# A Total Solution for Orifice Plate Calculations

Introduction

Flowel version 3.0 is an MS Windows^{TM} application that makes sizing orifice plates, nozzles, and venturis easier than ever. Recently revised, new features include updated calculation methods, an optional fluid properties package, and a redesigned user interface. Flowel is part of a total flow element solution that includes training, technical support, and ISO 9000 validation documentation. A 30 day trial is available. This document provides a summary of Flowel benefits.

Why Worry About Orifice Plates?

Industrial process facilities in the 1990s are experiencing rapid changes in competition, safety management, and quality assurance. To optimize production, processors must use accurate flow measurement to track energy, feedstocks, and products. Losses from inaccurate measurement are high. Recently, an audit of a natural gas facility revealed losses of $20 million over an eighteen month period due to measurement problems.
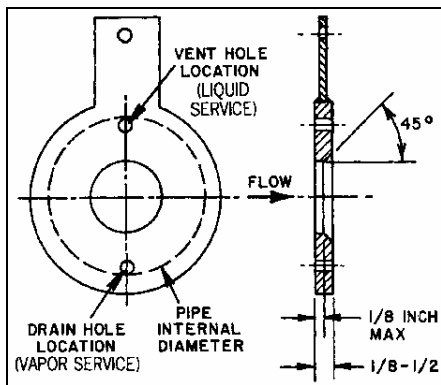
Orifice plates are commonly used to measure flow

The process industry commonly uses orifice plates, nozzles and venturis to measure flow. Relatively inexpensive, these devices provide accurate measurement when correctly sized and installed. Unfortunately, sizing and measurement calculations are complicated. Errors are common even though most organizations perform calculations with software. Bugs, poor user interfaces, and obsolete equations are wide spread.

Make sure your flow calculations are performed with the best software available. The cost of software is negligible compared to the cost of poor flow measurement. Look for a product that meets the needs of your entire organization: engineering, operations, network administration and quality assurance. Protect your investment by selecting a reputable vendor with a proven record.

Flowel: A Brief History

Flowel is the result of a long collaboration with our customers. Fifteen years ago, Kenonic Controls wrote the first version of Flowel for the DEC PDP 11/23 computer. In 1981, we rewrote Flowel for the just-introduced IBM personal computer. Much less expensive than a minicomputer, the PC offered instrument engineers accessible computing power. In 1985, we entered Flowel into a competition sponsored by the Instrument Society of America. Flowel won its class, and was included in the ISA catalog.

In 1985, most instrument engineers still manually performed flow calculations. The equations were familiar–computers were not. Given this user environment, and the limitations of the early PC's, Flowel version 1 had a "linear" program flow. An instrument engineer started up Flowel and progressed through a series of screens. It was an inflexible, but simple, user interface.

Flowel version 1 used the equations from L. K. Spink's book Principles and Practice of Flow Meter Engineering. For many years, this work was the most widely accepted reference on flow measurement. Later, the American Gas Association (AGA 3) and the International Standards Organization (ISO 5167) released new standards that superseded Spink's work. Released in 1988, Flowel version 2 incorporated these new standards.

Spink's classic work on Flow Meters

The new methods were more accurate, and more complicated. Many instrument engineers were using programs like Flowel to perform flow calculations. On average, users were more familiar with computers and less familiar with flow equations. In Flowel version 2 we provided these users with a suitable user interface. For simple calculations, Flowel provided a simple, linear screen sequence. For more complicated situations, such as ones involving AGA 8 gas compressibility calculations, Flowel provided "setting sheets".

Today, the challenge is not calculation speed. Most of us are familiar with computers, and no one performs manual flow calculations. As a result, instrument specialists are unfamiliar with the latest standards. These standards are more accurate, cover more situations, and are often more complex. Today, we are challenged to accurately employ these new standards.

Few of us have time to study (or even find) the latest flow calculation methods–we must rely on our software tools. Flowel version 3 provides the latest flow calculation methods from the American Gas Association, American Society of Mechanical Engineers, the British Standards Institute and the International Standards Organization. It provides a database of over six hundred fluids, and methods for calculating density, viscosity, isentropic exponent and vapor pressure.

Flowel 3 provides access to all major functions with only a few screens. Before designing Flowel 3, we reviewed

hundreds of customer comments and technical support calls. Built for MS Windows®, the Flowel 3 user interface provides for both new and experienced users. New users can access on-line help, and follow a guided sequence of screens. Experienced users can proceed directly to a desired screen, and set extensive program defaults for element type, base conditions, etc.

Flowel 3 went through six months of beta testing to ensure that Flowel truly offered exciting increases in productivity. Testers included operating companies, equipment vendors, and engineering contractors. The production version of Flowel 3 has been on the market since November 1994. Extensive sales to customers throughout the world indicate Flowel's wide acceptance by a broad user community.

Who Needs Flowel?

Operating Companies: Do More With Less
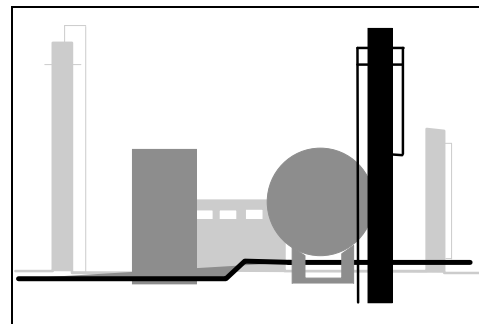
Process facilities face increasing global competition

For companies that operate process facilities, increased competition means lower margins. Simultaneously, customers and regulators are imposing new demands:

- compliance with tougher safety legislation such as the Occupational Safety and Health Act 1910.119 (USA),

- compliance with environmental standards such as the Clean Air Act (USA), and

- increased product quality through Total Quality Management and ISO 9000 programs.

Flowel can help meet these demands.

- For safety, use Flowel to create accurate, updated documentation of all flow elements used in hazardous conditions. In many places, workers have a legislated **right to know** about information required for safe operations. Such information includes materials of construction and flow rates. Around the world, plants use Flowel to keep accurate records.

- To track fugitive emissions and leaks, you need accurate flow measurement. Use Flowel to determine the accuracy (i.e. uncertainty) of any flow calculation.

- Your organization's Total Quality Management or ISO 9000 procedures may require that you verify software against known standards. Flowel complies with all major standards used in the world: AGA 3 (also known as ANSI/API 2530 or GPA 8185), ISO 5167, ASME MFC 3M.

Failure to comply with regulations can result in crippling fines and plant closures. Ineffective quality programs mean lost markets and higher costs. Many operating companies use Flowel for a cost effective answer to these problems.

Engineering Contractors:
## *On Time and On Budget*
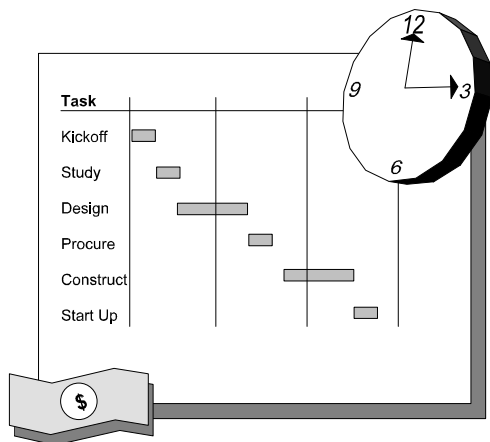
Contractors work under time and budget constraints

Contractors that provide instrument engineering services must deliver design documents that are on time, on budget, and meet customer specifications. Authored by an engineering contractor, Flowel has a number of features specifically designed for contractors.

- Use Flowel to reduce training time and required skill levels. We consistently receive reports that Flowel insulates users from the complexities of flow calculations. Consult on-line help for assistance. Pick up the phone for fast answers from a knowledgeable Flowel technical support engineer.

- Flowel helps you track costs. Print out job reports showing the number of instruments in a given project, and the number of calculations expended on each instrument. To document charges, attach job reports to invoices.

- Flowel supports your customers' standards. Flowel includes the methods and devices used in existing and new facilities. It provides the methods used in Europe, North America, South America, East Asia, and elsewhere. Use one product for all of your customers.

- Flowel provides a variety of specification sheet formats, including one based on the International Society for Measurement and Control ISA S-20 standard. Customize Flowel specification sheets with your company logo. Flowel supports laser printers, so your reports look great.

Some of the world's largest engineering companies use Flowel. They report that Flowel has dramatically increased productivity and decreased errors.

Equipment Vendors: Generate Revenue
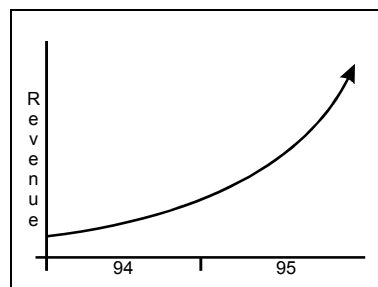
Some revenue generating ideas for Equipment Vendors

As margins on equipment continue to drop, vendors need new services and products. Flowel offers some interesting possibilities.

- Sell flow calculations to your customers. Your customers may not need a sophisticated product like Flowel, but would appreciate Flowel's accuracy. Dis-

tinguish yourself from the competition with Flowel generated flow graphs, fluid composition reports, and uncertainty calculations.

- In a small market, it may take time to recoup your investment in Flowel. As an option, you may purchase Flowel through a lease arrangement that dramatically reduces your initial investment. Call for more details.

- For your larger customers, become a Flowel reseller. It's a great way to encourage equipment sales–both you and your customers use the same sizing software. Please call us for more details.

We invited several equipment vendors to participate in the Flowel 3 development process. Today, Flowel is a true profit center for these vendors. Join them and give your customers the quality they deserve.

Regulators: Checking the Meter

In many places, government regulators check flow measurement calculations involving custody transfer (e.g., natural gas sales). These individuals inspect meter installations to confirm correct calculation of flows. Ideally, regulators want a software tool that industry accepts as a standard. Flowel is a *de facto* standard for the measurement community.

- Flowel has a long association with the International Society for Measurement and Control (formerly Instrument Society of America).

- A variety of industries use Flowel throughout the world.

- No other product for the IBM PC has been on the market longer than Flowel.

A number of government regulators are using Flowel. They report that inspected parties readily accept Flowel. Regulators find that Flowel is easy to use, which reduces errors, which in turn builds confidence among inspected parties. Make a hard job a little easier–use the industry standard Flowel.

How Will Flowel Benefit You?

Managers

If you manage an instrumentation group, you know that good software is more than a user manual and some floppy disks. The difficult issues are training, technical support, upgrades, and product longevity. We offer a total solution that addresses all of these issues.

- For ninety days after a Flowel purchase, we will provide support and upgrades. After ninety days, you may purchase a maintenance agreement that provides for continued support and select upgrades. Alternatively, you may elect to purchase support when necessary and upgrades upon availability. Ask us about the details.

- The Flowel user manual provides a tutorial on program usage. Most users familiar with orifice plate calculations, or with other programs, will find the tutorial sufficient. For users that are not familiar with flow measurement concepts, we can provide training either at our location or on site. We have also custom developed courses for delivery by computer. Contact us for more details.

Our engineers perform work around the world

- We can provide engineering services related to any aspect of flow measurement or control systems. Our engineers have performed work throughout North and South America. Projects have involved PLCs, flow computers, SCADA and DCS applications. Of special note is our Flow Measurement group. This group can help you with plant balance and custody transfer applications. Please call us for a detailed description of our qualifications.

- We constantly upgrade Flowel with the latest standards from AGA, ISO, ASME and others. We also upgrade Flowel to support the latest computer operating systems and networks. We protect your investment in Flowel.

- Flowel 3 includes a utility to import your existing Flowel 2 database -- another example of how we protect your investment.

Network Administrators

Software has become a major corporate asset. To optimize software usage, while minimizing administration costs, many organizations use networks.

- You can install Flowel on any network server running DOS, MS Windows or Novell Netware. (See *System Requirements* for more details.) We ship Flowel with all necessary instructions and files required for network installation.

- Our technical support engineers help you achieve a successful network installation. In our test facility, we have servers running Netware, DOS and Windows.

- Flowel is an MS Windows® application. As a result, it is compatible with virtually all popular computers, monitors and printers.

Quality Assurance

To verify Flowel's accuracy, your QA group must verify hundreds of equations. To minimize your expenses, we provide a number of documents.

- The Flowel documentation includes a complete description of each equation, including detailed footnotes that reference original publications. This allows an auditor to compare Flowel equations against original source material.

- We describe each equation using a common set of symbols. Flowel documentation is a valuable reference for anyone that deals with a variety of flow sizing standards.

- We test every calculation in Flowel against an independent source to verify accurate and correct implementation. In every test case, we provide a reference to an independent source. If no sources are available in literature or from regulatory bodies, we provide an independent calculation performed in MathCad™ or Flowel 2. The Flowel Validation document consists of multiple volumes and describes over 20,000 tests and sample calculations. Before a release of a new version of Flowel, we re-run all 20,000 calculations and verify their accuracy.

- Flowel supports Quality Assurance reviews. Flowel generated specification sheets indicate calculation methods.

Property Method

AGA 8 (1992)
LUCAS Viscosity
Lee Kesler "k"
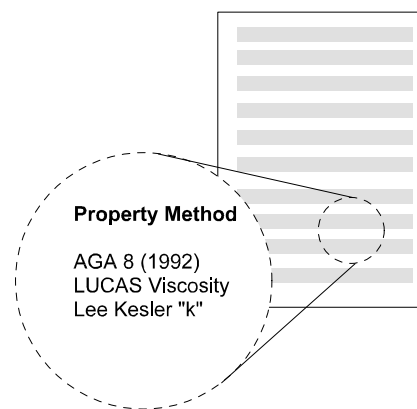
Flowel Specification Sheets indicate calculation methods

Designers

For designers that specify orifice plates, nozzles and venturis, Flowel offers productivity.

- As a designer, the main enemy of your productivity is incomplete information. With Flowel, you can stop searching for obscure equations and fluid properties. You get devices, old standards, new standards, fluid properties and more.

- For occasional users, Flowel provides an intuitive user interface with guided screen progressions. There is no need to remember special key strokes or peculiar rules. Flowel prompts you for all needed information, and warns you when special circumstances require your attention.

- For experienced users, Flowel has full data import and export capability. Perform bulk data entry into a spreadsheet, and then import the data into Flowel.

Import process data from other software. Export data for backup, or for use in other programs.

Purchasing

To ensure compliance with your company's equipment standards, attach a Flowel generated specification sheet to your purchase orders or quotation requests.

- Most company standards for flow elements are based on AGA 3, ISO 5167, or ASME MFC 3M. Use Flowel "off-the-shelf" to support your company standard.

- With Flowel, generate specification sheets that completely and unambiguously describe your equipment requirements. Minimize follow up discussions with vendors. Avoid expensive errors in delivered materials. Flowel generated specification sheets have been used throughout the world since 1985.

Plant Maintenance

Keep track of your plant's fluids and flow elements with Flowel.

- If you deal with hazardous materials, government regulations (e.g., OSHA 1910 in the USA) may require you to store and maintain the design documents for orifice plates, nozzles and venturis. Flowel lets you to electronically store and update your specification sheets.

- Operators often need a quick way to estimate flow. Use Flowel to create graphs of flow rate versus differential pressure.

- When the composition of a process fluid changes, use Flowel to quickly re-calculate fluid properties. Create an unlimited number of fluids, both pure and mixed. Associate any fluid with any device. No need to call a process engineer, or look for references.

- Changes in flowing rates, pressures or temperature are common. Use Flowel to easily re-calculate beta ratios or orifice sizes. Note the change in the Flowel database for the next shift.

User Interface

Flowel presents users with thousands of possible options. Yet, users report that the Flowel user interface is very easy to use. Flowel achieves usability by closely following a few principles.
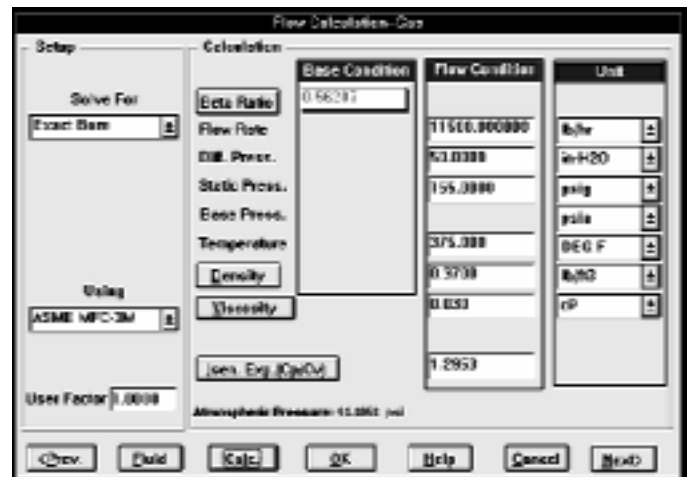
- Simple Navigation. Users new to Windows often become lost. Flowel provides a graphical summary screen that is always present, and a logical progression of dialog windows.

- Visual Cues. There are no hidden functions in Flowel. Users initiate actions by clicking buttons, or by selecting menus. There are no special keys to memorize.

- Intelligent Selection Lists. Flowel supports thousands of different combinations of devices, fluids and methods. Flowel makes your choices manageable by using intelligent selection lists. It only presents options that apply to your situation. For example, if you select "gas - critical flow", we only present flow elements that are applicable to critical gas flow.

- Guided Screen Sequences. In Flowel, each user choice affects subsequent options. For ease of use, it is important that Flowel presents choices in the right order. For example, instrument engineers do not specify the process fluid. Therefore, Flowel initially presents fluid related choices, followed by meter run choices, and finally offers choices related to sizing.

System Architecture

The diagram below illustrates the various modules that compose Flowel™.
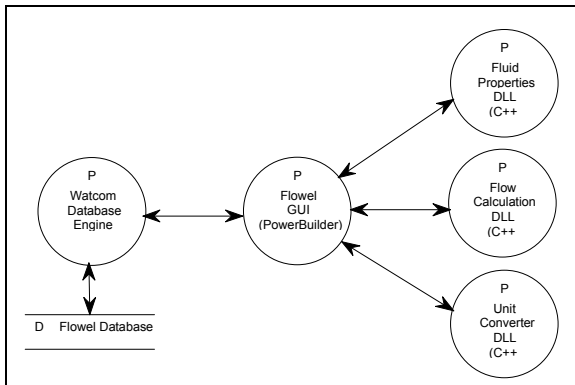
The Fluid Properties library contains routines used for the calculation of density, compressibility, viscosity, isentropic exponent and vapor pressure. The Flow Calculation library contains routines used for the calculation of bore size, differential pressure and flow rate. The Unit Converter library contains all routines used to convert values from one measurement unit into another unit. Kenonic Controls Ltd. writes these libraries in the C++ programming language.

Kenonic Controls Ltd. writes the Flowel graphical user interface in the PowerBuilder™ basic programming language. PowerBuilder™ is a development environment product sold by Powersoft Corporation of Burlington, USA. Kenonic licenses PowerBuilder™ from Powersoft for both product development and distribution.

Flowel™ employs the Watcom SQL relational database engine. Kenonic licenses the engine from Watcom International Corporation of Waterloo, Canada. Kenonic Controls authors Flowel™ database files.

System Requirements

As a minimum, Flowel 3.0 requires MS Windows™ 3.1, a 486 computer with 8 megabytes RAM, a hard drive with 10 megabytes free, a single floppy drive, a mouse, and a VGA monitor. We recommend a PENTIUM computer with 16 megabytes of RAM, a CD-ROM drive, and a Super VGA monitor. Flowel supports MS Windows™ 3.11, Win 95, NT 3.5, and NT 4.0

Network Server Support

Flowel supports installation on network servers running one of the following operating systems:

- DOS 6.0 or higher
- MS Windows for Workgroups 3.1
- MS Windows 3.11, Win 95, NT 3.5, and NT 4.0
- Novell Netware version 3.1 or 4.1 (not 4.0)

We may provide support for other network operating systems. Please call for information.

Fluid Property Calculator

We provide Flowel with an **optional** Fluid Property Calculator that provides methods for determining viscosity, isentropic exponent, vapor pressure, and bubblepoint, as well as additional methods to calculate density:

- **Density Methods** - Soave-Redlich-Kwong; Peng-Robinson; Lee-Kessler; and various NBS methods
- **Viscosity Methods** - IAPS (1975) Viscosity Eqn. (water/steam only) and Lucas Viscosity Eqn. (gases only)
- **Isentropic Exponent Methods** - Ideal Gas heat Capacity Ratio; Real Gas with Redlich-Kwong Correction; and Real Gas with Lee-Kessler Correction
- **Vapor Pressure Method** - Antoine
- **Bubblepoint Methods** - Soave-Redlich-Kwong and Peng-Robinson

For a detailed listing of methods, please see the *Flowel Features* section. You may purchase Flowel with or without the optional Property Calculator. See our price list for current prices and terms.

Evaluating Flowel

For a small fee, we also offer a **30 Day Trial** of Flowel. This trial includes all software, user manual, network files, technical support and the Property Calculator Option. Should you decide to buy Flowel, we apply the cost of the trial towards your first purchase. You keep the user manual regardless of purchase.

Flowel Feature List

Fluid States Supported:
gas
gas, wet
gas, critical flow
liquid
liquid, critical flow

Fluid Database
Unlimited User Definable Mixtures
water / steam
natural gas (AGA 8 - 85)
natural gas (AGA 8 - 92)
ammonia
argon.
carbon dioxide
ethane
ethylene
hydrogen
i-butane
methane
n-butane
nitrogen.
oxygen.
propane
approx. 600 other fluids

Devices Supported:
Orifice Plate-Standard
Orifice Plate-Standard, Drain/Vent
Orifice Plate-Conical Entrance
Orifice Plate-Quadrant Edged
Orifice Plate-Eccentric
Orifice Plate-Segmental
Orifice Plate-1d-6d Thick
Orifice Plate- 6d-20d Thick
Orifice Plate-Restriction
Honed Orifice Meter Run
Venturi-Cast
Venturi-Machined
Venturi-Welded
Nozzle-ISA 1932
Nozzle-ISA 1932, Drain/Vent
Nozzle-Long Radius, High Ratio
Nozzle-Long Radius, Low Ratio
Venturi Nozzle
Venturi Nozzle-Toroidal Throat
Venturi Nozzle-Cylindrical Throat

Differential Pressure Tap Configurations Supported:
Corner
Flange
Radius
Flange, 180 deg. Offset
Flange, 90 deg. Offset
Vena Contracta
Vena Contracta, 180 deg. Offset
Vena Contracta, 90 deg. Offset
Pipe
Wall (Venturi only)
Throat (Venturi only)

Flow Measurement Standards:
ISO 5167-1980
ISO 5167-1991
AGA 3-1990
AGA 3-1985
ASME MFC-3M
ASME MFC-7M
BS 1042
General

Density Calculation Methods:
AGA 8 (1985), Detailed
AGA 8 (1985), SG, CO2, N2
AGA 8 (1985), SG, HV, CO2, N2
AGA 8 (1985), SG, HV, CO2
AGA 8 (1985), HV, CO2, N2
AGA 8 (1985), SG,CH4,CO2,N2
AGA 8 (1992), Detailed
AGA 8 (1992), SG, HV, CO2
AGA 8 (1992), SG, CO2, N2
Ideal Gas Method, SGi, Zf
Liquid SG Method, SG, Density H2O
Molecular Weight Method, MW, Zf
NBS/NRC Steam Eqn.
NX-19, Detailed
Real Gas Method, SGr, Zair
Redlich-Kwong
Redlich-Kwong (Wichert-Aziz)

Density Calculation Methods:
Requires Optional Fluid Prop. Calc.
Soave-Redlich-Kwong
Peng-Robinson
Lee-Kesler BWR
Thompson-Brobst-Hankinson
   (or COSTALD)
Modified Rackett
Modified Antoine
NBS Ammonia Eqn.
NBS Nitrogen Eqn.
NBS Argon Eqn.
NBS Oxygen Eqn.
IUPAC Carbon Dioxide
NBS Hydrogen
NBS Methane
NBS Ethane
NBS Ethylene
NBS Propane
NBS i-Butane
NBS n-Butane

Viscosity Methods:
Requires Optional Fluid Prop. Calc.
IAPS (1975) Viscosity Eqn. (for water/steam only)
Lucas Viscosity Eqn. (for gases only)

Isentropic Exponent (Ratio of Specific Heats Cp/Cv):
Requires Optional Fluid Prop. Calc.
Ideal Gas Heat Capacity Ratio
Real Gas with Redlich-Kwong Correction
Real Gas with Lee-Kesler Correction

Vapor Pressure:
Requires Optional Fluid Prop. Calc.
Antoine

Bubblepoint:
Requires Optional Fluid Prop. Calc.
Soave Redlich Kwong
Peng Robinson

Material Tables:

Unlimited User Definable	347 SS	Hastelloy B
316 SST	Hastelloy B	Hastelloy C
316L SST	Hastelloy C Iconel X, annealed	347 SS
Hastelloy C-276	Haynes Stellite 25	Hastelloy B
Monel 400	Copper	Hastelloy C
Carbon Steel	Yellow Brass	
301 SS	Aluminum bronze	**Pipe Tables:**
304 SS	Beryllium Copper 25	Unlimited User Definable
310 SS	Cupronickel 30%	Built in 1/8 inch to 32 inch
316 SS	K-Monel	
330 SS	347 SS	**Atmospheric Pressure:**
		US Std. Atm., 1976 by NOAA, NASA, USAF

Measurement Units:

CFD	NIMPBPD	SL/day	in-H2O
CFH	NIMPBPH	SL/hr	kg/cm2
CFM	NIMPGPD	SL/min	kPa
CFS	NIMPGPH	SL/sec	mm-H2O
hL/day	NIMPGPM	Sm3/day	MPa
hL/hr	NIMPGPS	Sm3/hr	psia
IMPBPD	NL/day	Sm3/min	cm
IMPBPH	NL/hr	Sm3/sec	ft
IMPGPD	NL/min	SUSBPD	in
IMPGPH	NL/sec	SUSBPH	m
IMPGPM	Nm3/day	SUSGPD	micron
IMPGPS	Nm3/hr	SUSGPH	mm
kg/day	Nm3/min	SUSGPM	yd
kg/hr	Nm3/sec	SUSGPS	cP
kg/min	NUSBPD	ton/day	gm/cm.sec
kg/sec	NUSBPH	ton/hr	gmf.sec/cm2
L/day	NUSGPD	ton/min	kg/m.hr
L/hr	NUSGPH	ton/sec	lb/ft.hr
L/min	NUSGPM	tonne/day	lb/ft.sec
L/sec	NUSGPS	tonne/hr	lb/in.sec
lb/day	SCFD	tonne/min	lbf.sec/in2
lb/hr	SCFH	tonne/sec	mPa.sec
lb/min	SCFM	USBPD	N.sec/m2
lb/sec	SCFS	USBPH	P
m3/day	ShL/day	USGPD	Pa.sec
m3/hr	ShL/hr	USGPH	Btu/ft3
m3/min	SIMPBPD	USGPM	Btu/in3
m3/sec	SIMPBPH	USGPS	kcal/m3
NCFD	SIMPGPD	DEG C	kJ/dm3
NCFH	SIMPGPH	DEG F	kJ/m3
NCFM	SIMPGPM	DEG K	MJ/m3
NCFS	SIMPGPS	DEG R	in/(in F)
NhL/day		atm	mm/(mm C)
NhL/hr		Bar	