TS310 MOD4A Digital Controller

Users Guides

Document No. 93-2952

April 1998

Rev. 1

This manual contains outdated information (part numbers, addresses, and so on) and is provided on CustomerNet as a courtesy to owners of TS310 systems.

TRICONEX

La Marque, Texas

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TRICONEX reserves the right to make improvements in the design, construction, and appearance of its products without prior notice.

Revision History

Rev. C	July 1991	Changes to all parts except MODBUS®
Rev. D	September 1991	Technical changes to: **Installation Configuration Operation Maintenance:** Sections 3, 4, 6, and 7; and **Troubleshooting Guide:** Section 2.
Rev. E	November 1993	Replaced P/N Manual 310 4A GEN2 with P/N 93-2952. Replaced pages i through xi with pages i through x.
Rev. F	May 1995	Added Triconex Offices to front matter and changed TRI-SEN to Triconex on pages i through xiii.
Rev. G	May 1996	Updated the front matter. **Installation Configuration Operation Maintenance:** Added an additional copy of Section 9, Configuration (Part No. 4108-00002A), to be bound separately for use as a stand-alone document.
Rev. 1	April 1998	Incorporated general editorial and technical revisions by Customer Service Department and others to all parts; all parts reformatted including A4. All parts released at Rev. 1.

Warnings!

READ THIS ENTIRE MANUAL AND ALL RELATED PUBLICATIONS PERTAINING TO THE WORK TO BE PERFORMED BEFORE INSTALLING, OPERATING, OR SERVICING THIS EQUIPMENT.

- **Practice all plant and safety codes and standards. Failure to follow instructions can result in personal injury and/or property damage.**
- To prevent ignition of hazardous atmosphere, do not remove covers of Class I Division I (explosion-proof) units with power applied.
- All servicing should be performed by qualified technicians. Dangerous voltages may be present on the circuit boards.
- Use extreme caution when working around power-input cables. These cables may have potentially lethal voltages on them.
- Be very careful when working on the digital (or discrete) input/output field termination panels. The external devices being controlled can have high, potentially lethal voltages on them. Turn off the power to the external devices before disconnecting or connecting the cable or a wire between the digital (or discrete) input/output field termination panels and the field wiring.
- Replace fuses only with specified parts for continued safe operation.
- Equip the engine, turbine, or other type of prime mover with an overspeed (overtemperature or overpressure, where applicable) shutdown device that operates totally independently of the prime mover control device. This protects against run-away or damage to the engine, turbine, or other prime mover, or personal injury or loss of life, should the mechanical-hydraulic or electronic governor, actuator, fuel control, driving mechanism, linkage, or controlled device fail.
- Make sure the charging device is turned off before disconnecting the battery from the system to prevent damage to a control system that uses an alternator or battery-charging device.
- Prior to energizing the equipment, have qualified personnel verify all wiring and connections against vendor drawings. Incorrect wiring and/or connections can result in equipment damage.
- Contact appropriate manufacturer for instructions on operation of engine, turbine, or driven unit. This manual does not contain this information.

If you have questions or need more information on installing and operating Triconex equipment, contact Triconex

Disclaimer

Because of the variety of uses for this equipment, the user of and those responsible for applying this equipment must satisfy themselves as to the acceptability of each application and the use of the equipment.

The illustrations in this manual are intended solely to illustrate the text of this manual. Because of the many variables and requirements associated with any particular installation, Triconex cannot assume responsibility or liability for actual use based upon the illustrative uses and applications.

In no event will Triconex be responsible or liable for indirect or consequential damages resulting from the use or application of this equipment.

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Warranty

All Triconex products are warranted to be free of defects in materials and workmanship for a period of one year from date of start-up of our equipment or 18 months from date of shipment, whichever comes first. In case of failure, Triconex liability shall be limited to furnishing, but not installing, necessary repair parts; or at the option of Triconex, to repairing the defective product at its manufacturing location, providing the equipment is returned at purchaser’s expense.

This warranty does not apply to equipment showing abuse or damage or to equipment which has been altered or repaired by others, except as authorized by Triconex Nor does it extend to products that have been subjected to a corrosive and/or abnormal atmosphere, or to product components (such as batteries, lamps, etc.) which have provided a normal service life.

Triconex will determine if warranty applies when material is received at its manufacturing location. A purchase order and a Returned Merchandise Authorization (RMA) must accompany all returned material. The purchase order number as well as the RMA number should be clearly marked on the outside of the shipping container. Triconex Customer Service Department issues RMA numbers.

In no event will responsibility be assumed or implied for consequential damages arising from interrupted operation or any other causes.

This warranty is in lieu of all other warranties expressed or implied, and no one is authorized to assume any liability on behalf of Triconex, or to impose any liability on behalf of Triconex, or to impose any obligation on it in connection with the sale of any equipment other than as stated above.

Electrostatic Discharge Awareness

Electrostatic discharge can damage or destroy electronic components, assemblies, or systems.

1. Keep the following materials away from components and work area:
   - Styrofoam® (polystyrene): cups, packing material
   - cellophane: cigarette packages or candy wrappers
   - vinyl: books or folders
   - plastic: cups, bottles, ash trays
2. Avoid synthetic clothing. Instead wear cotton or cotton-blend materials. Keep components away from elastics, clothing, and hair.
3. *Before* handling electronic components, discharge static electricity buildup from your body by using a properly connected wrist strap.
4. *Do not handle components in the field unless properly grounded via wrist strap*. If you are not properly grounded:
   - Do *not* pick up components.
   - Do *not* touch the printed circuit board.
   - Do *not* remove components from the chassis.
5. Transport all static-sensitive components only in static-shielding carriers or packages. Place static awareness labels on all components to prevent removal from static-shielding container during transit.
6. Handle all static-sensitive components at a static-safe work area including floor mat, wrist strap, air ionizer, ground cord, and conductive table mat.
7. *Wear a grounded wrist strap in the field whenever possible*. Where wrist straps are impractical, wear grounded heel straps or special footwear on properly grounded dissipative flooring.
8. Do *not* subject components to sliding movements over any surface at any time.

Triconex Offices

WORLD HEADQUARTERS

Triconex Corporation
15091 Bake Parkway
Irvine, CA 92718
Phone: +1-714-699-2100
Fax: +1-714-768-6601

MANUFACTURING LOCATIONS

TMR Products & Systems
15091 Bake Parkway
Irvine, CA 92718
Phone: +1-714-699-2100
Fax: +1-714-768-6601

TRISEN Products & Systems
4916 FM 1765
La Marque, TX 77568
Phone: +1-409-935-3555
Fax: +1-409-935-3881

AMERICAS/MIDDLE EAST SALES & SERVICE OFFICES

Customer Business Center
4916 FM 1765
La Marque, TX 77568
Phone: +1-409-935-3555
Fax: +1-409-935-3881

Western Region
15091 Bake Parkway
Irvine, CA 92718
Phone: +1-714-699-2100
Fax: +1-714-768-6601

Latin America
15091 Bake Parkway
Irvine, CA 92718
Phone: +1-714-699-2100
Fax: +1-714-768-6601

Gulf Coast
4916 FM 1765
La Marque, TX 77568
Phone: +1-409-935-3555
Fax: +1-409-935-3881

Northeast Region
972 East Broadway, Suite 202
Stratford, CT 06497
Phone: +1-203-386-1936
Fax: +1-203-386-0864

Middle East
Dubai World Trade Center, Suite 1704
P.O. Box 9237, Suite 1704
Dubai, UAE
Phone: +97-1431-4949
Fax: +97-1431-4780

Baton Rouge
4664-Jamestown Avenue, Suite 325
Baton Rouge, LA 70808
Phone: +1-504-926-6983
Fax: +1-504-926-6987

Southeast Region
3200 Northline Drive
Forum VI, Suite 501M
Greensboro, NC 27408
Phone: +1-910-294-8656
Fax: +1-910-294-3063

Saudi Arabia
S. National/Saudi American Bank Bldg.
P.O. Box 1557
Al-Khobar 31952
Kingdom of Saudi Arabia
Phone: +966-3-894-0087
Fax: +966-3-895-0050

EUROPE/AFRICA SALES & SERVICE OFFICES

Customer Business Center
10 Avenue du Centaure
BP 8409 Cergy
95806 Cergy-Pontoise Cedex
France
Phone: +33-1-34-43-26-26
Fax: +33-1-34-43-26-27

Great Britain
Broomwade Works, Hughenden Avenue
High Wycombe, Buckinghamshire
HP13 5SF
UK
Phone: +44-0-1494-452535
Fax: +44-0-1494-452030

South Africa
Babcock Controls, Delta Division
67 Port Road, Robertsham 2091
P.O. Box 2194, Southdale 2135
Republic of South Africa
Phone: +27-11-680-5420
Fax: +27-11-680-0206

ASIA-PACIFIC SALES & SERVICE OFFICES

Customer Business Center
750E Chai Chee Road
#07-01/02 Chai Chee Industrial Park
Singapore 469005
Phone: +65-738-5488
Fax: +65-738-5188

Thailand
c/o Polytechnology Co Ltd
108/59 Moo5 Soi Tonson
Changwattana Road
Pakkred, Nonthanburi 11120
Thailand
Phone: +66-2-960-5070
Fax: +66-2-584-6771

Malaysia
c/o Tri-Systems Sdn Bhd
36A Jalan BM 1/2
Taman Bukit Mayang Emas
47301 Petaling Jaya, Selangor
Malaysia
Fax: +60-3-704-7217
Fax: +60-3-704-7218

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	Serial No.		*Serial No.*	**Application/Remarks**
❑ TS3000	________________	❑ M306	________________	____________________________
❑ TS1500	________________	❑ MPS390	________________	____________________________
❑ TS410	________________	❑ HA152	________________	____________________________
❑ TS330	________________	❑ HA100	________________	____________________________
❑ TS310	________________	❑ HSC3	________________	____________________________
❑ TS160	________________	❑ HCX21	________________	____________________________
❑ TS130	________________	❑ RCD100	________________	____________________________
❑ TS110	________________	❑ Other	________________	____________________________

Fax this form to Triconex at the number above. Or, fold this sheet in thirds ensuring the address on the back is visible, tape closed (please do not staple), add postage, and drop in the mail.

Thank you for choosing Triconex products.

Place
Stamp
Here

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Marketing, TRISEN Products
4916 FM 1765
La Marque, TX 77568
U.S.A.

Contents - TS310 Documentation Set

Tabs

TS310 MOD4A Digital Controller

Installation, Configuration, Operation, Maintenance Guide

Document No. 4933-0014

April 1998

Rev. 1

TRICONEX

La Marque, Texas

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Revision History

Rev. 0	March 1990	Initial issue.
Rev. A	September 1990	General technical and editorial revision, and incorporated narrative discussion of new software.
Rev. B	April 1991	Technical revisions to **Installation, Configuration, Operations, Maintenance** machine data in Chapter 9, part numbers in Chapter 7, and Channel 144 in Chapters 9 and 2.
Rev. C	July 1991	General editorial revisions. Technical revisions to Sections 2, 3, 4, 7, 9 and 10.
Rev. D	September 1991	Technical revisions to Sections 3, 4, 6, 7
Rev. 1	April 1998	Incorporated general technical and editorial revisions by Customer Service and others to all chapters; reformatted including A4.

Contents

Illustrations

Foreword - Important *TS310* Tips

The *TS310* is different from conventional prime-mover controls. Its micro-processor design and user configurable features offer capabilities far beyond conventional electronic controllers. To ensure that your *TS310* application is a success we offer the following suggestions:

- Review your requirements with a Triconex application engineer and have Triconex assist in configuring and documenting your unit.
- Order spare parts with your *TS310* and have them available at startup.
- Arrange for operator and technical personnel training prior to installation of your unit.
- Have a Triconex field service engineer present at startup.
- Take advantage of Triconex support services. These include:
- Application engineering
- Turnkey installations

Our experience shows that customers who follow these recommendations achieve the smoothest, least expensive startup, and ultimately derive the greatest benefit and savings from their units.

IMPORTANT: *Your* TS310 *warranty covers factory repair or replacement of a defective item. It does not cover:*

Installation
Startup assistance
Training
On-site repairs

Please contact your local TRISEN representative if you have any questions regarding our products or services.

Chapter 1 - Introduction

This manual describes the *TRISEN 310* Digital Controller.

About This Manual

As its name implies, this manual is a *guide* to familiarize the user with how to install it, how to configure it and how to operate it. In depth user training is available from Triconex.

The material in this manual is arranged according to function; such as startup sequence, cascade control, limits, and so on.

The first part of this manual is designed for customers who want to use the *TS310* controller immediately in a basic speed control application and are not interested, at least for now, in the broader capabilities of the *TS310* controller. Also, the first part of the manual is recommended as the place to start for those who wish to become familiar with the more complex uses and functions of the *TS310*, but are starting from scratch.

After becoming familiar with the simpler aspects of the *TS310*, you can then move further into the manual to those functions of interest, skipping those you do not intend to use.

This manual contains the following chapters:

- Chapter 1 - Introduction
  This chapter contains information about this document and related reference documents.
- Chapter 2 - General Description
  This chapter presents a general description of the TS310 including listings of software programs and product upgrades.
- Chapter 3 - Hardware
  This chapter describes the hardware included in the TS310.
- Chapter 4 - Installation & Wiring
  This chapter explains how to install the TS310 including mounting details, as well as wiring scenarios for various applications.
- Chapter 5 - Operating Functions
  This chapter describes the primary startup sequence, and discusses alternate startup sequences.
- Chapter 6 - Maintenance
  This chapter presents information on changing software EPROMS, and electrostatic discharge awareness.
- Chapter 7 - Spare Parts
  This chapter provides a list of spare parts.
- Chapter 8 - Specifications
  This chapter lists all the specifications for the TS310.
- Chapter 9 - Configuration
  This chapter describes how to configure the TS310 and provides brief reminder channel descriptions. This information is arranged by channel number. It is intended for use as a quick reference guide, once you are familiar with TS310 configuration and operation.

- Chapter 10 - Configuration - Expanded Discussion
  This chapter explains in detail the various channels of the *TS310* and how to configure them. The information in this chapter is arranged alphabetically by operating variable type; e.g., alarms, cascade control; through to trips, etc.

By reading this manual, you will be able to:

- Understand the components of the *TS310* Digital Control System.
- Navigate through the display channels and enter data to configure all control, speed, pressure and synchronization parameters.
- Navigate through the display channels and enter data to configure all analog inputs, analog outputs, digital inputs, digital outputs and pressure inputs.
- Navigate through the display channels and enter data to configure all analog trips and alarms.

Documentation Conventions

This manual uses the following typographic conventions:

Example	Description
NOTE	Notes contain supplementary information.
⚠ **CAUTION**	This symbol precedes information about potential equipment damage.
⚠ **WARNING**	**This symbol precedes information about potential personnel hazards.**

User Experience Prerequisites

Extremely advantageous, though not required, is some experience with the use of digital control systems, or an instrumentation background.

Simple applications require little specialized knowledge of controls, electronics or computers. These applications are easily understood and used, quickly accepted by operators, and can be configured in a few minutes.

The basic process is:

- Mount the *TS310* controller.
- Connect power to the *TS310* power supply.
- Connect the magnetic speed pickups.
- Connect the control output to the valve actuator.
- Enter values in a minimum of sixteen of the *TS310* channels. (See paragraph 9.8).

Once you are familiar with details of the simpler applications, grasping the complete control flexibility and the configuration details of more complex applications comes easy.

Reference Documents

- *TS310* Troubleshooting Guide
- *TS310* ModBus Guide
- *TS310* Auto-Configuration Guide
- *TS310* Extraction & Admission Operations Guide
- *TS310* Synchronous Generator Operations Guide

Chapter 2 - General Description

The versatile TRISEN *TS310* Digital Controller is designed using the latest computer techniques that relate uniquely to rotating equipment. This may sound imposing, yet the *TS310* remains simple to apply and simple to operate. Computer techniques eliminate calibration, create flexibility for applications, and provide a simple, operator-friendly interface.

The *TS310* controller is totally digital in all respects. For example, the unique speed measurement system brings the magnetic pickup frequency signal directly into the microprocessor for counting. There is no interposing frequency-to-voltage converter or analog-to-digital converter. There is no calibration. In fact, this measurement technique is so accurate, so precise, that two or more *TS310* controllers measuring speed from the same toothed wheel will read precisely the same RPM.

Good control requires accurate measurement. The *TS310* Digital Controller provides both. Although the *TS310* stands out with rugged compact simplicity as well as ease of application for simple installations, the *TS310* is equally at home solving complex control schemes with comparable ease of application.

Hundreds of TS310s are now in use operating new and retrofit fans, pumps, compressors and other simple applications with unsurpassed reliability. Hundreds more, however, are now controlling new and retrofit complex generator and extraction control installations all over the world, with far more flexible capability than has ever been available on previous governing systems.

For example, the *TS310* can automatically synchronize and close the generator breaker with the touch of a button. The *TS310* easily slips from DROOP control mode into frequency control automatically when the utility grid is lost. Then, the *TS310* easily and automatically slips back into DROOP control bumplessly when the utility tie breaker is closed again.

The *TS310* will transfer to or from extraction control at the touch of a button (or from an external contact). The *TS310* provides a wide variety of possible startup sequencing, all of which are keyboard selectable. For installations with widely varying load situations, *TS310* has startup tuning built-in.

The list goes on and on. As a matter-of-fact, a full grasp of the many *TS310* possibilities will require considerable reading.

At the same time, *TS310* configuration is in sections so that simple installations will require only a small amount of reading and a few channel entries. You don't even have to be aware of all the other *TS310* capabilities.

The nice part is that all TS310s are alike. Learning one means you've learned them all. They are completely interchangeable (with two program-software options furnished in non-volatile EPROM chips).

One *TS310* fits all, training is simplified, maintenance is reduced to almost nothing, no calibration is required, application is simplified and standardized, and spare parts are reduced to an absolute minimum.

2.1 General Arrangement

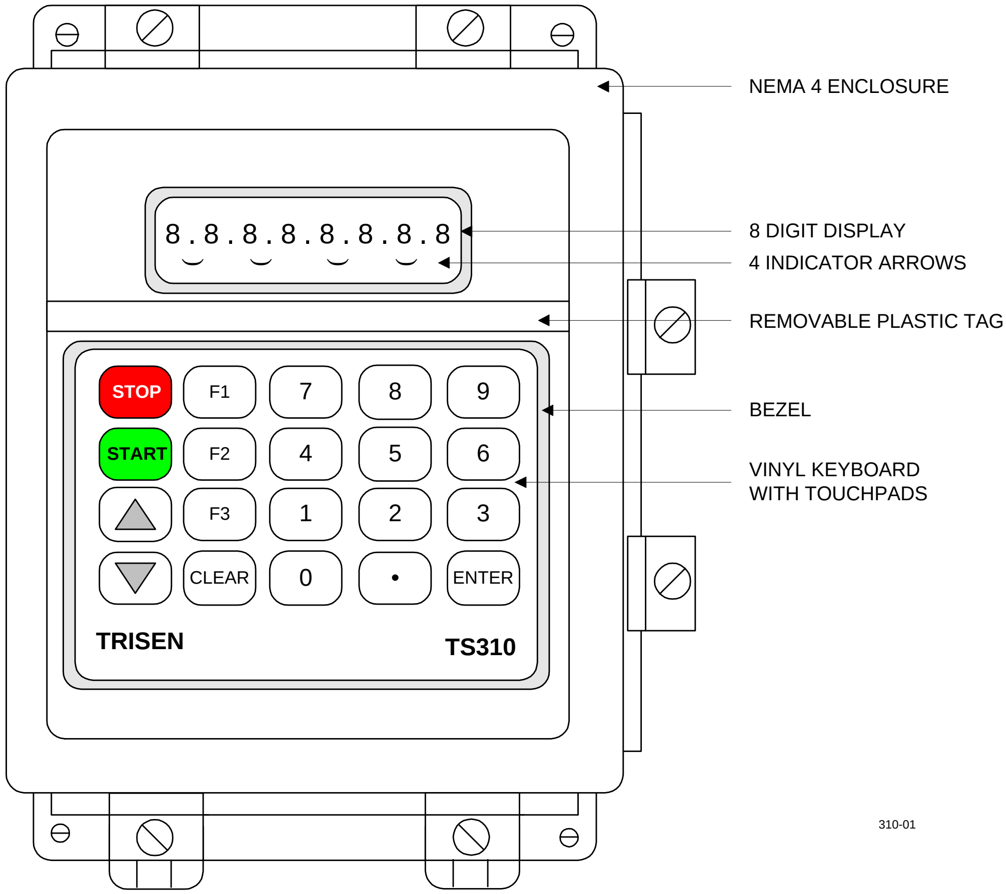


Figure 1. *TS310* Front View

Front Panel

The *TS310* keyboard is used to START and STOP the turbine, and to ⮝ RAISE and ⮟ LOWER the speed. F1 and F3 function keys are not used with simple speed control applications.

Keypad keys 0 through 9 are used to access *Channels* which display data pertinent to the operation of the turbine. These keys are also used to enter and change data. These data are shown on the eight-character LCD display above the keyboard. Pressing two numbers will access a channel. For example:

Press **00**	the value in Channel 0 will be displayed, indicating	Speed Used (RPM)
Press **05**	the value in Channel 5 will be displayed, indicating	Speed Setpoint (RPM)
Press **08**	the value in Channel 8 will be displayed, indicating	Output Signal (%)
Press **10**	the value in Channel 10 will be displayed, indicating	Magnetic Pickup #1
Press **11**	the value in Channel 11 will be displayed, indicating	Magnetic Pickup #2

Refer to Chapters 9 and 10 for detailed information regarding accessing the channels and configuring the controller.

2.2 Software Programs

TS310 Digital Controller has been continuously improved over time. Serial numbers identify MOD1 through MOD4 types and software types as follows:

Serial Numbers	*Designation*	*Software Version*
S83001Ds through S83028D3	MOD1	SO31---
S83029D3 through S86310D3	MOD2	SO32---
S86400D3 and up	MOD3	SO33---
11402-01-01 and up	MOD3	SO33---
Name Plate States *TS310* MOD3	MOD3	SO33---
Name Plate States *TS310* MOD4	MOD4	SO34---

MOD4 circuit boards interchange with MOD3, MOD2, and MOD1.

SO34R1, SO34R2, and SO33 software EPROMS will fit MOD3 and MOD4 circuit boards. These EPROMS will NOT fit MOD1 or MOD2 circuit boards.

SO31 and SO32 software EPROMS will NOT interchange with MOD3 or MOD4 circuit boards.

The *TS310* software programs reside in non-volatile EPROM memory. Two standard programs with the DX8 option are available.

Application	*EPROM 1*	*EPROM 2*
SINGLE VALVE	03C-01049-01 08A-6-14	03C-01049-01 08B-5-14
TWO VALVE	03D-01049-01 08A-6-14	03D-01049-01 08B-5-14
SINGLE VALVE WITH DX8	08C-01009-01 08A-6-09	08C-01009-01 08B-5-09
TWO VALVE WITH DX8	08D-01009-01 08A-6-09	08D-01049-01 08B-5-09

These updated programs, will be found in *TS310* MOD4A controllers. These software EPROMS will interchange with earlier *TS310* MOD3 and MOD4 software, identified by TL33 and TL34. An enhancement package is available for updating earlier controller Main Boards.

The figure on the following page illustrates *TS310* software. Notice that the 3rd PID Control, Output No. 2, Priority, and Ext/Adm Map Computation blocks are included only in the *TS310* Two Valve software.

TS310 Two Valve software can be configured for *TS310* One Valve operation; in that case, configuration and operation will be identical to that provided in the *TS310* One Valve software.

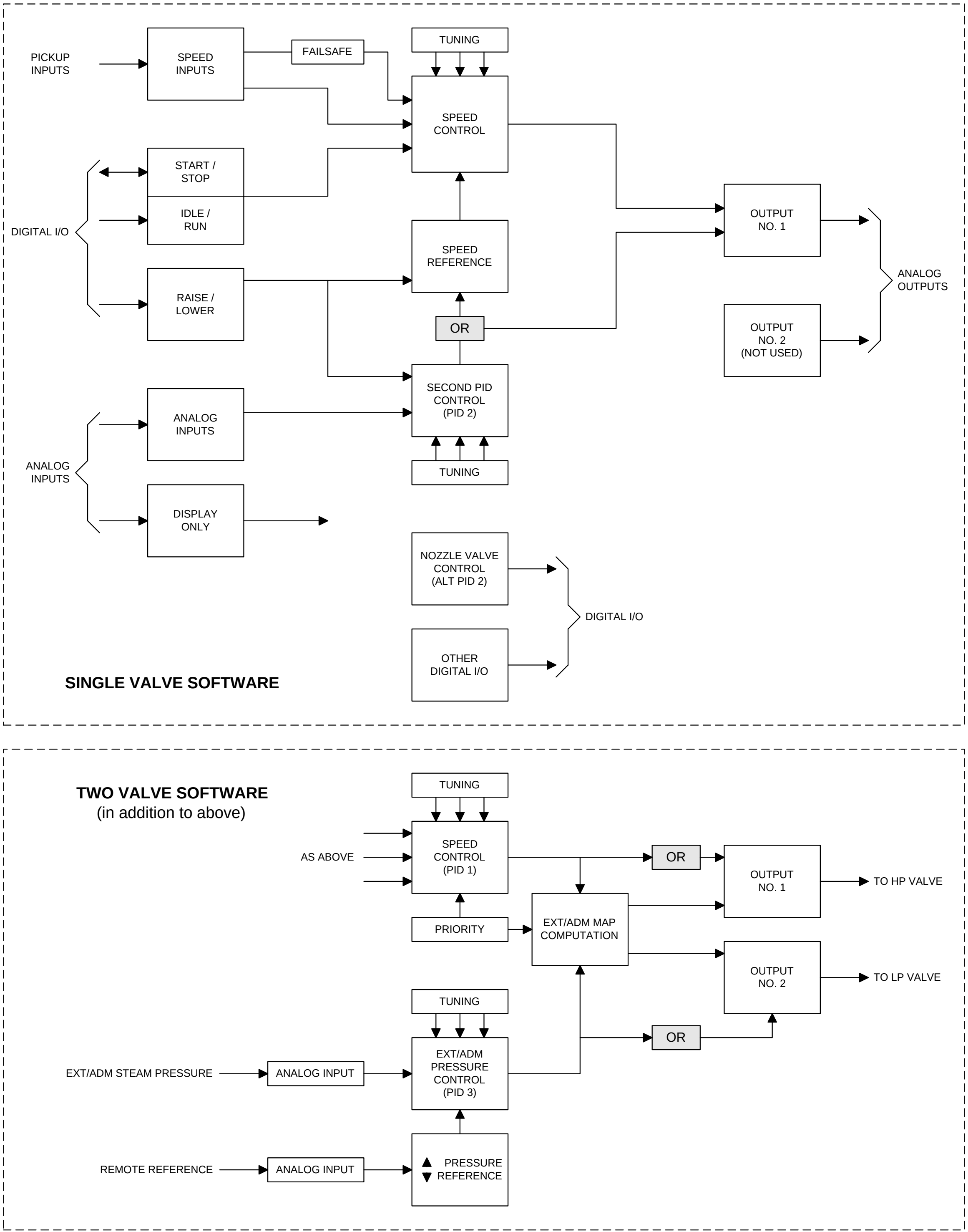


Figure 2. *TS310*-02 Software Block Diagram

2.3 *TS310* Upgrades

TS310 product improvements are listed below. Features not listed as improvements are included in all versions of the *TS310* controller.

Software Upgrades

MODEL - | MOD1 | MOD2	MOD3	MOD4	MOD4	MOD4
EPROMS - | SO31 | SO32	**SO33**	**SO34R1**	**SO34R2**	**0(3,8)(C,D)-01049-01***
DIGITAL INPUTS				
16-External Trip	X	X	X	X
17-Enable Remote Speed Setpoint	X	X	X	X
DIGITAL OUTPUTS				
29-Common Alarm		X	X	X
30-3 Second Pulse Trip	X	X	X	X
31-Synchronizing	X	X	X	X
32-Load Breaker Closed		X	X	X
33-Tie Breaker Closed		X	X	X
34-Cascade Enabled		X	X	X
35-Overspeed Trip		X	X	X
36-Overspeed Test Enabled		X	X	X
37-Externally Tripped		X	X	X
38-Load Limited			X	X
39-Extraction/Admission Enabled			X	X
CHANNELS				
81-Local/Remote Setpoint (Select)			X	X
81-Local Only Setpoint (Snapback)			X	
82-Running Setpoint			X	X
82-Startup Tuning	X	X	X	X
84-System Problem	X	X	X	X
84-Extraction/Admission Enabled	X	X	X	X
82-V2 Enable (Extraction/Admission)	X	X	X	X
82-V2 Disable (Extraction/Admission)			X	X
86-Decoupling	X	X	X	X
86-Speed Signal	X	X	X	X
86-Speed Setpoint	X	X	X	X
86-Stand-Alone Disable 0%				X
86-Stand-Alone Disable 100%				X
97-Last Shutdown Record	X	X	X	X
128-Load Preset				X
129-Snapback Setpoint Configuration				X
144-CPU Interruption Recovery Counter				X
156-Regulator/Tracking PID Configuration				X
155-Extraction/Admission Limit				X
157-ModBus Configuration				X
158-Remote Setpoint Ramp Rate				X
159-ModBus Checkback				X
160-Critical Speed Acceleration				X

*** Software Revision**

MODEL -	MOD1	MOD2	MOD3	MOD4	MOD4	MOD4
EPROMS -	**SO31**	**SO32**	**SO33**	**SO34R1**	**SO34R2**	**0(3,8)(C,D)-01049-01***
ANALOG INPUTS						
Display Only (Sq. Root)	21	21	11	11	11	11
2nd PID Meas. (Sq. Root)	22	22	12	12	12	12
3rd PID Meas. (Sq. Root)	28	28	16	16	16	16
Nozzle Valve	41	41	17	17	17	17
3rd PID Remote Set	--	--	10	10	10	10
Inverse Load Limit	--	--	13	13	13	13
Inverse 3rd PID Remote Set	--	--	18	18	18	18
External 3rd PID	--	--	--	19	19	19
Limiting Function Meas.	--	--	--	--	20	20
Inverse Limiting Function	--	--	--	--	21	21
Generator Software Adds RMP to Minimum Governor	10	10	100	100	100	100
Setpoint Ramp Rate % Maximum Governor	0.1	0.1	0.1	0.01	0.01	0.01
Press Start to Acknowledge Pickup Failure	--	--	X	X	X	X
Fast Start Feature	--	--	X	X	X	X
Snapback Setpoint Feature	--	--	--	X	X	X

*** Software Revision**

NOTICE: *The* TS310 *Software (Release .09) contains a recovery program that will recover from a CPU program interruption. A further discussion about the recovery program can be found in Chapter 9, under Channel 144.*

The Release .09 software utilizes an EEPROM with a larger memory. The new EEPROM requires a jumper change. Jumper A36 is located to the left of the U36 chip. This jumper must be located in the center position. See Note on Component Layout Figure in the next chapter for information on relocating the jumper.

Termination Board Upgrades

- Isolated DC and AC grounding.
- New termination has separate terminal strip for shields.
- Speed inputs are transformer coupled.
- Circuits for I/O module protection.
- This board is also multi-layered.
- All analog I/O grounds are terminated on the termination board instead of on the main board.

Main Board Upgrades

- New board is multi-layered, versus a single layer on the old board.
- Voltage and surge protection on the speed input circuits.
- Voltage and surge protection on the analog input circuits.
- 1% resistors are used instead of 10%.
- Analog ground is separated from digital ground.
- Analog inputs are self-calibrating and do not require calibration.

Power Supply Upgrades

- Constantly loaded to improve efficiency and regulation.
- Separate chassis and DC ground are provided.

Chapter 3 - Hardware

Opening the door of the *TS310* reveals the Main Board on the back of the door. The *TS310* hardware interconnects as shown below.

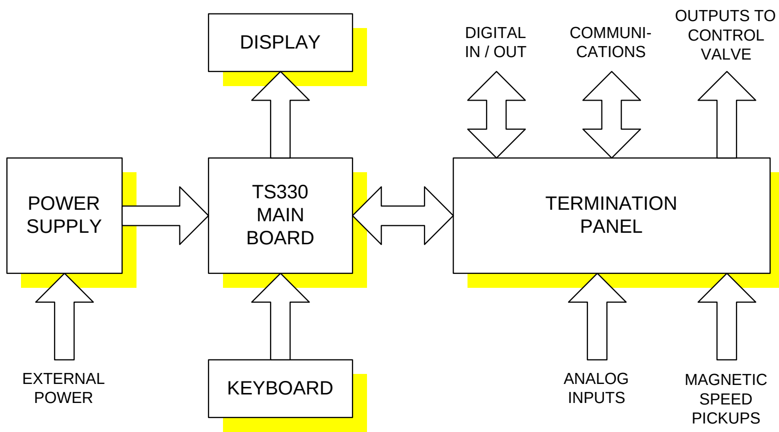
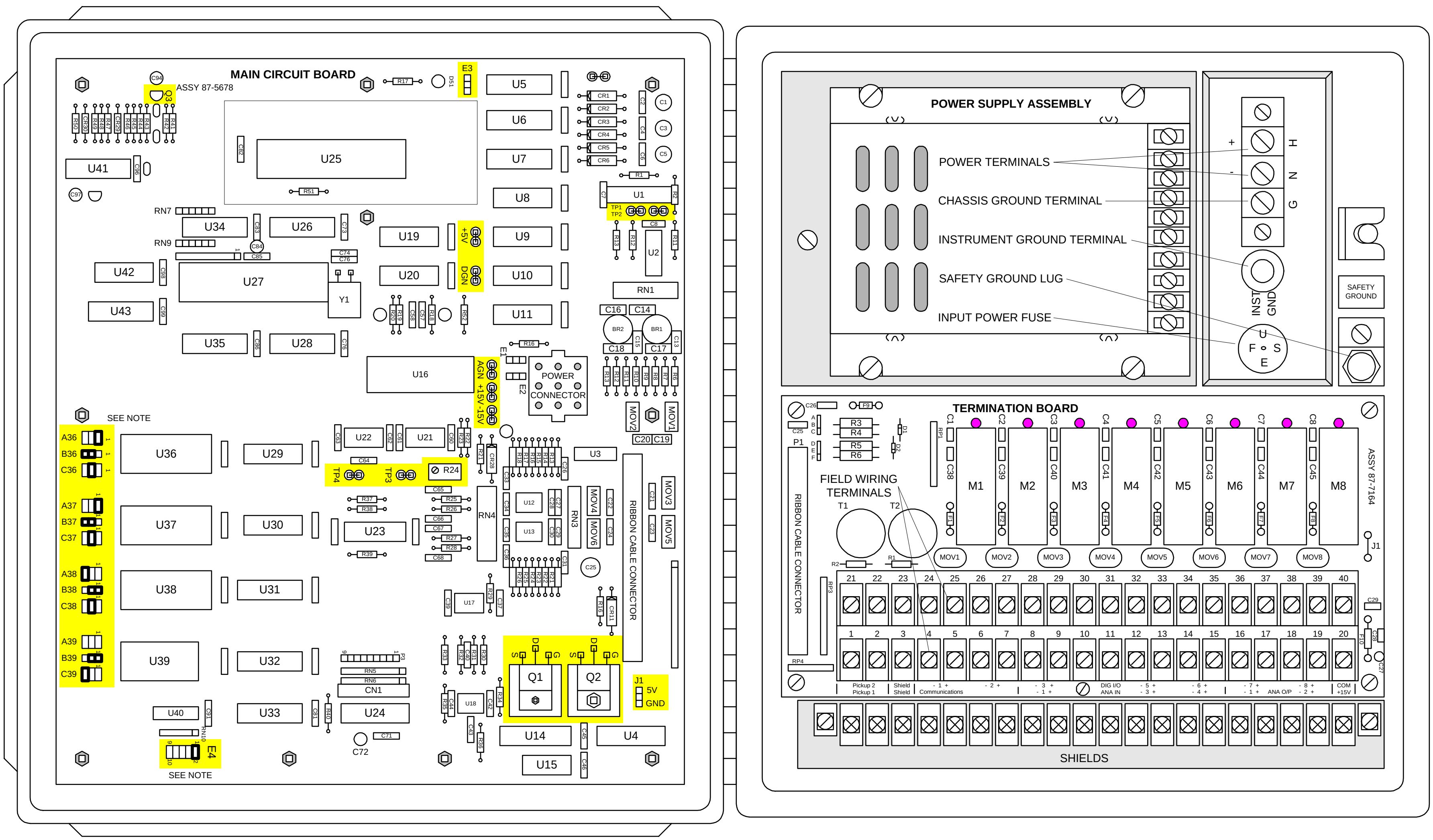


Figure 3. Hardware Interconnections

A 9-pin plug-in connector supplies power to the Main Board from the Power Supply. A 40 connector ribbon cable connects the Termination Panel to the Main Board.

A 9-conductor ribbon cable connects from the bottom of the Main Board to the keyboard. The Display is mounted on the door side of the Main Board and is integrally connected to the Main Board.

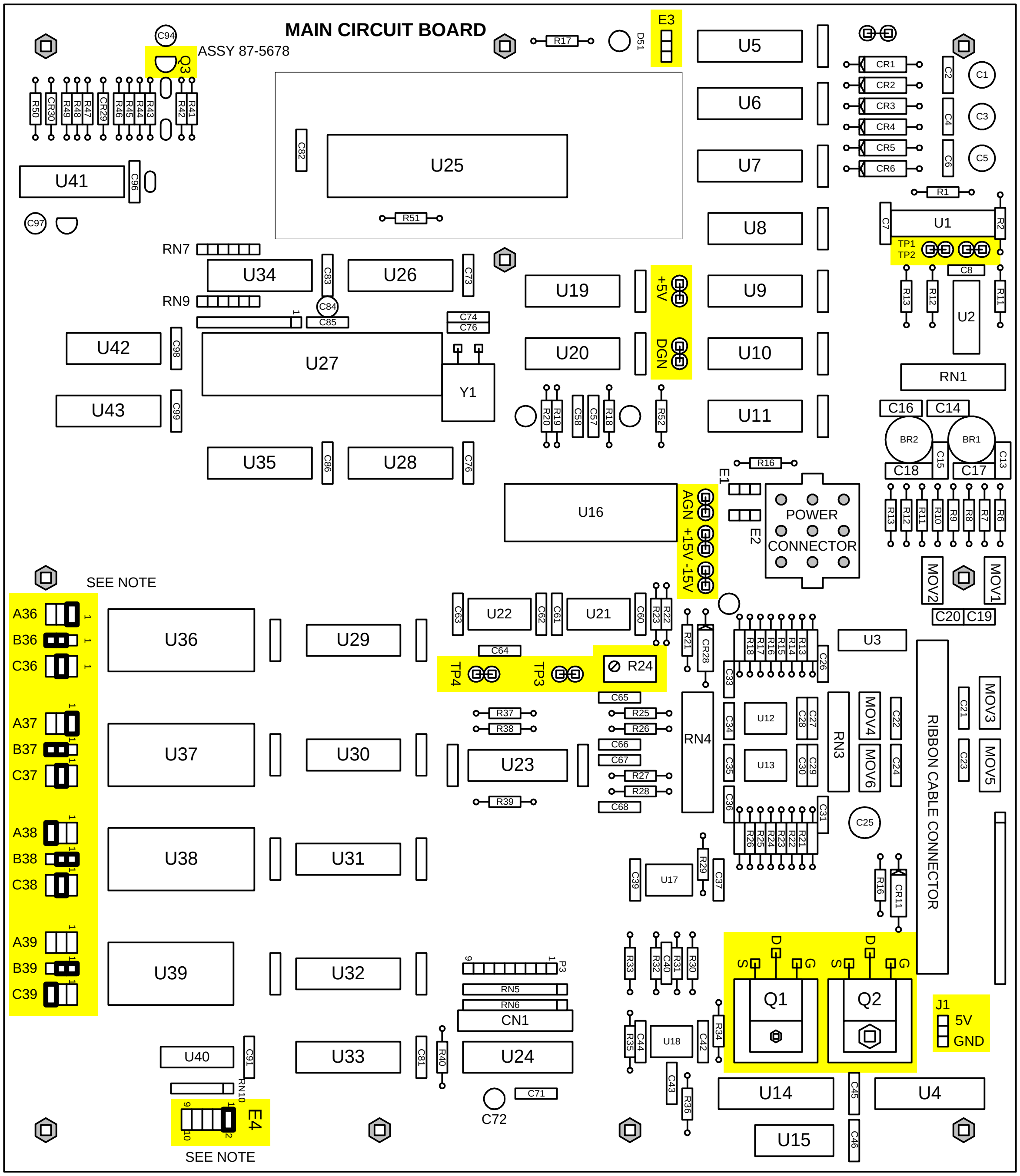
Hardware components are shown in the figure on the following page.



NOTES: For software versions 9 and higher, jumper A36 must be moved to the center position.
Jumper E4 must be moved to the 3/4 position to change the password.

Figure 4. ***TS310*** **Component Layout**

3.1 *TS310* Main Board



NOTES: For software versions 9 and higher, jumper A36 must be moved to the center position. Jumper E4 allows access to overspeed test, diagnostics and other functions.

310-41

Figure 5. ***TS310*** **Main Board**

3.2 *TS310* Power Supply

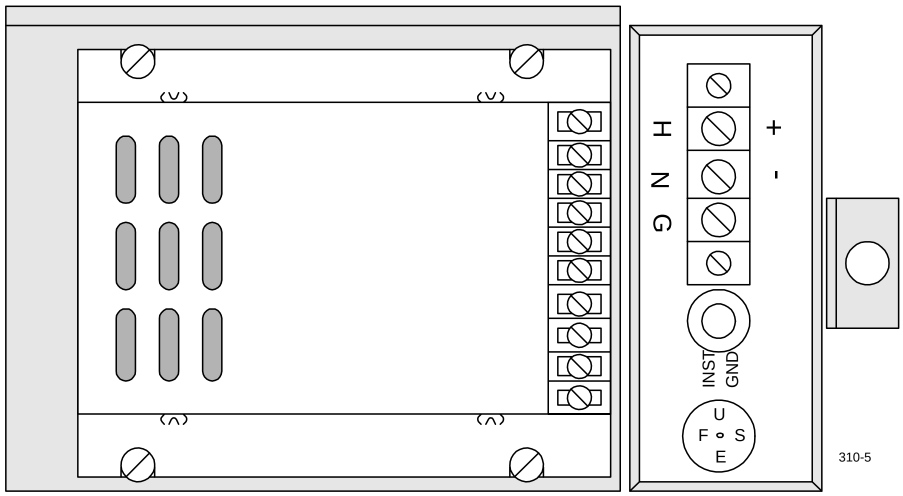


Figure 6. *TS310* Back View Showing Power Supply

The Power Supply is located in the upper half of the back of the *TS310* cabinet. Power consumption is less than 10 watts. In-rush currents at power-up are:

- 0.25 amps for 110 V source;
- 2.5 amps for 24 V source; and
- 5 amps for 10 V source.

Number 14 AWG wire should be used for power source connections.

The POWER SUPPLY ASSEMBLY converts the input power source (as measured on the main board, just above the lower left-hand screw as shown in the figure above) to

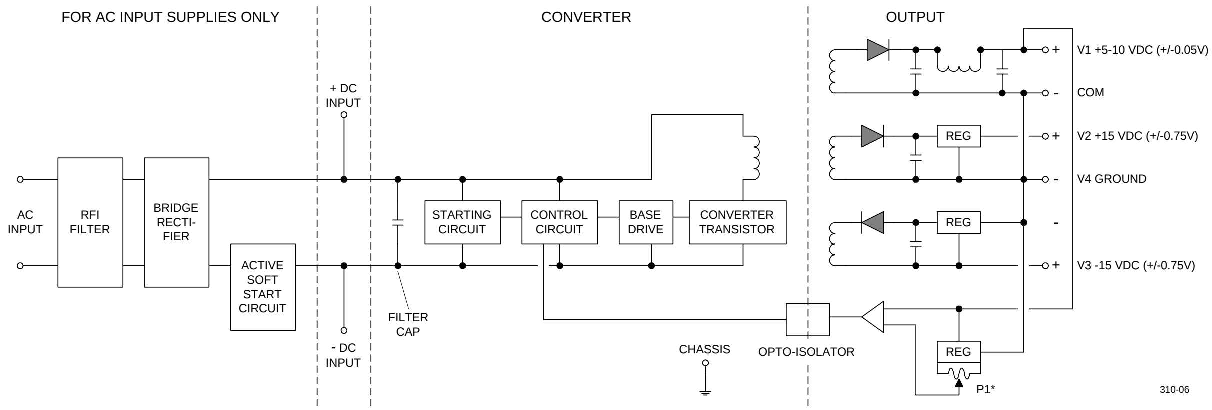
- +5.125 VDC (±0.05 V),
- +15 VDC (±0.75 V), and
- -15 VDC (±0.75 V),

to operate the *TS310* circuitry.

NOTE*:* *Power Supply calibration is normally a one-time, factory assembly adjustment. The proper Power Supply measurement is made at two test points, +5V and DGN, on the* TS310 *main board, on the back side of the front door of the* TS310 *enclosure (reference figure of Main Board in this chapter), with the power supply connected to the main board.*

The standard power supply is rated at 25 watts and operates on 100 to 350 VDC or 90 to 250 VAC, at 50 to 440 Hz. Input power is connected to barrier-type, 6-32 screw terminals. A 0.75 amp slow-blow fuse, TRISEN Part Number 9276-0000, and fuse holder are mounted on the power supply chassis along with an EMI filter and surge suppressors.

For battery back-up installations, a special *TS310* power supply operates on 12 VDC furnished by the battery back-up option. The *TS310* 12 VDC power supply is rated at 10 to 40 VDC input. A 5 amp slow-blow fuse is furnished with this power supply.



***NOTES**: V1 +5.125 V (±0.05 V) Precalibrated.*
V2 +15 VDC (±0.75 V) No calibration adjustment is provided.
V3 -15 VDC (±0.75 V) No calibration adjustment is provided.
** P1 is factory adjusted to +5-10 VDC (±0.05 V)*

All voltages should be checked/measured at test points "+5V" and "DGN" on main board, with power supply connected to main board.

Figure 7. Power Supply Wiring

3.3 Termination Panel

The Termination Panel is located in the lower half of the back of the *TS310* cabinet. Forty terminals accommodate all I/O. Eight sockets, M1 through M8, accommodate the digital I/O relays.

Fuses F1 through F8 protect the eight digital I/O circuits external to the *TS310*. These are 5 amp plug-in picofuses Part Number 9274-0000. F10 protects the +15 VDC circuit (terminal 20). This is a 1/2 amp picofuse Part Number 9250-0000. F9 protects the internal 5 VDC I/O relay circuit. This is a 1/2 amp plug-in picofuse Part Number 9250-0000.

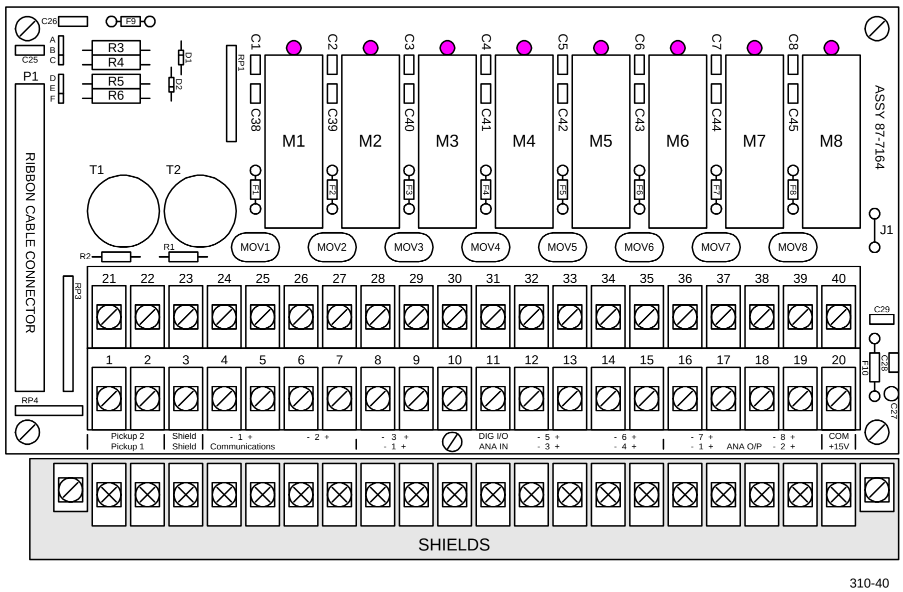


Figure 8. *TS310* Termination Panel

Analog Outputs

Analog Output No. 1

Jumper B-A for 0 to 200 mA range
Jumper B-C for 0 to 20 mA range

Analog Output No. 2

Jumper E-D for 0 to 200 mA range
Jumper E-F for 0 to 20 mA range

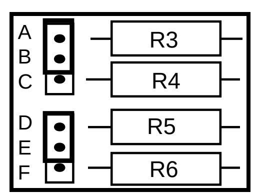


Figure 9. Analog Output

NOTE: *B-A and E-D jumpers multiply output configurations in Channels 62, 63, 64, 65 by 10! That is, if Channel 62 = 3 and Channel 63 = 16, No. 1 analog output will be 30 to 160 mA.*

Analog Inputs

High level - 0 to 10 VDC

Precision dropping resistors must be installed across terminals to convert 4 to 20 mA current signal to 1 to 5 VDC signal (or 2 to 10 VDC, if appropriate).

RTDs and Thermocouples

These require external conditioning.

Digital Inputs and Outputs

These circuits must use the appropriate **I/O MODULE** (M1 through M8) as configured.

3.4 Calibration of Analog Outputs (Channels 62, 63, 64, 65)

No. 1 and No. 2 analog outputs can be calibrated within a range of 0 to 20 mA or, by employing jumpers which multiply by ten, within a range of 0 to 200 mA (see jumpers in Figure 9).

Schedule	*Minimum*	*Maximum*
OUTPUT NO. 1	CH 62	CH 63
OUTPUT NO. 2	CH 64	CH 65

Thus, if OUTPUT NO. 1 should be a 4 to 20 mA signal, enter 4.00 in CH 62 and 20.00 in CH 63.

***NOTE**: When using the TRISEN M360 TESTER/SIMULATOR, always configure outputs for 0 to 20 mA.*

If an output should be in the 0 to 200 mA range, say 30 to 160 mA, configure CH 62 (or CH 64) for 3.00 mA and CH 63 (or CH 65) for 16.00 mA. Jumpers (paragraph 3.3) are then set to multiply by ten, resulting in the 30 to 160 mA output signal(s).

TS310 OUTPUTS can drive 7 volts. Therefore, the output element (actuator) resistance will be limited according to the following table.

Table A.
Output Element (Actuator) Resistance

Current	*Resistance*	*Volts*
20 mA	350 ohms	7
40 mA	175 ohms	7
100 mA	70 ohms	7
160 mA	43 ohms	7
200 mA	35 ohms	7

3.5 Keyboard

The operator keyboard consists of a membrane type keypad which is bonded to the door of the *TS310* enclosure and then sealed with a bezel.

The keyboard is then connected to the main circuit via a ribbon cable connected to P3.

Chapter 4 - Installation & Wiring

The discussion in this chapter is not theoretical. All recommendations listed here are the result of field experience. If they are followed, a good installation will result. If they are not followed, operating problems may occur.

The TRISEN *TS310* digital controller is a high performance, high speed, sensitive control system. As such, it requires and deserves careful installation.

CONSULT THE FACTORY
IF IN DOUBT ABOUT
ANY INSTALLATION

4.1 Installation

The following recommendations have been compiled from actual field service startup and service call experience. These highlight many of the common problems which can be encountered when installing *TS310* controllers.

Choosing a Location for the *TS310*

The location where the *TS310* will be mounted in the field is a critical decision. Factors such as accessibility, lighting, and temperature affect the success of the installation. Other important factors include area classification, length of wiring, proximity to sources of electrical noise, and availability of instrument ground. The following should be considered in making this decision.

Noise

Prior to mounting the *TS310*, an inspection of the area should be performed to check for sources of electrical noise. Motors, radio antennas, arcing contacts, etc., may cause interference problems. If the *TS310* must be mounted near known sources of noise, steel conduit must be used for all wiring, and the wires should be kept as short and direct as possible.

Temperature

Although the *TS310* operating temperature is specified from 0 to 160° F, areas where the temperature will remain constant at or near the limits should be avoided. Temperature extremes also make operation and service inconvenient.

Access

Since the *TS310* usually is operated through the front panel, it should be mounted so that the operator can stand in front of the controller comfortably. The display should be at eye level; the most common installations are between 5 feet and 5 feet, 6 inches high.

Service access should also be considered. Assure that:

- the door can be fully opened;
- the unit will not be subjected to steam or dripping
- water or other liquids; and
- that locating the *TS310* in a given area will not be in violation of area classification with the door open.

The *TS310* should be mounted to rigid structures only so that the unit will not sway when the keyboard is operated.

Lighting

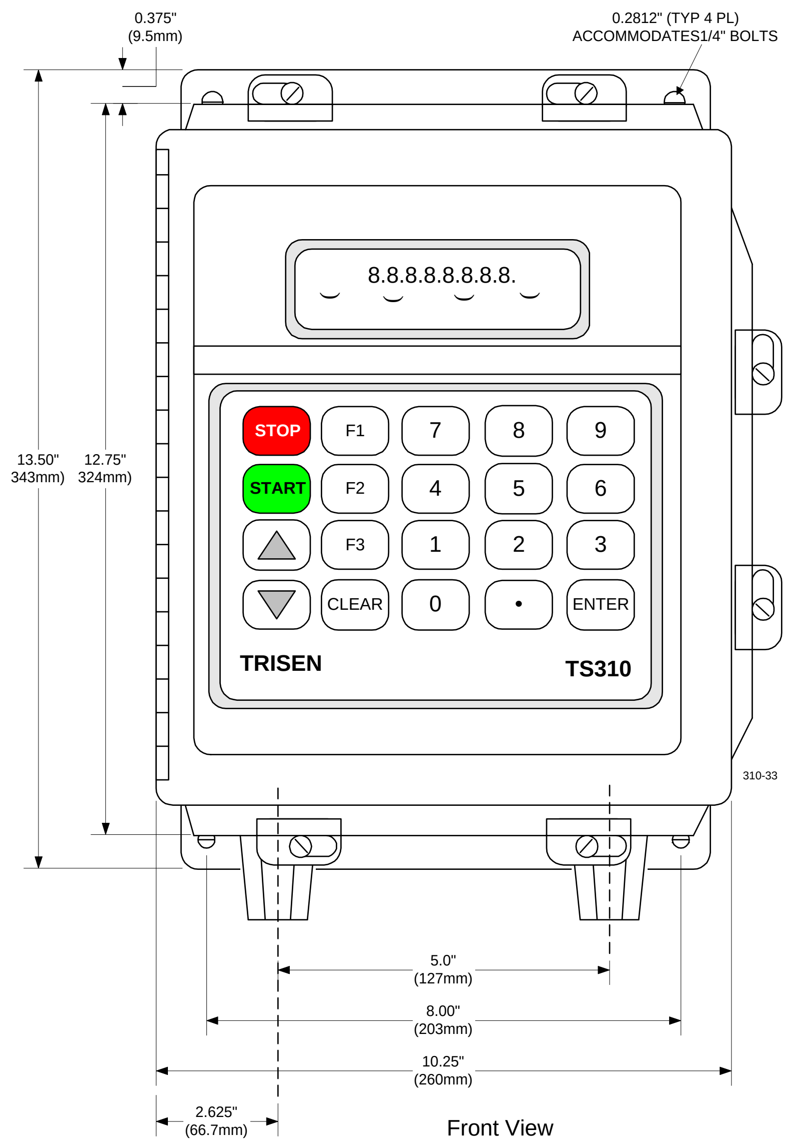
The liquid crystal display is difficult to read in low light, so avoid dark areas; but do not mount the *TS310* in direct sunlight.

If any of these items is doubtful, consider another location.

All of the above factors should be considered and, of course, compromises may be necessary, but careful attention to these factors will result in a more successful installation.

Mounting

The *TS310* should be mounted in an appropriate location as shown in the following figures.



Front View

Figure 10. Surface Mounting Dimensions, Front View

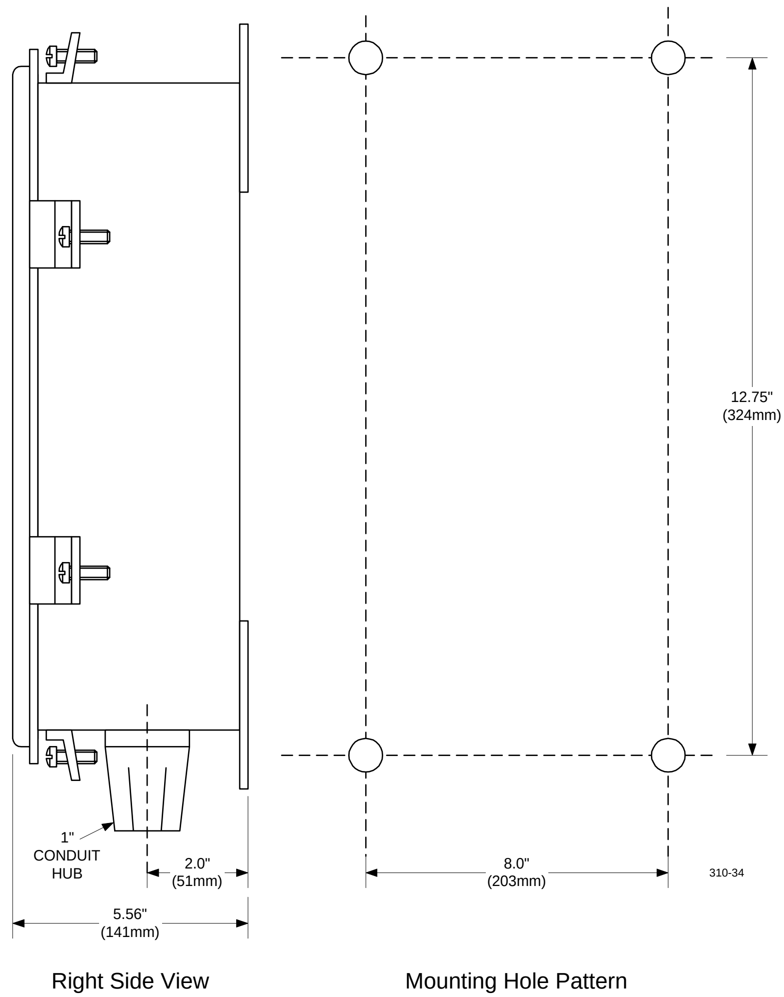


Figure 11. Surface Mounting Dimensions, Side View and Mounting Holes

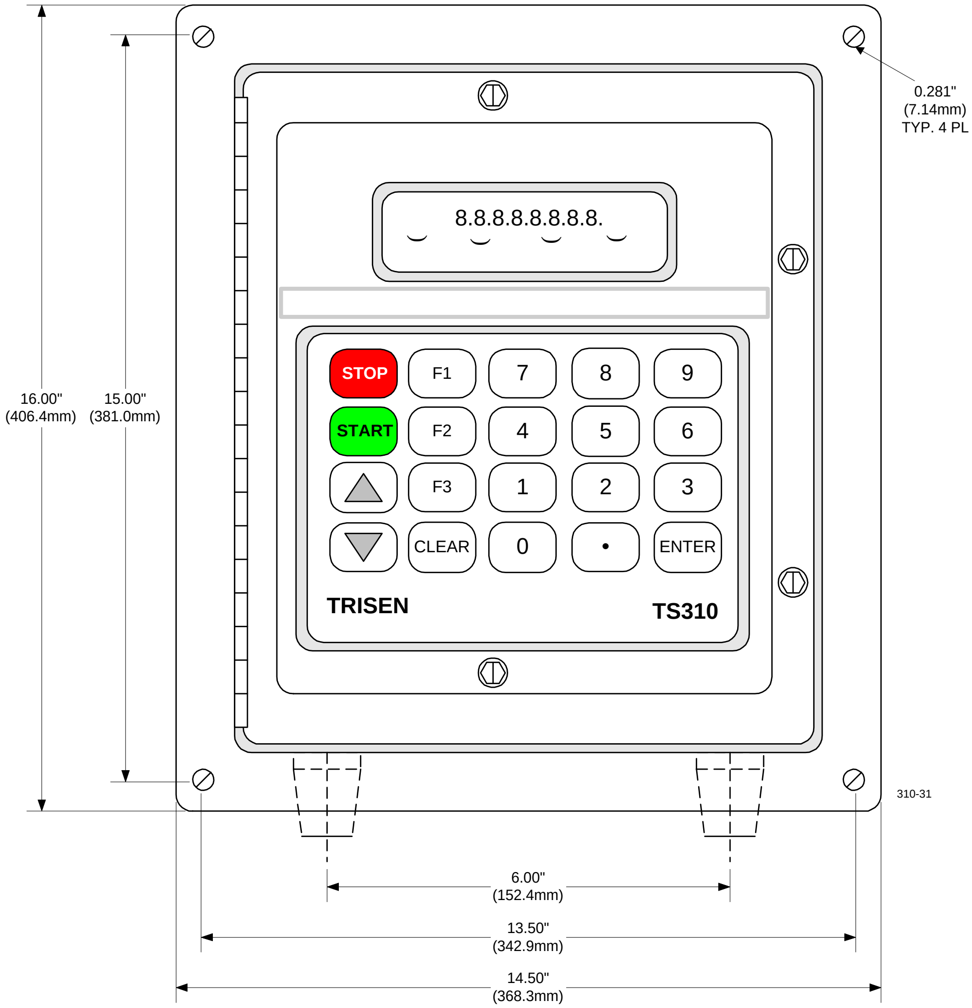


Figure 12. Flush Mounting Dimensions, Front View

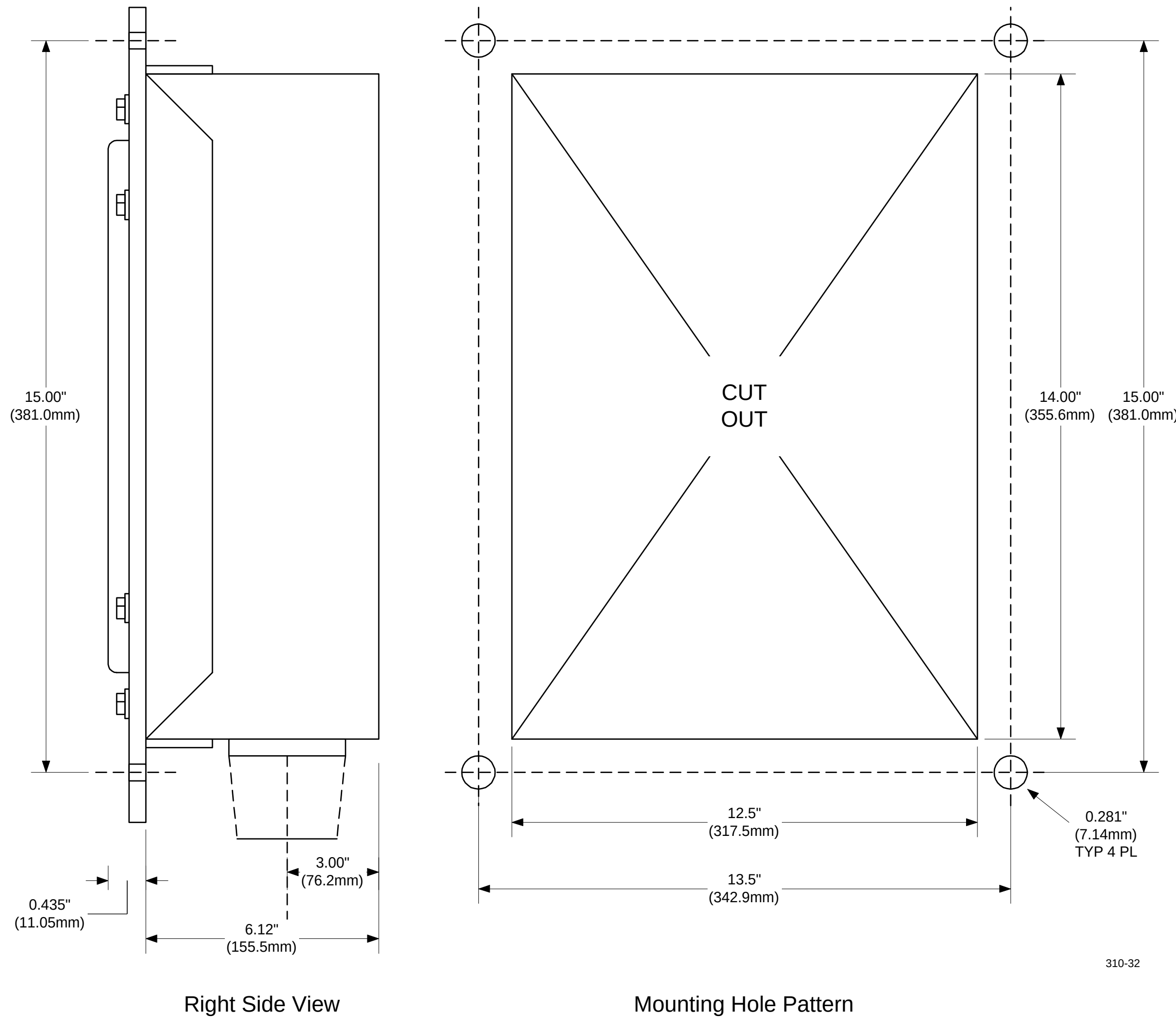


Figure 13. Flush Mounting Dimensions, Side View and Mounting Holes

4.2 Wiring - General

Failure to use the following wiring recommendations will result in instability of control and/or intermittent shutdown from random electrical noise which can and will enter the *TS310* if these procedures are not followed.

- Keep all wire runs as short and direct as possible. Long wire runs are vulnerable to picking up stray electrical noise. Also, long wire runs are costly, but remote mounting may be necessary because of area classification, convenience, or other extreme field conditions.
- All signal wires (terminals 1 through 23 and terminal 40) must be shielded twisted pairs. Shields must terminate only at the *TS310*. The other end of the shield should be left floating and taped.
- Wire size should be selected to provide one ohm of resistance or less over the entire length of the run.
- Place wiring in conduit or cable trays.
- Use rigid steel conduit for all installations subject to high levels of electrical noise, or that must use long wire runs.
- Never run analog signal wires in conduit or cable trays with any AC or DC power wiring. In fact, signal wiring should be separated as far as possible from high voltage AC or DC wiring.
- Never run signal wires in conduit or cable trays with wiring which provides power to inductive loads, such as motors, solenoids, etc.
- Use care when running signal wiring near to or crossing conduit or wiring that supplies power to motors, solenoids, lighting, horns, bells, etc.
- Avoid bringing *TS310* wiring into junction boxes which contain other wiring.

Grounding

Grounding complex systems to minimize electro-magnetic interference (EMI) is a complex task. Guidelines are difficult to develop since all systems have different operating characteristics, are configured differently, and are exposed to different environments.

A basic *TS310* control system can be viewed as a central system with extensions, as shown, very simply, in Figure 14. Integral elements extend from the central system at long physical and electrical distances. Figure 15 illustrates a simplified application.

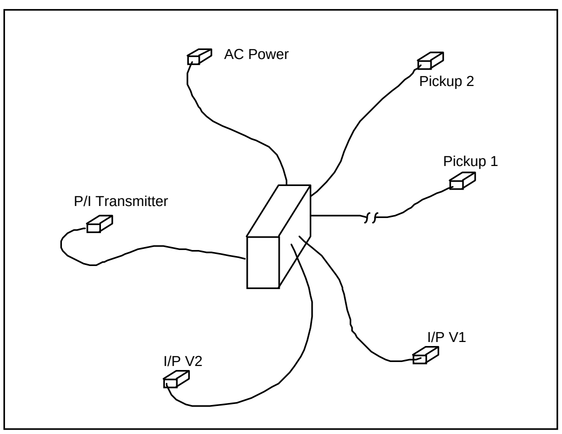


Figure 14. Central Processor with Extensions

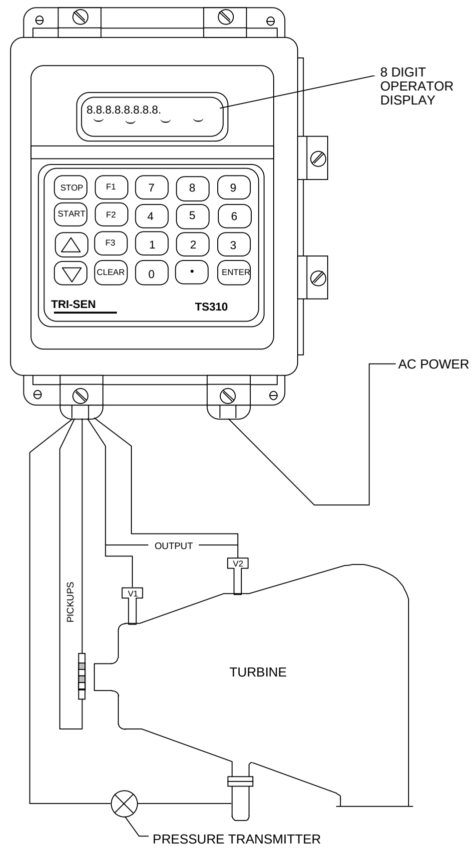


Figure 15. Simplified Application Diagram

The system shown in the figures above is distinguished from a distributed system in that the extended elements obtain power from the central element (*TS310*). Connections to a power source are not made anywhere except at the *TS310*.

If both the source end and the load end of a cable pair in a noisy environment are grounded, common mode interference is likely to occur. Generally, the end that maximizes the signal-to-noise ratio in the loop should be grounded; i.e., usually the source end. However, in the case of a *TS310* installation, where multiple sensors are feeding one processor, grounding every source end would ultimately create a multiple-grounded system. Therefore, the *TS310* end as the ground point is the most practical solution in order to maintain a single-point ground.

The central element (the *TS310*) of this system should be grounded as though it were an isolated system. TRISEN control systems involve relatively low frequencies; therefore, a single-point tree or star grounding scheme is used. The ground node would be at the central element (*TS310*) with one connection (the safety ground) made to the structure. The transducers should be floated; i.e., not grounded at the transducer end. Shielded, twisted pair cable should be used and grounded at the *TS310* end only.

Cable Routing

To avoid inter-cable noise coupling (crosstalk), it is necessary to identify and categorize the separate cable routings.

Category 1: AC power cables - noise carriers

Category 2*: DC distribution cables - noise carriers and/or victims

Category 3: Signal and logic cables - victims

a) Analog, low level signals

b) Digital signals

***NOTE**: Signal wires from relays, circuit breakers, thermal switches, etc., fall into Category 2.*

Basic guidelines for routing these cables are:

Category 1: Route along frame members and in separate metal cable trays.
Category 2: Route along frame members and metal cable trays, but separate from Category 1. (Avoid open space hanging.)
Category 3: Route as far as possible from Categories 1 and 2.

In general,

- For cables from Subcategory 3a), the spacing is dependent on the sensitivity of the circuits they are connected to; a spacing of 25 cm (10 inches) from Category 1 for every meter of possible parallel run is required to protect an analog circuit having 10 mV sensitivity.

- Cables from Subcategory 3b) which carry digital signals should be placed 2.5 cm (1inches) from Category 1 for every 1 meter of their possible parallel run.

Remember that power wiring not only carries 60 Hz voltages, but it also has associated line spikes which couple strongly with near-by victim wiring.

Example: If a routing constraint forces analog signals to be run parallel to AC cables over a distance of 10 meters, a separation of 10 X 2.5 cm = 25 cm is required.

4.3 I/O Relay Module Wiring

Solid-state output relays are subject to small levels of current leakage. While this presents no problem when used with normal loads such as coils, solenoids, hard relays or motors, the leakage is significant for applications which interface with high impedance inputs such as alarm circuits, computer inputs or solid-state logic.

In cases of alarm circuits, computer inputs or solid-state logic inputs, a dry contact relay should be used; the DRY5 relay is recommended for such applications. See Termination Panel Wiring.

When using a DC output module (e.g., ODC5) to operate an inductive load, such as a trip solenoid, breaker closing coil or electro-mechanical relay, the load MUST be by-passed by a protective diode. See typical field wiring connections, paragraph 4.4. For most applications a 1 amp 400 VDC diode (TRISEN Part Number 4092-0000) will suffice. Higher current diodes are usually available from local electronics distributors.

Input modules MUST be powered, either internally or externally. See typical field wiring connection sketches in the following paragraphs.

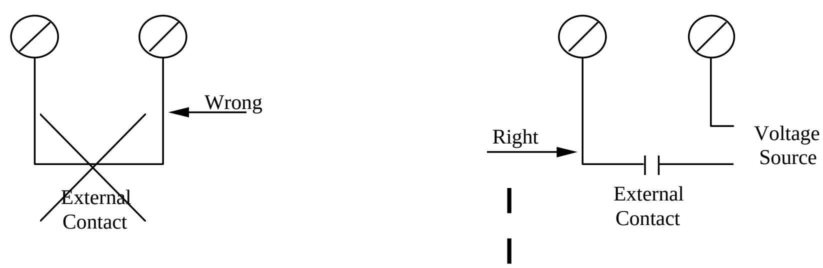


Figure 16. Input Relay Module Wiring

NOTE: *Be certain the module matches the voltage source.*

- Observe polarity on all DC connections.
- Output modules MUST be externally powered. See Typical Field Wiring connections, paragraph 4.4.

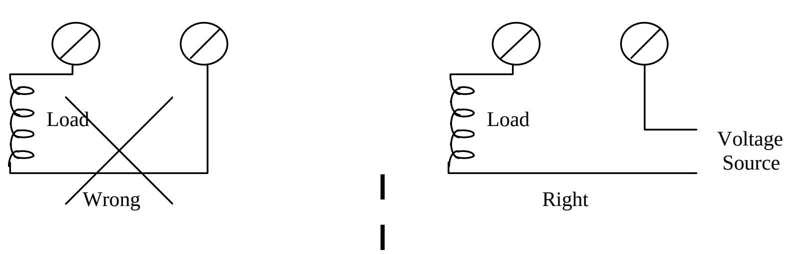


Figure 17. Output Relay Module Wiring

4.4 *TS310* Termination Panel Wiring

Refer to Figure 7 and wire the termination panel as follows:

1	No. 1 PICKUP (+)	21	No. 2 PICKUP (-)
2	No. 1 PICKUP (-)	22	No. 2 PICKUP (+)
3	PICKUP SHIELD	23	PICKUP SHIELD
4	RS422 XMIT B (-)	24	No. 1 CONTACT (-)
5	RS422 XMIT A (+)	25	No. 1 CONTACT (+)
6	RS422 REC B (-)	26	No. 2 CONTACT (-)
7	RS422 REC A (+)	27	No. 2 CONTACT (+)
8	No. 1 ANALOG IN (-)	28	No. 3 CONTACT (-)
9	No. 1 ANALOG IN (+)	29	No. 3 CONTACT (+)
10	No. 2 ANALOG IN (-)	30	No. 4 CONTACT (-)
11	No. 2 ANALOG IN (+)	31	No. 4 CONTACT (+)
12	No. 3 ANALOG IN (-)	32	No. 5 CONTACT (-)
13	No. 3 ANALOG IN (+)	33	No. 5 CONTACT (+)
14	No. 4 ANALOG IN (-)	34	No. 6 CONTACT (-)
15	No. 4 ANALOG IN (+)	35	No. 6 CONTACT (+)
16	No. 1 ANALOG OUT (-)	36	No. 7 CONTACT (-)
17	No. 1 ANALOG OUT (+)	37	No. 7 CONTACT (+)
18	No. 2 ANALOG OUT (-)	38	No. 8 CONTACT (-)
19	No. 2 ANALOG OUT (+)	39	No. 8 CONTACT (+)
20	+15 VDC	40	SYSTEM COMMON

***NOTE**:* *Terminals that are shaded are for external power;*
Terminals 16 through 19 are for TS310 power.

4.5 Typical Field Wiring

Installation should carefully follow recommendations listed in this chapter.

It is extremely important to avoid installation mistakes. It is equally important to avoid improper grounding and shielding practices as outlined in this chapter.

4.5.1 *TS310* Contact Input Wiring

Power requirements depend upon input module used.

Module	*Load*	*Amps*
IDC5	10-32 VAC/DC	25 mA
IAC5	90-140 VAC/DC	11 mA
IAC5A	180-280 VAC/DC	6.5 mA

NOTE: *Internal power (Terminals 20 and 40), +15 VDC and common, may be used for contact input circuits. Use IDC5 modules. Be careful to observe polarity. Positive 15 VDC at a maximum of 250 mA is provided to interface field contacts and specific sensors.*

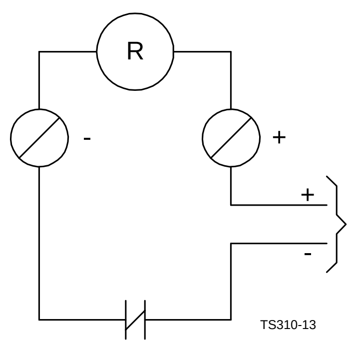
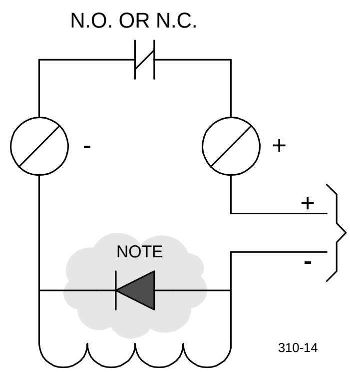


Figure 18. Contact Input

4.5.2 *TS310* Contact Output Wiring

Power requirements depend on load and output module used:

Module	*Load*
200 VDC/VAC	DRY5
5/60 VDC	ODC5
12/140 VAC	OAC5
24/280 VAC	OAC5A
5/200 VDC	ODC5A



NOTE: Omit diode if circuit is AC powered.

Figure 19. Contact Output

For inductive DC loads such as a solenoid, install 1 AMP 1000 PIV diode (part number 4092-0000) across the load as shown to protect the solid state module.

For high impedance alarm systems use module DRY5. Do not use internal *TS310* power from Terminals 20 and 40 for powering output loads.

Do not exceed module current ratings of
3 AMP for ODC5, OAC5 and OAC5A;
1 AMP for ODC5A (1 second surge - 5 AMP);
and
10 VA for DRY5 (200 volts maximum).

Do not use +15 VDC (Terminal 20) for contact outputs!

4.5.3 *TS310* to PX102 Transmitter Wiring

The PX102 transmitter is a voltage output device powered by the *TS310* +15 VDC supply (Terminals 20 and 40). PX102 provides a nominal 0.5 to 5.5 VDC signal used by the *TS310* as an analog input for process measurement for backpressure control, extraction, inlet pressure control, etc.

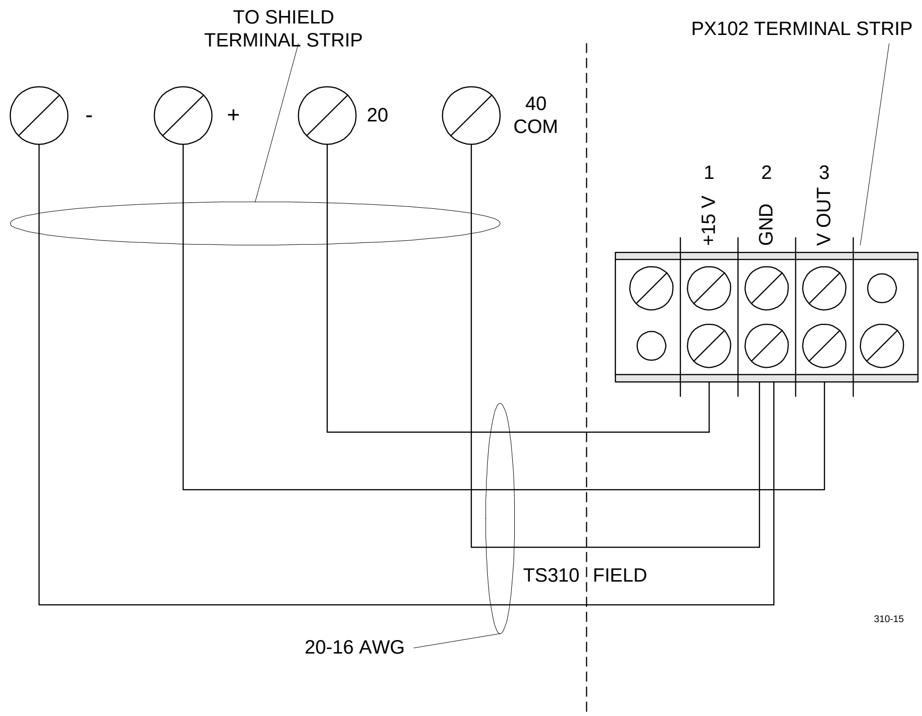


Figure 20. *TS310* to PX102 Transmitter Wiring

4.5.4 *TS310* Analog Input to 4 to 20 mA External Power Wiring

An analog input powered by an external circuit should be connected as shown in the figure below.

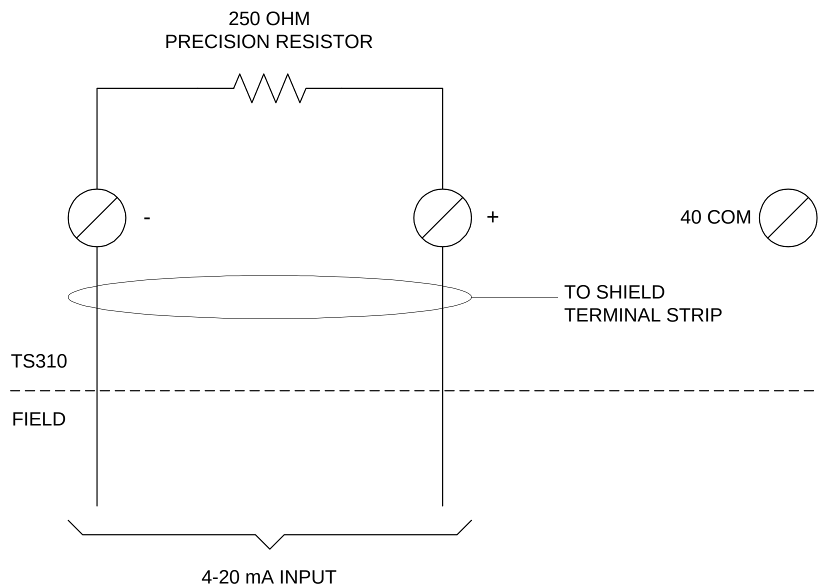


Figure 21. Analog Input to External Power Wiring

⚠ **CAUTION** Beware of ground loops. Use an isolator when in doubt.

NOTE: *If the 4 to 20 mA analog source is capable of driving a 500 OHM precision resistor, twice the resolution will be obtained from the analog input. (The voltage drop will be 2 to 10 volts rather than the 1 to 5 volts obtained across a 250 OHM precision resistor.) The* TS310 *analog input channel must be configured accordingly.*

⚠ **CAUTION** The *TS310* input common mode range must not be exceeded. This range is approximately ±12 V from instrument ground.

4.5.5 *TS310* to Two-Wire Transmitter Wiring

Two-wire transmitters (Foxboro, Rosemount, Gould, etc.) should be wired to the *TS310* as shown in Figure 17.

NOTE: *These cannot be powered from the* TS310.

CAUTION Beware of ground loops. Use an isolator when in doubt.

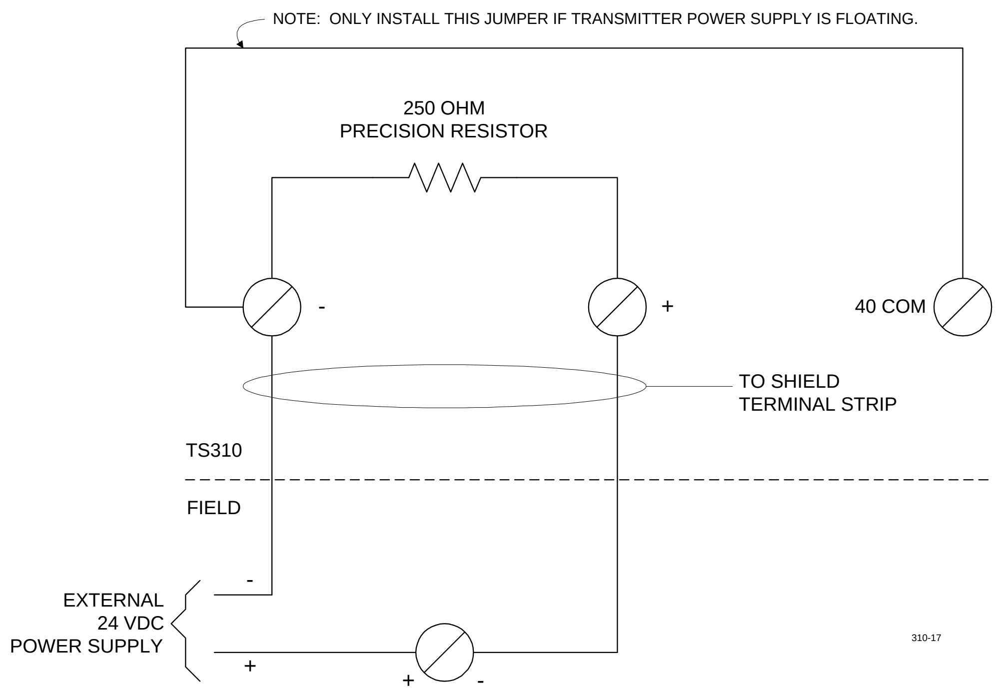


Figure 22. Two - Wire Transmitter Wiring

4.5.6 Communications Wiring

The RS422 multi-drop port communications should be connected as shown in the figure below.

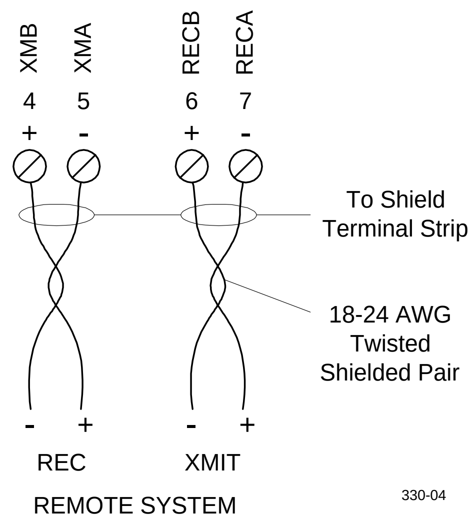


Figure 23. RS422 Communications Wiring

NOTE*:* *The shields grounds to Terminals 3 or 23.*

Grounding practice ***must*** follow instructions on Figures 29 and 30 later in this chapter. Also see the discussion on grounding earlier in this chapter.

Noise immunity is of the utmost importance!

Signal cables must be run in separate conduit from AC cables. The conduits must be steel and must be multipoint grounded for increased noise immunity.

4.5.7 Magnetic Speed Pickup Wiring

The *TS310* controller requires an accurate and dependable sensed speed signal. Standard two-wire magnetic speed pickups should be used. Other devices can be used in some instances; in this case, consult the factory. Magnetic pickup connections should be made as shown in the figure below.

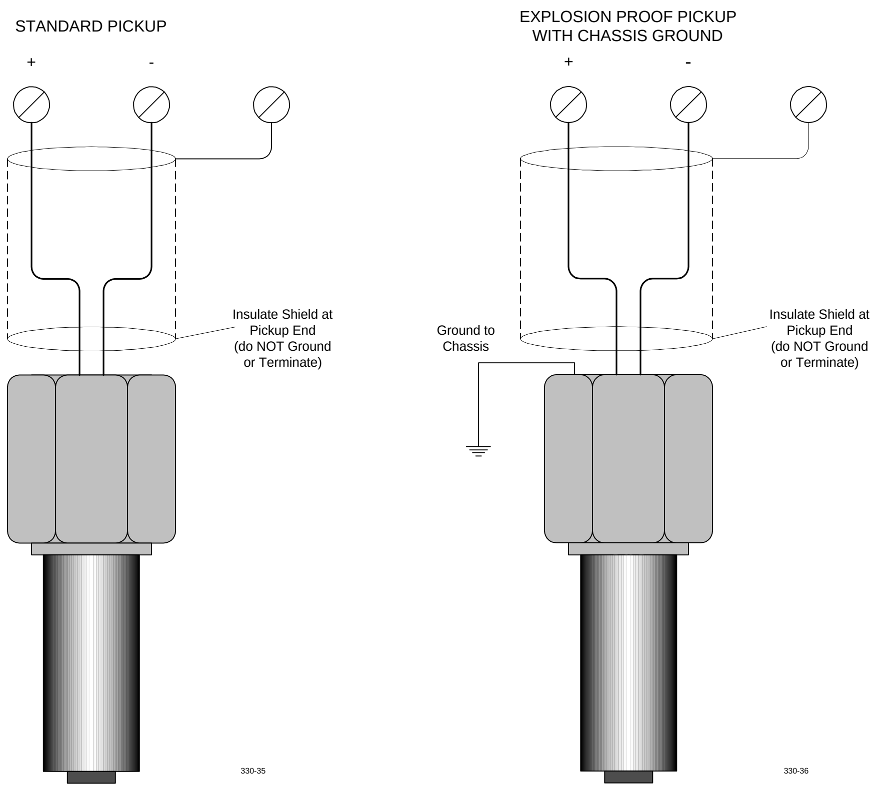


Figure 24. Magnetic Speed Pickup Wiring

Polarity is for active pickups only, not for passive pickups.

Signal cables must be run in separate conduit from AC power cables. Conduits must be steel and must be multi-point grounded for increased noise immunity.

***NOTE**: Insulate shields at the pickup. Shields must be grounded only as shown.*

A pickup fail alarm will latch until acknowledged by pressing the START key.

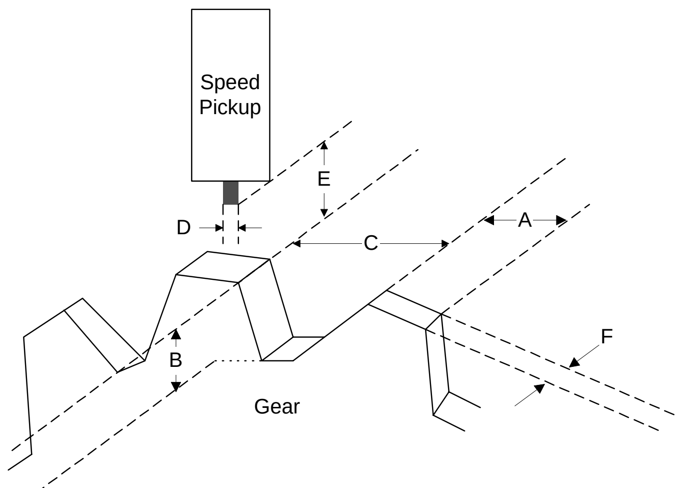
The choice of gear to use with a magnetic speed pickup is very important in obtaining a good speed signal. For best results the five items below should be considered:

- Dimension of tooth top surface should be equal to or more than pickup pole piece diameter.
- Tooth height should be equal to or more than the space between the teeth.
- Space between teeth should be approximately three times pole piece diameter.
- Air gap between pickup pole piece and tooth top surface should be as small as possible, 0.015" minimum.

  NOTE: *Pickup gap may have to be larger if clearance problems exist.*

- Gear width should be at least equal to or more than pole piece diameter of pickup.

The previous suggestions are shown graphically in the figure below.



A equal to or greater than D
B equal to or greater than C
C equal to or greater than three times D
E as close as possible, typically 0.015 inch minimum
F equal to or greater than D

Figure 25. Speed Pickup/Gear Dimensions

4.5.8 *TS310* to HCX21 Transducer Wiring

The HCX21 current to hydraulic transducer should be connected as shown in the figure below. The HCX21 provides hydraulic pressure proportional to the *TS310* 4 to 20 mA current output.

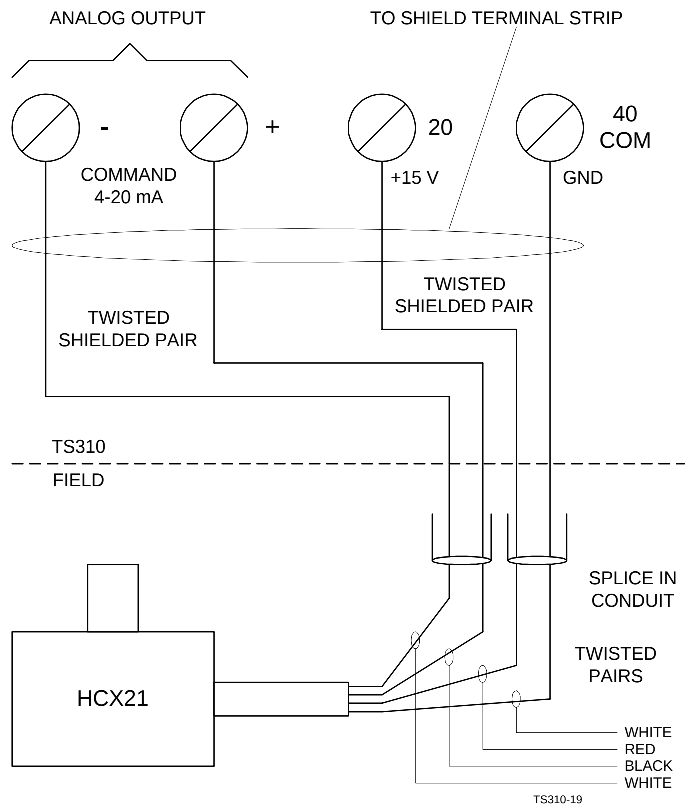


Figure 26. *TS310* to HCX21 Transducer Wiring

The signal cables must be run in separate conduit from the AC power cables. The conduits must be steel and must be multi-point grounded for increased noise immunity.

NOTE: *Refer to paragraph 10.14 for a discussion of testing the output.*

4.5.9 *TS310* to HSC3 Hydraulic Actuator Wiring

The HSC3 Hydraulic Actuator should be connected as shown in the figure below. A 0 to 2 inch position signal is available on the green wire and optionally may be connected as an analog input for position readout.

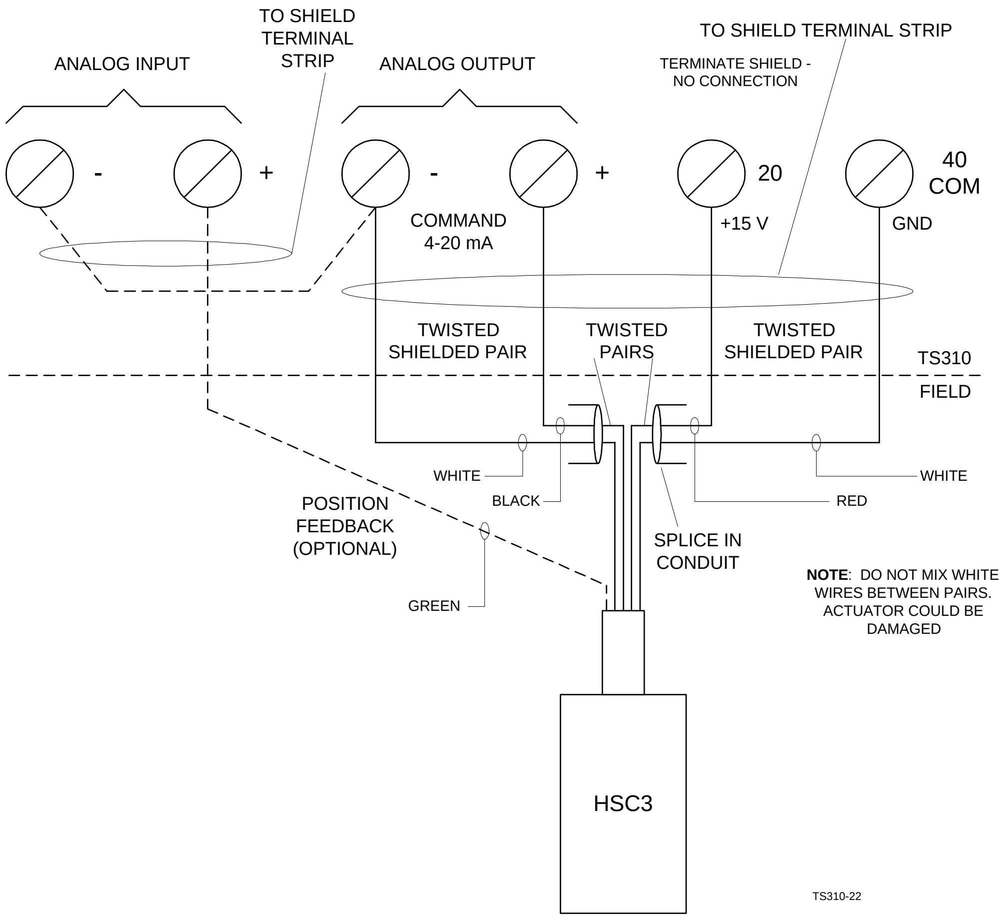


Figure 27. *TS310* to HSC3 Hydraulic Actuator Wiring

HSC3 FORCE AVAILABLE

Pressure	***Lbs Stall***	***Velocity at 1/2 Stall***
100	180	5 inches per second
400	720	10 inches per second
1000	1800	14 inches per second

NOTE: *Refer to paragraph 10.14 for a discussion of testing the output.*

4.5.10 Current-to-Pneumatic (I/P) Transducer Wiring

This transducer is used to convert *TS310* output to a 3 to 15 psig or other pneumatic signal to operate pneumatic actuators.

An I/P transducer should be connected as shown in the figure below.

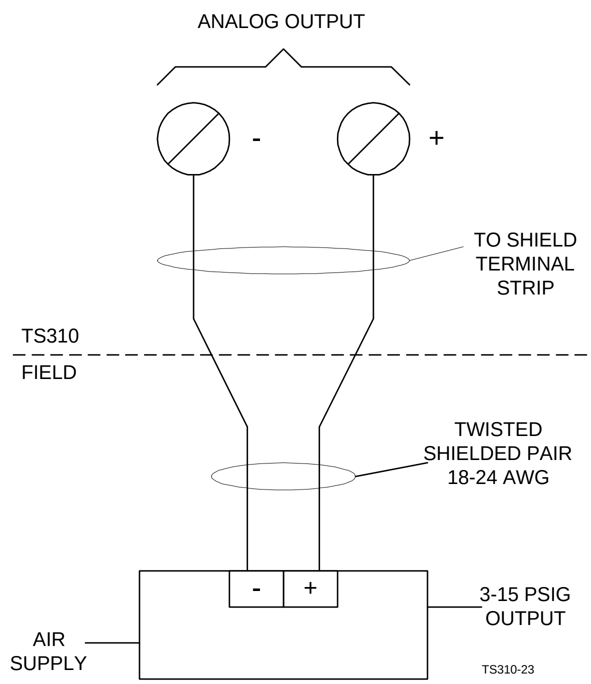


Figure 28. Current to Pneumatic Transducer Wiring

NOTE: *Refer to paragraph 10.14 for a discussion of testing the output.*

4.5.11 DC Input Power & Ground Wiring

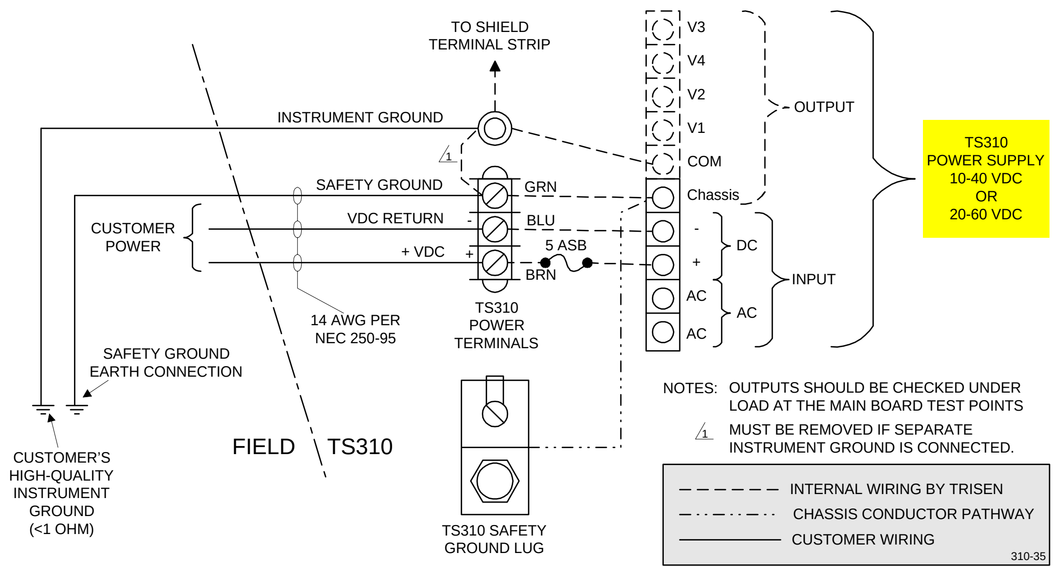


Figure 29. 10-40 VDC or 20-60 VDC Input Power & Ground Wiring

4.5.12 AC & DC Input Power & Ground Wiring

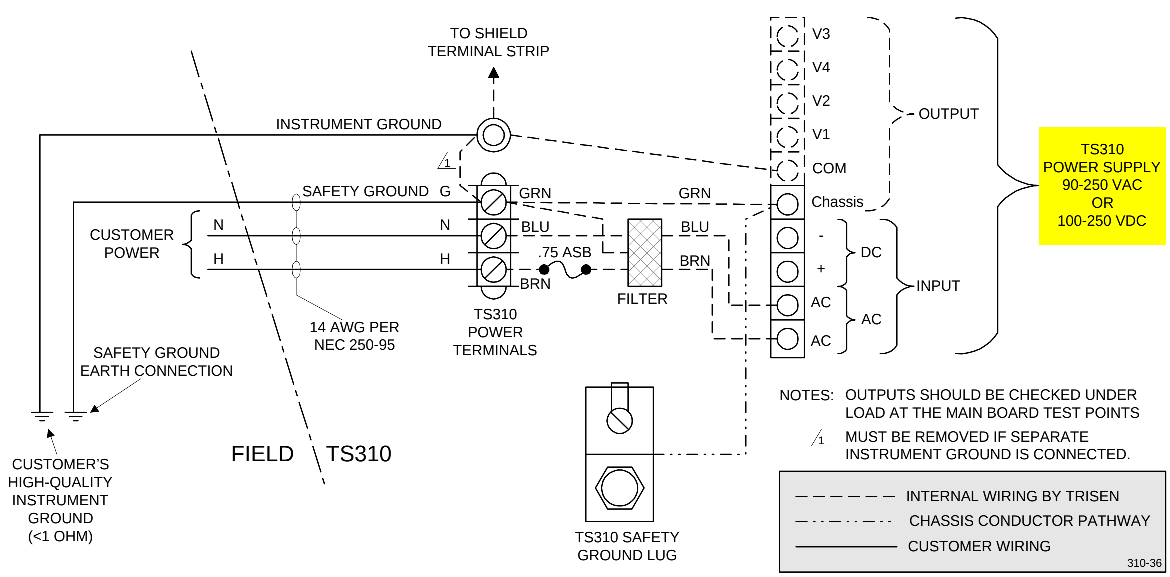


Figure 30. 90-250 VAC & 100-250 VDC Input Power & Ground Wiring

Chapter 5 - Operating Functions

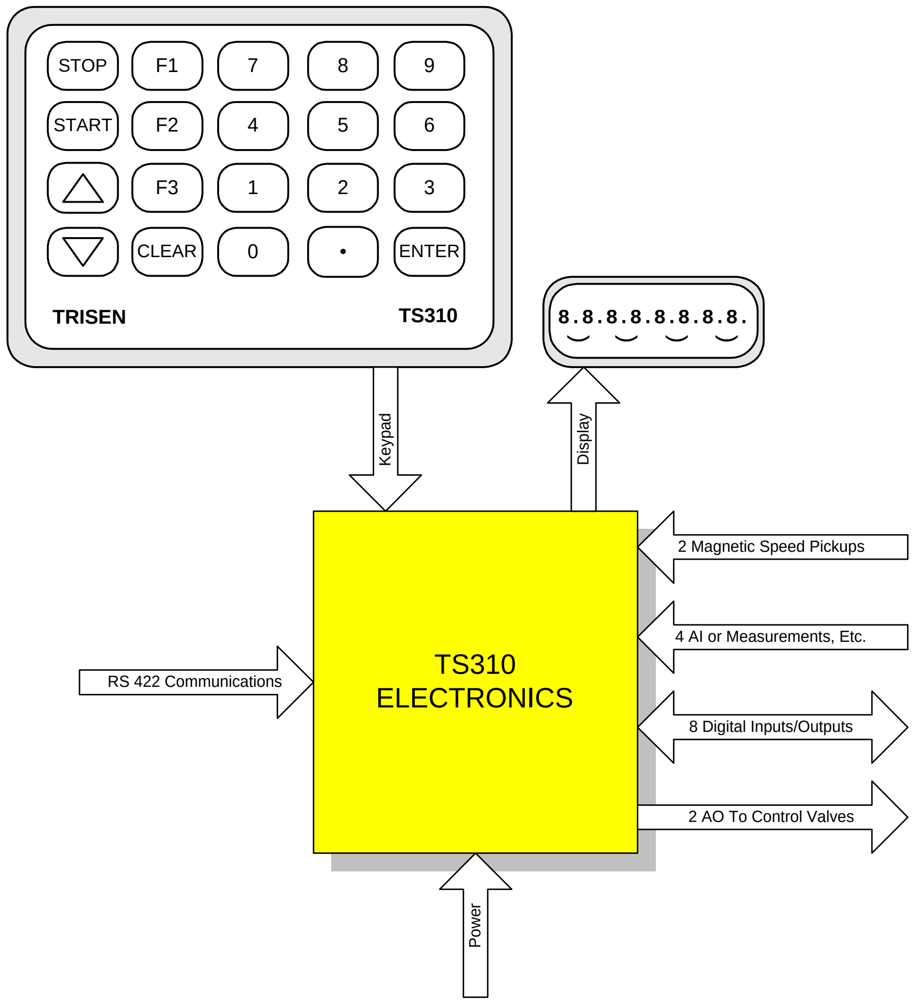


Figure 31. Function Relationships

Commonly used keyboard and operating functions are listed below:

- The **START** key will initiate the startup sequence.
- The **STOP** key will close the governor valve, stopping the turbine.
- The **RAISE** key ▲ will increase the reference at the setpoint ramp rate.
- The **LOWER** key ▼ will decrease the reference at the setpoint ramp rate.
- During startup, pressing **RAISE** or **LOWER** momentarily will halt acceleration.
- Pressing **RAISE** or **LOWER** keys for less than one second will change turbine speed by ONE RPM regardless of the setpoint ramp rate setting in Channel 67.
- Pressing the **F2** function key after a **HALT** will resume acceleration.
- **ACCELERATION** (Channel 12) in RPM per minute is only used during startup and is no longer used after turbine speed reaches the minimum governor.
- **SETPOINT RAMP RATE** is defined as percent per second of maximum governor. It is used any time the speed is changed by the RAISE or LOWER keys, or when a new entry is made in Channel 05 (speed reference) from the keyboard.

5.1 Startup Sequence

The startup sequence illustrated and described in these paragraphs is called *NO IDLE* and is configured in Channel 82 as (0XXX).

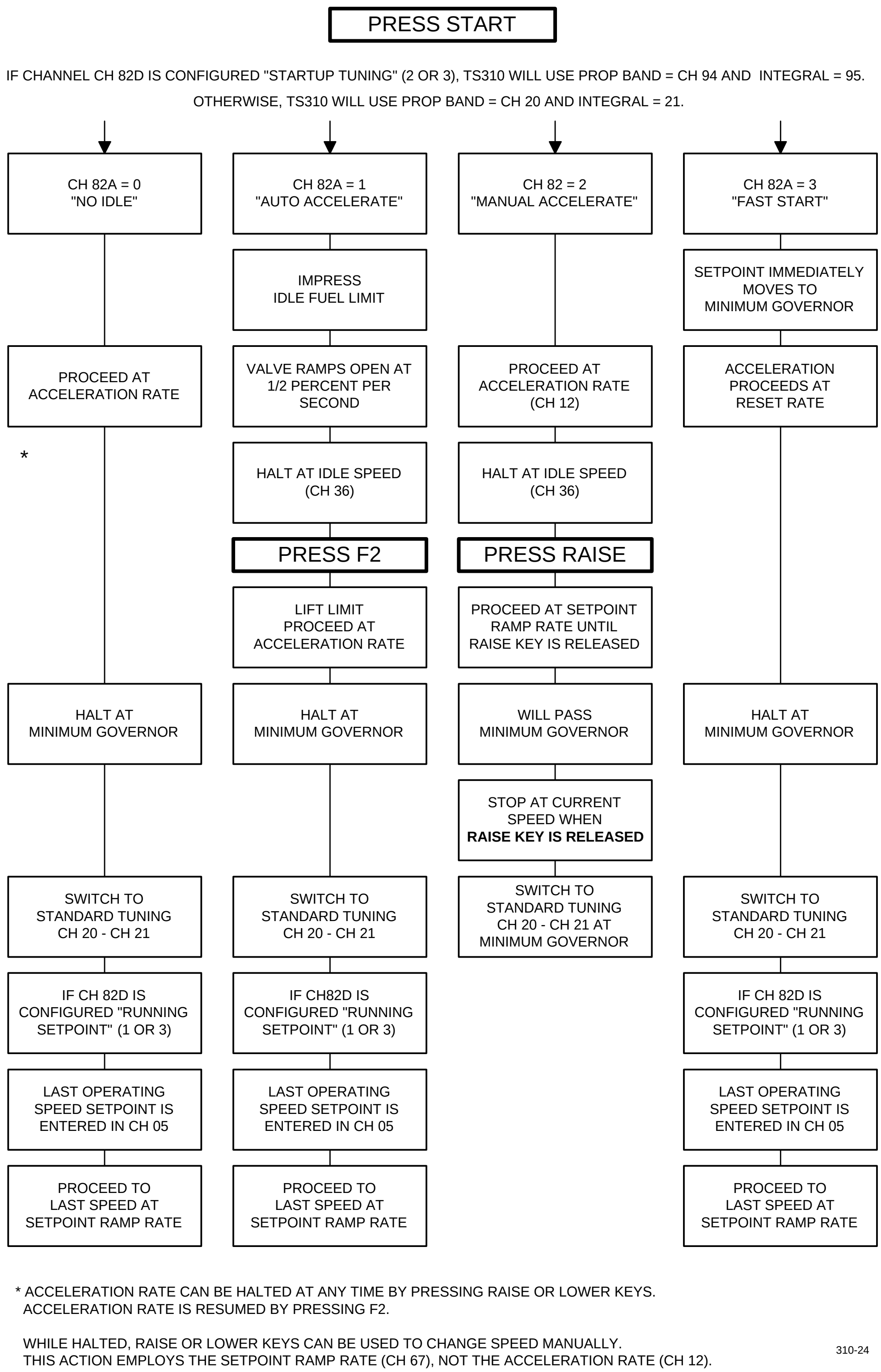


Figure 32. Startup Sequence

No Idle - Channel 82 = (0XXX)

As shown in the startup sequence diagram (figure above), the steam turbine governor valve will begin to open when the START key is pressed.

The speed reference will rise at the acceleration rate which is set in Channel 12. Actual turbine speed will then follow the speed reference as determined by the controller tuning which is set in Channels 20 and 21.

Acceleration will continue until speed reaches minimum governor, where it will remain until changed. Speed reference (Channel 05) is controlled by the startup sequence and cannot be manually changed until the actual turbine speed reaches the minimum governor setting.

However, acceleration can be HALTED during the startup sequence as described in startup sequence variations, paragraph 5.3.

NOTE: Controls *oriented people use the term* speed setpoint *while those schooled in the rotating equipment tradition will use the term* speed reference. *The terms are the same.*

5.2 Startup Sequence With Halt

Anytime the RAISE or LOWER keys are pressed momentarily while the turbine is accelerating in the startup sequence, the sequence will HALT and the speed reference will freeze at that value.

While HALTED, Channel 05 (speed reference) can be increased by pressing the RAISE key, or decreased by pressing the LOWER key. This speed reference change will take place at the setpoint ramp rate, not at the acceleration rate.

The startup sequence and acceleration can be resumed at any time by pressing the F2 function key. This procedure may be repeated as many times as desired during the startup process until turbine speed reaches minimum governor setting.

If a critical speed setting has been configured in channels 13 and 14, the *TS310* controller will not allow a HALT in this critical speed band but will stop turbine speed at either the top or the bottom of the critical band.

Once turbine speed has reached the minimum governor setting, the speed reference (Channel 05) cannot be increased above the maximum governor setting or reduced below the minimum governor setting. A channel entry into Channel 05 that falls outside of this range will cause an error message to be displayed. Press CLEAR and enter the correct value.

The acceleration rate may be set fast or slow. The setpoint ramp rate may be set fast or slow. These two functions do not interact or interfere with each other.

5.3 Startup Sequence Variations

Several variations are available for Startup Sequencing.

NO IDLE - Channel 82 is configured (0XXX) - This sequence was described previously.

AUTO ACCELERATE (F2) - Channel 82 is configured (1XXX) - This startup procedure is identical to NO IDLE except that the speed reference will automatically HALT at the IDLE SPEED (or slow-roll) RPM which has been entered in Channel 36. Turbine speed will remain at this setting until the F2 function key is pressed. Thereafter, acceleration performs the same as NO IDLE. RAISE or LOWER keys will HALT acceleration again and F2 will resume acceleration as in NO IDLE.

An additional feature includes a temporary output (or steam valve) limit which has been set as a percentage value in Channel 37. This limit is imposed when START is pressed and will remain in effect until RPM reaches IDLE SPEED and F2 has been pressed. At this time, the IDLE FUEL LIMIT will be disabled.

MANUAL ACCELERATE - Channel 82 is configured (2XXX) - This startup procedure resembles AUTO ACCELERATE, above. RPM will automatically rise to the IDLE SPEED and the IDLE FUEL LIMIT is imposed as above. However, after warm-up, F2 is not used, but speed can be increased only by using the RAISE key. Speed will HALT anytime the RAISE key is released. The IDLE FUEL LIMIT will be disabled as soon as speed reaches the IDLE SPEED setting and RAISE is pressed. Acceleration Rate is not used above the IDLE SPEED.

FAST START - Channel 82 is configured (3XXX) - This startup procedure is intended for use with equipment such as forced draft fans, boiler feedwater pumps and emergency generators which must be put into operation quickly.

When START is pressed, the speed reference is instantly set at the minimum governor and the steam valve will open quickly. When properly tuned, the *TS310* will not allow the turbine to overshoot but will bring the turbine speed up to minimum governor setting in ten to twenty seconds.

Chapter 6 - Maintenance

GENERAL: The *TS310* is completely solid-state and requires no routine maintenance as such. It should be inspected periodically to assure that the internals are tight and dry.
Any problems with the *TS310* will usually fall into one of the following areas:

- Speed sensor
- Final actuator
- Electrical-to-pneumatic or hydraulic transducer
- Controller electronics

Prior to any detailed troubleshooting, be sure that the power is turned on and the supply voltage is correct. Check that the air and/or hydraulic supply is on. Check test points +5V and DGN for 5.10 VDC, ±0.05 , on the main board.

Also, check that the steam or fuel is correctly lined up. If the actuator or governor valve has a bypass, handjack, manual station or trip device, make sure that they are not in service, preventing control of the machine by the *TS310*.

SPEED SENSORS: Speed sensors are normally magnetic pickups. They must be functional for the *TS310* to operate. Standard pickups must be mounted with a gear-to-pickup gap of 0.015 in. to 0.020 in. The gear must be made of ferro-magnetic material.

Measure the pickup output at the *TS310* and refer to the specifications for minimum requirements. Magnetic pickups are extremely reliable and will rarely fail if properly installed. Most failures are caused by excessive temperatures or mechanical rubbing on the gear. Pickup failure results in loss of signal.

ACTUATORS: Final actuators may be pneumatic, hydraulic or electric. Troubleshooting actuators requires a thorough understanding of actuators and their operation.

The actuator must move the valve or pilot smoothly. Hysteresis or dead band from loose links or pins will produce unsatisfactory operation causing the control to swing or to hunt without stabilizing.

Actuator motion may have to be linear with control output. Non-linear positioners may cause poor and erratic operation. The actuator should stroke in a minimum of time. Rare exceptions may require slower stroking time to match machine dynamic response.

TRANSDUCERS: A variety of electric-to-pneumatic or hydraulic transducers is available. Consult the *TS310* output specifications for requirements. The *TS310* output must be configured to match the transducer.

Consult the specific manufacturer's literature for calibration and maintenance information on actuators, transducers, speed sensors and hydraulic systems.

TS310: The *TS310* is designed using the latest semiconductor technology and maintenance should be minimal. Repairs should be restricted to replacing circuit boards or assemblies.

All circuit boards and assemblies are connected using plug-in connectors. Determine what is causing the problem by running operational checks or voltage readings, and replace the defective assembly.

By substituting parts, any hardware problem should be corrected in a few minutes. The defective part should be returned to the factory for repair or exchange (see Appendices B and E).

There are only four assemblies in the unit. These are the Main Circuit Board, the Termination Panel, the Power Supply assembly and the Keyboard. Consult the hardware chapter of this manual for a detailed discussion of these parts.

Be sure that replacement parts are configured for the particular application. If the Main Board is replaced, it must be configured before it will work. Critical applications should have spare Main Boards that are already configured and have been checked out in advance.

Units must be tuned for the application. Each controller is a PID three-mode controller. Tuning constants must be entered when the unit is configured. They should be adjusted with the unit in operation for optimum performance. Use Derivative Action only when necessary and then start with very small amounts.

OPERATIONAL CHECKOUT: To check out the *TS310*, perform the following steps:

- Apply power to the *TS310*. The display should show *00000000* with no indicator arrows. In addition, the green LED on the Main Board should blink at 1/3 second intervals. This step verifies that the display is working and that the program is functioning. See DIAGNOSTICS (paragraph 6.1) for detail of the diagnostics test which is run each time the *TS310* is powered up.
- Press the 0 Key twice. The display should show *0* on the extreme left and *0* on the extreme right. Press ENTER and the display should flash *EEEEE*. Now press *41*, and then press ENTER. The display will show *41* to the left and should flash *PPPPP* to the right. This verifies the keyboard, the invalid entry display, and the password protected display.
- Call up the individual channels and verify that they contain the correct code or reading. When Channel 24 is called up, try changing the proportional band. This will verify the non-volatile memory. Return the proportional band to its original setting.
- Press START and verify that the control valve or valves open. Press STOP and verify that the valve or valves close.

6.1 Configuration-Diagnostics, Changing Eproms

While it is possible to change some channels with the *TS310* in the RUN mode, this is not recommended. Since it is possible to change configuration while a contact output or other flag is high, there will then be no command to drive the flag low. To avoid errors due to this possibility, always exit configuration mode FIRST, then power down and power up the *TS310*. This will insure dropping any flag or digital signal left high inadvertently after changing a configuration.

⚠ **CAUTION**

THE *TS310* SHOULD NEVER BE POWERED DOWN WHILE IN THE CONFIGURATION (PASSWORD) MODE.
Always exit the configuration mode before powering down.

DIAGNOSTICS are always run on power up (see paragraph 10.1). If EPROMS are changed, the *footprint* of the EPROM is compared to the footprint of record in the EEPROM. If these differ, the configuration will be *wiped* from the EEPROM and the *TS310* must be reconfigured. This will prevent operation with *faulty* configuration.

If EPROMS are changed but the footprint is the same, it is possible the checksum will not compare. In this case, as will be the case above, one or more *E* errors will show in the eight digit display. If this occurs, the *TS310* must be powered down and then powered up again to permit recalculation and reentry of the checksum or reentry of the new footprint. If this is not done, a system problem (8) in Channel 84 will persist and will, in turn, trigger a common alarm output if it has been configured. This cannot be acknowledged until the *TS310* has been powered down and then up again.

Of course, if the *E* error persists after power down and power up, this does indicate a system problem.

6.2 Electrostatic Discharge Awareness

It is imperative to protect electronics from static damage. Precautions are straight forward and include the following:

- Ground yourself to a pipe or other metal object to discharge any static potential on your body *before* servicing the equipment.
- Wear a grounded wrist strap whenever possible while handling electronics to avoid further static buildup.
- Wear cotton, or cotton blend, clothing to reduce static buildup.
- Handle PCBs only when absolutely necessary and hold them by the PCB edge. Do not touch components unless they require servicing. It is essential that grounded wrist straps be worn when touching components.
- Keep PCBs away from plastic, vinyl, and Styrofoam® which can generate and store high electrostatic potentials.

See additional discussion on electrostatic discharge awareness at the front of this manual.

Chapter 7 - Spare Parts

Major *TS310* Assemblies

1310	*TS310* Main Board
1311	*TS310* Termination Panel, less I/O modules
0085-3293	*TS310* Keyboard
84-2228	*TS310* Power Supply Assembly, 100-250 VAC/90-350 VDC
85-2301	*TS310* Power Supply Assembly, 10-40 VDC
90-0650	Spare PCB and Software, Two Valve

Set of EPROMs with software for particular application. (See Chapter 2 for software part numbers.)

Digital Input/Output Modules

7061-0000	IAC5	N.O., input,	90-140 VAC/VDC	@ 11 mA
7061-0001	IAC5A	N.O., input,	180-280 VAC/VDC	@ 6.5 mA
7049-0000	IDC5	N.O., input,	10-32 VAC/VDC	@ 25 mA
	IDC5G	N.O., input,	35-60 VAC/VDC	
7022-0000	OAC5	N.O., output,	12-140 VAC	@ 3 amp
7022-0001	OAC5A	N.O., output,	24-280 VAC	@ 3 amp
7045-0000	OAC5A-5	N.C. output,	280 VAC	@3 amp
7023-0000	ODC5	N.O., output,	5-60 VDC	@ 3 amp
7023-0001	ODC5A	N.O., output,	5-200 VDC	@ 1 amp
7026-0003	DRY5	N.O., contact relay output,	5 V	@ 1 amp
7026-0005	DRY5-B	N.C., contact relay output,	5 V	@ 1 amp

Magnetic speed pickups, current-to-pneumatic or hydraulic transducers, and final control actuators should be spared. Be sure to specify model or part number for devices as installed.

Miscellaneous Accessories

P324	Battery Backup
M360	*TS310* Test/Simulator
MPS390	Synchronous Generator Control Module
PX102	Pressure Transmitter
RCS116	Remote Control Station (with tachometer)
T113	Tachometer, Digital Panel Mount
9945	I/P Transducer, 4-20 mA, 3-15 psi
4092-0000	Diode, 1 amp, 400 VDC (for external use)
7120	Magnetic speed pickup, explosion-proof, UL approved
7121	Magnetic speed pickup, standard
7123-1	Connector w/10’ of cable for 7121 and 7125 speed pickups
7125	Magnetic speed pickup, long reach

9250-0000	Fuse, 0.5 amp plug-in pico (for F9 and F10)
9274-0000	Fuse, 5 amp plug-in pico (for F1 to F8)
9276-0000	Fuse, 0.75 amp slow-blow (for power supply)
9277-0000	Fuse, 5 amp slow-blow (for power supply)

MOVs 1-8

9272-0005	14 VAC RMS max,	18 VDC max
9272-0000	30 VAC RMS max	38 VDC max
9272-0004	50 VAC RMS max	66 VDC max
9263-0000	130 VAC RMS max	175 VDC max
9272-0002	250 VAC RMS max	330 VDC max

Spare Parts Kit

One of the following kit is shipped with every *TS310*.
Additional spare parts kits can be purchased, or these parts can be purchased individually.

87-7102 *TS310* Service Parts **KIT**, including:

9274-0000	Pico Fuse, 5 amps
9250-0000	Pico Fuse, 0.5 amp
9276-0000	Slo-Blo Fuse, 0.75 amps
9277-0000	Slo-Blo Fuse, 5 amps
2521-0000	Resistor, RN60E, 0.1%, 100 ohm, 25 ppm (for use with 0.4 to 2 V analog input)
2522-5000	Resistor, RN60E, 0.1%, 249 ohm, 25 ppm (for use with 1 to 5 V analog input)
2525-0000	Resistor, RN60F, 0.1%, 500 ohm, 25 ppm
6667-0000	Anti-static bag, 4x6"

Chapter 8 - Specifications

Electrical

Factory Mutual Approved

Approved for Hazardous Locations

NEMA Approved	Non-incendive Class I, Div. 2 Groups A,B,C,D
Canadian Standards Assn #	LR 48564
Temperature Rating	T5 (T3C-C5A)
Voltage Surge Rating	Conforms to IEEE-472-1974
EMI/RFI Tolerance	Conforms to MIL-STD-461

Power

Standard	100-350 VDC or 90-250 VAC (50/440Hz)
Optional	10-40 VDC or 20-60 VDC Power Supplies
Consumption	Less Than 10 Watts

Environmental

Humidity	0-95% Non-condensing
Temperature	0-70^{o}C (CSA temperature rating T4A)

Passes 1000 hour accelerated life and temperature test

Complete in-house final test performed before shipment

Mechanical

Shock	Conforms to MIL-STD-810D
Vibration	Conforms to MIL-STD-167-1

Enclosure

NEMA 4	Rugged steel weather-proof enclosure
Surface Mount	13.5" H x 10.25" W x 5.56" D 34.29 cmH x 26.04 cmW x 14.12 cmD
Flush Mount	16" H x 14.5" W x 6.12" D 40.64 cmH x 36.83 cmW x 15.54 cmD
Wiring Access	Two, one inch (2.54cm) hubs (bottom)
Keyboard	Sealed High Reliability Membrane
Display	Eight 0.5" high digits - seven segment

Electronics

CPU	16 bit TMS 9995 - 12MHz Clock
RAM Memory	8K Bytes
EEPROM	2K Bytes Non-volatile Read-Write Memory
EPROMs	32K Bytes Non-volatile Program Memory
A/D Converter	12 bit, 200 microsecond/channel
Watchdog Timer	Monitors Computer for Failsafe Shutdown

Critical Parameters Reside in Non-volatile EEPROM

Program Data Retained Through Power Loss

Functional

Pickup Inputs	Single or Dual (automatic switching upon loss)
Frequency Range	10 Hz to 20K Hz
Amplitude	1.0 VRMS minimum
Input Impedance	1K ohms (referenced to ground)

Loss of Speed Signal Failsafe Trip

Internal Electronic Overspeed Trip

History Retention of the Last Four Shutdowns

Analog Inputs	4, Fully Differential, 0 to +10 VDC maximum
Multiplexer	CMOS Solid State
Differential	± 15 VDC maximum to system common

Voltage Range and Engineering Units are Keyboard Entered

Field Power	+15 VDC at 250 mA available to power external transducers and field contacts.
Analog Outputs	2, 0-20 mA or 0-200 mA Range
Scaling	Keyboard Entered - Jumper Selection of Range
Voltage	+7 VDC at Maximum Current Flow
Accuracy	2.0% (10 bit)
Digital Input/Outputs	8, each configured as Input or Output

Interface through Industry-Standard Plug-In Modules

Modules are Individually Fused

LED Status Lights Indicate State of Each Module

Power	Input Circuits may be powered by Internal +15 VDC or may be powered externally
	Output Circuits must be Externally Powered (3 amp max)

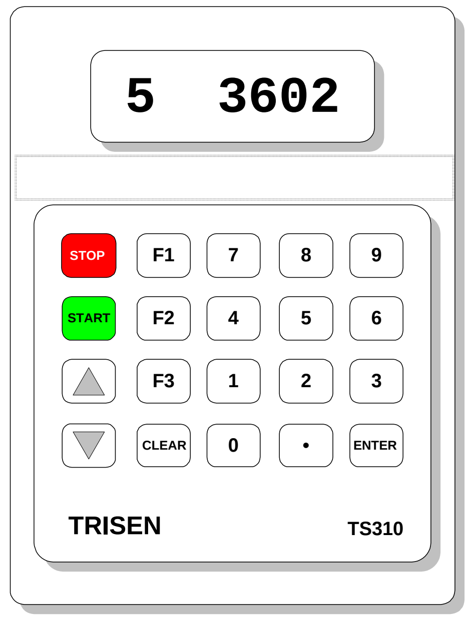
Chapter 9 - Configuration

This chapter is a *quick reference guide*, intended for use primarily during configuration changes. It will also be helpful during initial configuration, especially if the application is for a basic control scheme. A sample minimum configuration is also included at the end of this chapter.

The following Chapter 10 provides in depth discussions of the channels covered in this chapter.

9.1 Channel Access

Configuration of the *TS310* is accomplished by entering, from the keypad on the front panel, numerical values into *channels*. The keypad is shown in the figure at right. In order to enter these numerical values, channels are accessed as follows:



Channels 0-99: By pressing two numbers on the *TS310* keypad, you can access, or *call up*, any of the first 99 channels in the *TS310*. To change any of these channels, other than setpoints or tuning, you need to enter a password in Channel 99 as follows:

1. Press **99** to call up Channel 99.
2. Press **ENTER** and the display reads **99E**.
3. Enter your **PASSWORD** number.
4. Press **ENTER** again.
5. The display now reads **99 HELLO** with four flashing status indicators below.

NOTE: If an ACON configuration was used the ACON number is shown in Step 5 above.

You are now in the *configuration mode*.

Channels above 99: Extra channels have been added to the *TS310* to enhance its capabilities. The channels cannot be accessed in the previous fashion since the new channels are above Channel 99, and the *TS310* display cannot accommodate a three-digit channel number. Therefore, these channels are accessed with the *three-dot mode*, as follows:

1. Call up Channel 99.
2. Enter your **PASSWORD**; the display then reads **HELLO**.

NOTE: If an ACON configuration was used the ACON number is shown in Step 5 above.

3. Press the decimal point key three times. The display should now read **99. - - - - -**. Notice the decimal point after the 99. This indicates that all channel numbers now are 100 plus the channel number shown. ***Example***: 25**.** = 125
4. Call up one of the added channels and configure it to your requirements.

5. When fininshed with your configuration, exit the three-dot mode as follows.

   – At any channel, press the decimal point three times.
     The decimal point should no longer appear on the display.

To save a configuration, call up Channel 99 and enter any single-digit number, *other than the password*, and then press **ENTER**.

9.2 Password

Operating values, such as speed reference and tuning parameters, can be entered by way of the keypad at any time. All other values are PASSWORD protected and cannot be entered without first placing the *TS310* in the configuration mode by entering the password into Channel 99.

⚠ **CAUTION** PASSWORD PROTECTED CHANNELS SHOULD NOT BE CHANGED WHILE THE *TS310* IS RUNNING THE TURBINE.
(Except CHs 34, 35, 38, and 39, valve limits, and CH 66 load limit, can be changed with the turbine running.)

Example:

Call Channel 12 and press <ENTER>:	the display will read	`1 2   P P P P P`

This indicates that this channel is password protected. To enter the PASSWORD:

Call Channel 99:	the display will read	`9 9   - - - - -`
Press **ENTER**:	the display will read	`9 9 E         0`
Press **1234**:	the display will read	`9 9 E   1 2 3 4`
Press **ENTER** again:	the display will read	`9 9   H E L L O`

Any channel can now be accessed and changed. The four flags (status indicators) below the display will blink on and off to indicate that the *TS310* is in the configuration mode. These flags will show when any channel is accessed to remind the operator that the *TS310* is still in the configuration mode. The *TS310* can be taken out of the configuration mode at any time by entering **3** in Channel 99.

NOTE: *The actual default Password is not 1234.*

9.3 Changing The Password

THIS PAGE CAN BE REMOVED FROM THE MANUAL, IF DESIRED.

All *TS310* controllers are shipped with Password **6883**.

If it is necessary to change the Password, this is accomplished, as follows:

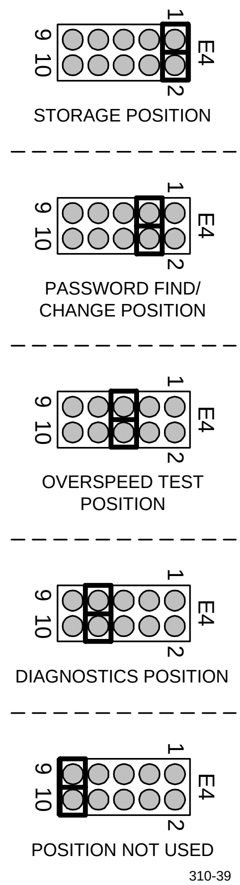
The figure at right shows the various positions of the E4 jumper, which is located in the bottom left-hand corner of the *TS310* Main Board.

The Password is displayed in Channel 99 *only* when the E4 jumper in the 3-4 position, or PASSWORD FIND/CHANGE POSITION, as shown at right.

In Channel 99, with the jumper in the 3-4 position, the Password can be changed to any other one to five digit number. For ***example***:

Press **ENTER.**
Press **1234.**
Press **ENTER** again.
The Password is now **1234** until it is changed again.

After the Password has been changed, remove the jumper from the **3-4** position and return it to the **1-2**, or STORAGE POSITION.



E4 Jumper Position Definitions

NOTE: *If the configuration is lost due to malfunction of the Main Circuit Board, the password may revert to the default password, 6883.*

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9.4 Entering Data

Whether a Password is required or not, all configuration value entry procedures are accomplished as follows:

Example #1: Change speed setpoint (reference) from 3600 RPM to 3620 RPM

Press **05**	the display will read	_ 5 _ _ 3 6 0 0
Press **ENTER**:	the display will read	_ 5 E _ _ _ _ 0
Press **3620**:	the display will read	_ 5 E _ 3 6 2 0
Press **ENTER** again:	the display will read	_ 5 _ _ 3 6 2 0

And the transaction is complete.

Example #2: Enter 180 (seconds) in Channel 88

Press **88**	the display will read	8 8 _ _ _ 0 . 0
Press **ENTER**:	the display will read	8 8 E _ _ _ _ 0
Press **180**:	the display will read	8 8 E 1 8 0 . 0
Press **ENTER** again:	the display will read	8 8 _ 1 8 0 . 0

And the transaction is complete.

NOTE: *If a mistake is made during the entry procedure (while the E is still displayed) pressing **CLEAR** will return the channel display to its original state. You can then press **ENTER** again and start over.*
Unless you wish to continue, you have accomplished all of the procedures necessary to configure and operate the TS310 *controller in a simple application.*

9.5 Function Keys

The **F1** key performs the following functions in the *TS310*:

- When configured to do so, the F1 key enables/disables the 2nd PID controller.
- When applied to a generator the *TS310* will enable or disable auto-sync when F1 is configured.
- When applied to a generator with 2nd PID and auto-sync, F1 enables auto-sync; i.e., load breaker is open, and 2nd PID if machine is operating in droop.

The **F2** key is used for two functions in the *TS310*:

- When configured for auto acceleration, F2 key initiates the auto acceleration function; and
- When configured for 3rd PID control, the F2 key will enable/disable the 3rd PID control function. The F2 key can be used as a dual function key since auto-accelerate always occurs before ext enable/disable 3rd PID control is required.

The **F3** key is used for one function only.

- When configured for sync generator mode with parallel isochronous, the F3 key will initiate or disable the parallel isochronous mode.

9.6 *TS310* Machine Data Listing

The channels (CH) listed in the following table define, or configure, the *TS310* as a controller; what it will be and how it is to operate. Everything in this manual revolves about the information in these channels.

***TS310* MACHINE DATA LISTING**											
FUNCTION	*****	***DISPLAY***								***RANGE***	***UNITS***
* = Required for minimum operation (see ¶9.8) D = Display only K = Password protected T = Tuning S = Setpoint		***C***	***H***								
SETPOINTS & VALUES AVAILABLE FOR DISPLAY											
SPEED USED	D	0	0							0-29999	RPM
ANALOG INPUT #1	D	0	1							0-29999	VARIES
ANALOG INPUT #2	D	0	2							0-29999	VARIES
ANALOG INPUT #3	D	0	3							0-29999	VARIES
ANALOG INPUT #4	D	0	4							0-29999	VARIES
SPEED SETPOINT	S	0	5							0-29999	RPM
2ND PID SETPOINT	S	0	6							0-29999	VARIES
3RD PID SETPOINT	S	0	7							0-29999	VARIES
ANALOG OUT #1 (VLV POS)	D	0	8							0-100	PERCENT
ANALOG OUT #2 (VLV POS)	D	0	9							0-100	PERCENT
SPEED INPUT #1	D	1	0							0-29999	RPM
SPEED INPUT #2	D	1	1							0-29999	RPM

***TS310* MACHINE DATA LISTING**					
FUNCTION * = Required for minimum operation (see ¶9.8) D = Display only K = Password protected T = Tuning S = Setpoint	*******	***DISPLAY*** ***C***	***H***	***RANGE***	***UNITS***
GOVERNOR SPEED DEFINITION VALUES					
ACCELERATION RATE	* K	1	2	0-29999	RPM/MIN
MIN CRITICAL SPEED #1	K	1	3	0-29999	RPM
MAX CRITICAL SPEED #1	K	1	4	0-29999	RPM
MIN GOVERNOR SPEED	* K	1	5	0-29999	RPM
MAX GOVERNOR SPEED	* K	1	6	0-29999	RPM
OVERSPEED TRIP SETTING	* K	1	7	0-29999	RPM
SPEED SWITCH #1 SET	K	1	8	0-29999	RPM
SPEED SWITCH #2 SET	K	1	9	0-29999	RPM
TUNING VALUES					
SPEED PROPORTIONAL BAND	* T	2	0	0-1000	PERCENT
SPEED INTEGRAL (RESET)	* T	2	1	0-500	SECONDS
SPEED DERIVATIVE (RATE)	T	2	2	0-200	SECONDS
SPEED DROOP	T	2	3	0-20	PERCENT
2ND PID PROP BAND	T	2	4	0-1000	PERCENT
2ND PID INTEGRAL (RESET)	T	2	5	0-500	SECONDS
2ND PID DERIVATIVE (RATE)	T	2	6	0-200	SECONDS
2ND PID DROOP	T	2	7	0-20	PERCENT
SYNCHRONIZING INTEGRAL	T	2	8	0-500	SECONDS
SYNCHRONIZING DERIVATIVE	T	2	9	0-200	SECONDS
3RD PID PROP BAND	T	3	0	0-1000	PERCENT
3RD PID INTEGRAL (RESET)	T	3	1	0-500	SECONDS
3RD PID DERIVATIVE (RATE)	T	3	2	0-200	SECONDS
3RD PID DROOP	T	3	3	0-20	PERCENT
LIMITS & IDLE					
V2 MIN LIMIT	K	3	4	0-100	PERCENT
V2 MAX LIMIT	K	3	5	0-100	PERCENT
IDLE SPEED	K	3	6	0-20000	RPM
IDLE FUEL	K	3	7	0-100	PERCENT
V1 MIN LIMIT	* K	3	8	0-100	PERCENT
V1 MAX LIMIT	* K	3	9	0-100	PERCENT
NOZZLE VALVES					
MIN #1 NOZZLE VALVE	K	4	0	0-100	PERCENT
MAX #1 NOZZLE VALVE	K	4	1	0-100	PERCENT
MIN #2 NOZZLE VALVE	K	4	2	0-100	PERCENT
MAX #2 NOZZLE VALVE	K	4	3	0-100	PERCENT
MIN #3 NOZZLE VALVE	K	4	4	0-100	PERCENT
MAX #3 NOZZLE VALVE	K	4	5	0-100	PERCENT

TS310 MACHINE DATA LISTING					
FUNCTION * = Required for minimum operation (see ¶9.8) D = Display only K = Password protected T = Tuning S = Setpoint	*****	***DISPLAY*** ***C***	***H***	***RANGE***	***UNITS***
ANALOG INPUTS DEFINITION & CALIBRATION					
MIN ANALOG INPUT #1	K	4	6	0-10.00	VOLTS
MAX ANALOG INPUT #1	K	4	7	0-10.00	VOLTS
MIN ENGRG UNITS #1	K	4	8	0-29999	ENG UNITS
MAX ENGRG UNITS #1	K	4	9	0-29999	ENG UNITS
MIN ANALOG INPUT #2	K	5	0	0-10.00	VOLTS
MAX ANALOG INPUT #2	K	5	1	0-10.00	VOLTS
MIN ENGRG UNITS #2	K	5	2	0-29999	ENG UNITS
MAX ENGRG UNITS #2	K	5	3	0-29999	ENG UNITS
MIN ANALOG INPUT #3	K	5	4	0-10.00	VOLTS
MAX ANALOG INPUT #3	K	5	5	0-10.00	VOLTS
MIN ENGRG UNITS #3	K	5	6	0-29999	ENG UNITS
MAX ENGRG UNITS #3	K	5	7	0-29999	ENG UNITS
MIN ANALOG INPUT #4	K	5	8	0-10.00	VOLTS
MAX ANALOG INPUT #4	K	5	9	0-10.00	VOLTS
MIN ENGRG UNITS #4	K	6	0	0-29999	ENG UNITS
MAX ENGRG UNITS #4	K	6	1	0-29999	ENG UNITS
ANALOG OUTPUTS CALIBRATION					
#1 ANALOG OUTPUT MIN	* K	6	2	0-20	m AMPS
#1 ANALOG OUTPUT MAX	* K	6	3	0-20	m AMPS
#2 ANALOG OUTPUT MIN	K	6	4	0-20	m AMPS
#2 ANALOG OUTPUT MAX	K	6	5	0-20	m AMPS
MISCELLANEOUS					
LOAD LIMIT	K	6	6	0-100	PERCENT
LOCAL SETPOINT RAMP RATE	* K	6	7	0-100	% MAX GOV
LOAD (KW) OVERRIDE RESET	T	6	8	0-200	SECONDS
PARALLEL ISOCH DELAY	K	6	9	*SEE CHANNEL*	*DESCRIPTION*
CONFIGURATION WORDS					
ANALOG INPUTS #1 & #2	K	7	0	WORD #1	
ANALOG INPUTS #3 & #4	K	7	1	WORD #2	
CONTACT (DIGITAL) I/O #1	K	7	2	WORD #3	
CONTACT (DIGITAL) I/O #2	K	7	3	WORD #4	
CONTACT (DIGITAL) I/O #3	K	7	4	WORD #5	
CONTACT (DIGITAL) I/O #4	K	7	5	WORD #6	
CONTACT (DIGITAL) I/O #5	K	7	6	WORD #7	
CONTACT (DIGITAL) I/O #6	K	7	7	WORD #8	
CONTACT (DIGITAL) I/O #7	K	7	8	WORD #9	
CONTACT (DIGITAL) I/O #8	K	7	9	WORD #10	
SPEED CONTROL	* K	8	0	WORD #11	
SPEED CONTROL	* K	8	1	WORD #12	
SPEED CONTROL	* K	8	2	WORD #13	

***TS310* MACHINE DATA LISTING**											
FUNCTION * = Required for minimum operation (see ¶9.8) D = Display only K = Password protected T = Tuning S = Setpoint	*****	***DISPLAY***								***RANGE***	***UNITS***
		C	***H***								
2ND PID CONTROL	K	8	3							WORD #14	
STATUS INDICATORS	K	8	4							WORD #15	
SPEED SWITCH CONF.	K	8	5							WORD #16	
3RD PID CONTROL	K	8	6							WORD #17	
GENERATOR CONTROL	K	8	7							WORD #18	
MISCELLANEOUS											
FAILSAFE SETTING	* K	8	8							0-400	SECONDS
GEAR TEETH	* K	8	9							0-320	TEETH
H VALUE	K	9	0							0-10	RATIO
F VALUE	K	9	1							0-10	RATIO
B VALUE	K	9	2							0-100	PERCENT
GEAR RATIO	K	9	3							0.000-9.999	RATIO
STARTUP PROP. BAND	T	9	4							0-1000	PERCENT
STARTUP INTEGRAL (RESET)	T	9	5							0-200	SECONDS
HOUR METER	K	9	6							0-29999	HOURS
LAST SHUTDOWN	D	9	7							*SEE CHANNEL*	*DESCRIPTION*
COMPUTER ID	K	9	8							0-32	
PASSWORD	K	9	9							UP TO 4 DIGITS	
LOAD PRESET	K	[1]2	8.							0-10	% FULL TRAVEL
SNAPBACK CONFIGURATION	K	[1]2	9.							WORD #19	
RECOVERY COUNTER		[1]4	0.							0-29999	OCCURRENCES
RECOVERY COUNTER	DK	[1]4	4.							0-29999	OCCURRENCES
EXTR/ADM LIMIT	K	[1]5	5.							0-100	PERCENT
REGULATOR/TRACKING	K	[1]5	6.							WORD #20	
MODBUS CONFIGURATION	K	[1]5	7.							WORD #21	
REMOTE SETPT RAMP RATE	K	[1]5	8.							0-100	% MAX GOV
MODBUS CHECKBACK	K	[1]5	9.							0-29999	DATA
CRITICAL SPEED ACCEL RATE	K	[1]6	0.							0-29999	RPM

9.7 Channel Definitions

CH 0-4 Speed And Analog Input Displays

Range: 0-29,999
Units: RPM
Ref.: Channels 10 and 11

These four channels are known as display channels. The information that is displayed by these channels cannot be changed via the keypad. CH 0 will display the speed measurement used to control your machine. CH 1 through 4 will display the value of the four analog inputs if they have been configured for use. The value will be the engineering units that you would have entered in the correct channels. The value displayed will not be the voltage or current level of the analog input signal. The analog inputs will be covered in much more detail later.

CH 5-7 Setpoints

Range: 0-29,999
Units: Varies
Ref.: Channel 46-61

These three channels are used to display or enter setpoints for the speed PID, 2nd PID, and 3rd PID. The entering of setpoints in these channels will be covered as we cover control of each type of control. Keep in mind that if you are only going to configure for speed control you need not be concerned with 2nd and 3rd PID. These values can be written via ModBus®, or they can be slaved to analog inputs configured for remote setpoint.

CH 8-9 Analog Output Displays

Range: 0-100
Units: Percent
Ref.: V1 - Channel 38, 39, 62, and 63
V2 - Channel 34, 35, 64, and 65

These channels display the amount of valve output the *TS310* is using. CH 8 displays the first valve output and if you are using "TWO VALVE" software, CH 9 will display the second valve output. You may be asking yourself "how do I know if I have one or two valve software?". Using the keypad to call up CH 9, if the display shows (9 -----) you have one valve software. If it displays (9 X.X) (X being any number 0-9) you have two valve software.

CH 10-11 Speed Input Displays

Range: 0-29,999
Units: RPM
Ref.: Channel 0, 81, 89 and 93

These two channels will display the speed of each magnetic pickup you use on your machine. Keep in mind that if you only use one pickup then only CH 10 will display speed.

CH 12 Acceleration Rate * Configuration Required

Range: 0-29,999
Units: RPM/MIN
Ref.: Channel 82

This channel is probably the first channel you will need to consider configuring. The acceleration rate is the rate at which you would like your machine to accelerate to the minimum governor speed (minimum running speed). Under two types of startup sequences, FAST START and MANUAL ACCELERATE, this information is not required. If you select FAST START or MANUAL ACCELERATE later in the configuration you may omit this data. If you are in doubt, just by pass this channel until later.

* *Some channels (noted in these descriptions with an asterisk) must be configured, as a minimum, for basic control. See Minimum Basic Configuration toward the end of this chapter.*

CH 13-14 Critical Speed

Range: 0-29,999
Units: RPM
Ref.: CH 156, 160

These two channels will take a value to set up a critical speed jumper. When a machine has a speed at which the vibration becomes high, a critical speed jumper can be used. This is done to prevent operating machines at these speeds. The *TS310* will accelerate beyond these speeds upon startup as quickly as possible, unless an entry in CH 160 holds ramp to a lower value. This is when we would set up a critical speed jumper. For ***example***, we have a unit that vibrates badly at 2500 RPM. We would then decide on a band (area) above, at, and below this speed we wanted to prevent operation in. Let’s make the band 100 RPM wide. To do this then we would set the minimum critical speed (CH 13) at 2450 and set the maximum critical speed (CH 14) at 2550. What we have then is an area 100 RPM wide around 2500 RPM. The control system will not allow a setpoint in this range, and will rush the machine through this range as quickly as possible. Values in these two channels are not required for normal operation. If not used, set the values to 0.

CH 15-16 Speed Range * Configuration Required

Range: 0-29,999
Units: RPM
Ref.

These two channels must be configured in all applications. In CH 15 you need to configure the value for the minimum speed (minimum governor speed) you want your machine to run at. In CH 16 enter the maximum speed (maximum governor speed) of your machine.

CH 17 Overspeed Trip Set * Configuration Required

Range: 0-29,999
Units: RPM
Ref.: Channels 72-79, 82, and 85

This channel is used by the *TS310* as an overspeed setpoint. The value you enter in this channel will set the point at which the control system will shutdown. This channel also sets the maximum speed for the 2nd analog output when it is configured to repeat machine speed.

CH 18-19 Speed Switch Settings

Range:	0-29,999
Units:	RPM
Ref.:	Channels 72-79, and 85

These two channels will contain the settings for speed switches, if you decide to use them. A later discussion will explain how to configure the switches in several different fashions. If you wish, at this point, you can enter a setpoint for either number one speed switch (CH 18) or both switches. If you are only planning to use one, then you should always use number one.

CH 20-33 Control Tuning * Configuration Required in CHs 20, 21

Range	Prop. Band - 0-1000
	Integral - 0-500
	Derivative - 0-200
	Droop 0-20
Units:	Prop. Band - Percent
	Integral - Seconds
	Derivative - Seconds
	Droop - Percent
Ref.	

In these channels you will enter the control tuning for each type of control to be used. CH 20, 24, and 30 are used as the proportional band for each controller. The proportional band will control the amount of change that will occur when an amount of error is detected. As an example, if CH 20 were 50, and if the speed has an error of 10%, then the output would change 20% to correct. To determine the amount of correction, divide the constant, 100, by the value in CH 20 then multiply the error (100/50 * 10% = 20%). This, then, would indicate that the higher the number we put in as a proportional band the less percentage of change will occur. CHs 21, 25, 28, 31 and 68 are the integral (reset) tuning functions. This function is more easily understood if we say that the number of times the correction would occur is defined by integral setting. CHs 22, 26, 29, and 32 are the derivative tuning functions. I think of derivative action as an anticipating action. The controller will respond much quicker to quick changes in the conditions; the larger the value for derivative, the quicker the response. Derivative action is seldom used except in generator applications. CHs 23, 27, and 33 are channels that will be used by the controller to set up the percent of Droop control that is required. Droop control is used when one of the controls in a *TS310* is a base loaded controller. By this I mean that the *TS310* will not try to control the variable but will assist in carrying the load of the variable. Proportional band and integral will always be required for speed control. Proportional band and integral will only be required for the other controls if they are going to be used. Derivative and Droop will only be entered when necessary.

Some typical settings for the PID controls are:

SPEED PID	Proportional Band	=	50.0
	Integral	=	5.0
2nd PID	Proportional Band	=	75.0
	Integral	=	15.0
3rd PID	Proportional Band	=	100.0
	Integral	=	25.0
SYNC	Integral	=	100.0

These are suggested turning values to start with. The system will require further tuning after you get your machine up to speed.

CH 34-35 V2 Limits

Range: 0-100
Units: Percent
Ref.: Channels 9, 64, 65, 72-79, and 86

These channels are limits for the second valve output, when used; CH 34 is the minimum valve position, and CH 35 is the maximum valve position. These limits will not be imposed until the machine reaches minimum governor speed.

CH 36-37 Idle Speed and Idle Fuel (Limit)

Range: 0-20,000
Units: Percent
Ref.: Channel 82

These channels provide data for the *TS310* to use for idle control, if implemented. CH 36 will define an idle speed and CH 37 will define what maximum valve output will be allowed to put and keep your machine at idle. Again, by-pass these channels if you do not need an idle speed.

CH 38-39 V1 Limits * Configuration Required

Range: 0-100
Units: Percent
Ref.: Channels 8, 62, 63, 72-79, and 80

These channels are similar to those used to set the minimum and maximum travel of the second valve output. CH 38 sets the minimum value and CH 39 sets the maximum. These limits are imposed when your machine is at minimum governor speed. For most applications a value of 0.0 is appropriate in CH 38, and 100.0 in CH 39. This gives the *TS310* complete use of the valve travel to control with.

NOTE: *With Sync Gen Configuration, CH 38 becomes effective when load breaker closes.*

CH 40-45 Nozzle Valves

Range: 0-100
Units: Percent
Ref.: Channels 72-79, and 81

These channels are to be used to set values to open and close one to three nozzle valves (auto-hand valves). If you have a steam turbine, you would be a candidate for using these channels. If you are going to automate a nozzle valve, you will configure the maximum value to open the valve, and the minimum value to close the valve. These values are the percent of the V1 output or an analog input. The use of the analog input will be covered later.

CH 46-61 Analog Inputs

Ref. CH 70 and 71
ACON Chapter 4

Use of the four analog input signal positions (wiring terminals 8 through 15 of the terminal board) is optional. The configuration options (CH 70 and 71) are selected from 22 different configuration possibilities available. The only individual configuration option that should ever be duplicated (used more than once) is the 00, NOT USED, option.

Analog Inputs/ Display CHs	Termination Board Wiring Terminal Nos	Channel to Enter Min Acknowledged Input Voltage Limit	Channel to Enter Max Acknowledged Input Voltage Limit	Channel to Enter Min Acknowledged Input Display Units	Channel to Enter Max Acknowledged Input Display Units	Channel Positions that Define How Used
#1/01	8(-), 9(+)	46	47	48	49	70 **XX**XX
#2/02	10(-), 11(+)	50	51	52	53	70 XX**XX**
#3/03	12(-), 13(+)	54	55	56	57	71 **XX**XX
#4/04	14(-), 15(+)	58	59	60	61	71 XX**XX**

NOTE: *When entering data into channels for Min Ack Input Display (CHs 48, 52, 56, 60), the decimal places are being determined for those channels, as well as for Max Ack Input Display (CHs 49, 53, 57, 61).*

In order to easily communicate the intended use of these channels, configuration examples for some common analog inputs are described below.

Example 1: A 4 to 20 mA DC input signal that represents a remote speed setpoint of from 2000 RPM to 5000 RPM at analog input position #1:

The 4 to 20 mA input signal would be connected to wire terminals 8(-) and 9(+) of the termination board. A 250 ohm resistor would also be placed across terminals 8 and 9 to transform the 4 to 20 mA current signal into a 1 to 5 volt DC input.

Minimum signal input voltage, 1.0, would be entered in Channel 46.
Maximum signal input voltage, 5.0, would be entered in Channel 47.
Minimum speed setpoint, 2000, would be entered in Channel 48.
Maximum speed setpoint, 5000, would be entered in Channel 49.

The configuration would be to enter 04 in positions A and B of Channel 70 (displayed as: 70 **04**XX), which selects the remote direct speed setpoint configuration. (Reference Channels 70 and 71 for more details.)

Example 2: A 0 to 10 volt DC input signal that represents a 100 to 500 psig steam turbine back pressure signal at analog input position #2:

The 0 to 10 volt input signal would be connected to wire terminals 10(-) and 11(+) of the termination board:

Minimum input voltage, 0.00, would be entered in Channel 50.
Maximum input voltage, 10.00, would be entered in Channel 51.
Minimum units (psig), 100, would be entered in Channel 52.
Maximum units (psig), 500, would be entered in Channel 53.

The configuration for analog input #2 would be to enter 02 in positions C and D of Channel 70 (displayed as: 70 XX**02**), to select the 2nd PID measured linear input. (Reference channels 70 and 71 for more details.)

***NOTE**: The number of decimal places displayed are set in the minimum units. Example: 100 = no decimal; 100.0 = 1 decimal; and 100.00 = 2 decimal places. Maximum engineering units cannot exceed 29999 counts. This means 29999 = OK, 2999.9 = OK; 299.99 = OK, 300.00 = NOT ACCEPTED.*

Example 3: A 4 to 20 mA DC input signal that represents a remote 2nd PID setpoint range of 200 to 350 psig (such as a steam turbine back pressure control) at analog input position #3:

For this example, assume that an increased degree of setpoint resolution is desired, and that the 4 to 20 mA current source is capable of driving 20 mA through greater than 500 ohms of load.

The 4 to 20 mA signal would be input to wire terminals 12(-) and 13(+) of the termination board. A 500 ohm resistor would also be placed between terminals 12 and 13 to transform the 4 to 20 mA current signal into a 2.0 to 10.0 volt DC input signal.

Minimum signal input voltage, 2.0, would be entered in Channel 54.
Maximum signal input voltage, 10.0, would be entered in Channel 55.
Minimum units, 200, (psig) would be entered in Channel 56.
Maximum units, 350, (psig) would be entered in Channel 57.

The analog input #3 configuration would then be completed with 05 in positions A and B of Channel 71 (displayed as: 71 **05**XX), which selects it as a remote direct 2nd PID setpoint signal. (Reference Channels 70 and 71 for more details.)

CH 62-65 V1/V2 Output Calibration CHs 62, 63 * Configuration Required

Range	0-20
Units	mA
Ref.	V1 - Channels 8, 38, 39, and 80
	V2 - Channels 9, 34, 35, and 86

These four channels will be used by the *TS310* to determine the current output levels that are required for each of the outputs. The normal will be 4-20 mA. To do this you need only configure the minimum channel as a 4.00 and the maximum channel as a 20.00. You may require a signal that is much higher. Some devices require up to 200 mA. This is easily done. You will configure the minimum and maximum as a two digit number. As an example, if we need 180 mA output we would enter 18.00. The times ten multiplication required to make it 180 mA is done on the termination board. Please refer to the *TS310* user manual for more information about the multiplier.

CH 66 Local Load Limit

Range: 0-100
Units: Percent
Ref.: Channels 72-79, 84, and 87

The entry you make in this channel will be used by the *TS310* to limit the horsepower of your machine. You may simply wish to set this channel at 100.0 giving you full horsepower. The limit is used by the *TS310* as it compares the 1st PID output in percent to the value of this channel. If you have a 50 in this channel, the *TS310* will not allow the 1st PID output to go above 50% (calculated 50% horsepower). When we get to the definition of analog signals you will discover that this limit might be calculated as a percent of a KW signal or a limit function measurement. Remember, don't worry about KW if you are not applying the *TS310* to a generator drive.

CH 67 Local Setpoint Ramp Rate * Configuration Required

Range: 0-100
Units: Percent of Maximum Governor/Second
Ref.: Channels 16 and 158

This channel will take an entry to develop the rate at which you will be able to ramp the setpoint between minimum and maximum governor speed. The number you configure will be the percent of maximum governor setting (CH 16). The rate of change then will be this percent per second.

This channel also affects the remote setpoint unless an entry is made in CH 158, Remote Setpoint Ramp Rate.

CH 68 KW Override Reset

Range: 0-200
Units: Seconds
Ref.: Generator Chapter/*TS310* Manual

This channel will need a value entered in it only when the *TS310* is applied for generator use and a KW signal is provided. The value entered will be used as an integral-only control for KW limiting.

CH 69 Parallel Isochronous Delay

Range: 0-12
Units: Seconds
Ref.: Synchronous Generator Chapter/*TS310* Manual

This channel is for generator applications data and will provide a damping effect for parallel isochronous operation. It will be necessary only when the system is configured in parallel isochronous mode.

CH 70-71 Analog Input

Configuration **Words 1 and 2**
Ref.: Channels 1-4, and 46-61

These two channels are the first of the *Configuration Words* (the four digit number you configure for each channel) that will define the four analog inputs. The following illustrates the positions on the *TS310* display of the four digits in a configuration word, positions A, B, C and D.

Display Positions

	C	*H*			*A*	*B*	*C*	*D*
Word 1	7	0			X	X	X	X
Word 2	7	1			X	X	X	X

The first two digits, positions A and B, of Configuration **Word 1** in CH 70 will define the number one analog input. The last two digits, positions C and D, of the configuration word will define the second analog input.

The first two digits in of **Word 2** in CH 71 will define the number three analog input and the last two digits will define the fourth analog input. Always remember that you may use the inputs in any order you wish. If you do not need to use an input, enter a 00 for the first two digits.

Below is a list of the two digit numbers that define the analog input.

00	Not Used		
01	Display Only (Linear)	11	(Square Root)
02	2nd PID Meas. (Linear)	12	(Square Root)
03	Remote Load Limit (Direct)	13	(Reverse)
04	Speed Setpoint (Direct)	14	(Reverse)
05	2nd PID Remote Set (Direct)	15	(Reverse)
06	Parallel Line Signal		
07	Sync. Phase		
08	3rd PID Meas. (Linear)	16	(Square Root)
09	KW (Generator)		
10	3rd PID Remote Set (Direct)	18	(Reverse)
17	Nozzle Valve Control		
19	External 3rd PID		
20	Limit Function Meas. (Direct)	21	(Reverse)

As an ***example***, let's say we want the second analog input to be a direct speed setpoint (min. input = min. speed; max. input = max. speed). We would configure CH 70 with "0004". The first two digits "00" would mean that the first analog input was not used. The last two digits are "04" which mean "Speed Setpoint (Direct)". CH 71 might be any number from "0000" on. This would depend on whether you were going to use the third and fourth analog inputs.

NOTE: *In the following descriptions I will not attempt to cover the exact function of each input. In most cases you will find a more complete discussion covering the use of the input in the* TS310 *user manual.*

01 & 11 - DISPLAY ONLY: 01-Linear means exactly that. The *TS310* will display, in engineering units, the correct value based on the signal-in level. 11-Square Root has been provided for use with flow meters.

02 & 12 - 2ND PID MEASUREMENT: 02 or 12 provide the *TS310* with the necessary input for the 2nd PID control function.

03 & 13 - REMOTE LOAD LIMIT: These two numbers will define a signal that the *TS310* will use to limit the load of your machine. The only difference between 03 and 13 is that the 03 signal would mean, as an example:
0 VDC=0 PSIG/10 VDC=100 PSIG.
13 would be an inverse function:
0 VDC=100 PSIG/10 VDC=0 PSIG.

04 & 14 - SPEED SETPOINT: These numbers define a remote signal that will be used as a speed signal. 14, like 13, just inverts the meaning of the signal.

05 & 15 - 2ND PID REMOTE SET: These numbers will provide a remote setpoint for the 2nd PID controller in the *TS310*. Again, 15 is the inverse function.

06 - PARALLEL SIGNAL: This number will only be needed when your application is a parallel isochronous generator application.

07 - SYNC. PHASE: This number will only be needed when the *TS310* is doing auto synchronizing for a generator application.

08 & 16 - 3RD PID MEASUREMENT: These numbers define the input as a measurement for the 3rd PID controller.

09 - KW: This number will be used on generator applications only. It gives the *TS310* the KW value of the generator.

10 & 18 - 3RD PID SET: These two numbers will define the input as a setpoint or the 3rd PID controller.

17 - NOZZLE VALVE CONTROL: This number will define the input to be used in place of the valve position. This input will open and close nozzle valves, if configured.

19 - EXTERNAL 3RD PID: This number defines the input to be a 3rd PID controller. In this case the internal 3rd PID controller is disabled.

20 & 21 - LIMIT FUNCTION MEASUREMENT: These two numbers define the input to be used to limit the horsepower of your machine based on the percent configured in CH 66.

CH 72-79 Input/Output Contacts

Configuration **Words 3-10**
Ref.:

These eight channels (Configuration Words) will define the requirement of the eight input/output modules. Keep in mind that when we say eight input/output we mean, any combination of I/O, up to eight. We do not mean there are eight of each. You will find that the configuration of these channels is a bit different from those discussed so far.

The first digit, A position (starting from the left), defines the type of contact.

The second digit, B position, defines the requirement for a status indicator.

The last two digits, C and D positions, define the I/O itself.

Display Positions

	C	***H***			***A***	***B***	***C***	***D***
Word 3	7	2			X	X	X	X
Word 4	7	3			X	X	X	X

Let's start with the **<u>A</u> position**, the definition of the type of I/O. Below is a list of the possible types of I/O. Take just a moment to look them over.

<u>A</u> Position

0 - Not Used
1 - Input/N.O.
2 - Input/N.C.
3 - Output/N.O.
4 - Output/N.C.

We are going to cover the type of contacts we have to configure next. Do not be concerned about what function you want the contact to work as. We will cover the function of each contact input/output later

0 - Not Used is self explanatory. If the channel has a 0, it indicates that you are not using the contact.

1 - Input/N.O. tells us that the contact will be used as an input. The N.O. (meaning normally open) tells us that the input should function when we close a contact into the *TS310*.

2 - Input/N.C. tells us that the contact will be used as an input. The N.C. (meaning normally closed) tells us that the input should function when we open a contact into the *TS310*.

3 - Output/N.O. tells us that the contact will be used as a contact output. The N.O. (meaning normally open) tells us that the contact will be closed on a function.

4 - Output/N.C. tells us that the contact will be used as a contact output. The N.C. (meaning normally closed) tells us that the contact will be opened on a function.

With a contact input you must open or close a contact to supply power to the *TS310*. This will cause the input to function. When a contact is configured as an output, the power you supply to the *TS310* will be switched on and off as the *TS310* functions. The voltage you can utilize will vary. By installing the correct modules in the *TS310* termination board, you will be able to cover a wide variety of voltage levels. For more information on the ranges we can cover you need to refer to the Operation Chapter of the *TS310* Users Manual.

B Position of the Configuration Words for contacts can be used to turn on and off a status indicator. The status indicators are four inverted triangles located on the bottom of the *TS310* display. As you are about to discover, they can be turned on at a function or turned off at a function. Take a moment to look over the choices below.

B Position

0 - None	
1 - LCD #1 "ON"	5 - LCD #1 "OFF"
2 - LCD #2 "ON"	6 - LCD #2 "OFF"
3 - LCD #3 "ON"	7 - LCD #3 "OFF"
4 - LCD #4 "ON"	8 - LCD #4 "OFF"

0 - As before a zero indicates "Not Used"

1 - Indicates that the first status indicator from the left will come on as the I/O functions.

2 - Indicates that the second status indicator from the left will come on as the I/O functions.

3 - Indicates that the third status indicator from the left will come on as the I/O functions.

4 - Indicates that the fourth status indicator from the left will come on as the I/O functions.

5 - Indicates that the first status indicator from the left will be on and go off as the I/O functions.

6 - Indicates that the second status indicator from the left will be on and go off as the I/O functions.

7 - Indicates that the third status indicator from the left will be on and go off as the I/O function.

8 - Indicates that the fourth status indicator from the left will be on and go off as the I/O function.

Later you will come to a channel that will allow you to use the status indicators again. Keep in mind that in these channels and the channels to come, you can use a status indicator for more than one function. That is to say, the same status indicator can be configured to turn on and off for more than one reason. To prevent confusion I would suggest that you only give each of the four indicators one use.

In the **C and D positions** of these Configuration Words, you will set the function of the contact I/O. There are many choices to choose from. Below is the list of functions. Please take a few minutes to look them over.

C and D Positions

Input	*Output:*
01 - Remote Start	20 - Trip Output
02 - Remote Stop	21 - Pickup Fail Alarm
03 - Remote Raise	22 - Nozzle Valve No. 1
04 - Remote Lower	23 - Nozzle Valve No. 2
05 - Load Breaker In	24 - Nozzle Valve No. 3
06 - Tie Breaker In	25 - Load Breaker Out
07 - Idle/Run	26 - Speed Switch No. 1
08 - 3RD PID Raise	27 - Speed Switch No. 2
09 - 3RD PID Lower	28 - Valve Limit Alarm
10 - Remote F1	29 - Common Alarm
11 - Remote F2	30 - 3 Second Pulse Trip Out
12 - Remote F3	31 - Synchronizing
13 - Start Permit	32 - Load Breaker Closed
14 - Overspeed Test	33 - Tie Breaker Closed
15 - Live/Dead Bus	34 - Cascade Enabled
16 - External Trip In	35 - Overspeed Trip
17 - Enable Remote Speed Set	36 - Overspeed Test Enabled
	37 - External Trip
	38 - Load Limited
	39 - Ext/Adm Enabled

As you can see the selections cover a variety of contact types. Do not get confused. We will now look at each and cover their uses in the *TS310*.

Inputs:

01 - REMOTE START: When you set the remote start function you will duplicate the function of the start key on the front of the *TS310*. Later on you will discover that you may select the start button. You can configure the start key only, the REMOTE START only, or both to operate the start function.

02 - REMOTE STOP: When you set the remote stop function you will duplicate the function of the stop key on the front of the *TS310*. Later in the configuration you will have many selections for the stop function.

03 - REMOTE RAISE: When you set the remote raise function you will duplicate the function of the up arrow key on the front of the *TS310*.

04 - REMOTE LOWER: When you set the remote lower function you will duplicate the function of the down arrow key on the front of the *TS310*.

05 - LOAD BREAKER IN: If you are not applying a generator now, you need not concern yourself with this input. This channel needs to be configured for synchronous generator applications. The use for this will be apparent in the generator applications discussion.

06 - TIE BREAKER IN: If you are not applying a generator, you need not concern yourself with this input. Like the load breaker input, this input will be covered later.

07 - IDLE/RUN: To use this input you must configure an idle speed. To command your machine to either "RUN" or "IDLE", you change the status of this input. The type of contact will determine when each function is to happen. An example would be:

CH 72 = 1007 - When a switch is closed (power to the input) you will be in IDLE function. Opening the switch will cause the RUN function to activate.

08 - 3RD PID RAISE: If you are utilizing the 3RD PID then you may wish to have an external contact for raising the setpoint.

09 - 3RD PID LOWER: If you are utilizing the 3RD PID, you may wish to have an external contact for lowering the setpoint.

10 - REMOTE F1: This input will function as the "F1" key on the front of the *TS310*. Later we will discuss the F1 function.

11 - REMOTE F2: This input will function as the "F2" key on the front of the *TS310*. Later we will discuss the F2 functions.

12 - REMOTE F3: This input will function as the "F3" key on the front of the *TS310*. Later we will discuss the F3 function.

13 - START PERMIT: This input will be used to halt the start function until this input is cleared.

14 - OVERSPEED TEST: Later you will be given a choice of selecting an overspeed test. You will also decide how you wish to implement this test. If you select, "external contact", you will need to configure a contact input using this number.

15 - LIVE/DEAD BUS: If you are not applying a generator drive, this contact input is not necessary. This input will be used by the *TS310* to determine the status of the utility bus. For GC880 applications, the contact is closed when the bus is "live", and open when the bus is "dead"; configure as **2X15**.

16 - EXTERNAL TRIP: You may have a requirement to trip your machine other than those in the *TS310*. This input is used by the *TS310* to trip a machine from an external source. If you use an N.C. type contact then opening the input (loss of power to the input) will trip the machine. To reverse the input, just use the N.O. contact type.

17 - ENABLE REMOTE SPEED SET: If you are using a remote and local speed setpoint you may use this input. To enable a remote set by closing a contact input (applying power) to the input, you would use a N.O. input. As above, to reverse the input just select a N.C. type input.

Outputs:

20 - TRIP OUT: This contact will activate any time the *TS310* has an internal or external trip applied. By using a N.O. contact type, when a trip function happens the contact will close. To reverse this function use an N.C. type contact output.

21 - PICKUP FAIL ALARM: This contact output will activate whenever the *TS310* has a bad speed input.

22 - NOZZLE VALVE No.1: Back in CHs 40 and 41 you may have configured a value to open and close a nozzle valve. This contact output will be used to output the action of the nozzle valve.

23 - NOZZLE VALVE No.2: In CHs 42 and 43 you may have configured a value to open and close a second nozzle valve. This contact would be used to output the action to the nozzle valve.

24 - NOZZLE VALVE No.3: In CHs 44 and 45 you may have configured a value to open and close a third nozzle valve. This contact would be used to output the action to the nozzle valve.

25 - LOAD BREAKER OUT: If you are not applying a generator you will not need to be concerned with this contact. If you are using the *TS310* as an auto-synchronizer then you will need this output to give a signal to close the load breaker.

26 - SPEED SWITCH No.1: If you have entered a value in CH 18, you will use this function to operate a contact. When the machine reaches the value in CH 18 it will operate the output. By using the different types of contacts (N.O. or N.C.) you can open the output at the time the value is reached or close the output. The N.O. would close as the value is reached and the N.C. would open.

27 - SPEED SWITCH NO. 2: The function of this output is the same as number 26. The only difference is that it will use the value in CH 19 to operate by.

28 - VALVE LIMIT ALARM: This contact will operate when either of the valve outputs are limited. If, for example, V1 were at 100% and the speed still drooped, this output would alarm.

29 - COMMON ALARM: This output would function if any of the following trips are sensed by the *TS310*: PICKUP FAIL, OVERSPEED TRIP, EXTERNAL TRIP, SPEED SWITCH SHUTDOWN, KW LIMITING or SYSTEM PROBLEM (CH84). If you use a N.O. type contact the output will close on a trip. An N.C. type contact would open.

30 - 3 SECOND PULSE TRIP: This output will activate as does the trip output (20). This trip differs only in its action. When this trip activates it only stays active for 3 seconds and then clears.

31 - SYNCHRONIZING: If you are not applying a generator, you need not concern yourself with this output. The *TS310* will activate this contact whenever it is in the auto-sync mode.

32 - LOAD BREAKER CLOSED: This is another generator-only applied output. When the *TS310* receives an input that the load breaker is closed it will activate this output as a verification.

33 - TIE BREAKER CLOSED: This contact, like the load breaker closed, will activate as the *TS310* verifies that it has received the information.

34 - CASCADE CLOSED: This output will activate whenever the *TS310* has put the 2nd PID control in control.

35 - OVERSPEED TRIP: This output will be activated whenever the *TS310* senses the speed to be greater that the value in CH 17.

36 - OVERSPEED TEST ENABLED: This output will activate as soon as you put the *TS310* in the overspeed test mode.

37 - EXTERNAL TRIP: This output will be activated as soon as an input by an external device indicates to the *TS310* to trip.

38 - LOAD LIMITED: This contact output is true when the controller is limiting its output to control machine load. It is enabled when the *TS310* speed reaches minimum governor. By definition, it is true when the V1 output reaches 100%. If no analog input is configured, for this function, it becomes true when the V1 output equals the value in CH 66 or 100%, which ever is greater.

***NOTE**:* *For extraction/admission applications, the contact looks at the first PID output instead of V1.*

When an analog input is configured 20 or 21 (limit function measurement), or 09 (KW), in Channels 70 and 71, this output becomes true when that analog input value reaches the percentage of span set in CH 66. If the *TS310* trips or is stopped while this output is true, the output will latch. It will not clear until the *TS310* is restarted and attains minimum governor speed.

39 - EXTRACTION/ADMISSION ENABLED: This contact will be activated when the *TS310* enable the Extraction/Admission, Extraction, or Admission control.

CH 80 Speed Control Configuration * Configuration Required

Configuration **Word 11**
Ref.: Channels 8, 38, 39, 62, 63, 72-79

This channel is the first of three channels we will configure to set up the speed controller in the *TS310*. Like the last two Configuration Words, this one consists of four parts.

The number you select will be the first digit, **A position**, from the left in **Word 11**. The list below is the A position of **Word 11**. The number you select here will be for the control action.

A Position = Control Action

	Output Action Direction	*Output Readout % Direction*
0	Reverse	Direct
1	Direct	Direct
2	Direct	Reverse
3	Reverse	Reverse

0 - REVERSE/DIRECT: REVERSE indicates that the control action is a reverse acting controller. As the speed goes above the setpoint the controller will decrease the V1 output. DIRECT defines the direction the value will change in CH 8. CH 8 being the value of the V1 output in percent. If the V1 output goes from 10% to 20% output, the display of CH 8 will read from 10% to 20%.

1 - DIRECT/DIRECT: The first DIRECT indicates that the control action would be direct. As the speed goes above the setpoint the V1 output would increase. The second DIRECT indicates that the value in percent for CH 8 would increase as the V1 output increases. This portion would work the same as selection "0".

2 - DIRECT/REVERSE: DIRECT indicates that the control action would be direct. As the speed goes above the setpoint the V1 output would increase. REVERSE indicates that the value in percent for CH 8 would decrease as the percentage of output increased. If the V1 output was at 10% output, the display of CH 8 would read 90%. If the V1 output was to change to 20% out, CH 8 would display 80%.

3 - REVERSE/REVERSE: The first REVERSE indicates that the control action would be reverse. As the speed goes above the setpoint, the V1 output would decrease. The second REVERSE would indicate as it would in selection "2" above.

The most commonly used selection for speed control would be "0". The second most commonly used selection is "2". There may be times when "1" or "3" is required.

The second digit, **<u>B</u> position**, from the left for **Word 11** will configure the action of the start function. Below is the list of selections:

<u>B</u> Position = Start Button

0 - None
1 - Local Only
2 - Remote Only
3 - Local and Remote

There is little to explain here, as the definitions are very self explanatory. I would caution you to remember that, to the *TS310*, any button on the keypad is a local function. Any function that comes through the termination board is a remote function.

The third digit, **<u>C</u> position**, from the left for **Word 11** will set the stop function in the *TS310*. Below is the list for this function.

<u>C</u> Position = Stop Button

0 - None
1 - Local
2 - Remote
3 - Local and Remote

The same rules apply here as applied for the start function.

The fourth digit, **<u>D</u> position**, in **Word 11** tells the *TS310* what type of application we are going to use. The list of selection is below.

<u>D</u> Position = Applications

0 - Speed Control
1 - Synch. Generator
2 - Recip. Engine
3 - Gen. Recip. Engine

0 - SPEED CONTROL: For all applications where a turbine is going to drive a mechanical drive (compressor, pump, fan, etc.) this would be the selection required.

1 - SYNCH. GENERATOR: For all applications where a turbine is going to be used to drive a sync. generator this would be the selection.

2 - RECIP. ENGINE: For all applications where a reciprocating engine is going to be driving a mechanical drive (see "0") then this would be the selection.

3 - GEN. RECIP. ENGINE: For all applications where a reciprocating engine will be driving a sync. generator this would be the selection.

CH 81 Nozzle Valve Control * Configuration Required

Configuration **Word 12**
Ref.: CH 40-45, 70-71, 72-79,

This channel is the second of the speed Configuration Words. A list of the selections for the first digit, **A position**, of **Word 12** appears below.

A Position = Nozzle Valves

0 - Disable
1 - Enable 1 Valve
2 - Enable 2 Valves
3 - Enable 3 Valves

0 - DISABLE: Selecting a "0" will instruct the *TS310* to use no nozzle valves.

1 - ENABLE 1 NOZZLE VALVE: Selecting this option will enable one nozzle valve. The *TS310* will use the values in CHs 40 and 41 to operate one valve. The *TS310* will function a contact output to operate the nozzle valve. You need to configure a contact for the number one nozzle valve in one of the contact I/O channels (72-79).

2 - ENABLE 2 NOZZLE VALVES: Selecting this option will enable two nozzle valves. The *TS310* will use the values in CHs 40-43 to operate the two valves. Remember that you need to have contact outputs for each valve. They are configured in the contact I/O channels (CHs 72-79).

3 - ENABLE 3 NOZZLE VALVES: Selecting this option will enable three nozzle valves. The *TS310* will use the values in CHs 40-45 to operate the three valves. Remember that you need to have contact outputs for each valve. They are configured in the contact I/O channels (CHs 72-79).

The second digit, **<u>B</u> position**, of **Word 12** is used to define the setpoint to the speed controller. The setpoint to the speed controller is use by the *TS310* to set the speed of a machine. We will cover both remote and local setpoints. I would remind you, the *TS310* refers to itself as local and anything outside the *TS310* as remote. The list of selections appears below.

<u>B</u> Position = Setpoint To Speed Control

0 - Local Only
1 - Remote Only
2 - Local and Remote (HI Select)
3 - Local and Remote (LO Select)
4 - Local and Remote (Select)

0 - LOCAL ONLY: This selection will tell the *TS310* to look at CH 5 for the speed setpoint. It will not look for any other speed setpoint. To enter a setpoint in CH 5 you have two choices. You may enter a setpoint using the keys known as arrow keys. When you press the up arrow key you will increase the setpoint in CH 5. By pressing the down arrow key you will decrease the setpoint in CH 5, or you may enter a digital number directly into CH 5. To do this you call up CH 5, press enter, and enter the setpoint. Pressing enter one more time will enter the new setpoint.

1 - REMOTE ONLY: This selection is used when you have an analog input configured as a remote setpoint (Ref. CH 70-71). The speed control will get its setpoint from an analog input. The *TS310* will not take an entry in CH 5 or accept the arrow keys as a speed setpoint.

2 - LOCAL & REMOTE (HI SELECT): This selection will tell the *TS310* to use both setpoints. The *TS310* will take the highest of the setpoints and use it for the speed controller. The value in CH 5 is used if the value of the analog input is less. If the value is greater for the analog input, it will be used. If either becomes greater than the other the *TS310* will select the highest. Remember, you need an analog input configured as a speed setpoint in CHs 70 and 71.

3 - LOCAL & REMOTE (LO SELECT): This selection will tell the *TS310* to use both setpoints. The *TS310* will take the lowest of the setpoints and use it for the speed controller. The value in CH 5 will be used if the analog input is greater. If the value of the analog input is less, it will be used. If either becomes less than the other the *TS310* will select the lowest. Remember you need an analog input configured as a speed setpoint in CHs 70 and 71.

4 - LOCAL & REMOTE (SELECT): When using this selection you will need a setpoint select contact input configured (Ref. CH 72-79). The *TS310* will select which setpoint to use by the status of the contact input. Both setpoints will not be used at the same time.

The third digit, **<u>C</u> position**, in **Word 12** can use either one or two pickups (speed sensors) with the *TS310*. If you are using one pickup, enter a "0" in this position. If you are using two pickups, enter "1". If you use only one pickup you will trip (shutdown) if the signal is lost. The selection of two pickups will allow the machine to run if one pickup signal is lost. The *TS310* will alarm for a loss of the pickup signal in either case.

The fourth digit, **<u>D</u> position**, in **Word 12** will select the fail-safe action. The normal selection will be "0". By entering a 0 you enable the fail-safe function. The "1" will disable the feature. The fail-safe feature safeguards your machine. If the speed pickups are lost and the fail-safe is enabled the *TS310* will trip the machine . With the fail-safe disabled the machine would run out of control.

CH 82 Startup/Stop/Overspeed/Tuning * Configuration Required

Configuration **Word 13**
Ref.:

The first digit, **A position**, of **Word 13** sets up the startup mode. The selections are listed below.

A Position = Startup

0 - No Idle
1 - Auto Acceleration
2 - Manual Acceleration
3 - Fast Start

0 - NO IDLE: The no idle selection tells the *TS310* to provide "no idle". The *TS310* will not check the values in CHs 36 and 37 (idle speed and idle fuel). When you press start the setpoint (CH 5) will go to minimum governor speed (CH 15). The *TS310* will not allow a machine to operate below minimum governor speed.

1 - AUTO ACCELERATE: Selecting this option will instruct the *TS310* to operate the auto acceleration mode. After you press start, the *TS310* will bring a machine to the idle speed (CH 36). The *TS310* will limit the amount of fuel to idle, by using the value in CH 37. After the machine reaches the idle speed, pressing F2 will initiate the auto acceleration mode. Your machine will accelerate (speed up) to the minimum governor setting. The rate of acceleration will depend upon the value entered in CH 12. You may, during the auto acceleration mode, halt the acceleration. If you press either the raise or lower arrow key the acceleration will stop. The *TS310* will hold the speed of your machine at the setpoint you stopped auto-acceleration. To continue acceleration, press the F2 key.

2 - MANUAL ACCELERATION: The selection of this option will allow an idle speed with no auto acceleration. By pressing the start key, the machine will come to idle speed and hold. To accelerate the machine, press the raise arrow key. The machine will accelerate at the rate set in CH 12. At any time you wish to halt acceleration, release the raise key. You can increase or decrease the speed by using the arrow keys. To take the unit to the minimum governor speed, press the raise arrow key . Hold the key until the setpoint (CH 5) reaches minimum governor speed.

3 - FAST START: This selection will set up the fast start mode in the *TS310*. When you press start the *TS310* will take a machine to minimum governor speed as fast as possible. While increasing the speed quickly, the *TS310* will keep the machine in control. When the machine reaches minimum governor speed it will stabilize at that speed.

The second digit, **B position**, of **Word 13** is used to set up the stop function. The list below provides the selections.

B Position = Stop Function

0 - None
1 - Stop Causes Trip
2 - Stop Causes Stop Only
3 - Stop = Return to Idle

0 - NONE: This selection disables the stop function. With some applications you may wish trips only to stop the machine. Neither the stop key nor the stop contact input would work if this selection were to be made.

1 - STOP CAUSES TRIP: When selected, this function will cause the *TS310* to trip on a stop command. The trip function will cause two actions: the analog outputs (V1 and V2) will go to minimum output immediately; and if any contacts are configured for trip or alarm, they will be activated.

2 - STOP CAUSES STOP ONLY: This selection will cause a stop when STOP is pressed. The valve outputs will go to minimum setting immediately. No trips or alarms will activate.

3 - STOP = RETURN TO IDLE: Pressing STOP will cause the machine to return to idle. Remember if you use this selection, you will need an external trip input. The external trip contact will cause a trip to occur. This will stop your machine.

The third digit, **C position**, of **Word 13** will select the method of overspeed test. Take a moment to look over the selections below.

C Position = Overspeed Test

0 - None
1 - With Jumper #2 (for overspeed test jumper E4, 5-6 position, reference Figure 5)
2 - External Contact

Entering a "0" tells the *TS310*, no overspeed test is required. If you select a "1", you will use a jumper on the *TS310* mainboard to initiate the test. The last selection, "2", sets up the test when a contact input is activated. Refer to Chapter 10, paragraph 10.9 for further details.

The last digit, **D position**, in **Word 13** is used to set up the setpoint to the controller. You will also find that it selects the type of tuning for startup as listed below for this function.

D Position = Setpoint/Startup Tuning

0 - Standard Setpoint
1 - Running Setpoint
2 - Standard Setpoint/Startup Tuning
3 - Running Setpoint/Startup Tuning

0 - STANDARD SETPOINT: By selecting this function you will instruct the *TS310* to use the standard setpoint. By initiating a start to the *TS310*, the setpoint in CH 5 will be one of two values. If you have configured the *TS310* with idle speed, CH 5 will be idle setpoint (CH 36). If you have no idle, then the setpoint in CH 5 will be the minimum governor setpoint (CH 15).

1 - RUNNING SETPOINT: This selection will set the running setpoint function in the *TS310*. Each time you stop your machine after it has reached minimum governor, the *TS310* will record the speed setpoint. The next time you start up your machine, the *TS310* will set the setpoint at the last known speed above minimum governor. An example of this action would be: machine speed at 3000 RPM, you press the stop key, the machine stops and comes to a halt, the machine is started again, the *TS310* will set the setpoint at 3000.

2 - STANDARD SETPOINT/STARTUP TUNING: The function of the setpoint for this selection is the same as for selection "0" except in the startup procedure. In two channels (CHs 94 and 95) you enter values for startup tuning. The *TS310* uses the normal tuning in CHs 20 and 21 after the machine reaches minimum governor, or in the case of a generator application, after the load breaker is closed. Before the machine reaches this speed, the *TS310* uses the tuning in CHs 94 and 95.

3 - RUNNING SETPOINT/STARTUP TUNING: This selection will give you the same setpoint features as selection "1". The startup tuning will be as described in selection "2" and will be active in this selection.

CH 83 2ND PID Controller

Configuration **Word 14**
Ref.:

This Configuration Word is used by the *TS310* to enable the use of the 2nd PID controller. The 2nd PID controller cascades (ties in with) the speed controller. This controller can control back pressure (exhaust pressure), inlet pressure, discharge pressure , etc. The 2nd PID control is used as a limiting function for "not to exceed" or "not to go below" functions.

Before we go into any discussion of limits and control, let's look at the first digit in **Word 14**. The first digit, **A position**, of **Word 14** defines the action of the controller. Look through the list of the selections below.

A Position = Action

0 - Reverse #
1 - Direct #
2 - Reverse *
3 - Direct *

0 - REVERSE #: This selection defines the 2nd PID controller as a reverse acting control. A reverse acting controller will decrease the output as the measurement goes above the setpoint (CH 6). The pound sign following REVERSE tells us, the controller will cascade at minimum governor or load breaker close if generator configuration CH 80 = ###1. *Cascade* will be explained in more detail later in this chapter.

1 - DIRECT #: This selection will define the controller as a direct acting control. A direct acting controller decreases the output as the measurement goes below the setpoint (CH 6). The pound sign carries the same definition as in selection "0".

2 - REVERSE *: This selection is the same as selection "0", except in the cascading. The asterisk following REVERSE tells us, the cascade will be enabled or disabled by pressing F1.

3 - DIRECT *: This selection will define the action of the controller to be the same as in selection "1", except the cascade will be enabled or disabled as in selection 2 above.

The second digit, **B position**, of **Word 14** sets up the function of the 2ND PID controller. Look over the selections below for just a moment, then continue with your reading.

B Position = Function

0 - Not Used
1 - Speed Cascade
2 - Output HI-Limit
3 - Output LO-Limit

0 - NOT USED: Entering a 0 tells the *TS310* not to use this function.

1 - SPEED CASCADE: The selection of this function sets up the *TS310* as a cascade control. It does not matter when the cascade is enabled, only that it is enabled. When the 2nd PID cascades with the speed control, the 2nd PID is in control. The speed control is placed in tracking mode to speed up its response to setpoint changes. The 2nd PID controller will stay in control as long as the speed of the machine stays within the governor range. The governor range is defined by CHs 15 and 16 respectively (minimum to maximum speed). For example, if you were controlling inlet pressure, the pressure would be controlled as long as the speed of the machine stayed within the speed range. Remember that this PID can function for almost any type of secondary control.

2 - OUTPUT HI-LIMIT: This selection sets up a high limiting function. When enabled, this function will limit the analog outputs. This is done to prevent the 2nd PID measurement from exceeding the setpoint (CH 6). You must understand, this function will override the minimum to maximum governor range (CH 15-16). If the 2nd PID control must, it will stop a machine to maintain the limit.

3 - OUTPUT LO-LIMIT: This selection functions much like selection "2", except it will limit the outputs to make certain the 2nd PID measurement stays above the setpoint. Caution should be used when using this selection. The 2nd PID control will take a machine up to overspeed to hold the limit.

The last two digits, **C and D positions**, of **Word 14** are not used.

CH 84 Status Indicators

Configuration **Word 15**
Ref.:

This Configuration Word will define the use of the four positions on the *TS310* display. The configuration of **Word 15** is just a bit different from the previous words. The selection of functions will stay the same for all four digits in **Word 15**. The first digit will define the first position to the left. Then the second digit will define the second position from the left. The last two digits define the last two positions.

0 - Not Used Here
1 - Pickup Failed
2 - Overspeed Trip
3 - Not Used
4 - Parallel Isochronous (F3)
5 - Cascade Enabled (see end of paragraph 10.10)
6 - Synchronizing
7 - Kilowatt or Remote Load Limit
8 - System Problem
9 - Extraction/Admission Enabled

These selections are self-explanatory. The status indicator will only turn on as the function occurs. Remember, in CHs 72-79 you may have selected a use for each status indicator.

CH 85 Speed Switches

Configuration **Word 16**
Ref.: CH 18-19, and CH 72-79

The selections you make for this Configuration Word will describe the speed switches. The list of selections is the same for both speed switches. The first two digits of **Word 16** define speed switch one. The last two digits describe speed switch two. In each of the two numbers, the first digit will set the function of the switch. The second digits in each of the two numbers will define the shutdown status of the switch.

Function

0 - None
1 - High Speed Latching
2 - High Speed Non-Latching
3 - LO Speed Latching - No Bypass
4 - LO Speed Non-Latching - No Bypass
5 - LO Speed Latching - Bypass By Timer
6 - LO Speed Non-Latching -Bypass By Timer
7 - LO Speed Latching - Bypass Until Minimum Governor
8 - LO Speed Non-Latching - Bypass Until Minimum Governor

Shutdown Enable

0 - No Shutdown
1 - Shutdown

Before, we configure a number for this channel, let's define each of the functions listed above. The definitions for the list will be unlike those you have seen before. I will not be listing by the number of the selection. I will define high speed, low speed, latching, etc.

- HIGH SPEED - A high speed switch is activated above the value set in CH 18 or 19.
- LOW SPEED - A low speed switch is activated below the value set in CHs 18 and 19.
- LATCHING - Latching simply means, the switch will lock up as the switch is activated. The speed may then go above or below the value in CH 18 or 19 with no change to the switch. To clear the latch, press the start key.
- NON-LATCHING - The non-latching switch will activate at the proper time. It will stay activated until the speed goes above or below the value in CH 18 or 19. Hysteresis is fixed at 0.1% of maximum governor.
- NO BY-PASS - The speed switch will activate either above or below the value in CH 18 or 19 at any time.
- BY-PASS BY TIMER - The speed switch will not activate until the timer has expired. The length of time for the timer is set in CH 88.
- BY-PASS UNTIL MINIMUM GOVERNOR - The speed switch will not be activated until the speed of the machine has reached minimum governor speed (CH 15).
- SHUTDOWN - A contact output can be configured for your speed switches in CHs 72-79. If you want the system to shutdown (trip) as the speed switch is activated, select "SHUTDOWN". Selecting no shutdown will allow a contact to operate with no shutdown function.

For example: Here is **Word 16** for two speed switches:

SPEED SWITCH ONE - I want a LO speed, non-latching, bypass by timer switch, with shutdown. I would like the switch to be activated below 1000 RPM.

SPEED SWITCH TWO - I want a HI speed, latching switch with no shutdown. I would like the switch to be activated above 3000 RPM.

Here is **Word 16** and setting to achieve the above speed switches:

CH 85 - 6110

The following are required settings for related channels:

CH 18 - 1000 RPM
CH 19 - 3000 RPM
CH 72 - 3026
CH 79 - 3027
CH 88 - 180

Look at the number for CH 85 and make certain you understand what I have done.

The action that will now take place is as follows:

If the machine reaches and stays above 1000 RPM (CH 18) before 180 seconds (CH 88), the number one switch will not activate. After 180 seconds have passed, if the speed of the machine goes below 1000 RPM, the contact number 1 (CH 72) will activate. The *TS310* control system will then shutdown the machine.

If the machine reaches 3000 RPM (CH 19) the second speed switch will activate and latch. The number eight digital output (CH 79) will activate and stay activated until start is pressed.

CH 86 3RD PID Control

Configuration **Word 17**
Ref.:

A Position - Action Control/Valve
0 - Reverse/Direct
1 - Direct/Direct
2 - Direct/Reverse
3 - Reverse/Reverse

B Position - Function
0 - None
1 - Extraction
2 - Admission
3 - Ext/Adm
4 - Stand-Alone (Disable = 0%)
5 - Stand-Alone (Disable = 100 %)
6 - V2 = Speed Signal Range = 0 RPM to EOS setting
7 - V2 = Speed Setpoint

C Position - Priority/V2 Enable
Horsepower Priority
0 - V2 Enabled Always
2 - V2 Enabled at Min. Gov.
4 - V2 Enabled by F2

Ext/Adm Priority
1 - V2 Enabled Always
3 - V2 Enabled at Min. Gov.
5 - V2 Enabled by F2

D Position - Decoupling
0 - Standard Ext/Adm
1 - Decouple V1
2 - Decouple V2

CH 87 Synchronous Generator

Configuration **Word 18**
Ref.:

These channels provide more complex controls. The complexity of the controls is not caused by the *TS310*. It is caused by their application. A complete and well defined discussion of these channels is in Chapter 10 of this *TS310* users guide.

A Position - Auto Synch
0 - Disable
1 - Enable Always
2 - Enabled by F1 (or contact)

B Position - Not Used

C Position - Control Mode
0 - DROOP Only
1 - Isolated Isochronous (Frequency Control)
2 - Parallel Isochronous (enabled always)
3 - DROOP/Parallel Isochronous (F3)
4 - Isolated/Parallel Isochronous (F3)

D Position - Kilowatt Limit
0 - Off
1 - On (set in Channels 66 and 68)

CH 88 Fail-Safe Setting * Configuration Required

Units: Seconds
Range: 0-400
Ref.:

The value entered in this channel will be used as a timer. The timer is used by the fail-safe by-pass in CHs 81 and 85.

CH 89 Gear Teeth * Configuration Required

Units: Teeth
Range: 0-320
Ref.:

The value entered in this channel is used by the *TS310* to calculate speed. You enter the number of teeth on the gear your speed pickups are reading.

CH 90-92 B, H, and F Values

Like CHs 86 and 87 these channels are used by the *TS310* to control extraction. There is a write-up in the *TS310* user manual devoted to their use. If you need to use them, refer to the *TS310* user manual.

CH 93 Gear Ratio

Units: Ratio
Range: 0.000-9.999
Ref.:

A value in this channel will set up a gear ratio used by the *TS310* for speed calculation. The gear your pickup is reading may be on a secondary shaft, not the machine's shaft. If the shaft speeds are not the same, you can enter the ratio here. If the main shaft runs twice as fast as the secondary shaft, a ratio of 2.000 is required.

CH 94-95 Startup Tuning

Units: Seconds
Range: 0-400
Ref. :

These two channels provide the tuning needed if you have configured CH 82 for startup tuning. The tuning of the machine is done like it was for CHs 20-21.

CH 96 Hour Meter

This is a display-only channel. It displays the number of hours the unit has been running. This channel is password protected and changeable. The maximum enterable value is 29999 hours.

CH 97 Last Shutdown

This is a display-only channel. It indicates the last four shutdowns. The number on the extreme right is the last in. The channel updates on every shutdown. There is no reset function for this channel. Below is a list of the numbers that are displayed and their definitions.

0 - Power Failure
1 - Speed Signal Fail
2 - Overspeed Trip
3 - Stop Key Pressed
4 - External Trip
5 - Speed Switch No. 1
6 - Speed Switch No. 2
7 - Remote Stop Pressed

This list is self explanatory. If you have a shutdown, call up this channel and check the number on this list.

CH 98 Computer Identification

The value in this channel will be used by a computer communicating via MODBUS®. This number identifies the *TS310* for the other computer.

CH 99 Password

This channel is where you enter your password. If you wish to configure the *TS310*, you need to enter the password in this channel. A very good description of the use of this channel is in the *TS310* user manual.

CH 128 Load Preset

This channel has a range of 0 to 10 percent. The value configured in this channel will be used to increase the valve position on load breaker closure. This will allow the *TS310* to pick up a small amount of load on a generator. Prior to V14 of the *TS310* software, the percent of increase is removed at the reset rate in Channel 21. This should keep a generator drive from going off line on reverse power until the operator can establish load. Now, with V14 and later *TS310* software, the setpoint is also increased by the same percentage, max gov = 3750, sync = 300 = span 150 RPM. If CH 128 = 10% the setpoint will be adjusted up 15 RPM when load breaker closes.

CH 129 Snapback Setpoint

Configuration **Word 19**
Ref.:

This channel allows the configuration of snapback control on all three PID loops. If it is not configured, it will default to all zeros. The following options are available.:

A Position - Speed
0 - None
1 - Snapback

B Position - 2nd PID
0 - None
1 - Snapback

C Position - 3rd PID
0 - None
1 - Snapback

D Position - Not Used

CH 140 Recovery Counter, Mid Fail/Illegal Inst

Range 0 - 65,535 then recycles

Counts the number of times the CPU halts execution, due to the detection of an illegal instruction, and recovers. Errors logged here may also increment CH 144. Program interruptions can be caused by electro-magnetic interference or radio frequency interference; poor installation of grounding or shielding; etc.

In the event of an actual loss of power, or actual power-up, the display in Channel 144 will revert to 0, and the last digit on the right of the display in Channel 97 will also be 0.

CH 144 Recovery Counter, Power Fail & WD Timer Interrupt

Range 0 - 65,535 then recycles

Any CPU program interruption and consequential recovery will cause this channel display to advance by one count for each occurrence. Program interruptions can be caused by electro-magnetic interference or radio frequency interference; poor installation of grounding or shielding; etc.

In the event of an actual loss of power, or actual power-up, the display in Channel 144 will revert to 0, and the last digit on the right of the display in Channel 97 will also be 0.

CH 155 Extraction/Admission Limit

Range: 0-100
Units: Percent
Ref.: Channels 70-79, 86, and 87

The entry you make in this channel will be used by the *TS310* to limit the extraction/admission of your machine. You may simply wish to set this channel at 100.0 giving you full extraction/admission capability. The limit is used by the *TS310* as it compares the 3rd PID output in percent to the value of this channel. If you have a 50 in this channel, the *TS310* will not allow the 3rd PID output to go above 50% (calculated 50% extraction/admission). When we get to the definition of analog signals you will discover that this limit might be calculated as a percent of an external 3rd PID signal. Remember, don't worry about extraction/admission if you are not applying the *TS310* to an extraction/admission turbine.

CH 156 Regulator/Tracking PID

Configuration **Word 20**
Ref.:

The *TS310* offers two PID methods of operation. The first is called regulator control which will use the PID functions to make corrections to the output when an error is detected that was caused by the measurement. If an error is detected that was caused by a new setpoint, then the regulator control will use only the integral function for a correction. The second method is tracking which will use the PID control for errors caused by either measurement or setpoint. The following options are available for this channel:

A Position - Speed PID
0 - Regulatory
1 - Tracking

B Position - 2nd PID
0 - Regulatory
1 - Tracking

C Position - 3rd PID
0 - Regulatory
1 - Tracking

D Position - Not Used

CH 157 MODBUS® Configuration

Configuration **Word 21**
Ref.:

This channel will configure the MODBUS communications parameters. The following entries are available:

A Position - Parity
0 - None
1 - Odd
2 - Even

B Position - Stop Bits
0 - One
1 - Two

C Position - Baud Rate
0 - 300 *not recommended*
1 - 600 *not recommended*
2 - 1200 *not recommended*
3 - 2400
4 - 4800
5 - 9600

D Position - Not Used

CH 158 Remote Setpoint Ramp Rate

The units entered in this channel will be in percent of maximum governor per second. The range for the entries in this channel is 0 to 100 percent. With 0% in this channel, CH 67 ramp rate is used. With 100% in this channel, the setpoint in the *TS310* will change as quickly as the remote setpoint changes. All other entries will cause the setpoint to change at the configured rate.

CH 159 MODBUS® Checkback

The *TS310* is a slave device on the MODBUS® communication line. The *TS310* normally will transmit data only when polled by a master device. To assist with communications testing, the *TS310* can transmit data in an automatic mode. Configuring any number from 1 to 29,999 in this channel will enable this test mode. When enabled, the *TS310* will transmit the number configured. The transmission of data will occur every 2-3 seconds. To disable this mode, configure a *0* in this channel. This test function should not be used on an active network.

CH 160 Critical Speed Acceleration Rate

The range of data entered into this channel is 0 to 29999. The units are in RPM. Entering any value above 0 in this channel will set the acceleration rate through the critical zone. If a 0 is left in this channel, the *TS310* will push the acceleration of the turbine at the reset rate for the speed controller, if regulatory is selected for 1st PID in CH 156. If tracking is selected in CH 156, the setpoint will move through in one step.

9.8 Minimum Basic Configuration

As a minimum, values must be entered in sixteen of the *TS310* channels in order for the controller to operate. These values are shown below and on the next several pages.

CHANNEL	**PURPOSE**
CH 12	Acceleration Rate
CH 15	Minimum Governor
CH 16	Maximum Governor
CH 17	Overspeed Trip
CH 88	Failsafe Timer
CH 89	Number of Gear Teeth

CHANNEL 12 The acceleration rate sets acceleration in RPM to be used during the startup sequence.

CHANNEL 15 The minimum governor setting is that value in RPM below which the user does not want speed to fall after the turbine is in operation.

CHANNEL 16 The maximum governor setting is that value above which the user does not want speed to rise.

CHANNEL 17 The electronic overspeed trip is entered in Channel 17 and becomes the trip point at which the *TS310* will close the governor valve and shut down operation if this speed is exceeded. This function is not intended to be a replacement for the mechanical overspeed trip device. It can serve as a backup for the overspeed bolt, since the governor valve will close and stop the turbine even if the trip and throttle valve should stick, or if the mechanical bolt should fail to operate for some reason. The *TS310* will not run unless there is a setting in Channel 17.

CHANNEL 88 A fail-safe feature causes the *TS310* controller to shut down the turbine if the speed signal is lost. In order to start the turbine, this failsafe function must be bypassed. The bypass timer is set in Channel 88. The time can be set from one second to as much as 400 seconds. For normal turbine operation, this timer should be set between 60 and 180 seconds. For an automatically started turbine (unattended), the timer should be set at about three or four seconds to forestall a runaway turbine if the speed signal should fail upon startup. The timer starts when the START key is pressed or when a remote start contact is operated.

CHANNEL 89 The number of gear teeth to be counted by the magnetic pickups is entered in Channel 89. The *TS310* can look at a wide range, from one tooth per revolution to as many as 320 teeth per revolution. The normal number of teeth is usually thirty or sixty. On small or simple turbines, the presumption is that the gear is turning at shaft speed. If this is not the case, a gear ratio entry must be made in Channel 93.

CHANNEL	PURPOSE
CH 67	Setpoint Ramp Rate
CH 80	Defines Speed Control Functions
CH 81	Defines Speed Control Functions
CH 82	Defines Speed Control Functions

CHANNEL 67 The setpoint ramp rate determines how fast a setpoint or reference will change when the RAISE/LOWER functions are used. It also determines how fast a setpoint entry change is implemented even though the full change may be promptly displayed when it is entered.

The setpoint ramp rate is defined as percent per second of full range or of maximum governor value.

Example: If the setpoint ramp rate is set at 0.1% and the maximum governor is set at 4000 RPM, then a setpoint change will be implemented at 4 RPM per second whether RAISE or LOWER is used or whether a new entry is made via the keypad.

ENTER **CHANNEL 80** as 0110

- 0 means reverse acting control/direct acting actuator
- 1 means enable the local (keypad) START key
- 1 means enable the local (keypad) STOP key
- 0 means this is a speed control (not generator) application

ENTER **CHANNEL 81** as 0010

- 0 means no automatic hand valves are enabled
- 0 means local setpoint (reference) only is enabled
- 1 means that two magnetic pickups are to be used
- 0 means that the loss-of-speed-signal failsafe feature is enabled

ENTER **CHANNEL 82** as 0200

- 0 means NO IDLE startup sequence
- 2 means pressing STOP will cause STOP only (no trip)
- 0 means no overspeed test is enabled
- 0 means only standard tuning is enabled (no startup tuning)

CHANNEL	PURPOSE
CH 20	Proportional Band Setting (in percent)
CH 21	Reset Setting (in seconds)
CH 38	Output Low Limit (normally 0.0%)
CH 39	Output High Limit (normally 100.0%)
CH 62	Minimum Output Signal (normally 4.00 milliamps)
CH 63	Maximum Output Signal (normally 20.00 milliamps)

CHANNEL 20 and **CHANNEL 21** The proportional band and reset (integral) settings are tuning parameters that are found on any normal process controller. A reasonable tuning procedure might be to start with 50% proportional band and ten seconds of reset time. The proportional band setting is gradually reduced until instability (hunting) is observed. Multiply this value by 1.5 and enter this value for the final proportional band tuning value. Now, gradually reduce the reset value (by decreasing the entry in this channel by small increments) until instability (hunting) is observed. Then multiply this value by 1.5 and enter it as the final tuning value for reset.

CHANNEL 38 and **CHANNEL 39** The output high and low limits are used to restrict movement of the final actuator or steam valve position. The high limit might be used to keep the turbine from going past a certain maximum loading by stopping the steam valve from opening further. The low limit might be used to assure a minimum steam flow through the turbine after it has been started up. The low limit will not enable until turbine speed has passed the minimum governor setting.

CHANNEL 62 and **CHANNEL 63** The minimum and maximum output signal values are entered in Channels 62 and 63. The normal output signal range is 4 to 20 milliamps. However, by using the appropriate jumpers on the *TS310* termination panel, any signal range between 0 and 200 milliamps may be set. If this option is required, refer to the termination panel detail under installation.

Sample Minimum Configuration

A sample minimum configuration is shown below:

CHANNEL	CONFIGURATION	DESCRIPTION
12	1000	ACCELERATION RATE
15	3000	MINIMUM GOVERNOR
16	5000	MAXIMUM GOVERNOR
17	5500	OVERSPEED TRIP
20	20	PROPORTIONAL BAND
21	2	RESET RATE
38	0	MINIMUM VALVE POSITION
39	100	MAXIMUM VALVE POSITION
62	4.00	MINIMUM OUTPUT SIGNAL
63	20.00	MAXIMUM OUTPUT SIGNAL
67	1.00	SETPOINT RAMP RATE
80	0110	SPEED CONTROL CONFIG. #1
81	0010	SPEED CONTROL CONFIG. #2
82	0200	SPEED CONTROL CONFIG. #3
88	60	FAILSAFE TIMER (SECONDS)
89	30	NUMBER OF GEAR TEETH

Now,

- Pressing START enables 1000 RPM per minute acceleration until minimum governor of 3000 RPM.
- Pressing RAISE/LOWER during acceleration will halt speed.
- Pressing F2 function key resumes acceleration. Once speed has reached minimum governor, speed cannot be reduced below minimum nor raised above maximum governor.
- Pressing STOP will close governor valve until START is pressed.
- An overspeed trip condition will also close the governor valve.

To save a configuration, call up Channel 99 and enter any single-digit number, *other than the password.*

Chapter 10 - Configuration - Expanded Discussion

10.1 Alarms, Diagnostics, Flags (CH 84, 97)

A number of alarms, diagnostics and flags are available in the *TS310* controller to report various conditions, and for reviewing recent operating history. Some of these are:

CHANNEL 97 Is a record of the last four shutdowns. This item is quite useful in diagnosing the cause of a unit shutdown. Channel 97 contains a four digit code (see key below) which will indicate what the controller used to shut down the last four times.

Example: Channel 97 = `97_X3334`

Means that the last shutdown (4) was because of an external trip, and that the three previous shutdowns were due to the local STOP key being pressed.

KEY:
- 0 = POWER FAILURE
- 1 = SPEED SIGNAL FAILURE
- 2 = OVERSPEED TRIP
- 3 = STOP KEY PRESSED
- 4 = EXTERNAL TRIP
- 5 = SPEED SWITCH #1
- 6 = SPEED SWITCH #2
- 7 = REMOTE STOP USED

CHANNEL 84 Four indicator flags, or status indicators, located below the digital display can be configured to illuminate whenever various actions are enabled, or whenever certain trips have occurred. By entering the codes below in the four left-to-right slots of Channel 84, the four left-to-right indicators or flags will illuminate in response to the indicated function.

KEY:
- 1 = PICKUP FAIL
- 2 = OVERSPEED TRIP
- 3 = NOT USED
- 4 = PARALLEL ISOCHRONOUS GENERATOR OPERATION
- 5 = CASCADE CONTROL ENABLED
- 6 = SYNCHRONIZING (GENERATOR)
- 7 = KILOWATT OR LOAD LIMITED
- 8 = SYSTEM PROBLEM
- 9 = EXTRACTION CONTROL ENABLED

DIAGNOSTIC TESTS 1 through 8 run each time the *TS310* is powered up. These tests also run periodically while the system is energized. If one or more of these tests fail while the system is running, a System Problem indicator and Common Alarm are activated, if one or both are configured. (See Channel 84 option 8 on the previous page for the System Problem. See Chapter 9 Channels 72 through 79 for Common Alarm.)

To determine which test was failed, move the mode control jumper, E4, to the diagnostic position, MC 1. That position is the second pair of pins from the left. The diagnostic data will appear on the *TS310* display. It can be interpreted using the KEY below.

The tests are displayed from right to left:

KEY:
- 1 = RAM Fault

2 = EPROM Fault
3 = EEPROM Fault
4 = KEYBOARD Fault
5 = Analog to Digital Converter Fault
6 = Digital to Analog Converter Fault
7 = Digital Input/Output fault
8 = Communications Interface Fault

For ***example***, the following display indicates that both the EPROM and the EEPROM diagnostics have failed:

```
0 0 0 0 0 E E 0
```

Contact Triconex technical support if you need assistance interpreting diagnostic displays.

When you remove the E4 jumper to put it back in the storage location (the last two pins on the right), the diagnostic is reset and the indications should clear if the fault is no longer present.

10.2 Analog Inputs (CH 54-61, 70, 71)

The *TS310* controller can accept up to four analog input signals. These inputs are not dedicated until they have been coded. Each input will function according to the code you have entered. Examples include a remote speed reference, a remote load limit, a kilowatt measurement, etc.

Both the signal value and the engineering unit values the signal represents can be configured in the *TS310*. Since there are four possible input signals, there are four sets of channels in the *TS310* for entering these values and their associated codes.

Example: A remote speed reference is to be furnished from a signal outside the *TS310*. This is a 4 to 20 milliamp signal but the *TS310* accepts a 0 to 10 volt input signal. Therefore, the 4 to 20 milliamp signal must be connected across a 250 ohm precision resistor in order to furnish the *TS310* an input signal of 1.00 to 5.00 volts.

The definition of a remote speed reference says

- that the signal minimum (1.00 volt) represents minimum governor, say 3000 RPM,
- and that the signal maximum (5.00 volts) represents maximum governor, say 5000 RPM.

Entries for Analog Input No. 1 are therefore made as follows:

Enter 1.00 in Channel 46
Enter 5.00 in Channel 47
Enter 3000 in Channel 48
Enter 5000 in Channel 49

Analog Input No. 1 is read in Channel 01, therefore

- 3.00 volts (12 milliamps) would cause Channel 01 to read 4000, and would cause the turbine to run at 4000 RPM;
- 4.00 volts (16 milliamps) would cause Channel 01 to read 4500, and cause the turbine to run at 4500 RPM, etc.

Since Analog Input No. 1 is coded in Channel 70 (AB), Channel 70 will be configured as (04XX) since 04 is the code for remote speed reference.

Similarly, if Analog Input No. 2 is to be configured as a remote load limit, we will configure the following:

Enter 1.00 in Channel 50
Enter 5.00 in Channel 51
Enter 0.0 in Channel 52
Enter 100.0 in Channel 53
(since remote load limit represents percent valve position)

Channel 70 is then coded (0403) since 03 is the code for remote load limit. Likewise, analog input No. 3 is entered in Channels 54-55-56-57 and is coded in Channel 71AB (ABXX). And, analog input No. 4 is entered in Channels 58-59-60-61 and is coded in Channel 71CD (XXCD)

CODE 01 configures for	Display Only
CODE 02 configures for	2nd PID (cascade) measurement
CODE 03 configures for	Remote Load Limit
CODE 04 configures for	Remote Speed Reference
CODE 05 configures for	2nd PID (Cascade) Remote Set
CODE 06, 07, and 09 are used for	Generator Applications
CODE 08, 10, and 19 are used for	Extraction Control And 2nd Analog Outputs
CODE 17 is used for	Automated Hand Valves (See Hand Valves)
CODE 20 will configure for	A Limiting Function (See Limits)

10.3 Automated Hand Valves (CH 40-45, 81)

The *TS310* provides for automation of up to three hand (nozzle) valves. These are enabled in Channel 81 as (1XXX) or (2XXX) or (3XXX) depending on how many hand valves are to be automated.

The hand valve action is made to **open** as set (in percent of *TS310* output) in Channel 41 (No. 1); Channel 43 (No. 2); and Channel 45 (No. 3). Hand valves will **close** as set (in percent of *TS310* output) in Channel 40 (No. 1); Channel 42 (No. 2); and Channel 44 (No. 3). Having configured the hand valve action, contact outputs can be coded to operate circuits external to the *TS310* which can operate the respective automated hand valves.

- Contact output code (22) operates No. 1 hand valve;
- Contact output code (23) operates No. 2 hand valve; and
- Contact output code (24) operates No. 3.

Another option can be used to open and close the hand valve circuits at a given percent of some analog input signal rather then as a percentage of the *TS310* output signal. This analog input signal will be coded (17). All configuration is the same as above. Steam chest pressure and generator output are ***examples*** of the types of analog input signals that might be coded (17) and employed in this manner.

ASCO type solenoid valves are ordinarily employed to give 100 psi air which, in turn, operates a spring-loaded poppet valve (the automated hand valve) which is mounted in the back of the turbine case. These poppet valves can be supplied by the turbine manufacturer or they can be custom modifications of the original manually operated hand valves.

Since the poppet valves are an ON/OFF operation, they normally will open quickly when air is supplied by the solenoid valve. This can cause the steam chest pressure to change suddenly, and will disturb the control equilibrium of the controller.

This tendency can be minimized or eliminated by inserting an orifice union (say, 1/8 inch or 1/16 inch) in the air line to the poppet valve. The orifice union will cause the poppet operated hand valve to open and close more slowly, allowing the controller time to respond to the changing conditions in the steam chest.

10.4 Cascade Control (CH 5, 6, 24-27, 70, 71, 83, 84)

Cascade Control is a control scheme where one controller *tells* another controller what to do.

If, for example, we want to regulate the discharge pressure of a boiler feedwater pump so that the boiler feedwater header pressure is always held at 1000 psi, we could assign an operator the task of watching the pressure gage and then raising or lowering the speed reference of the turbine which drives the feedwater pump to maintain the constant 1000 psi header pressure.

But this task can be accomplished in a more practical and more economical manner by using a standard process controller whose output (assume 4 to 20 milliamp signal) is brought into the *TS310* controller as a remote speed reference. This pressure controller is then said to be *cascaded* to the speed controller. These cascaded controls will regulate the pressure quite satisfactorily with the pressure controller increasing speed to maintain the pressure setpoint when boiler feedwater demand is high, and reducing speed when feedwater demand is low.

This combination of *cascaded* controllers provides many advantages including

- Greatly reduced steam requirements,
- Longer turbine life,
- Lower bearing loads,
- Longer pump life,
- Reduced maintenance,
- Reduced stress on the pump packing, and so on.

Cascade control within the *TS310* is provided by the 2nd PID control loop. This is a modern 3 mode control contained within the *TS310* computer program and it offers many advantages over the *external cascade control* described above. The *TS310*'s integral cascade control can easily be *nulled* automatically, and it can be made to *track* the measurements, setpoints, and outputs as can be necessary to the automated operation of the *TS310* controller.

This 2nd PID control can be configured in a number of arrangements.

- It can be set as a direct acting control (for compressor suction pressure control, for ***example***) where an increasing measurement requires higher turbine speed.
- It can be configured as a reverse acting control (for pump or compressor discharge pressure control) where an increasing measurement requires lower turbine speed.

Tuning parameters for cascade control (2nd PID) are set in Channels 24, 25, 26 and 27. DROOP, Channel 27, and Derivative, Channel 26, are normally left at zero setting. Tuning procedures for Proportional Band, Channel 24, and Integral (Reset), Channel 25, should follow the same procedure as recommended for speed control tuning as described in paragraph 10.18, Tuning Controls.

Cascade control can be configured to enable (turn on) automatically when turbine speed reaches minimum governor. In this case, the 2nd PID setpoint remains where it has been set, whether the turbine is running or stopped, and whether the 2nd PID control is enabled or not.

Cascade control also can be configured to enable only when the turbine speed is above the minimum governor setting AND the F1 function key is pressed. In this case, the 2nd PID setpoint will *track* the 2nd PID measurement at all times when the 2nd PID is not enabled. The setpoint will then *freeze* whenever the 2nd PID is enabled, providing a *bumpless* transfer.

The 2nd PID control output cascades to the local (internal) *TS310* speed reference so that, whenever the 2nd PID is disabled (by pressing F1 key again) the local speed reference will *freeze*, to provide a bumpless transfer when the 2nd PID is disabled.

The pressure or other variable to be controlled by the 2nd PID control, when it is in cascade control mode, is brought into the *TS310* as a 2nd PID MEASUREMENT analog input and it is coded as (02) in Channel 70 or 71 as required.

All of the 2nd PID control functions are provided within the *TS310*. As discussed above, cascade control can be enabled by the F1 function key. The 2nd PID setpoint, which is read in Channel 06, can be changed by the RAISE or LOWER keys whenever cascade control is enabled. (The RAISE/LOWER keys will change the speed reference, of course, when cascade is not enabled.)

If a 2nd PID remote set is introduced as an analog input (coded 05), it will change Channel 06 which, of course, now will not be able to *track*. Also RAISE/LOWER now will not be able to change Channel 06 since its value is determined by the fixed analog input.

A flag or status indicator can be configured (5) in Channel 84 to turn on and indicate when cascade has been enabled or disabled. A contact output can also be configured (34) to operate, and to indicate externally or to an alarm system whenever cascade control is enabled.

If Channel 83 has been configured (0100) or (1100), cascade control will enable automatically when turbine speed reaches minimum governor. Cascade control will remain enabled and cannot be disabled with this configuration until the turbine is shutdown.

If Channel 83 has been configured (2100) or (3100), cascade control can be enabled by pressing the F1 function key, but only after turbine speed has reached minimum governor. Cascade control will disable whenever the F1 function key is pressed again. A remote F1 contact input will enable cascade control when closed, and will disable cascade control whenever the contact is opened.

The RAISE/LOWER keys will change function whenever cascade control is enabled. When cascade control is NOT enabled, RAISE and LOWER or remote raise and lower contacts will change the speed reference (Channel 05) at the setpoint ramp rate. However, when cascade control IS enabled, the RAISE and LOWER functions no longer change Channel 05 (speed reference) but will now change the cascade control setpoint (Channel 06). These also function at the setpoint ramp rate.

10.5 Control Action/Actuator Action (CH 80)

Some controllers must be direct-acting; some must be reverse-acting. The nature of *speed control* determines that it must be reverse-acting. That is, an *increase in speed* (RPM) must produce an action that will *decrease steam flow* to the turbine (and thus speed). Or, stated differently, an increasing measurement must cause a decreasing output.

Channel 80 configured (0XXX) specifies

CONTROL ACTION = REVERSE,

VALVE ACTION = DIRECT.

This means that an increasing measurement (speed) should cause a *decreasing output*. Since VALVE ACTION is DIRECT, a *decreasing output* will close the valve and decrease steam flow to the turbine. The total control loop (including actuator and steam valve) is therefore REVERSE-ACTING.

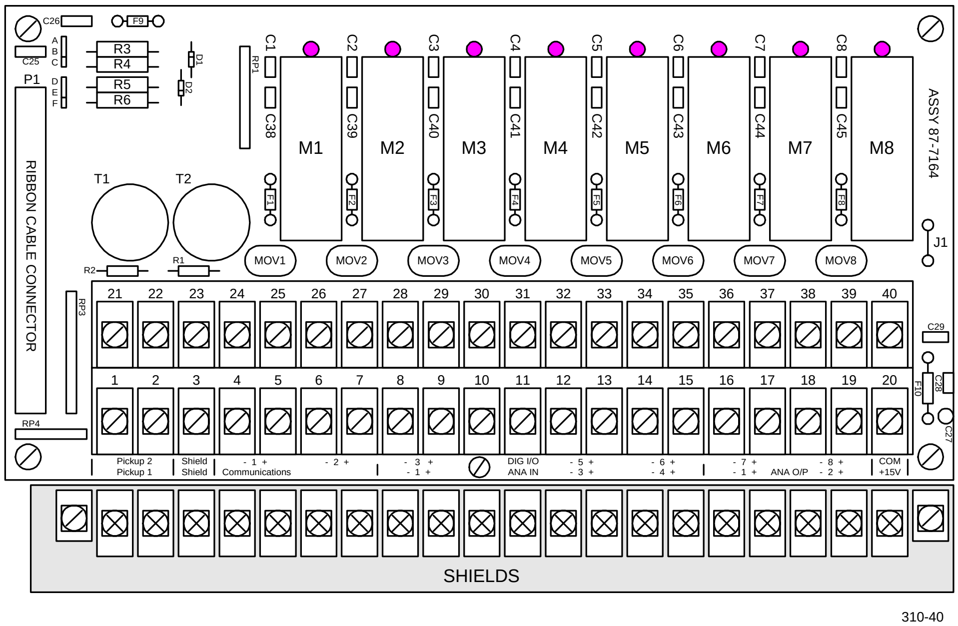
However, if a reverse-acting *actuator* is used, the picture is not as clear. The total control loop must still be reverse-acting but now the action of the control loop is reversed in the actuator action. An increasing measurement now must provide an INCREASING OUTPUT (direct acting controller) because an increasing output now will close the valve, reducing steam flow to the turbine. The actuator is defined as REVERSE-ACTING since it will decrease steam flow (close) as the controller output signal rises (moves toward 20 milliamps).

The definition of a REVERSE-ACTING actuator, then, is one which is open at 4 milliamps and closed at 20 milliamps. This calls for Channel 80 to be configured as (2XXX) - DIRECT (CONTROL)/REVERSE (VALVE ACTION).

NOTE: Channel 80 configured as (1XXX) or (3XXX) is never used with speed control.

10.6 Digital Input/Outputs (CH 72-79)

Channels 72 through 79 each can be configured as either an input digital contact or as an output digital contact. These contacts then interface with the outside world by way of solid state switches, or relays. The switches are identified as M1 through M8 on the *TS310* termination panel. See below.



***TS310* Termination Panel**

The four positions in each channel are designated:

A	Input or output, normally open or normally closed
B	Whether a flag or status indicator should turn on with its contact
CD	Definition code for that contact

As is the case with the analog inputs, the input/output contact channels are not dedicated. Any contact definition can appear in any channel. The *TS310* determines what action should be taken solely as a result of the coding. Position has no bearing except to determine which terminals are to be connected.

A Position

A channel configured (0000)	is NOT USED
A channel configured (1XXX)	is an INPUT - NORMALLY OPEN
A channel configured (2XXX)	is an INPUT - NORMALLY CLOSED
A channel configured (3XXX)	is an OUTPUT - NORMALLY OPEN
A channel configured (4XXX)	is an OUTPUT - NORMALLY CLOSED

B Position

A channel configured (X1XX)	turns on No. 1 FLAG (LEFT)
A channel configured (X2XX)	turns on No. 2 FLAG
A channel configured (X3XX)	turns on No. 3 FLAG
A channel configured (X4XX)	turns on No. 4 FLAG (RIGHT)
A channel configured (X0XX)	does NOT turn on a FLAG

C and D Positions

Code definitions are entered in the C and D positions; thus, (XX01) will designate a remote START contact input; (XX16) will designate an external TRIP contact input; etc. A normally open contact will enable the function when closed, etc.

INPUTS ARE CODED:	**OUTPUTS ARE CODED:**
(XX01) remote START	(XX20) Trip Output
(XX02) remote STOP	(XX21) Pickup Fail Alarm
(XX03) remote RAISE	(XX28) Valve Limit Alarm
(XX04) remote LOWER	(XX29) Common Alarm
(XX07) IDLE/RUN contact	(XX30) 3 second "pulse" Trip
(XX11) remote F2	(XX35) Overspeed Tripped
(XX13) Start Permit	(XX36) Overspeed Test Enabled
(XX14) Enable Overspeed Test	(XX37) Externally Tripped
(XX16) External Trip	(XX38) Load Limited
05, 06, 08, 09, 10, 12, 15 and 17 codes are devoted to generators, extraction control, or setpoints, and are discussed under those headings in this chapter.	22, 23, 24, 25, 26, 27, 31, 32, 33, 34 and 39 codes are devoted to generators, extraction or cascade control, automated hand valves, and speed switches, and are discussed under those headings in this chapter.

10.7 Reserved for future use.

10.8 Limits, Limit Alarms, Gear Ratio (CH 13-17, 37-39, 66, 68, 83, 84, 88, 93, 155)

A number of limits are provided within the *TS310* program. These consist of *fixed limits* and *adjustable limits*. Fixed limits can be changed only by entering the PASSWORD and reentering the value in some channel. This should only be done with the turbine down. Adjustable limits are limiting functions which change or can be changed while the turbine is in operation.

Fixed limits include:

CH 13 Min Critical Speed	CH 37 Idle Fuel Limit
CH 14 Max Critical Speed	CH 38 Min Valve Output Limit
CH 15 Min Governor Setting	CH 39 Max Valve Output Limit
CH 16 Max Governor Setting	CH 66 Local Load Limit or KW
CH 17 Electronic Overspeed Trip Setting	CH 88 Failsafe Timer Setting
	CH 155 Ext/Adm Limit

Channel 13 sets the minimum side of the critical speed band. Channel 14 sets the maximum side of the critical speed band. The *TS310* automatically accelerates rapidly through this critical speed range in order to minimize critical speed vibration effects.

Channel 66, another fixed limit, sets the maximum valve position just like the maximum valve output limit, Channel 39, above. Channel 66 has other uses that are detailed in the chapters concerning generator control and extraction control and detailed below, as an adjustable limit used with single valve mechanical drive steam turbines.

Continuously adjustable limits include:

CH 70-71	An analog input coded	(03) - Remote Load Limit
CH 70-71	An analog input coded	(20) - Limit Function Measurement
CH 83	2nd PID Control configured	(X200) - Hi Limit Control
	or configured	(X300) - Lo Limit Control

REMOTE LOAD LIMIT (03) - An analog input coded (03) will act as an adjustable valve or output high position limit. After configuration and coding as an analog input, no other enabling entry is necessary. This limit will act as an upper stop to the *TS310* output signal, and thus limit valve travel.

If, for example, the Remote Load Limit (which might be a 4 to 20 milliamp signal) is set at 75% (16 milliamps), then the *TS310* output will be limited to 75%. If the Remote Load Limit signal is gradually reduced to 25%, then the valve will gradually close to 25%, etc.

This Remote Load Limit can be manually adjusted; or it might be the output of an external controller you may wish to employ in some limiting capacity, such as high pressure limiting of a pump discharge pressure, and so on.

LIMIT FUNCTION MEASUREMENT (20) - If an analog input is coded (20) or (21) it becomes the measurement (or the inverted measurement) of an integral (reset)-only control whose setpoint is entered (in percent) in Channel 66, and whose reset rate is set (normally 0.5 to 2 seconds) in CH 68.

This reset-only control can then be used, for ***example***, as a (reverse acting) controller, internal to the *TS310*, for some limiting capacity such as high pressure limiting of a pump discharge pressure, etc. Thus, if the pressure range happens to be 1000 psi and we wish to limit the pump discharge pressure to 800 psi, we would bring the 1000 psi pressure signal into the *TS310* as an analog input coded (20), and set Channel 66 (the setpoint) at 80%. Now, when pump pressure exceeds 800 psi, the reset-only control will high limit valve output and prevent the turbine from driving pump speed above what is required to provide 800 psi discharge pressure.

The Limit Function Measurement control can also be used for control requiring direct acting control action. For ***example***, if we wish to limit inlet steam pressure drop to the turbine, we would require a control whose output will close the steam governor valve whenever inlet steam pressure drops below some fixed setpoint. This will be a direct acting control since the output should fall as the measurement falls. This task can be handled by coding the Limit Function Measurement as (21). Now, the measurement is inverted and the control action becomes direct.

With an inverted measurement, let's say the range is still 1000 psi, if we wish to limit steam valve position when the steam pressure falls to 750 psi, we will place a setpoint of 25% (not 75%, since the measurement is inverted) and we will see that the steam valve will be limited as is necessary in order to prevent inlet steam pressure from falling below 750 psi.

This Limit Function Measurement will not enable until the turbine has reached minimum governor speed. It will close the steam valve as required to accomplish the function, but it will not close the steam valve past the minimum valve position which has been set in Channel 38.

The 2nd PID CONTROL loop can be configured in Channel 83 as output high limiting (0200) reverse acting, or (1200) direct acting. This function will control variables like high limiting pump discharge pressure or low limiting inlet steam pressure as discussed above, but will use the internal 3 mode 2nd PID control loop rather than the reset-only control mentioned above. Both this function and the Limit Function Measurement can be used at the same time so one can be used to high limit a pump discharge pressure while the other is used to low limit steam inlet pressure or similar variables.

Although seldom used, the 2nd PID control can also be configured in Channel 83 as output low limiting (0300) reverse acting, or (1300) direct acting.

⚠ **CAUTION** Be aware that this function will low limit the valve output (causing the steam valve to open) and can take the turbine to overspeed.

ALARM FUNCTIONS can be implemented to alert the operator when the *TS310* valve output or load is limited. These are:

Channel 84		(7XXX) Kilowatt Or Load Limited
Channels 72 through 79:	Contact output	(28) Valve Limit Alarm
	Contact output	(38) Load Limited

The LOAD LIMITED flag and contact output will function whenever a variable limit, such as 2nd PID Hi Limiting, Limit Function Measurement or Remote Load Limit, is restricting valve travel because of some limiting condition.

The VALVE LIMIT ALARM contact output will function whenever the *TS310* output is restricted by one of the valve limits like Channel 38 or Channel 39.

GEAR RATIO, Channel 93, will default to 1.000 value whenever a zero entry exists. If, however, the toothed wheel used to measure speed by the magnetic pickups is not turning at shaft speed, the correct gear ratio should be entered in Channel 93. Gear ratio values can be entered between 0.001 and 9.999.

- If the gear turns at 1/2 shaft speed, enter a gear ratio value of 2.000.
- If the gear turns at twice shaft speed, enter a gear ratio value of 0.500.

10.9 Overspeed Test (CH 16, 17, 72-79, 82)

Channel 82C can be configured for two kinds of overspeed test, as described below.

If Channel 82C is coded (XX1X), it is then possible to enable an overspeed test by changing the position of the mode control jumper (E4, see Figure 5) on the main circuit board which is located on the back (inside) of the cabinet door. When Channel 82C is coded (XX1X), using the jumper enable is made possible by opening the *TS310* cabinet door and locating the jumper set labeled E4 at the lower left hand corner of the inside of the door. There are five possible jumper positions. Position 1-2 is nearest the E4 label; Position 9-10 is the most distant from the E4 label. Overspeed Test is enabled by placing the jumper in the 5-6 (center) position. (See Figure 5.)

⚠ **CAUTION** IT IS IMPERATIVE THAT THE JUMPER BE RETURNED TO THE 1-2 (INERT) POSITION WHEN THE OVERSPEED TEST IS COMPLETED!

If Channel 82C is coded (XX2X), then it is possible to enable an overspeed test by using a contact input (CH 72-79) which has been coded (XX14). ***Example***: (72 XX14). When Channel 82C is coded (XX2X) the overspeed test is enabled by closing a normally open contact (CH 72-79) coded (1X14), or by opening a normally closed contact coded (2X14).

NOTE: In generator applications, the Overspeed Test cannot be enabled unless the generator load breaker is open.

When the overspeed test is enabled by either of the options above, the remainder of the Overspeed Test details are the same.

- Overspeed Test still will not enable until actual turbine speed is several RPM above the minimum governor setting.
- When these conditions have been met, Channel 16, the maximum governor value, will automatically change to 112% of its *original* setting.
- Channel 17, the normal Electronic Overspeed Trip Setting, will automatically change to 114% of the *original maximum* governor setting.

  Turbine speed can now be raised, under controlled conditions, to as much as 112% of original maximum governor setting, and is protected by an electronic overspeed trip temporarily set at 114% of original maximum governor setting. This will permit testing of the mechanical overspeed device, which normally is set at 110% of maximum governor, under controlled conditions.

NOTE: If an overspeed trip contact output or status indicator is configured, this ouput or indicator will indicate that the machine has exceeded the overspeed setting when the machine's speed exceeds the overspeed setting originally entered in Channel 17. THIS OVERSPEED INDICATION DOES NOT MEAN THAT THE MACHINE IS TRIPPED. It means that the machine speed is higher than the normal electronic overspeed setting.

NOTE: If an analog remote speed setpoint is controlling the speed of the machine, the TS310 *automatically readjusts the span of the remote setpoint to match the overspeed test maximum governor when the test is enabled. The engineering units display for the speed setpoint analog input is not adjusted. This results in the machine's speed appearing to run higher above the setpoint's indicated value as the operator raises the setpoint.*

10.10 Speed Setpoints (CH 5, 6, 81, 84)

A number of setpoint combinations are provided in the TS310 program. These are configured in Channel 81, B position.

The basic local SPEED SETPOINT (reference) is read and is set in Channel 05. This is the speed reference used during the startup sequence, and is the reference that is adjusted using the RAISE/LOWER functions, either with local (keypad) keys or by remote contact inputs. Any remote Speed Setpoint which has been configured as an analog input is ignored by the TS310 controller until minimum governor speed is reached.

CH 81 B provides for the following setpoint variations:

0 LOCAL ONLY
1 REMOTE ONLY
2 LOCAL AND REMOTE (HI SELECT)
3 LOCAL AND REMOTE (LOW SELECT)
4 LOCAL AND REMOTE (SELECT)

Channel 81 B CONFIGURED = 0 - LOCAL ONLY -
The *TS310* will use *only the local* speed setpoint. Remote speed setpoints will not be recognized even if configured as an analog input.

Channel 81 B CONFIGURED = 1 - REMOTE ONLY -
The *TS310* will use *only the remote* speed setpoint, which must be configured as an analog input. The local speed setpoint will no longer be recognized after turbine speed reaches minimum governor.

Startup sequence will still use the local speed setpoint as described under STARTUP SEQUENCE. HALT, RAISE and LOWER will still function as described earlier, until reaching minimum governor speed.

Channel 81 B CONFIGURED = 2 - LOCAL AND REMOTE (HI SELECT) -
Both the *local and remote* speed setpoints will be recognized above minimum governor. The *TS310* will control on the **higher** of the two setpoints. Either of these can be changed at any time after reaching minimum governor speed while the machine is in operation.

Channel 81 B CONFIGURED = 3 - LOCAL AND REMOTE (LOW SELECT) -
Both the *local and remote* speed setpoints will be recognized above minimum governor. The *TS310* will control on the **lower** of the two setpoints. Either of these can be changed at any time after reaching minimum governor speed while the machine is in operation.

Channel 81 B CONFIGURED = 4 - LOCAL AND REMOTE (SELECT) -
A configured remote speed setpoint will be recognized only after reaching minimum governor **and** being enabled by a contact input labeled ENABLE REMOTE SPEED SET. While the remote speed setpoint is enabled, the local speed setpoint is ignored. The local speed setpoint will *track* the remote speed setpoint as long as the remote speed setpoint is enabled. Thus, when the remote speed setpoint is disabled, the local speed setpoint will remain at the last value for a bumpless transfer.

The CASCADE CONTROL setpoint is displayed and set in Channel 06. Its use is described in greater detail in paragraph 10.4, Cascade Control. Cascade Control and Remote Speed Setpoint *interactions* are as follows:

When Cascade Control (within the *TS310* by the 2nd PID control loop) is enabled, it will raise or lower the local speed setpoint as necessary to accomplish the cascade control.

If LOCAL AND REMOTE (HI or LOW SELECT) are also configured, the remote speed setpoint will override (or under-ride) the local speed setpoint as if the cascade control were not there. Likewise, the LOCAL AND REMOTE (SELECT) combination will function as if cascade control were not there when there is an override.

If a CASCADE ENABLED flag has been configured in Channel 84 (i.e., a 5 in any position XXXX), it will turn on when cascade control is enabled. However, whenever the remote speed setpoint is overriding the local speed setpoint with cascade enabled, the flag will flash on and off to indicate that the remote speed setpoint is overriding the local speed setpoint and that cascade control is temporarily not in control.

If a remote 2nd PID setpoint is configured as an analog input, it will provide the setting in Channel 06 which then cannot be changed by either the RAISE or LOWER keys or keypad entry.

10.11 Speed Control Channels (CH 5, 6, 12, 20, 21, 40-45, 70, 71, 80-82, 94, 95)

Channels 80, 81 and 82 are used to configure the basic speed control and startup characteristics of a *TS310* controller. Detailed entries for CH 81 and CH 82 will be found in Chapter 9 or on the next pages.

Channel 80

CH 80 A configures the *TS310* to match the actuator action of the steam governor valve. (See paragraph 10.5, Control Action/Actuator Action, for more detail.)

(0XXX) for direct acting actuators; that are open at 20 milliamps and closed at 4 milliamps
(2XXX) for reverse acting actuators; that are open at 4 milliamps and closed at 20 milliamps
(1XXX) or (3XXX) DO NOT USE for speed control

CH 80 B and C enables local and remote START and STOP

(X11X) enables keypad START and STOP only
(X22X) enables remote START and STOP only (disables keypad START/STOP)
(X33X) enables both keypad and remote START and STOP
(X23X) enables remote START only; both keypad and remote STOP, etc.

CH 80 D configures the *TS310* for

(XXX0) SPEED CONTROL or for
(XXX1) SYNCHRONOUS GENERATOR OPERATION .

Channel 81, Word 12

A = Nozzle Valves
0 Disable
1 Enable 1 Valve
2 Enable 2 Valves
3 Enable 3 Valves

B = Setpoint to Speed Control
0 Local Only
1 Remote Only
2 Local & Remote (Hi Select)
3 Local & Remote (Lo Select)
4 Local & Remote (Select)

C = Pickups
0 One Pickup
1 Two Pickups

D = Failsafe
0 Enabled
1 Disabled

	C	H			A	B	C	D
Word 12	8	1			X	X	X	X

CH 81 A selects and enables one, two or three NOZZLE (AUTOMATED HAND) VALVE relays. These can be used for other functions as well. They will close contacts as entered in Channels 41, 43 and 45. The contacts open as entered in Channels 40, 42 and 44. These open and close in response to V1 (control output). The NOZZLE VALVE contacts will open and close in response to an analog input (say, steam chest pressure) if configured 17 in Channels 70 or 71.

CH 81 B enables local and remote setpoints as indicated. If remote-only setpoint is configured with, for ***example***, backpressure control, then the remote setpoint is disabled when cascade (backpressure) is enabled. However, when cascade is disabled, the remote setpoint will again operate.

If LOCAL & REMOTE (SELECT) is configured as 4, contact input (17) ENABLE REMOTE SETPOINT must also be configured. When enabled, the remote setpoint will control speed; the local speed setpoint (CH 05) will *track* and remain at the last setting when remote speed setpoint is disabled. *TS310* is then under the control of the local setpoint until remote is again enabled, then speed will move to the remote setting at the setpoint ramp rate.

RAISE/LOWER keys or raise/lower contacts will change CH 06, the 2nd PID SETPOINT whenever cascade control is enabled. RAISE/LOWER keys or contacts will change CH 05, the local speed setpoint, whenever cascade control is disabled.

CH 81 C enables *TS310* for one or two magnetic speed pickups as may be required.

CH 81 D enables or disables speed signal failure Failsafe feature.

⚠ **CAUTION** It can be dangerous to disable the failsafe feature unless there is some compelling special application which requires the disable.

Channel 82, Word 13

A = Startup
0 No Idle
1 Auto Accelerate (F2)
2 Manual Accelerate
3 Fast Start

B = Stop Function
0 None
1 Stop Causes Trip
2 Stop Causes Stop Only
3 Stop = Return to Idle

C = Overspeed Test
0 None
1 With Jumper #2
2 External Contact

D = Setpoint/Startup Tuning
0 Standard Setpoint
1 Running Setpoint
2 Standard SP/Startup Tuning
3 Run SP/Startup Tuning

	C	H			A	B	C	D
Word 13	8	2			X	X	X	X

CH 82 A defines the type of startup sequencing to be used.

If Channel 82 A = 0 (NO IDLE),
pressing START ramps the *TS310* to minimum governor at the Acceleration Rate, CH 12. Acceleration can be halted by pressing the RAISE or LOWER keys. Acceleration will resume if F2 is pressed.

If Channel 82 A = 1 (AUTO ACCELERATE),
action will duplicate NO IDLE after pausing at IDLE SPEED until F2 is pressed. IDLE FUEL LIMIT will be in force until F2 is pressed.

If Channel 82 A = 2 (MANUAL ACCELERATE),
machine will rise to IDLE SPEED until RAISE is pressed. If RAISE is released, ramping will stop. This action proceeds at the SETPOINT RAMP RATE, not at the ACCELERATION RATE. F2 is not enabled.

If Channel 82 A = 3 (FAST START),
pressing START or closing remote contact will bring the machine up to the minimum governor speed at the fastest possible stable rate.

CH 82 B defines the type of STOP function to be used (also see paragraph 10.13).

CH 82 C defines the type of overspeed test to be used (also see paragraph 10.9).

CH 82 D enables STARTUP TUNING and RUNNING SETPOINT.

- STANDARD SETPOINT = Speed returns to minimum governor.
- STARTUP TUNING (2) or (3) utilizes CH 94 (Prop Band) and CH 95 (Integral) until minimum governor is reached, or until load breaker closes, when Prop Band reverts to CH 20 and Integral reverts to CH 21 settings.
- RUNNING SETPOINT = Speed returns to last value.

10.12 Speed Switches (CH 18, 19, 85)

Two internal speed switches are provided in the *TS310* controller. Either one can be labeled a high speed switch or a low speed switch. Speed settings are entered in Channel 18 for speed switch number 1 and in Channel 19 for speed switch number 2.

A high speed switch will function (that is, a normally open switch will close and vice versa) exactly when increasing turbine speed reaches the setting in Channel 18 or Channel 19. If the speed switch is configured NO-LATCH in Channel 85, the switch will reset automatically on a decreasing speed signal, approximately three or four RPM below the set value in order to *debounce* the relay.

A low speed switch functions in the reverse manner (that is, a normally open switch will close and vice versa) as decreasing turbine speed reaches the set value. A NO-LATCH switch will reset three or four RPM above the set value.

A speed switch configured LATCH will not automatically reset as defined above. The START key must also be pressed in order to reset the speed switch. This can be done with the turbine running.

High Speed or Low Speed Switches can be set for shutdown. That is, the controller will stop the turbine when the switch functions. Obviously, a low speed switch configured to be an underspeed trip must be bypassed or the *TS310* will not start the turbine. Therefore, provisions are made in Channel 85 to bypass the switch, once it has been reset, until turbine speed reaches minimum governor.

Two contact outputs are provided, coded (26) and (27), to allow the speed switches access to the outside world, if desired.

10.13 Start, Stop, Idle/Run (CH 36, 80, 82)

Several variations on the START-STOP theme can be configured in Channels 80 and 82, in addition to remote START and STOP contact inputs.

CH 80 enables local and/or remote START and STOP functions.

CH 80 = (X11X) enables local (keypad) but not remote START or STOP
CH 80 = (X22X) enables remote but not local (keypad) START or STOP
CH 80 = (X33X) enables local and remote START and STOP
CH 80 = (X12X) enables local START and remote STOP but
does not enable remote START or local STOP.

Thus, Channel 80 Positions B&C can enable any combination of START and STOP functions. For ***example***, a user may not wish to enable the local (keypad) START or STOP functions, but may want instead to use a remote START contact located at the turbine, a remote STOP contact located somewhere else, and an EXTERNAL TRIP contact input located at the turbine.

CH 82 B can also be configured in several ways:

CH 82 B = (X1XX) means pressing STOP will also cause any TRIP OUTPUT contact or 3 SECOND *PULSE* TRIP output to operate, and will also cause the turbine governor valve to close.

CH 82 B = (X2XX) means pressing STOP will cause the turbine governor valve to close but will not cause any TRIP to function. (Trip functions will still operate when overspeed is exceeded, when both magnetic pickups fail, or when the EXTERNAL TRIP contact input is operated.)

CH 82 B = (X3XX) means pressing STOP will cause turbine speed to return to the IDLE SPEED (CH 36). Pressing the F2 function key will cause turbine RPM to return to the minimum governor setting. This function can only be configured with AUTO ACCELERATE, CH 82 = (13XX).

Likewise, the IDLE/RUN contact input function will only operate when CH 82 = (11XX) or (12XX). The IDLE/RUN switch replaces the F2 function. That is, when the switch is in the IDLE position, (normally off, turned on) turbine speed will HALT at or return to the IDLE SPEED. When the switch is in the RUN position, (normally off, turned off) turbine speed will continue to the minimum governor setting.

AUTO ACCELERATE: CH 82 = (1XXX) must be used with any of the above.

F2 cannot function if IDLE/RUN or STOP CAUSES RETURN TO IDLE is configured.

IDLE/RUN cannot operate if CH 82 = (X3XX) STOP CAUSES RETURN TO IDLE.

10.14 Stroking The Actuator (CH 62, 63)

At installation, it may be desirable to stroke the actuator on the turbine. This is easily accomplished by the *TS310* controller without disconnecting any wires or using any calibration aids.

Stroking V1: Minimum output for V1 (#1 analog output) is entered in Channel 62, and maximum output value is entered in Channel 63. Thus, if the actuator is closed at 4 milliamps and wide open at 20 milliamps, the valve travel can be stroked by entering increasing values in Channel 62. Or, if the actuator is closed at 20 milliamps and wide open at 4 milliamps, valve travel can be stroked by entering decreasing values in Channel 63. For ***example***:

DIRECT ACTING CH 62	POSITION	REVERSE ACTING CH 63
4 mA	CLOSED	20 mA
8 mA	1/4 OPEN	16 mA
12 mA	1/2 OPEN	12 mA
16 mA	3/4 OPEN	8 mA
20 mA	FULL OPEN	4 mA

***NOTE**:* *Be certain to return CH 62 and 63 to the configured values after testing.*

⚠ **CAUTION** Make certain steam, fuel or water is blocked and safe before operating the control valves.

10.15 3RD PID Control, Channel 86, Configuration Word 17

A = Action Control/Valve

0 Reverse/Direct
1 Direct/Direct
2 Direct/Reverse
3 Reverse/Reverse

B = Function

0 None
1 Extraction
2 Admission
3 Ext/Adm
4 Stand-Alone (Disable = 0%)
5 Stand-Alone (Disable = 100%)
6 V2 = Speed Signal
7 V2 = Speed Setpoint

C = Priority/V2 Enable

Horsepower Priority
0 V2 Enabled Always
2 V2 Enabled At Min Gov
4 V2 Enabled By F2
Ext/Adm Priority
1 V2 Enabled Always
3 V2 Enabled At Min Gov
5 V2 Enabled By F2

D = Decoupling

0 Standard Ext/Adm
1 Decouple V1
2 Decouple V2

	C	H			A	B	C	D
Word 17	8	6			X	X	X	X

With two-valve software, *TS310*s can be configured to operate the second valve (V2) of a single admission or extraction turbine. Other uses for the second analog output can be configured as detailed below.

CH 86 A configures the action of the controller and the action of the control valve.

CH 86 B Stand-alone 0% (4) configures as a separate control and disables to 0%. Stand-alone 100% (5) configures as a separate control and disables to 100%. SPEED SIGNAL (6) 2nd analog output becomes signal proportional to speed. SPEED SETPOINT (7) 2nd analog output becomes signal proportional to speed setpoint.

CH 86 C configures PRIORITY and designates the mode in which extraction/admission control is enabled. When it is desirable to open V2 fully in order to warm the low pressure stage nozzle plate, (2) or (4) will open V2 fully when START is pressed. If the (2) is used, extraction/admission will enable automatically at minimum governor and cannot be disabled.

If configured (4), however, extraction/admission control enables whenever the F2 function key is pressed. Extraction/admission control will disable again whenever F2 is pressed again. A remote F2 contact will enable and disable extraction/admission control as it is opened or closed.

Extraction/admission PRIORITY should only be used with synchronous generators that are always connected to an infinite bus.

Priority designation for an extraction turbine specifies what action is to be taken in the event a conflict arises between extraction requirements and horsepower requirements.

For ***example***, a turbine can be horsepower limited due to the extraction requirements. A horsepower priority would force not required extraction in order to satisfy horsepower requirements.

Conversely, an extraction priority would force the turbine to continue increasing extraction even though this can penalize speed or load demands dictated by the speed control section of the *TS310*. Thus, extraction priority should never be used except where horsepower (speed) is not controlled.

***NOTE**: Standard Software V14 (03D-01049-01-14) automatically disables EXT priority when Isoc is enabled.*

Example: A synchronized generator which never runs in Frequency Control.

Channel 86C = V2 ENABLE In some instances, the user requires that the control bring the turbine up at minimum extraction until some point at which extraction control is to be enabled. In this case, (2), (3), (4) or (5) permit variations on this function.

Channel 86C = (2) or (3) This configuration keeps extraction at minimum until the minimum governor setting is reached. It then enables extraction control automatically at that point. V2 ramps to the control position at one percent per second (of output). If configured for sync generator control, EXT is enabled when the load breaker closes.

Channel 86C = (4) or (5) Denote the same function as (2) and (3) above but with the further stipulation that F2 must be pressed AFTER Min. Gov. setting has been reached. This version of the function requires the manual action of pressing F2 and will not initiate extraction control until F2 has been pressed. Pressing F2 again will disable extraction control - V2 will go to wide open position again.

Channel 86C = (0) or (1) These entries enable V2 and extraction control as soon as the START key is pressed.

In this example, if no extraction or admission demands exist (pressure transmitter inside the extraction header block valve and the block valve is closed), V2 will position itself so that there will be no extraction or admission steam.

The 3rd PID setpoint can be changed at any time.

STANDARD EXTRACTION CONTROL is designed to operate both the V1 and V2 valves simultaneously in order to isolate pressure control from speed control. Thus, if extraction requirements increase, V1 should open while V2 closes by an amount required to increase extraction flow without changing the power output of the machine. (The first valve increases horsepower by the same amount that the second valve reduces horsepower.)

EXTRACTION/ADMISSION MAPS (performance curves) are easily entered. Three entries, Channel 90, Channel 91 and Channel 92, provide the *TS310* with data necessary to define the EXTRACTION MAP. (See Extraction Chapter.)

Channel 90 (H value) represents the ratio of horsepower between the first and second turbine cases. H value of 2.46 would indicate second case horsepower 2.46 times that of the first case.

Channel 91 (F value) represents the ratio of steam flows V2/V1. An F value of 0.5 indicates that V2 passes 0.5 times as much steam as V1 when fully open.

Channel 92 (B value) represents in percent the amount of steam required to run the turbine at rated speed with zero net horsepower output.

Equations will be found in Extraction Chapter that can be used to calculate these three values from the extraction map (performance curves). See Extraction Chapter.

It must be emphasized that extraction maps can not be true models of the turbine. For example, what is drawn as the zero steam flow line can actually be the zero horsepower line, etc.

However, these values are used by the *TS310* for Feed Forward Control, so approximate values work quite well. Obviously, the more accurate values will provide better control.

Bear in mind that three *identical* steam turbines can use the same extraction map when, actually, like fingerprints, no two turbines are exactly alike. The F, H and B value entries offer the advantage of being empirically adjustable after the turbine has been run.

CH 86 D for synchronous generator applications, it is sometimes desirable to use extraction/admission and backpressure or inlet pressure control at the same time. In such cases, load is uncontrolled and it can be advantageous to utilize DECOUPLING to minimize interaction between backpressure and extraction/admission.

DECOUPLE V1 means that V1 is controlled ONLY by inlet pressure (2nd PID cascade) control, while V2 is controlled by both inlet pressure and extraction/ admission. DECOUPLE V2 means that V2 is controlled ONLY by backpressure (2nd PID cascade) control, etc. When cascade control is disabled, decoupling is disabled and extraction/admission control returns to a normal mode.

For best backpressure control, V2 should only function when it is required to change the steam demanded by the backpressure control. In this example, DECOUPLE V2 is appropriate. Backpressure controls V2 and V1. Extraction controls V1 only.

Conversely, best inlet-pressure control results when inlet steam pressure alone operates V1, and extraction control demands determine the position of V2. In this case, DECOUPLE V1 is appropriate. Inlet pressure control V1 and V2. Extraction demands control V2 only.

DECOUPLING IS ENABLED only when the *TS310* is in the cascade mode. When cascade control is disabled, decoupling is not conducive to best extraction control. Therefore, DECOUPLING is only enabled when cascade is enabled and DECOUPLING is disabled when cascade is disabled.

KILOWATT or LOAD high limit will cause the *TS310* to exit decoupled mode so long as limit is in effect.

10.16 Synchronous Generator, Channel 87,
Configuration Word 18 (Also CHs 66, 68, 70, 71)

<u>A</u> = AUTO SYNCH
0 Disable
1 Enable Always
2 Enabled By F1 (or contact)

<u>B</u> = NOT USED

<u>C</u> = CONTROL MODE
0 Droop Only
1 Isolated Isochronous (Frequency Control)
2 Parallel Isoch (enabled always)
3 Droop/Parallel Isochronous (F3)
4 Isolated/Parallel Isochronous (F3)

<u>D</u> = KILOWATT LIMIT
0 OFF
1 ON (set in Channels 66 and 68)

	C	H			A	B	C	D
Word 18	8	7			X	X	X	X

CH 87 A enables AUTO SYNCH (used with MPS390, Synchronous Generator, see below and paragraph 10.16.4).

CH 87 B not used.

CH 87 C

0 = DROOP (droops on KW if analog input is configured with **09**) switches from ISOCHRONOUS to DROOP, and enables cascade control, upon load breaker closing.

1 = FREQUENCY switches to DROOP, and enables cascade control on utility tie breaker closing. Disables cascade, and returns to FREQUENCY if tie breaker opens.

NOTE: *DROOP setting (Channel 23) should always be entered in either case. 100 RPM is added to minimum governor setting, when configured as generator in Channel 80D, to facilitate synchronizing. See Generator Chapter.*

When load breaker opens in either case above, *TS310* reverts to Isochronous, Cascade is disabled, and throttle position immediately closes in order to minimize the possibility of a runaway.

CH 87 D provides KW limit if KW is configured (09) in Channels 70 through 71. Limit is set in Channel 66. RESET-ONLY control of KW limit is tuned (in seconds) in Channel 68. ZERO must be entered here if KW limiting is provided via limit function measurement (20). See Generator Chapter.

SYNCHRONOUS GENERATOR OPERATION: Because of the wide scope of applications, the *TS310* generator software configuration is discussed in several phases: (See Generator Chapter for more information.)

- GENERATOR DRIVES, GENERAL
- GENERATOR DRIVES WITH TRISEN MPS390
- GENERATOR DRIVES WITH CASCADE CONTROL
  - Backpressure control
  - Inlet-pressure control
- AUTO SYNCHRONIZING
- KW CONTROL - KW LIMITING
- IMPORT/EXPORT CONTROLS
- PARALLEL ISOCHRONOUS OPERATION

10.16.1 Generator Drives, General

The TRISEN *TS310* is provided with a number of features which simplify engineering, installation and operation of synchronous generators.

Three contact configurations provide for a load breaker input, a utility tie breaker input, and a load breaker output. These will function only when the *TS310* is configured for generators in Channel 80D, and require the generator software option.

LOAD BREAKER INPUT Input contacts connected to the load breaker auxiliary contacts. The *TS310* is thus informed as to status of the generator load breaker; (05) under Contact I/O (CH 72-79: XX05, or 1X05, 2X05).

UTILITY TIE BREAKER INPUT Input contacts connected to the auxiliary contacts of the utility tie breaker; (06) under Contact I/O (CH72-79: XX06, or 1X06, 2X06).

LOAD BREAKER OUTPUT Output contacts which permit the *TS310* to close the load breaker (or to allow a closing permissive). Normally this feature is used only with Auto Synchronizing, (25) under Contact I/O (CH 72-79: XX25, or 3X25, 4X25).

Most generator applications are DROOP (base loaded) or ISOLATED ISOCHRONOUS (frequency control). *TS310* controllers configured for synchronous generator always come up to speed in isochronous speed control mode. This enables synchronizing more effectively.

IF THE *TS310* **IS CONFIGURED FOR DROOP ONLY** (Channel 87C = 0), closing the load breaker input contact causes the *TS310* to switch from ISOCHRONOUS to DROOP control.

WARNING **DROOP setting Channel 23, as well as Prop Band Channel 20 and Reset Channel 21, must be entered and must be properly adjusted for proper operation of the** ***TS310*****. See Synchronous Generator Chapter. In this case it is not necessary to configure a utility tie breaker contact input.**

TRANSITION from isochronous to droop control is performed bumplessly by the *TS310*. When the load breaker closes, the *TS310* back-calculates the droop setpoint required to provide the current control output (valve position). This droop setpoint is automatically entered in Channel 05 at the time the switch is made.

At the same time, a small increase in output (about 5%) is provided by the *TS310*. This action (increases in valve position) insures that the generator will pick up some load upon breaker closing to prevent motoring of the generator.

When the load breaker opens, the *TS310* immediately reduces the control output to zero valve position, anticipating any increase in speed from loss of load. The *TS310* returns to isochronous speed control and is again ready for synchronizing.

IF THE *TS310* IS CONFIGURED FOR ISOLATED ISOCHRONOUS OPERATION (FREQUENCY CONTROL) (Channel 87C = 1), the *TS310* will remain in Isochronous control when the load breaker is closed. However, since the machine is in frequency control, further action will take place when the utility tie breaker is closed.

Upon *seeing* **CLOSURE OF THE TIE BREAKER**, the *TS310* will switch to droop control even though it has been configured for frequency control. This feature insures that the generator will not remain in frequency control while paralleling with the utility. Again, entries are required in DROOP Channel 23, in Prop Band Channel 20, and in Reset Channel 21.

This transition is made in the same manner as before, with back-calculation of the setpoint to maintain bumpless transition of the control output. No increase in control output occurs when the tie breaker closes, however.

When the tie breaker opens, the procedure is reversed. The *TS310* back-calculates a bumpless transfer from droop back to frequency control automatically.

MANUAL SYNCHRONIZING When entering minimum governor setting, it should be noted that when Channel 80D is configured (1), for synchronous generators, 100 RPM is automatically added to the minimum governor setting by the *TS310*.

Thus, if 3500 RPM is entered in Channel 15 for minimum governor, the *TS310* will bring the turbine up to 3600 RPM on startup to allow "room" to change speed for synchronizing.

With the generator running at synchronous speed, small changes in RPM are now possible manually. Pressing RAISE or LOWER keys for less than one second will produce speed setpoint changes of ONE RPM. This facilitates manual synchronizing.

OVERSPEED TEST It should be noted that the *TS310* will not permit OVERSPEED TEST function while the load breaker is closed.

10.16.2 Generator Drives with a TRISEN MPS390

The TRISEN MPS390 Generator Control Module is a multi-purpose analog device which provides features for auto-synchronizing, kilowatt measurement, voltage matching, parallel isochronous operation of multiple generators and dead bus contact to enable bypassing the auto-synchronizing limitations and enable closure of the load breaker on a dead bus.

Employed in conjunction with the *TS310*, a MPS390 computes KW from potential transformers and current transformers. This provides the *TS310* with a 0 to 10 VDC signal which is proportional to kilowatt output. This signal can be used for KW control or for KW limiting.

The MPS390 also compares phase signals before and after the generator load breaker to provide another 0 to 10 VDC signal to the *TS310*. This signal is used in auto-synchronizing.

Two contacts in the MPS390 provide the capability to drive a potentiometer for voltage matching. Permissive contacts in the MPS390 prevent the *TS310* from closing the load breaker until voltages are matched if this feature is used.

A contact output to the *TS310* from the MPS390 is used to enable the *TS310* to close the load breaker on a dead bus when auto-synchronizing has been configured. This contact is "normally closed", meaning that it will be closed when the bus is "live" and open when the bus is "dead".

A 0 to 10 VDC signal is computed and output to the *TS310* representing a parallel line signal.

The *TS310* uses this signal for parallel isochronous operation in conjunction with other generators so that several generators on an isolated bus can be operated together to provide frequency control (all the machines will swing together to maintain frequency and to share load.).

The MPS390 will disconnect a particular *TS310* from participation in this load sharing whenever that machine's load breaker is open.

Generator Control - TS310 *with MPS390*

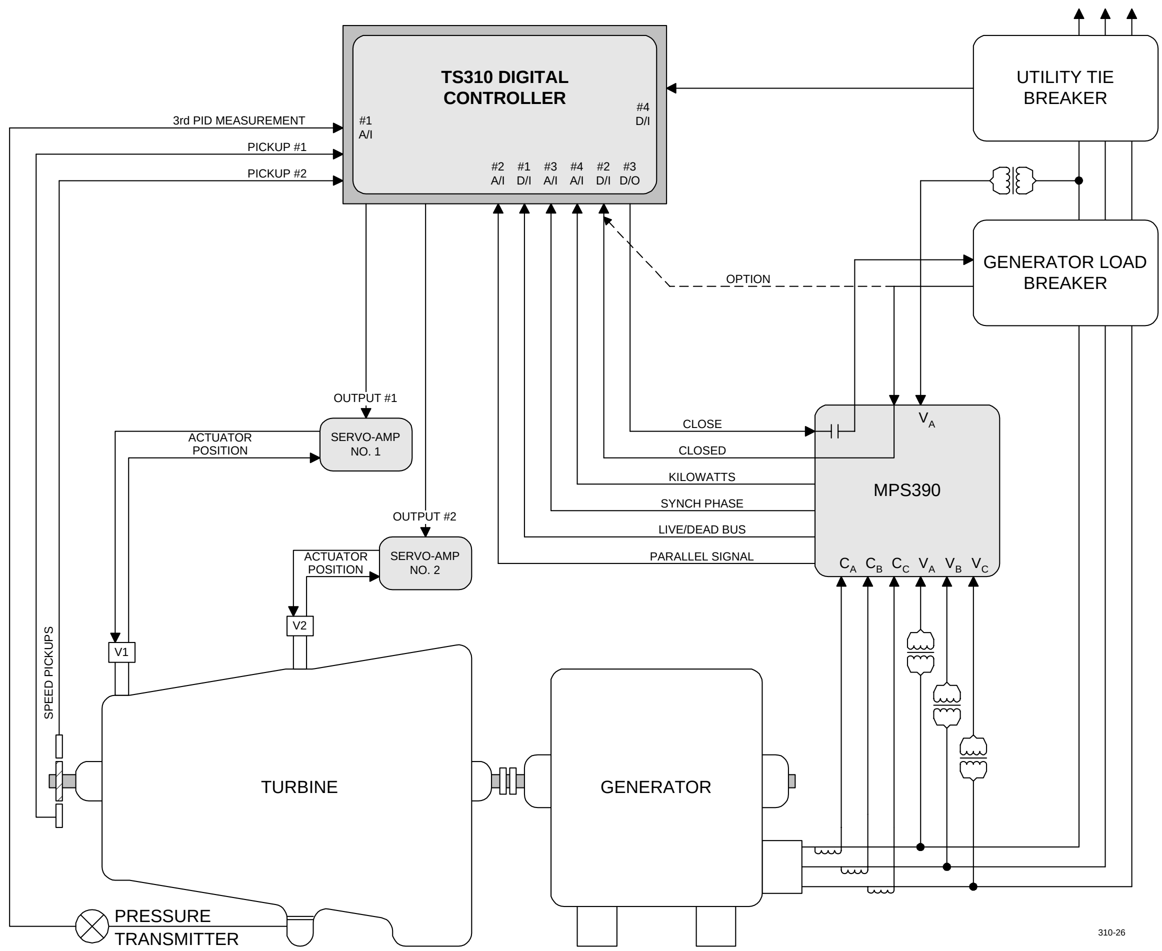
A *fully loaded* generator application driven by an extraction steam turbine is shown in the following figure. The MPS390 provides 0 to 10 volt signals to the *TS310* for SYNCH PHASE, KILOWATTS and PARALLEL LINE SIGNALS. Contact inputs to the *TS310* indicate LIVE/DEAD BUS, generator load breaker closure, and utility tie breaker closure.

Many of these functions may not be used on some applications. The parallel line signal would be used only if the generator is going to operate in parallel isochronous mode. The generator load breaker auxiliary contacts (closed) can go directly to the *TS310* (need not be routed through the MPS390) if parallel isochronous operation is not used.

SYNCH PHASE signal, LIVE/DEAD BUS contacts and voltage matching (not shown in the figure) are used only with the auto synchronizing feature of the *TS310*.

The utility tie breaker auxiliary contact connection is necessary only if the generator is to run in frequency speed control mode at times.

The SERVO-AMPLIFIERS are also optional, and normally would be used on larger, more sophisticated applications.



Extraction Steam Turbine/Generator Application Including an MPS390

10.16.3 Generator Drives with Cascade Control

The *TS310* contains features which permit backpressure control or inlet-pressure control whenever the machine is in DROOP control mode (speed or KW), but will prevent cascade control whenever the machine is switched to frequency control mode.

Example 1: If a *TS310* is configured for DROOP ONLY (Channel 87C = 0) the system will allow cascade control as long as the load breaker is closed. It will disable cascade control whenever the load breaker is open.

Example 2: If a *TS310* is configured for ISOLATED ISOCHRONOUS (frequency) control, closing the load breaker will not enable cascade control since frequency control and backpressure control are not compatible.

If the tie breaker closes, however, the *TS310* will switch to DROOP mode because the generator is in parallel with the utility and the *TS310* will enable cascade control since these are now compatible.

So long as the machine continues in DROOP mode, cascade control is enabled. If the tie breaker opens, however, the *TS310* will return to frequency control and cascade control is immediately disabled.

10.16.4 Auto-Synchronizing

As noted earlier, the TRISEN MPS390 furnishes a 0 to 10 VDC signal which the *TS310* uses to detect when phases are synchronized. This is input as SYNCH PHASE (07) in Channel 70 or 71.

The SYNCH PHASE signals the *TS310* when the generator is in phase as follows:

0 volts = 0°;
5 volts = 360°; and
10 volts = 720°.

When the signal is at 4.95 volts and is increasing, the *TS310* will close the load breaker.

If Channel 87A is configured = (2) as AUTO SYNCHRONIZING and Channel 84 has been configured for #1 status indicator as SYNCHRONIZING, the status indicator will turn on when **F1** is pressed. When the synchronous condition is reached, the *TS310* will close the load breaker output contact (25) (CH 72-79: 3X25 or 4X25).

When the load breaker input contact (from the load breaker auxiliary contacts) closes, indicating to the *TS310* that the load breaker has in fact closed, the status indicator will turn off.

Function key **F1** can now be pressed to enable cascade control. Cascade cannot be enabled until the load breaker has closed. In addition, the cascade control mode cannot be enabled under the other restraints mentioned earlier.

10.16.5 KW Control/KW Limiting

The 0 to 10 VDC signal furnished to the *TS310* by the MPS390 representing kilowatts can be used in several ways.

If this signal is configured (02) in Channel 70 or 71, the 2nd PID Measurement, the 2nd PID control becomes a kilowatt control.

If the signal is configured (09) in Channel 70 or 71, as KW (Generator Load), it can be used as a kilowatt limit by configuring Channel 87D = 1 (ON), and setting the percent limit in Channel 66. The previous load limit now becomes a KW limit due to Channel 87D configuration = 1.

The signal can be used for both purposes by entering the 0 to 10 VDC signal as two separate analog inputs, one configured (02) in Channel 70 or 71 and one configured (09) in Channel 70 or 71.

10.16.6 Import or Export Control

Import and Export Control can be provided by the 2nd PID, if a 2nd PID Measurement is furnished from a MPS390 (connected to the appropriate circuits) which measures the kilowatts to be imported or exported.

10.16.7 Parallel Isochronous Control

Parallel Isochronous Control can be achieved with several parallel generators driving an isolated bus (not connected to a utility). The MPS390 provides another 0 to 10 VDC signal which is impressed upon a signal bus common to several other MPS390 modules such that the signal bus provides an average of the output of the several generators.

Each of these *TS310*s is provided with a separate 0 to 10 VDC parallel signal by its respective MPS390. Each *TS310* drives itself in isochronous control so that its output matches the average output of the several machines. All machines will thus control in parallel frequency mode so that they share load to maintain frequency.

If one of the load breakers opens, the MPS390 for that machine senses this action through contacts to separate the *TS310* from the parallel bus, leaving the other *TS310*s and MPS390s to continue in the parallel isochronous control mode to pick up jointly that portion of the load dropped by the machine that has tripped.

PARALLEL ISOCHRONOUS DELAY is built in to the parallel isochronous *TS310*/MPS390 application. This delay or lag prevents turbine-generator sets from interacting or *fighting* each other because of changing parallel line signals that result from large or abrupt load changes.

Parallel isochronous operation is defined as isolated operation of two or more turbo-generators in order to provide frequency control in concert or load sharing operation.

The delay or lag was previously fixed. In order to permit more flexible adaptation of turbo-generators to varying load conditions, this lag has been made adjustable. Setting the lag in Channel 69 at any value between 1 and 12 will provide a lag varying from 60 milliseconds up to 2 minutes. Each larger number doubles the lag of the previous number. Thus, 1 provides a lag of 60 milliseconds; 2 provides a lag of 120 milliseconds; 3 provides 240 milliseconds, and so on.

10.17 Trip (CH 17, 97)

The definition of a turbine *trip* can vary somewhat from manufacturer to manufacturer, however, most people will agree that a turbine *trip* is a function that stops the turbine. The digital controller has not substantially changed this definition but it does allow more features and a broader definition.

Originally, a *trip* meant overspeed trip. This was caused by a spring-loaded mechanical bolt imbedded in the turbine shaft which slipped out slightly when driven by centrifugal force at a predetermined RPM to trigger some external mechanism that then closed the *trip and throttle* valve. This stopped steam flow to the turbine, shutting it down. The governor valve was not influenced by this mechanism and went to the wide open position as the turbine slowed down.

The digital controller provides some additional features. It can close the governor valve as well as the trip and throttle valve. This increases the safety margin so that the governor valve can now stop the turbine if the mechanical bolt should stick or otherwise fail to operate.

In a TRISEN *TS310* controller, a TRIP OUTPUT contact or a 3 SECOND *PULSE* TRIP output contact will act when turbine speed surpasses that RPM set for over-speed trip in Channel 17. The *TS310* controller thus duplicates electronically the function provided by the mechanical OVERSPEED BOLT. The electronic over-speed function is not designed to replace the mechanical overspeed device but it does augment that feature, providing a "trip" in the event that the mechanical bolt does not work.

In addition to activating one of the trip output contacts, the *TS310* will also close the governor valve or valves any time an electronic trip condition occurs. This increases safety because the controller closes the steam governor valve in addition to activating the trip output. This permits the governor valve to act as a backup in the event that the trip and throttle valve should fail to operate for some reason.

The microprocessor-based program is sufficiently versatile to cause a trip condition when other out-of-bounds variations occur. All of the items listed below can activate a trip output and close the governor valve as well whenever appropriately configured. The trip or stop condition will be recorded in Channel 97 with the last four trips indicated, the last one at the right hand position, indexed by the code numbers shown.

0 = POWER FAILURE
1 = SPEED SIGNAL FAILURE
2 = OVERSPEED TRIP
3 = STOP KEY WAS PRESSED
4 = EXTERNAL TRIP CONTACT INPUT OPERATED
5 = SPEED SWITCH NO 1
6 = SPEED SWITCH NO 2
7 = REMOTE STOP WAS USED

The contact output (CH 72-79) coded (3X35 or 4X35) OVERSPEED TRIP is intended to interface with external alarm systems. It should not be used to trip the *trip and throttle* valve since it is not bypassed during the OVERSPEED TEST condition and it will only operate for overspeed trip, not as a result of any other trip conditions.

10.18 Tuning Controls (CH 20, 21, 28, 29, 68, 94, 95)

The speed control loop, the 2nd PID (cascade) control loop and the 3RD PID (extraction or standalone) control loop are all provided with tuning channels for Proportional Band, Integral (reset), Derivative (rate) and DROOP action. The speed control is also provided with an additional STARTUP TUNING proportional band and reset setting.

Proportional Band and Reset settings must always be provided for each control loop in use. Derivative action is seldom used and is normally set at zero. DROOP control is seldom used except when controlling a synchronous generator drive that is tied to the utility grid. In this case, the use of DROOP control action is mandatory.

A reasonable starting point for tuning the control loop is 50% Proportional Band setting and ten seconds reset. Gradually reduce the Proportional Band setting until instability (hunting) is observed. (A small change in speed or in pressure, depending on the loop being tuned, will expose any tendency towards instability.) As soon as instability is observed, multiply that Proportional Band setting by 1.5 and enter this value for the final Proportional Band setting.

Next, gradually reduce the reset setting (in seconds) until instability (hunting) is observed. (A small change in speed or in pressure, depending on the loop being tuned, will expose any tendency towards instability.) As soon as instability is observed, multiply that reset setting by 1.5 and enter this value for the final reset setting.

STARTUP TUNING is particularly helpful during generator synchronizing. Proportional Band setting in Channel 94 and Reset setting in Channel 95 must be tuned before closing the generator load breaker. Since the *TS310* switches to standard tuning at breaker closing, Channels 20 and 21 must be tuned with the generator load breaker closed.

If startup tuning is used with a non-generator application, it must be tuned at RPM below the minimum governor setting since the *TS310* will switch to standard tuning upon reaching the minimum governor. By the same token, Channels 20 and 21 must then be tuned at an RPM above the minimum governor setting.

TUNING FOR AUTO-SYNCH is set in Channel 28 (reset). About 100 seconds to 200 seconds is appropriate for most applications. However, some applications can require faster action with a reset setting of perhaps 5 to 10 seconds. The derivative function, which is set in Channel 29, is very seldom used. If it is used, start with a setting of one second and gradually work higher, observing turbine response after a speed change.

TUNING FOR KILOWATT LIMITING (OR LIMITING FUNCTION) is normally set quite fast. A normal setting in Channel 68 would be from 0.5 to 2 seconds.

TS310 MOD4A Digital Controller

Troubleshooting Guide

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Rev. 1	April 1998	General technical and editorial revision; reformatted including A4.

Contents

Chapter 1 - Introduction

This guide was designed to assist you in solving problems that might occur in your TRISEN TS310 Control System. It has been compiled in such a way that it will take you through a problem one step at a time. We suggest that you take each step one at a time and check after each to see if you have solved your problem.

Many problems may not be caused by your TS310. They may very well be caused by something external to the TS310 -- problems with the mechanics of the turbine valves, feedback transducers, loose wiring, etc. These types of problems are not covered in this guide. We suggest that if you are unable to solve a problem after checking with the guide, you call TRISEN's Customer Service Department. The department has highly skilled technicians on duty 24 hours a day. The department is open for calls at the factory from 8:00 a.m. to 4:30 p.m. Monday through Friday. After hours, calls are directed to on-call technicians by our answering service.

Chapter 2 - Displays

Symptom	*Troubleshooting Steps*
2.1 Display Blank	1. Check to make certain there is main power being supplied to the power supply. 2. Check the power fuse in the power supply. 3. Check the green LED on the Main Board. It should be blinking. If it is not power down the system and then back up. Check again. 4. Check the +5.10 VDC (±0.05 V), +15, -15 VDC levels on the Main Board at the test points located near the power connection, +5V, DGN, +15V, -15V, and AGN. 5. Check AC on +5VDC; must be less than 15m VAC. If power is OK, continue with steps below. If not, replace power supply. 6. Pull the connector for the keypad from the Main Board. If the display comes on you need to replace the keypad. 7. Pull the 40 pin ribbon cable from the Main Board. If the display starts working wait until the display shows all 0s and reconnect the cable. If display fades again, then change the cable. If display still fades change the termination board. Display should show CH 0. 8. Replace the Main Board.
2.2 Display Showing All 0’s	1. Press [CLEAR] key on the keypad. 2. Check the green LED on the Main Board. It should be blinking. If it is not, power down the system and then power back up. Check again. 3. Check the +5.10 VDC (±0.05 V), +15, -15 VDC levels on the Main Board at the test points located near the power connection, +5V, DGN, +15V, -15V, and AGN. 4. Check AC on +5VDC; must be less than 15m VAC. If power is OK, continue with steps below. If not, replace power supply. 5. Replace the Main Board. 6. If still not fixed, change power supply.

2.3 Display Fading

1. Check the +5.10 VDC (±0.05 V), +15, -15 VDC levels on the Main Board at the test points located near the power connection, +5V, DGN, +15V, -15V, and AGN.
2. Check AC on +5VDC; must be less than 15m VAC. If power is OK, continue with steps below. If not, replace power supply.
3. Replace the Main Board.

Chapter 3 - Keypad/Function Keys

Symptom	*Troubleshooting Steps*
3.1 Keypad Unresponsive	1. Disconnect the keypad from the Main Board and connect a spare keypad. If the spare keypad operates then replace the keypad. 2. Check +5 VDC or AC ripple. If over 15 mV Rms change power supply. 3. Replace the Main Board.
3.2 Local *START* Not Working	1. Check Channel 80 and make certain the TS310 is configured for a local start. If remote stop is present, make certain it is not in STOP state. Check for EXTERNAL TRIP. 2. Check Channels 72 through 79 to see if a digital input is configured as a permissive to start. If so then check the permissive input signal. 3. Make certain that Channel 12 has a value for the acceleration rate. 4. Look at Channel 05 after pressing start. The speed setpoint should increase to idle or minimum governor. If it does not, go to STEP 8. 5. Look at Channel 08 after pressing start. The display should increase. If it does not, go to STEP 8. 6. Check the current output of the TS310. If it is increasing then the problem is in your hardware. 7. Check Pico fuse F9 on the termination board. 8. Replace the Main Board. 9. Replace the termination board.
3.3 Remote *START* Not Working	1. Check Channel 80 and make certain that the TS310 is configured for a remote start. 2. Refer to SYMPTOM 8.1, STEPS 2 through 6. 3. Refer to SYMPTOM 3.2, STEPS 2 through 9.

Symptom	*Troubleshooting Steps*
3.4 Local *STOP* Not Working	1. Check Channels 80 and 82 and make certain the TS310 is configured for a local stop. 2. Look at Channel 05 after pressing stop. The speed setpoint should go to 0 or to idle speed. 3. Look at Channel 08 after pressing stop. The display should decrease to 0 or should be moving in the decrease direction. 4. Make certain the output current is increasing or decreasing in the direction that should close the governor valve. If it is not go to STEP 6. 5. Make certain the governor valve is closing. 6. Replace the Main Board. 7. Replace the termination board.
3.5 Remote *STOP* Not Working	1. Check Channels 80 and 82 and make certain that the TS310 is configured for a remote stop. 2. Refer to SYMPTOM 3.4, STEPS 2 through 7. 3. Refer to SYMPTOM 8.1, STEPS 1 through 8.
3.6 Local *RAISE/LOWER* Not Working	1. Check Channel 81 and make certain that the TS310 is configured for local remote/local setpoint to speed controller. 2. Look at Channel 05 to see if the setpoint is increasing or decreasing as you press raise or lower. If it does not change, then go to SYMPTOM 3.1, STEPS 1 through 2. 3. Look at Channel 08 to see if the output increases or decreases as you change the setpoint. If it does not then go to STEP 5. 4. Check the current output to see if it increases or decreases with Channel 08. If it does not, go to STEP 5. 5. Check your I/P, actuator, or turbine valve to make certain the are operating. 6. Replace Main Board. 7. Replace termination board.

Symptom	*Troubleshooting Steps*
3.7 Remote Digital *RAISE/LOWER* Not Working	1. Check Channel 81 and make certain that the TS310 is configured for local or remote/local setpoint to speed controller. 2. Look at Channel 05 to see if the setpoint is increasing or decreasing as you press the remote raise or lower. If it does not change then go to SYMPTOM 8.1, STEPS 1 through 6. 3. Look at Channel 08 to see if the output increase or decreases as you change the setpoint. If it does not, then go to STEP 5. 4. Check the current output to see if it increases or decreases with Channel 08. If it does not, go to STEP 5. 5. Check your I/P, actuator, or turbine valve to make certain they are operating. 6. Replace Main Board. 7. Replace termination board.

Symptom	*Troubleshooting Steps*

3.8 Local *F1* Not Working

1. If F1 is being used to enable AUTO SYNC then check Channel 87 to make certain that the configuration is set up to perform AUTO SYNC via F1.
2. If F1 is being used to enable the 2nd. PID controller then check Channel 83 to make certain that the configuration is set up to enable the 2nd PID controller.
3. If the configuration covers a generator application make certain that the Load and Tie breakers are open to sync. or closed to cascade the 2nd PID.
4. If you have not already done so, go to Channel 84 and configure an arrow indicator to indicate either CASCADE CLOSED or SYNCHRONIZING. Choose the one definition that covers the use of the F1. In some cases you may be using F1 for both purposes. If so then configure both indicators.
5. If you are not operating a sync. generator then skip to STEP 6. If you are operating a sync. generator then at the time you would use F1 to auto sync., look at the display after you press F1. At this time you should see the arrow indicator flash as the unit tries to sync. If you do not then go to SYMPTOM 3.1, STEPS 1 through 2.
6. If the F1 button worked to cause the unit to auto sync. then it will also function to operate the 2nd PID. If you are unable to enable the 2nd PID then it is an indication the Tie Breaker input is not coming in.
7. When using the F1 button to enable the 2nd PID controller you should see the arrow come on after pressing the button. If you do not then go to SYMPTOM 3.1, STEPS 1 through 2.

3.9 Remote *F1* Not Working

1. Make certain that one of the eight digital I/O Channels (72 through 79) has been configured to be a remote F1.
2. Refer to SYMPTOM 8.1, STEPS 2 through 6.
3. Refer to SYMPTOM 3.8, STEPS 2 through 5.
4. When using the F1 button to enable the 2nd PID controller you should see the arrow come on after pressing the button.
5. Replace the Main Board.

Symptom	*Troubleshooting Steps*

3.10 Local *F2* Not Working

1. If the F2 button is to initiate auto acceleration then make certain that Channel 82 is configured to do so.
2. If the F2 button was to initiate the 3rd PID controller make certain that Channel 86 is configured to do so.
3. If you are not using F2 to enable the 3rd PID controller go to STEP 4. If you have not already done so, configure a status indicator in Channel 84 to come on when the 3rd PID controller is enabled.
4. If you are not using F2 for Auto acceleration then go to STEP 7. Make certain that Channel 12 has a value for acceleration rate if configured for auto accelerate.
5. After the turbine speed has reached idle speed press the F2 button. Looking at Channel 05 you should see the speed setpoint raise to minimum governor.
6. Refer to SYMPTOM 3.1, STEPS 1 through 2.
7. If you are applying the system on a generator drive then make certain the load breaker input is functioning.
8. After you reach minimum governor speed press F2 and watch Channel 09 on the display. First you should see the valve position change and then the status indicator will come on as soon as the 3rd PID is in control.
9. Replace the Main Board.

3.11 Remote *F2* Not Working

1. Make certain that one of the eight digital I/O have been configured to be a REMOTE F2 in Channels 72 through 79.
2. Refer to SYMPTOM 8.1, STEPS 2 through 6.
3. Refer to SYMPTOM 3.10, STEPS 1 through 9.

Chapter 4 - Valve Output

Symptom	*Troubleshooting Steps*
4.1 V1 Output Not Working	1. Check Channels 37, 38, 39, 62, and 63 and make certain that you have configured them correctly. 2. Make certain that a PERMISSIVE to START digital input is not keeping you from starting. 3. Check the configuration in Channel 66 to make certain you do not have a load limit of 0%. 4. Check Channel 05 and make certain that after you press START the speed setpoint goes to either idle or minimum governor setpoint. 5. Check Channel 08 and make certain that the display is showing an increase in the valve output in percentage. 6. Check the current output with a meter and make certain it is working. If it is not, then go to STEP 8. 7. Check the wiring to your I/P or actuator and make certain that all is correct. If it is the problem is in the I/P or actuator. 8. Check Pico fuse 9 on the termination board. 9. Make certain that the analog jumper is in place on the termination board. 10. Replace the termination board. 11. Replace the Main Board.
4.2 V2 Output Not Working	1. Check Channels 34, 35, 64, and 65 and make certain that you have configured them correctly. 2. Check Channel 09 after the 3rd PID controller has been enabled to see what percentage of output you should be getting. 3. Check the current output with a meter and make certain it is working. If it is not, then go to STEP 5. 4. Check the wiring to your I/P or actuator and make certain that all is correct. If it is, the problem is in the I/P or actuator. 5. Check Pico fuse 9 on the termination board. 6. Make certain that the analog jumper is in place on the termination board. 7. Replace the termination board. 8. Replace the Main Board.

Symptom	*Troubleshooting Steps*
4.3 V1 Output Action Incorrect	1. Determine the direction you want the TS310 V1 current output to go to fully open the governor valve(s). 2. Use an external current, voltage, or pneumatic source to check the action of your governor valve. 3. If, as the actual speed goes above the speed setpoint, you want the current output to go lower in order to close the valve, then in Channel 80 your first number of the four digit configuration word should be 0 (REV/DIR). 4. If, as the actual speed goes above the speed setpoint, you want the current output to go higher in order to open the valve, then in Channel 80 your first number of the four digit configuration word should be 1 (DIR/DIR). 5. If, as the actual speed goes above the speed setpoint, you want the current output to go higher in order to close the valve, then in Channel 80 your first number of the four digit configuration word should be 2 (DIR/REV). 6. If, as the actual speed goes above the speed setpoint, you want the current output to go lower in order to open the valve, then in Channel 80 your first number of the four digit configuration word should be 3 (REV/REV).

Symptom	*Troubleshooting Steps*

4.4 V2 Output Action Incorrect

1. Check Channel 86 to determine how the 3rd PID is configured.
2. Use an external current, voltage, or pneumatic source to check the action of the valve you are going to control with the 3rd PID.
3. If you have configured the TS310 for Extraction, Admission, or Ext./Adm. control in Channel 86 then go to STEP 6.
4. If you have configured the TS310 for a stand-alone controller in Channel 86 then go to STEP 11.
5. Re-check your configuration in Channel 86.
6. With Channel 86 configured for Extraction, Admission, or Ext./Adm. and the first number of the configuration word is 0 (REV/DIR), the following will be the action of the V2 output:

MEAS	CURRENT	CHANNEL	VALVE
UP	INCREASE	INCREASE	OPEN

7. With Channel 86 configured for Extraction, Admission, or Ext./Adm. and the first number of the configuration word is 1 (DIR/DIR), the following will be the action of the V2 output:

MEAS	CURRENT	CHANNEL	VALVE
UP	DECREASE	DECREASE	CLOSED

8. With Channel 86 configured for Extraction, Admission, or Ext./Adm. and the first number of the configuration word is 2 (DIR/REV), the following will be the action of the V2 output:

MEAS	CURRENT	CHANNEL	VALVE
UP	DECREASE	INCREASE	OPEN

9. With Channel 86 configured for Extraction, Admission, or Ext./Adm. and the first number of the configuration word is 3 (REV/REV), the following will be the action of the V2 output:

MEAS	CURRENT	CHANNEL	VALVE
UP	INCREASE	DECREASE	OPEN

10. With Channel 86 configured for a stand-alone controller and the first number of the configuration word is 0 (REV/DIR), the following will be the action of the V2 output:

MEAS	CURRENT	CHANNEL	VALVE
UP	DECREASE	DECREASE	CLOSED

11. With Channel 86 configured for a stand-alone controller and the first number of the configuration word is 1 (DIR/DIR), the following will be the action of the V2 output:

MEAS	CURRENT	CHANNEL	VALVE
UP	INCREASE	INCREASE	OPEN

12. With Channel 86 configured for a stand-alone controller and the first number of the configuration word is 2 (DIR/REV), the following will be the action of the V2 output:

MEAS	CURRENT	CHANNEL	VALVE
UP	INCREASE	DECREASE	CLOSED

13. With Channel 86 configured for a stand-alone controller and the first number of the configuration word is 3 (REV/REV), the following will be the action of the V2 output:

MEAS	CURRENT	CHANNEL	VALVE
UP	DECREASE	INCREASE	OPEN

Chapter 5 - Speed Control

Symptom	*Troubleshooting Steps*
5.1 Remote Analog Speed Setpoint Not Working	1. Check Channel 81 to make certain the TS310 is configured to have remote or remote/local setpoint. Also determine whether it is a HI or LO signal select. 2. Check Channel 70 or 71 to make certain that one of the analog input Channels had been configured for a remote speed setpoint. 3. Check Channels 46 through 61 to make certain the input Channels have been configured for the proper voltage or current input. Also in this area you need to make certain that the proper speed engineering units are entered. 4. Looking at the appropriate display Channel for the analog input (Channels 01 through 04), change the remote analog setpoint. The display should increase or decrease as you make changes. If it does not, go to STEP 8. 5. Looking at Channel 05 as you change the remote setpoint, the setpoint should change. If it does not, go to STEP 8. 6. Check the current output to see if it increases or decreases with Channel 08. If it does not go to STEP 8. 7. Check your I/P, actuator, or turbine valve to make certain they are operating. 8. Replace Main Board. 9. Replace termination board.
5.2 Speed Input Not Displaying	1. Check Channels 81, 89, and 93 to make certain the configuration is complete. 2. Check the wiring from the pickup(s) to make certain it is correct. 3. Using either a signal generator or your turbine in manual control, check the input signal(s) with meter. You should have at least 1 VAC, TRMS. If the signal is correct, go to STEP 5. 4. Make certain that your pickup is set to have a 0.005 to 0.020 inch gap between the pickup(s) and he gear. 5. Replace the termination board. 6. Replace the Main Board.

Symptom	*Troubleshooting Steps*
5.3 Turbine Not Accelerating At Correct Rate	1. Check Channel 12 to make certain you have entered the rate you need. The entry is in RPM per minute. 2. Check Channels 13 and 14 for a critical speed jumper. 3. Check Channel 82. If you are using STARTUP TUNING then check your tuning values in Channels 94 and 95. 4. Check the calibration of your governor valve versus the TS310 current output.
5.4 Critical Speed Jumper Not Working	1. Check Channels 13 and 14 and make certain you have the correct information configured in the TS310. 2. As your turbine increases in speed watch Channel 05. As the actual speed comes to the minimum critical determine whether the speed display indicates that the speed setpoint went to the maximum critical speed setpoint. If it does not, then go to STEP 5. 3. Check Channel 08 as the turbine is going through the critical speed. The output should increase at a faster rate than it had been. If it is not, then go to STEP 5. 4. Check the calibration of the TS310 output versus the governor valve. 5. Replace the Main Board.
5.5 Speed Switch #1 Not Working	1. Check Channels 18, 81, and 72 through 79 to make certain the configuration in the TS310 is complete. 2. If you have not already configured a status indicator for the #1 speed switch, do so in Channel 84. 3. At the point the speed switch should activate check the status indicator. If the indicator does not function then go to STEP 5. 4. If you have a digital output configured in Channels 72 through 79 then refer to SYMPTOM 8.1, STEPS 2 through 6. 5. Replace Main Board.

Symptom	*Troubleshooting Steps*
5.6 Speed Switch #2 Not Working	1. Check Channels 19, 81, and 72 through 79 to make certain the configuration in the TS310 is complete. 2. If you have not already configured a status indicator for the #1 speed switch, do so in Channel 84. 3. At the point the speed switch should activate, check the status indicator. If the indicator does not function, then go to STEP 5. 4. If you have a digital output configured in Channels 72 through 79 then refer to SYMPTOM 8.1, STEPS 2 through 6. 5. Replace Main Board.
5.7 Idle Speed Not Working	1. Check Channels 36, 37, 82, 94, and 95. Make certain the configuration is complete and correct for the TS310 to control an idle speed. 2. Check the configuration for an idle run contact. The contact must be in IDLE to stop at idle. 3. If the problem is unstable operations then you need to tune the system in Channels 94 and 95. If tuning does not remove the instability, then go to STEP 5. 4. If the problem you are having is no idle speed, then go to next step. 5. Check the calibration of the TS310 output versus the governor valve. If the output is not working refer to SYMPTOM 4.1, STEPS 1 through 10. 6. Replace the Main Board.

Symptom	***Troubleshooting Steps***
5.8 Speed Change Too Slow/Fast	1. If the rate of speed change is too fast/slow from 0 speed to minimum governor then refer to SYMPTOM 5.2, STEPS 1 through 3. 2. If the rate of speed change is too fast/slow between minimum and maximum governor then check Channel 67 to determine the rate of change. If the rate is too fast/slow adjustment can be done by entering the correct rate here. 3. Check Channels 20, 21, and 22 to determine the tuning of the speed controller. It may be necessary to make changes here to speed up or reduce the rate. 4. Look at Channel 05 as you make a change. This Channel will display the speed setpoint. You can see how fast the control is trying to make a speed change. If the setpoint changes too fast/slow make adjustment at Channel 67. 5. Check your I/P or actuator to be certain that they are operating correctly. 6. Replace the Main Board.
5.9 Turbine Speed Changes Too Fast/Slow In Governor Range	1. Check Channel 67 in the TS310 configuration for the rate of change. The rate of change will be some percentage of maximum governor per second. 2. Check the tuning of the speed controller. It might be set to change slowly. 3. Make certain by looking at Channel 08 that the V1 output is changing at a rate not too fast or too slow for the expected speed change. 4. Check the calibration of the governor valve versus the current output for V1. 5. Replace the Main Board.

Symptom	*Troubleshooting Steps*
5.10 Turbine Will Not Go Above Idle Speed	1. Check Channel 82 to determine how the TS310 has been configured to operate the idle speed and acceleration. 2. If the configuration is set for no idle then go to STEP 6. 3. If the configuration is set for auto acceleration by pressing F2 then go to SYMPTOM 3.10, STEP 1 through 8. 4. If the configuration is set for manual acceleration then go to STEP 6. 5. If the configuration is set for fast start then go to STEP 6. 6. Press stop and check the governor valve to see that it can stop the turbine. 7. Check the calibration of the governor valve versus the V1 current output. 8. Check Channels 39. Make certain you are not imposing a valve limit on the output. 9. Change the Main Board.

Chapter 6 - Nozzle Valves

Symptom	*Troubleshooting Steps*
6.1 Nozzle Valve #1 Not Working	1. Check Channels 40, 41, 72 through 79, and 81 to make certain the TS310 is configured correctly for the #1 nozzle valve. 2. Refer to SYMPTOM 8.1, STEPS 2 through 7.
6.2 Nozzle Valve #2 Not Working	1. Check Channels 42, 43, 72 through 79, and 81 to make certain the TS310 is configured correctly for the #1 nozzle valve. 2. Refer to SYMPTOM 8.1, STEPS 2 through 7.
6.3 Nozzle Valve #3 Not Working	1. Check Channels 44, 45, 72 through 79, and 81 to make certain the TS310 is configured correctly for the #2 nozzle valve. 2. Refer to SYMPTOM 8.1, STEPS 2 through 7.

Chapter 7 - Analog Inputs

Symptom	*Troubleshooting Steps*
7.1 #1 Analog Input Not Working	1. Check Channels 46 through 49, and 70 to make certain the #1 analog input is configured in the TS310. 2. Look at Channel 01 on the TS310 display. You should see in engineering units a value between what is configured in Channels 48 and 49. If not, then go to STEP 4. 3. As you have arrived at this step then it is assumed that the digital readout for Channel 01 is working. This is an indication that the hardware part of the #1 analog input is working. You need to look through the SYMPTOMS and find one that covers the use of this analog input. This could take you to problems with the 2nd PID controller, extraction controller, etc. 4. Check the input wiring to the #1 analog input. Make certain all connections are correct. If you are inputting a current signal it must be imposed across a resistor. *For example*: a 4-20 mA signal needs a 250 ohm resistor across the terminations to develop a 1 to 5 volt input. 5. Check the voltage or current input with a meter. 6. Replace the termination board. 7. Replace the Main Board.

Symptom	*Troubleshooting Steps*
7.2 #2 Analog Input Not Working	1. Check Channels 50 through 53, and 70 to make certain the #2 analog input is configured in the TS310. 2. Look at Channel 02 on the TS310 display. You should see, in engineering units, a value between what is configured in Channels 52 and 53. If not then go to STEP 4. 3. As you have arrived at this step then it is assumed that the digital readout for Channel 02 is working. This is an indication that the hardware part of the #2 analog input is working. You need to look through the SYMPTOMS and find one that covers the use of this analog input. This could take you to problems with the 2nd PID controller, extraction controller, etc. 4. Check the input wiring to the #2 analog input. Make certain all connections are correct. If you are inputting a current signal it must be imposed across a resistor. *For example*: a 4-20 mA signal needs a 250 ohm resistor across the terminations to develop a 1 to 5 volt input. Measure the voltage at the input terminal to terminal 40 of the termination board. The difference cannot be greater than 10 VDC. If it is, then you have a common mode problem. 5. Check the voltage or current input with a meter. 6. Replace the termination board. 7. Replace the Main Board.

Symptom	*Troubleshooting Steps*
7.3 #3 Analog Input Not Working	1. Check Channels 54 through 57, and 71 to make certain the #3 analog input is configured in the TS310. 2. Look at Channel 03 on the TS310 display. You should see, in engineering units, a value between what is configured in Channels 56 and 57. If not then go to STEP 4. 3. As you have arrived at this step then it is assumed that the digital readout for Channel 03 is working. This is an indication that the hardware part of the #3 analog input is working. You need to look through the SYMPTOMS and find one that covers the use of this analog input. This could take you to problems with the 2nd PID controller, extraction controller, etc. 4. Check the input wiring to the #3 analog input. Make certain all connections are correct. If you are inputting a current signal it must be imposed across a resistor. *For example*: a 4-20mA signal needs a 250 ohm resistor across the terminations to develop a 1 to 5 volt input. 5. Check the voltage or current input with a meter. 6. Replace the termination board. 7. Replace the Main Board.
7.4 #4 Analog Input Not Working	1. Check Channels 58 through 61, and 71 to make certain the #4 analog input is configured in the TS310. 2. Look at Channel 04 on the TS310 display. You should see, in engineering units, a value between what is configured in Channels 60 and 61. If not, then go to STEP 4. 3. As you have arrived at this step then it is assumed that the digital readout for Channel 04 is working. This is an indication that the hardware part of the #4 analog input is working. You need to look through the SYMPTOMS and find one that covers the use of this analog input. This could take you to problems with the 2nd PID controller, extraction controller, etc. 4. Check the input wiring to the #4 analog input. Make certain all connections are correct. If you are inputting a current signal it must be imposed across a resistor. *For example*: a 4-20 mA signal needs a 250 ohm resistor across the terminations to develop a 1 to 5 volt input. 5. Check the voltage or current input with a meter. 6. Replace the termination board. 7. Replace the Main Board.

Chapter 8 - Digital I/O

Symptom	*Troubleshooting Steps*
8.1 Digital I/O Not Activating	1. Make certain the digital I/O is configured correctly in the correct Channel location. 2. Watch the red LED just above the digital I/O module you are having problems with and enable the I/O. The LED should change state. If it does not, replace the termination board. 3. Make certain the wiring for the digital I/O is going to the correct terminals. 4. Make certain the module for the digital I/O you are having problems with is the correct module. 5. Pull the small Pico fuse located to the left of the digital I/O module that is not operating. Check to make sure that it is good. 6. Inspect the 40 pin ribbon cable between the Main Board and the termination board and make certain that the cable is securely plugged in at both ends. 7. Cycle the power off to the TS310 then back on. 8. Replace the Main Board.

Symptom	*Troubleshooting Steps*
8.2 Contact I/O Working In Reverse Order	1. Check the proper channel where a contact I/O is configured (Channel 72 through 79). The first number of the four digit configuration word determines the state of the contact I/O. 2. If the contact I/O has a first number of 0 then the contact I/O is configured to be unused. 3. If the contact I/O has a first number of 1 then the contact I/O is configured to be an input from and outside contact. N.O. means the input will function as the input contact closes. 4. If the contact I/O has a first number of 2 then the contact I/O is configured to be an input from and outside contact. N.C. means the input will function as the input contact opens. 5. If the contact I/O has a first number of 3 then the contact I/O is configured to be a N.O. output. This means that as the function happens in the TS310 the output contact will close. 6. If the contact I/O has a first number of 4 then the contact I/O is configured to be a N.C. output. This means that as the function happens, the TS310 will open the contact output. 7. If you are using an output from the TS310 check the solenoid, relay, or whatever device you are driving. Make certain of its status (N.O. or N.C.). 8. If you are using an input to the TS310 check the switch, relay, or what ever device you are inputting. Make certain of its status (N.O. or N.C.).

Chapter 9 - Miscellaneous

Symptom	*Troubleshooting Steps*
9.1 Local Load Limit Not Working	1. Check Channels 70, 71, and 87. Make certain the TS310 is not configured for a remote limiting function in one of these Channels. 2. Check Channel 66 and make certain you have entered into the configuration a limit. 3. Look at Channel 08 and make certain the percentage in this Channel does not go above the value set in Channel 66. If it does go to STEP 8. 4. Check the current output and make certain that it does not go above the percentage set in Channel 66. If it does go to STEP 6. 5. Check the calibration of the TS310 output versus the governor valve. 6. Check the V1 jumper on the termination board to make certain that it is in the correct location. 7. Replace the termination board. 8. Replace the Main Board.

Symptom	*Troubleshooting Steps*
9.2 Inlet Pressure Not Controlling	1. Check Channel 83 to make certain the configuration is correct for your application. 2. Check Channels 24 through 27 to make certain you have some type of tuning data configured. 3. If you do not already have a status indicator that comes on when the 2nd PID is cascaded, then do so in Channel 84. 4. If you are configured in Channel 83 to enable the 2nd PID controller at minimum governor then go to STEP 8. 5. After the turbine reaches minimum governor press F1. The status indicator should come on. (If you are driving a sync generator, you must first close the load and tie breakers.) 6. If you are using a LOCAL F1 then go to SYMPTOM 3.8, STEPS 2 through 6. 7. If you are using a REMOTE F1 then go to SYMPTOM 3.9, STEPS 1 through 5. 8. As the turbine reaches minimum governor speed, the status indicator should come on indicating the 2nd PID has enabled (if you are driving a sync generator, the load breaker and tie breaker must close first). 9. Replace the Main Board.
9.3 Exhaust Pressure Controller Not Working	1. As far as the TS310 knows Exhaust pressure control is a 2nd PID function. You can, therefore, use the same STEPS for checking out this problem as in SYMPTOM 3.8, STEPS 1 through 7.
9.4 Suction Pressure Controller Not Working	1. As far as the TS310 knows Suction pressure control is a 2nd PID function. You can, therefore, use the same STEPS for checking out this problem as in SYMPTOM 3.8, STEPS 1 through 7.

Symptom	*Troubleshooting Steps*

9.5 Autosync Not Working

1. Check Channel 87 to make certain you have configured the TS310 for auto sync.
2. If you have not already done so, configure in Channel 84 a status indicator that will come on when the TS310 goes into auto sync.
3. If you have configured the auto sync to enable via F1 then go to STEP 5.
4. As soon as you reach minimum governor the status indicator should come on. If it does not then replace the Main Board.
5. At minimum governor speed press F1. The status indicator should come on.
6. If you are using a LOCAL F1 then go to SYMPTOM 3.8, STEPS 1 through 6.
7. If you are using a REMOTE F1 then go to SYMPTOM 3.8, STEPS 1 through 7.

9.6 Extraction/ Admission Control Not Working

1. Check Channels 30-33, 34, 35, 64, 65, 70, 71, 86, 90, 91, and 92 to make certain the configuration in the TS310 is complete.
2. Make certain the analog input for measurement is working. This is done easily by checking the display in Channels 01 through 04 for the analog input you are using for the measurement.
3. If you do not have a status indicator for 3rd PID Enabled then configure one in Channel 84.
4. If you are enabling at start then go to STEP 7.
5. If you are enabling with the use of the local F2 then go to SYMPTOM 3.10, STEPS 2 through 9.
6. If you enable with a remote F2 then go to SYMPTOM 3.11, STEPS 1 through 3.
7. If your problem is instability then try tuning the 3rd PID controller in Channels 30 through 32.
8. If the V2 output does not seem to be working correctly then go to SYMPTOM 4.4, STEPS 1 through 8.
9. If the pressure is being controlled at an incorrect pressure then check the configuration of your measurement input. This will be configured in Channels 46 through 61 depending upon which analog input you are using.
10. Replace the Main Board.

TS310 MOD4A Digital Controller

ModBus® Protocol
Programmers Reference Guide

Document No. 4933-0018

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Rev. 1

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Revision History

Rev. A	May 1990	General editorial revision. Removed reference to EICM. Deleted Performance Considerations paragraph. Added registration mark to ModBus®.
Rev. B	September 1990	General revision to upgrade to new *TS310* software.
Rev. 1	April 1998	General editorial revision only; reformatted including A4.

Contents

Chapter 1 - Overview

Effective with Release 07 of the *TS310* software, ModBus® will be the standard protocol for host communications. This will allow the *TS310* to communicate directly to a wide variety of commonly available Programmable Logic Controllers and SCADA systems.

Scope

This document is for those who wish to program or configure devices to communicate with the *TS310* using the ModBus® Protocol. It includes an explanation of the *TS310* Data Base and a description of the ModBus® functions implemented. It is intended to be used in conjunction with the *TS310* Configuration Summary and with the Modicon ModBus® Protocol Reference Guide. The former document gives much more detail on the governor's Data Base, and the latter is a complete definition of the communications protocol.

ModBus® Network

A ModBus® network connects a single master device to up to 247 slave devices. The *TS310* will function as a slave in such a network. It's slave id. can be read (and changed) through the front panel, in channel 98. Values in the range of 1 through 32 will be accepted.

Configuration

The ModBus® Protocol recognizes two modes to transmission: ASCII, and RTU. The *TS310* uses RTU mode. The communication rate is adjustable Baud, with adjustable parity. This can be set in CH 157. (See *TS310* Configuration Guide.)

Functions Implemented

The following ModBus® functions are implemented in the *TS310*:

Code	Meaning
01	Read coil status
02	Read input status
03	Read holding registers
04	Read input registers
05	Force single coil
06	Preset single register
08	Loop-back diagnostic test (diagnostic code 0 only)

TS310 Data Base

Each record in the *TS310* Data Base defines a channel. Each channel references a single value, which may be displayed on the front panel display. The channel associates scaling data with the value, and, optionally, alarm or trip limits. The organization of the Data Base is explained in the *TS310* Configuration Summary, which includes a complete Machine Data Listing.

TS310 ModBus® Data Base

The ModBus® Protocol implementation in the *TS310* provides the following extensions to the Data Base as described above:

- Digital points are defined as input status or coil status, for access via ModBus® functions 01, 02, and 05.
- The channels defined are mapped into registers for access via ModBus® functions 03, 04, and 06.

Digital Points

Digital values (bits) are defined within the *TS310* to make this data available to the ModBus® master device.

Coil Status

These are bits in the *TS310* memory which may be read (with Function 01), or written to (with Function 05).

Contact Outputs

Each of the 8 digital I/O points of the *TS310* can be accessed as contact outputs. Only those which are configured as outputs will return meaningful data when they are read. Those configured as inputs will return a value, but it has no meaning.

The memory bits which control contact outputs of the *TS310* can be written to by the master. However, they may be overwritten by the *TS310*, possibly before they affect the physical output device. This is consistent with the normal Master/Slave interaction in a ModBus® network. Writing to a point configured as an input will actually set a bit within the *TS310*'s memory, but there will be no verifiable effect from it.

LCD Status/Alarm Indicators

The bits which drive the front panel LCD status/alarm indicators are treated exactly like contact outputs by the ModBus® routines.

Function Codes

Five bits are reserved to correspond to the Start key, the Stop key, and the three function keys on the front panel of the *TS310*. Setting one of these bits (via ModBus® Function 05) is equivalent to pushing the corresponding key.

Input Status

These bits can only be read (with Function 02). They reflect the logical state of the contact inputs of the *TS310*. The logical state of a contact input is the Boolean exclusive or of its physical state with its configured normal state. (Refer to the *TS310* Configuration Summary for an explanation of configuring contact inputs.)

Analog Points

Analog values are stored internally in the *TS310* as 16-bit integers, and they are transmitted via ModBus® in the same format. Most values are scaled internally to 0 - 4000 counts. The ModBus® routines access the internally stored values directly. That is, if an analog input is configured as having a range in engineering units of 0.0 to 100.0, and the current value is 50.0, then reading that register will return a value of 2000. To force the setpoint for this value to 75.0, a value of 3000 should be written to the appropriate ModBus® register.

Configuration words (channels 70 - 87) are 16-bit hexadecimal values. No scaling is used.

Finally, speed readings are unscaled integers, which may have any value up to 29999. Two channels have been added to the *TS310* to support scaling of speed readings when accessed via ModBus®. This logic is needed for host computers which cannot handle the full range of possible values in these registers. A maximum speed value must be entered in channel 176, and a scaling factor in channel 177. (These values can be entered only through the *TS310* front panel.) Ordinarily, the maximum speed would be chosen to correspond to the overspeed trip limit. The scaling factor would be the largest value which can be accepted by the host. (4095 for a host with 12-bit registers, for example.) The resulting scaling calculations will be performed on all speed readings, setpoints, and limits, when they are accessed via ModBus® Functions 03, 04, or 06. If either channel 176 or 177 contains a 0, no scaling will be performed.

Channels which specify minimum engineering units for analog inputs pose a special problem. When a value is entered into one of those channels via the front panel, the value entered is stored as an integer in the range of 0 - 4000, and the number of digits after the decimal point is stored in a separate location. Both pieces of information are necessary for scaling the input. However, values transmitted via ModBus® are sent as 16-bit integers. There is no provision in the protocol for representing a decimal point. The solution chosen was to map each of these channels to two ModBus® holding registers. The first holds the internally stored minimum value, and the second holds the number of digits after the decimal. Thus, to scale analog input #1 to a range of 0.00 - 50.00, you would: first) Write 0 to register 40042; second) Write 2 to register 40043; third) Write 5000 to register 40044. Note that the number of decimal places is the same for both the minimum and maximum engineering units channels, and it is set only through the minimum e.u. channel. This is consistent with the interface through the front panel of the *TS310*.

Holding Registers

These channels can be read with Function 03 and written to with Function 06. Function 06 accepts any data that is valid for both the particular channel and for the current running conditions. Invalid data will result in an exception response with an "Illegal Data Value" code. Unlike manual entry of data using the *TS310* keyboard, the password is not required for Function 06.

Input Registers

These channels are defined in the *TS310* as Display only. They can be read with Function 04, but ModBus® has no facility for writing to Input registers.

Chapter 2 - Description

ModBus® Message Protocol

This section describes the message protocol which the *TS310* is programmed to utilize when configured to communicate with a ModBus® network. This protocol controls the query and response cycle which takes place between a ModBus® master and its slaves, determining the following aspects of system operation:

- How the master and slaves establish and break off contact.
- How the sender and receiver are identified.
- How messages are exchanged in an orderly manner.
- How errors are detected.

The following topics are covered in this section:

- Selecting a mode of transmission.
- General ModBus® message formats.
- Description of message functions.
- Error detection, exception responses, and checksum calculation.

Mode of Transmission, RTU Mode

To structure the individual units of information within a message, and to provide a numbering system to transmit data between the *TS310* and the ModBus® Master, the *TS310* uses the following mode of transmission:

- the Remote Terminal Unit (RTU) mode

In RTU mode, data is sent in eight-bit binary characters which must be transmitted in a continuous stream. RTU mode uses a 16-bit Cyclical Redundancy Check (CRC) to detect errors that occur during the transmission of messages. Refer to "Error Detection & Exception Responses" later in this chapter for information about the CRC-16 polynomial used to compute a checksum in RTU mode.

General ModBus® Message Formats

The figure below shows the general order in which ModBus® messages are formatted for RTU Mode:

Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7	Byte 8
Station Address	Function Code	Data		Data		CRC	

General ModBus® Message Format

Sample Message Content

This table compares the content of a sample message in RTU modes:

Table A
Sample Message Content for RTU Modes

Query Message		***RTU***	
Header		None	
Station Address	0000		0010
Function Code	0000		0001
Starting Address (High Order)	0000		0000
Starting Address (Low Order)	0001		0011
Quantity of Points (High Order)	0000		0000
Quantity of Points (Low Order)	0010		0101
Error Check	0000		1110
	1000		0100
Trailer		None	
		None	
Response Message		RTU	
Header		None	
Station Address	0000		0010
Function Code	0000		0001
Byte Count	0000		0101
	1100*		1101**
	0110		1011
Data	1011		0010
	0000		1110
	0001		1011
Error Check	0100		0101
	1110	None	0110
Trailer		None	

* The underscored digit indicates that Coil #27 is in the ON state.
** The underscored digit indicates that Coil #20 is in the ON state.

Message Field Definitions

The following paragraphs explain the meaning of each field in the general message format.

Station Address Field

The Station Address field indicates which station a message is intended for. In RTU mode, the station address is one character (eight bits).

The address range is 1-32. You can assign any address in this range to a station, but each address can be used only once in a network.

Messages containing addresses 1 - 32 are processed by one specific station which takes appropriate action and responds to the Master.

Function Code Field

The Function Code field contains a control character that specifies the operation to be performed (query), or the operation that was performed (response). In a response serving as an error message, the most significant bit of the Function Code is set to 1. Section 5.3 describes the function codes currently implemented in the TRI-SEN ModBus® system.

Data Fields

The data fields contain all the information that a station needs to act on a command from the ModBus® Master: data addresses within the station, values, references, limits, modifiers, data, and/or response information. The length of the message data varies, depending on the message function that is specified.

Checksum Field

The Checksum field contains a 16-bit word which is the result of a Cyclical Redundancy Check (CRC). This error check is performed by the transmitting and receiving interface units for both ModBus® Masters and stations to detect errors that occur during message transmission.

The rate of transmission errors in a data communication system depends on noise in the environment, transmission speeds, and rate of use. Refer to "Error Detection & Exception Responses" later in this appendix for more information about error checking, including details about CRC checksum calculation.

ModBus® Function Descriptions

This section describes the functions currently implemented for the TRI-SEN ModBus® system. The following table lists the instruction names and function codes which comprise each ModBus® function:

Instruction Name	Function Code
Read Coil Status	01
Read Input Status	02
Read Holding Registers (R/W Integer)	03
Read Input Registers (Read Integer)	04
Force Single Coil	05
Preset Single Register	06
Loop Back Diagnostic Test	08

Each description of a message format includes an instruction name, a function code, a definition, a query format, and a response format.

By ModBus® conventions, the "starting address" field of a message ranges from 0 to one less than the number of coils or registers available. For this reason, the *TS310* adds specific constants to the starting address to determine the Alias number being referenced. The constants used are based on the Function Codes, as follows:

Function Code	Coil / Register	Added to Compute Alias Number
01	Coil	1
02	Coil	10001
03	Register	40001
04	Register	30001
05	Coil	1
06	Register	40001

The leftmost byte of a two-byte number is always the most significant byte, and the rightmost byte is always the least significant byte.

Read Coil Status (Function Code 01)

The Read Coil Status query requests the ON/OFF status of a group of logic coils from a station. The ModBus® Master can request the status of as many as 2000 coils with each query. (Although 2000 is the maximum parameter allowed, the query/response time required by some ModBus® Masters may dictate a much smaller quantity parameter.) The coils are numbered beginning with zero -- for example, zero refers to the coil with Alias 1, one refers to the coil with Alias 2, etc.

Query Format - RTU Mode:

Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7	Byte 8
Station Address	Function Code	Starting Address		No. of Coils		CRC	

The Read Coil Status response includes the station address, the function code, the length of the response values in bytes, the response values, and the error-check word. Data in a response is packed with one bit for each coil, where 1 = ON, and 0 = OFF. The low-order bit of the first character contains the addressed coil, and the remaining coils follow. For coil quantities that are not even multiples of eight, the last character will be zero-filled at the high-order end.

Response Format - RTU Mode:

Byte 1	Byte 2	Byte 3	Bytes 4	→	through *n*	Bytes n + 1, n + 2
Station Address	Function Code	Length of Data	Data	→	Data	CRC

Read Input Status (Function 02)

The query and response for Read Input Status operate in the same manner as those for Read Coil Status (Function Code 01), except that the status of discrete inputs is obtained. Inputs are also numbered beginning with zero -- for example, Input 10001 equals zero, Input 10002 equals one, etc.

The maximum number of discrete input points whose status can be obtained by the Read Input Status function is 2000. (Although 2000 is the maximum parameter allowed, the query/response time required by some ModBus® Masters may dictate much a smaller quantity parameter.)

Query Format - RTU Mode:

Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7	Byte 8
Station Address	Function Code	Starting Address		No. of Input Points		CRC	

Response Format - RTU Mode:

Byte 1	Byte 2	Byte 3	Bytes 4	→	through *n*	Bytes n + 1, n + 2
Station Address	Function Code	Length of Data	Data	→	Data	CRC

Read Holding Registers (Function Code 03) (Read/Write Integer)

The Read Holding Registers query requests the binary content of holding registers from a station. The ModBus® Master can address a maximum of 125 registers with each query. (Although 125 is the maximum parameter allowed, the query/response time required by some ModBus® Masters may dictate much a smaller quantity parameter.) The registers are numbered beginning with zero; for example, Register 40001 equals zero, Register 40002 equals one, etc.

Query Format - RTU Mode:

Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7	Byte 8
Station Address	Function Code	Starting Address		No. of Holding Registers		CRC	

The Read Holding Registers response includes the station address, the function code, the length of the response values in bytes, the response values, and the error-check word. The data consists of two bytes for each register queried, with the binary content right-justified. The leftmost character includes the high-order bit, and the rightmost character includes the low-order bit.

Response Format - RTU Mode:

Byte 1	Byte 2	Byte 3	Bytes 4	→	through *n*	Bytes n + 1, n + 2
Station Address	Function Code	Length of Data	Data	→	Data	CRC

Read Input Registers (Function Code 04) (Read Integer)

This function operates in the same manner as the Read Holding Registers query (Function Code 03), except that the status of input registers is obtained. A ModBus® Master can address a maximum of 125 input registers with Function Code 04. (Although 125 is the maximum parameter allowed, the query/response time required by some ModBus® Masters may dictate a much smaller quantity parameter.)

Query Format - RTU Mode:

Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7	Byte 8
Station Address	Function Code	Starting Address		No. of Input Registers		CRC	

Response Format - RTU Mode:

Byte 1	Byte 2	Byte 3	Bytes 4	→	through *n*	Bytes n + 1, n + 2
Station Address	Function Code	Length of Data	Data	→	Data	CRC

Force Single Coil (Function Code 05)

This function turns a single coil within the *TS310* to ON or OFF, depending on its current state. However, since the *TS310* is actively scanning, it too can alter the state of the coil unless the coil is disabled. Coils are numbered beginning with zero -- for example, Coil 00001 equals zero, Coil 00002 equals one, etc.

The coil value 65,280 (FF00 in hex) turns the coil ON, and the data value zero (0000 in hex) turns the coil OFF. All other values are illegal and will not affect that coil.

Query Format - RTU Mode:

Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7	Byte 8
Station Address	Function Code	Address to Modify		Coil Value		CRC	

Response Format - RTU Mode:

Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7	Byte 8
--- Same as Query Format for Force Single Coil Function ---							

Preset Single Register (Function Code 06)

This function modifies the content of one holding register. Any holding register that exists within the *TS310* can have its contents changed by Modify Register Content. However, since the *TS310* is actively scanning, it also can alter the content of any holding register at any time. The values are provided in binary up to the maximum capability of the *TS310*, which is 16 bits; unused high-order bits must be set to zero. Holding registers are numbered beginning with zero. For example, zero represents register 40001, one represents 400002, etc.

Query Format - RTU Mode:

Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7	Byte 8
Station Address	Function Code	Address to Modify		Register Value		CRC	

Response Format - RTU Mode:

Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7	Byte 8
--- Same as Query Format for Preset Single Register Function ---							

Loop-Back Diagnostic Test (Function 08)

Use this function to test the physical communication link between the ModBus® Master and a *TS310*. (The function does not affect point values in the *TS310*.) If no communication faults are present, any data sent in the Query Format is "looped back" unchanged in the Response Format. Differences in the response, or no response at all, indicate faults in the data communications system.

Query Format - RTU Mode:

Byte 1	Byte 2	Bytes 3 through 6	Bytes 7 & 8
Station Address	Function Code	Data	No. of Input Registers

Response Format - RTU Mode:

Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7	Byte 8
--- Same as Query Format for Loop-Back Diagnostic Test Function ---							

Error Detection & Exception Responses

This section provides information on the following topics:

- types of data communication errors.
- CRC error checking.

The TRISEN ModBus® system handles each type of error with specific methods.

Transmission Errors

The most frequent cause of transmission errors is noise: unwanted electrical signals on a communications channel. These signals occur because of electrical interference from some machinery, damage to the communications channel, atmospheric conditions such as lightning, etc. You can identify transmission errors by character framing, parity checking, or redundancy checking.

When a transmission error occurs, processing of the message stops; in other words, an *TS310* will not act on or respond to the message. Processing also stops if a non-existent station is addressed. The ModBus® Master assumes a communications error has occurred if there is no response within three seconds.

Parity checking helps detect single-bit transmission errors. However, if there are two errors within a single message, parity checking cannot detect a change. For example, if 1100 0100 is distorted to 1110 0110, the number of 1's in the data is still odd.

The ModBus® system provides several levels of error checking in order to assure the quality of the data transmission. To detect multi-bit errors where the parity has not changed, the system uses Cyclical Redundancy Check (CRC) for RTU mode.

Exception Responses

A programming or operation error which involves an illegal or illogical query results in an exception response from the *TS310*. When a station detects an error, it sends a response message to the Master consisting of station address, function code, error code, and error-check fields. To indicate that the response is an error notification, the high-order bit of the function code is set to 1.

Currently Exception Response Code 06, called a "busy" or "reject" response, is the only exception response the ModBus® Master will receive following an incorrect query. It means that the message was received without a checksum error, but one or more of the query message fields is not consistent with the configuration in the *TS310*.

CRC Checksum Calculation

The following paragraphs describe the calculations that are performed during the CRC error check of ModBus® messages in RTU mode.

CRC Error Check for RTU Mode

During a CRC error check, the CRC-16 polynomial is used to compute a checksum for the entire message content. The formula for the CRC-16 polynomial is stated as follows:

x * * 16 + x * * 15 + x * * 2 + 1, divisor preset to 0FFFFH

For query and response messages, the error check is computed over the station address, the function code, and data. The resulting CRC is appended to the end of the message.

Recommended Parameters for ModBus® Functions

The descriptions of ModBus® functions earlier in this chapter mention the *maximum* data parameters for queries and responses. However, the query/response time required by some ModBus® Masters may dictate much smaller query/response parameters. ***Each ModBus® Master must allow three or more seconds for the*** **TS310*****'s to provide error-free responses to its queries.***

We recommend the following quantity parameters for optimal performance. Be sure to check on the limitations of the ModBus® Master for compatibility with these quantity parameters.

Instruction Name	Function Code	Parameter
Read Coil Status	01	17 coils
Read Input Status	02	8 discrete inputs
Read Holding Registers	03	-- registers
Read Input Registers (Read Integer)	04	-- registers
Force Single Coil	05	not applicable
Preset Single Register	06	not applicable
Loop Back Diagnostic Test	08	not applicable

ModBus® Referencing Of *TS310* Points

In a ModBus® communications network, the host computer (ModBus® Master) can reference *TS310* points having alphanumeric tag names only if "Alias" numbers have been assigned to the points.

TS310 ModBus® Data Definitions

Coil Status

The following digital points can be either read (with Function 1) or written (with Function 5) via ModBus®:

Coil #	Function
00001	Digital Output #1
00002	Digital Output #2
00003	Digital output #3
00004	Digital Output #4
00005	Digital Output #5
00006	Digital Output #6
00007	Digital Output #7
00008	Digital Output #8
00009	LCD Status/Alarm Indicator #1
00010	LCD Status/Alarm Indicator #2
00011	LCD Status/Alarm Indicator #3
00012	LCD Status/Alarm Indicator #4
00013	Start
00014	Stop
00015	F1
00016	F2
00017	F3

Writing to coils 00013 through 00017 will have the same effect as pushing the corresponding button on the front panel of the *TS310*. Reading them will indicate the status of the function:

- Coil 00013 will be on if the turbine is running, and off if it is not.
- Coil 00014 will be on if the turbine is shut down, and off if it is not.
- Coil 00015 will be on if F1 has been successfully executed, and off otherwise.
- Coil 00016 will be on if F2 has been successfully executed, and off otherwise.
- Coil 00017 will be on if F3 has been successfully executed, and off otherwise.

Input Status

The following digital points can be read (with Function 2) via ModBus®:

Input #	Function:
10001	Digital Input #1
10002	Digital Input #2
10003	Digital Input #3
10004	Digital Input #4
10005	Digital Input #5
10006	Digital Input #6
10007	Digital Input #7
10008	Digital Input #8

For those digital I/O points configured as inputs, the value returned for the corresponding input status will indicate the logical state of the input. The logical state is the exclusive or of the physical state of the contact with its configured normal state.

Holding Registers

The following channels are defined as holding registers. They can be read (with Function 3) and written (with Function 6).

Register #	*Description*	*Channel #*
40001	Speed Setpoint	05
40002	2nd PID Setpoint	06
40003	3rd PID Setpoint	07
40004	Analog Output #1	08
40005	Analog Output #2	09
40006	Acceleration Rate	12
40007	Minimum Critical	13
40008	Maximum Critical	14
40009	Min. Gov. Speed	15
40010	Max. Gov. Speed	16
40011	Overspeed Trip Set	17
40012	Speed Switch No. 1	18
40013	Speed Switch No. 2	19
40014	Speed Prop. Band	20
40015	Speed Reset	21
40016	Speed Rate	22
40017	Speed Droop	23
40018	2nd PID Prop. Band	24
40019	2nd PID Reset	25
40020	2nd PID Rate	26

Register #	***Description***	***Channel #***
40021	2nd PID Droop	27
40022	Synch. Integral	28
40023	Synch Derivative	29
40024	3rd PID Prop. Band	30
40025	3rd PID Reset	31
40026	3rd PID Rate	32
40027	3rd PID Droop	33
40028	Minimum V2 Limit	34
40029	Maximum V2 Limit	35
40030	Idle Speed	36
40031	Idle Fuel (Limit)	37
40032	Minimum V1 Limit	38
40033	Maximum V1 Limit	39
40034	Min #1 Nozzle Valve	40
40035	Max #1 Nozzle Valve	41
40036	Min #2 Nozzle Valve	42
40037	Max #2 Nozzle Valve	43
40038	Min #3 Nozzle Valve	44
40039	Max. #3 Nozzle Valve	45
40040	Min Analog Input #1	46
40041	Max Analog Input #1	47
40042	Min #1a Engrg. Units	48
40043	Min #1b Engrg. Units	48
40044	Span #1 Engrg. Units	49
40045	Min Analog Input #2	50
40046	Max Analog Input #2	51
40047	Min #2a Engrg. Units	52
40048	Min #2b Engrg. Units	52
40049	Span #2 Engrg. Units	53
40050	Min Analog Input #3	54
40051	Max Analog Input #3	55
40052	Min #3a Engrg. Units	56
40053	Min #3b Engrg. Units	56
40054	Span #3 Engrg. Units	57
40055	Min Analog Input #4	58
40056	Max Analog Input #4	59
40057	Min #4a Engrg. Units	60
40058	Min #4b Engrg. Units	60
40059	Span #4 Engrg. Units	61
40060	Min ma. Output #1	62

Register #	***Description***	***Channel #***
40061	Max ma. Output #1	63
40062	Min ma. Output #2	64
40063	Max ma. Output #2	65
40064	Local Load Limit	66
40065	Setpoint Ramp Rate	67
40066	kW Override Reset	68
40067	Parallel Isoc. Delay	69
40068	Analog Input #1 & #2	70 (Hex)
40069	Analog Input #3 & #4	71 (Hex)
40070	I/O Contact #1	72 (Hex)
40071	I/O Contact #2	73 (Hex)
40072	I/O Contact #3	74 (Hex)
40073	I/O Contact #4	75 (Hex)
40074	I/O Contact #5	76 (Hex)
40075	I/O Contact #6	77 (Hex)
40076	I/O Contact #7	78 (Hex)
40077	I/O Contact #8	79 (Hex)
40078	Speed Control Config.	80 (Hex)
40079	Speed Control Config.	81 (Hex)
40080	Speed Control Config.	82 (Hex)
40081	2nd PID Configuration	83 (Hex)
40082	Status Indicators	84 (Hex)
40083	Speed Switches	85 (Hex)
40084	3rd PID Configuration	86 (Hex)
40085	Generator Configuration	87 (Hex)
40086	Fail-safe Setting	88
40087	Gear Teeth	89
40088	H Value	90
40089	F Value	91
40090	B Value	92
40091	Gear Ratio	93
40092	Startup Speed P.B.	94
40093	Startup Integral	95
40094	Hour Meter	96
40095	Load Preset ("Kick")	128
40096	Snapback Configuration	129
40097	Extraction Limit	155
40098	Reg/Tracking Config	156
40099	Remote Setpt Ramp Rate	158
40100	Critical Ramp Rate	160

Input Registers

The following channels are defined as input registers. They can be read (with Function 4).

Register #	***Description :***	***Channel #***
30001	Speed Used	00
30002	Analog Input #1	01
30003	Analog Input #2	02
30004	Analog Input #3	03
30005	Analog Input #4	04
30006	Speed Input #1	10
30007	Speed Input #2	11
30008	Last Shutdown	97
30009	Computer Id.	98

Evaluation of ModBus® Data

Reading Coils 00001-00017

COIL #	*DESCRIPTION*			
00001-00008	EXAMPLE:	D/O Conf.	Output	ModBus®
		N.C.	energized	coil off
		N.C.	de-energized	coil on
		N.O.	energized	coil on
		N.O.	de-energized	coil off
00009-00012		The data received via ModBus® will indicate the true status of the status indicator.		
00013	EXAMPLE:	On = Running, Off = Stopped		
00014	EXAMPLE:	On = Stopped, Off = Running		
00015-00017		Will always read off as these function buttons are momentary.		

Reading Input Status 10001-10008

INPUT #	*DESCRIPTION*			
10001-10008	EXAMPLE:	D/I Conf.	Output	ModBus®
		N.C.	energized	coil off
		N.C.	de-energized	coil on
		N.O.	energized	coil on
		N.O.	de-energized	coil off

Reading/Writing to Holding Registers 40001-40095 30001-30009

REGISTER #	***DESCRIPTION***	
30002-30005		The data read by ModBus® for these registers will be scaled. The scale will be determined by max. value in engineering units and 4000 counts.
	EXAMPLE:	CH 123 - 500 Units (2nd PID Meas.)

Actual Units	ModBus® Return
500 Units	4000 Counts
250 Units	2000 Counts
100 Units	800 Counts
50 Units	400 Counts

40004-40005
40031-40033
40064
40128
40155

Scaled 0-100% is equal to 0-4000 counts.

EXAMPLE:

Actual %	ModBus® Return
100 %	4000 Counts
75 %	3000 Counts
15 %	600 Counts

40015-40017
40019-40023
40025-40027
40065-40066
40093
40095
40158

Scaled 0-100% is equal to 0-1000 counts.

EXAMPLE:

Actual %	ModBus® Return
100 %	1000 Counts
75 %	750 Counts
15 %	150 Counts
1 %	10 Counts

40014
40018
40024
40092

Scaled 0-750% is equal to 0-7500 counts.

EXAMPLE:

Actual %	ModBus® Return
100 %	1000 Counts
75 %	750 Counts
15 %	150 Counts
1 %	10 Counts

30001
30006-30007
30009
40001
40006-40013
40030
40042-40044
40047-40049
40052-40054
40057-40059

Direct one to one reading.

REGISTER #	***DESCRIPTION***		
40067 40087 40094 40160 40091		Scaled 0-1.000 is equal to 0-4000 counts.	
	EXAMPLE:	Actual	ModBus® Return
		2.000	8000 Counts
		1.000	4000 Counts
		0.100	400 Counts
40040-40041		Scaled 0-10 is equal to 0-4000 counts.	
40045-40046			
40050-40051	EXAMPLE:	Actual	ModBus® Return
40055-40056		10	4000 Counts
40088-40090		7	2800 Counts
		1	400 Counts
40086		Scaled 0-400 sec. is equal to 0-4000 counts.	
	EXAMPLE:	Actual sec.	ModBus® Return
		400 sec.	4000 Counts
		100 sec.	1000 Counts
		50 sec.	500 Counts
40060-40063		Scaled 0-20 mA is equal to 0-4000 counts.	
	EXAMPLE:	Actual mA	ModBus® Return
		20 mA	4000 Counts
		12 mA	2400 Counts
		1 mA	200 Counts
30008 40068-40085 40129 40156		The data from the *TS310* as it will be read needs to be converted. The conversion is done by taking the data and doing a Hex to decimal conversion.	
	EXAMPLE:	Actual CH (Hex.)	ModBus® Return (Dec.)
		1001	4097
		0030	48
		2332	9010

TS310 MOD4A Digital Controller

Auto-Configuration (ACON) Guide

Document No. 4933-0019

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Rev. 1

ACON Software Version 11

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Revision History

Rev. A	July 1991	Minor technical revisions, converted to standard format.
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Contents

Illustrations

Chapter 1 - Introduction

TS310 Auto-Configuration is a convenient feature that allows the controller to be configured for standard applications by making a single entry.

This single entry automatically loads most of the data required. All that remains is to enter basic machine data, and to connect the unit as shown in the wiring instructions.

Auto-Configuration is referred to in this manual as ACON. It is usually followed by a particular configuration variation; e.g., a period and a 3 digit number. For example, ACON.010 refers to the basic speed control application.

Standard ACON Configurations

The following ACON configurations are available:

Auto- Config #	***Application***
.010	Basic Speed Control
.020	Inlet/Suction Pressure Control
.021	Backpressure/Discharge Pressure Control
.030	Synchronous Generator Control
.040	Extraction/Admission Control

When to Use ACON

ACON can be used anytime a standard configuration of the *TS310* is to be implemented.

ACON saves the operator the time it takes to do the detailed channel entry procedure, and provides a standard I/O assignment.

Flexibility

ACON is very flexible. In addition to the standard configuration, most ACON variations set up options that can be utilized by entering a minimal amount of additional data, and then connecting any required field devices.

If it is necessary to modify the configuration further, this can be done, too. After ACON is implemented, data can be entered or changed in any channel to utilize any of the many features and capabilities of the *TS310*.

Usually, the easiest way to configure a complex application is to use the closest ACON version, then modify the necessary channels to complete the configuration.

Procedure for Loading ACON into a *TS310*

To initially, automatically configure your *TS310* with a version of ACON:

- Access Channel 99 and enter the password. (Refer to *TS310* Configuration Guide.)

  If no ACON configuration is present the display will read:

  99 HELLO

  If an ACON configuration is present it will display the ACON number; e.g.:

  99 .010

  If an ACON configuration is present and the configuration has been modified by changing one or more of the automatically configured channels, then the ACON number will be preceded by a dash rather than a decimal; e.g.:

  99 -010

- Enter the desired ACON configuration number, preceded by a decimal; e.g.:

  99E .020

- Now press ENTER to load the configuration.

  The *TS310* will then revert to the normal password mode and will display the ACON configuration number; e.g.:

  99 .020

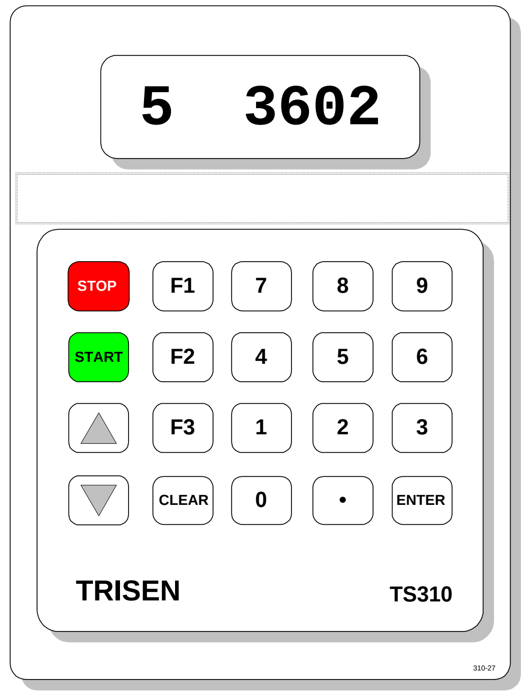


Figure 1. *TS310* Keypad

Additional Entries

Depending on the configuration selected, a minimal number of additional channel entries are required. The following chapters on each ACON configuration contain lists of required additional entries.

The PID tuning constants in Channels 20 through 23 are automatically loaded with conservative tuning values. These should be optimized for the dynamics of the application during startup

Chapter 2 - Basic Speed Control ACON.010

2.1 Application Description

ACON.010 is the simplest ACON configuration. It provides:

Speed control

Raise/ lower speed changing within the governor range

Dual pickup inputs

Loss of speed signal fail-safe

Fail-safe bypass timer (10 seconds)

Overspeed trip and test

Auto-start capability

Trip contact output

Status Indicators for:
- Pickup Fail
- Overspeed Trip
- Trip Output

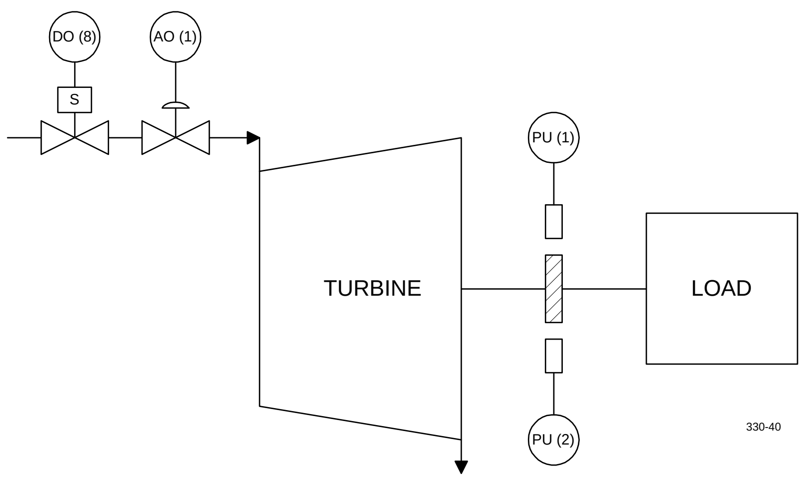


Figure 2. ACON.010 Basic Speed Control Typical Application

Refer to Chapter 1 for the procedure for loading ACON.010 into the *TS310*.

Startup

Startup can be manual or automatic.

Manual Start. The operator presses the *TS310* [START] button then opens the steam block or T&T valve slowly to bring the machine up to governor speed.

Auto Start. The block valve is left open. Pressing [START] ramps the governor valve open and rapidly controls the machine up to the governor speed. This mode of operation is sometimes called "Fast Start".

Shutdown

The machine will trip upon any of the following conditions:

- Failure of both speed pickups
- Speed exceeding the limit set in Channel 17
- Manual operation of the *TS310* STOP button

A trip causes closure of the governor valve and opening of the trip output contact.

Speed Control

After startup machine speed will be controlled to the speed displayed in CH05 (generally minimum governor speed). Upon reaching minimum governor, the speed can be changed by pressing [s] raise and [t] lower or by entering a new setpoint into CH05.

Overspeed Trip And Test

This configuration provides an electronic overspeed trip feature as a backup to the primary overspeed trip. It also provides a method for overspeed test.

Input/Output

Field devices required for the basic configuration are described below. Refer to the wiring chapter of ACON.020 for field connections.

- **Two magnetic speed pickups**:
  Recommended types:
  TRISEN #7120
  TRISEN #7121
  A ferrous toothed gear is also required. TRISEN can provide the proper gear upon request.

- **Governor/transducer**: A 4-20 mA actuator system is required. Action must be direct (e.g., 4 mA fully closes the steam valve, 20 mA fully opens the steam valve).
  Examples are:
  TRISEN #9907 I/P Transducer with pneumatic actuator.
  TRISEN #HCX21 Electro-hydraulic Transducer.

- **Trip output contact**: A trip output is configured for digital output position 8. An output relay module, with the correct rating, must be installed in the eighth position on the termination board. Contact types and ratings can be found in the *TS310*. This contact is configured to close on a trip condition.

Status Indicators

Status indicators on the *TS310* display are configured from left to right as follows:

Indicator #	***Function***
1	Speed Pickup Failure
2	Overspeed Trip
3	Trip Output

2.2 Required Additional Entries

Description	*CH#*
Min. Governor	15
Max. Governor	16
Overspeed Set	17
Speed Tuning	20-23
Analog Input	48-49 (Preset : 46=1.00, 47=5.00)
Setpoint Ramp Rate	67
No. Gear Teeth	89
I/O Assignments	
Speed Pickup #1	PU-1
Speed Pickup #2	PU-2
Governor Valve	AO-1
Trip Contact	DO-8

2.3 Options

In addition to the standard features, ACON.010 supports the following options:

Option	*Requires*
Remote Speed Set	4-20 mA External Input
Remote Start	External momentary contact (close to start)
Remote Stop	External momentary contact (close to trip the turbine)
Remote Raise	External momentary contact (close to raise the setpoint)
Remote Lower	External momentary contact (close to lower the setpoint)
Remote Start Permissive	External momentary contact (close to inhibit turbine startup)

In addition to the devices listed above, some minor configuration must be done.

- To use the **Remote Speed Set** you must make two entries into the configuration:

Channel #	*Data*
48	Min. Governor Speed
49	Max. Governor Speed

All other options require no additional configuration entries.

Optional I/O Assignments

I/O	***Required Field Devices (Customer Supplied)***
AI-1	Customer Remote Speed Set
DI-1	Remote Start Contact
DI-2	Remote Stop Contact
DI-3	Remote Raise Contact
DI-4	Remote Lower Contact
DI-5	Start Permissive Contact

2.4 Machine Data Listing

ACON.010 MACHINE DATA LISTING					
FUNCTION	*	*CH*	*DISPLAY*	*RANGE*	*UNITS*
SPEED USED	D	00	0	0-29999	RPM
ANALOG INPUT #1	D	01	0	0-29999	VARIES
ANALOG INPUT #2	D	02	0	0-29999	VARIES
ANALOG INPUT #3	D	03	0	0-29999	VARIES
ANALOG INPUT #4	D	04	0	0-29999	VARIES
SPEED REFERENCE	D	05	0	0-29999	RPM
2ND PID SETPOINT	D	06	0		VARIES
3RD PID SETPOINT	D	07	0		VARIES
ANALOG OUTPUT #1	D	08	0.0	0-100	PERCENT
ANALOG OUTPUT #2	D	09	0.0	0-100	PERCENT
SPEED INPUT #1	D	10	0	0-29999	RPM
SPEED INPUT #2	D	11	0	0-29999	RPM
* ACCELERATION RATE	K	12	_____	0-29999	RPM/MIN
MINIMUM CRITICAL SPEED #1	K	13	0	0-29999	RPM
MAXIMUM CRITICAL SPEED #1	K	14	0	0-29999	RPM
* MINIMUM GOVERNOR SPEED	K	15	_____	0-29999	RPM
* MAXIMUM GOVERNOR SPEED	K	16	_____	0-29999	RPM
* OVERSPEED TRIP SETTING	K	17	_____	0-29999	RPM
SPEED SWITCH #1 SET	K	18	0	0-29999	RPM
SPEED SWITCH #2 SET	K	19	0	0-29999	RPM
SPEED PROPORTIONAL BAND	T	20	50.0	0-1000	PERCENT
SPEED INTEGRAL (RESET)	T	21	5.0	0-500	SECONDS
SPEED DERIVATIVE (RATE)	T	22	0.0	0-200	SECONDS

ACON.010 MACHINE DATA LISTING					
FUNCTION	*****	***CH***	***DISPLAY***	***RANGE***	***UNITS***
SPEED DROOP	T	23	0.0	0-20	PERCENT
2ND PID PROPORTIONAL BAND	T	24	0.0	0-1000	PERCENT
2ND PID INTEGRAL (RESET)	T	25	0.0	0-500	SECONDS
2ND PID DERIVATIVE (RATE)	T	26	0.0	0-200	SECONDS
2ND PID DROOP	T	27	0.0	0-20	PERCENT
SYNCHRONIZING INTEGRAL	T	28	0.0	0-500	SECONDS
SYNCHRONIZING DERIVATIVE	T	29	0.0	0-200	SECONDS
3RD PID PROPORTIONAL BAND	T	30	0.0	0-1000	PERCENT
3RD PID INTEGRAL (RESET)	T	31	0.0	0-500	SECONDS
3RD PID DERIVATIVE (RATE)	T	32	0.0	0-200	SECONDS
3RD PID DROOP	T	33	0.0	0-20	PERCENT
V2 MINIMUM LIMIT	K	34	0.0	0-100	PERCENT
V2 MAXIMUM LIMIT	K	35	0.0	0-100	PERCENT
IDLE SPEED	K	36	0	0-20000	RPM
IDLE FUEL	K	37	0	0-100	PERCENT
V1 MINIMUM LIMIT	K	38	0.0	0-100	PERCENT
V1 MAXIMUM LIMIT	K	39	100.0	0-100	PERCENT
MINIMUM #1 NOZZLE VALVE	K	40	0.0	0-100	PERCENT
MAXIMUM #1 NOZZLE VALVE	K	41	0.0	0-100	PERCENT
MINIMUM #2 NOZZLE VALVE	K	42	0.0	0-100	PERCENT
MAXIMUM #2 NOZZLE VALVE	K	43	0.0	0-100	PERCENT
MINIMUM #3 NOZZLE VALVE	K	44	0.0	0-100	PERCENT
MAXIMUM #3 NOZZLE VALVE	K	45	0.0	0-100	PERCENT
MINIMUM ANALOG INPUT #1	K	46	1.0	0-10	VDC
MAXIMUM ANALOG INPUT #1	K	47	5.0	0-10	VDC
* MINIMUM ENGRG UNITS #1	K	48	_____	0-29999	_____
* MAXIMUM ENGRG UNITS #1	K	49	_____	0-29999	_____
MINIMUM ANALOG INPUT #2	K	50	0.0	0-10	VDC
MAXIMUM ANALOG INPUT #2	K	51	0.0	0-10	VDC
MINIMUM ENGRG UNITS #2	K	52	0	0-29999	_____
MAXIMUM ENGRG UNITS #2	K	53	0	0-29999	_____
MINIMUM ANALOG INPUT #3	K	54	0.0	0-10	VDC
MAXIMUM ANALOG INPUT #3	K	55	0.0	0-10	VDC
MINIMUM ENGRG UNITS #3	K	56	0	0-29999	_____
MAXIMUM ENGRG UNITS #3	K	57	0	0-29999	_____
MINIMUM ANALOG INPUT #4	K	58	0.0	0-10	VDC

ACON.010 MACHINE DATA LISTING					
FUNCTION	*****	***CH***	***DISPLAY***	***RANGE***	***UNITS***
MAXIMUM ANALOG INPUT #4	K	59	0.0	0-10	VDC
MINIMUM ENGRG UNITS #4	K	60	0	0-29999	_____
MAXIMUM ENGRG UNITS #4	K	61	0	0-29999	_____
#1 ANALOG OUTPUT MINIMUM	K	62	4.0	0-20	m AMPS
#1 ANALOG OUTPUT MAXIMUM	K	63	20.0	0-20	m AMPS
#2 ANALOG OUTPUT MINIMUM	K	64	0.0	0-20	m AMPS
#2 ANALOG OUTPUT MAXIMUM	K	65	0.0	0-20	m AMPS
LOAD LIMIT	K	66	100.0	0-100	PERCENT
* SETPOINT RAMP RATE	K	67	_____	0-100	PERCENT
LOAD (KW) OVERRIDE RESET	T	68	0.0	0-500	PERCENT
PARALLEL ISOCH. DELAY	K	69	0	0-12	SEE MAN
ANALOG INPUT #1 & #2	K	70	0400	WORD #1	
ANALOG INPUT #3 & #4	K	71	0000	WORD #2	
CONTACT I/O #1	K	72	1001	WORD #3	
CONTACT I/O #2	K	73	1002	WORD #4	
CONTACT I/O #3	K	74	1003	WORD #5	
CONTACT I/O #4	K	75	1004	WORD #6	
CONTACT I/O #5	K	76	2013	WORD #7	
CONTACT I/O #6	K	77	0000	WORD #8	
CONTACT I/O #7	K	78	0000	WORD #9	
CONTACT I/O #8	K	79	3320	WORD #10	
SPEED CONTROL	K	80	0330	WORD #11	
SPEED CONTROL	K	81	0210	WORD #12	
SPEED CONTROL	K	82	3110	WORD #13	
2ND PID CONTROL	K	83	0000	WORD #14	
STATUS INDICATORS	K	84	1200	WORD #15 Some software releases had 1280 as Word 15. 1200 is correct and current software has been changed.	
SPEED SWITCH CONF.	K	85	0000	WORD #16	
3RD PID CONTROL	K	86	0000	WORD #17	
GENERATOR CONTROL	K	87	0000	WORD #18	
FAILSAFE SETTING	K	88	10	0-400	SECONDS
* GEAR TEETH	K	89	_____	0-320	TEETH
H VALUE	K	90	0.00	0-10.0	TEETH
F VALUE	K	91	0.00	0-10.0	PERCENT
B VALUE	K	92	0.0	0-100	PERCENT
GEAR RATIO	K	93	0.000	0-9.99	RATIO

ACON.010 MACHINE DATA LISTING					
FUNCTION	*****	***CH***	***DISPLAY***	***RANGE***	***UNITS***
STARTUP PROP. BAND	T	94	0.0	0-1000	SECONDS
STARTUP INTEGRAL (RESET)	T	95	0.0	0-500	SECONDS
HOUR METER	K	96	0	READS HOURS	
LAST SHUTDOWN	D	97	0000	RECORDS TRIPS	
COMPUTER ID	K	98	0	RS422 ADDRESS	
PASSWORD	K	99	6883	FOUR DIGITS	

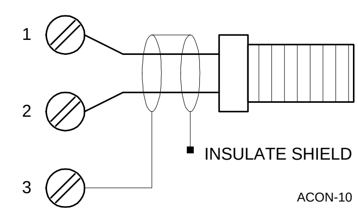
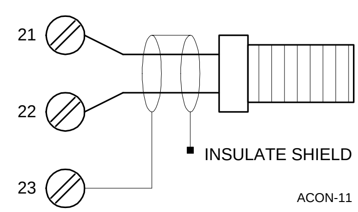
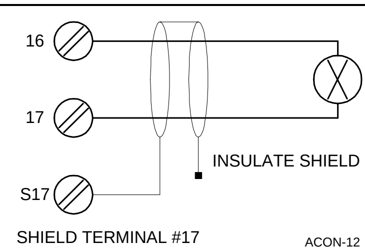
* The channels marked with the asterisks will require data entry before the *TS310* can be used.

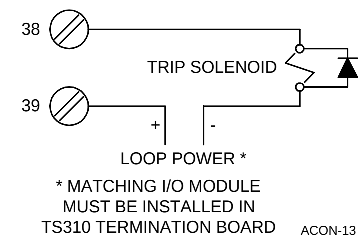
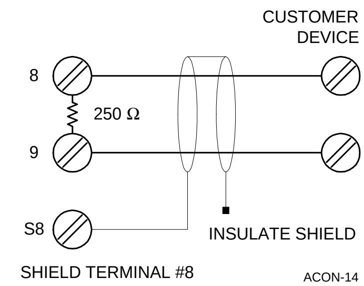
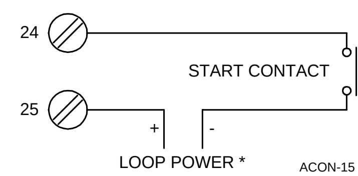
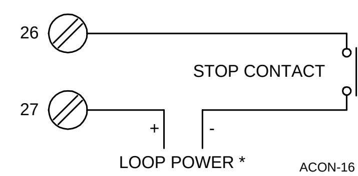
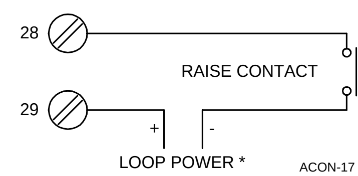
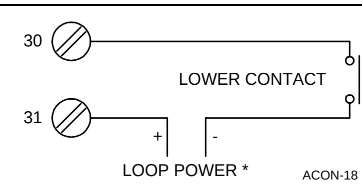
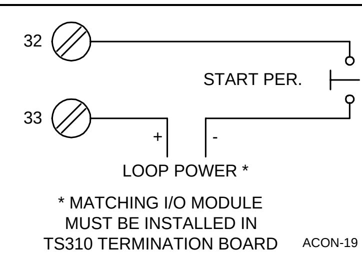
K = Channel is password protected.

D = Channel for display only.

T = Channel contains tuning values.

2.5 Wiring

I/O	Device	Remarks	Wiring
PU-1	Speed Pickup	Standard Magnetic Speed Pickup TRISEN P/N 7120, 7121, etc.	
PU-2	Speed Pickup	Standard Magnetic Speed Pickup TRISEN P/N 7120, 7121, etc.	
AO-1	Actuator	Direct Acting 4-20 mA Governor Actuator, I/P Transducer, HCX21, etc.	

I/O	Device	Remarks	Wiring
DO-8	Trip Solenoid	Trip Circuit Contact Output Opens Upon Pressing STOP Overspeed Trip Pickup Failure	
AI-1	Customer Signal	4-20 mA Signal From Customer Device for Remote Speed Setpoint	
DI-1	Remote Start Contact	Close Contact to Start Turbine	
DI-2	Remote Stop Contact	Close Contact to Trip Turbine	
DI-3	Remote Raise Contact	Close Contact to Ramp Turbine Speed Up	
DI-4	Remote Lower Contact	Close Contact to Ramp Turbine Speed Down	
DI-5	Start Permissive Contact	Close Contact to Inhibit Turbine Start	

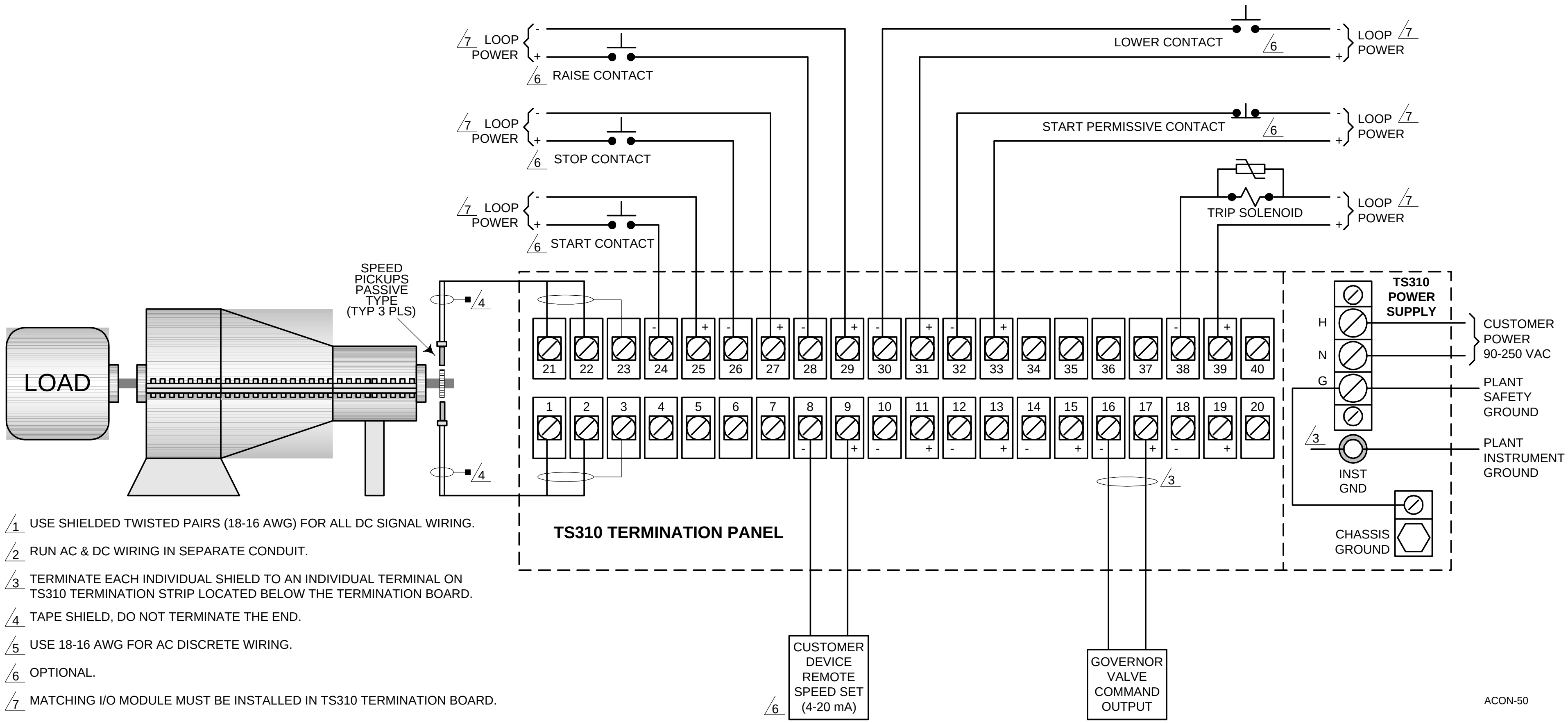


Figure 3. ACON.010 Wiring Diagram

Chapter 3 - Inlet/Suction Pressure Control ACON.020

3.1 Application Description

ACON.20 is a preset configuration that allows the 2nd Proportional, Integral, Derivative (PID) control algorithm to control either inlet or suction pressure. It provides:

Speed control

Inlet/Suction pressure control

Raise/Lower speed changing within the governor range

Raise/Lower Inlet/Suction pressure

Dual pickup inputs

Loss of speed signal fail-safe

Fail-safe bypass timer (10 seconds)

Overspeed trip and test

Auto-start capability

Trip contact output

Status Indicators for:
- Pickup Fail
- Overspeed Trip
- Trip Output
- 2nd PID Enabled

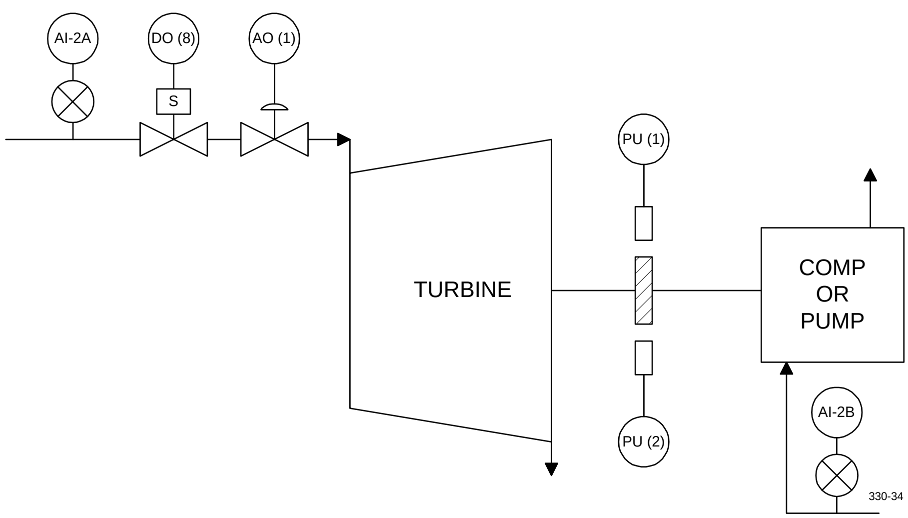


Figure 4. ACON.020 Inlet/Suction Pressure Control Typical Application

Startup

Startup can be manual or automatic.

Manual Start. The operator presses the *TS310* [START] button then opens the steam block or T&T valve slowly to bring the machine up to governor speed.

Auto Start. The block valve is left open. Pressing [START] ramps the governor valve open and rapidly controls the machine up to the governor speed. This mode of operation is sometimes called "Fast Start".

Shutdown

The machine will trip on any of the following conditions:

Failure of both pickups

Speed exceeding the limit set in channel 17

Manual operation of the *TS310* [STOP] button

A trip causes closure of the governor valve and opening of the trip output contact.

Speed Control

After startup machine speed will be controlled to the speed displayed in CH05 (generally minimum governor speed). Upon reaching minimum governor, the speed can be changed by pressing [s] raise or [t] lower or by entering a new setpoint into channel 05.

Enable/Disable Inlet/Suction Pressure Control

Inlet/Suction pressure control can be enabled and disabled at any time while the machine is operating in the governor control range.

Enabling pressure control is done using the [F1] button. As soon as the machine has reached minimum governor control, pressing [F1] will enable the pressure controller. After you enable the pressure controller, the fourth indicator from the left will indicate pressure control.

Disabling the control is done using the [F1] button. At any time speed control is desired instead of pressure control [F1] is pressed. The status indicator will disappear and the machine will return to speed control.

The pressure control setpoint is changed in a similar manner as speed control setpoint. The pressure setpoint is displayed in channel 06. The [s] raise or [t] lower buttons will change the setpoint. Channel 06 is used to enter the setpoint directly.

Overspeed Trip And Test

This configuration provides an electronic overspeed trip feature as a backup to the primary overspeed trip. It also provides a method for overspeed test.

Input/Output

Field devices required for the basic configuration are described below. Refer to the wiring chapter of ACON.020 for field connections.

- **Two magnetic speed pickups**
  Recommended types:
  TRISEN #7120
  TRISEN #7121
  A ferrous toothed gear is also required. TRISEN can provide the proper gear upon request.

- **Governor/transducer**: A 4-20 mA actuator system is required. Action must be direct (e.g., 4 mA fully closes the steam valve, 20 mA fully opens the steam valve).
  Examples are:
  TRISEN #9907 I/P Transducer with pneumatic actuator.
  TRISEN #HCX21 Electro-hydraulic Transducer.

- **Inlet/Suction pressure input transducer**: A transducer must be provided that will input a current or voltage signal that represents the actual suction/inlet pressure to the *TS310*. This information will be supplied to the #1 analog input channel.

- **Trip output contact**: A trip output is configured for digital output position 8. An output relay module must, with the correct rating, be installed in eighth position on the termination board. This contact is configured to close on a trip condition.

Status Indicators

Status indicators on the *TS310* display are configured from left to right as follows:

Indicator #	***Function***
1	Speed Pickup Failure
2	Overspeed Trip
3	Trip Output
4	Cascade Closed (Pressure Control Enabled)

3.2 Required Additional Entries:

Description	*CH#*	
Min. Governor	15	
Max. Governor	16	
Overspeed Set	17	
Speed Tuning	20-22	
2nd PID Tuning	24-26	
Analog Input	52-53 (Preset:	50=1.00, 51=5.00)
Setpoint Ramp Rate	67	
No. Gear Teeth	89	
Analog Input	50-53 (Preset =	50-1.00, 51-5.00, 54-1.00, 55-5.00)

I/O Assignments	
Speed Pickup #1	PU-1
Speed Pickup #2	PU-2
Governor Valve	AO-1
Trip Contact	DO-8
2nd PID Inputs	AI-1A or AI-1B

3.3 Options

In addition to the standard features ACON.020 supports the following options:

Option	*Requires*
Remote Speed Set	4-20 mA External Input
Remote 2nd PID Set	4-20 mA External Input
Remote Start	External momentary contact (close to start)
Remote Stop	External momentary contact (close to trip the turbine)
Remote Raise	External momentary contact (close to raise the setpoint)
Remote Lower	External momentary contact (close to lower the setpoint)
Remote Start Permissive	External momentary contact (close to inhibit turbine startup)

In addition to the devices listed above, some minor configuration must be done.

- To use the Remote Speed Set, two configuration entries must be made:

Channel #	***Data***
48	Min. Governor Speed
49	Max. Governor Speed

- To use the Remote 2nd PID, set three configuration entries must be made:

Channel #	***Data***
56	Min. Pressure
57	Max. Pressure
71	0500

All other options require no additional configuration entries.

Optional I/O Assignments

I/O	***Required Field Devices (Customer Supplied)***
AI-1	Customer Remote Speed Set
AI-2A	2nd PID Measurement (Turbine Inlet Pressure)
AI-2B	2nd PID Measurement (Compressor or Pump Suction Pressure)
AI-3	Customer Remote 2nd PID Set
DI-1	Remote Start Contact
DI-2	Remote Stop Contact
DI-3	Remote Raise Contact
DI-4	Remote Lower Contact
DI-5	Start Permissive Contact

3.4 Machine Data Listing

ACON.020 MACHINE DATA LISTING					
FUNCTION	*****	***CH***	***DISPLAY***	***RANGE***	***UNITS***
SPEED USED	D	00	0	0-29999	RPM
ANALOG INPUT #1	D	01	0	0-29999	VARIES
ANALOG INPUT #2	D	02	0	0-29999	VARIES
ANALOG INPUT #3	D	03	0	0-29999	VARIES
ANALOG INPUT #4	D	04	0	0-29999	VARIES
SPEED REFERENCE	D	05	0	0-29999	RPM
2ND PID SETPOINT	D	06	0		VARIES

ACON.020 MACHINE DATA LISTING					
FUNCTION	*****	***CH***	***DISPLAY***	***RANGE***	***UNITS***
3RD PID SETPOINT	D	07	0		VARIES
ANALOG OUTPUT #1	D	08	0.0	0-100	PERCENT
ANALOG OUTPUT #2	D	09	0.0	0-100	PERCENT
SPEED INPUT #1	D	10	0	0-29999	RPM
SPEED INPUT #2	D	11	0	0-29999	RPM
* ACCELERATION RATE	K	12	_____	0-29999	RPM/MIN
MIN CRITICAL SPEED #1	K	13	0	0-29999	RPM
MAX CRITICAL SPEED #1	K	14	0	0-29999	RPM
* MIN GOVERNOR SPEED	K	15	_____	0-29999	RPM
* MAX GOVERNOR SPEED	K	16	_____	0-29999	RPM
* OVERSPEED TRIP SETTING	K	17	_____	0-29999	RPM
SPEED SWITCH #1 SET	K	18	0	0-29999	RPM
SPEED SWITCH #2 SET	K	19	0	0-29999	RPM
SPEED PROPORTIONAL BAND	T	20	50.0	0-1000	PERCENT
SPEED INTEGRAL (RESET)	T	21	5.0	0-500	SECONDS
SPEED DERIVATIVE (RATE)	T	22	0.0	0-200	SECONDS
SPEED DROOP	T	23	0.0	0-20	PERCENT
2ND PID PROPORTIONAL BAND	T	24	75.0	0-1000	PERCENT
2ND PID INTEGRAL (RESET)	T	25	10.0	0-500	SECONDS
2ND PID DERIVATIVE (RATE)	T	26	0.0	0-200	SECONDS
2ND PID DROOP	T	27	0.0	0-20	PERCENT
SYNCHRONIZING INTEGRAL	T	28	0.0	0-500	SECONDS
SYNCHRONIZING DERIVATIVE	T	29	0.0	0-200	SECONDS
3RD PID PROPORTIONAL BAND	T	30	0.0	0-1000	PERCENT
3RD PID INTEGRAL (RESET)	T	31	0.0	0-500	SECONDS
3RD PID DERIVATIVE (RATE)	T	32	0.0	0-200	SECONDS
3RD PID DROOP	T	33	0.0	0-20	PERCENT
V2 MIN LIMIT	K	34	0.0	0-100	PERCENT
V2 MAX LIMIT	K	35	0.0	0-100	PERCENT
IDLE SPEED	K	36	0	0-20000	RPM
IDLE FUEL	K	37	0	0-100	PERCENT
V1 MIN LIMIT	K	38	0.0	0-100	PERCENT
V1 MAX LIMIT	K	39	100.0	0-100	PERCENT
MIN #1 NOZZLE VALVE	K	40	0.0	0-100	PERCENT
MAX #1 NOZZLE VALVE	K	41	0.0	0-100	PERCENT
MIN #2 NOZZLE VALVE	K	42	0.0	0-100	PERCENT

ACON.020 MACHINE DATA LISTING					
FUNCTION	*****	***CH***	***DISPLAY***	***RANGE***	***UNITS***
MAX #2 NOZZLE VALVE	K	43	0.0	0-100	PERCENT
MIN #3 NOZZLE VALVE	K	44	0.0	0-100	PERCENT
MAX #3 NOZZLE VALVE	K	45	0.0	0-100	PERCENT
MIN ANALOG INPUT #1	K	46	1.0	0-10	VDC
MAX ANALOG INPUT #1	K	47	5.0	0-10	VDC
* MIN ENGRG UNITS #1	K	48	_____	0-29999	_____
* MAX ENGRG UNITS #1	K	49	_____	0-29999	_____
MIN ANALOG INPUT #2	K	50	1.0	0-10	VDC
MAX ANALOG INPUT #2	K	51	5.0	0-10	VDC
MIN ENGRG UNITS #2	K	52	_____	0-29999	_____
MAX ENGRG UNITS #2	K	53	_____	0-29999	_____
MIN ANALOG INPUT #3	K	54	1.0	0-10	VDC
MAX ANALOG INPUT #3	K	55	5.0	0-10	VDC
MIN ENGRG UNITS #3	K	56	_____	0-29999	_____
MAX ENGRG UNITS #3	K	57	_____	0-29999	_____
MIN ANALOG INPUT #4	K	58	0.0	0-10	VDC
MAX ANALOG INPUT #4	K	59	0.0	0-10	VDC
MIN ENGRG UNITS #4	K	60	0	0-29999	_____
MAX ENGRG UNITS #4	K	61	0	0-29999	_____
#1 ANALOG OUTPUT MIN	K	62	4.0	0-20	m AMPS
#1 ANALOG OUTPUT MAX	K	63	20.0	0-20	m AMPS
#2 ANALOG OUTPUT MIN	K	64	0.0	0-20	m AMPS
#2 ANALOG OUTPUT MAX	K	65	0.0	0-20	m AMPS
LOAD LIMIT	K	66	100.0	0-100	PERCENT
* SETPOINT RAMP RATE	K	67	_____	0-100	PERCENT
LOAD (KW) OVERRIDE RESET	T	68	0.0	0-500	PERCENT
PARALLEL ISOCH. DELAY	K	69	0	0-12	SEE MAN
ANALOG INPUT #1 & #2	K	70	0402	WORD #1	
ANALOG INPUT #3 & #4	K	71	0000	WORD #2	
CONTACT I/O #1	K	72	1001	WORD #3	
CONTACT I/O #2	K	73	1002	WORD #4	
CONTACT I/O #3	K	74	1003	WORD #5	
CONTACT I/O #4	K	75	1004	WORD #6	
CONTACT I/O #5	K	76	2013	WORD #7	
CONTACT I/O #6	K	77	0000	WORD #8	
CONTACT I/O #7	K	78	0000	WORD #9	

ACON.020 MACHINE DATA LISTING					
FUNCTION	*****	***CH***	***DISPLAY***	***RANGE***	***UNITS***
CONTACT I/O #8	K	79	3320	WORD #10	
SPEED CONTROL	K	80	0330	WORD #11	
SPEED CONTROL	K	81	0210	WORD #12	
SPEED CONTROL	K	82	3110	WORD #13	
2ND PID CONTROL	K	83	1100	WORD #14	
STATUS INDICATORS	K	84	1205	WORD #15 Some software releases had 1285 as Word 15. 1205 is correct and current software has been changed.	
SPEED SWITCH CONF.	K	85	0000	WORD #16	
3RD PID CONTROL	K	86	0000	WORD #17	
GENERATOR CONTROL	K	87	0000	WORD #18	
FAILSAFE SETTING	K	88	10	0-400	SECONDS
* GEAR TEETH	K	89	_____	0-320	TEETH
H VALUE	K	90	0.00	0-10.0	TEETH
F VALUE	K	91	0.00	0-10.0	PERCENT
B VALUE	K	92	0.0	0-100	PERCENT
GEAR RATIO	K	93	0.000	0-9.99	RATIO
STARTUP PROP. BAND	T	94	0.0	0-1000	SECONDS
STARTUP INTEGRAL (RESET)	T	95	0.0	0-500	SECONDS
HOUR METER	K	96	0	READS HOURS	
LAST SHUTDOWN	D	97	0000	RECORDS TRIPS	
COMPUTER ID	K	98	0	RS422 ADDRESS	
PASSWORD	K	99	6883	FOUR DIGITS	

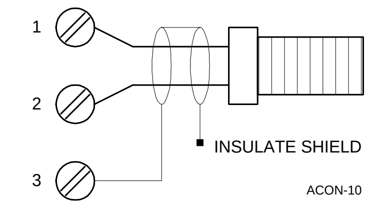
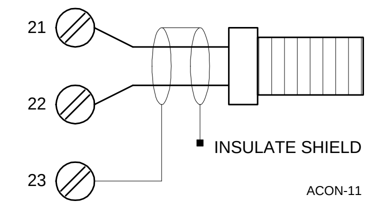
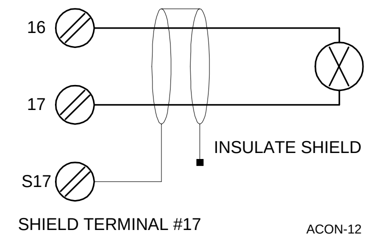
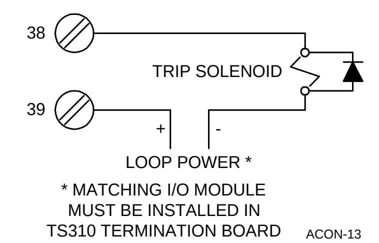
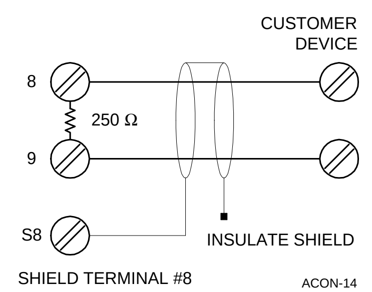
* The channels marked with the asterisks will require data entry before the *TS310* can be used.

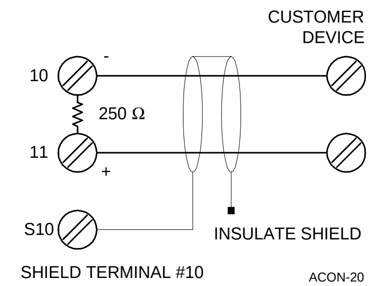
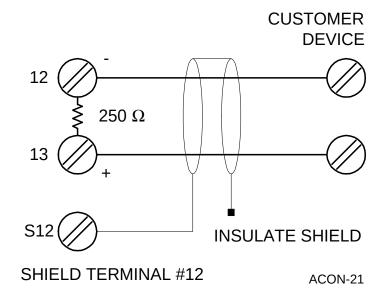
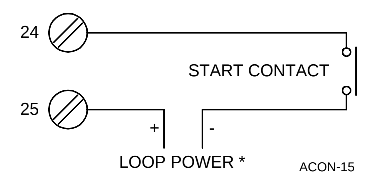
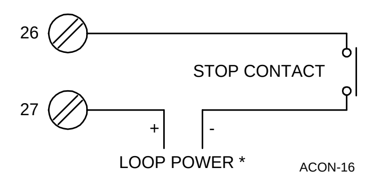
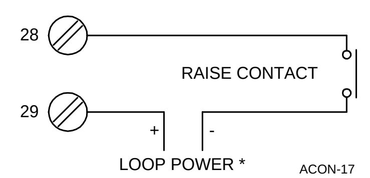
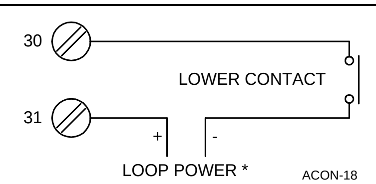
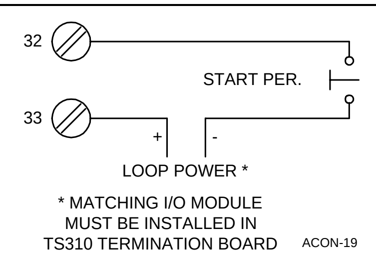
K = Channel is password protected.

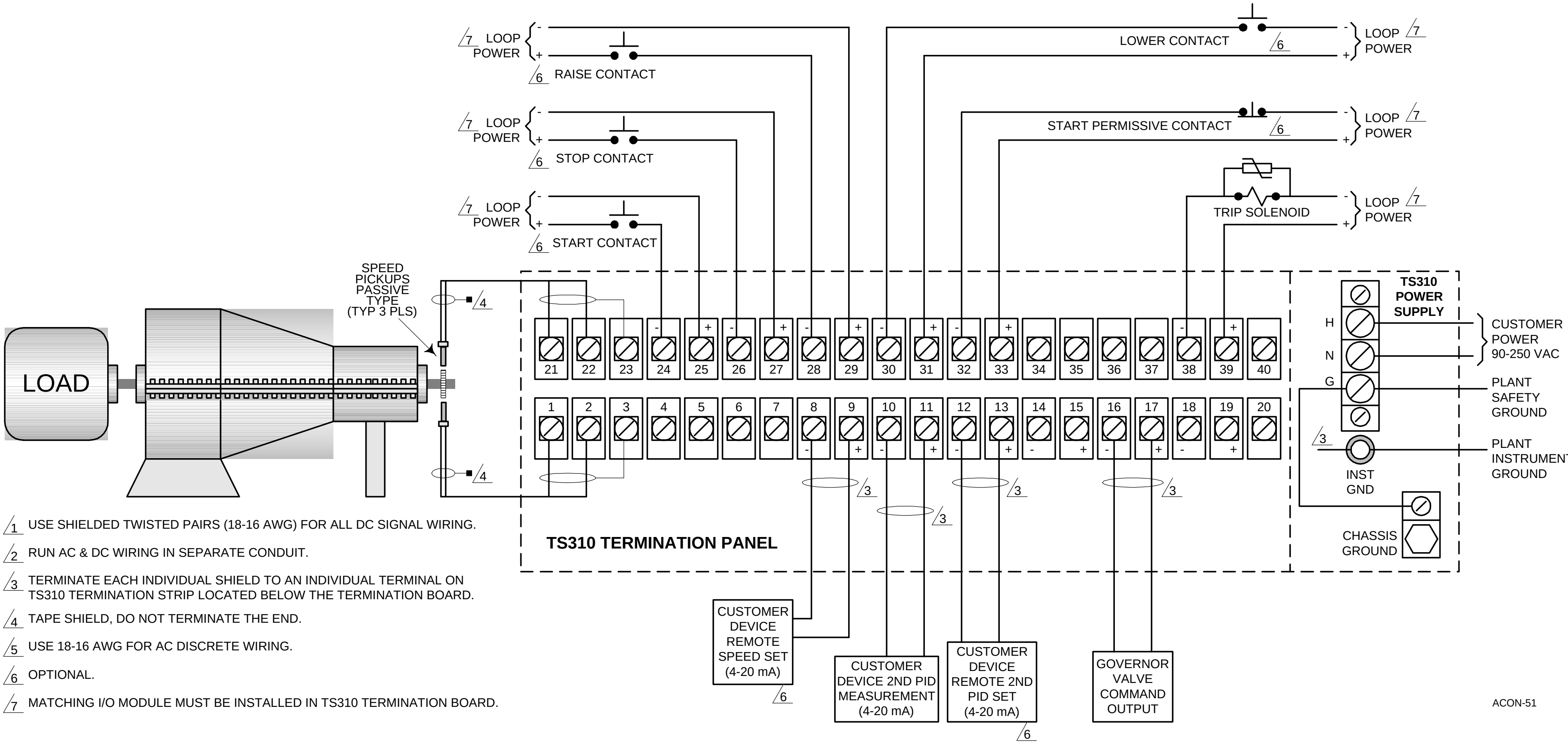
D = Channel for display only.

T = Channel contains tuning values.

3.5 Wiring

I/O	Device	Remarks	Wiring
PU-1	Speed Pickup	Standard Magnetic Speed Pickup TRISEN P/N 7120, 7121, etc.	
PU-2	Speed Pickup	Standard Magnetic Speed Pickup TRISEN P/N 7120, 7121, etc.	
AO-1	Actuator	Direct Acting 4-20 mA Governor Actuator, I/P Transducer, HCX21, etc.	
DO-8	Trip Solenoid	Trip Circuit Contact Output Opens Upon Pressing STOP Overspeed Trip Pickup Failure	
AI-1	Customer Signal	4-20 mA Signal From Customer Device for Remote Speed Setpoint	

I/O	Device	Remarks	Wiring
AI-2A or AI-2B	Customer Signal	4-20 mA Signal From Customer Device for 2nd PID Measurement	
AI-3	Customer Signal	4-20 mA Signal From Customer Device for Remote 2nd PID Setpoint	
DI-1	Remote Start Contact	Close Contact to Start Turbine	
DI-2	Remote Stop Contact	Close Contact to Trip Turbine	
DI-3	Remote Raise Contact	Close Contact to Ramp Turbine Speed Up	
DI-4	Remote Lower Contact	Close Contact to Ramp Turbine Speed Down	
DI-5	Start Permissive Contact	Close Contact to Inhibit Turbine Start	



1. USE SHIELDED TWISTED PAIRS (18-16 AWG) FOR ALL DC SIGNAL WIRING.
2. RUN AC & DC WIRING IN SEPARATE CONDUIT.
3. TERMINATE EACH INDIVIDUAL SHIELD TO AN INDIVIDUAL TERMINAL ON TS310 TERMINATION STRIP LOCATED BELOW THE TERMINATION BOARD.
4. TAPE SHIELD, DO NOT TERMINATE THE END.
5. USE 18-16 AWG FOR AC DISCRETE WIRING.
6. OPTIONAL.
7. MATCHING I/O MODULE MUST BE INSTALLED IN TS310 TERMINATION BOARD.

Figure 5. ACON.020 Wiring Diagram

Chapter 4 - Backpressure/Discharge Pressure Control ACON.021

4.1 Application Description

ACON.21 is a preset configuration that allows the 2nd Proportional, Integral, Derivative (PID) to control either backpressure (exhaust) or discharge pressure. This configuration provides:

Speed control.

Backpressure/Discharge pressure control

Raise/Lower speed changing within the governor range

Raise/Lower Backpressure/Discharge pressure

Dual pickup inputs

Loss of speed signal fail-safe

Fail-safe bypass timer (10 seconds)

Overspeed trip and test

Auto-start capability

Trip contact output

Status Indicators for:
- Pickup Fail
- Overspeed Trip
- Trip Output
- 2nd PID Enabled

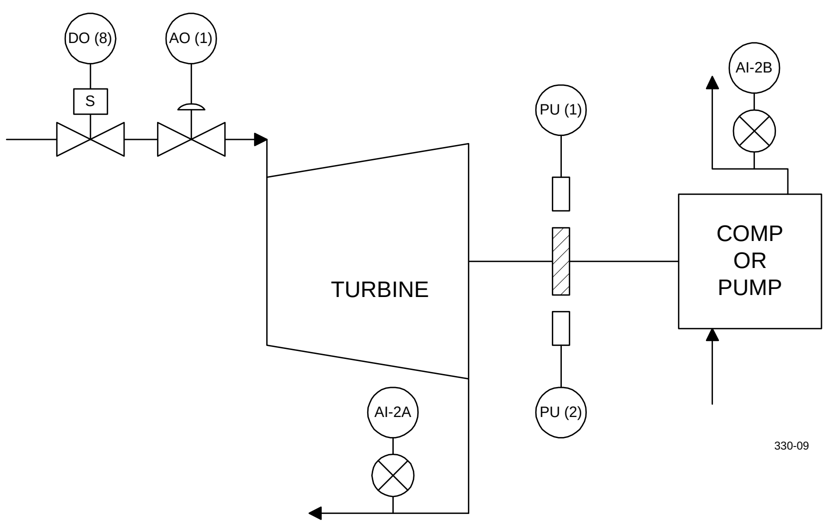


Figure 6. ACON.021 Backpressure/Discharge Pressure Control Typical Application

Startup

Startup can be manual or automatic.

Manual Start. The operator presses the *TS310* [START] button then opens the steam block or T&T valve slowly to bring the machine up to governor speed.

Auto Start. The block valve is left open. Pressing [START] ramps the governor valve open and rapidly controls the machine up to the governor speed. This mode of operation is sometimes called "Fast Start".

Shutdown

The machine will trip on any of the following conditions:

Failure of both pickups

Speed exceeding the limit set in channel 17

Manual operation of the *TS310* [STOP] button

A trip causes the governor valve to close and causes trip output contact to open.

Speed Control

After startup machine speed will be controlled to the speed displayed in CH05 (generally minimum governor speed). Upon reaching minimum governor, the speed can be changed by pressing [s] raise or [t] lower or by entering a new setpoint into channel 05.

Enable/Disable Backpressure/Discharge Pressure Control

Backpressure/Discharge pressure control can be enabled and disabled at any time while the machine is operating in the governor control range.

Enabling pressure control is done using the [F1] button. As soon as the machine has reached minimum governor control, pressing [F1] will enable the pressure controller. After you enable the pressure controller the fourth indicator from the left will indicate pressure control.

Disabling the control is done using the [F1] button. At any time speed control is desired instead of pressure control [F1] is pressed. The status indicator will disappear and the machine will return to speed control.

The pressure control setpoint is changed in a similar manner as speed control setpoint. The pressure setpoint is displayed in channel 06. The [s] raise or [t] lower buttons will change the setpoint. Channel 06 is used to enter the setpoint directly.

Overspeed Trip And Test

This configuration provides an electronic overspeed trip feature as a backup to the primary overspeed trip. It also provides a method for overspeed test.

Input/Output

Field devices required for the basic configuration are described below. Refer to the wiring chapter of ACON.020 for field connections.

- **Two magnetic speed pickups**
  Recommended types:
  TRISEN #7120
  TRISEN #7121
  A ferrous toothed gear is also required. TRISEN can provide the proper gear upon request.

- **Governor/transducer**: A 4-20 mA actuator system is required. Action must be direct (eg. 4 mA fully closes the steam valve, 20 mA fully opens the steam valve).
  Examples are:
  TRISEN #9907 I/P transducer with pneumatic actuator
  TRISEN #HCX21 electro-hydraulic transducer

- **Backpressure/Discharge pressure input transducer**: A transducer must be provided that will input a current or voltage signal that represents the actual backpressure/ discharge pressure to the *TS310*. This information will be supplied to the #1 analog input channel.

- **Trip output contact**: A trip output is configured for digital output position 8. An output relay module, with the correct rating, must be installed in eighth position on the termination board. This contact is configured to close on a trip condition.

Status Indicators

Status indicators on the *TS310* display are configured from left to right as follows:

Indicator #	***Function***
1	Speed Pickup Failure
2	Overspeed Trip
3	Trip Output
4	Cascade Closed (Pressure Control Enabled)

4.2 Required Additional Entries

Description	*CH#*
Min. Governor	15
Max. Governor	16
Overspeed Set	17
Speed Tuning	20-22
2nd PID Tuning	24-26
Setpoint Ramp Rate	67
No. Gear Teeth	89
Analog Input	52-53 (Preset: 50=1.00, 51=5.00)

I/O Assignments	
Speed Pickup #1	PU-1
Speed Pickup #2	PU-2
Governor Valve	AO-1
Trip Contact	DO-8
2nd PID Input	AI-1A or AI-1B

4.3 Options

In addition to the standard features ACON.021 supports the following options:

Option	*Requires*
Remote Speed Set	4-20 mA External Input
Remote 2nd PID Set	4-20 mA External Input
Remote Start	External momentary contact (close to start)
Remote Stop	External momentary contact (close to trip the turbine)
Remote Raise	External momentary contact (close to raise the setpoint)
Remote Lower	External momentary contact (close to lower the setpoint)
Remote Start Permissive	External momentary contact (close to inhibit turbine startup)

In addition to the devices listed above some minor configuration must be done.

- To use the **Remote Speed Set** two configuration entries must be made:

Channel #	*Data*
48	Min. Governor Speed
49	Max. Governor Speed

- To use the **Remote 2nd PID** set three configuration entries must be made:

Channel #	*Data*
56	Min. Pressure
57	Max. Pressure
71	0500

All other options require no additional configuration entries.

Optional I/O Assignments

I/O	***Required Field Device (Customer Supplied)***
AI-1	Customer Remote Speed Set
AI-2A	2nd PID Measurement (Turbine Backpressure)
AI-2B	2nd PID Measurement (Compressor or Pump Discharge Pressure)
AI-3	Customer Remote 2nd PID Set
DI-1	Remote Start Contact
DI-2	Remote Stop Contact
DI-3	Remote Raise Contact
DI-4	Remote Lower Contact
DI-5	Start Permissive Contact

4.4 Machine Data Listing

ACON.021 MACHINE DATA LISTING					
FUNCTION		***CH***	***DISPLAY***	***RANGE***	***UNITS***
SPEED USED	D	00	0	0-29999	RPM
ANALOG INPUT #1	D	01	0	0-29999	VARIES
ANALOG INPUT #2	D	02	0	0-29999	VARIES
ANALOG INPUT #3	D	03	0	0-29999	VARIES
ANALOG INPUT #4	D	04	0	0-29999	VARIES
SPEED REFERENCE	D	05	0	0-29999	RPM
2ND PID SETPOINT	D	06	0	VARIES	
3RD PID SETPOINT	D	07	0	VARIES	
ANALOG OUTPUT #1	D	08	0.0	0-100	PERCENT
ANALOG OUTPUT #2	D	09	0.0	0-100	PERCENT
SPEED INPUT #1	D	10	0	0-29999	RPM
SPEED INPUT #2	D	11	0	0-29999	RPM
* ACCELERATION RATE	K	12	_____	0-29999	RPM/MIN
MIN CRITICAL SPEED #1	K	13	0	0-29999	RPM
MAX CRITICAL SPEED #1	K	14	0	0-29999	RPM
* MIN GOVERNOR SPEED	K	15	_____	0-29999	RPM
* MAX GOVERNOR SPEED	K	16	_____	0-29999	RPM
* OVERSPEED TRIP SETTING	K	17	_____	0-29999	RPM
SPEED SWITCH #1 SET	K	18	0	0-29999	RPM
SPEED SWITCH #2 SET	K	19	0	0-29999	RPM

ACON.021 MACHINE DATA LISTING					
FUNCTION		***CH***	***DISPLAY***	***RANGE***	***UNITS***
SPEED PROPORTIONAL BAND	T	20	50.0	0-1000	PERCENT
SPEED INTEGRAL (RESET)	T	21	5.0	0-500	SECONDS
SPEED DERIVATIVE (RATE)	T	22	0.0	0-200	SECONDS
SPEED DROOP	T	23	0.0	0-20	PERCENT
2ND PID PROPORTIONAL BAND	T	24	75.0	0-1000	PERCENT
2ND PID INTEGRAL (RESET)	T	25	10.0	0-500	SECONDS
2ND PID DERIVATIVE (RATE)	T	26	0.0	0-200	SECONDS
2ND PID DROOP	T	27	0.0	0-20	PERCENT
SYNCHRONIZING INTEGRAL	T	28	0.0	0-500	SECONDS
SYNCHRONIZING DERIVATIVE	T	29	0.0	0-200	SECONDS
3RD PID PROPORTIONAL BAND	T	30	0.0	0-1000	PERCENT
3RD PID INTEGRAL (RESET)	T	31	0.0	0-500	SECONDS
3RD PID DERIVATIVE (RATE)	T	32	0.0	0-200	SECONDS
3RD PID DROOP	T	33	0.0	0-20	PERCENT
V2 MIN LIMIT	K	34	0.0	0-100	PERCENT
V2 MAX LIMIT	K	35	0.0	0-100	PERCENT
IDLE SPEED	K	36	0	0-20000	RPM
IDLE FUEL	K	37	0	0-100	PERCENT
V1 MIN LIMIT	K	38	0.0	0-100	PERCENT
V1 MAX LIMIT	K	39	100.0	0-100	PERCENT
MIN #1 NOZZLE VALVE	K	40	0.0	0-100	PERCENT
MAX #1 NOZZLE VALVE	K	41	0.0	0-100	PERCENT
MIN #2 NOZZLE VALVE	K	42	0.0	0-100	PERCENT
MAX #2 NOZZLE VALVE	K	43	0.0	0-100	PERCENT
MIN #3 NOZZLE VALVE	K	44	0.0	0-100	PERCENT
MAX #3 NOZZLE VALVE	K	45	0.0	0-100	PERCENT
MIN ANALOG INPUT #1	K	46	1.0	0-10	VDC
MAX ANALOG INPUT #1	K	47	5.0	0-10	VDC
* MIN ENGRG UNITS #1	K	48	_____	0-29999	_____
* MAX ENGRG UNITS #1	K	49	_____	0-29999	_____
MIN ANALOG INPUT #2	K	50	1.0	0-10	VDC
MAX ANALOG INPUT #2	K	51	5.0	0-10	VDC
MIN ENGRG UNITS #2	K	52	_____	0-29999	_____
MAX ENGRG UNITS #2	K	53	_____	0-29999	_____
MIN ANALOG INPUT #3	K	54	1.0	0-10	VDC
MAX ANALOG INPUT #3	K	55	5.0	0-10	VDC

ACON.021 MACHINE DATA LISTING					
FUNCTION		***CH***	***DISPLAY***	***RANGE***	***UNITS***
MIN ENGRG UNITS #3	K	56	_____	0-29999	_____
MAX ENGRG UNITS #3	K	57	_____	0-29999	_____
MIN ANALOG INPUT #4	K	58	0.0	0-10	VDC
MAX ANALOG INPUT #4	K	59	0.0	0-10	VDC
MIN ENGRG UNITS #4	K	60	0	0-29999	_____
MAX ENGRG UNITS #4	K	61	0	0-29999	_____
#1 ANALOG OUTPUT MIN	K	62	4.0	0-20	m AMPS
#1 ANALOG OUTPUT MAX	K	63	20.0	0-20	m AMPS
#2 ANALOG OUTPUT MIN	K	64	0.0	0-20	m AMPS
#2 ANALOG OUTPUT MAX	K	65	0.0	0-20	m AMPS
LOAD LIMIT	K	66	100.0	0-100	PERCENT
* SETPOINT RAMP RATE	K	67	_____	0-100	PERCENT
LOAD (KW) OVERRIDE RESET	T	68	0.0	0-500	PERCENT
PARALLEL ISOCH. DELAY	K	69	0	0-12	SEE MAN
ANALOG INPUT #1 & #2	K	70	0402	WORD #1	
ANALOG INPUT #3 & #4	K	71	0000	WORD #2	
CONTACT I/O #1	K	72	1001	WORD #3	
CONTACT I/O #2	K	73	1002	WORD #4	
CONTACT I/O #3	K	74	1003	WORD #5	
CONTACT I/O #4	K	75	1004	WORD #6	
CONTACT I/O #5	K	76	2013	WORD #7	
CONTACT I/O #6	K	77	0000	WORD #8	
CONTACT I/O #7	K	78	0000	WORD #9	
CONTACT I/O #8	K	79	3320	WORD #10	
SPEED CONTROL	K	80	0330	WORD #11	
SPEED CONTROL	K	81	0210	WORD #12	
SPEED CONTROL	K	82	3110	WORD #13	
2ND PID CONTROL	K	83	2100	WORD #14	
STATUS INDICATORS	K	84	1205	WORD #15 Some software releases had 1285 as Word 15. 1205 is correct and current software has been changed.	
SPEED SWITCH CONF.	K	85	0000	WORD #16	
3RD PID CONTROL	K	86	0000	WORD #17	
GENERATOR CONTROL	K	87	0000	WORD #18	
FAILSAFE SETTING	K	88	10	0-400	SECONDS
* GEAR TEETH	K	89	_____	0-320	TEETH
H VALUE	K	90	0.00	0-10.0	TEETH

ACON.021 MACHINE DATA LISTING					
FUNCTION		***CH***	***DISPLAY***	***RANGE***	***UNITS***
F VALUE	K	91	0.00	0-10.0	PERCENT
B VALUE	K	92	0.0	0-100	PERCENT
GEAR RATIO	K	93	0.000	0-9.99	RATIO
STARTUP PROP. BAND	T	94	0.0	0-1000	SECONDS
STARTUP INTEGRAL (RESET)	T	95	0.0	0-500	SECONDS
HOUR METER	K	96	0	READS HOURS	
LAST SHUTDOWN	D	97	0000	RECORDS TRIPS	
COMPUTER ID	K	98	0	RS422 ADDRESS	
PASSWORD	K	99	6883	FOUR DIGITS	

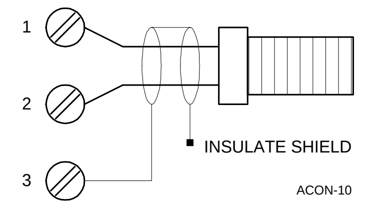
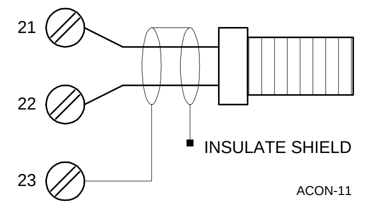
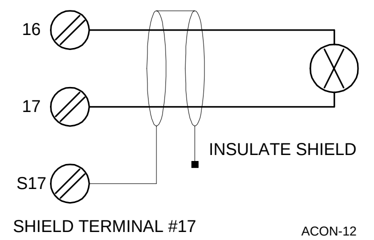
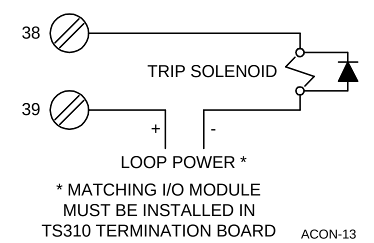
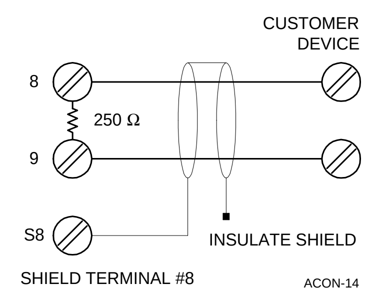
* The channels marked with the asterisks will require data entry before the *TS310* can be used.

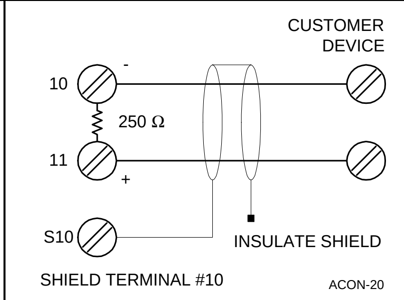
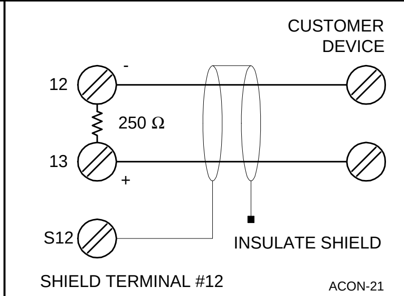
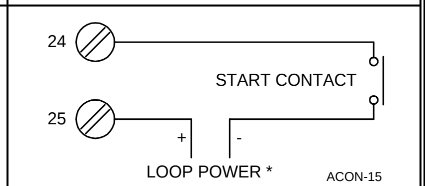
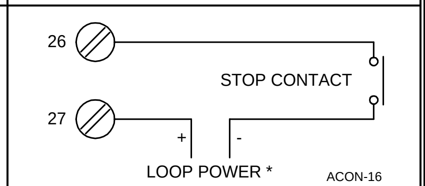
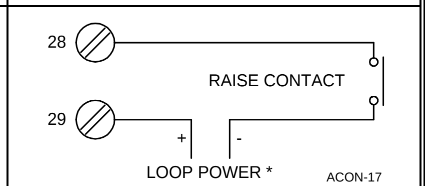
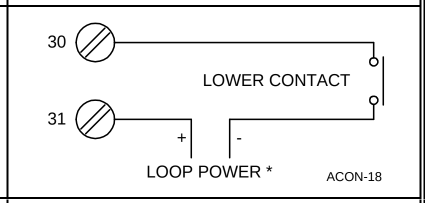
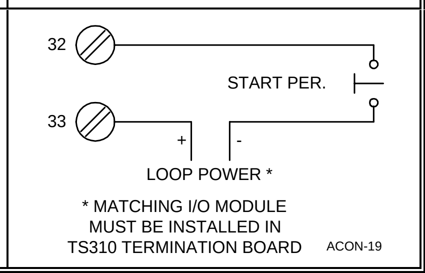
K = Channel is password protected.

D = Channel for display only.

T = Channel contains tuning values.

4.5 Wiring

I/O	Device	Remarks	Wiring
PU-1	Speed Pickup	Standard Magnetic Speed Pickup TRISEN P/N 7120, 7121, etc.	
PU-2	Speed Pickup	Standard Magnetic Speed Pickup TRISEN P/N 7120, 7121, etc.	
AO-1	Actuator	Direct Acting 4-20 mA Governor Actuator, I/P Transducer, HCX21, etc.	
DO-8	Trip Solenoid	Trip Circuit Contact Output Opens Upon Pressing STOP Overspeed Trip Pickup Failure	
AI-1	Customer Signal	4-20 mA Signal From Customer Device for Remote Speed Setpoint	

I/O	Device	Remarks	Wiring
AI-2A or AI-2B	Customer Signal	4-20 mA Signal From Customer Device for 2nd PID Measurement	
AI-3	Customer Signal	4-20 mA Signal From Customer Device for Remote 2nd PID Setpoint	
DI-1	Remote Start Contact	Close Contact to Start Turbine	
DI-2	Remote Stop Contact	Close Contact to Trip Turbine	
DI-3	Remote Raise Contact	Close Contact to Ramp Turbine Speed Up	
DI-4	Remote Lower Contact	Close Contact to Ramp Turbine Speed Down	
DI-5	Start Permissive Contact	Close Contact to Inhibit Turbine Start	

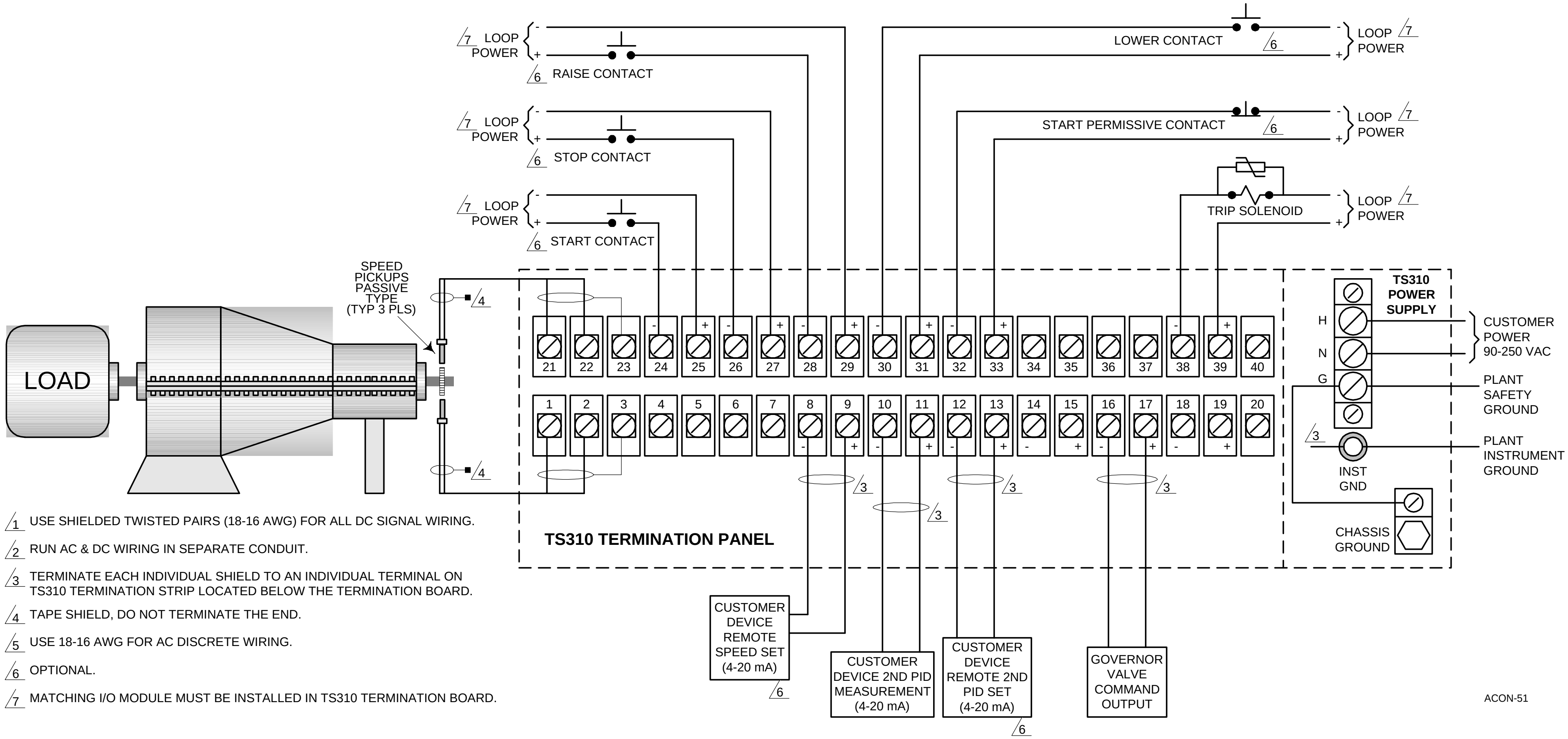


Figure 7. ACON.021 Wiring Diagram

Chapter 5 - Synchronous Generator Control ACON.030

5.1 Application Description

ACON.30 provides a preset configuration for a basic synchronous generator control. It provides:

Speed control.

Synchronous generator control

(droop only)

Raise/Lower speed changing within the governor range

Raise/Lower generator load

Dual pickup inputs

Loss of speed signal fail-safe

Fail-safe bypass timer (10 seconds)

Overspeed trip and test

Auto-start capability

Trip contact output

Status Indicators for:
Pickup Fail
Overspeed Trip
Trip Output
Load Breaker Closed

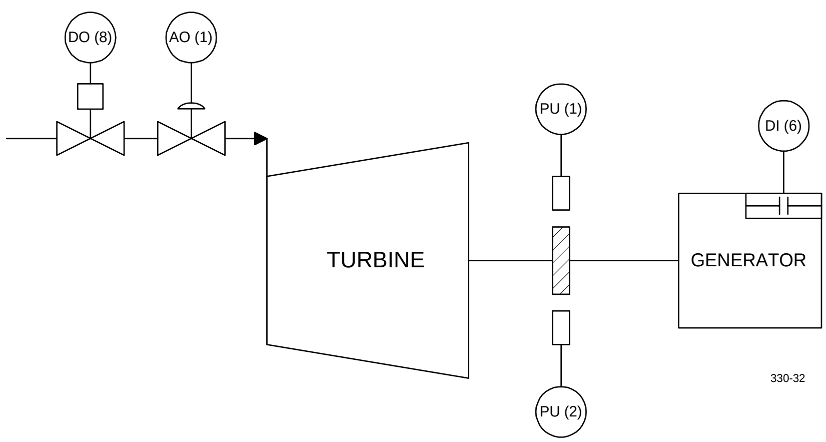


Figure 8. ACON.030 Synchronous Generator Control Typical Application

Startup

Startup can be manual or automatic.

Manual Start. The operator presses the *TS310* [START] button then opens the steam block or T&T valve slowly to bring the machine up to governor speed.

Auto Start. The block valve is left open. Pressing [START] ramps the governor valve open and rapidly controls the machine up to the governor speed. This mode of operation is sometimes called "Fast Start".

Shutdown

The machine will trip on any of the following conditions:

Failure of both pickups

Speed exceeding the limit set in channel 17

Manual operation of the *TS310* [STOP] button

A trip causes closure of the governor valve and opening of the trip output contact.

Speed Control

After startup machine speed will be controlled to the speed displayed in CH05 (generally minimum governor speed). Upon reaching minimum governor, the speed can be changed by pressing [s] raise or [t] lower or by entering a new setpoint into channel 05.

Synchronous Generator Control

ACON.030 provides 4% droop only control for synchronous generator control. The *TS310* will start up in isochronous (frequency) control. After the generator has been synchronized and the load breaker closes, the *TS310* will go into droop control. When the load breaker opens while in droop, the *TS310* will go back to isochronous control. The droop control will droop on the output of the *TS310* in this application. One of the few entries required to use this program is the minimum governor speed. *TS310* will automatically add 100 RPM to the requested minimum governor speed so that the generator will take on a small portion of the load when the breaker closes. To increase or decrease the load you need only use the [s] raise or [t] lower key.

Overspeed Trip And Test

This configuration provides an electronic overspeed trip feature as a backup to the primary overspeed trip. It also provides a method for overspeed test.

Input/Output

Field devices required for the basic configuration are described below. Refer to the wiring chapter of ACON.030 for field connections.

- **Two magnetic speed pickups**
  Recommended types:
  TRISEN #7120
  TRISEN #7121
  A ferrous toothed gear is also required. TRISEN can provide the proper gear upon request.

- **Governor/transducer**: A 4-20 mA actuator system is required. Action must be direct (e.g., 4 mA fully closes the steam valve, 20 mA fully opens the steam valve).
  Examples are:
  TRISEN #9907 I/P transducer with pneumatic actuator
  TRISEN #HCX21 electro-hydraulic transducer

- **KW Transducer**: A transducer must be provided that will input a current or voltage signal that represents the actual KW to the *TS310*. This information will be supplied to the #1 analog input channel.

- **Trip output contact**: A trip output is configured for digital output position 8. An output relay module must, with the correct rating, be installed in eighth position on the termination board. This contact is configured to close on a trip condition.

Status Indicators

Status indicators on the *TS310* display are configured from left to right as follows:

Indicator #	***Function***
1	Speed Pickup Failure
2	Overspeed Trip
3	Trip Output
4	Load Breaker Closed

5.2 Required Additional Entries

Description	*CH#*
Min. Governor	15
Max. Governor	16
Overspeed Set	17
Speed Tuning	20-23
Setpoint Ramp Rate	67
No. Gear Teeth	89
Analog Input	46-53

I/O Assignments	
Speed Pickup #1	PU-1
Speed Pickup #2	PU-2
Governor Valve	AO-1
Trip Contact	DO-1
Load Breaker	DI-6

5.3 Options

In addition to the standard features ACON.030 supports the following options:

Option	*Requires*
Remote Speed Set	4-20 mA External Input
KW Signal	4-20 mA External Input
Remote KW Set	4-20 mA External Input
Remote Start	External momentary contact (close to start)
Remote Stop	External momentary contact (close to trip the turbine)
Remote Raise	External momentary contact (close to raise the setpoint)
Remote Lower	External momentary contact (close to lower the setpoint)
Remote Start Permissive	External contact (close to inhibit turbine startup)

In addition to the devices listed above some minor configuration must be done.

- To use the Remote Speed Set you must make two entries into the configuration:

Channel #	***Data***
48	Min. Governor Speed
49	Max. Governor Speed

- To use the KW Limiting function the following additions and changes to the configuration must be made:

Channel #	***Data***
50	Min. Signal In
51	Max. Signal In
52	Min. KW
53	Max. KW
68	KW Override Reset
70	0403
87	0010

All other options require no additional configuration entries.

- To use the remote KW setpoint the following additions and changes to the configuration must be made:

Channel #	***Data***
54	Min. Signal In
55	Max. Signal In
56	Min. KW
57	Max. KW
71	2000

All other options require no configuration entries.

Optional I/O Assignments

I/O	***Required Field Device (Customer Supplied)***
AI-1	Customer Remote Speed Set
DI-1	Remote Start Contact
DI-2	Remote Stop Contact
DI-3	Remote Raise Contact
DI-4	Remote Lower Contact
DI-5	Start Permissive Contact
DI-6	Load Breaker Contact

5.4 Machine Data Listing

ACON.030 MACHINE DATA LISTING					
FUNCTION	*	*CH*	*DISPLAY*	*RANGE*	*UNITS*
SPEED USED	D	00	0	0-29999	RPM
ANALOG INPUT #1	D	01	0	0-29999	VARIES
ANALOG INPUT #2	D	02	0	0-29999	VARIES
ANALOG INPUT #3	D	03	0	0-29999	VARIES
ANALOG INPUT #4	D	04	0	0-29999	VARIES
SPEED REFERENCE	D	05	0	0-29999	RPM
2ND PID SETPOINT	D	06	0	VARIES	
3RD PID SETPOINT	D	07	0	VARIES	
ANALOG OUTPUT #1	D	08	0.0	0-100	PERCENT
ANALOG OUTPUT #2	D	09	0.0	0-100	PERCENT
SPEED INPUT #1	D	10	0	0-29999	RPM
SPEED INPUT #2	D	11	0	0-29999	RPM
* ACCELERATION RATE	K	12	_____	0-29999	RPM/MIN
MIN CRITICAL SPEED #1	K	13	0	0-29999	RPM
MAX CRITICAL SPEED #1	K	14	0	0-29999	RPM
* MIN GOVERNOR SPEED	K	15	_____	0-29999	RPM
* MAX GOVERNOR SPEED	K	16	_____	0-29999	RPM
* OVERSPEED TRIP SETTING	K	17	_____	0-29999	RPM
SPEED SWITCH #1 SET	K	18	0	0-29999	RPM
SPEED SWITCH #2 SET	K	19	0	0-29999	RPM
SPEED PROPORTIONAL BAND	T	20	50.0	0-1000	PERCENT
SPEED INTEGRAL (RESET)	T	21	5.0	0-500	SECONDS
SPEED DERIVATIVE (RATE)	T	22	0.0	0-200	SECONDS
SPEED DROOP	T	23	4.0	0-20	PERCENT
2ND PID PROPORTIONAL BAND	T	24	0.0	0-1000	PERCENT
2ND PID INTEGRAL (RESET)	T	25	0.0	0-500	SECONDS
2ND PID DERIVATIVE (RATE)	T	26	0.0	0-200	SECONDS
2ND PID DROOP	T	27	0.0	0-20	PERCENT
SYNCHRONIZING INTEGRAL	T	28	0.0	0-500	SECONDS
SYNCHRONIZING DERIVATIVE	T	29	0.0	0-200	SECONDS
3RD PID PROPORTIONAL BAND	T	30	0.0	0-1000	PERCENT
3RD PID INTEGRAL (RESET)	T	31	0.0	0-500	SECONDS
3RD PID DERIVATIVE (RATE)	T	32	0.0	0-200	SECONDS
3RD PID DROOP	T	33	0.0	0-20	PERCENT

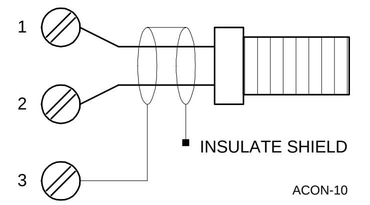
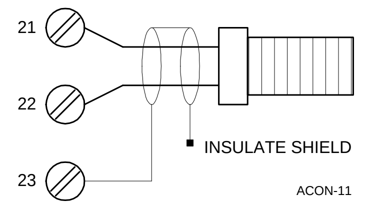
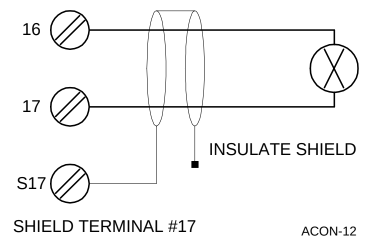
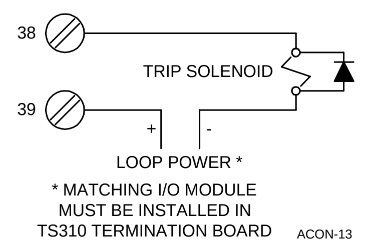
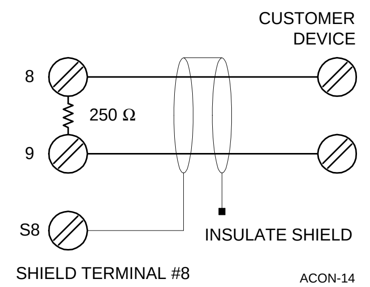
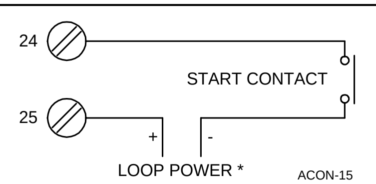
ACON.030 MACHINE DATA LISTING					
FUNCTION	*****	***CH***	***DISPLAY***	***RANGE***	***UNITS***
V2 MIN LIMIT	K	34	0.0	0-100	PERCENT
V2 MAX LIMIT	K	35	0.0	0-100	PERCENT
IDLE SPEED	K	36	0	0-20000	RPM
IDLE FUEL	K	37	0	0-100	PERCENT
V1 MIN LIMIT	K	38	0.0	0-100	PERCENT
V1 MAX LIMIT	K	39	100.0	0-100	PERCENT
MIN #1 NOZZLE VALVE	K	40	0.0	0-100	PERCENT
MAX #1 NOZZLE VALVE	K	41	0.0	0-100	PERCENT
MIN #2 NOZZLE VALVE	K	42	0.0	0-100	PERCENT
MAX #2 NOZZLE VALVE	K	43	0.0	0-100	PERCENT
MIN #3 NOZZLE VALVE	K	44	0.0	0-100	PERCENT
MAX #3 NOZZLE VALVE	K	45	0.0	0-100	PERCENT
MIN ANALOG INPUT #1	K	46	1.0	0-10	VDC
MAX ANALOG INPUT #1	K	47	5.0	0-10	VDC
* MIN ENGRG UNITS #1	K	48	_____	0-29999	_____
* MAX ENGRG UNITS #1	K	49	_____	0-29999	_____
MIN ANALOG INPUT #2	K	50	1.0	0-10	VDC
MAX ANALOG INPUT #2	K	51	5.0	0-10	VDC
MIN ENGRG UNITS #2	K	52	_____	0-29999	_____
MAX ENGRG UNITS #2	K	53	_____	0-29999	_____
MIN ANALOG INPUT #3	K	54	1.0	0-10	VDC
MAX ANALOG INPUT #3	K	55	5.0	0-10	VDC
MIN ENGRG UNITS #3	K	56	_____	0-29999	_____
MAX ENGRG UNITS #3	K	57	_____	0-29999	_____
MIN ANALOG INPUT #4	K	58	0.0	0-10	VDC
MAX ANALOG INPUT #4	K	59	0.0	0-10	VDC
MIN ENGRG UNITS #4	K	60	0	0-29999	_____
MAX ENGRG UNITS #4	K	61	0	0-29999	_____
#1 ANALOG OUTPUT MIN	K	62	4.0	0-20	m AMPS
#1 ANALOG OUTPUT MAX	K	63	20.0	0-20	m AMPS
#2 ANALOG OUTPUT MIN	K	64	0.0	0-20	m AMPS
#2 ANALOG OUTPUT MAX	K	65	0.0	0-20	m AMPS
LOAD LIMIT	K	66	100.0	0-100	PERCENT
* SETPOINT RAMP RATE	K	67	_____	0-100	PERCENT
LOAD (KW) OVERRIDE RESET	T	68	0.0	0-500	PERCENT
PARALLEL ISOCH. DELAY	K	69	0	0-12	SEE MAN

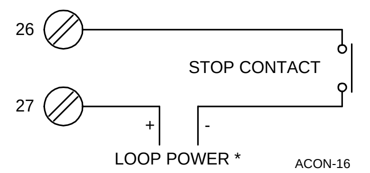
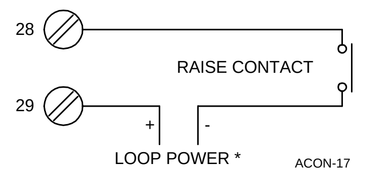
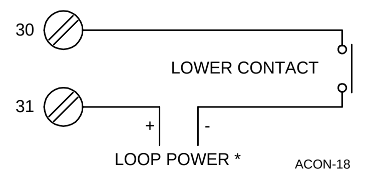
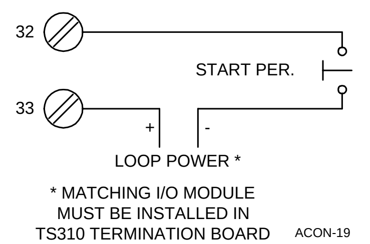
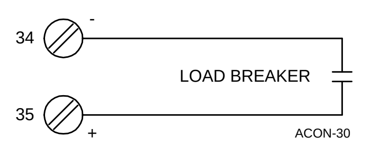
ACON.030 MACHINE DATA LISTING					
FUNCTION	*****	***CH***	***DISPLAY***	***RANGE***	***UNITS***
ANALOG INPUT #1 & #2	K	70	0400	WORD #1	
ANALOG INPUT #3 & #4	K	71	0000	WORD #2	
CONTACT I/O #1	K	72	1001	WORD #3	
CONTACT I/O #2	K	73	1002	WORD #4	
CONTACT I/O #3	K	74	1003	WORD #5	
CONTACT I/O #4	K	75	1004	WORD #6	
CONTACT I/O #5	K	76	2013	WORD #7	
CONTACT I/O #6	K	77	1405	WORD #8	
CONTACT I/O #7	K	78	0000	WORD #9	
CONTACT I/O #8	K	79	3320	WORD #10	
SPEED CONTROL	K	80	0331	WORD #11	
SPEED CONTROL	K	81	0210	WORD #12	
SPEED CONTROL	K	82	3110	WORD #13	
2ND PID CONTROL	K	83	0000	WORD #14	
STATUS INDICATORS	K	84	1200	WORD #15 Some software releases had 1280 as Word 15. 1200 is correct and current software has been changed.	
SPEED SWITCH CONF.	K	85	0000	WORD #16	
3RD PID CONTROL	K	86	0000	WORD #17	
GENERATOR CONTROL	K	87	0000	WORD #18	
FAILSAFE SETTING	K	88	10	0-400	SECONDS
* GEAR TEETH	K	89	_____	0-320	TEETH
H VALUE	K	90	0.00	0-10.0	TEETH
F VALUE	K	91	0.00	0-10.0	PERCENT
B VALUE	K	92	0.0	0-100	PERCENT
GEAR RATIO	K	93	0.000	0-9.99	RATIO
STARTUP PROP. BAND	T	94	0.0	0-1000	SECONDS
STARTUP INTEGRAL (RESET)	T	95	0.0	0-500	SECONDS
HOUR METER	K	96	0	READS HOURS	
LAST SHUTDOWN	D	97	0000	RECORDS TRIPS	
COMPUTER ID	K	98	0	RS422 ADDRESS	
PASSWORD	K	99	6883	FOUR DIGITS	

* The channels marked with the asterisks will require data entry before the *TS310* can be used.

K = Channel is password protected.
D = Channel for display only.
T = Channel contains tuning values.

5.5 Wiring

I/O	Device	Remarks	Wiring
PU-1	Speed Pickup	Standard Magnetic Speed Pickup TRISEN P/N 7120, 7121, etc.	
PU-2	Speed Pickup	Standard Magnetic Speed Pickup TRISEN P/N 7120, 7121, etc.	
AO-1	Actuator	Direct Acting 4-20 mA Governor Actuator, I/P Transducer, HCX21, etc.	
DO-8	Trip Solenoid	Trip Circuit Contact Output Opens Upon Pressing STOP Overspeed Trip Pickup Failure	
AI-1	Customer Signal	4-20 mA Signal From Customer Device for Remote Speed Setpoint	
DI-1	Remote Start Contact	Close Contact to Start Turbine	

I/O	Device	Remarks	Wiring
DI-2	Remote Stop Contact	Close Contact to Trip Turbine	
DI-3	Remote Raise Contact	Close Contact to Ramp Turbine Speed Up	
DI-4	Remote Lower Contact	Close Contact to Ramp Turbine Speed Down	
DI-5	Start Permissive Contact	Close Contact to Inhibit Turbine Start	
DI-6	Load Breaker	Contact Closes to Initiate Droop Control	

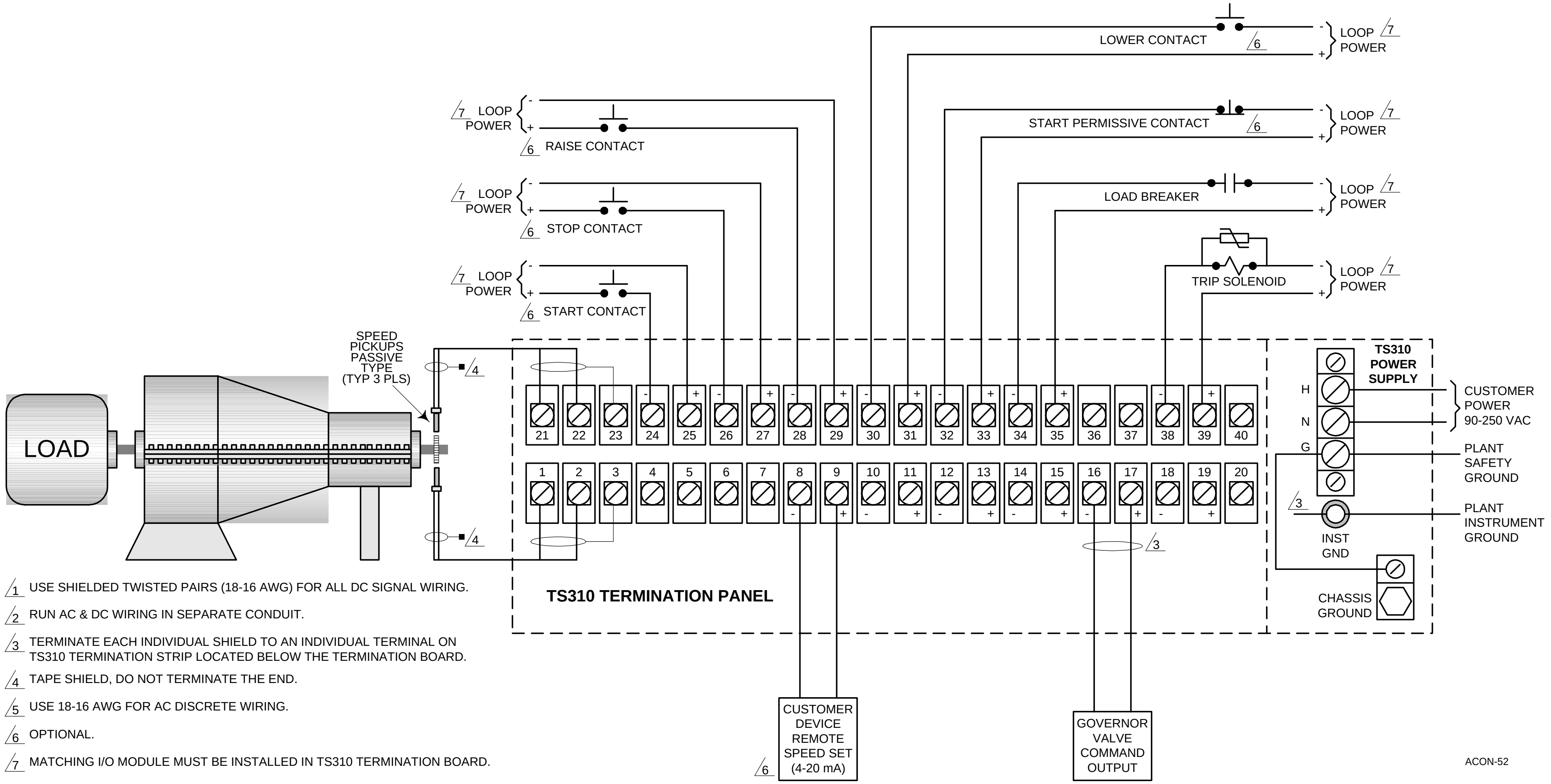


Figure 9. ACON.030 Wiring Diagram

Chapter 6 - Speed/Load, Extraction Control (ACON.040)

6.1 Application Description

ACON.040 is basic extraction control. Only TS310s with two valve output can utilize ACON.040. This configuration provides:

Speed control

Raise/Lower speed changing within the governor range

Raise/Lower extraction pressure

Dual pickup inputs

Loss of speed signal fail-safe

Fail-safe bypass timer (10 seconds)

Overspeed trip and test

Auto-start capability

Trip contact output

Status Indicators for:
- Pickup Fail
- Overspeed Trip
- Trip Output
- Extraction Enabled

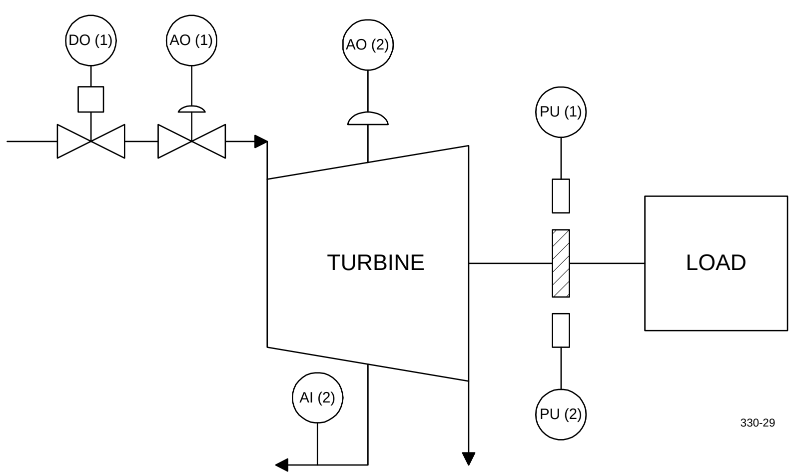


Figure 10. ACON.040 Speed/Load, Extraction Control Typical Application

Startup

Startup can be manual or automatic.

Manual Start. The operator presses the *TS310* [START] button then opens the steam block or T&T valve slowly to bring the machine up to governor speed.

Auto Start. The block valve is left open. Pressing [START] ramps the governor valve open and rapidly controls the machine up to the governor speed. This mode of operation is sometimes called "Fast Start".

Shutdown

The machine will trip on any of the following conditions:

Failure of both pickups

Speed exceeding the limit set in channel 17

Manual operation of the *TS310* [STOP] button

A trip causes closure of the governor valve and opening of the trip output contact.

Speed Control

After startup machine speed will be controlled to the speed displayed in CH05 (generally minimum governor speed). Upon reaching minimum governor, the speed can be changed by pressing [s] raise or [t] lower or by entering a new setpoint into channel 05.

Extraction Control

When the [START] button is pressed, the *TS310* will open the extraction valves full open. The valves will stay in this position until the extraction pressure controller is enabled. To enable the extraction pressure controller the machine must first be at minimum governor speed. After the machine has reached minimum governor and is within the speed range, [F2] is pressed to enable the extraction pressure controller. After pressing [F2] the extraction valves will start to close. The setpoint for the extraction pressure is set in channel 07. During startup the setpoint tracks the extraction header. When control is enabled the setpoint is equal to the last extraction pressure for *bumpless* transfer. When extraction pressure is under control the fourth status indicator from the left will come on. This indicates that the controller is enabled. [Enter a new setpoint in channel 07.]

Overspeed Trip And Test

This configuration provides an electronic overspeed trip feature as a backup to the primary overspeed trip. It also provides a method for overspeed test.

Input/Output

Field devices required for the basic configuration are described below. Refer to the wiring chapter of ACON.040 for field connections.

- **Two magnetic speed pickups**
  Recommended types:
  TRISEN #7120
  TRISEN #7121
  A ferrous toothed gear is also required. TRISEN can provide the proper gear upon request.

- **Governor/Extraction transducers**: A 4-20 mA actuator system is required. Action must be direct (e.g., 4 mA fully closes the steam valve, 20 mA fully opens the steam valve, a direct acting valve is also required).
  Examples are:
  TRISEN #9907 I/P Transducer with pneumatic actuator
  TRISEN #HCX21 Electro-hydraulic Transducer

- **Trip output contact**: A trip output is configured for digital output position 8. An output relay module, with the correct rating, must be installed in eighth position on the termination board. This contact is configured to close on a trip condition.

Status Indicators

Status indicators on the *TS310* display are configured from left to right as follows:

Indicator #	***Function***
1	Speed Pickup Failure
2	Overspeed Trip
3	Trip Output
4	Extraction Enabled

6.2 Required Additional Entries

Description	*CH#*
Min. Governor	15
Max. Governor	16
Overspeed Set	17
Speed Tuning	20-22
Extraction Tuning	30-32
Analog Input	52-53 (Preset: 50=1.00, 51=5.00)
Setpoint Ramp Rate	67
No. Gear Teeth	89
H Value	90
F Value	91
B Value	92

I/O Assignments	
Speed Pickup #1	PU-1
Speed Pickup #2	PU-2
Governor Valve	AO-1
Trip Contact	DO-1
Extraction Pressure In	AI-2
Extraction Valve	AO-2

6.3 Options

In addition to the standard features ACON.040 supports the following options:

Option	*Requires*
Remote Speed Set	4-20 mA External Input
Remote Ext. Set	4-20 mA External Input
Remote Start	External momentary contact (close to start)
Remote Stop	External momentary contact (close to trip the turbine)
Remote Raise	External momentary contact (close to raise the setpoint)
Remote Lower	External momentary contact (close to lower the setpoint)
Remote Start Permissive	External momentary contact (close to inhibit turbine startup)

In addition to the devices listed above some minor configuration must be done.

- To use the Remote Speed Set the following entries must be made:

Channel #	***Data***
48	Min. Governor Speed
49	Max. Governor Speed
56	Min. Ext. Press
57	Max. Ext. Press
71	1000

Optional I/O Assignments

I/O	***Required Field Device (Customer Supplied)***
AI-1	Customer Remote Speed Set
AI-2	Extraction Pressure Input
AI-3	Customer Remote Ext. Set
DI-1	Remote Start Contact
DI-2	Remote Stop Contact
DI-3	Remote Raise Contact
DI-4	Remote Lower Contact
DI-5	Start Permissive Contact

6.4 Machine Data Listing

ACON.040 MACHINE DATA LISTING					
FUNCTION	*****	***CH***	***DISPLAY***	***RANGE***	***UNITS***
SPEED USED	D	00	0	0-29999	RPM
ANALOG INPUT #1	D	01	0	0-29999	VARIES
ANALOG INPUT #2	D	02	0	0-29999	VARIES
ANALOG INPUT #3	D	03	0	0-29999	VARIES
ANALOG INPUT #4	D	04	0	0-29999	VARIES
SPEED REFERENCE	D	05	0	0-29999	RPM
2ND PID SETPOINT	D	06	0	VARIES	
3RD PID SETPOINT	D	07	0	VARIES	
ANALOG OUTPUT #1	D	08	0.0	0-100	PERCENT
ANALOG OUTPUT #2	D	09	0.0	0-100	PERCENT
SPEED INPUT #1	D	10	0	0-29999	RPM
SPEED INPUT #2	D	11	0	0-29999	RPM

ACON.040 MACHINE DATA LISTING					
FUNCTION	*******	***CH***	***DISPLAY***	***RANGE***	***UNITS***
* ACCELERATION RATE	K	12	_____	0-29999	RPM/MIN
MIN CRITICAL SPEED #1	K	13	0	0-29999	RPM
MAX CRITICAL SPEED #1	K	14	0	0-29999	RPM
* MIN GOVERNOR SPEED	K	15	_____	0-29999	RPM
* MAX GOVERNOR SPEED	K	16	_____	0-29999	RPM
* OVERSPEED TRIP SETTING	K	17	_____	0-29999	RPM
SPEED SWITCH #1 SET	K	18	0	0-29999	RPM
SPEED SWITCH #2 SET	K	19	0	0-29999	RPM
SPEED PROPORTIONAL BAND	T	20	50.0	0-1000	PERCENT
SPEED INTEGRAL (RESET)	T	21	5.0	0-500	SECONDS
SPEED DERIVATIVE (RATE)	T	22	0.0	0-200	SECONDS
SPEED DROOP	T	23	0.0	0-20	PERCENT
2ND PID PROPORTIONAL BAND	T	24	0.0	0-1000	PERCENT
2ND PID INTEGRAL (RESET)	T	25	0.0	0-500	SECONDS
2ND PID DERIVATIVE (RATE)	T	26	0.0	0-200	SECONDS
2ND PID DROOP	T	27	0.0	0-20	PERCENT
SYNCHRONIZING INTEGRAL	T	28	0.0	0-500	SECONDS
SYNCHRONIZING DERIVATIVE	T	29	0.0	0-200	SECONDS
3RD PID PROPORTIONAL BAND	T	30	100.0	0-1000	PERCENT
3RD PID INTEGRAL (RESET)	T	31	20.0	0-500	SECONDS
3RD PID DERIVATIVE (RATE)	T	32	0.0	0-200	SECONDS
3RD PID DROOP	T	33	0.0	0-20	PERCENT
V2 MIN LIMIT	K	34	0.0	0-100	PERCENT
V2 MAX LIMIT	K	35	100.0	0-100	PERCENT
IDLE SPEED	K	36	0	0-20000	RPM
IDLE FUEL	K	37	0	0-100	PERCENT
V1 MIN LIMIT	K	38	0.0	0-100	PERCENT
V1 MAX LIMIT	K	39	100.0	0-100	PERCENT
MIN #1 NOZZLE VALVE	K	40	0.0	0-100	PERCENT
MAX #1 NOZZLE VALVE	K	41	0.0	0-100	PERCENT
MIN #2 NOZZLE VALVE	K	42	0.0	0-100	PERCENT
MAX #2 NOZZLE VALVE	K	43	0.0	0-100	PERCENT
MIN #3 NOZZLE VALVE	K	44	0.0	0-100	PERCENT
MAX #3 NOZZLE VALVE	K	45	0.0	0-100	PERCENT
MIN ANALOG INPUT #1	K	46	1.0	0-10	VDC
MAX ANALOG INPUT #1	K	47	5.0	0-10	VDC

ACON.040 MACHINE DATA LISTING					
FUNCTION	*****	***CH***	***DISPLAY***	***RANGE***	***UNITS***
* MIN ENGRG UNITS #1	K	48	_____	0-29999	_____
* MAX ENGRG UNITS #1	K	49	_____	0-29999	_____
MIN ANALOG INPUT #2	K	50	1.0	0-10	VDC
MAX ANALOG INPUT #2	K	51	5.0	0-10	VDC
MIN ENGRG UNITS #2	K	52	_____	0-29999	_____
MAX ENGRG UNITS #2	K	53	_____	0-29999	_____
MIN ANALOG INPUT #3	K	54	1.0	0-10	VDC
MAX ANALOG INPUT #3	K	55	5.0	0-10	VDC
MIN ENGRG UNITS #3	K	56	_____	0-29999	_____
MAX ENGRG UNITS #3	K	57	_____	0-29999	_____
MIN ANALOG INPUT #4	K	58	0.0	0-10	VDC
MAX ANALOG INPUT #4	K	59	0.0	0-10	VDC
MIN ENGRG UNITS #4	K	60	0	0-29999	_____
MAX ENGRG UNITS #4	K	61	0	0-29999	_____
#1 ANALOG OUTPUT MIN	K	62	4.0	0-20	m AMPS
#1 ANALOG OUTPUT MAX	K	63	20.0	0-20	m AMPS
#2 ANALOG OUTPUT MIN	K	64	4.0	0-20	m AMPS
#2 ANALOG OUTPUT MAX	K	65	20.0	0-20	m AMPS
LOAD LIMIT	K	66	100.0	0-100	PERCENT
* SETPOINT RAMP RATE	K	67	_____	0-100	PERCENT
LOAD (KW) OVERRIDE RESET	T	68	0	0-500	PERCENT
PARALLEL ISOCH. DELAY	K	69	0	0-12	SEE MAN
ANALOG INPUT #1 & #2	K	70	0408	WORD #1	
ANALOG INPUT #3 & #4	K	71	1000	WORD #2 Some software releases had 0000 as Word 2. 1000 is correct and current software has been changed.	
CONTACT I/O #1	K	72	1001	WORD #3	
CONTACT I/O #2	K	73	1002	WORD #4	
CONTACT I/O #3	K	74	1003	WORD #5	
CONTACT I/O #4	K	75	1004	WORD #6	
CONTACT I/O #5	K	76	2013	WORD #7	
CONTACT I/O #6	K	77	0000	WORD #8	
CONTACT I/O #7	K	78	0000	WORD #9	
CONTACT I/O #8	K	79	3320	WORD #10	
SPEED CONTROL	K	80	0330	WORD #11	
SPEED CONTROL	K	81	0210	WORD #12	
SPEED CONTROL	K	82	3110	WORD #13	

ACON.040 MACHINE DATA LISTING					
FUNCTION	*****	***CH***	***DISPLAY***	***RANGE***	***UNITS***
2ND PID CONTROL	K	83	0000	WORD #14	
STATUS INDICATORS	K	84	1209	WORD #15 Some software releases had 1289 for Word 15. 1209 is correct and current software has been changed.	
SPEED SWITCH CONF.	K	85	0000	WORD #16	
3RD PID CONTROL	K	86	0140	WORD #17	
GENERATOR CONTROL	K	87	0000	WORD #18	
FAILSAFE SETTING	K	88	10	0-400	SECONDS
* GEAR TEETH	K	89	_____	0-320	TEETH
H VALUE	K	90	_____	0-10.0	TEETH
F VALUE	K	91	_____	0-10.0	PERCENT
B VALUE	K	92	_____	0-100	PERCENT
GEAR RATIO	K	93	0.000	0-9.99	RATIO
STARTUP PROP. BAND	T	94	0.0	0-1000	SECONDS
STARTUP INTEGRAL (RESET)	T	95	0.0	0-500	SECONDS
HOUR METER	K	96	0	READS HOURS	
LAST SHUTDOWN	D	97	0000	RECORDS TRIPS	
COMPUTER ID	K	98	0	RS422 ADDRESS	
PASSWORD	K	99	6883	FOUR DIGITS	

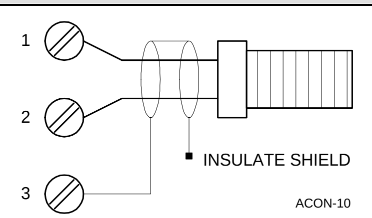
* The channels marked with the asterisks will require data entry before the *TS310* can be used.

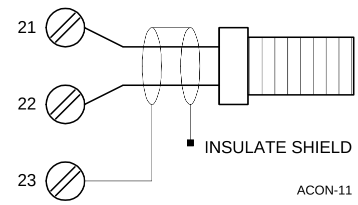
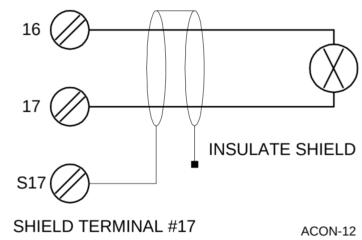
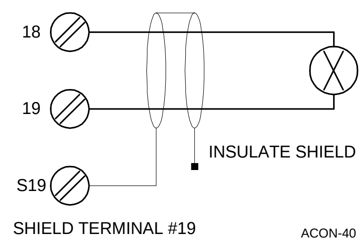
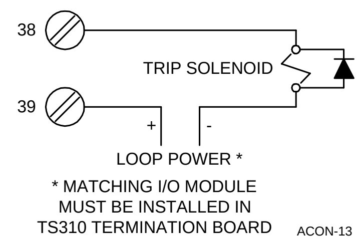
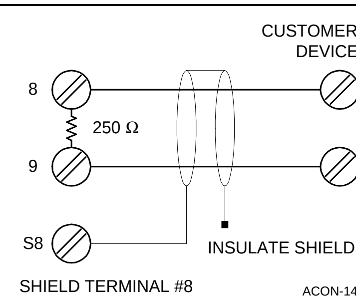
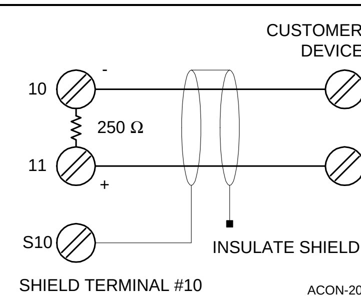
K = Channel is password protected.

D = Channel for display only.

T = Channel contains tuning values.

6.5 Wiring

I/O	Device	Remarks	Wiring
PU-1	Speed Pickup	Standard Magnetic Speed Pickup TRISEN P/N 7120, 7121, etc.	

I/O	Device	Remarks	Wiring
PU-2	Speed Pickup	Standard Magnetic Speed Pickup TRISEN P/N 7120, 7121, etc.	
AO-1	Actuator	Direct Acting 4-20 mA Governor Actuator, I/P Transducer, HCX21, etc.	
AO-1	Actuator	Direct Acting 4-20 mA Governor Actuator, I/P Transducer, HCX21, etc.	
DO-8	Trip Solenoid	Trip Circuit Contact Output Opens Upon Pressing STOP Overspeed Trip Pickup Failure	
AI-1	Customer Signal	4-20 mA Signal From Customer Device for Remote Speed Setpoint	
AI-2A or AI-2B	Customer Signal	4-20 mA Signal from Customer Device for 3rd PID Measurement	

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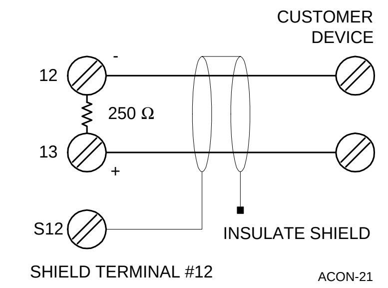
<tr><th>I/O</th><th>Device</th><th>Remarks</th><th>Wiring</th></tr>
<tr><td>AI-3</td><td>Customer Signal</td><td>4-20 mA Signal from Customer Device for Remote 3rd PID Setpoint</td><td>
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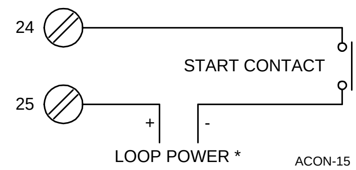
<tr><td>DI-1</td><td>Remote Start Contact</td><td>Close Contact to Start Turbine</td><td>
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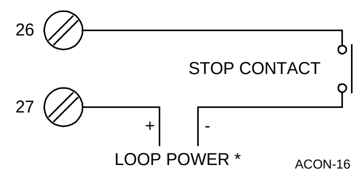
<tr><td>DI-2</td><td>Remote Stop Contact</td><td>Close Contact to Trip Turbine</td><td>
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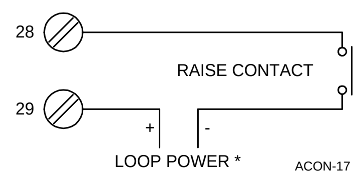
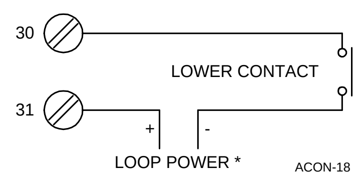
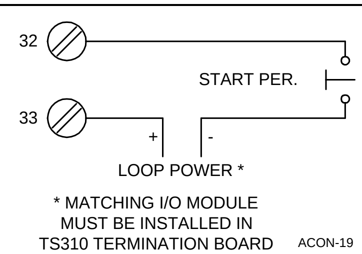
<tr><td>DI-3</td><td>Remote Raise Contact</td><td>Close Contact to Ramp Turbine Speed Up</td><td>
</td></tr>
<tr><td>DI-4</td><td>Remote Lower Contact</td><td>Close Contact to Ramp Turbine Speed Down</td><td>
</td></tr>
<tr><td>DI-5</td><td>Start Permissive Contact</td><td>Close Contact to Inhibit Turbine Start</td><td>
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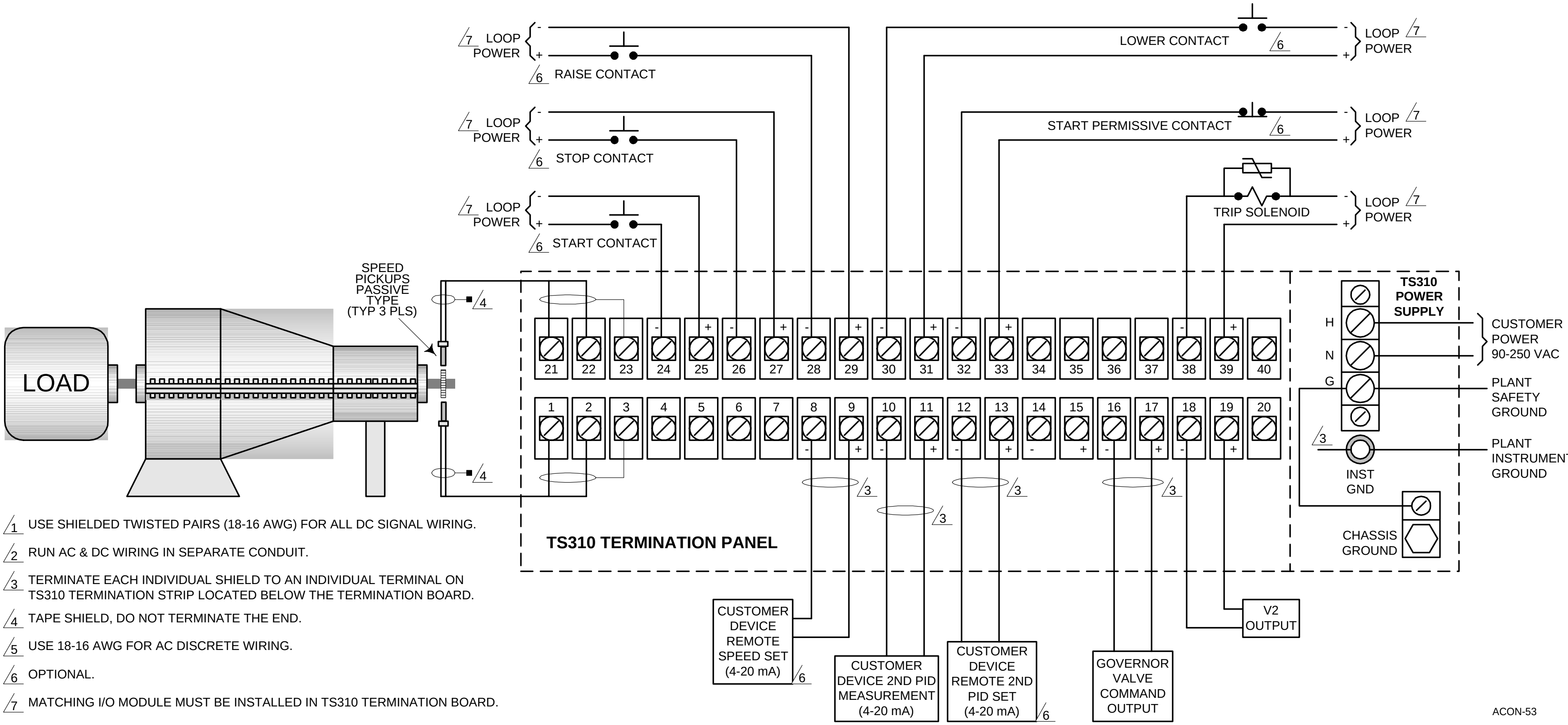

1. USE SHIELDED TWISTED PAIRS (18-16 AWG) FOR ALL DC SIGNAL WIRING.
2. RUN AC & DC WIRING IN SEPARATE CONDUIT.
3. TERMINATE EACH INDIVIDUAL SHIELD TO AN INDIVIDUAL TERMINAL ON TS310 TERMINATION STRIP LOCATED BELOW THE TERMINATION BOARD.
4. TAPE SHIELD, DO NOT TERMINATE THE END.
5. USE 18-16 AWG FOR AC DISCRETE WIRING.
6. OPTIONAL.
7. MATCHING I/O MODULE MUST BE INSTALLED IN TS310 TERMINATION BOARD.

Figure 11. ACON.040 Wiring Diagram

TS310 MOD4A Digital Controller

Extraction Admission Operation Guide

Document No. 4933-0016

April 1998

Rev. 1

TRICONEX

La Marque, Texas

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TRICONEX reserves the right to make improvements in the design, construction, and appearance of its products without prior notice.

Revision History

Rev. A	September 1990	General editorial revision.
Rev. B	July 1991	General editorial revision.
Rev. 1	April 1998	General editorial revision only; reformatted including A4

Contents

Chapter 1 - Introduction

The TRISEN *TS310* digital controller is the most flexible and versatile control system available today for operating extraction or admission steam turbines. A number of features make this possible:

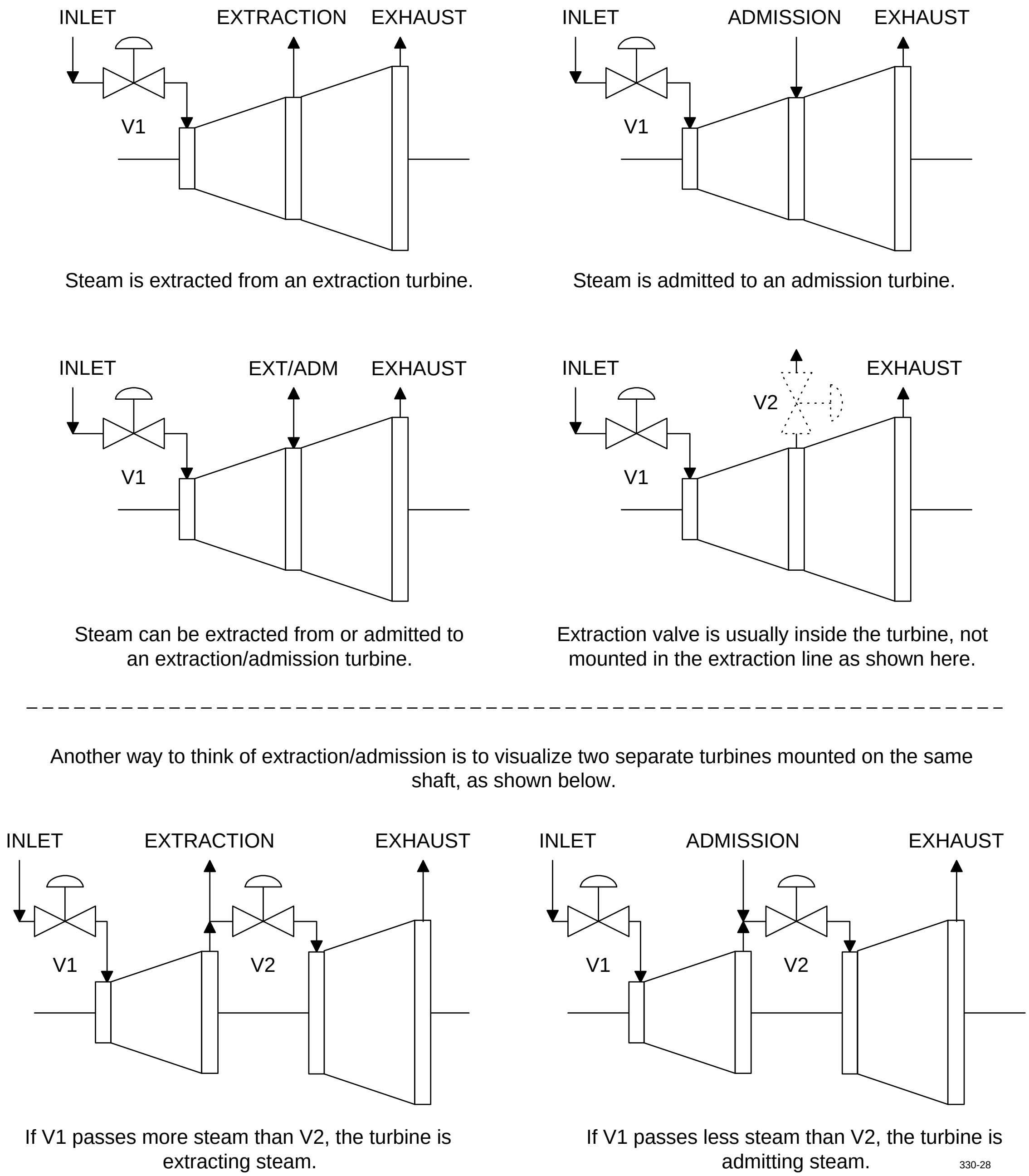
- The microprocessor-based controller and accompanying sequencing capabilities provide extremely wide range control which is so necessary for accurate, dependable control of extraction turbines. The limited turn-downs of analog electronic and mechanical controls inhibit their ability to satisfactorily control extraction/admission turbines.
- The same microprocessor-based architecture has eliminated all calibration of components. Previously, the calibration drift of analog electronic or mechanical controls caused variations in output and coordination that resulted in severe interaction between speed control and extraction control.
- Since the digital controller is a computer, the capability to incorporate complex sequencing, to turn-on and turn-off sophisticated accessory control functions, and to modify the control scheme with the turbine in operation is easily accomplished in a *bumpless* manner.
- The variable gain that should be used whenever one of the valves is limited can be easily implemented with computer-based control.
- The extraction control can be turned-on or turned-off by a contact closure.
- The list goes on but these complex functions, so easily incorporated into a computer-based controller, should begin to indicate the vast potential for improvement in this or any other type of complex control.

Operating extraction or admission steam turbines does include some quite complex control functions and for this reason it may not always be easily understood.

For those who would like to review what extraction and admission turbines are and how they work, the next several pages are devoted to a review of the principles involved, starting from the beginning.

Chapter 2 - Definitions

Confusion sometimes surrounds the meanings and functions of EXTRACTION turbines and ADMISSION turbines. Before proceeding further, let us clarify what these are and what they do.

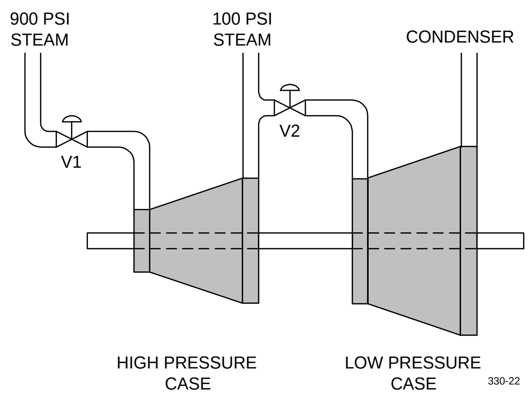


Admission turbines are sometimes called INDUCTION turbines. Because of the current popular use of induction generators, we prefer to use the term ADMISSION turbine in order to minimize the possibility of confusion.

Chapter 3 - Basics

A typical extraction/admission steam turbine can be created by mounting two simple steam turbines on the same shaft as shown below. This assembly will not have the external appearance of a production-line extraction/admission turbine since an extraction/admission turbine is constructed with both rotors and both inlet steam valves integrated into the same case.

However, the model shown will operate exactly like any standard extraction/admission turbine and it must be controlled in the same way. This model can be used to visualize and to demonstrate how an extraction/admission turbine works and how it must be controlled.



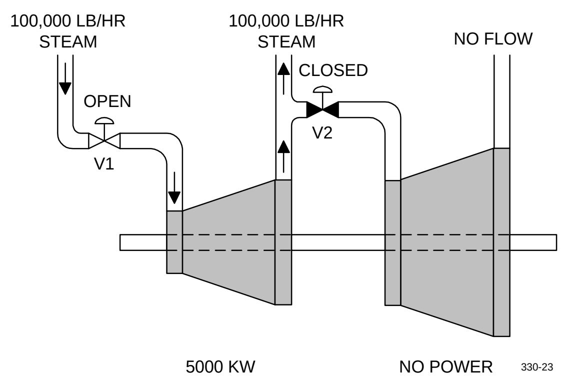
3.1 Typical Operation

Let us choose some typical operating conditions. Assume the inlet steam pressure to be 900 PSI; assume the extraction/admission (or intermediate) steam pressure to be 100 PSI; and assume that the low pressure (LP) turbine case exhausts to a condenser. Let us refer to the high pressure inlet valve as V1 and the low pressure inlet valve (sometimes mistakenly called the extraction valve) as V2.

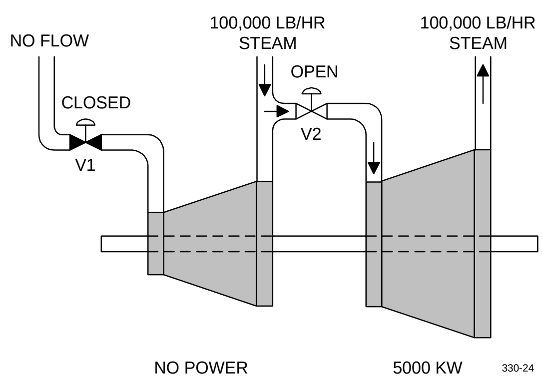
In the model below, the inlet valve V1 is capable of passing full steam flow of 100,000 pounds per hour of 900 PSI steam. This steam flow will produce 5000 kilowatts of power from the high pressure (HP) case. The intermediate valve V2 is capable of passing a full steam flow of 100,000 pounds per hour of 100 PSI steam. This steam flow will produce 5000 kilowatts of power from the low pressure case. If both valves are fully open, 100,000 lbs/hr of steam will pass through both cases and the turbine will produce 10,000 kW, 5000 from each case.

SEVERAL OBSERVATIONS ARE IMMEDIATELY APPARENT:

If V1 is open and V2 is closed, the HP case will produce 5000 kW from 900 PSI steam; 100,000 lbs/hr of steam will flow to the intermediate steam header; the LP case will produce zero kilowatts; and no steam will flow to the condenser.

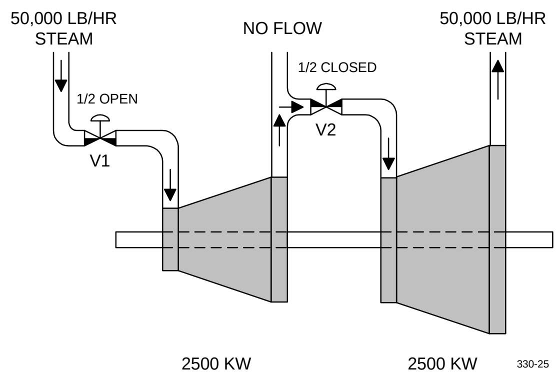


If V2 is open and V1 is closed, the LP case will produce 5000 kW from 100 PSI steam; 100,000 lbs/hr of steam will flow from the intermediate steam header; the HP case will produce no kilowatts; and no 900 PSI steam will be used.



Both of the above examples are idealized fictitious situations since some *cooling steam* must always flow in each turbine case. In addition, we have not considered the amount of steam required to overcome friction, oil whorl and to drive turbine accessories. This can amount to 15 or 20% of the total steam consumed by the turbine and it produces no net power at the turbine coupling. However, the controller must account for this steam flow as well when controlling extraction turbines.

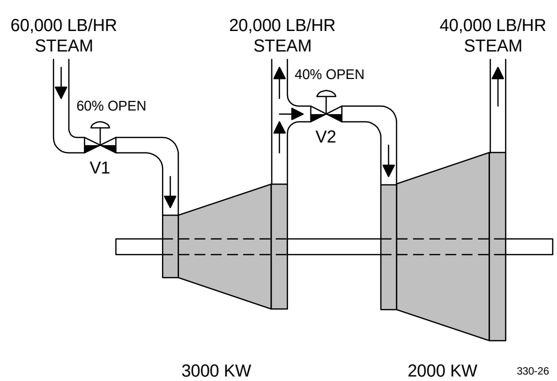
If V1 is half open and V2 is half open, the HP case will produce 2500 kW from 900 PSI steam; the LP case will produce 2500 kW from 100 PSI steam; and since the 50,000 lbs/hr of steam exhausting from the HP case will be consumed or *admitted* to the LP case, no steam will be consumed from, or contributed to the intermediate header. There will be no steam *extracted* or *admitted* in-so-far as the intermediate or extraction steam header is concerned.



3.2 Extraction Control

Now, consider the dynamic relationship between V1 and V2. If the demand for extraction steam increases, V1 and V2 must be manipulated to increase extraction steam flow without changing power output of the turbine.

EXAMPLE: Move V1 from 50% to 60% position. V1 will now pass 60,000 lbs/hr of 900 PSI steam which produces 3000 kW in the HP case. Move V2 from the 50% to 40% position. V2 will now pass 40,000 lbs/hr of 100 PSI steam which produces 2000 kW in the LP case.



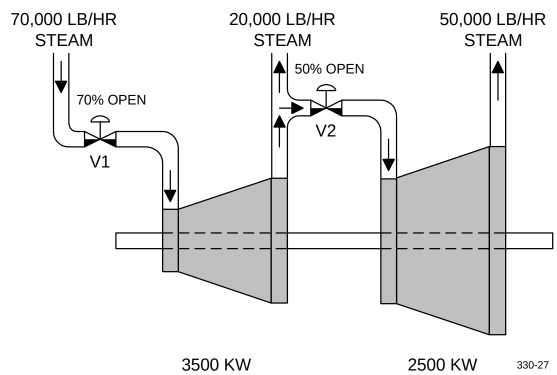
Thus, 20,000 lbs/hr of steam is now being extracted from the turbine to the intermediate steam header but total power is still 5000 kW. By following this pattern, the controller is able to increase (or decrease) the extraction steam flow without affecting power output.

3.3 Speed (Load) Control

Conversely, now consider what must occur to change power output (or speed) without affecting the extraction steam flow.

EXAMPLE: Power must be increased by 1000 kW while at the same time holding extraction steam flow constant at 20,000 lbs/hr.

Open V1 from 60% to 70%. V1 will now pass 70,000 lbs/hr of 900 PSI steam which will produce 3500 kW from the HP case. Open V2 from 40% to 50%. V2 will now pass 50,000 lbs/hr of 100 PSI steam which will produce 2500 kW from the LP case.



Thus, 20,000 lbs/hr of steam is still being extracted from the turbine to the intermediate steam header but the total power has increased from 5000 kW to 6000 kW. By following this pattern, the controller is able to increase (or decrease) power output of the turbine without affecting the extraction steam flow.

3.4 Principles

Several operating principles begin to emerge that tell us how the extraction/ admission turbine must be controlled.

- Both V1 and V2 must open together in order to increase power output while holding extraction (or admission) steam flow constant.
- Both V1 and V2 must close together in order to decrease power output while holding extraction (or admission) steam flow constant.
- V1 must open while V2 closes in order to increase extraction (or decrease admission) steam flow yet hold power output constant.
- V2 must open while V1 closes in order to decrease extraction (or increase admission) steam flow, yet hold power output constant.

3.5 Operation Variations

Until now, our model turbine could be used to extract steam (from the turbine to the intermediate steam header) or to admit steam (to the turbine from the intermediate steam header), depending upon the relative positions of V1 and V2 steam inlet valves.

However, most steam turbines are intended to be extraction only or admission only turbines. In earlier mechanical governors, the valve linkage geometry was constructed so that V2 could not open wider than V1. This limited the turbine to extraction control only (it could not admit steam). In addition, a check valve might be installed in the exit line connecting to the intermediate steam header to ensure that the turbine could not admit steam from the intermediate steam header.

A turbine designed for admission only would be calibrated so that V2 could not pass less steam than V1, in which case the turbine could only admit steam from the intermediate steam header. In this case, a check valve might be installed so as to physically prevent extraction.

Digital electronic controllers like the *TS310* are designed so that the valve geometry is provided by the computer program. Therefore, if an application is designed for EXTRACTION ONLY, the computer will not allow V2 to pass more steam than V1 even if no check valve is installed. The reverse is true, of course, for ADMISSION ONLY applications.

3.6 Extraction Map (Performance Curves) Variations

So far, our model extraction turbine is straightforward. The steam flow capacities of V1 and V2 are equal and the power generated from the HP and LP cases is also equal.

This means that to increase extraction, V1 must open and V2 must close by the exact same amount since opening V1 ten percent will increase the power output by the same value that power is reduced when closing V2 ten percent.

However, this is seldom the case. Extraction turbines are usually designed so that the high pressure case (V1) will pass considerably more steam than the low pressure case (V2). In such an application it is of course impossible to put as much steam through V2 as through V1 at maximum load. If V1 is wide open, some steam must be extracted to the intermediate steam header even if V2 is also wide open.

This means that the one-to-one ratio used formerly with V1 and V2 is no longer valid. If, for instance, V2 can only pass 50% of the steam flow passed by V1, then, in order to increase power output without affecting the extraction flow rate, V2 must open twice as fast as V1.

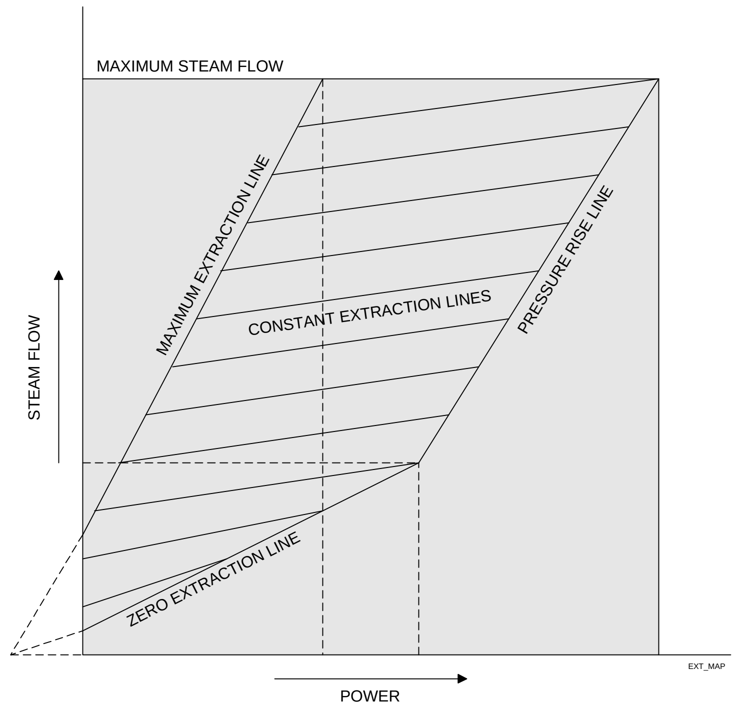
In like manner, horsepower ratios are also seldom one-to-one. Even though the typical extraction turbine may pass twice as much steam through V1 as through V2, the efficiency of the low pressure case may be considerably better than that of the high pressure case. This can mean in a steam flow (Channel 91, F value) ratio result of 0.5 (V2 capacity divided by V1 capacity); while the power output (Channel 91, H value) ratio result may be 2.0 (full power output from the LP case divided by the full power output from the HP case).

TRISEN controllers use these ratios as F value (steam flow ratio) and H value (horsepower ratio) to establish the geometry of valve movement. These values are normally obtained from the extraction map (performance curve) of that particular turbine. More about these values and how to calculate them later.

Observe that the H value (horsepower ratio) is used when extraction steam flow rate is changing, whereas the F value (steam flow ratio) is used when the power output is changing. Thus, a turbine with an H value of 2 would require that V1 open twice as fast as V2 closes in order for the power output to remain constant when extraction flow is increased. The F value of 0.5 would require that V2 open twice as fast as V1 in order for extraction flow to remain constant while the power output of the turbine is increasing. The reverse will be true for both, of course.

These two ratios match the controller to the individual turbine for each application. These are keyboard entered values and can be adjusted for error at a later time if it is found that the extraction map is not correct or if modifications have been made to the turbine which would affect these values.

Earlier it was mentioned that the controller must be aware of the *lost* power of the turbine; that power devoted to friction, accessories, etc., which is not available at the turbine shaft as net power. This is referred to as the B value and is a percent of the total power output of the turbine. More about how to determine this value later, as well.



Typical Extraction Map

3.7 Calculation of F, H and B Values

The *TS310* is configured to operate an extraction steam turbine by calculating the F, H and B values with information obtained from the manufacturer's EXTRACTION MAP (turbine performance curve).

1. Extrapolate the *zero extraction line* to the origin.
2. Extrapolate the *pressure rise line* until it intersects the *maximum steam flow* line.

THEN DETERMINE:

For POINT A: F1 = Steam flow through the high pressure case (V1)
H3 = Horsepower produced by the high pressure case

For POINT B: F3 = Steam flow through the low pressure case (V2)
(equivalent to F1 less the extraction steam flow)
H5 = Total horsepower produced by both cases

For POINT C: F4 = Steam flow through HP and LP cases (V1 and V2)
H4 = Horsepower produced at POINT C by both cases

NOW CALCULATE:

$$C = \frac{H5 - H3}{F3}$$

$$b = \frac{H4 - H3 - (C \times F4)}{F4 - F1}$$

$$a = H3 - (b \times F1)$$

Calculate the F Value: $F = \frac{F4}{F1}$ (Ratio)

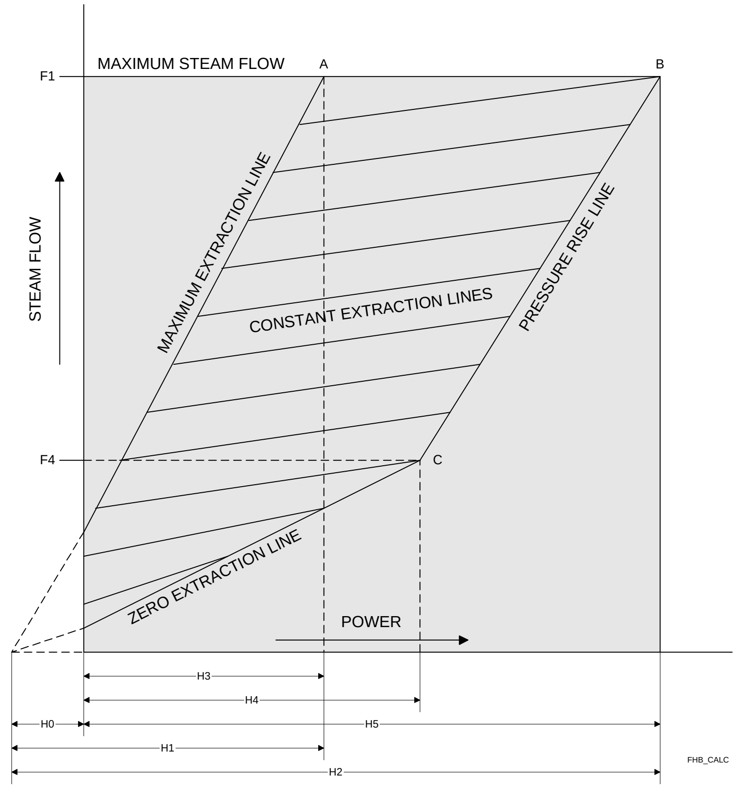
Calculate the H Value: $H = \frac{C \times F4}{B \times F1}$ (Ratio)

Calculate the B Value: $B = \frac{-a}{-a + H5}$ (Percent)

OR, ESTIMATE FROM THE MAP BY EXTRAPOLATION:

$$H = \frac{H2 - H1}{H1} \quad \text{(Ratio)}$$

$$B = \frac{H0}{H2} \times 100 \quad \text{(Percent)}$$



F, H, & B Values

After calculating F, H and B, these values are entered into the controller configuration. As noted earlier, power required to rotate the turbine at zero net horsepower (H0) must be controlled by the controller in addition to the net power delivered at the coupling. Therefore, the H value, or horsepower ratio (low pressure case divided by the high pressure case), must be based on H1 and H2, not on H3 and H5.

Since the F and H values are ratios, they can be calculated from horsepower or from kilowatts, and from pounds per hour steam flow as well as kilograms per hour.

Extraction maps are usually drawn with straight lines. This is seldom perfectly representative of the turbine's performance. Since the extraction map values calculated are used in a feed-forward control manner, however, the approximated values will work quite well. In addition, turbine performance normally will be non-linear and the performance curves are also only approximations of the turbine performance.

F, H and B values are sometimes difficult to calculate. This may be because the manufacturer's extraction map is not complete or is not correct, perhaps because the turbine has been modified or rerated, or perhaps because the operating conditions (steam pressure) have changed and no extraction map is available to match the new conditions.

It should be emphasized that, for an estimated B value, extrapolation of the zero extraction line is a straight line. This is seldom, if ever, a straight-line function in the turbine. Also, calculation of the B value is based on other straight lines which are, in fact, non-linear functions in the turbine. The calculated B value and estimated B value will probably not be the same. However, either value will probably control the turbine satisfactorily.

F Value

The F value is a ratio which should represent the steam flow capacity of V2 (the low pressure case) divided by the steam flow capacity of V1 (the high pressure case). If the F value is incorrect, this will be reflected whenever a change in speed or load is made.

If speed or load is increased, V1 and V2 both should open in such a manner that the increased flow through V1 is the same as the increased steam flow through V2. If the F value is too large, V2 will open too little in relation to V1 and the extraction steam flow (and pressure) will increase.

THEREFORE: IF EXT PRESSURE RISES AS LOAD IS INCREASED,
MAKE F SMALLER

IF EXT PRESSURE FALLS AS LOAD IS INCREASED,
MAKE F LARGER

The F value is entered in Channel 91 of the *TS310*.

H Value

The H value is a ratio which should represent the horsepower capability of the LP case divided by the horsepower capability of the HP case. If the H value is not correct, this will be reflected by a change in speed or load whenever a change is made in the extraction steam rate.

If the extraction steam flow is increased, V1 should open in such a manner that the horsepower increase of the HP case is just matched by the horsepower reduction of the LP case as V2 closes. If the H value is too large, V2 will close too little in relation to V1 opening and speed or load will increase.

THEREFORE: IF SPEED/LOAD INCREASES AS EXTRACTION
INCREASES, MAKE H SMALLER

IF SPEED/LOAD INCREASES AS EXTRACTION
DECREASES, MAKE H LARGER

The H value is entered into Channel 90 of the *TS310*.

B Value

The B value represents, in a percentage, that portion of the turbine horsepower used by the turbine itself. Bearing friction, steam windage and pressure drop losses, oil whorl and the power requirements of accessories such as shaft-driven oil pumps, all require horsepower (and steam) before any power can be delivered to the coupling. The controller must control total power output of the turbine including these losses.

The B value is a small item in comparison to total horsepower delivered and is, therefore, difficult to examine empirically. If extraction map data are not available or are suspected of being incorrect, the B value can be set somewhere between twelve and fifteen percent. This will usually provide reasonable control results.

The B value is entered into Channel 92 of the *TS310*

Chapter 4 - Control Actions

4.1 Control Variations

Extraction/admission steam turbines can be controlled in a number of different modes. Different variables associated with the turbine are controllable. These are: power output (or speed); inlet steam pressure; extraction steam pressure (or admission); and backpressure (sometimes called exhaust pressure). Since there are only two steam inlet valves, only two of these variables can be controlled simultaneously.

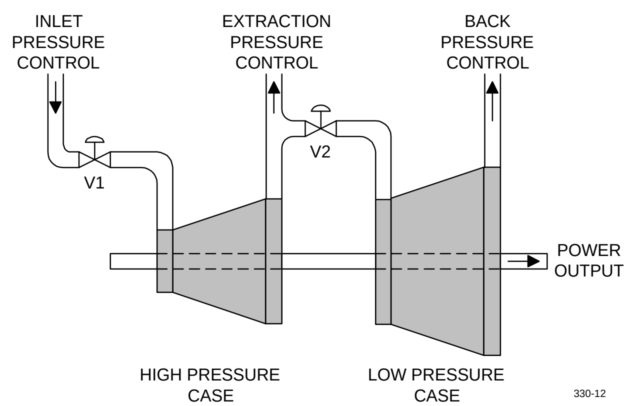
Mechanical drive (non-generator) applications require that one controlled variable be speed (RPM). Any one of the other three variables can also be controlled at the same time.

The second variable normally controlled in a mechanical drive application is extraction pressure. However, special applications such as Synthetic Gas Compressor Drive Turbines for ammonia plants and methanol plants may sometimes use other combinations. The most commonly encountered combination for Syn-Gas compressor drives is speed (RPM) and inlet steam pressure.

A wide variation in the combinations of controlled variables is found on steam turbines driving synchronous generators. Here, speed is fixed to the synchronous speed of the generator, turbine speed is locked to that RPM and now it is not necessary to control the power output of the turbine.

Combinations can be any of the following:

POWER OUTPUT / EXTRACTION PRESSURE
INLET PRESSURE / EXTRACTION PRESSURE
BACKPRESSURE / EXTRACTION PRESSURE
POWER OUTPUT / INLET PRESSURE
POWER OUTPUT / BACKPRESSURE
INLET PRESSURE / BACKPRESSURE



As mentioned above, only two of these variables can be controlled simultaneously since there are only two valves. Further, if one of the valves becomes limited, only one variable can be controlled. Priority entries determine which of the two will be allowed to control the turbine when this happens.

4.2 Control Action/Actuator Action

Some controllers must be direct-acting; some must be reverse-acting.

The nature of extraction or admission control determines that the *TS310* must be reverse-acting. That is, an increase in extraction steam pressure must produce an action that will decrease the extraction steam flow, etc.

Some might say that this is arbitrary. However, this happens to be the way the *TS310* digital controller controls extraction or admission steam.

Channel 86 configured (0XXX) specifies CONTROL ACTION = REVERSE/ ACTUATOR ACTION = DIRECT. This means that an increasing measurement (extraction) must produce an output change which will tend to decrease the extraction steam flow.

If the valve (V2) action is direct (4 milliamps to close), then the control action must be reverse.

If the valve action is reverse (20 milliamps to close), then the control action must be direct. In this case, Channel 86 should be configured (2XXX).

Channel 86 normally will very rarely be configured (1XXX) or (3XXX).

4.3 Stroking The Actuator

At installation, it may be desirable to stroke the actuator on the turbine. This is easily accomplished by the *TS310* controller without disconnecting any wires or using any calibration aids.

Stroking V2: Minimum output for V2 (#2 analog output) is entered in Channel 64, maximum output is entered in Channel 65. Thus, if the actuator is closed at 4 milliamps and wide open at 20 milliamps, the valve travel can be stroked by entering values in Channel 64. Or, if the actuator is closed at 20 milliamps and wide open at 4 milliamps, valve travel can be stroked by entering decreasing values in Channel 65.

EXAMPLE:

DIRECT ACTING (CH64)	POSITION	REVERSE ACTING (CH65)
4 mA	CLOSED	20 mA
8 mA	1/4 OPEN	16 mA
12 mA	1/2 OPEN	12 mA
16 mA	3/4 OPEN	8 mA
20 mA	FULL OPEN	4 mA

Chapter 5 - Function Configuration

Channel 86 provides a variety of options to use with extraction/admission control. As described under CONTROL ACTION/ACTUATOR ACTION, (paragraph 4.2) CH86A must be configured (0XXX) for direct acting actuators (those that close at 4 milliamps) or must be configured (2XXX) for reverse acting actuators, (those that are closed at 20 milliamps).

Channel 86B provides for EXTRACTION CONTROL ONLY (X1XX), in which case the controller will not allow admission steam flow into the turbine.

Channel 86B provides for ADMISSION CONTROL ONLY (X2XX), in which case the controller will not allow extraction steam flow from the turbine.

Channel 86B provides for EXTRACTION/ADMISSION CONTROL (X3XX), in which case the controller will control the turbine to full extraction steam flow as may be required to supply any steam deficiency in the intermediate steam header, or will control the turbine to full admission steam flow as may be required to utilize any excess steam from the intermediate steam header. In this last case, the *TS310* will switch from extraction control to admission control and back to extraction control as needed with no outward evidence of the switch, and it will maintain the intermediate steam header pressure in both cases.

Channel 86B can also be configured (X4XX). This configuration will separate the 3RD PID control loop from any speed control effects and from extraction/admission control, and will cause the 3RD PID to act as a PID STAND-ALONE CONTROL LOOP which will operate unaffected by the speed control whether the controller is operating the turbine or the turbine is shut down.

The STAND-ALONE configuration permits the 3RD PID control loop to independently operate semi-related functions such as a minimum flow bypass for a boiler feedwater pump or compressor, or completely non-related functions such as a steam let-down valve or make-up valve.

The 3RD PID control output, which is the #2 analog output of the *TS310* controller, can also be configured to furnish a 4 to 20 milliamp signal representing speed or speed reference. Configuration is (X6XX) or (X7XX).

In these configurations, the 4 to 20 mA speed range will be zero to whatever RPM entry has been made in Channel 17 (overspeed trip setting). Thus, for example, if Channel 17 is 5000, 4 milliamps will represent zero RPM, 12 milliamps will be output at 2500 RPM and 20 milliamps will be output at 5000 RPM, etc.

Chapter 6 - Extraction/Admission Enabling

6.1 Enabling Extraction-Variations

The user can choose between several options to enable extraction control. These are:

- (X10X) = V2 enabled always
- (X12X) = V2 enabled at minimum governor
- (X14X) = V2 enabled by F2 function key

Option 1 is configured (X10X) in Channel 86.

With this option, extraction control is always enabled. The 3RD PID (Extraction) control loop setpoint (CH 07) will *track* the extraction measurement until the START key is pressed.

After START is pressed, the startup sequence will proceed with V1 and V2 opening together so as to control extraction steam flow from the start. The extraction control setpoint will *freeze* when START is pressed. This configuration should be used with extraction turbines where no check valve is installed in the extraction steam line or when the check valve is inoperative.

Option 2 is configured (X12X) in Channel 86.

With this option, extraction control is not enabled when the START key is pressed. The V2 valve will move to the full open position when the START key is pressed (will admit steam if there is no check valve).

Extraction control will enable automatically when turbine speed reaches the minimum governor setting. At this time, the V2 valve will close until reaching the appropriate extraction control position. The closing rate will be at one percent per second of valve position. The extraction control setpoint (CH 07) does not *track* but will remain where it has been set, whether the turbine is operating or is shut down.

Option 3 is configured (X14X) in Channel 86.

With this option, extraction control is not enabled when the START key is pressed. The V2 valve will move to the full open position when START is pressed (will admit steam if there is no check valve).

Extraction control is enabled by pressing the F2 function key after the turbine speed reaches the minimum governor setting. At this time, the V2 valve will close until reaching the appropriate extraction control position. The closing rate will be at one percent per second of valve position. The extraction control setpoint (CH 07) does not *track* but will remain where it has been set whether the turbine is operating or is shut down. Extraction control will not enable until the F2 function key has been pressed.

Once extraction control has been enabled, pressing the F2 function key again will cause extraction control to disable, with the V2 valve moving to the full open position, again at a rate of one percent per second of valve position. Extraction control may be enabled and disabled as often as desired.

A remote F2 function contact input can be configured. This contact will enable extraction control when it is closed and it will disable extraction control when it is opened. If the F2 function key has enabled extraction control at the keyboard, closing and then opening the remote contact again will disable extraction from the remote position. If extraction has been enabled by F2 contact input it cannot be disabled by F2 on the keyboard.

WARNING

Options 2) and 3) should not be used if there is no check valve in the extraction steam line. Trying to enable these options with a STOP VALVE in the extraction steam line, and then opening the STOP VALVE after the V2 valve has moved to some intermediate position is a cumbersome procedure and could produce hazardous consequences. This is not recommended.

6.2 Enabling Admission Control

Option 1 in paragraph 6.1 is the only option that is recommended for use with ADMISSION CONTROL. Since V2 valve goes fully open with any of the other options, this is hardly a recommended procedure for use with admission control.

Thus, always configure Channel 86 as (X20X) for admission control. With this configuration, the turbine will always start up with admission control enabled and the admission control setpoint (CH 07) will *track* until the START key is pressed.

6.3 Enabling Extraction-Admission

Option 1 in paragraph 6.1 is the only option recommended for use with EXTRACTION/ADMISSION CONTROL. Therefore, always configure Channel 86 as (X30X) for EXTRACTION/ADMISSION CONTROL. With this configuration the turbine will always start up with EXTRACTION/ADMISSION CONTROL enabled and the control setpoint (CH 07) will *track* until the START key is pressed.

6.4 Priority

All of the options discussed so far have been for HORSEPOWER PRIORITY. EXTRACTION/ADMISSION PRIORITY (XX1X), (XX3X) or (XX5X) should never be used except when operating a turbine driving a synchronous generator which is always in DROOP control and is always connected to the utility grid. EXTRACTION/ADMISSION PRIORITY should not be used in any other application due to its propensity to cause a turbine to run away if the extraction/admission control overrides the horsepower requirements.

Chapter 7 - Limiting Functions/Decoupling

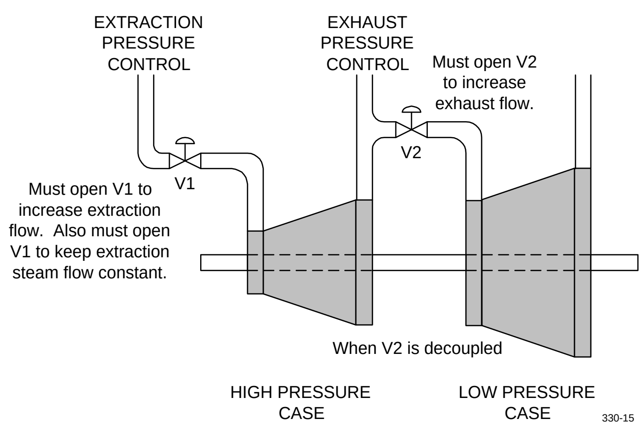
7.1 Decoupling

The **D** position in Channel 86 can be configured:

- (XXX0) = NO DECOUPLING
- (XXX1) = DECOUPLE V1 VALVE
- (XXX2) = DECOUPLE V2 VALVE

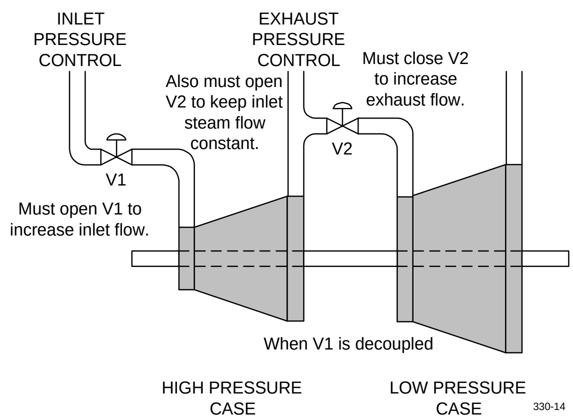
This option is designed for use with synchronous generator applications only. In such applications, it may be desirable to operate extraction pressure control simultaneously with inlet pressure control with power output unregulated. In this case, decoupling V1 will operate as follows:

> When the turbine is in DROOP control (connected to the utility grid), inlet pressure control can be enabled. If V1 is decoupled, the extraction controller will move only V2, thus changing extraction steam flow without disturbing V1 valve position which is controlling inlet steam pressure. The 2ND PID (cascade) controller will control inlet pressure by moving the V1 valve but will also move V2 valve position at the same time so as to maintain constant extraction steam flow.
>
> If the utility tie breaker should open, this will place the turbine in isochronous (frequency) speed control and inlet steam pressure control will be disabled. When this occurs, the decoupling function will also be disabled and extraction control will return to a *normal* mode of control, changing both V1 and V2 valve positions so as not to disturb horsepower demands.



Conversely, it may be desirable to operate extraction pressure control and backpressure control simultaneously without controlling power output. In this case, decoupling V2 will operate as follows:

> When the turbine is in DROOP control (connected to the utility grid), backpressure control can be enabled. If V2 is decoupled, the extraction controller will move only V1, thus changing extraction steam flow without disturbing V2 valve position which is controlling backpressure. The 2ND PID (cascade) controller will control backpressure by moving the V2 valve but will also move V1 valve position at the same time so as to maintain extraction steam flow constant.
>
> If the utility tie breaker should open, the turbine will be placed in isochronous (frequency) speed control and backpressure control will be disabled. When this occurs, the decoupling function will also be disabled and extraction control will return to a *normal* mode of control, changing both V1 and V2 valve positions so as not to disturb horsepower demands.



7.2 Kilowatt (Generator Output) Limiting

This will disable decoupling whenever the limit is reached, since decoupled operation cannot control the power output. When the kilowatt limit is reached, however, the *TS310* will disable decoupling so as to be able to control power as long as the limit is in force. When the limit is released, the *TS310* will return turbine operation to the decoupled state again.

7.3 Extraction Limit

A percent value may be entered in Channel 155 to limit the extraction flow. This entry will limit the output of the extraction control algorithm of the *TS310* and is directly proportional to the total extraction capability of the turbine. This assumes that the correct F, H and B values have been entered in Channels 90, 91 and 92 (see paragraph 3.7).

Thus, if the total extraction flow potential of the turbine with V1 wide open and V2 fully closed, for example, is 100,000 lbs per hour, a limit of 55% will allow a maximum extraction flow of only 55,000 lbs per hour under any load conditions. This limit is disabled if either 0% or 100% is entered.

See Chapter 9 of the Installation Configuration Operation Maintenance portion of this manual for a discussion on channel access.

Chapter 8 - Analog/Digital Inputs/Outputs

8.1 Analog Inputs-Setpoint

Several analog inputs to the *TS310* are specific to the 3RD PID control which regulates the extraction/admission functions of the *TS310*. These are:

- 3RD PID measurement - configured (08) in CH 70 or CH 71
- 3RD PID remote setpoint - configured (10) in CH 70 or CH 71
- EXTERNAL 3RD PID - configured (19) in CH 70 or CH 71

The 3RD PID measurement is necessary for extraction/admission control.

The 3RD PID REMOTE SETPOINT is optional. If this is configured, the internal setpoint (Channel 07) cannot be changed from the keyboard but will be governed by this analog input. Channel 07 will read whatever value is set by the remote signal. RAISE or LOWER contact inputs cannot be used if a 3RD PID REMOTE SET is used.

EXTERNAL 3RD PID is an optional provision which allows the extraction/ admission function to be operated from an external controller or other external analog signal. The 3RD PID control loop does not function in this instance. For example, an analog input signal will set the relationship between #1 and #2 analog outputs (V1 and V2) while the *TS310* will still impose the extraction map values set by the F, H and B values. The extraction steam rate will only change when this EXTERNAL 3RD PID analog input signal is changed. Speed control capabilities of the two valves will not be affected by this change in extraction control mode.

8.2 Contact Inputs-Outputs-Setpoint

Several of the contact inputs/outputs are specific to the 3RD PID loop. These are:

- 3RD PID RAISE - configured (08) in CH 72-79
- 3RD PID LOWER - configured (09) in CH 72-79

These contact inputs will raise or lower the 3RD PID control setpoint (Channel 07) providing no 3RD PID REMOTE SET analog input has been configured. RAISE and LOWER will function at the setpoint ramp rate which is defined as percent per second (of the transmitted measurement signal full range).

- REMOTE F2 function key - configured (11) in CH 72-79
- This function can be configured so that extraction control is enabled when the contact is closed and the extraction control is disabled when the contact is open (or vice versa). This configuration functions only whenever Channel 86 is configured (X14X). When extraction is enabled by this contact input, it cannot be disabled by F2 on the keyboard.
- A CONTACT OUTPUT configured for this definition will turn on whenever extraction control is enabled and will turn off whenever extraction is disabled (or vice versa). This function operates whether the F2 key is used on the *TS310* keyboard or the remote F2 contact input is used.
- A *TS310* display flag can also be configured to turn on, reflecting when extraction control is enabled. This flag is configured (9) and is one of the four flags in Channel 84.

Chapter 9 - Troubleshooting Extraction Control

Symptom	*Cause*	*Troubleshooting Steps*
Extraction pressure **rises** as load increases	Incorrect F VALUE in Channel 91.	Make F VALUE smaller.
Extraction pressure **falls** as load increases	Incorrect F VALUE in Channel 91.	Make F VALUE larger.
Speed (or load) increases when extraction flow **increases**	Incorrect H VALUE in Channel 90.	Make H VALUE smaller.
Speed (or load) increases when extraction flow **decreases**	Incorrect H VALUE in Channel 90.	Make H VALUE larger.
Extraction pressure rises above setpoint and cannot be controlled	External supply to the extraction header is greater than the demand. Turbine is already at zero extraction flow.	Look elsewhere. The *TS310* cannot reduce extraction pressure further without admitting steam which it is not configured to do.
	Turbine may be horsepower limited and must force unwanted extraction steam flow in order to maintain speed or load.	Reduce turbine load until V2 valve is no longer wide open. OR - Vent steam from the extraction steam header and live with it, the controller cannot control both power and extraction when one of the valves is limited. OR - Reduce some other external steam flow contribution to the extraction steam header until extraction pressure is again under control.
Turbine continues to extract some steam even when extraction steam flow should obviously be zero.	Steam governor valves may be out of calibration (V2 is not using all the steam being passed by V1).	Calibrate V2 to be wider open without changing V1, or calibrate V1 to pass less steam without changing V2 position under these conditions.
	F VALUE in Channel 91 is incorrect.	Make F VALUE smaller until extraction steam flow stops under these conditions.
	Turbine has been rerated or modified since the original extraction map was prepared.	Empirically adjust the F, H and B values for best operation as suggested in paragraph 3.7.

TS310 MOD4A Digital Controller

Synchronous Generator Operation Guide

Document No. 4933-0015

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Rev. 1

TRICONEX

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Revision History

Rev. A	September 1990	General technical and editorial revision.
Rev. B	July 1991	Technical revisions to the following: Paragraphs 8.3, 8.4, 8.5.
Rev. 1	April 1998	General technical and editorial revisions; reformatted including A4.

Contents

Figures

Chapter 1 - Introduction

The control of synchronous generator drives is simple and straightforward if one is already familiar with the control principles involved, plus the peculiarities of synchronous generators and electrical transmission.

Two kinds of control modes are used for most generator drives: DROOP control and FREQUENCY control. Frequency control is the more sophisticated of the two but seems to be the easiest to understand. However, most generator drives operate in DROOP control mode.

A good description of these control modes begins with the terminology, an area where different disciplines use different terms for the same function.

Rotating equipment people refer to DROOP control. However, controls or instrumentation people call this PROPORTIONAL ONLY control and might not recognize the term DROOP, even though they have the same meaning. Frequently, utilities or power-house people will refer to this as SPEED-LOAD control and may not recognize either of the other terms.

***NOTE**: In this document, DROOP control and PROPORTIONAL ONLY control and SPEED-LOAD control all refer to the same thing. The term LOAD control is also used sometimes and it also has essentially the same meaning.*

Similarly, people with a rotating equipment background, like mechanical engineers, refer to ISOCHRONOUS control. Those with a controls oriented background call this PROPORTIONAL PLUS RESET or PID control. And, utilities or power-house people call the same thing FREQUENCY control.

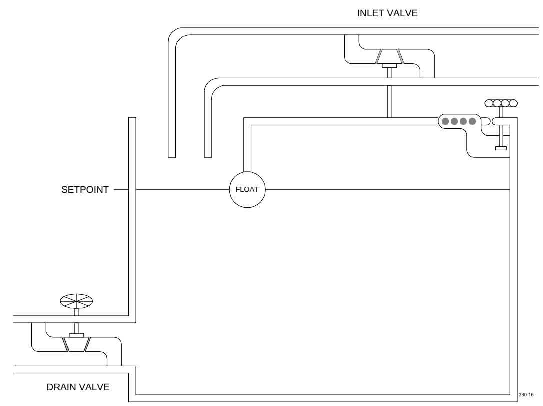
Probably the reason most people find FREQUENCY or ISOCHRONOUS control easier to understand is that it more closely resembles human response, where we, as controlling devices, will continue to adjust our outputs until the measurement matches the setpoint precisely. We manually *reset* our outputs so long as an error (the difference between measurement and the setpoint) exists.

Since microprocessor-based control is being applied more and more frequently to rotating equipment and to turbo-generator installations, mechanical people, electrically oriented people and controls people are thrust together more than ever. The importance of everyone understanding terminology formerly used exclusively by other disciplines cannot be over emphasized.

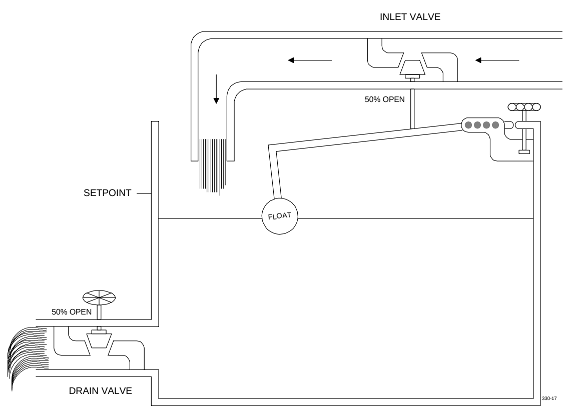
Chapter 2 - Droop Control

2.1 Droop Control - Visual Examples

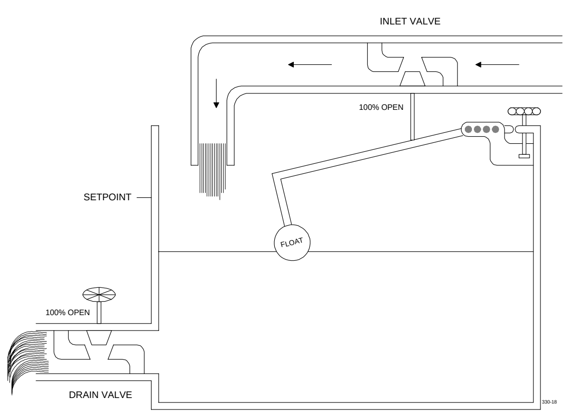
Visualizing DROOP control is somewhat difficult at first until we realize just how simple (and useful) it is. A good analogy is a float-controlled level in a tank.



In this figure, the drain valve *D* has been completely closed. The inlet valve *I* will let water flow into the tank until the float *F* rises to the setpoint *S* (that level where the float causes valve *I* to shut off completely).



Now, if we partially open the drain valve *D* as shown in this figure, water will begin to drain from the tank. The float will begin to fall with the water level, opening inlet valve *I* until the volume of water flowing in exactly matches the volume flowing out, at which point the level (and float) will stabilize at some intermediate level below the setpoint.



If the drain valve is now opened fully, the level will fall even more until the inlet water flow equals the outflow. The level (or measurement) will now stabilize at an even lower level, offset still further from the setpoint, as shown in this figure.

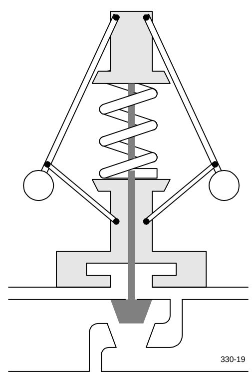
Figure 1. Droop Control Example: Float-Controlled Level in a Tank

It is important to understand that the level will never return to the setpoint (or reference) so long as there is demand at the drain valve. The only time the level will be at the reference is when the load is zero.

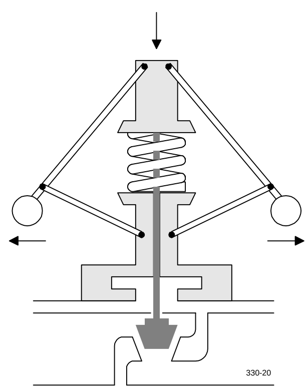
There will be a different level corresponding to each set of load conditions. The system does not automatically *reset* to eliminate the offset or measurement error caused by a load change.

There are other types of load change which can affect the level. These might include a higher water supply pressure, a leak in the tank, and so on.

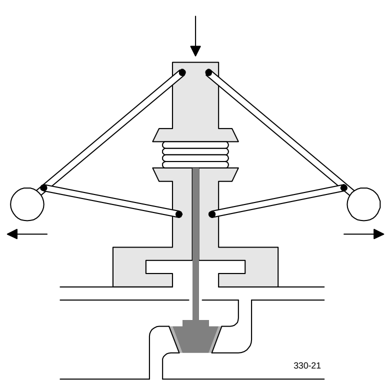
An analogy closer to rotating equipment is the archaic *flyball* governor.



In this figure, we see a flyball governor at rest. The spring, which opposes the centrifugal force of the flyballs when turning, has forced the steam valve fully open. The valve will remain in this position until the centrifugal force of the flyballs reaches the level necessary to overcome the spring; it will then start to close the valve.



In this figure, centrifugal force of the flyballs is high enough to partially depress the spring and close the governor valve about halfway. Observe that turbine speed will stabilize at some RPM higher than that required to just barely compress the spring.



In this figure, centrifugal force of the flyballs has compressed the spring sufficiently to almost close the governor valve. (balls out) This would be a low load (high speed) condition where speed will keep the governor valve almost closed. If the load should increase, speed must fall. This in turn will cause the governor valve to open somewhat. RPM will then stabilize at a lower value.

Figure 2. Droop Control Example: Flyball Governor

The level control and the flyball governor are both examples of PROPORTIONAL ONLY or DROOP control. The diagram below shows how a governor valve will open as the speed falls (DROOPs) and how the governor valve will close as the speed rises. The mechanical characteristics of the governor valve (linkage, spring tension, etc.) will determine the maximum governor and minimum governor operating speeds of the turbine. The total speed range (reference) can be adjusted up or down by a small amount, as limited by the mechanical adjustments of the governor.

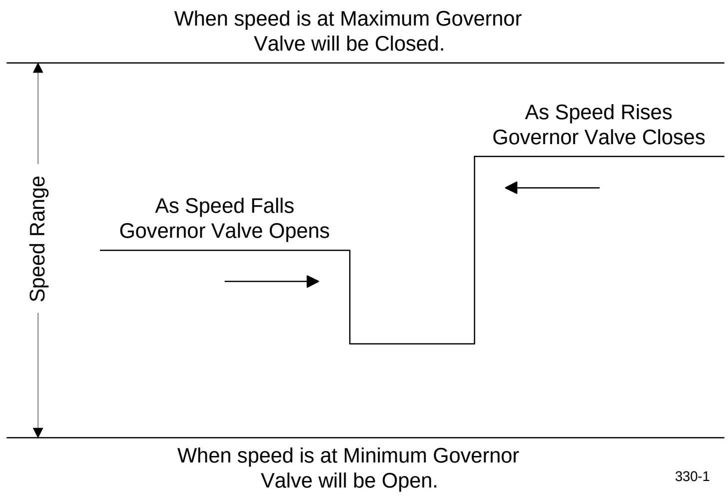


Figure 3. Valve Open/Close vs. Speed Increase/Decrease

If the speed does not change but the speed range is raised, then the governor valve will open more. If the speed does not change but the speed range is lowered, then the governor valve will close more.

2.2 Droop Control And Synchronous Generators

A natural characteristic of synchronous generators is that they must turn at a fixed (synchronous) speed. If two or more synchronous generators are connected to the same electrical system (utility grid), they will be electrically locked together as if they were on the same shaft.

The typical utility grid may have dozens or even hundreds of synchronized generators. Since there is no way an individual generator can affect the speed (electrical frequency) of the whole grid, it is pointless to try to use speed control under these conditions. Isochronous speed control would only cause the individual turbine to either load up completely if its reference is slightly higher than that of the utility grid, or to totally unload if its reference is slightly lower than that of the utility grid.

DROOP control is a different matter. Since there is no *automatic reset* in DROOP control, the controller will open the steam valve a fixed amount determined by the relationship between speed (frequency) and speed reference.

2.3 Enter LOAD Control

Turbine speed cannot be changed when driving a synchronous generator locked to the utility grid but we can change the speed reference of the controller. When we raise the reference, the governor valve will open, increasing load and when we lower the reference, the governor valve will close, decreasing load. Thus, we find that the *archaic* mechanical governor may be useful, after all, as a LOAD controller. What was previously a *poor* speed control now becomes a useful load control when the generator is synchronized and locked to the grid. Thus arises the term SPEED/LOAD control as commonly used by power house people.

2.4 Droop Stabilizes The Grid

We mentioned that dozens or even hundreds of synchronous generators may be connected to the utility grid. Most of these are in DROOP control mode. Although these turbines will control load when the speed is fixed, they will change load if the speed (frequency) of the utility grid should fall (DROOP). Therefore, all of these load controlled machines will pickup up load if the grid frequency falls and will drop load if the grid frequency rises. This provides an effective stabilizing influence on the frequency of the whole utility grid.

This demonstrates that DROOP control is not archaic at all; only the one-hundred year old mechanical governor is archaic because of its mechanical limitations. DROOP control is therefore a very useful mechanism and by incorporating DROOP control performance in modern digital control devices we can preserve the useful functions of DROOP yet at the same time eliminate the objectionable limitations of the mechanical governor.

2.5 Droop-On-Output Or Droop-On-Kilowatts

The modern digital controller easily provides the capability of automatically switching from FREQUENCY control to DROOP control and back as required by operation. The controller can back-calculate the DROOP reference required to hold output or valve position at a constant value and thus make the transfer with no bump or change in control output. Also, the digital controller has the capability to DROOP on control output (the DROOP function discussed previously) but it can also DROOP-ON-KILOWATTS. This involves using the kilowatt output signal as feedback for the control algorithm, instead of using control output as a feedback signal as shown below.

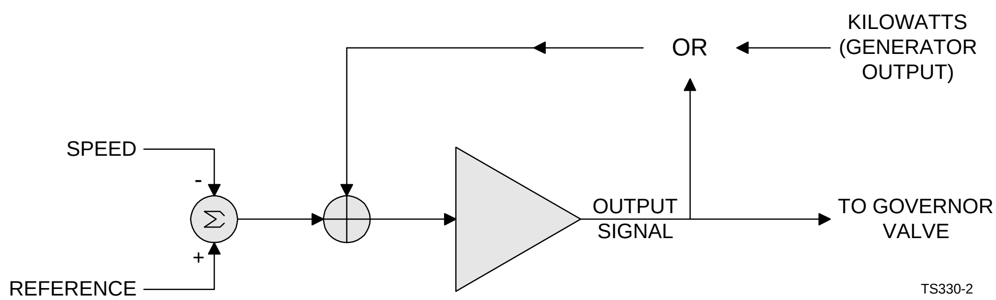


Figure 4. Droop-On-Output Or Droop-On-Kilowatts

2.6 True Load Control

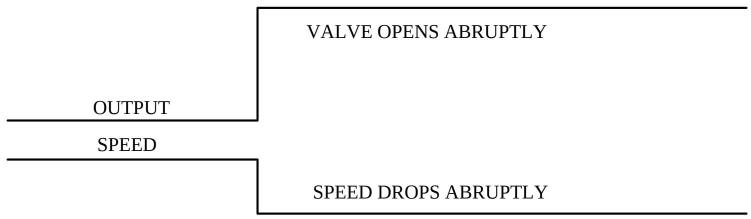
When the controller is configured for DROOP-ON-KILOWATTS, the speed reference becomes a *load setpoint*; i.e., if the DROOP speed reference is set at midpoint (halfway up the speed range), the control output will drive open or closed as necessary to provide one-half generator load (kilowatts) since the control feedback is now a kilowatt signal, not the control output.

This function will hold generator output at 50%, or whatever the reference has been set, despite changes in turbine steam pressures.

NOTE: *The speed/speed reference relationship still acts to stabilize the grid by reducing the load when the speed rises, and by increasing the load when the speed falls (DROOPs).*

2.7 PIP Droop

There is another difficulty with plain DROOP control. It is strictly a displacement function. That is, if load (or speed) should suddenly change, the control output (valve position) will change just as suddenly. This characteristic causes some instability of control due to the abrupt change in control output. This requires a DROOP setting of perhaps six to ten percent (of full governor speed value) in order to obtain stable operation.



PIP DROOP provides short term stability based on the PI value (Proportional and Integral) while DROOP (the other P) is maintained independent of stability. With this control mode, DROOP settings of three or four percent are common and will furnish much more stable control of the turbogenerator.

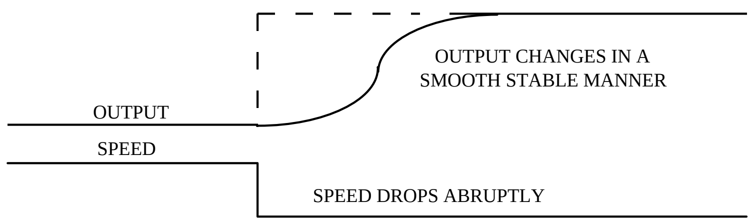


Figure 5. PIP Droop

Again, the modern digital controller can easily provide flexible performance. This includes PIP DROOP control.

2.8 When The *TS310* Is Used For Generator Control

TS310 software is designed to be used for SYNCHRONOUS generator drives. Generator configuration should NOT be used with INDUCTION generators.

If it is intended that the controller operate in DROOP control mode at all times (never in FREQUENCY control) it will be necessary to configure a contact input labeled LOAD BREAKER IN (1005) in Channels 72 through 79. A contact input labeled TIE BREAKER IN is not necessary when Channel 87 is configured for DROOP ONLY.

If it is intended that the controller operate in DROOP control mode when connected to a utility grid, but should change to FREQUENCY control during isolated bus operation, it will be necessary to configure a contact input labeled LOAD BREAKER IN (1005) in Channels 72 through 79 and it will be necessary to configure a contact input labeled TIE BREAKER IN (1006) in Channels 72 through 79. This will be required any time Channel 87 is NOT configured DROOP ONLY.

The contact inputs should be connected to the appropriate auxiliary breaker contacts because whenever the *TS310 sees* a LOAD BREAKER IN closed contact it will perform as if the LOAD BREAKER is closed. The contact inputs should also be appropriately powered.

Whenever the *TS310 sees* a TIE BREAKER IN closed contact it will always switch bumplessly to DROOP control mode and will perform as if it is connected to an infinite utility bus.

Whenever the *TS310 sees* a closed LOAD BREAKER IN contact change to the open condition, whether the TIE BREAKER IN contact is open or closed, the assumption is that there is total load rejection and the *TS310* will close the steam governor valve before any speed increase is registered. The *TS310* will continue to close the governor valve, completely if necessary, until a decrease in RPM is registered.

Chapter 3 - Startup

3.1 Improved Startup Sequencing

Digital controllers can provide still one more valuable feature. If the controller is configured for DROOP control, the startup sequence, acceleration and synchronizing to the utility bus are somewhat awkward in that the speed (RPM) is never at the reference when using DROOP control. The digital controller easily solves this problem by operating in ISOCHRONOUS speed control through the startup and synchronizing phases and then automatically switching to DROOP control when the generator load breaker closes. Even *startup* tuning can be employed to make synchronizing easier when the actual running tuning constants are not quite satisfactory for no-load conditions.

3.2 Upon Startup

Any startup sequence may be configured for generator operation. Startup will proceed in ISOCHRONOUS speed control until the *TS310 sees* the LOAD BREAKER IN contact close. At this time, the *TS310* will take appropriate action as it may be configured, above.

On reaching minimum governor speed, the *TS310* will automatically add 100 RPM if it has been configured SYNCH GENERATOR in Channel 80. Minimum governor should therefore be set at 100 RPM below synchronous speed. If Channel 80 has not been configured SYNCH GENERATOR, none of the *TS310* synchronous generator features will function.

NOTE: The overspeed test will not enable unless the load breaker is open.

Chapter 4 - Synchronous Generators Vs Induction Generators

Two types of electrical generators are found in common use today. These are synchronous generators and induction generators. Their characteristics differ considerably. The *TS310* generator software is designed to be used with synchronous generators. It is not appropriate for use with induction generators. Induction generator control should be configured as plain speed control.

4.1 Synchronous Generators

Synchronous generators require a source of DC power which is used to create a magnetic field in the rotor (the part that turns) of the generator. This magnetic field spins with the rotor and, as the magnetic field passes through the stator windings (the shell of the generator that does not turn), creates alternating current that is precisely coordinated with the rotation (RPM) of the rotor.

Speed (RPM) of the synchronous generator thus creates an alternating current whose frequency is a function of the rotation speed. This is referred to as *synchronous speed*. If two or more synchronous generators are connected to the same electrical system (grid) they will be electrically locked together as if they were on the same shaft. They must be carefully coordinated and must be electrically *in-phase* before the generator load breaker is closed.

⚠ **CAUTION** Severe damage can result if a generator load breaker is closed when a synchronous generator is out-of-phase.

4.2 Induction Generators

Induction generators are not self-excited. The magnetic field of the rotor is created (induced) when the rotor SLIPS in relation to synchronous speed. This is established by an alternating current flowing in the stator windings of the induction generator. This current is furnished from the utility grid. If the induction generator turns slower than synchronous speed, it will act as an induction motor; if it turns faster than synchronous speed, it will act as an induction generator. Most induction generators are in fact induction motors that are being driven above synchronous speed by a steam turbine or a water turbine. If the induction generator turns exactly at synchronous speed, it will be inert and will generate no electricity at all.

The magnetic field in the rotor of the induction generator is caused by the alternating current which flows in the stator and is furnished by the connected utility grid. Therefore, if the utility grid fails, this current ceases to flow and the induction generator will cease to generate electricity.

The more negative the SLIP (when actual RPM is greater than the synchronous speed), the more electricity that will be generated by the induction generator. A turbine driving an induction generator should use plain isochronous speed control because the induction generator application is more closely related to driving a centrifugal pump or a compressor than to the DROOP LOAD control that is required for driving a synchronous generator which is tied to the utility grid.

Typically, induction generator SLIP will range from about ten RPM to as much as 40 or 50 RPM. Once rated output has been obtained from an induction generator, driving the generator to a higher speed can damage the generator just as overloading an induction motor will cause overheating and damage to the motor.

4.3 Differences In Control

The control schemes used with Synchronous and Induction generators must then be quite different.

The Synchronous generator control scheme should use PIP DROOP control when connected to a utility grid but should at the same time be capable of switching to Isochronous (FREQUENCY) control when required. It should also be able to switch bumplessly (without bumping the control output) back to DROOP control mode when the generator is reconnected to the grid.

Changing the DROOP speed reference changes the load, not speed, when the generator is connected to the grid. However, changing the reference when disconnected from the grid will change the local frequency, not load. The load is determined by the connected electrical load of the *isolated* (local) electrical bus.

In contrast, the Induction generator control scheme should always be isochronous speed control. Here, changing speed does change the load, just as if the turbine were driving a compressor or a centrifugal pump. The induction generator will require a much smaller speed range, however, than a centrifugal pump or a compressor. The speed range should match the SLIP range of the induction generator.

Chapter 5 - Synchronizing

5.1 Manual Synchronizing

The *TS310* will function in isochronous speed control mode until the generator load breaker is closed.

After the startup sequence, the operator will observe that the *TS310* brings the turbine up to synchronous speed and waits there for the operator to initiate manual or automatic synchronizing.

Manual synchronizing is relatively simple since startup tuning will fit the controller and turbine response to no-load conditions and then pressing the RAISE/LOWER function for less than one second will change the speed reference by ONE RPM.

5.2 Closing The Generator Load Breaker

When the LOAD BREAKER IN contact closes, several options which will affect generator loading are available to the *TS310*.

- If the TIE BREAKER IN contact is open (the controller is to remain in FREQUENCY control) the *TS310* will take no action when the LOAD BREAKER IN contact closes. The controller will remain in isochronous (frequency) speed control mode.
- If the TIE BREAKER IN contact is closed, or if the *TS310* is configured DROOP ONLY, the *TS310* will back-calculate that DROOP speed reference required to hold controller output (valve position) constant. The effect is that DROOP speed reference changes but the valve position does not.
- If the *TS310* has been configured to DROOP-ON-KILOWATTS by coding an analog input (09) in Channels 70 and 71 generator output, the *TS310* will immediately raise output (open the valve) until it *sees* five percent generator load.
- If the *TS310* is configured DROOP-ON-OUTPUT (that is, no code 09 analog input signal has been configured), the controller output will remain where it is until the operator presses RAISE to increase the generator load, OR;

  If a controller MINIMUM VALVE POSITION has been set in Channel 38 (in percent), the controller will move to that minimum loading as set in Channel 38 whenever in DROOP control mode. (Anytime the controller exits DROOP control, the minimum limit will be removed.)
- If the *TS310* has been configured for STARTUP TUNING in Channel 82, startup tuning (Channels 94 and 95) will be used until the LOAD BREAKER IN contact closes. At this time, controller tuning constants will change bumplessly to Channels 20 and 21.

5.3 How The *TS310* Performs Autosynchronizing

The MPS390 (discussed in Chapter 8 of this manual) provides a 0 to 10 volt signal which represents phase angle as measured by potential transformers that are connected to the *A* phase on each side of the open generator load breaker.

While the generator runs faster than the utility grid, this 0 to 10 volt signal will read zero volts when the circuits are in phase; it will read 5.00 volts when the circuits come into phase the second time; and it will read 10.00 volts when the circuits come into phase the third time. (The signal immediately reverts from 10.00 volts to 0.00 volts at 720 degrees if the signal continues to increase.)

The 0.00 to 10.00 volt signal therefore represents zero to 720 degrees of phase angle. The *TS310* interprets the signal as follows:

- If the signal is **increasing** (equivalent to a clockwise turning synchroscope), then the *TS310* will energize a contact output (configured 3025 in Channels 72 through 79) to close the generator load breaker when the signal passes 4.95 volts increasing.
- If the signal is **decreasing** (equivalent to a counter-clockwise turning synchroscope), then the *TS310* will not try to close the generator load breaker but will adjust the speed control output gradually higher to cause the signal to increase.

The reset-only controller, which adjusts for synchronizing speed, is normally tuned with 100 to 200 seconds of reset setting in Channel 28. Derivative action in Channel 29 is seldom used and is normally set at zero.

- If the signal is **increasing**, the *TS310* will reduce speed gradually until the circuits are in phase and will reverse and begin the process over again.

The *TS310* will briefly energize the contact output configured (3025) in Channels 72 through 79 each time the synch phase signal passes 4.95 volts increasing, until a contact input configured (1005) in Channels 72 through 79 connected to the load breaker auxiliary contacts indicates that the generator load breaker has in fact closed. The *TS310* will stop autosynchronizing functions at this time.

5.4 Autosynchronizing Cautions

CAUTION

IMPORTANT: When using the *TS310* controller and MPS390 generator control module for autosynchronizing a synchronous generator, the following guidelines should be followed.

- Check the MPS390 calibration at installation. It can change output slightly due to any variation in the +15 VDC power supply output.
- Install a separate SYNCH-CHECK (Basler or equivalent) device to protect against out-of-phase breaker closing due to wiring connection errors, equipment malfunction, etc.
- Test synchronizing AND BREAKER CLOSING functions with the generator load breaker DISABLED.
- NEVER enable the breaker closing function until the system has been thoroughly checked and tested with the breaker racked out or otherwise disabled. There are too many connections and associated pieces of equipment which are subject to erroneous installation. Protect your installation against human error and equipment malfunction!

Chapter 6 - Tuning & Setpoints

6.1 Control Tuning For Generator Operation

Whether STARTUP TUNING is used or not, generator operation requires that tuning constants be set in Channel 20 (proportional band), Channel 21 (reset) and Channel 23 (DROOP). Typical tuning constants might be: Channel 20 - 20%; Channel 21 = 2 seconds; Channel 23 = 4%. PIP DROOP requires that all three of these tuning constants be entered.

***NOTE**: Proportional band setting, Channel 20, must always be at least twice the DROOP setting in Channel 23. If the proportional band is reduced to a setting below this limit, the DROOP setting will automatically change to one half the proportional band setting.*

6.2 Cascade Control

If cascade control (2ND PID control loop) is to be used for backpressure control or inlet pressure control or some other function like pond level, then it should be noted that cascade control will only enable when the *TS310* controller is in DROOP control mode.

If Channel 83 has been configured (0100) or (1100), cascade control will enable automatically when the controller goes into DROOP control mode. Cascade control will disable automatically when the *TS310* exits DROOP control.

If Channel 83 has been configured (2100) or (3100), cascade control can be enabled by pressing **F1** function key but only after the controller goes into DROOP control mode. Cascade control will disable automatically when the *TS310* exits DROOP control. If the *TS310* then returns to DROOP control mode, cascade control does not re-enable automatically. The **F1** key must be pressed again in order to re-enable cascade control.

***NOTE**: If the turbine is using extraction control and decoupling has been configured in Channel 86, decoupling will enable only when cascade control is enabled.*

6.3 Remote Speed Setpoints

A number of variations are available for remote speed setpoints or remote speed reference. These will enable and disable somewhat differently when the *TS310* controller is configured for synchronous generator operation.

An analog input configured (04) in Channels 70 and 71 will be used as a remote speed setpoint or speed reference by the *TS310* controller. Minimum input signal (say, 4 milliamps) will constitute synchronous speed (minimum governor plus 100 RPM) while maximum input signal (say, 20 milliamps) will constitute the equivalent of maximum governor. Therefore, engineering units to accompany this input signal should be configured accordingly. The engineering units are merely display values. Changing the engineering units to some other value will have no effect on the remote speed setpoint action.

Whenever a remote speed setpoint has been configured for use with synchronous generator configurations, the remote speed setpoint will be ignored so long as the *TS310* controller is in isochronous (frequency) control mode. The remote speed setpoint will only be recognized and used, as it has been configured in Channel 81, when the *TS310* controller is in DROOP control mode.

Chapter 7 - Limits

In addition to the limits listed in the *TS310* manual, several limits are or can be specific to synchronous generator applications.

7.1 Maximum Load Limits

The governor valve travel can be high-limited by a fixed limit set in Channel 39 or by a fixed limit set in Channel 66 (if no kilowatt limit has been configured). Both of these limits are set in percent and will limit the speed control output (valve travel) to that percent.

7.2 Kilowatt (Generator Output) High Limits

The entry in Channel 66 will become a kilowatt (generator output) high-limit if an analog signal representing generator output is input to the *TS310* and is configured (09) in Channels 70 and 71. This requires a reset setting in Channel 68 to tune the reset-only controller which outputs the high-limit. Channel 87 must be configured (XXX1) to enable this kilowatt limit. Typical tuning in Channel 68 is one second or 0.5 seconds.

Since the analog input signal configured (09) in Channels 70 and 71 will also cause the *TS310* to DROOP-ON-KILOWATTS, an alternative is provided which permits kilowatt high limiting without DROOP-ON-KILOWATTS.

Configuring the generator output signal as an analog input (20) instead of the (09), above, will cause the reset-only controller to act on the measurement which has been configured (20). This can be a generator output signal or some signal other than generator output if desired. The limiting setpoint still goes in Channel 66 (in percent) as above, the tuning is still typically one second or 0.5 seconds and is still entered in Channel 68, but Channel 87 must be configured (XXX0).

7.3 Load (Generator Output) Low Limits

When a kilowatt signal is configured (09) in Channels 70 and 71, the *TS310* will automatically DROOP-ON-KILOWATTS as mentioned before. When configured as such, the *TS310* will perform a minor change in loading to ensure a minimum generator load when the generator load breaker closes (if the *TS310* has been configured DROOP ONLY or if the utility tie breaker is already closed).

Under these conditions, the *TS310* will *look for* a five percent generator output in the signal configured (09) in Channels 70 and 71. Since the load breaker is closing under no-load conditions, the five percent output will not be there, so the *TS310* will proceed to drive the control output (valve position) higher until the *TS310 sees* five percent generator load in that signal.

When no generator output signal is input as a code (09), the *TS310* has no way of measuring five percent load. Thus, when configured without the (09) signal, DROOP-ON-OUTPUT will prevail and the *TS310* will hold the control output constant when the load breaker closes.

Two things can be done to ensure that the generator does not MOTOR and trip out on reverse current:

- If the RAISE key is pressed immediately on the generator load breaker closing, the turbine should pick up load until a minimum loading is observed; or
- A fixed percent entry can be set in Channel 38 as a low-limit to the control output (valve position). This low-limit is not desirable during isochronous (frequency) operation and therefore does not enable until the *TS310* goes into DROOP control. The limit will disable whenever the *TS310* switches back to frequency control. This is not a minimum generator output limit but is rather a minimum governor valve position limit which should be set empirically to hold the steam governor valve in such a position that it will produce the desired minimum generator output.

7.4 Adjustable Load Limit

If an analog input signal is configured (03) in Channels 70 and 71, it will become a remote load limit. The remote load limit is another governor valve high-limit, but it is adjustable. Thus, if the remote load limit happens to be at 75%, this will limit control output (and valve position) to 75%. This limits in FREQUENCY and in DROOP mode.

The remote load limit might be a 4 to 20 milliamp signal input from an external electronic manual station or from a computer or from some external controller which might be used to limit export electricity or to maintain a minimum import of electricity or to low limit inlet steam pressure, and so on.

Chapter 8 - The TRISEN MPS390

The TRISEN MPS390 Generator Control Module is used for obtaining a generator output (kilowatt) signal; to provide a synch phase signal to the *TS310*; and to calculate and distribute a parallel line signal. The parallel line signal is used when two or more *TS310* controllers with MPS390 modules are configured for parallel load sharing operation on an isolated bus.

Only *TS310* to MPS390 interconnections are shown on the following pages. Refer to the MPS390 manual for connecting PTs, CTs, etc.

8.1 Kilowatt Input

The MPS390 generates a 0 to 10 volt signal representing generator kilowatt output. This signal can be input to the *TS310* as shown on Figures 6, 7 and 8 to serve kilowatt limiting or DROOP-ON-KILOWATTS. Any kilowatt transmitter can be used if it outputs a 4 to 20 mA signal, a 0 to 10 volt signal; etc.

8.2 Autosynchronizing - MPS390

As shown on Figures 6, 7 and 8, the MPS390 can also provide a 0 to 10 volt signal which the *TS310* will use as a synch phase signal to control autosynchronizing. The *TS310* actually does the synchronizing and closes the generator load breaker using the synch phase signal from the MPS390 as a control guide.

Figures 6, 7 and 8 showing autosynch connections indicate that the *TS310* contact output to close the generator load breaker must be connected through MPS390 terminals #17 and #18. This permits the MPS390 to *vote* on breaker closing pending correct voltage matching which is done by the MPS390.

8.3 Minimum *TS310*/MPS390 Connections For Generator Output (Kilowatts)

Typical Configuration:

No. 2 Analog Input
CH 71 = XX09 (KW)
CH 50 = 0.00 Volts
CH 51 = 10.00 Volts
CH 52 = 0 KW
CH 53 = Full Range KW

No. 4 Digital Input
CH 75 = 1005 (Load Breaker In)

No. 5 Digital Input
CH 76 = XXXX

No. 6 Digital Input
CH 77 = XXXX

No. 7 Digital Output
CH 78 = 1006 (Tie Breaker In)

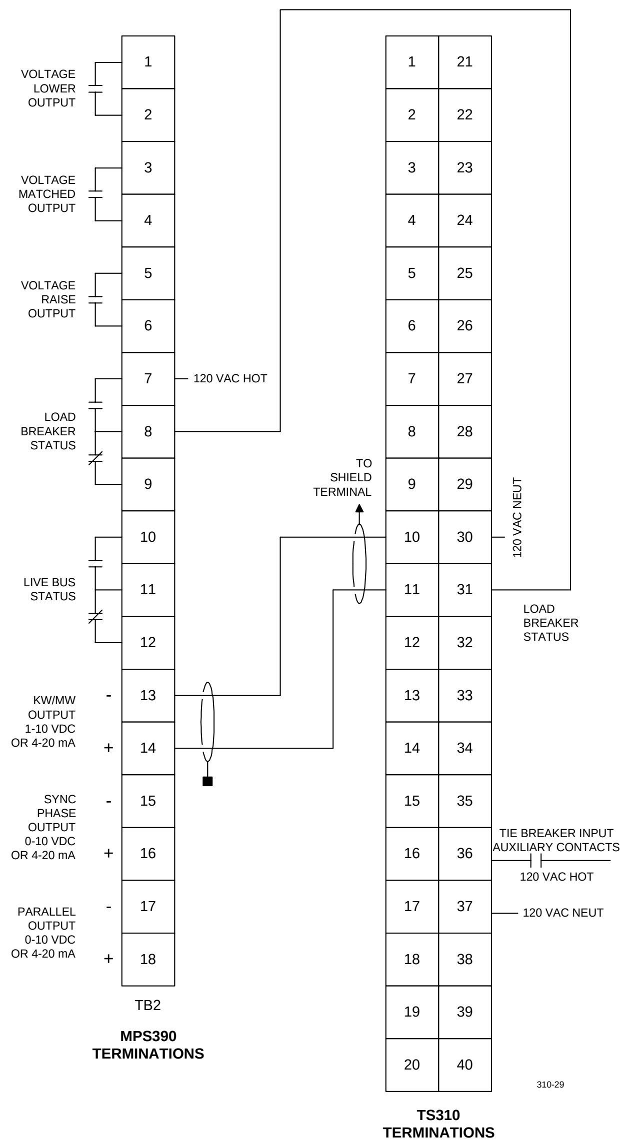


Figure 6. Minimum *TS310*/MPS390 Connections for Generator Output (Kilowatts)

8.4 Minimum *TS310*/MPS390 Connections For Kilowatts And Autosynchronizing

Typical Configuration:

No. 2 Analog Input
CH 71 = XX09 (KW)
CH 50 = 0.00 Volts
CH 51 = 10.00 Volts
CH 52 = 0 KW
CH 53 = Full Range KW

No. 3 Analog Input
CH 71 = 07XX (Sync Phase)
CH 54 = 0.00 Volts
CH 55 = 10.00 Volts
CH 56 = 0 Degrees
CH 57 = 720 Degrees

No. 4 Digital Input
CH 75 = 1005 (Load Breaker In)

No. 5 Digital Input
CH 76 = 2015 (Dead Bus Signal)

No. 6 Digital Input
CH 77 = 3025 (Close Load Breaker)

No. 7 Digital Output
CH 78 = 1006 (Tie Breaker In)

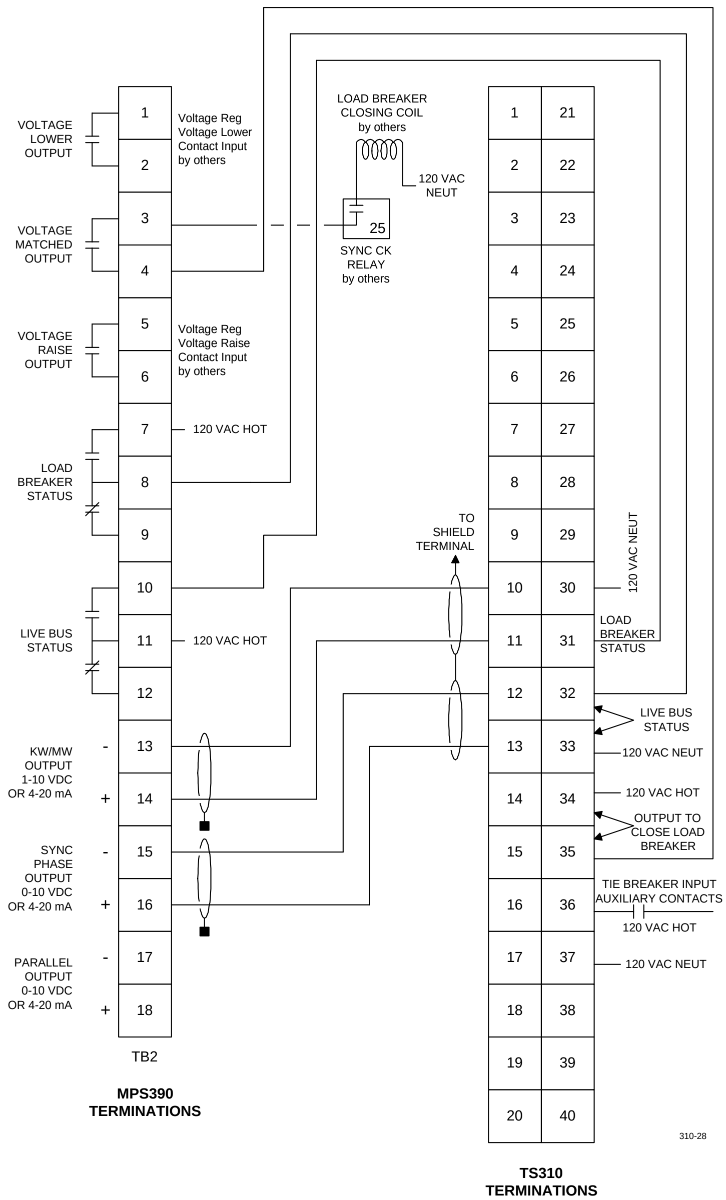


Figure 7. Minimum *TS310*/MPS390 Connections for Kilowatts and Autosynchronizing

8.5 Minimum *TS310*/MPS390 Connections For Kilowatt , Autosynchronizing, and Parallel Isochronous

Typical Configuration:

No. 2 Analog Input	**No. 3 Analog Input**	**No. 4 Analog Input**
H 70 = XX009 (KW)	H 71 = 07XX (Sync Phase)	CH 71 = XX06 (Parallel Isoc)
H 50 = 0.00 Volts	H 54 = 0.00 Volts	CH 58 = 0.00 Volts
H 51 = 10.00 Volts	H 55 = 10.00 Volts	CH 59 = 10.00 Volts
H 52 = 0 KW	H 56 = 0 Degrees	CH 60 = 0.0 % System
H 53 = Full Range	H 57 = 720 Degrees	CH 61 = 100.0% System Load

No. 4 Digital Input
CH 75 = 1005 (Load Breaker In)

No. 5 Digital Input
CH 76 = 2015 (Dead Bus Signal)

No. 6 Digital Input
CH 77 = 3025 (Close Load Breaker)

No. 7 Digital Output
CH 78 = 1006 (Tie Breaker In)

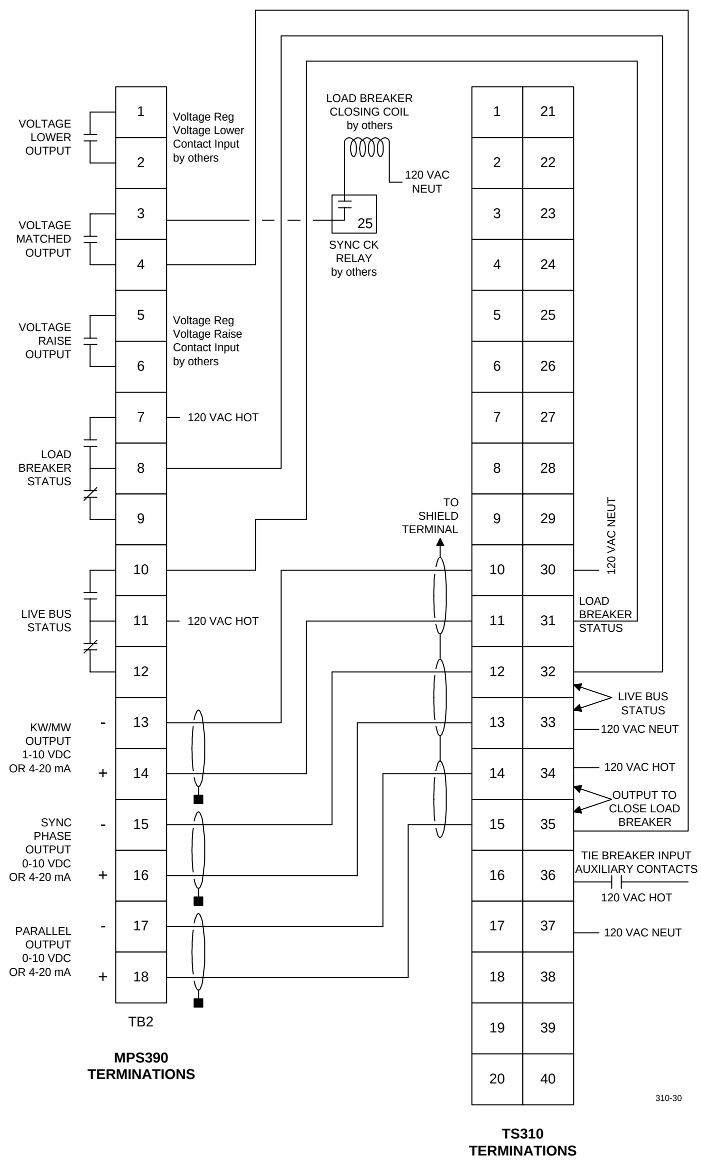


Figure 8. *TS310*/MPS390 Connections for Kilowatt Signal, Autosynchronizing, and Parallel Isochronous Operation

Chapter 9 - Parallel Isochronous Operation

The *TS310* can provide parallel isochronous operation of two or more turbogenerators when driving an isolated bus. When Channel 87 is configured XX2X, XX3X or XX4X, the *TS310* will *look for* a parallel line signal from the MPS390 if the utility tie breaker is open.

If the utility tie breaker is closed, the *TS310* will revert to DROOP control. Whenever the utility tie breaker is open, the *TS310* will switch to parallel isochronous operation, depending on the configuration used.

Specifics of parallel isochronous operation include two or more MPS390s calculating a percent generator output which is then impressed upon an averaging parallel line signal (MPS390 terminals 23 and 24). This parallel line signal is then used by the *TS310* as a setpoint causing each *TS310* to drive its percent output to that percentage value provided by the parallel line signal.

NOTE: *For parallel isochronous operation, the generator load breaker auxiliary contacts terminate at the MPS390, not at the* TS310. *This must be done so that each MPS390 can stop its contribution to the parallel bus when its respective generator load breaker opens.*

9.1 Parallel Isochronous Delay

Channel 69 allows entry of values one through twelve. This is an adjustable damping provision used only with PARALLEL ISOCHRONOUS OPERATION. The purpose of the DELAY function is to stabilize parallel operation of generator drives when configured in PARALLEL ISOCHRONOUS MODE. A setting of one will provide a 60 millisecond lag or delay. Each higher number will double the value of the delay. Thus, a setting of two will provide a delay of 120 milliseconds; a setting of three will furnish a delay of 240 milliseconds; a setting of four will delay by approximately one/half second and so on. A reasonable starting place would be a setting of six.

9.2 Parallel Isochronous Definition

Parallel isochronous operation is defined as the isolated operation of two or more turbogenerators which will provide frequency control in concert or in a load sharing operation.

Chapter 10 - Troubleshooting Generator Operation

Symptom	*Troubleshooting Steps*
Backs-off-the-line, Is motoring, or Tends to trip out on reverse current	• Configure a minimum valve position in Channel 38. Set this limit empirically so that generator output is held at some minimum value. This low limit will enable whenever the *TS310* controller goes into DROOP control mode. The limit will disable whenever the *TS310* switches to frequency control. **OR -** Immediately press the RAISE key to provide a minimum generator load as soon as the generator load breaker closes.
Kilowatt output fluctuates	This can be caused by varying kilowatt signal from the generator output or kilowatt transmitter to the *TS310* controller. This symptom may also indicate a poorly calibrated or sloppy steam valve actuator or valve rack. The following is a temporary remedy: • Reconfigure the kilowatt analog input signal to code (01) display only, from the code (09) which causes the controller to DROOP-ON-KILOWATTS. • If this eliminates the problem, correct the cause of the fluctuating kilowatt signal.