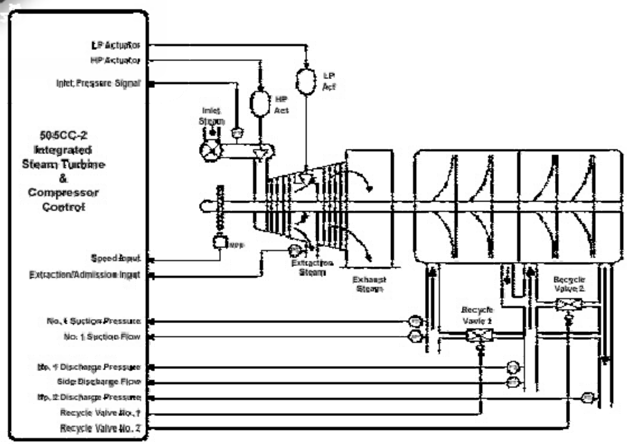
Product Manual 26542V3
(Revision D, 10/2014)
Original Instructions



505CC-2 Atlas-II™
Steam Turbine and Compressor Control

Compressor Control Manual
Part Number 8301-1258

Volume 3

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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Proper Use	**Any unauthorized modifications to or use of this equipment outside its specified mechanical, electrical, or other operating limits may cause personal injury and/or property damage, including damage to the equipment. Any such unauthorized modifications: (i) constitute "misuse" and/or "negligence" within the meaning of the product warranty thereby excluding warranty coverage for any resulting damage, and (ii) invalidate product certifications or listings.**

Translated Publications	**If the cover of this publication states "Translation of the Original Instructions" please note:** **The original source of this publication may have been updated since this translation was made. Be sure to check manual *26311* , *Revision Status & Distribution Restrictions of Woodward Technical Publications*, to verify whether this translation is up to date. Out-of-date translations are marked with ⚠. Always compare with the original for technical specifications and for proper and safe installation and operation procedures.**

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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

⚠WARNING

IOLOCK. When a CPU or I/O module fails, watchdog logic drives it into an IOLOCK condition where all output circuits and signals are driven to a known de-energized state as described below. The System MUST be designed such that IOLOCK and power OFF states will result in a SAFE condition of the controlled device.

- **CPU and I/O module failures will drive the module into an IOLOCK state.**
- **CPU failure will assert an IOLOCK signal to all modules and drive them into an IOLOCK state.**
- **Discrete outputs / relay drivers will be non-active and de-energized.**
- **Analog and actuator outputs will be non-active and de-energized with zero voltage or zero current.**

The IOLOCK state is asserted under various conditions including:
- **CPU and I/O module watchdog failures**
- **Power Up and Power Down conditions**
- **System reset and hardware/software initialization**
- **Entering configuration mode**

NOTE: Additional watchdog details and any exceptions to these failure states are specified in the related CPU or I/O module section of the manual.

1.1 Introduction

The 505CC-2 is a steam and compressor control designed for use on a single- or two-valve steam turbine driving a one- or two-loop dynamic compressor. This is volume 3 of the 26542 Woodward 505CC-2 Atlas-II™ manual. The manual encompasses three separate volumes:

- **Volume 1—**Provides information on the Commissioning Configuration software Tools (CCT), hardware interface, such as a description of the Atlas-II platform, modules, I/O interfaces used, installation, maintenance, and troubleshooting.
- **Volume 2—**Provides information on steam turbine control, configuration, service, and run mode configuration and settings.
- **Volume 3—**Provides information on compressor control, configuration, service, and run mode configuration and settings.

This volume is dedicated to the compressor control describing compressor control functionality, configuration, service, and run mode settings.

The 505CC-2 manual does not contain instruction for the operation of the complete turbine and compressor systems. For turbine, compressor, or plant operating instructions, contact the plant-equipment manufacturer.

1.2 Quick Start Guide

The following links provide shortcuts to pertinent information within this manual required of a typical installation. However, they are not intended to replace comprehensive understanding of the 505CC-2 and its functionality, it is still recommended to read and understand the manual fully.

Topic	Location (manual 26542)
Physical Installation / Wiring	Volume 1, Chapter 2
Software / System Configuration	Volume 1, Chapter 8
Modbus® *	Volume 1, Chapter 7
Security / Login Passwords	Volume 1, Chapter 8
Turbine Configuration Mode	Volume 2, Chapter 4
Turbine Service Mode	Volume 2, Chapter 5
Turbine Run Mode	Volume 2, Chapter 6
Compressor Configuration Mode	Volume 3, Chapter 4
Compressor Service Mode	Volume 3, Chapter 5
Compressor Run Mode	Volume 3, Chapter 6

*—Modbus is a trademark of Schneider Automation Inc.

Chapter 2.
Control Functionality

2.1 Introduction

The 505CC-2 is designed for compressor applications where protection and control are the primary concern. Typical applications include pipeline, utility (air, nitrogen, etc.), and chemical and refinery service. The 505CC-2 controls one or two recycle loops (or blow-off lines) on one- or two-section machines in a variety of physical configurations. Figure 2-1 shows a typical 2-section, 2-valve compressor train with an admission side-stream.

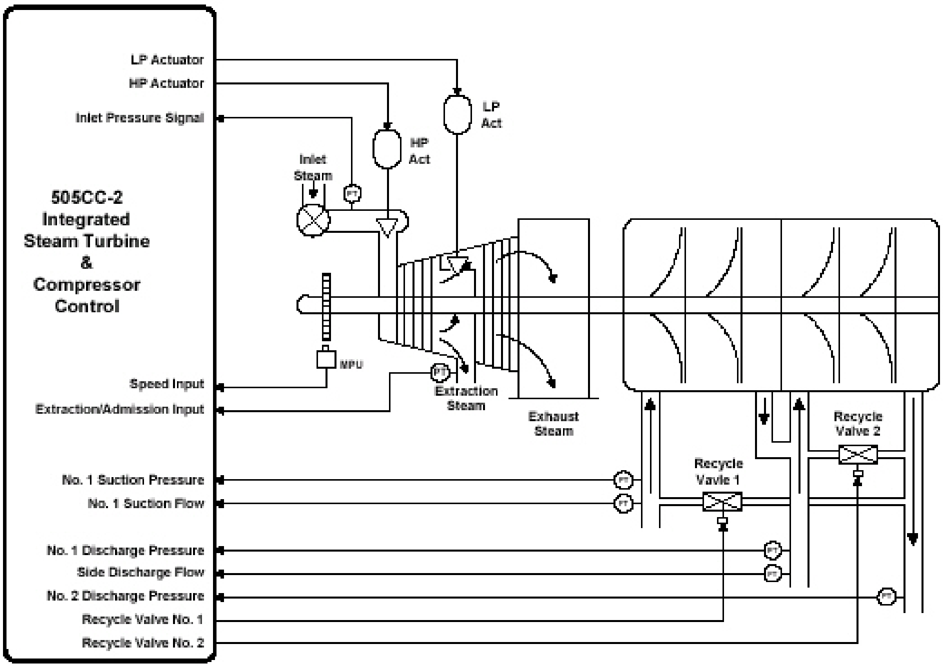


Figure 2-1. Typical Compressor Application

2.2 What is Surge?

Since the fundamental purpose of any compressor control is to prevent or limit the effects of surge, it is appropriate to review the phenomenon itself. Surge occurs when the low flow operation limit of a compressor has been exceeded, resulting in flow reversal. It is an unstable, pulsating condition that is usually evident by an audible boom, piping vibration, rapid increase in discharge temperature and oscillation of flow and discharge pressure. Violent surging may cause the following compressor damage:

- Open internal clearances which damage impeller seals and balance piston seals.
- Damage the compressor shaft end seals.
- Damage to compressor thrust bearings.
- Damage to compressor radial bearings.
- Cause impellers to rub against stationary diaphragm.
- Cause a shaft coupling failure.
- Possible shearing of drive shaft.

Along with compressor damage, the process flow and pressure can become very unstable contributing to upstream and downstream process upsets.

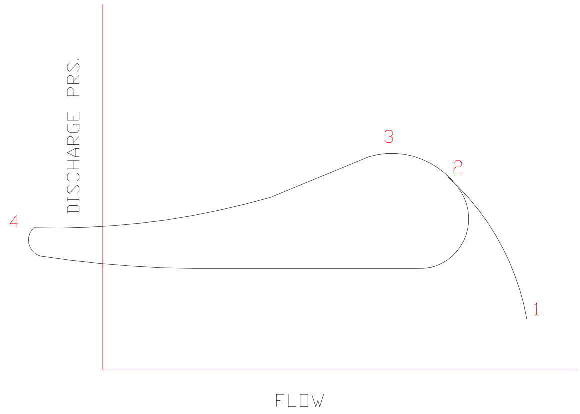


Figure 2-2. Surge Cycle

Figure 2-2 shows a simple surge cycle at a constant speed and constant suction pressure. The compressor, operating at point 1, has low discharge pressure and the output flow is at its maximum value. As the system resistance increases (e.g. discharge valve closes, downstream processes shutdown or decrease load, series units drop off-line, or parallel units come on-line), the compressor flow decreases, and discharge pressure increases. At operating point 2, the compressor is near the surge limit. As the system resistance increases further, the flow continues to decrease, and discharge pressure continues to increase. Eventually, a limit is reached where the compressor can no longer increase discharge pressure, such as at operating point 3. If the system resistance increases further, the discharge pressure at the compressor becomes greater than the machine's capability. This initiates a surge that spans between points 3 and 4. Flow may actually reverse through the compressor, as shown at point 4. A now reduced system resistance will allow increased flow back through the compressor that brings the operation back to point 2. This surge cycle will continue until broken by some control or operator action.

Maintaining flow above the compressor's surge limit prevents these surge conditions. The controller must continually monitor the operating point and compare it to the surge limit of the compressor. If the operating point reaches a minimum flow value, the controller responds by opening the anti-surge valve(s). This simultaneously causes the flow to increase and polytropic head to decrease, moving the operating point away from the surge limit.

2.3 Functional Overview

An overview of the 505CC-2 anti-surge and capacity control functions is shown in Figures 2-4 and 2-5. Use this diagram to match the 505CC-2's control features to the site-specific application.

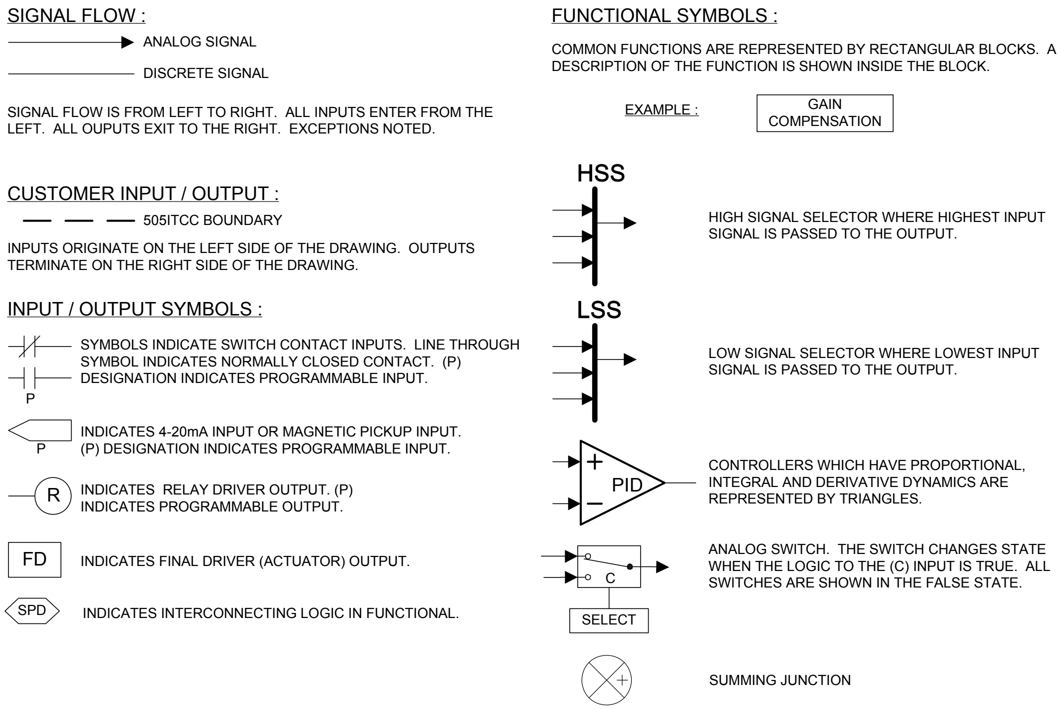


Figure 2-3. Overview of 505CC-2 Functionality Notes

See the next page for an overview of 505CC-2 anti-surge control functionality.

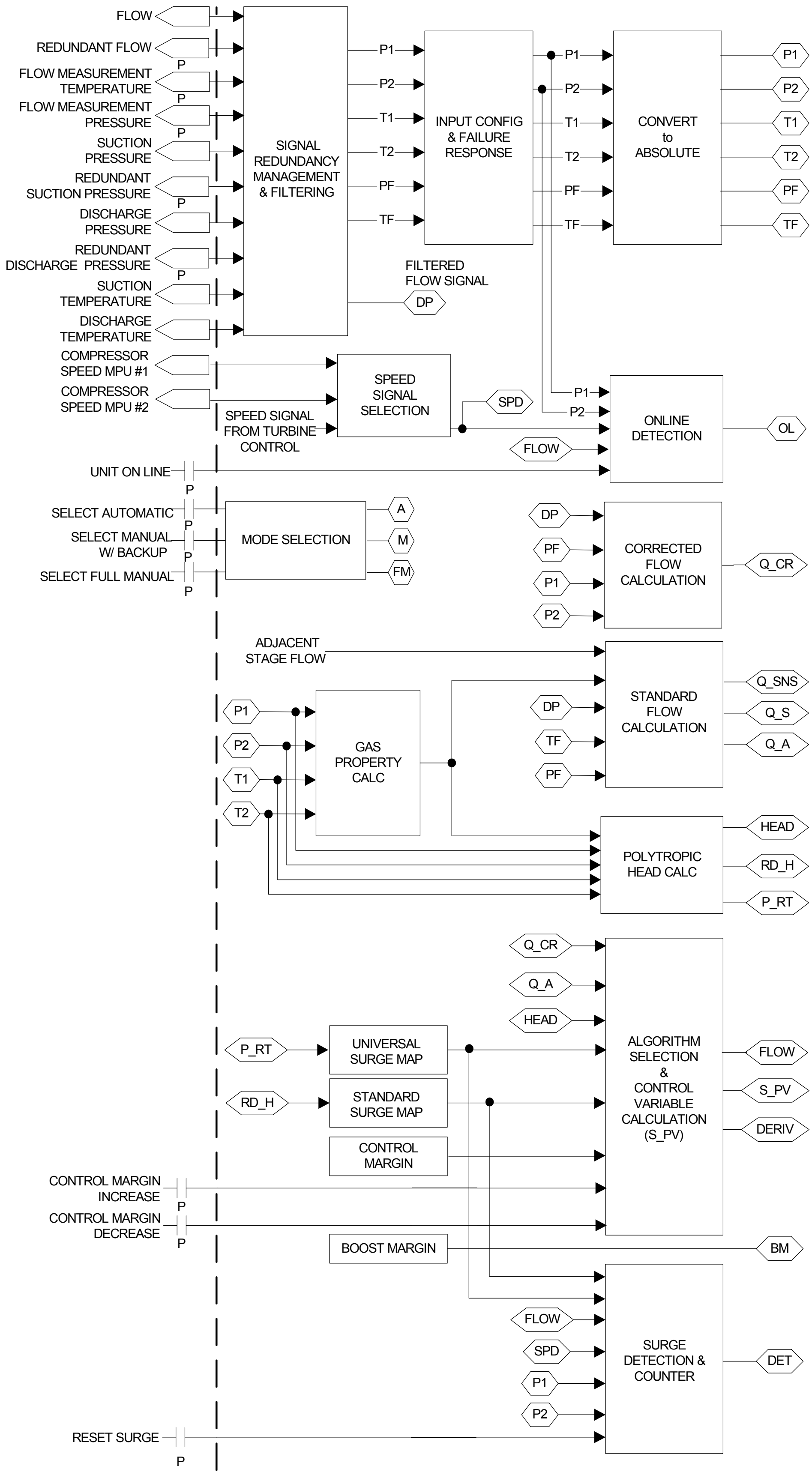


Figure 2-4. Overview of 505CC-2 Anti-Surge Control Functionality

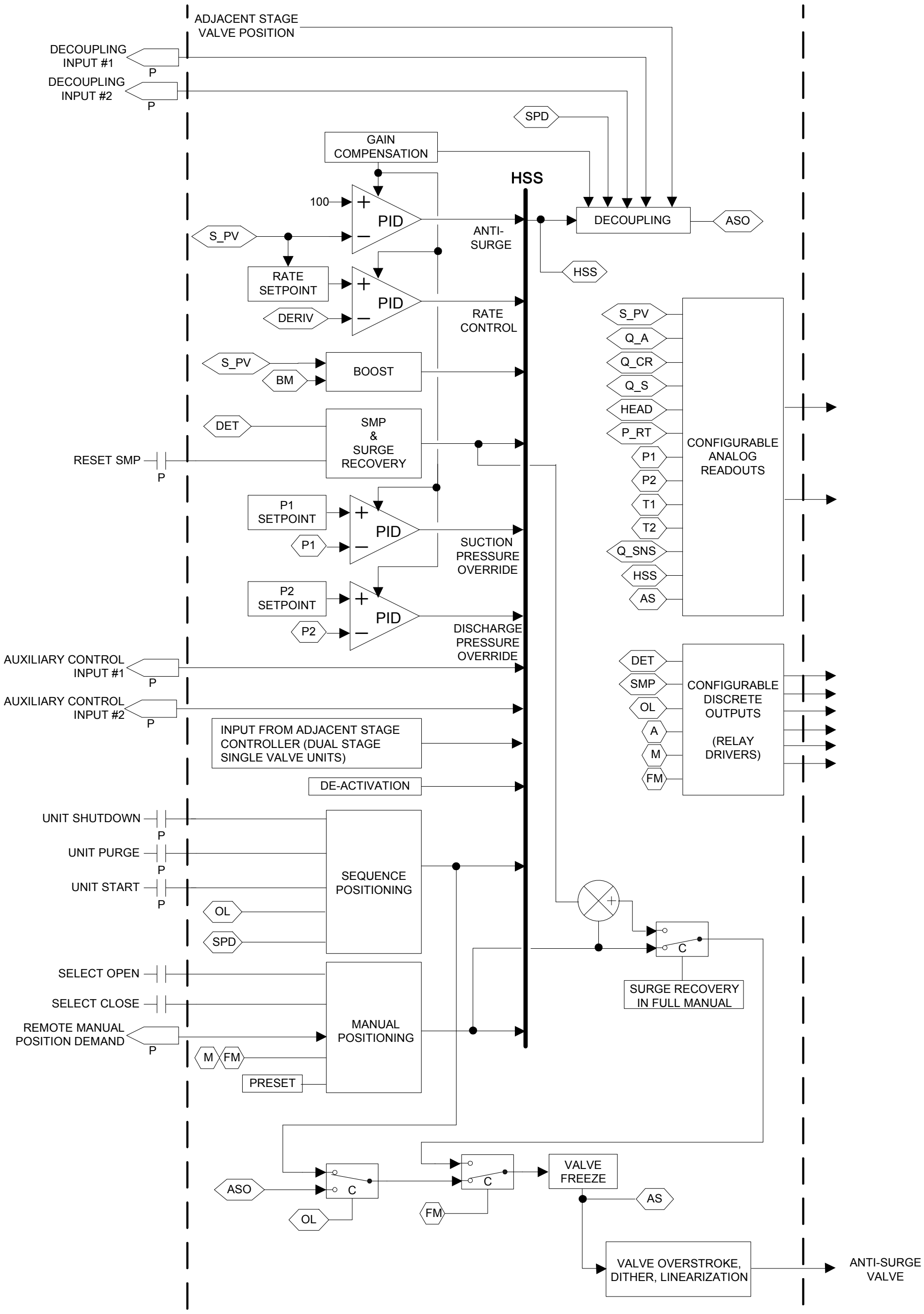


Figure 2-5. Overview of 505CC-2 Anti-Surge Control Functionality

2.4 Anti-Surge Control Theory

By modulating the anti-surge valve, the anti-surge controller maintains certain process conditions to:

- Prevent the compressor from operating in an unstable condition (surge or near surge), thereby preventing any surge related compressor damage.
- Reduce process upsets.
- Maximize the compressor and total train efficiency through utilization of control parameters.
- Assist the station or total compressor process control strategy.

In order to perform these tasks, the controller must monitor the current operating point, generate a Surge Control Line (SCL), and compare the two to determine if movement of the anti-surge valve is necessary.

The compressor performance map describes the relationship between speed, pressures, temperatures, gas properties, and inlet flow. This map will also describe the operating limits of the compressor in terms of a Surge Limit Line (SLL) or surge region. Several variations are possible on how this information is presented, each describing the compressor with a different set of variables. The 505CC-2 accommodates two such compressor map definitions, Standard and Universal.

2.5 Standard Compressor Performance Map

The Standard Compressor Map is described by polytropic head, Hp, versus actual volumetric suction flow, Qa, and compressor speed, N, Figure 2-6. Depending upon the compressor configuration and instrumentation, changes in molecular weight, temperature, and compressibility are compensated for accurate representation of the compressor operation.

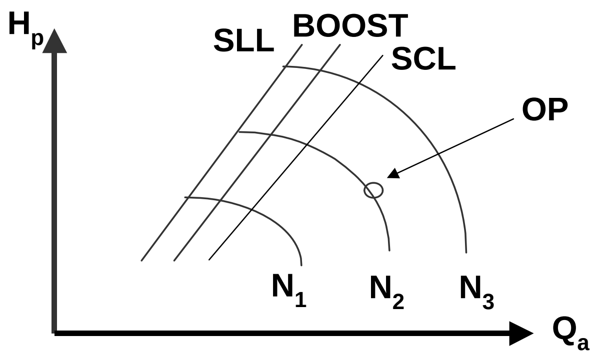


Figure 2-6. Standard Compressor Map

2.5.1 Standard Operating Point

The definition of an operating point is necessary for any digital controller. It is easy for a person to identify the current operating parameters and relate these parameters to a surge control line on a compressor map. However, this is a difficult task for a controller to perform in varying process applications. Therefore it is necessary to define an operating point as a single number that can be handled easily. A further enhancement is to normalize this calculation for ease of understanding.

The Standard compressor map is presented in terms of polytropic head, Hp, versus volumetric inlet flow, Qa, Figure 2-6. The operating point is also defined using these parameters. Simply, the operating point is defined as volumetric inlet flow squared divided by polytropic head.

$$\text{Operating Point} = \frac{(Q_a)^2}{H_p}$$

The result is a single number that identifies the operating point that can easily be manipulated by the controller and compared to a corresponding point on the Surge Control Line.

This calculation can be expanded to show that the operating point is invariant of the gas composition. All of the critical parameters in this equation can be measured, and the others can be estimated or assumed constant. A detailed explanation of the necessary equations can be found in the Operating Point Calculations section later in this chapter. For a simplified view of the measurements necessary to determine the operating point, refer to the process control diagram in Figure 2-7.

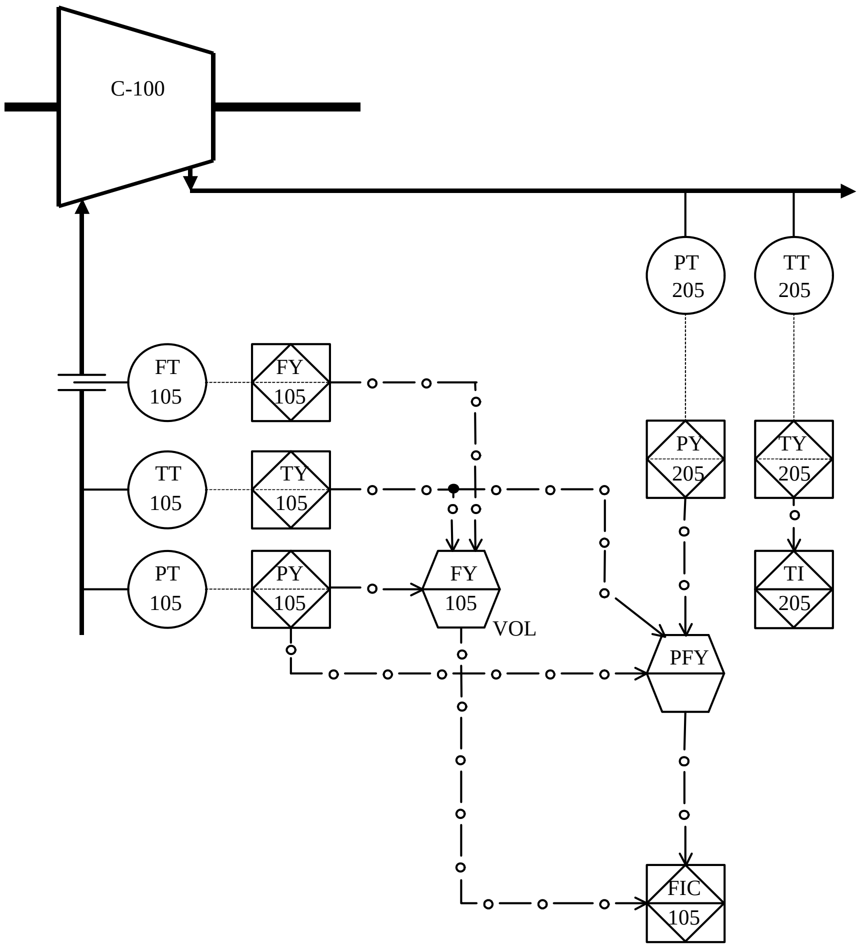


Figure 2-7. Process Control Diagram

Here it can be seen that the volumetric flow calculation is carried out using three measurements.

- PT-105, compressor suction pressure
- TT-105, compressor suction temperature
- FT-105, differential pressure across the flow element

The polytropic head calculation also requires three measurements.

- PT-105, compressor suction pressure
- PT-205, compressor discharge pressure
- TT-105, compressor suction temperature

If the gas composition through the compressor changes, the discharge temperature measurement, TT-205, would be necessary to calculate gas properties. This example assumes a suction flow element. Discharge flow elements are handled similarly.

2.5.2 Standard Surge Control Line

Only a portion of the compressor map must be programmed into the anti-surge controller. Data points from the surge limit line are collected from the compressor map, Figure 2-6, and entered into the controller. Combining the surge line and a safety margin (user configured as a percentage of flow from surge) defines the Surge Control Line (SCL). This is the point at which the controller will limit operation by modulating the anti-surge valve.

The BOOST Line, or Backup Line, provides additional anti-surge protection. When the operating point (OP) reaches this line, a fixed response is triggered to prevent a surge. The BOOST Line is defined as a percentage of flow behind (to the left of) the Surge Control Line.

The Surge Limit Line is programmed into the controller as a series of six operating X-Y points. Compressor maps can be defined in different units. The 505CC-2 supports the following compressor map unit entries:

- Discharge pressure versus actual flow, P2=F(flow)
- Pressure ratio versus actual flow, P2/P1=F(flow)
- Polytropic head versus actual flow, H=F(flow)
- Woodward operating point versus reduced head, Q2/H=F(red head)

Occasionally the given compressor map is described in a different unit and will need to be converted.

Additionally, surge limits might be unproven or unknown, so it is sometimes desirable to determine the values used for the surge points by field mapping the compressor.

It is recommended that all six points are different and entered successively lowest to highest. Compressors typically have higher flow requirements with higher head values.

2.6 Universal Compressor Performance Map

While similar to the Standard Compressor Map, the Universal Compressor Map relates corrected suction flow, Q_{CR}, and pressure ratio, Pd/Ps, with compressor speed, N. This compressor map implementation, with the calculation of corrected flow, is invariant with process changes, such as molecular weight, pressure, temperature, and compressibility.

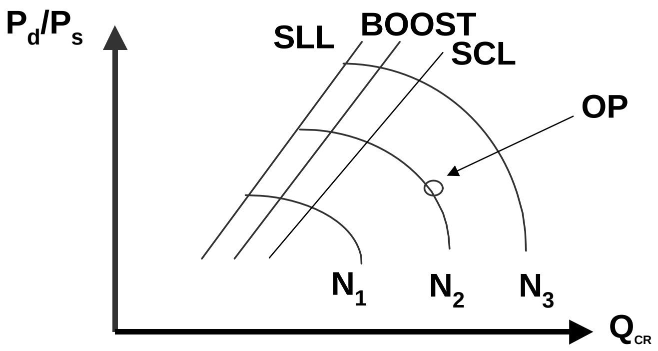


Figure 2-8. Universal Compressor Map

2.6.1 Universal Operating Point

The Universal Compressor Map is in terms of pressure ratio, Pd/Ps, versus corrected inlet flow, Q_{CR}. Since corrected flow itself is invariant of the gas composition, the operating point is defined simply as the corrected flow.

$$\text{Operating Point} = Q_{CR}$$

The result is a single number that identifies the operating point and can easily be manipulated by the controller and compared to a corresponding operating point on the Surge Control Line.

The calculation of the corrected flow variable, Q_{CR}, is the key to the Universal Algorithm's immunity to process changes. It is related to mass flow (Q_M) and more completely described as:

$$Q_{CR} = \frac{Q_M}{\rho \cdot \sqrt{RTZ}} = k\sqrt{\frac{h}{P}}$$

A detailed explanation of the necessary equations can be found in the Operating Point Calculations section later in this chapter. For a simplified view of the measurements necessary to determine the operating point, refer to the process control diagram in Figure 2-9.

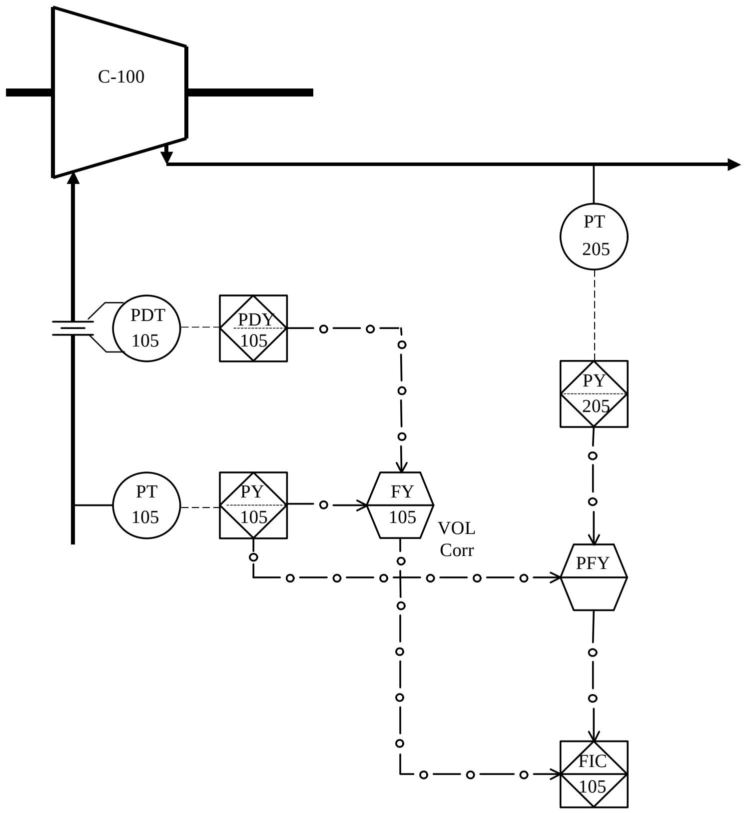


Figure 2-9. Process Control Diagram

Here it can be seen that the corrected volumetric flow calculation is carried out using only two measurements:

- PT-105, compressor suction pressure
- PDT-105, differential pressure across the flow element

The pressure ratio calculation also requires only two measurements:

- PT-105, compressor suction pressure
- PT-205, compressor discharge pressure

This example assumes a suction flow element. Discharge flow elements are handled similarly.

2.6.2 Universal Surge Control Line

The first step in configuring the control for use of the Universal Algorithm is to convert the manufacturer's compressor map, specifically five Surge Limit Line pairs, into the Q_{CR} versus Pd/Ps representation. These data pairs are entered into the controller.

As with the Standard Algorithm, a safety margin (user configured as a percentage of flow from surge) and BOOST, or Valve Step margin (defined as a percentage of flow behind, or to the left of, the Surge Control Line) determine the points at which the controller will limit operation by modulating or stepping open the anti-surge valve.

2.7 Standard or Universal Algorithm?

The decision of which algorithm to choose is largely subjective. The Standard Algorithm has been in use for compressor control for decades and is well accepted in the industry. The map is the same as that usually provided by the compressor manufacturer and is, thus, easily implemented. It also accepts any flow measurement input: linear, calibrated in mass or normal / standard volumetric units; or head-type, calibrated in flow element differential pressure with or without square root extraction. And, compensations are made for process changes in certain configurations.

The Universal Algorithm, one of several invariant coordinate systems, was developed as a more accurate predictor of compressor performance by eliminating any variances due to gas composition changes. Suction pressure, discharge pressure, and flow element differential pressure are the only measurements required, reducing instrumentation, cost, failure modes, etc. The corrected flow variable is calculated as a function of these measurements and a special corrected flow constant. This constant is calculated and input to the control during configuration and accounts for the method's immunity to gas composition changes.

The physical configuration of the compressor train occasionally dictates the use of one algorithm over another. See also Appendix B Valid Compressor Configurations.

2.8 S_PV (Surge Process Variable)

Regardless of the chosen map / algorithm, the anti-surge controller generates a single variable, S_PV (Surge Process Variable), to describe the relationship between the current operating point and the corresponding point on the surge control line. This is done to provide the user and the control one number that reflects the current operating condition.

Once the actual operating point and the corresponding surge control line point are calculated, the ratio of these two parameters is calculated and then normalized to the value of 100 as shown below.

$$S\_PV = \frac{operating\_point}{surge\_control\_line} \cdot 100$$

By normalizing the process variable, each compressor section that is protected will control to the same number, 100. Notice that this is independent of the control margin that is programmed. In all cases, if S_PV is equal to 100, the compressor is operating on the Surge Control Line.

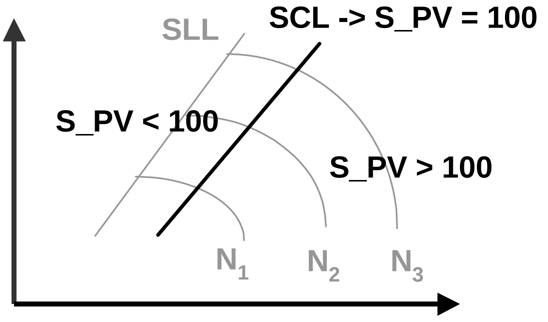


Figure 2-10. Compressor Map S_PV Regions

A surge control margin is programmed by adding between 5%-25% to the flow values for the actual surge points, establishing a Surge Control Line. A typical surge control margin of 10% is attainable on most applications with proper anti-surge valve sizing, stroking speed, etc. However, if the anti-surge valve stroking speed or sizing is not optimal, the surge margin may need to be increased to insure protection of the compressor.

If S_PV is greater than 100, the compressor is operating in a safe region of the compressor map. During this condition the anti-surge controller is able to close the anti-surge valve. When the value is equal to or less than 100, the anti-surge control will modulate the anti-surge valve to limit the operation of the compressor to be no further left than the Surge Control Line. Additionally, since compressor flow is proportional to speed, any speed reference lower commands in the motor control are inhibited when compressor operation is on or near its control line. Failure to do so could inadvertently drive the compressor into surge by reducing flow.

To an operator, S_PV is an indication of how far away the compressor is operating from the surge control line. Since the control set-point is always 100, regardless of the control margin, the operator can judge if the anti-surge valve will open when performing a process function. For example, a value of 180 indicates that the compressor is 80% of flow beyond the surge control line--The compressor is operating far from surge and the anti-surge system should close the anti-surge valve.

2.9 505CC-2 Anti-Surge Control Description

The anti-surge software provides all necessary functions from manual control to sequencing to closed loop PID control.

When the anti-surge control is in the Automatic mode or Manual with Backup mode, there are several controllers that can position the anti-surge valve. Each routine is an input into a high signal selector (HSS). The input with the highest value will control the anti-surge valve. These routines can be broken down into anti-surge control and process control routines.

In addition to compressor protection there are other supporting functions of the anti-surge control that reduce upsets, increase accuracy, and simplify programming.

2.9.1 Control Modes

While on-line, the anti-surge controller is designed to operate in one of three control modes, Automatic, Manual with Backup, and Full Manual. These modes are provided to give the operator any level of control that is desired.

If the milliamp signal of the flow input is out of range (below 2 mA), an alarm will occur, the system reverts to Full Manual mode, and the anti-surge valve is positioned a configured percentage open. In this case, the Automatic and Manual w/ Backup modes will be inhibited until the input signal is corrected. If configured, a high-scale failure (above 22 mA) may alarm only—It is common for compressors to operate beyond the scale of a flow transmitter that is calibrated closer to surge limit flows. If desired, the same Fail to Full Manual response to a flow signal failure can be enabled for other inputs (pressures and temperatures).

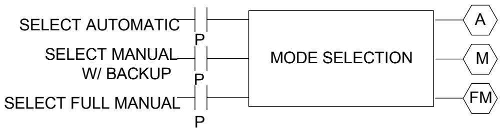


Figure 2-11. Mode Select

2.9.1.1 Automatic Mode

This is the strictest form of anti-surge control. There are no means for the operator to open or close the valve, except to change the process conditions.

The surge controller determines the operation of the anti-surge valve. The control monitors S_PV and then determines the position of the anti-surge valve. While the control is in Automatic, the Manual mode will track the current valve position for a bump-less transfer to Manual, if performed. From Full Manual, the transfer back to Automatic is not bump-less if the automatic routines require a higher valve position.

2.9.1.2 Manual with Backup Mode

In this mode, the operator is allowed to open the anti-surge valve, but the valve may not be closed below the automatic demand. Effectively, the output to the anti-surge valve is the higher of the manual signal or the automatic signal.

The control still monitors the compressor operating parameters and the compressor map. If the control determines that the manual position demand will decrease the compressor flow below that of the surge control line, the automatic control will override the manual demand and open the anti-surge valve. Decoupling, if configured, is still active while in this mode.

2.9.1.3 Full Manual Mode

In this mode, the operator manually moves the anti-surge valve. The automatic controllers are bypassed and cannot operate the anti-surge valve, no matter where the operating point is on the compressor map. Decoupling is not active while in this mode. If enabled (recommended), “Surge Recovery in Full Manual” will allow the open-loop surge recovery routine to activate if a surge is detected when in Full Manual control. Full Manual is available in the Engineering or higher login level.

2.9.1.4 Manual Valve Positioning

There are discrete inputs available for opening and closing the anti-surge valve when in Manual Mode. These inputs should be momentary, not sustained (toggles). When the input is closed, the valve is ramped at the configured “Manual Valve Rate.” If the input is held for five seconds, the ramp speed will increase to three times that rate. A maintained contact will result in continuous change of valve position until the valve reaches its limits (fully open or fully closed).

Additionally, if an exact position is desired, a preset value can be entered and the valve will ramp to that position at the configured rate, described above.

Each of these positioning commands is disabled if Remote Positioning, described below, is active.

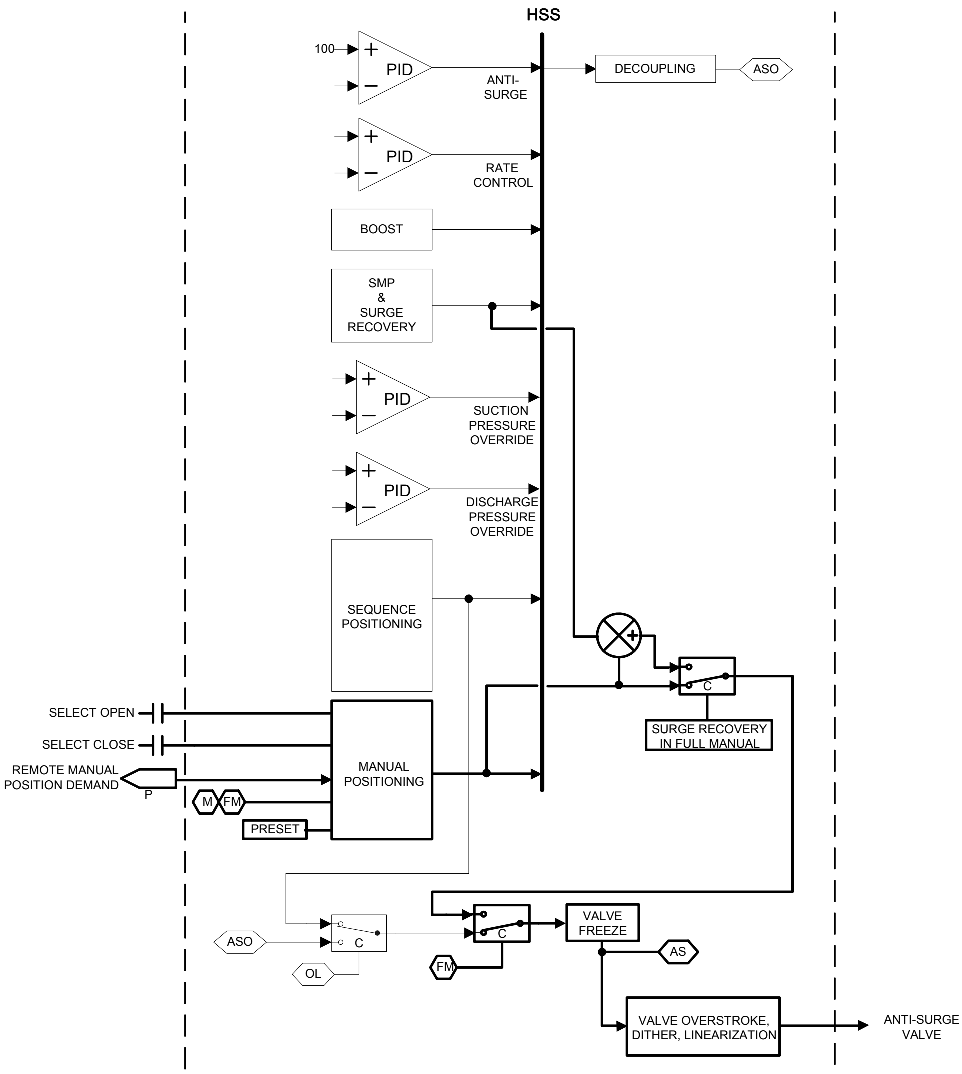


Figure 2-12. Manual Setting of Anti-Surge Valve

2.9.1.5 Remote Manual Valve Positioning

The Manual position can also be controlled via an analog signal. This allows an external control, such as a DCS (Distributed Control System) or other device, to position the anti-surge valve. The Remote Manual Valve Position’s range is determined by the analog input’s 4–20 mA range. While this range is configurable like any other analog input, it should not be set outside of 0 to 100%. “Remote Enable” must be selected in the compressor configuration.

If enabled, the Remote Manual Valve Position must match the current Manual position within 0.5% to permit remote control. Otherwise, remote positioning is inhibited. Once within 0.5%, the Remote Manual Valve Position will take over control. Regardless of the rate of change of the remote input, the valve will ramp at the configured “Auto Decay Valve Rate.” Remote Manual Valve Positioning is automatically disabled on failure of the analog input or on any Fail to Manual condition (flow signal failure, etc.). Other Manual mode controls, such as the open/close discrete inputs and preset command, are disabled when remote positioning is active.

2.9.2 Sequencing Functions

During start-up and shutdown of the compressor, the compressor flow is fluctuating, and the process is unstable. This time between a start and stable automatic control is termed “off-line.” A separate routine is focused on detecting when automatic, or “on-line,” operation is allowable.

To prevent the anti-surge controller from attempting any control function during the off-line period, sequencing provides fixed valve positioning. There are four programmable positions:

- Purge Position
- Start Position
- Shutdown Position
- Zero Speed Position

Speed set-points, discrete inputs, or combinations of both determine when to select the start, shutdown, and zero speed positions. The purge position can only be selected with a contact input or Modbus command.

Using speed can simplify sequencing by allowing software speed switches to determine what state of start-up/shutdown the prime mover is in. Alternatively, discrete inputs or Modbus commands can signal a start or shutdown.

2.9.2.1 Purge Position

A purge sequence is required during the start-up of some processes to close the anti-surge valve, partly or fully, and send forward the process gas. During start-up, but before an “on-line” condition is triggered, a sustained discrete input or Modbus command will position the anti-surge valve in the configured “Purge Position.” The valve will remain in that position as long as the input is held and the unit remains off-line. At least one Online Detection method must be configured, but not yet satisfied, to allow a Purge cycle.

2.9.2.2 Start Position

If speed is available, the start condition begins when speed exceeds the configured “Zero Speed Setpoint.” The anti-surge valve is ramped from the “Zero Speed Position” to the configured “Start Position” at the “Manual Valve Rate.” It will maintain this fixed position until the compressor is determined to be on-line. A momentary discrete input or Modbus command may also be used, but the software speed switch described here is always active. This start sequence is also reinitiated if any on-line trigger is deactivated while in normal operation.

2.9.2.3 Shutdown Position

At any time, the compressor can be shutdown from the motor software, from an ESD (Emergency Shutdown) or motor trip for example, or by a discrete input or Modbus command. In any case, the anti-surge valve is immediately positioned and held at the configured “Shutdown Position.” If the shutdown condition is cleared (discrete input opened or Modbus command cleared), the unit can be restarted as described above.

2.9.2.4 Zero Speed Position

The anti-surge valve will remain in the shutdown position until the unit is re-started or the speed drops below the "Zero Speed Setpoint" for a configured "Shutdown Delay Time." Once this delay timer expires, the anti-surge valve will be moved to the "Zero Speed Position." This position can be useful in applications requiring the anti-surge valve be closed for process isolation after the compressor is shutdown. If the application does not require this final sequencing step, configure the Zero Speed Position to the same value as the Shutdown Position and the Zero Speed Delay Time to 0 seconds.

IMPORTANT	**The zero speed sequencing described above is active only if a valid speed signal is available. If not, the unit will sequence to and from the shutdown position only. In this case, a "start" signal (discrete input, Modbus, HMI/DCS command) must be used to sequence the compressor online. If the unit is configured for compressor-only Mode, speed inputs are optional.**

2.9.2.5 On-Line Detection

Once all on-line triggers are satisfied (see below), the control will slowly close the anti-surge valve until the automatic anti-surge routines take control. If any on-line trigger is deactivated while in normal operation, the control returns to the start sequence.

On-line detection is an important determination made by the anti-surge controller. Once the compressor is determined to be on-line, the surge detection and automatic control routines are activated. Suction pressure, discharge pressure, flow, speed, and an auxiliary input may be used together or independently to determine when the compressor is on-line.

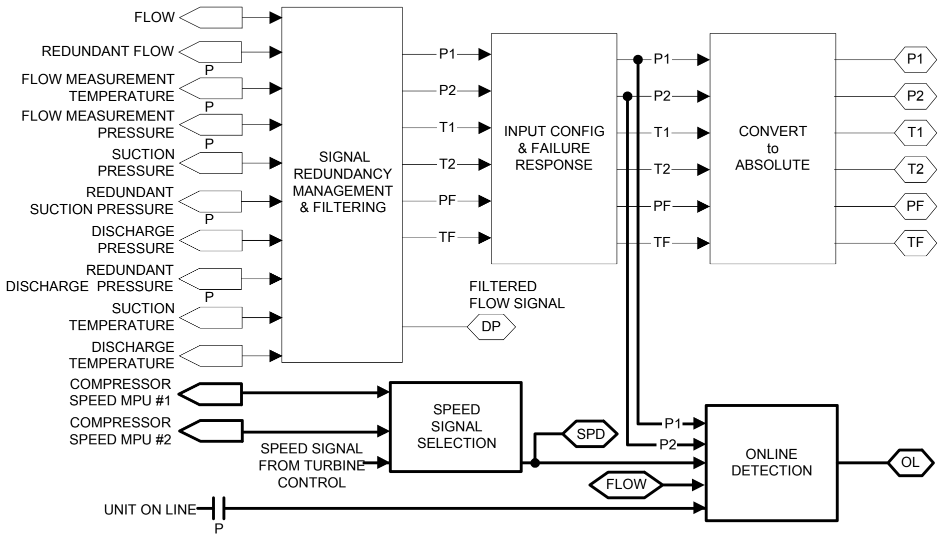


Figure 2-13. On-Line Detection

Each on-line detection method may be enabled or disabled and set-points configured in the Compressor Configuration section of the software. The Auxiliary Input (configurable discrete input or Modbus command), if enabled, must be a sustained input (toggle). It is often connected to a discharge check valve limit switch, for example. Speed, discharge pressure, and flow must exceed their respective set-points to signal the on-line condition. Conversely, suction pressure must drop below its set-point (Suction pressure of a second compressor section must exceed its setpoint, if enabled). If more than one method is enabled, all must be satisfied before the compressor is considered on-line. If none are enabled, the unit will transfer directly to automatic, online control during start-up, i.e. the anti-surge valve will not be held at its Start Position. This is usually undesirable as most compressors will be susceptible to surge during start-up. And, a Purge cycle, if requested, is not possible unless in a Start Sequence and prior to Online control.

IMPORTANT

If utilized, the on-line contact input must be maintained closed the entire time the compressor is operating. If the contact is opened, the 505CC-2 will assume the compressor is off-line and revert to the start sequence and position the anti-surge valve at its start position.

Speed or the discrete input is the recommended, and usually the primary, on-line detection method. If other parameters are to be used, exercise care in selecting their set-points so as not to interfere with normal start-up procedures. Some start-up valve sequencing may inadvertently trigger the on-line status if set-points are configured too low (flow, discharge pressure).

IMPORTANT

The speed-based online detection described above is active only if a valid speed signal is available. If the unit is configured for compressor-only mode, speed inputs are optional.

2.9.3 Anti-Surge Control Routines

Each anti-surge routine is designed to operate in a certain region of the compressor map. In total, these routines encompass the entire operating region, see Figure 2-14.

Starting in the surge, or unstable operating region, there are three routines dedicated to preventing or responding to a surge. Surge Recovery and Surge Minimum Position (SMP) are the routines that react to a surge with a fixed (open loop) valve action. The amount of corrective action taken by these routines is not dynamic; it is pre-configured in the controller.

The next open loop function is BOOST, or Valve Step Opening. This routine monitors the operating point with respect to the BOOST, or Backup Line. If the operating point crosses the line it initiates a momentary, small, step increase in the anti-surge valve to prevent further movement toward the Surge Limit Line.

The two PID controllers are the main anti-surge protection routines. They monitor process conditions and provide a corrective action until the process returns to an acceptable operating point. These routines provide a continuous modulated output for the anti-surge valve. When the operating point is at the Surge Control Line (SCL), the Anti-Surge PID is active. If the operating point is away from the control line but approaching the SCL rapidly, the Rate Controller PID anticipates the need for action, opening the anti-surge valve earlier to slow the approach of the operating point.

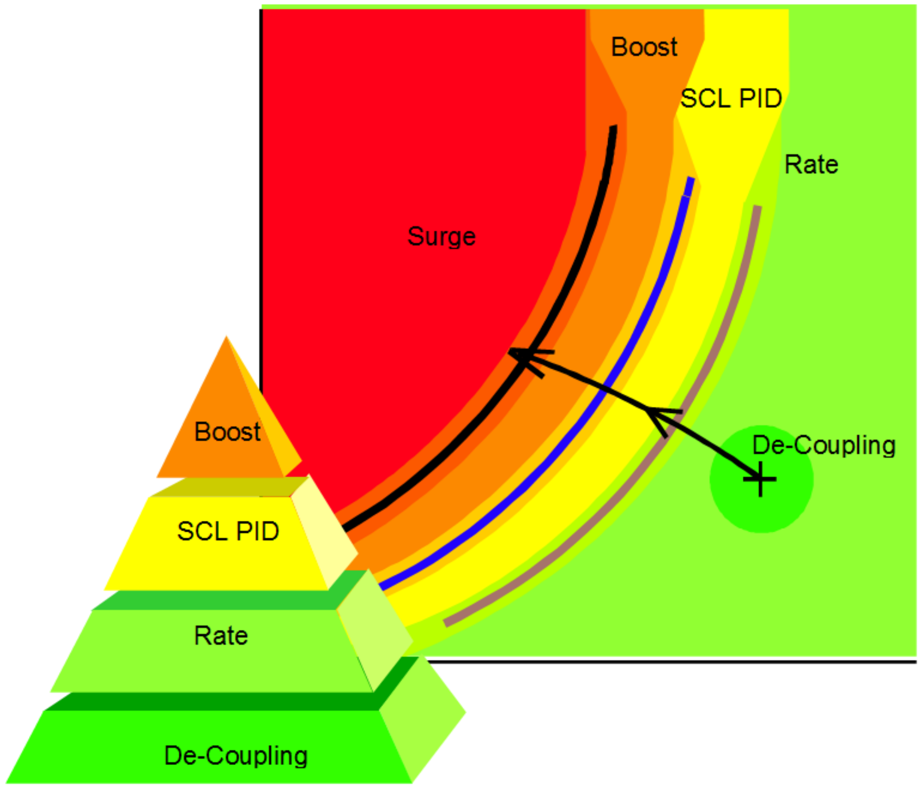


Figure 2-14. Anti-Surge Functions

Even when the operating point is not on the SCL, decoupling acts to stabilize the process by minimizing the interaction of controllers.

2.9.3.1 Surge Detection

The Surge Detection routines are configured to determine when a surge event has occurred, capture the surge signature, and maintain a surge counter. Refer to 2.2 What is Surge? section earlier in this chapter for further details of the actual surge event. The surge signature is a collection of values indicating how parameters change when a surge occurs. The routines available for surge detection are:

- Flow Derivative
- Suction Pressure Derivative
- Discharge Pressure Derivative
- Speed Derivative
- Minimum Flow
- Surge Limit Line Flow

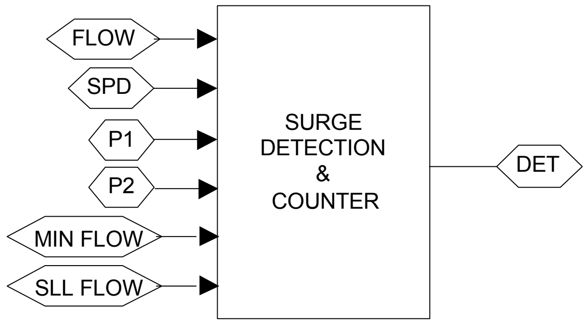


Figure 2-15. Surge Detection and Counter

IMPORTANT **The speed-based surge detection described above is active only if a valid speed signal is available. If the unit is configured for compressor-only mode, speed inputs are optional.**

Note that the latter two routines, Minimum Flow and Surge Limit Line Flow, may not detect an actual compressor surge or incipient compressor surge since they are not based on process variation but on steady flow reference.

These surge detection routines may be enabled as deemed appropriate and adjusted after the surge signature has been established (usually by recording data from a surge of the compressor). The most reliable detection routine is flow derivative. This routine is typically enabled before any surge data is available. The remaining routines are enabled as set-points are found during system tests. A detection routine should be enabled only if it is possible to discriminate a surge event from typical process upsets and signal noise.

The compressor must be on-line and the field sensors need to be operating to arm the detection routines. This prevents the surge control from falsely sensing a surge event during start up or when an input signal fails.

When the anti-surge control detects a surge, assuming surge detection and recovery functions have been configured, the following events will occur:

1. The surge counter will count the number of surges that were detected.
2. The anti-surge valve will open to the surge recovery amount.
3. The individual surge detection routines will capture the surge signature.
4. The individual surge detection routines will indicate which ones detected the surge.
5. An alarm will indicate that a surge was detected
6. The Surge Minimum Position (SMP) will be enabled.

2.9.3.2 Surge Counter

The Surge Counter records the number of surges detected by the anti-surge controller. The counter increments one for each detection and is reset with the surge signature data. The Total Surges counter is also incremented, but it cannot be reset without special software maintenance tools.

2.9.3.3 Surge Recovery

The anti-surge control cannot always prevent a surge from occurring. If the anti-surge routines do not prevent a surge, the surge recovery system takes over.

Once the controller detects a surge, Surge Recovery is programmed to open the anti-surge valve a fixed amount above the current position, see Figure 2-16. There is also a minimum amount that the valve must be opened to recover from the surge. The actual position will be the greater of the two values. The valve will remain open for the loop period time (see the Loop Period section) and then decay towards the closed position. This should stop the current surge cycle and allow the anti-surge routines to take control. The decay time can be set on “Valve Open/Close Automatic Rates Used” (see section 4.2.8.4). Surge Recovery is inhibited when the unit is not on-line.

2.9.3.4 Surge Minimum Position

When the control detects that a surge event has occurred, the Surge Minimum Position (SMP) function will be activated. After the surge recovery routine breaks the surge cycle, the SMP routine will be enabled to prevent subsequent surges.

This routine captures the valve position when the compressor surges and then adds a small amount (SMP Amount) to that position. After the surge recovery decays to zero this routine will not allow the anti-surge valve to close beyond the SMP value (value at surge plus SMP Amount). Once process conditions are stabilized the operator can reset SMP and return to normal operation. This allows the operator to focus on the process if a surge occurs and return to the anti-surge control after the cause and/or a solution was found.

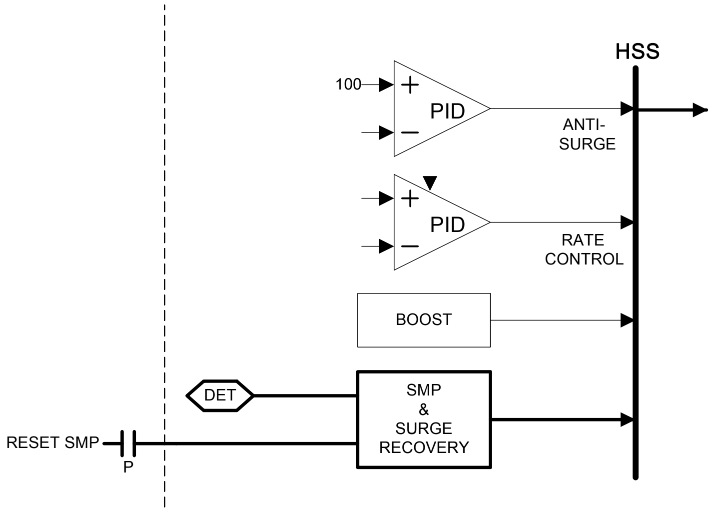


Figure 2-16. Surge Recovery and Surge Minimum Position (SMP)

For example, in Figure 2-17, the Anti-Surge PID and a single 3% BOOST response were not sufficient to prevent a surge, and the anti-surge valve was 34% open when a surge was detected. The SMP Amount was configured for 5%, generating an SMP value of 39%. The Surge Recovery Amount was configured for 14%, stroking the valve to 48% open to break the surge cycle. After the Loop Period duration, the Surge Recovery response ramped out. The anti-surge routines regained control but could not close the valve below 39%. The operator determined that a valve had inadvertently closed in the process and the problem was bypassed. Now, the operator can reset the SMP function that allows the anti-surge routines to close the valve further and move the operating point to the surge control line. As in any surge event, the cause of the surge needs to be investigated before resetting SMP. Resetting SMP may cause the compressor to surge again if the conditions that created the surge have not been corrected.

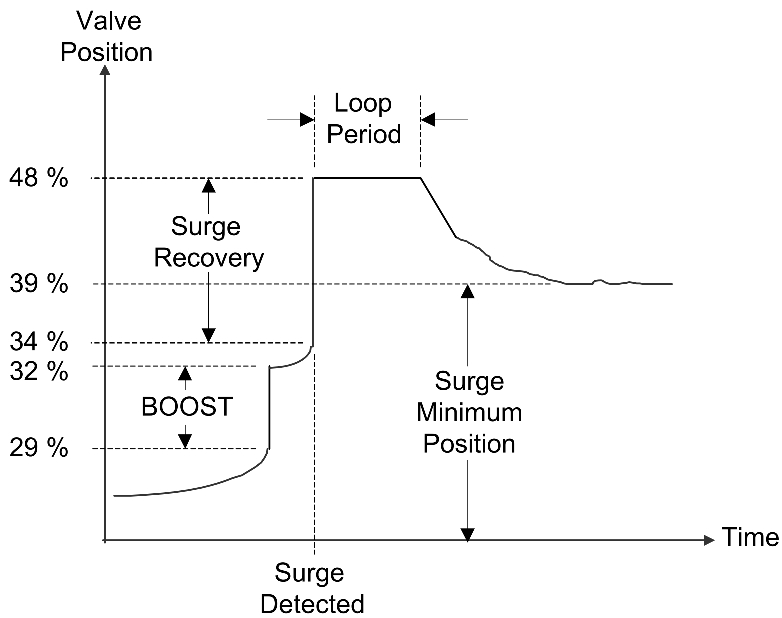


Figure 2-17. Anti-Surge Valve Response to a Surge

2.9.3.5 Boost

The anti-surge control establishes a Boost, or backup, line that is programmed between the Surge Limit Line and the Surge Control Line. If the anti-surge routines do not react fast enough, the operating point may cross the Boost Line heading toward the Surge Limit Line. Once this occurs, the Boost routine will open the valve an additional amount and act to prevent a surge. The location of the Boost Line is determined by the Boost Margin, a percentage to the left of the Surge Control Line.

If the SCL margin is 15% and the Boost Margin is 5%, then the SCL is 15% from the SLL and the Boost Line is 9.25% from the SLL (1.15 * 0.95). The Boost Line is always left of the SCL by the amount of the Boost Margin. Hence, as the SCL moves so does the Boost Line.

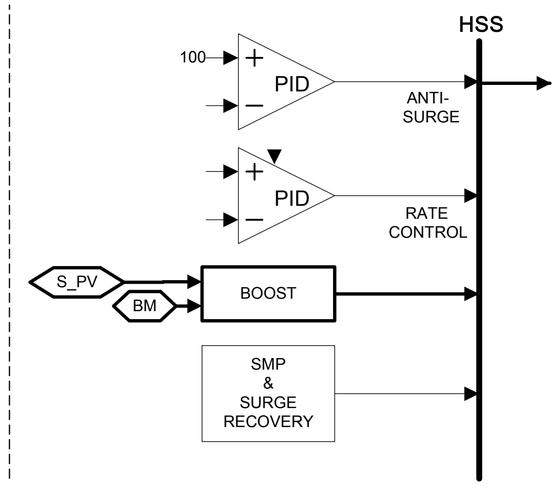


Figure 2-18. Boost

The Boost action will open the anti-surge valve a configured amount above its current position. The valve will remain open this amount for a fixed amount of time (the loop period) and then check the operating point to determine if more action is required. If the operating point is above the Boost Line, the Boost action will begin to decrease and allow the anti-surge controllers to regain control. The decay time of boost control can be set on “Valve Open/Close Automatic Rates Used” (see section 4.2.8.4). However, if the operating point is still below the Boost Line, this sequence will repeat until the operating point is in a safe operating region of the compressor.

In normal circumstances, functioning as a safety net to the closed loop controls, this routine assists the Anti-Surge PID. The BOOST action is only a temporary event that is at zero output during steady state operation. It is inhibited when the unit is not on-line.

2.9.3.6 Anti-Surge PID

This is the main anti-surge control routine. The Anti-Surge PID compares the process variable, S_PV, to 100 in order to determine the proper position of the anti-surge valve. If S_PV is greater than 100, the PID will move toward zero percent (closing the anti-surge valve). When the value is equal to or less than 100, the PID output will increase until the flow through the anti-surge valve restores S_PV to the set-point of 100.

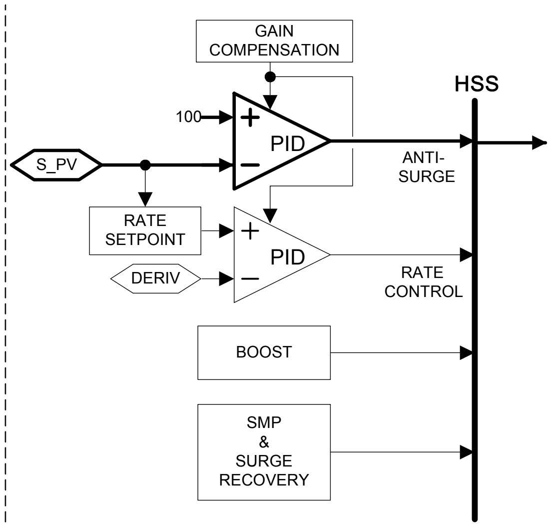


Figure 2-19. Anti-Surge PID

2.9.3.7 Rate Controller PID

If the flow through the compressor reduces too rapidly, the Anti-Surge PID may not react fast enough to prevent a surge. The rate controller monitors the time derivative of S_PV and acts to open the anti-surge valve if this rate is too fast for the system to respond. This action will take place before the operating point reaches the Surge Control Line. It is a proactive routine that takes the place of derivative action in the Anti-Surge PID. The Rate PID is automatically disabled if any input signal is failed.

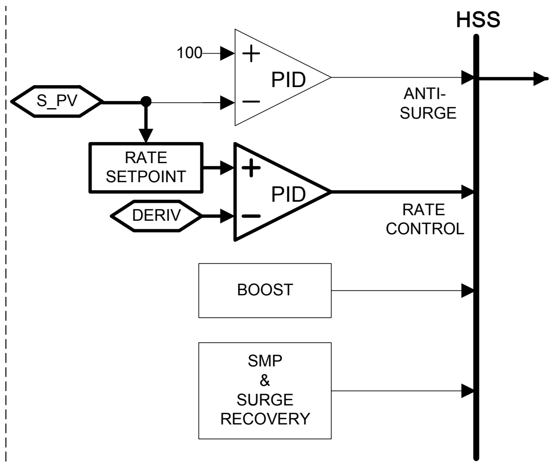


Figure 2-20. Rate Controller PID

The set-point for the Rate Controller PID is a percentage of the maximum safe rate of approach to the Surge Control Line. The allowable rate of approach to the SCL is dynamically calculated from the proximity to the SCL and the system response time (loop period), as shown below.

$$\frac{S\_PV - 100}{LoopPeriod}$$

The further the operating point is from the SCL (S_PV > 100), the greater the allowable rate. Likewise, the faster the system can respond to changes (shorter Loop Period), the greater the allowable rate. As the operating point moves closer to the SCL, the rate set-point is reduced. This ensures that operation is not limited under normal conditions with the compressor loaded. As the operating point approaches the SCL it becomes more critical to limit the velocity of the operating point to maintain stability.

To ensure the controller has time to react, the actual rate set-point is a percentage, typically 60-80%, of this maximum allowed rate. Therefore, if the system dynamics require that the controller act sooner when the anti-surge valve is closing prior to reaching the SCL, reduce this Rate Setpoint. As this value approaches 100%, the Rate Controller set-point approaches the calculated maximum allowable rate.

IMPORTANT

As Loop Period decreases, the maximum allowable S_PV rate increases, effectively “detuning” the Rate PID—It may not act fast enough for rapid operating point moves. For short Loop Periods, it may be necessary to decrease the Rate PID set-point. Obviously, system dynamics and tuning affect these values, so ample testing is the key to determine the best settings.

2.9.3.8 Gain Compensation

The Anti-Surge, Rate Controller, and Pressure Override PID dynamics include proportional, integral, and derivative action. These dynamics can be compensated by the Automatic Gain Compensation (AGC) routine as the compressor operating conditions change. This means that the PIDs can be tuned once during commissioning of the unit, and as the process conditions change, the PIDs will remain stable over the entire operating region. Refer to 5.2.3.2 Dynamics Adjustments for aid in tuning.

The gain compensation routine scales the proportional gains of all PID loops (Anti-Surge, Rate Control, Suction Pressure Override, and Discharge Pressure Override) as well as Fast Speed Decoupling, discussed later in this chapter. Gain compensation is calculated differently depending upon the choice of Algorithm. If the Standard Algorithm is utilized, the gain compensation routine constantly calculates full-open anti-surge valve flow under the current process conditions. The same calculation generates a “Normal Value” at the chosen operating point during initial commissioning and PID tuning. The resulting gain compensation value is the ratio of this fixed normal value to the current value that is constantly calculated. Hence, as compressor loading increases for a constant speed (higher flow, lower head), the calculated anti-surge valve flow will decrease. This increases the gain compensation value and results in more aggressive proportional gains, where gain compensation is applied. Without compensation, the overall control loop gain has been reduced since opening the anti-surge valve would divert relatively lower flow. Conversely, as compressor loading decreases (lower flow, higher head), the anti-surge valve flow calculation will lower the gain compensation value, detuning those proportional gains, since the valve gain has been increased by the process conditions.

Since the Universal Algorithm does not utilize temperature measurements and process parameters such as compressibility, valve flow cannot be calculated. Hence, a slightly different gain compensation routine is required. Standard condition valve flow (scfm, N·m³/hr) is highly correlated to the valve pressure drop ratio, or the compressor pressure ratio, which is measured. Actual flow at process conditions (Acfm, Am³/hr) will then vary with temperature and compressibility. Assuming compressibility near 1.0 that does not significantly change with process conditions, the latter can be ignored without introducing significant error, leaving only temperature as the unknown variable. Most compression processes can be characterized by relatively stable suction temperatures across the normal operating range. While this is not an absolute, it simplifies the gain compensation calculation to compressor pressure ratio instead of valve flow.

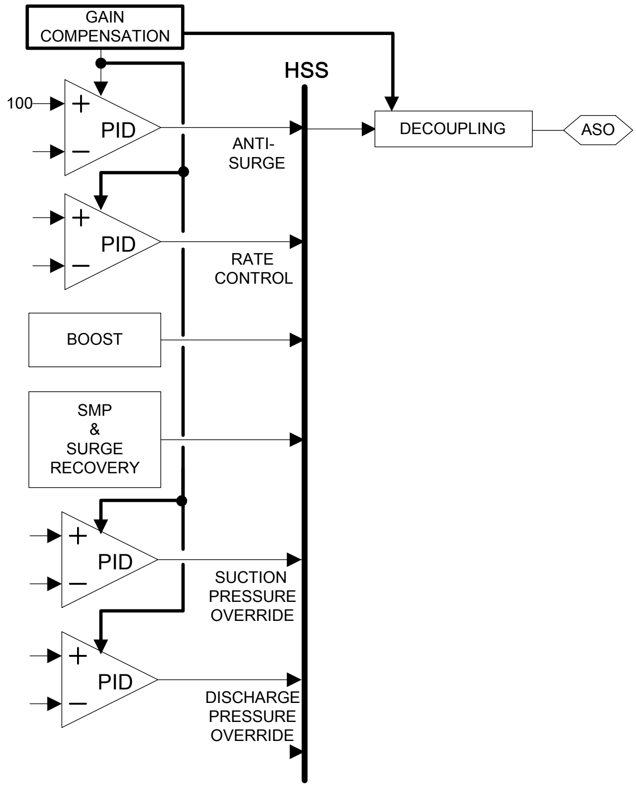


Figure 2-21. Automatic Gain Compensation

AGC must be configured if it is enabled on any of the four PID controls or if Decoupling is enabled and the "Fast Speed Amount" is not 0.0. That is, for Decoupling, Gain Compensation applies only to the Fast Speed routine. So, if that particular routine is disabled by tuning its amount to 0.0, AGC configuration is not necessary. The gain factor is automatically limited to a range of 0.2 to 5.0 within the control so as not to cause instability when applied to the PID gains. Gain Compensation is inhibited when any input signal is failed and when the unit is not on-line.

To configure AGC, first place the compressor in an operating condition where the operating point is above minimum head/flow conditions and below maximum head/flow conditions. Ideally this would be exactly in the middle of the compressor's map or near the normal operating point, although AGC can be tuned at any operating condition. The compressor must be on-line, and it is preferable to have the unit in Manual to prevent instability during this procedure. If the Standard Algorithm was selected previously, configure the anti-surge valve's full-open Cv value, which is required to calculate flow through the valve. The "Normal Value" is anti-surge valve flow (Am^3/hr)—Tune this value until the "Gain Factor" equals 1.00. At this point, the "Normal Value" equals the flow through the anti-surge valve if it were 100% open at the current conditions. If the Universal Algorithm was selected previously, the "Normal Value" is compressor pressure ratio. As above, tune this value until the "Gain Factor" equals 1.00. At this point, the "Normal Value" equals the current compressor pressure ratio.

AGC is now configured at the current operating point. The gain factor will move above and below 1.0 as the compressor moves from this operating point.

IMPORTANT

AGC may be configured before or after PID tuning, but in either case, PID loops should be tuned with AGC disabled. And, both PID tuning and AGC configuration should be done with the compressor at the same, or similar, operating conditions.

2.9.3.9 Decoupling

In order to maintain a stable system, Decoupling may be necessary to provide action before an upset occurs. Upsets are anticipated from knowledge of the operating parameters and their relation to the operation of the anti-surge valve. For instance, a pressure set-point change will usually require a speed change, and this usually results in a compressor operating point change, in percent from the surge line. By the nature of changing speed, S_PV changes and the Anti-Surge PID will respond. The decoupling routines are designed to anticipate the PID change and preset the anti-surge system to the final position without any PID action. Decoupling drives the system to stable operation much quicker than waiting for the PID output to settle. Additionally, the dynamics of the anti-surge control may be too close in response time to the pressure control/speed control and the two systems may fight. Decoupling will also drive this situation to a stable point.

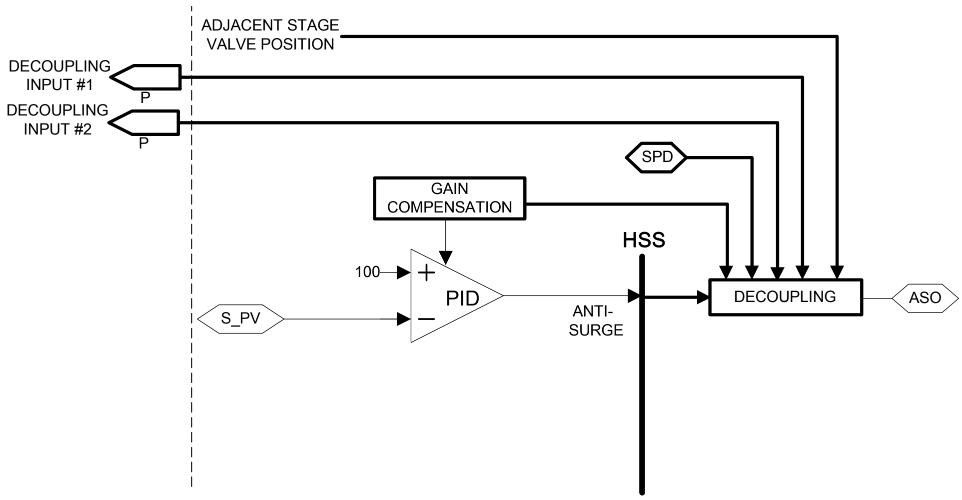


Figure 2-22. Anti-Surge Decoupling

There are five separate Decoupling routines: two based on speed, two configurable inputs from separate processes, and one based upon an adjacent compressor section's anti-surge valve. Decoupling is enabled as a whole. Disabling any of the five routines individually is done by configuring their respective "Amounts" to 0.0. In addition, the action is not allowed to influence the anti-surge valve until the compressor is on-line and in Automatic Mode. Also, since there is no need to manipulate the anti-surge valve if the compressor is operating far from the Surge Control Line, Decoupling is inhibited if the current S_PV value is greater than the configured "S_PV Range" value. And, since Decoupling is a supplemental function, not a primary control, its output is limited by the configured "Decoupling Output Limit". The sum of all five decoupling responses may not open the valve more than this amount.

As mentioned previously, speed decoupling can be performed in two cases, one to prevent a surge and the other to stabilize the process. Once the compressor is stable at an operating point, a decrease in speed would move the operating point towards surge. The first form of speed decoupling uses a direct relationship from change in speed to generate the appropriate valve movement. This form is called "dynamic" and is fast acting and momentary. It is configured as the "Fast Speed Amount" in percent per rpm. Usually, the relationship of speed to S_PV is direct so this value is set greater than zero. The time constant is configured as "Fast Speed Delay Time" and represents the total length of time that the decoupling action will last. The decoupling in this section is usually half or less the "Slow Speed Amount." Gain Compensation impacts fast Speed Decoupling, so the decoupling should not be configured until after gain compensation has been configured.

The second form of speed decoupling uses knowledge of the relationship between speed and flow to anticipate the necessary movement of the anti-surge valve. The change in speed is related to a change in flow, and the anti-surge valve moves to maintain the previous flow. This type of decoupling is also quick to initiate, however, it lasts for a much longer period of time and is removed slowly. It is most helpful in load-sharing applications where there are several units piped in parallel or series. This slower acting decoupling is configured as "Slow Speed Amount" and is usually greater than zero. The time constant is set at "Slow Speed Delay Time."

Field-testing is the only method to determine the relationship between a change in speed and a necessary change in valve position or flow. Both speed decoupling routines are disabled in the event of a speed signal failure.

IMPORTANT	**The speed-based decoupling detection described above is active only if a valid speed signal is available. If the unit is configured for compressor-only mode, speed inputs are optional.**

Decoupling from an adjacent section anti-surge valve uses a direct relationship from a change in one valve position to generate the appropriate movement in another valve. Like all Decoupling routines, there is a filter component and an amount. However, piping arrangement, how one compressor's recycling affects flow through the other, must be considered when configuring the decoupling amount. Consider a two-section machine for which decoupling is configured for the first stage. If the second stage begins to recycle to the inter-stage piping, the system resistance to the first stage is increased, moving it towards surge. In this case, the "Another Stage Amount" would be a positive value. If, however, the second compressor section recycles to the first stage suction piping, the first stage flow would increase, moving away from surge. This situation would require a negative "Amount." Similar relationships exist relative to decoupling the second compressor section from the first stage anti-surge valve. See Figure 2-23 for examples of Another Stage Decoupling values based upon piping arrangement.

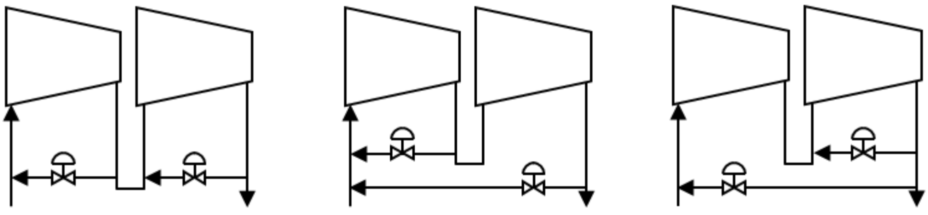


Figure 2-23. Effect of Valve Layout on Adjacent Stage Decoupling Amounts

Lastly, there are two configurable inputs of Decoupling. These inputs can be any other process variables that directly affect the flow through the anti-surge valve or the compressor. This form of decoupling relates a unit change in the process variable to a necessary change in the anti-surge valve position. Each decoupling input has a "Delay Time" and an "Amount" to configure (as with speed decoupling). As before, the larger the filter time constant, the longer the decoupling lasts before it is removed. The "Amount" value is the relationship of input change to decoupling output; a larger amount value translates into a higher impact of anti-surge valve movement to input change. And, like the Adjacent Stage Decoupling described above, the amount should be positive if the process variable is inversely proportional to compressor flow and negative if the relationship is directly proportional. These decoupling routines are disabled if their respective input signals fail.

2.9.4 Process Control Routines

The following routines can operate the anti-surge valve to control a process condition other than anti-surge control. Contained within the 505CC-2 software are suction and discharge pressure controllers. When the prime mover's speed is varied to maintain suction or discharge pressure, two problems can occur. First, the response to a change in speed and a change in pressure may be too slow. Second, if the prime mover's minimum speed is reached, suction or discharge pressure cannot be maintained at their respective set-points. In these cases, this controller will modulate the anti-surge valve to control pressure and assist the primary controller. Both Suction Pressure Override and Discharge Pressure Override may be simultaneously activated. Both may also utilize Automatic Gain Compensation, described previously. Each is automatically disabled if its respective input signal fails.

In the case of 2-loop compressors, the recycle piping arrangement can affect the implementation of these override controllers. Consider a dual stage, 2-valve compressor with a common suction, or "Stage + Overall," valve configuration. In this scenario, opening either valve will boost the unit suction pressure; opening the Stage 1 valve will relieve interstage pressure; and opening the Stage 2 valve will relieve unit discharge pressure. There is no override routine for Stage 2 suction pressure—The Stage 2 Suction Pressure Override controller acts on the unit suction pressure, not the interstage pressure. Since both Suction Overrides act on the same process variable, only one should be enabled, or their setpoints staggered to prevent interaction if both are enabled. Similar caution should be applied to common discharge piping arrangements.

Since the pressure override controllers are high signal selected with all other anti-surge control routines, their effect may be negated if normal compressor operation is on the control line. In this case, the Anti-Surge controller will already be modulating the valve at some open position. If an override controller begins to act, it must exceed the demand of the Anti-Surge PID in order to increase the current valve position. This probably will not occur unless the override controller tuning is very aggressive (undesirable) or the valve is open only a small amount. As such, enabling and tuning the override controllers may be helpful only when the compressor is loaded sufficiently for the Anti-Surge PID to keep the valve closed, or nearly closed.

To allow external control of the anti-surge valve, two auxiliary inputs to the HSS are also available. These inputs will position the compressor anti-surge valve based upon demands from external devices, but all automatic routines within the 505CC-2 are still active. The HSS will select the highest valve position regardless of its control source.

2.9.4.1 Suction Pressure Override

The Suction Pressure Override routine monitors the difference between the suction pressure set-point and the compressor suction pressure. If enabled, the override controller will open the valve to help boost the suction pressure as needed. Obviously, the anti-surge valve cannot be used to reduce suction pressure, in which case the prime mover's speed controller, or other control loop, acts alone.

2.9.4.2 Discharge Pressure Override

The Discharge Pressure Override routine monitors the difference between the compressor discharge pressure and the discharge pressure set-point. The override controller will open the valve to help reduce the discharge pressure. Obviously, the anti-surge valve cannot be used to increase discharge pressure, in which case the prime mover's speed controller, or other control loop, acts alone.

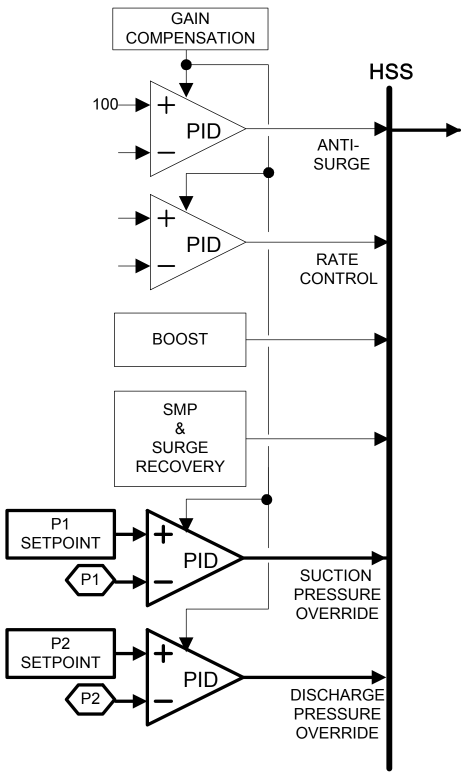


Figure 2-24. Pressure Override Control

2.9.4.3 Auxiliary Control

One or two custom controllers may be added to the High Signal Select (HSS) bus within the 505CC-2. These are configurable analog inputs that must be calibrated for 0–100% open on the anti-surge valve. Enable use of these “HSS Aux #1” and “HSS Aux #2” inputs on the I/O Configuration screen. If necessary, a first-order lag filter delay time may also be configured. If either input signal fails, it is ignored by the HSS.

A third such auxiliary HSS input is used internally when a two-section compressor train is protected with a single anti-surge valve. The single anti-surge valve is driven from the first-stage controller. The second-stage controller’s valve output provides a signal to the first controller’s HSS bus. To provide tracking, the first controller supplies a valve output signal to the second controller’s HSS bus. Connected such, either compressor section’s anti-surge control may position the single anti-surge valve depending on their individual operating points.

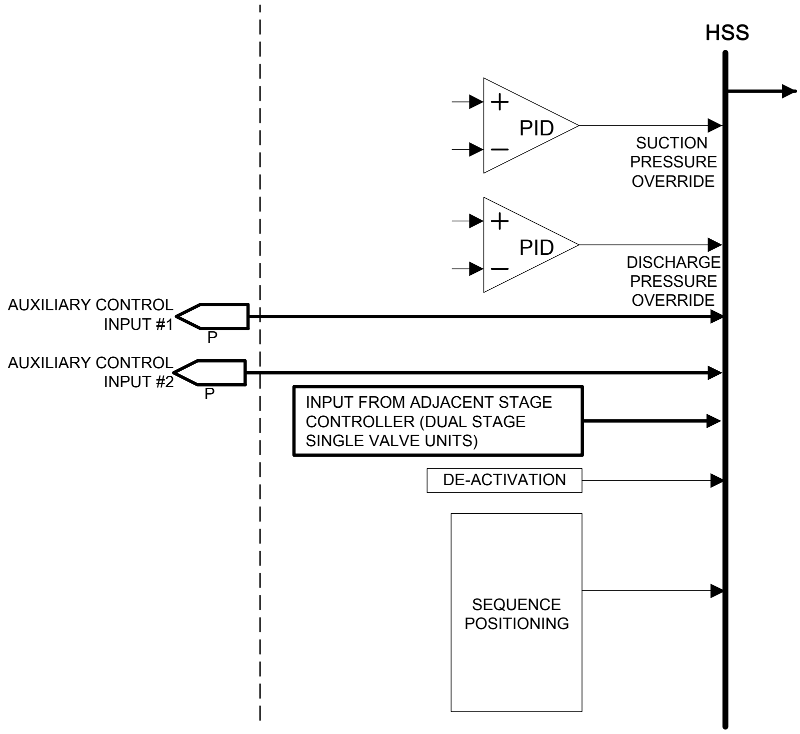


Figure 2-25. Auxiliary Control Variables

2.9.5 Support Functions

In addition to anti-surge control routines, there are support functions that enhance the 505CC-2 abilities:

- Configurable analog inputs may be used for redundant flow and pressure transmitters.
- Input signals are filtered and monitored for failures that trigger fallback routines.
- The Surge Control Margin may be automatically increased, to provide more conservative control, when surges are detected.
- Freeze, over-stroke, dither, and characterization functions provide customization of the anti-surge valve output signal.
- When system response time (loop period) is excessive, Pre-Pack may be used to decrease system reaction time.
- Deactivation logic provides bumpless transfer between the various control routines.

- Gas properties are calculated for greater accuracy (Standard Algorithm).
- A high-speed datalog function is provided.

2.9.5.1 Signal Redundancy

While the 505CC-2 hardware platform does not incorporate true fault tolerance, redundant field instruments (flow, suction pressure, discharge pressure) can be assigned to the available configurable analog inputs to provide some protection against typical transmitter failures. There are only five configurable compressor inputs, so redundancy will be limited for a two-section compressor. The redundancy management and signal selection occurs before filtering.

Range and failure set-point calculations are made from the primary transmitters' configurations, so it is strongly advised that redundant transmitters have the same calibration ranges as their respective primary transmitters. Any single input that fails (outside the default 2–22 mA window) will generate an alarm, but the control will continue to operate on the good signal.

A gradual deviation between the two signals will force the control to choose a "good" value from the two. This situation will generate a Max Difference alarm if the deviation exceeds 1% of range. Since there is no way to predict which of the two, if either, is the "good" signal, the control will select the most conservative value for control—that which will produce the lower S_PV calculation:

- Stage 1 Flow – LSS (Low Signal Select)
- Stage 1 Suction Pressure – HSS (High Signal Select)
- Stage 1 Discharge Pressure – LSS (Low Signal Select)
- Stage 2 Flow – LSS (Low Signal Select)
- Stage 2 Suction Pressure – HSS (High Signal Select)
- Stage 2 Discharge Pressure – HSS (High Signal Select)

Each of these choices (HSS or LSS) might be different for different flow element locations, side stream direction (if applicable), and algorithm (Standard or Universal). For example, Stage 1 suction flow is directly proportional to the Stage 1 Flow input in all cases, except when the flow element is located in an admission side stream. In this latter configuration, choosing the higher of two flow input signals would result in a lower calculated suction flow (Stage 1 Flow = Stage 2 Flow – Admission Flow). However, the selection of high or low input is fixed—The software cannot change between HSS and LSS. Therefore, the most common applications were used to establish the high/low select method, even though it may not produce the desired effect in absolutely every configuration. In any case, when using redundant inputs for flow and/or pressure and a Max Difference alarm occurs, it is strongly recommended that the compressor operation be carefully monitored and the faulty input signal identified and corrected as quickly as possible,

Failure of both inputs will revert to the failure routines described below.

2.9.5.2 Signal Filtering

All of the signals that are input into the anti-surge controller may be filtered for noise. This aids in preventing false surge detections, prevents unnecessary response to noise, and stabilizes the control routines. All input signals are filtered after scaling and redundancy management. If process measurements are clean enough to provide adequate control without filtering, configuring filter time constants of 0 seconds would optimize the controller's speed of response. In any case, if filtering is deemed necessary, it is recommended to enable it in the control, not in the field device—Disable or minimize any transmitter filtering.

Temperature and pressure measurements can be filtered with a high level of accuracy due to the expected responsiveness of these process signals. The filter is a simple first-order lag. The lag time constant, in seconds, is configured on the Stage I/O Configuration Screen. Since it is a time constant, a high value is required if the noise is of low frequency or high amplitude. Typical defaults are 3.0 seconds for temperature inputs and 0.2 seconds for pressure signals.

In contrast, the flow sensor requires careful consideration as it is typically noisy but is the primary surge detection signature. As a result, the anti-surge controller employs a more elaborate filtering scheme. A simplified ARMA (Auto-Regressive Moving Average) filter provides a highly correlated signal without excessive delay times. A lag time constant is configured similarly to the other inputs but is used in a fourth-order filter scheme that weights the lagged signals according to their respective "ages." The most recent value is given the largest weighting, while the "oldest" value has the lowest weighting. Flow signals require much faster filtering than do pressures and temperatures. Lag time constants are typically less than 100 milliseconds.

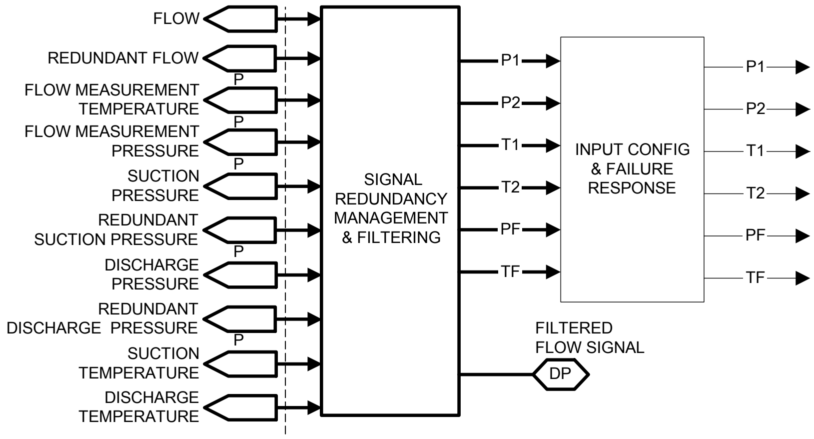


Figure 2-26. Analog 4-20 mA Input Signal Filtering and Failure Monitoring

2.9.5.3 Control Line Shift

Occasionally, changing process conditions will move a compressor's normal operation toward its surge limit. Consider an aging compressor in a dirty gas service. Internal fouling may reduce the compressor's efficiency, reducing flow output at a given head. These situations may eventually deteriorate into frequent but unnecessary surge events because of compressor mechanical conditions or process conditions changing over time. As a result, it may be necessary to increase the control margin to account for this deteriorating controllability.

The 505CC-2 offers automatic biasing of the control margin to shift the Surge Control Line when surges are detected. This feature is a temporary solution to a surge event. If enabled, the control margin will shift to the right a configured amount for each surge detected, as enumerated by the surge counter. For example, if the control margin is at 10% and a surge event records 3 individual surges, a configured SCL Shift Amount of 1% would bias the control margin to 13% from 10%, or 1% for every surge detected. When the surge counter is reset, the shift amount ramps slowly back to 0, gradually returning the SCL to its original location determined by the configured base control margin. If the process change that initiated the surge event is deemed chronic, as in the fouling example noted above, the base control margin should be increased to permanently move the SCL.

This biasing would normally be used only if the compressor's normal operation is at or near the Surge Control Line and the unit is susceptible to intermittent but significant process disturbances that can lead to surge.

2.9.5.4 Signal Failure Routines

When a field sensor (or both sensors, if redundant) used for surge protection fails, three automatic actions are possible. The first action, if enabled, verifies steady state operation and uses the last good process value (LGV) for that signal before the sensor failed. This action is inhibited if the compressor operation was not stable prior to the failure, rendering the validity of “last good value” questionable. LGV can be enabled or disabled for individual inputs.

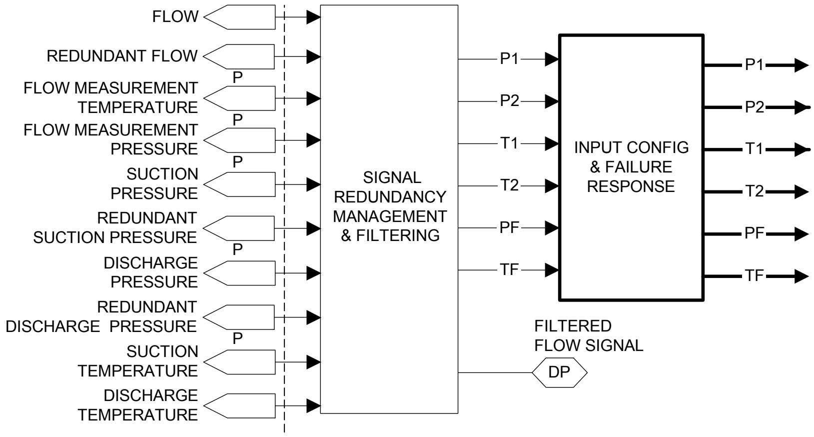


Figure 2-27. Input Signal Configure and Failure Response

Operational stability is determined by monitoring speed, flow, suction pressure, and discharge pressure. If each input is stable for approximately one minute, the compressor is in a steady state condition, and the last good value selections, 30 seconds previous, would be valid. If the compressor were to move from this operating point, at least two of these four inputs will change, indicating an unstable operating condition and inhibiting last good value selection. Movement of the compressor operating point requires that at least two inputs are changing. Therefore, if only one input moves from the stable condition, it may be an indication of a failing signal while the actual compressor operation remains stable. In this case, last good value remains enabled.

IMPORTANT

Last Good Value monitors for approximately one minute of stable operation and selects the value from 30 seconds prior to the failure. Failure is defined as an input signal that moves outside of the normal 2–22 mA (or other) operating range. If a transmitter is failing slowly, or drifting, and the signal takes longer than 30 seconds to reach the milliamp limits, the LGV routine may select an inappropriate value.

IMPORTANT

The speed-based stability monitoring described above is active only if a valid speed signal is available. If the unit is configured for Compressor-Only Mode, speed inputs are optional.

The second action is taken if the system steady state condition changes or a second signal failure occurs while using the last good value for any input. In this case, or if LGV is not enabled, the control value for that input is transferred to a configured fail-safe default. At the moment any signal failure occurs, the values of speed, flow, suction pressure, and discharge pressure are captured. If the current values of these sensors change (one percent for pressure, three percent for flow, one percent of minimum governor for speed), or if a second sensor fails, the system can no longer be considered steady state. At that point, the last good value, if it is being used, is discarded and the control will transfer to the constant fail-safe value. These default values should be chosen to generate a conservative S_PV.

The third signal failure routine is to switch to Manual control and step open the anti-surge valve on any signal failure. This is a single strategy that is enabled or disabled for all inputs. The Last Good Value and Default Value routines will allow the compressor to run uninterrupted, thereby eliminating unnecessary recycling because of a transmitter failure. But, predicting the actual compressor operating point is somewhat compromised. Fail to Manual is the most conservative reaction, opening the anti-surge valve a configured amount beyond the current position to ultimately protect the machine when important process data is unavailable.

This Fail to Manual scheme is the only available routine if the flow sensor fails--The system does not have the capability of using the last good value or a default value for flow. Without the flow signal, the operating point of the compressor cannot be determined, which makes it impossible to automatically control the anti-surge valve.

While a flow signal failure has but one backup routine, there are several possible response sequences to other signal failures, depending upon compressor operational stability and the configuration of Last Good Value and Fail to Manual. See Table 2-1 for the order of events after an initial signal failure and subsequent operational instability.

Signal	LGV Enabled?	Fail to Manual Enabled?	Operation Stable?	1st Response to Initial Signal Failure	2nd Response to Steady State Failure
Flow	N/A	N/A	N/A	Fail to Manual	N/A
Others	Enabled	Disabled	Stable	LGV	Default Value
	Enabled	Disabled	Unstable	Default Value	N/A
	Enabled	Enabled	Stable	LGV	Fail to Manual
	Enabled	Enabled	Unstable	Fail to Manual	N/A
	Disabled	Disabled	Stable	Default Value	N/A
	Disabled	Disabled	Unstable	Default Value	N/A
	Disabled	Enabled	Stable	Fail to Manual	N/A
	Disabled	Enabled	Unstable	Fail to Manual	N/A

Table 2-1. Input Signal Failure Response Sequences

2.9.5.5 Valve Freeze Mode

Under some operating conditions the anti-surge control will constantly modulate the anti-surge valve to some partially open position. The nature of PID action is to open and close a valve to eventually eliminate any error between set-point and process. If the routines are constantly and perhaps unnecessarily moving the valve, the Freeze Mode will hold the valve position until the process changes. This can prevent unnecessary wear in the anti-surge valve and help stabilize minor process swings.

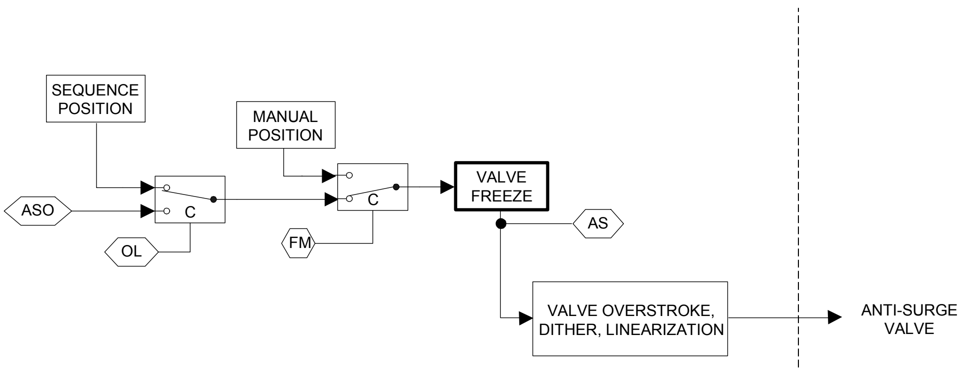


Figure 2-28. Valve Position Freeze Routine

The “Freeze Delay Time” defines the time interval at which the Freeze function is enabled, or sampled. In other words, after that time delay, the Freeze routine is initiated. However, to determine if the valve movement should be stopped, two criteria must be met. First, the valve position must be moving less than two percent (peak-to-peak). Second, S_PV must stay within a window of six percent (peak-to-peak). If both of these conditions are satisfied, the valve demand will remain clamped by the Freeze routine. Conversely, if either of these conditions is exceeded after the valve is held, Freeze mode will be disabled, the valve will move, and the timer will be reset.

Freeze mode is inhibited during start-up and shutdown (sequence positioning), when in Full Manual or Manual with Backup control modes, if the anti-surge valve is closed (<2%), and when the operating point is far from the Surge Control Line (S_PV>115).

2.9.5.6 Valve Overstroke

Some applications may require positive seating of the anti-surge valve in the fully open and closed positions. If enabled, over-stroke will add the configured “Overstroke Amount Open” to the valve position once it reaches 99.8% open. If, for example, the over-stroke amount is tuned to 5%, the valve demand will step to 105% once the control output reaches 99.8%. Conversely, the “Overstroke Amount Closed” value is subtracted from the control output once it reaches 0.2% open. If the same 5% were tuned for the closed position, a control output of 0.2% would yield a valve demand of –5%, positively seating the valve closed.

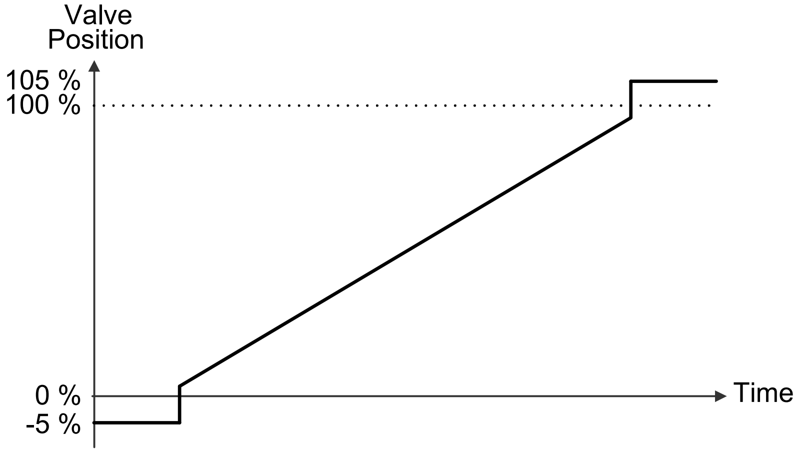


Figure 2-29. Valve Overstroke

2.9.5.7 Valve Dither

Many valve designs can develop memory if their positions remain constant for long periods of time. Other mechanical, electrical, or electro-mechanical devices in the anti-surge valve’s 4–20 mA loop, such as current to pneumatic transducers (I/Ps), can also suffer from this phenomenon. Mechanical inertia also plays a role, particularly in large anti-surge valves with tight seals. The combination of these factors is often referred to as stiction, a contraction of static and friction, and can be detrimental to good control, especially in high gain systems requiring fine valve control. For applications susceptible to this condition, the 505CC-2 offers a dither function added to the valve demand output. Dither applies a 12.5 Hz signal of configurable amplitude onto the valve demand. Figure 2-30 shows a 0.5% dither applied to a constant 39.5% valve output. Dither, if applied, should not be visible as movement in the valve. The dither function is always active. Configure the “Amount” to 0.0% for no dither.

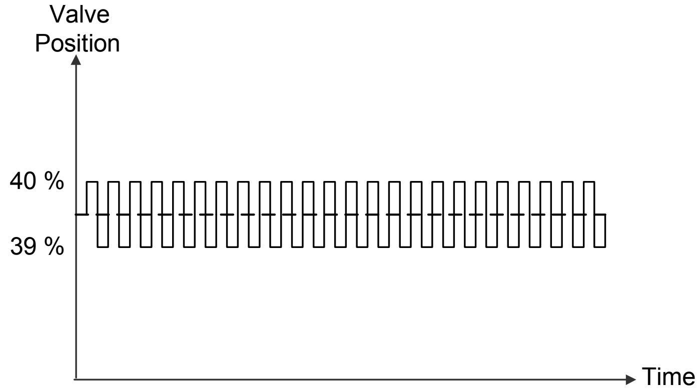


Figure 2-30. Valve Dither

2.9.5.8 Valve Characterization

Valve characterization plays an important role in any control application. Because of tuning concerns and the wide operating range of most compression processes, linear anti-surge valves are generally preferred. However, quick opening, equal-percentage, and other valve characterizations are prevalent, especially as line sizes increase and globe valves become cost prohibitive. Alternative rotary valves are rarely able to produce a truly linear response. As a result, an eleven-point linearization block is provided to characterize the demand output to the anti-surge valve's flow characteristics.

See Figure 2-31 for a sample equal percentage valve characteristic and the corresponding linearization curve that results in a linear flow characteristic.

Original Valve Demand (Valve % Stroke)	Inherent Equal Percentage Valve Characteristic (% of Max Flow)	Linearization Curve (Y-values) (Valve % Stroke)
0	0	0
10	5	30
20	7	52
30	10	64
40	14	72
50	19	77
60	25	81
70	37	86
80	57	91
90	78	95
100	100	100

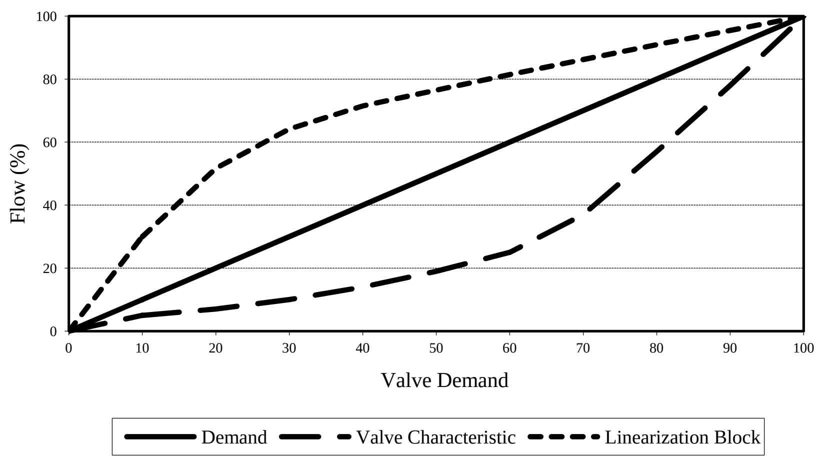


Figure 2-31. Valve Characterization

2.9.5.9 Pre-Pack

Pre-pack is used on applications where long piping runs and large tanks create a significant system lag. In other words, the time between a movement of the anti-surge valve and a change in the operating point is large because of process delays. The 505CC-2 can compensate for this if the system is lag limited, but not if it is rate limited. Rate limited means that the system will only react at a set rate, regardless of how quickly the valve acts. Lag limited means the system has no measurable response for a set time, and then at some point, a response is measured.

To help overcome this control lag, the Pre-Pack routine will over-stroke the anti-surge valve momentarily at the beginning of the Boost and Surge Recovery responses. This temporary overreaction can reduce the total response time of the system. See Figure 2-32 for a sample valve output illustrating a Boost response with Pre-Pack enabled.

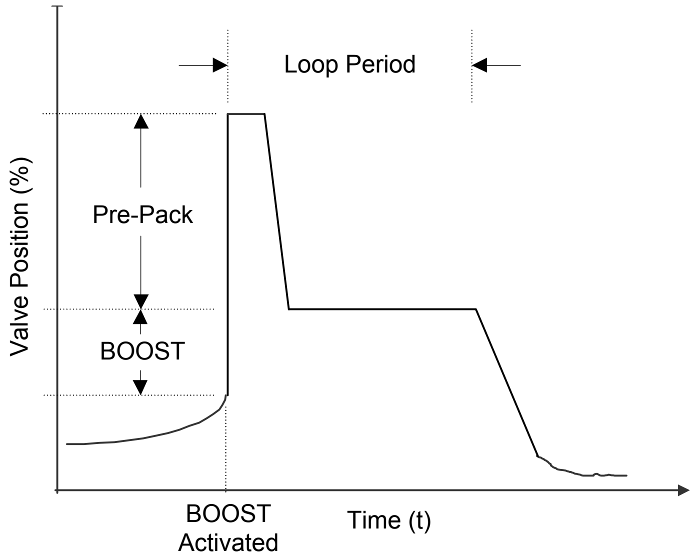


Figure 2-32. Boost Response with Pre-Pack

This routine should be enabled only if it is determined that the response time of the system is excessive (greater than 10 seconds) and if the system will respond to this action as described. In some cases the anti-surge valve or other components in the system are the limiting factors, which will not be affected by this routine. A value of 10% to 40% is common, depending on the system’s ability to react and process stability required.

2.9.5.10 Deactivation

If a routine is abruptly disabled while in control of the anti-surge valve or control is transferred from one routine to another, the deactivation function provides for a smooth transition of the valve demand output. Deactivation is an internal function that only occasionally has control of the valve--It is mentioned here merely for explanation.

2.9.5.11 Compressibility Calculation (Standard Algorithm)

If the Standard Algorithm is selected, the gas compressibility must be known to calculate the individual parameters of head and flow correctly. The compressibility may be entered as default values for suction (Z1) and discharge (Z2) conditions and used as constants, or it may be calculated on-line, in which case the critical temperature and pressure of the process gas are required. If the on-line calculation is utilized, then one value is calculated for the flow sensor conditions, a second value for the compressor inlet, and a third for the compressor outlet.

If the default values are used, compressibility at the flow sensor (Zf) is selected based upon the configured flow element location, i.e. suction or discharge. In either case, the calculated average compressibility (Zavg = (Z1+Z2)/2) is used for head calculations.

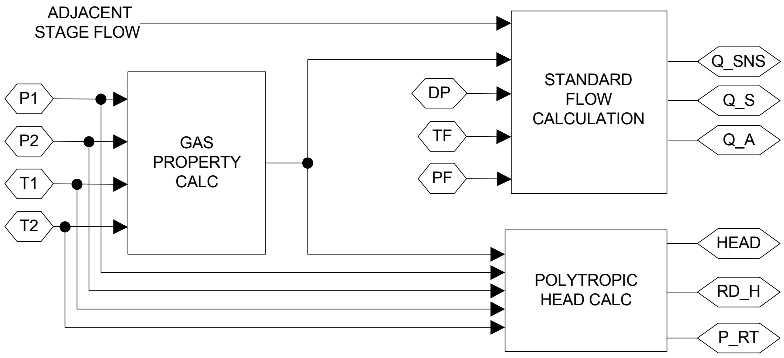


Figure 2-33. Gas Properties Calculations

2.9.5.12 Specific Heat Ratio Calculation (Standard Algorithm)

If the Standard Algorithm is selected, the specific heat ratio, or isentropic exponent, for the process gas must also be known to calculate the individual parameters of head and flow correctly. Default values for specific heat ratio and efficiency are configured into the control and used in the polytropic head calculation. However, the control will automatically calculate the specific heat ratio from on-line temperature and pressure measurements if the original “Gas Component” configuration is “Variable.” This automatic calculation is disabled until the unit is online, when operation is not steady state, and if the calculated value exceeds the configured default ± 0.25.

2.10 Operating Point Calculations

2.10.1 Standard Algorithm

The Standard Algorithm operating point for a compressor is simply the volumetric inlet flow squared divided by the polytropic head, shown below. This equation can be expanded to show that it reduces to a form that only contains measurable quantities and constants. This is critical for applications where the gas composition changes. First, the flow term will be explored. Then, the polytropic head calculation is detailed, and the combination of the two is expanded to produce the operating point.

$$\text{Operating Point} = \frac{(Q_A)^2}{H_P}$$

Flow can be input to the control in various unit calibrations: flow element differential pressure with or without square-root extraction, normal or standard volumetric flow, or mass flow. The latter two require an external flow computer or transmitter calibration using fixed process data. While these are suitable for simple flow measurement and display, they are not ideal for surge control because of accuracy limitations and response time delays. For these reasons, the preferred flow measurement for surge prevention and control is raw flow element differential pressure without square-root extraction. The calculations described below assume this configuration.

Volumetric inlet flow is calculated in two steps. First the standard/normal volumetric ($N \cdot m^3/hr$) or mass (kg/hr) flow through the flow element is calculated using the measurements of flow element differential pressure, pressure at the flow sensor, and temperature at the flow sensor. The selection of standard / normal condition volumetric flow or mass flow is made during initial configuration and will dictate what flow units are displayed on the 505CC-2 operating screens. The mass flow equation, with flowing process parameters substituted for density, is:

$$Q_M = N \cdot C \cdot Y \cdot d^2 \cdot \sqrt{\frac{h_f \cdot P_f \cdot MW}{R_g \cdot T_f \cdot Z_f \cdot (1-\beta^4)}}$$

Where:

QM is mass flow
N is a unit sizing factor
C is the flow element Discharge Coefficient
Y is the flow element Gas Expansion Factor
d is the flow element bore
h_f is the differential pressure across the flow element
P_f is the gas pressure at the flow element
MW is the gas molecular weight
Rg is the Universal Gas Constant
T_f is the gas temperature at the flow element
Z_f is the gas compressibility at the flow element
β is the flow element Beta ratio (bore divided by pipe internal diameter)

Combining constant parameters, the equation is rewritten as:

$$Q_M = \frac{N \cdot C \cdot Y \cdot d^2}{\sqrt{R_g \cdot (1-\beta^4)}} \cdot \sqrt{\frac{h_f \cdot P_f \cdot MW}{T_f \cdot Z_f \cdot}}$$

$$Q_M = K_M \cdot \sqrt{\frac{h_f \cdot P_f \cdot MW}{T_f \cdot Z_f \cdot}}$$

Where:

KM is a mass flow constant, combining other constant values

The flow constant (KM) and Molecular Weight (MW) are input to the control during initial configuration. Flow element differential (h_f), pressure (P_f), and temperature (T_f) are measured. As discussed previously, compressibility (Z_f) is either configured as a constant or calculated on-line.

If, instead of mass flow, normal volumetric flow is selected during configuration, the calculation is similar:

$$Q_{nor} = \frac{Q_M}{\rho_{nor}} = \frac{N \cdot C \cdot Y \cdot d^2 \cdot \sqrt{\frac{h_f \cdot P_f \cdot MW}{R_g \cdot T_f \cdot Z_f \cdot (1-\beta^4)}}}{\frac{P_{nor} \cdot MW}{R_g \cdot T_{nor} \cdot Z_{nor}}}$$

Where:

Qnor is normal volumetric flow
ρnor is the normal condition gas density
Pnor is the normal condition gas pressure
Tnor is the normal condition gas temperature
Znor is the normal condition gas compressibility

Combining constant parameters, the equation is rewritten as:

$$Q_{nor} = N \cdot C \cdot Y \cdot d^2 \cdot \sqrt{\frac{h_f}{1-\beta^4} \cdot \frac{P_f \cdot MW}{R_g \cdot T_f \cdot Z_f} \cdot \frac{R_g \cdot T_{nor} \cdot Z_{nor}}{P_{nor} \cdot MW}}$$

$$Q_{nor} = \frac{N \cdot C \cdot Y \cdot d^2 \cdot T_{nor} \cdot Z_{nor} \cdot \sqrt{R_g}}{P_{nor} \cdot \sqrt{1-\beta^4}} \cdot \sqrt{\frac{h_f \cdot P_f}{T_f \cdot Z_f \cdot MW}}$$

$$Q_{nor} = K_{nor} \cdot \sqrt{\frac{h_f \cdot P_f}{T_f \cdot Z_f \cdot MW}}$$

Where:

Knor is a normal volumetric flow constant, combining other constant values

As seen in these equations, the selection of mass or normal volumetric flow will affect the calculation of the flow constant (KM or Knor), which is input to the control during initial configuration. While this calculation is performed automatically by the 505CC-2, the equations are provided here for verification:

If Mass Flow is selected:

$$K_M = 0.0438521 \cdot \frac{C \cdot Y \cdot d^2}{\sqrt{(1-\beta^4)}}$$

If Normal Volumetric Flow is selected:

$$K_{nor} = 0.9829 \cdot \frac{C \cdot Y \cdot d^2}{\sqrt{(1-\beta^4)}}$$

IMPORTANT

These formulas for calculating flow constants assume SI engineering units of kPa, °C, kg/hr, m^3/hr, and mm. This matches the required inputs of the 505CC-2. These constants will be different when compared to other flow measurements in different engineering units.

If an annubar is used as the flow element, substitute pipe internal diameter (D) for bore diameter (d) and 0 for beta ratio (β) in these equations.

Beta ratio (β), flow element bore (d, millimeters), Discharge Coefficient (C), and Gas Expansion Factor (Y) are all taken from the Flow Element Calculation or Data Sheets. The latter value, but to some degree all four, will vary with process conditions and flow rate. And, flow element calculations are often made at a maximum flow condition for calibration of the flow (differential pressure) transmitter. As such, the flow element calculation sheet's data may not be relevant to normal compressor operation. If possible, maximum accuracy is achieved by selecting these "constants" that correspond to the compressor's normal operating conditions and flow rate. The numerical constants are calculated from the Universal Gas Constant (Rg), N-factor (N), and normal condition process parameters in SI units.

The calculated normal/standard volumetric or mass flow through the flow element can then be combined with any side-stream or adjacent stage flows resulting in the total flow through the compressor stage, Qs. However, actual volumetric suction flow is necessary to plot on the chosen compressor map, so the conversion is made with the one of the following equations:

If Mass Flow is selected:

$$Q_A = \frac{Q_S}{\rho_1} = \frac{Q_S \cdot R_g \cdot T_1 \cdot Z_1}{P_1 \cdot MW}$$

If Normal Volumetric Flow is selected:

$$Q_A = Q_S \cdot \frac{P_{nor}}{P_1} \cdot \frac{T_1}{T_{nor}} \cdot \frac{Z_1}{Z_{nor}}$$

Where:

Q_A is actual volumetric suction flow
Q_S is total compressor stage flow (normal or mass)
ρ_1 is the gas density at suction conditions
T_1 is the gas temperature at suction conditions
Z_1 is the gas compressibility at suction conditions
P_1 is the gas pressure at suction conditions
T_{nor} is the normal condition gas temperature
Z_{nor} is the normal condition gas compressibility
P_{nor} is the normal condition gas pressure

By substituting the flow sensor calculation (Qs), the result is:

$$Q_A = K\sqrt{\frac{T_1^2 \cdot Z_1^2}{P_1^2} \cdot \frac{h_f \cdot P_f}{T_f \cdot Z_f \cdot MW}}$$

Where:

K is a combination of those flow constants calculated previously, for mass or normal volumetric flow (KM or K_{nor}), and the Universal Gas Constant (Rg) or normal condition process parameters (T_{nor}, P_{nor}, Z_{nor}).

Assume, for example, that the flow element is located in the compressor suction line (f=1). The equation can be simplified as:

$$Q_A = K\sqrt{\frac{T_1 \cdot Z_1 \cdot h}{P_1 \cdot MW}}$$

In order to determine the second half of the operating point, the following equation is used to calculate the polytropic head for the compressor:

$$H_P = \frac{R_g \cdot T_1 \cdot Z_{avg}}{MW} \cdot \frac{\left(\frac{P_2}{P_1}\right)^{\sigma} - 1}{\sigma}$$

Where:

H_P is polytropic head
Z_{avg} is the average gas compressibility for the compressor
P_2 is the gas pressure at discharge conditions
σ is the polytropic exponent which can be defined as:

$$\sigma = \frac{k-1}{k \cdot \eta_P} = \frac{\ln\left(\frac{T_2}{T_1} \cdot \frac{Z_2}{Z_1}\right)}{\ln\left(\frac{P_2}{P_1}\right)} \cong \frac{\ln\left(\frac{T_2}{T_1}\right)}{\ln\left(\frac{P_2}{P_1}\right)}$$

Where:

k is the specific heat ratio, or isentropic exponent, of the gas
η_P is the polytropic efficiency of the compressor
T_2 is the gas temperature at discharge conditions
Z_2 is the gas compressibility at discharge conditions

After volumetric flow and polytropic head have been calculated, the controller can now combine these two values and calculate a single value representing the operating point of the compressor. If this is continued in equation form we have the following:

$$OperatingPoint = \frac{(Q_A)^2}{H_P} = \frac{K^2 \cdot \frac{T_1^2 \cdot Z_1^2}{P_1^2} \cdot \frac{h_f \cdot P_f}{T_f \cdot Z_f \cdot MW}}{\frac{R_g \cdot T_1 \cdot Z_{avg}}{MW} \cdot \frac{\left(\frac{P_2}{P_1}\right)^{\sigma} - 1}{\sigma}}$$

Now it can be seen that several of the terms on the top and bottom of the ratio can be canceled out. The gas molecular weight (MW) cancels out of the numerator and denominator. In most cases, the gas compressibility does not change much between the suction and discharge, so the compressibility terms may be canceled with little or no error introduced. This leaves the following equation:

$$OperatingPoint = \frac{K^2 \cdot T_1 \cdot P_f \cdot h_f \cdot \sigma}{R_g \cdot T_f \cdot P_1^2 \cdot \left(\left(\frac{P_2}{P_1}\right)^{\sigma} - 1\right)}$$

K and R_g are constants that do not change, and all that remain are measured variables.

As for sigma, this requires another calculation but it is still found from measured values. The following equation is the relationship between pressures and temperatures for an isentropic process such as compression:

$$\sigma = \frac{\ln\left(\frac{T_2}{T_1}\right)}{\ln\left(\frac{P_2}{P_1}\right)}$$

The only additional parameter not mentioned previously is discharge temperature. Therefore, this measurement is necessary if the gas composition passed through the compressor is expected to change. That is, if the “Gas Component” configuration is “Variable,” then temperature measurements are required in the suction and discharge. Conversely, if the “Gas Component” configuration is “Constant,” then, at a minimum, a temperature measurement is required in the location of the flow element (suction or discharge). If only one temperature measurement is available, the control will automatically calculate the other temperature using the relationship of sigma (σ), described above, or from a mass balance flow equation. Then all of the necessary parameters for calculating an accurate operating point are measured and variances compensated.

2.10.2 Universal Algorithm

Calculation of the Standard Algorithm operating point, volumetric inlet flow squared divided by polytropic head, is especially important to achieving accuracy when the gas composition is expected to change. However, the Universal Algorithm, with its corrected flow, was developed for its immunity to such variances. At a given compressor pressure ratio, the inlet volumetric flow will change with temperature, compressibility, and molecular weight. But, by appropriate manipulation of the volumetric flow equation, we can compensate for variations in suction gas conditions without actually measuring the changes in temperature, compressibility, and molecular weight. The result is a corrected flow variable that is indicative of compressor flow at the suction conditions of the reference performance map used for anti-surge control.

Starting with the flow equations presented earlier:

$$Q_A = \frac{Q_M}{\rho_1} = N \cdot C \cdot Y \cdot d^2 \cdot \sqrt{\frac{h_f \cdot P_f \cdot MW}{R_g \cdot T_f \cdot Z_f \cdot (1-\beta^4)} \cdot \frac{R_g^2 \cdot T_1^2 \cdot Z_1^2}{P_1^2 \cdot MW^2}}$$

Assume, for example, that the flow element is located in the compressor suction line (f=1). The equation can be simplified as:

$$Q_A = \frac{N \cdot C \cdot Y \cdot d^2}{\sqrt{1-\beta^4}} \cdot \sqrt{\frac{h_f \cdot R_g \cdot T_1 \cdot Z_1}{P_1 \cdot MW}}$$

The corrected flow variable eliminates the process parameters (T, Z, MW) as follows:

$$Q_{CR} = \frac{Q_A}{\sqrt{R \cdot T_1 \cdot Z_1}} = \frac{Q_A}{\sqrt{\frac{R_g}{MW} \cdot T_1 \cdot Z_1}} = K_{CR} \cdot \sqrt{\frac{h_f}{P_1}}$$

Corrections are made online for alternate flow element pressure sensors or for flow elements located in the compressor discharge. The result is a much simpler operating point calculation, which is the corrected flow itself:

For Suction Flow Elements:

$$\text{OperatingPoint} = Q_{CR} = K_{CR} \sqrt{\frac{h_f}{P_f} \cdot \frac{P_f}{P_1}}$$

For Discharge Flow Elements:

$$\text{OperatingPoint} = Q_{CR} = K_{CR} \sqrt{\frac{h_f}{P_f} \cdot \frac{P_f}{P_2} \cdot \left(\frac{P_2}{P_1}\right)^{\frac{n+1}{2n}}}$$

Where:

Q_{CR} is the corrected volumetric suction flow
K_{CR} is the corrected flow constant
h_f is the differential pressure across the flow element
P_f is the flow element pressure (if other the P1 or P2)
P1 is the compressor suction pressure
P2 is the compressor discharge pressure
n is the polytropic exponent, calculated from sigma (σ) as:

$$n = \frac{1}{1-\sigma}$$

As can be seen in these equations, all parameters are measured except for the corrected flow constant (K_{CR}) and polytropic exponent (n). Since the corrected flow variable,

$$\frac{Q_A}{\sqrt{RTZ}}$$

is equal for all process conditions (RTZ) at a given pressure ratio, the corrected flow constant (K_{CR}) and polytropic exponent (n) are calculated for the compressor performance map's rated or reference condition and configured into the control.

Chapter 3. General Description

3.1 Introduction

The 505CC-2 has incorporated Woodward Integrated Turbine Compressor CORE (ITCC) software logic which contains compressor control algorithms jointly developed by a global Woodward application engineering team. The CORE software is under engineering control by its own GAP part number and can be enhanced by Woodward without affecting site configurations.

The 505CC-2 interfaces with a compressor's recycle, or anti-surge, valve to control a compressor section relative to its performance map surge line. Two compressor sections, or loops, with a variety of instrument locations can be accommodated (See Appendix B Valid Compressor Configurations and 4.2.2 All Stages Main Configuration).

The user may choose either of two compressor map implementations, the Standard Performance Map Algorithm or Universal Performance Map Algorithm, described in detail in 2.10 Operating Point Calculations. Either algorithm will accurately represent the current compressor operating point. The 505CC-2 compressor control can also assist process control functions to boost compressor suction pressure or limit discharge pressure by modulating the compressor anti-surge valve.

Configuration and operation are available through the provided Commissioning Configuration Tool (CCT) software running on any connected computer. Additional operational and monitoring capabilities are available over serial Modbus.

3.2 Additional Features

The 505CC-2 also provides the following features:

- The calculation of gas properties such as specific heat ratio (k) and compressibility (Z) are available for additional accuracy in the Standard Algorithm.
- Four robust surge detection routines detect a surge within 50 milliseconds. These user-configurable surge detection routines are flow derivative (rate of change), speed derivative (rate of change), suction pressure derivative (rate of change), and discharge pressure derivative (rate of change). Additionally, the anti-surge valve may be opened once the compressor operating point reaches the configured Surge Limit Line or flow drops below a configured minimum value, whether or not surge has been detected by the other routines.
- Transmitter failures automatically initiate backup routines to provide redundancy style protection without extra hardware. Upon a signal failure, the 505CC-2 analyzes the compressor operation for stability to determine if the last good value is viable, otherwise default values are used. Even if every transmitter except flow fails, the 505CC-2 can still provide surge protection in automatic, based upon a flow derivative surge signature. Optionally, other signal failures can initiate the same fail to Full Manual routine as a flow failure, providing the most conservative protection strategy.
- Bump-less transfer between three control modes is provided: Automatic, Manual with Backup, and Full Manual. The controller can fully automate the process; allow manual anti-surge valve control with backup protection override, or provide full manual control for maintenance purposes.

- To stabilize interrelated processes, Decoupling routines are provided between the anti-surge valve and speed (fast and slow), as well as from a second valve. Two additional decoupling routines can be configured from external sources.
- Start-up and shutdown sequencing of the anti-surge valve, including an optional purge position, provide complete compressor control from zero speed to full loading.

3.3 505CC-2 Inputs and Outputs

3.3.1 Control Inputs

3.3.1.1 Analog Inputs

The 505CC-2 has in total 21 4-20 mA analog inputs. The first six (1-6) analog inputs on the SmartCore CPU A5200 Board are reserved for turbine control. The next fifteen (7-21) configurable analog inputs on the Analog Combo Board are available for compressor control. The following analog input compressor control configurations are possible for each compressor loop:

- Flowmeter;
  - Delta-pressure from the compressor flow element at suction or discharge.
- Redundant Flowmeter;
  - Accommodates a second flow transmitter for redundancy.
- Suction Pressure;
  - Compressor inlet pressure.
- Redundant Suction Pressure;
  - Accommodates a second inlet pressure transmitter for redundancy.
- Discharge Pressure
  - Compressor outlet pressure.
- Redundant Discharge Pressure;
  - Accommodates a second outlet pressure transmitter for redundancy.
- Pressure at Flow Element;
  - The Flow Element Pressure input may be used for a pressure transmitter at the flow element for flow calculations, if its location is far from the compressor suction or discharge pressure measurements.
- Suction Temperature
  - Compressor inlet temperature.
- Discharge Temperature
  - Compressor outlet temperature.
- Temperature at Flow Element;
  - The Flow Element Temperature input may be used for a temperature transmitter at the flow element for flow calculations, if its location is far from the compressor suction or discharge temperature measurements.
- HSS Auxiliary Input 1;
  - Auxiliary HSS (High Signal Select) inputs are provided for anti-surge valve positioning (0% = Closed, 100% = Open) in Automatic Mode.
- HSS Auxiliary Input 2;
  - Auxiliary HSS (High Signal Select) inputs are provided for anti-surge valve positioning (0% = Closed, 100% = Open) in Automatic Mode.
- Decoupling Input 1;
  - Auxiliary Decoupling inputs are provided for limited feed-forward biasing of the anti-surge valve, based upon a separate process change.

- Decoupling Input 2;
  - Auxiliary Decoupling inputs are provided for limited feed-forward biasing of the anti-surge valve, based upon a separate process change.
- Remote Manual Valve Position;
  - Remote valve positioning (0% = Closed, 100% = Open) in Manual Mode.
- Upstream Pressure Anti-Surge Valve
  - This can utilized for correct flow calculations through the anti-surge valve.
- Downstream Pressure Anti-Surge Valve
  - This can utilized for correct flow calculations through the anti-surge valve.
- Temperature at Anti-Surge Valve;
  - This can utilized for correct flow calculations through the anti-surge valve.
- Alternate Psuc Override;
  - Utilizing another suction pressure transmitter for anti-surge for suction pressure override control.
- Alternate Pdisch Override;
  - Utilizing another discharge pressure transmitter for discharge pressure override control.

In addition to these the following side stream analog inputs can be configured:

- Side Stream Flowmeter (Extraction/Admission)
  - Measuring the flow of the side stream leg.
- Side Stream Redundant Flowmeter (Extraction/Admission)
  - Accommodates a second flow transmitter of the side stream leg for redundancy.
- Side Stream Pressure
  - Pressure in the side stream leg utilized for flow calculations.
- Side Stream Redundant Pressure
  - Accommodates a second side stream pressure transmitter for redundancy.
- Side Stream Temperature
  - Temperature in the side stream leg utilized for flow calculations.

When cascade export flowmeter is configured (from Turbine Configuration, see manual 26542V2), exported gas flowmeter analog inputs also can be configured:

- Exported Gas Flowmeter 1
  - Measuring the delta pressure of the flowmeter located downstream of the compressor. Flowmeter#1 has smaller measurement range compare to the range of flowmeter#2.
- Exported Gas Flowmeter 2
  - Measuring the delta pressure of the flowmeter located downstream of the compressor. Flowmeter#2 has bigger measurement range compare to the range of flowmeter#1.

The above are pre-defined analog inputs. An extra four customer defined monitor inputs are available for configuration.

3.3.1.2 Discrete Inputs

The 505CC-2 has in total 24 discrete inputs on the SmartCore CPU A5200 Board. The first (1) discrete input is reserved for Emergency Shutdown functionality. The next two (2-3) discrete inputs are reserved for turbine control, but can also be used in case of compressor only control since these function for the reset and start command. Subsequent (4-24) discrete inputs are configurable discrete inputs for either turbine or compressor control. The following discrete input compressor control configurations are possible for each compressor loop:

- Close Anti-Surge Valve;
  - While sustained closed the Anti-Surge valve when in Manual with Backup or Full Manual.
- Open Anti-Surge Valve
  - While sustained is opening the Anti-Surge valve when in Manual with Backup or Full Manual.
- Anti-Surge Valve Opened
  - This functionality is reserved for future use.
- Reset SMP;
  - Resets the Surge Minimum Position hold on valve position (pulse).
- Reset Capture Info;
  - Resets the Surge Capture information (counter, signature values). Note: does not reset the Total Surges Counter (pulse).
- Select Auto Mode;
  - Selects the Automatic control mode (pulse).
- Select Manual with Backup Mode
  - Selects the Manual with Backup control mode (pulse).
- Select Full Manual Mode
  - Selects the Full Manual control mode (pulse).
- Purge Position
  - Selects the anti-surge valve's Purge position during start-up (sustained).
- Online Auxiliary Input
  - Initiates the transition from offline to online automatic anti-surge control, i.e. starts the anti-surge control instead of, or in addition to, using speed, flow, or pressure setpoint (sustained).
- Control Margin Increase;
  - Increases the current Control Margin by 0.1% per second while the input is closed.
- Control Margin Decrease
  - Decreases the current Control Margin by 0.1% per second while the input is closed. It is not possible to decrease below the configured margin.
- Anti-Surge Valve Fault;
  - Anti-Surge Valve output fault, which will force the control into Full Manual Mode and move the valve output to the shutdown position. This discrete input configuration is provided for an external circuit monitoring device to signal such a fault (sustained).
- Start Position;
  - Initiates a compressor "start" by positioning the anti-surge valve in the configured start position from zero-speed. Also acts as a restart command when received after a shutdown but before slowing to zero-speed (pulse).
- Shutdown;
  - Initiates a compressor shutdown by positioning the anti-surge valve in the configured shutdown position. Restarts are inhibited if the input is sustained.

3.3.2 Control Outputs

3.3.2.1 Analog Outputs

The 505CC-2 has in total 6 4-20 mA analog outputs. The first analog output (1) on the SmartCore CPU A5200 Board is dedicated for Anti-Surge valve 1. When two anti surge valves are used for two compressor application, the second (2) analog output is dedicated for Anti-Surge valve 2. The next four (3-6) configurable analog outputs on the Analog Combo Board are available for compressor control. The following analog output compressor control configurations are possible for each compressor loop:

- Valve Demand;
  - Final valve demand including Decoupling and Freeze routines (excludes valve overstroke, dither, and linearization).
- Surge Process Variable;
  - The Surge Process Variable (S_PV), see 2.8 S_PV (Surge Process Variable).
- Actual Flow at Suction;
  - The actual volumetric inlet flow.
- Corrected Flow at Suction;
  - The corrected volumetric inlet flow.
- Mass Flow;
  - The mass flow through the compressor.
- Polytropic Head;
  - The calculated polytropic head.
- Suction Pressure Used;
  - Suction Pressure value after redundancy management (if applicable), filtering, and failure routines.
- Discharge Pressured Used;
  - Discharge Pressure value after redundancy management (if applicable), filtering, and failure routines.
- Suction Temperature Used;
  - Suction Temperature value after filtering and failure routines.
- Discharge Temperature Used;
  - Discharge Temperature value after filtering and failure routines.
- HSS Output;
  - Output of the High Signal Select bus for all automatic control routines.
- Actual Speed;
  - An output of the compressor speed.
- Calculated Exported flow;
  - Flowmeter at the downstream of compressor will be used for cascade.

3.3.2.2 Discrete Outputs

The 505CC-2 has in total 12 discrete outputs on the SmartCore CPU A5200 Board. The first (1) discrete output is reserved for the Trip Relay functionality. The next eleven (2-12) discrete outputs are configurable discrete outputs for either turbine or compressor control. A distinction can be made in the configurable discrete outputs between status indication and level switch. The following discrete output compressor control configurations are possible for each compressor loop:

Status Indication

- Shutdown Active
  - Energizes when a shutdown is active.
- Trip Relay
  - Energizes when a trip is active.

- Alarm Active;
  - Energizes when an alarm condition is active.
- Surge Detected
  - Energizes when a surge has been detected.
- Surge Minimum Position Active
  - Energizes when Surge Minimum Position (SMP) is active.
- Is Online
  - The Anti-Surge control is online and active.
- In Auto Mode
  - The control is in Automatic mode.
- In Manual/Backup Mode
  - The control is in Manual with Backup mode.
- In Full Manual Mode
  - The control is in Full Manual mode.
- Internal Level Switch On (1-8)
  - This functionality is to energize a relay if the selected 1 to 8 internal level switches set in the configuration mode alarm screen reach the on level.
- Reset Pulse (1 second)
  - A reset issued is to the compressor control is issued out through a relay to be able to reset for example other devices in the control cabinet.

Level Switch

The on and off level for energizing the relay output can be configured, based on the following values (see 4.2.20.3, Internal Level Switches):

- Actual Speed
- Actual Flow (display)
- Mass/Std Flow (display)
- Operating point (WSPV)
- Actual Suction Pressure
- Actual Discharge Pressure
- Actual Suction Temperature
- Actual Discharge Temperature

Invert can be configured to energize when function not-active.

3.4 Anti-Surge Control Recommendations

Compressor control systems are but one element in the entire anti-surge control loop. Particularly, field instrumentation and final control elements (anti-surge valves) often do not receive an appropriate level of attention during the design phase of the compressor system. Speed of response and sophisticated software routines are the primary differentiators that set compressor controls apart from typical process controls. But, users often rely on “typical” process equipment for transmitters and valves, while spending significant time and resources to select the control system. The speed and accuracy of the entire control loop, including instruments and valves, is critical—The system is only as good as its weakest link.

With this in mind, the following recommendations are provided as a reminder to look at the entire control loop when designing a fast, accurate, and reliable anti-surge control system. These recommendations are not intended to replace good engineering analysis but do provide typical, industry accepted guidelines.

Instrumentation

Speed is the primary factor in selecting transmitters. Most compressor systems will utilize analog electronic transmitters with time constants from about 250 milliseconds. As a comparison, pneumatic transmitters can have time constants of several seconds, which obviously eliminates their use in surge protection. As digital transmitters have become more prominent, it is becoming increasingly more difficult to procure their analog predecessors. The extra signal processing in these transmitters add time, albeit small amounts, to the loop response. For the fastest response, some diffused silicon sensors can have time constants as short as 10 milliseconds. Impulse lines should be kept as short as possible, and transmitters should be mounted above the process line to promote liquid drainage. Proper application of the flow element should be followed. Upstream pipe run recommendations or the use of flow conditioners not only improve accuracy but also reduce signal noise.

Anti-surge Valves

Anti-surge valves should be sized properly, capable of the full capacity flow of the compressor at reduced pressure. A typical valve sizing coefficient (Cv) is roughly double the highest surge limit line flow. Stroking speeds are typically 2 seconds or less from closed to fully open. This often requires the use of volume boosters, particularly on larger valve sizes, for normal operation. Linear valves are preferred, but non-linear valves can be characterized within the compressor control application. Positioners can be problematic in anti-surge applications, but their use is sometimes required because of the type of valve being used. Consult with the valve manufacturer carefully. Noise abatement may be required in some applications.

Chapter 4.
Configuration Mode

4.1 Introduction

The 505CC-2 may be configured using the Commissioning Configuration Tool (CCT) software running on a connected computer. See Volume 1 for a description of the software tools and Volume 2 for the turbine configuration mode. This chapter will provide detailed information concerning the compressor configuration mode only.

The Configuration Mode of the ToolKit Tool Application, 54183682CF, is a step by step procedure to program the 505CC-2 compressor control. A series of pages are used to escort the user through every option the 505CC-2 compressor control contains. The following screens will step a user through all of the configurable features of the control system.

4.2 Compressor Configuration Screens

4.2.1 Home Page

The home page is displayed up after starting the ToolKit Tool Application, 54183682CF.wtool. It can display full or limited configuration access. The full configuration mode is used to configure the control to the application, and is only accessible when the turbine is shutdown with full configuration authorization. The limited configuration mode allows the user to view these same page screens, change some selections, but disables the selection of configuration settings that should not be changed with the turbine running.

Figure 4-1. 54183682CF.wtool Home Page

It displays the following:

- Turbine Full or Limited Configuration
  - o See Volume 2 for more information on Turbine Configuration Screens.

- Compressor Full or Limited Configuration
    - This will be explained in this Chapter.
- External Programs; see B26542V1 for a more detailed description of these programs.
    - AppManager enables functionality such as application loading and datalog retrieval.
    - Control Assistant can be tunable extraction, and datalog viewing.
    - On-Screen Keyboard enables usage of a mouse operated keyboard.
- System Info
    - Displays the GAP application P/N and revision, and coder version used.
- Authorization Level
    - Shows the authorization level for the miscellaneous functionality.

The screen shown in Figure 4-1 shows the initial screen with factory default tunables. The error no turbine and/or compressor configured indicates that the user has not successfully completed the configuration mode steps.

NOTICE

Entering full configuration mode will issue a CPU I/O lock to the hardware interface modules and all outputs from the control will be disabled.

Ensure the turbine and/or compressor is in a shutdown condition and that devices are properly locked out or that a safety issue is not created.

Perform the following steps to enter the full configuration mode from a limited configuration mode condition:

1. Ensure the turbine and/or compressor is shutdown and steam block valves closed.
2. Press the button Enter Full Configuration Mode.
3. Press the Confirm Action button that will appear. If not pressed with a few seconds will result in returning to the Enter Full Configuration Mode button.
4. The CPU will now issue an I/O lock to the hardware interface modules and all outputs from the control will be disabled.
5. The Compressor Full Configuration button is available now

The 505CC-2 provides a compressor configuration wizard to ensure the configuration is done in the correct order. Click on Compressor Full Configuration to start the compressor configuration wizard and proceed with the Main Configuration, see 4.2.2 All Stages Main Configuration.

4.2.2 All Stages Main Configuration

This is the initial screen for configuration of a particular compressor application. The first step is to select the compressor layout. The following options are available:

- No Anti-Surge controller used
- Single stage compressor
    - Only a single compressor applies.
- Dual with one flow element
    - Two compressors are driven utilizing one flow element.
- Dual with two flow elements
    - Two compressors are driven utilizing two flow elements.

- Dual with side stream extraction
  - o Two compressors with a side stream extraction. Two flow elements are mandatory for this layout.
- Dual with side stream admission
  - o Two compressors with a side stream admission. Two flow elements are mandatory for this layout.

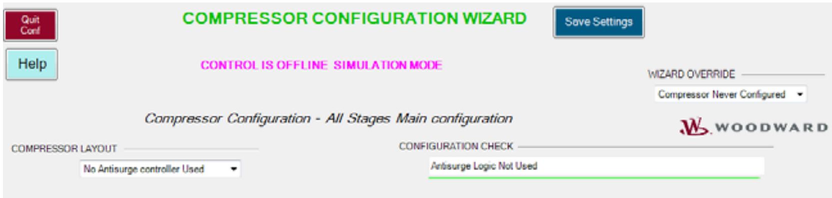


Figure 4-2. Configure compressor layout

Screens and configuration option are shown or hidden depending on the compressor layout and configured control functionality.

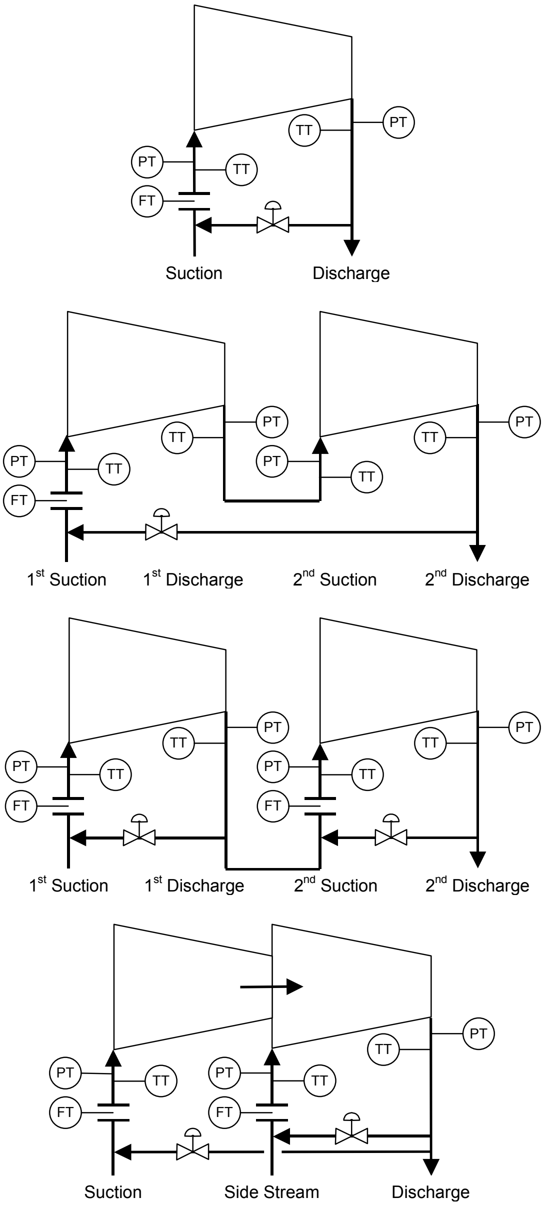


Figure 4-3. Examples of Compressor Layouts

4.2.2.1 Single Compressor

Following are descriptions of the shown functionality when a single compressor layout is configured. Addition sensor locations and/or an anti-surge valve layout selection would be needed when the other layout are selected.

Measurement Units

Select the measurement units system used from the following list:

- Metric units for all signals
- Imperial units for all signals

With this selection the units will be defined to be further used in configuring the compressor control. This parameter is critical since the surge map and operating point will be calculated based on this information.

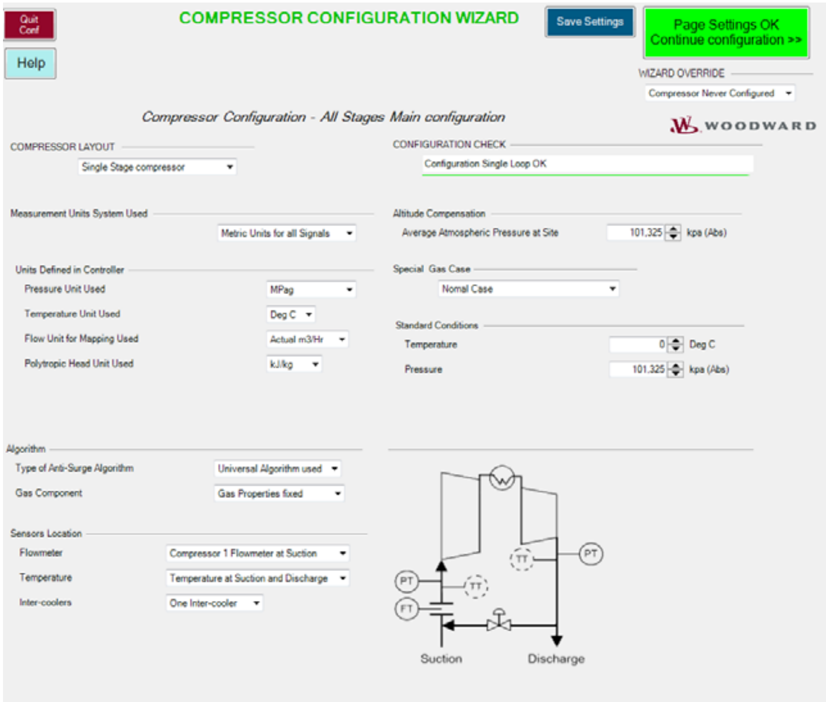


Figure 4-4. Main configuration, example single stage compressor

Units defined in controller

The selected unit for pressure, temperature and flow will be generic for all these sensor measurements used in the control.

Select the pressure unit used for all pressure transmitters with the exception of the flow element. The options are:

Metric	Imperial
kPa (Absolute)	Psia (Absolute)
BarA (Absolute)	Ft or H2O (Absolute)
Kg/cm2 (Absolute)	Atm (Absolute)
kPag (Gauge)	Torr (Absolute)
MPag (Gauge)	Tons-force/ft2 (Absolute)
Barg (Gauge)	Inch of Hg (Absolute)
Kg/cm2 (Gauge)	Psig (Gauge)
	Ft or H2O (Gauge)

Select the temperature unit used for all temperature transmitters. The options are:

Metric	Imperial
Deg C	Deg F
Deg K	Deg R

Select the flow unit used for entering the compressor map. The options are:

Metric	Imperial
Actual m3/Hr	Actual ft3/Hr
Actual m3/min	Actual ft3/min

The polytropic head unit used can only be selected when selected metric units. A fixed unit is applicable for imperial units:

Metric	Imperial
N-m/kg	Ft-lbf/lbm
Kg-m/kg	
kJ/kg	

Altitude Compensation

Set the average atmospheric pressure at site in metric kPaA or imperial psiaA, both are absolute pressure entries.

Most internal calculations use absolute pressure measurements, but it is possible to configure the 505CC-2 for usage with gauge pressures such as for P1, and P2. Then the altitude compensation would be used to be added to the gauge pressure input signals to generate absolute pressures. See also Table 4-1 for a chart of altitude-referenced atmospheric pressures.

Altitude Above Mean Sea Level		Atmospheric Pressure	
Feet	Meters	psiA	kPaA
0	0.0	14.70	101.33
500	152.4	14.43	99.49
1000	304.8	14.16	97.63
1500	457.2	13.91	95.91
2000	609.6	13.66	94.19
2500	762.0	13.41	92.46
3000	914.4	13.17	90.81
3500	1066.8	12.93	89.15
4000	1219.2	12.69	87.50
4500	1371.6	12.46	85.91
5000	1524.0	12.23	84.33
6000	1828.8	11.78	81.22
7000	2133.6	11.34	78.19
8000	2438.4	10.91	75.22
9000	2743.2	10.50	72.40
10000	3048.0	10.10	69.64
15000	4572.0	8.29	57.16

Table 4-1. Atmospheric Pressure Chart

Special Gas Case

This selection defines a distinction between a gas or air compressor, and in case of an air compressor, whether suction pressure is available or not:

- Normal case;
  - The medium is gas, and compressor control requests a suction pressure transmitter to be connected.
- Air compressor with suction pressure;
  - The medium of the compressor is air and a suction pressure transmitter will used in the compressor control.
- Air compressor without suction pressure;
  - The medium of the compressor is air, but no suction pressure transmitter will be used in the control. Instead the value set for average atmospheric pressure will be used.

Standard Conditions

Standard conditions are not identical everywhere. Miscellaneous organizations have established a variety of definitions for standard conditions. The site standard conditions that are applied in the particular compressor application should be entered here. The 505CC-2 uses this entry for flow normalization.

Temperature	**Absolute pressure**	**Relative Humidity**	**Publisher**
Deg C	**kPa**	**% RH**	
0	100.000		IUPAC (new)
0	101.325		IUPAC (old), NIST, ISO10780
15	101.325	0	ICAO's ISA, ISO13443, EEA, EGIA
20	101.325		EPA, NIST
25	101.325		EPA
25	100.000		SATP
20	100.000	0	CAGI
15	100.000		SPE
20	101.3	50	ISO 5011
Deg F	Psi	% RH	
60	14.696		SPE, US OSHA, SCAQMD
60	14.73		EGIA, OPEC, US EIA
59	14.503	78	US Army Standard Metro
59	14.696	60	ISO 2314, ISO 3977-2
F	In Hg	% RH	
70	29.92	0	AMCA
59	29.92		FAA

Table 4-2. Standard reference conditions

Algorithm

The type of algorithm can be selected which is used in the 505CC-2 to control the surge operating point, see also 2.10 Operating Point Calculations for more details on the different algorithms. The options are:

- Standard algorithm
- Universal algorithm

The universal algorithm does not require a temperature measurement at the flow element, suction, or discharge. It can only be used for single or dual stage compressor control with two flow elements.

Gas Component

The gas properties can be selected to be fixed or calculated. This selection depends on the process gas compensation, i.e. molecular weight, ratio of specific heats, etc. For example, select fixed for a closed-loop refrigeration compressor, but a hydrocarbon recycle compressor in a refinery may require calculated gas properties.

Calculated gas properties are only possible in combination with the standard algorithm since the universal algorithm is largely immune to gas compensation changes. In addition to this temperature measurements are required in both suction and discharge of the compressor for calculated properties.

Gas properties calculated enables the compressor control capability to calculate the polytropic exponent while the compressor is running and re-adjust automatically when the gas composition changes. All temperature sensors are needed to utilize this functionality.

Regardless of the selection no calculation will be done in case the universal algorithm is used or when the required temperature measurements are missing.

Sensor location

These selections can differ depending on the compressor layout selected. The description below matches a single stage compressor.

Select the location of the flow meter used, i.e. at the suction or discharge of the compressor.

Select the location of the temperature sensor(s) when used. Further selections can be made to use a default or calculated value of the temperature measurement instead of a measured value. The options are:

- Temperature at suction and discharge
- Temperature at suction only
- Temperature at discharge only
- No temperature sensor used

The status shown underneath configuration check displays an error if selections have a discrepancy with each other when using the standard algorithm. An example of error conditions:

- Temperature location is not at the flow sensor.
- Gas properties variable is selected without having all temperature sensor available.

One or multiple inter coolers might be used. Inter coolers will introduce an error in the polytropic exponent. The 505CC-2 uses an advanced algorithm to correct for this. A selection need to be made on the number of inter coolers in the installation to enable this correction. Entry should be regardless of the 505CC-2 considering it to be one loop, i.e. no process values available before or after the coolers.

4.2.2.2 Dual Compressor

The sensor location and inter coolers for both compressors would need to be entered on this screen when a dual compressor layout is selected.

In addition the valve layout or piping arrangement need to be defined in case of a dual compressor with two flow elements and two anti-surge valves.

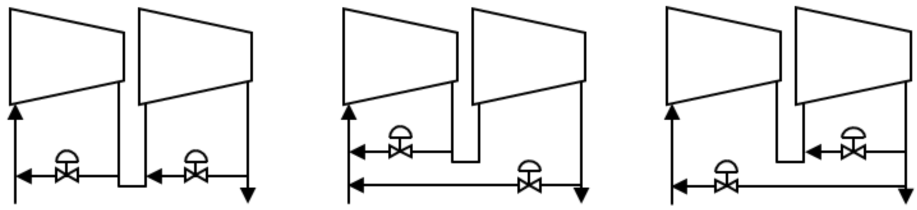


Figure 4-5. Dual with two flow elements

4.2.3 All Stages Gas Characteristics

The following gas characteristics need to be entered on this screen:

- Molecular weight;
  - In case of air the MW is fixed at 28.95 g/mol else an entry of the selected gas is needed in g/mol.
- Specific heat ratio
- Critical Pressure
- Critical Temperature

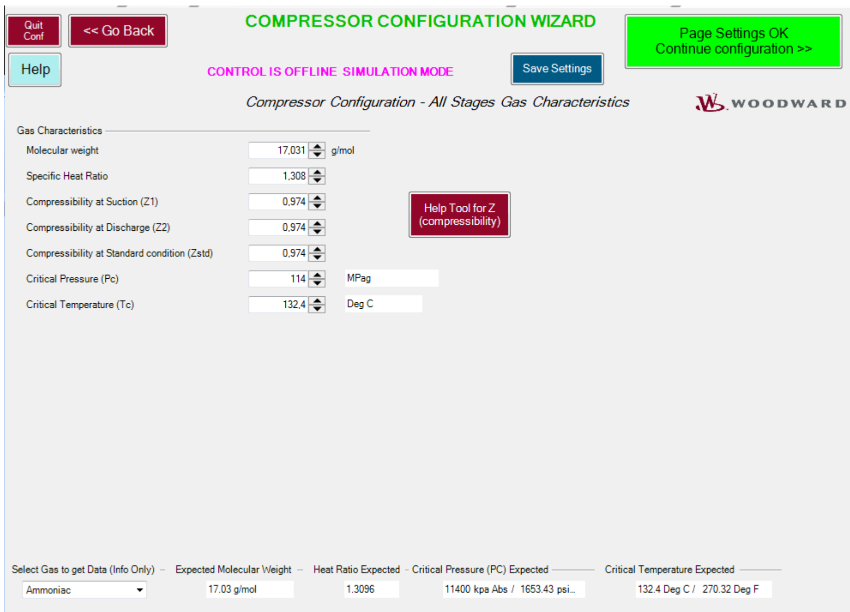


Figure 4-6. Gas Characteristics

The molecular weight is expressed in g/mol. Minor deviations smaller will not affect the accuracy of the anti-surge controller, but for optimization it is necessary to set the value. The value set should be identical as provided by the compressor manufacturer as shown on the surge map. It will be used to calculate the entered surge map and to display the mass flow.

The specific heat ratio (Cp/Cv) should be invariant. It is used for the calculation of the polytropic exponent.

The compressibility at suction and discharge, Z1 and Z2, is the gas compressibility expected at suction and discharge side of the compressor. It depends on the condition at that location. A help tool is available to determine the compressibility.

Although the compressor control can calculate these compressibility factors while running, it is mandatory to set this values according design specification to be used for the defining the surge map.

The critical pressure (Pc) is mandatory in case the compressor control has been configured that a variable gas is used and the gas properties are calculated.

The critical temperature (Tc) is mandatory in case the compressor control has been configured for variable gas properties so the gas properties are calculated.

Gas data information is available at the bottom of this screen and in Table 4-3.

IMPORTANT **The gas data provided at the gas characteristics screen is for information only. The user should determine the accuracy with the gas used which could consist of a combination of properties. Alternatively a gas analysis could be required.**

Selected Gas	Molecular Weight g/mol	Heat Ratio	Critical Pressure kPa Abs / psia	Critical Temperature Deg C / Deg F
Acetylene	26.038	1.2598	6191 / 897.93	35.18 / 95.32
Air	28.959	1.4028	3771 / 546.94	-140.5 / -220.9
Ammoniac	17.03	1.3096	11400 / 1653.43	132.4 / 270.32
Argon	39.948	1.67	4898 / 710.39	-122.29 / -188.1
Benzene	78.11	1.12	4924 / 714.16	288.85 / 551.9
Isobutene	58.123	1.1	3720 / 539.54	134.98 / 275
Butane-n	58.123	1.11	3796 / 550.56	152.03 / 305.7
Isobutene	56.107	1.11	4001 / 580.15	144.85 / 292.7
Carbon Dioxide	44.01	1.2937	7382.5 / 1070.74	31.06 / 87.908
Carbon Monoxide	28.010	1.4024	3498.7 / 507.44	-140.24 / -220.43
Chlorine	70.906	1.33	7700 / 1116.79	144 / 291.2
Ethane	30.069	1.1932	4883.9 / 708.35	32.27 / 90.1
Ethylene	28.054	1.2426	5076 / 736.21	9.49 / 49.1
Fluor	37.997	1.36	5215 / 756.37	-128.85 / -199.9
Freon 11	137.38	1.14	4374 / 634.39	198 / 388.4
Freon 12	120.91	1.13	4115 / 596.83	112 / 233.6
Freon 13	104.47	1.14	3869 / 561.15	28.78 / 83.8
Freon 22	86.48	1.18	4936 / 715.9	96 / 204.8
Helium	4.0026	1.66	227.5 / 32.996	-267.9 / -450.2
Heptane-n	100.20	1.05	2736 / 396.82	266.85 / 512.33
Hydrogen	2.016	1.3842	1298 / 188.26	-239.91 / -399.8
Hcl	36.46	1.41	8319 / 1206.57	51.85 / 125.33
Fluor Acid (HF)	20.01	0.97	6485 / 940.57	187.85 / 370.13
Methane	16.043	1.3054	4596 / 666.59	-82.62 / -116.7
Methanol	32.04	1.2	8084 / 1172	240 / 464
Chloric-methyl (CH3CL)	50.488	1.24	6680 / 968.85	143.1 / 289.6
Natural gas(*)	17.74	1.27	4634 / 672.1	-70.15 / -94.3
Neon	20.179	1.64	2756 / 399.72	-228.75 / -379.7
Nitrogen Monoxide	30.006	1.4	6485 / 940.57	-93 / -135.4
Nitrogen	28.0134	1.4	3399.9 / 493.11	-146.95 / -232.51
Octane	114.23	1.66	2513 / 364.48	295.85 / 564.5
Oxygen	31.9988	1.3933	5043 / 731.43	-118.574 / -181.4
Pentane	72.15	1.06	3374 / 489.36	196.85 / 386.33
Propane	44.096	1.15	4250 / 616.41	96.67 / 206
Propylene	42.08	1.1568	4610 / 667.17	91 / 195.8
Saturated Steam	18.016	1.25-1.32	22119 / 3208.09	373.85 / 704.9
Sulfur dioxin	64.06	1.2825	7884 / 1143.48	157.65 / 315.8
Over Heated Steam	18.016	1.315	22119 / 3208.08	373.85 / 704.9

Table 4-3. Gas Data, Reference at 25 °C

Press the help tool button to show the compressibility calculation tool. Ensure the correct critical temperature and pressure have been determined and entered previously.

Enter the expected gas pressure and temperature and hit the calculate button. The tool will display the expected Z value.

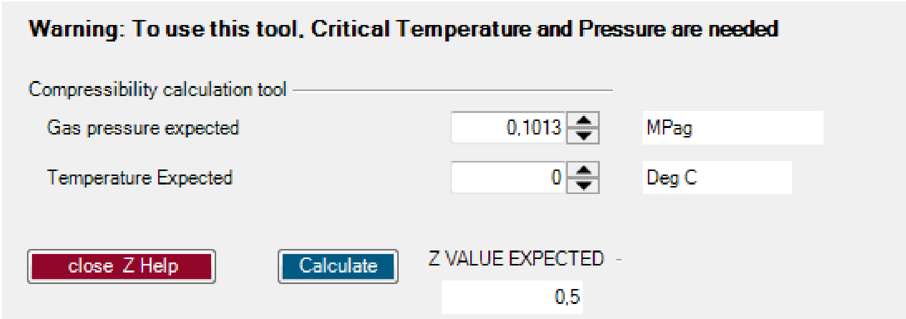


Figure 4-7. Compressibility Tool

For example, the pressure and temperature at suction can be entered to determine the compressibility at suction to be entered in the gas characteristics.

4.2.4 All Stages Flow Element

The amount of flow meters will adapt on this screen pending the compressor layout set on the first configuration screen, see 4.2.2 All Stages Main Configuration.

This configuration screen is used to calculate the flow element coefficient used by the compressor control. This parameter is critical since the configuration will request and verify that a value has been or else the status will indicate an error message.

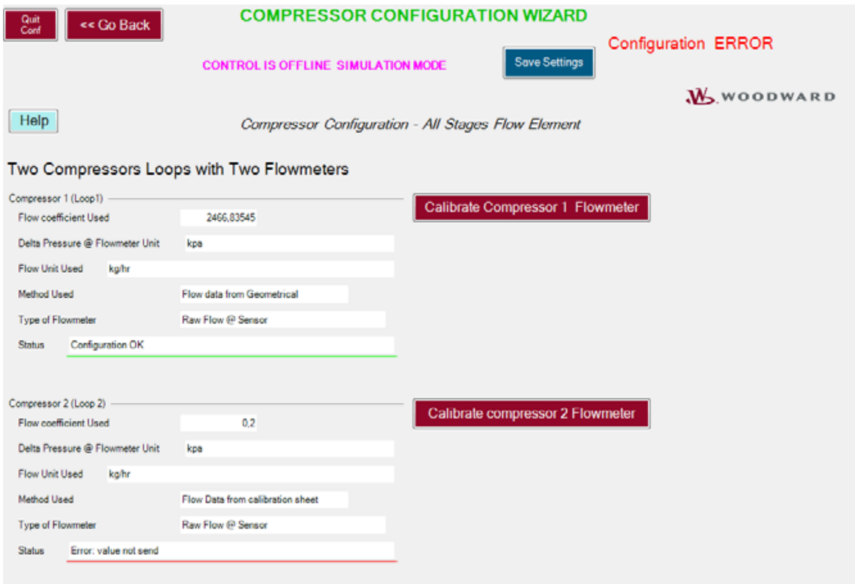


Figure 4-8. Flow Element Screen

Press the calibrate compressor flow meter button to start entering the required calibration data. Calibration data can be based on a calibration sheet or geometry data of the flow element.

Flow sensor type

Selection of flow sensor type is depending on the flow element used. The compressor control requires this setting. The following selections are available:

- Raw flow;
  - The flow element will provide a raw value only, i.e. a delta pressure.
- Square root;
  - The flow element will provide the square root of the delta pressure; therefore the compressor control will not perform this calculation.
- Square root and pressure compensated;
  - The flow element will provide the square root of the delta pressure, and compensate the value based on the actual pressure at the sensor.

Calculation method used

Select the method used to calculate the flow element coefficient. The following selections are available:

- Flow data from calibration sheet
- Flow data from geometry
- Manual setting of flow coefficient

4.2.4.1 Method 1: Flow data from calibration sheet

The flow data from calibration sheet method can be used when the calibration sheet of the flow element is available.

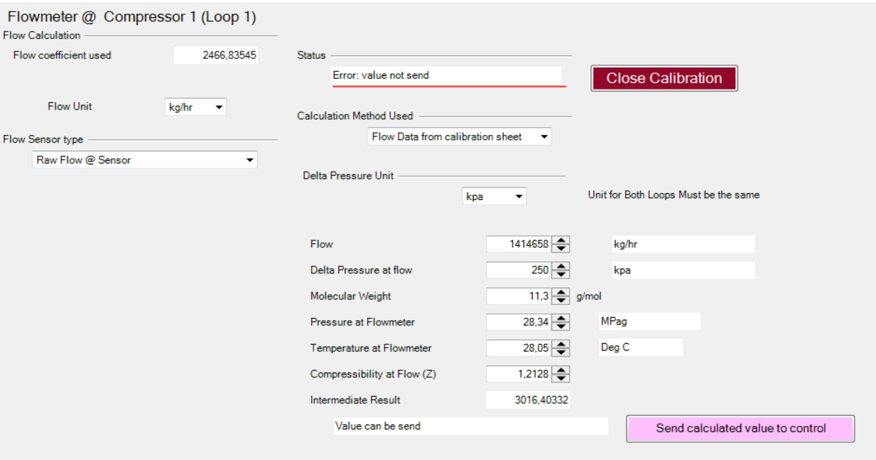


Figure 4-9. Flow data from calibration sheet

Enter the data based on the calibration data sheet. The units are pending on the unit system configured.

Enter the flow value and unit. Both a volume and mass flow are available to be entered in the units show in the following table:

Metric	Imperial
Nm3/hr	SCFM x 1000
kg/hr	lb/hr

Enter the delta pressure at the given flow and the unit used. The unit is critical when using the geometry method. Units available are shown in the table below:

Metric	Imperial
kpa	psi
mbar	Inch H2O
mmH2O	Inch Hg
mmHg	

Enter the molecular weight of the gas used during the calibration in the units shown. This gas may be different from the gas running through the compressor.

Enter the pressure of the gas at the flow meter during calibration in the units shown.

Enter the temperature of the gas at the flow meter during calibration in the units show.

Enter the compressibility factor (Z) of the gas during calibration.

The intermediate result will be the flow coefficient that will be used by the compressor control. The button "send calculated value to the control" will set this value and the status will change to configuration ok.

4.2.4.2 Method 2: Flow data from geometry

The flow data from geometry can be used when the geometry of the flow element is known. The compressor control can calculate the coefficient based on this data.

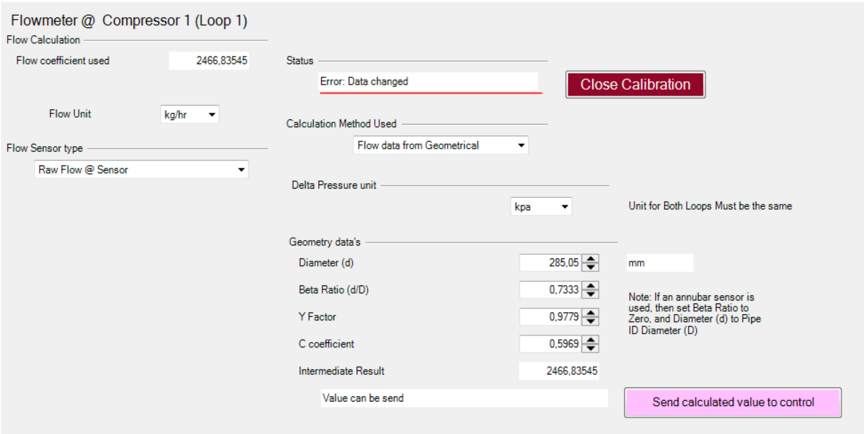


Figure 4-10. Flow data from geometry

Enter the following data based on the flow element data. The units are pending on the unit system used. See delta pressure unit in Method 1. This value is critical for calculating the coefficient based on the geometry data:

- Enter the diameter of the flow element in mm or inch pending units used.
- Enter the beta ratio of the flow element.
- Enter the Y factor of the flow element.
- Enter the C coefficient of the flow element.

The intermediate result will be the flow coefficient that will be used by the compressor control. The button "send calculated value to the control" will set this value and the status will change to configuration ok.

4.2.4.3 Method 3: Manual setting of flow coefficient

The flow element coefficient can be entered directly and send to the control. This option is only recommended for users that have the expertise to determine this value else the other method should be used.

4.2.5 All Stages Anti-Surge Valve Settings

This page is used to set the anti-surge valve behavior and characteristics in the compressor control. One or two valve settings may be requested depending on the compressor layout configured.

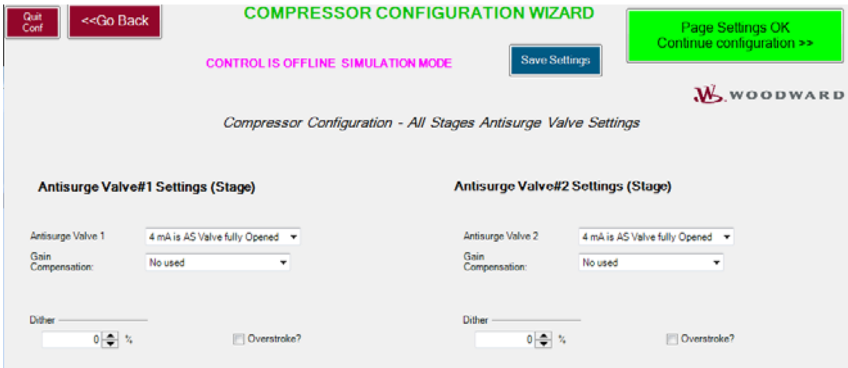


Figure 4-11. Anti-Surge Valve Settings

Gain compensation can compensate the anti-surge valve based on either linearization data sheet or CV provided by the valve supplier. An additional display will be shown depending on the following selections:

- Linearization curve used;
  - Enables curve data to be entered.
- Compensation based on CV;
  - Enables entry of the normal (standard) flow through the valve expected when fully opened in normal conditions, and enter the CV of the valve.

In addition dither can be set if needed which will generate a pulsation signal at high frequency. Selecting over-stroke will provide a surplus on the open or close demand ensuring this position is mechanically seated.

4.2.6 Mapping

The following screen will be shown when mapping is selected or in the next step of the compressor configuration wizard. The values shows are the actual surge map data currently set in the control.

Adjustments can be made to the Modbus multiply factors the X and Y value, and scaling for displaying the surge map.

Figure 4-12. Map Configured in Control

The following maps can be displayed:

- Discharge pressure versus actual flow, P2=F(flow)
- Pressure ratio (absolute) versus actual flow, P2/P1=F(flow)
- Polytropic head versus actual flow, H=F(flow)
- Woodward operating point versus reduced head, q2/H=F(red head)

These cover the main surge maps provided by compressor manufacturers. . The first two maps based on pressure would automatically adapt when the molecular weight, actual suction pressure and/or temperature changes, so the map displayed might not match the entered values.

Press the calibrate/modify compressor surge map button for entry of surge map data, see the next figure.

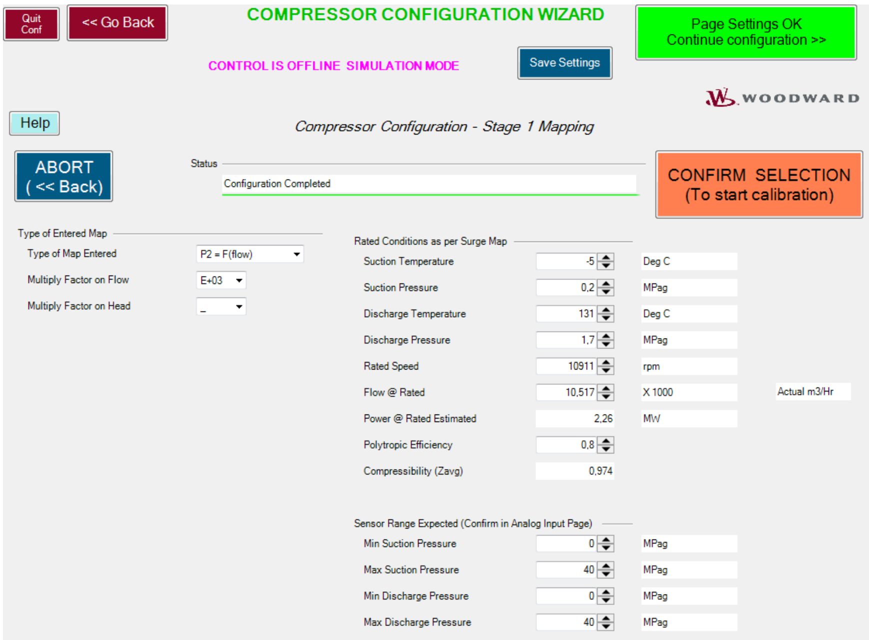


Figure 4-13. Entry Surge Map Data

NOTICE

Entry of surge map data is critical and must match the actual surge map data of the compressor and/or as delivered by the compressor manufacturer.

The first page for entry of surge map data is for the rated condition as per surge map meaning the operating conditions used to create the surge map. All units have been defined on the first configuration screen and cannot be changed here. A manual conversion would be needed in case these do not match the compressor manufacturer units used for the surge map.

The first step is to enter the type of map to be entered. A multiply factor could be chosen to use the X and Y entered values with an exponent, usually matching the exponent as displayed on the surge map.

The following rated conditions are required:

- Suction temperature per surge map
- Suction pressure per surge map
- Discharge temperature per surge map
- Discharge pressure per surge map
- Rated speed, the speed of the compressor at these rated conditions
- Polytropic efficiency is an average value of the efficiency of the compressor. The estimated power is derived from this. Alternative in case the polytropic efficiency can be adjusted to match the compressor power.
- Compressibility value is derived from the gas properties and cannot be adjusted.

Surge map data entry performs error checks during entry. The suction and discharge pressure sensor range should be entered for verification that the surge map entered is within the sensor range or else and error will be detected and displayed.

Proceed with entry of the surge map data after the rated conditions have been entered by pressing the button confirm selection (to start calibration).

The surge map entry will be six X and Y values. It is recommended to obtain these points at equal speed differences across the operating range. For example, the rated condition is 100 % speed and the other points are at 85, 90, 95, 105 and 110 % from rated speed.

Press the button next point to step through the six point data entry.

IMPORTANT	**The next step to enter surge map data should be requested only when the rated conditions have been set.**

The status display will show the error when detected. In addition the related entered point could be highlighted red. A configuration completed status will be shown if no errors during data entry have been detected. It is also possible to press the back button in case an adaption is needed in the previous rated condition screen.

4.2.7 Control Settings

The following screen for entry of control settings will be displayed when selected or in the next step of the compressor configuration wizard. It contains the following sub-screens:

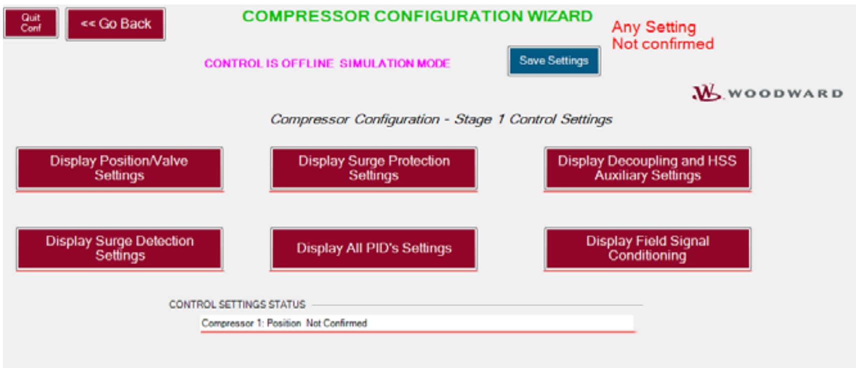


Figure 4-14. Control Settings

- Position / Valve Settings;
  - Valve position at shutdown and start-up
  - Control online detection
  - Valve open/close rates
- Surge Detection Settings
  - Surge detection methods used
  - Action taken when surge is detected
- Surge Protection Settings
  - Surge prevention
  - Action taken to prevent surge
- PID Settings
  - Normal PID settings
  - Rate controller PID settings
  - Valve freeze options
  - Suction override controller
  - Discharge override controller

- Decoupling and HSS Auxiliary Settings
  - Decoupling on speed
  - Decoupling on other stage
  - Decoupling on external input #1
  - Decoupling on external input #2
  - Auxiliary control 1
  - Auxiliary control 2
- Field Signal Conditioning
  - Last good values
  - Field signal filtering
  - Default value settings
  - Field signal fault action

4.2.8 Position / Valve Settings

4.2.8.1 Valve position at shutdown and start

The anti-surge valve position during compressor purge cycle, shutdown or startup can be configured on this sub-screen.

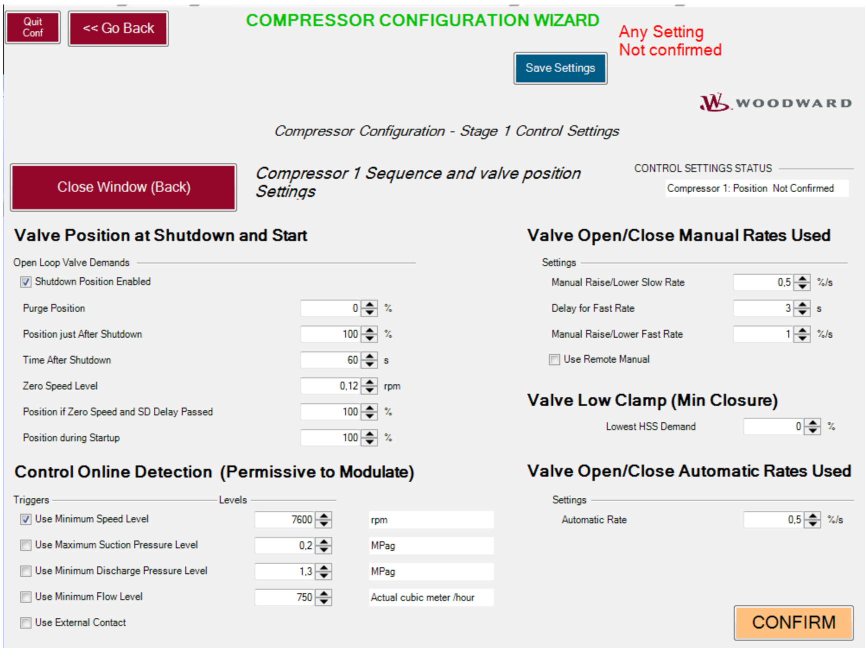


Figure 4-15. Position / Valve Settings

Shutdown Position Enabled, Initial=disabled

When enabled, the options below will be active.

Purge position, Initial=0.0 (0.0, 100.0)

Enter the required anti-surge valve position for a purge cycle during startup, i.e. 0 to 100% open.

Position just after shutdown, Initial=100.0 (0.0, 100.0),

Enter the required shutdown position, 0 to 100% open, of the anti-surge valve. Typically this is set to 100%, i.e. a full recycle position of the anti-surge valve.

Time after shutdown, Initial=60.0 (0.0, 100.0)

Enter the delay time in seconds used by the control to determine when to transition to the zero-speed sequence. The anti-surge valve is transitioned from the shutdown position to the zero-speed position after a shutdown and when the speed falls below the configured zero-speed level and remains there for the set time after the shutdown delay time.

Zero speed level, **Initial=0.0 (0.0, 10000.0)**

Enter the speed level in rpm at which the compressor is considered started. This is the speed at which the anti-surge valve transitions from its configured zero-speed position to the configured start position.

This is also the speed at which the unit is considered zero-speed after a shutdown.

The zero speed level switching will only come in to effect when other start conditions have been fulfilled.

IMPORTANT

The zero speed functionality described is only active if a valid speed signal is available.

The sequence will go instead to and from the shutdown position when a speed signal is not available. In this case a start signal, discrete input or manual command, is required to sequence the compressor online.

Position if zero speed and SD delay passed **Initial=100.0 (0.0, 100.0)**

Enter the required anti-surge valve position, 0 to 100% open, when below zero speed and the time after shutdown has passed.

This shutdown sequence could be used to close the anti-surge valve after a shutdown to provide process isolation instead of leaving the valve open. Configure the position identical to the shutdown position and set the delay time to 0 when this function is not required.

Position during startup **Initial=100.0 (0.0, 100.0)**

Enter the required startup position, 0 to 100% open, for the anti-surge valve. Typically this is set to 100%, i.e. a full recycle position of the anti-surge valve.

The valve will transition to this position on startup and remain there until the configured online conditions are met.

At least one online trigger must be enabled to enable this start sequence. The control will skip the start sequence and transition immediately to automatic, online control, if no online triggers are configured which is not recommended.

4.2.8.2 Control on-Line detection

All the enabled triggers here must be satisfied to transition from the start sequence to automatic, online control. While online, loss of any single trigger will cause the control to revert to its start sequence.

Use minimum speed level **Initial=0.0 (0.0, 25000)**

Check this box to enable the speed detection method for the online condition.

Enter the required speed setpoint in rpm for the online condition. The online trigger is satisfied during startup once speed increases beyond this setpoint.

Use maximum suction pressure level **Initial=0.0 (-14.0, 25000)**

Check to enable the suction pressure detection method for the online condition.

Enter the required suction pressure setpoint in the unit shown for the online condition. On startup, once suction pressure decreases beyond this setpoint, the online detection trigger is satisfied.

Use minimum discharge pressure level **Initial=0.0 (-14.0, 25000)**

Check to enable the discharge pressure detection method for the online condition.

Enter the required discharge pressure setpoint in the unit shown for the online condition. On startup, once discharge pressure increases beyond this setpoint, the online detection trigger is satisfied.

Use minimum flow Level **Initial=0.0 (0.0, 1000000)**

Check to enable the flow detection method for the online condition.

Enter the required flow setpoint at suction in the unit shown for the online condition. On startup, once flow increases beyond this setpoint, the online detection trigger is satisfied.

Use external contact

Check to enable the auxiliary discrete input for the online condition. This auxiliary input can be through Modbus or hardwired.

4.2.8.3 Valve open/close manual rates used

The settings for manually open and closing the anti-surge valve can be configured in this section.

Manual raise/lower slow rate **Initial=0.5 (0.0, 100.0)**

Enter the slow ramp rate value, in percent per second, to be used when the raise or lower valve command is requested in the manual or manual with backup mode.

Delay for fast rate **Initial=3.0 (0.0, 30.0)**

Enter the value, in seconds, to activate the fast rate when the raise or lower valve command is requested in the manual or manual with backup mode.

Manual raise/lower fast rate **Initial=1.0 (0.0, 100.0)**

Enter the fast ramp rate value, in percent per second, to be used after the delay time when the raise or lower valve command is requested in the manual or manual with backup mode.

Use remote manual

Check this box to enable remote manual. When auxiliary inputs are being used for manual control for raise or lower.

4.2.8.4 Valve open/close automatic rates used

The setting for automatic anti-surge valve control can be configured in this section.

Automatic valve rate **Initial=1.0 (0.0, 10.0)**

Enter the ramp rate value, in percent per second, to be used by the automatic open-loop routines when ramping down the anti-surge valve.

4.2.9 Surge Detection Settings

The surge detection methods and actions to be taken when surge has been detected can be configured on this screen.

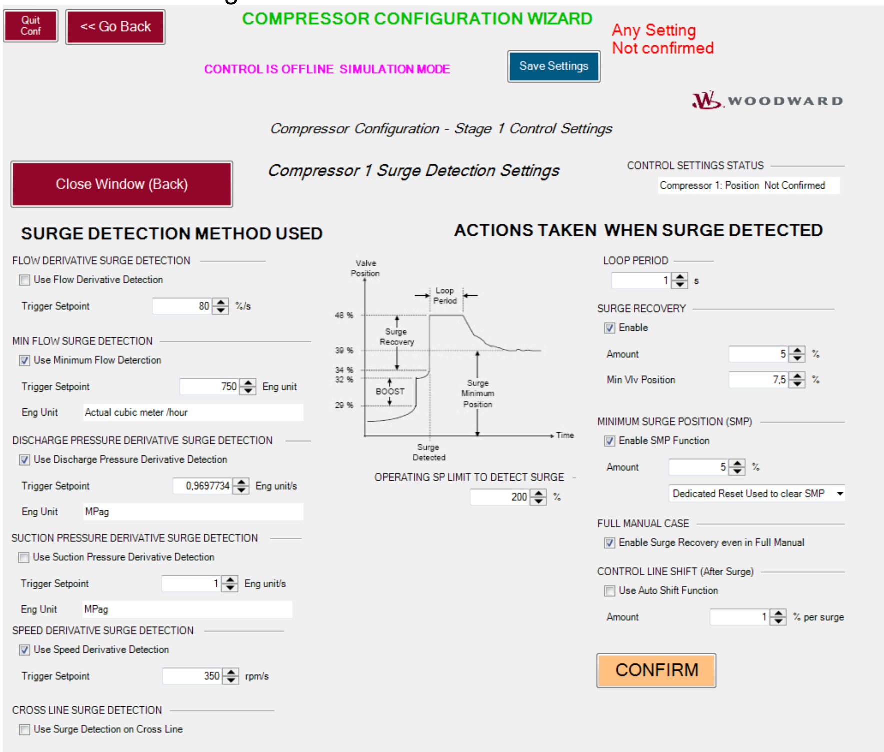


Figure 4-16. Surge Detection Settings

4.2.9.1 Surge Detection Method Used

Flow derivative **Initial=80.0 (1.0, 300.0)**

Check to enable the flow derivative surge detection routine. This routine detects surge by monitoring the rate of change of calculated compressor flow.

Enter the flow derivative value, in percent of suction volumetric flow units per second, above which the Surge Recovery and Surge Minimum Position routines, if enabled, are to be triggered. The setpoint is configured in percent to account for the wide range of most compression processes and to eliminate false triggers on noise at low flow levels. For example, if the current operating flow is 10,000 m^3/hr and this setpoint is configured as 50%, a surge will be detected if the rate of flow change exceeds 5,000 m^3/hr. However, the same derivative at a nominal flow rate of 50,000 m^3/hr is only 10%, and could be caused by a noisy signal, not surge.

Data from an actual surge event is helpful in establishing an appropriate setpoint to exclude normal signal noise and process fluctuations.

Minimum flow **Initial=1.0 (1.0, 1.0E+8)**

Check to enable the minimum flow surge detection routine. This routine, though included as a surge detection method, does not actually detect surge. It merely initiates the same open-loop Surge Recovery and Surge Minimum Position responses when the compressor operating point falls below the configured minimum flow setpoint.

Enter the minimum flow value, in engineering units, of suction volumetric flow below which the Surge Recovery and Surge Minimum Position routines, if enabled, are to be triggered.

Discharge pressure derivative **Initial=100.0 (0.001, 1000000)**

Check to enable the discharge pressure derivative surge detection routine. This routine detects surge by monitoring the rate of change of measured compressor discharge pressure.

Enter the discharge pressure derivative value, in engineering units per second, above which the Surge Recovery and Surge Minimum Position routines, if enabled, are to be triggered.

Data from an actual surge event is helpful in establishing an appropriate setpoint to exclude normal process fluctuations.

Suction pressure derivative **Initial=1.0 (0.001, 100000)**

Check to enable the suction pressure derivative surge detection routine. This routine detects surge by monitoring the rate of change of measured compressor suction pressure.

Enter the suction pressure derivative value, in engineering units per second, above which the Surge Recovery and Surge Minimum Position routines, if enabled, are to be triggered.

Data from an actual surge event is helpful in establishing an appropriate setpoint to exclude normal process fluctuations.

Speed derivative **Initial=1.0 (1.0, 30000.0)**

Check to enable the speed derivative surge detection routine. This routine detects surge by monitoring the rate of change of measured compressor speed.

Enter the speed derivative value, in engineering units per second, above which the Surge Recovery and Surge Minimum Position routines, if enabled, are to be triggered.

Data from an actual surge event is helpful in establishing an appropriate setpoint to exclude normal process fluctuations.

Cross line

Check to enable the surge limit line crossing surge detection routine.

This routine, though included as a surge detection method, does not actually detect surge. It merely initiates the same open-loop Surge Recovery and Surge Minimum Position responses when the compressor operating point falls below the configured Surge Limit Line.

4.2.9.2 Action taken when surge is detected

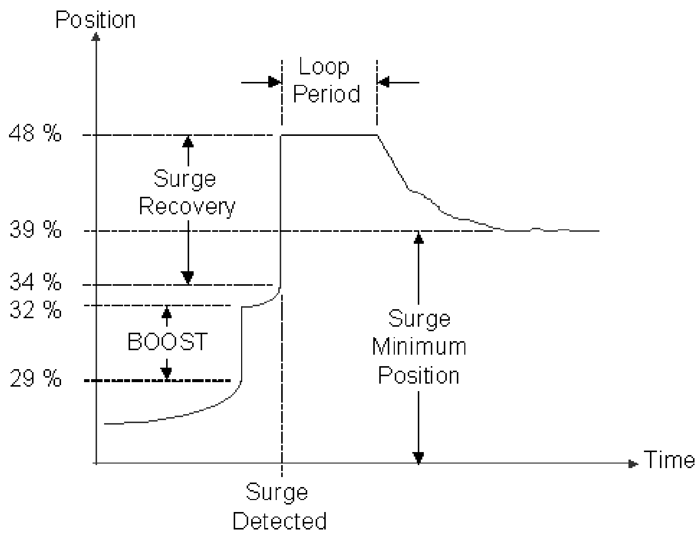


Figure 4-17. Actions when Surge Detected

Loop period **Initial=10.0 (1.0, 300.0)**

Enter the appropriate system loop delay time in seconds

This is the time required for a step change in anti-surge valve position to be realized in the flow measurement once the flow measurement reaches 70~90% of its final steady-state value. This value is depending on piping volumes.

Surge Recovery

Check to enable the open-loop step response triggered when surge is detected by any of the configured surge detection methods.

Amount **Initial=1.0 (0.5, 50.0)**

Enter the value in valve percent that will be added to the current anti-surge valve position when surge is detected by the control. This new valve position remains active for the configured loop period duration and then slowly ramps out at the configured valve decay rate.

Minimum valve position **Initial=1.0 (1.0, 100.0)**

Enter the value in valve percent open that will act as a low limit for the Surge Recovery Response. When surge is detected, the control will position the anti-surge valve at this position or at the current position plus the configured surge recovery amount value, whichever is greater.

Surge Minimum Position (SMP)

Check to enable the Surge Minimum Position function, which will, after the surge cycle has been broken, prevent the anti-surge valve from closing to the point at which surge was detected.

Amount **Initial=1.0 (0.5, 50.0)**

Enter the value in valve percent, typically 3~5%, that will be added to the anti-surge valve demand when surge was detected to establish the SMP valve limit. After the open-loop Surge Recovery response ramps out, the valve will not be allowed to close to the demand at surge plus this amount, so as not to drive the unit into surge again.

This Surge Minimum Position requires a dedicated or normal reset input prior to allowing the valve to close further:

- Dedicated reset used to clear SMP
- Normal reset used to clear SMP

Full manual

Check to enable the Surge Recovery open-loop step response even when in full manual mode. This protection is the only automatic routine that will override manual anti-surge valve control in the full manual mode.

Control line shift

Check to enable Surge Control Line shifting based upon the surge counter.

The Surge Control Line will be shifted a configured percentage for each detected surge, i.e. % per surge. When the surge counter is reset, the shifted amount will slowly ramp back to 0, returning the SCL to its original position.

4.2.9.3 Loop Period, Test Procedure

The system response time for the 505CC-2 is measured as the Loop Period. This is the time from making a change in the anti-surge valve until the change is detected in the S_PV calculation. The detected change is most often determined to be 90% of the total change. So if S_PV changes from 120% to 130%, the loop period is the time from the change of valve demand until S_PV indicates 129%.

Test each anti-surge valve's loop period by following this procedure. If operators are uncomfortable with doing this complete test, just do a single valve step and record the time.

1. At the Position / Valve Settings screen (Figure 4-15), see 4.2.8.3, increase the Manual Valve Rate to some large value, 50 %/s for example. This will better simulate a step change in valve position as opposed to a slower ramp.
2. In Manual with Backup or Full Manual Mode, use the preset function to complete each of the following steps from 0%.

    - Open the anti-surge valve to 5%. Determine the time it takes from opening the valve to seeing the flow signal stabilize.
    - Open the anti-surge valve to 10%. Determine the time it takes from opening the valve to seeing the flow signal stabilize.
    - Open the anti-surge valve to 15%. Determine the time it takes from opening the valve to seeing the flow signal stabilize.

3. Put the control back into Automatic Mode and return the Manual Valve Rate to its original setting.

4.2.10 Surge Protection Settings

The surge protection methods and actions to be taken can be configured on this screen, i.e. configuring the Surge Control Line (SCL) or Boost line margins and actions when reached. In addition consecutive surge alarm and trip functionality can be set, and to selection of full manual mode can be inhibited.

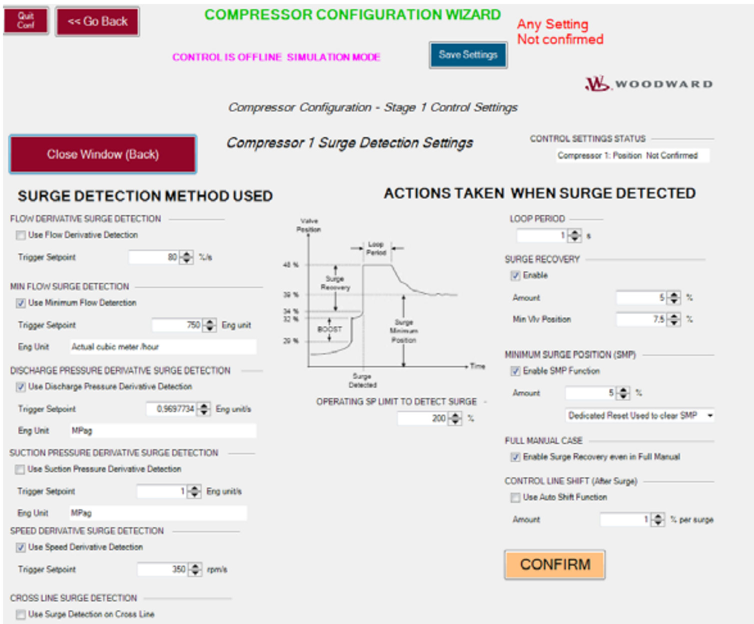


Figure 4-18. Surge Protection Settings

4.2.10.1 Surge prevention

The surge preventions to be configured are the surge control line and boost protection margin on the surge map.

Surge Control Line (SCL) Margin **Initial=10.0 (-30.0, 50.0)**

Enter the margin, typically 8~10 %, used to calculate the setpoint or Surge Control Line (SCL) when the standard algorithm is used. This margin is expressed as a percentage of additional flow, shown on the map to the right of the configured Surge Limit Line (SLL).

Boost Protection Margin **Initial=1.0 (0.5, 50.0)**

Enter the margin in percent flow, typically 3~5%, to locate the boost or backup line to the left of the configured Surge Control Line.

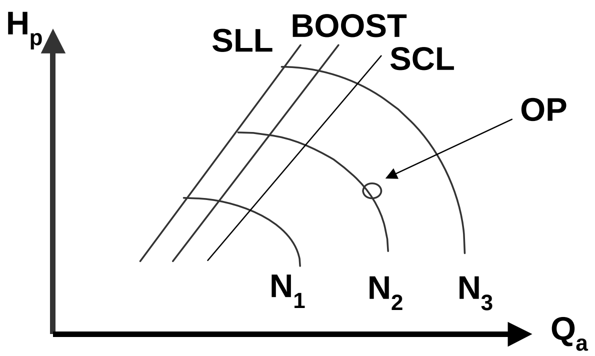


Figure 4-19. Surge Prevention Lines

4.2.10.2 Consecutive Surges Protection

A time and count can be defined for consecutive surge protection resulting in alarm and/or trip actions. For example, 3 surges detected within 20 seconds issues a consecutive surge alarm.

Alarm maximum surges **Initial=3 (0, 100)**

Set the counts that when reached within the defined time will issue the alarm action defined.

Alarm time for maximum surges **Initial=20 (0, 3600)**

Set the time during which the surges need to be counted for the alarm actions.

Alarm if consecutive surges

Enable this option to generate an alarm in case of the set alarm consecutive surge detection.

Full opening if consecutive surges detected

Enable this option to open the fully open the anti-surge valve in case of the set alarm consecutive surge detection.

Trip maximum surges **Initial=4 (0, 7)**

Set the counts that when reached within the defined time will issue the trip action defined.

Trip time for maximum surges **Initial=20 (0, 10000)**

Set the time during which the surges need to be counted for the trip actions.

Trip if consecutive surge SD detected

Enable this option to issue a shutdown in case the set trip consecutive surge detection activates.

4.2.10.3 Actions taken

The actions to be configured are the loop period, boost and pre-pack percentages.

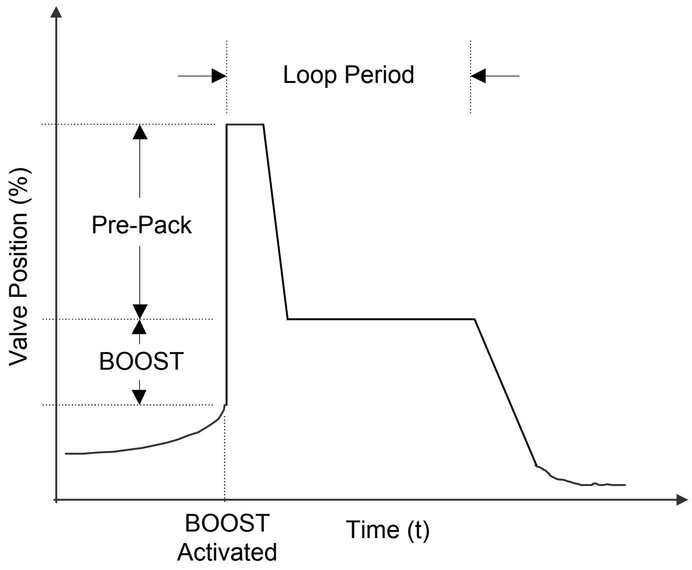


Figure 4-20. Actions Taken

Time loop **Initial=10.0 (1.0, 300.0)**

Define the loop period for the boost and pre-pack. This is the loop period, see also 4.2.9.2 Action taken when surge is detected.

Enable boost **Initial=1.0 (0.0, 50.0)**

Check the box to enable the boost or backup line open-loop step response.

Enter the amount in valve percent that will be added to the current anti-surge valve position when the compressor operating point reaches the boost or backup line. This new valve position remains active for the configured time loop and then slowly ramps out at the configured valve decay rate.

Typically, this value will be what will increase compressor flow by the percent configured as the boost margin. In other words, this amount of valve opening should move the compressor from the boost or back-up line to the Surge Control Line.

Enable Pre-Pack **Initial=0.0 (0.0, 50.0)**

Check to enable the Pre-Pack function.

This function will briefly over-stroke the anti-surge valve at the beginning of the boost and surge recovery open-loop steps to help decrease system response time. It is typically used on processes with excessive loop periods due to large piping volumes.

Enter the value in valve percent that will be added to the anti-surge valve demand at the beginning of the boost and surge recovery steps. This over-stroke amount will remain in effect for 12%, which is the default, but may be tuned in the operation, of the loop period time.

4.2.11 PID Settings

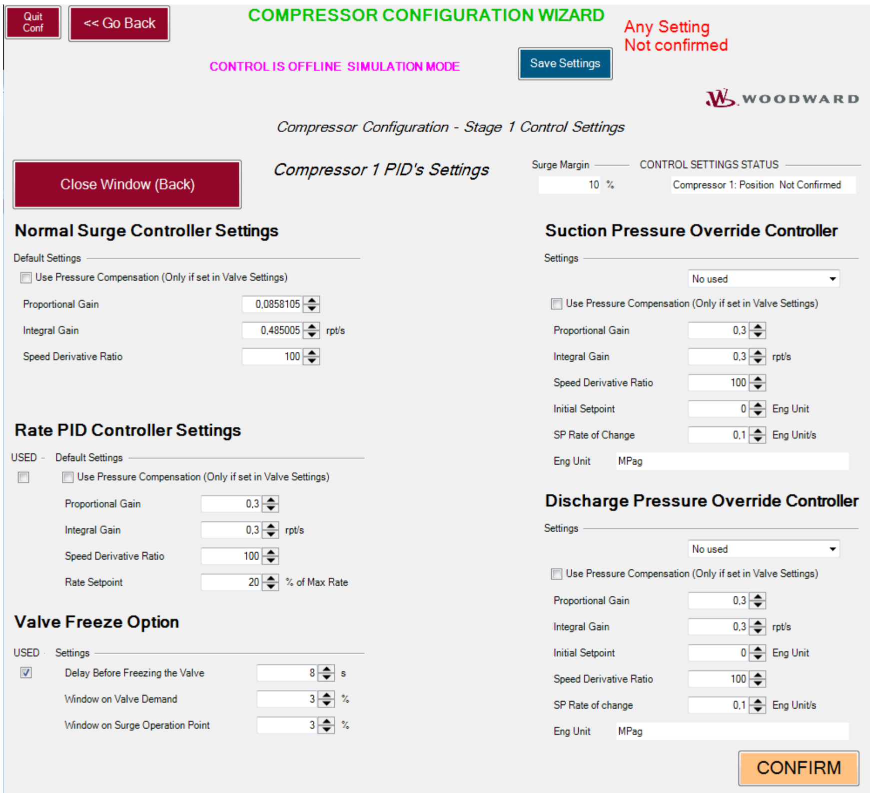


Figure 4-21. PID Settings

4.2.11.1 Normal Surge Controller Settings

Use Pressure compensation

Check to enable automatic gain compensation of the anti-surge PID's proportional gain (see Chapter 3 for a complete description of this function). If enabled, gain compensation will scale the proportional gain relative to the compressor's current operating conditions.

Proportional Gain **Initial=0.3 (0.0, 50.0)**

Enter the appropriate proportional gain (in percent) of the anti-surge PID.

Integral Gain **Initial=0.3 (0.0, 50.0)**

Enter the appropriate integral gain (in repeats per second) of the anti-surge PID.

Speed derivative ratio **Initial=100.0 (0.0, 100.0)**

Enter the appropriate speed derivative ratio (in percent) of the anti-surge PID. Leave this value at 100% for proportional and integral control (recommended). Refer to the 5.2.3.2 Dynamics Adjustments section for more details on tuning speed derivative ratio.

4.2.11.2 Rate Control

See 2.9.3.7 Rate Controller PID for a complete description of this function.

Used

Check to enable the Rate Controller, which limits the rate of movement of the compressor operating point toward its Surge Control Line. As the operating point moves closer to the Surge Control Line, its speed of approach becomes more critical. If the control deems the rate of approach excessive, it will open the anti-surge valve to slow the operating point before it reaches the Surge Control Line, thereby lessening overshoot and instability during a severe transient condition.

Use Pressure compensation

Check to enable automatic gain compensation of the rate PID's proportional gain. If enabled, gain compensation will scale the proportional gain relative to the compressor's current operating conditions.

Proportional Gain **Initial=0.3 (0.0, 50.0)**

Enter the appropriate proportional gain (in percent) of the rate PID.

Integral Gain **Initial=0.3 (0.0, 50.0)**

Enter the appropriate integral gain (in repeats per second) of the rate PID.

Speed derivative ratio **Initial=100.0 (0.0, 100.0)**

Enter the appropriate speed derivative ratio (in percent) of the rate PID. Leave this value at 100% for proportional and integral control. Refer to the 5.2.3.2 Dynamics Adjustments section for more details on tuning speed derivative ratio.

Rate Setpoint (% of max rate) **Initial=20.0 (1.0, 100.0)**

Enter the appropriate rate controller setpoint, in percent of maximum allowable rate.

4.2.11.3 Valve Freeze

See 2.9.5.5 Valve Freeze Mode for a complete description of this function.

Used

Check to enable the anti-surge valve freeze function. This routine will clamp the valve demand at a fixed output if unit operation varies within confined windows of anti-surge valve demand and S_PV. This may aid in settling an unnecessarily swinging process.

Delay before Freezing the Valve **Initial=30.0 (0.0, 300.0)**

Enter the time delay, in seconds, at which the freeze function is enabled or sampled. In other words, after this time delay the freeze routine is initiated provided that the valve demand and S_PV criteria are satisfied.

Window on Valve demand **Initial=3.0 (0.1, 10.0)**

Enter the value of internal valve demand, in %, at which the freeze function remain active

Window on Surge Operating Point **Initial=3.0 (0.0, 10.0)**

Enter the value of internal S_PV, in %, at which the Freeze function remain active

4.2.11.4 Suction Pressure Override

See 2.9.4.1 Suction Pressure Override for a complete description of this function.

Used

Check to enable suction pressure override control. This auxiliary controller will modulate the anti-surge valve to boost compressor suction pressure and is usually used as a backup to other primary controllers, such as when the motor speed which is controlling suction pressure reaches minimum governor. The actual P1 or another dedicated channel can be selected to be used for suction pressure override controller.

Use Pressure compensation

Check to enable automatic gain compensation of the suction pressure PID's proportional gain. If enabled, gain compensation will scale the proportional gain relative to the compressor's current operating conditions.

Proportional Gain **Initial=0.3 (0.0, 50.0)**

Enter the appropriate proportional gain (in percent) of the suction pressure PID.

Integral Gain **Initial=0.3 (0.0, 50.0)**

Enter the appropriate integral gain (in repeats per second) of the suction pressure PID.

Speed derivative ratio **Initial=100.0 (0.0, 100.0)**

Enter the appropriate speed derivative ratio (in percent) of the suction pressure PID. Leave this value at 100% for proportional and integral control. Refer to the 5.2.3.2 Dynamics Adjustments section for more details on tuning speed derivative ratio.

Initial Setpoint **Initial=0.0 (-1000000.0, 1E+07)**

Enter an appropriate pressure override setpoint value, such as compressor suction pressure setpoint. This setpoint should be chosen carefully if other devices or logic will be controlling the same process parameter.

SP Rate of change **Initial=0.1 (0.001, 10000)**

This defines the rate of change when the setpoint is raised or lowered during running.

4.2.11.5 Discharge Pressure Override

See 2.9.4.2 Discharge Pressure Override for a complete description of this function.

Used

Check to enable discharge pressure override control. This auxiliary controller will modulate the anti-surge valve to relieve compressor discharge pressure and is usually used as a backup to other primary such as when the motor speed which is controlling suction pressure reaches minimum governor. The actual P2 or another dedicated channel can be selected to be used for discharge pressure override controller.

Use Pressure compensation

Check to enable automatic gain compensation of the suction pressure PID's proportional. If enabled, gain compensation will scale the proportional gain relative to the compressor's current operating conditions.

Proportional Gain **Initial=0.3 (0.0, 50.0)**

Enter the appropriate proportional gain (in percent) of the discharge pressure PID.

Integral Gain **Initial=0.3 (0.0, 50.0)**

Enter the appropriate integral gain (in repeats per second) of the discharge pressure PID.

Speed derivative ratio **Initial=100.0 (0.0, 100.0)**

Enter the appropriate speed derivative ratio (in percent) of the discharge pressure PID. Leave this value at 100% for proportional and integral control. Refer to the 5.2.3.2 Dynamics Adjustments section for more details on tuning speed derivative ratio.

Initial Setpoint **Initial=0.0 (-1000000.0, 1E+07)**

Enter an appropriate pressure override setpoint value, such as compressor discharge pressure setpoint. This setpoint should be chosen carefully if other devices or logic will be controlling the same process parameter.

SP Rate of change **Initial=0.1 (0.001, 10000)**

This defines the rate of change when the setpoint is raised or lowered during running.

4.2.12 Decoupling and HSS Auxiliary Settings

Decoupling may be necessary to provide action before an upset occurs. Upsets are anticipated from knowledge of the operating parameters and their relation to the operation of the anti-surge valve.

The following four decoupling can be configured on this page:

- Decoupling on speed
- Decoupling on other stage
- Decoupling on external input #1
- Decoupling on external input #2

In addition configuration of the High Signal Select HSS auxiliary control can be configured.

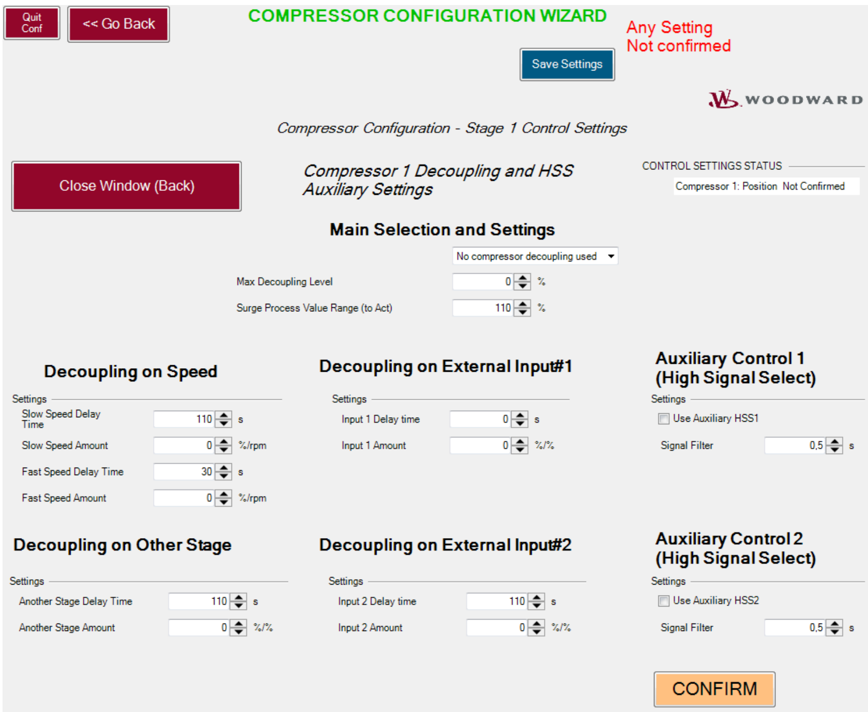


Figure 4-22. Decoupling and HSS Auxiliary Settings

4.2.12.1 Main selection and settings

The following selections can be made to activate decoupling:

- No compressor decoupling used
- Compressor decoupling used

Maximum decoupling level **Initial=0.0 (0.0, 20.0)**

Maximum values added/subtracted to the valve as demand by the decoupling action.

Surge process value range **Initial=110.0 (100.0, 140.0)**

This is the minimum value of the surge operating point to activate decoupling.

4.2.12.2 Decoupling on speed

Slow speed delay time **Initial=110.0 (0.0, 500.0)**

Enter the appropriate delay time (in seconds) that the steady-state speed decoupling routine will remain in effect.

Slow speed amount **Initial=0.0 (0.0, 300.0)**

Enter the appropriate gain, or scalar, (in percent valve demand per rpm) applied to a change in prime mover speed to generate a feed-forward bias of the anti-surge valve demand.

Decoupling is enabled by setting the amount separately for all routines. Set the amount to 0.0 to disable a particular decoupling routine.

Fast speed delay time **Initial=30.0 (0.0, 5000.0)**

Enter the appropriate delay time (in seconds) that the emergency speed decoupling routine will remain in effect. After this time delay, the bias will be removed from the valve demand.

Fast speed amount **Initial=0.0 (0.0, 200.0)**

Enter the appropriate gain or scalar (in percent valve demand per rpm), applied to a change in prime mover speed, to generate a feed-forward bias of the anti-surge valve demand.

Decoupling is enabled by setting the amount separately for all routines. Set the amount to 0.0 to disable a particular decoupling routine.

IMPORTANT

Slow speed decoupling is automatically disabled when using the universal algorithm.

Automatic Gain Compensation (AGC) is applied to Fast Speed Decoupling, so AGC should be configured prior to Decoupling.

Decoupling on speed as described above is only active when a valid speed signal is available.

4.2.12.3 Decoupling on other stage

Another stage delay time **Initial=110.0 (100.0, 140.0)**

For dual compressor, two anti-surge valve lay-out, this is the delay time in seconds that another stage decoupling from the adjacent stage valve will remain in effect. After this time delay, the bias will be removed from the valve demand.

Another stage amount **Initial=0.0 (-300.0, 300.0)**

For dual stage 2 anti-surge valve trains, this is the gain in percent per percent valve demand of the adjacent stage valve that is multiplied by the other stage's decoupling to modulate the anti-surge valve.

Similar to the amounts noted above, another stage amounts may be positive or negative depending upon the adjacent valve's effect on compressor flow.

This value should be less than zero on stage 1 for common suction valve layouts and on stage 2 for common discharge arrangements.

Conversely, configure greater than zero on stage 1 for common discharge valve layouts, on stage 2 for common suction arrangements, and on both stages with individual recycles.

4.2.12.4 Decoupling on external input#1

Input 1 delay time **Initial=0.0 (0.0, 500.0)**

This is the delay time in seconds that an external input decoupling will remain in effect. After this time delay, the bias will be removed from the valve demand.

Input 1 amount **Initial=0.0 (0.0, 300.0)**

This is the gain in percent per percent valve demand of the external demand that is multiplied by the external decoupling to modulate the anti-surge valve.

4.2.12.5 Decoupling on external input#2

Input 2 delay time **Initial=110.0 (100.0, 140.0)**

This is the delay time in seconds that an external input decoupling will remain in effect. After this time delay, the bias will be removed from the valve demand.

Input 2 amount **Initial=0.0 (0.0, 300.0)**

This is the gain in percent per percent valve demand of the external demand that is multiplied by the external decoupling to modulate the anti-surge valve.

4.2.12.6 Auxiliary control 1 (HSS)

Use auxiliary HSS1

Check to enable the High Signal Select (HSS) bus for auxiliary input #1. The auxiliary input has to come from a 4–20 mA input, but should be configured 0-100% open. It is routed through the HSS bus, so all other anti-surge functions are still active.

Signal filtering **Initial=0.5 (0.0, 300.0)**

Filter applied to the signal by the compressor control.

4.2.12.7 Auxiliary control 2 (HSS)

Use auxiliary HSS2

Check to enable the High Signal Select (HSS) bus for auxiliary input #2. The auxiliary input has to come from a 4–20 mA input, but should be configured 0-100% open. It is routed through the HSS bus, so all other anti-surge functions are still active.

Signal filtering **Initial=0.5 (0.0, 300.0)**

Filter applied to the signal by the compressor control.

4.2.12.8 Auxiliary control 3 (HSS)

Use auxiliary HSS3

Check to enable the High Signal Select (HSS) bus for auxiliary input #3. The auxiliary input has to come from a 4–20 mA input, but should be configured 0-100% open. It is routed through the HSS bus, so all other anti-surge functions are still active.

Signal filtering **Initial=0.5 (0.0, 300.0)**

Filter applied to the signal by the compressor control.

4.2.13 Field Signal Conditioning

This screen can be used for setting up the condition of field signals. The options for configuration are:

- Last good values
- Default value settings
- Field signal filtering
- Field signal fault action on control

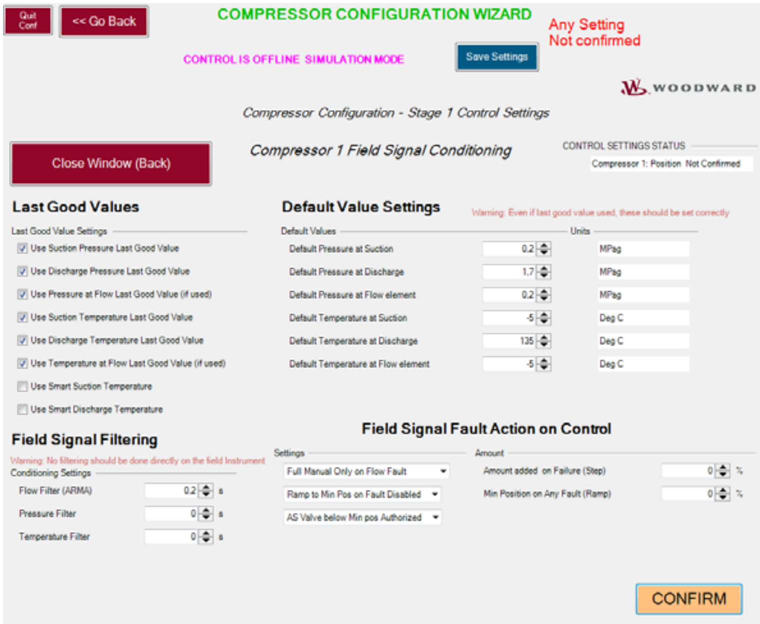


Figure 4-23. Field Signal Conditioning

4.2.13.1 Last good values

Use suction pressure last good value

Check to enable the last good value failure response for the compressor suction pressure signal. If the signal fails, and compressor operation has been stable for approximately one minute, the stable suction pressure value will be retained for control, even though the input has failed.

Use discharge pressure last good value

Check to enable the last good value failure response for the compressor discharge pressure signal. If the signal fails, and compressor operation has been stable for approximately one minute, the stable discharge pressure value will be retained for control, even though the input has failed.

Use pressure at flow element last good value

Check to enable the last good value failure response for the flow measurement when the alternate pressure signal is enabled. If the signal fails, and compressor operation has been stable for approximately one minute, the stable alternate pressure value will be retained for control, even though the input has failed.

Use suction temperature last good value

When checked, the last good value failure response for the compressor suction temperature signal is enabled. If the signal fails, and compressor operation has been stable for approximately one minute, the stable suction temperature value will be retained for control, even though the input has failed.

Use discharge temperature last good value

When checked, the last good value failure response for the compressor discharge temperature signal is enabled. If the signal fails, and compressor operation has been stable for approximately one minute, the stable discharge temperature value will be retained for control, even though the input has failed.

Use temperature at flow element last good value

When checked, the last good value failure response for the flow measurement when the alternate temperature signal is enabled. If the signal fails, and compressor operation has been stable for approximately one minute, the stable alternate temperature value will be retained for control, even though the input has failed.

IMPORTANT

The use of pressure/temperature at flow element last good value should be checked regardless of a dedicated sensor being used.

The 505CC-2 rev New control will use this setting for pressure/temperature for flow instead of the suction/discharge setting, pending flow meter location.

4.2.13.2 Default value settings

Default pressure at suction **Initial=1.0 (-10000.0, 10000.0)**

Enter a conservative default value for the compressor suction pressure This value will be used for control after a signal failure if last good value is not enabled or not suitable because of unstable operation, or if compressor operation becomes unstable while the last good value is in use. Generally, this default value should be chosen to generate a conservative calculation of compressor operation in the case of a signal failure.

Default pressure at discharge **Initial=1.0 (-10000.0, 10000.0)**

Enter a conservative default value for compressor discharge pressure. This value will be used for control after a signal failure if last good value is not enabled or not suitable because of unstable operation, or if compressor operation becomes unstable while the last good value is in use. Generally, this default value should be chosen to generate a conservative calculation of compressor operation in the case of a signal failure.

Default pressure at flow element **Initial=1.0 (-10000.0, 10000.0)**

If an alternate pressure signal is used for the flow measurement, enter a conservative default value to be used in the event that the alternate pressure signal fails This value will be used for control after a signal failure if last good value is not enabled or not suitable because of unstable operation, or if compressor operation becomes unstable while the last good value is in use. Generally, this default value should be chosen to generate a conservative calculation of compressor operation in the case of a signal failure.

IMPORTANT — **The default pressure at flow element should always be set to the value at flow meter location regardless of a dedicated sensor being used.**

Default temperature at suction **Initial=1.0 (-273.0, 3000)**

Enter a conservative default value for compressor suction temperature. This value will be used for control after a signal failure if last good value is not enabled or not suitable because of unstable operation, or if compressor operation becomes unstable while the last good value is in use. Generally, this default value should be chosen to generate a conservative calculation of compressor operation in the case of a signal failure.

Default temperature at discharge **Initial=1.0 (-273.0, 3000)**

Enter a conservative default value for compressor discharge temperature. This value will be used for control after a signal failure if last good value is not enabled or not suitable because of unstable operation, or if compressor operation becomes unstable while the last good value is in use. Generally, this default value should be chosen to generate a conservative calculation of compressor operation in the case of a signal failure.

Default temperature at flow element **Initial=1.0 (-273.0, 3000)**

If an alternate temperature signal is used for the flow measurement, enter a conservative default value to be used in the event that the alternate temperature signal This value will be used for control after a signal failure if last good value is not enabled or not suitable because of unstable operation, or if compressor operation becomes unstable while the last good value is in use. Generally, this default value should be chosen to generate a conservative calculation of compressor operation in the case of a signal failure.

Use smart suction temperature

Check to enable smart suction temperature calculation base on pressures and discharge temperature in case of suction temperature sensor fault.

Use smart discharge temperature

Check to enable smart discharge temperature calculation base on pressures and suction temperature in case of discharge temperature sensor fault.

IMPORTANT — **The default temperature at flow element should always be set to the value at flow meter location regardless of a dedicated sensor being used.**

4.2.13.3 Field signal filtering

Flow filter **Initial=0.0 (0.0, 30.0)**

Enter the appropriate filter time constant, in seconds, to be used with the flow signal filter within the core control software. Filtering should be minimized if at all possible, but this value can be adjusted as necessary to provide a clean, noise-free flow signal. Because the flow signal is the fastest and most important anti-surge process variable, filter times should usually be restricted to 100 milliseconds or less.

Pressure filter **Initial=0.0 (0.0, 30.0)**

Enter the appropriate filter time constant, in seconds, to be used with the pressure signal filters within the core control software. Filtering should be minimized if at all possible, but this value can be adjusted as necessary to provide clean, noise-free pressure signals. Because pressure processes are generally moderate in speed and signals clean, filter times, if necessary at all, are usually in the hundreds of milliseconds.

Temperature filter **Initial=0.0 (0.0, 30.0)**

Enter the appropriate filter time constant, in seconds, to be used with the temperature signal filters within the core control software. Filtering should be minimized if at all possible, but this value can be adjusted as necessary to provide clean, noise-free temperature signals. Because temperature processes are generally slow and signals clean, filter times, if necessary at all, can be extended to seconds.

4.2.13.4 Field signal fault action on control

Full manual on any critical sensor fault

Select to enable the fail to manual strategy on all critical input failures, not only flow, but also pressures and temperatures. This is the most conservative strategy for handling input signal failures but last good value, if enabled, takes priority.

Full manual only on flow fault

Select to enable the fail to manual strategy only on flow sensor fault.

Ramp to min pos on fault enabled

Select to enable antisurge valve demand ramp transition in case of critical sensor fault or flow sensor fault to configured min position on any fault when actual antisurge valve demand is lower than min position on any fault.

AS valve below min pos Inhibited

Select to inhibit antisurge valve demand below min position on any fault when critical sensor fault or flow sensor fault (conservative strategy).

AS valve below min pos authorized

Select to authorize antisurge valve demand below min position on any fault when critical sensor fault or flow sensor fault

Amount added on failure (step) **Initial=0.0 (0.0, 100.0)**

Specify the amount to add to antisurge valve demand in case of critical sensor fault or flow sensor fault.

Min position on any fault (ramp) **Initial=0.0 (0.0, 100.0)**

Specify minimal demand of antisurge valve in case of critical sensor fault or flow sensor fault .

4.2.14 Analog Inputs

The next step of the compressor configuration wizard would be to assign the analog inputs. The configuration check status message will support this by indicating the missing assignments.

The default settings for detecting analog input failures are a fail setpoint of low 2 mA and high 22 mA. These can be adjusted if required:

Fail Low Setpoint **Initial=2.0 (0.0, 4.0)**

Fail High Setpoint **Initial=22.0 (20.0, 24.0)**

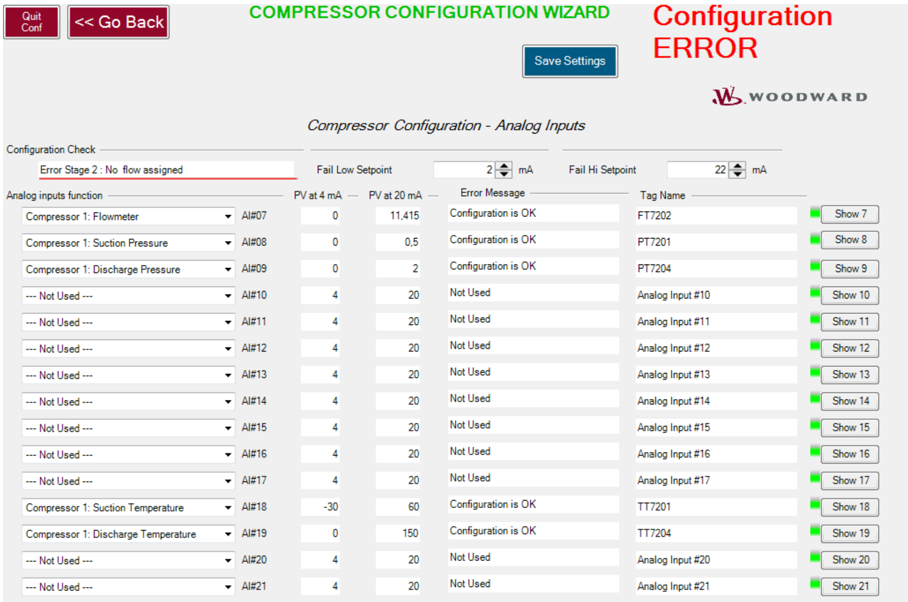


Figure 4-24. Analog Inputs

The following analog input compressor control configurations are possible for each compressor loop, see also 3.3.1.1 Analog Inputs :

- Flowmeter;
  - o Delta-pressure from the compressor flow element at suction or discharge.
- Redundant Flowmeter;
  - o Accommodates a second flow transmitter for redundancy.
- Suction Pressure;
  - o Compressor inlet pressure.
- Redundant Suction Pressure;
  - o Accommodates a second inlet pressure transmitter for redundancy.
- Discharge Pressure
  - o Compressor outlet pressure.
- Redundant Discharge Pressure;
  - o Accommodates a second outlet pressure transmitter for redundancy.
- Pressure at Flow Element;
  - o The Flow Element Pressure input may be used for a pressure transmitter at the flow element for flow calculations, if its location is far from the compressor suction or discharge pressure measurements.
- Suction Temperature
  - o Compressor inlet temperature.
- Discharge Temperature
  - o Compressor outlet temperature.

- Temperature at Flow Element;
  - The Flow Element Temperature input may be used for a temperature transmitter at the flow element for flow calculations, if its location is far from the compressor suction or discharge temperature measurements.
- HSS Auxiliary Input 1;
  - Auxiliary HSS (High Signal Select) inputs are provided for anti-surge valve positioning (0% = Closed, 100% = Open) in Automatic Mode.
- HSS Auxiliary Input 2;
  - Auxiliary HSS (High Signal Select) inputs are provided for anti-surge valve positioning (0% = Closed, 100% = Open) in Automatic Mode.
- Decoupling Input 1;
  - Auxiliary Decoupling inputs are provided for limited feed-forward biasing of the anti-surge valve, based upon a separate process change.
- Decoupling Input 2;
  - Auxiliary Decoupling inputs are provided for limited feed-forward biasing of the anti-surge valve, based upon a separate process change.
- Remote Manual Valve Position;
  - Remote valve positioning (0% = Closed, 100% = Open) in Manual Mode.
- Upstream Pressure Anti-Surge Valve
  - This can utilized for correct flow calculations through the anti-surge valve.
- Downstream Pressure Anti-Surge Valve
  - This can utilized for correct flow calculations through the anti-surge valve.
- Temperature at Anti-Surge Valve;
  - This can utilized for correct flow calculations through the anti-surge valve.
- Alternate Psuc Override;
  - Utilizing another suction pressure transmitter for anti-surge for suction pressure override control.
- Alternate Pdisch Override;
  - Utilizing another discharge pressure transmitter for discharge pressure override control.

In addition to these the following side stream analog inputs can be configured:

- Side Stream Flowmeter (Extraction/Admission)
  - Measuring the flow of the side stream leg.
- Side Stream Redundant Flowmeter (Extraction/Admission)
  - Accommodates a second flow transmitter of the side stream leg for redundancy.
- Side Stream Pressure
  - Pressure in the side stream leg utilized for flow calculations.
- Side Stream Redundant Pressure
  - Accommodates a second side stream pressure transmitter for redundancy.
- Side Stream Temperature
  - Temperature in the side stream leg utilized for flow calculations.

When cascade export flowmeter is configured (from Turbine Configuration), exported gas flowmeter analog inputs also can be configured:

- Exported Gas Flowmeter 1
  - o Measuring the delta pressure of the flowmeter located downstream of the compressor. Flowmeter#1 has smaller measurement range compare to the range of flowmeter#2.
- Exported Gas Flowmeter 2
  - o Measuring the delta pressure of the flowmeter located downstream of the compressor. Flowmeter#2 has bigger measurement range compare to the range of flowmeter#1.

The above are pre-defined analog inputs. An extra four customer defined monitor inputs are available for configuration.

Further configuration of the range is possible by pressing the button Show for the assigned analog inputs. In addition the Modbus multiplier and a field tag can be set, see Figure 4-25.

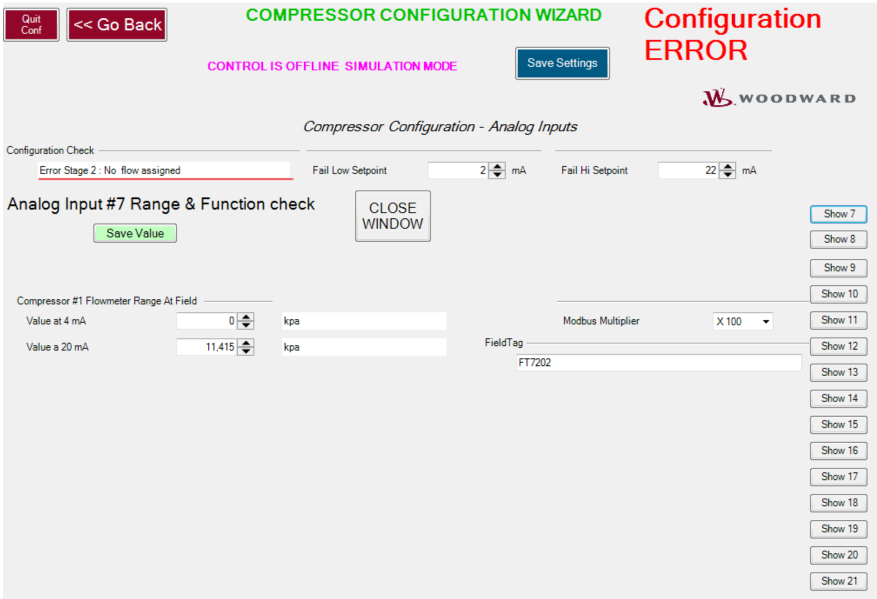


Figure 4-25. Analog Input Range and Tag

4.2.15 Analog Outputs

The next step of the compressor configuration wizard would be to assign the analog outputs. In addition the 4 mA and 20 mA ranges can be defined, and a tag name entered.

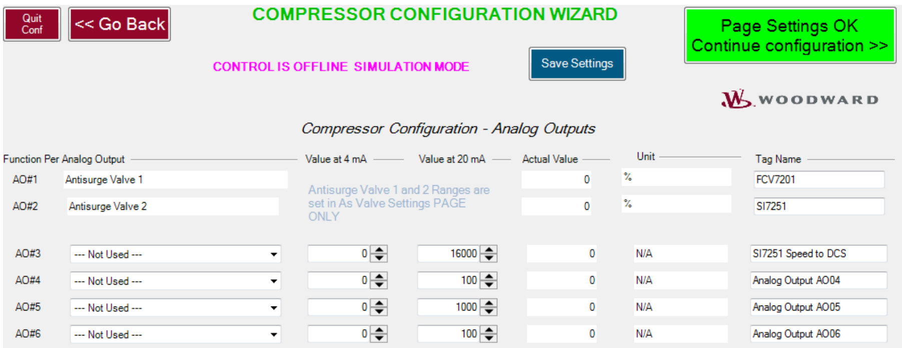


Figure 4-26. Analog Outputs

The first two analog outputs are dedicated for Anti-Surge valve 1 and 2. The following analog output compressor control configurations are possible for each compressor loop, see also 3.3.2.1 Analog Outputs:

- Valve Demand;
  - Final valve demand including Decoupling and Freeze routines (excludes valve overstroke, dither, and linearization).
- Surge Process Variable;
  - The Surge Process Variable (S_PV), see 2.8 S_PV (Surge Process Variable).
- Actual Flow at Suction;
  - The actual volumetric inlet flow.
- Corrected Flow at Suction;
  - The corrected volumetric inlet flow.
- Mass Flow;
  - The mass flow through the compressor.
- Polytropic Head;
  - The calculated polytropic head.
- Suction Pressure Used;
  - Suction Pressure value after redundancy management (if applicable), filtering, and failure routines.
- Discharge Pressured Used;
  - Discharge Pressure value after redundancy management (if applicable), filtering, and failure routines.
- Suction Temperature Used;
  - Suction Temperature value after filtering and failure routines.
- Discharge Temperature Used;
  - Discharge Temperature value after filtering and failure routines.
- HSS Output;
  - Output of the High Signal Select bus for all automatic control routines.
- Actual Speed;
  - An output of the compressor speed.
- Calculated Exported flow;
  - Flow value at the downstream of compressor

IMPORTANT	**The message Already Used by Turbine is shown when an analog output is already assigned by the turbine configuration. The turbine selection has priority versus compressor selection. Therefore it is possible to re-assign the channel for another function and the previous assignment done in compressor configuration will be erased.**

4.2.16 Binary Inputs

The next step of the compressor configuration wizard would be to assign the binary inputs. In addition the tag name can be entered.

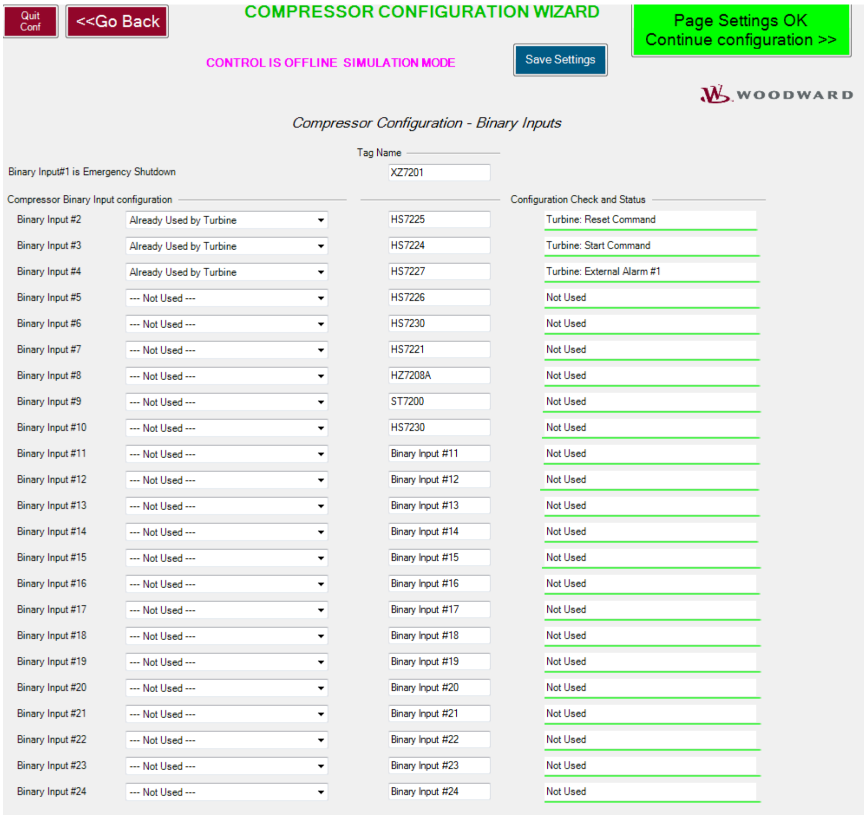


Figure 4-27. Binary Inputs

The first discrete input is reserved for Emergency Shutdown functionality into the 505CC-2. The next two discrete inputs are reserved for turbine control, but can also be used in case of compressor only control since these function for the reset and start command. The following discrete input compressor control configurations are possible for each compressor loop.

- Close Anti-Surge Valve;
  - While sustained closed the Anti-Surge valve when in Manual with Backup or Full Manual.
- Open Anti-Surge Valve
  - While sustained is opening the Anti-Surge valve when in Manual with Backup or Full Manual.
- Anti-Surge Valve Opened
  - This functionality is reserved for future use.
- Reset SMP;
  - Resets the Surge Minimum Position hold on valve position (pulse).
- Reset Capture Info;
  - Resets the Surge Capture information (counter, signature values). Note: does not reset the Total Surges Counter (pulse).
- Select Auto Mode;
  - Selects the Automatic control mode (pulse).
- Select Manual with Backup Mode
  - Selects the Manual with Backup control mode (pulse).
- Select Full Manual Mode
  - Selects the Full Manual control mode (pulse).

- Purge Position
  - Selects the anti-surge valve's Purge position during start-up (sustained).
- Online Auxiliary Input
  - Initiates the transition from offline to online automatic anti-surge control, i.e. starts the anti-surge control instead of, or in addition to, using speed, flow, or pressure setpoint (sustained).
- Control Margin Increase;
  - Increases the current Control Margin by 0.1% per second while the input is closed.
- Control Margin Decrease
  - Decreases the current Control Margin by 0.1% per second while the input is closed. It is not possible to decrease below the configured margin.
- Anti-Surge Valve Fault;
  - Anti-Surge Valve output fault, which will force the control into Full Manual Mode and move the valve output to the shutdown position. This discrete input configuration is provided for an external circuit monitoring device to signal such a fault (sustained).
- Start Position;
  - Initiates a compressor "start" by positioning the anti-surge valve in the configured start position from zero-speed. Also acts as a restart command when received after a shutdown but before slowing to zero-speed (pulse).
- Shutdown;
  - Initiates a compressor shutdown by positioning the anti-surge valve in the configured shutdown position. Restarts are inhibited if the input is sustained.

IMPORTANT

The message Already Used by Turbine is shown when an analog output is already assigned by the turbine configuration. The turbine selection has priority versus compressor selection. Therefore it is possible to re-assign the channel for another function and the previous assignment done in compressor configuration will be erased.

4.2.17 Binary Outputs

The next step of the compressor configuration wizard would be to assign the binary outputs. In addition the tag name can be entered.

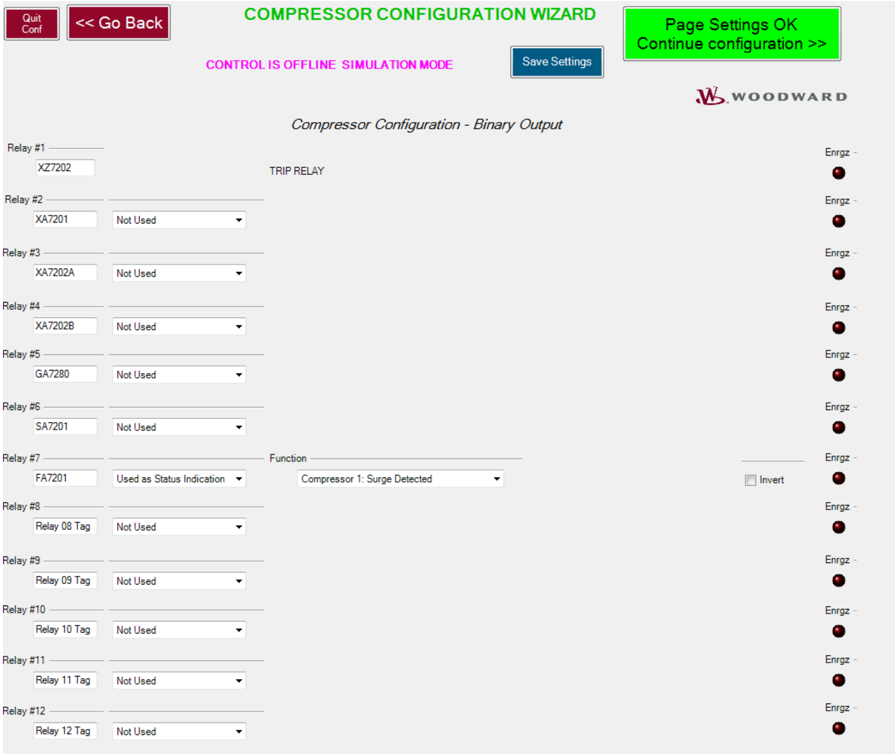


Figure 4-28. Binary Outputs

- The first discrete output is reserved for the summery trip relay functionality from the 505CC-2. A distinction can be made in the configurable discrete outputs between status indication and level switch. The following discrete output compressor control configurations are possible for each compressor loop, see also Calculated Exported flow;
  - o Flowmeter at the downstream of compressor will be used for cascade.

Discrete Outputs:

Relays configured as status indication require the functionality to be assigned. The following functionality is available:

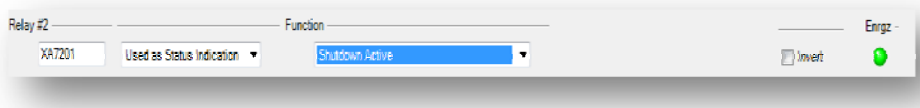


Figure 4-29. Relay Status Indication

- Shutdown Active
  - o Energizes when a shutdown is active.
- Trip Relay
  - o Energizes when a trip is active.
- Alarm Active;
  - o Energizes when an alarm condition is active.
- Surge Detected
  - o Energizes when a surge has been detected.

- Surge Minimum Position Active
  - o Energizes when Surge Minimum Position (SMP) is active.
- Is Online
  - o The Anti-Surge control is online and active.
- In Auto Mode
  - o The control is in Automatic mode.
- In Manual/Backup Mode
  - o The control is in Manual with Backup mode.
- In Full Manual Mode
  - o The control is in Full Manual mode.
- Internal Level Switch On (1-8)
  - o This functionality is to energize a relay if the selected 1 to 8 internal level switches set in the configuration mode alarm screen reach the on level, see also 4.2.20 Alarms.
- Reset Pulse (1 second)
  - o A reset issued is to the compressor control is issued out through a relay to be able to reset for example other devices in the control cabinet.

Relays configured as level switch require the functionality to be assigned, and an on/off level defined.

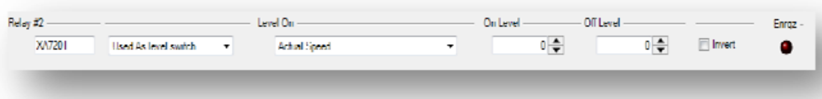


Figure 4-30. Relays Level Switch

The on and off level for energizing the relay output can be configured based on the following values:

- Actual Speed
- Actual Flow (display)
- Mass/Std Flow (display)
- Operating point (WSPV)
- Actual Suction Pressure
- Actual Discharge Pressure
- Actual Suction Temperature
- Actual Discharge Temperature

Invert

It is possible to invert the signal.

ON Level

Level based on the parameter selected set to activate the relay.

OFF Level

Level based on the parameter selected set to de-activate the relay.

IMPORTANT	**The relay will behave as a high select switch, energized at ON and de-energized at OFF, when the ON level > the OFF level.** **The relay will behave as a low select switch, energized at ON and de-energized at OFF, when the ON level < the OFF level.** **Therefore it might not be needed to use the Invert functionality.**

IMPORTANT

The message Already Used by Turbine is shown when an analog output is already assigned by the turbine configuration. The turbine selection has priority versus compressor selection. Therefore it is possible to re-assign the channel for another function and the previous assignment done in compressor configuration will be erased.

4.2.18 Speed Channel

Note: Screens only available in compressor control only configuration, i.e. turbine control not used. Else this configuration needs to be done in the turbine control configuration screens, see manual 26542V2.

Configuration is possible for a single speed input or redundant. In addition the tag can be set for each configured speed channel. The possible types for speed input are:

- MPU
- Proximity Probe

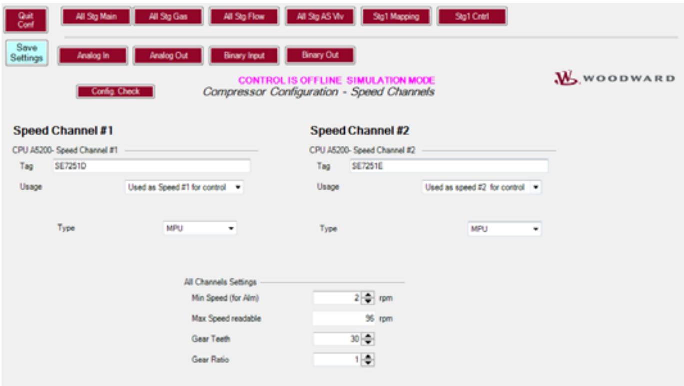


Figure 4-31. Speed Channel

Following are setting required to be set for each channel:

- Minimum speed
  - o This setting is the setpoint for detecting loss of speed. A limitation is that the value at which it is set cannot be lower than 1/50 of the range.
- Max Speed readable
  - o This is automatically set based on the minimum speed setting based on the range limitations. Ensure the minimum speed is set sufficient for the maximum speed to cover the speed range of the application.
- Gear teeth
  - o This setting should be the number of teeth on the gear the speed sensing device is mounted to. This value is used to determine the conversion from hertz to rpm.
- Gear ratio
  - o Enter here the relationship of the speed of the gear on which the speed sensing device is mounted to the driven equipment shaft speed. This value is used to determine the hertz to rpm relationship. The hertz to rpm is calculated as:

$$\text{Gear teeth} \times \text{Gear ratio} \times 0.016667$$

-
  - o For example, if the number of gear teeth is 30 and the gear ratio is 1.0 (1:1), the hertz to rpm relationship could be 0.5, i.e. 2.0 rpm for every hertz input.

4.2.19 Communication

Note: Screens only available in compressor control only configuration, i.e. turbine control not used. Else this configuration needs to be done in the turbine control configuration screens, see volume 2 of this manual, 26542V2.

See also volume 1 of the manual, 26542V1, for the available Modbus list.

Modbus is the software protocol for how data is packet, how commands are interpreted, and how errors are checked. The 505CC-2 can communicate through Modbus slave with external monitoring interfaces such as a DCS. Modbus slave defines a device that will only respond when requested to by a master, i.e. Modbus master. A Modbus slave will never generate a request for data. Two ports are available with the following usage configurations possible:

- Modbus over Serial Port
- Modbus over Ethernet TCP
- Modbus over Ethernet UDP
- Modbus backup over Ethernet TCP
- Modbus backup over Ethernet UDP

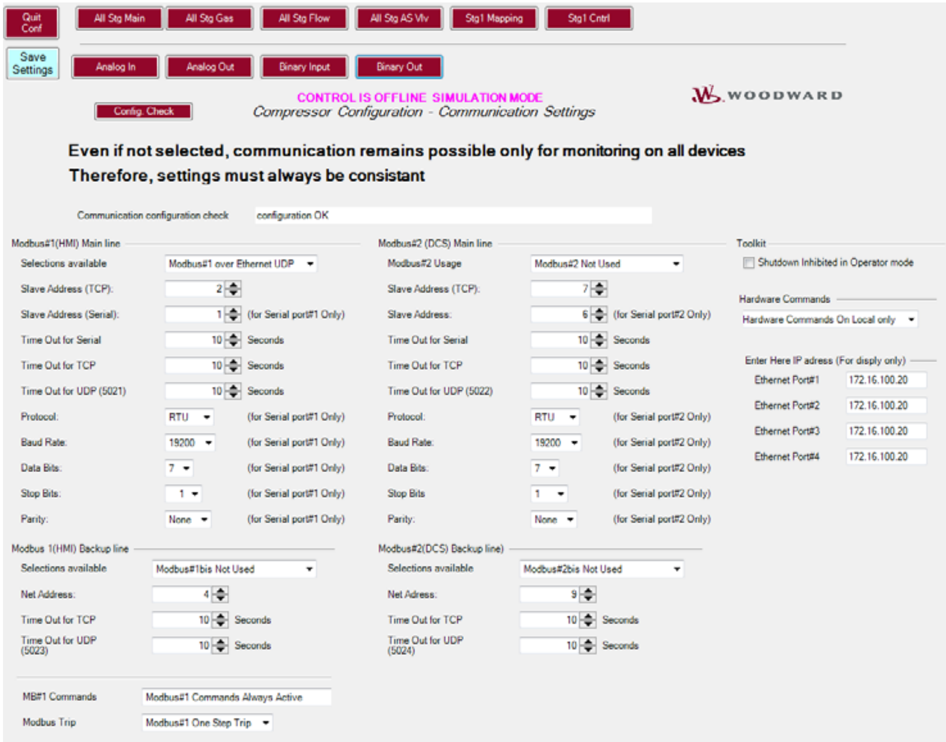


Figure 4-32. Communication

IMPORTANT **IP address of Atlas-II shown on the page is only for display. To configure the IP address, follow procedure in manual 26542V1.**

Writes or in other words commands can also be issued to the 505CC-2 through Modbus. The functionality for this can be configured after selecting the usage:

- Commands always active
- Commands active when remote selected
- Commands always disabled
- Commands for trip only

The hardware command can be configured to be always active or only in local selected mode on the bottom of the communication page.

Enabling shutdown inhibited in operator mode disable the trip functionality from the Toolkit Tool run pages.

The command for trip can be further configured underneath Modbus Trip:

- Modbus trip not used
  - o Disables the Modbus trip command.
- Modbus one step trip
  - o A trip issued directly results in a trip condition.
- Modbus two step trip
  - o An acknowledgment need to be issued in addition to the trip command for the trip condition to activate.

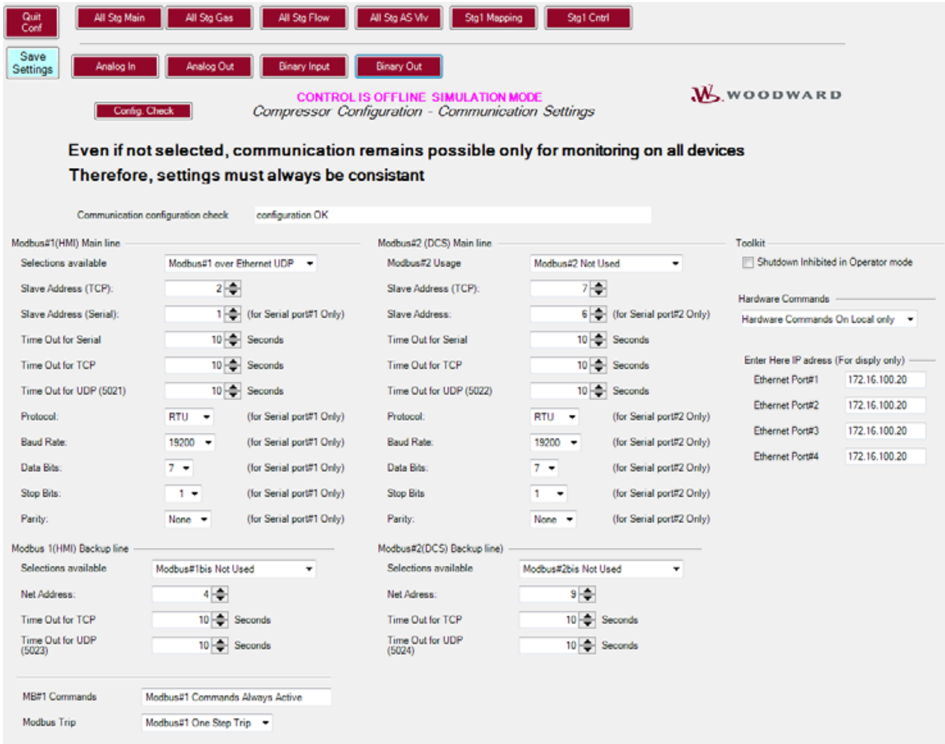


Figure 4-33. Modbus Serial and Ethernet Configuration

4.2.19.1 Modbus over serial port

The protocol is the set of rules governing the format, timing, sequencing and error control of exchanged messages. ASCII and RTU are two modes of data representations associated with Modbus.

- ASCII;
  - o hex coding / 7 bits per character (4 transmitted) / any parity / 1 or 2 stop bits
- RTU;
  - o 8 bit binary coding/ 8 bits per char (8 transmitted) / any parity / 1 or 2 stop bits

RTU sends data in 8-bit binary characters. ASCII firsts divides each RTU character into two 4-bit parts (high order and low order) and then represents them by their hexadecimal equivalent. The ASCII characters representing the hexadecimal characters are used to construct the message thus using twice as many characters as RTU mode. Additionally, RTU message characters are transmitted in a continuous stream, whereas ASCII can have breaks of up to one second between characters.

The driver is the definition for electrical connection between devices. The options in the 505CC-2 are the following:

- RS-232;
  - An ANSI (American National Standards Institute) standard definition of electrical, functional and mechanical connections for communications between DTE (Data Terminal Equipment) and DCE (Data Communications Equipment) such as connection of a computer to a modem. It has gained wide usage in very short haul applications (15 meter / 50 feet).
- RS-422;
  - Also an ANSI standard definition of electrical connections for communications between devices. Because it uses balanced drivers it can communicate over long distances (1200 meter / 4000 feet) at high baud rates. The standard RS-422 features a multidrop function is implemented as well. This allows more than one device to be connected to a common bus (up to 32 devices) with a single master requesting data. It requires two twisted pairs and ground to operate.
- RS-485;
  - Also an ANSI standard definition of electrical connections for communications between devices. This protocol is implemented identically to RS-422 at Woodward with the exception that only one twisted pair is required. Both transmitted and received data use the same pair of wires. It will generally only be used to communicate with external devices which are on a 485 network.

IMPORTANT

RS 485 multi node is not yet available.

Slave address **Initial=1 (1, 246)**

The slave address input defines the network address on the Modbus network. The address may depend on the Modbus master allowable addresses. The address must be unique when using Modbus in a network, such as with TCP Modbus.

Baud rate determines the rate of bit transmission in a serial communication scheme in bits per second. The selections that the 505CC-2 supports are:

- 9600 bps
- 19200 bps
- 38400 bps
- 57600 bps

Data bits define then number of bits in the data packages. The number selected equals the number of data bits:

- 7 bits
- 8 bits

Stop bits define the number of stop bits for the communications protocol. Stop bits specify the time that elapses between transmitted characters:

- 1 stop bits
- 2 stop bits
- 1.5 stop bits

Parity input defines protocol for the parity. If you selected 8 data bits then select none else select the following:

- None
- Odd
- Even

Time out **Initial=10.0 (1.0, 100.0)**

Time out defines the Modbus link dead time allowed before a link communication alarm occurs.

4.2.19.2 Modbus over Ethernet TCP

Ethernet is a high speed (10 Mbit/sec) communication protocol. The 505CC-2 has the facility for TCP/IP and UDP packets via Ethernet. The software protocol is Modbus.

The protocol is the set of rules governing the format, timing, sequencing and error control of exchanged messages. ASCII and RTU are two modes of data representations associated with Modbus.

- ASCII;
  - hex coding / 7 bits per character (4 transmitted) / any parity / 1 or 2 stop bits
- RTU;
  - 8 bit binary coding/ 8 bits per char (8 transmitted) / any parity / 1 or 2 stop bits

RTU sends data in 8-bit binary characters. ASCII firsts divides each RTU character into two 4-bit parts (high order and low order) and then represents them by their hexadecimal equivalent. The ASCII characters representing the hexadecimal characters are used to construct the message thus using twice as many characters as RTU mode. Additionally, RTU message characters are transmitted in a continuous stream, whereas ASCII can have breaks of up to one second between characters.

The slave address input defines the network address on the Modbus network. The address may depend on the Modbus master allowable addresses. The address must be unique when using Modbus in a network, such as with TCP Modbus.

Time out **Initial=10.0 (1.0, 100.0)**

Time out defines the Modbus link dead time allowed before a link communication alarm occurs.

4.2.19.3 Modbus over Ethernet UDP

Ethernet is a high speed (10 Mbit/sec) communication protocol. The 505CC-2 has the facility for TCP/IP and UDP packets via Ethernet. The software protocol is Modbus.

The port number through which UDP is communicating are:
- Port 5021: Modbus#1 main line over UDP
- Port 5022: Modbus#2 main line over UDP
- Port 5023: Modbus#1 backup line over UDP
- Port 5024: Modbus#2 backup line over UDP

The protocol is the set of rules governing the format, timing, sequencing and error control of exchanged messages. ASCII and RTU are two modes of data representations associated with Modbus.

- ASCII;
  - hex coding / 7 bits per character (4 transmitted) / any parity / 1 or 2 stop bits
- RTU;
  - 8 bit binary coding/ 8 bits per char (8 transmitted) / any parity / 1 or 2 stop bits

RTU sends data in 8-bit binary characters. ASCII firsts divides each RTU character into two 4-bit parts (high order and low order) and then represents them by their hexadecimal equivalent. The ASCII characters representing the hexadecimal characters are used to construct the message thus using twice as many characters as RTU mode. Additionally, RTU message characters are transmitted in a continuous stream, whereas ASCII can have breaks of up to one second between characters.

The slave address input defines the network address on the Modbus network. The address may depend on the Modbus master allowable addresses. The address must be unique when using Modbus in a network, such as with TCP Modbus.

Time out **Initial=10.0 (1.0, 100.0)**

Time out defines the Modbus link dead time allowed before a link communication alarm occurs.

4.2.20 Alarms

Note: Screens only available in compressor control only configuration, i.e. turbine control not used. Else this configuration needs to be done in the turbine control configuration screens, see volume 2 in the manual, 26542V2.

See also volume 1 of the manual, 26542V1, for the alarm and shutdown list.

4.2.20.1 External Alarm Settings

Specific settings can be set in this page when a binary input has been configured for External Alarm. The functionality that has been defined is:

- Alarm Only;
  - The binary input is used just generate an alarm.
- Start Inhibit Only;
  - The binary input is used to prevent the turbine to start and not for alarm.
- Alarm and Start Inhibit
  - The binary input is used to generate an alarm and to prevent the turbine from starting.

Invert

Each individual external alarm can be reversed. An open contact will give an alarm and/or start inhibit command when reversed.

Use non Latching Alarm

Alarms will be non-latching when selected. This option is not applicable for shutdown commands.

A customized tag can be entered, which will also be shown on the alarm message display.

4.2.20.2 External Shutdown Settings

It must be confirmed in this page by selecting Used when a binary input has been configured for External Shutdown.

Invert

Each individual external shutdown can be reversed. An open contact will give a shutdown command when reversed.

A customized tag can be entered, which will also be shown on the alarm message display.

4.2.20.3 Internal Level Switches

The 505CC-2 has the option to configure eight internal level switches to generate additional alarms, start inhibits and/or shutdowns.

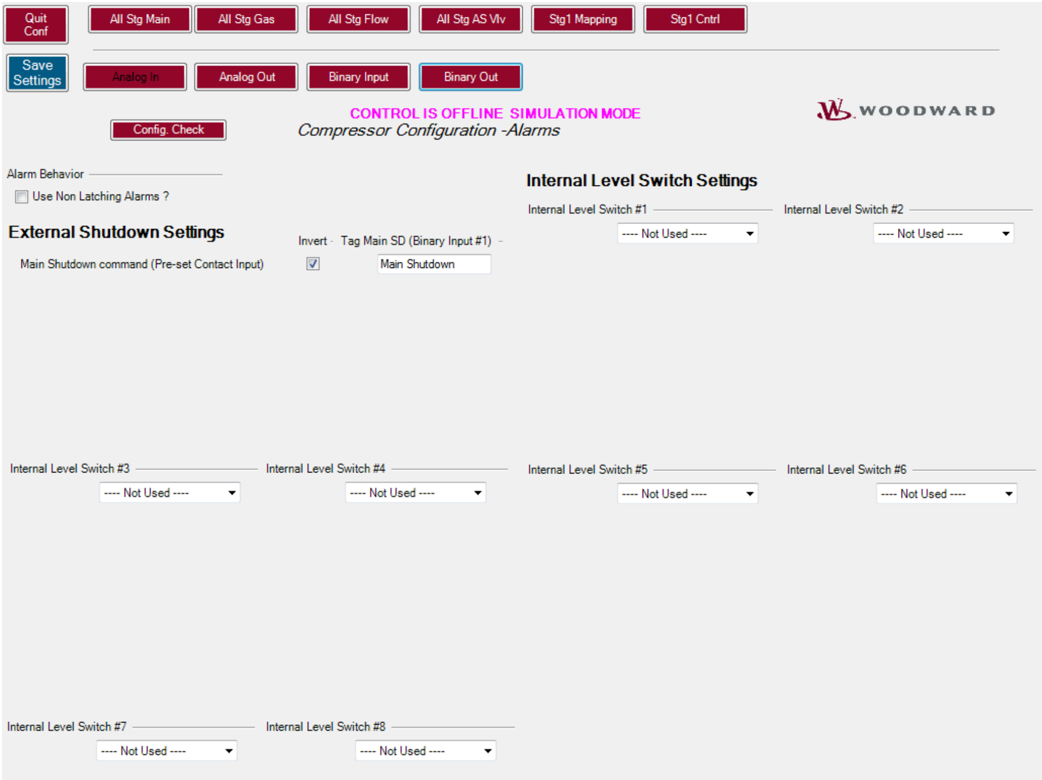


Figure 4-34. Alarms

The internal level switch options for compressor control are:

- Customer defined monitor inputs, #5, #6, #7, #8, see 4.2.14 Analog Inputs for configuration of these.

And for each compressor:

- P1, Suction pressure
- T1, Suction temperature
- P2, Discharge pressure
- T2, Discharge temperature
- Actual flow
- WSPV, Operating point

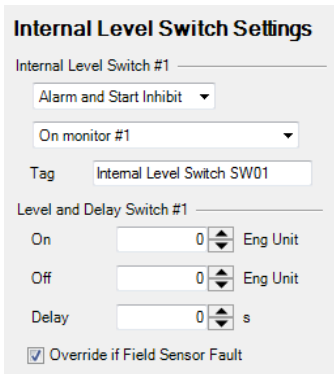


Figure 4-35. Internal Level Switch

A typical usage of the customer defined monitor inputs would be for example the oil pressure, send via a customer defined analog input. In that case a Low Pressure could initial an alarm, start inhibit or shutdown command. Oil temperature, exhaust pressure and exhaust temperature are other typical signals which can be connected to the 505CC-2.

A customized tag can be entered, which will also be shown on the alarm message display. Configuration of the on/off level, and delay time completes the internal level switch settings. The possibility to override the internal level witch on sensor fault can be enabled, i.e. analog input exceeding defined values for fault, such a 2 and 22 mA.

On Level **Initial=0.0 (-100000.0, 100000)**

Level based on the parameter selected set to activate the switch.

Off Level **Initial=0.0 (-100000.0, 100000)**

Level based on the parameter selected set to de-activate the switch.

Delay **Initial=0.0 (0.0, 1000)**

Delay in seconds that the level needs to maintain at the on level to activate the switch.

Override if sensor Fault

It might be desired not to generate an alarm or shutdown in case of sensor failure. In that case this option must be selected.

IMPORTANT

The internal level switch will behave as a high select switch, energized at ON and de-energized at OFF, when the ON level > the OFF level.

The internal level switch will behave as a low select switch, energized at ON and de-energized at OFF, when the ON level < the OFF level.

Therefore it might not be needed to use the Invert functionality.

IMPORTANT

The configuration check will not verify for settings to be based on existing signals.

Selecting a non-existing signal won't be detected by the 505CC-2.

4.2.21 Configuration Check

A configuration check will be displayed upon completion of the compressor configuration wizard. Errors detected are displayed and a button enables to go to the configuration screen related to the displayed error.

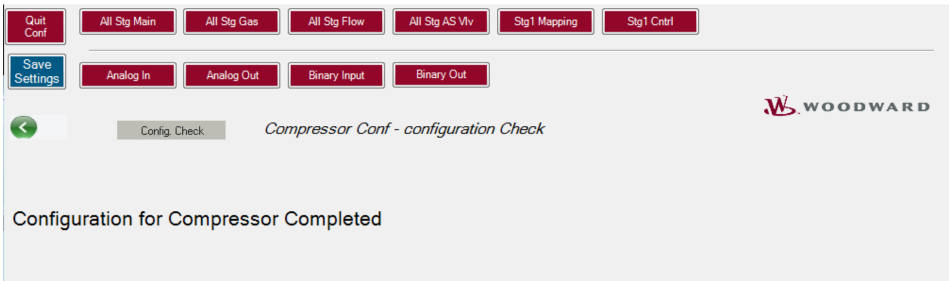


Figure 4-36. Configuration Check

The configuration check error that the unit never has been configured can be cleared by checking the configured once selection. This check mark will disappear after this acknowledgement.

The user will not be allowed to exit the full configuration mode until all configuration errors are corrected.

It is recommended to fill in the configuration worksheet attached to this manual to record an overview of the configuration applied, see Compressor Configuration Worksheet.

Menu buttons to direct to each configuration screen will be displayed once the compressor configuration wizard has been completed and the compressor has been configured once.

4.3 Save / Exit Configuration Mode

Once all the program settings have been configured, they can be saved to the control.

The values are saved in the control by clicking on the Save Value button.

To leave configuration mode return to the home page by using the displayed button.

You will not be able to exit configuration mode if any configuration errors have been detected. You can click on the Quit Configuration mode button when no errors are present. Then the CCT program performs a final configuration error check before any values are saved. A pop-up box appears and displays a message to wait while the control re-initializes and releases the I/O lock.

Chapter 5.
Service Mode

5.1 Introduction

Operational requirements of compressor trains are as varied as the processes in which they operate. This chapter is intended to provide an overview of compressor operation with respect to the 505CC-2's functionality only. For more complete, process-specific compressor or plant operating instructions, contact the plant-equipment manufacturer.

The service mode screens give the user access to pages specially designed for tuning and signal forcing once the unit has been initially configured – t.

Some parameters set in configuration may be available in these pages for fine adjustment. To use this mode, the 505CC-2 control hardware should not be in IO LOCK, meaning that in Service mode the output signals from the control are active.

The service mode is for qualified personnel to adjust and tune control parameters that may need to be tuned with the control & turbine in operation, such as dynamic tuning of PID controllers. The service mode can be used to change control settings, test control hardware, and calibrate control inputs/outputs while the unit is on-line, i.e. operating at any load. The parameters that are tuned in the service mode may affect system performance. Caution is advised when tuning any parameter with the turbine not shutdown. The Service Mode can be used to operate the turbine or to perform Run Mode functions when tuning is needed, but should not be used for normal operation.

IMPORTANT

Not all page parameters are referred to or explained in this chapter. This chapter provides descriptions for parameters which only exist in the Service Mode. Refer to the configuration mode chapter for all other page parameter descriptions.

5.2 Compressor Service Screens

5.2.1 Home Page

The home page for run and service mode is displayed up after starting the ToolKit Tool Application, 54183682RS.wtool.

This chapter explains the service mode screen so select the Compressor Service Pages button to proceed to the general configuration screen.

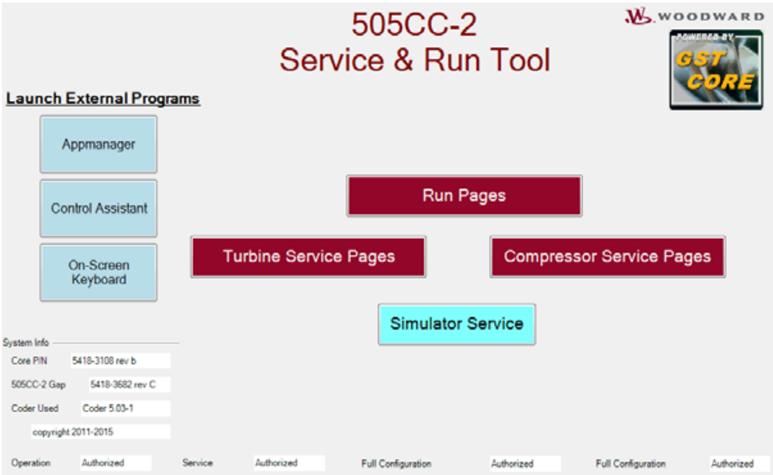


Figure 5-1. 54183682RS.wtool Home Page

5.2.2 General Configuration

This page shows the summary of the control main configuration that was setup in configuration mode; see 4.2.2 All Stages Main Configuration.

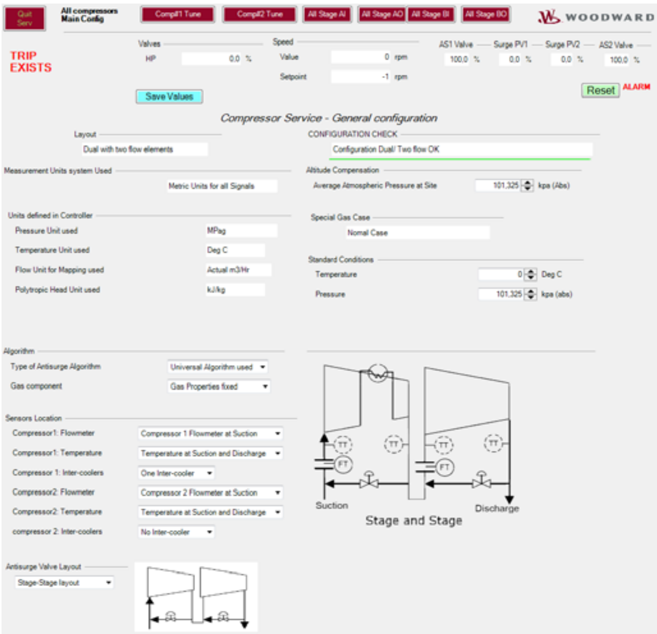


Figure 5-2. General Configuration

5.2.3 Compressor Tuning

This page is used to tune the following dynamics:

- Normal anti-surge controller
- Rate PID controller
- Suction pressure override controller
- Discharge pressure override controller

In addition the status is displayed and most commands are combined on this page to give the ability to fine tune the application without having to change screens. An overview of the available commands behind each button:

- Button Commands;
  - Selection of automatic, manual with backup and full manual mode
  - Reset Surge Minimum Position (SMP)
  - Reset surge counter
  - Raise and lower margin
  - Compressor events
  - Setting of valve automatic/manual rates
- Button Values;
  - Display of process values and units
- Button Speed;
  - Commands for raise and lower speed
  - Issuing speed target
  - Turbine messages
- Button Messages;
  - Turbine messages
  - Activated field sensor alarms, displayed with field tags
  - Compressor 1 and 2 events
- Button PID & Freeze (see 4.2.11, PID Settings);
  - Normal anti-surge controller settings
  - Rate PID controller settings
  - Valve freeze option
- Button Test Function (see 5.2.3.1, Test Function);
  - Loop response test functionality, miscellaneous methods available are;
  - Step response test
  - Triangle oscillation test
  - One shot response test
  - Sinus oscillation test
- Button Signal Conditioning (see 4.2.13, Field Signal Conditioning);
  - Enabling last good values functionality
  - Setting default value settings
  - Setting field signal filtering
  - Setting action on fault
- Button Surge Detections (see 4.2.9, Surge Detection Settings).
  - Setting surge recovery amount and minimum position
  - Setting SMP amount
  - Enabling surge recovery in full manual
  - Setting and enabling SCL auto shift percent/surge
  - Show surge captures
  - Setting and enabling of surge detection levels
  - Setting operating limit to detect surge
- Button Surge Protections (see 4.2.10, Surge Protection Settings);
  - Setting Surge Control Line (SCL) margin
  - Setting Boost protection margin
  - Enabling and setting boost amount
  - Enabling setting pre-pack amount
  - Setting time loop/loop period

- Button P1 Override (see 4.2.11.4, Suction Pressure Override);
    - Enabling suction pressure override controller
    - Suction pressure override controller settings
- Button P2 Override (see 4.2.11.5, Discharge Pressure Override);
    - Enabling discharge pressure override controller
    - Discharge pressure override controller settings
- Button Decoupling (see 4.2.12, Decoupling and HSS Auxiliary Settings);
    - Enabling decoupling
    - Decoupling on speed settings
    - Decoupling on other stage settings
    - Decoupling on external input #1 margin
    - Decoupling on external input #2 margin

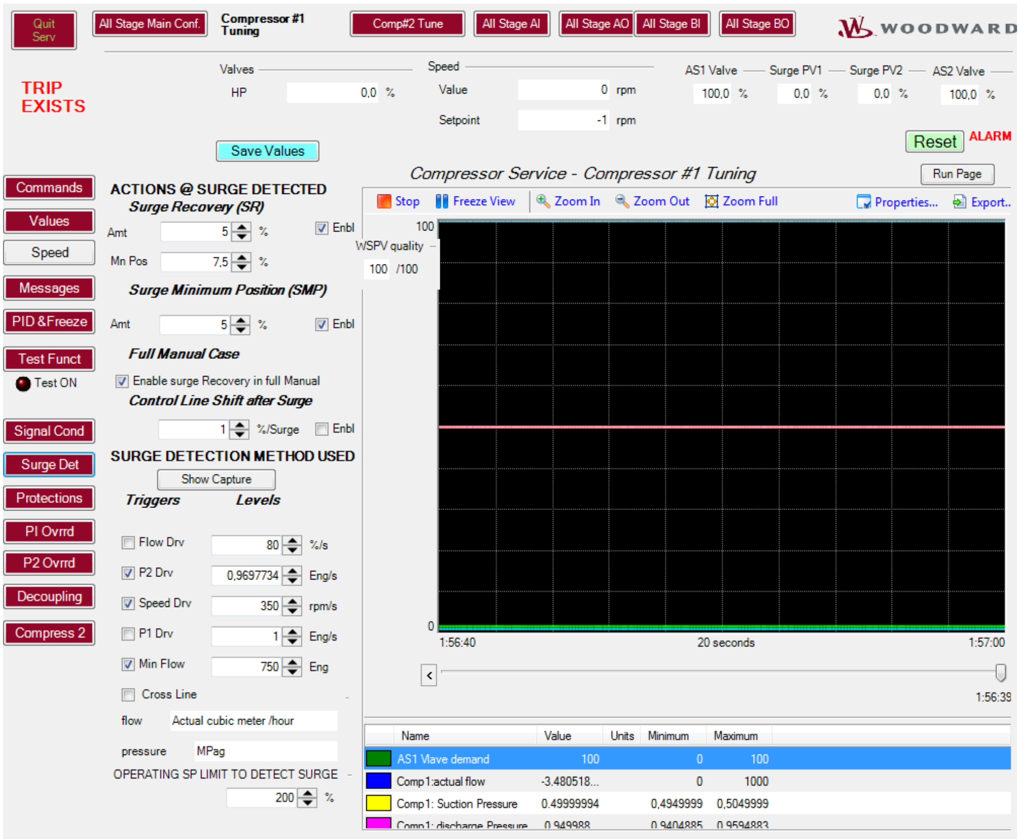


Figure 5-3. Compressor Tuning

Interactive Trend Graph

The trend graph provides a view of the configured control parameters. Functionality supported is zoom, start/stop graph and freeze view capabilities. The user can adjust the range of any parameter to allow the graph to be more useful for specific tuning, for example around a smaller speed window range, by using the properties icon.

The export icon will export the data from the trend to an html document.

5.2.3.1 Test Function

A special feature is available for most PID's used in the 505CC-2 which is called loop response test.

Type

The following tests can be selected:

- o Step response test
- o Triangle oscillation test
- o One shot response test
- o Sinus oscillation test

The following figures show the behavior during of the loop response test available:

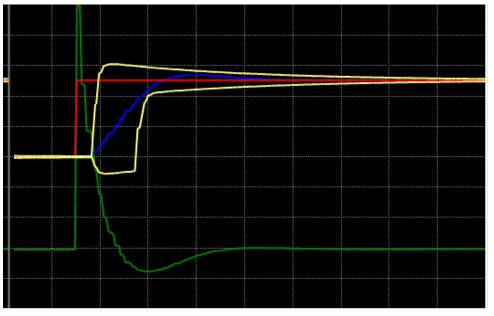


Figure 5-4. Step response test

Figure 5-5. One shot test

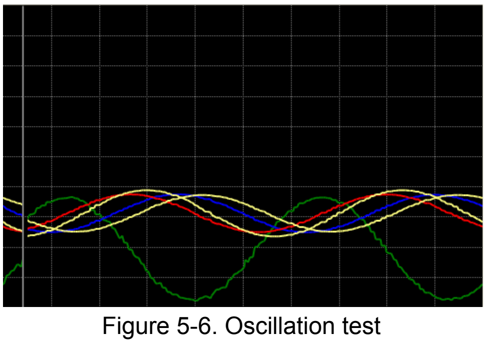


Figure 5-6. Oscillation test

Freq **Initial=0.09765625 Hz**

This setting is used only when the oscillation test is selected and concerns the oscillation frequency of the signal added to the reference. The frequency must be selected with care according the expected response time desired for the control.

Level **Initial=10.0 (1.0, 300.0)**

This is the amplitude of the signal added to the setpoint used for all types of loop response testing. Setting this to 1 – 3 % of rated speed should be considered a sufficient setting. Higher levels are not recommended, but can be considered in case of a one shot test if the pulse delay is short.

Ramp **Initial=0.1 (0.1, 10.0)**

This is used for the triangle oscillation test only.

Pls dly **Initial=1.0 (0.01, 20.0)**

This is used for the one shot test only.

Press the test request button to accept using the loop response test function. Subsequent press the toggle to start the selected test.

5.2.3.2 Dynamics Adjustments

The Anti-Surge, Rate Control, Suction Pressure Override, and Discharge Pressure Override controls are PID controllers. The response of each control loop can be adjusted by configuring the proportional gain, integral gain (stability), and SDR (speed derivative ratio) at the compressor tuning screen. These are 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 505CC-2 as follows:

- P = Proportional Gain (% output per unit error)
- I = Integral Gain (repeats per second)
- D = Speed derivative ratio

Refer to the sections below for general tuning theory and procedures.

Tuning P & I Gains

Proportional gain must be tuned to best respond to a system transient or step change. 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 the integral gain is set too high the control may hunt or oscillate at cycle 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 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, and 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, and the 505CC-2's adjustable gains. If the accumulated mechanical gain (actuators, valves, valve linkage, etc.) is very high, the 505CC-2's adjustable gains must be very low to result in a system gain that affords stability.

In cases where a small change in the 505CC-2's output results in a large load change (high mechanical gain) it may not be possible to take the 505CC-2'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 such that 0-100% 505CC-2 output corresponds to 0-100% valve travel.

Tuning Derivative

The value of the Speed derivative ratio (DR) term can range from 0.01 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 .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 coming into control, i.e. at start-up, during a 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, and can therefore prevent overshoot of the set-point better than a feedback dominant controller. Although this response is desirable during a start-up or load rejections, it can cause excessive control motions in some systems where a smooth transition response is desired and where noise is present.

A controller configured as feedback dominant is more sensitive to the change-of-rate of its feedback (the HSS bus). A feedback dominant controller has the ability to limit the rate of change of the HSS bus when a controller is near its set-point but is not yet in control. This limiting of the HSS bus allows a feedback dominant controller to make smoother control transitions than an input dominant controller. However, the feedback dominant controller is slightly slower to respond to the initial input disturbance. Because it is more forgiving (easier to tune) and less sensitive to signal noise, most PIDs will be configured as feedback dominant (1 < DR < 100).

Tuning Example

If the system is unstable, first verify whether or not the control is the cause. Place the control in Manual with Backup Mode and open the valve until the manual ramp has control of the actuator output. If the system continues to oscillate when Manual is in control of the valve, the system instability is caused by an external device/function. If the controller is causing the oscillation, time the oscillation cycle. Generally, if the system's oscillation cycle time is less than 1 second, reduce the proportional gain term. Conversely, if the system's oscillation cycle time is greater than 1 second, reduce the integral gain term (proportional gain may need to be increased as well).

On an initial start-up with the 505CC-2, 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 505CC-2's PIDs to assist in determining the gain terms that provide optimum control loop response times (Ziegler Nichols, etc.). The following method is a simplified version of other tuning methods, and can be used to achieve PID gain values that are close to optimum:

1. Place the control in Automatic Mode
2. Increase the Speed derivative ratio (DR) to 100.00 (This is the default setting).
3. Reduce integral gain to minimum.
4. Increase the proportional gain until the system just starts to oscillate.
5. Record the system gain (G) as the current proportional gain value and time the oscillation period (T) in seconds.
6. Set the dynamics as follows:

- For PID control set the proportional gain=0.60*G; integral gain=20/T; SDR=5
- For PI control set the proportional gain=0.45*G; integral gain=12/T; SDR=100

This method of tuning will result in acceptable gain settings. They can be fine-tuned from this point. Figure 5-7 shows the typical response to a load change when the dynamics are optimally adjusted.

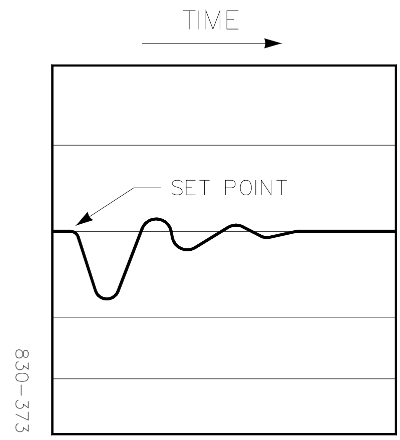


Figure 5-7. Typical Response to Load Change

5.2.4 Analog Inputs

The configured analog inputs are shown. The show button enables adjusting settings, see also 4.2.14 Analog Inputs.

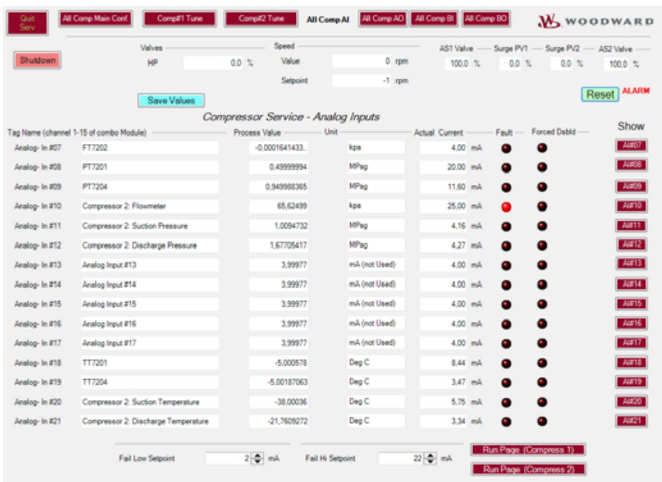


Figure 5-8. Analog Inputs

5.2.5 Analog Outputs

The configured analog outputs are shown. The show button enables adjusting settings Analog Outputs.

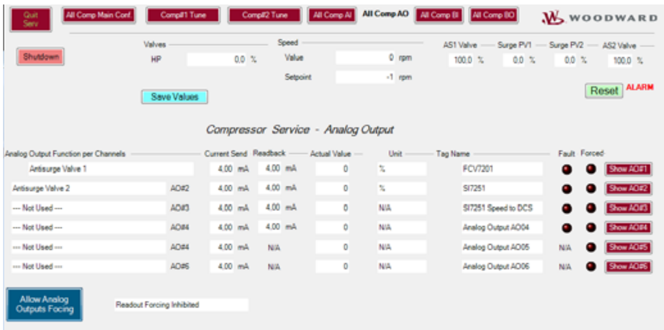


Figure 5-9. Analog Outputs

5.2.6 Binary Inputs

This screen display the configured binary inputs are shown.

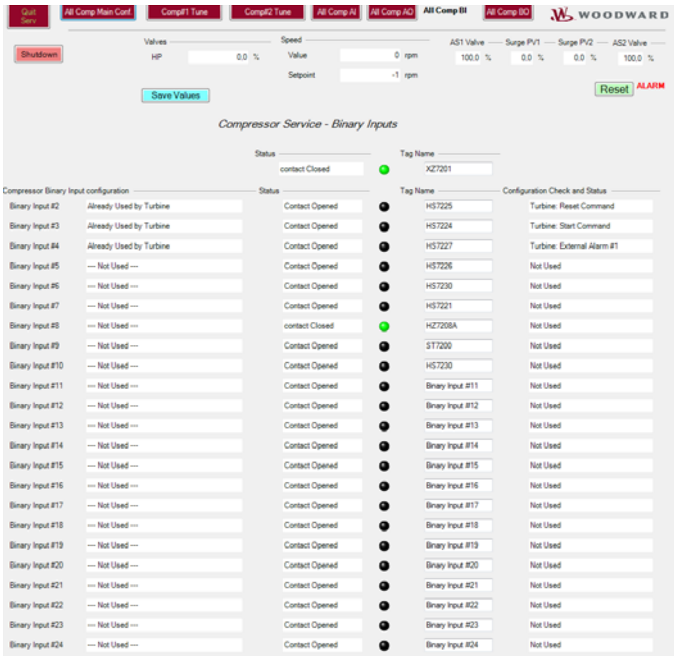


Figure 5-10. Binary Inputs

5.2.7 Binary Outputs

The configured binary outputs are shown.

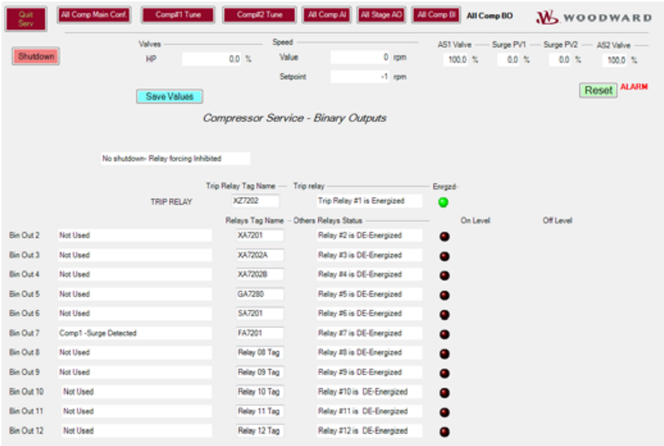


Figure 5-11. Binary Outputs

5.2.8 Speed Channels

The configured speed channels are shown.

Max Speed Deviation Authorized **Initial=10.0 (0.1, 100.0)**

The difference between the speed inputs can be set. An alarm will generate when this difference is exceeded.

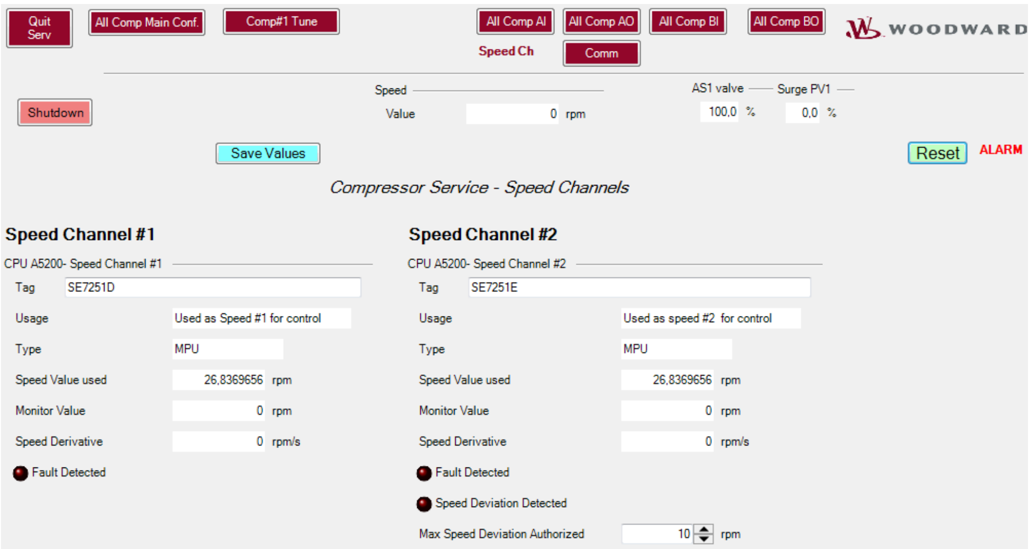


Figure 5-12. Speed Channels

5.2.9 Communication

The configured Modbus communication is shown. Most option except for the type of connection can be changed in service mode.

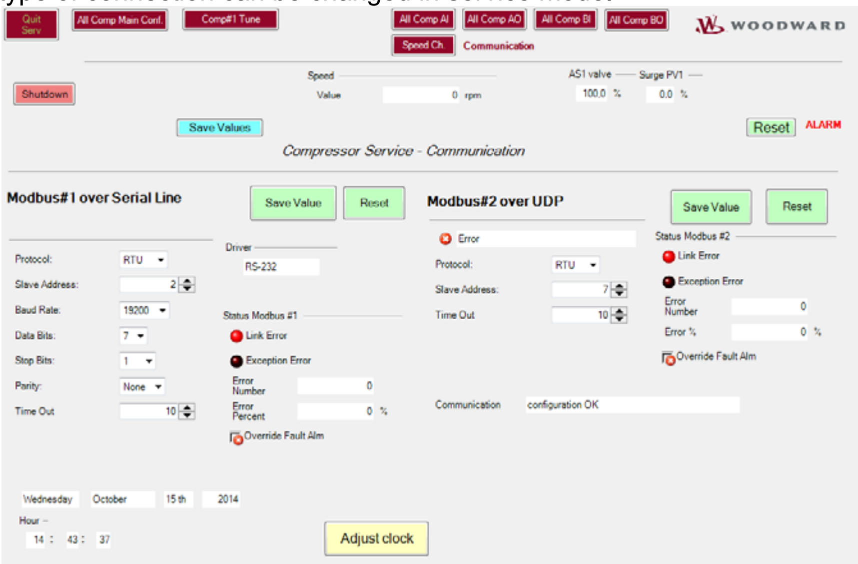


Figure 5-13. Communication

In addition the 505CC-2 internal clock can be adjusted by pressing the button adjust clock.

5.2.9.1 Adjust clock

The 505CC-2 date and time can be adjusted. Set the date and time to the current values and press the button Set Date or Set Time to have it updated.

Leave the time values on the required settings in case a binary input pulse is configured for clock synchronization. Each time the binary input pulse is received will result in the clock setting the entered values. A setting around midnight, i.e. 0:00:00 is not recommended, because this might result in date errors. Recommended instead is a setting of 3:00:00.

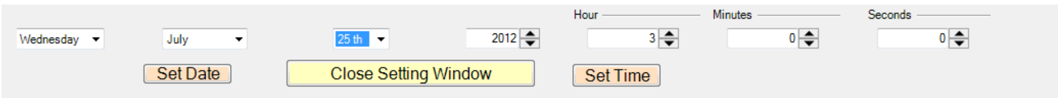


Figure 5-14. Adjust Clock

Chapter 6. Compressor Run Mode

6.1 Introduction

Operational requirements of compressor trains are as varied as the processes in which they operate. This chapter is intended to provide an overview of compressor operation with respect to the 505CC-2's functionality only. For more complete, process-specific compressor or plant operating instructions, contact the plant-equipment manufacturer.

Once configured, the 505CC-2 provides fully automatic control of the compressor's anti-surge valve(s). During normal operation, there is generally little or no intervention required by an operator. The compressor run screens, available from the main screen shown in Figure 6-1, provides access to all pertinent data used by the control to position the anti-surge valves. The following paragraphs describe the available screens and data to interpret compressor operation and intervene as required. In addition start-up, online operation, and shutdown scenarios are described.

6.2 Compressor Run Screens

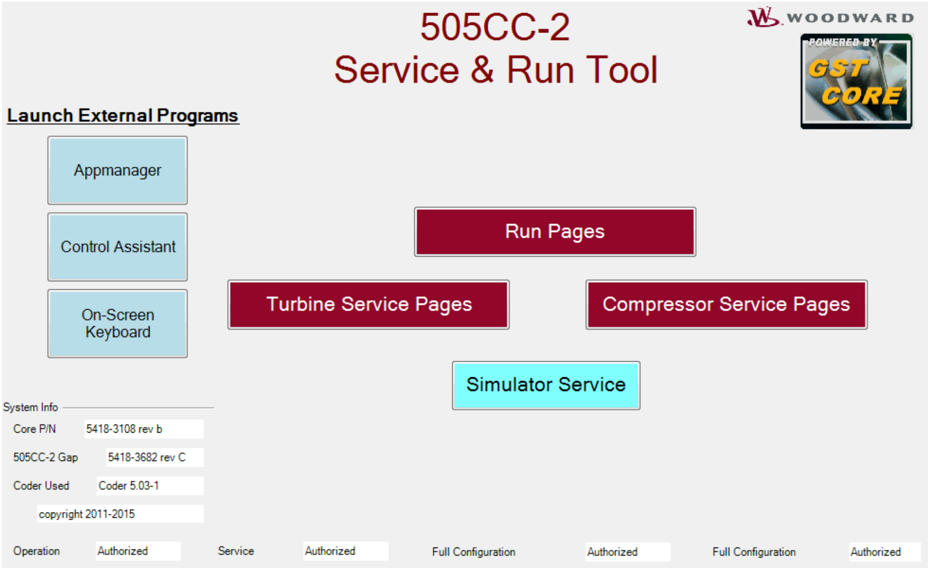


Figure 6-1. Run and Service Pages

6.2.1 Run Page

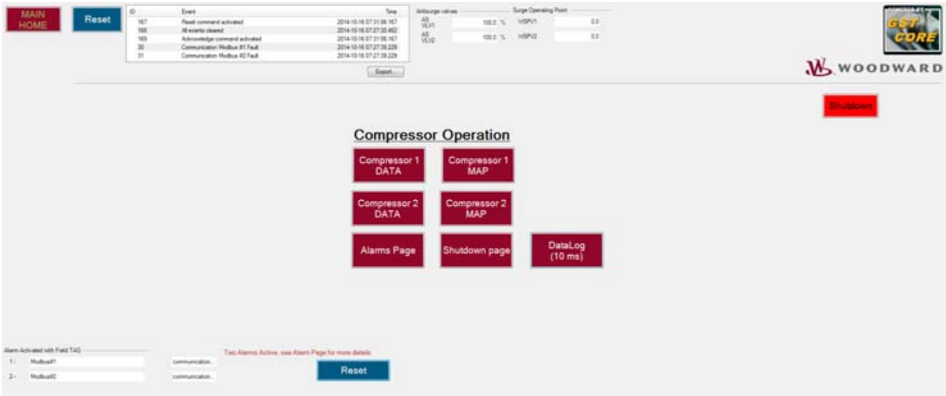


Figure 6-2. Compressor Run Pages

6.2.2 Alarms

See also volume 1 of the manual, 26542V1, for the alarm and shutdown overview of the compressor control. The numerical reference can be used as an index to determine the first alarm received via the first-alarm number in the Datalog or Modbus.

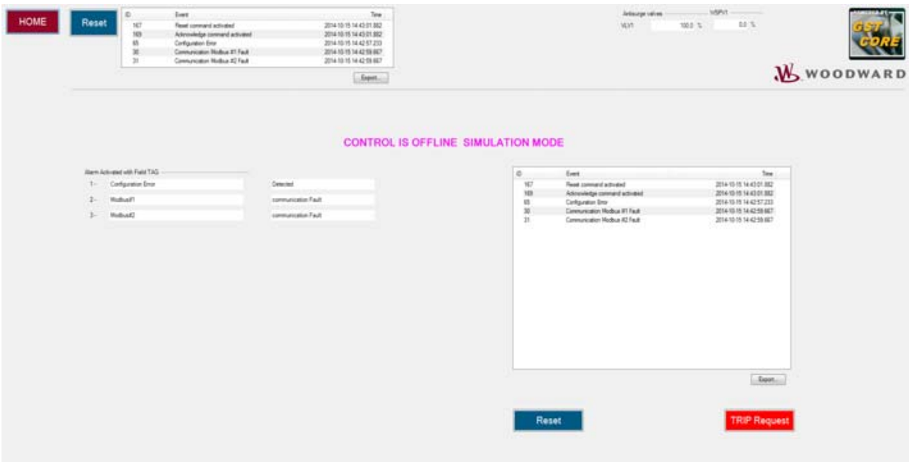


Figure 6-3. Alarm Screen

6.2.3 Shutdowns

See also volume 1 of the manual, 26542V1, for the alarm and shutdown overview of the compressor control. The numerical reference can be used as an index to determine the first alarm received via the first-alarm number in the Datalog or Modbus.

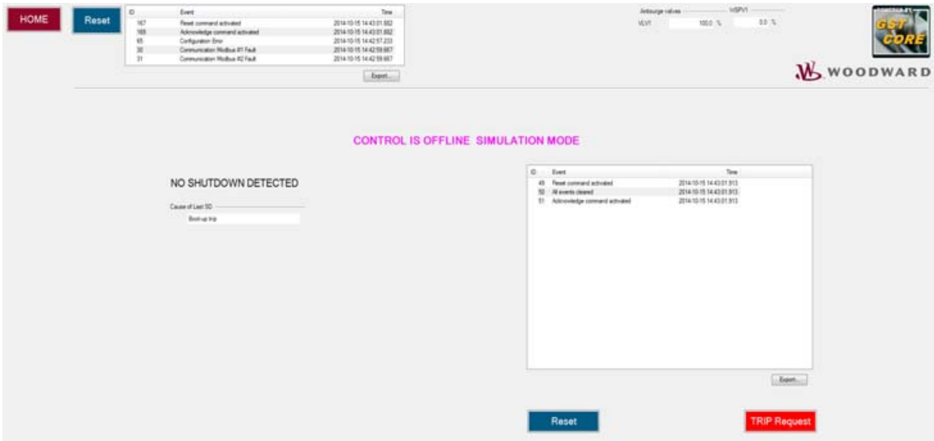


Figure 6-4. Shutdown Screen

6.2.4 Datalog (10 ms)

The 505CC-2 includes a high-speed datalog facility that can assist in troubleshooting a surge or other event. It records all typical data for both compressor loops at a 10-millisecond sample rate. The data that are recorded are fixed. The sample rate can be changed but only with special software tools.

The datalog is a circular buffer that is stored in CPU memory. As shown in Table 2-1, it records 40 discrete values (TRUE/FALSE) and 40 analog values for each compressor, as well as speed. This amount of data sampled every 10 ms results in a 32-second datalog. After the buffer is full, the datalog begins overwriting the oldest data. Recording automatically begins when the compressor train is started and automatically stops 10 seconds after a surge or shutdown. Using special software tools, starting and stopping the datalog can also be done manually to record specific transient events, process swings, etc. Two compressor datalogs can be stored on the CPU at any given time. If two completed datalog files already exist, the older of the two will be overwritten by the next datalog file.

AppManager and Control Assistant software, included on the Application CD, can be used to retrieve and view the datalogs. (These may also be downloaded from the software page at www.woodward.com) See AppManager's online help menu for details on retrieving files, including datalogs, from the control. The AppManager Datalog Retrieval Tool, available with an extra, purchased license, can also be configured to automatically archive datalogs from the control to a connected network computer. See Control Assistant's online help menu for details on viewing the .log datalog files. The file is a comma delimited text file, so it can also be imported into most trending or spreadsheet software for viewing and data manipulation.

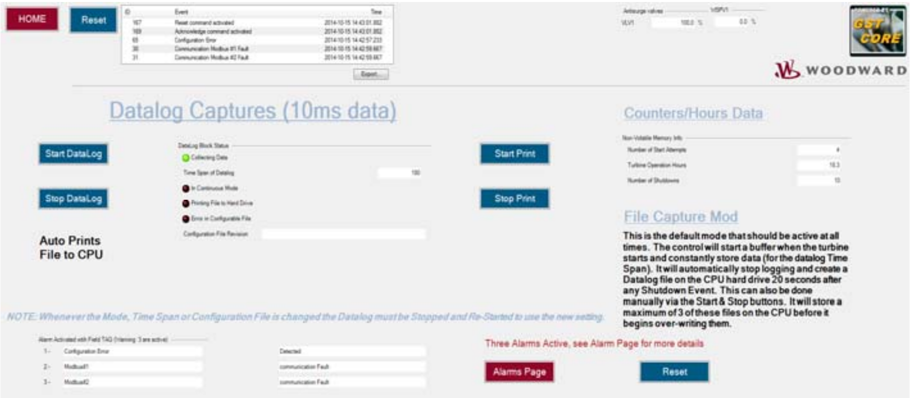


Figure 6-5. Datalog Screen

Discrete Values (TRUE/FALSE = 1/0)	Analog Values
Compressor 1: Surge Detected	Compressor 1: Valve demand
Compressor 1: Boost Activated	Compressor 1: HSS Demand
Compressor 1: SMP Active	Compressor 1: Operating point
Compressor 1: Surge Det On Flow Deriv	Compressor1: Actual flow
Compressor 1: Surge Det On Min Flow	Compressor 1: Mass/Std flow
Compressor 1: Surge Det On P1 Deriv	Compressor 1: Polytropic Head
Compressor 1: Surge Det On P2 Deriv	Compressor1: Reduced Head
Compressor 1: Surge Det On Spd Deriv	Compressor 1: Suction Pressure
Compressor 1: Surge Det On Cross line	Compressor 1: Discharge Pressure
Compressor 1: Configuration Error	Compressor 1: Suction Temperature
Compressor 1: Online	Compressor 1:Discharge Temperature
Compressor 1: In Automatic	Compressor 1:Delta P for flow
Compressor 1: In Manual with Backup	Compressor 1: Flow drv @ Surge
Compressor 1: In Full Manual	Compressor 1: Spd drv @ Surge
compressor 1 Flowmeter Fault	Compressor 1: Max P2 Deriv@ Surge
compressor 1 P1 Override Enabled	Compressor 1: Max P1 Deriv@ Surge
compressor 1 P2 Override Enabled	Compressor 1: Operating Pt @ Surge
Compressor 2: Surge Detected	Compressor 1: Manual dmd
Compressor 2: Boost Activated	Compressor 2: Valve demand
Compressor 2: SMP Active	Compressor 2: HSS Demand
Compressor 2: Surge Det On Flow Deriv	Compressor 2: Operating point
Compressor 2: Surge Det On Min Flow	Compressor 2: Actual flow
Compressor 2: Surge Det On P1 Deriv	Compressor 2: Mass/Std flow
Compressor 2: Surge Det On P2 Deriv	Compressor 2: Polytropic Head
Compressor 2: Surge Det On Spd Deriv	Compressor1: Reduced Head
Compressor 2: Surge Det On Cross line	Compressor 2: Suction Pressure
Compressor 2: Configuration Error	Compressor 2: Discharge Pressure
Compressor 2: Online	Compressor 2: Suction Temperature
Compressor 2: In Automatic	Compressor 2:Discharge Temperature
Compressor 2: In Manual with Backup	Compressor 2:Delta P for flow
Compressor 2: In Full Manual	Compressor 2: Flow drv @ Surge
compressor #2 Flowmeter Fault	Compressor 2: Spd drv @ Surge
compressor 1 P1 Override Enabled	Compressor 2: Max P2 Deriv@ Surge
compressor 1 P2 Override Enabled	Compressor 2: Max P1 Deriv@ Surge
	Compressor 2: Operating Pt @ Surge
	Compressor 2: Manual dmd

	Side Stream Flow
	Side Stream Temperature
	Side Stream Pressure

Table 6-1. 505CC-2 Compressor Datalog

6.2.5 Operation

6.2.5.1 Startup

When shutdown and at zero speed, the unit is off-line, and the 505CC-2 maintains the compressor anti-surge valve at the position at zero speed. Typical compressor start-ups are on full recycle during a steam turbine warm-up, which may last several hours. As steam is initially admitted to the turbine and speed increases past the compressor's configured zero speed level, the control ramps the anti-surge valve to the position during startup. This start sequence may also be triggered by a configurable discrete input or Modbus command.

The control will remain off-line, in the start sequence, with the valve at the position during startup until an on-line condition is triggered. All enabled on-line triggers (speed, suction pressure, discharge pressure, flow, and/or auxiliary input) must be satisfied to go on-line and transfer from sequencing to automatic control. If a shutdown (i.e. turbine trip, ESD, configurable discrete input, Modbus command) is received at any time during start-up, the control will sequence the valve to the position after shutdown and await a restart (configurable discrete input, Modbus command) or slow to zero speed. A delay time can be configured to have the anti-surge valve position move from shutdown position to zero speed position.

6.2.5.2 On-Line / Normal Operation

After the unit goes on-line, as determined by the 505CC-2's on-line detection routines, control of the anti-surge valve is transferred from sequence positioning to full automatic control. Provided that load is sufficient and S_PV is greater than 100, the anti-surge PID control will slowly close the anti-surge valve. The 505CC-2 will monitor operation and position the valve as determined by the various configured control routines:

- Anti-Surge PID
- Rate PID
- Boost
- Surge Recovery
- Surge Minimum Position
- Decoupling
- Suction Pressure Override
- Discharge Pressure Override
- Two Auxiliary Control Inputs
- Manual Control, i.e. Manual with Backup or Full Manual

Removal of an on-line trigger such as speed, suction pressure, discharge pressure, flow, and/or auxiliary input will change the control to the start sequence and ramp the valve to the position during startup. The control will remain as such until the on-line trigger is restored.

If a shutdown (turbine trip, ESD, configurable discrete input, Modbus command) is received, the control will sequence the valve to the position after shutdown and await a restart (configurable discrete input, Modbus command) or slow to zero speed.

6.2.5.3 Emergency Shutdown

When a shutdown is received, the anti-surge valve is immediately moved to the configured position after shutdown. The shutdown sequence remains active until the unit slows below the configured zero speed level, at which time the valve is ramped to the configured position at zero speed after the shutdown delay has passed. If, however, before slowing to zero speed, the shutdown is cleared and reset and a restart commanded, sequence control takes over as described previously for a start-up. The anti-surge valve(s) will revert to the configured start position until an online condition is detected, at which time the 505CC-2 transfers to automatic anti-surge control.

6.2.5.4 Controlled Shutdown

A controlled shutdown, or normal stop, is initiated through the turbine control and is designed to slowly ramp unit speed down in a controlled manner. This condition will not cause the compressors anti-surge valve(s) to immediately trip to the shutdown position. Rather, the automatic anti-surge routines remain in control of the valve(s) until an online detection trigger, described previously, is released, at which time the anti-surge valve(s) is ramped to the configured shutdown position at the configured manual valve rate.

NOTICE

Consideration should be given to the relationship of:
- **Online detection trigger setpoints**
- **Valve rates, and**
- **The turbine controlled shutdown speed rate.**

As the unit slows during a controlled shutdown, compressor flow will likely become unstable, possibly leading to surge if the anti-surge valve does not open quickly enough.

The combination of a slow to moderate speed ramp, moderate to fast anti-surge valve rate, and higher online detection trigger is recommended.

The controlled shutdown sequence remains active until the unit slows below the configured zero speed setpoint, at which time the valve is ramped to the configured zero speed position. If, however, before slowing to zero speed, the controlled shutdown is aborted, sequence control takes over as described previously for a start-up. The Anti-Surge Valve(s) will revert to the configured start position until an online condition is detected, at which time the 505CC-2 transfers to automatic anti-surge control.

6.2.6 Mode

In this screen the control mode can be selected. The user will be able to switch from automatic mode to manual or full manual mode.

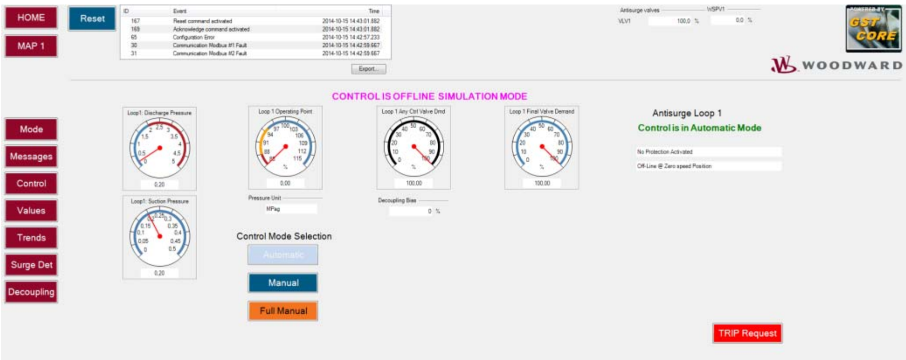


Figure 6-6. Control Mode Selection

6.2.7 Alm/Msg

This screen shows the messages coming from the turbine together with two active alarms. The alarms are shown with the additional field tag. This screen shows how many alarms are active in total as well. For additional information about these alarms, go to the alarm page. See also volume 1 of the manual, 26542V1, for the alarm and shutdown overview of the compressor control.

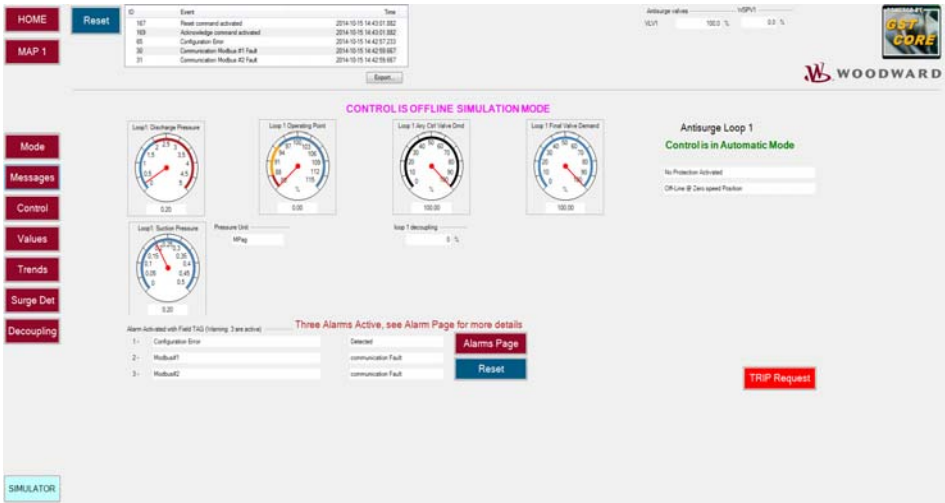


Figure 6-7. Alm/Msg

6.2.8 Control

This screen shows the demand of the controls and the actual surge margin.

Figure 6-8. Control

6.2.9 Values

The compressor values are displayed on this screen. The temperature and pressure at suction and discharge can be found here as well as actual and standard flow.

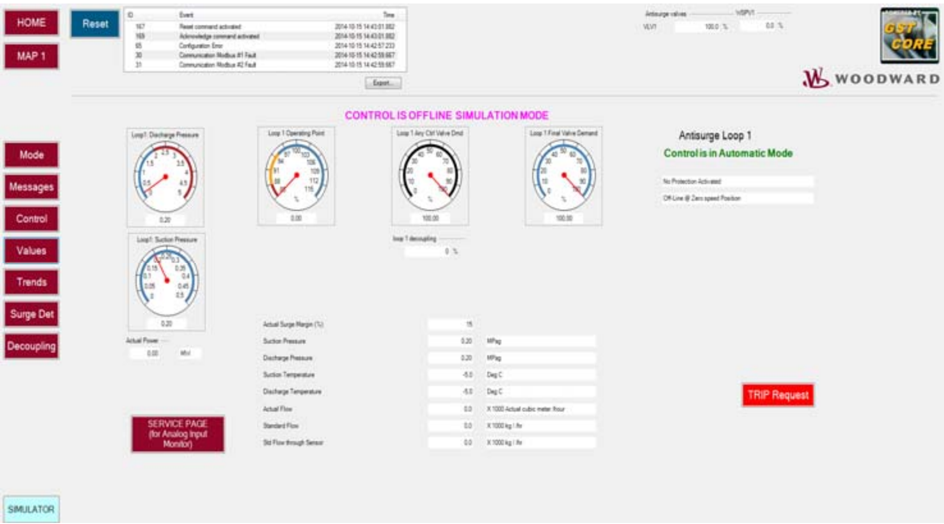


Figure 6-9. Values

6.2.10 Surge Detection

In case of a surge the control captures some values and displays them on this screen.

The following maximum derivatives and operating point reached at surge is displayed:

- Maximum flow derivative
- Operating point
- Maximum inlet pressure derivative
- Maximum discharge derivative
- Maximum speed derivative

A detected surge will set the Surge Minimum Position (SMP). The dedicated reset button for resetting this SMP is available on this page. Using the raise or lower margin buttons allows for adjustments to the margin between Surge Limit Line (SLL) and Surge Control Line (SCL).

Every surge detected is counted with in addition the configured surge consecutive alarm and shutdown. Using the reset counter button will clear these counters back to zero except for the total number of surges which requires using the reset counter button three times within one second to clear this.

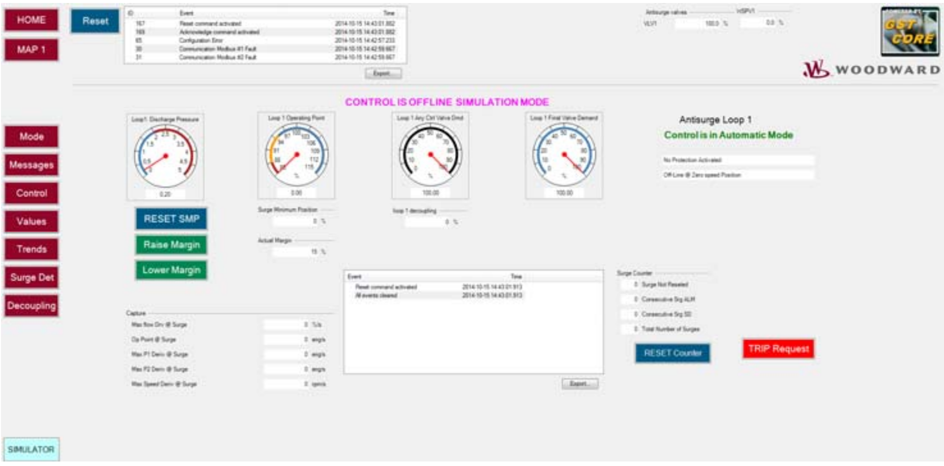


Figure 6-10. Surge Detection

6.2.11 Decoupling

This page displays the percentage decoupling, when enabled and configured, that will be applied to the anti-surge valve. For information about decoupling refer to 2.9.3.9.

6.2.12 Other Stage

This screen gives an overview of the two stages together. The discharge pressure, the operating point, the control valve demand and the final valve demand of both the compressor stages are shown here.

Figure 6-11. Other Stage

6.2.13 P1 Override

At this page the set point of the suction pressure of compressor stage 1 can be manually adjusted. Refer to 2.9.4.1 for additional information.

6.2.14 P2 Override

At this page the set point of the suction pressure of compressor stage 2 can be manually adjusted. Refer to 2.9.4.2 for additional information.

Appendix A. Compressor Configuration Worksheet

Compressor Configuration Sheet	Setting	Unit
All Stages Main Configuration		
Compressor Layout		
Measurement Units system Used		
Units Definition used in Controller		
Pressure Unit at Sensors		
Temperature Units at Sensor		
Flow Units for Mapping		
Polytropic Head Unit used		
Average Atmospheric Pressure on-site [kPA] or [psi]		
Special gas case (if available)		
Standard Conditions		
Temperature		
Pressure		
Algorithm		
Type of Algorithm Used		
Gas Component		
Location of Sensors - Single Stage Compressor (if configured)		
Flowmeter Location		
Temperature Location		
Inter-coolers		
Location of Sensors - Dual with one Flow Element (if configured)		
Flowmeter Location		
COMP1: Temperature Location		
COMP2: Temperature Location		
COMP1: Inter-coolers		
COMP2: Inter-coolers		
Location of Sensors - Dual with two Flow Elements (if configured)		
COMP1: Flowmeter Location		
COMP2: Flowmeter Location		
COMP1: Temperature Location		
COMP2: Temperature Location		
COMP1: Inter-coolers		

COMP2: Inter-coolers
Anti-surge Valves Layout

Location of Sensors - Dual with Side Stream Extraction (if configured)
Flowmeters combined Location
Temperature Sensors combined Location
COMP1: Inter-coolers
COMP2: Inter-coolers

Location of Sensors - Dual with Side Stream Admission (if configured)
Flowmeters combined Location
Temperature Sensors combined Location
COMP1: Inter-coolers
COMP2: Inter-coolers

All Stages Gas Characteristics - Single Stage (if configured)
Molecular weight [g/mol]
Specific Heat Ratio
Compressibility at Suction
Compressibility at Discharge
Compressibility at Standard Condition
Critical Pressure [Press Unit]
Critical Temperature [Temp Unit]

All Stages Gas Characteristics - Dual Stage (if configured)
Molecular weight [g/mol]

Specific Heat Ratio
Comp1: Compressibility at Suction
Comp1: Compressibility at Discharge
Comp2: Compressibility at Suction
Comp2: Compressibility at Discharge
Critical Pressure [Press Unit]
Critical Temperature [Temp Unit]

All Stages Flow Element Settings

Flowmeter 1 - Calibration settings

Flow sensor type
Calculation Method Used

Flow Data from calibration sheet (if used)
Delta Pressure Input Engineering Units
Flow
Delta Pressure at Flow
Molecular Weight

Pressure at Flowmeter
Temperature at Flowmeter
Compressibility at Flow
Flow 1 Coefficient Used (result from calculation)

Flow Data from Geometry spec (if used)
Delta Pressure Input Engineering Units
Diameter
Beta Ratio
Y Factor
C Coefficient
Flow 1 Coefficient Used (result from calculation)

Manual Setting of Flow 1 Coefficient (if used)
Flow 1 Coefficient Used

Flowmeter 2 - Calibration settings (if used)
Flow sensor type
Calculation Method Used

Flow Data from calibration sheet (if used)
Delta Pressure Input Engineering Units
Flow
Delta Pressure at Flow
Molecular Weight
Pressure at Flowmeter
Temperature at Flowmeter
Compressibility at Flow
Flow 2 Coefficient Used (result from calculation)

Flow Data from Geometry spec (if used)
Delta Pressure Input Engineering Units
Diameter
Beta Ratio
Y Factor
C Coefficient
Flow 2 Coefficient Used (result from calculation)

Manual Setting of Flow 1 Coefficient (if used)
Flow 2 Coefficient Used

All Stages Antisurge Valve Settings
Anti-surge Valve#1 Settings

Actuation Direction
Gain Compensation
Dither [%]
Use Overstroke?
Overstroke Open [%] (if used)
Overstroke Closed [%] (if used)

Anti-surge Valve#1 Linearization Curve (if used)

X1 [%], Y1 [%]
X2 [%], Y2 [%]
X3 [%], Y3 [%]
X4 [%], Y4 [%]
X5 [%], Y5 [%]
X6 [%], Y6 [%]
X7 [%], Y7 [%]
X8 [%], Y8 [%]
X9 [%], Y9 [%]
X10 [%], Y10 [%]
X11 [%], Y11 [%]

Anti-surge Valve#1 CV-based Compensation Parameters (if used)

Normal Flow Value
AS Valve CV

Anti-surge Valve#2 Settings (if used)

Actuation Direction
Gain Compensation
Dither [%]
Use Overstroke?
Overstroke Open [%] (if used)
Overstroke Closed [%] (if used)

Anti-surge Valve#2 Linearization Curve (if used)

X1 [%], Y1 [%]
X2 [%], Y2 [%]
X3 [%], Y3 [%]
X4 [%], Y4 [%]
X5 [%], Y5 [%]
X6 [%], Y6 [%]
X7 [%], Y7 [%]
X8 [%], Y8 [%]
X9 [%], Y9 [%]
X10 [%], Y10 [%]
X11 [%], Y11 [%]

Anti-surge Valve#2 CV-based Compensation Parameters (if used)

Normal Flow Value
AS Valve CV

Stage 1 Mapping

Map Displayed on HMI
Adjust Max X for Display
Adjust Max Y for Display

Type of Map used
Multiply Factor on Flow
Multiply Factor on Head

Rated Conditions as per Surge Map
Suction Temperature
Suction Pressure
Discharge Temperature
Discharge Pressure
Rated Speed
Flow @ Rated
Polytropic Efficiency

Min/Max Sensor Range Expected
Min Suction Pressure
Max Suction Pressure
Min Discharge Pressure
Max Discharge Pressure

Surge Map 1 Curve
X1 , Y1
X2 , Y2
X3 , Y3
X4 , Y4
X5 , Y5
X6 , Y6

Stage 1 Control Settings - Sequence/Valve Position
Valve Position at Shutdown and Start
Shutdown Position Enabled
Purge position
Position just After Shutdown [%]
Time After Shutdown [s]
Zero Speed Level [rpm]
Position if Zero Speed and SD Delay Passed [%]
Position during Startup [%]

Control Online Detection (Permissive to Modulate)
Use Minimum Speed Level
Minimum Speed Level [rpm] (if used)
Use Minimum Suction Pressure Level
Minimum Suction Pressure Level (if used)
Use Minimum Discharge Pressure

Level
Minimum Discharge Pressure Level (if used)
Use Minimum Flow Level
Minimum Flow Level (if used)
Use External Contact

Valve Open/Close Manual

Manual Raise/Lower Slow Rate [%/s]
Delay for Fast Rate [s]
Manual Raise/Lower Fast Rate [%/s]
Use Remote Manual

Valve Open/Close Automatic

Automatic Rate [%/s]

Stage 1 Control Settings - Surge Detection

Surge Detection Method

Use Flow Derivative Detection
Flow Derivative Detection Trigger setpoint
Use Minimum Flow Derivative Detection
Minimum Flow Derivative Trigger Setpoint [Eng Unit/s] (if used)
Use Discharge Pressure Derivative Detection
Discharge Pressure Derivative Trigger Setpoint [Eng Unit/s] (if used)
Use Suction Pressure Derivative Detection
Suction Pressure Derivative Trigger Setpoint [Eng Unit/s] (if used)
Use Speed Derivative Detection
Speed Derivative Trigger Setpoint [rpm/s] (if used)
Use Surge Protection on Cross Line

Actions Taken When Surge Detected

Operating SP Limit to Detect Surge [%]
Loop Period [s]
Surge Recovery Enabled
Surge Recovery Amount [%]
Surge Recovery Min Valve Position [%]

SMP Function Enabled
SMP Amount [%]
SMP Reset Function

Enable Surge Recovery even in Full Manual

Use Auto Control Line Shift after Surge

Auto Control Line Shift Amount [%]

Stage 1 Control Settings - Surge Protection

Surge Prevention

Surge Control Line (SCL) Margin [%]
Boost Protection Margin [%]
Alarm Protection Maximum number of surges
Alarm Protection Time for maximum number of surges
Trip Protection Maximum number of surges
Trip Protection Time for maximum number of surges
Time Loop (Set in Surge Detection [s])
Enable Boost Function
Boost Function Amount [%] (if used)
Enable Pre-Pack Function
Pre-Pack Function Amount [%] (if used)
Alarm if consecutive surges
Full opening if consecutive surges alarm detected
Trip if consecutive surges SD detected
Full Manual Mode Request Inhibited

Stage 1 Control Settings - PID's

Normal Surge Controller Settings

Use Pressure Compensation (only if set in Valve Settings)
Proportional Gain
Integral Gain [rpt/s]
Speed Derivative Ratio

Rate PID Controller Settings

Use Rate PID Controller
Use Pressure Compensation (only if set in Valve Settings)
Proportional Gain
Integral Gain [rpt/s]
Speed Derivative Ratio
Rate Setpoint

Valve Freeze Option

Use Valve Freeze Option
Delay Before Freezing the Valve [s]
Window on Valve Demand [%]
Window on Surge Operation Point [%]

Suction Pressure Override Controller

Suction Pressure Override Controller usage

Use Pressure Compensation (only if set in Valve Settings)
Proportional Gain
Integral Gain [rpt/s]
Speed Derivative Ratio
Initial Setpoint [Eng Unit]
SP Rate of Change [Eng Unit/s]

Discharge Pressure Override Controller
Discharge Pressure Override Controller usage
Use Pressure Compensation (only if set in Valve Settings)
Proportional Gain
Integral Gain [rpt/s]
Speed Derivative Ratio
Initial Setpoint [Eng Unit]
SP Rate of Change [Eng Unit/s]

Stage 1 Control Settings - Decoupling and HSS Auxiliary
Decoupling Usage
Max Decoupling Level [%]
Surge Process Value Range (to Act) [%]

Decoupling on Speed
Slow Speed Delay Time [s]
Slow Speed Amount [%/rpm]
Fast Speed Delay Time [s]
Fast Speed Amount [%/rpm]

Decoupling on other Stage
Other Stage Delay Time [s]
Other Stage Amount [%/%]

Decoupling on External Input#1
Input#1 Delay Time [s]
Input#1 Amount [%/%]

Decoupling on External Input#2
Input#2 Delay Time [s]
Input#2 Amount [%/%]

Auxiliary Control 1 (HSS)
Use Auxiliary HSS#1
Signal Filter

Auxiliary Control 2 (HSS)
Use Auxiliary HSS#2
Signal Filter

Stage 1 Control Settings - Field Signal Conditioning

Last Good Values

Use Suction Pressure Last Good Value
Use Discharge Pressure Last Good Value
Use Pressure at Flow Last Good Value (if used)
Use Suction Temperature Last Good Value
Use Discharge Temperature Last Good Value
Use Temperature at Flow Last Good Value (if used)

Default Value Settings

Default Suction Pressure Last Good Value
Default Discharge Pressure Last Good Value
Default Pressure at Flow Last Good Value (if used)
Default Suction Temperature Last Good Value
Default Discharge Temperature Last Good Value
Default Temperature at Flow Last Good Value (if used)

Field Signal Filtering

Flow Filter (ARMA) [s]
Pressure Filter [s]
Temperature Filter [s]

Field Signal Fault Action on Control

Full Manual Mode Selected in Any Fault
Added Amount on Flow Failure [%]

Stage 2 Mapping (if used)

Map Displayed on HMI
Adjust Max X for Display
Adjust Max Y for Display

Type of Map used
Multiply Factor on Flow
Multiply Factor on Head

Rated Conditions as per Surge Map

Suction Temperature
Suction Pressure
Discharge Temperature
Discharge Pressure
Rated Speed
Flow @ Rated
Polytropic Efficiency

Min/Max Sensor Range Expected

Min Suction Pressure
Max Suction Pressure
Min Discharge Pressure
Max Discharge Pressure

Surge Map 2 Curve

X1 , Y1
X2 , Y2
X3 , Y3
X4 , Y4
X5 , Y5
X6 , Y6

Stage 2 Control Settings - Sequence/Valve Position

Valve Position at Shutdown and Start

Shutdown Position Enabled
Purge position
Position just After Shutdown [%]
Time After Shutdown [s]
Zero Speed Level [rpm]
Position if Zero Speed and SD Delay Passed [%]
Position during Startup [%]

Control Online Detection (Permissive to Modulate)

Use Minimum Speed Level
Minimum Speed Level [rpm] (if used)
Use Minimum Suction Pressure Level
Minimum Suction Pressure Level (if used)
Use Minimum Discharge Pressure Level
Minimum Discharge Pressure Level (if used)
Use Minimum Flow Level
Minimum Flow Level (if used)
Use External Contact

Valve Open/Close Manual

Manual Raise/Lower Slow Rate [%/s]
Delay for Fast Rate [s]
Manual Raise/Lower Fast Rate [%/s]
Use Remote Manual

Valve Open/Close Automatic

Automatic Rate [%/s]

Stage 2 Control Settings - Surge Detection

Surge Detection Method

Use Flow Derivative Detection
Flow Derivative Detection Trigger setpoint
Use Minimum Flow Derivative Detection
Minimum Flow Derivative Trigger Setpoint [Eng Unit/s] (if used)
Use Discharge Pressure Derivative Detection
Discharge Pressure Derivative Trigger Setpoint [Eng Unit/s] (if used)
Use Suction Pressure Derivative Detection
Suction Pressure Derivative Trigger Setpoint [Eng Unit/s] (if used)
Use Speed Derivative Detection
Speed Derivative Trigger Setpoint [rpm/s] (if used)
Use Surge Protection on Cross Line

Actions Taken When Surge Detected
Operating SP Limit to Detect Surge [%]
Loop Period [s]
Surge Recovery Enabled
Surge Recovery Amount [%]
Surge Recovery Min Valve Position [%]

SMP Function Enabled
SMP Amount [%]
SMP Reset Function

Enable Surge Recovery even in Full Manual

Use Auto Control Line Shift after Surge
Auto Control Line Shift Amount [%]

Stage 2 Control Settings - Surge Protection
Surge Prevention
Surge Control Line (SCL) Margin [%]
Boost Protection Margin [%]
Alarm Protection Maximum number of surges
Alarm Protection Time for maximum number of surges
Trip Protection Maximum number of surges
Trip Protection Time for maximum number of surges
Time Loop (Set in Surge Detection [s])
Enable Boost Function
Boost Function Amount [%] (if used)
Enable Pre-Pack Function
Pre-Pack Function Amount [%] (if

used)
Alarm if consecutive surges
Full opening if consecutive surges alarm detected
Trip if consecutive surges SD detected
Full Manual Mode Request Inhibited

Stage 2 Control Settings - PID's

Normal Surge Controller Settings

Use Pressure Compensation (only if set in Valve Settings)
Proportional Gain
Integral Gain [rpt/s]
Speed Derivative Ratio

Rate PID Controller Settings

Use Rate PID Controller
Use Pressure Compensation (only if set in Valve Settings)
Proportional Gain
Integral Gain [rpt/s]
Speed Derivative Ratio
Rate Setpoint

Valve Freeze Option

Use Valve Freeze Option
Delay Before Freezing the Valve [s]
Window on Valve Demand [%]
Window on Surge Operation Point [%]

Suction Pressure Override Controller

Suction Pressure Override Controller usage
Use Pressure Compensation (only if set in Valve Settings)
Proportional Gain
Integral Gain [rpt/s]
Speed Derivative Ratio
Initial Setpoint [Eng Unit]
SP Rate of Change [Eng Unit/s]

Discharge Pressure Override Controller

Discharge Pressure Override Controller usage
Use Pressure Compensation (only if set in Valve Settings)
Proportional Gain
Integral Gain [rpt/s]
Speed Derivative Ratio
Initial Setpoint [Eng Unit]
SP Rate of Change [Eng Unit/s]

Stage 2 Control Settings - Decoupling and HSS Auxiliary

Decoupling Usage
Max Decoupling Level [%]

Surge Process Value Range (to Act) [%]

Decoupling on Speed

Slow Speed Delay Time [s]
Slow Speed Amount [%/rpm]
Fast Speed Delay Time [s]
Fast Speed Amount [%/rpm]

Decoupling on other Stage

Other Stage Delay Time [s]
Other Stage Amount [%/%]

Decoupling on External Input#1

Input#1 Delay Time [s]
Input#1 Amount [%/%]

Decoupling on External Input#2

Input#2 Delay Time [s]
Input#2 Amount [%/%]

Auxiliary Control 1 (HSS)

Use Auxiliary HSS#1
Signal Filter

Auxiliary Control 2 (HSS)

Use Auxiliary HSS#2
Signal Filter

Stage 2 Control Settings - Field Signal Conditioning

Last Good Values

Use Suction Pressure Last Good Value
Use Discharge Pressure Last Good Value
Use Pressure at Flow Last Good Value (if used)
Use Suction Temperature Last Good Value
Use Discharge Temperature Last Good Value
Use Temperature at Flow Last Good Value (if used)

Default Value Settings

Default Suction Pressure Last Good Value
Default Discharge Pressure Last Good Value
Default Pressure at Flow Last Good Value (if used)
Default Suction Temperature Last Good Value

Default Discharge Temperature Last Good Value
Default Temperature at Flow Last Good Value (if used)

Field Signal Filtering

Flow Filter (ARMA) [s]
Pressure Filter [s]
Temperature Filter [s]

Field Signal Fault Action on Control

Full Manual Mode Selected in Any Fault
Added Amount on Flow Failure [%]

Compressor Analog Inputs

Fail Low Setpoint [mA]
Fail High Setpoint [mA]

Analog Inputs

AI#07 Function
AI#07 Value at 4 mA
AI#07 Value at 20 mA
AI#07 Modbus Multiplier
AI#07 Units
AI#07 Tag Name

AI#08 Function
AI#08 Value at 4 mA
AI#08 Value at 20 mA
AI#08 Modbus Multiplier
AI#08 Units
AI#08 Tag Name

AI#09 Function
AI#09 Value at 4 mA
AI#09 Value at 20 mA
AI#09 Modbus Multiplier
AI#09 Units
AI#09 Tag Name

AI#10 Function
AI#10 Value at 4 mA
AI#10 Value at 20 mA
AI#10 Modbus Multiplier
AI#10 Units
AI#10 Tag Name

AI#11 Function
AI#11 Value at 4 mA
AI#11 Value at 20 mA
AI#11 Modbus Multiplier
AI#11 Units
AI#11 Tag Name

AI#12 Function
AI#12 Value at 4 mA
AI#12 Value at 20 mA
AI#12 Modbus Multiplier
AI#12 Units
AI#12 Tag Name

AI#13 Function
AI#13 Value at 4 mA
AI#13 Value at 20 mA
AI#13 Modbus Multiplier
AI#13 Units
AI#13 Tag Name

AI#14 Function
AI#14 Value at 4 mA
AI#14 Value at 20 mA
AI#14 Modbus Multiplier
AI#14 Units
AI#14 Tag Name

AI#15 Function
AI#15 Value at 4 mA
AI#15 Value at 20 mA
AI#15 Modbus Multiplier
AI#15 Units
AI#15 Tag Name

AI#16 Function
AI#16 Value at 4 mA
AI#16 Value at 20 mA
AI#16 Modbus Multiplier
AI#16 Units
AI#16 Tag Name

AI#17 Function
AI#17 Value at 4 mA
AI#17 Value at 20 mA
AI#17 Modbus Multiplier
AI#17 Units
AI#17 Tag Name

AI#18 Function
AI#18 Value at 4 mA
AI#18 Value at 20 mA
AI#18 Modbus Multiplier
AI#18 Units
AI#18 Tag Name

AI#19 Function
AI#19 Value at 4 mA
AI#19 Value at 20 mA
AI#19 Modbus Multiplier
AI#19 Units
AI#19 Tag Name

AI#20 Function
AI#20 Value at 4 mA
AI#20 Value at 20 mA
AI#20 Modbus Multiplier
AI#20 Units
AI#20 Tag Name

AI#21 Function
AI#21 Value at 4 mA
AI#21 Value at 20 mA
AI#21 Modbus Multiplier
AI#21 Units
AI#21 Tag Name

Compressor Analog Outputs

Analog Output Channels

AO#1 Function
AO#1 Value at 4 mA
AO#1 Value at 20 mA
AO#1 Tag Name

AO#2 Function
AO#2 Value at 4 mA
AO#2 Value at 20 mA
AO#2 Tag Name

AO#3 Function
AO#3 Value at 4 mA
AO#3 Value at 20 mA
AO#3 Tag Name

AO#4 Function
AO#4 Value at 4 mA
AO#4 Value at 20 mA
AO#4 Tag Name

AO#5 Function
AO#5 Value at 4 mA
AO#5 Value at 20 mA
AO#5 Tag Name

AO#6 Function
AO#6 Value at 4 mA
AO#6 Value at 20 mA
AO#6 Tag Name

Compressor Binary Inputs

BI#2 Function
BI#2 Tag Name

BI#3 Function
BI#3 Tag Name

BI#4 Function
BI#4 Tag Name

BI#5 Function
BI#5 Tag Name

BI#6 Function
BI#6 Tag Name

BI#7 Function
BI#7 Tag Name

BI#8 Function
BI#8 Tag Name

BI#9 Function
BI#9 Tag Name

BI#10 Function
BI#10 Tag Name

BI#11 Function
BI#11 Tag Name

BI#12 Function
BI#12 Tag Name

BI#13 Function
BI#13 Tag Name

BI#14 Function
BI#14 Tag Name

BI#15 Function
BI#15 Tag Name

BI#16 Function
BI#16 Tag Name

BI#17 Function
BI#17 Tag Name

BI#18 Function
BI#18 Tag Name

BI#19 Function
BI#19 Tag Name

BI#20 Function
BI#20 Tag Name

BI#21 Function
BI#21 Tag Name

BI#22 Function

BI#22 Tag Name

BI#23 Function
BI#23 Tag Name

BI#24 Function
BI#24 Tag Name

Compressor Binary Outputs

Relay #2 Function
Relay #2 Tag Name
Relay #2 Status indication (if used)
Function
Invert
Relay #2 Level Switch (if used)
Parameter
ON Level
OFF Level
Invert

Relay #3 Function
Relay #3 Tag Name
Relay #3 Status indication (if used)
Function
Invert
Relay #3 Level Switch (if used)
Parameter
ON Level
OFF Level
Invert

Relay #4 Function
Relay #4 Tag Name
Relay #4 Status indication (if used)
Function
Invert
Relay #4 Level Switch (if used)
Parameter
ON Level
OFF Level
Invert

Relay #5 Function
Relay #5 Tag Name
Relay #5 Status indication (if used)
Function
Invert
Relay #5 Level Switch (if used)
Parameter
ON Level
OFF Level
Invert

Relay #6 Function
Relay #6 Tag Name

Relay #6 Status indication (if used)
Function
Invert
Relay #6 Level Switch (if used)
Parameter
ON Level
OFF Level
Invert

Relay #7 Function
Relay #7 Tag Name
Relay #7 Status indication (if used)
Function
Invert
Relay #7 Level Switch (if used)
Parameter
ON Level
OFF Level
Invert

Relay #8 Function
Relay #8 Tag Name
Relay #8 Status indication (if used)
Function
Invert
Relay #8 Level Switch (if used)
Parameter
ON Level
OFF Level
Invert

Relay #9 Function
Relay #9 Tag Name
Relay #9 Status indication (if used)
Function
Invert
Relay #9 Level Switch (if used)
Parameter
ON Level
OFF Level
Invert

Relay #10 Function
Relay #10 Tag Name
Relay #10 Status indication (if used)
Function
Invert
Relay #10 Level Switch (if used)
Parameter
ON Level
OFF Level
Invert

Relay #11 Function
Relay #11 Tag Name
Relay #11 Status indication (if used)

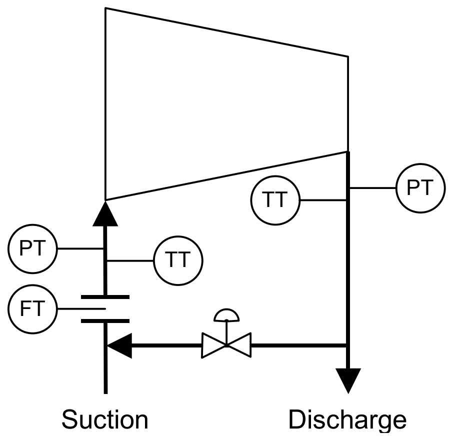
Function
Invert
Relay #11 Level Switch (if used)
Parameter
ON Level
OFF Level
Invert

Relay #12 Function
Relay #12 Tag Name
Relay #12 Status indication (if used)
Function
Invert
Relay #12 Level Switch (if used)
Parameter
ON Level
OFF Level
Invert

Appendix B. Valid Compressor Configurations

The following tables and figures can be used to review a particular configuration, from the Comp General configuration screen, as valid or invalid. If a configuration variable is not shown in the chart, it does not impact that layout. The 505CC-2 will generate an error message for invalid configurations but will not automatically correct or pinpoint the problem.

Standard Algorithm / Single Stage

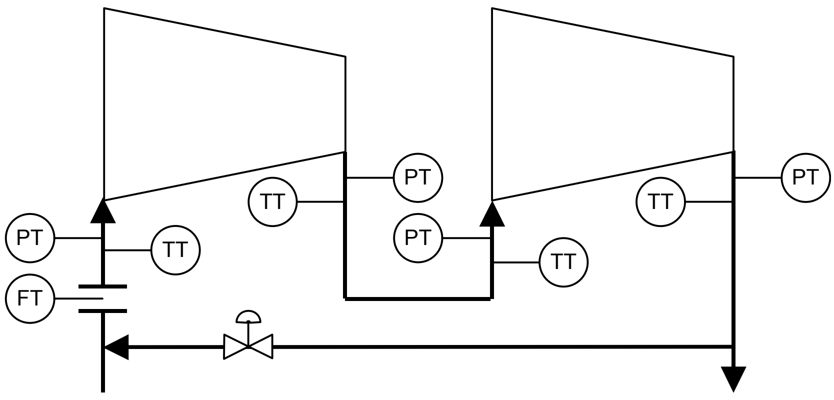


Gas Component	Flow Element	Temperature Sensor	Number of Valves	Config.
Constant	Suction	Suct. + Disch.	1	Valid
		Suct.	1	Valid
		Disch.	1	-
	Discharge	Suct. + Disch.	1	Valid
		Suct.	1	-
		Disch.	1	Valid

Gas Component	Flow Element	Temperature Sensor	Number of Valves	Config.
Variable	Suction	Suct. + Disch.	1	Valid
		Suct.	1	-
		Disch.	1	-
	Discharge	Suct. + Disch.	1	Valid
		Suct.	1	-
		Disch.	1	-

Figure B-1. Standard Algorithm, Single Stage Configurations

Standard Algorithm / Dual with 1 Flow Element



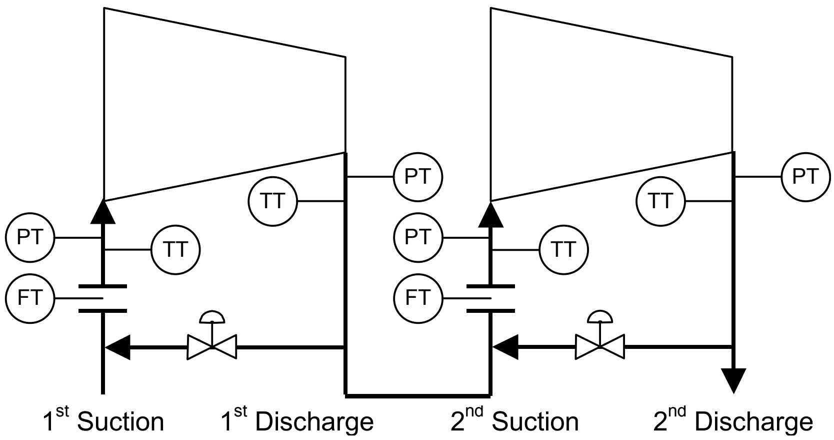
Gas Component	Flow Element	Temperature Sensor	Number of Valve	Config.
Constant	1st Suct.	(Suct. + Disch.) + (Suct. + Disch.)	1	Valid
		(Suct. + Disch.) + (Suct.)	1	Valid
		(Suct. + Disch.) + (Disch.)	1	Valid
		(Suct.) + (Suct. + Disch.)	1	Valid
		(Disch.) + (Suct. + Disch.)	1	-
		(Suct.) + (Suct.)	1	Valid
		(Suct.) + (Disch.)	1	Valid
		(Disch.) + (Suct.)	1	-
		(Disch.) + (Disch.)	1	-
	1st Disch.	(Suct. + Disch.) + (Suct. + Disch.)	1	Valid
		(Suct. + Disch.) + (Suct.)	1	Valid
		(Suct. + Disch.) + (Disch.)	1	Valid
		(Suct.) + (Suct. + Disch.)	1	-
		(Disch.) + (Suct. + Disch.)	1	Valid
		(Suct.) + (Suct.)	1	-
		(Suct.) + (Disch.)	1	-
		(Disch.) + (Suct.)	1	Valid
		(Disch.) + (Disch.)	1	Valid
	2nd Suct.	(Suct. + Disch.) + (Suct. + Disch.)	1	Valid
		(Suct. + Disch.) + (Suct.)	1	Valid
		(Suct. + Disch.) + (Disch.)	1	-
		(Suct.) + (Suct. + Disch.)	1	Valid
		(Disch.) + (Suct. + Disch.)	1	Valid
		(Suct.) + (Suct.)	1	Valid
		(Suct.) + (Disch.)	1	-
		(Disch.) + (Suct.)	1	Valid
		(Disch.) + (Disch.)	1	-
	2nd Disch.	(Suct. + Disch.) + (Suct. + Disch.)	1	Valid
		(Suct. + Disch.) + (Suct.)	1	-
		(Suct. + Disch.) + (Disch.)	1	Valid
		(Suct.) + (Suct. + Disch.)	1	Valid
		(Disch.) + (Suct. + Disch.)	1	Valid
		(Suct.) + (Suct.)	1	-
		(Suct.) + (Disch.)	1	Valid
		(Disch.) + (Suct.)	1	-
		(Disch.) + (Disch.)	1	Valid

Figure B-2. Standard Algorithm, Dual with 1 Flow Element Configurations

Gas Component	Flow Element	Temperature Sensor	Number of Valve	Config.
Variable	1st Suct.	(Suct. + Disch.) + (Suct. + Disch.)	1	Valid
		(Suct. + Disch.) + (Suct.)	1	-
		(Suct. + Disch.) + (Disch.)	1	-
		(Suct.) + (Suct. + Disch.)	1	-
		(Disch.) + (Suct. + Disch.)	1	-
		(Suct.) + (Suct.)	1	-
		(Suct.) + (Disch.)	1	-
		(Disch.) + (Suct.)	1	-
		(Disch.) + (Disch.)	1	-
	1st Disch.	(Suct. + Disch.) + (Suct. + Disch.)	1	Valid
		(Suct. + Disch.) + (Suct.)	1	-
		(Suct. + Disch.) + (Disch.)	1	-
		(Suct.) + (Suct. + Disch.)	1	-
		(Disch.) + (Suct. + Disch.)	1	-
		(Suct.) + (Suct.)	1	-
		(Suct.) + (Disch.)	1	-
		(Disch.) + (Suct.)	1	-
		(Disch.) + (Disch.)	1	-
	2nd Suct.	(Suct. + Disch.) + (Suct. + Disch.)	1	Valid
		(Suct. + Disch.) + (Suct.)	1	-
		(Suct. + Disch.) + (Disch.)	1	-
		(Suct.) + (Suct. + Disch.)	1	-
		(Disch.) + (Suct. + Disch.)	1	-
		(Suct.) + (Suct.)	1	-
		(Suct.) + (Disch.)	1	-
		(Disch.) + (Suct.)	1	-
		(Disch.) + (Disch.)	1	-
	2nd Disch.	(Suct. + Disch.) + (Suct. + Disch.)	1	Valid
		(Suct. + Disch.) + (Suct.)	1	-
		(Suct. + Disch.) + (Disch.)	1	-
		(Suct.) + (Suct. + Disch.)	1	-
		(Disch.) + (Suct. + Disch.)	1	-
		(Suct.) + (Suct.)	1	-
		(Suct.) + (Disch.)	1	-
		(Disch.) + (Suct.)	1	-
		(Disch.) + (Disch.)	1	-

Figure B-3. Standard Algorithm, Dual with 1 Flow Element Configurations

Standard Algorithm / Dual with 2 Flow Elements



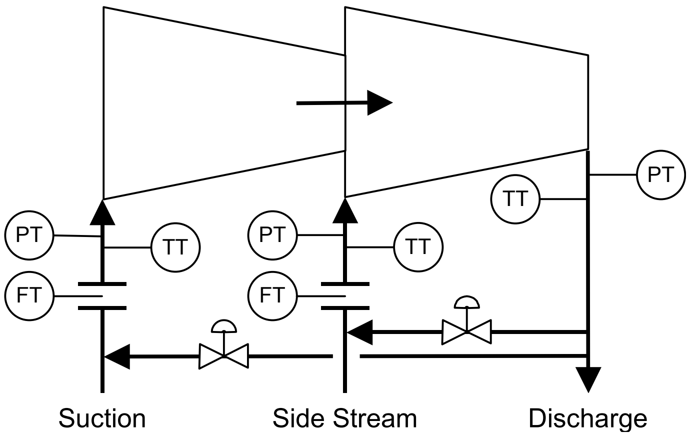
Gas Component	Flow Element	Temperature Sensor	Number of Valve	Config.
Constant	1st Suct. + 2nd Suct.	(Suct. + Disch.) + (Suct. + Disch.)	2 or 1	Valid
		(Suct. + Disch.) + (Suct.)	2 or 1	Valid
		(Suct. + Disch.) + (Disch.)	2 or 1	-
		(Suct.) + (Suct. + Disch.)	2 or 1	Valid
		(Disch.) + (Suct. + Disch.)	2 or 1	-
		(Suct.) + (Suct.)	2 or 1	Valid
		(Suct.) + (Disch.)	2 or 1	-
		(Disch.) + (Suct.)	2 or 1	-
		(Disch.) + (Disch.)	2 or 1	-
	1st Suct. + 2nd Disch.	(Suct. + Disch.) + (Suct. + Disch.)	2 or 1	Valid
		(Suct. + Disch.) + (Suct.)	2 or 1	-
		(Suct. + Disch.) + (Disch.)	2 or 1	Valid
		(Suct.) + (Suct. + Disch.)	2 or 1	Valid
		(Disch.) + (Suct. + Disch.)	2 or 1	-
		(Suct.) + (Suct.)	2 or 1	-
		(Suct.) + (Disch.)	2 or 1	Valid
		(Disch.) + (Suct.)	2 or 1	-
		(Disch.) + (Disch.)	2 or 1	-
	1st Disch. + 2nd Suct.	(Suct. + Disch.) + (Suct. + Disch.)	2 or 1	Valid
		(Suct. + Disch.) + (Suct.)	2 or 1	Valid
		(Suct. + Disch.) + (Disch.)	2 or 1	-
		(Suct.) + (Suct. + Disch.)	2 or 1	-
		(Disch.) + (Suct. + Disch.)	2 or 1	Valid
		(Suct.) + (Suct.)	2 or 1	-
		(Suct.) + (Disch.)	2 or 1	-
		(Disch.) + (Suct.)	2 or 1	Valid
		(Disch.) + (Disch.)	2 or 1	-
	1st Disch. + 2nd Disch.	(Suct. + Disch.) + (Suct. + Disch.)	2 or 1	Valid
		(Suct. + Disch.) + (Suct.)	2 or 1	-
		(Suct. + Disch.) + (Disch.)	2 or 1	Valid
		(Suct.) + (Suct. + Disch.)	2 or 1	-
		(Disch.) + (Suct. + Disch.)	2 or 1	Valid
		(Suct.) + (Suct.)	2 or 1	-
		(Suct.) + (Disch.)	2 or 1	-
		(Disch.) + (Suct.)	2 or 1	-
		(Disch.) + (Disch.)	2 or 1	Valid

Figure B-4. Standard Algorithm, Dual with 2 Flow Element Configurations

Gas Component	Flow Element	Temperature Sensor	Number of Valve	Config.
Variable	1st Suct. + 2nd Suct.	(Suct. + Disch.) + (Suct. + Disch.)	2 or 1	Valid
		(Suct. + Disch.) + (Suct.)	2 or 1	-
		(Suct. + Disch.) + (Disch.)	2 or 1	-
		(Suct.) + (Suct. + Disch.)	2 or 1	-
		(Disch.) + (Suct. + Disch.)	2 or 1	-
		(Suct.) + (Suct.)	2 or 1	-
		(Suct.) + (Disch.)	2 or 1	-
		(Disch.) + (Suct.)	2 or 1	-
		(Disch.) + (Disch.)	2 or 1	-
	1st Suct. + 2nd Disch.	(Suct. + Disch.) + (Suct. + Disch.)	2 or 1	Valid
		(Suct. + Disch.) + (Suct.)	2 or 1	-
		(Suct. + Disch.) + (Disch.)	2 or 1	-
		(Suct.) + (Suct. + Disch.)	2 or 1	-
		(Disch.) + (Suct. + Disch.)	2 or 1	-
		(Suct.) + (Suct.)	2 or 1	-
		(Suct.) + (Disch.)	2 or 1	-
		(Disch.) + (Suct.)	2 or 1	-
		(Disch.) + (Disch.)	2 or 1	-
	1st Disch. + 2nd Suct.	(Suct. + Disch.) + (Suct. + Disch.)	2 or 1	Valid
		(Suct. + Disch.) + (Suct.)	2 or 1	-
		(Suct. + Disch.) + (Disch.)	2 or 1	-
		(Suct.) + (Suct. + Disch.)	2 or 1	-
		(Disch.) + (Suct. + Disch.)	2 or 1	-
		(Suct.) + (Suct.)	2 or 1	-
		(Suct.) + (Disch.)	2 or 1	-
		(Disch.) + (Suct.)	2 or 1	-
		(Disch.) + (Disch.)	2 or 1	-
	1st Disch. + 2nd Disch.	(Suct. + Disch.) + (Suct. + Disch.)	2 or 1	Valid
		(Suct. + Disch.) + (Suct.)	2 or 1	-
		(Suct. + Disch.) + (Disch.)	2 or 1	-
		(Suct.) + (Suct. + Disch.)	2 or 1	-
		(Disch.) + (Suct. + Disch.)	2 or 1	-
		(Suct.) + (Suct.)	2 or 1	-
		(Suct.) + (Disch.)	2 or 1	-
		(Disch.) + (Suct.)	2 or 1	-
		(Disch.) + (Disch.)	2 or 1	-

Figure B-5. Standard Algorithm, Dual with 2 Flow Element Configurations

Standard Algorithm / Dual with Sidestream

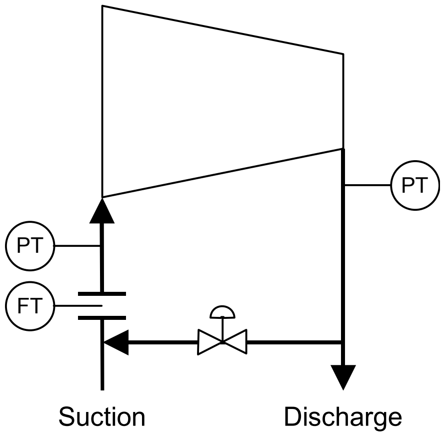


Gas Component	S.S. Direction	Flow Element	Temperature Sensor	Number of Valve	Config.
Constant	Admission	Suct. + S.S.	(Suct.) + (S.S. + Disch.)	2 or 1	Valid
			(Suct.) + (S.S.)	2 or 1	Valid
			(Suct.) + (Disch.)	2 or 1	-
		Suct. + Disch.	(Suct.) + (S.S. + Disch.)	2 or 1	Valid
			(Suct.) + (S.S.)	2 or 1	-
			(Suct.) + (Disch.)	2 or 1	Valid
		S.S. + Disch.	(Suct.) + (S.S. + Disch.)	2 or 1	Valid
			(Suct.) + (S.S.)	2 or 1	-
			(Suct.) + (Disch.)	2 or 1	-
	Extraction	Suct. + S.S.	(Suct.) + (S.S. + Disch.)	2 or 1	Valid
			(Suct.) + (S.S.)	2 or 1	Valid
			(Suct.) + (Disch.)	2 or 1	-
		Suct. + Disch.	(Suct.) + (S.S. + Disch.)	2 or 1	Valid
			(Suct.) + (S.S.)	2 or 1	-
			(Suct.) + (Disch.)	2 or 1	Valid
		S.S. + Disch.	(Suct.) + (S.S. + Disch.)	2 or 1	Valid
			(Suct.) + (S.S.)	2 or 1	-
			(Suct.) + (Disch.)	2 or 1	-

Gas Component	S.S. Direction	Flow Element	Temperature Sensor	Number of Valve	Config.
Variable	Admission	Suct. + S.S.	(Suct.) + (S.S. + Disch.)	2 or 1	-
			(Suct.) + (S.S.)	2 or 1	-
			(Suct.) + (Disch.)	2 or 1	-
		Suct. + Disch.	(Suct.) + (S.S. + Disch.)	2 or 1	-
			(Suct.) + (S.S.)	2 or 1	-
			(Suct.) + (Disch.)	2 or 1	-
		S.S. + Disch.	(Suct.) + (S.S. + Disch.)	2 or 1	-
			(Suct.) + (S.S.)	2 or 1	-
			(Suct.) + (Disch.)	2 or 1	-
	Extraction	Suct. + S.S.	(Suct.) + (S.S. + Disch.)	2 or 1	-
			(Suct.) + (S.S.)	2 or 1	-
			(Suct.) + (Disch.)	2 or 1	-
		Suct. + Disch.	(Suct.) + (S.S. + Disch.)	2 or 1	-
			(Suct.) + (S.S.)	2 or 1	-
			(Suct.) + (Disch.)	2 or 1	-
		S.S. + Disch.	(Suct.) + (S.S. + Disch.)	2 or 1	-
			(Suct.) + (S.S.)	2 or 1	-
			(Suct.) + (Disch.)	2 or 1	-

Figure B-6. Standard Algorithm, Dual with Side Stream Configurations

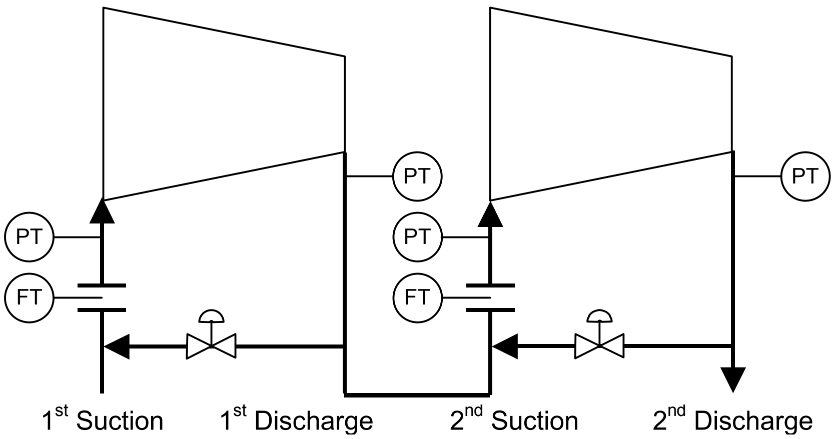
Universal Algorithm / Single Stage



Flow Element	Number of Valve	Config.
Suction	1	Valid
Discharge	1	Valid

Figure B-7. Universal Algorithm, Single Stage Configurations

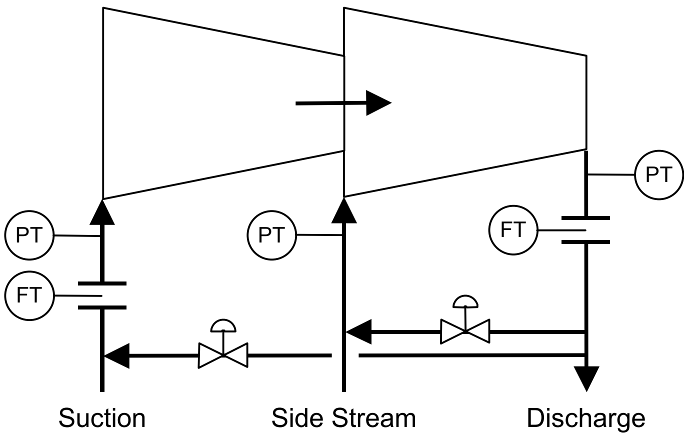
Universal Algorithm / Dual with 2 Flow Elements



Flow Element	Number of Valve	Config.
1st Suct. + 2nd Suct.	1	Valid
	2	Valid
1st Suct. + 2nd Disch.	1	Valid
	2	Valid
1st Disch. + 2nd Suct.	1	Valid
	2	Valid
1st Disch. + 2nd Disch.	1	Valid
	2	Valid

Figure B-8. Universal Algorithm, Dual with 2 Flow Element Configurations

Universal Algorithm / Dual with Sidestream



Flow Element	Number of Valve	Config.
1st Suct. + 2nd Disch.	1	Valid
	2	Valid
Side Stream + 2nd Disch.	1	-
	2	-
1st Suct. + Side Stream	1	-
	2	-

Figure B-9. Universal Algorithm, Dual with Side Stream Configurations

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