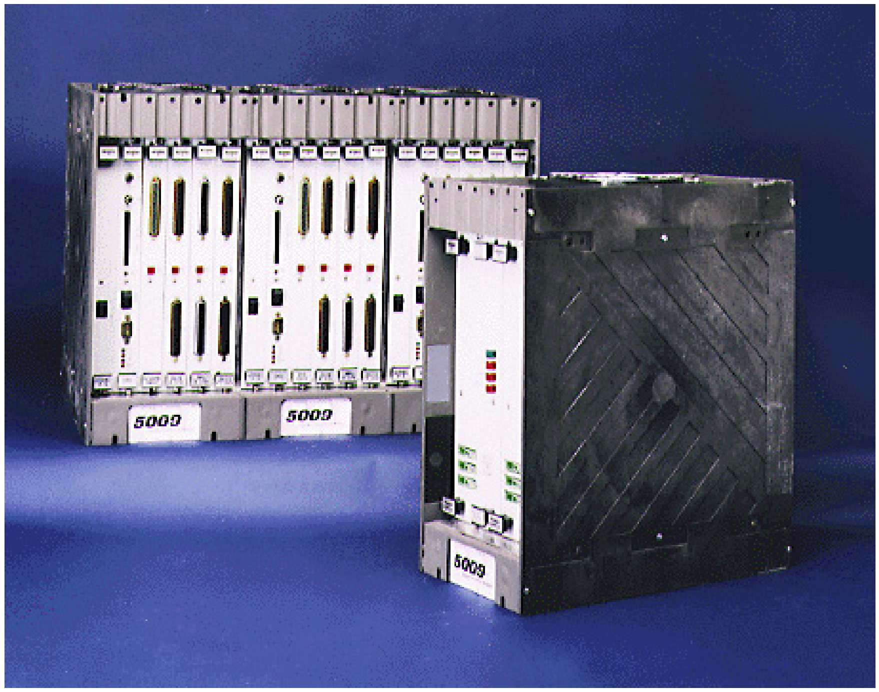
Product Manual 26320V1
(Revision B)
Original Instructions



MicroNet™ TMR 5009C
Digital Control System

Volume 1
Operations Manual

Manual 26320 consists of 3 volumes (26320V1, 26320V2, 26320V3).

Operations Manual

General Precautions	**Read this entire manual and all other publications pertaining to the work to be performed before installing, operating, or servicing this equipment.** **Practice all plant and safety instructions and precautions.** **Failure to follow instructions can cause personal injury and/or property damage.**

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Revisions—Changes in this publication since the last revision are indicated by a black line alongside the text.

Contents

WARNINGS AND NOTICES .... **IV**

ELECTROSTATIC DISCHARGE AWARENESS .... **V**

CHAPTER 1. GENERAL INFORMATION **1**
Introduction 1
Control System Installation Procedure 1

CHAPTER 2. DESCRIPTION **3**
General 3
Control Fault Tolerance 3
5009C Control System Inputs and Outputs 20
Pilot Valve Control (Cascade Position Loop) 27
PC Interface Program 29

CHAPTER 3. CONTROL FUNCTIONALITY OVERVIEW **31**
Control Overview 31
Block Diagrams 35

CHAPTER 4. CONTROL FUNCTIONALITY **38**
Introduction 38
Valves Selection 38
Turbine Start Modes 42
Valve Limiters 48
Turbine Start Routine 49
Speed Control Overview 53
Speed PID Operational Modes 54
Valve Redundancy Controller 58
Cascade Control 76
Cascade Droop 78
Remote Cascade Set Point 78
Seal GAS PID Control 79
Emergency Shutdown 80
Controlled Shutdown 81
Relays 84

CHAPTER 5. 5009C CONTROL SYSTEM OPERATION **85**
Introduction 85
5009C System Power-up 85
Valve / Actuator Calibration & Test 86
Turbine Start 89
General Field Tuning Guidelines 99
Speed, Casc, Decoupling, Seal Gas PID, and Ext/Adm Dynamics Adjustments 101
Overspeed Test Function 103
Operation Information 105

CHAPTER 6. SERVICE OPTIONS **109**
Product Service Options 109
Woodward Factory Servicing Options 110
Returning Equipment for Repair 110
Replacement Parts 111
Engineering Services 111
How to Contact Woodward 112
Technical Assistance 112

Contents

DECLARATIONS 114

Illustrations and Tables

Figure 2-1. System Module Diagram...4
Figure 2-2. Double Exchange and Vote Structure..5
Figure 2-3. Fault Tolerant Analog Input..7
Figure 2-4. Fault Tolerant Discrete Input..8
Figure 2-5. Fault Tolerant Analog Output...10
Figure 2-6. Fault Tolerant Single Coil Actuator Output 12
Figure 2-7. Fault Tolerant Dual Coil Actuator Output...13
Figure 2-8. Fault Tolerant Discrete Output...16
Figure 2-9. Fault Tolerant DDE Communication Ports...17
Figure 2-10. Fault Tolerant Modbus Communication Ports 18
Figure 2-11. Fault Tolerant Modbus Communication Ports 19
Figure 2-12. Interface/Communications Logic...20
Figure 2-13. Proportional Controller Diagram 22
Figure 2-14. P Controller Diagram...23
Figure 2-15. PI Controller Diagram..23
Figure 2-16. PI Lag Controller Diagram 24
Figure 2-17. PI Lead Lag Controller Diagram 24
Figure 2-18. Three-Wire Transducer...25
Figure 2-19. Four-Wire Transducer...26
Figure 2-20. Five-Wire Transducer..26
Figure 2-21. Six-Wire Transducer 26
Figure 2-22. Main Screen..30
Figure 3-1. Typical Extraction and/or Admission Steam Turbine.........................31
Figure 3-2. Split Range or Admission Type of Turbine Configuration..................32
Figure 3-3. Extraction and/or Admission Steam Turbine 33
Figure 3-4. Overview of 5009C Control System Functionality Notes...................35
Figure 3-5. Single or Split-Range Turbine Configurations (Speed PID with Remote Set Point) 36
Figure 3-6. Single or Split-Range Turbine Configurations 36
Figure 3-7. Extraction and/or Admission Turbine Configurations (coupled mode)..36
Figure 3-8. Example of a Single Stage Turbine using Dual Loop Actuator and Remote Speed Set Point 37
Figure 4-1. Typical Dual Loop Valve with Cylinder’s LVDT and Pilot’s LVDT as Represented in Woodward’s HMI..40
Figure 4-2. Dual Control Loop Valve With Cylinder’s LVDT and Pilot’s LVDT and Degraded Mode 41
Figure 4-3. Manual Start Mode Example...43
Figure 4-4. Semiautomatic Start Mode Example...44
Figure 4-5. Automatic Start Mode Example 45
Figure 4-6. Automatic Start Sequence 50

Illustrations and Tables

Figure 4-7. Speed Control Functional Diagram....53
Figure 4-8. Speed Relationships....57
Figure 4-9. Typical Redundant I/H System with a Transfer Valve....59
Figure 4-10. Typical Redundant I/P System with a Pressure Selecting Relay Valve....59
Figure 4-11. Ext/Adm Control Diagram....64
Figure 4-12. Coupled HP & LP Mode....74
Figure 4-13. Decoupled Inlet or Exhaust Mode....75
Figure 4-14. Decoupled HP&LP Mode....76
Figure 4-15. Cascade Functional Diagram....77
Figure 5-1. Proportional Gain Setting Effects....92
Figure 5-2. Open Loop Proportional and Integral Response....93
Figure 5-3. Closed Loop Proportional and Integral Response....94
Figure 5-4. Integral Gain (Reset) Setting Responses....95
Figure 5-5. Closed Loop Proportional and Derivative Action....96
Figure 5-6. Derivative Setting Effects....97
Figure 5-7. Closed Loop Proportional, Integral and Derivative Action....98
Figure 5-8. Typical Response to Load Change....100

Table 2-1. Redundancy Manager Truth Table....8
Table 6-1. Actuator combo Driver Limits....86

Warnings and Notices

Important Definitions

⚠ This is the safety alert symbol. It is used to alert you to potential personal injury hazards. Obey all safety messages that follow this symbol to avoid possible injury or death.

- **DANGER**—Indicates a hazardous situation which, if not avoided, will result in death or serious injury.
- **WARNING**—Indicates a hazardous situation which, if not avoided, could result in death or serious injury.
- **CAUTION**—Indicates a hazardous situation which, if not avoided, could result in minor or moderate injury.
- **NOTICE**—Indicates a hazard that could result in property damage only (including damage to the control).
- **IMPORTANT**—Designates an operating tip or maintenance suggestion.

⚠WARNING Overspeed / Overtemperature / Overpressure	**The engine, turbine, or other type of prime mover should be equipped with an overspeed shutdown device to protect against runaway or damage to the prime mover with possible personal injury, loss of life, or property damage.** **The overspeed shutdown device must be totally independent of the prime mover control system. An overtemperature or overpressure shutdown device may also be needed for safety, as appropriate.**

⚠WARNING Personal Protective Equipment	**The products described in this publication may present risks that could lead to personal injury, loss of life, or property damage. Always wear the appropriate personal protective equipment (PPE) for the job at hand. Equipment that should be considered includes but is not limited to:** • **Eye Protection** • **Hearing Protection** • **Hard Hat** • **Gloves** • **Safety Boots** • **Respirator** **Always read the proper Material Safety Data Sheet (MSDS) for any working fluid(s) and comply with recommended safety equipment.**

⚠WARNING Start-up	**Be prepared to make an emergency shutdown when starting the engine, turbine, or other type of prime mover, to protect against runaway or overspeed with possible personal injury, loss of life, or property damage.**

⚠WARNING Automotive Applications	**On- and off-highway Mobile Applications: Unless Woodward's control functions as the supervisory control, customer should install a system totally independent of the prime mover control system that monitors for supervisory control of engine (and takes appropriate action if supervisory control is lost) to protect against loss of engine control with possible personal injury, loss of life, or property damage.**

NOTICE **Battery Charging Device**	**To prevent damage to a control system that uses an alternator or battery-charging device, make sure the charging device is turned off before disconnecting the battery from the system.**

Electrostatic Discharge Awareness

NOTICE **Electrostatic Precautions**	**Electronic controls contain static-sensitive parts. Observe the following precautions to prevent damage to these parts:** • **Discharge body static before handling the control (with power to the control turned off, contact a grounded surface and maintain contact while handling the control).** • **Avoid all plastic, vinyl, and Styrofoam (except antistatic versions) around printed circuit boards.** • **Do not touch the components or conductors on a printed circuit board with your hands or with conductive devices.** **To prevent damage to electronic components caused by improper handling, read and observe the precautions in Woodward manual *82715*, *Guide for Handling and Protection of Electronic Controls, Printed Circuit Boards, and Modules*.**

Follow these precautions when working with or near the control.

1. Avoid the build-up of static electricity on your body by not wearing clothing made of synthetic materials. Wear cotton or cotton-blend materials as much as possible because these do not store static electric charges as much as synthetics.
2. Do not remove the printed circuit board (PCB) from the control cabinet unless absolutely necessary. If you must remove the PCB from the control cabinet, follow these precautions:
   - Do not touch any part of the PCB except the edges.
   - Do not touch the electrical conductors, the connectors, or the components with conductive devices or with your hands.
   - When replacing a PCB, keep the new PCB in the plastic antistatic protective bag it comes in until you are ready to install it. Immediately after removing the old PCB from the control cabinet, place it in the antistatic protective bag.

Chapter 1.
General Information

Introduction

The technical documentation for the 5009C control system consists of the following volumes:

Volume 1—provides information on system application, control functionality, fault tolerant logic, control logic, PID setting instructions, and system operation procedures.

Volume 2—provides hardware descriptions, mechanical and electrical installation instructions, hardware specifications, hardware troubleshooting help, and basic repair procedures.

Volume 3—provides installation procedures for the 5009C control's personal computer based interface software program (PCI), information on all PCI features and modes (Program, Service and Run), and a lists of the control's Modbus® * registers and DDE tag names.

*—Modbus is a registered trademark of Schneider Automation Inc.

Control System Installation Procedure

1. Review all system manuals to gain an understanding of the control system.

2. Create a site specific wiring diagram by referencing Volume 2's wiring diagrams, then perform mechanical and electrical installation following Volume 2 instructions and the generated wiring diagram.

3. Apply power to the 5009C Control and reset all three CPU's (refer to Volume 2).

4. Connect the provided RS-232 serial cable between the control's CPU-C or SIOA J4 or SIO-B J3 serial port and a computer which will have the PCI program installed.

5. Install the PCI programming software on a Windows® 95, Windows 2000 or Windows NT® based computer. Configure the system using the PCI's menu-driven programming screens (refer to Volume 3).

6. Perform a full system checkout; clear all system trips and alarms; adjust linkages and stroke actuators.

When ready to start the turbine, follow the operation instructions of Chapter 5 in this volume. During initial start-up, the dynamics of each PID controller will need to be adjusted (Chapter 5).

This volume provides control system description, and operation instructions for the Woodward MicroNet TMR 5009C Control System. It includes:

- General description of the control system
- Detailed functionality descriptions including I/O handling
- Control system operation
- Information on optional equipment
- Detailed functionality description of start up procedures
- Detailed information on alarm and trip messages
- Detailed information on Modbus parameters

This manual applies to all 5009C Control Systems but does not include information that is unique to your system. The 5009C Control System can be provided in a number of hardware configurations: with different power supply configurations, with or without a cabinet, with or without an OpView, or with or without a Rolling Restart Station. Because this manual addresses all configurations, many of the system software and hardware descriptions may not apply to your particular 5009C System.

When an optional cabinet is included with the 5009C Control System package, all equipment is pre-wired and the control is shipped fully assembled within the cabinet. If a cabinet is not included with the system, each component is packaged separately. After a control system is received each item must be located and installed via this manual’s instructions.

This manual does not contain instructions for the operation of the complete turbine system. For turbine or plant operating instructions, contact the plant-equipment manufacturer.

Chapter 2. Description

General

The 5009C Fault-Tolerant Control System is designed to control single valve, split- range valve, single controlled-extraction, single controlled-admission, or single controlled-extraction/admission steam turbines. The 5009C Control System is field programmable which allows a single design to be used in many different control applications and reduces both cost and delivery time. It uses Windows-based computer program (PCI) to allow a user to configure the control, perform on-line program changes, perform on-line hardware tests, and alternatively operate the turbine from HMI. This control can be used as a stand-alone unit or in conjunction with a plant's Distributed Control System (DCS).

Control Fault Tolerance

The basis of this control's fault tolerance architecture is to detect control related faults, annunciate these faults, and allow on-line service/replacement of modules and/or transducers to correct these faults.

This control's architecture allows it to operate with any single point of failure, without shutting down the turbine. A CPU fault tolerance logic of 3-2-0 allows the control to function normally with any CPU module failed or removed. An analog I/O fault tolerance logic of 3-2-1-0 allows the control to function normally with any one or two analog modules failed or removed. A discrete I/O fault tolerance logic of 3-2-0 allows the control to function normally with any one discrete module failed or removed. A power supply fault tolerance logic of 2-1-0 allows the control to function normally with any one power supply failed or removed.

Three isolated kernel sections (A, B & C) each house a Kernel Power Supply module, CPU module, Analog I/O module, and a Discrete I/O module. Kernels A and B each house a Serial Input/Output (SIO) module (see Figure 2-1). A single motherboard supplies nine electrically isolated data paths. Each CPU has a data path to its VME modules and two separate data paths, one to each of the other CPU modules. There is a total of six paths between CPUs allowing for redundancy and error checking.

All control inputs and outputs are Triple Modular Redundant (TMR) with the exception of the actuator cards (dual redundant); meaning that each individual analog and speed input is monitored by all three 5009C Control System kernels, then voted upon to insure that the correct input value is used for control. Each input is split at one of the control's field termination module, and routed to the three kernels (A,B,C) via separate I/O cables; this allows on-line module replacement. Each control output signal is the sum of the three kernels outputs. Because the control monitors the health of each kernel's output signal, it can detect, alarm, and react to any system output fault.

The 5009C Control System allows redundancy to be extended beyond the control, by allowing multiple transducers to be used for any critical control parameter. Optionally the control can be configured to accept up to three speed sensor inputs, and three analog input signals (from separate transducers) for any single critical control parameter.

A fourth speed input can be configured for null speed detection. If used, the control will use this signal during start-up to control the engine at a very low speed.

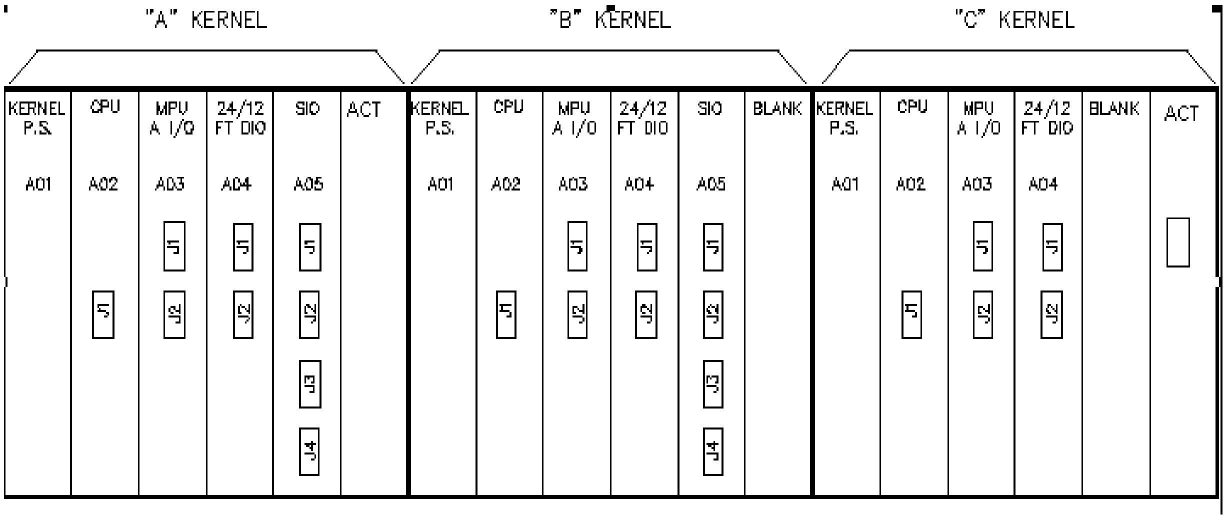

Figure 2-1. System Module Diagram

Each CPU module runs the identical software application as the other two. All inputs from each kernel are distributed to the other two kernels. Each CPU then compares the value it read, with the value the other two CPUs read, before outputting a signal to the application software. Depending on the configuration, a total of nine values for the same input parameter could be used in the voting logic to provide the best signal to the application software. Even if a data value has been corrupted along any one of the data paths shown in Figure 2-2, all CPUs use the same correct data for their application calculations. All CPUs use the same voted input signals in the same application calculations to generate the same outputs.

All output values are exchanged between kernels, the results are voted and the appropriate value is output from each kernel. Since the system can handle significant single errors, even multiple errors may not shutdown a kernel section. In the event of consistent errors from one of the kernel section, an alarm will be annunciated and that particular kernel will be shut down. Figure 2-2 shows the input to output structure of the MicroNet TMR.

The 5009C Control System's redundancy architecture allows all control modules to be replaced one at a time while the turbine is on-line and operating at full power (sometimes referred to a Hot Replacement). This type of architecture also allows it to perform all control system functions while only utilizing the following modules:

- Main Power Supply module (2 typical)
- 2 Kernel Power Supply modules (3 typical)
- 2 CPU modules (3 typical)
- 2 Discrete I/O modules (3 typical)
- 1 Analog I/O module (3 typical)
- 1 Actuator module (2 typical)
- 1 Serial I/O module (2 typical)

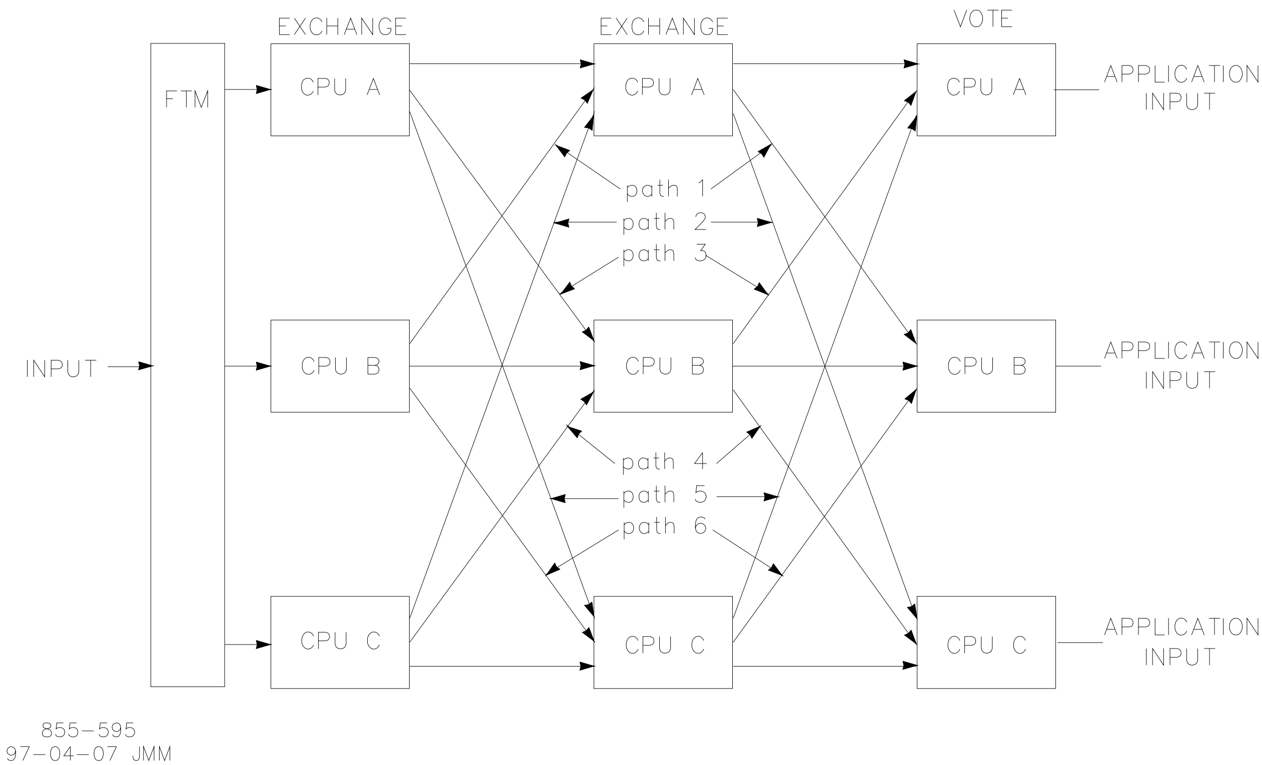

Figure 2-2. Double Exchange and Vote Structure

Speed Inputs

The control can accept one, two, or three speed inputs. Each speed input is monitored by all three kernels. With nine possible speed signals from which to control with, the control can withstand multiple speed input failures with no loss of control functionality. Only one of the possible nine inputs is required for speed control.

All speed inputs are connected to the control, via analog termination modules (ATMs). An input's termination module is used to terminate customer control wiring and distribute each input signal to all three kernels. After the control's kernels double exchange their input values, and vote out any erroneous values, the Application Software Redundancy Manager then compares each kernel's voted result to select a value to be used within the application logic. Figure 2-3 is a graphical view of a control input's architecture. Table 2-1 displays the redundancy manager's input selection logic, for each possible input condition.

A speed input signal is determined to be faulty and is taken out of the input voting logic when it is below its "Speed Failure Level" setting. This failure level setting is common to all inputs and can be adjusted via the PCI program's Service mode. Refer to Volume 3 for all PCI program procedures.

An input deviation alarm is also used to annunciate if any of the three possible speed input channels is sensing a value that is different then the voted-good value used by the application. If an input channel's sensed value deviates from the voted-good signal value, by a greater margin than the speed control's "Max Deviation" setting, an input channel alarm will be issued. This type of annunciation can be used to indicate when an input channel, or magnetic pickup unit is intermittently failing high or low. Max Deviation input settings are tunable via the PCI program's Service mode, and are defaulted to 1% (deviation range = .01 to 20%) of the "Overspeed Limit" setting. If a deviation alarm condition occurs, the alarmed input is not removed from the control's voting logic and still can be used to control with, in case all other channels fail.

The voting logic when more than one speed input (MPU or proximity probe) is used is as follows:
- With 3 good sensors, use the median value
- With 2 good sensors, use the higher value
- With 1 good sensor, use the good sensor's value

Zero Speed Inputs

The Speed input #4 channel is separated from the others. Its range can be set for a low speed detection. During start-up, this reading will be used by the control, up to the maximum range of this sensor.

Relay output configured for speed level will use this channel to increase the accuracy of the reading for very low speed.

The usage of this channel is recommended, while a turning gear must not start while engine is still rotating.

Special protection feature have been added for this channel, in conjunction with relay output configured for null speed detection.

The signal from channel #4 , is compared with the other channels and an alarm will be initiated if discrepancy is notice. Null speed relay won't energize until null speed detection function is re-armed, via a dedicated input (Modbus/hardware). Normal RESET won't re-arm this function.

When zero speed is reached, a delay can be applied before the "null speed" relay energize.

To increase the zero speed detection safety, a contact input called " zero speed permissive" can be configured. If configured, the null speed relay will energize only if this contact is closed.

The zero speed probe is always used in the control. Should no extra protections be needed to detect zero speed, a relay can be set as a level switch on speed with a very low speed level.

Analog Inputs

The control can accept one, two, or three transducer inputs for all critical parameters (ext/adm, decoupling, casc inputs). Only one input signal is accepted for non-critical functions (remote set point inputs). Each analog input can withstand up to two failures with no loss of control functionality. If any two of an analog input's three "legs" are failed, the control uses the third healthy leg's sensed input signal from which to control with.

All analog inputs are connected to the control, via analog termination modules (ATMs). An input's termination module is used to terminate customer control wiring and distribute each input signal to all three kernels. After the control's kernels double exchange their input values, and vote out any erroneous values, the Application Software Redundancy Manager then compares each kernel's voted result to select a value to be used within the application logic. Figure 2-3 is a graphical view of a control's input architecture. Table 2-1 displays the redundancy manager's input selection logic, for each possible input condition.

Optionally, each leg of an input channel can be tested and its calibration verified through the PCI program's Service mode, by individually removing the other two input legs. Refer to Volume 3 for all PCI program mode procedures.

An analog input signal is determined to be faulty when it is below 2 mA , or above 22 mA. and 22 mA respectively. If an input is determined to be failed, that input is removed from the control's voting logic.

Input deviation alarms are used to annunciate if any of the input channels or input legs are sensing a value that is different then the voted-good value used by the application. If an input channel's sensed value deviates from the voted-good value, by a greater margin than its "Max Deviation" setting, an input channel alarm will be issued. This type of annunciation can be used to indicate when an input channel, or system transducer is going out of calibration. Max Deviation settings are tunable via the PCI program's Service mode, and are defaulted to 1% (deviation range = .1 to 10%) of the configured input range. If a deviation alarm condition occurs the alarmed input is not removed from the control's voting logic, and still can be used to control with, in case all other channels fail.

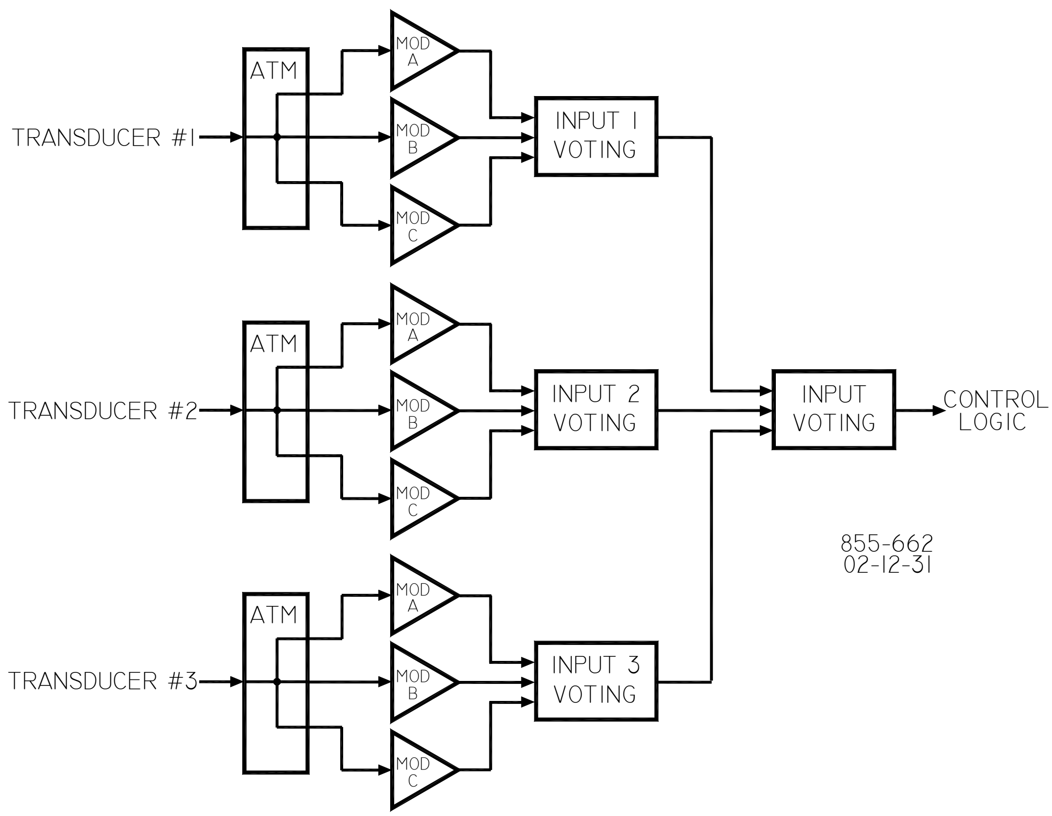

Figure 2-3. Fault Tolerant Analog Input

A-FAULT	B-FAULT	C-FAULT	OUTPUT OF BLOCK (APPLICATION INPUT)
FALSE	FALSE	FALSE	MEDIAN OF A, B, & C-INPUT
FALSE	FALSE	TRUE	HSS* OF A & B-INPUT
FALSE	TRUE	FALSE	HSS* OF A & C-INPUT
FALSE	TRUE	TRUE	A-INPUT
TRUE	FALSE	FALSE	HSS* OF B & C-INPUT
TRUE	FALSE	TRUE	B-INPUT
TRUE	TRUE	FALSE	C-INPUT
TRUE	TRUE	TRUE	APPL. INPUT SET TO ZERO/FAULT SET TRUE

*HSS -> HIGH SIGNAL SELECT

855-594
97-04-07 JMM

Table 2-1. Redundancy Manager Truth Table

Discrete Inputs

Each discrete input can withstand up to two failures with no loss of control functionality. If any two of a discrete input's three "legs" fail, the control uses the third healthy leg's sensed input signal from which to control with.

All discrete inputs are connected to the control via discrete termination modules (DTMs). A DTM is used to terminate customer control wiring and distribute each input signal to all three kernels. After the control's kernels double exchange their input values and vote out any erroneous inputs, the Application Software Redundancy Manager then compares each kernel's voted result to select a value to be used within the application logic. Figure 2-4 is a graphical view of the control's discrete input architecture.

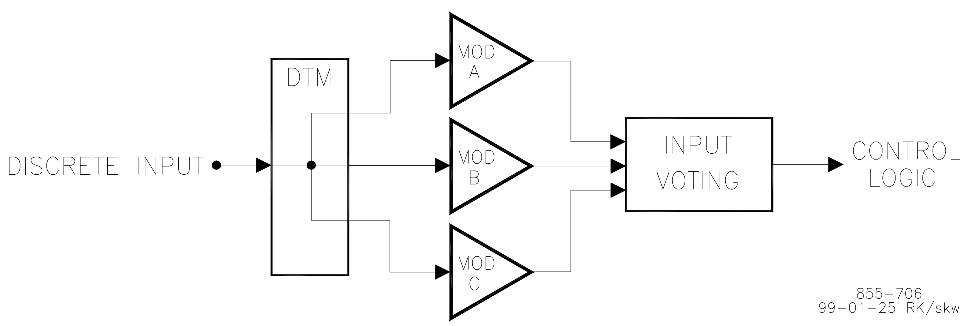

Figure 2-4. Fault Tolerant Discrete Input

A discrete input signal is determined to be faulty when it is determined to be different then the voted-good value used by the application. If an input is determined to be faulty, the input is removed from the control's voting logic and an input channel alarm is issued. Once the input fault is corrected the alarm condition can be reset by issuing a control "Reset" command.

Readouts (Analog Outputs)

Each control readout can withstand up to two failures with no loss of output functionality. Any leg of an output channel can drive a readout’s full 4–20 mA current signal. After each CPU generates an analog output signal, the signals are exchanged between CPUs, voted on, and sent to the Redundancy Manager for output. The Redundancy Manager divides the output signal based on the number of known good output channels and distributes each portion of the signal to the respective output channel.

Precision resistors are used in each channel’s readback circuitry to measure and verify the health of each output “leg”. If a fault condition is detected, the faulty output leg is disabled, and the Redundancy Manager redistributes the output signal to the remaining legs. In a case where two failures are experienced at the same time within different legs, the single good channel (leg) will drive the entire output. Figure 2-5 shows a Fault Tolerant Analog Output’s architecture. The Analog Termination Module (ATM) combines each analog output signal from all three kernels into one signal at the ATM’s terminal blocks.

An output is considered failed, and an alarm issued, if a channel’s combined output or any leg of the output measures a difference of more than 10% from the output demand. Optionally, each leg of a readout channel can be tested and its calibration verified through the PCI program’s Service mode, by individually removing the other two output legs. Refer to Volume 3 for all PCI program functionality.

With this output architecture, any single output driver failure results in the output signal only stepping to 66.66% of its original value. The time between when a failure is sensed and when the control corrects for it by redistributing current through the other drivers can be as long as 50 milliseconds.

Upon the correction of an output failure, and a “Control Reset” command, each failed output performs a continuity check though the its external load before current is again redistributed evenly between all output drivers. This continuity check entails, the failed driver to output a small amount of current through its output load, and compare that value with what is readback. The time between when a continuity check is performed and when the control redistributes current through the all drivers can be as long as 50 milliseconds.

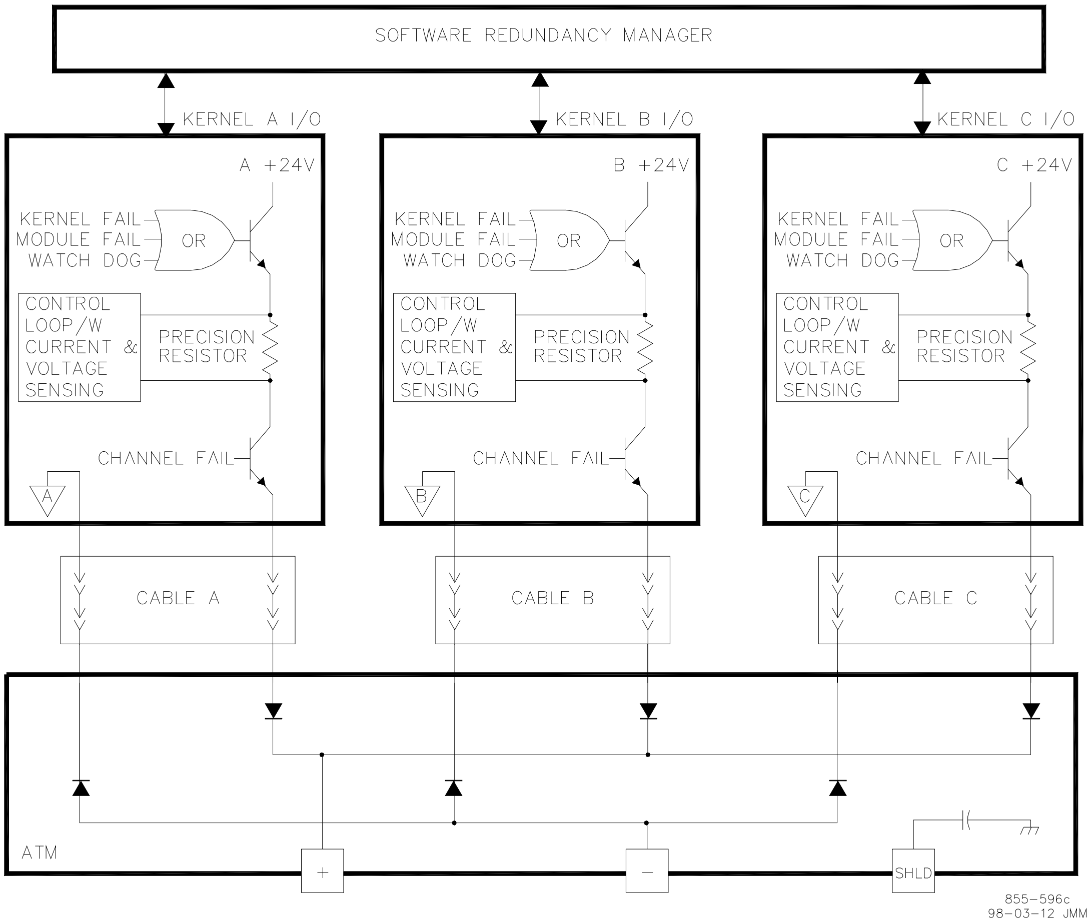

Figure 2-5. Fault Tolerant Analog Output

Actuator Outputs from Combo card

Each actuator output can withstand up to two failures with no loss of output functionality. Any leg of an output channel can drive an output's full current signal (4–20 mA or 20–160 mA). After each CPU generates an actuator output signal, the signals are exchanged between CPUs, voted on, and sent to the Redundancy Manager for output. The Redundancy Manager divides the output signal based on the number of known good output channels and distributes each portion of the signal to the respective output channel.

Precision resistors are used in each channel's readback circuitry to measure and verify the health of each output "leg". If a fault condition is detected, the faulty output leg is disabled, and the Redundancy Manager redistributes the output signal to the remaining legs. In a case where two failures are experienced at the same time within different legs, the lone good channel (leg) will drive the entire output. Figures 2-6 and 2-7 show a Fault Tolerant Actuator Output's architecture. The Analog Termination Module (ATM) combines each actuator output signal from all three kernels into one signal at the ATM's terminal blocks.

An output is considered failed, and an alarm issued, if a channel's combined output or any leg of the output measures a difference of more than 10% from the output demand. Optionally, each leg of a readout channel can be tested and its calibration verified through the PCI program's Service mode, by individually removing the other two output legs. Refer to Volume 3 for all PCI program functionality.

Actuator outputs, or HP and LP valve outputs, are treated the same way as the other analog outputs, with the exception of a an added precision resistor in the actuator output's return path. This resistor is used to measure and detect ground loops and coil shortages that are possible when interfacing to an actuator. If a single coil actuator is being driven, the dual coil terminal blocks are jumpered (wired) to the single coil terminal blocks and the redundancy manager shares the current equally between all three kernels. In the event of a fault, the Redundancy Manager will redistribute the load.

If the actuator connected to is a dual coil actuator, the Redundancy Manager shares half the current evenly between Kernels A & B outputs, and the other half comes from the Kernel C output. In the event of a fault, the Redundancy Manager redistributes load current.

With this output architecture, any single output driver failure results in the output signal only stepping to 66.66% of its original value (possibly 50% for dual coil applications). The time between when a failure is sensed and when the control corrects for it by redistributing current through the other drivers can be as long as 50 milliseconds.

Upon the correction of an output failure, and a "Control Reset" command, each failed output performs a continuity check though the actuator before current is again redistributed evenly between all output drivers. This continuity check entails, the failed driver to output a small amount of current through its output load, and compare that value with what is readback. The time between when a continuity check is performed and when the control redistributes current through the all drivers can be as long as 50 milliseconds.

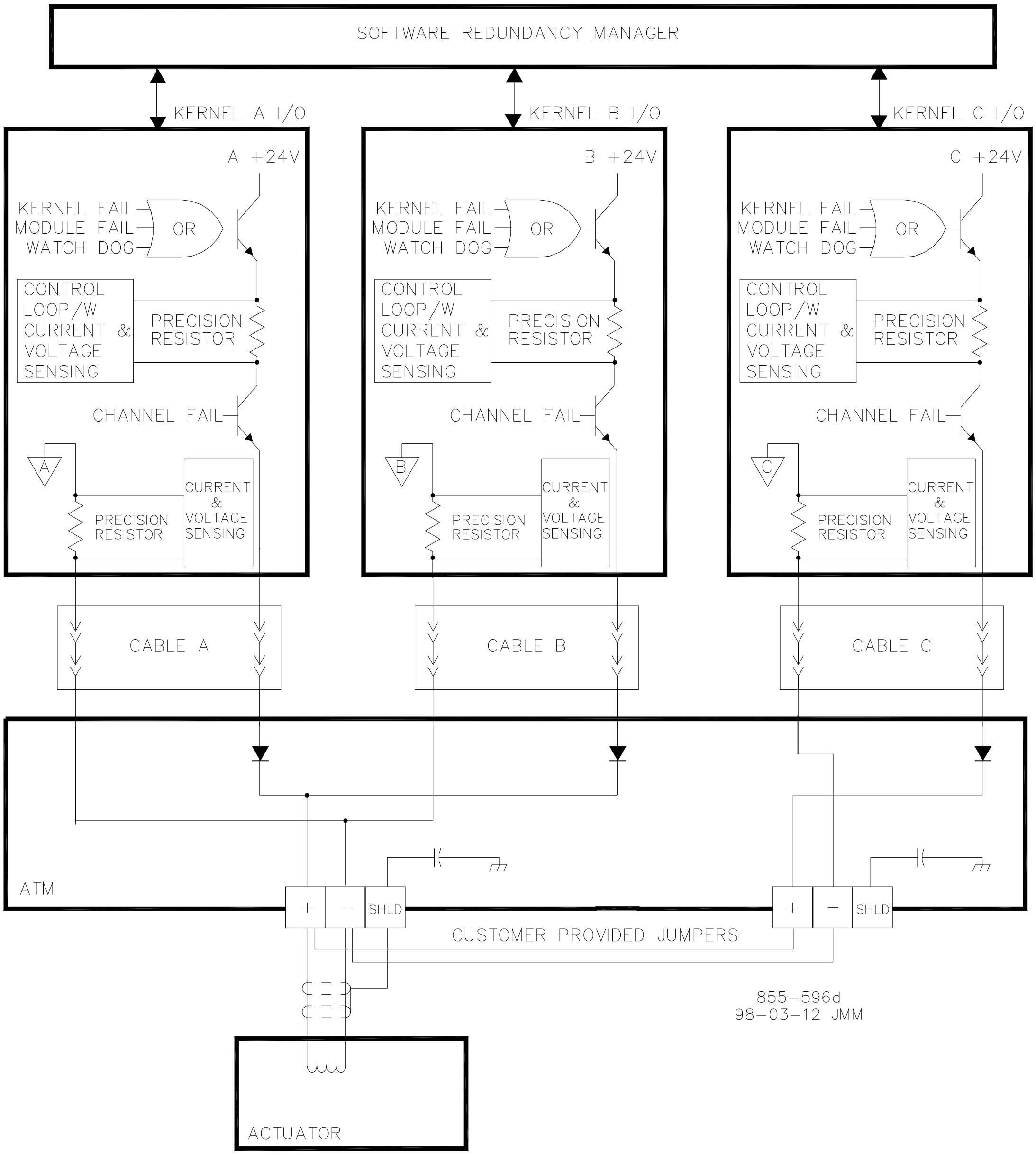

Figure 2-6. Fault Tolerant Single Coil Actuator Output

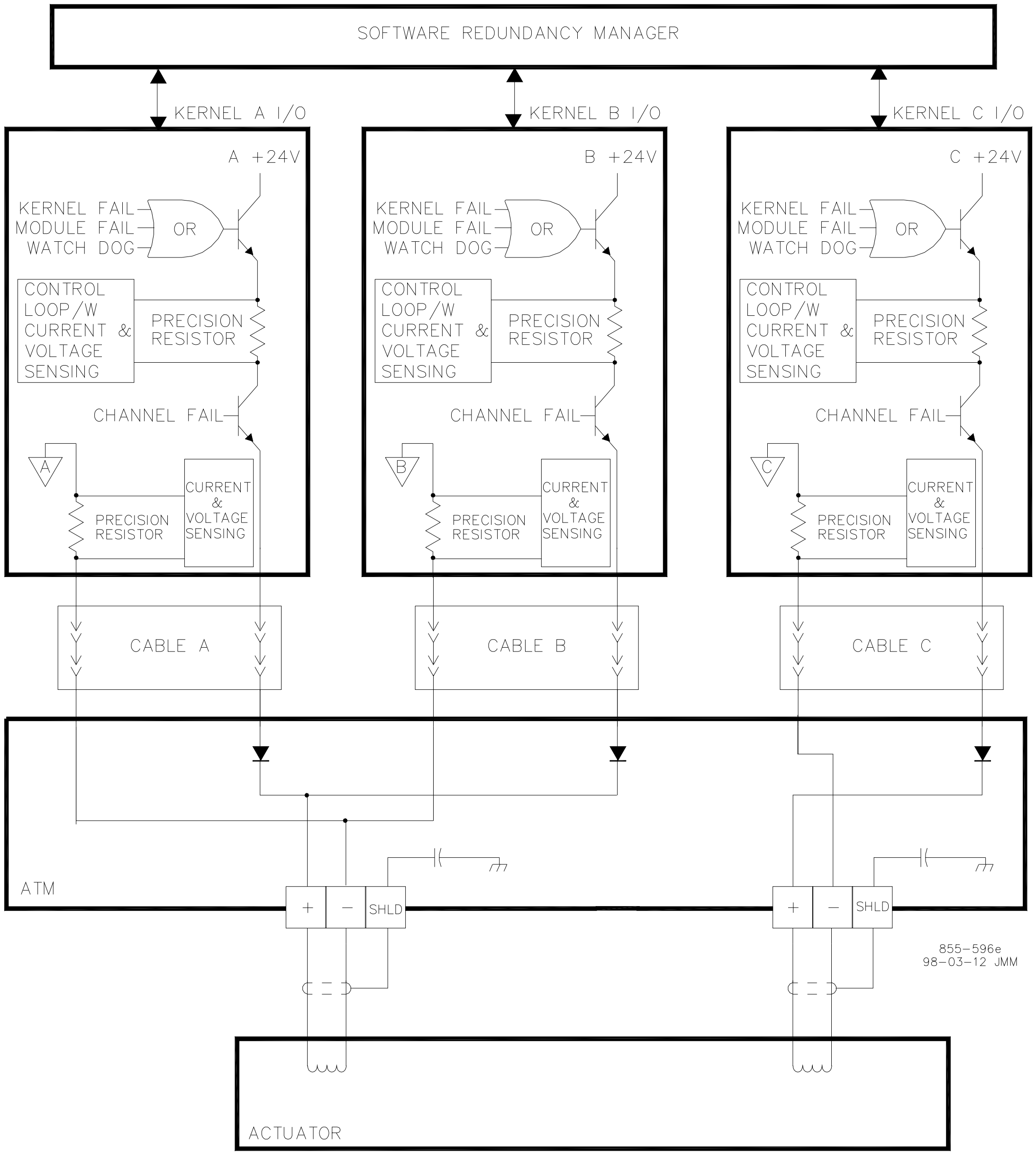

Figure 2-7. Fault Tolerant Dual Coil Actuator Output

Actuator card Outputs Setup

Because the 5009C offers so many options for actuation control, read this section carefully in order to choose the correct equipment and settings.

Though each actuator acts independently according to the 5009C control logic, each of the two actuator pairs' output configuration and tuning consists of the same parameters, and as such, actuator setup will be discussed here generically. This does not mean that all actuators must be the same; they may be applied and setup differently as needed.

⚠WARNING

Before calibrating or testing, the unit must be tripped and the steam supply removed. This is to ensure that opening the control valve(s) will not allow steam into the turbine. Overspeeding the turbine may cause damage to turbine and can cause severe injury or death to personnel. STEAM TO THE TURBINE MUST BE SHUT OFF BY OTHER MEANS DURING THIS PROCESS.

The 5009C can be configured to utilize Woodward 2 Channel Actuator Modules and FTMs to drive a current source to the actuators. Each Valve is assigned two actuator drivers, whether wired in parallel to one actuator coil or separately to each coil in a dual coil actuator. If wired in parallel to one coil, no diode or suppression devices should be necessary in the circuit.

For analysis purposes, position demand, position feedback, and the output of 2-channel actuator controller modules are in %. To obtain the actuator current, multiply the output of the controller by:

Proportional Actuator: (MA_AT_100 - MA_AT_0)(MA) / 100%
Integrating Actuator (all others): (MAX_I - MIN_I)(MA) / 200%

Setup information is identical for each coil in a redundant set and is entered only once for each redundant pair. Settings are first entered on the Configuration -> Valve Setup screen of the PCI Configuration Tool. On this page of the Configuration Tool the Actuator Controller Type, Actuator Direction, Position Feedback Transducer Type and Excitation Amplitude must be selected. Command Trim Enable may be deselected if the Actuator Controller Type is Proportional.
Proportional gain, integral gain, lead time constant, lag time constant and dither current amplitude are configured in PCI software only.

The following descriptions will discuss choosing the correct settings for each of the following configuration parameters:

Actuator Controller Type
Command Trim Enable
Actuator Direction
Position Transducer Type
Excitation Amplitude

And the following tuning parameters:

Proportional Gain = KP
Integral Gain = KI
Lead Time Constant = T_LEAD
Lag Time Constant = LAG_RATIO
Dither Current Amplitude
Enable Open Circuit Alarm
Feedback Fail High / Low Select

Configuration Parameters can be adjusted at any time but will not take affect until the 5009C is reset. Tuning parameters may be adjusted at any time and will instantaneously update operation with the new values.

Relay Outputs

Twelve fault tolerant relay outputs are provided with this control. With this control's architecture, a six relay configuration is used to form each fault tolerant relay output. When a relay output is closed, the contacts of all six relays are closed. Because of the series-parallel configuration that the relays are in, the failure of any individual relay will not cause the output to be open. This series-parallel configuration also allows any single relay of the six relay configuration to be removed and replaced "on-line" with no affect on the state of the fault tolerant relay output.

When a relay output is open, the contacts of all six relays are open. Because of the series-parallel configuration that the relays are in, the failure or removal of any one relay will not cause the output to be closed. The relay output would continue to be open.

Since this control's fault tolerant architecture can tolerate a single fault, it is possible for this fault to go undetected. This is called a latent fault. If a second fault occurs while a latent fault exists, the state of the fault tolerant relay output may be affected, possibly resulting in a shutdown condition. This is why it is important to detect and annunciate latent faults in a fault tolerant system.

Latent fault detection is provided with this control to detect any relay related failure without affecting the state of the overall relay output. Each individual relay output can be configured to use or not use latent fault detection. A latent fault detection test is performed periodically or on command through the PCI. The period of time between tests can be set from 1 to 3000 hours.

A relay output is tested by cycling the output's individual relays closed then open (or vice-versa depending on the output state), to ensure that they are in the correct state, and that they can change state. Position readback circuitry allows the state of each relay contact to be detected. Any failures are annunciated, and further testing is disabled without affecting the state of the relay output contact or control operation.

Each fault tolerant relay configuration consists of 6 relays, driven by two discrete outputs from each kernel (as shown in Figure 2-8). The relays are configured in three legs of two relays each. Customer circuit power is connected to one side of the resulting configuration, and customer load to the other side. Field selectable jumpers, located on system FTMs, are provided to allow each output's latent fault detection logic to be compatible with the circuit being interfaced to. Latent fault detection is used to monitor the actual contact positions of each of the six relays, and to momentarily change states of each relay one at a time. This verifies each relay's "normally open" or "normally closed" contacts.

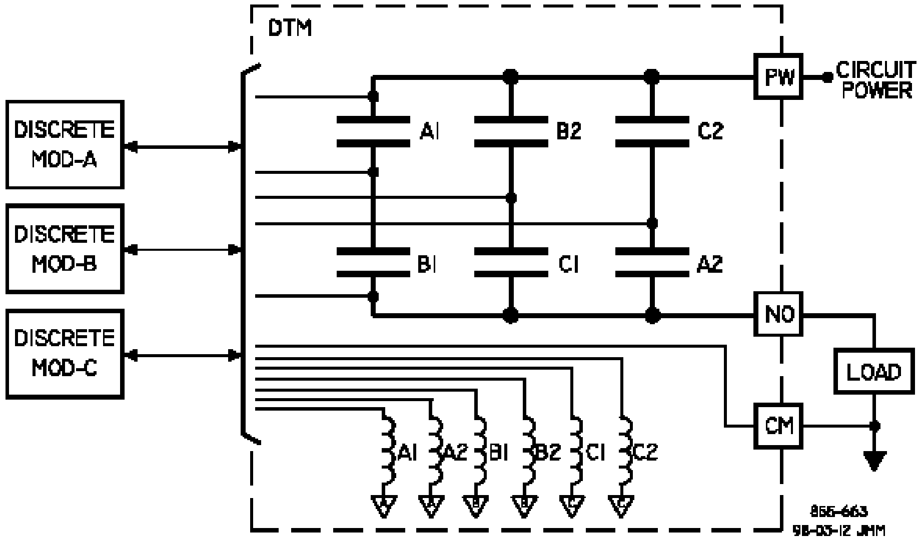

Figure 2-8. Fault Tolerant Discrete Output

Latent fault detection (LFD) is not usable with all applications or circuits. The control's LFD logic can only work with circuits using voltages between 18- 32Vdc, 100-150Vdc, or 88-132Vac. For latent fault detection to work, a small leakage current is passed through the circuit's load. Depending on the size of the load, the leakage current may be enough to cause a load to be on or active, when a relay contact is open. In this case, the individual relay's latent fault detection logic may be disabled, eliminating the leakage current, or a shunt resister can be used across the load to reduce the leakage current. Refer to Volume 2 of this manual to determine if Latent Fault Detection can be used with a circuit.

DDE Communication Ports

The CPU-C RS-232 port is dedicated for the use with the control's PCI program (communicating via DDE). Serial Input/Output (SIO) modules are provided in the A and B kernel sections to increase communication redundancy or the number of available communications port. SIO-A port 4 (RS-232/422/485) and SIO-B port 3 (RS-232/422/485) can be configured to communicate with the PCI program (DDE).

CPU-B (RS-232) can also be configured to revert from its normal communications function to PCI (DDE) communications in the event that the kernel-C CPU fails. Once the Kernel-C CPU is restored and reset, the CPU-B port will revert back to its original functionality (Modbus or printer).

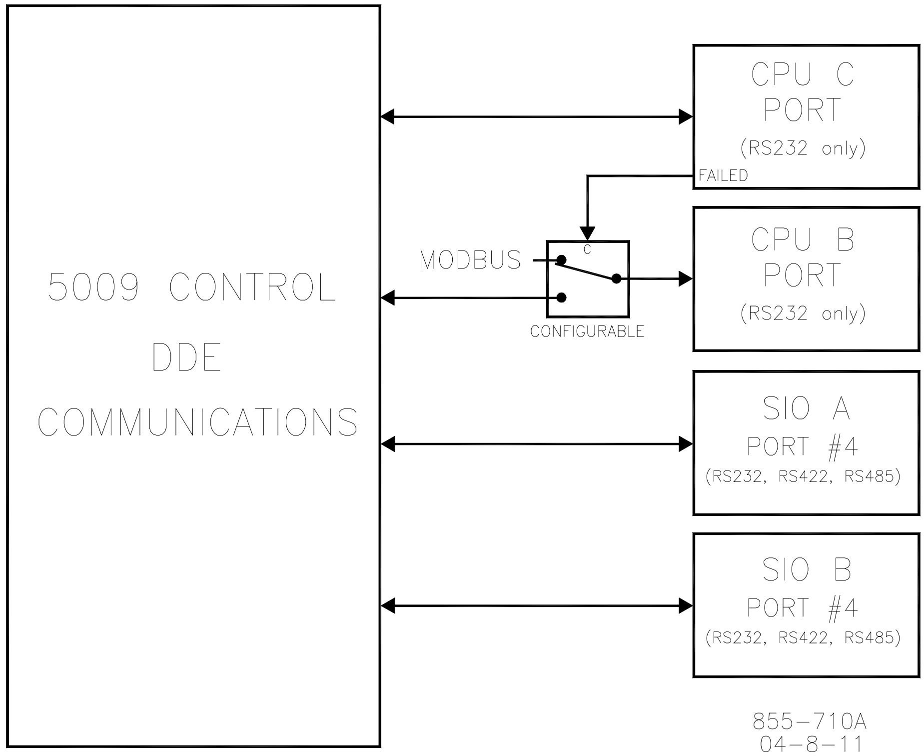

Figure 2-9. Fault Tolerant DDE Communication Ports

All communication input values and commands from each port are double exchanged between all three CPUs and voted on to vote out any erroneous input values or commands before the application software is given the value or command. All communication output values or indications are also double exchanged between all three CPUs and voted on to vote out any erroneous output values or indications before the value or indication is output to the communications port.

Modbus Communication Ports

The CPU-A and CPU-B RS-232 ports can be configured for Modbus Communications with a distributed control system (DCS) or other serial operator control panel.

Serial Input/Output (SIO) module are provided in the A and B kernel sections to increase communication reliability, redundancy or the number of available communication ports. When an SIO is installed, it will replace the CPU port for Modbus communication. SIO-A port 3 (RS-232/422/485) will replace CPU-A port, and SIO-B port 4 (RS-232/422/485) will replace CPU-B (if configured for Modbus). SIO-A port 4 (RS-232/422/485) and SIO-B port 3 (RS-232/422/485) can be configure as redundant Modbus lines.

All communication input values and commands from each port are double exchanged between all three CPUs and voted on to vote out any erroneous input values or commands before the application software is given the value or command. All communication output values or indications are also double exchanged between all three CPUs and voted on to vote out any erroneous output values or indications before the value or indication is output to the communications port.

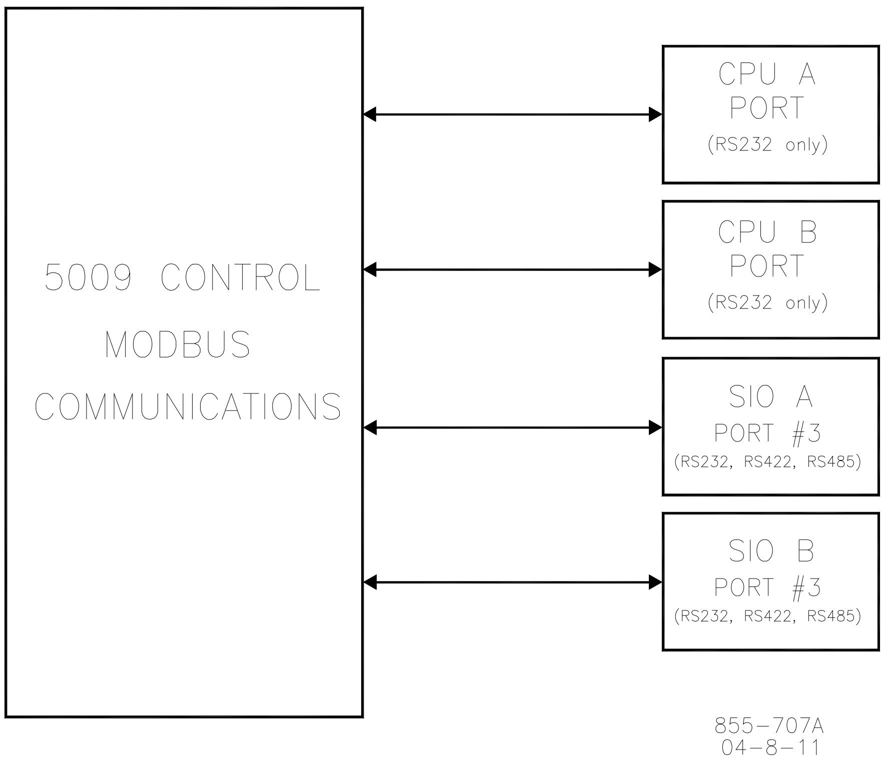

Figure 2-10. Fault Tolerant Modbus Communication Ports

Printer Communication Ports

The CPU-B RS-232 port can be configured to interface with a serial line-printer to provide a hard-copy of any Major alarm or trip condition. Serial Input/Output (SIO) modules are provided in the A and B kernel sections to increase communication redundancy or the number of available communication ports. All SIO module ports are dedicated to a communication protocol or function. Each SIO module’s port # 1 is dedicated to function as a Major Alarm/Trip printer port. With two SIO modules in one 5009C Control, up to three ports are available for Major Alarm/Trip printer communications.

All communication output indications are also double exchanged between all three CPUs and voted on to vote out any erroneous output indications before the indication is output to the communications port.

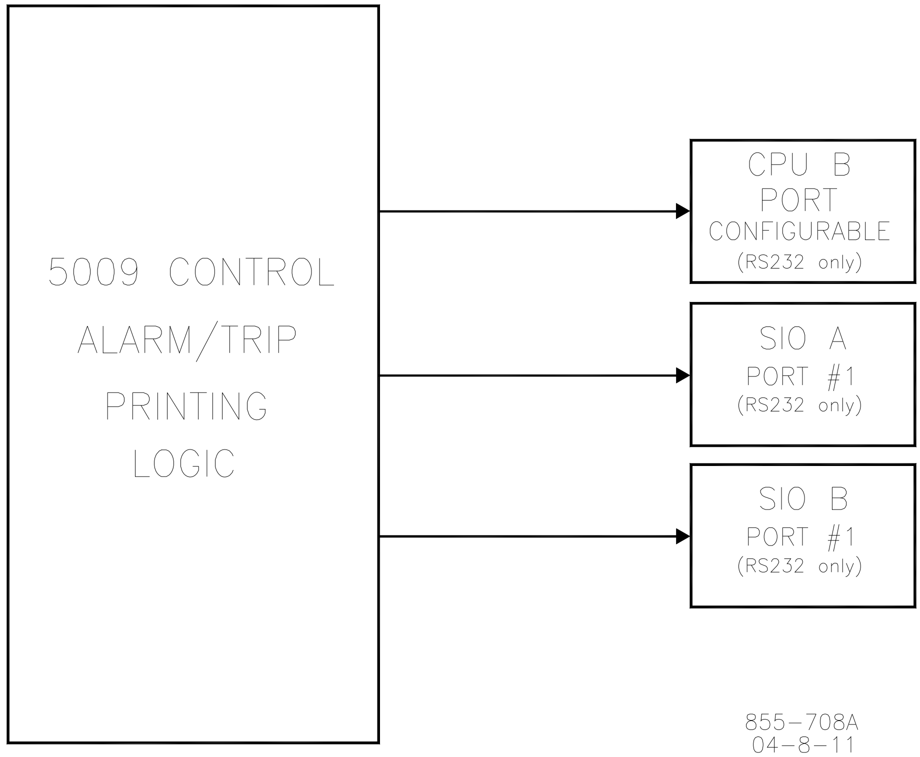

Figure 2-11. Fault Tolerant Modbus Communication Ports

Interface/ Communications Logic

Internal control logic referred to as LOCAL/REMOTE functionality, permits a combination of Modbus ports and or contact input commands to be temporarily disabled. This logic allows a user at one interface panel to lockout commands from other turbine/control interface panels. For safety reasons, the PCI (engineering workstation) ports are not affected by this logic.

The selection of the “Local” interface mode disables all ports so configured. The selection of the “Remote” interface mode enables all interfaces. Modbus port 1, Modbus port 2, and the control’s contact input commands, each have individual Local mode settings to allow a customer to configure the interface lockout functionality desired. Optionally the control can be configured such that all interfaces are enabled at all times. Refer to Figure 2-12 for a graphical view of the control’s interface logic.

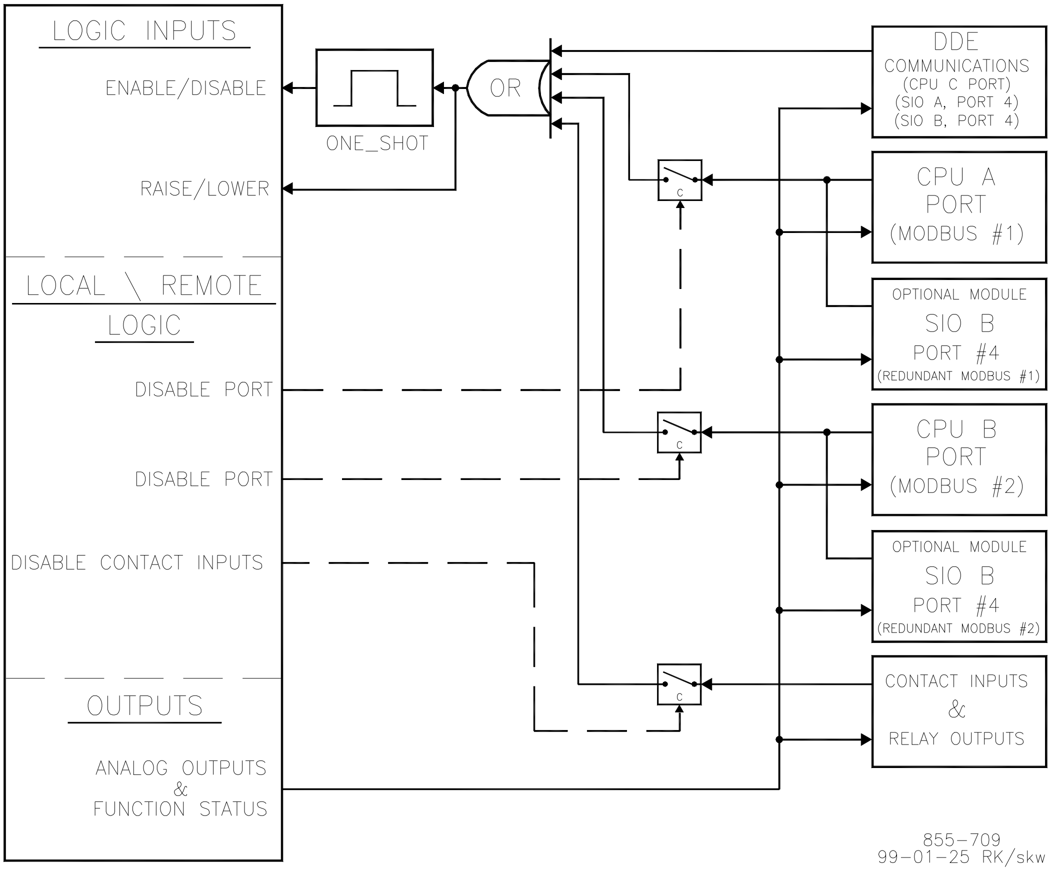

Figure 2-12. Interface/Communications Logic

5009C Control System Inputs and Outputs

Speed Sensor Inputs

Available Speed Sensor Inputs: 3+1(null speed)

Of the 3 available fault-tolerant speed sensor inputs, one input is required for operation and the 3 additional inputs are optional for system redundancy. Each speed input can interface with a passive speed probe (magnetic pickup unit - MPU) or an active speed probe (proximity). Refer to Volume 2 for input wiring and specifications.

Analog Inputs

Available Analog Inputs: 8

Any analog input can be configured to perform any of the listed control input functions. This control only accepts 4–20 mA signals. These 4–20 mA inputs, however, can be configured to interface with loop-powered or self-powered transducers, through ATM input wiring. Refer to Volume #3 for a complete list of all possible analog input functions.

Discrete Inputs

Available Discrete Inputs: 24

Of the 24 total discrete inputs, 7 are dedicated and 17 are configurable. The seven dedicated inputs are Emergency Trip#1, Emergency Trip#2, Control Reset, Start Command, Speed Set Point Raise, Speed Set Point Lower, and Halt/Continue Start Sequence. Only one discrete input may be programmed for any one listed option; more than one will result in a configuration error. Refer to Volume #3 for a complete list of all possible discrete input functions.

First out—By configuring multiple discrete inputs to function as external trips or alarms, the control can function as a “First-Out” monitor to assist in system troubleshooting. The other discrete inputs are not time stamped.

Readouts—Analog Outputs

Available Readouts: 4

Any readout can be configured to perform any of the listed control readout functions. These readouts only drive an output current of 4–20 mA. There are no configuration limitations on the analog output programming. For example, all four outputs could be configured to function as a speed readouts, if desired. These outputs are driven at a slower rate than the actuator outputs, and are not intended to function as actuator drivers. Refer to Volume #3 for a complete list of all possible readout functions.

Actuator Combo Outputs

Available Actuator Outputs: 2

Each actuator output can be configured to output current ranges of 4–20 mA or 20–160 mA, and to interface with single or dual coil actuators. When a single-coil actuator is used, all three kernel output drivers are tied together and share current proportionally. When a dual-coil actuator is used all three also share output current, however, kernels A & B are tied directly together through the ATM to the coil #1 output and kernel C provides the coil #2 output.

The usage of the actuator output is configurable in PCI software.

The options available are:
- HP valve
- HP2 valve (split or redundant)
- LP valve (if extraction turbine only)
- LP2 valve (split, Extraction & Admission with separated valves)

If an actuator combo output is not used to control a valve, then it can be configured as a simple 4–20 mA Analog readout, with the same option as for normal analog readouts.

Actuator Cards-Controller Type

Proportional actuators will simply scale the demand (0-100%) to the actuator module to a 0% milliamp and 100% milliamp. If no feedback is used, then command trim enable must not be used and positioning will be open loop based on the 0% and 100% parameters set during actuator calibration. If feedback is used with command trim enable, then positioning will be based on the 0% and 100% milliamp values but position will also be adjusted to trim out any error between the output and feedback. Proportional actuators will only use the actuator mA at 0% and actuator mA at 100% parameters during calibration.

Integrating actuators utilize a null current and minimum current and maximum current settings to position the valve based on a closed loop with position feedback. 0% demand does not correspond to minimum current nor does 100% demand correspond to maximum current. Changing the demand to the module will create an error between demand and feedback and the module will accordingly increase or decrease current to get a different position feedback and correct the error. In a forward acting controller, maintaining constant demand will output the null current and maintain the actuator position. Increasing demand will cause the module to increase current above the null and will increase actuator position. Decreasing demand will cause the module to decrease the current below the null setting and will decrease actuator position. The amount by which current increases above, or decreases below, the null current results from the magnitude of the demand – position error and along with the controller settings affects how fast the actuator reacts. Integrating actuators will only use the minimum output current, maximum output current and null current parameters during calibration.

The type chosen in the configuration tool (Figure 2-13) will be one of the following:

1 - Proportional	(proportional)
2 - P	(integrating)
3 - PI	(integrating)
4 - PI Lag	(integrating)
5 - PI Lead	(integrating)

Following are further descriptions of each type.

Proportional Actuator (Proportional or PROP):

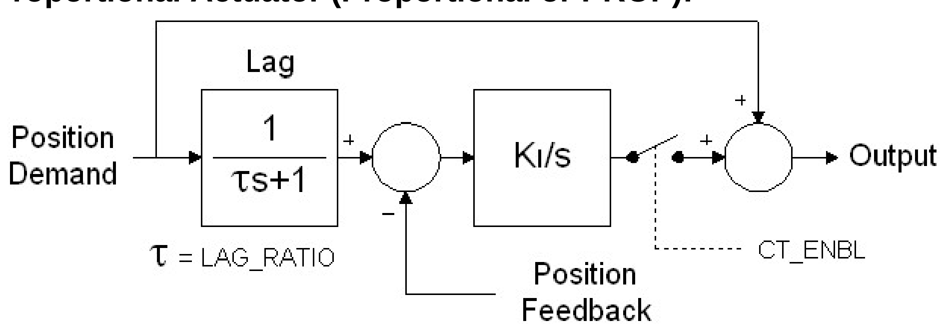

Figure 2-13. Proportional Controller Diagram

CTRL_TYPE	= PROP
KP	= N/A
KI	= integral time constant
T_LEAD	= N/A
LAG_RATIO	= lag time constant

The proportional actuator controller uses a "command trim" scheme to reduce steady-state position errors. When the CT_ENBL input is false, the output equals the input. When CT_ENBL is true, the integrator trims the error between the position demand and the position feedback to zero. The output of the integrator is limited to 10% of the range defined by MA_AT_0 and MA_AT_100. The lag block reduces overshoot when the position demand changes faster than the actuator can respond. Ideally, the lag exactly matches the response of the actuator and therefore no change is required out of the Ki/s block.

Integrating Actuator (P):

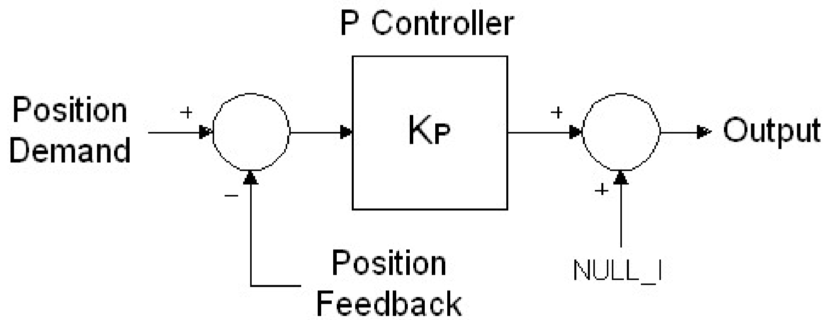

Figure 2-14. P Controller Diagram

CTRL_TYPE	= P
KP	= proportional gain
KI	= N/A
T_LEAD	= N/A
LAG_RATIO	= N/A

The P controller is the simplest controller, is very robust and works well for systems that aren't very sensitive to position errors. Steady-state errors will exist if the NULL_I input value does not equal the actual null current of the actuator.

Tuning can be accomplished by increasing the gain until the actuator just starts to oscillate, then reducing the gain by a factor of 2.

Integrating Actuator (PI):

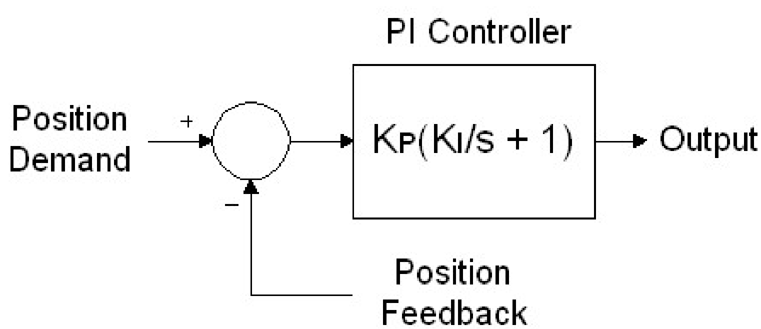

Figure 2-15. PI Controller Diagram

CTRL_TYPE	= PI
KP	= proportional gain
KI	= integral gain
T_LEAD	= N/A
LAG_RATIO	= N/A

The PI controller is suitable for most applications. The following procedure may be used as a starting point to finding the optimal dynamic settings:

1. Adjust Ki to a minimum value.
2. Increase Kp until the actuator just starts to oscillate. Record the Period of the oscillation (Posc) and Kp (Kosc).
3. Set Kp = 0.45 * Kosc and I = 1.2/Posc.

This gives stable response. Test the actuator response and further refine the tuning until the desired performance is obtained.

Integrating Actuator (PI Lag or PI_LAG):

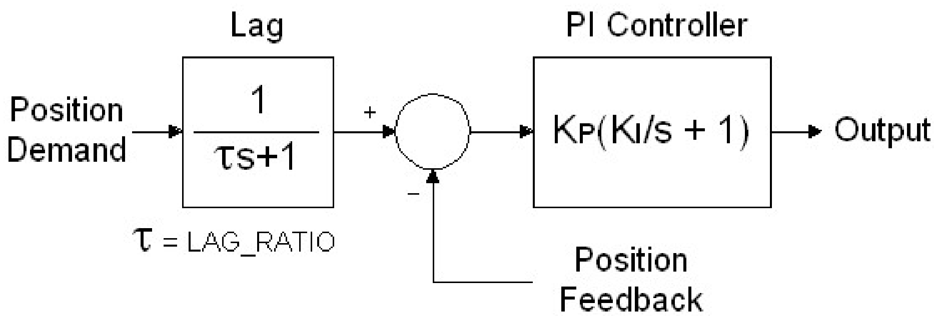

Figure 2-16. PI Lag Controller Diagram

CTRL_TYPE	= PI_LAG
KP	= proportional gain
KI	= integral gain
T_LEAD	= N/A
LAG_RATIO	= lag time constant

The PI-Lag controller is a PI controller with a lag block conditioning the demand signal. The lag term may be used to cancel, or partially cancel, a zero in the closed-loop transfer function. Tuning of this control is exactly the same as the PI control. Use this control only if you have a critical process which cannot tolerate overshoots. This control will limit actuator response although the lag can be set to a very low value to avoid excessive delay.

Integrating Actuator (PI Lead or PI_LEADLAG):

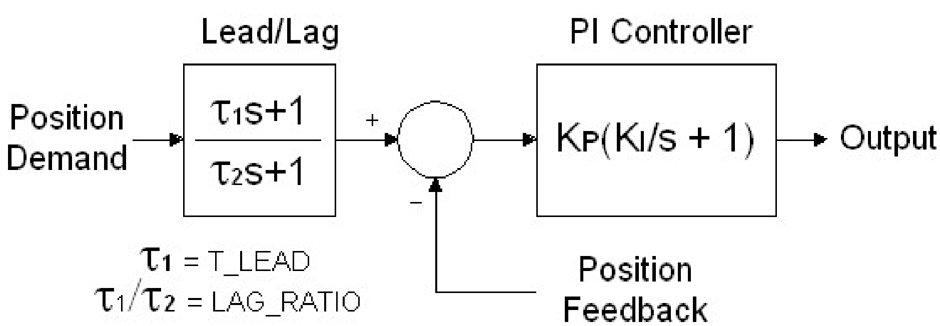

Figure 2-17. PI Lead Lag Controller Diagram

CTRL_TYPE	= PI_LEADLAG
KP	= proportional gain
KI	= integral gain
T_LEAD	= lead time constant
LAG_RATIO	= lead/lag ratio

The PI-Lead/Lag controller is a PI controller with a lead/lag block conditioning the demand signal. The T_LEAD input sets the lead time constant. Note that the lag time constant is not entered directly. The LAG_RATIO input sets the lead/lag ratio. Tuning this control is the same as the PI control. The lead/lag term may be used to set the actuator response to some ideal value. The lead/lag may be used for increasing or decreasing the apparent bandwidth of the actuator thereby tailoring performance for the application. Of course, the control cannot force the actuator to exceed its physical limits, e.g., slew rate and dead time.

Command Trim Enable

Command trim enable is only available when actuator type is selected to be proportional. When command trim is disabled, the proportional controller acts as an open loop position demand. When enabled the proportional controller will still position based on milliamp at 0% and milliamp at 100% settings, but will also adjust demand to correct any error between it and % position feedback.

Actuator Direction

When Actuator Direction is selected to be FORWARD, then an increasing position demand will result in an increasing current output. When actuator direction is selected to be REVERSE then an increasing position demand will result in a decreasing current output.

Position Feedback Transducer Type

The position transducer must be an LVDT or an RVDT. The Position Feedback Transducer Type field determines how the signals from the transducer are interpreted. In the configuration tool enter:

- “None” if no position feedback will be used.
- "A" for devices with a single pair of return wires,
- "A–B" is for devices with two pairs of return wires that have a simple difference output.
- "(A–B)/(A+B)" is for devices with two pairs of return wires that have a difference/sum (also known as constant sum, or D/S) output.

For devices with two pairs of return wires, the device manufacturer's drawing should be consulted to determine if it is a difference type or difference/sum type.

Wiring methods for different transducer examples are shown below:

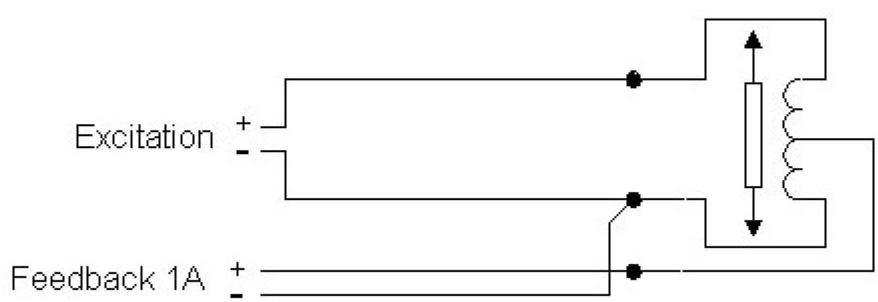

Figure 2-18. Three-Wire Transducer

The three-wire device has no primary-to-secondary isolation, which prevents the open-wire detection circuit from functioning properly. Under the tune menu of the configuration tool, uncheck the enable open circuit alarm checkbox to avoid nuisance feedback open and feedback failure alarms.

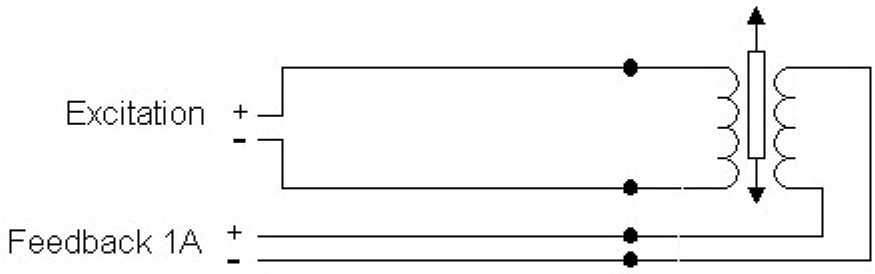

Figure 2-19. Four-Wire Transducer

The "+" and "-" designations shown here are arbitrary. Note: The output voltage of devices with a single pair of return wires must not pass through zero volts.

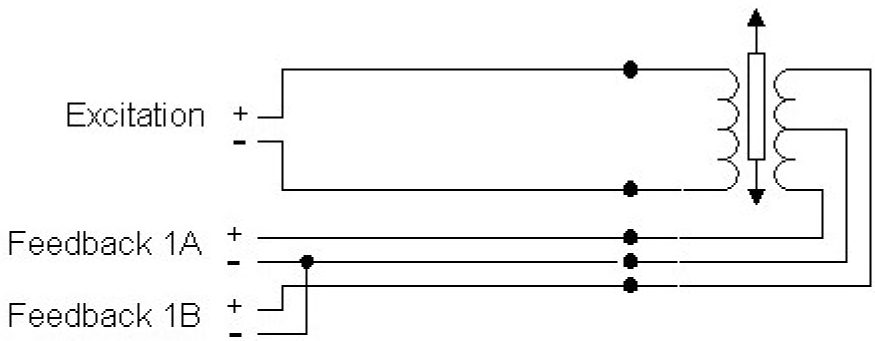

Figure 2-20. Five-Wire Transducer

The "+" and "-" designations for the exciter are arbitrary. The (-) side of feedbacks 1A and 1B should be tied to the output center tap as shown. This device could be a simple difference or difference/sum type. Consult manufacturer to determine if this is an “A–B” or “(A–B)/(A+B)” type transducer.

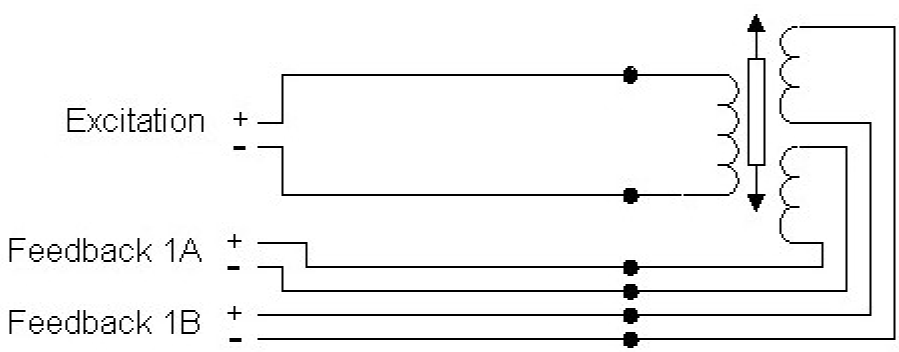

Figure 2-21. Six-Wire Transducer

The "+" and "-" designations shown here are arbitrary. This device could be a simple difference or difference/sum type. Consult manufacturer to determine if this is an “A–B” or “(A–B)/(A+B)” type transducer.

Excitation Amplitude

Consult the position transducer’s manufacturer for the ideal excitation amplitude.

Proportional Gain (KP)

Used for P, PI, PI Lag, PI Lead controller types. See Figures 2-1—2-17.

Integral Gain (KI)

Used for Proportional with command trim enable, PI, PI Lag, PI Lead controller types. See Figures 2-13, 2-15—2-17.

Lag Time Constant (LAG_RATIO)

Used for PI Lag and PI Lead controller types. See Figures 2-16 and 2-17.

Lead Time Constant (T_LEAD)

Used for PI Lead controller types. See Figure 2-17.

Enable Open Circuit Alarm

Uses feedback open circuit detection. Generally will not work with a 3-wire transducer. See Figure 2-18.

LVDT Linearization

In some cases, after calibration (at zero and 100%), the LVDT position readouts at mid position may not match. This difference can result in a small “bump” in the valve position in case of failure of one of the LVDTs.

To compensate, it is possible in service mode (see volume 3) to linearize the LVDT connected in kernel A (card A106), so that the position matches with the LVDT connected in kernel C (card C106).

Pilot Valve Control (Cascade Position Loop)

Normal Mode

The 5009C can be configured to control a valve with a dual position loop (cascade loop). The primary loop (Integrating pilot) needs to be enabled in PCI software. Pilot LVDT signals can be simplex or dual redundant.

In any case, this signal must be connected to the FDBK2 input of the actuator card, while the cylinder LVDT is to be connected to FDBK1.

K pilot * (Pilot null position- Pilot position) will be added to the valve demand. K pilot is the gain of this loop. Pilot null position is the pilot position when valve is stable.

Range and null position are easy to set during Valve calibration.

Degraded Mode

The degraded mode can be enabled in PCI software.
If the LVDT signal of the pilot is lost, and only because the 5009C scanning time is extremely fast, the control will maintain a stable operation of the valve, by extrapolating the pilot position, based on the cylinder LVDT derivative signal.

This mode needs to be tested and tuned during valve calibration, prior to be enabled in normal operation.
Valve stroke must be performed with very big step (>20%) to verify the stability of this loop during sudden load changes.

In service mode, estimated values are available. During valve calibration, in manual stroke mode, the estimated value must first be reset.
The valve demand must be raised/lowered prior to collecting data.
This procedure must be performed for different manual rates (tunable with the PCI software only).

Relay Outputs

Available Relay Outputs: 12

Of the 12 relay outputs, 3 are dedicated and 9 are configurable. Relay #1 and #2 are to dedicated outputs for Emergency Trip (10 ms), and realy#3 is used for Alarm condition.
There are no configuration limits on relay output programming. For example, all 9 of the programmable relays could be configured to function as a Speed PID In-Control indication, if desired.

Communication Ports

Available Communication Ports: a total of 11 RS-232 ports are provided with each system by the addition of two SIO modules (4 ports each).

The CPU-A RS-232 port is dedicated for Modbus Communications with a distributed control system (DCS) or other serial operator control panel.

The CPU-B RS-232 port can be configured to function as a Modbus Communications port like CPU-A's port or interface with a serial line-printer to provide a hard-copy of any alarm or trip condition. Alternatively this port can also be configured to act as a backup PCI communications port in-case the Kernel-C CPU fails.

The CPU-C RS-232 port is dedicated for use with the control's PCI program. The PCI program is loaded on to a site computer to act as unit engineering workstation. The PCI program is used to configure the control, perform on-line program changes, perform on-line hardware tests, and alternatively operate the turbine from.

The control's CPU module communication ports are configured for RS-232 communications only. RS-232 communications is limited to a distance of 50 feet. In cases where a device which is being interfaced to is located a distance of greater than 50 feet from the control, it is recommended that an RS-232-to-RS-422 converter, RS-232-to-RS-485 converter, or a Woodward SIO Module be used.

To allow an RS-232-based port to reach farther than 50 feet, a Model 285 Superverter from Telebyte Technology Inc. of Greenlawn NY, or equivalent can be used as an RS-422 or RS-485 interface converter. RS-422 and RS-485 communications also support multidropping (multiple slaves on a single communications line); RS-232 communications does not.

Each SIO module has four ports, with each port dedicated to a particular function: Port1 - Alarm/Trip printing, Port2 - ServPanel Com, Port3 - Modbus, Port4 - DDE Com. The Modbus and DDE Com ports are configurable for RS-232, RS-422, or RS-485 communications. With the use of RS-422 or RS-485 communications the control can interface with a device through serial communications up to 4000 feet from the control. Two SIO modules are installed within the control's chassis.

PC Interface Program

The 5009C Control System is a field configurable steam turbine control that utilizes a DDE Windows-based PC Interface program to configure, operate, and service the 5009C Control. Two software application programs are provided with the control (ServLink & PCI).

The ServLink program communicates directly with the control, and allows any program that can communicate via Dynamic Data Exchange (DDE) to access control data. Most Microsoft based programs (Excel, Access, Word) use DDE protocol to link to other programs, and can be used in conjunction with the ServLink program to access and record control data. The DDE interface program allows non-Woodward software applications access to control data, for monitoring, trending, and report creating purposes. Refer to Volume 3 for details on connecting to the control via the ServLink program.

The PCI program, is a user interface program, which like Microsoft based programs interfaces with the control through the ServLink program using DDE communications. This interface program has three levels of access (Program, Service, Run). Each of these access levels have different levels of password security. These security levels allow only users who are qualified (and have access to the mode's password) access to perform changes in a specific interface mode.

All three PCI interface modes can be monitored at any time, however, changes cannot be made in the Program and Service modes unless the correct password has been entered. The program's "Start" mode has no password protection. Refer to Volume 3 for details on the PCI program and its functionality.

The Program mode is used to initially configure the control to the application. The Service mode is used to perform changes to the control's configuration, test control hardware, and calibrate control I/O, all while on-line at any operating level.

The Run mode is used to start the turbine, stop the turbine, and enable or disable any operating mode. The run mode options are limited. It should be used only during commissioning/services.

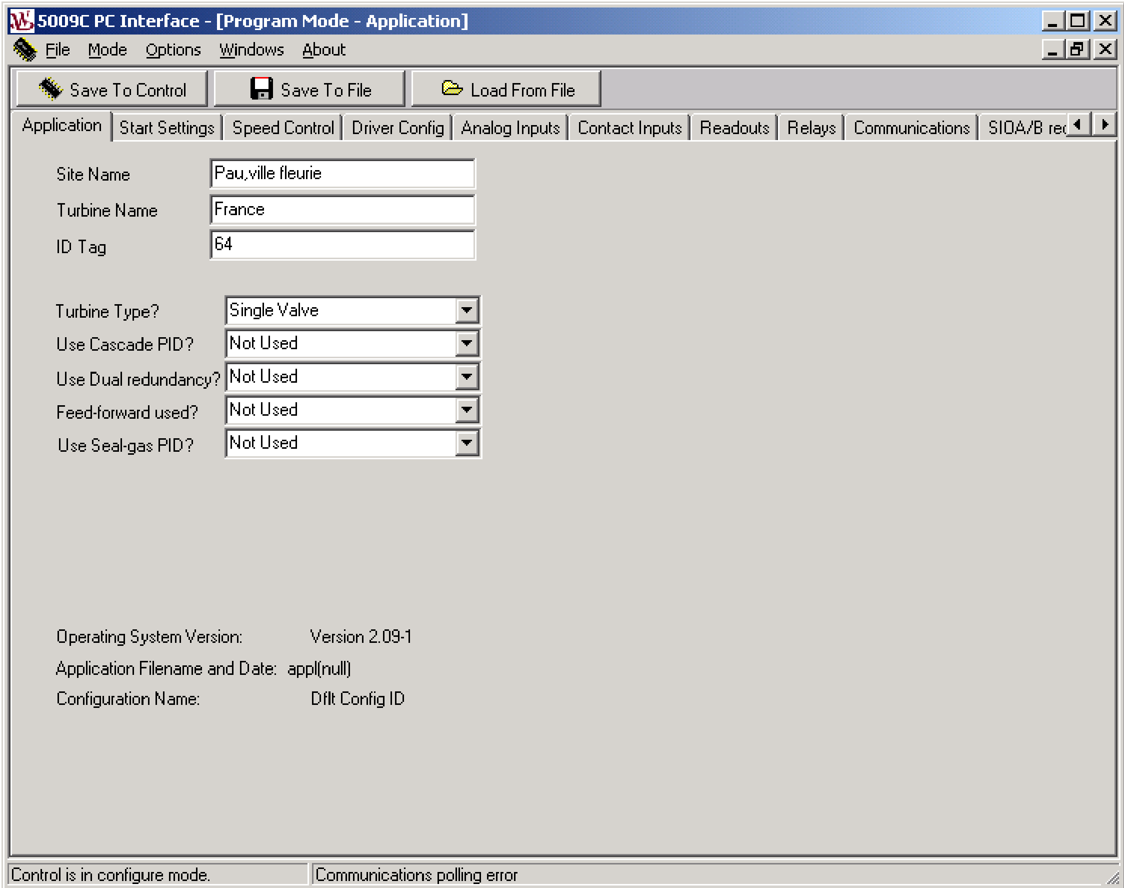

Figure 2-22. Main Screen

Chapter 3. Control Functionality Overview

Control Overview

This control is designed to control single valve, split-range valve, single controlled-extraction, single controlled-admission, or single controlled-extraction/ admission steam turbines. Refer to the following turbine control descriptions and block diagrams to match the control's configuration to your type of turbine and application.

Single Valve or Split Range Valve Turbines

This control can be configured to control turbines with one or two turbine control valves (or valve racks) feeding into a single steam chest, or separate steam chests. With this type of configuration the control interfaces with the turbine control valve(s) to control one parameter at a time and limit an additional parameter if desired.

With this type of turbine, the one controlled parameter is typically speed, however, the control could be utilized to control: turbine inlet pressure or flow, exhaust (back) pressure or flow, first stage pressure, compressor inlet or discharge pressure or flow, process temperature, or any other turbine related process parameter. Refer to the following block diagrams for possible control configurations, and PID relationships.

When the control is configured for a split-range turbine type, HP2 can be configured to begin opening at an offset value of actuator output #1 position. If this offset setting is 50%, then Valve #2 will begin opening when Valve #1 reaches 50%. The control will continue to open both valves to 100%, with a position difference of 50%.

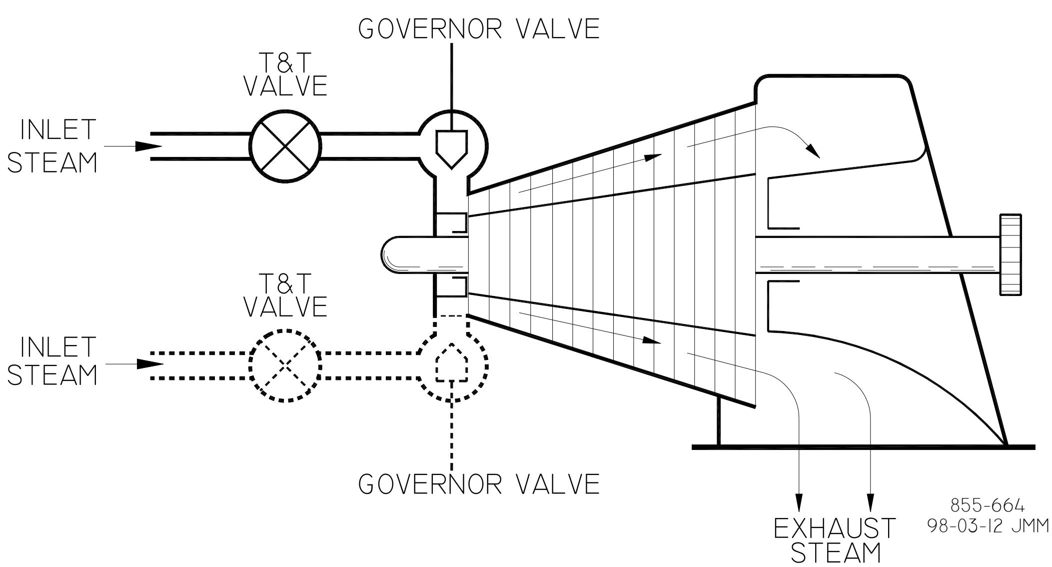

Figure 3-1. Typical Extraction and/or Admission Steam Turbine

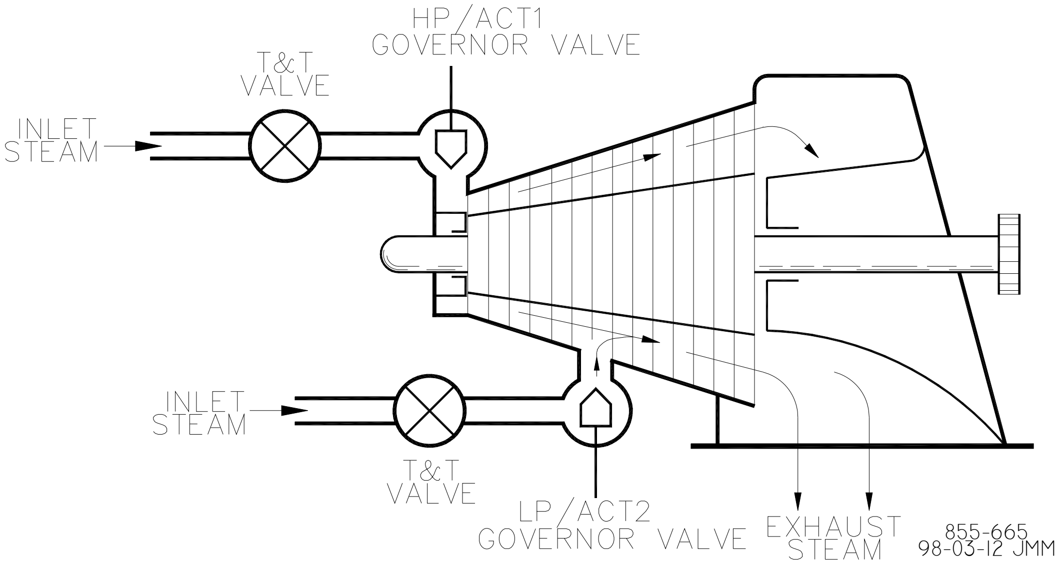

Figure 3-2. Split Range or Admission Type of Turbine Configuration (depending on the parameters being controlled)

Extraction Turbines

When configured to operate single controlled-extraction steam turbines, the control, manages the interaction between the turbine's governor valve (HP) and extraction valve (LP) valve to control two turbine related parameters at the same time, while minimizing the affect each parameter has on the other.

Single controlled-extraction turbines have a high pressure stage and a low pressure stage, each controlled by a valve. Steam enters the turbine through the HP valve (see Figure 3-3). At the downstream end of the HP turbine stage and before the LP valve, steam can be extracted. The LP valve controls the entry of steam into the LP turbine stage, and the diverting of steam out the extraction line. As the LP valve is opened, more steam enters the LP stage and less is extracted.

When configured for an extraction type of turbine, this control uses Ratio/Limiter logic to control the interaction of the HP and LP valves. Due to a turbine's design, the positioning of either valve (HP or LP) has an effect on both parameters being controlled. This interaction between valves (controlled parameters) can cause undesirable fluctuations in a process not requiring a change.

The ratio logic controls the interaction of both HP and LP valves to maintain desired turbine speed (or Cascade PID processes) and extraction pressure/flow levels (or Inlet/Exhaust pressure) . Because a single extraction turbine has only two control valves, only two parameters at a time can be controlled. By controlling valve interaction, the ratio logic minimizes the effects of one controlled process on the other controlled process.

When system conditions cause a turbine to reach an operating limit (Min LP), only one process parameter can be controlled. The control's limiter logic allows the process parameter which has priority on that limit to be controlled by limiting the second parameter.

The interaction of both valves is automatically calculated by the 5009C Control System's ratioing logic, based on entered turbine performance parameters. HP & LP valve decoupling modes are available, depending on the process parameters being controlled. Refer to the following block diagrams for possible control configurations, and PID relationships. Refer to the Ratio/Limiter section of this Volume for Ratio/limiter configuration options.

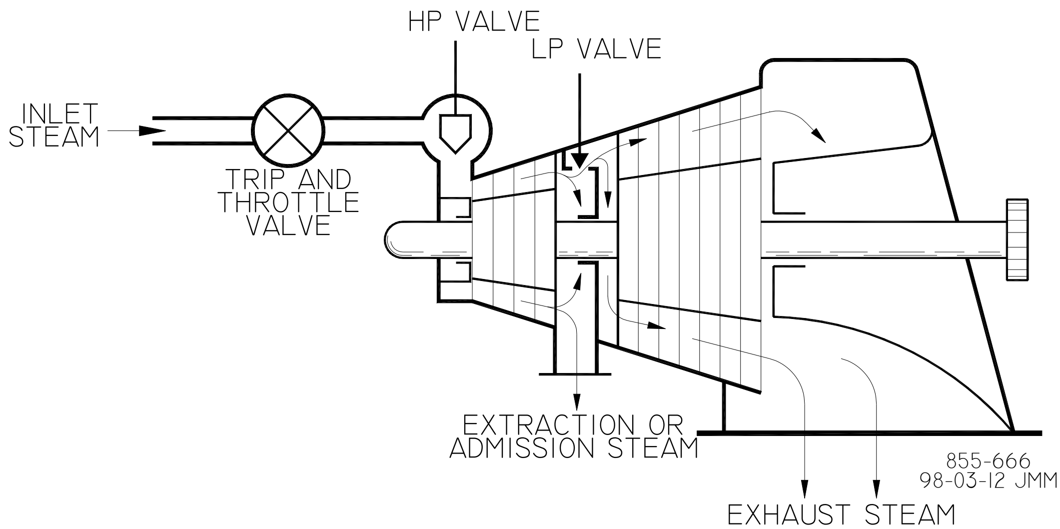

Figure 3-3. Extraction and/or Admission Steam Turbine

Admission Turbines

When configured to operate single controlled-admission steam turbines, the control, manages the interaction between the turbine's governor valve (HP) and extraction valve (LP) valve to control two turbine related parameters at the same time, while minimizing the affect each parameter has on the other.

Typical single automatic admission turbines have a high pressure stage and a low pressure stage, each controlled by a valve. Steam enters the turbine through the HP valve (see Figure 3-3) and at the downstream end of the HP turbine stage, before the LP valve. The LP valve controls the entry of steam into the LP turbine stage and through the admission line. As the LP valve is opened, more steam enters the LP stage.

When configured for an admission type of turbine, this control uses Ratio/Limiter logic to control the interaction of the HP and LP valves. Due to a turbine's design, the positioning of either valve (HP or LP) has an effect on both parameters being controlled. This interaction between valves (controlled parameters) can cause undesirable fluctuations in a process not requiring a change.

The ratio logic controls the interaction of both HP and LP valves to maintain desired turbine speed (or Cascade PID processes) and admission pressure/flow levels (or Inlet/Exhaust pressure via decoupling) . Because a single admission turbine has only two control valves, only two parameters at a time can be controlled. By controlling valve interaction, the ratio logic minimizes the effects of one controlled process on the other controlled process.

When system conditions cause a turbine to reach an operating limit (Min LP), only one process parameter can be controlled. The control's limiter logic allows the process parameter which has priority on that limit to be controlled by limiting the second parameter.

The interaction of both valves is automatically calculated by the 5009C Control System's ratioing logic, based on entered turbine performance parameters. HP & LP valve decoupling modes are available, depending on the process parameters being controlled. Refer to the following block diagrams for possible control configurations, and PID relationships. Refer to the Ratio/Limiter section of this Volume for Ratio/Limiter configuration options.

Extraction/ Admission Turbines

When configured to operate single controlled-extraction/admission steam turbines, the control, manages the interaction between the turbine's governor valve (HP) and ext/adm valve (LP) valve to control two turbine related parameters at the same time, while minimizing the affect each parameter has on the other.

Single automatic extraction/admission turbines have a high pressure stage and a low pressure stage, each controlled by a valve. Steam enters the turbine through the HP valve. At the downstream end of the HP turbine stage and before the LP valve, steam can either be extracted or admitted (inducted) into the LP turbine stage. The LP valve controls the entry of steam into the LP turbine stage. As the LP valve is opened, more steam enters the LP stage and less is extracted.

When configured for an ext/adm type of turbine, this control uses Ratio/Limiter logic to control the interaction of the HP and LP valves. Due to a turbine's design, the positioning of either valve (HP or LP) has an effect on both parameters being controlled. This interaction between valves (controlled parameters) can cause undesirable fluctuations in a process not requiring a change.

The ratio logic controls the interaction of both HP and LP valves to maintain desired turbine speed (or Cascade PID processes) and ext/adm pressure/flow levels. Because a single ext/adm turbine has only two control valves, only two parameters at a time can be controlled. By controlling valve interaction, the ratio logic minimizes the effects of one controlled process on the other controlled process.

When system conditions cause a turbine to reach an operating limit (Min LP), only one process parameter can be controlled. The control's limiter logic allows the process parameter which has priority on that limit to be controlled by limiting the second parameter.

The interaction of both valves is automatically calculated by the 5009C Control System's ratioing logic, based on entered turbine performance parameters. HP & LP valve decoupling modes are available, depending on the process parameters being controlled. Refer to the following block diagrams for possible control configurations, and PID relationships. Refer to the Ratio/Limiter section of this Volume for Ratio/Limiter configuration options.

The 5009C is also capable to be configured for Extraction & Admission turbines having two separated LP valves. One used for extraction, one used for admission.

The ratio limiter will position the Extraction and admission valves, depending on the null flow line. The admission valve will start to open, when the extraction flow through Extraction valve is null, according steam Map configured, and when lees pressure is requested.

Block Diagrams

Overviews of possible 5009C Control System configurations are shown in Figures 3-5 through 3-11. Use these block diagrams to match the control features to the site-specific application requirements. Figure 3-4 lists symbols and their respective explanations. The Cascade and Decoupling PIDs are optional controllers, and are shown in the following diagrams for PID relationship purposes only. For more information on the functionality of the Ratio/Limiter block, refer to the Ratio/Limiter Section of this manual.

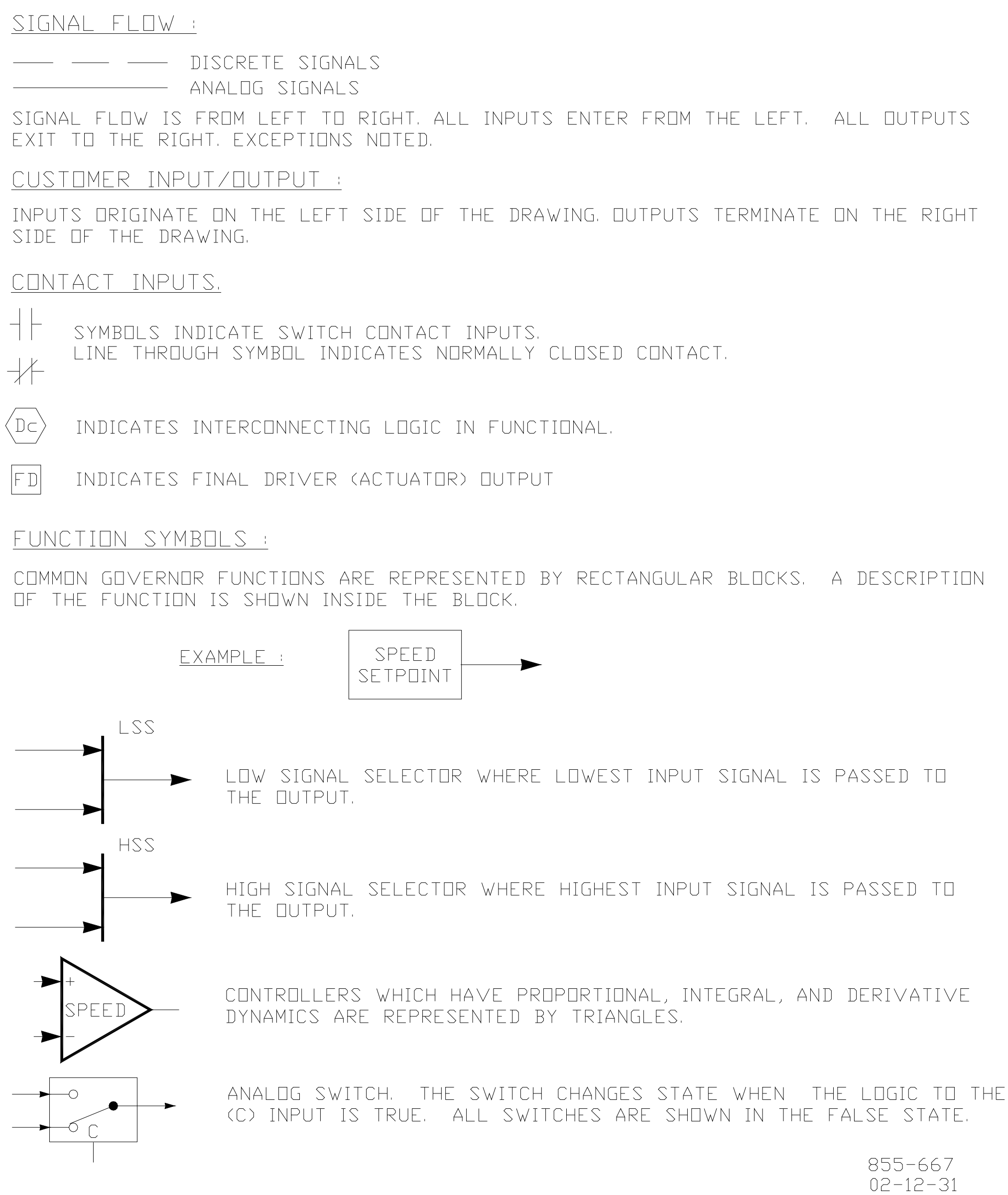

Figure 3-4. Overview of 5009C Control System Functionality Notes

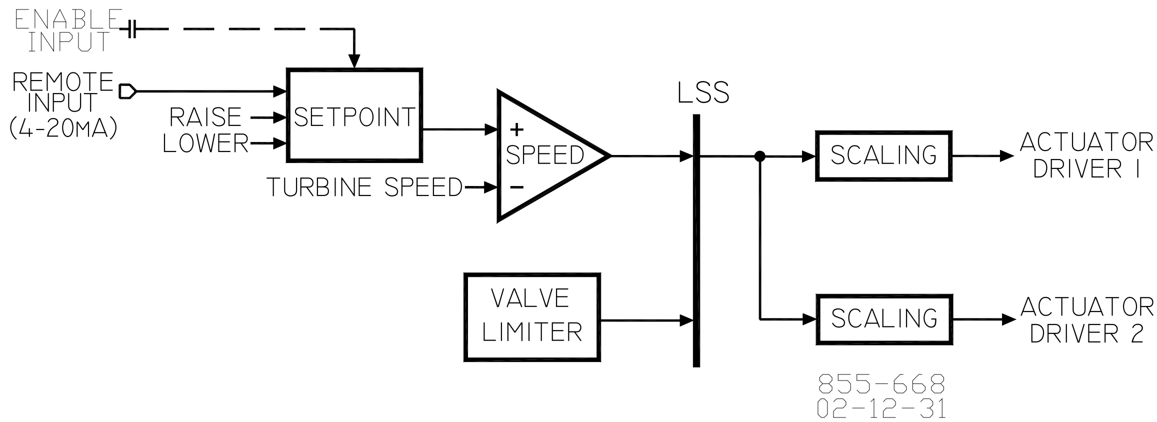

Figure 3-5. Single or Split-Range Turbine Configurations
(Speed PID with Remote Set Point)

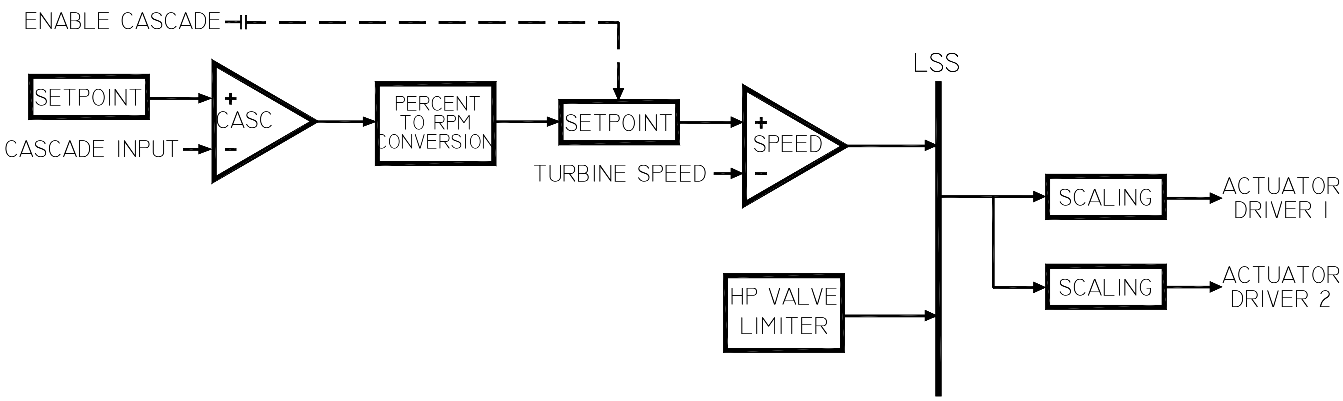

Figure 3-6. Single or Split-Range Turbine Configurations

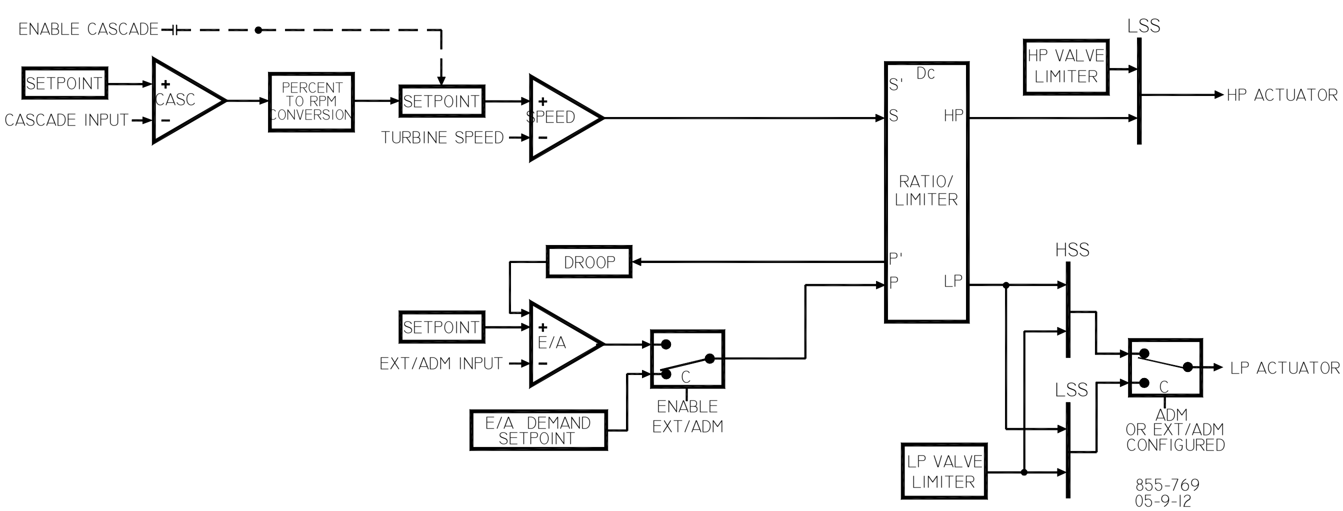

Figure 3-7. Extraction and/or Admission Turbine Configurations (coupled mode)

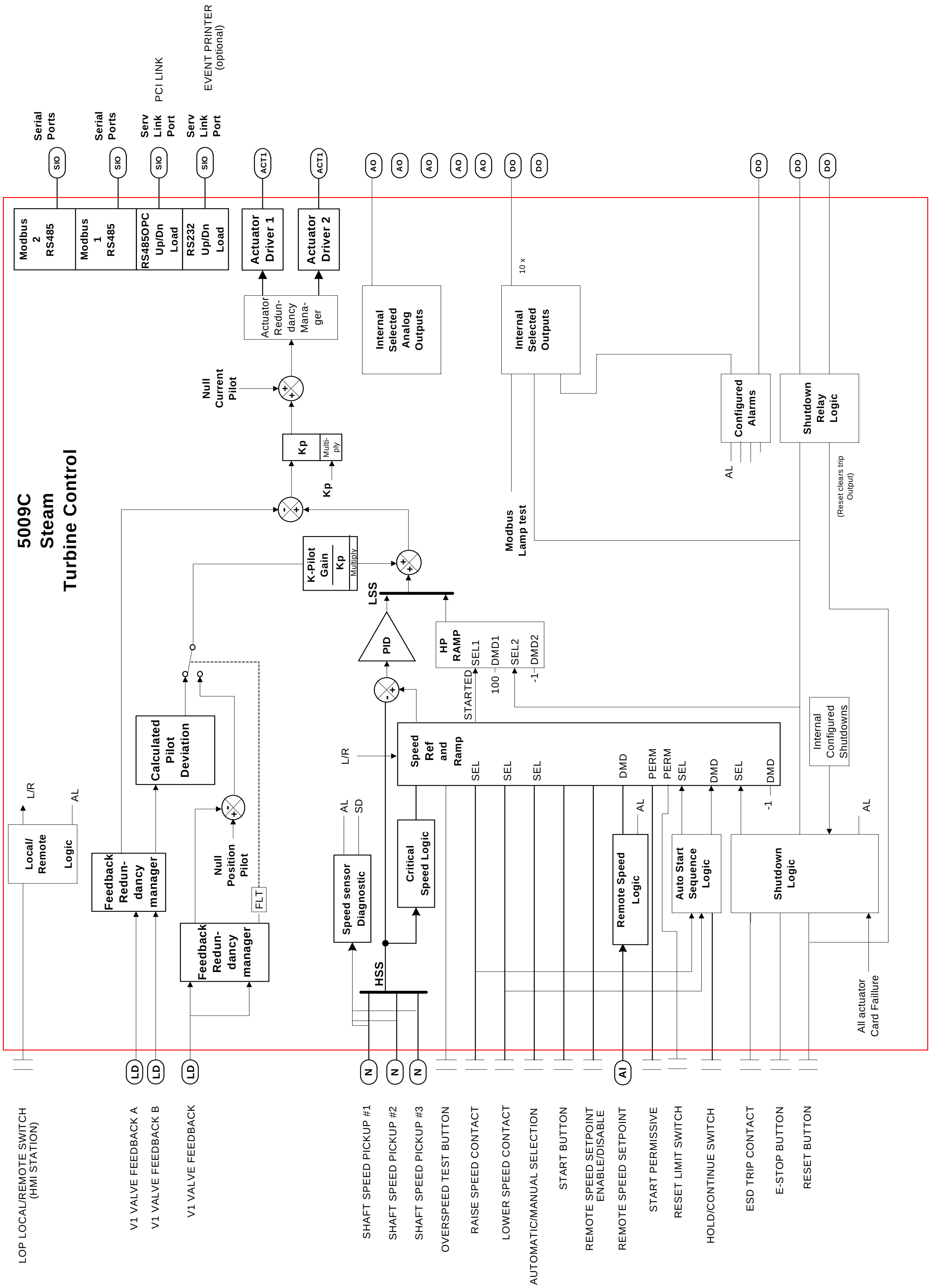

Figure 3-8. Example of a Single Stage Turbine using Dual Loop Actuator and Remote Speed Set Point

Chapter 4.
Control Functionality

Introduction

The 5009C Control System may be programmed to operate single valve, split-range valve, single extraction, single admission, or single extraction/admission turbines. For each of the extraction and/or admission turbine applications, the 5009C Control's Ratio/Limiter logic may be configured to allow the turbine's HP and LP valves interact differently depending on the turbine's function within a system. When there is no controlled-extraction, a Ratio/Limiter is not used. In addition, none of the extraction/admission logic is used either.

IMPORTANT

In this manual the term "HP valve" refers to a non-extraction turbine's inlet control valve, or an extraction/admission turbine's High Pressure inlet control valve. If configuring the control for a non-extraction turbine, ignore all references to the LP valve, extraction control, and ratio/limiter.

Valves Selection

The 5009C has been specially designed to handle different type of valves. Therefore, no specific actuator channels have been allocated for HP and LP valves.
Up to two HP valves, and two LP valves, can be configured in the control.

The channel to be used for HP1, HP2 (if used), LP and LP2 (if used) valves can only be set in Program mode, using PCI software (see volume 3). The options are:

- Actuator combo 1: channel 1 of HD combo cards
- Actuator combo 2: channel 2 of HD combo cards
- Actuator card channel 1: channel 1 of actuator cards A/C106
- Actuator card channel 2: channel 2 of actuator cards A/C106

The PCI software will take care that for each valve, only one channel is allocated.

IMPORTANT

If the 5009C has been purchased without actuator cards, these actuator channels must NOT be selected from PCI. Engine will be holding a Shutdown condition in case of error.

IMPORTANT

For Extraction valves, care should be taken that an actuator channel has been allocated for LP valve using the PCI software. Failure to do so, will maintain the LP closed, resulting to a possible damage of the engine while starting.

Single Loop Valve

This type valves is the most common valve.

The possibilities are:

1. Proportional only without LVDT.
The actuator current is directly proportional to the valve lift.
The current is:
4–20 or 20–160 for channels from actuator combo
±200 mA maximum for actuator card channels. (Max range can be changed on special requested to increase resolution)

2. Proportional (P) with LVDT.
Only actuator card channels can be used in this case.

The valve will generally, integrate when the card output deviated form the null current. When the demand equal to the LVDT position, the current output equals the null current and the valve doesn't move (see volume #2 for more details).

3. Proportional Integrating with LVDT/with or without LAG/LEAD
Only actuator card channels can be used in this case.

The valve will generally, integrate when the card output deviated form the null current. When the demand equal to the LVDT position, the current output equals the null current + integration part, and the valve doesn't move.

LAG/LEAD option is described in volume #2.

Dual Loop Valves (or Cascade Type Valves)

This type of valve can only be handled by actuator card channels.

1. Normal operation

In normal operation, the Pilot valve position will be integrating when the actuator current output is not equal the null current.

When the current output equals the null current, the pilot doesn't move

The cylinder movement will depend on the pilot NULL position.

When the pilot deviates from its null position, the cylinder will continuously open or close (integrating).

Therefore, it is necessary to control not only the cylinder position, but also the pilot position.

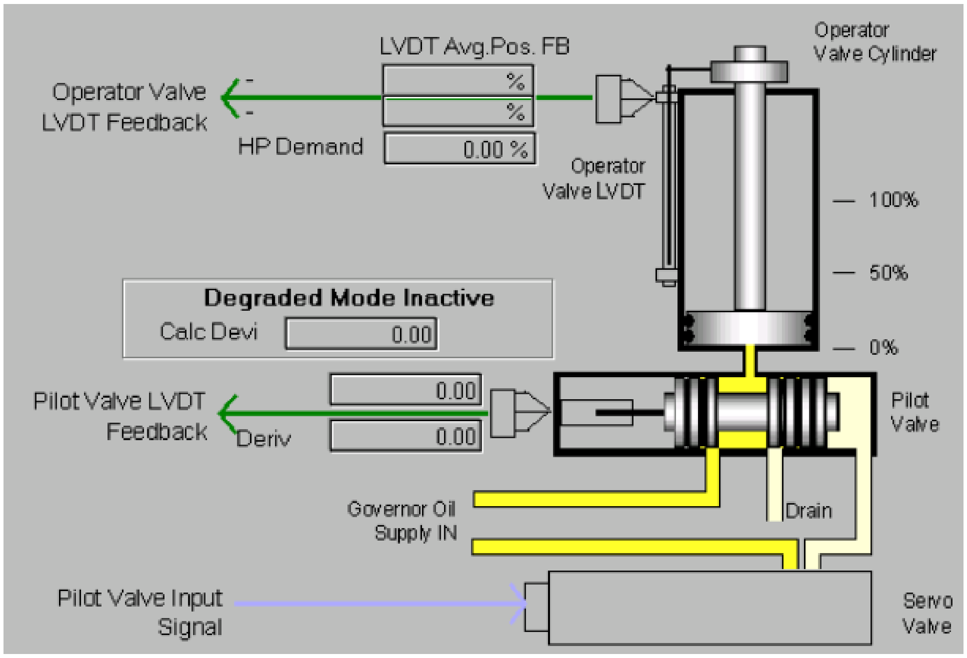

Figure 4-1. Typical Dual Loop Valve with Cylinder's LVDT and Pilot's LVDT as Represented in Woodward's HMI

2. Degraded mode

Dual loop valve cannot be operated without the Pilot position feedback.

A failure of this signal will result in instabilities of the valve position and will necessitate to SD the turbine in a very short delay.

Due to the valve's design, it might be impossible to install redundant Pilot LVDT.

To compensate this lack of redundancy, Woodward has developed a unique algorithm, capable to maintain the valve in stable operation, even if the Pilot valve feedback position as failed.

This mode called "degraded mode" will extrapolate the pilot deviation from its null position, based on the derivative signal of the Cylinder LVDT.

This calculation will be then used by the control.

If the valve is not moving, the pilot is supposed to be at its null position.
If the valve are opening/closing, the deviation is proportional the opening/closing rate (%/s)

Special protections will verify integrity of this loop and perform if necessary, a phase correction in case of instabilities during sudden load changes.

Tuning parameters are available in service mode, to extrapolate the deviation based on the opening/closing rate.

In any case at 0%/s opening/closing rate, the deviation (%) must be set at zero.

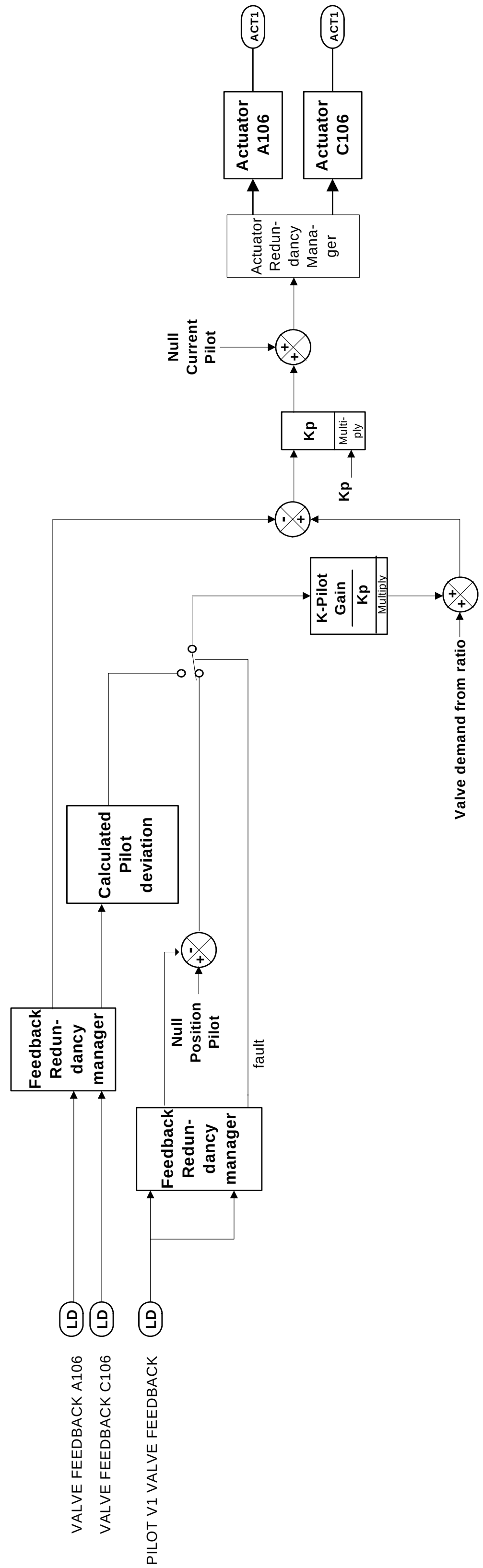

Figure 4-2. Dual Control Loop Valve With Cylinder's LVDT and Pilot's LVDT and Degraded Mode

Turbine Start Modes

This control can be configured for any of three possible turbine start modes (manual, semi-automatic or automatic). These start-up modes determine how the turbine is taken from a shutdown state to low idle or minimum turbine speed position. One of these start modes must be chosen and programmed to perform a system start-up.

Once a turbine is started and the control is controlling turbine speed, the configured “Turbine Start Routine” determines the control sequence used to bring the turbine from an idle speed up to the turbine’s rated speed. Refer to the Turbine Start Routines section of this chapter for details.

Once a ‘Start’ command is issued, the valve limiter and speed setpoint are manipulated manually or automatically, depending on the start mode selected. After a turbine start has been completed, turbine speed will be controlled at a minimum controlling speed. The minimum controlling is low idle.

A ‘Start’ command may be issued from the PCI program, an external contact, or through Modbus. with External Start’ contact, a ‘Start’ command is issued when the contact is closed. If the contact is closed prior to start-up it must be opened and re-closed to issue a ‘Start’ command.

If turbine speed is sensed when a ‘Start’ command is issued, the control will instantly set the Speed Set Point to the sensed speed and hold for an operator command or continue towards the next highest idle speed setting, depending on the start mode selected. In the event the sensed turbine speed is greater than the minimum controlling speed setting, the Speed Set Point will match this sensed speed, the Speed PID will control at this point, and the control will wait for further action to be taken by the operator.

If turbine speed is first sensed within a critical speed band, the control will take control of turbine speed, ramp the Speed Set Point to the upper limit of the critical speed band setting, and wait for action to be taken by the operator.

Start mode are selected using PCI software.

However, in some cases, depending on external conditions, it may be desired to switch the type of start mode.

In this case, it is always possible to request a manual start when engine is ready to start , Using Modbus/Hardware. When engine is started, the start mode cannot be changed.

At shutdown, the software will automatically re-select the start mode configured with the PCI software.

Manual Start Mode

The Manual Start Mode can be used to allow an operator to start the turbine via a hand-operated throttle valve. With this mode, when a start command is issued the inlet HP valve will be raised to its maximum limit. For extraction turbines, this maximum limit depends on the steam map parameters entered, and may be less than 100%. When turbine speed increases to the minimum controlling speed (idle or min control speed), the control’s Speed PID will take control of turbine speed through positioning the turbine’s inlet HP valve. The following start-up procedure is employed when the **Manual start mode** is configured:

1. Issue a RESET command (to reset all alarms and shutdowns)
   - If programmed for an extraction-only turbine, the LP valve position will ramp to its maximum limit until extraction is enabled.
   - If programmed for admission or ext/adm turbines, the LP valve position will follow the turbine's steam map to try to maintain zero flow.

2. Issue a START command (verify Trip & Throttle (T&T) valve is closed before issuing)
   - At this point the control will ramp open the governor (HP) valve to its maximum position at the HP valve limiter rate.
   - The Speed Set Point will ramp from zero to its low idle speed setting at the Rate-to-min rate. It can be later on manipulated, even if speed is not sensed.

3. Open HP T&T valve at a controlled rate
   - When turbine speed increases to the actual speed reference, the control's Speed PID will take control of turbine speed through positioning the turbine's inlet HP valve.

4. Open HP T&T valve to 100%
   - Speed will remain at the minimum controlling speed until action is taken by the operator or the auto start sequence, if programmed, will continue its sequence.

The HP valve limiter rate, and the rate-to-min settings are tunable via the PCI program's Service mode.

⚠WARNING	**The HP trip-and-throttle valve must be closed before pushing the 'START' key in Manual Start mode. If a START command is given while the trip-and-throttle valve is open, there exists a possibility of turbine runaway with resultant serious injury or loss of life.**

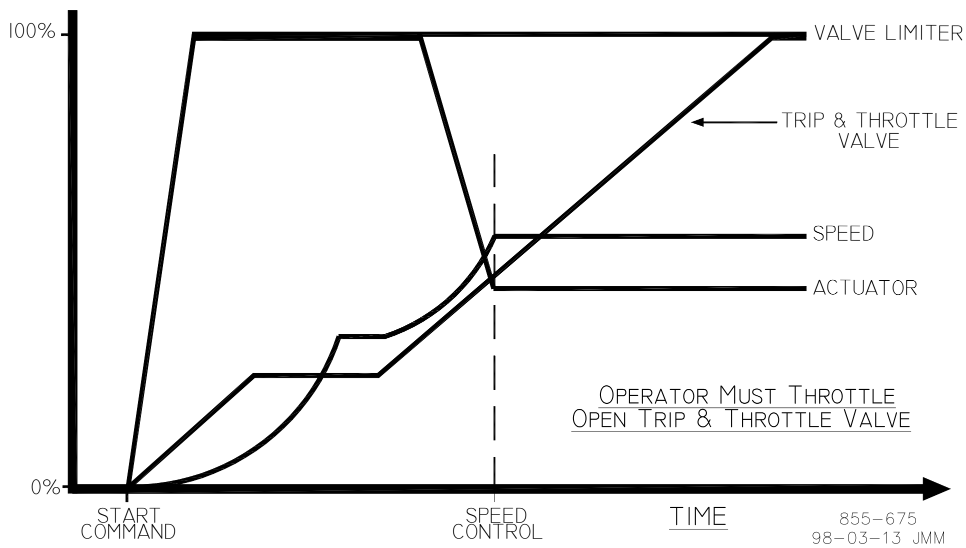

Figure 4-3. Manual Start Mode Example

Semiautomatic Start Mode

The Semiautomatic Start Mode can be used to allow an operator to open the unit Trip & Throttle valve (T&T valve), then start the turbine by manually increasing the control's inlet HP valve limiter. With this mode, when a start command is issued the inlet HP valve will stay at 0% until the control's inlet HP valve limiter is manually raised. The HP valve limiter can be raised, via PCI program, external contact, or Modbus commands. When turbine speed increases to the minimum controlling speed (Low idle), the control's Speed PID will take control of turbine speed through positioning the turbine's inlet HP valve. The following start-up procedure is employed when the Semiautomatic Start mode is configured:

Issue a RESET command (to reset all alarms and shutdowns)

- If programmed for an extraction-only turbine, the LP valve position will ramp to its maximum limit until extraction is enabled.
- If programmed for admission or ext/adm turbines, the LP valve position will follow the turbine's steam map to try to maintain zero flow.

1. Open the HP Trip & Throttle valve (verify that the turbine does not accelerate).

2. Issue a START command.
   - At this point the Speed Set Point will ramp to its lowest speed setting at the Rate-to-min rate.

3. Raise the control's HP valve limiter at a controlled rate.
   - When turbine speed increases to the minimum controlling speed, the control's Speed PID will take control of turbine speed through positioning the turbine's inlet HP valve.

4. Raise the control's HP Valve Limiter to 100%.
   - Speed will remain at the minimum controlling speed until action is taken by the operator or the auto start sequence, if programmed, will continue its sequence.

The HP valve limiter will open at the HP valve limiter rate and may be moved via PCI, external contacts, or Modbus commands. The HP valve limiter rate, and the rate-to-min settings are tunable via the PCI program's Service mode.

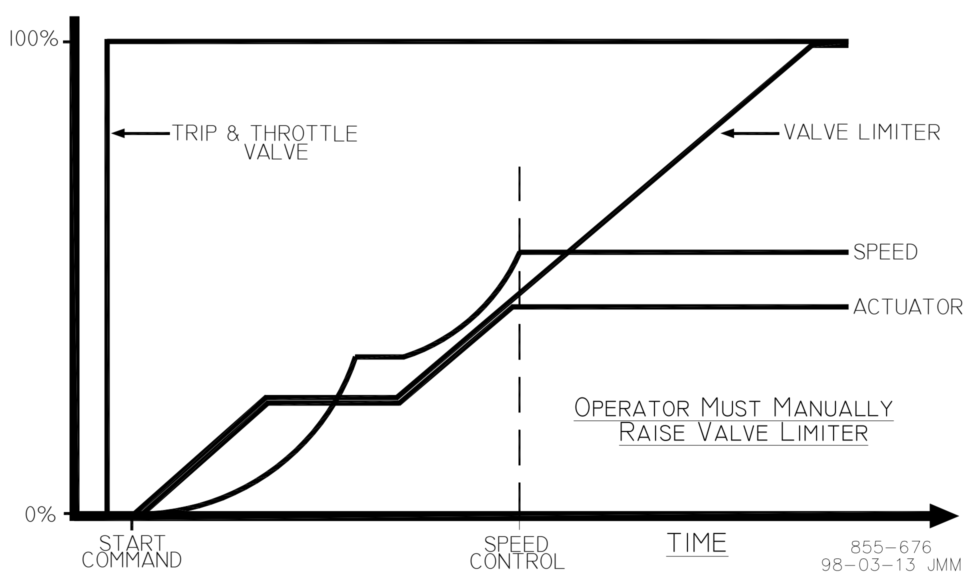

Figure 4-4. Semiautomatic Start Mode Example

Automatic Start Mode

The Automatic Start Mode can be used to allow an operator to open the unit Trip & Throttle valve (T&T valve), then start the turbine by issuing a Start command. With this mode, when a start command is issued the inlet HP valve will ramp from 0% towards V1% until the control's Speed PID takes control of the inlet HP valve and speed is above low Idle. Then, the HP ramp will go to 100%.

The HP valve limiter is used to ramp the HP valve open and can be halted at any time by momentarily issuing a HP valve limiter raise or lower command. When turbine speed increases to the Low Idle speed, the control's Speed PID will take control of turbine speed through positioning the turbine's inlet HP valve.

A Turbine Start Command must be issued to re-initiate an automatic ramp up, while the HP ramp has been manually stopped.

The following start-up procedure is employed when the Automatic start mode is configured:

1. Issue a RESET command (to reset all alarms and shutdowns)
   - If programmed for an extraction-only turbine, the LP valve position will ramp to its maximum limit until extraction is enabled.
   - If programmed for admission or ext/adm turbines, the LP valve position will follow the turbine's steam map to try to maintain zero flow.

2. Open the HP Trip & Throttle valve (verify that the turbine does not accelerate)

3. Issue a START command
   - At this point the 5009C Control will ramp open the HP valve limiter to its maximum position at the HP valve limiter rate setting.
   - The Speed Set Point will ramp to its lowest speed setting at the Rate-to-min rate.
   - When turbine speed increases and matches the ramping Speed Set Point, the control's Speed PID will take control of turbine speed through positioning the turbine inlet HP valve.
   - Speed will ramp up to and remain at the minimum controlling speed until action is taken by the operator or the auto start sequence, if programmed, will continue its sequence.

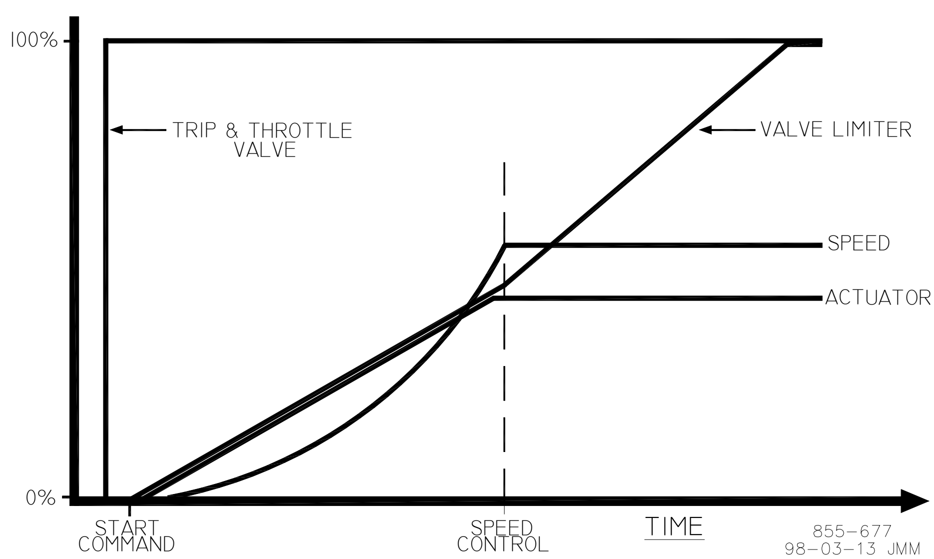

Figure 4-5. Automatic Start Mode Example

The automatic start routine may be aborted at any time by issuing a halt command, HP valve limiter raise or lower commands, speed raise or lower commands, or an Emergency Shutdown command. Once halted this routine can be continued by issuing a continue command. The HP valve limiter rate, and the rate-to-min settings are tunable via the PCI program's Service mode.

The automatic start sequence can also be:
- Automatically enabled at shutdown: It will remain enabled as long as the engine is tripped.
- Automatically disabled at shutdown: It will remain disabled as long as the engine is tripped.
- Not affected by the shutdown condition: It can be enabled/Disabled at any time.

The selection is done in program mode and service mode under start settings folder (see volume 3 for more details)

V1 Initial Position

This option is always available". If it used is not desired, V1 must be set to 100%.

- When start command is issued mode, the V1 (HP) valve can be set to ramp to a specific position (0–100%) upon a start command.
- The "V1 Init Position" programmed will be the percentage the inlet control (HP) valve limiter is initialized to when a Start command is given. From this position, the HP limiter can be lowered as desired.
- When the 5009 is in control of the speed and speed is above low idle, HP ramp will automatically ramp to 100%.
- A feature like this may be desirable to increase the resolution of the Trip & Throttle valve, allowing an operator using the T&T valve to have better control of turbine speed during start-up.

If the option in PCI software "SD if Rotor stuck" (not available in manual mode) is set true, the engine will trip if the HP valve reaches V1 position and Low idle speed is not reached.

Max speed deviation protection

- In PCI Software a maximum speed deviation can be configured.
- Once Low Idle speed is reached, this protection will compare the actual speed and the actual speed reference.
- If the difference is greater than the max speed deviation authorized, during more than the Alarm delay, an alarm will be generated.
- If SD option is selected, ff the difference is greater than the max speed deviation authorized, during more than the SD delay, a shutdown will be generated.

Zero Speed Signal Override

The 5009C Control issues a shutdown if no speed signal is detected (magnetic pickup voltage less than 1Vrms or speed is less than the 'Failed Speed Level'). To allow the control to start with speed not being sensed, this shutdown logic must be overridden. The control can be configured to provide an automatic speed override, or allow a manual speed override. The status of the MPU override logic may be viewed in the PCI program's Service mode or through Modbus communications. This override logic applies to both passive and active speed probes.

Automatic Speed Override—The control's automatic speed override logic is used, if the "Override Speed Sensor Fault" contact is not programmed. This logic, overrides the "loss of speed detection circuit" when the turbine is being started, or when any other shutdown command is given. During a turbine start routine, this logic overrides the "loss of speed detection circuit" until the sensed turbine speed exceeds the programmed failed speed level setting + 250 rpm. Once turbine speed exceeds this level, the loss of speed detection circuit is enabled and the control will execute a system shutdown if sensed speed drops below the failed speed level setting.

Alternatively, an Override Timer can be configured (in the PCI program's Service mode) as an extra level of protection. A sixty minute maximum time limit is applied to a manual override command (as defaulted in the Service Mode). This timer starts when the START command is initiated and re-arms the loss-of-speed detection logic when the time expires. The 5009C Control will execute a system shutdown if turbine speed is not above the 'Failed Speed Level' setting when the time expires.

Manual Speed Override—Manual Speed override functionality is selected by configuring an "Override Speed Sensor Fault" contact. If the 'Override Speed Sensor Fault' function is assigned to a contact input, the 'loss-of-speed detection circuit' is overridden as long as this contact is closed. Opening the assigned contact input, enables the 'loss of speed detection circuit", and the control will execute a system shutdown if sensed speed drops below the failed speed level setting.

Alternatively, an Override timer can be configured (in the PCI program's Service mode) as an extra level of protection in the event the contact input is left closed. A sixty minute maximum time limit is applied to a manual override command (as defaulted in the Service Mode). This timer starts when a START command is initiated and enables the 'loss of speed detection circuit' when the time expires. The 5009C Control will execute a system shutdown if turbine speed is not above the 'Failed Speed Level' setting when the time expires.

Underspeed Configuration

When this option is selected from PCI Software, once the engine has reached min governor speed, this protection is activated.

If the speed PV becomes lower than the underspeed level, during more than the alarm delay, an alarm is generated, and, if configured a shutdown can be generated.

Start Permissible Contact

An external contact may be used as a turbine start-up permissive. When configured for this functionality, the contact input must be closed in order for a 'Start' command to be executed. Should the contact be open when a 'START' command is given, an alarm will be issued and the 5009C display will indicate that the start permissive was not met. The contact must be closed, before the 5009C Control will accept a 'START' command. After a 'START' command has been accepted, the start permissive contact has no effect on operation. If used, this input is typically connected to a Trip & Throttle valve's closed limit switch to verify that it is in the closed position before a turbine start-up is performed.

Valve Limiters

There are two valve limiters (HP & LP) available when the unit is programmed as an extraction turbine control and only one (inlet, HP) when used in a non-extraction control application. The HP and LP valve limiters are used to limit the HP and LP valve outputs to aid in starting and shutting down the turbine and in enabling of extraction control. In a non-extraction control, only the HP valve limiter is used. The limiters can be adjusted through the PCI program, external contact closures, or Modbus commands.

In a non-extraction application, the output of HP valve limiter is the output of the LSS bus. The lowest signal will control the HP valve position. Thus, the HP valve limiter limits the maximum HP valve position (and HP2 valve position, if configured).

In an extraction application, the output of the HP valve limiter is low-signal selected with the output of the ratio/limiter. The lowest signal will control the HP valve position. Thus, the HP valve limiter limits the maximum HP valve position.

The LP Limiter is only used when the unit is configured for extraction, admission, or extraction/admission type turbines. The output of the LP valve limiter is high- signal selected with the output of the ratio/limiter when configured for extraction steam turbines, and low-signal selected when configured for admission or extraction/admission steam turbines. Thus, the LP valve limiter limits the minimum or maximum LP valve position depending on the configuration selected.

Refer to the Starting Procedures section of this Volume for information on using the valve limiters during start-up. Valve limiters also can be used to troubleshoot system dynamic problems. If it is believed that the 5009C Control is the source of system instability, the valve limiters can be positioned to manually take over control of the valve positions. Care should be taken when using the valve limiters in this fashion, so as not to allow the system to reach a dangerous operating point.

The level of each valve limiter can be adjusted through the PCI program, contact inputs, or Modbus communications. When raise or lower commands are received, the respective limiter ramps up or down, at its programmed valve limiter rate. In all cases a limiter's range is defaulted to 0-100%. Each valve limiter's rate and maximum valve position setting can be adjusted via the PCI program's Service Mode.

When automatic start is selected, any R/L command on the HP valve limiter will stop the automatic ramp up.

To re-initiate an automatic ramp-up, START command must be given (even if engine is already running)

Minimum HP and LP Lift Limiters

The minimum HP lift limiter is used with only Admission or Extraction applications to limit the HP valve's minimum position above 0% to insure HP section cooling steam. This limiter prevents the Ratio/Limiter from taking the HP valve fully closed. Unless specified by the turbine manufacture, this setting should be set to zero. The minimum HP lift limiter is only active if the following conditions are true:

- Unit is programmed for Adm or Extr/Adm applications
- Ext/Adm control is enabled
- HP valve demand is above the Minimum HP lift limiter

The minimum LP lift limiter is used to limit the LP valve's minimum position. With the exception of shutdown conditions, this limiter is active at all times and prevents the Ratio/Limiter from taking the LP valve fully closed. During shutdown conditions the LP valve is taken fully closed. Unless specified by the turbine manufacture, this setting should be set to zero.

Turbine Start Routine

Once a turbine is started and the control is controlling turbine speed, the Turbine Start Routine configured determines the control sequence used to bring the turbine from low idle speed up to the turbine's rated speed. The minimum governor controlling speed will depend on normal plant starting procedures and turbine manufacturer's recommendations.

The start routine allows the control to perform a hot start routine, cold start routine, or an in-between start routine depending on how long the turbine has been shutdown. With this routine, the turbine's starting ramp rates and idle speed hold times change depending on the length of time the unit was shut down. This routine may be used with any of the three start modes (manual, semiautomatic, automatic), and is initiated by a START command.

This routine uses three idle settings or hold points between zero and min governor speed, referred to as low idle, medium Idle and high idle. With this routine the Speed Set Point ramps to a low idle setpoint, holds at this setting for a duration (and until turbine speed is at or above this setting), ramps to a medium idle setpoint, holds at this setting for a duration ramps to a high idle setpoint, holds at this setting for a duration, then ramps the Speed Set Point to a rated speed setting. All ramp rates and hold times are programmable for both hot start and cold start conditions.

- If Medium/High idle are desired, they can be disable using PCI software.
- Disabling Low idle, will result to an IDLE/Rate start.

When a START command is given, the automatic start sequence logic determines what ramp rates and delay times (at the idle settings) to use during the start routine, based on the hours-since-trip timer. This timer starts when a shutdown has been executed and turbine speed has decreased below the low idle speed setting.

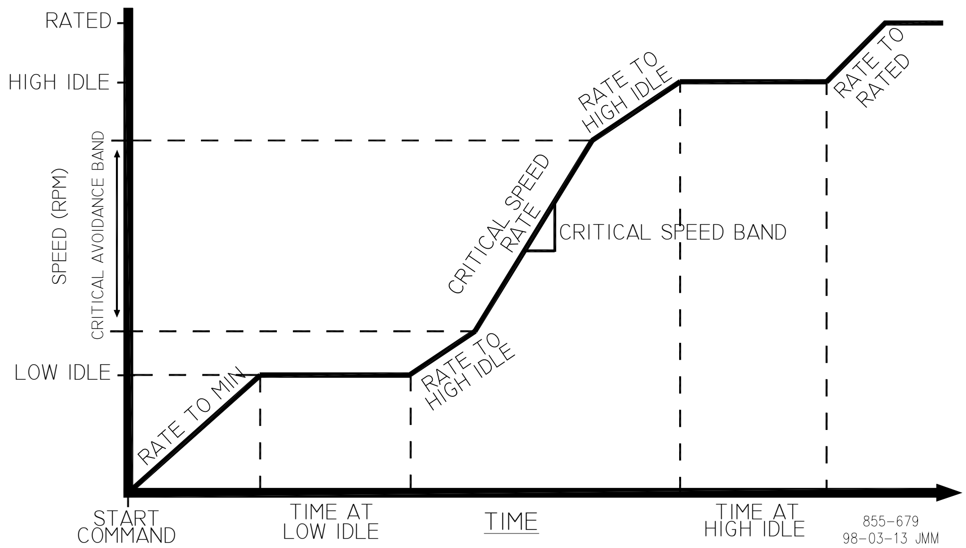

Figure 4-6. Automatic Start Sequence

With this sequence, a set of hot-start ramp rates and hold times is programmed for use when a START command is given and the turbine has been shutdown for less than the programmed 'HOT START' time setting. A set of cold-start ramp rates and hold times is also programmed for use when a START command is given and the turbine has been shutdown for longer than the programmed 'COLD START' time setting.

If a turbine START command is given when the length of time the system has been shutdown is between the 'HOT START' and 'COLD START' time settings, the control will interpolate between the hot and cold programmed start values to determine starting rates and hold times. For example, if the unit had the following automatic start sequence settings:

COLD START (> xx HRS)	=	22	HRS
HOT START (< xx HRS)	=	2	HRS
LOW IDLE SETPT	=	1000	RPM
LOW IDLE DELAY (COLD)	=	30	MINIMUM
LOW IDLE DELAY (HOT)	=	10	MINIMUM
MEDIUM IDLE SETPT	=	1500	RPM
RATE TO MEDIUM IDLE (COLD)	=	5	RPM/SEC
RATE TO MEDIUM IDLE (HOT)	=	15	RPM/SEC
HI IDLE SETPT	=	2000	RPM
RATE TO HI IDLE (COLD)	=	5	RPM/SEC
RATE TO HI IDLE (HOT)	=	15	RPM/SEC
HI IDLE DELAY TIME (COLD)	=	20	MINIMUM
HI IDLE DELAY TIME (HOT)	=	30	MINIMUM
RATE TO RATED (COLD)	=	10	RPM/SEC
RATE TO RATED (HOT)	=	20	RPM/SEC
RATED SETPT	=	3400	RPM
LOADING GRADIENT (COLD)	=	10 RPM/S	
LOADING GRADIENT (HOT)	=	20 RPM/S	

If the unit was tripped for 12 hours, the control would interpolate between the hot and cold parameters and use the following rates and delays (viewed in the Service Mode, see Volume 3):

LOW IDLE DELAY	=	20	MINIMUM
RATE TO MEDIUM IDLE	=	10	RPM/SEC
MEDIUM IDLE DELAY	=	10	MINIMUM
RATE TO HI IDLE	=	10	RPM/SEC
HI IDLE DELAY	=	10	MINIMUM
RATE TO RATED	=	15	RPM/SEC
HOT RESET LEVEL	=	3500	RPM
HOT RESET DELAY	=	10	MINUTES

Based on the example's configuration and trip time, the Speed Set Point would ramp to 1000 rpm at the rate to minimum setting and hold for 20 minutes (turbine speed must also be at or above 1000rpm), move to 1500 rpm at 10 rpm/sec and hold there for 10 minutes, move to 2000 rpm at 10 rpm/sec and hold there for 10 minutes and lastly, move to 3400 rpm at 15 rpm/sec. At 3400 rpm, the sequence would be completed.

- The Speed reference rate will be the loading gradient, in any case.
- However, speed must be above the HOT RESET LEVEL during more than HOT RESET DELAY, to fully use the HOT parameter
- This will protect the engine to be loaded too fast after the start-up, when its still not a its rated temperature.
- If the unit was tripped for 2 hours or less and restarted, the control would use the hot start parameters. If the unit was tripped for 22 hours or longer and restarted, the control would use the cold start parameters.

IMPORTANT **The control will automatically set the hours-since-trip timer to its maximum setting after a power up or upon exiting the Program mode. The hours-since-trip timer will reset only when a unit trip has occurred and turbine speed has decreased below the minimum governor speed setting.**

It is also possible to configure an Analog input called “remote HOT/COLD timer. In this case, the internal timer is by-passed, and the start-up logic will use this 4–20 mA signal to determine the start-up up curve to be used.

In case of failure of this signal, the internal timer is re-enabled.

The auto start sequence can be halted or continued at any time through the PCI, a contact input, or Modbus communications. The last command given from any of these three sources determines the mode of operation. The routine can be halted by a halt command, a raise or lower Speed Set Point command.

When the sequence is halted, the delay timers do not stop if they have already started counting down. The sequence will resume when a continue command is issued. If there were 15 minutes remaining to hold at an idle speed and the halt command was issued for 10 minutes before a issuing a continue command, the sequence would remain at the idle speed for the remainder of the hold time, which in this example is 5 minutes.

However, if the speed reference is above the Idle level (manually raised), the autostart sequence will ramp to the next level, regardless to the hold timer.

Alternatively, this routine can be configured via the Service mode to halt at each idle setting until given a continue command. By selecting the “Automatically Halt at Idle Set Points” option in the Service mode, the control will then halt at each idle setting and wait for a continue command to be given by the operator. Optionally a relay can be programmed to indicate when the auto start sequence is halted.

If the contact input halt/continue command is used, the sequence is halted when the contact is open, and continued when the contact is closed. The halt/continue contact can be either open or closed when a reset command is given. If the contact is closed, it must be opened to allow the sequence to be halted. If the contact is open, it must be closed and reopened to halt.

If Low idle priority is selected in PCI, when Auto Start Sequence is halted from Modbus/PCI or contact input, the engine will ramp down to low idle.

This setting is only valid during start-up.

Note: If R/L speed are pressed, then the Auto Start Sequence is halted, but speed set point remains at its positions. To ramp back to Low Idle, Auto Start Sequence must Enabled/Disabled.

Critical Speed Avoidance

In many turbines it is desirable to avoid certain speeds or speed ranges (or pass through them as quickly as possible) due to excessive turbine vibration or other factors. This control allows up to two critical speed ranges to be configured. The idle/rated or auto start sequence functions must be programmed to allow critical speed avoidance to be configured.

The Speed Set Point cannot be stopped in the critical band. If a raise or lower Speed Set Point command is issued while in a critical band, the Speed Set Point will ramp up or down (depending on raise or lower command) until out of the critical range. Since the lower Speed Set Point has priority over a raise setpoint, issuing a lower command while increasing through the band will reverse the setpoint direction and return it to the lower limit of the band. If a lower Speed Set Point command is given while in a critical band, turbine speed must reach the bottom of the band before another command can be executed.

In PCI software, the Lower command can be by-passed if desired, when engine is in critical speed.

If another controlling parameter, besides the Speed PID, drives the turbine’s speed into a critical band for longer than five seconds, the Speed Set Point can be configured to go back to the bottom of the critical range and a “Stuck in Critical” alarm will occur.

During a start-up routine if the Speed PID cannot accelerate the unit though a critical speed band within a calculated length of time, a stuck in critical alarm will occur and the Speed Set Point can be configured to go back to the bottom of the critical range .
. The calculated length of time is a value of five times the length of time it should normally take to accelerate through the band (based on the critical speed rate & range). If the “stuck in critical” alarm occurs on a regular basis, it may be indicating that the critical speed rate is set too fast for the turbine to respond to.

Critical speed bands are defined in the Program mode on the Start Settings page (see Volume 3). All critical speed band settings must be set between the idle speed and the minimum governor Speed Set Point settings. A configuration error will occur if an idle setpoint is programmed within a critical speed band. The rate in which the Speed Set Point moves through a critical speed band is set by the critical speed rate setting. The critical speed rate setting should be set no higher than the turbine's rated maximum acceleration rate.

It can be decide, not to use a fixed rate, but still using the HOT/Cold rates. In this case, the Configuration can be done in PCI.

Also, when a critical band is passed, the control can be configured to not allow any more, the speed reference to become less than the MAX critical speed (MAX critical becomes min speed option in PCI).

Speed Control Overview

Turbine speed is sensed through one to Three MPUs or proximity probes. The MPU gear ratio and the teeth seen by MPU settings are configured to allow the 5009C Control to calculate actual turbine speed. Any combination of MPUs and proximity probes can be used at the same time. However, they must be mounted on the same gear since the gear ratio and teeth seen by the MPU must be the same for all four inputs. The 5009C Control's Speed PID compares this speed signal to a setpoint to generate a speed/load demand signal to the Ratio/Limiter in an extraction and/or admission turbine, and to the low signal select bus for a non- extraction turbine.

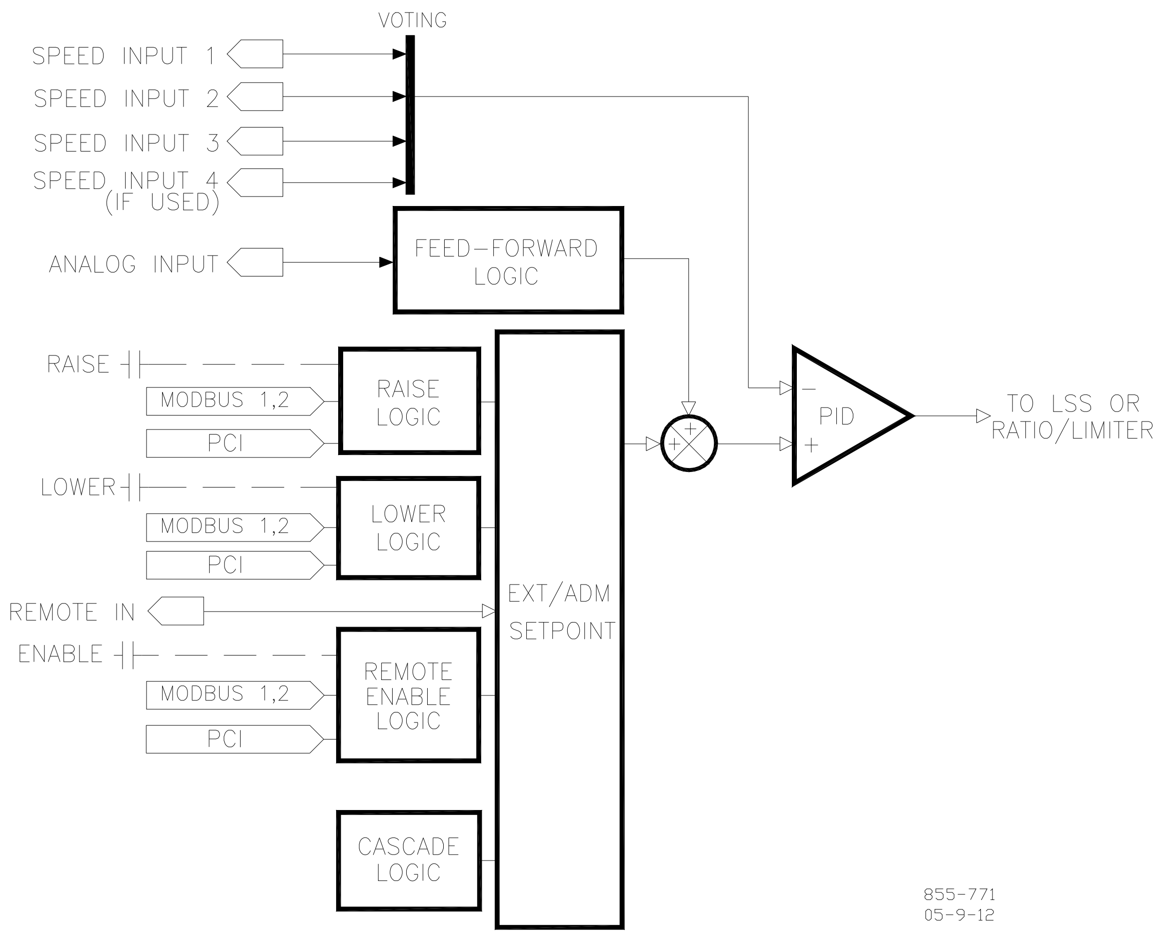

Figure 4-7. Speed Control Functional Diagram

Speed PID Operational Modes

Speed Control

The 5009C Control Speed PID operates in a Speed Control mode at all times. All pertinent Speed Control parameters are available through the 5009C Control PC Interface and Modbus.

Feed-Forward Control

Normal Loop
In some case, while the engine is for example controlling the suction pressure of a compressor with Cascade, a coupling effect can be noticed between the Anti-surge controller (external) and the Cascade controller.

If the anti-surge valve opens to protect the compressor, the suction pressure will increase. The cascade controller will raise the speed. By raising the speed, the flow through the compressor will increase, and the anti-surge controller will close the anti-surge valve, resulting in a decrease of pressure etc. Stabilizing the process might be very difficult.

The feed-forward should solve this problem when configured.

An analog Input must be configured as feed-forward. The signal should be the anti-surge valve demand.

In PCI software only, configuration parameters (range delay, etc) are available. When Min governor speed is reached, and when enabled via contact input or Modbus, this loop will be activated.

Based on (Feed-forward signal minus Feed-forward Lagged), the speed reference will be temporary corrected, regardless of the internal reference.

For protection, speed reference cannot be lower than Min Governor and higher than Max Governor in any cases.

The filter time (LAG) must be set quite long (typically 120 seconds).

When the anti-surge valve moves, the amount of speed correction should match with the expected speed variation needed to maintain the pressure.

Later, the speed correction will slowly ramp back to zero, based on the LAG time configured (typically 120 second). During this recovering, the cascade controller, (slow controller), should correct its outputs to perfectly maintain the pressure (see volume 3 for more details).

⚠WARNING **This loop can only be tuned by experienced people.**

Emergency Loop
An emergency feed-forward loop can also be activated. At the difference of the normal loop, its action time (LAG) should be equal or lower than the surge time loop, and will not correct the speed in normal operation.

In case of compressor surge, huge speed upset may occur, and recovery might be very difficult.

When this even occurs, in order to decrease the amplitude of the speed oscillations, Emergency Feed-forward must act on the speed reference.

If the anti-surge valve opens very fast, the engine speed must be raised immediately, even if probably, due to the surge, real speed is far higher.

With this, coupling effect will be limited.

The action of this loop must be limited the surge time loop.

Trigger level must be tuned perfectly, to avoid accidental activation of this loop (see volume 3 for more details).

⚠WARNING	**This loop can only be tuned by experienced people.**

Direct action
When configured for direct action, the feed-forward loop will correct the speed directly, proportionally to its 4–20 mA calibration.

The direct action cannot be used the decrease speed below Min governor, and above Max Governor.

HP Pressure Compensation

This new feature, when configured, intent to compensate the effect of any variation of the Inlet Steam pressure.

When, during start-up of even in normal operation the Inlet Steam pressure derivate from its normal value, speed PID settings might become too slow or too fast.

For extraction turbines, the steam MAP has been specified for a specific Inlet and extraction pressure. Estimated flow is calculated based of these standard pressures.

Any variation of these pressures might generate an error in the calculation.

During turbine start, if the Inlet pressure is really lower than specified, the steam MAP limitation might limit the HP opening.

The pressure compensation calculation will directly correct the HP valve demand. The action level should be the square root of P standard/P actual.

A curve is available in PCI software, to determine the action level (range 0.1–2)

This action level will become a multiply fact on the HP valve demand.
- If the Pressure is higher than standard pressure, the compensation should be lower than 1 (min value possible is 0.1)
- If the Pressure is lower than standard pressure, the compensation should be higher than 1 (max value possible is 2)
- To avoid interaction with the speed controller, the HP compensation signal should be Delayed (Lagged).

It is also possible to use the cascade input as a pressure compensation signal (configurable in PCI)

LP Pressure compensation

This new feature, when configured, intent to compensate the effect of any variation of the Extraction Steam pressure.

In normal operation, if the Extraction Steam pressure derivate from its normal value, speed PID settings and/or extraction PID settings might become too slow or too fast.

The steam MAP has been specified for a specific Inlet and extraction pressure. Estimated flow is calculated based of these standard pressures.

Any variation of these pressures might generate an error in the calculation.

While running in decoupled mode Inlet & speed, the LP valve is controlling the speed. Extraction pressure must be controlled by an external device.

A coupling effect could be noticed between the LP valve movement, and the Extraction Pressure control valve (external) resulting in oscillations. These Oscillations might become critical, in case of sudden loss of an extraction steam User.

The LP compensation will dump these oscillations.

The pressure compensation calculation will directly correct the LP valve demand. The action level should be the square root of P standard/P actual.

A curve is available in PCI software, to determine the action level (range 0.1–2)

This action level will become a multiply fact on the LP valve demand.

- If the Pressure is higher than standard pressure, the compensation should be lower than 1 (min value possible is 0.1)
- If the Pressure is lower than standard pressure, the compensation should be higher than 1 (max value possible is 2)
- To avoid interaction with the speed controller, the LP compensation signal should be lagged.

It is possible to use the Extraction input or another signal configured has “ LP compensation” as a pressure compensation signal (configurable in PCI)

Speed Set Point

The Speed PID’s setpoint may be adjusted from the 5009C Control PC Interface, contact inputs, Modbus, or through a 4–20 mA analog input. The Cascade PID also directly controls this setpoint when it is used.

The Speed Set Point range must be defined in the program mode. The minimum and maximum governor Speed Set Points define the normal operating speed range of the turbine. The Speed Set Point cannot be raised above the maximum governor Speed Set Point setting unless an overspeed test is performed. Once the Speed Set Point is taken above the minimum governor Speed Set Point, it cannot be varied below this setting again unless a controlled stop is selected.

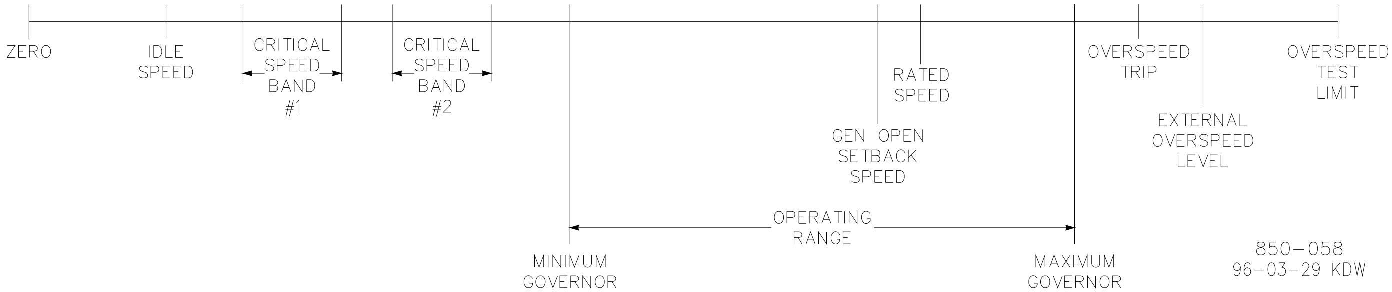

Figure 4-8. Speed Relationships

Once turbine speed is equal to or greater than the minimum governor Speed Set Point, the Speed Set Point may be adjusted through discrete raise and lower commands. When a raise or lower speed command is issued, the setpoint moves at the programmed Speed Set Point slow rate. If a speed raise/lower command is selected for longer than three seconds, the Speed Set Point will then move at a faster rate which is the loading gradient rate. The Speed Set Point slow rate delay can all be adjusted in the Service Mode (see volume 3).

- A speed setpoint can be entered directly from Modbus/PCI. A “Go To” target command must be send from Modbus to get this setpoint an any new target accepted.
- When the engine is starting up, the minimum possible entered speed is Low Idle.
- Autostart sequence will be de-activated when a speed setpoint is entered.
- An entered speed cannot be set inside any critical band.
- When Startup is completed, the minimum entered speed is “Min governor speed”.

Dual Speed Dynamics

The Speed PID has two sets of dynamics; Off-Line and On-Line. When a system has variable response times, do to changing system conditions, these dynamic variables allow the Speed PID to be tuned for optimal response.

The 5009C Control uses the programmed minimum governor Speed Set Point’ setting to determine which set of dynamic values are used by the Speed PID. The Speed PID’s off-line dynamics are selected when turbine speed is below the minimum governor Speed Set Point. The Speed PID’s On-Line dynamics are selected when turbine speed is above the minimum governor Speed Set Point. (see Table 5-1).

Remote Speed Set Point

The Speed Set Point can be positioned remotely through an analog signal by programming the Remote Speed Set Point (RSS) analog input. This allows the Speed Set Point to be set remotely by a process control or distributed plant control system.

The RSS range is determined by the programmed analog input’s 4 mA and 20 mA settings. The RSS range is tunable in the Service Mode, but cannot control outside of the minimum and maximum governor Speed Set Points.

Since RSS is a secondary speed setting function, the Speed PID must be in-control of the 5009C Control's LSS bus to allow the RSS to position the actuator. The cascade controls are automatically disabled if RSS is enabled.

The RSS may be enabled or disabled from the 5009C PC Interface, external contact or Modbus. The last command given from any of these three sources dictates the enabled/disabled state.

A contact input can be programmed to perform as an external RSS enable. When this programmed contact is open the RSS is disabled, and when it is closed the RSS is enabled. The contact may be either open or closed when a trip condition is cleared. If the contact is open it must be closed to enable the RSS. If the contact is closed it must be opened and re-closed to enable the RSS.

If the milliamp signal to the RSS is out of range (below 2 mA or above 22 mA) an alarm will occur and the RSS will be inhibited until the input signal is corrected and the alarm is cleared.

If, when enabled, the RSS does not match the Speed Set Point value, the Speed Set Point will ramp to the RSS at the "RSS Not-Matched-Rate. Once the RSS function is "in control" of the Speed Set Point, the Speed Set Point will move at the same rate as analog input value, up to the "Rmt Sept Max Rate setting" rate. (If the RSS maximum rate was set at 10 rpm/sec and the RSS instantly moved from 3600 rpm to 3700 rpm, the Speed Set Point will move to 3700 rpm at 10 rpm/sec.)

Refer to Volume #3 of this manual for information on related Service Mode tunables.

Valve Redundancy Controller

The 5009C can be applied in single-coil, dual-coil, or dual/redundant actuator systems in extraction or non-extraction steam turbines. When the actuator output configuration is programmed as a "Dual Redundant" system, both actuator driver circuits provide full current to the driven device, whereas the dual-coil option only provides one-half of the total required current from each driver. For example if the actuator demand is 50% and a 4–20 mA driver is programmed, the dual-redundant circuits will each drive 50% or 12 mA verses 25% or 8 mA for the dual-coil.

Selection between converter output signals can be accomplished using either shuttle valves or solenoid transfer valves. Converter status (I/H or I/P) and pressure feedback signals can be optionally programmed into the 5009C. If required, relay outputs can be programmed to transfer between converter outputs. Manual transfer between converters can be initiated through discrete input, Modbus, or pc interface commands. Automatic transfer between converters is provided by the 5009C based on driver failure(s), converter status, converter output pressures, and servo input pressure feedback signals.

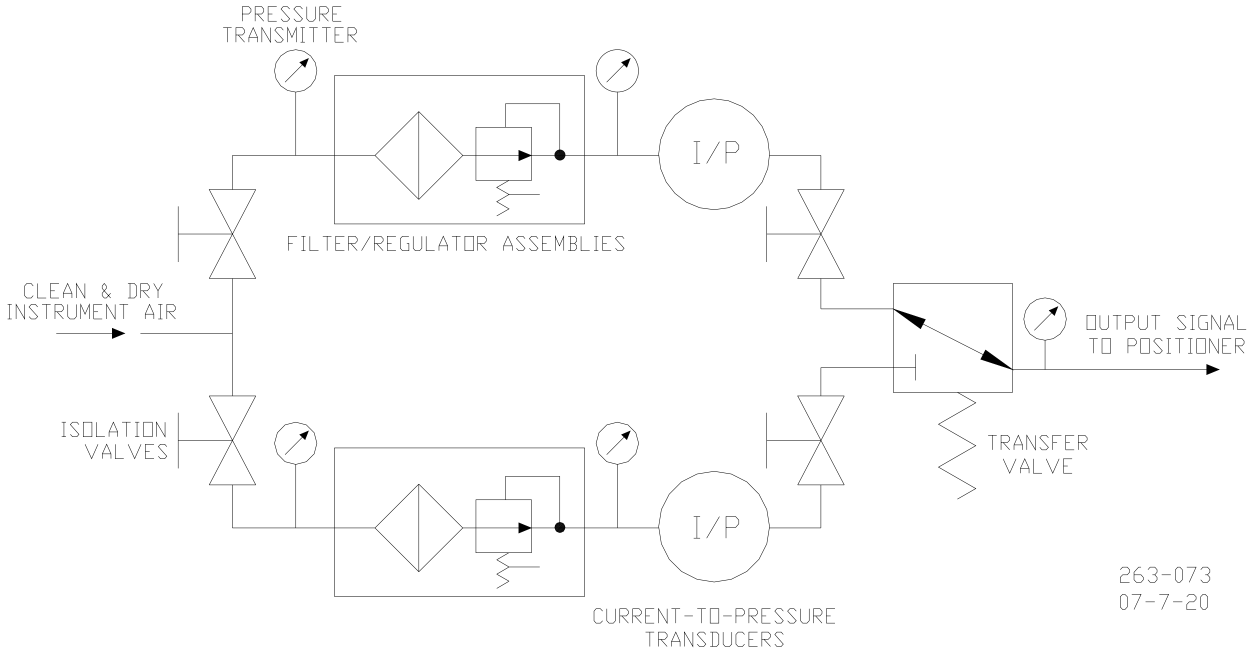

Figure 4-9. Typical Redundant I/H System with a Transfer Valve

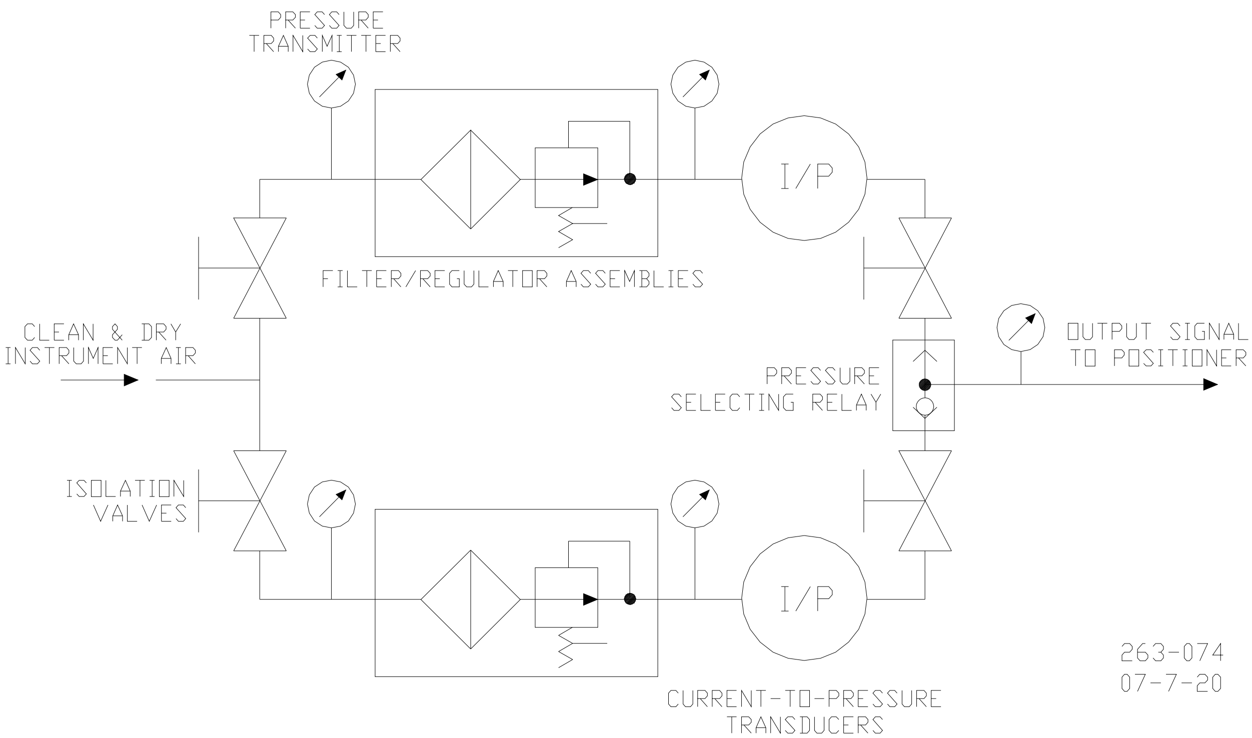

Figure 4-10. Typical Redundant I/P System with a Pressure Selecting Relay Valve

Utilizing a dual redundant actuator output configuration provides redundancy all the way to the actuator level. The typical redundant I/H (or I/P) system will convert the 5009C actuator milliamp output into a corresponding hydraulic (or pneumatic) pressure positioning the servo-cylinder. Both converters are supplying the appropriate pressure to position the steam valves to the demand requested by the control. One of the converters will be in control of the valve demand and the other will be in a standby mode. Selection between converter output signals can be accomplished using either shuttle valves or solenoid transfer valves. The shuttle valve will select the higher pressure output between the two converters whereas the solenoid transfer valve selects one converter output and transfers between converters based on a relay command from the 5009C control. Either valve type can be used, refer to the transfer valve section for additional information on advantages/disadvantages of each.

Converter status (I/H or I/P) and pressure feedback signals can be optionally programmed into the 5009C. If required, relay outputs can be programmed to transfer between converter outputs. Manual transfer between converters can be initiated through discrete input, Modbus, or PC interface commands. Automatic transfer between converters is provided by the 5009 based on driver failure(s), converter status, converter output pressures, and servo input pressure feedback signals. In addition, an automatic transfer based on elapsed time can be programmed to test system transfers.

Automatic transfer is based on the I/O programmed (refer to I/O options available). If a converter malfunction discrete input is programmed, then it is used for malfunction alarming and automatic transfer. Similarly for the converter output pressures and servo valve input pressure, if programmed then it's used for position error alarming and converter transfer.

Properly installed isolation valves allow on-line converter replacement.

Transfer Valve Selection

Selection between converter output signals can be accomplished using either shuttle valves or solenoid transfer valves. The shuttle valve selects the higher pressure output between the two converters whereas the solenoid transfer valve selects one converter output and transfers between converters based on a relay command from the 5009C control.

The advantage of the pressure selecting valve is that transfer occurs automatically on pressure loss. In addition, there is no I/O required for monitoring and control transfer. Care must be taken to ensure the converters will not fail to a high pressure output condition. The Woodward CPC (I/H) for example, will not fail high, on an internal failure the hydraulic pressure is ported to drain. The converters must be set up with an offset such that one is the primary controller and the other is the backup, without an offset the controllers would tend to fight each other.

The solenoid transfer valve provides complete isolation between converters but requires a relay command from the 5009C to select between a primary and standby converter. The control automatically transfers to the standby controller upon a converter malfunction, on a 5009C fault, or on a position error. The transfer between converters can also be done manually. The Woodward CPC I/H converter provides a discrete output and an analog output which can be optionally programmed into the 5009C to monitor the health of the converter and transfer on a malfunction or position error of the output pressure. Position error detection can be utilized if an analog input is programmed for either converter output pressure feedback or for servo input pressure feedback. Position error transfers are only used if a pressure feedback analog input is programmed.

A limit switch on the transfer valve can also be programmed to provide feedback to the 5009C to minimize any potential failed/uncompleted transfers. If a completed transfer is not detected as indicated by the transfer valve position, the 5009C will transfer back if the original converter is healthy. The maximum time to detect a completed transfer is set in the Service Mode and is defaulted to 5 seconds. When the transfer valve position does not match the 5009C selected position, a transfer is initiated and an alarm is issued.

The switching time of the transfer valve will determine the amount of “bump” the system will see on a failure, a transfer time of less than 200 ms is recommended. Similarly with the shuttle valve, a larger the offset will result in a larger disturbance on a failure of the primary converter loop. At the same time an offset that is too small will result in poorer performance due to fighting of the two converter outputs.

Automatic Transfer (Backup Converter Test/Health Monitoring)

An option is available to transfer to the backup valve automatically based on elapsed time. If used, the automatic time-based transfer has 2 options. The first option simply transfer to the standby unit after the elapsed interval timer expires. The second option, referred to as the Transfer Back mode, assumes a primary converter (I/H-1) is in normal operation and merely transfers to the standby converter (I/H-2) for a short period of time to make sure it is operational.

Using Transfer Back Mode option, the 5009C transfers to the standby unit and waits a pre-programmed time to determine if the standby unit is operating correctly and then transfers back to the primary converter. If a problem is detected in the standby unit or if a completed transfer is not detected, control is immediately transferred back to the primary unit and the problem is alarmed.

The completed transfer is based on the transfer valve’s position feedback contact closure. If a Transfer Valve Position indication contact input is not programmed and this feature is used, the transfer back will always occur on the ‘max time to detect transfer’ delay time-out. An alarm is issued whenever a max transfer time delay occurs.

With both transfer options, the auto transfer interval timer sets the frequency of the transfer test. This elapsed timer is based on the latter of the last transfer or the last fault cleared. See Program and Service Modes for details on the I/H Auto Transfer option settings.

Transfer Back Feature Summary

The Auto Transfer to standby unit is initiated when:

- the Auto Transfer Interval timer expires (MUST be in converter #1 control for timer to count) .
- The Transfer Back occurs when either:
- the Max Time to Detect Standby timer expires (Service Mode adjustment defaulted to 5 seconds) OR
- the Standby Control Duration timer expires (this is the time delay required, after standby control is confirmed, to determine the health of the standby unit).

Transfer Commands/Permissives

Transfer between controllers, when using a transfer valve, requires a selection relay output from the 5009 to determine the primary and standby units. Transfer can occur automatically or manually. A manual transfer can be initiated from a discrete input, from a PC Interface command, or from either Modbus communications link.

A discrete input options available, selects the Actuator B when closed, if and A when opened. If the contact input is closed, and actuator A has been selected from HMI, then the contact must be opened/closed to accept another transfer

The Transfer to I/H-1 permissives are:
- I/H #1 not failed (unless both I/H are failed)
- I/H #1 not by-passed

The Transfer to I/H-2 permissives are:
- I/H #2 not failed (unless both I/H are failed)
- I/H #2 not by-passed

A Transfer to I/H-2 is initiated if I/H-2 is healthy and any of the following occurs (similarly for transfer to #1):
- I/H #A Malfunction is detected (contact input opens)
- I/H #A 5009 Fault detected (kernel, module, driver, load)

Fallback Modes

The following is a summary of the fallback modes based on the control mode.

If the I/H-1 pressure input is programmed and fails (<2 mA or >22 mA), only an alarm is issued .Transfer can be operated manually.
If the pressure of the I/H in control is higher then a tolerated deviation, the transfer will be done automatically, and if a bypass solenoids is used, it will be isolated.

If the I/H-1 pressure input is programmed and fails (<2 mA or >22 mA), only an alarm is issued .Transfer can be operated manually.

If an I/H-1 Malfunction contact input is programmed and opens, an alarm is issued and control is transferred to I/H-2. Transfer to I/H-1 is not allowed until the problem is fixed and reset, however, if both I/H drivers have faults then transfer is allowed (similarly for I/H-2).

If the 5009C detects a fault in I/H-1 the driver, an alarm is issued and control is transferred to I/H-2. Transfer to I/H-1 is not allowed until the problem is fixed and reset, however, if both I/H drivers have faults then transfer is allowed (similarly for I/H-2).
If both I/H are determined to be failed, an alarm is issued - the 5009 can be programmed to trip, see Programming options. If both I/H have faults and one I/H becomes healthy, the output will automatically transfer to the healthy I/H.

Inputs/Outputs (I/O) Options Available

The following itemizes all available I/O for Dual-Redundant output control. The only I/O points that are required are the "Output Selector" relays and only if a solenoid transfer valve is used to select which converter output is to be used by the servo. All additional I/O listed is optional, however, if an I/O point is programmed it will be used in the logic for transferring control.

Analog Input Options

RED-1 (2) I/H-A Output Pressure	Converter controlled output pressure
RED-1 (2) I/H-B Output Pressure	Converter controlled output pressure

Discrete Input Options

RED-1(2) I/H-A Malfunction	Indicates a problem with the converter (open = fault)
RED-1(2) I/H-B Malfunction	Indicates a problem with the converter (open = fault)
RED-1(2) I/H-B Transfer Command	Front Edge closure toggles control to actuator B Front Edge opening toggles to actuator A
RED-1(2)- B selected	Contact closure indicates position of transfer valve

Discrete Output Options

RED1 (2) I/H-B Output Selector	Selects converter B (required if using transfer valve)
RED1 position error	Indicates a discrepancy between the actuator requested and the transfer valve position

Actuator Selection

Two valve's redundancy controller can be configured in the 5009C.(REDundancy1 and REDundancy2)

For each one, the redundant valves must be defined.

The options are:

1. ACT1:When configured to be Dual redundant, one actuator will be connected to A&B output, and the other to C output

2. ACT2: When configured to be Dual redundant, one actuator will be connected to A&B output, and the other to C output

3. ACT1-2: When both actuator output are controlling the same valve, via two different actuators

4. ACT-FDBK 1-2: When actuator cards Channel 1 and Channel 2 outputs are controlling the same valve, via two different actuators

Extraction, Admission, or Extr/Adm Turbine Control

The control (extraction, admission, or extraction/admission) can receive up to three input (4–20 mA) signals from pressure or flow transducers. The Ext/Adm PID controller then compares the voted good input signal to its setpoint to generate an output signal to the Ratio/Limiter. The Ratio/Limiter receives input signals from the Speed/Aux LSS bus and the Ext/Adm PID. The ratio logic ratios these signals based on the turbine performance parameters to produce two output signals, one to control the HP valve and one to control the LP valve. The limiter logic keeps the outputs to the valves within the boundaries of the turbine steam map.

Extraction-Only Turbine Control

When configured to operate single controlled extraction steam turbines, the control manages the interaction between the turbine's governor valve (HP) and extraction valve (LP) valve to control two turbine related parameters at the same time. With this type of configuration, the control's LP valve limiter is high signal selected with LP Valve demand output, allowing an operator to manually limit extraction flow if desired.

During turbine start-up the LP valve limiter (and LP Valve) is held at 100% to allow the inlet steam to pass non-restricted through the turbine's front and back-sections. After a shutdown, and before a turbine start, the LP valve limiter is ramped to its 100% position upon issuing a reset command to the control. This allows the turbine to warm-up and expand evenly, before starting the turbine. Upon a shutdown condition, the LP valve limiter is taken to 0%.

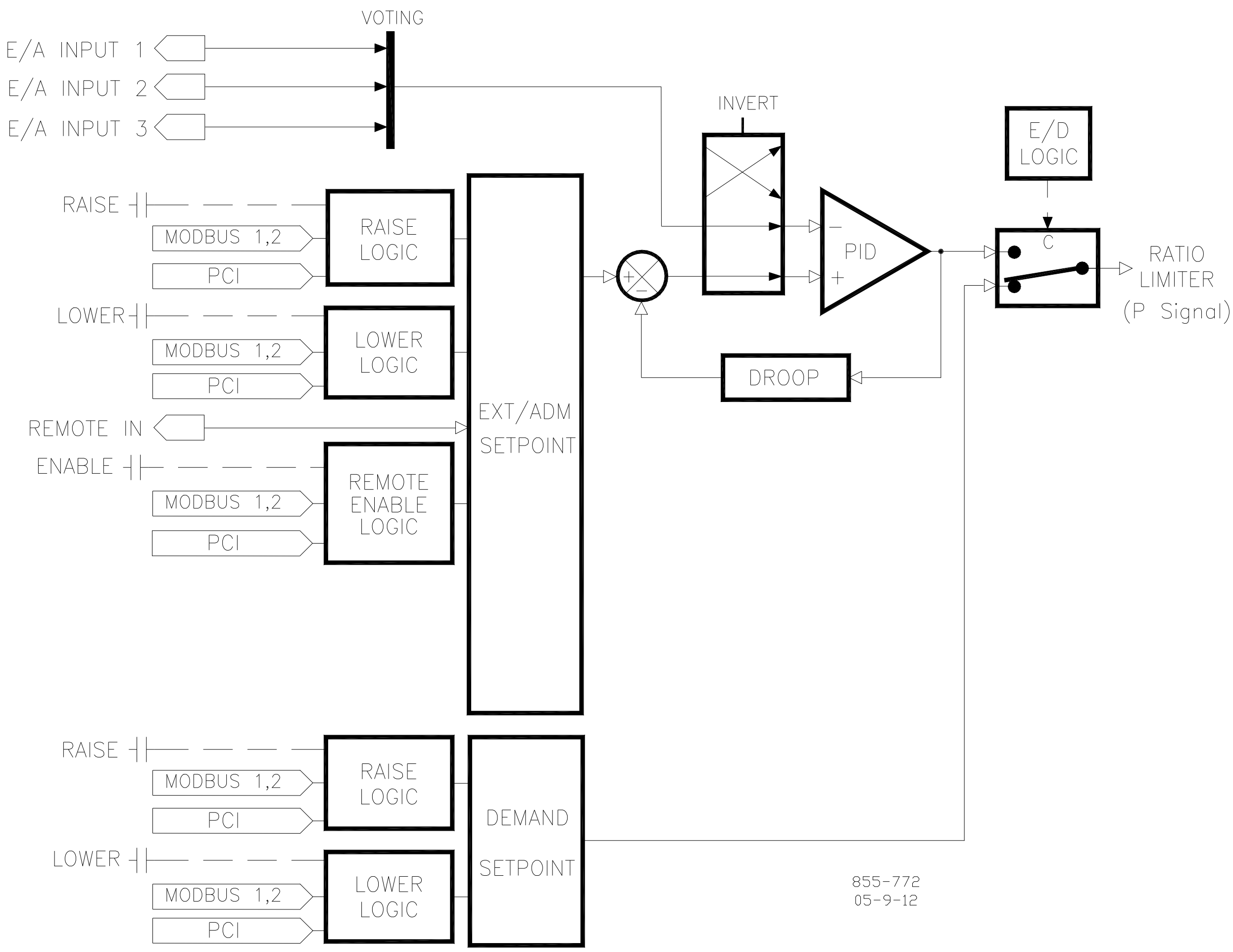

Figure 4-11. Ext/Adm Control Diagram

The Extraction PID can be enabled automatically or manually. Extraction control is enabled by lowering the LP valve limiter to its 0% position. After a start-up, the HP and LP valve limiters should normally both be fully open. If the HP valve limiter is not fully opened, it will act as a speed/load limiter and will interfere with automatic governor operation. Typically, a turbine is controlled at a rated speed setting or loaded to a minimum load point before Extraction Control is enabled. All related Extraction permissives must be met before the 5009C Control will allow the Extraction PID to take control of a process. The enable permissives are:

- Ext/Adm input not failed
- Turbine speed above programmed permissive speed

Manual Enable/Disable—To manually enable Extraction Control slowly lower the LP valve limiter until the Extraction PID takes control of its process, then continue running the LP valve limiter to its minimum (closed) position. If the LP valve limiter is not fully closed, it will act as an Extraction limiter and will interfere with automatic governor operation. All related Extraction permissives must be met and Extraction Control enabled before the 5009C Control will allow the LP valve limiter to be lowered.

To disable Extraction Control slowly raise the LP valve limiter until the Extraction PID loses control of its respective process. Continue running the LP valve limiter to its maximum (open) position.

Automatic Enable/Disable—If the “Use Automatic Enable” function is selected, the LP valve can be lowered automatically by issuing an “Ext/Adm Control Enable” command. After receiving an enable command, the 5009C Control will automatically lower the LP valve limiter at the LP valve limiter rate. Once the Extraction PID takes control of its process, the LP valve limiter will continue lowering to its minimum (closed) position.

The LP valve limiter may be stopped at any time during the automatic enabling routine by momentarily issuing a LP limiter raise or lower command (or by entering a valid setpoint). Upon stopping the automatic enabling routine from lowering the LP valve limiter, the Extraction PIDs output will still continue to be enabled. This allows an operator to continue the enabling routine manually as desired. By re-issuing an enable command, the enable routine will continue lowering the LP valve limiter. If a contact is programmed for this function it will have to be opened and re-closed to re-issue an enable command.

The 5009C Control only accepts an Extraction enable command if all related permissives are met (see above list). An enable/disable command may be issued through the PCI, a contact input, or Modbus. The last command given from any of these three sources dictates the state of the Extraction Control.

When a contact input is programmed to function as an “Ext/Adm Control Enable” command, a closed state represents an enable command and an open state represents a disable command. This contact can either be open or closed when a 5009C Control trip condition is cleared. If the contact is open it must be closed to issue an enable command. If the contact is closed, it must be opened and re-closed to issue an enable command.

Upon receiving a disable command the 5009C Control will instantly step the LP valve limiter to the LP valve’s current position and then raise the LP limiter to its maximum (open) position at the LP valve limiter rate. At some point, depending on system conditions, the Extraction PID will lose control of its process.

The LP valve limiter may be stopped at any time during the automatic disabling routine by momentarily issuing an LP limiter raise or lower command. Once stopped, an operator can continue to manually adjust the valve limiter as desired or issue a disable command. By issuing a disable command the disable routine will continue raising the LP valve limiter to its maximum (open) position. With automatic Extraction enabling programmed, an operator can also enable and disable extraction control manually if desired.

Depending on the configuration, when extraction has been enabled, the extraction PID can be put in Manual or in Automatic mode at any time.

When Extraction PID is in manual mode, the operation can increase/decrease the extraction flow manually using R/L extraction demand external contact, R/L command form PCI or R/L Modbus commands.

The transfer manual/automatic and automatic/manual is 100% bumpless.

In case of extraction sensor failure, the control can be configured to put the PID in manual mode automatically.

In some cases, it is not desired to control the extraction (Inlet/Exhaust decoupling mode only).

The control can be configured to never enable the automatic mode of this PID.

Admission-Only or Extraction/ Admission Turbine Control

The procedure for enabling the Ext/Adm PID with admission or extraction/ admission applications is the same. In all cases it is assumed that an external trip valve or a trip-and-throttle valve is used to completely stop any admission steam from entering the turbine upon a system shutdown condition.

Admission or Extraction/Admission Control can be enabled and performed after one of the three starts has been performed. After a start-up, the HP and LP valve limiters should normally both be fully open. If either limiter is not fully opened, it will interfere with automatic governor operation.

Demand Set Point—To perform a bumpless transfer into Ext/Adm Control the pressures on each side of the admission trip valve or T&T valve should be matched, before control is enabled. The Ext/Adm Demand setpoint is used to manually change a unit's flow demand, thus the turbine's internal pressure at the admission header's inlet. An operator must manually vary the Ext/Adm Demand setpoint to manually match the turbine's internal pressure to that of the pressure on the plant side of the Ext/Adm T&T valve.

The Demand setpoint is a manual admission or ext/adm flow demand, and allows an operator to manually change the turbine's adm or ext/adm flow. When the Ext/ Adm PID is not enabled, this flow setpoint is the "P" term input into the control's Ratio/Limiter. This flow demand setpoint is defaulted to 100% for Admission turbines, and to a calculated zero ext/adm flow point for Extr/Adm turbines. All default settings can be changed via the PCI program's Service mode.

The following procedure allows a bumpless transfer into Admission or Extraction/ Admission Control to be performed. The Admission or Extraction/Admission enabling procedure is:

1. Verify that all Ext/Adm enable permissives are met.

2. Match the Ext/Adm setpoint to that of the pressure on the plant side of the Ext/Adm T&T valve. (Skip this step if setpoint tracking is used).

3. Vary the Ext/Adm Demand setpoint to match the turbine's internal Ext/Adm pressure to the pressure on the plant side of the Ext/Adm T&T valve.

4. Open the Ext/Adm T&T valve.

5. Issue an Adm or Ext/Adm Control Enable command.

All functions required to bumplessly enable and disable Adm or Ext/Adm Control can be performed through the PCI program, contact inputs, or Modbus. The control only accepts an enable command if all related permissives are met. An enable/disable command may be issued through the PCI program, a contact input, or Modbus. The last command given from any of these three sources dictates the state of the Adm or Ext/Adm Control.

When a contact input is programmed to function as an "Ext/Adm Control Enable" command, a closed state represents an enable command and an open state represents a disable command. This contact can either be open or closed when a 5009C Control trip condition is cleared. If the contact is open it must be closed to issue an enable command. If the contact is closed, it must be opened and re-closed to issue an enable command. The following procedure allows Adm or Ext/Adm Control to be disabled in a controlled manner:

1. Issue a Disable Adm or Ext/Adm Control command. At this point the Ext/ Adm Demand setpoint will step to the Extraction PID's last position, take control of the process from the PID, then ramp back to the default flow demand setting.

2. If necessary manually adjust the ext/adm demand setpoint to reach zero extraction/admission flow.

3. Close the extraction/admission Trip-and-Throttle valve.

EXT/ADM Input

Depending on the control action required, the Ext/Adm PID's input signal can be inverted. When used with a typical Ext/Adm and/or admission turbine application this input should not require inverting. Upon loss of the Ext/Adm input signal during operation, the control can be programmed to:

- Disable extraction
- Ramp the P demand to 0%
- Ramp the P demand to 100%
- Switch to manual flow demand

The control senses an input failure and issues an alarm if the 4–20 mA Ext/Adm input signal goes < 2 mA or > 22 mA.

Refer to Chapter 2 of this Volume for details on input fault tolerant logic.

PID Dynamics

The Ext/Adm PID uses its own set of dynamic settings. These values are programmable and may be tuned at any time from PC Interface or Modbus. Refer to Chapter 5 of this manual for information on PID dynamic adjustments.

EXT/ADM Droop

When sharing control of a parameter with another external controller, the Ext/ Adm PID can also receive a programmable droop feedback signal for control loop stability. This feedback signal is a percentage of the Ext/Adm PID's output, or the back-calculated Ratio/Limiter "P" term, depending on configuration. By including this second parameter into the control loop, the Ext/Adm PID does not fight with the other external controller over the shared parameter. If Ext/Adm droop is used, the Ext/Adm input signal will not match the Ext/Adm setpoint when in control. The difference will depend on the amount (%) of droop programmed and the output of the Ext/Adm PID. The droop value fed back to the Ext/Adm PID is equal to the following defaulted settings:

- PID OUTPUT % x 'EXT/ADM DROOP %' x 'RATED EXT/ADM SETPOINT' x 0.0001
- Example: 25% x 5% x 600 psi (4137 kPa) x 0.0001 = 7.5 psi (51.71 kPa)

The rated Ext/Adm setpoint is defaulted as the maximum Ext/Adm setpoint and is adjustable in the Service Mode. The Ext/Adm droop % and the maximum Ext/ Adm setpoint values are set in the Program Mode and the PID output is determined by the Ext/Adm demand. Refer to Volume #3 of this manual for information on related Service Mode tunables.

Set Point

The Ext/Adm setpoint may be adjusted from the 5009C PC Interface, external contacts, Modbus, or through a 4–20 mA analog input signal. A specific setting can also be directly entered from the 5009C PC Interface or through Modbus. The Ext/ Adm setpoint range must be defined in the program mode. The minimum Ext/ Adm setpoint and the maximum Ext/Adm setpoint define the range of the Ext/ Adm setpoint and control.

When a raise or lower Ext/Adm setpoint command is issued, the setpoint moves at the programmed Ext/Adm setpoint rate. If an Ext/Adm raise or lower command is selected for longer than three seconds, the Ext/Adm setpoint will move at the fast rate which is three times the Ext/Adm setpoint rate. The Ext/Adm setpoint rate, fast rate delay, and fast rate can all be adjusted in the Service Mode.

A specific setpoint may also be directly entered through the 5009C PC Interface or Modbus communications. When this is performed, the setpoint will ramp at the Ext/Adm setpoint rate. The setpoint can also me adjusted manually through the PC Interface or Modbus.

Set Point Tracking/no tracking
The extraction set point , when extraction is disable or in manual mode can be set for tracking or not tracking.

If tracking is selected, the setpoint will track the process value as long as the control is disabled or in manual mode.

If tracking is not enabled, the setpoint can be adjusted even when the PID controller is not in control.

If tracking is not selected, the 5009C will take care that the E/D automatic mode is 100% bumpless. If the actual setpoint is to far from the process value when automatic control is enabled, an internal reference (invisible for operator) will ramp forward the setpoint requested at the “not match rate” configured in PCI.

The Selection Tracking/Not tracking can be done in PCI software or via Modbus only, even when engine is running.

Remote EXT/ADM Set Point

One of the 5009C Control’s analog inputs can be programmed to set the Ext/Adm PID setpoint. This allows the Ext/Adm setpoint to be positioned remotely by a process control or distributed plant control system.

The remote Ext/Adm setpoint range is determined by the programmed analog input’s 4 mA and 20 mA settings. The remote Ext/Adm setpoint range is tunable in the Service Mode.

When enabled, the remote setpoint may not match the Ext/Adm setpoint. In this case, the Ext/Adm setpoint will ramp to the remote setpoint at the “Remote E/A Not-Matched Rate” (adjustable via the Service mode, and defaulted to the Ext/Adm Slow setpoint setting). Once matched, the Ext/Adm setpoint moves at the same rate the remote setpoint input moves up to the “Rmt Sept Max Rate” setting. If the remote Ext/Adm setpoint maximum rate were set at 10 and the remote setpoint analog input instantly moved from 0 units to 1000 units, the Ext/Adm setpoint will move to 1000 units at 10 units/sec.

If the milliamp signal to the remote Ext/Adm setpoint input is out of range (< 2 mA or > 22 mA) an alarm will occur and the remote Ext/Adm setpoint will be inhibited until the input signal is corrected and the alarm is cleared.

Remote Ext/Adm Set Point Enable Logic—The remote extraction will be enabled via Enable external contact , PCI software or Modbus.
The remote extraction mode is accepted only if extraction has been enabled and remote SP is not faulty.

Ratio/Limiter

The control’s Ratio/Limiter logic is only used with extraction, admission, and extraction/admission type turbines. The Ratio/Limiter receives input signals from the speed and ext/adm PIDs. The ratio logic uses these signals, and based on the turbine performance parameters, produces two output signals, one to control the HP actuator and one to control the LP actuator. The limiter logic keeps the actuator outputs within the boundaries of the turbine steam map.

Because a single ext/adm turbine has only two control valves, only two parameters at a time can be controlled. Due to a turbine’s design, the positioning of either valve (HP or LP) has an effect on both parameters being controlled. This interaction between valves (controlled parameters) can cause undesirable fluctuations in a process not requiring a change.

The ratio logic controls the interaction of both HP and LP valves to maintain desired turbine speed/load (or Auxiliary or Cascade PID processes) and ext/adm pressure/flow levels. By controlling valve interaction, the ratio logic minimizes the effects of one controlled process on the other controlled process. When system conditions cause a turbine to reach an operating limit, the limiter logic limits the HP or LP valves to maintain speed/load or ext/adm levels depending on the priority selected.

When correcting for a system demand change in one process it may be desirable to have the control move both turbine valves at the same time in order to reduce or stop the interaction of one process on the other. For this reason the Ratio/Limiter logic can be configured in the following operational modes depending on the parameters being controlled and the turbine's function within the system.

Ratio/Limiter Configurations:
- No Ratio/Limiter
- Coupled HP & LP
- Decoupled INLET (HP)
- Decoupled EXHAUST (LP)
- Decoupled HP & LP

No Ratio/Limiter

When configured for single actuator or split-range actuator type of turbines, ext/adm and Ratio/Limiter logic is not used. The Speed/Load Controller, Auxiliary Controller, and HP Valve Limiter are all low-signal-selected or command selected, in the case of Aux Enable/Disable, to position the actuator output(s).

Coupled HP & LP

This mode is typically used when the two controlled parameters during normal operation are turbine speed/load and ext/adm pressure (or flow).

In this operating mode the turbine's HP and LP valve actions are coupled (ratioed) together to control both processes without the two processes interacting with each other. Turbine load and ext/adm pressure are controlled by moving both the HP and LP valves simultaneously. For a change in either process both valves are repositioned to create a net effect of no change (pressure, flow or power) on the other process.

In most cases, the operator of an ext/adm turbine needs to maintain both turbine speed/load and ext/adm pressure/flow at constant levels. Changing the position of either the HP valve or the LP valve affects both turbine speed/load and extraction/ admission. If either the load on the turbine or the ext/adm demand changes, both the HP valve position and the LP valve position must be changed to maintain speed/load and extraction/admission. The movement of both valves is automatically calculated by the 5009C Control's ratioing logic based on the programmed turbine performance parameters to minimize valve/process interaction.

Refer to Figure 4-12 for details on the Coupled HP&LP mode logic.

Decoupled Inlet and Speed Mode

This mode is typically used when the two controlled parameters during normal operation are turbine inlet pressure and speed.

In this operating mode the turbine's HP and LP valve actions are de-coupled to allow control of a turbine's inlet pressure without interaction from speed-load changes. With this mode of operation, turbine speed is controlled by only moving the LP valve.

The turbine's HP and LP valve actions are still coupled to control turbine speed and inlet pressure or flow changes. Turbine inlet pressure is controlled by moving both the HP and LP valves simultaneously, thus no change in speed (load) is created. For a change in either process the valves are repositioned to create a net effect of no pressure or flow change on the other process. Refer to Figure 4-13 for details on the Decoupled Inlet mode logic.

With this mode of operation:

- Turbine inlet pressure can be controlled through the 5009C Decoupling PID Controller.
- Speed is controlled via speed PID and cascade if enabled.
- Ext/adm pressure/flow is not controlled anymore.

The decoupling mode can be Enabled/disable via external contact if configured, PCI software or Modbus commands.

This mode can be activated only when extraction has been enabled (manual or automatic control)

The decoupling PID can be configured to use up to three decoupling inputs.

A remote Decoupling setpoint can also be configured. It will be enabled when a configured contact Enable remote decoupling is closed, or via PCI or Modbus.

Like the extraction PID, the decoupling PID can be put in manual mode via external contact, PCI or Modbus commands. In this case, R/L demand can be use to open/close the HP valve. These commands can be the same external contacts use to R/L the extraction demand, or they can come form PCI or Modbus. In case of failure of the decoupling inputs, the control can be configured to automatically put the decoupling PID in manual mode.

Decoupled Exhaust and Speed

This mode is typically used when the two controlled parameters during normal operation are turbine speed and exhaust pressure.

In this operating mode the turbine's HP and LP valve actions are de-coupled to allow control of a turbine's exhaust pressure without interaction from speed/load changes. With this mode of operation, turbine speed pressure is controlled by only moving the HP valve.

The turbine's HP and LP valve actions are still coupled to control turbine speed without interaction from turbine exhaust pressure or flow changes. Turbine exhaust pressure is controlled by moving both the HP and LP valves simultaneously, thus no change in speed is created. For a change in either process the valves are repositioned to create a net effect of no pressure or flow change on the other process. Refer to Figure 4-14 for details on the Decoupled Exhaust mode logic.

With this mode of operation:

- Turbine exhaust pressure can be controlled through the 5009C Decoupling PID Controller.
- Speed is controlled via speed PID and cascade if enabled.
- Ext/adm pressure/flow is not controlled anymore.

The decoupling mode can be Enabled/disable via external contact if configured, PCI software or Modbus commands.

This mode can be activated only when extraction has been enabled (manual or automatic control)

The decoupling PID can be configured to use up to three decoupling inputs.

A remote Decoupling setpoint can also be configured. It will be enabled when a configured contact Enable remote decoupling is closed, or via PCI or Modbus.

Like the extraction PID, the decoupling PID can be put in manual mode via external contact, PCI or Modbus commands. In this case, R/L demand can be use to open/close the LP valve. These commands can be the same external contacts use to R/L the extraction demand, or they can come form PCI or Modbus. In case of failure of the decoupling inputs, the control can be configured to automatically put the decoupling PID in manual mode.

Decoupled HP & LP

This mode is typically used when the two controlled parameters during normal operation are turbine inlet pressure and exhaust pressure.

In this operating mode the turbine's HP and LP valve actions are fully de-coupled. The HP valve can be positioned by the 5009C Control's Speed, or Cascade. The LP valve can only be positioned by the 5009C Control's Ext/ Adm PID. This configuration allows control of a turbine's inlet pressure without interaction from exhaust flow changes. With this mode of operation, turbine exhaust pressure is controlled by only moving the LP valve.

The turbine's HP and LP valve actions are also decoupled to control turbine exhaust pressure/flow without interaction from turbine inlet pressure or flow changes. Turbine inlet pressure is controlled by only moving the HP valve, thus no change in exhaust pressure/flow is created. For a change in either process the respective valves are repositioned for a net effect of no pressure or flow change on the other process.

With this mode of operation, turbine inlet pressure can be controlled through either the 5009C Control's Auxiliary or Cascade PIDs and turbine exhaust pressure is controlled through the Ext/Adm PID. Although turbine load is not controlled with this configuration, it is recommended to use the Auxiliary PID as a load limiter for unit protection. Refer to Figure 4-14 for details on the Decoupled HP&LP mode logic.

Block Diagram Description—The block diagrams displayed below provide a detailed view of each Ratio/Limiter configuration, and the relationship between the ratio/limiter's input and output signals.

The “S” input signal originates from the Speed PID and represents Speed, or Casc PID demand. The “P” input signal originates from the Ext/Adm PID or the E/A demand setpoint, depending on selected modes, and represents Ext/Adm flow demand. The “A” input signal is a discrete signal that originates from the control’s decoupling map logic, and goes to a true state when ratio/limiter decoupling is selected.

The “S” and “P” signals must pass through map limiters, depending on the priority selected, before they are used in the ratioing equations. Only one parameter (S or P) at a time can be limited, thus if Speed priority is enabled only the P signal is limited. If Ext/Adm priority is selected only the S signal is limited.

These limiters allow the valves to be correctly positioned on each turbine operating limit. To simplify the limiter logic, the Min (HSS bus) and Max (LSS bus) limiters are displayed as one limiter bus. Each possible turbine operating limit is labeled and displayed graphically. All limiters are based on the entered steam map values, and actual HP & LP valve positions (as derived from the control’s actuator driver signals).

Once the “S” and “P” signals pass through their respective limiters, they are referred to as S’ (S-prime), and P’ (P-prime). When the turbine is not operating on a limit, the S’ value equals the S input signal, and the P’ value equals the P input signal.

If programmed for decoupled operation, the transfer from couple mode to decoupled mode or decouple to coupled mode is instantaneous and bumpless.

The “HP” output signal represents HP valve demand, and is connected to the control’s HP LSS bus. The “LP” output signal represents LP valve demand, and is connected to the control’s LP LSS bus.

Speed vs. EXT/ADM Priority

Because an extraction and/or admission turbine has two control valves, it can only control two parameters at a time. If the turbine reaches an operating limit, (a valve fully open or closed) the result is only one free moving valve to control with, thus the 5009C Control can only control one parameter. It is at these turbine limits that the control can be programmed to select which one parameter will remain in control, or has priority over the other parameter.

Because the 5009C is design for mechanical drive, speed must be controlled at any time, as much as possible. Therefore, the pressure Priority is limited to two lines.

LP max priority:
Once the steam Map brings the LP valve to 100%, it might be necessary to limit the load of the engine, in order to avoid overheating. In this case, if Extraction at LPmax priority is selected, Extraction/decoupling pressure will have priority over the speed controller. When limit is reached, the Speed reference cannot be raised (even via cascade) as long as this limit is reached.

If not selected, the extraction/admission will be Limited when this limit is reached.

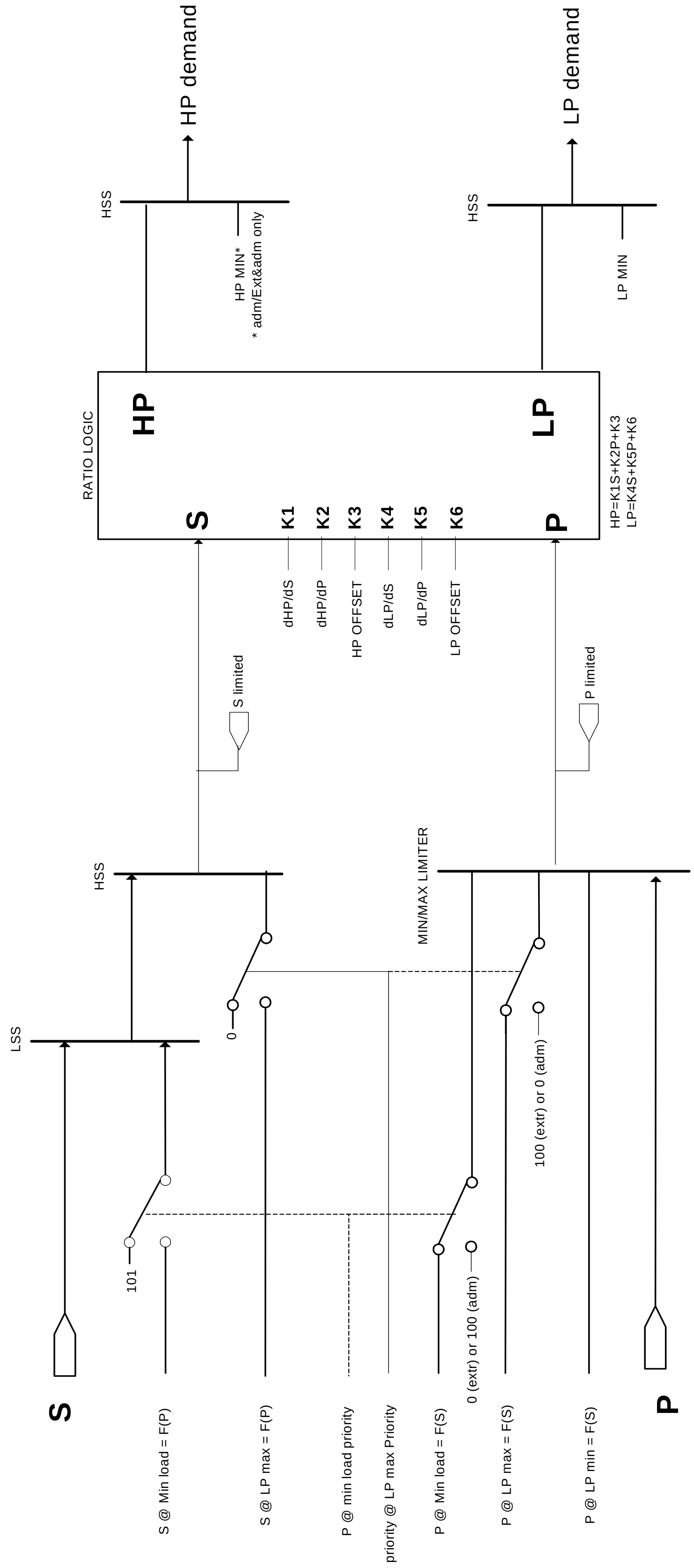

Figure 4-12. Coupled HP & LP Mode

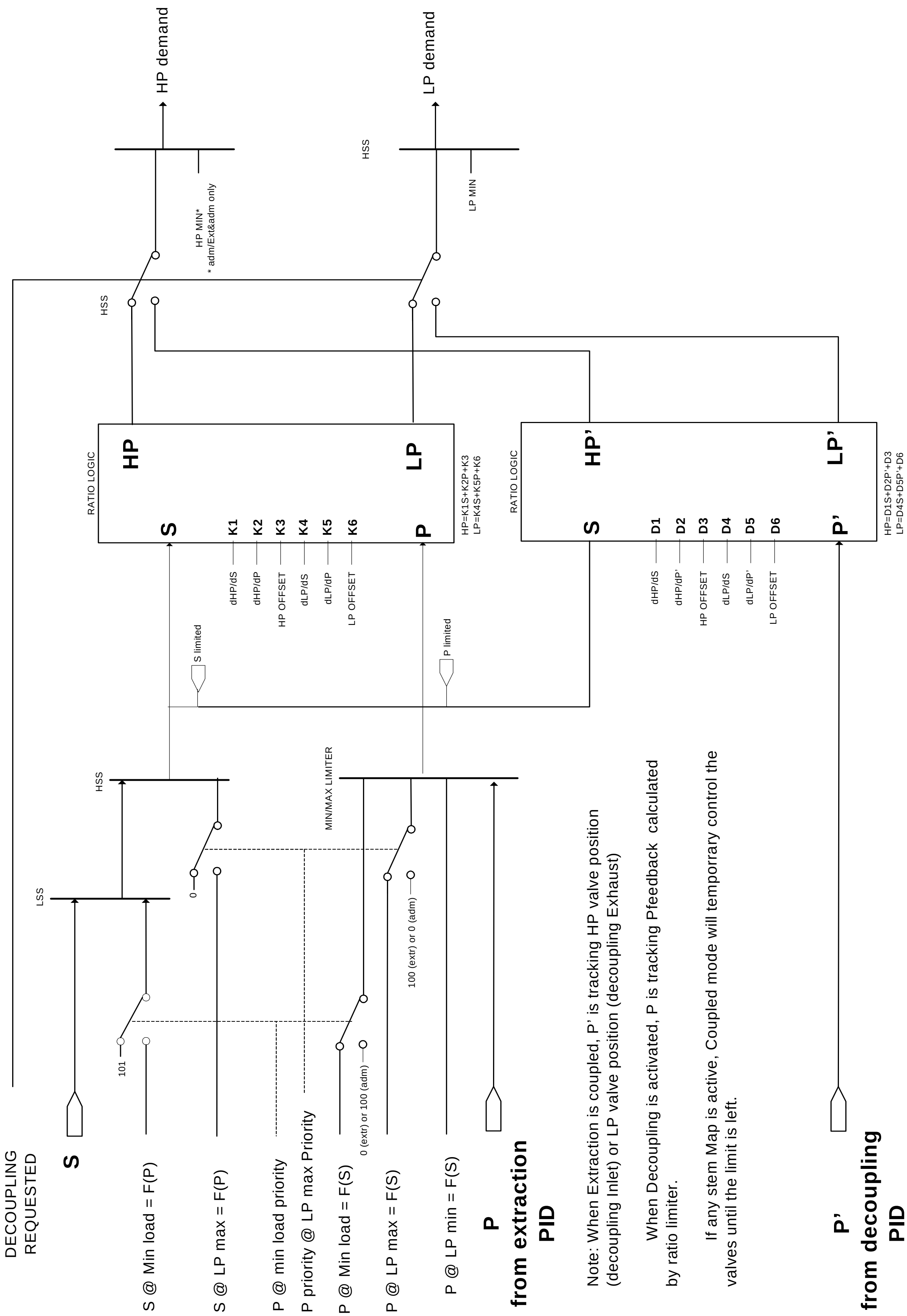

Figure 4-13. Decoupled Inlet or Exhaust Mode

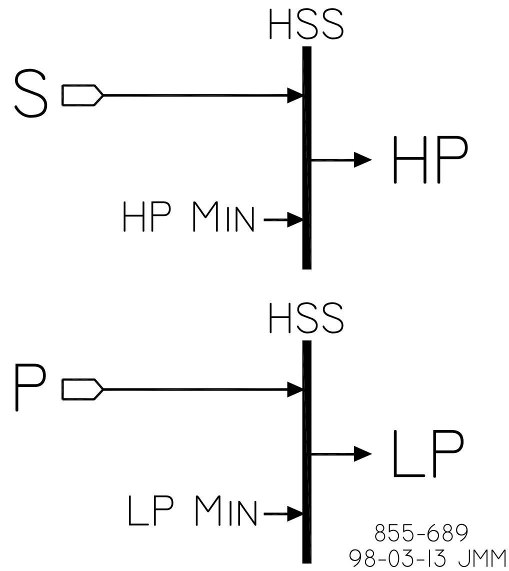

Figure 4-14. Decoupled HP&LP Mode

Min load priority
A new line in the steam map defines the minimum load possible for the turbine. When extraction is enabled, this line secures a minimum flow through the HP body, in order to prevent overheating at the exhaust side. When, speed as priority over extraction, the extraction demand and LP lift is limited.

If pressure priority is desired, then, when this line is reached, the extraction is kept in control, and speed PID is overridden, resulting in an increase of speed, regardless of the speed reference. Speed reference cannot be lowered (even with cascade) when this line is reached. Because the min load line is almost vertical, the increase of speed should be minimum, and just enough to avoid Over-temperature.

Care should be taken with this mode, to avoid interaction of the turbine speed loss protection.(see configuration manual).

Cascade Control

The Cascade Control can be configured to control any system process, related to or affected by turbine speed or load. Typically this controller is configured and used as a turbine inlet or exhaust pressure controller.

Cascade Control is a PID controller that is cascaded with the Speed PID. The Cascade PID compares a 4–20 mA process signal with an internal setpoint to directly position the Speed Set Point, thus changing turbine speed or load until the process signal and setpoint match. By cascading these two PIDs, a bumpless transfer between the two controlling parameters can be performed.

When enabled, the Cascade PID can move the Speed Set Point at a variable rate up to the maximum Speed Set Point rate, which is set in the Program Mode.

Turbine speed must be greater than the minimum governor setpoint before the Cascade PID can begin controlling.

Cascade Control may be enabled and disabled from the 5009C PC Interface, a contact input, or Modbus. The last command given from any of these three sources dictates the Cascade PID's control state.

If a contact input is programmed to function as a cascade enable contact, Cascade Control is disabled when the contact is open and enabled when it is closed. This contact can either be open or closed when a trip condition is cleared. If the contact is open it must be closed to enable Cascade Control. If the contact is closed it must be opened and re-closed to enable Cascade Control.

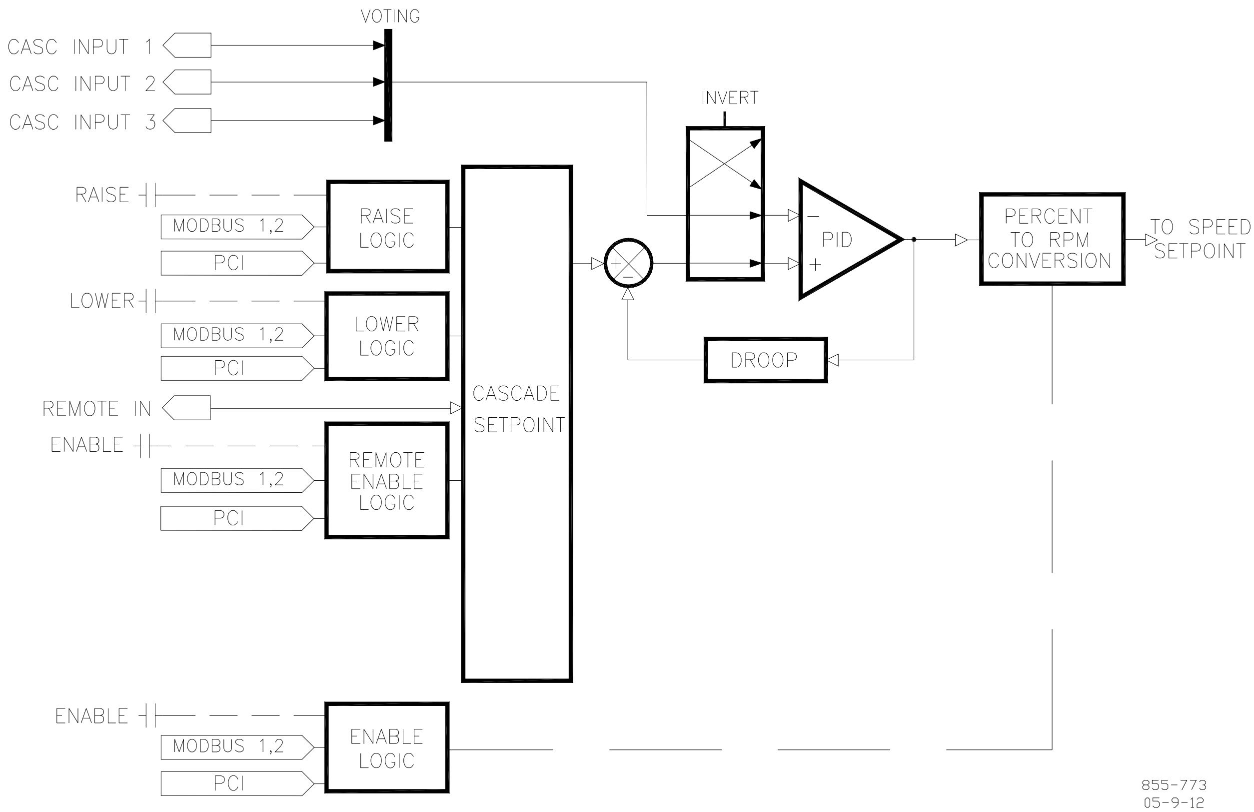

Figure 4-15. Cascade Functional Diagram

Cascade Control is automatically disabled on a shutdown condition and must be re-enabled after a successful system start-up. Cascade Control is disabled if the remote speed setpoint is enabled or auxiliary is configured as enable/disable is enabled. If another parameter on the LSS bus takes control of governor valve position from the Speed PID, Cascade Control will stay active and begin controlling again when the Speed PID is the lowest parameter on the LSS bus.

All pertinent Cascade Control parameters are available through Modbus.

Cascade Dynamics

The Cascade PID control uses its own set of dynamic settings. These values are programmable and may be tuned at any time from PC Interface or Modbus. Refer to the PID Dynamic Adjustments section in Chapter 6.

Cascade Set Point

The cascade setpoint can be adjusted from the 5009C PC Interface, external contacts, Modbus, or through a 4–20 mA analog input.
The cascade setpoint range must be defined in the Program Mode.

When a raise or lower cascade setpoint command is issued, the setpoint moves at the cascade setpoint rate. If a cascade raise or lower command is selected for longer than three seconds, the cascade setpoint will move at the fast rate which is three times the cascade setpoint rate. The cascade setpoint rate, fast rate delay, and fast rate can all be adjusted in the Service Mode.

A specific setpoint may also be directly entered from the 5009C PC Interface or through Modbus communications. When this is performed, the setpoint will ramp at the cascade setpoint rate (set in the Service Mode).

Refer to Volume #3 of this manual for information on which programmed settings are tunable through the 5009C Control's Service Mode. Service Mode values can be tuned/adjusted while the 5009C Control is shutdown or in the Start Mode.

Cascade Droop

When sharing control of a parameter with another external controller, the Cascade PID can also receive a programmable droop feedback signal for control loop stability. This feedback signal is a percentage of the Cascade PID's output. If cascade droop is used, the cascade input signal will not match the cascade setpoint when in control. The difference will depend on the amount (%) of droop programmed and the output of the Cascade PID. The droop value fed back to the Cascade PID is equal to the following defaulted settings:

PID OUTPUT % x 'CASCADE DROOP %' x 'MAX CASC SETPOINT' x 0.0001

Example: 25% x 5% x 600 psi (4137 kPa) x 0.0001 = 7.5 psi (51.71 kPa)

The 'CASCADE DROOP %' and 'MAXIMUM CASC SETPOINT' values are set in the Program Mode and the 'PID output %' is determined by the cascade demand.

Refer to Volume #3 of this manual for information on related Service Mode tunables.

Invert Cascade

Depending on the control action required, the cascade input signal can be inverted. If a decrease in HP governor valve position is required to increase the cascade process signal, program the cascade input to be inverted. As an example, when the Cascade PID is configured to control turbine inlet steam pressure the cascade input must be inverted. To increase turbine inlet steam pressure, the HP control valve position must be decreased.

Remote Cascade Set Point

The cascade setpoint can be positioned through an analog signal. This allows the cascade setpoint to be positioned remotely by a process control or distributed plant control system.

The Remote Cascade Set Point (RCS) range is set in the Program Mode and can be tuned in the Service Mode.

The RCS input may be enabled from the 5009C PC Interface, contact input, or Modbus communications. The last command given from any of these three sources dictates enable/disable.

If the milliamp signal to the RCS is out of range (below 2 mA or above 22 mA) an alarm will occur and the RCS will be inhibited until the input signal is corrected and the alarm is cleared.

When enabled, the RCS may not match the cascade setpoint. In this case, the cascade setpoint will ramp to the RCS at the programmed cascade setpoint rate setting (set in the Service Mode). Once in control, the RCS will adjust the cascade setpoint at the programmed remote cascade maximum rate. If the remote cascade maximum rate was set at 10 and the RCS analog input instantly moved from 0 units to 1000 units, the RCS will move to 1000 units at 10 units/sec).

Remote Cascade Enable Logic

The remote cascade setpoint can be enabled via a configured contact input, via Modbus or PCI. Closing the remote cascade enable contact input will enable remote Cascade Control. If Remote cascade is disabled via PCI or Modbus, the contact must be opened/closed to re-enable cascade.

Seal GAS PID Control

The Seal Gas PID Controller can be configured to control any system process. Typically this controller is configured and used to control seal gas pressure, but it can also be used for any type of PID loop.

The Seal Gas PID compares a 4–20 mA process signal with an internal setpoint to directly position an analog output configured as Seal Gas PID output.

The Seal Gas PID loop can be put in manual and automatic mode via dedicated contact input, Modbus commands or PCI tool.

If a contact input is programmed to function as a seal PID manual contact, Seal PID Control is in automatic when the contact is opened and in manual mode when it is closed. If a command is send via Modbus/PCI to put this PID in automatic, then the contact input must be closed/opened to bring back the manual mode.

Seal Gas PID Manual Mode

When the Seal gas PID is in manual mode, it is possible to manipulate its output directly using Raise/Lower demand commands. These commands are available via Modbus, PCI, or contact inputs configured as Seal Gas PID raise/lower demand.

In PCI software, it is possible to inhibit the manual mode selection. In this case, Seal Gas PID will be in manual mode only when its process value is lost. Should a Process value be lost, it is also possible to configure the 5009C to ramp the PID output up or down automatically.

Seal Gas PID Dynamics

The Seal Gas PID control uses its own set of dynamic settings. These values are programmable and may be tuned at any time from PC Interface only . Refer to the PID Dynamic Adjustments section in Chapter 6.

Seal Gas Set Point

The Seal Gas setpoint can be adjusted from the 5009C PC Interface, external contacts, or Modbus. The cascade setpoint range must be defined in the Program Mode.

When a raise or lower Seal PID setpoint command is issued, the setpoint moves at the Seal PID setpoint rate. If a Seal PID Set Point raise or lower command is selected for longer than three seconds, the setpoint will move at the fast rate, which is three times the cascade setpoint rate. The Seal Gas setpoint rate, fast rate delay, and fast rate can all be adjusted in the Service Mode.

Refer to Volume #3 of this manual for information on which programmed settings are tunable through the 5009C Control's Service Mode. Service Mode values can be tuned/adjusted while the 5009C Control is shutdown or in the Start Mode.

Seal GAS PID Droop

When sharing control of a parameter with another external controller, the Seal Gas PID can also receive a programmable droop feedback signal for control loop stability. This feedback signal is a percentage of the PID's output. If droop is used, the input signal will not match the setpoint when in control. The difference will depend on the amount (%) of droop programmed and the output of the PID. The droop value fed back to the PID is equal to the following defaulted settings:

PID OUTPUT % x 'SEAL DROOP %' x –0.01

Refer to Volume #3 of this manual for information on related Service Mode tunables.

Seal Gas PID Deadband

When a small fluctuation of PV must not affect the PID output, it is possible to set a deadband (% of seal PV range).

Invert Seal Gas PID

Depending on the control action required, the Seal Gas PVinput signal can be inverted. If a decrease of PID output is required to increase the cascade process signal, program the input to be inverted.

Emergency Shutdown

When an Emergency Shutdown condition occurs, both valve output signals are stepped to zero milliamps, and the Shutdown Relay(s) de-energize(s).
For actuator outputs from actuators, the Driver SD can be disabled, in order to send negative current during SD.

First Out Indication—This control can be configured to accept up to ten individual External Trip inputs (contact inputs) to cause an Emergency Shutdown. By wiring trip conditions directly into the control, instead of a trip string, the control can pass a trip signal directly to its output relay (to trip the T&T valve), and also indicate the first trip condition sensed. All trip conditions are individually indicated through the control's PCI program and Modbus communications. Alternatively, up to ten alarm inputs (contact inputs) can also be configured to indicate system related alarm conditions.

The "Trip Output Relays" (Relay #1 and #2) are intended to be connected to the unit trip-oil header solenoid, or trip logic. When another relay output is programmed as a Trip Relay, the respective relay will function like the dedicated Trip Relay (normally energized and de-energizes on a shutdown) to indicate the position of the dedicated Shutdown Relay.

The "Shutdown Condition" relay may be programmed to indicate a shutdown condition on a remote panel or to a plant DCS. The Shutdown Indication relay is normally de-energized. This relay will energize upon any shutdown condition and stay energized until all trips have been cleared. The reset clears trip function has no effect on the programmable Shutdown Indication Relay.

Controlled Shutdown

The Controlled Shutdown function is used to stop the turbine in a controlled manner, as opposed to an Emergency Trip. When a STOP command (controlled shutdown) is issued the following sequence is performed:

1. All control PIDs and functions are disabled except the Speed and Extraction PIDs.

2. The Extraction Control is disabled (the LP limiter is raised to maximum for extraction applications).

3. If used, the ratio/limiter map is transferred to the coupled HP & LP map.

4. The Speed Set Point is ramped to low at the fast (Hot) rates used by the auto start sequence once Extraction is fully disabled (if used).

4a. If Normal SD is configured for low idle only, the normal SD is stopped and held at this stage, and start-up mode is put in manual. The Normal shutdown will wait for the timer called "Max time at low Idle", and then:
- Either will be de-activated when the Timer is passed,
- Either will continue to step 5.

This selection is done in program and service mode (Speed control Folder) with the parameter: "Continue NSD after max time?"

If not,

5. The HP valve limiter is ramped to zero at a controlled rate.

5a. If the Normal SD has been configured to not issue a SD, the engine is set to "ready to start" and wait for a start command.

If not,

6. The 5009C Control executes a Shutdown (Shutdown Relay de-energizes, actuator drive currents = zero).

7. A 'Shutdown - Controlled Stop' message is indicated.

A controlled shutdown can be initiated or aborted from the 5009C PC Interface, a programmed contact input, or either Modbus communication link. Verification of the shutdown request is not required if a controlled shutdown command is initiated by a programmed contact input or Modbus communication link.

The controlled shutdown sequence can be aborted at any time. Refer to Chapter 6 (Start/Operation) of this manual.

Closing a contact programmed for the Controlled Shutdown Sequence will initiate the shutdown. The shutdown sequence will go through the same steps described above, with the exception that verification of the shutdown sequence is not needed. Opening the contact will stop the sequence. Stopping and continuing the Modbus initiated Controlled Shutdown Sequence requires two commands; one to start the sequence and the other to stop it.

See Volume 3 for all 5009C Control Service panel messages.

Synchronize Control Clock

This control has the capability of being configured to accept a discrete input to set its internal Real-Time clock to a set time of day. This allows the control's Real- Time clock to be aligned with a plant Distributed Control System, up to once a day. By synchronizing both systems' Real-Time clocks alarm data can be compared on a time basis, between the two systems without the confusion of time offsets.

The "Synchronize Control Clock" function is selected by configuring a contact input to function as a "Synchronize Time-of-Day" input. After this input is configured, the control's Real-Time clock will set its Hour, minute, and second settings to that of the PCI program's "Set Time & Date" edit box values, upon every closure of the respective contact input.

The control's discrete input scan time resolution for this function is once every 10milliseconds. The Real-Time clock's time-of-day settings are set upon the leading edge of the contact closure. Based on these issues, the minimal guaranteed offset between system clocks is +10milliseconds or better (not taking into account external relay delay times or tolerances).

Local / Remote Function

The 5009C Control's Local / Remote function allows an operator at the turbine skid or 5009C Control to disable any remote command (from a remote Control Room) that may put the system in a unsafe condition. This function is typically used during a system start-up or shutdown to allow only one operator to manipulate the 5009C control modes and settings.

The Local/Remote function must first be programmed before a Local or Remote mode can be selected by an operator (refer to Service Mode, CPU Comm Page, Port 3 'CPU' Settings). If this function is not programmed all contact inputs and Modbus commands (when Modbus is programmed) are active at all times. If the Local/Remote function is programmed, Local and Remote modes can be selected through a programmed contact input, the PCI program, or Modbus.

When Local mode is selected, the 5009C Control is defaulted to be operable from PCI program only. This mode disables all contact inputs and Modbus, with exceptions noted below:

External Trip Contact In	(defaulted in program)
External Trip Contact In	(defaulted in program)
External Trip 3 Contact In	(active at all times, if programmed)
External Trip 4 Contact In	(active at all times, if programmed)
External Trip 5 Contact In	(active at all times, if programmed)
External Trip 6 Contact In	(active at all times, if programmed)
External Trip 7 Contact In	(active at all times, if programmed)
External Trip 8 Contact In	(active at all times, if programmed)
External Trip 9 Contact In	(active at all times, if programmed)
External Trip 10 Contact In	(active at all times, if programmed)
External Alarm 1 Contact In	(active at all times, if programmed)
External Alarm 2 Contact In	(active at all times, if programmed)
External Alarm 3 Contact In	(active at all times, if programmed)
External Alarm 4 Contact In	(active at all times, if programmed)
External Alarm 5 Contact In	(active at all times, if programmed)
External Alarm 6 Contact In	(active at all times, if programmed)
External Alarm 7 Contact In	(active at all times, if programmed)
External Alarm 8 Contact In	(active at all times, if programmed)
External Alarm 9 Contact In	(active at all times, if programmed)
External Alarm 10 Contact In	(active at all times, if programmed)
Override MPU Fault Contact In	(active at all times, if programmed)
Start permissive Contact In	(active at all times, if programmed)
Local / Remote Contact In	(active at all times, if programmed)
Local / Remote Modbus	(active at all times, if Modbus programmed)
Trip Command Modbus	(active at all times, if Modbus programmed)

When the Remote Mode is selected, the 5009C Control can be operated through its PC Interface, contact inputs, and/or all Modbus. When using a contact input to select between Local and Remote Modes, a closed contact input selects the Remote Mode and an open contact input selects the Local Mode.

Optionally the contact inputs, Modbus Port 1, and Modbus Port 2 can be individually configured to be enabled in both the local and remote modes. Once the Local/Remote function is configured, a “Keep Contact Enabled for Local Selection” option becomes visible in the Service mode’s Contact Inputs folder, and a “Local Mode” selection box in each CPU port’s Modbus settings section. Use these Local Mode selection boxes to select the desired activity of the contact inputs and Modbus ports when the control’s local mode is selected.

Optionally a relay can be programmed to indicate when Local Mode is selected (energizes when the Local Mode is selected). There is also indication of the Local / Remote Mode selection through Modbus (address is true when the Remote Mode is selected and false when the Local Mode is selected).

The 5009C Control is defaulted to only allow control operation though its PC Interface when the Local Mode is selected. If desired, this defaulted functionality can be changed through the 5009C Control’s Service Mode. The 5009C Control can be modified to also allow operation through contacts inputs, and/or Modbus port #1, and/or Modbus port #2 when the Local mode is selected.

All pertinent Local/Remote control parameters are available through the Modbus links.

It is possible to configure the 5009C so that the contact input sends only a “LOCAL” or only a “REMOTE” command. This option enables Flip-Flop commands.

Relays

The 5009C Control has twelve relay outputs available. Three of these relays are dedicated; two for a system shutdown/trip command from the 5009C Control and one for alarm indication. The other nine relays can be programmed for a variety of indications and system functions.

The dedicated Alarm Relay is normally de-energized. This relay will energize upon an alarm condition and stay energized until the alarm condition is cleared. Optionally this relay can be configured through the 5009C Control's Service Mode, to toggle on and off repeatedly when an alarm condition has occurred. With this configuration if a reset command is given and the alarm condition still exists, the relay will stop toggling and stay energized. The relay will start toggling again, upon a new alarm condition. This option can be used to inform the operator when another alarm condition has occurred.

Any of the other nine relays can be programmed to function as a level switch or a mode or condition indication. When programmed as a level switch the relay will change state when the selected parameter reaches the programmed level (energizes when value is higher the programmed level). Relays not used as level switches can be programmed to indicate control states. Except for the Trip relay, when programmed to indicate a state or event, relay will energize upon the respective state or event occurring.

The present relay state (energized / de-energized) and relay configuration is indicated through both Modbus communication links and through the PC Interface.

Relay Clarifications

The Shutdown Condition relay may be programmed to indicate a shutdown condition on a remote panel or to a plant DCS. The Shutdown Indication relay is normally de-energized. This relay will energize upon any shutdown condition and stay energized until all trips have been cleared. The 'RESET CLEARS TRIP' function has no effect on the programmable Shutdown Indication relay.

When programmed as a Trip Relay, the respective relay will function like the dedicated Shutdown Relay (normally energized or normally de-energized, depending upon configuration) to indicate the position of the dedicated Shutdown Relay.

The Alarm Condition relay may be programmed to indicate an alarm condition on a remote control panel or to a DCS. The Alarm Indication relay is normally de-energized. This relay will energize upon any alarm condition and stay energized until all alarms have been cleared. If the 'BLINK ALARMS' option is 'YES' the programmable Alarm Condition relay will toggle on and off repeatedly when an alarm condition has occurred. With this configuration if a reset command is given and the alarm condition still exists, the relay will stop toggling and stay energized.

The Overspeed Test Enabled relay will energize when an Overspeed Test is performed. This relay toggles on and off when turbine speed is above the turbine Overspeed trip setting.

When the Modbus function is programmed, the assigned relay energizes when the respective Modbus "Turn On Relay X" is issued, then de-energizes when the respective Modbus "Turn Off Relay X" is issued. This feature allows a 5009C Control relay to be driven directly from Modbus to control a system related function (synchronizing).

Each of the nine relay can be configured for "lamp usage". In this case, this relay will be energized, as soon as a lamp test is requested from contact or PCI only.

Chapter 5.
5009C Control System Operation

Introduction

The 5009C Control System is designed to interface with the provided PCI program, discrete and analog input/outputs and devices communicating via Modbus (OpView). The 5009C Control's operating architecture is divided into two sections: Run Mode and Program Mode. The Program Mode is used to configure the 5009C Control for the specific application and set all operating parameters (Refer to Volume 3). The Run Mode is the normal turbine operation mode and is used to view operating parameters and run the turbine. All operating parameters can be controlled from the PC Interface program, Modbus commands (OpView), and/ or discrete and analog inputs to the 5009C Control.

⚠WARNING **Improperly calibrated devices can cause turbine damage and possible personnel injury or death. Before starting the turbine for the first time, and periodically thereafter, verify the calibration of all external input and output devices.**

⚠WARNING **This manual does not contain instructions for the operation of the complete turbine system. For turbine or plant operating instructions, contact the plant-equipment manufacturer.**

5009C System Power-up

The following procedure should be followed for the initial start up. Before power is applied, the control should be wired and installed as referenced in Volume 2. If at any time during this procedure the defined or expected result is not achieved, refer to Volume 2, and begin system troubleshooting.

1. Verify that the turbine is externally tripped (close the manual trip valve).
2. Verify that all modules are inserted firmly in the 5009C Control and that all cables connecting the modules to the FTMs are firmly in place.
3. Turn the power for one power supply on and verify that the power supply's green LED is the only power supply LED on.
4. Turn the power for second power supply on and verify that the power supply's green LED is the only power supply LED on.
5. Momentarily toggle the A, B, & C-Rack's CPU's RESET switch up (press the switch's top half), then back to its normal down position (press the switch's bottom half).

At this point the system will perform Off-Line diagnostics. When all CPUs have synchronized and completed their diagnostic tests, no red LEDs should be on, and the control will begin running the application program. The 5009C Control is now running. Before any Run Mode parameters or calibrations can be performed, it must be configured using the PC Interface program described in Volume 3. Once site specific data has been configured into the control, the remaining operations functions can be performed.

Valve / Actuator Calibration & Test

Before initial operation or after a turbine overhaul where any actuator or valve travel may have been affected, the below Valve Calibration procedure should be followed to insure that the 5009C Control is calibrated to both valves (HP & LP). The 5009C Control uses its actuator output currents to sense HP and LP valve positions. These valve positions are used by the 5009C Control to calculate internal turbine ratios, and operating limits. Thus if the 5009C Control is not correctly calibrated to each control valves actual travel, it will incorrectly calculate turbine operating limits. It is recommend that each valve be manually stroked after the 5009C Control's output has been calibrated to insure that the 5009C Control and the actual valve position match as closely as possible.

After a valid program has been entered the actuator and valve minimum and maximum positions can be adjusted and tested, if needed. Actuator and valve positions are determined by the drive current to the actuator. The maximum actuator current can not be adjusted lower than the minimum actuator current (see Table 6-1 below). The minimum actuator current can not be adjusted higher than the maximum actuator current. The driver current ranges are determined by the setting in the Program Mode under the Driver Configuration Block.

When adjusting or testing actuator and valve travel, verify that sufficient valve over travel at the minimum stop is achieved (1-2%). This assures that each valve can fully close to completely shut off the steam flow to the turbine.

Driver Limits	**20–160 mA Range**	**4–20 mA Range**
Overcurrent	10% above maximum setting	10% above maximum setting
Under current	10% below minimum setting	10% below minimum setting
Max Output Current Range	8-196 mA	1.8-24 mA
Max Output Impedance	45 ohms	360 ohms
Min Stop Adjust Range	8-100 mA	1.8–12 mA
Max Stop Adjust Range	100-196 mA	12–24 mA

Table 6-1. Actuator combo Driver Limits

To ensure proper control to actuator resolution do not calibrate the span of the actuator output to be less than a range of 100 mA (for the 20–160 mA option) or 12 mA (for the 4–20 mA option). If necessary, the actuator to valve linkage may need to be adjusted to ensure proper 5009C to valve resolution.

The stroking option is only available when the 5009C Control is in a shutdown state. The emergency shutdown input must be closed or jumpered (inactive), as this input being open will shut off the current outputs of the 5009C Control. After enabling the stroke mode, there are options available to adjust the minimum and maximum stops and to manually stroke the output(s). The manual adjustment mode can be used to stroke the actuators and valves from 0 to 100% after the minimum and maximum positions have been adjusted. This allows both the actuator and valve to be tested for binding, play, resolution, linearity, and repeatability. The actuator and valve positions can be varied by using the PC Interface program (Refer to Volume 3), or Modbus commands (OpView—see Volume 4). As a safety precaution, if turbine speed ever exceeds 1000 rpm, the Valve/Actuator Calibration and Test will be automatically disabled, and actuator currents taken to zero.

Valve Calibration / Stroking Procedure

⚠WARNING	**Before calibrating or testing, the unit must be tripped and the steam supply removed. This is to ensure that opening the control valve(s) will not allow steam into the turbine. Overspeed sensing and its relay are disabled during this process. Overspeeding the turbine may cause damage to turbine and can cause severe injury or death to personnel. STEAM TO THE TURBINE MUST BE SHUT OFF BY OTHER MEANS DURING THIS PROCESS.**

1. All Emergency shutdown inputs must be closed or jumpered throughout this procedure, or the actuator outputs will go to ZERO current.

2. Execute a system RESET command.

3. **PCI**: Unlock the Start mode's security logic. If the Start mode's Security logic is locked the calibration settings can only be monitored. If the Start mode's Security logic is unlocked, the calibration settings can be monitored and changed. Refer to the Security Button section in Volume 3 for instructions on locking and unlocking the Start Mode's Security logic.

4. **PCI/Modbus**: Select the actuator channel to be calibrated. Only actuator configured to be used can be calibrated. OR

5. **PCI/Modbus**: click on the Enable button to enable calibration.

6. **PCI/Modbus**: Select the "Go Min" button to Step the actuator driver output to its minimum output current level.

7. For proportional no fdbk valves, adjust the current (mA) such that the valve is just at the control minimum stop of its range. With the adjustment of the current, the operator can watch the valve move. In an optimum system, the valve should be against its control minimum stop at its minimum current (4 or 20 mA) and off its control minimum stop at slightly above it (1or2%).

   For proportional with fdbk, it might be necessary to adjust the null current, until the valve is at 0%. As the LVDT might have never been calibrated previously, the operator must physically verify that the valve is at 0%.

8. **PCI/Modbus** : Select the "Go Max" button to Step the actuator driver output to its maximum output current level. For integrating valves, the cylinder LVDT 0% position as well as the pilot 0% (if used) will be memorized.

9. For proportional no FDBK actuator, adjust the current (mA) of the valve such that the valve is just at the control maximum stop of its range. With the adjustment of the current, the operator can watch the valve move. In an optimum system, the valve should be against its control maximum stop at its maximum current (20 or 160 mA) and off its control maximum stop at slightly below it (1or2%). If the valve can not reach its control maximum stop adjust the linkage for more valve travel with respect to the actuator, repeat calibration procedure.

   For proportional with FDBK valves, it might be necessary to tune the null current value until the vale is at 100%.

   As the LVDT might have never been calibrated previously, the operator must physically verify that the valve is at 100%.

10. **PCI/Modbus**: When the valve is at maximum position, and the current output is at maximum, select goto manual stroke. For integrating valves, the 100% cylinder LVDT positions, as well as the pilot LVDT 100%position will be memorized.

    If the “at max” is selected before the current has reached its maximum, the calibration procedure must be performed again.

11. Verify that the valve has a full range of motion and is not binding by moving the manual stroke demand.

    For integrating valves, set the integer gain to zero, and adjust the null current value until the demand match the LVDT feedback. Bring back the I gain later.

    For proportional with feedback tune the null current until the valve is stable. Press “memorize” to sample the null current value, and the null position of the pilot if used. Wait and verify that at the end, the demand matches with the LVDT feedback.

    Tune the gains KP,KI (f integrating) and K pilot (if used) and verify the stability of the loops by stroking the valve.

    For proportional no FDBK, verify that the Actuator current range is at least 12 mA for a 4–20 mA valve or 100 mA for a 20–160 mA valve. If not, adjust the linkage for less valve travel with respect to the actuator, and repeat calibration procedure.

    The rate for manual stroke can be changed in the PCI software. This allows the possibility of performing ramp tests and Step tests.

12. **PCI/Modbus**: Click on the Save Settings button, then Confirm the action to permanently save all actuator settings into the control. If these settings are not saved they will be automatically saved when calibration mode is disabled. If these settings are not saved, and power is lost before the calibration is disabled all settings might revert back to their values before the change.

13. Repeat steps 4 through 11 for each valve to be calibrated. **For Actuator card outputs, each card (A106 and C106) must be calibrated independently prior to run the engine.**

Turbine Start

Refer to the turbine manufacturer's operating procedures for complete information on turbine start up, and Chapter 5 of this manual for a step by step procedure, depending on the start mode selected. The following is a typical start-up procedure:

WARNING

The engine, turbine, or other type of prime mover should be equipped with an overspeed shutdown device to protect against runaway or damage to the prime mover with possible personal injury, loss of life, or property damage.

The overspeed shutdown device must be totally independent of the prime mover control system. An overtemperature or overpressure shutdown device may also be needed for safety, as appropriate.

1. Initiate a control reset to clear all alarms and trips and increase the LP Valve Limiter to 100%. If the 5009C's 'RESET CLEARS TRIP' setting is programmed "YES" in the PC Interface program, the 5009C's shutdown relay will reset or energize upon initiating a control reset after a shutdown. If the 'RESET CLEARS TRIP' setting is programmed "NO", the 5009C's shutdown relay will reset or energize upon initiating a control reset ONLY after all trip conditions are cleared.

2. Initiate a START command to begin the configured start-up mode. If a semi-automatic start mode is configured, the valve limiter must be manually increased to open the control valve.
   - A 'Start Perm Not Closed' alarm will be issued if the application is using a Start Permissive contact input and this contact input was not closed when the START command was issued.

3. After the selected start-up mode has been performed, the turbine will operate at the minimum or idle speed setting. The 5009C's speed setpoint will move to minimum governor speed unless an idle speed is programmed. The Idle/Rated Manual R/L ONLY or Auto Start Sequence functions must be programmed for the turbine to control at idle speed. When using the Auto Start Sequence, the 5009C will begin stepping through its sequence once it gets to low idle. This sequence may be stopped, rated speed may be selected (if using idle/rated) or the operator may vary turbine speed with raise/lower speed commands through the external switches, or Modbus communication links (PCI, OpView).

The 'Start' and 'Reset' commands can be selected from contact input closures (if programmed), the PCI program, or Modbus communications links. In addition, the following indications are available through the Modbus links: Speed Setpt Moving to Min, Start Permissive Closed, Start Permissive Not Closed, etc. alarm indication.

Speed Screens

The PC interface program and the HMI have Turbine Start screens that allow the user access to all of the parameters necessary to start the turbine. For a detailed description of the screens and access to those parameters, refer to Volume 3 for the PCI and Volume 4 for the HMI. If configured, contact inputs will perform the same functions in the 5009C Control.

Auto Start Sequence

When a START command is issued the Speed setpoint is instantly set to the turbine's actual speed and the sequence will continue from this point. This sequence is automatic, however the sequence can be halted. Halting the Auto Start Sequence can be performed by opening the Halt/Continue contact (if programmed), selecting Halt from a Modbus communications link, or selecting Speed Setpt Raise or Lower command. To provide feedback, a relay can be programmed to indicate the Auto Start Sequence is Halted. The Sequence can be restarted again by closing the Halt/Continue contact, or selecting Continue from a Modbus communications link.

Dynamic Adjustments

The Speed, Cascade, Extr/Adm, and Decoupling control loops utilize PID controllers. The response of each control loop can be adjusted for optimum response, however it is important to understand what a PID controller is and the effect each controller adjustment has on the controller response. Proportional gain, integral gain (stability), and DR (speed derivative ratio) are the adjustable and interacting parameters used to match the response of the control loop with the response of the system. They correspond to the P (proportional), I (integral), and D (derivative) terms, and are displayed by the 5009C Control as follows:

P = Proportional gain (%)
I = Integral gain (%)
D = Derivative (determined by DR and I)

Proportional Control

Proportional response is directly proportional to a process change. Analogy: Setting hand throttle to keep constant speed on a straight and level highway. Proportional control (using the same analogy) results in a certain speed as long as the car is not subjected to any load change such as a hill. If a throttle is set to any particular setting, the speed of the car will remain constant as long as the car remains straight and level. If the car goes up a hill, it will slow down. Of course, going down a hill the car would gain speed.

Integral Control

Integral compensates for process and setpoint load changes. Analogy: Cruise control maintains constant speed regardless of hills. Integral, sometimes called reset, provides additional action to the original proportional response as long as the process variable remains away from the setpoint. Integral is a function of the magnitude and duration of the deviation. In this analogy the reset response would keep the car speed constant regardless of the terrain.

Derivative

Derivative provides a temporary over-correction to compensate for long transfer lags and reduce stabilization time on process upsets (momentary disturbances). Analogy: Accelerating into high speed lane with merging traffic. Derivative, sometimes called “preact” or “rate”, is very difficult to draw an accurate analogy to, because the action takes place only when the process changes and is directly related to the speed at which the process changes. Merging into high speed traffic of a freeway from an “on” ramp is no easy task and requires accelerated correction (temporary overcorrection) in both increasing and decreasing directions. The application of brakes to fall behind the car in the first continuous lane or passing gear to get ahead of the car in the first continuous lane is derivative action.

Proportional Response

The amount of controller change is directly related to the process change and the Proportional gain setting on the controller; Controller output change is Proportional to the process change. If there is no process change, there is no change in output from the controller (or valve change) regardless of the deviation. This results in an undesired offset between the original desired Set Point and the resulting drop in the Control Point.

Proportional Gain (Effect of Settings)

Figure 5-1 shows the effect of Proportional gain settings on control. Starting at the top of the graph a load change is introduced. With a small Proportional gain (meaning a large process change is required to produce full valve travel), stability is good but offset is very high. With a moderate gain setting (higher number setting) stability is still good - offset is still fairly high. With a high setting, offset is considerably smaller but the stability is poor. The 0.25 ratio effects a minimum area whereby the offset is reduced to a minimum while stability is in a decaying manner at 0.25% ratio. The decay ratio used (0.25%) means that if the second cycle is 1/4 of the first cycle, then each succeeding cycle will be 1/4 of the preceding cycle until the cycle is not visible.

Since Proportional gain is adjusted to produce the proper stability of a process, continually increasing its effect will not correct offset conditions. The amount of stability and offset is directly related to the setting of the Proportional setting. Stability is of course also affected by the stability of the process. In essence, the amount of output from the controller due to the Proportional setting is from the error. If there is no error, then there is no Proportional effect.

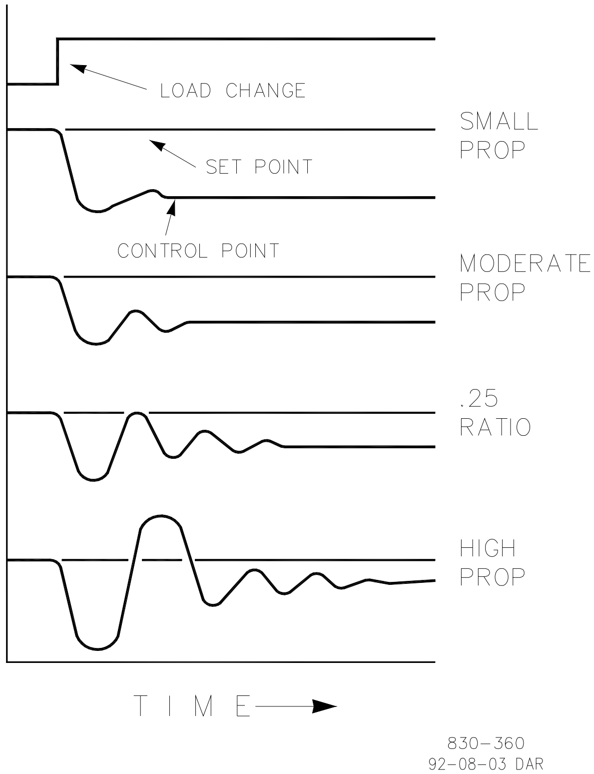

Figure 5-1. Proportional Gain Setting Effects

Integral Response

Integral Gain as stated in the Woodward controls is repeats per minute (or Reset Rate). Therefore, a high amount of Integral gain (high number) would result in a large amount of Reset action. Conversely, a low Integral gain (low number) would result in a slower reset action.

Integral response is provided to eliminate the offset that resulted from straight Proportional control. Figure 5-2 shows how the controller action is Proportional to the measurement change, but as we saw earlier, this results in offset. The Integral (or Reset) action is a function of both time and magnitude of the deviation. As long as an offset condition (due to load changes) exists, Integral action is taking place.

The amount of Integral action is a function of four things:
- The magnitude of the deviation.
- The duration of the deviation.
- The Proportional gain setting.
- The Integral setting.

In this Open Loop figure (5-2), the Integral response is shown increasing due to the offset condition existing between the temperature and the setpoint. The resultant action is the top curve showing the step Proportional response that ends as soon as the measurement stops changing. Then the Integral (or reset) action is added to the Proportional action in an amount equal to the Integral of the deviation. In other words, Reset action continues (in either or both directions) as long as there is a difference (deviation) between the setpoint and the process measurement. In this case, the deviation will never be eliminated (or even reduced) because the system is in Open Loop.

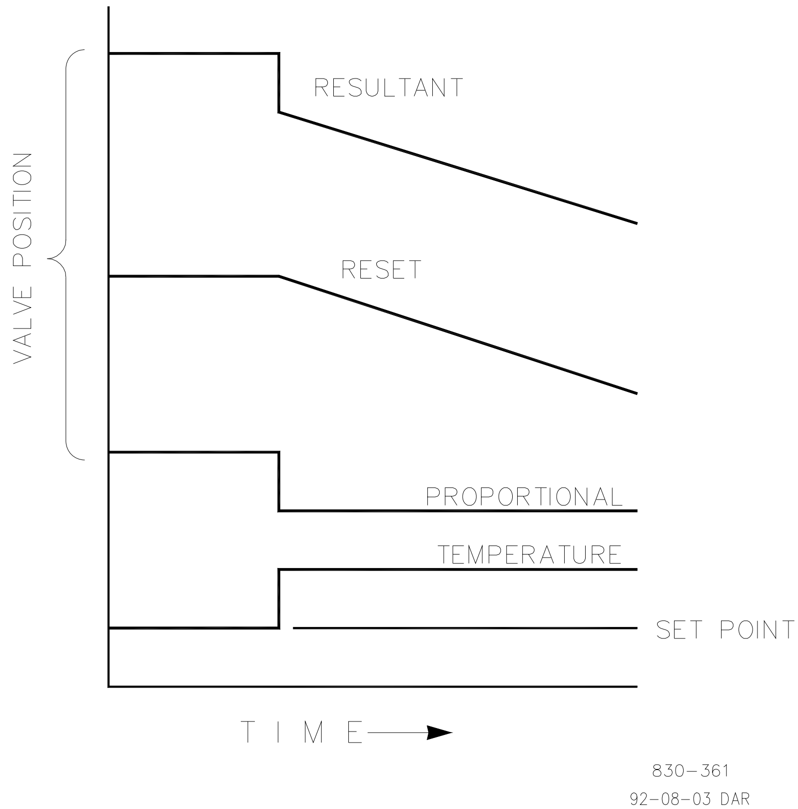

Figure 5-2. Open Loop Proportional and Integral Response

Proportional + Integral (Closed Loop)

Figure 5-3 shows the closed loop effects of integral action. The bottom curve displays the load change. The next curve up shows the setpoint and the measured variable, temperature. With the load change the temperature droops or deviates from the setpoint. The next highest curve is the Proportional action and follows the measured variable proportionately. The Integral curve adds to the Proportional curve resulting in a different valve position, thereby returning the process to the set point.

In Closed Loop, however (as opposed to Open Loop), as the measurement decays toward the set point, the proportional action is taking place proportionally to the measurement change, and the Integral action is decaying proportionately to the magnitude and duration of the deviation until the measurement reaches the setpoint at which time the Integral action is zero.

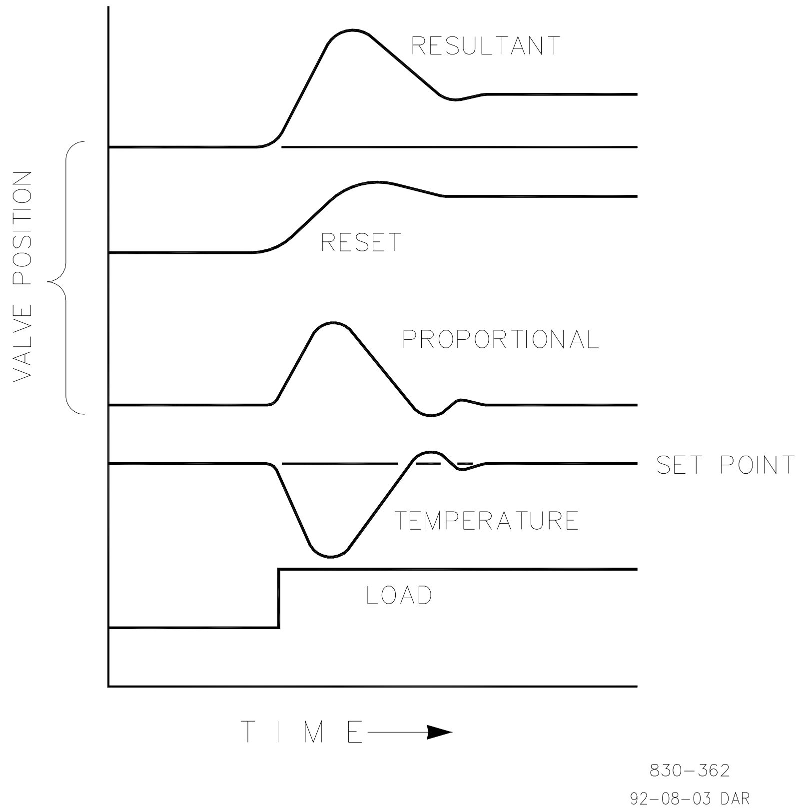

Figure 5-3. Closed Loop Proportional and Integral Response

Integral (Effects of Settings)

Figure 5-4 shows the effect of fast or slow Integral action. For a given load change an offset results with Proportional response only. Since recovery time (for a given load change) is important, the Integral setting should remove the offset in minimum time without adding additional cycling. If two cycles are added, then too much Integral Gain has been added. Of course, Proportional only must first establish the 1/4 decay ratio. If increased cycling occurs, the Integral must be turned off or the controller switched to “manual” if allowed to go too far. Ideally, the process should not continue to cycle after the setpoint has been reached as in the second curve from the bottom.

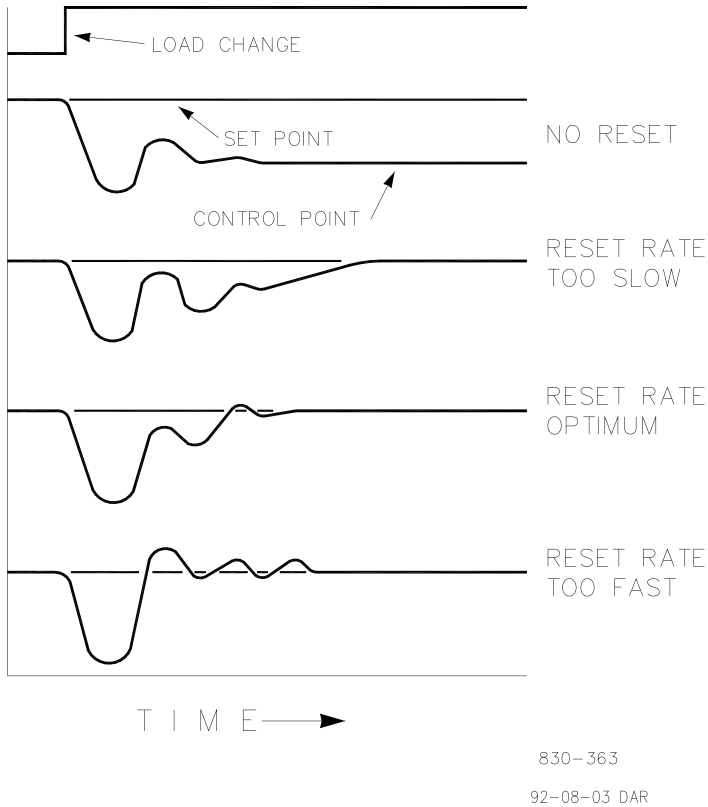

Figure 5-4. Integral Gain (Reset) Setting Responses

Derivative Response

In a process control loop the Derivative action is directly related to how fast the process changes (rate of change). If the process change is slow then the Derivative action is proportional to that rate of change. Derivative acts by advancing the Proportional action. Derivative acts at the start of the process change, when the process changes its rate and when the process stops its change.

Derivative action takes place at only three times:

- When the process starts to change.
- When the rate of change takes place in the process.
- When the process stops changing.

The net result of Derivative action is to oppose any process change and combined with Proportional action to reduce stabilization time in returning the process to the setpoint after an upset. Derivative will not remove offset. Woodward Derivative is split into two working domains, Input dominant and Feedback dominant. The allowed values for DR range from 0.01 to 100. The most common derivative is Feedback dominant, it is automatically selected with an Derivative Ratio (DR) from 1 to 100. The Input dominant domain is selected with DR values between 0.01 to 1.

Feedback dominant applies the derivative action to the integrator feedback term of the PID equation and is more stable than input dominant derivative. This will not take corrective action as early and it will be less noise sensitive. When tuning the derivative, the DR will be established in the 1 to 100 range because it is easier to tune and more forgiving of excessive values. Most PIDs will employ feedback dominant derivative.

Input dominant derivative applies the DR term before the integrator term of the PID equation. When the DR is less than 1, the derivative is input dominant and reacts very quickly to process upsets. This function is very adapted for PIDs that control the load parameter, such as load shaft turbine speed. Since the input dominant derivative is so sensitive, it should be reserved only for applications without high frequency noise.

Except for input dominant and feedback dominant features, the reciprocal of one domain will appear identical in the other domain. As an example, consider an DR of 5.0, the reciprocal being 1/5. That means that an DR of 5.0 will appear the same as DR of 0.200. The difference in response between these values of 5.0 and 0.2 is in the dominance feature. If in doubt about the type of derivative to use, then set up for feedback dominant, 1 < DR < 100.

Proportional + Derivative (Closed Loop)

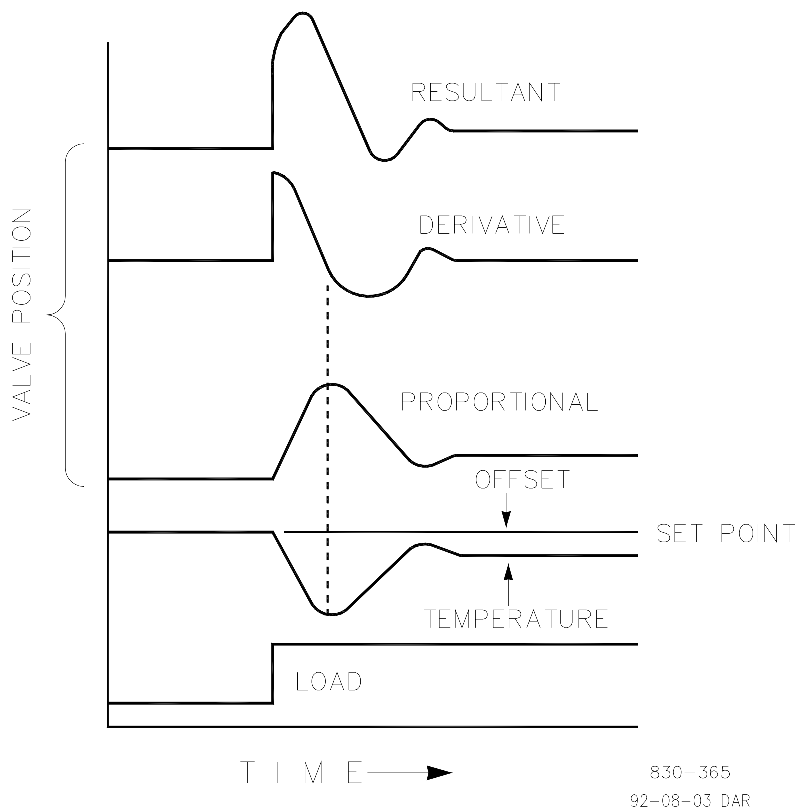

Figure 5-5. Closed Loop Proportional and Derivative Action

Figure 5-5 shows how Derivative acts to oppose a change in process in either direction. The dashed line shows the Derivative action going through zero to oppose the process deviation traveling toward zero. Notice offset still exists between the desired setpoint and the drooped control point that resulted from the load change. The top curve is the resultant controller output, Proportional plus Derivative. If an upset (momentary) had occurred rather than a load change, there would be no offset.

Derivative (Effects of Settings)

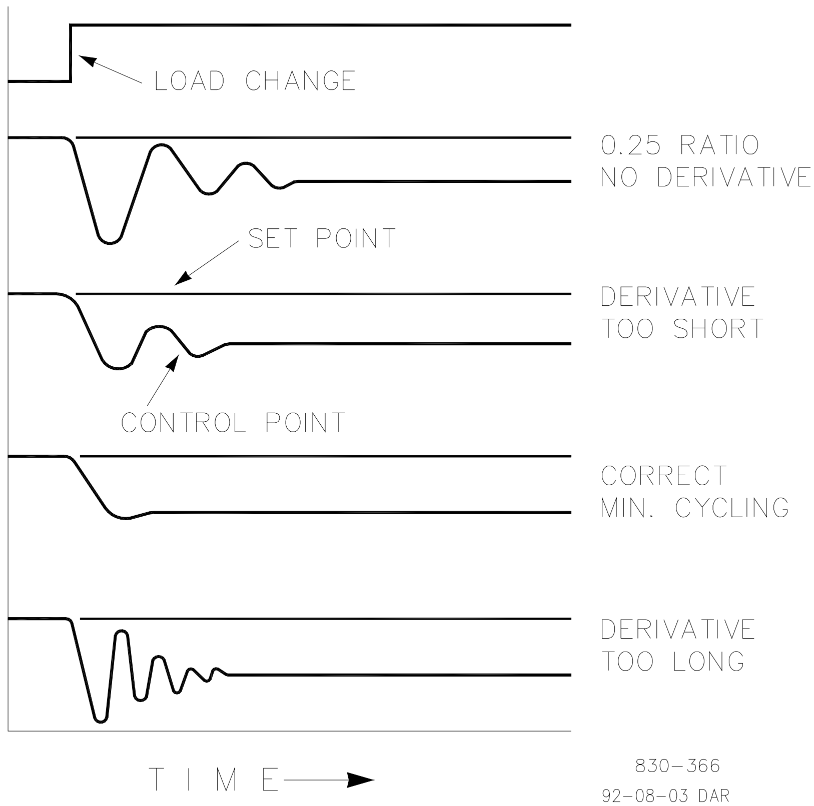

Figure 5-6. Derivative Setting Effects

Figure 5-6 shows the effect of different Derivative settings. The curves are relative since it depends on what type of control is desired in order to properly adjust Derivative time. For example, if minimum cycling is desired (as is shown here) then Derivative is added to the 1/4 decay cycle provided by Proportional until more than one cycle is removed and of course the 1/4 decay is destroyed. However, in most cases it is desirable to retain the 1/4 decay cycle, in which case Derivative is added to the point of removing only one cycle from the 1/4 decay ratio then the gain is increased until the 1/4 decay ratio is restored. In all the above curves, you will note offset exists since offset can only be eliminated by the addition of Integral (or Reset).

Proportional + Integral + Derivative (Closed Loop)

Figure 5-7 shows the relationship of valve position to the interaction of the PID modes of control whenever a load change takes place in closed loop. As the temperature drops due to the load change, the proportional action moves the control valve proportionately to the measurement (temperature) change. The integral gain/reset adds to the proportional action as a result of the magnitude and time (duration) of the deviation. And the derivative temporarily over-corrects based on the speed at which the measurement moves in any direction. The resultant curve (at the top) shows a similar over-correction (in this case), but in addition the valve will stay at the new position required to keep the measurement at the setpoint.

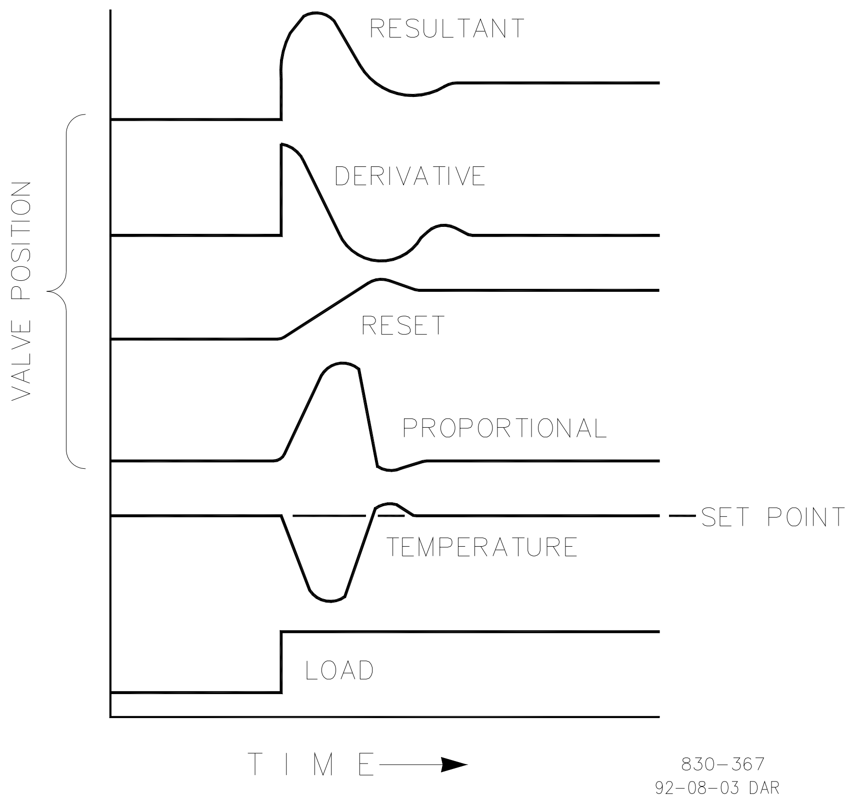

Figure 5-7. Closed Loop Proportional, Integral and Derivative Action

In summary, Derivative provides a temporary over-correction to compensate for long transfer lags and reduce stabilization time on process upsets (momentary disturbances).

NOTICE	**Do not use if high frequency noise is normally in the measured variable or the main lag is dead time. After Proportional is set to 1/4 decay ratio and Derivative is adjusted to remove one cycle as well as decreasing the 1/4 decay ratio, then the Proportional gain can be increased to restore the 1/4 decay ratio.**

Adding Derivative

The value of the Derivative Ratio (DR) term can range from 0.01 to 100. In order to simplify adjustment of the dynamics of the 5009C Control, adjusting the integral gain value sets both the I and D terms of the PID controller. The DR term establishes the degree of effect the integral gain value has on the "D" term, and changes the configuration of a controller from input rate sensitive (input dominant) to feedback rate sensitive (feedback dominant) and vice versa. Another possible use of the DR adjustment is to reconfigure the controller from a PID to a PI controller. This is done by adjusting the DR term to its upper or lower limits, depending on whether an input or feedback dominant controller is desired.

- A DR setting of 1 to 100 selects feedback dominant mode.
- A DR setting of .01 to 1 selects input dominant mode.
- A DR setting of .01 or 100 selects a PI only controller, input and feedback dominant respectively.

The change from one of these configurations to the other may have no effect during normal operation, however, it can cause great differences in response when the governor is coming into control. (at start-up, during a full load change, or during transfer of control from another channel).

An input dominant controller is more sensitive to the change-of-rate of its input (Speed, Cascade in or Auxiliary in), and can therefore prevent overshoot of the setpoint better than a feedback dominant controller. Although this response is desirable during a start-up or full load rejections, it can cause excessive control motions in some systems where a smooth transition response is desired.

A controller configured as feedback dominant is more sensitive to the change-of-rate of its feedback (LSS). A feedback dominant controller has the ability to limit the rate of change of the LSS bus when a controller is near its setpoint but is not yet in control. This limiting of the LSS bus allows a feedback dominant controller to make smoother control transitions than an input dominant controller.

General Field Tuning Guidelines

The quality of regulation obtained from an automatic control system depends upon the adjustments that are made to the various controller modes. Best results are obtained when the adjustment (tuning) is done systematically. Prior training and experience in controller tuning are desirable for effective application of this procedure.

This procedure will lead to controller settings which will provide:

- Process control without sustained cycling.
- Process recovery in a minimum time

Controller settings derived for given operating conditions are valid over a narrow range of load change. The settings made for one operating set of conditions may result in excessive cycling or highly damped response at some other operating condition. This procedure should be applied under the most difficult operating conditions to assure conservative settings over the normal operating range. It is good practice to keep the average of the setpoint changes near the normal setpoint of the process to avoid excessive departure from normal operating level. After each setpoint change, allow sufficient time to observe the effect of the last adjustment (see Figure 5-8). It is wise to wait until approximately 90% of the change has been completed.

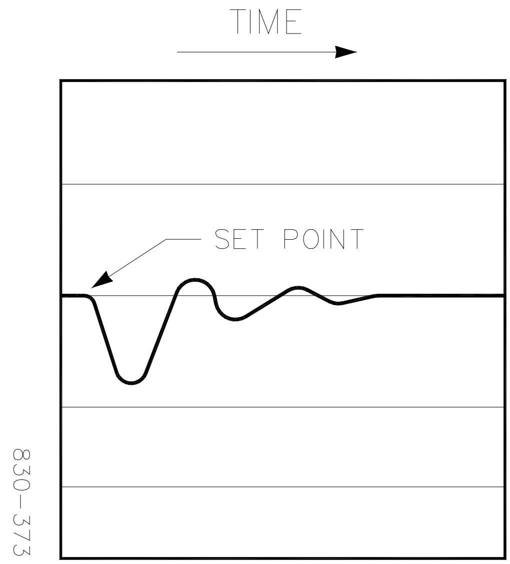

Figure 5-8. Typical Response to Load Change

Tuning Example

If the system is unstable, make sure the governor is the cause. This can be checked by closing the valve limiter until it has control of the actuator output. If the governor is causing the oscillation, time the oscillation cycle time. A rule-of-thumb is, if the system's oscillation cycle time is less than 1 second reduce the Proportional gain term. A rule-of-thumb is, if the system's oscillation cycle time is greater the 1 second reduce the Integral gain term (proportional gain may need to be increased also). On an initial start-up with the 5009C Control, all PID dynamic gain terms will require adjustment to match the respective PID's response to that of its control loop. There are multiple dynamic tuning methods available that can be used with the control's PIDs to assist in determining the gain terms that provide optimum control loop response times.

The following method can be used to achieve PID gain values that are close to optimum:

1. Increase Derivative Ratio (DR) to 100 (Service Mode adjustment)

2. Reduce integral gain to 0.01 (Start Mode adjustment)

3. Increase proportional gain until system just starts to oscillate (Start Mode).

   The optimum gain for this step is when the system just starts to oscillate and maintains a self-sustaining oscillation that does not increase or decrease in magnitude.

4. Record the control gain (Kc) and oscillation period (T) in seconds.

5. Set the dynamics as follows:
   For PI control: G=P(I/s + 1)
   Set: Proportional gain = 0.45*Kc
   Integral gain = 1.2/T
   Derivative ratio = 100

   For PID control: G=P(I/s + 1 + Ds)
   Set: Proportional gain = 0.60*Kc
   Integral gain = 2/T
   Deriv ratio = 8/(T*Integral Gain) for fdbk dominant
   = (T*Integral Gain)/8 for input dominant

This method of tuning will get the gain settings close, they can be fine-tuned from this point.

Speed, Casc, Decoupling, Seal Gas PID, and Ext/Adm Dynamics Adjustments

Dynamic control values are programmed in the program mode and adjusted in the Run mode. They can be accessed by the PC Interface program (refer to Volume 3) or the OpView (refer to Volume 4). The Speed, Cascade, Auxiliary, and Extr/ Adm controls are PID controllers. The response of each control loop can be adjusted by selecting the dynamics mode as described above. Proportional gain, integral gain (stability), and SDR (speed derivative ratio) are the adjustable and interacting parameters used to match the response of the control loop with the response of the system. They correspond to the P (proportional), I (integral), and D (derivative) terms, and are displayed by the 5009C Control as follows:

P = Proportional gain (%)
I = Integral gain (%)
D = Derivative (determined by SDR and I)

Tuning P & I Gains

Proportional gain must be tuned to best respond to a system transient or step change. If system response is not known, a typical starting value is 5%. If proportional gain is set too high the control will appear to be overly sensitive, and may oscillate with a cycle time of less than 1 second.

Integral gain must be tuned for best control at steady state. If system response is not known a typical starting value is 0.5%. If the integral gain is set too high the control may hunt or oscillate at cycles times of over 1 second.

For best response the proportional gain and integral gain should be as high as possible. To obtain a faster transient response, slowly increase the proportional gain setting until the actuator or final driver output begins to oscillate or waver. Then adjust the integral gain as necessary to stabilize the output. If stability cannot be obtained with the integral gain adjustment, reduce the proportional gain setting.

A well tuned system, when given a step change, should slightly overshoot the control point then come into control.

A PID control loop's gain is a combination of all the gains in the loop. The loop's total gain includes actuator gain, valve gain, valve linkage gain, transducer gain, internal turbine gains, and the control's adjustable gains. If the accumulated mechanical gain (actuators, valves, valve linkage, etc.) is very high, the control's gain must be very low to be added to the system gain required for system stability.

In cases where a small change in the control's output results in a large speed or load change (high mechanical gain) it may not be possible to take the control's gains low enough to reach stable operation. In those cases the mechanical interface (actuator, linkage, servo, valve rack) design and/or calibration should be reviewed and changed to achieve a gain of one where 0-100% 5009C output corresponds to 0-100% valve travel.

Dual Dynamics (Speed/Load)

The Speed PID has two sets of dynamics, On-Line and Off-Line; each include Proportional Gain, Integral Gain, and Derivative Ratio (SDR) variables.

The on-line PID will be selected as soon as the engine reaches min governor speed.

Cascade, Decoupling, Seal Gas, or Extr/Adm Droop

The Cascade, Decoupling, and Extr/Adm controllers can be programmed to use droop for control loop stability. If the parameter being controlled (Casc, Aux, Extr/Adm) is also being controlled by another device (letdown station, boiler, or other turbine), droop is typically required for control loop stability. If required, no less than 5% droop is recommended for stable operation.

Tuning Derivative

The value of the Derivative Ratio (DR) term can range from 0.01 to 100. If unsure of the correct value, set the Speed control's DR term to 5% and the Aux, Cascade, & Extr/Adm controllers' DR terms to 100%. In order to simplify adjustment of the dynamics, adjusting the integral gain value sets both the I and D terms of the PID controller. The DR term establishes the degree of effect the integral gain value has on the "D" term, and changes the configuration of a controller from input rate sensitive (input dominant) to feedback rate sensitive (feedback dominant) and vice versa.

Another possible use of the DR adjustment is to reconfigure the controller from a PID to a PI controller. This is done by adjusting the DR term to its upper or lower limits, depending on whether an input or feedback dominant controller is desired.

- A DR setting of 1 to 100 selects feedback dominant mode.
- A DR setting of .01 to 1 selects input dominant mode.
- A DR setting of .0101 or 100 selects a PI only controller, input and feedback dominant respectively.

The change from one of these configurations to the other may have no effect during normal operation, however, it can cause great differences in response when the governor is coming into control. (at start-up, during a full load change, or during transfer of control from another channel).

An input dominant controller is more sensitive to the change-of-rate of its input (Speed, Cascade in, Auxiliary in, or Extr/Adm in), and can therefore prevent overshoot of the setpoint better than a feedback dominant controller. Although this response is desirable during a start-up or full load rejections, it can cause excessive control motions in some systems where a smooth transition response is desired.

A controller configured as feedback dominant is more sensitive to the change-of-rate of its feedback (LSS in the case of Speed and Aux). A feedback dominant controller has the ability to limit the rate of change of the LSS bus when a controller is near its setpoint but is not yet in control. This limiting of the LSS bus allows a feedback dominant controller to make smoother control transitions than an input dominant controller.

Overspeed Test Function

The Overspeed Test function allows an operator to increase turbine speed above its rated operating range to periodically test the turbines electrical and/or mechanical overspeed protection logic and circuitry. This includes the control's internal overspeed trip logic and any external overspeed trip device's settings and logic.

There are two types of overspeed tests available depending on whether you are testing the control's trip logic or and external device. The Electrical (5009C Control) Overspeed Test tests the overspeed functionality of the 5009C control. The External Overspeed Test tests the functionality of any external overspeed device and overrides the 5009C Control's overspeed trip. An overspeed test is only allowed under the following conditions:

- The Speed PID must be in control.
- Cascade, Ext/Adm, and Remote Speed Set Point functions must be disabled.
- Speed setpoint must be at the maximum governor speed setting.

Peak Speed Register—The control uses a Peak Speed register to save the highest speed sensed by the control. This register can only be reset through the control's PCI program or a "Clear Highest/Max Speed Hold Value" Modbus command. It is recommended that this register be reset before every overspeed test.

Testing Notes

- During an Overspeed Test, the speed setpoint can only be raised up to the "Overspeed Test Limit" setting. The control is defaulted to automatically trip if turbine speed reaches the Overspeed Test Limit setting (changeable via the PCI program's Service mode).
- If the speed remains above the maximum governing speed for more than 60 seconds (as defaulted in Service mode) without any adjustment to the speed set point, the speed set point will automatically ramp back down to the maximum governing speed. If the speed remains above the Overspeed trip (External Test) setting for more than 60 seconds (as defaulted in Service mode) without any adjustment to the speed set point, an emergency shutdown will be issued.
- The programmable "Overspeed Trip" indication relay only energizes when an Emergency shutdown is performed due to an Overspeed Trip condition.

- The programmable "Overspeed Test Enabled" indication relay will energize when an Overspeed Test is performed. This relay toggles on and off when turbine speed is above the turbine Overspeed trip setting.

Electrical (5009C Control) Overspeed Test Procedure—The Electrical (5009C Control) Overspeed Test tests the overspeed functionality of the 5009C Control.

1. Reset the control's Peak-Speed register.

2. Verify that the turbine is in speed control then raise the speed setpoint to the "maximum control speed" setting.

3. Initiate the Overspeed Test through the PCI program, a contact input or Modbus command (OpView).

4. Raise the speed setpoint to the Electrical Overspeed Trip point.

5. **PCI or Modbus based test**—If performing this test through the PCI program or Modbus, when the turbine reaches the overspeed trip point the control will issue an alarm, and perform an emergency shutdown. OR

External (5009C Control) Overspeed Test Procedure—The External Overspeed Test tests the functionality of any external overspeed device and overrides the 5009C Control's overspeed trip. The following procedure will test the turbine's external overspeed trip(s).

1. Reset the control's Peak-Speed register.

2. Verify that the turbine is in speed control then raise the speed setpoint to the "maximum control speed" setting.

3. Initiate the Overspeed Test through the PCI program, a contact input or Modbus command (OpView).

4. Raise the speed setpoint to the Electrical Overspeed Trip point.

5. **PCI or Modbus based test**—If performing this test through the PCI program or Modbus, when the turbine reaches the overspeed trip point the control will issue an alarm, but WILL NOT shut down the turbine. OR

   Contact Input based test—If performing this test with the Overspeed Test contact input, when the turbine reaches the overspeed trip point the control will issue an alarm. At this point the contact input must be held closed to allow turbine speed to be increased to test the external device. At this point if the contact input is opened the unit will perform an emergency shutdown.

6. When the turbine reaches the external overspeed trip point the external overspeed device (mechanical trip) will trip the turbine.

There are two programmable relay options available to indicate overspeed status. One programmable relay option indicates an Overspeed Trip condition. The second relay option provides indication that a Overspeed Test is being performed. All pertinent overspeed test parameters are available through Modbus.

Operation Information

Once the control has been configured, calibrated, and dynamically adjusted, it is considered to be in the operational or Run mode. All of the operating parameters necessary to run the turbine are available from either the configurable contact and analog inputs or from a Modbus port. Input changes or Modbus communications are referred to as Start mode “commands”. The two Modbus ports in the 5009C Control can talk to the PC Interface program, the HMI workstation, and/or any external control system(DSC) capable of communicating via Modbus. For detailed information on how the PCI and HMI access the Run mode parameters, Refer to Volume 3 (PCI) and Volume 4 (HMI). For detailed information on how PCI configures the contact and analog input “commands” and tunes the analog inputs (Service Mode), Refer to Volume 3.

IMPORTANT **In the event that more than one command is received(conflicting contact input and Modbus command) the last command received will be the command acted upon.**

Speed Control

The Speed controller can not be disabled. When Decoupling and cascade control have been disabled, the speed PID will try to control the turbine at the speed setpoint. The Cascade controller will track the speed PID in order to achieve a bumpless transfer if they are enabled. Control of the speed of the turbine is obtained by manipulating the speed setpoint, when the Speed controller is the controlling parameter.

During the initial start sequence the 5009C Control ramps the speed setpoint up to the configured idle or minimum control settings. The rate at which the setpoint changes is configured in the PC Interface program. Once the turbine is up to minimum control speed, the speed setpoint is adjusted through the RAISE SPEED and LOWER SPEED commands. Again, the rate of change is configurable through the PC Interface program. If the RAISE or LOWER command is continually given for more than three seconds, the rate of change goes to the fast rate (three times the configured rate). The speed setpoint adjustment commands are available whenever the Auxiliary controller and the Cascade controller are both disabled.

If the Cascade controller is enabled, the cascade setpoint will have tracked the speed setpoint and will provide a bumpless transfer to cascade control. The speed setpoint will be adjusted by the cascade PID and at the point of transfer they will be the same. The Speed controller will still control the turbine, but the Cascade controller will now control the speed setpoint. Since the Cascade controller is based on some other parameter (not speed), the raise and lower speed commands are disabled. Because the Cascade controller changes the speed setpoint and not the actual LSS bus, whenever the Cascade is disabled, a bumpless transfer back to speed control occurs. The raise and lower speed commands are then enabled.

Remote Speed Set Point—An additional feature of the Speed controller is the remote speed setpoint. The Remote Speed Set Point Mode can be enabled and disabled through ENABLE and DISABLE commands. It can only be enabled if the Auxiliary controller and the Cascade controller are both disabled. If the Remote Speed Set Point is enabled, the speed setpoint will ramp towards the remote speed setpoint at a configured rate (initial PCI configuration). The remote speed setpoint is determined by a 4–20 mA analog input. This input signal is controlled from an external device. This allows some other parameter not monitored by the 5009C to control the speed of the turbine. The actual speed setpoint will ramp to the remote speed setpoint at an initial configured rate whenever the Remote Speed Set Point Mode is enabled. Once in control, as the remote speed setpoint input changes, the speed setpoint will ramp towards it at the max speed setpoint rate (as configured in the PCI). If the Remote Speed Set Point Mode is disabled, the speed setpoint will remain where it is at until a new command is received.

In the event that the remote speed setpoint input(4–20 mA) is not within tolerance (failed input), an alarm will be given and the Remote Speed Set Point Mode will be automatically disabled.

Cascade Control

The Cascade controller can be enabled and disabled using the ENABLE and DISABLE cascade control commands. The Auxiliary controller must be disabled to initiate cascade control. While cascade control is disabled, the cascade PID output is automatically adjusted to track the LSS bus by the 5009C Control. When the enable command is given, the raise and lower speed commands are disabled and the control sets the cascade input as the controlling parameter. Since the cascade setpoint has tracked the LSS bus, the transfer is bumpless and the cascade setpoint matches the speed setpoint.

Once the Cascade controller has been enabled, the cascade setpoint can then be adjusted through the RAISE CASCADE and LOWER CASCADE commands. The rate at which the cascade setpoint changes is configured in the PC Interface program. If the RAISE or LOWER command is continually given for more than three seconds, the rate of change goes to the fast rate (three times the configured rate). The cascade setpoint adjustment commands are available whenever the Cascade controller is enabled.

IMPORTANT

The rate at which the cascade setpoint changes is independent of the P, I, & D terms of the actual cascade PID. Moving the setpoint at a slower rate will not slow down the rate at which the Cascade controller moves the speed setpoint.

Remote Cascade Set Point—An additional feature of the Cascade controller is the remote cascade setpoint. The Remote Cascade Set Point Mode can be enabled and disabled through ENABLE and DISABLE commands. It can only be enabled if the Cascade controller is enabled and the Auxiliary controller is disabled. If the Remote Cascade Set Point Mode is enabled, the cascade setpoint will ramp towards the remote cascade setpoint at a configured rate (PCI). The remote cascade setpoint is determined by a 4–20 mA analog input. This input signal is controlled from an external device. This allows some other parameter not monitored by the 5009C to control the turbine. The actual Cascade setpoint will ramp to the remote cascade setpoint at an initial configured rate whenever the Remote Cascade Set Point Mode is enabled. Once in control, as the remote cascade setpoint input changes, the cascade setpoint will ramp towards it at the max cascade setpoint rate (PCI). If the Remote Cascade Set Point Mode is disabled, the cascade setpoint will remain where it is at, until a new command is received.

In the event that the remote cascade setpoint input(4–20 mA) is not within tolerance (failed input), an alarm will be given and the Remote Cascade Set Point Mode will be automatically disabled.

Valve Limiters

The HP and LP valve limiters, once configured, are enabled at all times. The limiters “limit” the valve position. The HP limiter puts a high limit on the HP valve, and the LP limiter puts either a high or a low limit on the LP valve. High limit for extraction turbines and a low limit on admission or extr/admission turbines. The limiters are adjustable at all times by using the OPEN and CLOSE commands. The rate at which the limiters move and the span (in %) in which they can be adjusted are configurable in the PCI.

Extraction/ Admission Control

The Extraction/Admission controller can be enabled and disabled using the ENABLE and DISABLE Extr/Adm control commands, or it can automatically be enabled by the 5009C Control when all permissives have been met. Refer to Chapter 5 of this manual for a detailed description of all the features of Extr/Adm control. While Extr/Adm control is disabled, the Extr/Adm setpoint can be automatically adjusted to track the Extr/Adm input. When the enable command is given, the control is already controlling at the present setpoint and a bumpless transfer is made. The setpoint then can be raised and lowered through RAISE and LOWER Extr/Adm commands. If setpoint tracking has been disabled, the valve limiters as described above are used to slowly bring the Extr/Adm input into the control range. Once the Extr/Adm controller is in control, the RAISE and LOWER Extr/Adm commands will then change the Extr/Adm setpoint.

Remote Extraction/Admission Set Point—An additional feature of the Extr/ Adm controller is the Remote Extr/Adm setpoint. The Remote Extr/Adm Set Point Mode can be enabled and disabled through ENABLE and DISABLE commands. It can only be enabled if all permissives are met (refer to Chapter 5). If a contact input is programmed for enabling Remote Extr/Adm Set Point Mode, and another input is NOT programmed for Extr/Adm Set Point Mode, then the Remote Extr/ Adm Set Point Mode contact will perform both functions. Both inputs are available from the Modbus ports if Remote Extr/Adm Control is configured. The Remote Extr/Adm setpoint is determined by a 4–20 mA analog input. This input signal is controlled from an external device. This allows some other parameter not monitored by the 5009C to control the turbine. The actual Extr/Adm setpoint will ramp to the remote Extr/Adm setpoint at an initial configured rate whenever the Remote Extr/Adm Set Point Mode is enabled. Once in control, as the Remote Extr/ Adm setpoint input changes, the Extr/Adm setpoint will ramp towards it at the max Extr/Adm setpoint rate(PCI). If the Remote Extr/Adm Set Point Mode is disabled, the Extr/Adm setpoint will remain where it is at, until a new command is received.

In the event that the Remote Extr/Adm setpoint input (4–20 mA) is not within tolerance (failed input), an alarm will be given and the Remote Extr/Adm Set Point Mode will be automatically disabled.

Alarms

A listing of Alarm and Trip messages is available only through the Modbus ports (OpView, PCI program). Relay outputs can be configured in the PCI program for some individual alarm/trip indications (Refer to Volume 3) and also for any alarm/trip present indication. But for a description and time stamping as described in the following chapter, a Modbus port must be used.

Chapter 6.
Service Options

Product Service Options

If you are experiencing problems with the installation, or unsatisfactory performance of a Woodward product, the following options are available:

- Consult the troubleshooting guide in the manual.
- Contact the manufacturer or packager of your system.
- Contact the Woodward Full Service Distributor serving your area.
- Contact Woodward technical assistance (see "How to Contact Woodward" later in this chapter) and discuss your problem. In many cases, your problem can be resolved over the phone. If not, you can select which course of action to pursue based on the available services listed in this chapter.

OEM and Packager Support: Many Woodward controls and control devices are installed into the equipment system and programmed by an Original Equipment Manufacturer (OEM) or Equipment Packager at their factory. In some cases, the programming is password-protected by the OEM or packager, and they are the best source for product service and support. Warranty service for Woodward products shipped with an equipment system should also be handled through the OEM or Packager. Please review your equipment system documentation for details.

Woodward Business Partner Support: Woodward works with and supports a global network of independent business partners whose mission is to serve the users of Woodward controls, as described here:

- A **Full Service Distributor** has the primary responsibility for sales, service, system integration solutions, technical desk support, and aftermarket marketing of standard Woodward products within a specific geographic area and market segment.
- An **Authorized Independent Service Facility (AISF)** provides authorized service that includes repairs, repair parts, and warranty service on Woodward's behalf. Service (not new unit sales) is an AISF's primary mission.
- A **Recognized Engine Retrofitter (RER)** is an independent company that does retrofits and upgrades on reciprocating gas engines and dual-fuel conversions, and can provide the full line of Woodward systems and components for the retrofits and overhauls, emission compliance upgrades, long term service contracts, emergency repairs, etc.
- A **Recognized Turbine Retrofitter (RTR)** is an independent company that does both steam and gas turbine control retrofits and upgrades globally, and can provide the full line of Woodward systems and components for the retrofits and overhauls, long term service contracts, emergency repairs, etc.

You can locate your nearest Woodward distributor, AISF, RER, or RTR on our website at:

www.woodward.com/directory

Woodward Factory Servicing Options

The following factory options for servicing Woodward products are available through your local Full-Service Distributor or the OEM or Packager of the equipment system, based on the standard Woodward Product and Service Warranty (5-01-1205) that is in effect at the time the product is originally shipped from Woodward or a service is performed:

- Replacement/Exchange (24-hour service)
- Flat Rate Repair
- Flat Rate Remanufacture

Replacement/Exchange: Replacement/Exchange is a premium program designed for the user who is in need of immediate service. It allows you to request and receive a like-new replacement unit in minimum time (usually within 24 hours of the request), providing a suitable unit is available at the time of the request, thereby minimizing costly downtime. This is a flat-rate program and includes the full standard Woodward product warranty (Woodward Product and Service Warranty 5-01-1205).

This option allows you to call your Full-Service Distributor in the event of an unexpected outage, or in advance of a scheduled outage, to request a replacement control unit. If the unit is available at the time of the call, it can usually be shipped out within 24 hours. You replace your field control unit with the like-new replacement and return the field unit to the Full-Service Distributor.

Charges for the Replacement/Exchange service are based on a flat rate plus shipping expenses. You are invoiced the flat rate replacement/exchange charge plus a core charge at the time the replacement unit is shipped. If the core (field unit) is returned within 60 days, a credit for the core charge will be issued.

Flat Rate Repair: Flat Rate Repair is available for the majority of standard products in the field. This program offers you repair service for your products with the advantage of knowing in advance what the cost will be. All repair work carries the standard Woodward service warranty (Woodward Product and Service Warranty 5-01-1205) on replaced parts and labor.

Flat Rate Remanufacture: Flat Rate Remanufacture is very similar to the Flat Rate Repair option with the exception that the unit will be returned to you in "like-new" condition and carry with it the full standard Woodward product warranty (Woodward Product and Service Warranty 5-01-1205). This option is applicable to mechanical products only.

Returning Equipment for Repair

If a control (or any part of an electronic control) is to be returned for repair, please contact your Full-Service Distributor in advance to obtain Return Authorization and shipping instructions.

When shipping the item(s), attach a tag with the following information:

- return authorization number;
- name and location where the control is installed;
- name and phone number of contact person;
- complete Woodward part number(s) and serial number(s);
- description of the problem;
- instructions describing the desired type of repair.

Packing a Control

Use the following materials when returning a complete control:

- protective caps on any connectors;
- antistatic protective bags on all electronic modules;
- packing materials that will not damage the surface of the unit;
- at least 100 mm (4 inches) of tightly packed, industry-approved packing material;
- a packing carton with double walls;
- a strong tape around the outside of the carton for increased strength.

NOTICE

To prevent damage to electronic components caused by improper handling, read and observe the precautions in Woodward manual 82715, *Guide for Handling and Protection of Electronic Controls, Printed Circuit Boards, and Modules*.

Replacement Parts

When ordering replacement parts for controls, include the following information:

- the part number(s) (XXXX-XXXX) that is on the enclosure nameplate;
- the unit serial number, which is also on the nameplate.

Engineering Services

Woodward offers various Engineering Services for our products. For these services, you can contact us by telephone, by email, or through the Woodward website.

- Technical Support
- Product Training
- Field Service

Technical Support is available from your equipment system supplier, your local Full-Service Distributor, or from many of Woodward's worldwide locations, depending upon the product and application. This service can assist you with technical questions or problem solving during the normal business hours of the Woodward location you contact. Emergency assistance is also available during non-business hours by phoning Woodward and stating the urgency of your problem.

Product Training is available as standard classes at many of our worldwide locations. We also offer customized classes, which can be tailored to your needs and can be held at one of our locations or at your site. This training, conducted by experienced personnel, will assure that you will be able to maintain system reliability and availability.

Field Service engineering on-site support is available, depending on the product and location, from many of our worldwide locations or from one of our Full-Service Distributors. The field engineers are experienced both on Woodward products as well as on much of the non-Woodward equipment with which our products interface.

For information on these services, please contact us via telephone, email us, or use our website: **www.woodward.com**.

How to Contact Woodward

For assistance, call one of the following Woodward facilities to obtain the address and phone number of the facility nearest your location where you will be able to get information and service.

Electrical Power Systems

Facility	Phone Number
Brazil	+55 (19) 3708 4800
China	+86 (512) 6762 6727
Germany	+49 (0) 21 52 14 51
India	+91 (129) 4097100
Japan	+81 (43) 213-2191
Korea	+82 (51) 636-7080
Poland	+48 12 295 13 00
United States	+1 (970) 482-5811

Engine Systems

Facility	Phone Number
Brazil	+55 (19) 3708 4800
China	+86 (512) 6762 6727
Germany	+49 (711) 78954-510
India	+91 (129) 4097100
Japan	+81 (43) 213-2191
Korea	+82 (51) 636-7080
The Netherlands	+31 (23) 5661111
United States	+1 (970) 482-5811

Turbine Systems

Facility	Phone Number
Brazil	+55 (19) 3708 4800
China	+86 (512) 6762 6727
India	+91 (129) 4097100
Japan	+81 (43) 213-2191
Korea	+82 (51) 636-7080
The Netherlands	+31 (23) 5661111
Poland	+48 12 295 13 00
United States	+1 (970) 482-5811

You can also locate your nearest Woodward distributor or service facility on our website at:

www.woodward.com/directory

Technical Assistance

If you need to telephone for technical assistance, you will need to provide the following information. Please write it down here before phoning:

Your Name ______________________

Site Location ______________________

Phone Number ______________________

Fax Number ______________________

Engine/Turbine Model Number ______________________

Manufacturer ______________________

Number of Cylinders (if applicable) ______________________

Type of Fuel (gas, gaseous, steam, etc) ______________________

Rating ______________________

Application ______________________

Control/Governor #1

Woodward Part Number & Rev. Letter ______________________

Control Description or Governor Type ______________________

Serial Number ______________________

Control/Governor #2

Woodward Part Number & Rev. Letter ______________________

Control Description or Governor Type ______________________

Serial Number ______________________

Control/Governor #3

Woodward Part Number & Rev. Letter ______________________

Control Description or Governor Type ______________________

Serial Number ______________________

If you have an electronic or programmable control, please have the adjustment setting positions or the menu settings written down and with you at the time of the call.

DECLARATION OF CONFORMITY
According to ISO/IEC Guide 22 and EN 45014

Manufacturer's Name:	WOODWARD GOVERNOR COMPANY (WGC) Industrial Controls Group
Manufacturer's Address:	1000 E. Drake Rd. Fort Collins, CO, USA, 80525
European Representative's Name:	WOODWARD GOVERNOR NEDERLAND BV
European Representative's Address:	Hoofdweg 601 P.O. Box 34 2130 AA Hoofddorp, The Netherlands
Model Name(s)/Number(s):	MicroNet™ Simplex and TMR Digital Control Systems, including 5009, in a non-EMI cabinet, 18-36 VDC.
Conformance to Directive(s):	89/336/EEC COUNCIL DIRECTIVE of 03 May 1989 on the approximation of the laws of the Member States relating to electromagnetic compatibility.
Applicable Standards:	EN50081-2, August 1993: EMC Generic Emissions Standard, Part 2 : Industrial Environment EN61000-6-2, January 1999: EMC Generic Standards – Immunity for Industrial Environment

We, the undersigned, hereby declare that the equipment specified above conforms to the above Directive(s).

MANUFACTURER

Signature
Jennifer R. Williams

Full Name
Jennifer R. Williams

Position
Engineering Manager

Place
WGC, Fort Collins, CO, USA

Date
29 March 2001

DECLARATION OF CONFORMITY
According to ISO/IEC Guide 22 and EN 45014

Manufacturer's Name:	WOODWARD GOVERNOR COMPANY (WGC) Industrial Controls Group
Manufacturer's Address:	1000 E. Drake Rd. Fort Collins, CO, USA, 80525
European Representative's Name:	WOODWARD GOVERNOR NEDERLAND BV
European Representative's Address:	Hoofdweg 601 P.O. Box 34 2130 AA Hoofddorp, The Netherlands
Model Name(s)/Number(s):	5009 MicroNet™ TMR Digital Control Systems, when installed in a non-EMI cabinet, 88-264 VAC, and 100-300 VDC.
Conformance to Directive(s):	89/336/EEC COUNCIL DIRECTIVE of 03 May 1989 on the approximation of the laws of the Member States relating to electromagnetic compatibility. 73/23/EEC COUNCIL DIRECTIVE of 19 February 1973 on the harmonization of the laws of the Member States relating to electrical equipment designed for use within certain voltage limits.
Applicable Standards:	EN50081-2, August 1993: EMC Generic Emissions Standard, Part 2: Industrial Environment EN61000-6-2, January 1999: EMC Generic Standards – Immunity for Industrial Environment EN61000-3-2, January 2000: EMC - Limits For Harmonic Current Emissions (Equipment Input Current < or = 16 A Per Phase) EN61000-3-3, September 1997: EMC – Limitation of Voltage Fluctuations and Flicker in Low-Voltage Supply Systems for Equipment with Rated Current Up To and Including 16A. EN50178, January 1997: Electronic Equipment For Use In Power Installations

We, the undersigned, hereby declare that the equipment specified above conforms to the above Directive(s).

MANUFACTURER

Signature

Jennifer R. Williams

Full Name
Jennifer R. Williams

Position
Engineering Manager

Place
WGC, Fort Collins, CO, USA

Date
25 May 2001

We appreciate your comments about the content of our publications.

Send comments to: icinfo@woodward.com

Please reference publication 26320V1B.

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Email and Website—www.woodward.com

Woodward has company-owned plants, subsidiaries, and branches, as well as authorized distributors and other authorized service and sales facilities throughout the world.

Complete address / phone / fax / email information for all locations is available on our website.

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