged product, ever-crooked rollers and much much more. Like your own house, you wouldn't be happy with cracks in the foundation and plaster a couple of years after moving in, even if the contractor met all applicable codes and standards.

***1999.02 Feb 1999
Why are my web's edges baggy?

Bagginess is a common problem for webs of almost any material, construction or thickness (Web Works, April 1994). While bagginess can be caused by brutish handling, the web is more often formed crooked at the onset of manufacturing. Unfortunately, it is usually impractical to fix a baggy web once formed (Web Works, April 1995). Also, there is little that can be done to make certain types of machine elements, such as nips, tolerant to bagginess. For these reasons, there is ample incentive to determine how to prevent bagginess at its source.

While bagginess could take almost any combination of shape and location, it has been observed that edges are more commonly baggy than mere chance would allow. Why? While many explanations for why bagginess favors the edges have been postulated, very little research has been done to verify the mechanisms. Thus, pinpointing the specific cause in any particular application might be difficult.

One reasonable explanation for the propensity to edge bagginess comes from the observation that the edges of the web are usually formed or manufactured differently than the middle. No matter how hard we try, we can't seem to make flows, temperatures, nips and so on dead level out to the very end. Indeed, the smile or frown shaped 'profile' is ubiquitous in web manufacturing. While temperature and nip uniformity is easy enough to check, flow rates and flow directions out of a headbox or extruder are difficult to measure. Thus, an indirect means of checking uniformity, such as by basis weight or caliper/gage, could be useful.

Another common explanation for edge differences is that the edges have no 'neighbors' to restrain them during formation processes such as drying and cooling. Mechanics people would say that the center is under biaxial stress (MD and CD), while the edges are under uniaxial stress (MD only). The paper industry has found that biaxial restraint can be generated uniformly even to the edges by carrying the web on a forming fabric where the web does not slip on the fabric during forming. Alternatively, the web can be heated or cooled on a large cylinder in some applications.

Light weight webs suffer from the lack of edge restraint when air currents or other upsets in the area cause the web's edge to flutter. While the center flutters as a sinusoid (one plane of curvature), the ends can flutter as a saddle shape (two planes of curvature). This means that the average length of the web in a given span is longer at the ends than at the center. The web may remember this longer path as edge bagginess.

A last common explanation for edge bagginess is that roller misalignment causes the edges to be stretched more than the center. With inplane misalignment (lack of parallelism or tram), one edge is tighter than the rest of the edge at the upstream roller. With out-of-plane misalignment (skew), both edges are tighter than the center. With very tender webs, the web's edges may be stretched into yield. The riskiest elements for stretching the web due to path length differences are guides, bowed spreaders and grossly misaligned rollers.

This list is but a starting point for troubleshooting the generic baggy edge because there are other causes which are specific to certain applications. The reader must determine what potential causes could be responsible for bagginess on his or her machine. Next, all ideas which can't have a smile or frown shaped profile must be eliminated from the list. Finally, the remaining ideas must be checked to see that they have sufficient strength to yield the web differently in one place than another. With luck, the causes that remain are ones that can be addressed without a major rework of product or process.

***1999.03 Mar 1999
Why does my wound roll have ridges?

You may observe that your wound roll is not quite a perfect cylinder. Rather, it may have ridges that are randomly or regularly spaced. In some cases these ridges are only cosmetic. In other cases, however, the ridges may indicate a troubled raw material and/or possible product damage caused by winding. While a larger diameter variation across the roll indicates a larger potential problem, the value where trouble begins varies widely with the situation. While exceptional materials may tolerate diametral variations of more than a few percent, lightweight webs of paper, film, nonwovens and other materials may show damage with diameter variations as little as 0.1% .

The diameter variation can be measured directly with a flat tape around the circumference or by a feeler gauge under a straight edge laid across the roll. Ridges can be made visible by using a ‘crayon board’ to rub marks on the high spots of the roll. The ridges are also usually harder than the valleys so that they might be detected by pounding on the roll with a stick, or by using commercial roll hardness instruments such as the Paro Tester, Rhometer or Schmidt Hammer.

Ridges and valleys that are irregularly spaced are the result of winding materials which have an uneven profile across the width. In most cases, the ridge is an area of thicker material and the valley is an area of thinner material, though theory teaches that other properties can also be responsible. It is important not to put too much trust in scanners and lab test instruments as they often are not sensitive enough to resolve the small caliper variations that result in diameter varying wound rolls. In fact, the wound roll is by far the most sensitive caliper gage in existence. Thus, if the roll has ridges and valleys, the material is nonuniform in spite of anything our gages might tell us otherwise. This is because the roll accumulates hundreds or thousands of layers so that tiny differences in each layer add up to bigger results in the roll.

Some rolls display ridges and valleys that have a uniform pitch spacing. The pitch is the preferred buckling mode of the wound roll and is primarily determined by the nominal caliper of the web material. While this behavior can be seen on a wide variety of materials, it is most common on thin plastic film. While the physics of this defect is not well understood, we do know that ‘tin canning’ gets worse with higher winding tensions, time, roll diameter, and also that it is very sensitive to grade.

The irregular ridges and the regular ‘tin canning’ are, of course, unintentional. However, many product developers bring trouble upon themselves when they design materials with varying caliper due to adhesive, coatings, print, cutouts or any other number of similar features. The problem is simply this: caliper-varying products may not wind well. As the winding diameter increases, the buildup in the high caliper areas causes unusually high stresses that may damage the material in a number of ways including stretching into bagginess, blocking and so on. Also, the high caliper areas can drive coning or telescoping as the roll tries to relieve itself of energy. On the other hand, the low caliper areas may collapse or buckle.

When faced with ridges, the most successful treatment will be to reduce caliper variation as much as possible. One may have to disregard conventional caliper measurements and let the wound roll be the judge of uniformity. One may have to disregard conventional wisdom that says that product design can't be changed to reduce caliper variation. Barring progress at the root cause, one is left with winding loose and converting quickly. However, these options may be disappointingly weak.

***1999.04 Apr 1999
Are my operators operating proficiently?

Every web manufacturing or converting system is composed of 3 ‘M’s: man, machine and material. Though this column has focused primarily on mechanical aspects of converting, we now turn our attentions to people issues. In particular, operators are very important because they affect plant productivity, product quality, safety and many other areas of concern. Their attitude and skills can easily make the difference between ruin and return.

Common measures of plant performances, such as waste and delay, are not always most useful for evaluating human performance because they depend on other factors such as machine design and condition, product characteristics and so on. This makes separating individual contributions difficult. Nonetheless, there are ways of using this data. Begin by comparing the performances of different crews. If one crew stands out as better or worse, find out why. You will also probably find that performance varies cyclically throughout the week. For example, the best product/productivity may be 15 minutes after the first morning break on Tuesday. Conversely, the worst product/productivity may be one hour before dawn on Sunday morning. More can be learned if the timing of the waste and delay information is very fine. For example, a drop in productivity during a shift change indicates a poor handoff. Also, an increase in waste during the first hour of a shift may indicate that a ‘knob twiddler’ is at work.

You can also evaluate operator performance by mere observation. Approaching the machine from a distance, you will observe clues about operator motivation as they are either active/attentive or sitting/distracted. As you get closer, note the housekeeping around the area. Messy machines may indicate either the operators are overworked, the plant has a careless culture, or the operators lack pride. As you get even closer, the operator should bring you into his/her scan. After all, this is their machine and you are entering their territory. Your mere presence should engender many considerations including possible interference in the operation, as well as your safety.

When you talk with the operators they should be attentive and curious. They should be concerned enough to offer at least complaints, if not suggestions for improvement. They should know the precise names of every part of the machine, grades, customers, and defects. They should also know enough about their process to be able to ‘make a defect’ if so asked. While many have ideas about what causes problems, few ever test their theories, which results in much mythology. Unfortunately, not all operators are so knowledgeable because they were trained haphazardly by their predecessor instead of by formal instruction such as provided by the builder or developed by the plant (Web Works, July and August 1994).

Operators must also work well with others. Everyone in their crew should be where they need to be, at the time they need to be there, doing the things that need to be done. What little direction that is needed for routine tasks can be communicated clearly but briefly with a meaningful glance, gesture or word. In short, the crew should be a smooth and synchronous team, much like dancers in a ballet. The operator must also take every moment to pass on their knowledge to the crew as they will be his/her successors.

Finally, the operator must groom close relationships with people from other departments. The operators should be close to internal suppliers of material so that variations in raw material are noted before they hit the machine, and performance of the raw material is fed back to the supplier. Operators should work with quality control to understand what is not acceptable to the customer, why, and how to detect defects quickly and consistently. Finally, operators need to communicate to engineering and maintenance what might be improved with the process or machine.

***1999.05 May 1995
Are my mechanics masterful?

Product quality and productivity can depend on machine condition, which can depend on your maintenance department. Though maintenance must have sufficient resources such as budget, people, tools and time, they must also work effectively within the inevitable constraints. Also important is that the department be staffed by skilled tradesman in a variety of areas such as mechanical maintenance, rigging, machining, welding, instrumentation, electrical power, drives and so on.

Common measures of plant productivity, such as planned and unplanned downtime, are not always most useful for evaluating maintenance because they depend on many other factors. For example, frequent breakdowns may be due to poor machine design. I ran across one turret winder model which had weekly gearbox failures, and a calender whose bearings broke daily. In these and many other situations, the builder had not really ‘engineered’ the machine, but rather merely ‘drafted’ up an assemblage of parts to do some required functions. On the other hand, something that breaks within the first few hours of a maintenance down could well be due to improper maintenance.

The very first thing you expect is that all mechanics know the names of virtually every tool. However, I recently went to a textile plant producing aerospace materials on a dozen looms where neither the plant supervisor nor the mechanic knew what a ‘dial indicator’ was until I literally drew a picture of it. Next, mechanics should have access to any reasonably required tools, and they are all in like new condition, and that they are well organized. A quick test is to look at either Phillips screwdrivers or hex wrenches. There should be a full set ranging from jeweler’s size on up, and that the edges of the tools should not be worn, dulled or damaged. Finally, you would expect that mechanics know how to use their tools most effectively for any particular situation, but this requires a detailed knowledge of the trade that you may not have.

Nonetheless, even the layman can observe work to get clues as to the attitude of the maintenance. For example, you would expect that the area be cleaned prior to disassembly so that precision parts are not contaminated. Often parts need to be marked so that they can be later be returned to their original position and orientation. Precision parts should be set on a clean surface such as cardboard, toweling and so on rather than on the frame or floor. In many cases, the parts should be cleaned and inspected prior to assembly so that other ailments might be detected and fixed. ‘Dofer’ workmanship (it’ll do fer now) is easy to spot, even if you are not a mechanic.

Observation can also tell you whether maintenance is machine savvy. For example, nearly every part of every web machine must be tight so that there is no detectable play. Merely by shaking or prying on parts you can tell if clearance exceeds a hairsbreadth. Similarly, key parts of web machines, such as rollers, must be aligned to within hairsbreadth accuracy. Thus, observing machinery being set in with levels and tape measures should be cause for concern. Another telling test is to ask to look at the instruction/maintenance manuals for a particular machine.

Finally you can get clues about the effectiveness of the overall department by how they plan their work. In most cases, a work order system is an effective approach. Here, requests are submitted by operators, engineering, maintenance or other departments to fix or rework something. Decisions are made as to which tasks will be done now, later or not at all, and the disposition is communicated back to all. Maintenance priority must be graded by two basic criteria: importance and urgency. When the machine is finally taken down, the work proceeds according to a script which includes timelines for people, parts, time and tooling.

***1999.06 Jun 1999
Are my electricians energized?

The electrical department is responsible for many vital areas of the plant including power, drives (motors and controls), PLC's (Programmable Logic Controllers) and a variety of unusual instrumentation. Even so, it can be difficult for the layman to apprise the electrical savvy of their personnel for several reasons. First, they speak a language so much different from our own. It would include arcane vocabulary such as current minor loops, ground loops, PID, communication fault, normally open limit switch, latched PB, and zero drift to name just a few. However, the well-rounded electronics tech will necessarily also be a good communicator and translate the issues, options and status into everyday language. Similarly, just as in any communication situation, you must meet them part way. Take regular opportunities to learn more about the electrical world.

Another difficulty with making an electrical connection is the personnel may be more tightly focused than other groups. For example, many of us will have concerns that span a range from chemical, to electrical, to mechanical and other physical disciplines. We will also be concerned with areas that include product quality, productivity, production schedules, consumer complaints, and personnel issues to name a few. In order to work with the electrical, we must momentarily tighten our own focus, or include them on issues they may not always be as comfortable with.

This tight focus allows the electrical to better master what is a very complex and ever-changing field. However, the focus can at times be too tight. If for example, the drive engineer describes a control situation in strictly in terms of motor speeds, amperage, inertia comp, gains and other e-speak, we might have a problem. They may have forgotten who their client is. Their client is not the motor. Rather, it is the web. If for example, the drive engineer does almost all of the troubleshooting from the control room, we might have a problem. The problem is that even the best data gathering PLC's only see the tiniest portion of what is going on. They should spend as much time observing the machine and talking with the operators. If for example, the drive engineer always suggests upgraded controls to address waste and delay, we might have a problem. The problem is that new is not always better, and even if it was, it may not pay for itself.

The layman may also get hints at electrical savvy from the electrical condition of the web machine they work on. For example, drive health is most simply and often best measured as a minimal tension variation (<5-10% of setpoint) as read by responsive load cells. If the tension needle swings more, something may need attention. If there is no tension needle to look at, find out why the process is handicapped thus. Obviously we also expect that drive motors almost never fail and rarely shut down ungracefully.

Digital controls can be evaluated most easily by an absence of glitches and ghosts that interrupt the process. Also, safety features such as E-stops and permissives, are regularly tested. Good practice suggests that every change in a PLC program is annotated in a bound hardcopy printout. Control savvy can also be noted by the use of proximity switches (they look like large bolts with a wire on one end) instead of limit switches (they have a lever with a roller on the end). Similarly, one may also get useful impressions from the neatness of wiring runs using wire that is neither frayed nor cracked.

Instrumentation might be evaluated by a routine practice of independent calibration of all sensors and readouts. The calibration event should be recorded in brief on a sticker or other device, and in detail in a logbook.

***1999.07 Jul 1999
Are my product developers productive?

***[NOTE: this article was omitted from publication by oversight, it is included here]

Product developers are responsible for the future health of the company by innovating new constructions to meet the wants and needs of customers. They will often lead a cross-functional team to turn these ideas into process realities. This is a challenging position because it requires a variety of skills in areas which include consumer studies, marketing, economics as well as attributes like inter-personal skills, persistence and patience. However, to be a really good product developer, you must be very process literate. This is because is it quite possible to design products that can't be made well, or even at all on web machinery. The product developer can not design merely for end use. They must also design for manufacturability.

Thus, the product develop must know the tradeoffs between a certain factor desired by the customer, and the penalties which will often be paid by process waste and productivity. Examples are bountiful. In newspaper, for example, a high recycle content is desirable because it decreases material costs. However, a small increase in recycle fraction can trigger a rash of winding defects that are invisible until they reach the customer (crepe wrinkles & bursts). The paper developers must understand that costly additives, such as frictionizers, might be required solely for manufacturability rather than end use, especially if they continue to sell ever larger wound rolls.

In paper coating, for example, a thick coating makes for a more visually appealing product, except when that same coating causes wrinkles because of the water insult. Have you ever stopped to ask the paper whether it liked coating? If you did, you would find it clearly does not. Here, the product developer considered coating to be a benefit, when the results are not so universally beneficial. Similar problems occur when adding heat to film via heated rolls, ovens, curing and so on. Again, the product developer never asked the web whether it likes heat. It almost never does.

In poly package printing, for example, a thicker ink or adhesive will improve the opacity and bonding respectively. Yet a product which varies in caliper even slightly will not be able to be wound to very large diameters without a variety of roll defects. On the one hand we teach that caliper must be manufactured level to wind well, but on the other hand ask that exceptions be made if it was an outcome of intentional product design rather than unintentional manufacturing variability.

In lamination, it is very possible to make a beautiful web product on a benchtop. Yet these same constructions might not be manufactureable as a web without flatness problems such as curl. Here, the mismatch in moduli or other material properties could not be accommodated by typical tension control ranges.

In all products, we often find rejectable specifications that often seem like they were pulled out of the air instead of an optimum balance of consumer appeal and manufacturability for maximized profit. Just to give one example, I was at a converter who was frustrated trying to register print to within specs for a Fortune 100 customer. After a brief back of the envelope calculation, it was determined that tension control would need to be held within 4 ounces on the 60” wide machine in order to line up the colors. At another location, a printing machine builder promised registrations tighter than could be measured by any known technique.

How can we avoid these epidemic troubles? Simple. First, the web must be viewed as a customer rather than a commodity. Second, product developers must have a solid physical understanding of materials, mechanics and machinery. Alternatively, they should consider carefully the cautions of those who have. We can’t always get what we want. What we or the customer wants may not always be in the best interests of the company. Sometimes compromises are necessary.

***1999.08 Aug 1999
How can I keep rollers from marking my web?

The surfaces of some webs, especially those recently coated or printed, may be so tender that they can't be touched by rollers at all until the surface is cured or dried. In these cases we would float the web over a bar, pan or shoe. Floating a web is at best difficult and expensive. Floating can also cause operational difficulties such as environmental noise and difficulties in controlling web position and tension. Nonetheless, few options exist if the web can't be touched at all.

Other surfaces are more robust and can touch rollers, provided that attention is paid to the details of the contact. Unfortunately, creative product developers may give us tender formulations that may not run through all parts of an existing machine without marking. When marking happens, a three step program is needed. First, we must identify the offending roller(s). Second, we must identify the nature of the contact forces that cause the marking. Third, we must modify the contact.

Ideally, one should be able to point to the specific roller that is causing a specific mark. In some cases this is trivial as one may note a scratch emanating from a stopped idler. However, often the offender is not always so easy to identify because marks may be subtle, skippy or incomplete. Good machine lighting and a light booth (with overhead, through, incident and UV illumination) are important tools for revealing slight marks. These marks should next be highlighted with a pen. If they are caused by a roller, they will have a MD repeat corresponding to the circumference of the offending roller. If the roller is grooved or patterned, the pitch of the defect in the CD will corresponds to the pitch of the grooves. A 'marking defect' book can be made up that lists each type of roller used in a machine, their location, their geometries and include a tracing if grooved. Matching a mark to a roller is much like matching an incomplete fingerprint. The match can be made with only tiny fragments of the pattern or with multiple patterns if supplemented by computer analysis such as a 2-D FFT (Fast Fourier Transform). Once the type of roller is identified, the specific roller can be found by intermediate sampling or other technique.

There are three common types of contact that can cause marking. First, ZD pressure can 'emboss' the sheet something like making a footprint in web concrete. The most likely sources of ZD pressure is nipped process rollers and winder layon rollers, though it is possible in exceptional cases to emboss over an idler roller. Second, the web can be marked by wide roller grooves (more than 10x caliper) or roller segments by either embossing as above or by stretching plastically into the grooves. Many film, foil and other delicate materials carry the 'tractor tire' tread marks of idler grooving. Finally, the web can be marked by sliding over a roller that doesn't run precisely at web speed or by contact with some stationary object.

Since marking is often a classical time/temperature/pressure response, slow speeds will aggravate the severity. Thus, sampling on the top of a roll which slowed down at the end of winding will be show more vivid marking than in the middle of the roll which was run at speed. Also, the marks may be more pronounced in areas where the caliper or tension profile is nonuniform and high. Use these opportunities to see a problem at a more subtle level. Also, since marks are most readily detected by visual inspection, it may be necessary to groom a single person to grade and determine disposition.

***1999.09 Sep 1999
Why is my calender roll wrinkling my web?

Nips of any type are, without doubt, among the most wrinkle prone of machine components. Thus, the first line of defense is to eliminate any nip that is not absolutely required at any particular time. An example of redundant nip is many of the pull rollers which do not require the nip for traction, or may even be entirely redundant as a drive point, such as those following an unwind. There are many reasons for the wrinkle tendencies of nips. First, a web that is less than perfect, but still salable, may not pass through a nip successfully. Second, a web that is perfect may not pass through an imperfect nip (Profile of a Nip, June 1994). Finally, the calendering process itself can be the source of wrinkles. Thus, various root causes of wrinkling may be found upstream, at or after the nip.

First, the web may be imperfect upstream of the calender because it is not uniform across its length or width. By far the most common source of troubles here is the baggy web (Web Works: April 1994, April 1995 and February 1999). A baggy web is one where portions of its width are loose and long. This extra length gets behind the nip as a bubble which may be stable or unstable. If the bubble is unstable, it will grow until it burps through the nip as a diagonal crease whereupon the bubble will grow anew and start another cycle. If it were not for nips, the baggy web would travel successfully through most parts of most machines.

Another source of an upstream wrinkle cause is a lack of web flatness not due to bagginess such as mild MD troughing (Web Works, March 1994) and roller misalignment (Web Works, November 1995). If you can determine the specific upstream source, you may be able to work with the root cause. If not, you may try aggressive but effective spreading. However, spreading is by no means a cure-all for bagginess and misalignment, and can do nothing for problems whose source is at or after the nip.

Second, the source of the wrinkles may be at the nip due to a variation of nip pressure across the width. The nip pressure, best measured with nip impression paper, can be nonuniform due to variations of web thickness or related material properties. The nip pressure might also vary due to variations of roller diameter and/or cover hardness, or excessive roller deflection. Indeed, hairsbreadth errors can be an order of magnitude too much in many process nips.

Finally, the source of wrinkling may be at the exit of the nip due to the very nature of the calendering process itself. Here, a nip pressure sufficient to cause yielding of the material will cause an increase in length and width, as well as a decrease in thickness. It is the increase in width that can get you in trouble because the web is troughed immediately as it is released from the nip footprint. Spreaders can seldom reach with sufficient power into nip’s exit to do much of any good. Surprisingly, a width increase of as little as 0.1% may be enough to give wrinkle difficulties, and width increases as little as 1% can be almost unrunnable. Though the even spaced MD troughs at the calender’s exit is a good clue, comparison of very careful before and after width measurements is needed to verify this cause more surely. If expansion is the cause, one may have to redesign the process to change the material, reduce the nip pressure, or break the total expansion up into smaller parts by using multiple lightly calenders with spreaders in between.

Once the nature of the wrinkle source is known, you will quickly be able to identify the options. However, not all of the options are pleasant, as we have seen in the case of process expansion wrinkles. Good luck!

***1999.10 Oct 1999

Why do my rolls telescope during storage

Telescoping is a costly winding defect because it usually causes the loss of an entire roll. The word ‘telescope’ as well as scoping, coning, shooting and other unprintable aliases are used to cover a variety of defects that result in the sideways shifting of a wound roll during winding, storage or unwinding. Though there are many factors common with these various modes of telescoping, each is unique enough to warrant individual diagnosis and treatment. The most common winding and unwinding version was discussed earlier (November 1997).

The symptoms of the version we will discuss here are simple. First, the roll is built with relatively straight edges. Second, the roll telescope develops during storage over the course of minutes to days. Third, the web product will usually contain an adhesive or coating. The classic examples are label stock or adhesive tape. However, a simple consumer example readily demonstrates the mechanics. Take most any roll of adhesive tape out of its package and set it in the back window of your car. If you want results in a hurry, park the car in the sun. Soon you will have a telescoped roll with sticky edges.

There are two principles at work to make the telescope. First, the roll is axially bistable due to the energies supplied by winding. What this means is that the roll wants to pop to one side or another due to the forces inside of it. This is analogous to a yardstick that wants to pop sideways when a sufficient axial load is applied on the ends to cause it to buckle. Thus, we expect this defect to be worse if we wind tight, wind tight over loose, or make rolls with large diameter-to-width ratios. We also expect this defect to be worse with uneven profiles, such as a caliper taper from one end to another, even though nonuniformity is not a requirement for occurrence.

Second, the layers or plies in the roll slide over each other minutely. What holds any roll together is friction. However, many coatings and most adhesives shear under load. Thus, intuition aside, the adhesive acts more like a lubricant than a glue. The measurable property that resists this movement is called the viscosity or shear rate. Thus, high shear adhesives will cone less than low shear adhesives. The thickness of the adhesive also is a factor. If the adhesive is so thin that fibers from adjacent layers touch, coning may be prevented. On the other hand, thick adhesive layers allow ‘large’ sideways movements. Finally, the shear rate of all materials is very temperature dependent. Thus, do not be surprised to see the problem get worse during summer months or with southern customers.

The reader may wonder how the roll layers are shifting on themselves when it may not be readily apparent. First, we know by inference that they must be because that is the only means of explaining the changing shape of the edge of the roll. Second, a magnifying glass may reveal edges sheared much like a stack of cards shifted sideways. However, you must look very close as a 1” roll shift over 1,000 layers is only 0.001” shift per layer. Third, you my feel that one or both edges of the roll becomes sticky as the adhesive was uncovered during the shift.

Most people will tend to blame the winder or require that the remedy be made there. However, this defect is much more amenable to ‘better living through chemistry.’ In other words, the winder may at best cut the driving force in half by winding looser. However, the shear rate of adhesives can be varied by orders of magnitude which can swamp any of our efforts at the winder. Thus, we must design adhesive products for more than end use requirements. They must be designed to also allow successful handling, storage and converting.

***1999.11 Nov 1999
Why do my rolls 'dish' during winding?

Dishing is another roll edge straightness defect like telescoping. Since there can be several distinct defects going by the same or different names, we must be quite careful to ascribe the correct mechanics to our particular problem. The figure below [[*to be traced from an enclosed print and redrawn*]] shows just a few of the types which have distinctly different causes and remedies. Diagnosis is made sure only by careful observation of the changing shape of every side of every roll in a set.

A common form of dishing caused by Poisson expansion has the following symptoms. First, the roll edges initially wind straight, but then shift into a smooth bowl shape. Second, the dishing is symmetrically out from the centerline and progressively worse toward the outside rolls in a set. To truly verify that you have Poisson dishing, you must measure the magnitude of the 'outsie' on one side and the 'insie' (if that is the case) on the other side of the same roll. If the outsie is more than the insie, the roll has grown in width due to pressures in a winding roll. If this width increase is greater than the slit separation, then the rolls will push each other outward. The first thing to try with this type of dishing is to wind looser throughout by reducing the tension, nip load and torque differential as applicable on your winder. Next would be to increase the spreading to open up the slits to magnitudes similar to the roll growth. Failing that, you could resort to more aggressive treatments such as redesigning the product or duplex winding.

Another type of dishing is characterized by edges that are smoothly dished, but straight sided. In other words, the edge is a very shallow cone shape. This may be caused by misaligned frameways or pivot arms, as the case may be. If the roll set's edge shape is not smooth, you may have play or looseness in the shaft or chuck system. Alternatively, the drive, tension and/or nip control system that is allowing winding forces to wander. Rough roll edges have even more possible causes than telescoping, but are still diagnosed by methodical observation of changing shapes.

**[INSERT figures of Dishing and Telescoping]

***1999.12 Dec 1999
What is the master speed reference?

One and only one roller in a line has the prestigious position of being the master speed reference. This is the pacer for the web machine. It is the only roller that directly follows the line speed command from the operator's benchboard. Any other rollers that have a speed target are referenced or slaved off of the master in what is commonly known as draw control. The master has several unique features that deserve consideration.

Since the job of the master is to control speed, it must attend to that duty to the exclusion of almost everything else. The master can not, for example, be concerned about web tensions on either side. In fact, it is the adjacent drive positions that pull against master and it must hold steady against these pulls. The master can not even be concerned about the loads it is developing, short of protecting itself against meltdown. The reason is that any simple control system can follow only one target at a time and the master's target is speed. The quality of the master can be judged quite simply by how closely it holds target speeds. For example, a good master can hold speeds to 1 part in 1,000 provided that the applied loads do not vary too violently. If a master's speed wanders, all other sections in the machine are forced to work harder just to follow their now moving targets.

Changing speed is also the responsibility of the master. On any web drive, we expect the master to construct an 'S' ramp during acceleration or deceleration. (An exception to this is during an emergency stop where all drive points are expected to develop full safe stopping torques.) The 'S' is composed of three parts. The first part is 1-3 seconds of rounding from the initial speed to the linear ramp. The second part is the linear ramp whose slope may be on the order of 10-100 FPM/sec. The third part is 1-3 seconds of rounding from the ramp to the final speed. The acceleration and deceleration ramps may be different so that the master drive may need six or more parameters to describe the ramp. The importance of the rounding on both ends can not be overstated as without it the adjacent sections must create a step change in torque to follow without error. Thus, lack of rounding is one of the major reasons for troubles starting and stopping web machines gracefully (Web Works, December 1998).

Finally, the web must never slip on the master drive roller. Admittedly, the web might slip on an idler without noticeable waste or delay even though it is risky and poor practice to allow it. One might even slip on a driven roller and still run. If the web slips on the master, however, you are almost assuredly going down. This does not necessarily mean that the master need be a nipped point or vacuum roll. It only means that careful engineering design must use some technique to ensure traction at all times.

How does one select the prestigious speed reference? It is usually selected from prior experience on similar lines by noting that some points serve more easily and more reliably as the pacer. For example, the laminating point is almost always selected as the master on that type of machinery, else tension zones will 'talk to each other'. Obviously, traction is another consideration that may make a nipped point, for example, a better position than some lightly wrapped roller. Finally, the master is often a high inertia roll, though we would stay away from the wound roll because of the complications of the changing radius. Some coating/laminating machines are so versatile that the master may change positions for different configurations. Modern drives make changes of mode or target, such as moving a master, a mere software subroutine that follows a grade recipe.

***2000.01 Jan 2000
Are there different ways of stopping a machine?

There are several different ways to stop a web machine depending on the situation. Most machines will be equipped with a normal stop and an emergency stop. You may also have fast and slow stops, coast stops and other creative confusion. Once your are stopped you have additional choices for parking the machine's drives.

The normal stop is a fully controlled stop. By this we mean that the master constructs and follows an 'S' ramp down in speed as discussed last month. Additionally, all of the other drive sections continue to follow their previous targets for draw, dancer or tension. It is possible that the targets will change for deceleration, such as inertia compensation on a helper drive, but the idea is essentially the same. We want to maintain all tensions during the speed change as they were during steady state. The goal is to keep tension in control and thus perhaps product quality in spec. Some machines have a fast and slow stop. Here, we may give up product specs but not the web during fast stop, but try to retain both during the slow stop.

The emergency stop, or E-stop, is a maximum safe stopping effort. In most cases, this means that every drive point, whether mechanical or motor, develop full rated stopping torque. Motors can and will be overloaded by as much as 100% for the E-stop event that is too short to develop significant thermal overloads that would melt the motor. It is not uncommon for a drive point to be equipped with auxiliary mechanical brakes to assist with the E-stop and parking. Then, motors do not have to be oversized E-stop at the cost of control finesse during normal duties. Since motors now have a new target, maximum safe effort, they must temporarily abandon their previous targets of speed, tension and so on. While most drive points will be commanded to full torque, sometimes this can not be done safely. These exceptions are taken on a case-by-case basis.

The purpose of the emergency stop is to make every reasonable effort to protect man, machine and/or material from further damage in the event of an upset or accident. Much could be said about safe design stopping times and rates. Thus, there is risk in over-generalization in a short discussion such as this. However, it is usually not practical or common to stop large machinery in much less than a second or so, even at thread speeds (approximately 60 FPM). Much of this time is simply the reaction time of the human. Thus, an operator could be completely drawn into a nip. However, two aspects about E-stops are seldom debated. First, when (safely) possible the E-stop switch should be hard wired directly to the drive rather than going through a PLC or controller. Second, the E-stop switches should be numerous and accessible. Choices for E-stop inputs include the PLC program, a red mushroom button, a pull chain, a 'deadman' foot pedal, light curtains and so on.

Once a machine is brought to zero speed, we have several choices for parking the drives. In most cases, the master will be commanded to hold position. Here, stopped means stopped so that absolutely no drifting is allowed for obvious safety reasons. The other points could also commanded to stop as well. Often, however, a better choice is to employ ‘stall tension’ to keep the web from going slack and thus losing MD and CD positions. Here, the tension controlled sections still maintain a tension target, but the value is typically about half of what is used during run. Unfortunately, many drives are not skillful enough to hold a stall tension. Finally, most drives will eventually disengage electrically after some time delay. Then, the motors develop no torque other than mechanical friction, just as in the case of coast stop.

***2000.02 Feb 2000
Are there dangers with draw control?

In draw control we regulate the speed of the web at various drive points (February 1995). However, its alias 'speed control' avoids confusion with an alternative meaning of 'draw' which is to intentionally and permanently elongate the web in a forming section. In most cases our intention is to merely tension the web, not to yield it plastically. No matter what we call the function, however, the use of draw control is widespread. In fact, we may have draw control and not even know it. If we belt or gear two rollers together, we cause a fixed draw between them.

Despite draw's popularity, however, there are many issues to consider. Most of these result because draw is open loop on the web. Thus, we do not know how much the web is tensioned. This is disconcerting because controlling tension is the raison d'être of most drive points. In fact, we can't even control web speed except by assuming that the roll diameter is known precisely and that the web is not slipping on the roll. However, a rubber covered roll's effective diameter may not be precisely known if it is worn or in nip. Similarly, the pitch diameter of a V-belt pulley is also uncertain due to belt tension, wear, load and even temperature and thus should be avoided on a draw controlled roller. The following illustrate just a few additional complications of what appears to be a simple web tension control scheme.

1. Viewed broadly, draw is closed loop on tension. However, it is the operator's hands or eyes that serve as load cells for control adjustments. Obvious concerns here are operator accuracy, repeatability, and 'scan time' compared with electronic sensors and modern controls.

2. The tension in a draw section is affected by upstream tensions. Thus, process upsets are not corrected by draw control, but are rather passed downstream as a tension variation.

3. The tension in a draw section can be affected by changes in temperature, moisture and other expansive factors. Thus, turning up an oven may also require a simultaneous adjustment of the draw so that web tension remains at an appropriate level.

4. Controlling tensions on typical materials such as paper, foil, most films and most nonwovens requires exceptional speed accuracies. For example, a 10% variation in tension can be caused by a roller speed or diameter uncertainty as little as 1 part per 10,000. This far exceeds the resolution of all but the best mechanical and electrical drives. Thus, tensions may be erratic and unrepeatable.

5. Often we must temper the extreme rigidity and intolerance of draw by softening the control's gain. Thus, rollers are not forced to follow a speed precisely if the web starts tugging on it. This effectively makes the control neither speed nor torque control, but rather some complex combination.

Nonetheless, draw control has great appeal because of the equipment simplicity. This makes draw a practical choice for materials such as rubber, creped tissue, and polymeric materials with exceptional extensibility. Also, draw is the required choice when we are truly ‘drawing’ materials, such as at the forming section of paper machines and film extruders, because tension is indeterminate there. However, in all other cases we should carefully weigh the appeal of tradition and mechanical simplicity against the very real possibility of compromised web tensions. Even if we do choose draw for control, however, we should consider adding load cells for monitoring so the operators can better see tensions and so that E/I can better tune the drive. This also gives us the fallback of upgrading to tension control, by a mere change of software on modern drives, should draw prove troublesome.

***2000.03 Mar 2000
Are there dangers with dancer control?

In dancer control, the speed of a motor is trimmed by the position of a dancer (January 1995). While this may appear at first sight to be a type of speed control, the type is determined by the outer control loop. The outer loop in this case is a physical one, namely the web, rather than the more typical line of code embedded in software. Since equilibrium can be obtained only when tensions balance forces (roller weight + cylinder force), the dancer is in fact a type of tension control. Indeed, only three parameters vary between a dancer and a load cell. First, the stroke is a few inches instead of a few thousandths of an inch. Second, the dancer has significant mechanical friction, while the load cell has negligible hysterisis. Third, the dancer's position is an integrator of force error.

While the dancer has always been a popular form of tension control, it has been yielding majority share to the load cell. Yet the dancer stubbornly maintains a following and is even something of a cult in many cultures. Proponents wax about its virtues of tension oscillation and shock absorption. (The truth is that its capabilities here are very overstated.) They also sing about its more reliable performance as an input to the drive. (The truth that almost any modern and properly configured drive is quite capable of running with a load cell input without compromise). The also preach about its sturdiness compared to the electronics of a load cell. (The truth is that a failed load cell often means the designer has made a mistake such as not specifying mechanical overload protection).

I am not going to philosophize as to which is a 'better' control as either will perform without compromise in most situations if the details of design are attended to. Rather, I would like to alert you to a few dangers that can ruin the performance of dancers.

First, the friction of a dancer should be less than 1/10 of the lightest tension to be run else the sensitivity and thus tension control will be spoiled. For example, a mere pound of friction would be too much on a narrow 20" wide machine running a 1 PLI web tension. A dancer such as this could be easily moved with the little finger. Second, the arm's position should not be measured with the ubiquitous rotary potentiometer because this device is prone to fail as an erratic glitch that is hard to troubleshoot. Third, the dancer's cylinder pressure should be calibrated and overlaid with a PLI scale so that proper tension units are displayed. Fourth, the dancer should be followed by a load cell. The purpose of the load cell is to verify the average web tension and to keep an eye on tension excursions. Without a cell, it would be very difficult to judge the health of a drive system. A stable dancer does not imply stable tension. It could just mean that the dancer is bound up with friction. Conversely, dancer motion does not imply a serious tension error.

An intriguing belt-and-suspenders approach, both a dancer and load cell are employed in the same section. One might use the dancer for control and the load cell as a monitor of health and as a troubleshooting aid. Alternatively, the load cell might be the controller and the dancer a passive shock absorber. Also, it is not necessary that a line be either dancer or load cell controlled. It is common to use the dancer on a (flying splice) unwind to absorb what shocks it might, but use a load cell on the downstream winder where taper tension is employed.

***2000.04 Apr 2000
Are there dangers with load cells?

Tension is a vital web handling and web processing parameter because it affects so many things. Product dimensions, registration, laminator curl, bagginess, wrinkles, web breaks, guiding, slitting and wound roll tightness are but a few examples. We measure web tension most directly with load cells (December 1994). These sensors are simply an idler roller mounted upon a force gage, most commonly a strain gage cell. The output from the cells, displayed by a meter, is desirably calibrated to fundamental tension units of lb/in (PLI) in the English system or kN/m in the metric system. Since we are weighing the total force produced by web tension, the reading represents an average across the width. It can do little to alert us to baggy edges or other tension variations with respect to cross-machine position. Its forte is alerting us to tension variations with respect to time.

The tension reading from the load cell may provide us with three vital functions. First, it tells us what the average web tension is at that location. Obviously, the load cell can measure tension far more accurately and more consistently than the best operator can gage it by look or feel. However, the cell can also read tension far better than can be inferred by drive settings. Second, the health of the drive system can be verified. We normally expect a good drive to hold tension to within 5% of setpoint during steady state and 10% of setpoint during upsets as read by responsive load cells. While drive health can sometimes be inferred by motor amps and other indications, the load cell is far more direct. Third, the tension measurement may be used in some applications for feedback to a drive or brake controller.

However, the load cell is not without issues. First, it must be mechanically protected so that overloads of up to 10x rating can be sustained without damaging the cell. Electrical overload protection, on the other hand, is pretty much worthless as this is merely a derating of the cell. In years past it was more difficult to find mechanical overload protection. Thus, people would install cells that were not ‘mill duty’ and they would get easily broken or damaged. For example, the may get bumped during service, climbed on by an operator or snapped by a web break. (The quickest way to screen for damage is to watch for an unexplained drift of the zero). This gave the cell an undeserved reputation as being tender, when the mistake was one of details of the design selection.

Second, the load cell is prone to mechanical vibration and resonance, especially on high-speed machines. In these cases, one would either low tune the resonance to well under typical operating speeds, or mechanically and electrically damp the vibration and signal respectively. Also, superbalancing of the roll to ISO grade 2.5 or even 1.0 was vital. Similar loss of signal integrity could occur when a wimpy millivolt signal was run through an electrically noisy environment. The solution here is to use good shielding techniques or, better yet, put the amplifier on the cell itself and run a current loop.

Third, the load cell has much less travel and thus forgiveness than a dancer. This may allow tension to vary intolerably during process upsets such as during a splice or turnup, or when the drive is troubled in some other fashion. Thus, while it is usually safe to use a load cell for monitoring, it may not be safe to use for control. Load cell feedback usually demands good drives. This need not imply servo, AC vector or even DC drives. In fact, even a pneumatic brake can often be controlled without tension compromise using load cell feedback, if the details are attended to. Indeed, attention to details is the best way to successfully avoid the problems discussed above.

***2000.05 May 2000
Are there dangers with too much bow on a spreader?

It is the bow that steers the web outward on a bowed roller (February 1997). The outward steering in turn provides the spreading functions such as prevention or treatment of wrinkles, web widening, slit separation prior to winding and so on. At first sight, it would seem reasonable to expect that one would get more spreading as one increased the bow. However, this is only true to a point. If one pushes the bow beyond that point, spreading is lost and one even risks wrinkling the web. We have learned that any device that is capable of spreading is more than capable of wrinkling if details of the application are not attended to.

The bow is usually specified in terms of a percentage of roller width for an application class, which then translates to an absolute dimension for a specific roller. The appropriate bow magnitude depends, of course, on the application. The bows for the most common situation of an unslit, inextensible and untroughed web may be as little as 1/8%. However, even pushed to twice that value would translate to a bow magnitude of only 1/8" on a 50" wide machine. This value is on the lower threshold of manufacturability of the roller axle. Bows may be increased to perhaps 1% for very extensible materials, such as tissue, nonwovens or rubber, or those which have a lot of excess width as shown by multiple troughs oriented in the MD. Bows may be a couple of percent for spreading multiple slit webs, such as prior to winding.

Excessive bow on a bowed roller spreader is so common as to be epidemic. This bigger is better mentality has destroyed the effectiveness of the bowed roller spreader and even caused it to misbehave so that it damaged the web. Many think that the effective magnitude of the bow can be reduced by turning it out of the web run. While this is true for a bent pipe spreader, it is definitely not true of a bowed roller. If you have too much bow, you must remanufacture the spreader's axle to a larger radius of curvature.

There are several symptoms of an overbowed spreader. First, while the spreading looks very good at the web's center, the edges do not look good and do not lay flat. Rather, the edges form troughs that are chevron shaped at the approach to the bow and may progress to hard wrinkles if pushed hard enough. Second, the operator has turned the bow up into the web considerably from its nominal halfway between the ingoing and outgoing sheet run tangents. True, this could indicate the operator does not know how to aim the bow. More often, however, it indicates the engineer does not know how to apply a bowed roller. The engineer would be implicated if the web's condition degraded when the bow was returned to its nominal position.

First, the engineer could have overbowed the roller. Second, the wrap angle may be insufficient. Third, the web-to-roller coefficient of friction may be insufficient. Fourth, the roller may driven incorrectly or not driven when it should have been. The common theme of these four oversights is this: all caused the web to break loose traction on the outside edges where it was asked to bend outward too violently. The edges balked at this unreasonable demand and moved inward to interfere with its neighbors that were still in traction. In response to the ugliness that resulted, the operator found some relief by rotating the bow into the web run. What he was doing was to turn to bowed roller into the equivalent of a bent pipe spreader. The bent pipe type spreader does not require the traction that is necessary for a bowed roller to operate as a bowed roller.

***2000.06 Jun 2000
Why would you use crowned rollers?

A crowned roller is one that is intentionally larger in diameter at the middle than at the ends. The crowned or barrel-shaped roller is used for three primary purposes: nipped roller deflection compensation, spreading and guiding. The mechanical details and the mechanics of operation of each are distinctly different.

Nip load must be adjustable and controlled on many processes such as coating, laminating, printing, winding and so on. The problem is that when you push two rollers together at their ends, they bend apart in the middle. This would make the nip pressure higher at the ends, and thus the product and process would be nonuniform. To compensate, the roller may be made bigger in the middle than at the ends to fill in the nip.

The diameter difference or crown can be precisely calculated by the physics of roller deflection. If the load is too low for the crown, the nip pressure will be higher in the middle and vice versa if the load is too high. Nip pressure uniformity is easily checked with nip impression paper (June 1994). Because the deflection of a roller should not be excessive, we can quickly calculate an upper end of a reasonable crown. At a typical standard of no more than 0.00015 inches of roller deflection per inch of width (March 1995), the bending and thus crown for a 50" wide roller would be less than 7 mils. This is the thickness of a human hair.

The second use of a crowned roller is somewhat rarer. It is a rotating version of a D-bar or bent pipe spreader. The principle of operation here is that the web wants to slide outward, away from the hump. The crowned roller has no better spreading than the bent pipe, nor does it usually induce less drag. The advantages are, however, that the relative velocity between web and spreader is less so that the magnitude of spreader wear and web scratching are less. The magnitude of the crown depends greatly on the application. Wide machines with extensible webs (e.g., nonwovens) could have crowns more than several inches, while narrow machines with stiff webs (e.g., foil) may have crowns less than a few mils. Large crowns make for floppy web edges in that span, but may induce permanent center bagginess due to stretching.

The third use of a crowned roller is as a passive centering guide. Here, the shape of the roller brings the web to the middle, IF the web is in traction with that roller. The principle here, though well understood, is too complex to describe briefly. The application is to keep thick heavy webs, such as belts or steel strip, on their rollers without the expense of active guides that have moving parts and controls. The most common place you would find the crowned roller is on flat belts, such as on vacuum cleaner bristle brush drives, some older web machine drives and conveyor belts. The magnitude of the crown is usually just a few mils.

This guide will NOT work on thin webs that most of us have. If you tried it, you would find the web would bunch up in the middle of the roller. This principle also helps explain a couple of defects that you may have encountered. The first is the tendency to wrinkle on a roller that has a diametral bulge due to improper machining, wear, and tape or adhesive buildup. Some thin webs are so touchy that a hairs thickness bulge will readily start a wrinkle. Similarly, this principle explains the ‘knot’ defect of winding of thin materials such as film. Here, a caliper gage band starts a bulge in the winding roll, which tends to gather the web there. This makes the bulge even bigger, thus increasing the gathering power of the bulge in a snowballing cycle.

***2000.07 Jul 2000
Why would you use reverse crown rollers?

The reverse crown roller is one that has ends that are intentionally larger in diameter than it has at the middle. I am aware of only one common purpose of roller such as this. That is to provide spreading for thin webs on intermediate width machines. The principle of operation is similar to the crowned guide roller described last month. Briefly, the web tends to move to the high diameter portion of a roller, WHEN it is in traction. Thus, each of the larger diameter ends of a reverse crown roller will tend to pull the web outward, inducing a spreading force.

The most common implementation for this spreader is to put bands of tape on rollers at the outside edges of the web. This crudely simulates the diameter profile of a reverse crown roller. Astute operators in plants around the world know about this technique. Unfortunately, even more operators mistakenly believe that spiral tape spreads the web. Tape is like cockroaches and quackgrass. They are a devil to get rid of once you get them. Thus, here is a brief checklist to effectively manage taped rollers in a plant.

1. Tape can be used for improving traction and air handling. However, the mechanics and application for these purposes are quite different than tape used for spreading.
2. Reverse crown rollers are very weak spreaders and thus should not be used where vivid bagginess, troughs and/or wrinkles are found that indicates the need for more aggressive treatment.
3. Reverse crown rollers are not usually suitable for heavy materials (not enough pull), stiff materials such as foil and perhaps even paper (required diameter variation would be so tiny as to be difficult to machine). They are also not usually suitable for machines that are very narrow (causes web path stability problems) or wide (not enough pull for reasonable diameter variations).
4. This spreader REQUIRES traction. If the web slips even a little bit anywhere, the device will as likely wrinkle as it would spread. Thus, always choose a well-wrapped roller. Also, choose a roller that is in front of or at a wrinkle initiation position. Never treat more than a few rollers else web path instabilities or other problems can happen. Finally, you can’t use this with baggy-edged web, as there is no traction there.
5. Start with two thickness or wraps of tape. If this does not seem to do the trick, increase to four or possibly six wraps. If this does not spread as indicated by a CLEARLY flatter web at the spreader than upstream, remove the tape and do something different. The more is better approach to spreading is likely to backfire.
6. The tape must be located under the edges (only) of the web run, and wide enough to pull. In round numbers, this may be 5-10% of the web width on each end.
7. Neatness counts. If using several layers, many people will build an ever-increasing diameter buildup toward the outside edges. The craftsman will lay the tape so that there is no overlap, nor gaps between the wraps wide enough to fit a razor blade in. They may also dub the exposed edges with sandpaper to blur the hair thickness bump.
8. Only if a position is consistently found to benefit from taping would you go to the next step to cut a reverse crowned roller. While there is no significant spreading

performance improvement, a cut roller requires no tending as tape does due to wear or need for repositioning when changing web widths.

***2000.08 Aug 2000
When would you use spiral grooved rollers?

Conventional wisdom has it that you use spiral grooved rolls to promote spreading. Converters request spiral grooving from their supplier, and their suppliers are more than happy to comply. If spirals are not provided, the operator may well add them with masking tape. This science by consensus is further supported by the visual appearance of the spirals that is strongly suggestive of an outward movement when the roller is turning.

Unfortunately, this outward-running appearance is nothing more than a 'barber-pole' optical illusion. I am aware of no documented evidence to support the widespread belief that grooves can spread. Indeed, studies have shown that either the grooving has no effect whatsoever (1) or has the tendency to WRINKLE [italics] and mark the web (2). Why then do we persist in spiral grooving?

The roller may be spiral grooved for many reasons. First, the optical illusion is so very convincing. Second, no one checked whether there was any spreading going on, at least until very recently. It was assumed to take place because it appeared reasonable and everyone was doing it. Third, there are the practical reasons to avoid fixing something that ain't broke or fighting city hall. Finally, grooving of some shape may be needed to handle air entrainment when running thin smooth webs at higher speeds (3). Without grooving or texturing of some type, the web may loose traction with the roller. The spiral is as good as the annular shape in this regard, so why not spiral?

In fact, I am not proposing that spiral grooves be avoided. Use them if you wish. Two things, however. First, don't assume that any spreading is occurring. If you need spreading for wrinkle treatment or other reason, you must get it in some other way. Second, don't make the grooves too wide. Grooves wider than 10-20 times the caliper of the thinnest web risks wrinkling or marking as the web pulls into these crevices.

We can avoid making assumptions, such this one on spiral spreading, by asking more critical questions of our processes. If the questions have not been definitively answered by science, perhaps we should devise tests before we proceed. It is not just for the application of the moment that we need the answers. We need them so that we do not introduce any more mythology into the industry. Once it gets entrenched, it is as hard as quackgrass to get rid of. In this case the costs appear to be minor: some additional time on the lathe cutting grooves, some operator time cleaning and applying tape to rollers, a few marks on webs and a few wrinkles that may have been prevented by more aggressive treatment. Or maybe it isn't so minor if you look at the big picture. Consider the number of grooved rollers at the tens of thousands of web manufacturing and converting machines. Small things can up to significance.

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***2000.09 Sep 2000
What makes a good converting team?

A large converter recently invited me in to teach my web school. I mentioned that the seminar was targeted for process engineers, scientists as well as lead operators who work regularly around the machinery. I added; other positions such as Q/A, maintenance and customer service could also benefit. My host replied that their plant was a ‘team environment’. It became clear that ‘team environment’ was management doublespeak for an organization where operators and staff performed a variety of tasks that in other plants were done by specialists. For example, quality assurance testing and rejection was primarily the responsibility of the operator. The crew also did simple maintenance.

The word ‘team’ has been so overused that I seldom notice it anymore. This time, however, it triggered some real soul-searching on what makes a truly effective converting team. Obviously, a team is a collection of people who worked together toward common goals. In converting, such goals include profitability, productivity, quality, safety and so. Since working together has been covered so frequently in management books, programs and meetings, it seldom needs more than a reminder. Working together does not mean, however, that members agree with each other or even like each other. In fact, there are many examples of extraordinarily successful teams, such as the medical scientists Sabin and Salk who pioneered vaccines that were constantly at each other’s throats. It is easy to find examples such as these to show that it is at least possible to get the job done without warm and fuzzy feelings between the team members. Good will, though usually desirable, is neither necessary nor sufficient to effective teams. Indeed, good will taken to excess is counterproductive if it always encourages consensus over argument (logical reasoning) and debate (exploration of varying viewpoints).

Rather, it is my observation that a VITAL [underscore vital] characteristic of a truly effective team is a skillset that is deep, wide and complementary. Take a football team, for example. It is clear that you need players that specialize as quarterbacks, runningbacks and kickers in order to be professionally competitive. However, this team will also require coaches, doctors, accountants, marketing, and owners. If they do not have these skills, the team will not be competitive. Furthermore, each person may possess only a single specialized skill. It is unreasonable, for example, to expect that the quarterback also double as the team’s accountant in the off-season. It is similarly unreasonable; for example, to have the medical doctors do double-duty in marketing.

The same is true of the converting plant. It should have a Q/A department whose head is familiar with test standards, instrumentation, statistics and other skills. If not, the plant is at a disadvantage with those that do. It needs mechanical and electrical maintenance departments to cover even the simplest machine repairs and tuning. Similarly, we would tackle productivity issues with industrial engineering skills, while product and process design by those with chemical and mechanical backgrounds. Corporate librarians using commercial databases best do information searches. Travel specialists can find cheaper or smoother itineraries than we might.

However, I have observed a disturbing trend to decreasing specialization in large companies similar to what was always found in smaller companies. In part this is due to lean staffing so that everyone must wear many hats to cover the necessary territory. In part it may be hedging one's career bets by demonstrating work (not necessarily mastery) in many areas. In part it may be due to the reluctance of many to put in the apprenticeship necessary to truly learn an area. Whatever the reason, however, we are in great peril of becoming an industry where everyone is a jack of all trades and a master of none.

***2000.12 Dec 2000

Why do my defects get worse in summer or winter?

Our processes are no more isolated from the effects of seasons and weather than we are. True, we can attempt to regulate the temperature in the building via our HVAC system, much as we would dress ourselves in shorts or overcoat as appropriate to regulate our body's temperature. However, the results are far from perfect. Merely opening a door can spill hot or cold air into the machine room. Temperature can have noticeable affects on our processes, such as ovens and chill rollers, as well as thermally distort our machinery. More importantly, temperature affects a variety of material properties such as adhesion, strength, viscosity and so on. It is not unusual for air temperature to vary from 50°F in a poorly heated corner of a warehouse to more than 130°F near an oven. Our products will see an even greater temperature range in transportation. They might see less than -40°F in an Alaskan winter to more than 160°F in a semi-trailer parked in the Phoenix sun.

However, it is not merely temperature that can upset our products and processes. Humidity also plays a noticeable role in film processing, and a profound role in paper processing. Humidity affects physical processes such as drying, condensation of water on cold surfaces, poisoning of plastic pellets and static electricity. Humidity is seldom controlled in web processing and converting, and thus can range from less than 20% RH to a supersaturated 100% RH, depending on the geographic location, season and daily weather. Seasonal variations outside of the building can cause machine misalignment as foundations move with the contracting and swelling of the earth due to changing soil moistures.

Following are examples of the seasonally dependent problems I have worked on.

1. Machine alignment changed between night and day in an unheated building during construction.
2. Machine alignment changed due to Atlantic tides more than 10 miles away.
3. Machine alignment changed between wet and dry seasons.
4. Wound roll moisture welts occurred in summer months or after a rain shower at countless paper mills and converters.
5. Wound roll blocking only occurred in summer months at several coaters and converters.
6. Wound roll telescoping during storage only occurred in summer months at several adhesive label manufacturers.
7. Tissue roll unwinding problems only occurred in summer months.
8. Newsprint web breaks doubled on northern printing presses in the winter months.
9. Static electricity is troublesome only in the winter months at countless northern converters.
10. Film defects that occurred primarily in either winter or summer.

It may be revealing to plot the defect rate as a function of month for a given grade for a couple of years when troubleshooting a puzzling problem. If it shows a seasonal cycle, you will then know that either temperature or moisture is involved. This in itself may provide a vital key to unlocking the puzzle. You have several choices if you find a seasonal dependence. First, you might redesign the product and/or process to make is less sensitive to moisture or temperature. Second, you might regulate moisture or temperature more tightly. Third, you could steel yourself for the seasonal increases in waste, delay or customer complaints.

***2001.01 Jan 2001
How can I change the amount of spreading?

It is not unusual for a single spreader to adequately cover everything a machine might run in its lifetime. Sometimes the amount of spreading power should be varied, such as grade changes that include large changes in modulus. While aggressive spreading can be used on flexible materials, this same power focused in stiff materials can result in wrinkling. Similarly, spreading should be adjusted when grade changes include large changes in the flatness of the material. Aggressive spreading can and should be used when the material is profoundly troughed in the MD, but not when there is little excess width. Note that troughs at even a slight angle with the MD indicate something is crooked (June 1994). The specific cause of the crookedness should be identified and corrected rather than treating it with spreading. Finally, spreading should be adjusted when changing the number of slits with an after slitter spreader, especially when winding on the same axis. More slits would require more spreading power.

Insufficient spreading is easy to diagnose: the web is not as flat as a pane of glass. However, this ideal can only be reached when the web is in good condition to begin with. It is unrealistic to expect flatness if the web is profoundly troubled with baggy patches and lanes. Excess spreading can also be diagnosed. If the web is slit into multiple lanes, the separation at the center will be excessive, while the edges may be minimal and possibly even overlapped. The center of an unslit web may look good, while the edges are not flat. Indeed, you may often see chevron-patterned wrinkles at the edges of the web as it approaches the overly ambitious spreader. It is ironic that people will often induce wrinkles on the edges of their web in their zealous spreading to treat baggy edges. Unfortunately, baggy edges can seldom be treated or even touched by spreaders. It is a common fallacy and misunderstanding that spreading can treat what is essentially a web forming issue. Only when the web is anelastically reformed, such as hot film or nonwovens inside a tenter oven, can spreading moderate bagginess.

If large changes in spreading are needed, you may need to change the type of spreader. If the needs and budget are minimal, web flattening rather than spreading should be considered (see next month). Modest spreaders include banding (taping the ends of the idlers), concave rollers and compliant cover spreaders. Moderate spreaders include bent pipes, D-bars and bowed rollers. More powerful spreaders for separating numerous slit lanes are the dual spreaders that include the dual bowed roller, tandem bowed roller and Pos-Z. The most powerful spreaders are expander rollers (bands or slats), edge pull rollers, and tenters. Note that there is currently no evidence for spreading with either spiral grooved (August 1995 and August 2000) or herringbone rollers.

If modest changes in spreading are all that is needed, you may be able to adjust the spreading power of some spreaders. These include the bow magnitude on a D-bar or variable-bow roller, the wrap of the dual spreaders, the cam angle or wrap of the expander roller, the angle of the edge pull roller and the separation of the tenter tracks. Note: you can NOT adjust the power of a conventional bowed roller by aiming or orienting the bow. Interestingly, the only spreader that is profileable (selectable spreading power across the width) is the D-bar found on newsprint winders.

It is very important to avoid the more-is-better approach to spreading. Indeed, aggressive spreading when it is not needed can get you in as much trouble as insufficient spreading. Even if the need is high, however, attempting to aggressively spread and failing will more likely cause wrinkles as fix them. The classic example here is the ubiquitous overbowed spreader that has lost traction on the edges (February 1997).

***2001.02 Feb 2001

What are the Pros and Cons of Cantilevered Machinery?

Cantilevered machines have rollers or shafts that are supported only on one end, the back, instead of simply-supported on both front and back. Cantilevering becomes more common as the width of the web decreases. Thus, for example, cassette tape players and VCRs are always cantilevered. Narrow web machines used in the converting industry are often cantilevered. Machines less than 1 foot wide are usually cantilevered, while those wider than 3 feet are almost never cantilevered. Some narrow machines are hybrids so that unwinds might be cantilevered for ease of roll loading, while the process rollers are simply-supported on both ends for precision. As shown by these examples, web width is a determining factor. Why?

Roller deflection under loads is one limiting factor. Rollers will bend due to the combined forces of weight, tension and nip. This bending must be limited else the web will be perpetually loose on the front side, as well as risking web tracking and wrinkling problems. Bending is especially intolerable on process rollers in nip, such as in calendering, coating and printing. This bending, by standards endorsed by many converting machinery builders, must be far less than the thickness of a human hair (about 0.005”) for all but the widest machines to remove the risk of these web handling problems. The challenge with cantilevering is that a cantilever will deflect more than 10 times as much as the same sized roller supported on both ends! To resist deflection, the diameter of the shaft must increase. Thus, cantilevering merely 12” may require a shaft that is 2” in diameter, making the roller itself a minimum 4” diameter. Since deflection increases with the fourth power of web width, a 2-foot roller will deflect 16 times as much as a 1-foot wide roller! Thus, cantilevering is simply not practical for anything but the narrowest of machines.

Perhaps the only real advantage to cantilevering is that cleanup and threading can be easier. Thus, a prime candidate for cantilevering might be a diaper machine because the operator is frequently clearing and rethreading one of a half dozen or more component webs that have broken somewhere on the line. It makes much less sense for a printing machine where the operator may only take a few minutes out of an hour to thread a new roll. It is ironic that decision-makers would heavily weight the threading function on narrow machines, when narrow webs are often the easiest to thread anyway. With only a modicum of design effort and technique, a 100-foot long machine can often be webbed in just a few minutes, and a 1000-foot long run in just a few more. Indeed, paper machines 400” wide x ¼ mile long are threaded without even slowing from their 5,000 FPM speed. Thus, the benefits for ease of threading cantilevered machines may have been, at times, overstated.

Another fallacy with cantilevering is that it is cheaper than conventional framework. The costs are similar or even greater if one builds the machines to the same precision. Roller alignments, again with precisions to the thickness of a human hair, are more costly on a cantilever than a simply-supported design. Also, an alignable machine requires two backplanes to serve as the framework, which can be more costly than a front and back plane. Unfortunately, many cantilevers distinguish themselves by being in the minority of web machinery that is not alignable. They can sometimes get away with this if the length to width ratio of the web spans are large.

The choice of cantilevering boils down to weighing the benefits of ease of threading for improved productivity, against the increased costs of sound cantilever design, or against the increased costs of waste due to poor roller precisions of a poor cantilever design.

***2001.03 Mar 2001
What are Some Considerations for Pilot Machines?

In previous lives, I was a manager of an R&D lab for a large machine builder, built a pilot lab for a university, and was a senior R&D engineer for a Fortune 100 web maker. Having been around pilot machinery for a long time, I can say that from experience that they are a two-edged sword. Costs and benefits must be carefully considered so that a monetary payback is achieved for the company. Often the payback is in the form of improved product designs that can maintain market share or even create new markets. However, process efficiencies might be made on production machinery that were more easily learned from experiences on pilot machinery.

The first issue with pilot machinery is design philosophy. Too many people make the mistake of designing the pilot machine to look like their production machine, only scaled down in length, width or speed. This is extraordinarily and unnecessarily limiting. Sometimes the essence of a problem can be captured with equipment far simpler than production machinery. For example, I began pioneering research in tissue winding by ‘winding’ the rolls by hand on the floor. The physics of my hand was identical for that purpose to production winders, and was much simpler to work with. Later, simply for convenience, we made a benchtop version at a cost of 0.1% of what an adjacent production look-alike costs. The benchtop was also more versatile, had a greater range and was easier to work with.

Sometimes a pilot machine must be built with a greater range of operation than a production version. For example, one of my winders at Beloit was designed for 10,000 FPM when the fastest any commercial machine was running at the time was only 7,500 FPM. This winder was capable of running webs as delicate as tissue or cigarette paper, as well as webs as stout as food board such as you would find in cereal boxes. This range meant that the drive, tension control and rollers had to be designed to state-of-the art precisions. Some pilot coater machines can run multiple coating and drying methods on the same line. Machines such as these are not necessarily jack-of-all-trade compromises. If designed well, they can function in distinctly different modes with no sacrifice of quality. (Obviously, however, setup time and productivity will be poorer than their commercial cousins will). Machines such as these are in many ways the most difficult of machines to design well, and may cost much more than their commercial cousins.

The most obvious alternative to pilot machines is to use one of your commercial lines to do your experiments. While this can work, machine time is often expensive and availability limited. Sometimes commercial machines lack the flexibility and instrumentation that a pilot machine has. Also, there is the risk of rushing an experiment to keep on schedule, and seldom can one just explore if the run suggests a new avenue to investigate. Sometimes an off-line machine can get you the answers you need. Here, slitter rewinders might be able to house certain experiments easily, such as investigating alternative cutting methods, and other experiments such as coating and printing with a modest rebuild. Finally, explore the many machinery possibilities that contract converters have. Almost any converting operation can be done on a contract basis, and many will rent machine time for trials.

With any of these options for trials, the applied researcher must bear a heavy responsibility to use good judgment. It is not reasonable to expect that every dollar spent on trials will result in new products and improved processes. However, most development efforts should pay back with improved profitability for the company, just as is expected of any other investment. Thus, weight should be given to simple but telling experiments as opposed to complex trials because there is less investment to be recouped. Finally, design of experiments and good statistical practices are absolutely necessary to getting the most for your research dollar.

***2001.04 Apr 2001
How do I know if Winding Caused My Defect?

While winding causes many troubles, it is also convicted of crimes for which it was innocent. For example, if you see a defect on the wound roll, it would be tempting to conclude that it was due to winding. However, you may see the defect on the winder first simply because it is much more convenient to see there. To be certain the defect was not made elsewhere, it is wise to sample upstream of the winder. Sometimes the winder made the defect, but it did so with help from manufacturing. Examples include corrugations, gage bands and ridges which occur when caliper-varying web is wound. While some winders and process settings might minimize the severity, the basic problem remains a varying caliper. It is important to note that the wound roll is by far the most sensitive measure of caliper. Features can show up on the roll which easily exceed the resolution of the best lab test techniques and online scanners.

The first evidence that the problem is related to winding is if the problem is described by references such as Roll and Web Defect Terminology, The Mechanics of Winding, and The Anthology of Winding (all published by TAPPI PRESS). In these writings, the appearance, trends and symptoms are used for diagnosis. Also, the mechanics may be described so that you know why the defect occurs, perhaps enabling you to make predictions about other behaviors. (Good science yields theories general enough to make predictions beyond those used to generate the theories in the first place).

The second evidence that the problem is related to winding is the distribution of the defect. If the defect is diametrally dependent, then it is almost certainly related to winding. Examples of diametral dependence are troubles that occur near the core. The details of the insult may be due to non-cylindrical cores, flimsy cores, bad starts or higher interlayer pressure. The pressure at the core is almost always higher than elsewhere due to winding physics as well as from loads passed from the core to the inside of the roll when supported by the core. Other examples of diametral dependence are defects that disappear toward the very outside of the roll. Winding physics guarantees that the interlayer pressure drops to zero at the outside. Finally, the defect may prefer some intermediate diameter. This might indicate problems with the winding machine or control. To determine diametral dependence, you must make a frequency distribution diagram of the defect with respect to radial position in the roll.

If the defect prefers specific CD locations, the problem is almost certainly related to variations in manufacturing upstream. Most web makers and converting processes have banded fingerprints that vary more with respect to CD position than with MD position or time. It is possible that the winder takes manufacturing bands and turns them into defect bands. If so, they might retain the diametral preference described above.

The last primary evidence that the defect is winding related is that the problem is sensitive to wound-in-tension. In other words, troubles become better or worse if winding is tightened or loosened. To determine this relationship, you will need to use

DOE (Design of Experiments) to construct trials with either very exaggerated tension changes or with very large sample sizes.

These three evidences are a good starting point, but are not all-inclusive. For example, you may get defects related to winding nip (wrinkles or air bubbles behind the nip) or lack of winding nip (air entrainment) that do not conform to the above descriptions. You may also see time dependent behavior that may or may not be related to winding. Perhaps this is why winding is often blamed for difficulties. It is tempting to indict the thing whose complexity we do not understand.

***2001.05 May 2001
How Tight Should I Wind My Roll?

I am often asked by someone "How tight should I wind my roll?" A more complex version of this query is what taper or curve to run. This can not be answered until he answers my question first. "What defects are you trying to avoid?" If his reply is "I don't have any defects. I just want to wind a better roll," he needs to get a life. Real problems fill dumpsters. Real problems come in trucks as returned product. Real problems make noise as customer complaints long before they become the silence of lost orders. However, if he does have defects or customer complaints, we might first try varying tension to reduce the problem.

Some defects are reduced by decreasing the winding tightness. An example is blocking where the layers of a roll stick together, making the roll difficult or impossible to unwind. However, some types of blocking are not significantly reduced by tightness. An example is adhesive tape, such as cellophane, where layers bond to together with little dependence on pressure. (It is only slightly harder to peel off down near the bottom than it is at the top.) Thus, blocking may or may not be reduced by winding tightness. If it is, however, you should turn the knobs as far as possible to get as much relief as possible.

Some defects are reduced by increasing the winding tightness. An example is out-of-round rolls. As tension is increased, the pressure is increased between the layers, which in turn increases the friction that holds the roll together. However, there are other factors that determine how round a roll will be such as web-to-web COF (coefficient of friction), ZD modulus, and handling load history. Changing just one of these parameters, namely winding tension, may not get you as far as you might want. Nonetheless, you want to use that knob for maximum effect.

A few defects are reduced by tapering the winding tightness. The most common are starring or telescoping. In these cases, you would taper from maximum tightness at the beginning of the wind to minimum tightness at the finish of the wind. Maximum tightness is found by turning the knobs up until you break something (e.g. severe the web, smoke the motor, pull the rollers out of their mounts), and then backing off slightly. Minimum tightness if found by turning the knobs down until you break something (e.g. wrapping rollers because the web is so slack, a bubble behind the nip, etc.), and then backing off slightly.

Some defects may respond favorably by increasing or decreasing the tension depending on the situation. For example, you would decrease tension to reduce crushed cores if they were failed during winding, but increase tension to reduce crushed cores if they were failed after winding by handling loads. Another example is wrinkles that may respond favorably by either increasing or decreasing tension depending on the physics.

Sometimes you may have tight and loose roll defects at the same time, even on the same roll. If you have a poor web caliper profile, for example, you might build a roll with a carrot shape in response to a gage that is low on the front and high on the back. The roll may be so tight on the large diameter backside, that the web blocks or is stretched into bagginess there. Even so, the roll may be overall so loose that it telescopes readily. It is quite common to have defects at both ends of the tension range. If you want to increase the width of the sweet spot in the process, you may need to redesign the product, or make the web material and machine more uniform.

Finally, some defects are not strongly affected by winding tension. How do you know if yours is? We will attempt an answer next month.

***2001.06 Jun 2001
What is the most serious web business oversight?

The most serious business oversight is not knowing as much as possible about the economics of a plant. This would include the types and costs of waste, such as off-spec material, seconds, reworks, trim, grade change and, most importantly, customer returns. (Waste is not a dirty word, August 1997.) This would also include knowing the types and lost minutes per month for delay on a machine for reasons such as cleanup, grade change, planned and unplanned maintenance and so on. Finally, it would include a rough knowledge of the costs of materials, labor and other resources necessary to design, make, market, distribute and service a product. Without information such as this, we can not know for sure what we should be working on. Without it, our priorities might be driven by whoever shouted loudest or most recently, by someone's judgment or by blind faith in our bosses.

When I go into a plant to help with a problem, I will always ask what the top three causes of waste are even if my assignment was defined more narrowly. The answers give invaluable insight into the system. Also, different defects might be connected by a deeper common root cause. Only about half of the engineers and supervisors know for sure what they are. Some of the rest may only venture a guess. When I ask how much waste is costing the company a year, only a small fraction of plant people would know. They assume that economics is the business of management and bean-counters, not technical people. As politely and firmly as I can, I will tell my clients that that the economics of waste is EVERYONE's business.

I expect that all plant people from the broom sweep to the president not only have access, but also have current knowledge of this month's costs of quality. It should be posted on bulletin boards and it should be a regular item on all team meetings. Unfortunately, all too often a group that is most intimately involved in waste, the operators, are not given this information. They are seldom full and equal team members for waste reduction programs. However, they are the ones who make the product. They are the ones who choose process settings and make process adjustments. They often make the quality call for passing, holding or rejecting a roll. They should, if not already, be able to place work orders to maintenance to correct quality, productivity and safety deficiencies on their machine.

The same is true of delay. We must know how long a machine is down for various causes before we would know which ones are most serious. Here we would use real minutes to gather and report productivity if the machine were run at constant speed for a grade. If the machine runs different speeds, we might use pounds of output instead of lost time. In any case, we must convert delay or reduced speed to lost dollars so that delay can be compared with waste. Since materials are more expensive than labor, in most processes, a few percent waste is more costly than the same percentage downtime. The cost of customer returns is trickier to estimate because the true costs are much more than mere reimbursement for returned rolls. Indeed, it could be more than 10x as much, if one is about to lose a customer.

The economics of waste and delay should determine what our various efforts should be and how much of our time should be allocated to each. The economics will determine if a particular effort should be abandoned, maintained, or stepped up. If the economics are minor, we will seek only to do the best we can with the tools we have. If the economics are more significant, we may get expert help as well as consider redesigning products and upgrading equipment.

***2001.07 Jul 2001
What is the most serious customer oversight?

The most serious customer oversight is not understanding the customer. Only a few groups are specifically tasked with meeting with and understanding the customer. These could be product development, marketing, sales or service. In smaller companies, functions may be grouped together so that customer calls are made by a marketing/sales/service person. There are shortcomings with this jack-of-all trade approach. First, to be good at marketing and sales, you must be people oriented. However, to be good in service, you also need to be highly technical and machine oriented. Ideally, you would have experience as both a designer and as an operator of the customer's type of equipment. Second, to be in marketing or sales you are an advocate of the supplier, while in customer service or support, you would be an advocate of the customer.

Other groups also have a vital need to know the customer, but may never meet them. For example, quality control is tasked with selecting test procedures, sampling intervals and rejection criteria for the product. The whole point of this exercise is to meet the needs of the customer. Too often, we select testing based on the traditional, rather than on the customer's needs. Thus, for example, tensile strength might be specified as rejectable even if the customer doesn't tear the product in their usage. Sometimes it seems that test selection is something of a popularity contest where QA is the judge rather than the customer. Process engineering then gets entrained into this system so that their efforts become focused on meeting test specifications rather than meeting customer needs. It is quite telling how customer complaints and returns escape the testing process. While we might measure caliper, gauge bands in the roll still stretch the product into baggy lanes. Other bagginess is not captured by any of the process measurements or lab testing. A roll might look perfect, but then telescope on the customer's unwind because we don't have the equipment to even unwind the roll's we make.

However, the most common oversight is communication. The customer uses words for one thing and we interpret them as something else. An example is 'telescope' which can be used for more than a half-dozen distinctly different phenomena. Often the words are suggestive of causes that, upon further probing, are found not be the causes after all. Studies have shown that the most astute customers misdiagnose problems more than half of the time. If we take the customer's complaint at face value, we may be set on a dead-end path for troubleshooting and problem resolution. The chain of communication also mangles the message. The customer's operator complains to her supervisor, who then complains to purchasing, who calls the supplier's customer service, which talks to their management, then to process engineering and finally down to the supplier's operator who made and passed the material in the first place. Lead machine operators and process engineers must work directly with their counterparts with regular visits to avoid losses in translation and transmission.

Lastly, many suppliers take on too much when they take a 'customer is always right' approach. Sometimes the problem and solution is entirely with the customer's equipment, operation, product or understanding. In these cases, it is difficult to refocus some supplier's attention on shortcomings with the customer's equipment. "We can't tell them that" is something I hear far too regularly from suppliers who are terrified of their customers. If the most or only effective solution lies at the customer, you must work it that way or the problem will fester forever. It takes courage and tact, but some customers will respect a well-intentioned and carefully-studied criticism of their process. After all, it is a partnership where the health of either affects the other. The other extreme, assuming the problem is the customer's is not only naïve, it is dangerous.

***2001.08 Aug 2001

Is there more than one type of curl?

A sheet which is not dead flat as a sheet of glass is wrinkled, baggy and/or curled. The web can curl in two directions (up or down) and in three different orientations (MD, CD and diagonal). Some webs may be troubled by more than one type of curl at a time, though one is usually dominant. To complicate things further, curl can vary across the width, with time, grade and process settings. MD curl is common with lamination and one-sided treatments while CD edge curl may trouble other processes.

Curl can be measured in several ways. My favorite is to make an X-cut on the web and note which direction the center points move. A similar method is to lay a square sample flat on the table, measure the lift of the corners, then flip the sheet and repeat the measurement on the other side. Some people hang a square specimen and use a radius template. Others clamp a strip on one end and measure the curvature of the other end with a protractor. In all cases, extreme care in handling of the web is vital for consistent test results. In some cases, such as paper, the sample must be conditioned before measurement.

There are many ways to get curl. One is the strain mismatch of the plies that is the bane of laminators everywhere. This can be due to product design (dissimilar mechanical properties of the plies) or poor tension control (not lowering tension sufficiently on the most flexible member). Similar physics are present with one-sided coatings, moisture or heat application. Indeed, there may be as many ways to make residual stresses, such as bagginess or curl, as there are way to make webs.

Another source of curl is environmental. If moisture or temperature changes on a one sided web, the most expansive side will warp the product into a curl. An example is a paper/poly product that will curl toward the paper in Tucson and away from the paper in Tallahassee. Even if the paper is sized or sealed, moisture from the air will eventually get in. Even if you hold the web flat during these environmental changes, some curl will still spring back when the sheet is released. Similar physics occur when extrusion coating a hot web onto a cool one. Product developers must be quite careful about any thru-thickness mismatches in mechanical properties such as modulus, Poisson ratios as well as thermal and hygroscopic expansion coefficients.

Finally, roll set curl is common on many wound products. Roll set curl is easy to recognize because it curls in the direction of the wind. Also, the magnitude of the curl goes as the inverse of radial distance in the wound roll. This means there will be about ten times as much curl above the 4” OD core as at the 40” outside of the same wound roll. The factors that reduce roll set curl are caliper (decrease), core diameter (increase), winding tightness (decrease), time in roll (decrease) and grade. Web caliper and core diameter are much stronger factors than the others.

Since the two biggest factors in roll set curl are customer determined, it leaves the supplier in a somewhat difficult position. If they sell the product, it will have this ‘defect’. If they don’t sell it, they will lose the customer. If they try to sell the product on bigger cores, they will be suspected of speaking from self-interest and will be compared with other suppliers who are willing to use small cores. It would be comical, if it were not so common, to see groups struggling with curl issues. Product developers, process developers, operators, salesman and customers all see the problem as not being of their own making, when in fact, it is. It is simple physics.

***2001.09 Sep 2001
How can I decurl a web?

While decurling can't prevent the curl discussed last month, it can reduce any direction, type or source of existing curl. Decurling yields or resets the material. One way to do this is to raising the moisture (paper), or temperature (metals or polymers) of the web. This can be thought of as an annealing or stress relaxation process. This can also be done mechanically by reverse bending over decurling bars, sometimes enhanced by elevated moisture or temperatures.

Decurling bars are common equipment on (liner) board presses, envelope machines, sheeters and other paper converting equipment. Decurling bars are either small diameter rollers (thick webs) or bars with a radiused edge (thin webs). The web is reverse bent over one or more bars in an operation similar to curling a strip of paper by drawing it over the edge of a scissors or desk. The only difference is that web decurlers usually have a pair of bars that are Z-wrapped rather than just one edge.

The factors that increase the decurling effect of bars are:

1. Material properties of the grade
2. Web caliper (increase)
3. Radius of curvature (roller or bar edge) – decrease
4. Tension – increase
5. Angle of wrap – increase
6. # of bars – increase only those which counter the predominant curl direction

The strongest factor is radius of curvature, at least until it gets down to a nearly square edge when tension and angle then take over. Decurlers are usually adjustable on the fly by varying the wrap angle. They are also adjustable during a setup by changing the bar's radius. It is important that both bars be independently adjustable because the first bar tends to undo the efforts of the second as they are bent in opposite directions. It is vital that the web be routed such that the last bar counters the predominant direction of curl. Finally, it is best not to run the web over small diameter rolls in the predominant direction of curl after the decurler

Countering roll set curl is a little trickier because the magnitude of curl increases as the unwinding roll radius decreases. Thus, the operator must make several adjustments every roll. However, modern equipment relieves the operator of some of this by adjusting the decurler on the fly to match the ever-decreasing roll radius. The operator needs only to select the starting and ending values of wrap. Automatic adjustments may be more consistent, but may not be as good as a manual adjustment in the hands of a truly skilled operator.

Adjustments should be moved as necessary to counter curl until all of the factors have been pushed to their respective limits. Obviously, the radius of the bar is limited to a sharp edge and wrap angle is limited to less than 180 degrees. Tension may also be limited on the high end by web breaks or the design range of the equipment. There are also product limitations. For example, sliding over a sharp bar can scratch surfaces or shear the outer surface away. Also, brittle products can crack as they are bent. An example is the latex coating on coated food board. Sometimes you can raise the threshold of cracking damage by increasing moisture/temperature, but this is quite involved and reduces the abrasion resistance of the surface

Decurlers are simple and effective in the hands of a skilled operator in some situations. However, they can be frustrating if the operator does not understand how to adjust them or if the curl changes rapidly. Finally, there are limits to how much curl can be countered and on which products. While decurlers can do amazing feats of straightening, they can’t perform miracles. It is up to the product/process developer to deliver products with reasonable curl challenges.

***2001.10 Oct 2001

When is traction desirable?

The three modes of web-to-roller interaction are tracking, sliding and floating. There are advantages and disadvantages with each mode. If you need to change tension, for example, you will need a driven roller in traction to do so. Most guides and spreaders require traction to operate. If, however, you have a web whose coating is fragile, you may need an air float bar so that the web is not touched until dry.

Some machines will employ all three modes. However, a principle of good web machine design states that on any particular element you should pick a mode and maintain it. Changing modes on an element will always cause a tension upset and often a CD position upset as well. An analogy with a car might be helpful. In most cases you will have all four tires in traction with the road. If, however, you lock up the brakes on icy road, you may be lucky and continue in a straight path down the road. Should one tire grab a bare patch of pavement the situation will change in a heartbeat. First, you will feel a sudden jerk as the tire bites in. Second, your car will pivot about that tire. On an air float oven, therefor, we want to stay in floatation at all times and all the way across the width. A momentary touchdown anywhere can cause big problems.

Of the three modes, traction is by far the most common and thus the most important. In fact, we can’t handle webs without at least one tracking element. Traction is necessary to establish and control tension as well as CD position. This is not to imply, however, that you can control tension or position better with more elements. In fact, it is just the opposite. The more driven rollers you have, the more challenging drive control becomes. The more rollers you have, the greater the chance of a position upset on a misaligned or diameter varying roller. Thus, another principle of good web machine design states that a minimum roller count machine is usually best.

On most simple rollers, only three factors control traction. The first is the coefficient of web/roller friction. The friction depends in part on surface roughness and surface chemistry but also on other factors when air entrainment becomes a factor. While the details are complex, the net effect is friction. The second factor is wrap angle. The greater the wrap, the greater the potential traction. There is a common fallacy that radius affects traction, but this is only true in special situations such as non-coulomb friction and air entrainment. The final factor is drive torque. The greater the motoring or braking torque, the greater the potential to lose traction.

On more complex systems, other factors may contribute to traction. For example, unit nip load is the predominant factor in nipped roller sets. While most often very weak, static can approach noticeable levels when the web and roller carry opposite charges such as might be generated by systems similar to electro-static bars. Other complex systems include pin feed and vacuum rollers.

As you might guess, traction and especially friction are complicated to predict. In fact, it is not predictable without measurement and even then it will be difficult. This has led many machine designers to use nip rollers rather than the much simpler wrapped roller for some drive points. While adding a nip is a conservative means to get traction, nipped rollers have significant penalties. Nips increase machine and maintenance costs and make the process finicky and intolerant, especially to baggy webs.

No matter how you obtain traction, however, you must maintain traction at all times and all the way across the width of the roller. If you do not, you will lose control in the MD as tension and very possibly in the CD as position.

***2001.11 Nov 2001
When is sliding desirable?

Since traction is so common, we might be inclined to think that it is the best way to do business. While this is often the case, there are interesting and important exceptions. To understand why, we must understand what the penalties are for traction. While there are several, they all fall under the category of making the machine more intolerant.

Let's take a simple example of roller alignment. The tolerance of a web to misalignment depends on many factors. However, the two most significant are the in-plane versus out-of-plane directions and the state of traction. In plane misalignment, or lack of parallelism, is about one order of magnitude fussier because it causes bending rather than out-of-plane misalignment that merely twists the web. Let us take a simple decade approach to sensitivity. A fussy system may be aligned initially to 1mil. This may be to safely avoid wrinkling that could occur at a 10 mil in-plane misalignment. However, the roller might be misaligned as far as 100 mils in the out-of-plane direction before rejectable problems occur. These example numbers would be for the case of traction. If, however, we let the web slip over the roller, the former 10 mil in-plane threshold of problem may increase to 100 mils, making the system 10 fold more tolerant. Obviously, other factors also affect the sensitivity to misalignment such as web thickness, modulus and web span ratio, but they are usually much smaller.

Analogously, webs can wrinkle over rollers whose diameter varies across the width. Continuing with the above decade approach, a very thin web will almost assuredly object to a 10 mil diameter variation, if not much, much less. However, if we let the web break loose on the roller, the web may tolerate a somewhat greater diametral error. Thus, again the system becomes less fussy to wrinkling of thin webs.

Astute operators occasionally make use of this principle. If, for example, a web is wrinkling on a lightly wrapped roller. They might be inclined to lock the roller up and thus force the web into sliding. Often this will clear the wrinkles much faster than convincing management and maintenance that the machine is in need of attention at a level finer than previously practiced. Unfortunately, this practice also causes a tension rise and may scratch the web or wear a flat spot on the roller. Troubleshooters will note that rollers wrapped less than say 10-20 degrees, are much less prone to wrinkle.

Sliding is also the lesser of evils when drives misbehave. This could be an electrical drive not up to the precision demands of a web application. This could also be a mechanical drive such as slaving a bowed roller off of another drive point via a v-belt. Since a v-belt exceeds allowable speed variations by 1-2 orders of magnitude, it might be better to have the belt slipping in the pulley or the web slip on the roller than bust the web.

Light or fragile webs are sometimes difficult to manage on rollers in traction. Thus, you may find pans, foils and shoes used on things like tissue. In these cases, the sliding/floating foil is better, faster and cheaper than the ubiquitous roller. Some spreaders, such as the bent pipe, use sliding, while the expander roller spreader can tolerate it. One guide, the displacement guide, can tolerate spreading without debilitating effects. Many rollers, such as idlers or not-quite floated air bars, or even systems of rollers, such as arched ovens, can tolerate sliding.

Many processes, such as printing and coating, vary the add-on weight by overspeeding or underspeeding a pickup or transfer roller. On the odd occasion, you may find a sliding roller used for polishing a web or conversely raising the nap. Whether for web handling or web processing, sliding can be a useful option.

***2001.12 Dec 2001
What Causes Laminate Tunneling?

A laminate can delaminate if the adhesive or adhesion between the plies lets loose. This may result in a defect variously labeled as tunneling, gaping, worming and so on. The defect is readily recognized as a separation of the plies in an area than is narrow and oriented in the CD (Cross Direction). Typically, the delamination will span much of the width and often be spaced periodically in the MD (Machine Direction). Finally, the defect will not appear until some tension is released from the laminate, such as on the tail of a wound roll. Even then, however, the defect may take time to develop; seconds to hours depending on the product.

It is tempting to look at the release of ply bond and blame the adhesive. Certainly, if the bond were better the plies would not separate. While the problem is far more frequent with adhesives that cure slowly, it can happen on others as well. It is not merely a problem of 'green tack.' We will leave it to others to determine whether the failure is one of adhesion, cohesion or shear. We will leave it to others to determine whether the surface preparation and adhesive chemistries are optimum. Finally, we will leave it to others to determine whether the adhesive application has been optimized. What we will show here is that the failure is also one of product and process design.

If you look close at the tunnel by sectioning it across, you will note that the gap is D-shaped. In other words, one ply is tight and the other is buckled. Stated equivalently, the straight ply is tighter and/or shorter than the buckled ply. Also, careful observation will show that the product always curls toward the straight ply. However, the amount of curl will decrease slightly as the tunnels develop after web tension is reduced. What these key observations are telling us is that tunneling is just a form of curl. The only difference between more conventional curl and tunneling is the added ingredient of adhesive release. Indeed, you can often see a freshly cut web move from one form of curl (conventional) to the other (tunneled) if the release is slow enough

This gives us an additional set of tools to combat the tunneling problem. That is, like any other form of curl we need to more closely balance the MD strains caused by MD tension. Briefly, we would consider:

1. Educate product/process developers, salesman, customers and operators on the mechanics of curl
2. Avoid designing/selling products that have widely dissimilar moduli (and thermal coefficients)
3. Decrease the tension of the straight (usually lower modulus) ply
4. Increase the tension of the buckled (usually higher modulus) ply
5. Heat/moisturize the buckled ply
6. Cool/dry the straight ply
7. Use differential torque on a dual drive nip to further adjust strains

Note that all of these treatments must take place just prior to the laminating nip. After you reach the middle of the nip you fate has been sealed, literally. You only need to wait to observe the outcome. One final diagnostic is to note that if tunneling occurs, it should do so uniformly across the entire width. If the tunnel favors a lane or edges, for example, we know that the product and/or process are not uniform. In some cases, one of the plies may have baggy lanes. If tunneling is not uniform, you may need to address its cause at least as aggressively as trying to balance the strains in the two plies.

***2002.01 Jan 2002
What Causes Wound Roll Tin Canning?

Tin canning is a very common problem on wound rolls of thin films, but is rarely if ever seen on other materials. This defect is defined by narrow annular ridges (not on a diagonal or helix) that are somewhat evenly spaced. The pitch between the ridges may vary from as little as a centimeter for thin films to several centimeters on thicker films. Ridges that have other characters may be a different defect, such as a corrugation or gage band. For example, a corrugation occurs in a narrow annular region, but the buckles within the defect are oriented at an angle and have the appearance of a twisted rope. Also, the pitch spacing is not regular on either corrugations or gage bands. The tin canning gets worse with: decreasing caliper, decreasing MD modulus and increased time after winding. The trouble is also grade dependent, profile dependent and is sensitive to winding conditions. The defect is easily recorded by 'tracing' the surface with flat chalk or crayon, much like we traced leaves in kindergarten.

Unfortunately, as common as this problem is there has been no published study on the defect. One hint that science does gives us, however, is that the nearly uniform CD spacing is a reflection of the preferred buckling pitch. This is similar to a yardstick that wants to buckle as a half-sine when compressed on its axis. Because of this we know that the root cause must somehow involve CD compression. Also, the experience of the industry is inconsistent, probably because there are several ways to generate the defect. Many will blame poor film as the cause, but are not specific about what aspect of the film created the defect and how. Many will claim that changing winding tightness via web tension and more particularly layon roll pressure can reduce the severity. It is generally believed that winding looser is beneficial, but there appear to be many exceptions.

The fact that the defect sometimes gets worse with time in storage in the roll also hints as to possible mechanics. We know for a fact that the air inevitably entrained into the wound roll will weep out the edges of the roll over the course of minutes to hours, exactly the same sort of time period that we see the ridges develop and the roll harden. Thus, it is likely that air is involved in these cases so that excluding air during winding by aggressive layon roll pressure may be helpful. However, to exclude air is to wind tighter and we know that many wound roll defects get worse with tightness. Thus, we seem to have a dilemma. Another known is that rolls may creep or settle during storage. More accurately, the layers slide on each other ever so minutely rather than the material yielding. Thus, we find that the top of a core-supported roll is more buckled than the bottom due to the compression of beam bending. In these cases, wide rolls are at a much greater risk.

No matter what the cause, however, the first thing we try to do with most winding defects is to see if we can move the problem with the tightness knob. Run two trials. The first will be so tight that the web is almost necking and the layon is at a pressure that is at the threshold of wrinkling on the roll. The second will be so loose that the web is baggy and floppy entering the windup, and the layon is at the lowest pressure that can be maintained consistently without the roller bouncing off. Compare the rolls only on the basis of the tin can defect described above. Move winder settings on the basis of what you see with the exaggerated trials.

***2002.01 Jan 2002
What is the optimum core size?

Geometries such as length, diameter and core wall thickness must be specified when ordering cores. Length is the easiest. The core is typically sized to be the same as the width of the roll for most materials. An exception is some film, nonwovens and textiles where the core intended to stick out beyond the end of the roll. This stickout is used to either support the roll during shipment or to protect the delicate edge of the roll during handling. If length is intended to match roll width, it may not for one of three reasons. First, the slitters could be set up improperly. Second, the core cutter could have been set improperly. Third, the cores could be ‘green’. If cores are not dried to equilibrium with the converting environment, they may shrink as they dry. This shrinkage takes place over the course of a day or two.

Wall thickness is also easy. The wall should be just thick enough so that very few cores collapse due to internal winding pressure or external handling loads. In the former case, we would also consider winding less tightly. In the latter case, we would wind tighter or use core plugs to protect the core. The optimum wall size is determined as the minima of the core cost and core crush costs. If you crush too often, then the wall size should be increased. If you never crush, the walls are too thick. Economics tells us that the laws of diminishing returns indicates that ‘zero defects’ may not be a wise target. Defect rates of 1-100 parts per 10,000 could maximize system efficiency depending on the situation.

The most difficult geometry is nominal core size. The ubiquitous 3” diameter core must give way to larger diameters as roll size increase. As we increase either roll diameter or roll length, the inexorable pull of gravity can do us in. The list of troubles when winding or unwinding heavy rolls on small diameter cores is so large that it must be given careful respect. This list includes very serious difficulties such as blocking, bulk loss, core failure, telescoping, vibration, wrinkling and many more. In fact, if you or your customer has troubles near the core, it may well be due to the core being too small rather than some limitation of the winding machine or tension settings.

The problem is that customers insist on running ever larger rolls on the same old core size. If you try unilaterally to educate them, they may not listen and simply go to your competitors. If you offer to upgrade their chucks and shafts to larger sizes, they will always find someone else willing to supply large rolls on wimpy cores. Some will claim there is no justification for spending extra money on bigger cores nor losing the extra few percent of roll capacity. However, this is no more valid than trying to run a bicycle tire on an automobile because they are cheaper. While a 1” wide wheel might carry 100 lbs comfortably, it takes a 10” wide wheel to carry car loads.

One of the largest users of cores, the paper printing industry, fought increasing core diameters for decades as roll weights increased from a modest 2,000# to a crushing 10,000#. Finally it became clear to most everyone that they had went far too far. But it took mega-tons of waste, endless trials and tribulations and uncountable meetings before consensus was reached that core sizes must be increased. Europe led the move to 4” and 6” cores and the US is now following. Some pockets of resistance still remain. Scientists have even studied why cores exploded on the press, inadequate cores, yet management still wanted a more comforting answer like winding tighter. After many skirmishes, the battle is just now beginning in converting.

***2002.02 Feb 2002
What is the optimum wound roll diameter?

Customers and suppliers both want ever larger rolls. As the diameter increases, so does the run time between roll changes. Fewer roll changes means that the portion of waste at the top and bottom of the roll may be reduced. Fewer roll changes means a reduced chance of a miss during a flying splice or turnup. It also means reduced labor. The operator can spend more time watching the process instead of prepping rolls. Thus, big rolls are good.

However, as the diameter increases, so does the incidence of defects. As discussed last month, the large roll is much more prone to telescoping during winding or unwinding. Thus, the risk of adding an extra inch on the outside may be losing the entire roll. Since most winders and nearly every unwind is core supported, the core must bear the weight of the roll. If the roll is heavy, the material near the core can be crushed in a variety of ways. Since web was not 'designed' to be a load carrying material, it is not surprising to find the core area blocked, squashed or shredded. Thus, big rolls are bad.

How do we find the optimum roll diameter to minimize the losses that can occur due to the roll being both too small and too big. First, we must select a common objective, such as minimizing costs. Second, we plot the costs of being too small as a function of roll diameter. In the cases of top and bottom waste, this is quite simple. Perhaps you lose 1" at the bottom and 1/8" on the top of rolls, regardless of the size. Then the waste can be calculated as shown below. Third, we plot the costs of being too big as a function of roll diameter. Perhaps the incidence of telescoping skyrockets after a certain diameter. Fourth, you sum the curves as shown below. Finally, the most effective diameter is at the minima of the sum.

This analysis is adaptable to many different problems of optimizing a setting. It also quite powerful if the analysis is rigorous and uses accurate costs. However, the analysis can be used even if the costs are not known precisely. As seen in the figure, you are not at the optimum if there are no incidences of telescoping (or whatever the large roll penalty may be). Thus, it may be that striving for Six Sigma or Zero Defects may raise manufacturing costs or put you out of business. The purpose of business is to make money. Any analysis that does not consider costs and benefits is incomplete.

FIGURE BELOW

***2002.03 Mar 2002
Why isn't my web flat?

A web may not be flat for two reasons. First, it may have internal stresses built-in by manufacturing. Second, it may have external stresses imposed by web handling. It is often easy to tell the difference between the two. If the web does not lay dead straight and dead flat on a table, then it is distorted by residual manufacturing stresses. If the web is dead flat on the table but not in the machine, then web handling has distorted it.

Whether inspecting the web in situ or in the lab, the reference is always the same. Dead flat like a sheet of glass. By this measure all webs are flawed. However, this is the approach we must take as troubleshooters. If you take a more liberal reference, such as comparing it to a mere 'good' web, you are throwing away information. It is analogous to the near miss in accident reporting. Just because the person didn't get hurt (web didn't get rejected) this time, doesn't mean that there is no potential for an accident (rejection) next time. Skilled web handlers can look at features so subtle they are best described as shades or shadows. They know that these subtle features may hint at the seeds of layflat or web handling problems that are just waiting to sprout.

Thus, troubleshooters and quality inspectors must use different standards. In troubleshooting, you try to prevent a problem from occurring. In the quality, you try to prevent a problem from reaching the customer. In troubleshooting, for example, you can see a wrinkle long before it has occurred because the trough (shadow) hints at a foldover that may happen at some other time when conditions are just a bit more pronounced. In quality, the subtle trough grown to a bulge or foldover crossing the roller will leave a visible mark that the customer may object to.

Only after determining whether flatness problems are due to processing or handling do we go to the next step of breaking it into subcases. Let us assume the problem is internal residual stresses from manufacturing. If the stresses vary through the thickness, you have curl. If the stresses vary across the width linearly, you have pure camber. If the stresses vary irregularly across the width or length, you have the more general case of baggy lanes or patches. To improve the quality, you try to level the product in forming/processing. It is usually difficult to stress relieve the material after the fact by mechanical or thermal yielding.

If we assume the problem is with external residual stresses imposed by web handling, we will have an entirely different set of subcases. The first thing we look at is the angle of the wrinkle, or as we now know, angle of the shadow. If it is aligned with the MD (machine direction), the web wants to be wider than it currently is and has buckled due to CD compression. This case may be further broken down into subcases of excessive tension, tension drop, hygro-thermal expansion, improper spreading and so on. In most MD cases, we either eliminate the root cause or treat with spreading.

If the shadow is slightly angled with the MD, we know that either the web is crooked and/or machine is crooked. The angled orientation is the fingerprint of shear buckling.

In most cases, we begin our work with the web handling aspects of the machine. First, we have more control over our machine than raw material coming from upstream. Second, the machine is easier to get precise than the web. Finally, the list of web handling things to look for on the machine are fewer: rollers do not deflect excessively, roller diameter does not vary across the width, rollers are aligned, and nips are level.

***2002.04 Apr 2002
How can I prevent wrinkling?

Last month we found that a web may not be flat for many different reasons. No matter what the cause of flatness problems, however, wrinkling is a common outcome. Obviously, we would try to first identify and then to eliminate the root cause. Even a partial success here will be helpful to reduce wrinkling severity. However, root causes can be sometimes be difficult to budge, especially in the case of formation problems such as baggy webs. The causes can be so subtle that conventional practices of machine design, construction and maintenance may be too crude. Variations of gap, nip, roller geometry, flow, temperature and so on that can cause profile problems may be immeasurably small, literally. Nonetheless, we are obligated to consider manufacturing in the general wrinkling case and begin there for layflat problems.

However, the first step is to attacking most wrinkles is to change tensions at the section where they originate. Wrinkling severity is almost always affected by tension. Sometimes the connection is strong enough to solve the problem of creases and foldovers. Sometimes the effect of tension is weak and only able to reduce wrinkle incidence or severity. Curiously, wrinkles may be reduced by either increasing or decreasing tension depending on the situation. There is no ambiguity here, there are physics operating in both directions. Thus, the good web handler will both increase and decrease tension and try to judge changes in severity. If you did not break something in this effort, you did not try hard enough.

The second step is to identify the roller(s) that initiates wrinkles. It is usually the most upstream roller where the web crosses with a tiny bulge. An exception is extremely severe cases where wrinkles can be pushed upstream from the source. In even a very complex line with a hundred rollers, it would be rare to have more than a half-dozen places as initiators. In most lines, it is only one or two rollers. Check the geometry of the roller for hairsbreadth tolerances of diametral variation and alignment and rework as indicated. If the roller is good, the next step depends on whether the roller is a process roller or a transport roller. If it is a process roller, such as a heated or nipped roller, you might need to rework the process or product.

The third step is to consider spreading or flattening at or one position upstream from the initiating roller. There are a variety of spreader options to chose from including compliant covers, concave rollers, bent pipes, bowed rollers, expander rollers, edge pull rollers and tenters. In general, you chose a spreader type that is just aggressive enough to do the job. More is not better. Also, most spreaders in the industry are not working properly, if at all, because people have overlooked vital details such as traction. The interested reader will find chapters of detail on spreading and wrinkling in my books. Here I am just trying to get you started by summarizing what is a pretty big topic area.

Flattening is an option for treating modest cases of wrinkling that is not so well known in the industry. Flattening works by breaking down the traction on a roller so that a bulge will relieve the high energy compound curvature by sliding outward. Some operators make use of this principle by locking up an idler, usually the initiator, so that it doesn’t turn. Other less brutal methods are to increase roller diameter (try doubling it) or decreasing wrap (to 20 degrees or less) or reducing the web-roller friction such as by making it smoother. Flattening is often the best choice when there is no identifiable flaw with the web or roller. In fact, a near perfect web can choose to wrinkle on a near perfect roller, especially if the roller is highly wrapped and has a small diameter.

***2002.05 May 2002
Why does my wound roll have flared ends?

Wound rolls can have flared or belled ends for a variety of reasons. This may be more than cosmetic, the diametral bulge can stretch the web into bagginess there. Oscillation can sometimes be used to minimize the differential diameter buildup damage to the roll or web. Sometimes wound roll diameter has to be limited to limit damage. Sometimes you can wind looser to get a bit of relief.

To find an effective solution, you need to know the specific mechanics that are operating in your specific case. The distribution of the flared ends is an important clue, especially when several narrower rolls are cut from a wider sheet. If only the outside ends of the two outer rolls (A & Z) are flared, then the cause must be smile (or frown shaped) because that is the shape of the defect distribution. We could then eliminate roller alignment (taper) as a possible cause, but not roller deflection (smile). If all edges of all rolls are flared, we might suspect something having to do with the creation of an edge. If some edges are flared and others are not, we might suspect variations in edge creation or an interaction with variations in manufacturing. Clues are also provided when some grades perform worse than others.

A classic problem with plastic film and some other materials is a ‘raised edge’ due to slitting. In fact, this nomenclature may not be strictly correct because the edge is probably stretched into bagginess rather than thicker. In either case, the damage from the slitter is originally quite narrow, less than an inch, but can ruin the outer several inches if winding is pushed to large or tight rolls. Super attention to slitting blade sharpness and setup can be one remedy, especially if the edge gets better when a blade is changed. Note that there are many degrees of sharpness. A scalpel, for example, is much sharper than a conventional razor blade that is sharper than a box-cutter. Often it is not original sharpness that is inadequate. Rather, it is not changing blades out soon enough. Sometimes changing the slitter type (razor, score, shear or waterjet) can make a difference. Some materials, however, seem to give people trouble no matter how they attempt to cut the web.

Another classic problem is due to caliper variations that happen to line up with a slit edge. It is quite common for dies to have thicker lanes, especially on the edges. Newer dies have internal deckling mechanisms that can help reduce the edge bead. Paper makers have even more sophisticated tools for profiling or correcting the edges of their sheet. They avoid ‘hard ends’ at all costs as this can degrade runnability. In tentered materials, the clips restrain the material from stretching on the edges causing thicker and/or baggier edge. Taking more edge trim is a costly solution. Gage bands can also be formed in intermediate locations. When a slitter is dropped into any gage band, the new found freedom allows the edge to flair more than it would have had it not been cut.

Finally, stretchy materials have a different mechanism that can make the edges thicker. Netting is easiest to see because it has ‘grid lines’ on the material. While the grids are evenly spaced to begin with, they bunch up more on the edges than in the center as the material progresses down the machine. The edges are under uniaxial tension because there is nothing outboard to pull in the CD. The center, on the other hand, is under biaxial tension. The CD restraint in the center acts like a spreader. This behavior begins in the first few inches after leaving a roller into a higher tension zone. Materials prone to this differential necking include nonwovens, netting and textiles. In addition to pulling less tension, edge pull spreaders are sometimes effective in applying corrective CD tension at the edges.

***2002.06 Jun 2002

How do I know if my process is level?

Level webs may run faster and with less waste. Level profiles are so vital that they are often rejectable specifications set by either the supplier or the customer or both. Almost everyone measures profile, which usually refers the variation of gage (thickness) or basis weight (areal density) across the width. Measurements can be done online with scanners, offline in the test lab, or on the wound roll. Since gage uniformity is so important, you must ask which measurement methods are cheapest, easiest, fastest and most sensitive for your application.

Online scanners are brought to the highest levels of technology in papermaking. For several decades, they have measured basis weight, caliper and moisture on most of the thousands of paper machines throughout the world. These multi-million dollar devices are demanding. It is not unusual for the instrument supplier to provide a full time service engineer to be dedicated to scanners a single mill. Even so, only in the last two decades have these instruments become trustworthy enough to be given control of profile adjusters. Even now, it is not unheard of for mills to shut off the controls and allow the operator to manually adjust them because humans can do a better job. In not a few cases, profile has been improved by shutting off the controller and simply leveling the actuators.

The problem is usually not, as many think, with the profile adjustment or the control algorithm. Rather, it is more basic. The measurement is not sufficiently sensitive for the purpose of avoiding defects. I will illustrate with a common situation where there is a gage band in the wound roll. You can see the bulge with your eyes. You can feel the bulge with your hand. You can hear the bulge by striking it with a stick. When you look at the scanner, however, it shows no resemblance to the shape of the wound roll. It may look like the EKG of a heart patient ready to expire. The gage defect may be so pronounced that the roll may be stretched into bagginess or corrugate there, and the scanner still might not see it. It is interesting to observe the cultural reactions to this information discrepancy. In paper, operators trust the scanners because they've been around so long. In film, the operators usually ignore them as they seldom seem to relate. In any case, if you can see, feel and hear a bulge, you don't need a scanner. You HAVE a gage band no matter what other instruments may say.

Lab measurements of caliper have been around so long that few question their integrity. Test standards and instruments conforming to these standards are older than we are. However, the fundamental issue is still present. Gage variations too small to be picked up by bench instruments may cause rejectable sized problems during winding. Further complicating the test lab is sample size, something like trying to characterize a truckload of peas by sampling a handful. Also, the test lab results may be delayed by minutes to hours from the time of production. This is something like house-training a dog. If you don't push their nose into it within minutes, they will not figure out what they had done wrong.

I will make a long story short with two general conclusions. First, the most sensitive measure of caliper variation is usually the wound roll. Here, we might use hardness or diameter variation as a judge of manufacturing uniformity. Second, the fussiest customer for caliper is not the one you sell to. It is the winder. In fact, if you pay closer attention to your customer's language you would note that they don't usually complain of excessive gage variations. Instead, they complain of poor wound roll appearance. That is, however, assuming you don't reject it internally first due to bagginess, corrugations, telescopes, wrinkling or other gage related problems. Much more about this subject is found in my paper available from the following websites aimcal.org, tappi.org or roisum.com.

***2002.07 Jul 2002
What is the best winding tension?

The earliest strategy for winding tensions, nearly a century old, is sometimes referred to as ‘baby bear tightness.’ We want to wind “not too hard, not too soft, but just right.” This tenet still holds well even today with our three dimensional mechanics models of winding solved by Ph.D’s with supercomputers. Winding can be complicated if you let it. I will try to make it simple and applicable.

We want to wind tight enough to avoid any of a number of <low tension defects <italicize>> such as loose cores, poor roll edge quality and especially telescoping. The roll also needs to be tight enough so that is stays round during storage and handling so that it can be converted at higher speeds. What we are trying to do by increasing tension is to protect the wound roll so that it stays cylindrical enough for the next user. The ideal of a perfect cylinder is not necessarily a good goal. We only want it round enough to keep the customer happy.

At the same time, we want to wound loose enough to avoid any of a number of <high tension defects <italicize>>. The list here may be a bit longer. It includes things such as blocking, crushed cores, corrugations and ridges stretched into bagginess. This is not to say that looser is better. What we are doing by decreasing tension is to protect the web. The ideal of zero web stress is not a good goal. You would neither be able to wind nor transport such a roll. We only want to wind it tight enough to keep the web sufficiently free of those types of defects.

How do you know whether a defect is a high or low tension defect; or whether it is unrelated to tension (the most common situation)? You look it up in an article or book. Alternatively, you can crank the knob a bunch and see what happens to defect frequencies. If you are good and if you are lucky, you can find a tension that simultaneously avoids high and low tension defects. When you have neither, you need do nothing else with the tension knob. If you have a predominance of low tension defects, simply increase tightness. If you have a predominance of high tension defects, simply decrease tightness. You can use any or all of the TNT’s (Tension, Nip or Torque) at your disposal.

If you are not so lucky, you can have high and low tension defects simultaneously on the same roll. Let us take an example of a profile problem where the gage of the raw material tapers from low on the front side to high on the back. The high side may be so tight as to stretch the web into permanent bagginess. At the same time, the roll may be loose enough and imbalanced enough to dish or telescope during winding or handling. Having high and low tension defects simultaneously can indicate a non-robust product design, poor web profile, or poor machine mechanical/control condition. Making sure that rollers in the windup area are geometrically true is prophylactic but may not solve some problems. Making sure that control systems hold their tension and nip targets is prophylactic, but also may not solve some problems.

You should be prepared and perhaps even expect over-constrained situations. In the case you are asked to solve both low and high tension problems with but a single knob, the best you can do is optimize the setting so that you have similar losses of both sets defects. The principles of economic optimization were introduced in January and February columns and are detailed in my book Critical Thinking in Converting.

***2002.08 Aug 2002
What is the best winding curve or taper?

Most modern winders have the capability for running a linear taper or curve. This is a setpoint that varies as a function of the current winding diameter. There could be a separate curve for all of the TNT's (Tension, Nip and Torque). In the paper industry nip is most likely to be on a tapered while in film it is tension. The ability to run a linear taper instead of a constant adds complexity and a curve is even more complex. There are an infinite number of curves for each of the TNT's that you could try independently. Then you could try them out in combination for interactions. The ability to taper is a two-edged sword. It can reduce the incidence of some defect types. It can also frustrate people and tie up resources as they try to find the 'best curve'. While machine builders have given us these new knobs, they have not always taught us well on how to use them. I will attempt to give a simple explanation of why you might use a curve or taper and what to do with them.

The first use of a curve is to compensate for known changes in forces that happen during the course of winding. For example, the weight of the wound roll increases as it builds. If this roll weight is partially or fully supported on a drum, such as on two-drum and duplex winders, we would taper the nip applied through the rider roller or shaft loading to attempt a constant drum nip throughout the wind. On many film and converting winders, there are geometry changes as a layon roller swings through the arc. A curve here can vary cylinder pressure so that the wound roll nip remains constant throughout the wind. These compensations should, however, be completely transparent to the user in a good computer control interface. The user puts in a desired web tension or roll nip in PLI and the computer does whatever compensations are needed to achieve that target.

A second use of a curve is to 'structure' a roll so that it is wound tighter at the core than at the outside. Unfortunately, we have learned our lesson too well on roll structure or taper. Tapering largely affects only the related defects of dishing (during wind), plating (during handling), telescoping (during unwinding) as well as some starring defects. I am using the strict definitions of these words as given in TAPPI's Roll and Web Defect Terminology book rather than lumping the first three together as telescoping.

Use maximum taper if you have one of these defects. In other words, you would start so tight at the core as to nearly bust something and then linearly taper to so loose at the outside that you are also nearly bust something. Nearly everyone who has one of these defects is not nearly aggressive enough with their taper. It is sad to see clients who have remedy if not solution literally in their hands, the tension knob, and wimp out with tiny tweaks of the settings. Crank it till you bust something (you already have busting something or you wouldn't be still reading this), then back off slightly.

For those of you who do not have telescoping related defects or starring, do not worry about taper. In fact, taper is a poor and confusing concept. It was introduced by the builders for their convenience, not yours. A much better way to look at taper is using the four point method that is standard in the paper industry: starting and finish diameters for the current roll, starting and ending tensions. The starting tension should balance high and low defects in the first half of winding while the ending tension should balance high and low defects in the second half of winding. This is a much simpler and intuitive way to look at things.

***2002.10 Sep 2002
Can a Bowed Roller Cause Bagginess?

Web bagginess is a most common and troubling defect. Not surprisingly, there are many ideas about what may cause or cure baggy webs. Some of these ideas center on a common converting element, the spreader. My experience and understanding is that spreaders neither cause nor cure bagginess. Certainly there are exceptions to every rule, including this one. However, they are so rare that believing there might be a connection between spreading and bagginess is much more likely to be distracting than useful.

Though unlikely, the possibility exists that a bowed element could cause bagginess. Thus, we must use definitive tests to determine whether this possibility deserves further consideration in a specific situation. These tests are:

1. The bowed element must be so overbowed as to cause permanent DIFFERENTIAL YIELDING of the material. An appropriate bow for bowed rollers depends primarily on the extensibility (modulus) of the material and may be as little as 0.1% of width for stiff materials such as flat paper and high modulus films to more than 1% of width (e.g., 0.5” of bow for a 50” wide web) for very flexible webs such as creped tissue paper, low modulus nonwovens and rubbery compounds. The appropriate bow also depends on available MD troughing, traction and many other details. Appropriate bows are somewhat larger for bowed pipes, dual bow spreaders, and spreaders used for separating multiple slit lanes. By this numerical test, unfortunately, most spreaders are overbowed. However, this does not mean the material is yielding. We must look further.

2. The material must ENTER the bowed roller(s) WITHOUT a gentle center bag. How can you tell? Simple, you must intercept the web before it hits the bowed roller. While this might be disruptive, it is vital trouble shooting technique. Wait until the end of a run so that this disruption is minimal and bust the web if you need to.

3. The web must LEAVE the bowed rollers(s) WITH a gentle center bag. By this I mean that the looseness increases gradually from both ends of the web and is maximum at the center. Baggy lanes and baggy edges can not be created by a bowed roller because they do not have the a smile/frown ‘shape.’ The shape tool, a most flexible and powerful problem solving technique, is described in more detail in my book on industrial problem solving, Critical Thinking in Converting.

I have worked on many cases of bagginess and have seen more spreaders than I can count. How many spreaders have I seen which caused bagginess? Only a few cases that I can recall. One was an overbowed pipe on a heavy unbonded fiberglass matte and on a couple more on extremely delicate films of rare chemistry. Other cases were edge-pull spreaders on films and nonwovens that are extremely aggressive and easy to misadjust. The most common, however, is tenter frames that always distort material at the pins. I have yet to notice any of the more temperate spreaders such as compliant cover, concave roller or bowed roll misbehave to create bagginess on even the most delicate materials.

The much more common spreader misbehavior is to cause wrinkling due to misapplication.

What then causes bagginess? It is a variation of manufacturing across the width or brutish handling afterward. The most common profile variations are basis weight, caliper, nip, moisture or temperature. To troubleshoot this problem we commonly use two techniques. First, we screen elements out that do not have sufficient pressure, tension or temperature such that the material could be permanently yielded. Second, we screen out elements that do not have the right ‘shape.’ Then we must use creative testing to determine which of the few remaining suspects need to be arrested. This subject is treated in far more detail in my article “Baggy Webs: Making, Measurement and Mitigation thereof” which has been published in several places and is available on my website.

***2002.10 Oct 2002
Can a Spreader Treat Bagginess?

Baggy webs are trouble. First, they may refuse to go through a nip such as at a calender, coater, laminator, printer or winder. Because the baggy portion is longer, it may get 'behind' the rest of the web as a bubble behind the nip. If it gets big enough or bad enough, the bubble will burp through the nip as a wrinkle with a diagonal or chevron orientation. The wrinkle at an angle at the baggy location is a nearly determining symptom of cause.

Second, baggy webs look ugly because they refuse to lay flat as a final product, something like a dent in the fender of a car. While the fender may still be practically functional, it is not perceptionally acceptable and any insurance company should agree to its repair. Thus, even if you get bagginess through your machine and your customer's machine, you could still have trouble. Perception is reality and if you can see it you leave yourself open to both legitimate and illegitimate customer complaints.

So what can you do? Since we commonly put spreaders in front of nips to flatten the web, perhaps the spreader might help with bagginess. To understand how it might, we must distinguish between real bagginess and apparent bagginess. Real bagginess is when the web refuses to lie flat on an inspection table. Just because it does not lie flat in a machine does not mean it is baggy. Misaligned rollers, roller diametral variation across the width and nip pressure variation in that area can cause apparent bagginess. Just because it lies flat in a machine does not mean that the web is not baggy. Sometimes you can pull hard enough to tauten the web across its entire width.

The best we can do with the spreader is to tauten the web in the MD and CD such that the web enters the nip flat. It should be quite easy to pull in the CD to remove an MD oriented trough. Taking up bagginess, though, is a bit harder. On a bowed roller, the nominal bow orientation is midway between the incoming and outgoing web directions. If we have a baggy center, we orient the bow slightly into the web from this nominal orientation. If we have baggy edges, we orient the bow slightly out of the web from the nominal. If we have baggy lanes we can do nothing. What bow orientation does is to change the relative length of the paths of the web at the edges versus center which can take up the slightly different internal 'lengths' the baggy web has at the edges versus center. This effect is extremely short lived. It does not extend beyond the next roller after the spreader because the relative span lengths are equal there. Thus, there is NO permanent fix of bagginess. In fact it is so ephemeral, that it often doesn't even make it to the next roller.

Also, a bowed roller can not spread baggy edges for the following argument sequence. Baggy edges mean no tension at the edges. No tension means no traction there. No traction means no normal entry that is the principle by which this spreader operates. A simpler argument goes like this: how can you grab hold of the loose ruffly edges to pull on them? These arguments really need more explanation than I can give here. However, I can summarize thus. Work with the spreader, but do not be the least surprised if it does not help at all.

What can you do then to treat bagginess? If I were a manufacturer of webs, I would work on leveling my manufacturing profile. If I were a customer of webs, I would first complain and then send back any baggy material that gave my process fits. If I were a machine operator caught in the middle, I first try reducing tension till the web droops. Then I would try pulling like hell. Finally, I would pray for a new lot or grade or the end of my shift.

***2002.11 Nov 2002
How can I map defects?

Defect mapping is a most powerful troubleshooting technique. One, unfortunately, that few take full advantage of. Instead, if you ask "Where do the defects show up?", the response will invariably be a verbal one such as "It shows up on both sides, but the back is worse". It may be a million-dollar problem, but don't be surprised if there is no map, no graph and no statistical analysis. Same thing with customer returns. It is easy to find the number of rolls that were returned last month. Don't, however, expect to be blessed with even rudimentary mapping such as roll positions, roll diametral locations and shifts or crews.

If you are a detective and want to catch a crook, you must develop a profile or MO (modus operandi). Crooks will betray their identities based on behavior patterns. Some prefer to work in stealth at night, others snatch and grab during the broad daylight. Same thing with industrial problem solving. Patterns will lead to the cause. These patterns are with respect to CD position, MD position and time.

Perhaps the most important pattern is a histogram of CD position. A histogram is nothing more than a graph showing the number of occurrences each location. Many defects are wide and may prefer the ends or center. Examples here are baggy ends or baggy center respectively. Their CD positions may only be able pinpointed as close as the (center of the) roll that failed. Others, such as gage bands and corrugations, are relatively narrow. Not only can we locate the bands to a fraction of an inch; we also have another pattern to use, namely, width. The CD location and the width of the defect corresponds to the location and width of the specific offending element upstream. For example, it is not possible for a die bolt with a 2" wide spacing to cause or cure a 1" wide streak. For narrow defects, we visually mark the center of the defect area and use a tape measure to reference its location to some known datum. Differences in manufactured width, necking, edge trim, web tracking and other factors must be accounted for so that a defect location can be traced precisely to the upstream forming element. Defect maps make hidden patterns visible. For example, while gage band and corrugation locations may seem to come and go, you may find that they actually prefer to come and go in very distinct positions corresponding to an element upstream with a uniformity problem. Spacing between defects rather than positions may also a clue for some defects like tin-canning. Sometimes the CD position moves sinusoidally, indicating an oscillator or randomizer is involved

Another diagnostic pattern is MD position. Are the defects randomly located, or do they come in bunches? One example of an MD bunch pattern is defects that favor the inside or outside of a wound roll. This demonstrates that winding affects that problem, even though there will always be material factors as well. If there is no wound roll diametral preference, winding is (almost) certainly not involved. Another MD pattern is when defects repeat at a wavelength corresponding to the circumference of an upstream roller or at a time corresponding to some repetitive cycle in manufacturing upstream. This pattern is often masked by missing defects and the superposition of defects that are caused by other factors. To find the hidden patterns, you need an FFT (Fast Fourier Transform) analysis of the MD map.

Some people are blessed with map makers. In well equipped paper mills, for example, color coded maps of optical detectors show positions of flaws smaller than a fingernail on a 300” wide sheet traveling 3000 FPM. If you don’t have million dollar sensors, you can use a 10-dollar tape measure and graph paper to do the same thing. You just need to invest the time. It will be time well spent.

***2002.12 Dec 2002
What are plant biorhythms?

Last month we showed that defects favor patterns which can lead us to the cause. These patterns, like many others, are often hidden by the noisy manufacturing environment. To uncover these hidden patterns, you may need to cut, splice and plot your defect or productivity data corresponding to:

1. time since beginning of run
2. time since beginning of shift
3. time of day
4. time of week
5. time of year

For example, if you lay all of your defect and downtime occurrences on a scale that begins and ends with the run (y axis the same length no matter how long the run was), you will find more troubles on each end. The resulting graph is known in industrial engineering as the Weibull or bathtub curve. The beginning is characterized by infant mortality for products, break-in for components and startup troubles for manufacturing. The end is characterized by wearout in products, components and also on some manufacturing runs. The best reliability or runnability is in the middle of the run.

If you splice your defect and downtime data with respect to shift, you will often find more defects at the beginning as knob-twiddlers come on shift. You may also find reduced productivity due to a poor handoff. If you plot defect and downtime with respect to time of the week, you may find the extremes of plant biorhythms. The very worst product and productivity, as an industry average, tends to occur one hour before local dawn on Sunday morning (graveyard shift coming in Saturday evening). This is the plant equivalent of jet-lag as workers' schedules are most out-of-whack with their circadian rhythms. These rhythms are regulated in humans, as with almost all life forms, by sunlight. The best product and productivity, on the other hand, may occur 15 minutes after the first break on Tuesday morning. If the night shift shows poor results, it could be poor circadian rhythms (Southern swing shift), poor supervision or lack of resources. If the day shift shows poor results, it could be a sign of meddling by office people (e.g., bosses and engineers).

Finally, there are also seasonal cycles in a plant. For example, paper web breaks on printing presses are worse in the winter due to the embrittlement of paper as it dries out in the warehouse. Rolls of pressure sensitive adhesive coated webs are very prone to telescope in storage in the summer, but may be well behaved in the winter. Static electricity is worse in the winter. Cooling roll sweating is worse in the summer and so on. Office productivity hits the skids just before Christmas. Engineers go on spending sprees in the spring (just got money from new budget) and then again in fall (use it or lose it). These well-known examples are used to illustrate how profound the effect of natural cycles are on our processes. If you see a seasonal trend in data, you might assume one of the following dependencies: temperature, humidity or human.

If you find a cycle, you have found a connection. However, individual cycles may be hard to find because there are often many superposed, one on top of another. They are also masked by random variation and non-cyclic events. To find these patterns you must first have data, which most of you already have. However, data is only worth the recycle value of office scrap paper (<< $100/ton) unless it is analyzed properly and used to change behaviors. For cyclic data, you can cut and splice to fit suspected cycles. Alternatively, you can use FFT analysis of your time-based data. It will be time well spent.

***2003.01 Jan 2003
How can I speed up my machine?

Speeding up a machine is one way to reduce the cost to manufacture a product. It allows the same number of operators to produce more, thus decreasing the unit labor costs. Increasing speed is an especially effective measure for fully utilized machines (no lack of orders). However, other machines can benefit from reduced labor costs if crewing can be reduced to 2 shifts per day or 5 days per week or when the crew can perform other plant tasks. Increasing speed is also most effective for machines that have a high uptime. Machines which have large grade change time or maintenance might be better served by PM, SMED (an industrial engineering technique) or automation.

Speed is relatively easy to achieve. If we look at some of the web machines, we see incredible capabilities. Flat paper grades are formed, dried, coated and calendered at speeds better than 5,000 FPM. Tissue is even faster, 7,000 FPM. Printing can be done faster than 3,000 FPM and rewinding faster than 10,000 FPM. Similarly, packaging is done at rates that make a machinegun look slow.

From a web handling point of view, we usually have but a single challenge, air handling. Air entrained over rollers cause a loss of traction and air entrained into wound rolls can cause a loss of edge quality as well as defects such as buckles. The challenge is especially acute for plain film. However, if we coat and particularly if we print or emboss, the surface texture may be enough to give a place for the air to go. Similarly, uncoated grades of paper handle relatively easy at blistering speeds. If it were not for air, we would merely ask “How fast you want to go?” Even with air, however, we can achieve some pretty impressive performance. We engineer the idler roller and layon roller surfaces with an air handling texture.

From a machine design point of view, we may also only have one significant challenge, vibration. As we go ever faster, roller imbalance forces increase exponentially. Also, we inevitably cross many system resonances. (Roller critical speed is a meaningless concept because structures have much lower resonances than the individual rollers as calculated by simple formulas.) Resonance are not debilitating in many cases if the rollers are superbalanced (a 100# roller might be put out of balance with a piece of tape) and the structure is massive and rigid. Electrically we have only a couple of challenges, motor horsepower and motor control.

From a process point of view, the challenges are very application dependent. Drying, for example, is one of merely extending the length so that the product has enough dwell time. Paper machines have scores of 5-foot diameter dryer cans or hundreds of feet floater dryers to get the job done. Coating is a bit trickier. Depending on the application, speeding up may require a replacement of the coater and a redesign of the coating.

New machines are the least challenge. Mechanically, we first design to avoid RPM limitations with bearings, shafts and other drive elements that would prevent doubling of the speed some time in the future. Then, rollers and frame are made stout. Finally, rollers are machined precise and finely balanced. Electrically, however, we avoid oversizing motors to accommodate future growth. The penalty for increased horsepower is decreased control quality. If we need more speed a decade or so into the future, we will replace and upgrade the motors at that time. They may well be obsolete and unserviceable anyway.

With this philosophy of design, we can ensure that future generations can use the same machine. It is not unusual to see WWII vintage equipment still running profitably on specialty paper grades. There are some running machines that date back as far as WWI. This is a refreshing alternative to the disposable concept where machines are justified on short-term product needs and two-year paybacks. If you design a machine with a nearsighted focus, you will have a machine that is unreliable, unrepairable and unupgradeable.

***2003.02 Feb 2003
How do I know if my tension control is working well?

The most relevant measure of tension control health is if very little waste or delay is attributed to tension variations with respect to time. An example of waste which may be increased by tension variations would be going out-of-register during printing. An example of waste which may be increased by tension variations would be some types of web breaks on paper. Unfortunately, while economics of waste and delay are the ultimate measure, the connection to tension quality could be difficult to establish in a specific situation. Thus, we can only look at textbook measures of health. The danger of fallacy here, one of the general rule, is that some products and process are tolerant of even extreme tension variations. Examples here might be the winding of carpeting or paperboard. Other products, such as thin materials, or other processes, such as multi-color printing, can be very sensitive to tension variations.

There are several indicators of tension health. The most obvious would be instruments such as load cells, dancers and drive ammeters. However, the product will also react to tension in ways that can be observed as well. An indication of variability by any measure, whether by instrumentation or eye, is enough to cast suspicion on a drive system. Drive systems are composed of electrical items such as motors (or other actuators such as clutches, brakes etc.), motor controllers and control algorithms. Drive systems must also consider mechanical issues such as parasitic drag (nips, gearboxes and bearings) and roll/roller inertias. The mechanical design of load cells, dancers and accumulators also play a part in the drive system.

The load cell is the most useful read of tension control quality. Tension variations as read by fast acting load cells should be held to less some value. One common specification of control quality would be variations not to exceed 5% of setpoint during run and 10% during speed changes (and perhaps a bit more with violent transients such as wind/unwind roll changes or engagement of nips.) The problem here is that even if you have a load cell, it may not be reporting fast enough for this purpose. If the cell is read by a PLC or computer, chances are that the display is too sluggish for this purpose because of averaging and sampling. You may need to put a fast recorder directly on the output of the load cell amplifier. Alternatively, you could resort to the ‘old-fashioned’ but responsive analog meter with needle.

Dancers do not give us the same information as load cells. If the dancer moves we know that a tension variation exists. However, we have no idea how big the variation is. If, on the other hand, the dancer is steady, we can not assume that tension is steady. All we can say is that the tension variations did not exceed the friction of the dancer. Unfortunately, many dancers are not so free-moving (usually due to cylinder seal friction), so that tension variations can be large before the dancer breaks loose.

Alternative instruments to look at would be DC drive amperage, again with responsive analog meters. Unfortunately, most modern AC vector drives do not give us such a convenient read of motor effort. What we look for is amperage that is a good fraction of rated load and steady during steady state operation. During speed changes, we expect the needles of all drive points to move in concert without overshoot or being sluggish.

The web gives us another view of tension quality. Obviously, any bounce of the web run is a bad sign. However, bounce could be caused by flutter or bagginess as well as tension. Sideways movement of the web is a similarly a bad sign. Same for width variations or loss of registration tolerances. A web break could indicate tension variations or it could be caused by other means.

The most demanding time for a drive system is during speed changes, thus giving us the most demanding tests of all. If your registrations are lost during speed changes, tension variation is a likely candidate. If a speed change causes any ring or mark on the side of a wound roll, tension variation is a likely candidate. If you are not satisfied, you will need a drive expert who specializes in web handling to sort things out.

***2003.03 Mar 2003

What are the challenges of width?

The economic advantages of wider machines are similar to the faster machines described last month. A fast machine may have the same crew size as a slower machine. Thus, per unit labor costs decrease. However, another economic incentive for width is trim utilization. Industrial engineers call this nesting. For example, if you have a 10” wide machine, you can make an 8” wide product, but only by giving up a 2” trim. If you want to make an 8” wide product without giving up a trim, you need to redeckle the machine which takes a bit of time, if it can be done at all. However, if you have a 40” wide machine, you can make 8” and 10” widths with no loss of trim or efficiency. The paper industry regularly uses computer optimization for order sequencing to use just about every inch no matter what roll widths and quantities are in the order queue.

In the quest for ever more efficiency, the paper industry has pushed both speeds and widths. However, by the 1970’s the widths stalled out at about 400” and have remained there since. The reason has to do with economics. As widths increase, so do some other sizes. The problem was not controls, as doubling the width does not increase the size of the PLC controls very much at all. The problem was not so much with motors, you can readily get motors with hundreds if not thousands of horsepower without paying more than proportionally for the size. Similarly, the framework needs to be quite a bit heavier, but the cost of metal is so cheap that the fractional cost is not that significant.

The problem is with the rollers. As the widths increased, so do the roller diameters needed to avoid excessive deflection. Process rollers got to be so big that only a few foundries could cast the shells. Spools (the equivalent of cores) upon which the master rolls were wound began at 2 feet in diameter and findings now show that these ‘cores’ should be closer to 4 feet in diameter to avoid damaging the product near the core. Even ‘idler rollers’ were at least 1.5 feet in diameter and needed to be driven because of their large inertias. Thus, it did not make economic sense to go wider. The paper industry then refocused its efforts to ever increasing speeds and uptime.

Other web industries have not come anywhere close to this roller economic limitation. However, they do share other limitations of width that everyone faces. First, product consistency must increase more than proportionally. If you have a 1” wide streak on a master roll 10” wide, you lose 10” of product. If you have that same 1” wide streak on a master roll 400” wide, you may lose 400” of product. Similarly with the trim. Trim troubles may be little more than a nuisance on a 10” wide product. At 100 inches of product width, it may be debilitating. Second, product flatness must increase more than proportionally. Wrinkling might be almost nonexistent on a 10” wide product because the web can bend more readily. (Inplane bending is a result of imperfections such as roller misalignment and diametral variation.) Also, a wrinkle can work itself out when it is very near an edge. The wide web has none of this tolerance. The machine and product need to be dead on.

The benefits of width are often greater than speed due to trim and nesting. However, speed may fewer and more predictable challenges. The challenges of width, on the other hand, are not so predictable. If you merely stretched the middle, such as increasing width without increasing core diameters from a 3” to 6, you may risk problems such as wrinkling and other damage near the core. If you scaled the machine up proportionally, you may still end up with consistency issues that prevent successful commercialization. It might be something as small as troubles with trim.

***2003.04 Apr 2003
What is the best web guide?

Guides control the cross machine position of a web. Active guides are composed of three elements: an edge sensor, a controller and an actuator. Sensor selection is based on web material properties. It may be optical, ultrasonic, pneumatic, 2D or 3D cameras, paddles, whiskers or other device. An optical sensor, for example, would work well for opaque materials but not clear ones. Pneumatic or ultrasonics might work well for clear webs but perhaps not fuzzy ones. Paddles would work for thick web but not for thin. Machines which run a variety of materials may need more than one type of sensor. In addition to seeing the edge, the sensor must see it with sufficient resolution so that measurement is not the limiting factor for the system performance. Printing presses need to see a web's edge to a few mils. On a paper making machine, one inch may be close enough.

The controller may be analog or digital. Most new controllers are digital to enhance setup flexibility and communications with other devices. However, lest the owner of older equipment think that digital is better, only recently have digital devices approached the control performance of well designed analog ones. You may need to control on one edge (edge guiding), the centerline (center guiding) or to a feature on a web (registration). Alternatively, the guide may oscillate the web to keep caliper variations from stacking up or to superpose oscillation on top of guiding. The mechanical equipment is the same in any case. Thus, it is shortsighted to not have a controller capable of all of those modes as it is little more than a few lines of programming to allow this scope of operation. It also makes all controllers in the plant the same so that maintenance and spare parts are simplified.

The actuator is connected to rollers which move the web. It may be pneumatic, hydraulic, electrical or a hybrid. Each has its own advantages. Pneumatics are clean and cheap, while hydraulics are fast and powerful. Electrical actuators, such a stepping motors driving ball screws, have the finest resolution. Thus, small undemanding equipment may use pneumatics while hydraulics are required for moving heaving winders or unwinds.

For mechanical design, you have to first choose the location for the guide based on application needs. You may guide on the unwind to maintain a consistent feed position into a machine despite rough unwinding roll edges, varying positioning of the roll by operators and varying web widths. You may guide on the winder on the end of long machines to ensure straight wound roll edges. You may guide in the middle of a long machine to bring the web back after it has wandered. Guiding in the middle of a machine may be done by displacement guides for short spans and steering guides for long spans such as might follow an air float oven. In all cases, however, you position the guide very near to where position is most important. This rule of positioning holds true for slitting and spreading as well.

There is much more that could be said on guides because they are a relatively mature technology. Ph.D. theses have been written thirty years ago detailing design and performance. The devil here is in the details. Most applications which fail are not due to maintenance or operation. Rather they are due to product or process design. Web products that are troubled with bagginess or have edges that are not well slit will not guide as well. Process design means dozens of application rules, many related to geometry, must be observed for good performance. Many of the most spectacular failures I've seen were 'do it yourself' jobs where what the designer did not do was their homework. Guide rules are found in many sources such as my books. The easiest and safest approach to avoid disappointment is to let the OEM or guide supplier check the application against design rules.

***2003.05 May 2003

What is the best nip control?

Nips are everywhere. We can hardly manufacture or convert webs without them. They are found on calenders, coaters, laminators, printers, winders and other machinery. They are used on film, metal, nonwovens, paper and other materials. Nips are so important to control closely that variations of nip pressure are almost synonymous with variations of product. Yet, unfortunately, most nip controls are done quite poorly. Check yours against these dozen design guidelines and judge for yourself.

1. Nip load should be calibrated (not merely calculated) so that a nip setting of zero means zero force between rolls. Anything else is needlessly confusing to operators.
2. Nip load should be calibrated (not merely calculated) so that readouts are in PLI or lbs/in of web width. (Metric applications would be calibrated in kN/m). Total force does not allow us to readily translate experience between varying web widths. Pressure (PSI) to the cylinders is the worst of all choices. It does not allow us to translate experience anywhere. These units are needlessly confusing to operators, process developers and engineers alike.
3. Nip control should have a fixed pressure on one side of the cylinder to zero the system as given in Rule #1 and a control side on the other side of the cylinder. The fixed side is buried in the cabinets and is for service people only. (The word 'fixed' does not preclude varying this side by cam or computer to compensate for geometry changes.) Giving operators control of both sides of a cylinder is needlessly confusing.
4. The minimum control load for good performance, pneumatic or hydraulic, is around 10 PSI. Control load is not necessarily the load applied to the cylinders. A smaller pressure indicates poor design such as oversized cylinders or attempting to lift too-heavy rollers rather than move them sideways.
5. Pneumatics should not be used in applications that are prone to vibration or for those that require very precise control.
6. The total mechanical friction and control hysteresis should not exceed 10% of the minimum control load. The most common source of friction is the seals on the cylinder. Slides can be a problem and chains almost certainly are.
7. Biasing of a nip, front to back, must be done with great care as it can cause more problems than it cures. To make the system user friendly, the average should be set on one knob and the bias on the other. Unfortunately, most systems have a front and a back setting instead of an average and bias.
8. Nip load control selection should have three positions: open, close and load.
9. Nip rollers must not deflect so that nip pressure varies excessively between the middle and the edges.
10. Nip roller surfaces must be round such that the nip pressure footprint varies excessively across the width or with rotation.
11. The nip pressure footprint should be measured via nip impression paper on regular intervals during the expected life of the roller surface. This and the previous guideline speak to primarily to maintenance while the rest deal with design.
12. Nips are very dangerous. Safety includes guarding, E-stop quick opens, lock-outs for service, warnings and, most importantly, sensitivity training.

Web handlers everywhere now know how vital tension control is to process health. We now measure, calibrate and control tension. Nip is no less important. Yet, we have neglected nips so much that few installations measure or calibrate, without which we can't even talk about control. We need nothing less than a revolution in how we do our nip control business. Everyone must do their part because we have no less than a million nips out there. Many are performing poorly now and more are coming every day.

***2003.06 Jun 2003
How do caliper variations affect winding?

Caliper is never truly level across the width of a web. However tiny these variations might be, they may still be large enough to cause the winder to complain. In fact, the winder is often the most fussy customer for gage uniformity. If you can get the caliper varying web through the winder without defect, the purchaser of your web may have no further cause for complaint in this regard. Listen closely to the language the customer uses to complain. They do not usually talk about poor web caliper uniformity. Instead, they talk about poor roll quality. Not only is the winder the most fussy customer, the winder may also be the most sensitive measure for gage uniformity. Wound roll variations may develop where the corresponding web variations can not be picked up by conventional lab tests or online scanners. This situation is difficult for manufacturers because they can't tell for sure whether the web is good enough until after the roll is wound. Sometimes, such as the case with some films, it takes days for the air to escape leaving, ridges to bloom after it has been shipped to the customer.

First, which wound roll defects are commonly the result of winding a web with caliper variations?

Baggy lanes
Blocking
Corrugations
Crushed core
Out of Round
Ridges
Starring
Telescoping
Wrinkling on a roll

Second, how can you tell if caliper variations have an influence the severity of a winding defect? Some of these, such as corrugations and ridges, are almost certainly the result of caliper profile problems. Others are often exaggerated by poor profile. One way to differentiate is if one of these defects favors a certain CD position, such as a baggy lane coinciding with a ridge in the wound roll, you can be pretty sure it was made worse by profile. If the defect position moves around with time, you are almost certain that profile had a role, though not necessarily caliper profile. Caliper variations cause the window of defect-free operating tensions to be narrowed. However, tension sensitivity by itself only indicates winding is involved, not necessarily the winding of gage-varying web.

Third, what do you do when you have one of these 'winding' defects? The first thing to do is to reduce the tightness of the wind by lowering web tension and especially nip load. Tightness should be reduced to the point where it becomes obvious that going any farther would be counterproductive because loose defects would then outnumber the tight defects. After that, you may get relief by replacing the winder with a more tolerant arrangement, such as duplex with individual stations or duplex with differential shafts.

Ultimately, however, you will get the most benefit from eliminating the root cause, which is caliper variations. You must identify which specific manufacturing or converting element is responsible for a particular feature (there may be more than one source). Then you must identify what variation on the element is responsible. For example, on an extruder it may be temperature or gap variations that cause a particular problem. Finally, you must change the design or maintenance of the offending element so that it is more uniform across the width than anything you've ever done or ever seen to date. If you want to know if it is good enough, don't ask extrusion, coating or QA. Ask the winderman.

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***2003.07 Jul 2003
How does a differential or slip-core winding work?

The short answer: not very well. But before we evaluate the results, let's talk about mechanics. The root cause that may justify slip core winding is caliper variations across the width. If one roll has a thicker gage material than another in a set, its diameter will build larger. If both the large and small diameters are forced to rotate at the same RPM, as is the case with locked core winding, the large diameter roll in the set will have a higher surface speed. The higher speed results in higher 'draw' and thus tension. The problem, however, is with the small diameter roll. It may have insufficient or possibly no tension at all. In extreme cases the web puddles on the floor under the small roll.

How do you know that caliper variations are the root cause? You could check diameter variations carefully with a PI tape. Alternatively, you could check for hardness variations with an instrument or by sounding the roll with a stick. If the small or soft roll in the set is also the loose one, you have confirmation of the root cause being manufacturing. However, manufacturing is going to be quite reluctant to accept blame for this. They are going to say they are within spec. They are going to say the product is level as measured by lab test or scanner. They are going to tout impeccable die design or coater maintenance. They are going to want more proof. The final proof is to show that you can temporarily tighten any loose roll in a set merely by throwing in 'shims' of paper or whatever to fill out the low spots made by manufacturing.

Even if you get buy-in that the root cause is indeed manufacturing variations does not mean the pressure is off the winderman. Manufacturing will then say that this is the best they can do. Like it or lump it, you've got to wind it. All the winderman can do now is pull like hell and pray. Sometimes you can tension things enough to pull up the slack roll. Sometimes you have to rebuild the winder to give more tension capability, assuming the web and tight roll will tolerate it.

Next, we can think about slip core winding. In this arrangement, the rolls are tensioned by over-speeding the shaft and transferring torque to the rolls through a slip clutch arrangement. Slip clutches allow the varying diameter rolls to turn at their own speeds. The needs for this treatment increase when all of the following are present: high caliper variations, stiff ZD modulus (roll rings when struck with a stick) and multiple rolls (the more rolls the more risky).

However, slipped core winding is not without issues. Setup time and skills increase. Shafts are very expensive and require a lot of maintenance. If you over-speed the shaft too much, you can generate heat and debris from the rubbing friction. Lubricants can contaminate product. Also you lose closed loop control. When in locked core mode, the average tension of the set is often regulated by load cells, while variations across the width are caused by caliper variations. In slipped core you often lose closed-loop average tension depending on the design.

More to the point, the tension variations across the width are now caused by variations in clutch frictions. It is not at all unusual to have 2:1 tension variations across a set of clutches on even the best shafts. It can get much worse if operators use lubricants or if the friction elements get glazed. In other words, the tension variations of the cure may be more deadly than the tension variations of the disease. You must evaluate on a case by case basis which mode works best. It is done by comparing roll hardness variation of slipped core versus locked core mode on a particular grade.

***2003.08 Aug 2003
What are the best splicing techniques?

Many factors determine the best splicing technique for given situation. The first is whether the splice is temporary or permanent. A temporary splice might be made to reconnect a broken web or to attach an expiring wound roll to a new one. The best method here is usually operator determined because the splice is removed from the final product. It only needs be good enough to survive the threading process without breaking very often. On the other hand, both the supplier and the customer may specify details of a permanent splice.

No one wants splices. However, they often must be accepted to reduce system costs. The number of splices tolerated in a single wound roll is most commonly zero to three. Sometimes there are minimum distances from the ID (else start a new roll) or OD (else ship a small diameter roll) as well. As these specs are tightened, the supplier's costs rise because otherwise useable material is thrown away. As these specs are loosened, customer costs rise because the product containing the splice and often adjacent product must be thrown away.

The most common type of splice is the lap where the two tails overlap as a sandwich with the adhesive in between. The butt splice has a layer or two of tape over the butted joint of the tails. The lap is usually the easiest splice to make in a fully manual mode and on a flying splice unwind. Butt joints are easier to make on splicing tables and on some fully automatic splicers. Tape thickness and tape width are important details. Sometimes splices are made at a slight angle so that they go through nips easier.

The adhesive may be glue or sometimes a hot melt. However, most use splicing tapes with a removable liner. The adhesive must be chemically compatible with the substrate. It must adhere well, sometimes so that the product would tear before the adhesive lets loose. Adhesives can be a challenge for ovens and dryers. The adhesive must be tacky enough at room temperature to stick but not soften too much under heat. Something else to consider, especially for paper, is repulpability. Tape, adhesive and sometimes the liner itself must not contaminate the recycle streams. Finally, give some thought to adhesive applicators such as glue guns and tape dispensers. Cutting seconds off splicing time is important, especially to papermakers whose machine's output is worth more than $20,000/hr.

The best splicing technique for a particular application is simply the simplest one that avoids most problems. One example is web breaks, runnability or other reliability aspect caused by the splice. Manual splices are extremely dependent on operator technique. The tiniest offset, angle or pucker with either tail or tape will in effect make a locally 'baggy web.' The area will mistrack through a machine and will be the first to break if the web is brittle, such as on paper. Operator training and attitudes may be more important than the tape you use. There is a idea to get an operator to assume responsibility for quality. Have the splice tape imprinted with the operator's initials.

When you have a problem at a customer, you will know exactly where to turn for remedy.

Splice quality can be measured in several ways. The simplest may be to pull a tensile test on the splice area using a rewinder or other machine that has enough tension range to break the web. A tensile of 10% of the base web's strength is very poor while 50% is very good. Another is to look at break rates at the splice. The productivity of most machines suffers greatly if the break rate is greater than say 1%. On printing presses, one may use register measurements in the splice area to measure mistracking due to attaching web's of different bagginess or creating local bagginess at the splice. In any case, pay close attention to the customer when they talk about the splice.

***2003.09 Sep 2003
How do I prevent wrinkles from forming?

There is so much written about wrinkles (I plead guilty), that one could become mired in details before seeing the overall philosophy. The most obvious approach would be to identify the root cause and remove it. However, root cause analysis, or RCA for short, may be unnecessarily restricting as we will see.

Root causes are plentiful and include roller problems such as misalignment and diameter variations across the width. Misalignment is easily recognized by wrinkle troughs which are at an angle with respect to the machine direction and usually ‘walk’ sideways. Roller diameter variations, on the other hand, make wrinkle troughs that are in the machine direction and favor certain locations despite changing materials. If a roller is not right the obvious next step is to fix it.

However, root causes also include processing which may be much harder to prevent. For example, heating and cooling can cause expansion wrinkles. However effective turning off the oven may be to preventing this root cause, it will not be looked upon as a favorable idea by either your boss or your customer. Same thing with the application of many adhesives, coatings, metalizing and print: they can makes wrinkles. If you want to avoid the root cause you may have to work with process and product developers so that they understand the risks they incur when they design a web for end use without considering design for manufacturability.

The root cause may also be thin and/or baggy webs. Thin webs are unforgiving of variation in material or machine that may be below our threshold of detection or remedy. If the web is baggy, heaven help you. Few companies are equipped with the quantity and quality of expertise necessary to troubleshoot this thorny problem. Even if you could put your finger on the exact cause you have another high hurdle. What is the norm and even what are the best practices of the industry may still not be good enough.

Lets take a different approach. Let’s identify the component that makes a specific wrinkle. (Note that there are different types and causes for wrinkles).   In some cases the source is where the trough, soft wrinkle or hard wrinkle is first seen. Beware, however, that in severe situations a wrinkle may propagate upstream one or more rollers from its source. Also, many wrinkles form in one unforgiving location but in fact had invisible help from some upstream source. An example is wrinkling on a gage band on a wound roll.

If the source is a process and the wrinkles are roughly uniform in spacing, you will need to: live with wrinkles, use a different material, tone down the process or apply effective spreading immediately after the process and before the wrinkles initiate on a roller. If the source is a transport roller, first make sure geometry is impeccable. If so, you next determine whether the web is tracking, sliding, or floating. The reason is because you must apply a spreader that is compatible with that state of traction. For example, in the case of tracking you may start with a concave roller (bands of tape on the ends of the roller) and proceed to stronger spreading such as the bowed roller if needed and if applicable. In the case of sliding, you will probably use a roller with a slight barrel shape to flatten the web. In the case of floating, you will manage air film height for maximum wrinkle resistance. In the case of air bars, it will probably mean more air than the current system can put out. In the case of air turns, it will probably mean less air than you are comfortable with, perhaps to the occasional touchdown of the web.

First go to wrinkle school so you can identify the root cause and eliminate it. However, you may not always find the cause or you may not be able to undo it. In that case you will need to go to spreader school.

***2003.11 Nov 2003

How can I troubleshoot and treat winding defects?

The most useful classification of wound roll defects is by tension. All defects fall into one of the following categories: tight roll, loose roll, taper and other. Examples of tight roll defects would be blocking or corrugations. The tighter you wind, the more frequent and severe these defects will be. Examples of loose roll defects include rough roll edges and loose cores. Examples of taper defects are few and principally include just starring and telescoping. Finally, many defects such as offset cores and wrong roll width, are unaffected by winding tension. The best guide to these defects is the encyclopedic Roll and Web Defect Terminology published by TAPPI PRESS.

The reason why this classification is so useful is that it tells us what to do first. Since every winder is equipped with a tightness adjustment, we would crank the knob(s) in direction indicated above to see if we can get relief. We first crank the tightness knob enough to overshoot the answer. For example, if we tighten in response to a loose defect enough, we will begin to pick up tight defects. If we did not break something in our initial efforts, we simply have not tried hard enough in our troubleshooting.

After we have bounded the problem, we back off half way between where we were and where was clearly too much in the other direction. Then we run for a time in that condition to see what the balance is between tight roll and loose roll defects. If we are lucky, we may have no more further troubles with that grade. If not, we are likely to have a mix of tight and loose roll defects. If we see more tight roll than loose roll defects, we will back off and vice versa. Statistics and DOE (design of experiments) can be used to put some science to this process. However, the ultimate tool for process adjustments is economic optimization as described in my Critical Thinking in Converting book.

This is fine in principal, but how do we change roll tightness? All machines have a web tension adjustment. The higher the web tension, the tighter the wound roll. However, most winding machines also have an adjustable nip. Again, the higher the nip load the tighter the wound roll. Finally, a few machines are equipped with center-surface torque differential control. The more positive power put into the center wind drive versus the surface wind drive, the tighter the roll.

We can use any or all of the available TNT (tension, nip and torque) knobs to get the job done. The only question now is which is the most powerful. In all cases, the two T’s (tension and torque) are significant. The remaining question is how significant is nip. The answer depends on the web product. For products that are soft already, such as nonwovens, textiles, tissue and the like, nip is by far the strongest of the three knobs. On the other hand, products that tend to wind hard already, such as film, foil and most paper; nip tends to be weak. However, do not get bogged down in these details. If you need to make a tightness correction, move all three knobs aggressively to make sure you get a response that is easy to read. There is nothing so wasteful and useless as timid moves in troubleshooting. The ‘one knob at a time’ rule is fine for many things, but ignores the knowledge that all the knobs affect winding tightness.

Once we have optimized wound roll tightness, we are done at the winder. That is not to imply that the problems will go away, however. All I said is that the first thing you do is to change the wound roll tightness. Unfortunately, it is not always the best solution. The most powerful solutions often involve product redesign for manufacturability. If layers block, you need to rework the surface chemistry to make the web less sticky. If the roll has corrugations and ridges, you need to level the web in manufacturing.

***2003.12 Dec 2003
Can I hide defects by winding loose?

It is well known that winding looser (soft) will reduce the frequency and severity of some types of wound roll defects. Examples would be ridges, webs stretched into bagginess over ridges and corrugations. In the case of ridges, areas of the web that are ever so slightly thicker than their neighbors stack up into faster than the adjacent thinner areas. A ridge that is a mere 1/1,000 larger in diameter than the rest of the wound roll may visible, leaving you open to criticism from your customer. It does not matter at all whether this feature is a functional problem. Perception is the reality. If your feature it is more prominent than the competition's, your product will be viewed less favorably in that regard. Also, the customer could attach some other undesirable behavior to the feature, even if there is no real physical connection. It is equally possible that the ridge could damage the web by stretching it into a baggy lane at that location.

The corrugation, also known as a rope or chain mark, also has a caliper error as a root cause. Here, however, the error that causes the defect is a high-low or especially the high-low-medium gage error pattern across a narrow width. Typically, the corrugation is only ½"-4" wide. The same gage error over a wider band may not trigger the corrugation. However, there is a distinct difference between the ridge and the corrugation. The corrugation is almost always a nip-induced-defect. This means that of all of the three TNT's (tension, nip and torque), the nip is by far the most damaging with this corrugation. Thus, we would aggressively reduce nip load until we ran into some other limit or trouble and only then spend modest efforts on web tension.

One common misconception is that the gage errors stack up proportionally. This does not happen even on the stiffest of materials. All rolls have some tendency to self level. Thus, the high gage area will wind tighter there and thus bring the bulge down a bit and vice versa on the low gage area. For this reason, a 1/100 gage error may cause a 1/1,000 roll diameter bulge. As a practical matter, however, it does not matter whether the root problem is 1/100 or 1/1,000. It is still too small to be picked up by most lab or online gage measurement systems.

It is ironic that the QA or gauging system is often unable to measure, much less control, the very problem that it should be trying to prevent. Not only is the gauging system too insensitive, it is also too coarse. Corrugations and ridges are so narrow as to often fall between the bins or samples. How then do we know if we have a gage error? Simple, the wound roll will tell you. Diameter variations across the width, with the exception of tin canning and a few other situations, are all the proof one usually needs. If you need more, roll hardness variations as measured by Rhometer, Schmidt Hammer or other device is usually most sensitive to gage variations. Sometimes special sampling techniques can boost the resolution of lab instruments to the point of detecting problematic weight or gage errors.

Back to the question of whether you can hide a defect by winding looser. The answer is no. There simply might not be any defect to begin with unless you wind tight. In other words, a gage error in a web is not necessarily a problem with a web in manufacturing, converting or end use. It is a gage error in a tight wound roll that is the problem. Thus, the best way to view defects like this is with the following generalizations:

1. The most sensitive measure of a level web is a level wound roll.
2. The fussiest customer for a level web is the winder
3. Winding loose does not hide defects, it prevents them.

***2004.01 Jan 2004
Are We Having More Drive Difficulties?

I have seen more drive problems in the last two YEARS than I have seen in my first two DECADES in the industry. When I first started in the paper industry, it would be unusual to work on more than one or two troubled drives in a year. New designs and particularly automation were what was giving us fits beyond the usual headaches of ever-increasing demands for quality and productivity. True, the paper industry has much better equipment and technical resources. However, they also have far more demanding applications. At speeds approaching 10,000 FPM running tender materials like paper, you just can't afford to have a web break. But even when I started working in the converting industry as a consultant more than a decade ago, drive assignments were not all that common. Now, I am working on truly troubled drives every month. Drives that disable the process so much as to risk shutting down the line permanently due to spurting blood loss out of waste and delay arteries.

Perhaps it is my imagination. Perhaps it is just the reflection of a small sample size of but a single person's perspective. However, I don't think this is the case. I truly believe that tension control has risen to be one of the biggest of the web handling issues and a major contributor to waste and delay. Perhaps only wrinkles and winding problems surpass tension as overall causes of web handling troubles in our industry. However, both wrinkles and winding are very tension sensitive so that we probably underestimate its importance.

Maybe it is just that our equipment is aging and the current economy not longer allows proper maintenance. I am sure this is true on occasion. However, as a general case this does not make sense for two reasons. First, the incidence of troubles jumped as opposed to ramped up as predicted by wear out. Second, this jump seemed to have begun well before the current economy.

Maybe it is because we have better instrumentation and can detect problems easier. Load cell readings and even meters for dancer position make tension variations easier to detect than watching or feeling the web. However, I don't believe that this is the case either. As much as I would like to believe the preachings and teachings of web handling proponents are taking hold, we can not take credit for a jump in sensitivity to tension control. The calls I get are not "Help, my load cell reading is moving more than 10% when I change speed." It is more like "Help, my web is being ruined, my machine is shutting down and/or my customer is complaining that …" Tension is not varying beyond the textbook 10%. Rather, it is varying 100% and wrapping rollers or putting a puddle of web on the floor. You don't need a load cell to detect this. It is a pragmatic rather than theoretical concern that is driving people to call me about drives.

Maybe it is because we are more sensitive to waste, delay and customer complaints. However, I have trouble buying into the first two reasons. People are so busy that they can't even track waste and delay properly much less have the time to go after higher hanging fruit. They are just trying to keep their heads above the water. It is possible that increased sensitivity to customer complaints and increased demands of the customer could be a driving force for drive attention. There is a lot of excess machine capacity out there and a material buyer does not have to put up with what they might have before the new economy. Some material suppliers are scrambling just to keep their customers and will do things they never did before: call for expert help when in-house resources and suppliers have all come up short.

I am thus left to conclude that we SEEM to be having more drive troubles because we ARE having more drive troubles. Next month I will offer my opinions why this is so.

***2004.02 Feb 2004

Why We Are Having More Drive Difficulties – An Opinion

You would think that new drives would work better than old drives. Surprisingly, however, many of my clients with troubled drives have new or newly upgraded drives. I have seen a simple three motor drives misbehave so badly that only after months, four startup engineers and a threat of lawsuit did they finally get it running. I have seen a brand new two drum paper winder, of which there are about 5,000 similar machines in the world, refuse to start for months with similar results. In both of these cases, the drive was a name-brand state-of-the-art AC vector drive.

How can this be? Surely our HARDWARE is at least as good as two decades ago. Surely our SOFTWARE is at least as good as two decades ago. In fact, two decades ago computer controlled drives had just started to be an alternative to electronics. While computers certainly can make things challenging, they also are much more flexible than electronics (though not faster as commonly believed). I do not believe this is the root cause.

If it is not hardware and its not software, then what is it? It’s WETWARE. People configuring the drives do not always know what they are doing. For example, the winder builder I initially worked for would only allow three brands to be used because they were the only ones with significant web experience. More tellingly, we would allow only a few specific individuals from those name brand companies to tune the drive. We knew those individuals by name. The hundreds of other service engineers a large motor control supplier might have were simply untested in a demanding web environment and thus too risky.

Web drives are a specialty application that requires much effort to become proficient at. A lifetime of pump and fan experience is not enough to safely open the cabinet door of a web drive. Even extensive experience in robotics and machine tools does not come close to cutting it. These areas are demanding, to be sure, but quite different than web drives. We should no more allow an osteopath do work on our kidneys than a non-web drive service person work on a web drive.

It is easy to tell if you’ve got the right person (provided there are no hardware issues). As a rule of thumb, new drives should take only about 1 hr to 1 day of tuning per drive point. The very first digital drive on a winder in North America went on the winder in my lab. The engineer finished tuning this state of the art 10,000 FPM winder in less than one day. Neither he nor anyone else was ever needed again to service that machine. Why this superb performance on a nearly prototype drive? The supplier was so interested in getting this flagship pilot winder in top form that he sent his very best service engineer of the hundreds he could have chosen from.

Things are different now and the changes are not for the good. Web drive people are hard to find. Machine builders and even drive suppliers have not invested in this specialization. Instead, we are left with a mixed bag of what amounts to be self-taught computer generalists. They learn the hard way, on your time, how to construct ‘s’ curve rounding of ramps, inertia comp and a host of devil-the-detail web drive concerns. They write code in PC’s and PLC’s instead of using software that runs IN the drives. They don’t talk to operators. They don’t look at the mechanicals that are the muscle of the computer’s brain. They have very little time logged on web machinery and they don’t know web handling.

That is my opinion. The root of tension control problems is the same as all other technical problems: it is a people problem. People don’t know what they are doing because they haven’t spent enough time learning about the stuff they need to know. My advice is don’t touch your drive unless you can identify the skilled service engineer first.

***2004.03 Mar 2004

Why do guides work so well?

Many components and processes give us trouble in our web industry. For example, both tension control and winding have been the priority problem in hundreds of my assignments as a consultant. Rollers and slitters also trouble more than a few. Processes such coating and drying are near continuous challenges for people who own them. Calendering and printing seem to run a bit smoother but are nowhere near trouble-free.

It might be instructive to ask why we have these problems to look for trends. However, the complexity and uniqueness of the products, process and machinery in our industry make it difficult to draw general conclusions. Let’s try a different approach. Let’s see if we can find something that works relatively well and ask why. My first candidate would be edge guides. Of the thousands of calls I’ve answered, only one was for an edge guide. It turned out to be a simple application error with not so simple consequences, once you build a machine. While I’ve worked on more than a few guides, they were not the main reason for a visit to a plant.

This is not to say that guides are totally free of problems. I am sure if you ask the guide manufacturers they will be able to supply scores of troubled references. Sometimes this is a matter of unrealistic expectations. People want hairsbreadth positioning tolerances when these can only be achieved under ideal circumstances of a good web, good guide, good edge and modest incoming position error rates. Sometimes it is a simple matter of maintenance or application. In any case, however, guides are almost never mentioned in most daily production meetings. Why?

The first and most obvious difference is complexity. Guides just don’t have as much going on as say coaters or winders. However, rollers and slitters are also simple and they don’t have such rock solid performance. There must be something else also at work.

The second difference would be known only to those well-schooled in web handling. That is, guides have been researched for decades. Ph.D. level work at Fife, the Web Handling Research Center and other organizations has been done as far back as the mid 1960’s and continues to the present. While winding has been the subject of even more study, winding is also far more complicated. It is the ratio of study to complexity being higher for guides than winding means that we know the subject better.

The third difference is that guides are almost always turnkey applications under the direction of experts, i.e., the guide manufacturers. One of the common ingredients for failure is do-it-yourself. People may do-it-yourself on rollers because they look simple and on winders to save money. For some unknown reason, guides seemed to have escaped that pitfall.

The fourth difference is that guides are only infrequently touched by maintenance or operators. Slitters are also relatively simple. However, the short mean-time-between repair of slitters gets people involved who are not always properly trained or motivated. I am certain that if maintenance and operators had better training and took better care with slitters, we would have only a tiny fraction of the problems we now have.

I believe that these principles for reliable performance also apply to other areas of web handling and web processing. While we can do nothing about inherent complexity, we can make use of the other findings. To summarize, people who work on stuff must study it enough so that they understand it well enough. If you are not sure, turn to the builder who may be better equipped in regard to specialized expertise. If that builder does not have the expertise, find another. Keep looking until you find what you need. It is not machinery we buy, it is the expertise to avoid and solve problems.

***2004.04 Apr 2004
What can we do to improve tension control?

What if we could wave a magic wand and change one thing, what would it be? One proposal would be to put a load cell in every drive zone. No matter if the control mode is dancer or draw, we need a load cell tension readout just the same. Exemptions would be by special permit only.

The load cell gives us two invaluable pieces of information: average tension and tension variability. Average tension is vital for web handling. In the case of dancer or tension control, it is the object of the setpoint. In the case of draw control, it gives is useful process monitoring information. Variations in forming, coating, drying and so on can cause a change in tension.

Tension variability is the single best measure of drive health. Stand-ins such as motor amps, the look of the web, or the edge of a wound roll are supporting, not primary. If the tension variation exceeds some quality standard, the web handling process is not under good control. One common tension quality standard is tension variations not to exceed 5% of setpoint in steady state, 10% during speed changes and a bit more for upsets such as unwind/winder roll transfers or nip engagement. While we are quite familiar with the concept of web quality, the idea of machine quality is nebulous to many. It need not be. Machine quality can be measured and specified in key areas such as maximum allowable tension variations.

However, not just any tension readout will do. We will insist on a readout calibrated in real web units of lb/in (PLI) or kN/m. Total force, lbs, are found on many machines. However, it makes no more sense to display our automobile’s speed in wheel rpm than it does to display tension in lbs. In the former case, the driver must consider differing tire diameters when driving a different vehicle. In the latter case, the operator must consider changing web widths.

Also, not just any tension display will do. It must be responsive and ergonomic. Responsive just about rules out the use of PLC’s. They are just way too slow in most cases. Ergonomic rules out a numerical display. Flickering numbers don’t tell us the limits of oscillation. What works then?

One display has proven itself for decades in countless installations: a meter with a needle. Old fashioned you say. It works I say. You can see average tension and tension variation at a glance from a dozen feet away. All right, computers can work too. One is a dedicated drive display with the computer version of a needle or graph. Numbers are also displayed but need not be so responsive. Some of the high end drives found in the paper industry can sample and display several drive readings simultaneously at about one KHz. Speeds like this are vital for troubleshooting a sick drive. Another example is high speed computer data acquisition using generic ‘lab’ software and hardware boards hooked directly to the load cell amplifier output. Drive and portable computer can both be fast and flexible. The difference is primarily cost and convenience. Drive versions are expensive but dedicated and always online. Portable computer versions are hooked up temporarily for a specific case of troubleshooting. PLC’s, on the other hand, are the often worst of all worlds for this purpose. They are expensive, slow and inflexible. A custom display taking 10 minutes to write in a drive or generic lab computer program can take an hour or even a day to do as well in a PLC. Even then, the PLC will be an order of magnitude slower in response.

Load cells, lots of them. In every drive zone if possible. Tension readouts, hot and easy to read. That’s the ticket for troubleshooting tension problems.

***2004.05 May 2004
How can I adjust tension to improve winding?

Every winder is equipped with an adjustable tension. Most winders can taper this tension automatically as the roll diameter builds. Some winders can even program a curve. Whether we have a simple setpoint, linear taper or arbitrary curve, we must choose how to set the tension. The best setting is determined the same here as with any other adjustment: economics. Specifically, we choose a tension which avoids the most, but not necessarily all, defects.

We can group defects into low tension, high tension, taper tension or independent of tension categories. Examples of low tension defects are out-of-round rolls, some rough roll edges and loose cores. Examples of high tension defects would include blocking, gage bands and some crushed cores. Some defects are independent of tension such as wrong diameter rolls due to an operator setup error. A couple of defects, namely subsets of starring and tension, are very sensitive to a lack of taper.

If you had customer complaints of out-of-round rolls, you would look into roll handling practices as well as tighten up the tension. If you had loose cores, you would also consider increasing the tension. You also must check to make sure you don’t have wet cores. Increasing tension may not be strong enough to counter shrinking cores. If, on the other hand, you had gage bands you would look into manufacturing. Obviously, you would also decrease winding tension as much as possible. However, if the gage bands are severe enough you will not eliminate the problem solely by tension changes.

So how far do you move the tension in response to a defect? The answer is always the same: until you break something. In other words, if you have a high tension defect you will reduce the tension until you clearly have a low tension problem of some sort. Once you are clear what and where the limits on both ends are, try running half way between. If you are lucky, you will find a sweet spot where both high and low tension defects are absent. If not, you well have both high and low tension defects at the same time. Next steps may be to redesign the process or do economic optimization as described in my Critical Thinking book.

We use the same approach for the taper sensitive defects starring and telescoping. We make sure that a particular case is amenable to tension treatment. For example, starring on one side of a wound roll is not treatable by tension because it is probably caused by a gage variation. Gage variations may be unintentional due to profile variations in manufacturing or intentional such as printed patterns. If your case is amenable to tension, the appropriate amount of taper is maximum. You would start the roll at maximum, just short of breaking something. You would finish the roll at minimum, again just short of breaking something.

This tension strategy outlined here makes sense for several reasons. First, it is based solidly on economics rather than theory. Second, it adapts to any particular situation rather than conforming to a ‘one size fits all’ guideline that probably fits very few very well. Third, anyone can get the answers if they are willing to spend the effort and be willing to ruin a few rolls finding the limits. Notice that we have not promised complete relief from defects. Expecting any single knob to make the hurt go away completely is often unrealistic. Product/process design always offers alternative solutions and they should be considered too. Sometimes design is so much more powerful that continuing to think about tension is distracting. Even so, tension is always the right place to start.

***2004.06 Jun 2004
How would I adjust nip load on my winder?

Winding nips, such as a layon roller, do many things depending on the circumstances. The primary functions are to meter air into the roll, improve stack, increase wound roll tightness and to support the winding roll. Nips can also be destructive, however, by causing wrinkles, corrugations and other defects.

Nip rollers help keep some air out of the winding roll. This lets us reach higher speeds and/or wind tighter. The air handling function is negligible on materials that are not smooth. On smooth film, however, a nip is usually necessary at speeds more than a few hundred ft/min. Without enough nip, the roll will be soft, the edges will be rough and the roll may buckle when the air weeps out. However, if we exclude too much air the roll will get too tight causing gage bands to bloom and possibly causing the roll to block. Thus, metering rather than excluding air is the idea.

Unfortunately, there are many things that can spoil the metering function. Since the air layer going in is far less than one mil thick, geometrical errors such as layon roller deflection, alignment, wound roll gage variations or vibration will simply hold the roll off to far to do any good. Also, it may take as much as 5 lb/in of nip load to keep most of the air out. However, your winder may not be designed to load that high or your product may not be able to take loads that high without wrinkling.

Nip rollers improve the stack merely by keeping the air out and winding tighter. However, they will improve the roll edges even more if the layon or nipped roller is wrapped. This causes a precision ground roller to draw and control the web's path rather than a much more geometrically crude winding roll. However, nip rollers can make the wound roll edges rougher if the nip roller vibrates. Thus, nip rollers improve wound roll edges and degrade wound edges depending on the circumstances.

Nip rollers increase the wound roll tightness of 'fuzzy' materials in a very different way. Nonwovens, textiles, tissue and some paper grades will be tightened by the interlayer slippage generated by the rolling nip. With these materials, the nip is usually much stronger in tightening the wound roll than is tension or torque differential. Unfortunately, interlayer slippage can also create defects such as corrugations, crepe wrinkles and a type of telescoping. Nip induced slippage may be good if you want a tighter roll but may be bad if nonuniform slippage causes a defect.

In any case, a nip is inevitable because a nip is always necessary to support the weight of the winding or unwinding roll. Many people would be surprised that their unwind has a nip, but it does. It is the pressure between the core and the inside of the roll. The internal nip on a core-supported winder/unwind has the same mechanics and can be just as destructive as the more commonly considered external nip.

We now see that nip is neither good nor bad. It is both at the same time. In fact, every knob in your plant is both good and bad at the same time. Exceptions are easy to spot:

the knob is pegged or it does nothing. This is a hard concept for some people to accept. They think that a knob must have some sweet spot where the process will run good. The realities are very different, however. A knob has sets of both good and bad things at both ends of its adjustment. Our job is to find a position where the knob does the least harm (rather than the most good). From this vantage it is easy to understand why you can’t always eliminate problems by adjusting a setting. You may have as many as a dozen winding defects that are tension or nip sensitive. You may not be able to solve a dozen problems with a single knob.

***2004.07 Jul 2004
How does gage profile affect winding?

Gage uniformity has a profound affect on wound roll quality. In fact, gage variation can sometimes be so overwhelming that nothing can be done at the winder to effectively deal with it. This includes adjustment of any of the TNT's (Tension, Nip or Torque) of winding. Even changing to a different type of winder may not do it. But we get ahead of ourselves. First, lets define the subject. The word 'profile' is short hand for 'variation of something across the width of the web'. Here, we will confine our discussion to the affects of gage variation across the width and its affect on winding and wound roll quality. This is not to say other types of profile are not problematic. Variations of bagginess, for example, may be cause for wrinkling, especially with a nip.

I recently had a customer complain that one side of their rolls was loose while the other side was tight. They asked what could be done. "Fix the gage variation or throw away the wound rolls", was my reply. Either or, nothing more. Winding tighter to fix the loose side will aggravate the already tight side and vice versa. It does not matter which of the TNT's you choose because the relationship will remain. A similar situation exists for some cases where a roll is starred on one side but not the other. While a uniform case of starring is very amenable to roll structure (e.g., taper tension), starring on one side of a roll is usually not correctable at the winder.

The same is usually true if one roll of a set is starred, but its neighbors are not. The same can be true for other tension related defects such as blocking or gage bands. A defect occurring on only some rolls of a set is often a symptom of a profile problem. What many people do not appreciate is that winding tightness variation is more often determined by gage variation than it is by the winder settings themselves, especially for dense materials like film, paper and foil. The only way we can accommodate gage variations or wind one roll tighter or looser than its neighbors is to wind each roll separately such as on full duplex, differential or slip core winding (Web Works, July 2003).

Another area of problems with gage varying material is wrinkles. The area on either side of a gage band is at great risk for diagonal wrinkles which in themselves indicate that something is 'crooked.' The classic defect here is the corrugation also called chain marks or ropes and often improperly called tin-canning. (The true tin-can is annular ridges that align directly in the MD). However, wrinkles can also occur immediately under the nip. Here, we can reduce the problem by winder settings. In this case, the nip should be reduced to absolute minimum. What minimum means is so low that the material or machine will not let you go further because some even more serious problem develops. With layon rolls, it is often possible to completely remove them. In fact, if you have gage variations the air handling function of the nip is destroyed anyway because the roller is held off from complete contact by the high spots in the wound roll. This is not to say that all diagonal wrinkles in winding are caused by gage. Sometimes it is the machine that is 'crooked' such as by roller misalignment or nip load bias.

As we’ve seen, many defects are directly caused by winding gage-varying material. Gage variation is a root cause, is an ingredient and is in the mechanics of defect generation. However, you will also find that many other defects while not directly caused by gage variation, are affected by it. Mostly simply put, the wider the gage variation, the narrower the window of defect-free operation. If we want to troubleshoot these problems, we need to be able to measure the thing that is causing them, ie, gage variation. Stay tuned. Next month we will discuss some surprising aspects of gage measurement.

***2004.08 Aug 2004
How can I measure gage profile?

Take a seat and prepare yourself for a paradigm shift. What I am about to tell you flies in the face of conventional thinking and practice. Nonetheless, the opinions offered here are based on decades of experience with roll quality and winding in many industries.

If you took a poll and asked “What is the best measure of gage?”, many would cast their vote with scanners. In fact, they have already cast their vote with ther pocketbooks. Scanners have been standard practice in the paper industry for 2-3 decades and are beginning to be so in film. Certainly, the real-time computer display of profile is attractive as well as the many ‘slice and dice’ ways to present the data. Best here is defined as convenient.

Perhaps instead you may cast your vote with caliper or gage instruments found in test labs. They are so common that every Q/A department will have them. Lab instruments are more likely to reject out-of-spec gage than any other means. However, we need to be a little clearer on the usage. In most cases, rejection is based on exceeding some upper or lower limits rather than variation. Thus, you could have a relatively uniform profile but be too high or too low and the material would not be acceptable. It is not nearly as common to reject on standard deviation, pk-pk, derivative or some other measure of gage variation. Best here is defined as traditional.

However, I am going to propose a different ‘best’ measure of gage that is based on seeing and avoiding profile problems where they are most likely to be a problem: the wound roll. Defects that we talked about last month such as hard and soft spots, diagonal wrinkling, starring on one end, corrugations and so on. This measure is also more tuned to the customer. If you listen closely to your customer, you will hear complaints of bad rolls rather than out-of-spec gage. Even if gage variation were the root cause of the troubles, they will not use that language because they as well as many others simply did not or were not able to measure it well enough.

To bring closure to this involved topic, the wound roll is the fussiest customer for level gage. It is also the most sensitve measure of gage variation. We will measure something related to hardness or diameter variation on the wound roll because it is so sensitive and so predictive. Hundreds and even thousands of layers stack to produce highs and lows in the wound roll that are much easier to measure than with a single layer under a scanner or a test lab. A variation of roll hardness of say 5-10 points on the Rhometer or Schmidt Hammer or 10x that on the Parotester may result in ugly and defective wound rolls. [xxx Is it ok to mention trade-names? These are the only ones in common use so I have not left anybody out xxx] Diameter variations are more tedious to measure but nonetheless are also predictive. With nonwovens and textiles, a 2% variation might easily be tolerated. With film and paper, 1% might be too much or way too much respectively. I have seen one foil structure that was ruined, stretched into absolutely unrunnable bagginess, at a mere 5 parts per 1,000 diameter variation. Finally, a very good alternative for bulky products such as nonwovens, textiles and tissue, is roll density (weight/volume).

My experience is that most rolls that were clearly rejectable by wound roll appearance or wound roll measurement would not attract notice with single layer test lab measurements or scanners. Best here is defined as predictive. If you want to know whether your gage is level enough, merely ask the wound roll or an experienced winder operator.

For those that want to know more about gage measurement, my website has a downloadable entitled ‘Secrets of a Level Process and Product.’ There, I offer a more detailed and broader treatment of gage profile measurement.

***2004.09 Sep 2004
Do dancers absorb tension variations?

The short answer is ‘Yes, but …’

Dancers are one means of closed loop tension control. Closed loop control is often preferred because it can compensate for variations and upsets that open loop control such as draw, speed, torque, and differential shaft control cannot. Variations that a closed loop system can counter include bearing and gearbox friction that change while a machine warms up or with age. The most common machine tension upset is merely changing speed. Roller inertia causes a tension change that can not be remedied with most open loop systems.

However, dancers are not the only way to close the loop. More and more, load cells are doing this duty. Load cells have several advantages including the ability to indicate tension and usually being able to resolve (though not necessarily control to) smaller tension variations. One may be tempted to ask why you would ever want to use dancers when load cells are clearly superior in these important ways.

One reply has been that dancers absorb tension variations. However, the damping benefit is not universal. With variations that are low frequency, the dancer neither absorbs nor exaggerates upstream tension disturbances. At very high frequencies the dancer absorbs tension variations, especially if the roller inertia is high. Unfortunately, however, at intermediate frequencies the dancer actually EXAGGERATES the tension variations; makes them worse. Simply stated, at or near the mechanical resonant speed of the dancer system, the downstream tension upsets are worse than the upstream. This contrary behavior gets worse with higher roller inertia. Thus, we can extend the range of the beneficial high frequency response of the dancer by increasing the mass of the arm and roller, but we do so by making the detrimental intermediate frequency resonance worse. To complicate this already equivocating answer, there is an ‘inertia compensated’ design invented by Martin Automatic that improves the overall behavior of the dancer.

Leaving theory aside, let’s talk about application. There are situations where the tension variation absorption benefits of a dancer are clearly desirable. They are cases where the frequency of the upset is high. Examples may include flying splice unwinds and turnups on winder turrets. In both of these applications the shock of the changeover from one roll to the next is a shock with a lot of high-frequency components. Another good application would be rotary die-cutters. Another might be some cyclic advance-and-stop type machines such as a platen press fed by an unwind.

Contrary to common sense, however, you do not want friction in the dancer system. Not only does this not substantially help damping, it spoils the resolution of the dancer. A good design of dancer would have a breakaway friction much less than 10% of the minimum tension to be run on that machine. In my book, The Mechanics of Rollers, you will find how to easily calculate maximum acceptable friction and how to measure it. However, for most garden-variety machines the dancer would need to be moveable with your little finger. For thin webs and/or narrow machines, the dancer should be so friction-free that you could move it with a BROKEN little finger. Many if not most dancers fail this test. They almost always fail for the same reason: too much cylinder seal friction. Rolling diaphragm or glass cylinders are often required to reduce friction. Excessive friction of any type on the dancer will hobble the drive so that fine tension control is simply not possible.

The primary reason we use dancers, however, is not to absorb friction. It is to allow tolerance to a less than stellar drive. If you bought your drive when it was on year-end closeout from your local hardware store, you will not be able to use load cell control because the drive is not going to be responsive enough. Moreover, if your drive guy is the local 'Anything Electrical or Electronic' programmer, you will not be able to use load cell control because he will not know enough about what he is doing to make even a great drive work.

***2004.10 Oct 2004
How big should my rollers be?

Sizing rollers should be a science given certain standards. Standards in turn are based not on good experience, but rather on avoiding known cases of bad experience. Any standard that does not border on and even occasionally cross over into failure is too conservative. Zero defects is economic nonsense here as well as in any other industry. For example, airplane wings will very occasionally break (<<1% of all accidents) if the pilot is careless enough to fly into a big enough thunderstorm. To make the wings strong enough so as to never fail would mean the plane would be so beefy and so heavy as to have no extra payload capacity to carry passengers. Zero defects may mean zero profit.

What failures are we trying to avoid when sizing rollers? Excessive deflection determines roller size more than all other criteria combined. If the deflection is too much, thin materials tend to wrinkle, nips become uneven and vibration may limit speed. Many in the industry have more-or-less settled on a Class B deflection for most applications. Here, the bend of the rollers due to the combined loads of roller weight, web tension and nip will not exceed 0.00015 times roller width. Thus, a 100" wide roller could bend in the middle as much as the 2 thicknesses of a human hair. Some applications, such as with flexible or bulky materials, can tolerate more. A few, such as very precise calenders or coaters may tolerate less. Some applications, such as cores and spreaders, are a compromise: we really would like it to be tighter, but we can't afford it.

Once you determine deflection criteria, your roller size is determined. The width is slightly greater than the width of the web and the diameter is calculated to keep deflection within spec. Even though they do affect deflection, roller wall thickness and material are not significant factors compared with diameter. Surprisingly perhaps, journal stickout makes a big difference. You can judge the skill of a designer from 30' from his machine by merely noting how long the journals are. They should be so short as to have the roller heads almost rubbing on the bearing housing.

While deflection determines roller diameter in most cases, there are other criteria that sometimes require even larger diameters. On very high speed machines, you may want to avoid critical speed or resonance of rollers and this may up the size a notch. On extremely highly loaded rollers, you may exceed a fatigue stress of the roller unless you increase diameter. On heated and cooled rollers, you need a very large circumference to get the dwell time for heat transfer. These rollers are much bigger; usually several or many feet in diameter.

One last area of sizing would be for the inside of wound rolls. Consider the core or mandrel which supports a wound roll as a 'roller'. The diameter of a core supported unwind or winder must be big enough to distribute the wound roll's weight and shaft torque without overloading the web material at the bottom of the roll. Using too small of a core is like running a pickup truck on golf-cart wheels: expect the rubber to walk (telescope) or shred. We have similar learnings on layon rollers and especially winder drums. The paper industry now sizes winder drums to be 2-3' in diameter, even on narrow pilot machinery. Larger idler rollers are similarly more tolerant of wrinkling than smaller idler rollers.

Well, why not just make the rollers really big then? Two reasons: cost of equipment and cost of control. Large rollers cost more money and require larger components such as frames and motors. Also, driving a large inertia is quite tricky, especially during speed changes. Simplistically, large rollers (or many rollers) tend toward poorer tension control.

Thus, rollers are baby bear sized: not too big and not too small. In other words just big enough to avoid most troubles and no more. My book, The Mechanics of Rollers, has several chapters that put the science to the story.

***2004.11 Nov 2004
How important is wound roll edge quality?

Last month we looked at the bilge or the round part of the roll. We concluded that gage profile is most problematic and often best read there. Now we turn our attention to the ends of the roll with a bold statement. If you care about your processes, if you care about your customer, then you must care about roll edge quality. The ideal is often referred to as ‘book end,’ though real book ends are not nearly good enough for many rolls. Rather, a better visual would be roll ends that look like they were cut by a laser and polished.

Wound roll edge quality issues could be broken into performance and cosmetic categories. Some performance issues are rejectable. For example, web width could vary throughout the roll for many reasons. If, however, the customer makes 8 ½ x 11 sheets, the width had better be close to 8.5 inches. The width tolerance of many film and paper rolls may be 1/16” or even 1/32”. In either case, the tape measures you find in hardware stores, even name brand, are not accurate enough for tolerances this small. Certified tape measures or rulers are required.

Curiously, the width of the body of the roll is wider than the top where measurements are taken from. This is due to inviolate physics where interlayer pressure due to winding causes the width to grow because of the Poisson effect. This width growth of the body can be quite large on products such as nonwovens and textiles, but can also be seen on most other products if you look close.

Another performance issue would be offsets. Here, a layer or layers are the proper width, but do not align adequately with their neighbors. This can cause problems with registration on the customer’s machine if they do not have a guide. However, even with a guide the offset may exceed the travel or rate of correction of the guide and pass some of the initial edge position error on to the final product. Another problem with offsets is that the roll edge is very much more susceptible to handling damage.

Other performance issues relate to the cut edge itself, rather than how they align on the wound roll. Perhaps the greatest sin in the paper industry is fuzzy edges. Not that fuzziness itself is a problem, but rather because fuzzy edges are usually accompanied by dust which fouls printing equipment. Thus, fuzzy edges are a proxy for the real problem of dust. In the film industry, it may be angel hair which are tiny threads that got extruded by the blade instead of cut cleanly. Similar issues are found with the skippy cuts that are the bane of score cutting.

In truth, most features seen on the edge of a roll are cosmetic rather than performance. As a practical matter, however, it makes no difference whatsoever if the defect is ‘merely’ cosmetic. The results will be identical. Customers are free to attach that appearance to any trouble they have, with or without sound reasoning. If you have any visible blemish, you put yourself at a competitive disadvantage just as if you send them a performance problem. Perception is the only reality here.

To those with a mechanistic worldview, I will offer this as well: the roll edge is a good place to see process variation. Not just winder variation shows up on the roll, but also variations from forming or converting. If one edge of the roll is starred and the other is not, chances are good you have a caliper variation. If one side of a roll edge is rough, it may be a baggy lane crossing the slitter. If the roll edge has a bull’s-eye pattern, it may be due to upstream oscillation. An offset could be result from a tension upset or a forming upset.

What ever you job duty, mechanical, electrical, customer service, Q/A, operator and so on, paying attention to roll edges is a good first step toward process improvement.

***2004.12 Dec 2004
How can you read roll edge?

The first cut at diagnosing the reason for a specific roll edge feature requires you to determine if the wrap is offset or has a width change. You can do this simply by comparing both sides of the roll by unwinding or slabbing down to that layer(s). If there is an 'insie' on one side and an 'outsie' of the same size on the other side of the same wrap, then the wrap is offset. If there is an insie on both sides, then the wrap is narrow and vice versa for an outsie. Obviously, all wraps are a combination of offset and width variations. However, you only need to look at the largest factor to begin with.

You must do this bit of homework because, as we will see, there is virtually nothing in common between the causes of offset and width variations. In other words, two identically appearing outsies on the same side of the roll could have different causes because one is associated with an offset and the other with width.

Width changes typically come from only a few sources. One would be a tiny pucker that comes and goes in the slitter section. You would be quite surprised how small a pucker could be and still put you out of width spec. One common trouble here is improper pulling of the trim. If the trim is pulled at even a tiny angle with respect to the machine direction or is not pulled with the same tension, a shear pucker will form just ahead of the blade. In any case, our expectations of a good slitter area is a web that is as flat and stable as a table.

Another source of width variation is a variation of tension at the slitter section, going into the windup or as wound-in-tension in the roll. A momentarily higher tension makes a momentarily narrower web and vice versa due to the Poisson effect. A good place to see this is to change the speed of the machine and see the mark made on the side of the wound roll. This blemish is incorrectly called an acceleration offset. It is not the acceleration itself that made it, but rather less-than-perfect tension control during the acceleration. This is probably the most demanding test you can have of a drive is to be able to change speeds without changing the edge of the roll. Vibration of the web run, machine or wound roll also causes width variation that is so rapid that it might make the edge of the roll fuzzy or sometimes gives it a corduroy appearance.

There are other sources of width variation as well that we will simply list without explanation. Any change in the raw material, especially temperature (film) or moisture (paper) could do it. Movement of the slitter blades, holders or framework could do it. Bottom slitter blade wobble, for example, makes a bull's-eye appearance. Air entrained in wound rolls of film and other smooth webs can pull edges in.

Offsets can broken up into two sub-categories, in the web run and in the wound roll. Web paths stray for any number of reasons which will simply be recorded on the wound roll edges. A pair of edge sensors just upstream of the windup can separate web path offsets (difference) from web width variations (sum). Movement of the wound roll has several possibilities. Any axial movement of layers with respect to layers (such as telescoping), core to chucks or shafts, core arms or slides, framework and so on can cause the roll to shift during winding and the web will thus enter in a new place on the roll

A final clue to causes is the diametral distribution of a feature. If it favors the bottom, certain middle radii or the outside of the roll it is most probably winder related. If it is randomly distributed throughout the roll diameter, across the rolls in a set or between sets, the source might be the winder but could also be forming or process variation.

The edges of the roll can be read like the rings of seasonal growth in the cross section of a tree trunk. Some seasons were good; some seasons were not so good.

***2005.01 January 2005
How do you define machine quality?

We are familiar with web quality. We know, for example, that average web thickness should be suitable for the customer's needs and conform to specs for that grade. Tolerable variations of thickness, whether min/max, standard deviation or other measure, are equally important specifications for web quality. We could say the same for other web quality measures such as tensile strength, smoothness, color or chemistry depending on the grades we make.

The concept of machine quality is not as clear. Just as with webs, we could define it by 'fitness for duty'. However correct the concept; it is not so useful in practice because it lacks quantitative detail. Just as with webs, we must specify a mean and allowable tolerance. Let's start with an easy example, width. We would specify the machine to be capable of handling not only a typical width, but any falling in a range between minimum and maximum as determined by machine's owner. The allowable width variation affects the design and performance of both mechanical and control components.

But what about the nuts and bolts of design such as rollers which are the building blocks of machinery? How good do rollers have to be? For that matter, what do we mean by goodness? Fortunately, we have answers to both of these questions if you want to do a little homework. For example, rollers should be round (TIR and taper) and should be aligned. Similarly, rollers should not bend or vibrate excessively. The web should not slip on rollers. Rollers should not load up the web so that tension control is lost and so on. A textbook on the subject, The Mechanics of Rollers has a chapter on each aspect of roller 'goodness' and suggests tolerances. These quality tolerances reflect the successful operation of countless thousands of machines built by scores of builders. They are based on experience. They are a field proven compromise between inadequate quality and unjustified quality. These quality parameters could be written into purchasing specifications to protect the buyer from the occasional design that is not up to snuff and even save money from the occasional over-design. As a rough rule of thumb, rollers should be accurate to around the thickness of a human hair by all measures. Some, like diameter variation on a hard nip, may need to be less, literally a fraction of a hair's breadth. Others, like alignment of rollers with tolerant materials such as textiles, may tolerate several hairs breadths of crookedness.

What about controls? Again we can be guided by experience. The average tension should be able to cover the range between and agreed on minimum and maximum. Equally as important, the tension variation should not normally exceed 5-10% of setpoint, as read by responsive load cells (not filtered and displayed on a PLC). Same with nips. Nip load should cover the range and variations should normally not exceed 10% of setpoint.

Implicit in both of these vital controls are some very important details. First, the correct units for web handling (strength, tension, nip and motor torque) are the same; lb/in in the English system and kN/m in the metric system. Second, the system must be independently calibrateable else we could not be sure that we have the setpoint set at the value we think. Any system which does not include calibration procedures for analog settings or readouts should be refused. Third is to be able to accurately measure variations. Load cells make this easy for tension. Nips can be similarly equipped. However, this may be unnecessarily costly. Instead, there are simple procedures that can measure variation indirectly without using a load cell.

Caveat emptor; buyer beware. Some machinery does not conform to good design (or maintenance) practice. To protect yourself you merely need to write quantitative machine quality parameters such as these into the purchasing specs and include a last payment penalty clause as an incentive.

***2005.02 February 2005
How do you define machine reliability?

Machine reliability is more difficult to define in practice. This is because in normal operation, you can usually only talk about *system* reliability. Let's illustrate the concept with the case of web breaks. The reader can easily adapt this example to their own process.

Just because a web breaks on a machine does not mean that you can point the finger at the machine. It is not the machine it is breaking. It is the web. One might say there is nothing wrong with the machine if you run material that is not so ill behaved, such as carpeting. This may not be comforting to those who do not make carpeting, but the concept is still sound. Similarly, one can say there is nothing wrong with the brittle, cracked paper if you run in on a machine that did not load the web so brutishly. This may not be comforting to those who do not know how to process their web on a conveyor belt, but the concept is still sound.

Thus, web breaks are always a system issue, not a material or a machine as the simple-minded manager might want to conclude. Only when you run that material on that machine do you find that they don't get along together. It does no good to point to another machine and say that one doesn't have (so many) problems. That just reinforces what we already knew – machine details are involved. It does no good to point to another material and say that grade doesn't break (so often). That just reinforces what we already knew – material details are involved. What we must do is list all aspects of machine and material that bear on the issue of runnability. Only after both lists have been thoroughly constructed do we enter the next step – decision making.

This system nature makes is difficult to quantify 'fitness for use' when specifying machinery. Machine builders seldom guarantee that the machine will run even well known grades without defect. If the raw material is troubled enough, such as bagginess, even our best machines may turn the baggy lane into wrinkles. Builders may be more willing to guarantee 'minimal defect' performance if they partner to share profits above that already guaranteed by the purchase.

So how do you protect yourself for reliability? What you should do is to specify reliability in terms of machinery only, not material or process. You could require that the machine run without mechanical breakdown or without controls fault for a period of time. An example would be to run 200 consecutive hours without a mechanical or electrical fault (unrelated to webs). The builder can have as many attempts as they wish to get the machine to that level. However, the clock restarts every time the machine shuts down not related to the web or operator. Merely show them the broken part and you have all the evidence you need. Merely show them the drive fault not triggered by the web (such as a web break detector) and you have all the evidence you need.

On flying splice unwinds and winders with turnups we use a slightly different approach. Instead of time, we use turnups. Turnups need to be 99.x% reliable where the x depends on your tolerance for risk and the cost for downtime. Thus, we might require 200 consecutive turnups (99.5%) without a miss. Here we would need to make sure the operator correctly prepped the roll. We can not blame the equipment if the operator puts the tape on wrong.

Caveat emptor; buyer beware. Some machinery does not conform to good design (or maintenance) practice. To protect yourself you merely need to write quantitative minimum time to failure such as these into the purchasing specs and include a last payment penalty clause as an incentive.

***2005.03 April 2005
How can I measure footage?

The short answer is you can't measure something unless you first define it. This lack of definition causes more trouble between customers and suppliers than does the measurement itself. "Wait a minute," you say! "Length is easy to measure, all you need is to lay a tape measure alongside the web." In concept it is simple, but in practice it can be quite difficult because many rolls exceed 1,000 ft and some are approaching 100,000 ft in length. So tape measures won't work to verify lengths of any but the shortest of wound rolls.

"How about a footage counter," you counter? Better yet, you can count the revolutions of an idler roller using an optical or magnetic target. Even better still, borrow the motor tach output of a driven roller. Each of these is an improvement over the previous because there are fewer moving parts and the ones that remain are easier to work around. Wheel mounted footage tachs are a Fred FlinstoneTM way to do business because they are in the way, wheel diameter can vary due to wear, effective diameter will vary due to misalignment and they are short lived compared to the more elegant roller solutions.

In any of these cases, however, we have two issues to consider. The first is the diameter of the roller or wheel. The wheel's 'effective' diameter is not the diameter of the roller/wheel as measured by a micrometer. It is the diameter plus the web thickness in the case of the roller. The wheel is much more complicated because of the nip, but it also is not the same as the micrometer indicates. The second issue is possible slippage, especially with rollers.

You could avoid contact altogether and still not avoid complications. One way is to use a commercial laser to measure footage or speed. Though expensive, it does not have diameter or slippage issues and can resolve length to 1 part in 1,000. Even with the laser, however, we have all sorts of ways that footage measurement won't agree between the customer and the supplier.

Consider simple web tension. What happens if the supplier measures footage at 2 lb/in and the customer runs only 1 lb/in? The customer will read a length that indicates they were 'shorted' because the web will retract elastically due to the release of tension. Worse yet, consider a supplier 'measuring' 1,000 feet in the roll and the customer sheets 1 foot long products. The sheet under no tension will retract even more. The parts count will be less, even far less for low modulus materials, than the expected 1,000.

Other complications include paper made wet will dry out in storage and thus shrink. Similar behavior happens when film or foil web is measured hot, will contract when it cools. Many polymers exhibit yet another behavior; shrinkage due to crystallization, which occurs well after the roll is wound and packed for shipping.

Even with no instrumentation or material issues, we still have operational chances for discrepancy. When is the footage counter enabled and disabled during the winding cycle? Are wraps taken off the top of the roll during manufacture? Are wraps taken off the top of the roll prior to converting at the customer? Does the customer unwind right down to the last wrap on the core?

I hope this gives you some things to think about when resolving length issues with your customer or supplier. Padding the length does not necessarily solve the problem either. If you pad too much, you give away material. If you pad too little, the customer will notice short rolls. Synchronized systems, such as multiple rolls feeding into a single machine, present an even greater challenge. When the first runs out, all the remaining material will be discarded as waste.

It does no good to look for standards for length measurement to agree on, because there are none. We can only do our best to negotiate a common method or use conversion factors.

***2005.05 May 2005
How much can you trust measurements?

Not at all.

I have worked my entire adult life in and around measurements. Instruments to measure web thickness, length and width. Instruments to measure web tension and nip pressure. Instruments to measure wound roll hardness and roller cover hardness. Instruments to measure this, that and the other thing. When I check them out, however, I almost always find serious problems. Some instruments are bent and broken. Others are uncalibrated or even uncalibratable. Others still are operator dependent. Readings don't agree with other measurements or observations. The customer still complains even when everything is in spec.

At home you will have the clock that is a few minutes off or even stopped. Thermometers usually read close, though the one at the local bank thermometer reads high when the sun shines on it. None of this is of great concern. It is usually close enough, easy to tell when it is not and seldom a big deal. The problem, however, is that the plant is nowhere near so trivial nor so trustworthy.

I have written to you about the difficulties of gage profile measurement (July 2004) and length measurement (April 2005). Elsewhere I have written about wound roll hardness and moisture. I teach about tension, nip and temperature measurement in my web seminars. All have a consistent theme: watch out! Things are not as they seem nor as good as you might expect.

Home thermometers are simple, reliable and easy to check. Not so with plant equipments such as load cells Every single load cell needs to be field calibrated because every position has a different roller weight, mounting, web width, ingoing wrap angle and outgoing wrap angle. Calibrating a load cell is mostly straightforward; hang a weight on the end of a thin strap routed the same as the web. Calibrating a nip is much more difficult, especially if there are geometry changes. On many winders I've seen it take an engineering coop student a whole summer to figure out what a nip control curve was doing. In another winder model, no one in the world, including the builder, could tell you what tension was being pulled by a centerwind assist motor. Compare this to your home thermometer. You don't have to calibrate your thermometer differently whether you hang it on the tree or on the fence, or whether it is two feet or four feet off the ground.

Proper units are another area of confusion. Temperature this is a no brainer: degrees F or C. What are the proper tension units? Candidates include total force, force per unit width (tension) or force per unit width per unit thickness (stress). Yet we see many other tension-like units such as dancer pressure, %, motor amps and others that are nothing less than baffling. A number of our instruments, such as wound roll or cover hardness, have no means of independent calibration. These unique inventions have no simple first principles definition. The best we can do is to provide a test sample for calibration. However, this sample is for only one hardness so the rest of the range is not possible to check. Also, how do you know this test sample was manufactured the same way over the years and that it remained that same hardness (rubber hardens with age)? A good share of our test lab instrumentation is like this.

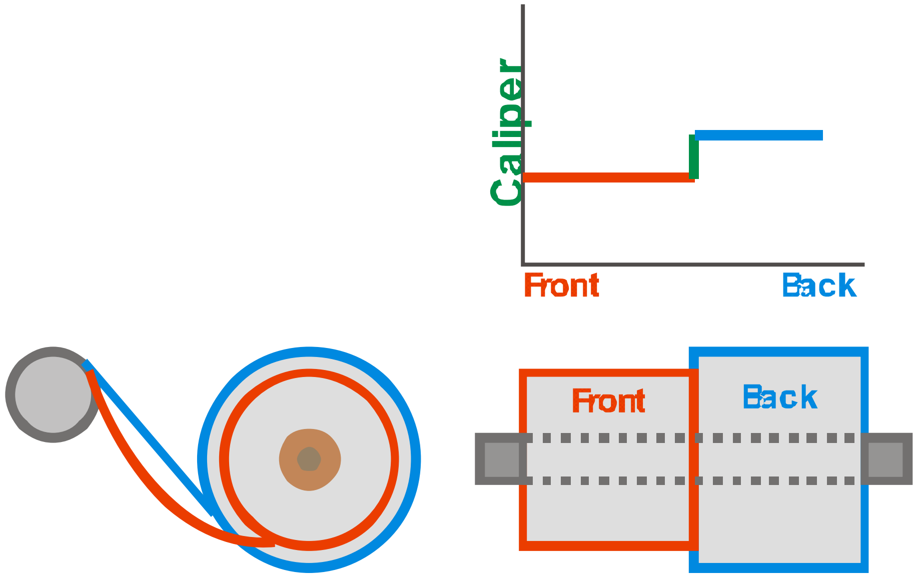
What is a person to do? First, don't trust anything to important decisions unless you check the measurement first. Check its conclusion with other measurements and observations for consistency. For example, a rejectable spec ought to align with customer returns else it is suspect for its primary use. The wound roll ought to look uniform if the scanner or test lab says it is. Second, regularly check and calibrate things that can be calibrated. Statistics are also very helpful to define confidence. Finally, avoid instrumentation when the supplier has not given independent calibration procedures, preferably in fundamental units.

***2005.06 June 2005

Why Should I Use Slip Core Winding?

Some rewinders can apply torque in either a locked or slip core mode. In locked core mode, every daughter roll across the width must turn at the same RPM because the expandable shaft connects them all together. Locked core works fine if the gage profile is quite level or the material is compressible. The problem is that gage variations are a way of life for certain incompressible grades such as film.

As seen in the figure, the individual rolls tend to build to reflect the incoming gage variations. Diameter is not, as commonly believed, proportional to local gage. (The actual gage variation could be an order of magnitude greater than the resulting diameter variation because the winding process tends to be self-leveling.) In any case, thick lanes wind bigger and thin lanes wind smaller. As we look at the side view, we see that the bigger roll will turn at a faster surface speed, thus higher draw and will necessarily pull a higher tension than the neighboring small roll. However, the real problem may be on the small roll. It will turn at a slower surface speed and won't be able to take up as much material. The small roll then winds looser than the big roll. How loose? Quite possibly so loose as to make a gathering puddle on the floor, if you could run that way.



What's the operator to do? The first thing to do is to crank the only knob available; winding tightness. If you pull really hard, you might be able to muscle your way through. If this doesn't do it for whatever reason, you will next look at the root cause; namely gage variation. Unfortunately, the pleas of the winder operator are always ignored. Even if they assemble a bullet-proof case such as:

> The smallest diameter rolls wind loose
> The small diameter rolls are softer by a hardness measurement
> The small diameter rolls weigh less
> The small diameter rolls can be temporarily fixed by throwing scrap into the roll

(To make up for the shortage of material from manufacturing)

There are many reasons that manufacturing will ignore the protests of the winder operator

They do not understand the physics
They do not want to acknowledge the fact that they are the root of the problem
They hide behind the flimsy shields of
    "The scanner/test lab gage measurements do not show troubled rolls."
    "We are in spec."
    "It's the best we can do."

Thus, getting absolutely no satisfaction and probably no sympathy either from extrusion, coating or whoever is responsible, the winder operator is back where they started. Now, they only have one card left to play to reduce waste levels: differential winding. With differential winding, also called slipped core winding, each roll can turn at its own RPM, is independently torqued and thus independently tensioned.

***2005.07 July 2005
Why Should I NOT Use Slip Core Winding?

Slipped core, a.k.a, differential winding, is one way to widen the window of gage variations that can be handled. While it is a way of life for many, however, it is not a cure-all for gage variation. There are situations where it has no application whatsoever. First, it is seldom suitable for surface winders. Second, it can only be applied to multiple rolls wound on the same shaft. Third, it has no utility on compressible materials. Why? Because compressible materials, such as nonwovens or textiles, have enough cushion to absorb gage variations. To check for compressibility, merely hit the roll with a stick. If it thuds, it is compressible. If the stick cracks or rings, then it is incompressible and could be a candidate for differential winding. By this definitive test you may get a different answer for the same material. Very loosely wound film is compressible while very tightly wound film is incompressible.

Not all gage variation patterns are helped by slip core winding. For example, an abrupt change in caliper in the middle of a single roll would not be a good candidate because you can’t have one end of a roll turn at a different RPM than the other end of the same roll. Thus, surface speeds would be inevitably different. The classic gage pattern of medium-low-high across a narrow lane in a roll, which causes the corrugation defect, is not a good candidate for slipped core winding.

Even if you do have a good application for slipped core winding, however, the equipment is quite expensive. A really good shaft on a wide machine could easily cost $100,000. Not only is the shaft expensive to buy, it is also expensive to maintain. The shaft needs to be frequently disassembled to check condition, to be cleaned and to replace worn pads as a set. Some of the cheaper shaft designs do not have clutch pads but rather brake directly on the core itself. On these styles you can generate fiber debris which may contaminate your product.

Then there is the confusion of tension and taper tension settings. Without going into details, taper tension is already so cryptically implemented by builders that even more straightforward locked core winders are not straightforward. With differential winders, any semblance of fundamental units such as starting and ending tensions in PLI (lbs per linear inch) are completely lost. So is everyone else. This is not inherent in the application; it is just the practice of the industry where craft still rules over science long past any sensible reason to do so.

Finally, differential shafts can actually INCREASE tension variations. It is true that since the rolls are allowed to turn independently, it is possible [xxx “possible” in italics xxx] to even out the tensions. There is, however, another bit of physics in play; friction is quite variable. Even with identical settings, such as side load, individual clutches will not develop identical torques. At its best with a brand new shaft of superb design, you might see a 2:1 tension variation from the loosest to tightest roll in the set due solely to friction variations. It gets worse with cheaper shafts, poor maintenance (mixing old and new parts) and poor operator habits (such as spraying WD-40 onto clutches which wind tighter than their neighbors). Here, we might see as much as an 8:1 tension variation. Thus, we merely trade one source of tension variation, gage, for another, namely clutch friction variability.

Just because you own a slipped core shaft does not necessarily mean you should always use it in the slipped core mode. To do so will at the very least wear out parts faster. It could also increase tension variation. The only way to know for sure which mode is best for a given grade or situation is to do a brief study. Run one set in locked core, the next in slipped core and so on for a half dozen sets. Measure and compare the hardness variability of the rolls wound in the two different modes. Whichever mode has the least variability is the one that should be used.

***2005.08 Aug 2005
When should I use gap winding?

Gap winding is used for thin wrinkle prone material. It also may be useful for adhesive coated webs which wind lumpy if a nip is used. Gap winding is a mode where the winding roll and a roller are kept apart with a small gap. The gap is typically as small as the machine controls can safely hold, perhaps 1/8”, but the benefits are still there with much larger values. The principle of operation is this: on the roller flat, on the roll flat. In other words, IF you can keep the web flat on the roller, THEN it has too little room and too little time for a wrinkle to develop. However, if you send a wrinkle toward the winder you will store that wrinkle in the wound roll for all to see. Also, if you inadvertently close the gap you may kick off a wrinkle.

There are tricks to keeping the web flat. The first is to use our best spreading efforts right before the windup. A concave roller or a bowed roller are but two of many possibilities. The concave roller is a roller whose ends are ever so slightly larger in diameter than the middle. The bowed roller is quite a bit more powerful but is often misapplied to the point of wrinkling in a pandemic of over bowing in our industry. In either case traction is required.

The second trick is to use the flattening principle. Here, the roller that forms the gap would be lightly wrapped and slippery to the onset of slippage. Also it is important that this roller is as large in diameter as practical. Thus, we perhaps should call it a drum rather than a roller so we get in the right frame of mind. This principle of flattening is not as widely known as it should be given that its benefits are nearly as useful as spreading.

Obviously as the roll diameter builds, the machine will have to move either the winding roll or the roller to maintain that gap. The diameter of the roll must be accurately known. The most sophisticated and accurate means is the ratio of roller RPM to the winding spindle RPM times the diameter of the roller. With high count encoders, the diameter can be measured to the nearest wrap. Ultrasonics is another means of diameter measurement. The machine would typically move the roll(er) by means of electric motor and gearbox.

The gap winder is a pure center winder. However, our machinery need not be so limited. A full-featured turret winder could be configured to run in a gap, centerwind, centerwind with layon and center-surface wind mode. It takes very little to convert many turrets to include a gap winding mode. Thus, you could use a layon roller for high speeds or thick products and gap winding for especially wrinkle prone materials.

Now the downside. Without a nip, you have no especially good way to exclude air from getting into the wound roll. Air brought in by the web gets between the layers. The problem is not so much going in. It is going out. The edges are not sealed so that air weeps out over a period of minutes to hours. As the air is removed, it is like pulling bricks out of a wall. Remove enough air/bricks and the roll/wall collapses. This is known as an air buckle. The danger of air outgassing on thin smooth webs begins at only a couple of hundred feet per minute (100 mpm). Without a nip you may have to slow the machine down or increase the tension. In the first case you have reduced productivity. In the second case increasing tension can cause defects.

***2005.09 Sep 2005

When should I use Center Wind Assist?

Center wind torque assist is the third knob in the TNT's of winding: Tension, Nip, Torque and speed. It is the least common, most expensive and is easily the most misunderstood. Centerwind torque assist, which we will refer to by the shorter 'torque', always requires two motors. One motor is attached to the winding roll. The other motor is attached to the roller. The roll and roller must be nipped together.

The sum of the two motors (minus drag) creates simple ingoing web tension. The difference between the two motors creates the torque (centerwind torque assist.) This motor application is unusual in that the motors may be opposing each other. In other words, one motor may be turning +20 amps and the other may be regenerating at -10 amps. Perhaps the only other common application for motors fighting each other is in curl control on dual drive laminators. The mechanics is quite similar.

To make the roll tighter, put more power into the winding roll and drag with the roller. To make the roll looser, put more power into the roller and drag with the winding roll. For this reason, centerwinds with an undriven layon roller will wind slightly tighter than a surface wind even for the same tension and power input. On two drum winders, the roll is made tighter by shifting torque to the front drum and looser by shifting torque to the back drum.

What does all of this do? Quite simple. Tension makes the roll tighter. Nip makes the roll tighter. Torque makes the roll tighter (and looser). In other words, at the end of the day when all is said and done, all of the knobs do just one thing: affect roll tightness. Thus, while the winding MACHINE may have as many as four knobs (TNT's), the winding PROCESS has only one knob (wound roll tightness).

Why would you need all of those knobs if they all do the same thing? We should demand a clear answer because these knobs cost money and greatly increase the complexity of the process. The answer is to extend the range. What if nip is giving you trouble, such as damaging material at a gage band? You can back off on nip and increase tension in its place and the roll will end up equally tight. What happens if tension is giving you trouble, such as necking or web breaks? You can back off on tension and increase nip and the roll will end up equally tight. What if you need a really tight roll? Increase both tension and nip.

So why a third knob (torque) when you already have two (tension & nip). Perhaps your first two knobs are maxed and you still need more tightness. Perhaps your first two knobs are in the mud and the roll is still too tight. Thus, the simple answer to the third knob: to extend the range to super loose or super tight. A more complicated but equally valid answer is that the nip knob is not effective on compressible materials over an incompressible surface (core). Thus, some materials will wind looser for the first inch or two because the nip is not effective. Thus, torque can take up the slack (excuse the pun) at the start of winding.

This third knob is expensive not only because there is another motor. Adding a motor to a moving component is not an easy task. Many people don’t know that adding the extra motor will degrade the nip knob. This is because adding offset weight will increase the friction and binding thus making nip more variable. Thus, the third knob degrades the second.

Is there a moral to all of this? Perhaps it is caveat emptor. Know what you are buying, why you are buying it and how you are going to use it. More knobs don’t necessarily increase efficiency. It may just increase confusion.

***2005.11 Nov 2005
What are good sources of web handling knowledge?

Most of our web handling knowledge comes from three principal sources: machine builders, machine owners and universities. I hope not to cause any offense, but of these the (larger) builders have been the single most important source. The reason is simple: critical mass. While a big plant might own a dozen winders, a big builder will have built hundreds if not thousands. The university will be lucky to have even a couple. The exceptions are very large companies such as 3M, IBM and Kodak, each of which had a group whose specialty was web handling. Other companies such as DuPont and Mead have contributed important work even though they never had a web handling group as such.

The role of universities has changed much during my tenure. Three decades ago, what little work they did was piecemeal and largely theoretical. The WHRC, (Web Handling Research Center) at Oklahoma State University changed that in a big way. It was built from the ground up with the guidance from industrial advisors and has been an important force for the past two decades. PAPRICAN (Pulp & Paper Research Institute of Canada) also contributed much in the area of winding. Today, many universities are researching tension control and other web handling subjects.

While the most important information sources were machine builders, owners and universities, they are not the best places to find information. Their product, if it even was publicly accessible, was scattered in thousands of magazine articles, conference papers and theses. When I started the problem was not that we did not know about web handling, just that we couldn’t find it very easily. The problem was at least partially addressed when organizations, such as TAPPI (Technical Assoc of the Pulp & Paper Industry) and later AIMCAL (Assoc. of Industrial Metallizers Coaters and Laminators) and CMM (Converting Machinery & Materials tradeshow), carved out a permanent web handling niche. Magazines, such as this one, also began a steady web handling content. Even so, the problem remained how to find stuff.

The breakthrough began in the 1990’s when the first books on web handling and related areas were written. TAPPI PRESS is the single largest source with over a dozen books in the area. The first web handling short courses also began to appear. Between books and courses it is possible to jump-start your web handling expertise. What took decades to learn in the haphazard fashion of stumbling across stuff could now be learned in days.

The next breakthrough began around 2000 with the internet. Organizations, such as AIMCAL, TAPPI and WHRC began posting web handling content. Magazines, such as Converting Magazine, did likewise. Companies, such as CAC and my own (roisum.com) also publish online. Also about this time, the first live web based seminars were broadcast. While web casts promised to save thousands of dollars in travel for every student, the economics for the supplier are still not clear. A brand new medium is blogs, such as webhandlingblog.com hosted by AIMCAL.

Even with all of this digital content it can still be a challenge to find stuff. Try typing key words such as coat, web, wind and so on into any search engine and you will quickly see what I mean. With so much stuff out there, it can still be hard to find what you want. So what do I do? I started a web handling database twenty years ago and it now contains thousands of articles, books, conference papers, theses and so on, all key worded. An even more important source of information, one that all of you can make use of, is people. If you have a question, it is important to know who to call.

Despite decades of advances in web handling and information handling, people are still often the best resource. My personal computer ‘Roldex’ contains over 10,000 names. Email me. If I don’t know the answer I may know who does. In any case, your name will be added to my ‘Rolodex.’ Who knows, next time it may be me calling on you.

***2005.12 Dec 2005
What are good sources of web handling data?

Last month we discussed where to find general information about web handling. This background is vital because it serves as a skeleton to support information specific to our processes. Without this background our machinery and processes would be an unintelligible mess of unconnected data and observations. Having a web handling background, however, is no more complete than a skeleton is alive. So what if we know about the science of wrinkling? We need further information from our process to know which type of wrinkle we battling at this moment. So what if we know about the science of winding defects? To proceed to a solution requires data to determine which telescoping case we have. Where do we get specific information such as this?

The most obvious source of web handling data, especially to the technical literati, would be sensors. This would include load cell tension readings if not motor loads. This would include nip pressure settings. This would include temperature if heating or cooling were involved. Lab instruments can quantify strength, stretchiness, thickness, color and any other number of important parameters. Some plants are blessed/cursed with a lot of this type of information. One large paper mill continuously gathers and records measurements from over 10,000 sensors. Perhaps we need all this to feed our data hungry programs such as Six Sigma.

Unfortunately, many of our web handling problems do not have practical or even useable sensors. For example, the most common problem in our industry, wrinkling, is not measurable by sensor. Baggy webs are barely measurable and only then at great cost or difficulty. The situation is no better with winding. Of the hundred or so types of winding defect, only a very few can be measured. Even something as basic as thickness often can not be measured good enough to predict troubles, such as seen at the winder.

So, what are we supposed to do if we can’t easily measure things we are most interested in? Simple: open your eyes. While wrinkling is not measurable, it is easily observed. It is certainly good enough to determine whether we have an MD wrinkle, diagonal shear wrinkle, TD wrinkle or so on. With only that to go on we will know how to proceed. Same thing with bagginess. While meaningful measurements are truly painful to gather, your eyes will clearly tell you: the location, width and severity of a slack lane. Same thing with winding defects. Open your eyes and you will see everything you need to know to fix the problem.

The problem is, however, is that technical people don’t like that answer. They insist on measurements because that is how they were groomed. When they can’t get measurements they tend to get lost. Operators, on the other hand, were not indoctrinated in measurements. It was natural for them to notice stuff because they were sensitized from the very first day on the job to pay attention to how their product looked. It did not take them long to figure out that how their in-process product looked was no less important.

So now I am going to share with you my most important troubleshooting tip. talk to but most importantly listen to the operators. In at least half of my problem solving missions, the key piece of data came from an operator rather than engineer, sensor or other source. This message could make some technical people uncomfortable because they were taught to trust science and measurement, not people.

Sadly, many technical people don’t even know how to talk to an operator. Their attitude often looks down at the less (formally) educated and their demeanor shows it. The operator may not respond well to this arrogance. When I work with an operator, they are not my equal. They are my superior. They know things I don’t and what they know is vital to figuring this problem out.

***2006.01 Jan 2006

What is the Best Surface for my Roller?

There are two aspects to roller surfaces; chemistry which we will cover here and topology which we will cover next month. The chemistry of the surface is important because it affects the coefficient of friction, release and abrasion resistance. Often we want a high coefficient of friction so that we can control tension without breaking loose on driven rollers or leave undriven rollers behind. Wrinkle resistance, however, is improved with slippery surfaces. Release is important only for materials which are tacky such as adhesive coated materials or uncured rubber. Abrasion resistance is important for only a few materials such as paper, which has abrasive clays and pigments, and glass.

The chemistry of the roller surface affects one other important property; cost. We want our machinery to cost no more than necessary to do the job. Thus, most roller surfaces are nothing more than the chemistry of the roller body itself. These would commonly included aluminum for idler rollers and steels or cast steels for process rollers. You will also see the occasional carbon-fiber idler roller, though carbon tends to be slippery and has very poor abrasion resistance.

Aluminum is not very abrasion resistant so you might see it anodized. Anodizing, sometimes called a ‘hard coat’ creates an abrasion-resistant oxide layer which is much thicker than forms naturally. This surface coating also serves as a tattle-tail of wear. If the surface wears more than say a ½ mil, the base metal will show through so you will know you need a regrind. Ironically, the people who need abrasion resistance the least, common converters, are the ones most likely to have it. On the other hand, the normally pioneering deep-pocket paper industry seldom does this even though they run abrasive materials at blistering speeds. Many plain aluminum idlers need regrinding after a decade or two of service under these conditions.

The odd thing about chemistry is that most metals tend to have similar COF’s and release. Thus, there would be little point in considering differences between aluminum, steel and spray metal coatings in this regard. Even so, there are several metal coatings that serve a vital function in certain processes. For example, electro-plated chrome makes a very smooth surface to cast against and is much more durable to abrasion and scratches than the roller base metal is. Tungsten carbide is a thermal spray product suitable for most metals and occasionally nonmetals. The challenge in any case is the integrity of the surface bond to avoid spalling. Tungsten carbide is an amazing material in a couple regards. First, it is very abrasion resistant. Second, it can be sprayed on or ground to create topologies ranging from near mirror smoothness to rougher than coarse sandpaper. Topologies, as we will see, can be used to handle air, increase traction against rough webs and improve release. Another amazing thermal spray is tungsten carbide with a Teflon-like material embedded in the matrix. Here you get the best of both worlds such as abrasion resistance plus release.

A very important category of roller surfaces is ‘rubber’ covering, though the material is almost never rubber. Urethane is by far the most common covering because it can be compounded in so many useful ways beyond the obvious cover hardness. However, there are many other cover chemistries that are important for niche applications. Here I will consider only silicone as illustrative. Silicone has two very useful properties. First, it has very excellent release. Second, it can withstand temperatures approaching 500F. It also has two serious deficiencies; it is very costly and has very poor abrasion and cut resistance. Tradeoffs are very common when selecting coverings. The most common reasons for covering rollers in the first place, however, is to reduce the intensity of the nip and to improve the uniformity of the nip profile. Occasionally covering may be used to improve traction. Alternatively, Teflon covers or sleeves provide excellent release. I hope this gives you a taste of better living through roller surface chemistry!

***2006.02 Feb 2006
Why are Rollers Grooved?

Roller topology is at least as important as chemistry. The most common topology is merely the normal finish of the roller body that may be around 32RMS roughness. Tolerant products may only need a less expensive 125RMS coarse finish for things like transport rollers. Drums used for casting optical film, on the other hand, may need super finishing to mirror smoothness.

The next most common roller topology is grooving. Here there is much more mythology than understanding. A near universal belief is that spiral grooving (or tape) spreads the web. Yet, measurement after measurement indicates no spreading. In fact, wide grooving has the contrary effect; wrinkling tendency because tension pulls the web into the grooves. Preaching and teaching of the web handlers does little to stem the illusion of spreading. The ‘barber pole’ optical illusion is so convincing to the eye that people look no further as their minds are already made up.

The primary purpose of most grooving is the same as the treads on your car; maintain traction in spite of fluid lubrication. In the case of tires, it is water handling on wet roads to avoid hydroplaning. In the case of rollers, it is air handling to maintain traction at speeds beyond a few hundred feet per minute. Treads do not increase traction per se and in fact decrease it. That is why race car tires are ‘slick.’ To restate in a different way, grooving does not make traction, it merely maintains it over the desired speed range of the machine.

What grooving pattern works best? At the time I worked at Beloit Corporation, it was the largest web machine builder in the world. A staff of a hundreds engineers working for more than a hundred years produced as much web machine understanding as any other organization. They had more than 1,000 grooving pattern drawings in their vault. Admittedly, most of these were for water handling on the paper machine. Even so, there were plenty of variations for the idler and drum rollers. One of these patterns stood out and became the de facto standard in paper and other industries. It was called the venta-groove.

The venta-groove is about 1/16” wide by 1/8” deep on a ½” pitch. Why these numbers? A 1/16” is about as narrow as can be cut economically with a saw and is not so narrow as to foul easily. Wider grooves may be easier to cut, but will tend to mark and wrinkle the web, especially on lightweight grades. The depth and pitch is enough to give volume needed to handle air at speeds up to 10,000 fpm. The annular groove is simply an economical way to cut a groove, though it was sometimes cut on an outward spiral as a nod to spreading mythology.

Considering the more modest converting needs of perhaps a couple thousand feet per minute, the grooving required to handle the tiny skin of air film would only need be similar to the texture of an old-fashioned vinyl record. Though some offer a ‘micro-groove’, this surface is too easy to fill the valleys and wear down the peaks. Thus, instead of many tiny grooves, fewer big grooves. Beloit got it about right even if they may not have known why.

Even the air handling aspects of grooving also is often misunderstood. Air does not flow through the grooving, rather too it. The best way of thinking about the groove is that is it just a place to park the air. Other topologies, shot peening, knurling, rough spray coatings and so on would be equally good candidates for the air parking function. In fact, the simplest surface is masking tape. It has surface roughness by virtue of the crepes which reach up through the air film to grab the web. We now know, however, that spiral taping does not spread. Rather, it is just a convenient way of applying the tape. Spiral front, spiral back, spiral center or no spiral at all – no difference that we can see if we ignore the optical illusion.

***2006.03 Mar 2006
Baggy Webs – You Don’t Have to Take It Any More

I regularly get calls and emails about what to do with baggy webs. Students in my classes eagerly await learning what web handling techniques or trick that will allow them to run baggy without wrinkling or other troubles. Boy are they in for a rude disappointment.

There is little you can do to effectively handle baggy material. People play endlessly with tensions, spreaders and other things, most often with limited if any success. This is not to say you shouldn’t try. By all means give it your very best shot. However, you should not expect much different results because you and thousands of others have tried the same things over and over with the same limited if any success. It then becomes an inescapable conclusion that excessively baggy material is unsuitable for the application. In other words, it is defective.

You should not have to put up with baggy stock from your supplier. Do not make their problem yours. Do not be dissuaded if the supplier is your own company and you are required to run it. Do not be dissuaded that sending it back may cause you to run short of a material that is in limited supply. Do not listen to their claims that the condition has been corrected. It binds you and your supplier into an endless cycle of beatings followed by pleas for forgiveness. Doing any of these things merely enables the offenders.

First, see if you can measure a profile corresponding to the especially baggy rolls. Great candidates would be the Parotester, Rhometer, Schmidt Hammer, diameter variation, (density variation for fluffy products), or other roll-based measure. If, for example, a hardness deviation of 10 units across a roll was your threshold of pain, then you could require the supplier to measure and cull rolls with variation greater than this. If you can't get a roll-based measure to correlate well to pain, then you should reject based on visual bagginess of the unwinding stock. The sooner the rejection is made, the better. At the supplier is better than before your unwind, is better than after your unwind, is better than at your windup after adding value and all of these are far better than getting a complaint from your customer.

On the first offense, carefully document the roll condition, process conditions and results. Take pictures. Grab samples. Take the offending roll off and carefully pack it for return. Follow up with a phone call. On the second offense, do the same but follow up in writing as well as with a phone call. On the third offense, you send not only the offending roll back with clear documentation; you also send the whole truck back. In this way you will get their much-needed attention.

That is not to say the supplier can fix it. They probably won’t be able to. Those who’ve been in my classes are in much better shape for troubleshooting. However, this only increases the odds from nil to slim. Even if they identify the source component that is not good enough, a problem requiring immense troubleshooting skills, they may not be able to fix it. The offending component may be as good as they can afford or as good as the industry knows how to make. However, if you do not send back the truck you will have zero chance of imparting enough energy to budge this seriously difficult problem. In the mean time, I would look for alternative suppliers. This is usually the quickest means of success. I have not much pity for those of you stuck with a single supplier as this is contrary to careful business practice.

You don't have to take it any more. If you choose to, there is little that any web handler can do for you. You must help yourself. Get out of that abusive relationship. If your purchasing agent, boss or plant manager does not support you, they become like the patriarch of old who arranges a marriage to an abusive husband.

***2006.05 May 2006
Why Can’t You Spread Out a Baggy Web?

There are two ways to define bagginess. Both involve profile variation and both are equivalent. The word “profile” is shorthand for “variation of x with respect to CD position.” One definition is a tension profile variation across the width. The other definition is a variation of length across the width. The baggy lane is longer than its neighboring tight lane. The extra length in that lane can get behind as a bubble in front of a roller, especially a nipped roller. If the bubble accumulates the extra length because it has no place to go, it may burp through the nip as a wrinkle. Bagginess also steers the web and causes path control issues.

Some machines are more intolerant than others even though none will be trouble free. The more rollers in the machine, the more the trouble. Nipped rollers have almost no tolerance to slackness whether caused by baggy webs or roller geometry error. The tighter the required path control, such as with multi-station printing registration, the more the trouble. Finally, thin and high modulus webs are more trouble everything else being equal.

Do spreaders help much to nurse a baggy web through? The experience of countless operators using countless spreading devices on countless webs suggests not. Even if spreaders do help it is so local as to provide no overall benefit. So what if you can nurse the web through one difficult span? What about the seven spans that precede the spreader and the five that follows it? What are you going to do, put a spreader in every span? Admittedly the argument is a little over-played because it may be only some roller positions turn a potential for trouble, bagginess, into real trouble, such as wrinkling. However, intolerant positions are likely to include all nips and most highly wrapped or grippy rollers.

Then there is the problem of how much spreading do you need and how do you adjust for changing conditions. Severe bagginess may require more spreading than on a flatter web. Also, a low modulus web can tolerate more spreading without misbehaving than a high modulus web. Is your spreader adjustable? Most are not, especially if you consider that the re-aiming bow roller orientation does not adjust spreading power for the traction mode.

So why doesn’t spreading work very well, if at all, for bagginess? There are many reasons. First, the nature of bagginess is extra length in the MD. On the other hand, spreading creates extra width in the CD. It is hard to see how these different directions couple together. Second, the defect is a profile problem. In other words, one CD position is different than another CD position. Yet most spreaders, with just a few rare exceptions, are not profileable. In other words, each CD position is treated the same as its neighbor. Thus, you might have far too much spreading in the non-baggy lane and far too little in the baggy lane. Lastly, baggy edges are one of the more common profiles. Yet the two strongest spreaders, the bowed roller and the bent pipe, can not even touch the edges if they are baggy.

So what should you do if you have to run baggy webs? The first thing to try is to adjust tensions. While tension does not cause this type of wrinkle, it can slightly modify the severity. Next, try spreaders of various styles. However, if tension and spreading don’t do it, and it probably won’t, you are pretty much stuck. This is an unpleasant answer because people want some way to salvage less than perfect webs. As we saw last month, however, we should spend less effort trying to save troubled webs and spend more efforts not making them or not buying them in the first place.

***2006.06 June 2006
What is the best type of grooving for my rollers?

This is a great question. However, it can’t be answered precisely for many reasons. First, there are many web types; some of which can’t handle narrow grooves (filling) and others of which can’t handle wide grooves (wrinkling). Second, there are several reasons to groove including handling air entrainment on an idler roller, burping air in a wound roll against a nip roller, traction in the case of very deformable substrates and so on. Motivations for grooving do not, however, include spreading with spiral grooves, despite the widespread belief to the contrary. In any case, the main reason we can’t always give good answers is that we simply don’t know. There has been almost zero research on the subject. Thus, much of the practice in the industry is just someone’s best guess. Hopefully this has been an educated guess where the education comes from trying several things and closely observing the results. All we can do here is to just describe the most common grooving patterns and give some typical applications.

Perhaps the best illustration of grooving patterns comes from the former Beloit Corporation, which in its time was one of the largest (paper) machine builders in the world. Every grooving pattern had a separate drawing. There were more than 2,000 different grooving patterns that had been used at one time or another, the majority for water removal on the wet end. This is not an endorsement, for example, of multiple grooving patterns on different idler rollers in the same machine. It is merely to illustrate that there are many guesses for many distinctly different types of applications. Almost all applications will be well served by just a few variations of the following roller surface options.

Plain Surface
    The most common surface for low speed applications is ‘as finished’
    Also common in narrow web converting

Roughened
    Tungsten carbide plasma flame coating, shot peening, knurling etc
    Used for air handling on idler rollers
    Used for traction on drive rollers against deformable or rough webs

Venta-groove
    About 1/8” wide by 1/8” deep on 1/2” pitch, annular or single lead spiral
    Most common in paper, common in converting
Great air handling
May cause wrinkling on very thin grades

Cross Hatch or Diamond
Common in converting for air handling
Not prone to generating wrinkles on thin webs
Can be noisy

Chevron
Grooving is much wider than deep
Low angle is expensive to machine
Popular for some film and foil machines, but marks or distorts many materials
Noisy at high speeds

Shallow Spiral
    Grooving is much wider than deep
Also single revolution ‘burping’ groove
Used to vent air collecting between layers of a winding roll behind a nip

Finally there are considerations related to the angle of the grooving beyond its web handling intent. A circumferential groove is sometimes costly to cut because of the numerous ‘starts’ on the lathe. A single start spiral (usually from the center out for perceptual reasons) may be easier to cut. A groove that is either circumferential or nearly so in the case of a spiral is much more prone to wrinkling of thin webs which fall into the grooves. A chevron or shallow angle groove is not nearly so prone to wrinkling but can be expensive to cut and can be noisy at higher speeds.

***2006.07 July 2006
Is flat always the best web profile?

Not necessarily, but this is by no means license to open up your tolerance for gage variations. An absolutely dead flat gage and weight profile is usually the best answer. Winders may easily object to profile variations so small that they escape the best scanners and test lab measures. This is especially critical for webs that are easily distorted by stretching over gage bands to cause baggy lanes. This is especially critical for winders which use or require nips such as layon rollers or surface winders.

In fact, the fussiest customer for a flat web is almost always your winder rather than your test lab or end-use customer. In fact, the most sensitive measure of a flat profile is a wound roll that is flat. In other words, what most people call roll build problems are in fact, manufacturing profile problems. Every effort must be made to improve communication from converting to manufacturing. The challenge, however, is that the delay for feedback is much longer from customers than from the test lab to manufacturing. The test lab will usually get results before the next master roll is finished. The winder, however, may be running material that was made days, weeks or even months ago if manufacturing is at another site. Also, (winder) customer feedback is usually qualitative rather than quantitative. If the winder operator or the customer complains of roll build problems, you should listen. These are valid clues for profile variations even though the product may well have been tested and conform to specs for basis weight, gage and so on.

Hints of manufacturing problems are quite easy to see if you look close. For example, a star on both ends of a roll MIGHT be either a web or a winding problem. However, a star on one end only of a roll is almost certainly a web problem. Telescoping that strongly favors one direction is another hint of gage variation. Defects that move from one CD location to another are a strong clue to profile variation. Narrow bands are another strongly suggestive clue for profile problems. There are few very special cases, however, where flat is not always the best answer.

Air Handling – Air will be entrained if you are winding a smooth product, such as film or some paper, at very high speeds. The amount of air depends much on whether a nip is used and if so what the nip load is. If too much air is entrained, roll edge quality may suffer during winding. If you are winding smooth thin film, buckles may form later as air escapes from rolls and allows the roll to collapse. In these cases, the best profile may be the barest hint of a football or convex shape. Even so, the best profile is probably so flat that you won’t even be able to measure the ends being low with typical instruments.

Wrinkle Prone Rolls – A very few rolls would benefit from a tiny concave shape. These cases would often be tacky low modulus products wound without a nip. The concave shape turns the wound roll itself into a ‘concave spreader roll.’

Traction – Another application for a tiny concave shape might be to nail the edges of the wound roll layers to each other so that the roll can be built without offsets and telescopes. This application is also very rare.

Bumpy – There are a few defects on special products where dead flat does not wind well. The only ones I have seen are rare cases involving film.

Even though there are cases where dead flat is not always best, this does nothing to relieve the challenges of manufacturing. To do a decent job on a mild football shape, for example, is far more difficult than mere flat that already escapes most of us.

***2006.08 Aug 2006
What is the best way to tape rollers?

Before we answer how to tape rollers we should ask why tape rollers? There are three common reasons given. First is to improve air handling at high speed. For this case, almost any rough tape put on in almost any pattern will do well provided that the tape is laid on such that it does not cause wrinkles. The second is to spread using spiral tape. For that reason we will say forget it. Spiral tape and spiral grooves do not spread despite much contrary folk wisdom. The third is to spread by taping the edges. We will use different language here, such as banding (bumpers or collars), to avoid any confusion for the type and purpose of taping. This will be the focus of this column.

Before we tape the rollers, we should describe the applications where it works well and where it does not. Taping the edges of the idler roller turns it into a concave spreader. While not a particularly powerful spreader, it is perhaps all that is needed for thin, low modulus materials. Polypropylene, elastomerics and some nonwovens all are good candidates, provided they are thin. In fact, the concave spreader may well perform such magic in these applications that it may be the only spreader you need to learn. Stiffer materials, such as polyester and paper, are marginal. Try it and see if it works. Heavy materials and even thin foils are out of the question. Don't even try as you will more likely make wrinkles than keep them at bay. One last limitation is width. This spreader does not work well at very narrow or very wide widths. Less than 10" seems to be marginal as is anything greater than 100".

If I teach this subject to operators, we will spend about an hour on it. The reason is that letting tape into the plant is like letting cockroaches into a plant. Once in, always in. Thus, we had better get it right from the start. Here, however, I will just give an executive summary for taping rollers to spread the web.

1. Determine which (couple/few) rollers need tape. Those requiring treatment are only those that initiate wrinkles and are probably well less than 10% of the total.
2. Tape only well wrapped rollers. There is no simple, hard and fast rule that works everywhere, but let's start with at least 90 degrees.
3. Both tape and roller must be grippy. Surprisingly, masking tape on plain idler rollers usually works well enough if the wrap angle is large enough.
4. Use only 1-4 wraps of masking tape or similar thickness. Use less tape on stiff webs and small rollers. More is not better.
5. Band is as much as 5-10% of web width.
6. Web edge must end at maximum diameter buildup on roller. Some people taper thickness on the band to avoid an abrupt sharp inner edge.
7. Neatness counts in taping.
8. Evaluate results. All you need is your eyes to tell if spreading is needed/working, provided you look close and without bias.
9. Remove tape, restart process, and evaluate results again using a different operator.
10. If consistently helpful on a certain roller, cut a permanent concave into that roller; provided that the usage always include suitably thin, low modulus and mid-width

applications. Thus, the tape can be used to teach us how to make the concave roller rather than just as an emergency band-aid that it is often used for.

***2006.09 Sep 2006

Why would I want to skew rollers?

Some rollers can be tipped, usually by a screw adjustment. For process rollers, such as calendering, coating and printing, one motivation is to attempt to 'level' the process so that the side to side variation is reduced. Another motivation is to scissors rollers, as is occasionally done on some calenders, to counter the frown shaped tendency caused by roller deflection. Providing adjustments such as this are a two-edged sword. A good operator might be able to take a marginal situation and tip it just enough so that the product becomes acceptable. We all know that for every good operator there are many who are not so good. There is the very real danger, in many people's minds anyway, that the not so good operator may ruin an otherwise acceptable web by misadjustment.

However, it is all too easy to blame the operator. I will claim that the difference in success in applying process skew depends more machine and measurement than operator skills. If the adjustments on the machine are coarse, have backlash or have no precision zero, then the best operators will have trouble. A rough analogy would be the challenge of keeping your car centered in your lane with a quarter turn of play in the steering wheel. If there is no quick and trustworthy measurement of process results, such coat weight and so on, the best operator will be running blind. It would be like trying to keep a car on the road by listening for which tire, the left or right, hits the gravel on the side of the road. Successful skewing requires good machinery and good measures of the process. Only then will a good operator do good.

Some idler or transport rollers can be skewed. The motivation here might be to compensate for a baggy lane. In printing these devices may be used to stretch or skew one side of an image versus the other. In the case of baggy webs or printing, the measurement of the results is visual. The bagginess of a web is far harder to see with as much resolution as a printing misregistration error. This is one reason that bagginess compensation is not so clear. I can give other reasons that bagginess compensation may not be effective. The compensation would be most effective for a pure case of camber, where tension varies linearly across the width, which is rare. Most baggy lanes are too narrow to be treated thus, even if they were conveniently located on one edge only. Also, so what if you did compensate at the skew position? It does nothing for the next span because the bagginess will immediately spring back as no plastic or permanent change has been made to the web.

Then there are the idler rollers mounting on springs or pivots that are somehow supposed to automatically compensate for a baggy edge, at least if you believe the inventor or salesmen. However, there is every web handling reason to believe that these are nothing but evil. They are unstable and usually make the problem much worse than hard mounting a roller in dead level alignment.

I will not claim whether your particular skewing position is a good idea or not. That is for you to carefully judge. What I will claim first is that all of these devices misalign rollers, which we know is extremely risky in its own right. These risks include the uneven processing, wrinkling and apparent bagginess that skewing is supposed to correct in the first place. Thus, you had better make sure that the results outweigh the very real risks. Also, if you do skew, do it well. First, you need a quantitative measure of side-to-side results that is fast, fine and very trustworthy. Second, the movement should be adjustable with a micrometer. Thousandths of an inch at a time in the case of transport rollers, ten-thousands of an inch at a time in the case of a process roller. Third, there should be an aligned zero so that the operator can always come right back to dead flat roller alignment when things are not going well.

***2006.10 Oct 2006
Why should I spread near slitters?

The gold standard of slitting design is spread > slit > spread > wind. In this ideal, we have use two different spreaders. The first spreader is called the pre-slitter spreader and the second the post-slitter spreader. Each has a separate and vital function for optimum converting health. The venerable paper industry has known this for decades but the message has been slow to reach converters. Let me try to explain why spreading should (almost always) be paired with slitting.

The pre-slitter spreader has two vital functions. The first is to make the web dead flat going through the slitter section. Even the slightest of puckers, barely visible to the eye, will be enough to destroy tight width tolerances of the slit product. The reason is simple. The width of the web with a pucker is slightly wider than the distance between the slitter blades. This would not be a problem if one had a constant pucker size, but this is not usually the case.

The second function of a pre-slitter spreader is to provide a small amount of CD tension. This can assist the other stresses at the slitter blade(s) to improve cut quality slightly. Beware, however, that there is a near epidemic of over sizing of almost all spreaders in converting resulting in web instability, wrinkles and LOSS of spreading.

The post-slitter spreader has one function that is totally different than the pre-slitter spreader. Its job is to provide a tiny separation between the slit lanes. This keeps the individual strands from tangling with each other. In paper the textbook separation is 0.030-0.050”. This is just enough so that rolls can be wound adjacent to each other without, in most cases, tying up. In film the separation will be a little more and in nonwovens we will have ten times as much as paper. Some of this separation is the result of a possible slight tension increase at the slitting span with respect the one just upstream.

If we are merely edge-trimming, rather than cutting a wider web into many smaller width webs, we do not use a ‘spreader’ in the conventional usage of the word. Rather, the trim chute pulls the trim at a very tiny angle away from the main web. There is an epidemic problem with converting operators who yank the web sideways in the belief that cutting will be improved. The result is actually the opposite, cutting is greatly degraded when the trim is directed at even a small angle because it forces a shear pucker in front of the blade that is seldom rock steady.

Just as good slitting requires a rock steady web in that area, so too does good edge trimming require a rock steady trim. This can be done in a number of different ways. One is to use a trim pan at the slitter instead of a trim opening some distance away. If the opening is away from the cut point, the trim can be stabilized by running it over the next roller which isolates trim flutter from the trim slitter. Some pull their trim at a ZD angle instead of a CD angle, which is more benign to cut quality, but the above principles apply there as well.

We now see the reasons for the two spreaders. We also see these reasons are different. Thus we expect that if we equip our slitters with two spreaders that they would be sized differently. Using a bowed roller on paper as just an illustrative example, the pre-slitter bow may be about 0.125% and the post-slitter bow about 0.5%. The after slitter bow has more (separation) work to do and the individual lanes are easier to move than increasing the width of an unslit web; thus two reasons for the difference in size.

As we have just seen, some troubles with slitting are in fact lack of proper spreading.

***2006.11 Nov 2006
What is the best way to float a web?

There are two kinds of air flotation: passive and active. Passive flotation is usually called air entrainment. It is a fact of physics that a moving web and rotating roller will bring in a tiny amount of air with them. The amount of air brought in increases with diameter and speed but decreases with tension (and nip in the case of winding). We should expect then that our large process rollers may be more problematic than the smaller idler rolls. We should expect that air entrainment might be a limitation for speeding up a line beyond a few hundred or a few thousand feet per minute. However, web and roller roughness greatly affect the tolerance to air entrainment. We expect that glossy paper and especially film be much more trouble in that regard than say newsprint or nonwovens.

This hairsbreadth of passive air entrainment has both good and bad aspects. The good aspect is that it can increase the wrinkle tolerance of that roller location. Obviously, this goodness only applies when you are at the edge of rejectable wrinkles at that spot. The better known and more common concern is the bad aspects. Passive air flotation decreases the effective coefficient of friction. A certain amount of friction is required to control edge position and traction. If you are at the edge of slipping at low speeds, it would be quite easy to lose it as the line speed increases.

This hairsbreadth or less of air has similar effects on winding. A small amount of air may make the wound roll more tolerant. We have heard the teaching to wind as loosely as possible. Yet looseness in film rolls is largely related to the amount of air in the roll. Loose rolls have relatively more air and tight rolls less in this case.

If, however, we want to float the web more aggressively or more reliably or at any speed; then passive flotation may not be enough. We will have to force air in to lubricate bars so that the web touches lightly (air greased) or more often not at all (air float ovens or air turns). There is a great difference between air greased and air floated bars even if the equipment looks similar.

Air greased bars are found commonly in two applications. One example is the oscillating bars at the top of blown film lines. Another example is the turnover (X-bars) to flip the web so the web can be coated or printed on both sides. The bars are usually piped from both sides and have hundreds of holes drilled into bars over the wrapped arc. Sometimes the air is supplied by compressors, but this is inexcusably expensive and wasteful. We don’t want high pressure and low volume that is the characteristic of compressors. What we want is in fact low pressure (tension/radius) and high volume. This is the characteristic of blowers. You can check whether an air bar is floating by bluing the surface to see if the coloring stays or is scrubbed off.

Sometimes even a light touch on a bar would be unacceptable. Examples include applications with wet coatings and wet inks. A touchdown here would cause a rejectable defect and probably cause downtime as well to clean the bar. To be sure we float we would use air turns to serve as a non-touch roller function or air float ovens (to dry). There is a balance to be achieved here. Too little air will allow touchdown, especially on non-uniform product designs or with baggy webs. Increasing air on air turns increases the risk of wrinkles but decreases the risk on air float ovens. Increasing air on ovens is, however, expensive and decreases the edge control of a long web. This at the very least will work the next edge guide. However, in a more extreme example the web may crash into the edge of the oven. Flotation, much like everything else, is gray rather than black-and-white. There is a best amount.

***2006.12 Dec 2006
Why does my web shift at roll change?

It is so common that you might expect that the web will shift sideways at a roll change. However ordinary, it is no more desirable than the common cold. Whether this is a mere nuisance or fatal depends on the health of the raw material, the converting machine and the product being made.

It is important to understand that an outcome, such as a sideways shift of the web, can be a result of many distinctly different causes. This is not unlike a stomach ache which might be a symptom common to many different maladies. We should not expect that any single remedy would help but a fraction of the cases. Most outcomes are not subject to a 'magic bullet' medicine. The best way to begin troubleshooting most problems is to first diagnose the single cause or mechanics that is present in a specific case. Knowing this will readily yield ideas for treatments. Here we will list some general mechanics as set of ideas to consider as working theories for diagnostics. We hope that the reader will not abuse them by getting lazy on the troubleshooting part.

One cause for shifting at roll change is due to a change in bagginess, sometimes called camber. If, for example, you have three rolls cut from the full width of a producing line that had baggy edges, you would have variable tracking at roll changes. The A roll might consistently turn to the back side, the C to the front and the B to the center. It is imperative that every web handler know how to read the roll ID to tell where it came from on the upstream machine. Astute operators in the printing industry will sometimes sequence the rolls to minimize this shift that would disturb registers for hundreds of feet. If I came on shift, I might cherry pick from the warehouse all of the B or center rolls and let Charlie on the next shift deal with the end rolls. If I ran out, I might then find all the A rolls so the path the web prefers would be similar across roll changes. Bagginess is a raw material defect so that the problem would lie mostly but not entirely with the supplier. (The customer is always responsible to have reasonable product tolerances and perhaps even good guiding in this case.)

It is possible that the winder has made the bottom of the roll different than the top for reasons too numerous to list here. What we will say is that this supplier caused issue on rolls whose appearance is decent is rare, except perhaps on very tender materials such as nonwovens. Thus, a good troubleshooter who knew this would not start looking there unless there were strong clues that the winder was connected.

Often a shift is due to a less than perfect threading or splicing. Whether automatic or manual, the splice might have three different errors: pucker, offset or angle. The pucker or offset is easy to see and thus not so likely to be the cause if one pays attention and practices diligence. However, even the tiniest angular error will result in a kink in the centerline that will give the path or guide a kick to the side that will last dozens of web widths long. In this case it would be the customer's equipment or operator that would be the cause so that a supplier remedy would not be expected unless it was the supplier who had made a mid-roll splice.

Lastly, changes in tension, a likely occurrence during roll change, coupled with any misalignment could easily cause a momentary web shift even on perfect product. Again, a customer equipment issue that is not fixable at the supplier.

I hope this illustrates the importance of good information, good technical knowledge and even better troubleshooting skills. Lists of causes and cures sometimes works, if you can find one, but depends a bit on luck whether the list is any good and that your specific issue is covered and that you work on the right item. Lists are seldom as fast and reliable as good troubleshooting skills.

***2007.01 Jan 2007
Is it hard to speed up a line?

There are two speed 'limits'; real and perceived. Most of the real limits are drive related. Maximum motor RPM or horsepower ratings are the most common. Most other limits exist only in the mind.

I can see thousands jumping out of their chairs claiming Dr. Roisum has off his rocker. What about dryer limits they may say? Dryer 'limits' are common on many coating, printing and other converting lines. It takes so many BTU's of dryer to evaporate so many pounds of water or solvent at the current coat weight, width and speed. If you go faster, the web will not be fully dried. However, even this case is not as black-and-white as it may first appear. What happens is that the defect rate increases, perhaps sharply, as you approach or exceed this 'limit'. Thus speed would appear to be bad. However, speed is also good because without it there would be no productivity. The long and short is that the unit cost as a function of speed is bathtub shaped. Very near the bottom will be maximum profitability. It can be shown that the best speed is not a location of zero (speed related) defects. If you do not occasionally bump into the occasional reject due to under-drying, you are not running fast enough to maximize profit. The interested reader can learn more in an article on optimization that is a download on my website.

However, even if we assume that the knee in the defect curve is so sharp that very nearly zero defect speed is best, we still have opportunities to improve both speed and profit. What about doing a better job of leveling the coating? You could run slightly faster if you don't have the occasional wet spots. What about reducing the average coat weight? If you run a more level coating, you can reduce the average while still maintaining the minimum the application or function might require. In fact, leveling the coating may also reduce winding defects. Lastly, we could ask whether the minimum coating weight was not in fact overly conservative to begin with.

Thus, this seemingly obvious speed limit is not a 'limit' any more than automobile speed is limited to 65.0 MPH on the highway. The limit is fuzzy. Other apparent limits are even fuzzier. Coating quality can degrade due to rheological issues (look into different formulations.) Curing takes time. Cooling takes time. Trim systems plug. Machines can vibrate. The list of items is long. However, none are as sharp edged as one might believe. Also, none are immovable. A modest rebuild may allow a speed increase without taking a waste hit.

Operators will contribute to limitations with a false dilemma of "Do you want it fast or do you want it good?" This is a fallacy of thinking in at least two ways. First, it assumes there are only two choices. I would prefer a third, fast and good. Second, it assumes that speed and defects are correlated. However, many defects are speed insensitive. In web handling only air entrainment and vibration tend to increase with speed. In fact, some defects are inversely related to speed. Wrinkles are one example. Have you ever notices how wrinkles tend to go away as you speed up? This is often easiest to see leaving thread speed.

So we see that most limits are perceptual. However, they can become quite real in the minds of the operators if long habit reinforces the ‘don’t push it’ psychology. The zero defects mentality of management further enables staying in the comfort zone. The limits can become quite real if management codifies these habits with SOP’s or best practices. While I not suggest that consistency is not good, it is just that it is also limiting. If you are not happy with where you are, you have to change something. Considering a speed increase is something we should all take a close and honest look at. There is a best speed to drive on the highway and it is seldom the one posted on the signs.

***2007.02 Feb 2007
What can I do about wrinkling?

The first thing you need to know is where the wrinkles form, not why. In most cases rejectable wrinkles form on a roller, even if the cause is upstream. This is no more difficult that just paying close attention. There only a couple of caveats. First, there may be a couple of rollers that initiates trouble so each source must be identified. Second, the roller that initiates the wrinkle is usually, but not always, the first roller where you see the problem. However, wrinkles are unusual in that they are one of the few defects that can progress upstream if severe enough. In that case, observe the more modest occurrences to find the troublesome roller.

Once you know where the wrinkle starts, observe the angle of the wrinkle such as MD, Diagonal (Shear) and CD. There is little in common between these types in terms of solution and even less in terms of mechanics. I have written and taught much on this subject so I will expect that the reader do some homework here. Briefly, even a small angle of the wrinkle indicates something is crooked. Thus, when you have the Diagonal Shear wrinkle you want to find out whether it is the web (bagginess etc) or roller (misalignment, deflection, diameter variation etc.) that is crooked. If you are not absolutely certain whether it is web or roller, assume for the moment it is your roller and give it your best attention.

If the wrinkle is almost exactly in the MD or very slightly fan shaped, the web wants to be wider. This major class of wrinkle is broken up into subcases that will not be listed here, but are all easily diagnosed. You might choose to identify the root cause and reduce it. Alternatively, you may wish to employ effective spreading. This has to be done precisely at the location you just identified. Two rollers upstream will do no good. Two rollers down stream will be too late. In addition to correct location, the spreader has to be effective. There are many choices here and again we will let the reader do their homework.

Other patterns can also be helpful. For example, a diagonal wrinkle on one side indicates a tipped or carrot shape in the system. However, diagonal wrinkles that are symmetric about the middle are chevron shaped which is a smile or frown shaped system in disguise. Thus, the cause of a wrinkle on one edge is probably quite different than identically appearing wrinkles on both edges.

Unfortunately, least useful information, when the wrinkle occurs (certain grades or conditions) is one most people latch on to. More often this is merely a severity factor rather than associated with the cause. An analogy is the common cold. You can’t catch a cold from getting cold despite your mother’s warnings. You catch a cold from exposure to a virus. However, being cold or more commonly being stressed can lower your resistance to the virus and thus perhaps increase the incidence even though there is no cause here. That is not to say we should ignore incidence, only that we should pay much closer attention to location and angle.

Another simple view is that the location where the wrinkle forms is either incorrect or intolerant or both. Incorrect could include roller misalignment or excessive deflection or diameter variation. Intolerant could mean the roller has excessive traction or is too small in diameter (even though not deflecting excessively). It could also mean that we have given a less than perfect web an excuse to misbehave, even if the roller were otherwise good enough or even perfect. In the case of intolerance we should always bear in mind the first commandment of good web machine design; minimum roller count.

There you have it. No fancy instruments are required. Just pay attention to where the wrinkles form and what their angle and pattern is.

***2007.03 Mar 2007
What is the most important web handling sensor?

Without a doubt, the most important web sensor is your eye.

I grew up with instrumentation at a machine builder who was considered the best in the world in its time. I spent at least a half decade as a manager of research and later as a Ph.D. student. In these environments I had the best instrumentation money could buy. One paper mill complex I visited had over 10,000 sensors logged to computers. Some of the winders I've worked on acquire dozens of sensors automatically at rates of about 1,000 samples a second. I use these resources on occasion, when appropriate.

Even so, the most important instrument in web handling is still the eye. Consider how many sensors do we have to even detect wrinkling, which may be the most devastating defect in our industry? Only one, the eye. Of 1,000 web machines, how many are equipped to measure bagginess which is epidemic in most plants? I doubt there would even be one. Yet bagginess is often easy to see. Of perhaps 100 distinct wound roll defects, how many can be detected with the eye? All of them as shown in Duane Smith's Web and Roll Defect book which has a picture for each. How many defects can be detected by instruments? Perhaps none. Only the risk of few of those defects is even estimated. An example here is an excessive gradient of roll hardness on some grades of paper and film may indicate that roll should be rejected.

Thus we have the bitter truth of the matter. Most web handling and wound roll defects have no electronic sensor to help us in quality control or troubleshooting. This handicaps most data based analysis like statistics or Six Sigma. Occasionally we will grade severity based on eye and use that as input. More often, we only have binary data based on appearance and judgment. These human based measured are notoriously inconsistent with time. Nonetheless, that is what we have and that is not likely to change much in our lifetime.

This lack of relevant data debilitates many technicians or engineers because they were only taught how to troubleshoot based on numbers. They were not taught how to observe or even merely pay attention. I can not even count how many times my client said that the timing of my visit was not good because the web was not wrinkling then. However, right before them was the shadows of wrinkles that if only slightly more severe would be rejectable. Stated in another way, they only had QA eyes of pass/fail, not the eyes of an observer who is already diagnosing the difficulty and estimating risk. A web that is not dead flat as a sheet of glass can be read much like a 'near miss' for an industrial accident.

Operators are not so handicapped. They are visually oriented. They did not grow up with numbers. They did grow up with eyes and ears and they sometimes use them. They can tell when things don't look good even before they are not good. They can do this without the sensors on their machine which by and large are pretty useless for most things web handling. This is why I prefer to spend my time with the operators; they often have the data needed to unlock the problem though it can not be expressed in numbers.

Provided that they have been paying attention, the only remaining hurdle is communication.

All this is not to say that instrumentation does not have its place. Of course it does for certain situations. You can not ‘see’ dryer temperature variation inside the hot box. Your fingers can not estimate web thickness as well as test lab instruments or scanners can estimate. It is just that if you limit yourself to those sources of data, you greatly limit your ability to troubleshoot problems your plant floor.

2007.04 April 2007
What is your favorite management program?

It has been two decades since I was a manager, so my credentials are a bit dated. Nonetheless, I have been in about 1,000 plants and have seen much. Programs come and go, almost like fads. This has left many a plant worker rolling their eyes when they hear about the next 'improvement' coming from above. Zero-defects, quality is king, the customer is always right, lean, 5s and six sigma are just a few of the more recent and popular methods which always begin with, you guessed it, a meeting. My somewhat cynical take on all this is that the only people who will surely benefit from things like this are the soldiers who are promoted into the program and are given a tiny share of the scarce resources of time, money and attention from management.

However, this is not to say that there are not ideas embedded in each of these structures that are not incredibly valuable. There obviously are. The problem begins when a program begins to have a life of its own so that it becomes an end in itself, instead of a carefully chosen tool among many choices that is best for a very particular goal. In other words, instead of a management method or philosophy, we would do better to choose just a particular aspect that best fits our resources and needs on a very narrowly defined problem. It is also important to define this treatment very temporarily so that it has to be re-justified based on merit, results to date and needs rather than allowing it to solidify or calcify into an institution.

I will just take one example from one of the most popular methods, six sigma. Again, I am not picking on this program in particular; similar criticism could be leveled at any other. For those of you not familiar, this statistically based program has the worthy goal of reducing defects. At first glance, this sounds great. Defects cost money and therefore reducing them will save money. Unfortunately, this is a premise or an assumption that is not necessarily true. To explain this in detail would be too difficult in this short space. Thus, I will refer the reader to my article "Optimization by Integration of Business and Engineering Models". This paper is the most important thing I've ever written and can be obtained from AIMCAL, TAPPI (was the keynote address in 2005) and from my website. However, even if we grant that reducing defects reduces costs, we have not shown that profits would improve. Perhaps the costs of the fix plus the costs of the program itself (which is never properly accounted for) exceeds the cost of the benefits. Consider also that a different method might be less costly and achieve even better results. These kinds of questions are seldom given the careful and deliberate thought they deserve.

So I am going to simplify the world as I am always wont to do. What follows is open to and deserves debate. It also poses a false dilemma which the discerning reader will immediately recognize. In any case, I will repose the question to "Which program do you favor, 5s or six sigma?" My favorite, by far, is Kaizen or 5s which stands for

Sort – (Seiri) eliminates unnecessary items, e.g. clutter, from the workplace.
Set In Order (Seiton) finds efficient and effective storage methods.

Shine: (Seiso) is to thoroughly clean the work area to begin with and then daily.
Standardize: (Seiketsu) on best practices in your work area
Sustain: (Shitsuke) demands a new status quo and standard of work place organization.

This is one program that does not cost much, almost always pays for itself, is simple to do (in principle) and is very hard to overdo. So we can resolve the false dilemma by saying that both programs have merit, but 5 should precede 6.

***2007.05 May 2007
What is your favorite troubleshooting method?

I have written a book on, teach and regularly practice a variety of troubleshooting methods. In that way, I may be considered almost as much of a problem solving expert as a web handling one. However, I value troubleshooting skills even more than web literacy. Consider this, even if you had read and understood every word ever written on web handling, you may still have difficulty solving many web handling problems. Why?

Web handling might teaches you how to recognize certain defects or troubles, suggests some potential solutions, but never finishes the job. Thus, for example, a wrinkle at an angle means 'something is crooked.' That knowledge alone is priceless. It gets you started off on the right foot. The crux of the problem is, however, to define precisely WHAT is crooked. It could be a roller that is crooked, such as by simple misalignment. It could be the web that is crooked, such as by being baggy. It could be something else being 'crooked' such as the dryer having a temperature profile variation. At the end of the day we want to be so specific as to be able to touch THE specific element that is crooked that is causing THAT wrinkle.

More daunting is the next step. That is to sell this explanation to everyone involved so that there is a paradigm shift. The selling of a cause and solution is usually the more difficult step, by far, of real-world problem solving. Perhaps we find this diagonal wrinkle was caused by misalignment. We might have to more than just realign that roller. We are likely going to need to retool maintenance practices which may fall woefully short of what is required by the web. Then we would have to retool management's allocation of maintenance money and machine time to fix what is likely to be a systemic rather than a specific issue. As this example typifies, selling is no less necessary and a whole lot harder than diagnosis (which would be easy for a web handler).

So how can you sell things most aggressively? Certainly it would be good to be well-read so that you could point to an article or book which explains/sells this diagnosis and treatment for you. However, as helpful as this is, it may in fact not be adequate to get the job done. Consider management who may not have the time or background to follow the reference article. Consider the operator who may also be similarly limited. Both will more readily respond to a 'show me' challenge that is well-met. So how could you then show them?

A convincing demo is often the best route. You could for this example say to your boss "I understand this problem so well that I can make that wrinkle go in either direction. Which direction would you like the wrinkle to go?" Obviously, he/she is not going to want a wrinkle in any direction and will be wondering about your dedication to company goals. You are just, however, setting them up for the kill. You say "Look, I will move it from the front to the back." (Web handlers will know how to do this by moving a roller mount.) "Now I will make it go away, but this is very difficult to do because we don't have the tools to do this properly." Then you bring mount back midway until the wrinkle disappears. You then go on to explain what must be done not only to fix this roller, but to fix what is likely to be scores of others in the plant that are causing similar difficulties.

I too have set you up by answering a more important question, the answer to which is that the hardest part of problem solving is not usually diagnosis, it is selling the diagnosis and solution. To be fair, I will answer the original question as the 'shape tool.' Now you go look it up.

***2007.06 June 2007
How do you calibrate load cells?

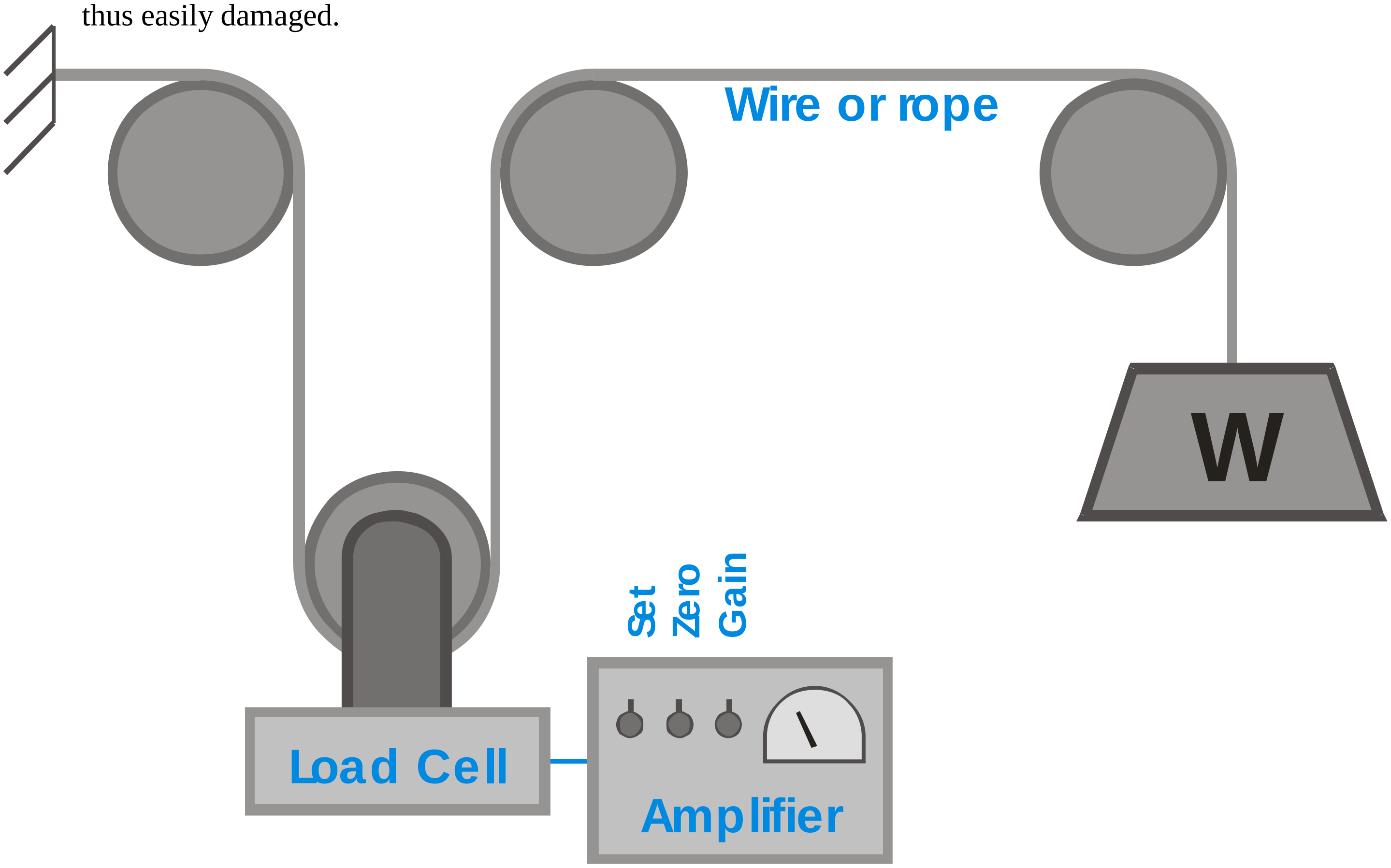
Calibration is required of all sensors simply because none can be trusted. Consider the ubiquitous scale for weighing groceries or the flow meter on gasoline pumps. Regular calibration with documentation is required by law even though these sensors are simple and seemingly bulletproof. One of the tenets of ISO is to calibrate important gauges. I strongly disagree that an ‘indicator’ can be deemed not important enough for this effort. All gauges should be important and should be trustworthy else they should be removed. Trustworthiness is not established merely by buying good equipment. That is necessary but not sufficient. Trustworthiness is established by regular calibration.

Load cells should be first calibrated at the design stage by calculation. The designer should understand enough about the mechanical and control details that the zero and gain can be set close before the equipment is even shipped. Upon installation, the zero and gain should be calibrated again, but this time physically. The zero is easy; turn the knob until the reading is zero. If there is more than one cell, each must be zeroed independently.

Gain is a little more involved. The procedure is to hang weights upon a wire (small machines) or strap that follows the web run in that local area as seen in the figure. The amount of weight should be similar to the full scale design capacity of the machine. If the machine is rated at a maximum of 2 PLI (lb/in) on a 40” wide web, you would need something like 80# available. It is important to note that the proper English units are force per unit width or lb/in. This complicates the procedure a bit because one must specify the current web width in order for the correct units to be computed by a PLC. Stand alone load cells do not usually have the ability to accommodate regular width changes.

Technique is very important. The setup must be as friction free as possible. This means that you run the wire over as few rollers as possible and all must be free turning. If the roller adjacent to the load cell is motor driven, you must use a pulley to simulate the geometry without touching that high friction roller. Even the wire or strap is important. It should be as thin as possible to avoid bending hysterisis. It is easy to check your setup. Reset the weights and the reading should be the same. If not, it is almost always a setup problem having to do with friction. Similarly the reading must return to zero again when the weight is removed. Some people check a mid span load. However, linearity is seldom a problem with modern load cells so efforts would be better spent in other areas. Finally, it is important to have the wire in the middle of the rollers so that each cell shares the load and calibration equally.

There are three indications that the load cell be recalibrated. The first is if the reading does not return to zero with the web off. The second is if there was an accident in the area which might have overloaded the cells. The third is to recalibrate at least once a quarter for precision processes. However, the required readjustment should be quite small. If maintenance finds that the cell needs frequent calibration, you have a design error. Re-zeroing the load cell in that case would be about as lasting as fixing a flat tire by putting air back in. The two common load cell application errors are where electronics drift and with cells that do not have mechanical overload protection and are thus easily damaged.



***2007.07 July 2007
How do you calibrate dancers?

There are even more reasons to calibrate dancers than load cells. Just like load cells, dancers are a tension indicator. Just like load cells, the native units are not proper tension units. In the case of load cells the native units might be 4-20 mA or 0-5 V which have to be converted to lb/in. In the case of dancers, the native units are cylinder pressure units which also must be converted to proper tension units of web force per unit web width.

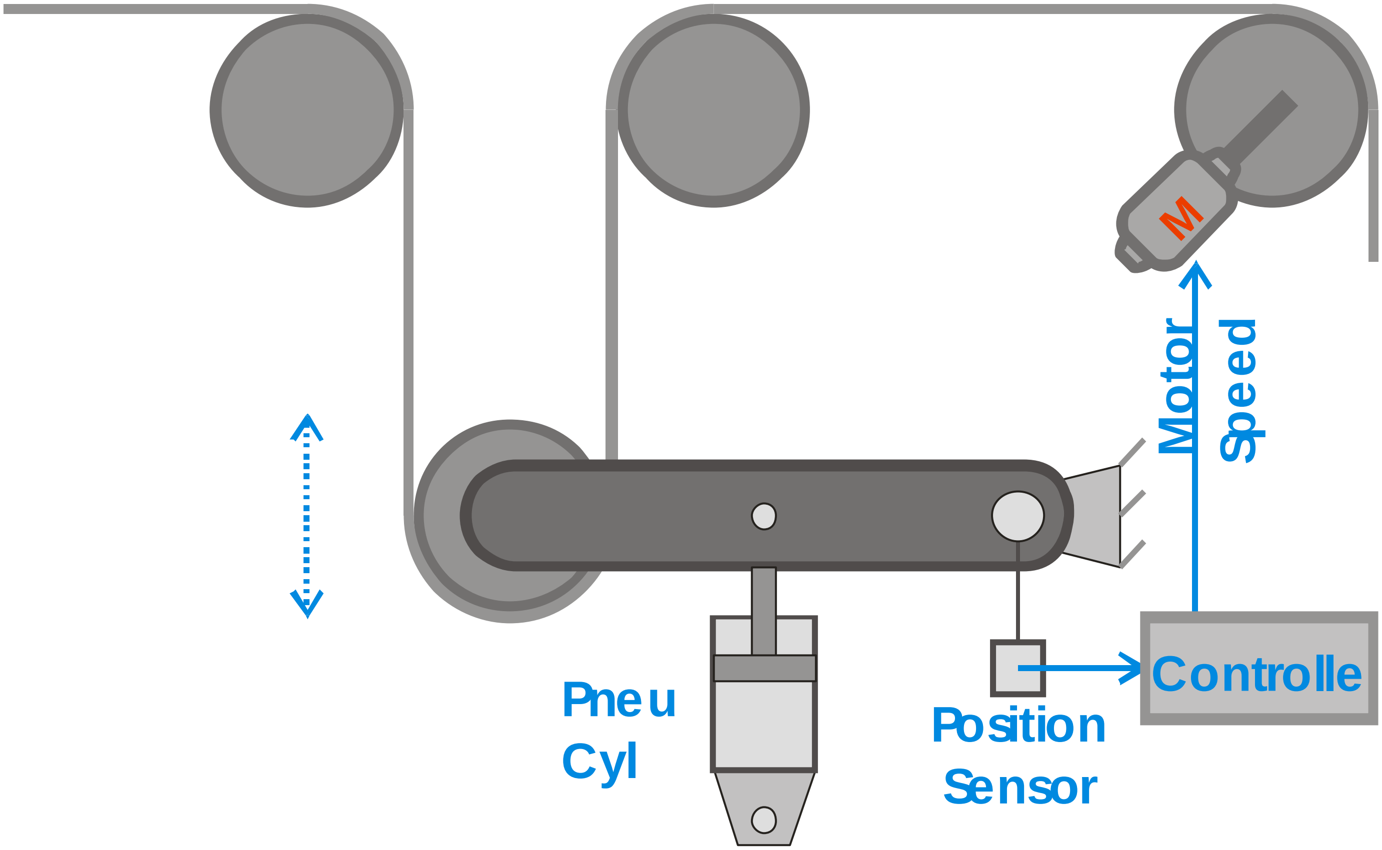
The zero for a dancer is defined just like a load cell. It is the amount of pressure on the control side that would be required to counter balance the weight of the assembly. Whether a counterbalance is actually used is immaterial in this discussion. (As seen in the figure, a good design might use a counterbalance pressure on the piston side of the cylinder to mechanically zero the system. The control pressure applied to the rod side would be then used purely for tensioning the web.)

The gain for a dancer is calibrated in the same way as load cells were described in last month's column. We merely hang weights corresponding to something like the full scale design tension of the machine. It is may be good to use a mid-weight check as well. What the instrument technician has done so far is to create a table with three pairs of numbers. The x column is the load applied and the y column is the pressure required to balance that load. A line is fitted and a conversion formula is obtained.

There are two ways to implement this calibration depending on the equipment you have. At the very least you can apply a stick-on overlay to a standard analog pressure gage where the new force per width scale accompanies the pressure scale. Alternatively, you could make marks on the glass with an indelible pen for the new scale in proper tension units. With PLC's, you can take the P/E transducer output into the PLC and compute a proper tension.

However, there is one distinct difference between load cells and dancers. Load cells have no significant hysterisis while dancers usually have debilitating hysterisis caused by mechanical friction. The piston seal alone is enough to cripple the sensitivity of most dancers. The amount of friction or uncertainty in a dancer can be measured in a number of ways. One is to find the amount of additional force required to move a balanced dancer. Another is to 'weigh' the friction as the difference between raise and lower pressures. Another would be seen by the calibration procedure itself as resetting the weights would give slightly or significantly different answers. How this friction is best obtained is a matter of what is easiest to set up. However, how much friction is allowable is even easier to state. Friction should be far less than 5% of the lightest tension to be run.

Most dancers fail this and thus hobble fine tension control. The drive is then in bang-bang control much like a furnace going on and off. In the case of dancers, the tension wanders in the dead band of the sensor. If friction is excessive, it is usually necessary to replace the cylinder. The simplest replacement would be a bucket with weights. Alternatively, a rolling diaphragm or seal-less cylinder might be used.



***2007.08 Aug 2007
How can I take away trim?

Nearly every web manufacturer and most web converters have to cut and remove trim at one time or another. Unfortunately, you can have as much trouble with this small piece of waste as the entire rest of the web. There are three vital tasks for smooth trim takeaway: cutting, pulling and removing.

First we must cut the trim which is often the same as cutting intermediate positions. However, consider that the trim slitter is almost always cutting while intermediates slitters may often be idle. You would then expect that even with greater attention to the trims, the reliability there may still be lower there. Also, the trim removal systems may not pull the trim flat and cause problems at the trim blade, which is not a risk for intermediate cuts. Sometimes the setup of the trim cut is slightly different than intermediates. With intermediate shear blades, for example, the toe in may be ½ degree all to one side, while the top trim blades may toe out by 1 degree at the trims. (These values are for paper; the values for film are less while bulky materials are greater). Operators and maintenance must take care when changing parts to make sure that the shims used to do this correspond to the correct slitter position. Perhaps the only thing that sometimes makes the trim easier to cut is that it may not be a final cut. A pre-trim or rough trim need only be reliable. It is not so fussy as to width tolerance and cut quality. You might, for example, be able to pre-trim with a water-jet when that type of slitter would not be good enough for a finished cut.

Second, we must pull the trim away. The exception to this is to wind butt rolls on the end positions that are then thrown away. Just as with trim, you can expect more troubles with the butt rolls than with the rest of the web because they tend to dish or otherwise fall apart during winding or handling. Some converters will wind the trim on a separate trim winder which has the same requirements as a trim system.

Pulling trim away is where most people lose it. The trim should ideally be pulled with the same tension vector as the main web. That means the same direction (as if it were not cut) and with the same magnitude. However, it is common to see operators set up the trim to pull a bit sideways. While this might help keep the trim from getting tangled in the main web, it puts an unstable pucker in front of the blade. The other requirement is to pull (almost) as hard on the trim as the main web. This is hard to do in practice so again the result is a diagonal pucker in front of the blade. Once the trim is passed over an isolating component such as a roller or a pan, then the trim can be bent or redirected. This isolating component keeps the trim system from talking to the trim slitter. In the order of best to worst, the direction to pull would be: along the path of the web, slightly out of plane, and sideways (which is the most common operator setup). Judging the quality of design and setup is easy. The trim is dead flat and dead stable near the cut point.

Finally, we must dispose of the trim. If it can be recycled internally, it must be re-pulped (paper) or reground (film). Here, it is not just the material savings that is important because trim is usually far less valuable that virgin material. Indeed, recycling often causes process chemistry headaches. Other benefits are the reduction in handling and disposal costs. Unfortunately, mixed materials, such as laminates, are seldom recyclable. Here, we may bale the trim to reduce the volume.

All of these steps and more are vital, for if you lose the trim, you’ve lost the web.

***2007.09 Sept 2007

What should I expect of pneumatic trim removal systems?

Pneumatic trim removal systems are something like industrial sized vacuum cleaners. Even so, there are many things that can go wrong.

The first component, the inlet or trim chute, has had the least attention and is often the most troublesome. Here is where there is some true economic disparity. In the paper industry these chutes may be $20,000 each. It is difficult to describe in words their complex construction so instead imagine the air scoop and carburetor on a race car and you will get a rough idea of the thing. In converting, however, they may spend all of $2 to cut a flexible pipe to length. The operator may then craft a precise positioning device using duct tape and baling wire. At the peak of creative effort, converters will sometimes put a funnel on the end.

The need for a serious effort on a trim chute is clear. You need to have a dead flat and dead stable trim at the cut point. This may be a challenge considering the breadth of materials that may be run. In paper, for example, the trim may need to be pulled away at speeds of 0-10,000 FPM. Speed ranges such as this usually require speed programmable blowers that track winder speed. Pulling too hard at low speeds can cause the trim to break intermittently and jump in the chutes. Pulling too little at high speeds can result in a nasty plug up in the blink of an eye. Consider also that trim widths may vary from 1” to 10” and that calipers may vary on order of magnitude and you see that the trim weight itself may vary two orders of magnitude. Also, web and trim width variations mean that the trim chute must be quickly and precisely positionable.

Piping is the next place for trouble. All piping should be appropriately sized, have a smooth interior, have extremely generous bend radii, have constant cross section and so on. Sometimes static electricity or fouling by contaminants dictates the materials that can be used on the piping. The piping may be interrupted by devices such as injectors, eductors, choppers, inline fans and so on.

Somewhere in the system there is a blower. There are at least three common blower problems. The most serious is to use a central blower to serve many machines. While the economies of scale sound attractive, instead of a separate blower for each machine, there or more ways this can fail than work well. The most common problem here is when one machine stops or goes down, the balance of air is disrupted for the others. A second problem is under sizing the blower. You must do more than pull the trim away; you must pull hard enough so that a diagonal wrinkle is not formed in front of the trim slitter blade. Finally, the inlet and the blowers are noisy which have a cost that is invisible to simple management metrics.

Lastly, we must separate the air (and possibly dust or other contaminants) from the trim. This can be done elegantly in a cyclone, but there are sometimes simpler methods that are adequate. In any case, the sum total of all of the components that must work together over a wide range of conditions clearly indicates this is not a do-it-yourself project.

There are only a couple of suppliers who specialize in web trim removal systems and we would rely on them for advice.

Judging the efficacy of trim removal is really simple. First, the trim is dead flat and dead stable at the cut point, always. Second, the trim always disappears down the hole so reliably people forgot what happens to it after that.

***2007.10 Oct 2007

What is the Best Instrument for Measuring Wound Roll Quality?

Your eyes. Seriously. If you look at the 100+ defects in the encyclopedic Roll and Web Defect Terminology, you will see a picture for every single defect. However, not a single measurement is given anywhere in this must-have reference. If you listen to your customer's complaints carefully, you will hear something like 'your roll looks like ____". Only a very sophisticated customer would use language such as gage variation is excessive. If you consider the customary practice in the industry, visual culling is the norm and roll quality measurements are not.

However, as an industry we are quite uncomfortable with this situation even though it will likely be common for our lifetime. Visual rejection is neither quantitative nor consistent. Since it is not quantitative, statistics and other tools are handicapped by the binary nature of the go/no-go data as opposed to the richness of analog data. Since visual measures are not consistent, our saleable product is not as well.

The only way we can make the product more consistent is to reject anything that is visible. There are advantages to this approach. First it avoids the foolishness of distinguishing between functional and cosmetic defects when there is none. To convince you of this, try to tell your customer that a particular defect is only cosmetic. If you do, you will find that the defect is not only real; you've just made the situation worse. Second, rejecting anything that can be seen more-or-less takes judgment out of the quality assessment process. Unfortunately, few make products that are blemish free and many could not stand the rejection losses from a bar this high.

Having said all of that, most everyone should have tried roll hardness measurements. They work on more products than any other class of instruments. They work on most paper grades with the exceptions of extremes in hardness such as tissue or board. They work on many film grades. They work on most laminates. By work I mean that they have been statistically proven to correlate to a number of common defects. By work I mean that they have proven themselves trustworthy enough to reject solely based on an excessive hardness variation across a roll. In the paper industry, it is the supplier that usually rejects. In the film industry, it is the customer that usually puts maximum hardness variations into a purchasing spec.

So why has roll hardness variation proven so useful? It is because many of supposed 'wound roll' defects are really directly caused by the winding of excessively gage-varying web. Common examples here are baggy webs and corrugations. However, even roll defects that are not directly caused by gage variation are made more frequent by variation. The reason is that gage variation is often responsible for a greater variation of stresses in a wound roll than the nominal stresses caused by the winding process itself. So in effect, roll hardness variation is really measuring gage uniformity that is either the root cause or a major contributor to most winding defects. We measure wound rolls because they are usually far more sensitive than direct measures of gage.

The roll hardness instruments that are currently available include: the Backtender's Friend, the Parotester, the Rhometer, the Schmidt Hammer and the TAPIO RQP. So which these roll hardness instruments are best for you? What alternatives to roll hardness might you try if hardness is not appropriate? What causes wound roll defects? Can wound roll defects be predicted? All of those questions and many more are answered by Winding: Machines, Mechanics and Measurements. This book is a must-have for anyone with winding troubles. Another resource that covers many subjects in web handling, converting, winding and industrial problem solving, including wound roll defects and measurements, is WEB101SM CD. All of these reference books are available from TAPPI PRESS and other book publishers and resellers. To paraphrase a Bell Laboratories saying "A month in the plant can save you an hour in the library."

***2007.11 Nov 2007

What is the Best Taper to Run on My Winder?

I wish taper tension had never been invented. It was invented solely as a convenience to the electrical people decades ago when cams and proportional controls were about all there was. There are far better ways to do things now. That is not to say that taper does not have utility, it is just that it is very confusing to the people who have to use it.

Taper tension has two settings that must be selected by an operator: starting tension and % taper. Starting tension is straightforward enough. % taper is not. First of all, taper is not in the correct web units of tension so comparing the first number to the second is literally comparing apples to oranges. Second, where you end the roll is anyone's guess. The taper is usually applied over the maximum diameter capacity of the machine rather than the actual roll diameter that is being run. Thus for example, you could calculate the ending tension of a 0.60 PLI start with a 15% taper on a 23" diameter roll for a winder with a 30" capacity, but only if you were an engineer. Finally, how to change a taper based setting to reduce winding defects is not at all clear.

The four point method is the most straightforward of the modern winder control schemes. Here, the computer needs four pieces of information: the core diameter, the roll diameter, the starting tension and the ending tension. While this seems to require twice as much work, a quick reflection will convince you that the modern winder will already know core and intended roll diameter. It will be part of a grade recipe that is extremely straightforward and only needs to be entered once. Thus, the operator will at most have to struggle with two inputs: starting and ending tensions. Already this is comforting because they are in the same units. The operator will know that a 2 PLI tension is twice as big as a 1 PLI tension whether that is staring tension, ending tension or in between tension.

So, how does the operator set these two values? First, the operator must know what defect(s) they are trying to reduce. Second, they must know whether these defects favor the core area, the outside area or are global. Finally, the operator must know whether the defects are tight defects or loose defects. This seems like a lot, but really is straightforward and everyone should know these things for their machine or they should learn them. Then a truth table can be made

Location	Tight/Loose	Example	Move
Core	Tight	Blocking, Crushed Core	Decrease Starting Tension
Core	Loose	Telescope During Unwinding	Increase Starting Tension
Outside	Tight	Baggy Lane Due to Gage Variation	Decrease Ending Tension
Outside	Loose	Out-of-Round Roll	Increase Ending Tension
Global	Taper	Telescope During Winding, Starring	Inc. Starting Tension & Dec. Ending Tension

This table shows just how straightforward most winder moves can be. If you have a tight defect in a part of a roll, decrease the tension in that part of the roll. If you have tight defects throughout the roll, decrease the tension at both ends of the roll. Perhaps the only conceptually challenging defects are the rare occurrence of global defects such as seen on certain types of starring and telescoping.

For the advanced reader, we have two additional complications. One is that for race car tuning for one type of telescope, we can do slightly better with a curve than merely by increasing the start and decreasing the ending tension. The other complication is more common. What if you have tight and loose defects in the same part of the roll? This is addressed in my paper Optimization by Integrating Engineering and Business Models that is perhaps the most important thing I've ever written. It can be downloaded from my website.

***2007.12 Dec 2007
How can I wind material with bad gauge profile?

This sounds like the setup for a joke. The punch-line is, of course, “very carefully”. More specifically, you really only have a few options: wind very short rolls (a few dozen wraps ought to be OK), send the ugly raw material back to the supplier, or wind soft and live with the remaining gauge related defects.

Our greatest fear in winding is being asked to wind a material with a profile problem. The word ‘profile’ means variation of ____ across the width, where ___ could be thickness (gauge), MD tension (bagginess) or any other property of interest. Some people would say this is like trying to make a silk purse out of a sow’s ear. However, that is not really a good analogy because in many cases the web itself is fine enough for end-use if the winding step could be avoided, such as by sheeting at the end of the manufacturing line. The web is not fine, however, if you regard the winder as your customer. The winder is usually the most sensitive customer to gauge variation and the wound roll is the finest measure of gauge variation.

The fear is that a number of serious defects are directly caused by gauge variation. The most common is the baggy lane created by yielding (stretching) over the ever-so-slightly bigger diameter at a gauge band. However, ANY defect that is sensitive to winding tightness is also sensitive to gauge bands. Whether you have a tight defect or a loose defect, all are made more frequent and more severe in the presence of gauge variation. Consider blocking, a tight defect, which is the sticking together of layers in the wound roll. The defect will form first at the high gauge area, it will form far earlier than it would have otherwise and it will be more frequent than if the web were level. While a winder might be able to have a useful range of 2:1 on tightness, gauge variation could easily cause a pressure variation of 20:1 or even 200:1 across the width of the roll on stiff materials. Thus, many pressure sensitive defects are more determined by (gauge) variation than the (winding) mean. The same principle applies to loose defects. If, for example, you get a bubble behind the nip during winding, it will be much worse with gauge variation because the air will seek the low spot in the wound roll. If the web were level, the air would be uniformly distributed and seldom a problem itself.

Not only do gauge variations limit the defect-free window of operation, they limit the range that the TNT’s of winding can be useful over. If you had a dead level product, you would have a wide useful range of nip load adjustment. At the low end, you could apply low (surface wind) or literally zero (center wind) nip load without the nip misbehaving. At the high end with a dead-level product, most papers and films could withstand a nip of dozens of PLI without direct damage from the nip. Thus with a level product the range is low to dozens of PLI. Now consider a mild gauge variation. You might not be able to apply even a couple of PLI without wrinkling near the gauge band. With a more vivid gauge variation, you may not even be able to touch the wound roll with the nip without it misbehaving. Thus, just as the material challenge rises, the useful range of the winder adjustment closes up.

The experience of operators and the science of the web handlers are quite clear and quite consistent on gauge variation. All you can do at the winder is to wind as loose as you can get away with without causing even worse problems. After that, the problem is no longer a winding problem because there is no winding solution. You then have to live with the problems or redesign the web or roll product. Specifically, the web might have to be made more level or the roll made much, much smaller.

***2008.01 Jan 2008

Can you apply DFM to winding?

Of course you can. However, you really have to think outside the box so that the winder is considered a vital step in manufacturing instead of an after-thought. DFM stands for Design For Manufacturability. It recognizes the futility of making a product that the end-use customer really likes if manufacturing costs, such as waste, prohibits profitability. It recognizes that sometimes waste and delay in manufacturing can be reduced by slight changes in product design that would be acceptable by the end-use customer.

So this is not really a new idea in itself. It is just that, until recently, winding was not considered on par with upstream manufacturing. That is, until winding defects forced a rethinking of this narrow view. There are scores of examples of products which are re-designed to make them more windable. The paper people change clay suppliers to reduce crepe wrinkles and change soaps to reduce winder vibration. They may add frictionizers to reduce the slipperiness of paper board and thus avoid telescoping. They may reduce frictionizers to avoid vibration of kraft paper. In all of these cases material costs rise noticeably and the chemistry consequences are far-reaching. Even so, the paper people recognize the payback. You can’t sell what you can’t wind. Film people have also started to modify the outer molecule of their products to keep them from being too tacky or too slippery.

Some properties, such as gauge variation, you always want to minimize. A converting example is to reduce the ink add-on during printing. For other properties, you want to avoid extremes. COF is a great example where problems arise at either end of the scale. The following table gives just a few examples to consider for DFM applied to winding.

Thickness
    minimize intentional variation such as ink add-on
    minimize unintentional variation such as gauge variation
    maximize symmetry with any variations that are otherwise unavoidable
Coefficient of web-web friction
    Low friction risks telescoping
    High friction risk blocking, out-of-round and vibration
MD modulus – extremely low and extremely high stiffness products may pose runnability issues
MD strength – avoid low strength to avoid runnability problems such as web-breaks
ZD resilience – avoid low durability else suffer from vibration and/or permanent bulk loss
Dimensional instability of any kind – even 1 part in 1,000 is truly frightening
Roll Size – small cores, large finish diameters and tall aspect ratios can all be risky

The major problem, as always, is seldom technical. Usually it is mostly a people problem. You have different people responsible for product design, manufacturing and winding. At its best, they merely do not understand each other. More typically, they don’t even communicate with each other. Thus it usually falls on the shoulders of management or the web handlers to explain the issues and how they relate to product and process design choices.

More often the problem is with debilitating attitudes such as complacency (let the winder people work it out), fear (we’ve not done that before) or paralyzing fright (we might upset our customer). That, coupled with a truly remarkable lack of understanding of winding, always has the same results. Continuous problems in the winding department and with the customer related to wound roll defects. Ever see anything like that?

***2008.02 Feb 2008
How close do I need to align my machine?

A decade ago in this column I tried to answer this complicated question and did not do a very good job. I can now answer this question definitively; it depends.

The first thing it depends on is whether you are looking at ingoing tolerances or outgoing tolerances. Ingoing tolerances apply when you decide to move a roller. A part of a hairsbreadth (0.002") level and square would be appropriate in most cases. The reason is simple; you can usually hit that target in but a single move using precision measurement methods such as optical tooling. We have done this for the better part of a century in the paper industry and know that hairsbreadth tolerances are rarely difficult. The exceptions have to do with specific parts of machinery that may have looseness; be bolt-bound or where the alignment measurement is compromised. The exceptions allow us to relax our aggressive standards IF we know from experience/theory that our best simple effort is good enough for that specific location.

Outgoing tolerances decide if you are going to move a roller and that is where the discussion gets interesting. Just because you can hit 0.002" does not mean you need to MAINTAIN outgoing tolerances of 0.002" or 0.020 or even 0.200." Like everything else, our roller maintenance efforts must pay off such as by reducing alignment sensitive causes of waste and delay such as wrinkling and web breaks. Sensitivity in turn depends on material (thickness, modulus etc) and roller (width, span etc) factors. We are now able to calculate how close alignment needs to be to avoid wrinkling and can make some estimates to avoid increasing the incidence of web breaks. These calculations are the result of decades of work at the Web Handling Research Center at Oklahoma State University, but are only available to their sponsors. Now, the public has access to similar tools. TopWeb can estimate the tendency to wrinkle as well as the stress riser that would exacerbate web breaks.

Something else that has a huge influence on the answer is whether the misalignment is in the parallel or skew direction. In-plane, parallel or tram misalignment is by far the worst. It is about 100X as damaging as out-of-plane, scissors or skew direction. Guides, for example, make use of large but controlled misalignment to move the web without damage. The good troubleshooter would make use of that knowledge by only moving where it counts. Consider an accumulator. We would only be concerned with the easier obtained level of each roller because that causes in-plane misalignment. Efforts to square those rollers would be totally wasted.

Thus all things considered, it depends. For very thick and tolerant webs such as textiles and rubber, we might be able to fine enough with a precision level (in a velvet lined case) and precision Pi tape (with a vernier that can read 0.001"). However, even more important is the skill of the machinist who makes the measurement. They must have much experience, the best tools and ample time. They must have the attitude of a model-maker. Finally, they must have the web handling and process knowledge to know what is important and what is not. For the latter, they might rely on a web literate engineer.

For very intolerant webs, such as typified by wide paper, the answer can vary enormously. On the one hand, 0.002" might not be close enough. (The gap between sectional rollers is one example because the gage length is not the width of the roller but rather the width of the gap.) On the other hand, another roller on that same machine may need only be within 2.000." (Skew direction on a wide roller wrapped 180 degrees.)

So where does all of this leave us. With a new installation or rebuild, we align every roller to a hairsbreadth because it can usually be done without costly machine downtime. It is the recurring alignment that depends. In general, paper has overdone alignment and film is still catching up to best practices. Textiles and rubber are so hopelessly behind what they can't see the people ahead of them.

***2008.03 Mar 2008
When do I need to align my machine?

Roller alignment costs money. It takes a couple of technicians something like an hour to move a typical roller into alignment. This is not a large cost if the machine is already down because it is being installed or rebuilt or it is not fully utilized. Thus, there is absolutely no excuse not to align to precision ingoing standards in those situations. Economics change when we take a running machine down specifically for alignment. We would be much more parsimonious for those situations. We only do what we have to do; only the specific rollers that exceed outgoing tolerances in order to improve specific aspects of quality and runnability that are alignment sensitive.

There are three or four events in a machine's life that would require alignment. The first alignment takes place after assembly at the machine builder's shop. The purpose of this initial alignment is to make sure that there is sufficient clearance between the bolts and their holes to allow a roller to be brought into the 0.002" precision ingoing alignment discussed last month. It is not unusual to have a few things that have to be tweaked a bit. It is much easier to do this in the shop than out in the field. The principle exception to this is some parts bolted to match-drilled side frame plates are not intended to be moved into alignment. There is some truth to that side-plates-are-good-enough philosophy, but it is a bit overstated.

The next alignment takes place during reassembly on your plant's floor. Every single roller is moved into square and level again if it is out more than the ingoing tolerance specification. There are at least two reasons for this seemingly redundant effort. The first is that even with the best stress relaxation of framework, it will continue to warp slightly during the truck ride out. The frame is full of residual stresses due to machining and particularly welding. If you do not relieve them by 'baking' in an oven or by vibration, the assembly will relieve itself (warp) with time. Even with the best post-machine stress relief step, however, things will still move on the truck. The other reason is that the frame may get distorted due to lifting and setting onto its pads which causes a micro-slip of bolted joints.

The third alignment takes place 1-2 years after installation. Now you will find out how good your foundation work was. You will find that the typical 6" slab floor on gravel is often not stable enough to mount precision machines on. Look at the cracks in your floor. Even the smallest is an order of magnitude wider than ingoing machine tolerances. This is why we specify mounting on sills and other sturdy elements. It keeps the inevitable motion of the earth, which is primarily seasonal wetting and drying, from shifting machinery so much. Many civil engineers do no understand that it is not load capacity that is most demanding, it is stability. If you have a good frame and foundation, very little will have moved and thus little will need to be realigned. Recall from last month's discussion that the more liberal outgoing tolerances now apply.

Several events might prompt a fourth or additional outgoing-toleranced alignment? One is if the machine moved a great deal in the first year or so in service. If so, we will be back into alignment regularly, forever. Another is if we had an accident which caused a large impact. Another is if we changed grades to a much more demanding (usually thinner) material. Another is if we do maintenance on a part of the machine, we may need to recheck the rollers which were moved.

Finally, and most importantly, you would realign based on alignment sensitive waste and delay issues such as wrinkling, web breaks, uneven forming/converting and so on. Here, however, we would use a targeted approach. Aligning a roller two positions upstream of the wrinkling location would be a wasted effort as would be aligning a roller two positions downstream of the web break location. To take a rifle instead of a shotgun approach, you need careful observation of your process as well as web handling literacy.

***2008.03 Apr 2008
What do you mean by process and product quality?

Everyone has an idea about what constitutes process quality. It is often defined as the absence of negatives such as manufacturing waste and customer complaints. However, if the machine crashes the cause may be related to man (operator), machine, material or some combination. So who or what is at fault, i.e., lacking in some key quality. Leaving the operator out for the moment, the problem is almost always machine AND material. In other words, the material is fine if you don't attempt to run it on that machine. Conversely, the machine is fine if you don't attempt to run that material on it.

This system approach does not fit well into the management black-and-white or us-or-them thinking. Yet, if you consider just about any issue, killer solutions to a single problem can be envisioned in either the machine or material arenas. As an exaggerated example, web breaks could be cured by entraining carbon fiber into the web or by carrying the web through the machine with a forming belt. The problem is not that many solutions are not possible. The problem is that constraints are applied at the outset which often precludes solution before we even get started. A machine constraint might be 'made on our unmodified machine.' A material constraint might be 'without changing the web which might upset our customer.'

The fix-it-but-don't-change-anything (of substance) constraints are what cause more people to get stuck than any laws of physics. Next time management constrains the solution space at the outset remind them that they are mixing the option generating and decision making steps. This is not a minor problem solving faux pas. It is a felonious assault on reason and the team members alike. It is similar to criticizing ideas in a brainstorming session.

Defining product quality is also problematic. Certainly customer complaints would seem to indicate some key qualities are lacking with our web product. However, is this the whole story or even the truth? Could the customer be complaining where the fault is not largely or solely with our web? It reminds me of a recent mission where the supplier sent me to their customer to investigate curl complaints. One objectionable outcome was that the curl caused a photo-eye to misbehave on occasion. Yes indeed the web was quite curled and we could look into curing curl on the supplier's manufacturing process. However, the far easier solution would be to simply have the customer move the photo-eye closer to a roller where it would be flat instead of midspan where the curl can act without constraint. Change an entire (supplier) process and product or move an eye. Solutions are available in both locations if one could look beyond the biases and self-interest of the company or department one works in. Once all solutions are listed without constraint, by which I mean interference by management, it will usually be apparent what makes the most sense.

Very often quality is defined in terms of conformance to targets as measured by the test lab for example. Here there is the highest level of disconnect between numbers and reality. Who says that a particular measurable property is important to either our machine or our customer's? Who says that there aren't other currently unmeasured properties that might be even more important? Bagginess comes to mind here. Who says that the chosen target is best for the product, process or system? Who says that exceeding a certain variation including process capability will be problematic? Who says that even variation below the threshold of measurement will not be important to runnability? Gage profile problems come to mind here.

Here we have presented more questions than answers. This is good. It stimulates thinking. The single minded person seeks the answers they are looking for. The smart person seeks the answers however they fall. The wise person seeks the questions.

***2008.05 May 2008
What do you mean by web machine quality?

We have lots of ways to define web quality. But how do we judge the machine's quality? Here, we can seldom use any conventional web or uptime measurements. For example, let us say that you have side-by-side machines with drastic differences in runnability? It could be due to a different product mix or raw material, neither of which is the machine's fault. Even if raw material and product were identical, one could not make conclusions. The machines have different operators. Even if operators rotated between the machines you could not conclude anything. The machines undoubtedly have some differences in their design. Even if they machines were made from the same set of blueprints, no conclusion could be made. The machines will not be identical in all respects (consider snowflakes) initially and will get more different with time due to maintenance. So, even in the best of cases we can not really pin down machine quality in any meaningful way by comparisons. (This, by the way, is also true of materials,) At best we can say there is a difference in performance but the reason would in general be unknown and untestable.

I will offer four different machine metrics. All are important to waste and delay. All are measurable. All could be written into purchasing specifications. We could, if we chose, hold the builder or maintenance to task for allowing any of these to slip. These metrics are for web handling alone. Obviously there are other considerations that are unique to each process.

The first is mechanical precision. As given in my Mechanics of Rollers book, roller precision can be measured as diametral variation, alignment, deflection and so on. In general, mechanical precisions are important (nonwovens, textiles, rubber) or extremely important (paper, film, foil). In general, precisions are held to the thickness of a human hair plus or minus an order of magnitude or so depending on the parameter, application and web.

The second is control precision. The TNT's of controls, Tension, Nip and Temperature can all be measured. We could insist, for example, that tensions be held to 5% of setpoint during steady state and perhaps 10% during speed changes as read by fast acting load cells. Nip loads can generally be held within 5% except on winders where 10% or even 20% (nonwovens, tissue) might be tolerated. Temperature could be held to 2-5 degrees F at important locations. No less important is to insist that the builder provide measurements in engineering rather than arbitrary units and provide calibration procedures for all control parameters.

The third measure of quality would be MTBF (Mean Time Between Failures). Here, we restrict failures to mean mechanical breakage or electrical faults for example. A web break, however, is a messy metric and could not be used meaningfully. For example, we could insist on 200 consecutive successful flying splices or turret transfers before the builder get the last check. (You did hold payment back pending successful startup didn't you?). Obviously, if the operator forgets to put tape on we would not reset the clock for this purpose.

The last metric is not so measurable and is only recently acknowledged by web handlers. It is tolerance. In general, tolerance means the fewest number of rollers (and components) as possible. It also means avoiding excessive traction. Tolerance is a different concept than flexibility to running different types of webs. You could, for example, have a single grade machine such as a wide newsprint winder that is quite tolerant to web profile problems. On the other hand, you could have a multi-purpose laminating machine that was very intolerant because, for example, a redundant pull-roller nip was used when wrap alone would have sufficed to drive.

We must learn to distrust the common sense of comparing one machine with another. Instead, we must replace that sense with a science of controlled comparative experiments with a dispassionate statistical evaluation. Lacking that, we can only turn to the easily measured parameters suggested here and which is completely determine by the machine rather than messily mixed with material and operation.

***2008.06 Jun 2008
What is draw control?

Draw control should be called what it actually is; speed control. The word draw is ambiguous. It could mean the intentional and permanent elongation of material which is a web forming concern. Alternatively, it could be an alias for speed control. In speed control, we make adjacent motors go an ever-so-slightly different speed. If the downstream of a pair of motors goes faster, the tension in the web will tend to rise and vice versa.

Speed control is required when we form materials such as on the headbox of a paper machine or the die of an extruder. In cases such as these we can not pull tension in the normal sense of the word because the material has no real strength. This may be where the word draw as an alias for speed control came from. We would also, for example, draw materials if we wanted them thinner. Molten metals and soft are run over rollers with a positive or progressive draw. These examples are just a few where speed control is used as a web forming process.

Speed control is also required for registration such as between two colors in a printing press. Consider two print cylinders rotating at precisely the same speed and with no high order concerns. There, one color can be aligned to another by increasing or decreasing the web length between the two color stations. The device to do this is called a compensator. Here, any thought of tension control must give way to the primary concern of registering colors.

Speed control is often used to reduce the cost of machinery. It is cheaper to supply one motor and then connect it two several other rollers that need to be driven. Here we must be quite careful. We must maintain the diameters of all rollers in that set to 4 or 5 digits. If one diameter is off, the web on one side will be quite tight and the other side quite loose. With a geared system, we can not readily change tensions if we need to. For these reasons, today's machinery breaks the mechanical connections and directly drives every roller that needs driving with a separate motor.

However, the most common application of speed control is as a form of tension control. The best candidate materials for this type of control are extremely stretchy. Materials that have a yield strain of at least 20% would qualify. Uncured rubber, some types of nonwovens and creped tissue are some common examples. While stiffer materials can be put into speed control, a number of serious concerns arise that will be discussed next month.

To make speed control work consistently, you must check a number of things. First, the material itself must be consistent. If unintentional changes in material properties occur or if you change grades, you may have to change the draw settings to make the web run without excessive slackness or tightness. Second, you must nail the speed with the motor and mechanical transmissions. This precludes the use of sloppy motors, V-belts and PID transmissions. Third, you must know the diameter of the driven roller, often to 4 or 5 significant digits. A hairsbreadth error in knowing the diameter of a speed controlled roller can cause huge changes in web tension. This can easily happen if maintenance grinds or replaces a roller. Finally, as with any tension control system, slippage between the web and roller can not be tolerated.

While speed control seems simple, it is only simple for the electrical engineer. For everyone else it is the most complex of all of the tension control schemes. While speed control seems inexpensive, that only considers initial cost. It does not consider operational costs. It also does not consider flexibility. If you choose to do speed control, it may be not possible to go to dancer or load cell control. However, if you choose dancer or load cell control, you could always get speed control if you wished.

***2008.07 Jul 2008
What are the drawbacks to draw control?

Speed or draw control is quite simple for the electrical engineer. They merely need to make a motor turn a target speed to an accuracy of a few parts per thousand. It is simple enough for maintenance, they merely need to know roller diameters accurately to 4 or 5 digits. However, speed control is exceptionally complex for everyone else. This would include everyone from operators to process control people.

If we use speed to control tension, what is the tension applied to the web? This simple and vital question has no simple answer. At best we can say the tension in the web between any two rollers is partly controlled by the tension coming into that section plus the speed control ratio. This is not very satisfying to the operator who finds the web drooping or breaking. This is not very satisfying to the web handler.

If we have a tension variation coming into a speed controlled section, that tension variation will be passed downstream. Thus, draw control is not even a control in the traditional sense of the word which means limiting variation. This makes the isolation nips seen just after many unwinds seem kind of silly.

If we have a change in moisture or temperature, the web tension will be affected. If it is paper and the moisture rises, the tension goes down. If it is paper and the temperature rises, the tension goes up. If it is film and the temperature rises, the tension goes down except for some materials in a certain temperature range will heat shrink and the tension will rise. How confusing! If you adjust just about anything, you may need to adjust the draws to compensate for the change in tension. It is undesirable to have one knob, say dryer temperature, do two things; change temperature and change tension.

Speed control is closed loop control where the operator’s hand or eyeball is the load cell. It does not matter that you have centerlines. It merely begs the question where the centerlines came from. They did not come from an engineering calculation. They came from an operator who found a setting that worked and the engineer copied it onto an SOP. Speed control can not get started and can not be maintained without the operator’s interpretation of the web’s tension. How does it make you feel to have your operator as a load cell? Do you think the process will be consistent or responsive?

Speed control is twitchy on stiff materials. Consider how close you need to get things to go into speed control and hold a steady tension for something like paper. Paper breaks at a 1% strain. This means that a lightly tensioned web may be strained at something like a 0.1% strain. If you want to do even a passable job of control, you would want to hold variations to no more than 10% of a 0.1% strain. This means you would need to control speed and diameters to 1 part in 10,000. Not in our lifetime! So how do we make draw control work on stiff materials? We use droop. Here, the motor is asked to follow a setting but will not do so if the web starts tugging on it too hard. In this case, we don’t have speed control and we don’t have torque control but rather a hybrid. While we don’t know where we are, if we ever did, the motor adds just enough forgiveness to make things run.

As we learn more about speed control, we learn more about the resulting process problems that arise from an inherently unforgiving control method. More and more, we are using load cell or dancer control in places were draw had been used. With load cell or dancer control, we know where we are at and we have a much more stable tension control situation. We leave draw for places where it is required, such as at web formation and when registration is required and for places where it is more tolerant, namely, extremely stretchy materials.

***2008.08 Aug 2008
What is gap winding?

Gap winding is many things to many people. A common arrangement is a centerwind with a layon roller where the layon roller has been lifted from the winding roll. The layon roller makes the wind tighter. Perhaps you don't want a tighter wound roll so then you would lift the layon roller to loosen. Perhaps you DO want a tighter roll but the nip is causing troubles such as exacerbating gage bands or causing wrinkles. We know that gage variation across the width greatly reduces the window of trouble-free winding. Just when you want as many tools as possible, winding troubled webs, you in fact have reduced tools because nips require near dead level product.

The layon roller now turned idler roller in front of the now simple centerwind also improves roll edge quality. Consider what steers the web on a simple centerwind with a distant idler roller in front. It is the wound roll whose cylindricity is quite poor which steers the web. On the other hand, with the layon now turned idler roller right in front of the winding roll it would be the very precise metal roller that steers the web.

Idler rollers which are big and slippery are quite resistant to wrinkling. This flattening effect is also desirable on the first roller after an unwind. The unwinding roll is geometrically troubled and just looking for the chance to misbehave. The first roller is the first opportunity. If you can get it by that roller, you may be home free. The roller just after an unwind and just in front of the winder both need to be big and slippery for wrinkle prone applications. Bigger than is needed to merely satisfy deflection standards.

Now let us consider the gap winding mode. Here we keep the roll and roller closely spaced, usually less than an inch. We do this because this mode is the most wrinkle resistant winding mode we have. The clue to success is getting the web dead flat on the gap (former layon) roller. We use our best spreading efforts in front of the roller. We use our best flattening efforts on the gap roller by making it big and slippery. If we get it flat on the gap roller, then it has too little time and too little space to go from flat to wrinkle. On the idler roller flat, on the wound roll flat.

Obviously there are some issues to consider in gap winding. The first is that in gap mode you have no layon roller so the winding roll will be looser, perhaps much too loose. In the case of thin smooth materials like film, you could not wind very fast before you filled the winding roll with air because you lack the best treatment for reducing air; the nip roller. Thus loose rolls and speed limitations make gap winding a bit of a niche mode. There is also the mechanical and control challenge of moving the roll or the roller to maintain a constant gap as the winding roll builds in diameter. This is not a huge challenge so that this mode is often provided as a matter of course for many turrets and other centerwinds with layon rollers.

Finally, if you have a centerwind with a layon roller you have a drive control subtlety that must be addressed when you go into gap mode. The driven layon roller now off the winding roll interferes with the load cell to centerwind motor control. However, the motor can not be simply turned off. It must be run in no-load-motor-amps to exactly counter drag with an inertia compensation calculation. Together these combine to make the roller ‘disappear’ from the web as far as tension is concerned. As simple as gap winding looks, there is really quite a bit of web handling know-how involved.

***2008.09 Sep 2008
What is the Best Winding Curve?

The best winding curve is one that straddles two types of defects at two different ends of the wound roll. Tight defects include some blocking, one type of core crush and many others. Loose defects include one type of loose cores, out-of-wound rolls and a few others. Some defects do not respond to changes in tightness, such as cores not aligned with the roll edge, or product/process design issues such as blocking. In these cases adjusting the winder would be a waste of time. The two ends of the wound roll are obviously the core or bottom and the outside or top.

The best winding curve begins by looking at the core area and asking the question “Do I see more tight defects or more loose defects?” If I see more tight defects then I loosen the core area and vice versa. No changes are made at the outside (for this example) because there is nothing wrong with the outside. Then I look at the outside and ask the same question “Do I see more tight defects or more loose defects?” Based on what you see you will either tighten (more loose defects), loosen (more tight defects) or make no move (no defects that favor the outside.)

This simple strategy works for most problems except the global defects such as one type of starring and a couple of the types of telescoping. For these, the best curve is maximum taper. However, in the lingo we’ve just described it would be start as tight as possible without getting excessively many tight defects at the bottom and finish as loose as possible without getting excessively many loose defects at the top. This strategy is simple because it just requires the operator to know whether defects are tight defects, loose defects or global defects and whether defects favor the bottom or the top of the roll. Most operators already know this. If you are not sure, just run trials with extremes of tightness and looseness and see whether the defect incidences increase or decrease.

Now the real challenge. The winder builders have not always made programs that accommodate a simple strategy. In times past, controls were too limited. You did not have much adjustment and no compensation for geometry and gravity. However, the much more common case now is overwhelming complexity. On some recent rewinders I documented 10 and even 14 adjustments the operator had available to adjust the tightness of the wind. In addition there were dozens of other parameters that were part of the hidden math inside the PLC computer. How many knobs do you want to give the night shift to avoid what might be a half dozen defects on hundreds of different grades? The winder computer not only can do straight line ‘taper’ but many can often make any curve you want. A near infinite combination of tension, nip, torque and speed curves! To make matters worse, the builder does not often include calibration methods so that one can ensure that once a good curve is found it can be reproduced next year or on the next machine. Finally, one almost never finds any advice on how to adjust the curves for any defect. This state of affairs has left operators and engineers alike totally baffled.

My proposal is first to get rid of knobs on the benchboard and replace them with transparent and calibrateable math in the computer. The most the operator will normally need is a starting and ending tension and nip. All complication should be inside the computer and well documented in the user's manual. The manual should include suggestions for moves for the common defects to guide the process engineer for setting up grade recipes. The manual should include test points and procedures, such as cylinder pressure, to make sure for example that a zero nip setting is really zero and a nip of 2 lb/in (or kN/m) is really 2.

***2008.10 Oct 2008
What do I need to know about accumulators?

Accumulators are used to temporarily store web material on medium speed continuous processing lines. This storage allows a manual roll change to made on an unwind or winder while stopped and yet still keep the process running by drawing upon that stored material. At very low speeds, say less than 100 FPM, manual roll changes can be sometimes be made at speed without accumulators. At very high speeds, such as more than 1000 FPM, accumulators become too large so that turret unwinds and winders become the only practical option. Though there are plenty of accumulators around, they can be challenging to design and maintain.

The first thing to do is to properly size the accumulator. You want it no bigger or smaller than needed for an efficient unwind or winder roll change. Once you know the length of storage (roll change time) you need to decide whether it will be tall (few rollers) or long (many rollers). Usually tall is used for sturdy materials but thin or wrinkle prone materials can't tolerate long spans even more than they dislike many rollers.

Pneumatic cylinders usually do the raise and lower of the accumulator. However, the sides must be timed precisely by well-maintained precision chains or gear rack to preserve alignment. Sloppiness here causes the accumulator to be out of level on at least part of its stroke. Roller alignment must be considered here just as in any other machine. Fortunately, accumulator alignment is simpler than with most machines. You need only allow for precision level of each individual roller because that is the tender in-plane bending direction. The square is not so important because that is the tolerant out-of-plane skew direction.

Accumulators are wrinkle prone components because: there are many rollers, they are highly wrapped and the spans may be long. In addition to using our best practices for machine design we can also help the situation by operating procedure. The accumulator should be run low (nearly empty) until the very last minute before filling and changing the roll. This allows less time for large spans to allow the web to misbehave.

However, the more demanding concerns are usually with tension control. All of those rollers have inertia and bearing drag. You do not want those combined tension upsets to exceed more than say 10% of the nominal tension at any point of the accumulator's cycle such as fill, run or empty. Careful engineering calculation, sizing and design are required here. Another concern is the friction of the cylinders and timing mechanism. When this device is used like a dancer, tension quality is probably poor. Thus the use of an accumulator as feedback to a drive should be limited to the fill and empty phases only. You should use a separate dancer or load cell for tension control during run because they are usually much more precise.

Finally, the accumulator will have an infeed or outfeed nip. This device is quite tricky both mechanically and control-wise. Since all nips are wrinkle prone, the rollers must be precisely designed and maintained for a dead level nip. Control is also tricky because the nip is in speed control during fill and empty with s-curve ramps. However, the nip should be taken out of the system during run so that a precise dancer or load cell commands the unwind or winder directly without the now redundant nip causing additional drive complexity.

One final issue is not caused by the accumulator but is seen there. That is the weaving at splices. The web weaves for dozens if not hundreds of feet as the web reestablishes its path through the machine. The cause of weave is most often a tiny pucker or angularity to the splice.

***2008.11 Nov 2008
Web-Handling – Looking back and looking forward

A quarter century has brought many positive changes to web-handling. The most obvious is computer control of our machinery. However, the most important may be simple name recognition. No matter what the chemistry or the construction of your web, no matter whether you manufacture, convert or use; web-handling is fundamental to what you do. Widely varying industries found common ground in topics of interest such as guiding, slitting, winding, wrinkle reduction to name a few. We learned from each other. We learned that applied science could reduce waste and delay beyond what mere craft and occasionally witchcraft could.

Machine designs began to reflect this new science. Some industries, such as printing, were changed overnight by technologies borrowed from other web industries. Load cell tension, precision roller alignment, servo drive control and optical defect detection took printing to a level that would have been unimaginable a decade or two ago. New products could take advantage of web-handling and jump start production with less trial and error. Electronics of all sorts, foam, filters, medical products and even food went from batch to web without having to learn web-handling from scratch.

Several mechanisms enabled this revolution. First there was a meteoric rise in published web-handling content. A quarter century ago what little that was written about web-handling was well buried within a particular industry such as paper. Now we have dozens of books and thousands of articles and columns. Second, trade shows and conferences started to include regular web-handling content. Now we have two entire conferences solely dedicated to the subject. Third, we have formal web-handling training. When I started three decades ago, no training was available. Now, multi-day web-handling courses are taught by four independent instructors and several more by internal experts in large companies. Even though thousands have been trained in web-handling, there are hundreds of thousands more that could benefit.

Surprisingly, the Internet has yet to catch up in our industry. Very little of the total web-handling content is currently on the web. It is not due to lack of trying. Web machine builders, trade organizations and magazines have put some information on the web but have failed almost totally in the area of training despite many attempts. I think the challenge is primarily monetization rather than lack of need or delivery mechanism. Also, Internet searches are problematic if you look for topics such as coating, winding, wrinkling and so on, which have many non-web-handling meanings. Much is lost between lack of content and difficult searches.

Unfortunately, some areas of web-handling have stalled out. Economic and other pressures have caused many machine builders and component suppliers to go out of business and many others to merge. We had three suppliers to the venerable paper industry, now we have two. We had hundreds in converting, now we have scores. We relied on and still rely on the expertise of the suppliers to guide us in everything from purchasing to operating to troubleshooting and upgrading a web machine. However, they have lost people and are stretched quite thin. Pilot labs, R&D, libraries and other sources of new ideas have been all but shut down suppliers and customers alike.

Now what? Certainly we need to do a better job putting web-handling content on the Internet. We also need to continue training because individuals and companies alike must become more self-reliant. We could consider certifying web handlers much as we do carpenters, plumbers and kayak instructors. Finally, we could hyphenate ‘web-handling’ because handling is a vital part of all web manufacturing, converting and end use.

***2008.12 Dec 2008
What tension is best for laminators?

Setting and controlling tension in laminators is more challenging than on almost any other machine. The tensions at the two unwinds are set first by the guidelines of web handling. Most webs like to run at tensions of 10-25% of their MD breaking (or yield) strengths. The laminate also would like to run in a similar range based on the strength of the laminate. However, you often hear that the laminate tension should be set as the sum of the tensions of the two plies. This is not true in general. The reason is that both plies of the laminate do not carry full load at failure.

Consider bonding paper to poly. The paper may yield at 1% while the poly might yield at 10%. Thus when the laminate is stressed/strained to the point of failure, the paper will break at 1% strain. True, the paper will carry its full breaking strength load but the poly in this example will carry only 1/10th of its breaking strength. The sum of the ply tension fallacy becomes worse with more plies and with a wider range of modulii (which tend to correlate with a wide range of ultimate strains).

If this were all we had for tension concerns we would have enough challenge. Controlling tension on center-driven unwinds is not trivial. The wide range of roll diameters, widths and inertias test both extremes of the drive's torque range. Add to that the typically much wider range of webs that must be serviced on a laminator than many other machines and you already have the ingredients for a notable drive control challenge.

However, the biggest challenge is that tension control on laminators is way over-constrained. In addition to keeping both plies happy with appropriate tensions, the strains of those plies must be equal else the material will curl in the MD, CD or both directions. Thus we have two constrains from web handling and two more from conventional laminate curl. We may have even constraints on tension if we have baggy webs, webs that are dimensionally unstable after manufacturing (such as crystallization) and webs that are dimensionally unstable in environments where moisture or temperature change. Thus, we may have to solve a half dozen or more problems with only two knobs: the tension of both plies. This over-constraint is why we can expect tension control and curl to be challenging forever for those who laminate.

One way to add a much-needed extension to the range a laminator is to drive both laminating rollers. In fact, it is expected that we do so given the challenges listed above. The principle is very similar to how the two motors of a center-surface winder give a wider range of winding tightness than the one of a center winder (with or without a layon) or surface winder. However, this important capability must be selected at the design of the machine because retro-fitting is difficult.

So how do you control the two motors? The motor that is connected to the steel roller is in speed control. In fact, it should be the master speed reference for the line. The other motor that is connected to the rubber covered roller is in torque difference control. Here, we pit one motor against the other in a last ditch effort to control curl given all of the other constraints. Thus, one motor may be running at -100 amps (regenerating) and the other at +200 amps (motoring) to adjust curl in one direction and vice versa to adjust curl in the other direction.

So now we see that if any web machine needed a gold plated drive, the laminator would be first in line. Anything less will exacerbate the already challenging tension control and curl problems.

***2009.01 Jan 2009
How do you measure web and roll length?

Roll length is such a common measure that few even think about it until they get customer complaints for discrepancies. A common prophylactic response is to 'pad' the roll with extra material. However, whether you supply more or less material than the contract calls for the result will be the same; increased costs.

The first thought may be that there is some problem with the footage counter. Most commonly we count revolutions of a roller or, much more primitively, a footage counter running on the product. Then length is defined as the number of revolutions of the roller or wheel times its circumference. I have seen machines that had three or more counters on them, presumably because the owner thinks that the more you measure the closer the answer will be to reality.

Yes there are many potential problems with footage counters of all types. It is possible that the web could slip on a roller. Many people are so afraid of that possibility even though slippage is rare and can be avoided by design calculation (band-brake equation) and can be detected by measurement (think about the Anti-lock Braking Systems on your car). Analogous and even more complicated issues arise on footage wheels. We presume to know the diameter when the plastic wheels can and do wear (detectable) and the wheel is not perfectly aligned (skew and tilt). Worse yet, especially for thicker products, is that the effective diameter of the wheel for measurement purposes is not actually the diameter of the wheel. The deformation under nip makes the wheel appear larger than it is as measured by a caliper.

Then there are operational issues. Do the counters start and stop precisely at the beginning and the end of a wound roll? Does the supplier or the customer take a few wraps off the top of the roll to clean it up? Did they start the counter while threading or after thread up has been completed? Did the customer consider the wraps left on the core in their accounting procedure? Did both supplier and customer account for losses when the web jams in the machine and must be cleared? Finally, there are higher order phenomena that cause the web's length to change with time. This includes things like crystallization of some film polymers and changes in length due to moisture on products such as paper.

However, the biggest problem of all has nothing to do with measurement, operation or exotic mechanics. The biggest problem is that roll length has no definition. No standards body, such as ASTM or TAPPI, has told us what length actually is. Consider that the supplier almost always defines/measures web length when the web is under tension. The customer, on the other hand, will often define/measure length as the number of units produced times the unit's length as measured under no tension in the test lab. The customer will thus measure a shorter roll. Who is right?

There are other ways to define length that are even prone to more discrepancy than the strain under tension that may amount to a part of 1% for many common web materials.

Some people use volumetric or weight methods. For example, you can define length as the area of the end of a wound roll divided by thickness measured in a test lab. A similar way is to take roll weight and divide by the web’s basis weight. There are even more definitions/measures of length that need not be discussed here.

So, what is the length of a roll? It depends on whom you ask and how it is measured. It is never, however, as simple as reading a calibrated footage counter.

***2009.02 Feb 2009
How do you measure wound roll diameter?

Roll diameter is vital in commerce and in operation. For example, unwind roll diameter is needed to avoid runoff at the core when the operator is busy or inattentive. Here, we automatically shut down or go into a roll transfer on a preset diameter, usually a part of an inch above the core to avoid damaged material there. On the winder we have analogous diameter needs to automatically stop or transfer the winder at a preset shipping diameter or to avoid breaking the winder if the operator falls asleep. These simple systems will usually pay for themselves a few months due to savings in waste, delay and labor.

Continuous diameter measurement is also essential for tension control purposes on unwinds and windups. It is not possible to do fine tension control without what is called inertia compensation. Most people think that closing the tension loop on a dancer or load cell trim signal with a proper PID adjustment is all that you need. Nothing can be further from the truth. Good tension control is 98-99% calculation and only 1-2% trim. To calculate how much brake/more torque is needed during speed changes requires knowing how much inertia must be accelerated. This then requires knowing roll density, roll width and, you guessed it, roll diameter. Inertia compensation or gain scheduling is, surprisingly, also required at steady speed because the winder/unwind has to change speeds ever so slightly to change tensions.

To these general needs we add another need for the winder that is known in converting as taper and but is more properly known as roll structure. Here, the TNT's of winding are automatically varied as the roll builds. Tension, Nip and Torque and possibly speed of the winder are programmed as a function of roll diameter. In converting this is often a simple linear function, i.e., taper, but we should not be so limited. We know, for example, that roll weight and swinging arm compensation requires a curve. We know, for example, that the best 'curve' to avoid the most common type of wound roll telescoping defects is something like a slanted s or z shape. In any case roll diameter measurement is essential.

You could measure roll diameter on some winders with a mechanical pointer on a scale. Just barely more evolved is a sensor arm that rides on the winding roll where the sensor may be a rotary pot. This is not very accurate, perhaps 0.1" at best. However, the big sin here is that the arm is in the operator's way and will get bent in short order. An improvement would be a non-contacting sensor such as ultrasonics. Here we get improved accuracy, perhaps 0.01", and the sensor is out of the way. If we have a nip we might be able to measure the movement of machinery during a roll build. An example is a rotary pot on a nip roller or a linear pot on a rider roller.

The gold standard of wound roll measurement is, however, the two-tachometer method. First we need to know web speed on one tach, pretty much a given these days. To this we add wound roll rotation on another tach or even just a precise target. Properly designed, these methods continuously measure roll diameter to the accuracy of a single wrap in commercial use and a fraction of a wrap in research. Here the operator can, for example, pick the specific unwind wrap to make an automated transfer on. On the winder the operator can make the transfer so that the unwind splice ends up on the outermost wrap facing him when the winding roll comes to a stop. This is the web-handling equivalent of NASA spacecraft threading the needle to reach a distant planet's orbit.

***2009.03 Mar 2009
What is the master speed reference?

Most web machines have one and only one master speed reference. This master drive is the timekeeper and pacer of all of the other drive motors and elements in the line. When the master moves, everyone else must move. When it comes to a stop, everyone else must come to a stop. It is the one drive that directly follows the speed command input by the operator. When the operator hits the go button, the command is sent to the master which then constructs an ‘S-curve’. It is this reinterpreted command that is ultimately sent to most of the other drives in the line.

The reason is simple. Drives can’t follow a step change such as go from thread speed to 300 FPM, that would require infinite torque. Instead, the master must construct an S-curve that has three parts: round, ramp and round. The rounding at both ends of the s-curve is to limit the jerk (first derivative of acceleration) to the system. It is set up to be around 2-3 seconds for many machines. The rounding is far more important than most people think. Many of the troubles during the ramp (speed changes) are in fact at the ends of the speed change rather than in the middle. An observant operator can help the drive tech by noting this detail. Slowing the accel/decel rate down or inching the speed pot are largely ineffective patches to the root problem of inadequate rounding.

The acceleration rate is very machine dependent. For many continuous processes, a rate something like 10-20 FPM/sec is ordinary. Thus it might take something like one minute to reach 1,000 FPM. There is no hurry to get to speed if you are going to run for a whole shift. In fact, hurrying is likely to break you down. In contrast, many offline rewinders must not dawdle because they start and stop many times every hour. Here acceleration rates can be upward of 100-150 FPM/sec. Obviously, this jackrabbit acceleration puts very high demands on the mechanical and electrical designers. Failure to master the details will result in tension related troubles. On a rewinder you will note an ‘acceleration offset’ on the side of the wound roll at speed changes. This has nothing to do with acceleration per se. What this is telling you is that the drive system is not holding tensions well during the demanding speed change condition.

The other drives are fully informed of everything the master is doing and what is expected of them. The master passes on its own speed to others as feed forward. Each of the other drives then does an inertial compensation. By this we me that the motor calculates the additional effort required to just make the speed change and makes the motor compensate BEFORE being told by the load cell that a tension upset has already occurred. This is one way to tell whether your drive tech knows what they are doing. 98% of the work of the motor is calculated and only 2% is trimmed by the dancer or load cell. Opening up the trim to accommodate sloppy drive program design and tuning too much will have one result: tension oscillations.

Which motor has this special position? This can be arbitrary because the truly expert programmer can sometimes even make an idler roller the master speed reference. Modern drives even allow you to switch masters, perhaps in response to a new threading path on a large coater laminator. However, some choices are far easier than others. These include large inertia locations and the laminating nip (if present). In all cases, however, traction is essential because the web will often break down within seconds if it slips on the master.

***2009.04 Apr 2009
What is a helper drive?

One way to think of a helper drive is as a poor man's dancer or load cell tension control. However, it is not always the case that we can't afford load cells. The more usual case is that we can't fit them in, literally. There is no space for a sensor or we don't want to make the space by adding rollers that are needed to set up the geometry of a dancer or load cell.

There are distinct differences between helper and dancer or load cell control, however. In the latter case we have feedback from the web on how much it is tensioned. (Hopefully people have taken the trouble to calibrate this tension in engineering units such as PLI or kN/m). In contrast, the helper drive has no feedback from the web. Thus, we really don't know for sure what we are doing to the web. Thus we must calculate, calibrate or guess. In reality, we do a bit of all three.

Motor torque requirements to achieve intended tension changes can be calculated. The same is true for inertial compensation required for speed changes. The only things needed are good motor performance characteristics. These are empirical and theoretical models provided by the drive manufacturers that run inside their firmware. Thus, if we ask for 100 lb-ft of torque, we should get it from the motor. That is not to say that all 100 lb-ft will be delivered to the web. We have gearboxes that change the torque. More importantly, we have friction or drag coming from a variety of sources such as gearboxes and bearings. Drag can't be calculated. It must be calibrated, sometimes several times during the life of a machine. Drag drops considerably during the first few days of break-in and may change later in life for other reasons. Sometimes drag is even more complicated such as the rolling resistance of a nip that depends on the amount of nip load and the modulus of the rolls or rollers.

So what is the guess part? The guess is that no model is a perfect description of reality and motors vary a bit in performance from textbook. Inertial compensation is especially complicated for winders because it requires good knowledge of web width, as well as wound roll diameter and density. Finally, drag is always a bit of a mystery. For these reasons, helper drives are usually much smaller than main drives. We don't want to use a drive to compensate for drag when it is very large compared to the (tensioning) work on the web. A small error on a big motor has big results. Similarly, we usually don't use helper drives to tension the web. Thus helper drives are usually relegated to merely making modest inertia and drag disappear so that they don't affect tension.

Examples of helper drives are many, but very machine dependent. For example, a large two-drum paper winder will have helper drives on the guide roller because inertia is large, on the bottom slitter bands because of drag and inertia might upset cutting, on the bowed rollers to allow more of the roller's traction capacity to do spreading work rather than turning the cover and bearings over and finally on the rider roller (even though I maintain this application is seldom needed or helpful.) Paper making machines have many more since there is almost no place for load cells. In this application almost every smaller (non-process) roller has a helper drive on it. Helper drives are rarer in converting machinery because they cost money, are complex and the (inertial) needs are far smaller. However, an example of a mechanical helper drive there is the tendency drive on arched ovens.

***2009.05 May 2009
How Can I Improve Roller Traction?

Traction in web handling is as important as traction is for driving your automobile. If you lose traction, you lose control of braking, steering, speed and many other vital concerns. In either case, losing traction is an invitation to a crash. It matters little whether the loss of traction is on the driven or undriven rollers (wheels). Thus motivated, scientists and engineers long ago figured out how to calculate traction. Skilled machine designers make use of this subset of web handling science to make sure that their customers don't crash. So what are the options to enhance traction?

The first options are foretold by the century old band-brake equation. This most fundamental law says that traction depends on the wrap angle and the coefficient of friction between the web and the roller. The wrap angle is the very first thing the designer should consider because it is usually the cheapest. With an 's' or bridle wrap, 360 degrees or more of wrap is possible. This is more than enough for most motor driven positions. The calculation is well documented in my textbook The Mechanics of Rollers. For those who don't want to crunch these trivial equations, the commercial TopWeb program that does that and much, much more for you.

The friction coefficient is both more expensive and more limited. Yes, you can put a rubber covering on a roller. However, this treatment is expensive, short-lived and disappointingly modest in achievement. Thus rubber covering is usually selected for other reasons. Roughness is similar. You usually have to pay extra for controlled roughness and the results are short-lived because the valleys fill while the peaks wear down, requiring you to redo the treatment regularly. You might be surprised that roughening a roller can actually decrease traction for the case of smooth webs at low speeds. Grooving is a more complicated topic. First of all, grooving does not make traction. Rather, it maintains traction at higher speeds by handling entrained air. Think of the treads on automobile tire that actually decrease traction on most days except when there is rain, snow or mud present.

One option that is so strong that traction is all-but guaranteed is to use a nip, such as is common for some driven pull rollers. A nip is also required for many of our processes such as calendering, laminating, printing and so on. However, nips are so destructive to runnability that they should always be considered a last resort. The nip is totally intolerant of variations of web, such as bagginess, and nip roller maintenance. We use nip only when it is required such as for processing or to avoid known slippage for pull rollers. Think of 4-wheel drive and you will get the idea. Kicking in 4-wheel drive when it is not needed will reduce handling, gas mileage and tire life. Seldom is the 4-wheel ever needed in even the most inclement climates, such as the one I live in; Wisconsin. A good driver or good designer will seldom if ever use 4WD or nips respectively.

There are many other niche methods to improve traction. These include vacuum rollers, tentering, and even static electricity. The appropriate method or combination thus depends very much on the application. However, I must issue a stern warning. While you do not want too little traction capacity, you also may not want too much. Excessive traction will noticeably increase the incidence of wrinkling on wrinkle-prone grades such as thin films. Traction capacity is simply NOT a case of more is better. That would be like using 4-wheel drive on your drive to work today.

***2009.06 Jun 2009
How Can I Improve Roller Release?

Sticky or tacky materials, such as coatings and adhesives, can cause enormous operational and runnability headaches. At the modest level, the tacky coating causes a delayed tangent of the web as it departs from the roller (or wound roll). This will quite likely upset the surface of the coating. It may even upset web handling by causing tension disturbances something like that seen during stripping (separating two webs). At a more serious level you can paint the rollers or even break the web.

These challenges need not be continuous to be troublesome. Perhaps you don't run the coated side against the roller. However, accidents do happen and when they do coating will often find its way to places where you did not intend. One of my clients had a tacky product that cured quickly by reacting. When the rollers got painted by an accident, the coating cured on the rollers before the operators could get them cleaned. An accident, though rare, cost nearly half a shift to clean up because they had to chisel the coating off. By treating roller surfaces as described below, they were able to get cleanups under an hour.

The options to improve roller release are many. However, they are very application, or more accurately, very chemistry dependent. While one trick may work well in one situation it may fail miserably on the next. Also, some situations are stubborn enough that multiple techniques must be used simultaneously. Some situations are impossibly stubborn in which case we can not ever touch the web; it has to be routed on the back side until the coating has set and/or floated on the front side to totally avoid contact.

One of the first candidates to consider for roller release is mechanical; to increase roughness. This will reduce the area of contact between the smooth web that will now sit on the peaks of the roller's surface instead of the more continuous contact of a smooth roller. Nano-coatings are now mimicking nature, the lotus leaf, to make a topography upon which oily or watery contaminants can not stick because the molecules will not fit. Reducing the wrap angle would achieve a similar effect of reducing contact area.

The next candidate to consider might be chemistry. Here the options are many but each is expensive and has limited life. For example, we could cover metal rollers with a covering or sleeve of silicone or Teflon. Either has excellent chemical release. However, both are extremely expensive. They are also extremely tender. Operator can destroy a rubber cover in minutes. That is why some plants forbid the use of knives of any kind on the floor. (Another is to eliminate one of the most common injuries; cuts). Rubber-like covers also have very low abrasion resistance and may wear out quickly.

There are several release tapes that can be applied to rollers. However, tape is also expensive and even shorter lived. Take care in application because sloppy taping can cause wrinkling on thin webs. At least one excellent release tape product combines the magic of topography and chemistry. It has a pebbled surface similar to a basketball and has a chemistry similar to Teflon. There are also plasma flame-spray products for rollers that have the same combo of topography and chemistry but are much more durable and, you guessed it, are even more expensive.

A final release technique that works very well is to cool the roller and/or the web. While cooling the web is usually a good idea for many other reasons anyway, cooling the roller is obviously complicated and expensive. We leave it to the reader to find the combination of cooling, topography and chemistry to get the total release that they need.

***2009.07 Jul 2009

What causes a wound roll to telescope? - I

There are several contributing factors to each of several different types of telescopes. Yes, that is right, telescoping is not a single defect but rather a collection of largely unrelated defects that use the same name. This state of confusion is not unlike core crushing that is in fact three totally different types of defects that have a single outcome; the core gives way. We are often guilty of looking at the outcome to discern causes. However, this rarely works well. Consider the outcome of a headache. It could be caused by stress or a tumor just to give two examples. Treating a tumor with aspirin would be totally inappropriate. The good troubleshooter instead works with causes or, more specifically, mechanics. We must also do so for the telescope. Just because the roll appears to have moved sideways is of little value for diagnostics.

There are three essential observations to discriminate what type of telescoping you have. The first and easiest observation is WHEN does the ‘telescope’ occur. The apparent sideways motion can occur during winding/unwinding, transport or storage. The second observation, only useful for winding, is whether or not the web moved sideways or the roll moved sideways. The web moving sideways is not even a telescope defect, it is an offset. A third and extremely important diagnostic is if there is interlayer slippage. The two primary choices are MD slippage that precedes and allows CD slippage or pure CD slippage. MD slippage is detected as the shift of an originally straight line struck on the side of the roll during winding or prior to unwinding. In this and the next column we will examine the most common types of ‘telescopes’.

Telescoping type IA occurs during center or center-surface winding. There is significant interlayer slippage at the core as evidenced by a spiral or hook (J-line) of an initially straight line drawn on the side of the roll. The shape of the side of the roll is often like a volcano with a central cone. It has three portions: curve, straight, curve. Note that the outer wrap lines up with the inner wrap. Note that this defect occurs during the latter part of winding. Telescoping type IB is essentially the same defect but occurring immediately upon unwinding rather than winding because both occur at large roll diameters. The unwinding telescope has no outer curve because that was generated during winding.

Telescoping types IA and IB are the most common. Note that just because you can wind a roll (avoid Type IA in your plant) does not mean you can unwind a roll (avoid Type IB at the customer). One reason is that this defect is most common with slippery materials. (It also can be seen on bulky materials such as tissue.) Many materials in fact get slipperier with time. The customer might also unwind this at a higher tension than was unwound. The customer may also unwind the roll with more jerks such as packaging material that is fed in a start-stop fashion.

Types I telescoping are best avoided by winding with maximum tightness near the core. The reason is pure mechanics; there is not enough torque carrying capacity of the inner layers to withstand web tension without slippage. The word maximum implies just short more serious limitation of web, roll or winding machine. In the case of winding (IA) a maximum taper is also helpful but will not matter in the case of unwinding (IB). After that, the problem is no longer a winding problem but rather a product/process design issue. You must consider redesigning the product such as increasing the web's COF, increasing core diameter or decreasing finished roll diameter or redesigning the process such as a more capable winder or using end plates.

***2009.08 Aug 2009
What causes a wound roll to telescope - II

The telescope described in last month's column is probably the most common. It was defined by a fingerprint observation of MD slippage that precedes and allows CD slippage. In this month's cases there will there be no shift of the radial line struck on the side of the roll.

Type II telescoping is common with products that have a viscous coating. (Though it can occur on fuzzy products due to dry slippage.). The classic example is PSA's (pressure sensitive adhesives) such as sticky tapes. Here the telescoping occurs during storage (though in extreme cases can occurring during winding). It is exacerbated by tiny changes in adhesive composition or environmental temperature. Large rolls or narrow rolls are more problematic. Gage variations are most problematic with Type II but they also make other types of telescoping worse as well. Winding as loose as possible throughout the roll, especially at the outside, is the first treatment. Taper has no utility on this telescope just as it did not on Type IB. After that, one has to work with product design factors such as changing the adhesive, changing geometries or special storage such as rigid packaging or cold storage.

Type III telescoping occurs during handling. The roll is simply not tight enough to be picked up by the core or outside without the roll falling apart. Wind tighter.

Type IV telescoping is unique to common axis winders such as wide two drum winders such as used in the paper industry. It is known in that industry as dishing and will not be further described here.

Then there are a number of loose winding defects called 'telescopes.' A loose start will allow the core and a number of layers to move sideways during winding or unwinding. However, beware that most loose core complaints are in fact caused by wet cores drying out. In this case the defects favor products manufactured during wet seasons and converted during dry seasons. If your fiber cores are wetter than equilibrium with the current customer, they will dry out and shrink radially. The most aggressive tightening efforts on a winder will seldom be enough when winding stiff products such as film or packaging products. Buy good quality (dried) cores and store them in a hot room and consume them within a few hours of taking out of the hot room for those at risk products/conditions/customers.

Some products are so slippery that the winder can't be safely stopped and restarted. This is especially true if the winder does not have gold-plated drives with excellent stall tension take-up. Just a few wraps of slackness can put a fault or area of weakness into a roll. If the reason for the stops is manufacturing related, such as editing out bad spots, then the defect must be charged to manufacturing because there is little that can be done at the winder to prevent these faults at a stop when running troublesome grades.

Other defects that resemble a telescope are in fact operational rather than winding related. For example, failure to air-up an expanding shaft or allowing the bladder to leak down will let the rolls go during winding. Failure to maintain exceptionally tight and rigid core holding hardware will result in similar troubles. In the wide paper winders, the chucks and frame must withstand upward of 10,000# of sideways thrust without moving otherwise roll edge quality is lost.

As we have seen, just because the roll edge is not straight means little. The devil really is in the details. For further information you should refer to books on the subject such as my Winding: Machines, Mechanics and Measurements or Duane Smith's Web and Roll Defect Terminology.

***2009.09 Sep 2009
How should I combat core crush?

The first thing you must realize is that core crush is not a single defect, but rather are three distinctly different defects. True, they all have outcome, the core gives way, and increasing core strength is a possible treatment option for all. However, we should first consider lower cost options, such as changing winding tightness by diagnosing which type of core crush we have.

Type I core crush is caused when winding tightness causes interlayer compression at the core that exceeds the core's buckling strength. It is the more common type in the film industry, particularly with stretchy low-modulus materials such as polyethylene, polypropylene, rubber and vinyl, because they readily generate compression from winding tightness. Type I core crush is most easily distinguished because the core gives way DURING winding. With Type I core crush you want to reduce winding tightness as much as possibly by reducing the TNT's of winding (reducing Tension, Nip and Torque, and increasing speed).

Type III core crush is a totally different defect. It is the most common in the paper industry but can also be seen in film as well, particularly with high-modulus materials such as polyester. It is a totally different defect because the loads that cause the core to give way are not INTERNAL loads from winding. Instead, the failure is caused by EXTERNAL loads such as handling. Loads from squeezing, bumping and dropping the roll propagate to the core and knock it out. It is a totally different defect because you don't want to wind looser. Instead, you want to wind as tight as possible. We use the tightness of the layers as a structure, something like an arch, to protect the core from the outside world. Why should I use my precious product to protect the cheap core you say? First, if you loose the core you loose your precious product. Second, it works. In summary, Type III is distinguished from Type one in three different ways. The loads come from the outside world instead of winding, the core crushes after winding instead of during winding and, most importantly, is a loose defect rather than a tight defect.

Type II core crush is quite rare. Here, the loads that are relevant do not come from winding or handling. They come from the material itself. Specifically, the material shrinks AFTER manufacturing as can happen with some freshly extruded lively polymers or when winding hot. Type II is, in most cases, not even a winding defect because there is no winding solution once one lowers winding tightness as much as possible. Instead, it may be a process/product design shortcoming. You must change the product; namely, increase the core's strength.

In fact, increasing core strength by increasing wall thickness, increasing core material stiffness/strength, decreasing core nominal diameter are treatment options for all crushed cores. The only reason not to change the core for Types I and III first is because that represents a continuing cost while changing winding tightness may not. Even so, increasing core strength will buy you time to explore other options and might be the most appropriate response in emergencies.

Thus, core crush is an outcome with several distinct causal mechanisms. Think of core crush like a headache that could be caused by stress, or a brain tumor. You really want to know which cause you are dealing with because aspirin may be appropriate for a headache but could be deadly for a tumor. The good web handler looks beyond superficial appearances to the underlying mechanisms for a more certain and complete list of remedy options.

***2009.10 Oct 2009

Why are accumulators so troublesome?

Accumulators are used to handle roll changes on continuous machines such as web makers and roll-to-roll processing. They are used in lieu of more expensive turret winders or unwinds for speeds in the 50-400 FPM range. (Slower webs can sometimes be changed manually and higher speeds require turrets.) Unfortunately, accumulators are big, expensive, hard to design, hard to maintain and hard to control. They commonly cause wrinkling and are the source of many tension upsets and web path control problems.

Some of the accumulator's challenges are mechanical. Since you have many rollers, you have many chances for misalignment that is a major cause/type of wrinkling. Misalignment can be for individual rollers within the upper or lower assembly or, more commonly, with the traversing upper carriage as a unit. It is difficult to 'time' the four corners of the carriage to the hairsbreadth accuracies required in many web applications. If you do get the four corners level at the bottom of the stroke they may not be at the top of the stroke or anywhere in between. Thus you often see diagonal wrinkles kicked off at one or all parts of the travel. The good news is that you only need to level the rollers because diagonal wrinkles caused by misalignment are far more often parallelism (level in this case) rather than skew (square). Little or no maintenance attention to squaring may be required.

Accumulators are great big headaches for precision tension control. Without going into detail, most accumulators are acting something like a dancer to control web tension. Just as with any dancer, a major contributor to variability is friction. This friction can come from any number of sources depending on the design details. Components contributing to friction may include cylinder seals, chain/pulley, gearboxes, rack-and-pinion, slides and others. If that were not enough, we have tension upsets induced during the roll change where the accumulator carriage moves. These inertial upsets come from the translation of the carriage and from rollers that change rotational speed. To this we can add shortcomings in the software that controls the accumulator during steady state, filling, unfilling and the transitions between states. Finally, most accumulators are running 'blind' in the sense that they have no tension readouts via load cells so the owner has no idea just how bad the tension control problem is.

Path control problems may be caused by a shortcoming of the accumulator, such as mentioned above, or react to it from a crooked splice or crooked (baggy or cambered) material. Thus it is not unusual to see the web move sideways many inches, perhaps precipitously close to roller edges during roll change. Because of these issues and the long path length it is common to add an edge guide after the accumulator even though they may not have the response to follow these fast moving edge position upsets.

However, even if an accumulator was designed and maintained PEFECTLY, without any mechanical or control fault, we may still have problems. A good web handler can just look at an accumulator and anticipate the potential for wrinkling, especially on lightweight webs. Even if the accumulator were perfect we still have lots of rollers (many opportunities to kick off a wrinkle), lots of wrap (increasing traction which increases the tendency to wrinkle) and long spans (run the accumulator down whenever possible). If all of that were not enough, the accumulator is the Rodney Dangerfield of converting; it gets no respect or attention. Only a very few people, namely Michal and Shelton, have ever researched this neglected component and both have concluded this component is most challenging.

***2009.11 Nov 2009
What are the TNT's of winding?

The TNT's of winding are the control settings on the winding machine that affect the tightness of the wound roll. The acronym stands for Tension, Nip, Torque and speed.

Web line tension entering the windup is straightforward on most winders. The operator dials a setting into the control panel and the computer/PLC/drive in turn modifies the motor's output in either open loop (torque) or closed loop (dancer or load cell) control. With extensible products, such as nonwovens, rubber and tissue, we might instead use speed/draw control. Though web tension is affected by the speed/draw setting, the relationship is neither clear nor simple. Whether taper tension is used or not and what kind of taper is employed is a totally separate discussion.

Nip is often controlled by air cylinders that load a nip roller, whatever it might be called in your plant, against the winding roll. In some winders, most notably the two-drum, the nip load is partially determined by wound roll weight. Nip is most effective on compressible materials such as nonwovens, textiles and tissue. Nip also affects smooth, thin materials wound at higher speeds by precluding air from the winding roll.

Center-surface wind torque differential, confusingly abbreviated as 'torque' is rare and complicated. Suffice it to say here that it requires two motors, one connected to the center of the winding ROLL and the other connected to the nip ROLLER (or to both drums of a two-drum winder).

The little 's' stands for speed. The 's' is little because only some applications are speed dependent; namely those where air is brought into the roll and thus loosens it. This may include smooth, thin materials wound at higher speeds, such as film and foils, but never rough materials such as nonwovens, textiles and so on. In rough materials the air simply goes along for the ride, filling the spaces where fibers are not, and having no affect whatsoever on winding.

The proper units for calibration and display for all of these TNT knobs (speed excepted) is PLI in the English system and kN/m in the metric system. Savvy machine builders and process engineers insist on these standard units. Builders should also provide and buyers should also insist that calibration curves and detailed calibration procedures be given in the machine's manuals. The reason is quite simple; we can never entirely trust calculations. We must use calibration procedures to check that tension is indeed pulling as hard and the nip is pushing as hard on the web as we think. Calibrating load cells and dancers is simple in concept; you hang weights on a strap that has the same route as the web over the load cell roller. Calibrating nips requires a bit of resourceful cleverness that depends on the application.

Since the TNT's knobs are the most important controls we have for the winding process, we must use proper units and calibration procedures to make sure that your winding process is reliable, repeatable and stable. Only then can your plant can replicate successful runs from day-to-day and between machines of varying makes and models.

***2009.12 Dec 2009

How do the TNT's affect the wound roll?

The TNT's of winding all do the same thing: make the wound roll tighter. However, the tightness of the wound roll can be measured in many different ways. Scientists like to use WIT (Wound-In-Tension). Quality control people might use any of a dozen commercially used measurements of tightness such as roll hardness and roll density. An analogy might be helpful. While an object, such as your body, has only one temperature, its temperature can be expressed (measured) in dozens of ways including the more commonly known Kelvin, Rankin, Celsius and Fahrenheit scales as well as less commonly thought of scales such as wavelength of peak amplitude of radiation or mean-free-path of a molecule. The only difference between winding tightness and temperature is that temperatures can be converted between various scales via a simple equation while roll tightness is more complicated.

So don't get hung up on which definition of tightness to use, especially to the point of not defining it at all due to paralysis. Find a measure that is fast, practical and repeatable for your process/product. At least a third of my latest book, *Winding: Machines, Models and Measurements,* covers this subject in great detail.

We define and measure tightness in our plants for good reasons: tightness affects the frequency and severity of many winding defects and troubles. We have long known that most defects come in three flavors, loose defects, tight defects and 'other.' The loose and tight defects are self-explanatory (presuming that we indeed know to which category our specific trouble lies in). The 'other' category includes operational problems such as loose winding machines or cores that are cut to the wrong length. A fourth much smaller category is 'roll structure defects' that include but two of the half-dozen types of telescoping and one of the half-dozen types of starring. Thus, if we have tight, loose or roll structure related defects, we must be quite attentive to wound roll tightness.

So, what do we do if we have a loose defect? Simple, turn any or all of the TNT's up because all of these knobs all do the same thing. You can tighten a wound roll by increasing Tension, Nip or Torque and by decreasing speed. The roll does not know if it got tighter by increasing web tension or by increasing nip, it is just tighter. So what if your product is not speed dependent (see previous column) and you do not have the two motors on the windup that makes the torque differential knob? Simple, work very hard on the two knobs you do have, tension and nip.

So what happens if one knob is giving you trouble? Simple, back off and make up (if you need) by turning another knob up. For example, if you are having brittle web breaks, take the tension down and increase the nip. If you are having trouble with nip, such as common with gage varying material, back off on the nip and compensate as needed by increasing tension and/or by decreasing speed.

What we now know is that while there is only one kind of wound tightness, there are many paths to get there.

**** Future Web Works Column Ideas

When do you need an unwind motor vs brake

TTP's of processing
Counting machine and process knobs

The special case of foil
  - Intolerant of roller imperfections
  - Thermal expansion
  - Good news is gage uniformity

Defect Map
  - MD
  - CD

Taper vs 4 pt

Automatic decurling

Gap winding – jkgood, on the roller flat, on the roll flat; not enough time or distance to form a wrinkle

MD Wrinkle
Diagonal Wrinkle
Baggy Web

Unwind
  - Over under
  - One and only one diam measurement (reasons for)

Splices

The biggest misunderstanding; what you did yesterday is good enough for today or tomorrow

Speed limit
  - Roll change time
  - Roll change speed
  - Air entrainment
  - vibration

The hardest problems in web handling
The easiest problems in web handling

Nip concerns: calibration, friction, uniformity and safety

Profile

Friction Dancers, nip

Gage measurement
Gage control

Taping rollers

Data Acquistion systems time and lot based
    Clipboard, PC and PLC

What is a winding problem: has a winding solution

Air entrainment
    Roll
    roller

How can I handle a baggy web

Curl
Manufacturing
Roll set
decurling

Align(ability)

Most important tools
Eyes, ears
Jackknife, tape measures & levels, force gages/scales

Cantilevering

What is WIT

Rolls that can be wound, but not unwound I – telescope
Rolls that can be wound, but not unwound II – duplex winder

Cleaning a Web

Dancer vs load cell

Gauge bands and bagginess
Gauge bands and corrugations

Differential Winding

Trim (chute) design, expectations
Two bowed roller modes and speed/traction

Unwind problems
Excessive clearance
Inadequate torque range

What is troubling you
Cost of waste, delay

Web info sources

Pilot > Commercial

Curl
Decurl – live with curl

Cof

Safety policies

Optics and hand tools
Match drilled sideframes

Favorite material properties

Daq including labview

Wrap angle other geometries through slitters

Web Drive

PLC’s versus Drives

Winding vs product design problems

Preemptive slitter change

Evidence for waste, web breaks

Optimum bow roller wrap too little traction, too much loss of spread and touchiness
Aiming the bow

Predicting Wound Roll Diameter

Roller Count

Wound Roll diam-length-gauge relationship

Bearing drag – importance
Bearing drag – measurement

Pet Peeves

Buckles

TCBWA

Which roller to drive (hard, rubber, both etc)