WOODWARD

Configuration & Operation Manual

Vertex-Pro
Motor-Driven Compressor Control

Volume 2
Configuration and Operation

Manual 26489 consists of 2 volumes (26489V1 & 26489V2).

Manual 26489V2

IMPORTANT

DEFINITIONS

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

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

WARNING

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.

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.

This publication may have been revised or updated since this copy was produced. To verify that you have the latest revision, be sure to check the Woodward website:
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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.

NOTICE

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.

NOTICE

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

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Chapter 1.
General Information

Introduction

The Vertex-Pro is an anti-surge controller, designed to control and protect industrial-sized motor-driven axial and centrifugal compressors. This controller is available in standard off-the-shelf models or custom models. Standard off-the-shelf models are available for one or two recycle loop applications. Custom models (Vertex-Pro-C models) are available for three and four recycle loop applications.

This manual should be used along with the Vertex-Pro installation and hardware manual (26489V1). The scope of this document is only to describe the Vertex-Pro application software functionality and assist the customer in configuration and start-up of the control. Refer to manual 26489V1 for information on hardware specifications, mounting information, and wiring details.

This manual, 26489, encompasses two separate volumes:
- Volume 1—Installation and Hardware
- Volume 2—Configuration and Operation

This volume is dedicated to the compressor control, describing compressor I/O, operating point calculations, control functionality, and configuration and tuning procedures.

This manual does not contain instructions for the operation of the complete motor and compressor system. For motors, compressors, or plant operating instructions, contact the plant equipment manufacturer.

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 Vertex-Pro and its functionality—***be sure to read and understand this manual fully***. As described above, refer to Manual 26489V1 for information on the physical installation and wiring of the Vertex-Pro control.

Topic	Location (manual 26489)
Vertex-Pro Systems	Volume 1, Chapter 2
System Overview	Volume 2, Chapter 2
Compressor Control Description	Volume 2, Chapter 3
General Description	Volume 2, Chapter 4
Configuration and Service	Volume 2, Chapter 5 and 6
Modbus® *	Volume 2, Chapter 8
Field Set-Up	Volume 2, Chapters 9
Compressor Operation Overview	Volume 2, Chapter 10
Security / Login Passwords	Volume 2, Appendix A

*—Modbus is a trademark of Schneider Automation Inc.

Control Accessories

The Vertex-Pro digital control is designed to interface with several Woodward service tools and commercial hardware and software products. Available accessories are listed below with a brief description of their functionality:

- **Control Assistant** —Provides an Ethernet or serial connection to the control to allow 1) initial configuration of the unit; 2) monitoring and tuning of system variables; and 3) management of configuration and setpoints. Ethernet connection to the control for viewing of high-speed data captures and other useful utilities.
- **Application Manager**—Ethernet access to the control for program loading, network configuration and support, and system diagnostics.
- **External Interfaces**—Commercially available HMI (Human Machine Interface) programs, Distributed Control Systems (DCS), and Programmable Logic Controllers (PLC) can interface to the Vertex-Pro control through serial or Ethernet connections to provide operator access and control of the application machinery.

Service Panel & Configuration Tool Software

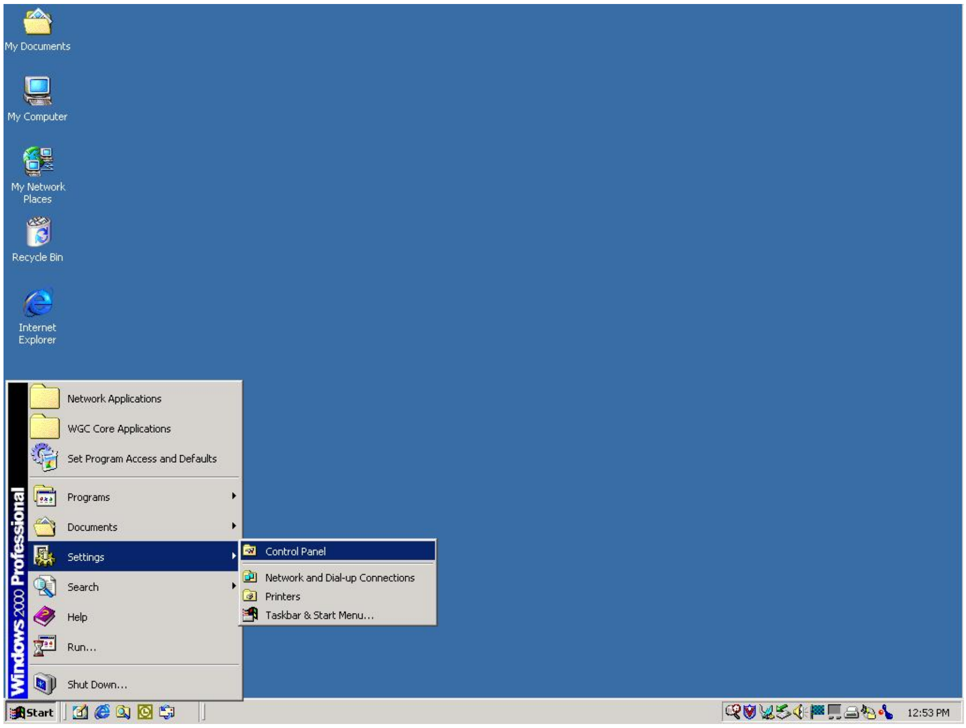
The Control Assistant software provides full configuration and operation of the Vertex-Pro control system through intuitive, menu-driven screens. The software is supplied with the Vertex-Pro on a compact disc (CD) for installation on any Microsoft Windows 2000/XP computer. The same software comes pre-loaded on touch screen Service Panel. This Service Panel consists of a 12.1 inch (307 mm) industrial touch-panel computer and 10 foot (3 meter) Ethernet cable (Woodward part number 5417-1033 or Similar). The Ethernet cable is an option although the Service Panel is normally supplied with the Vertex-Pro.

IP Addresses

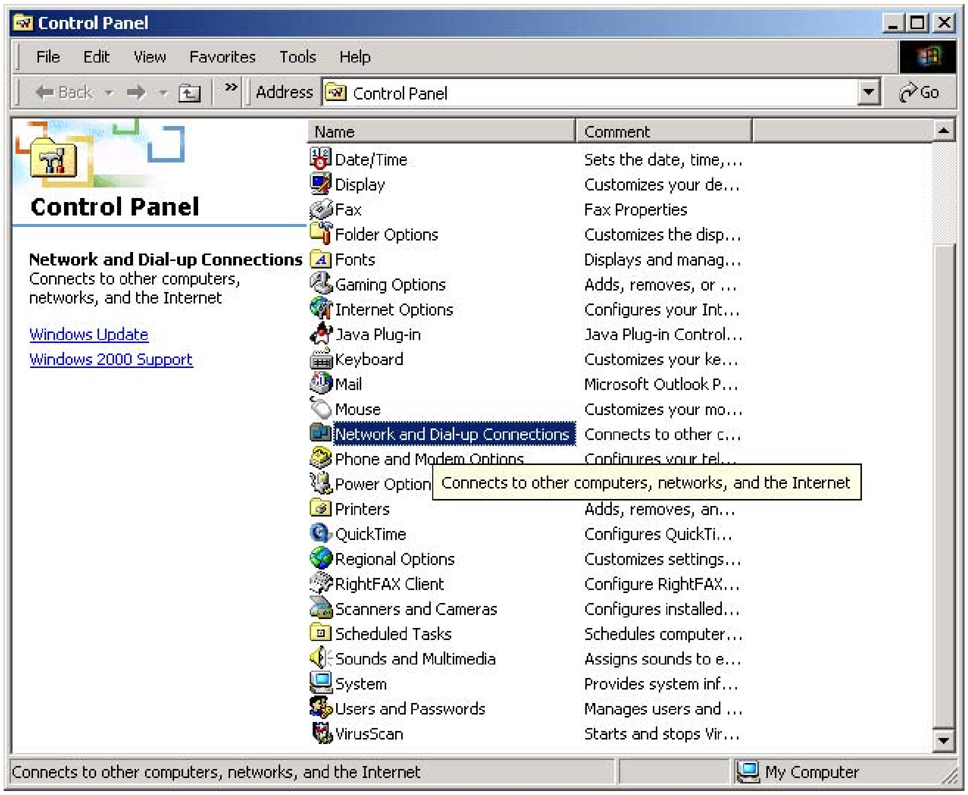
For Ethernet communications, all network devices must have similar but distinct IP addresses. From the factory, the Vertex-Pro’s MicroNet™ Plus control is preconfigured with fixed addresses on each of its two Ethernet ports on CPU. Likewise, the optional touch screen HMI comes addressed as 172.16.100.45 (ENET1) to permit immediate connectivity to the Vertex-Pro. Similarly, any connected computer running the Control Assistant software must be configured with an address of the same form. If desired, the other ports may be used if their IP addresses are modified as necessary.

Changing a Computer's IP Address

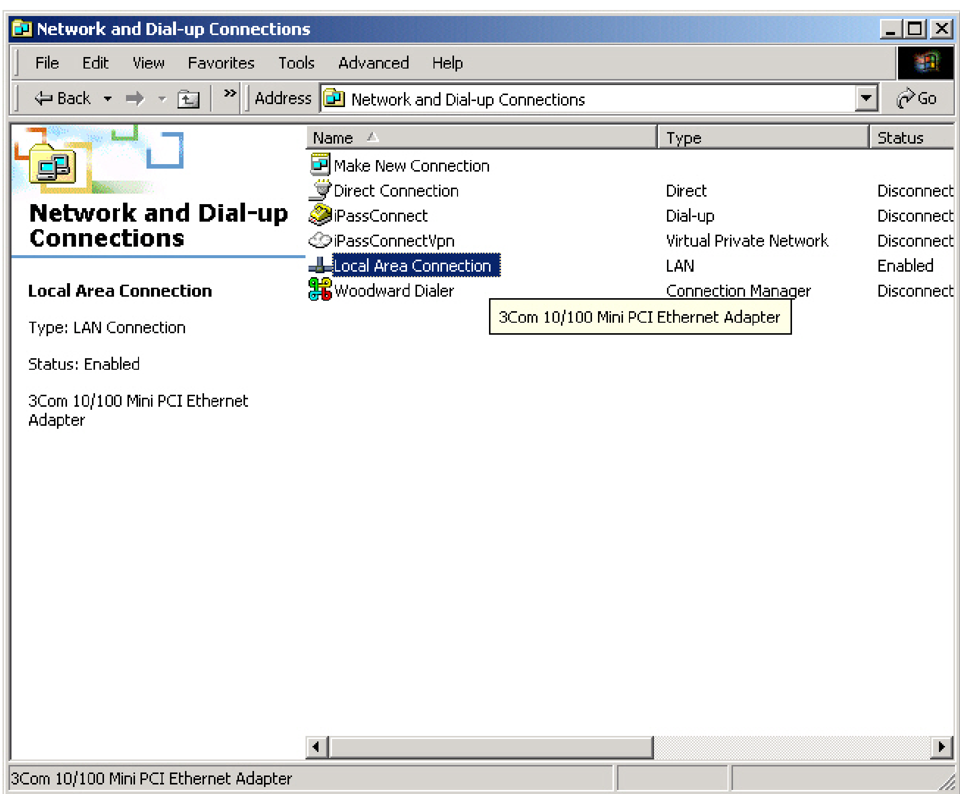
The Vertex-Pro is shipped with a Service Panel. User interface software is already installed in the Service Panel. When a user changes the IP address of control, it is necessary to unite the IP address with control. The IP address of the Service Panel must be changed to "match" that of the control for the two to communicate. Below are typical instructions for changing the IP address of the Service Panel which is a Microsoft Windows 2000/XP compatible computer.



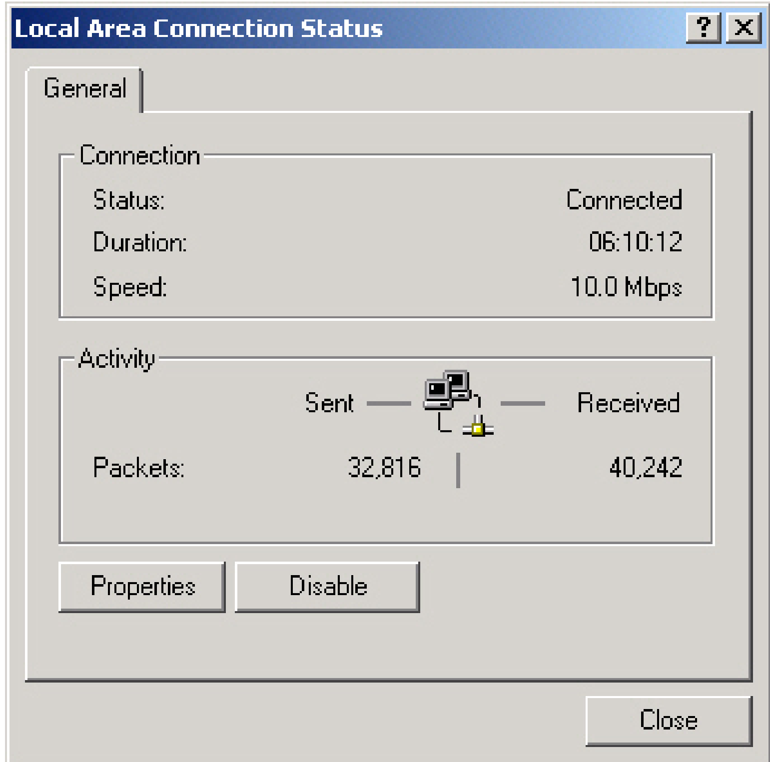
Select *Settings … Control Panel* from the *Start Menu*.



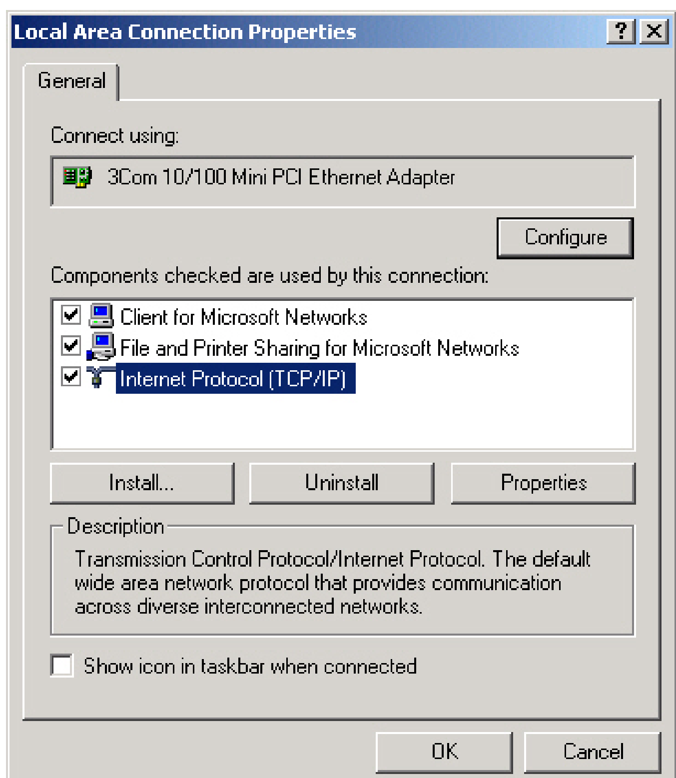
Select *Network and Dial-up Connections*.



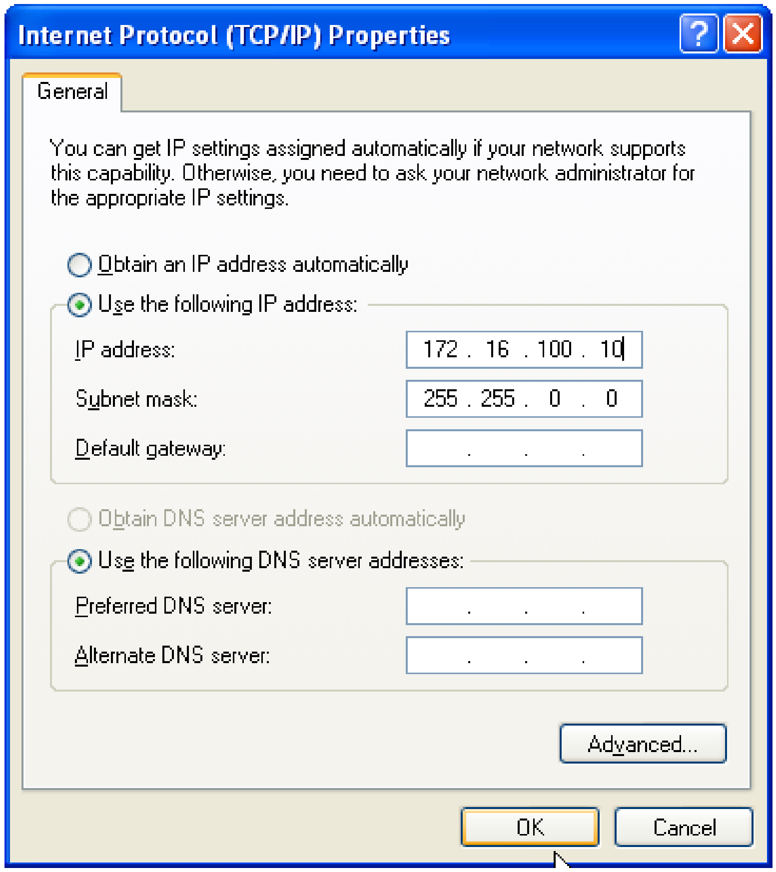
Select *Local Area Connection*.



Click the *Properties* button.



In the *Local Area Connection Properties* window, verify that *Internet Protocol (TCP/IP)* is checked and selected. Click the *Properties* button.



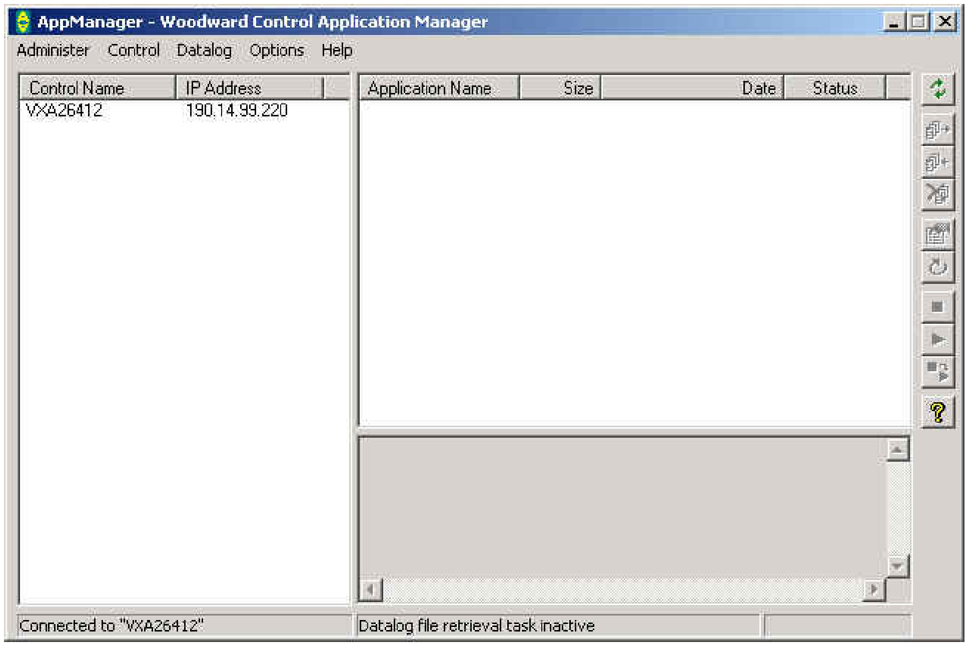
Click the *Use the following IP address:* radio button and enter an address in the correct format. The *Subnet Mask* will default to 255.255.0.0, which means that the first two numbers in the devices' addresses must match to facilitate proper communications. For example, to match the default IP address of the Vertex-Pro's port #1, enter an address for the computer in the form 172.16.XXX.XXX. Click *OK*. The computer may require rebooting.

Changing the Control's IP Address

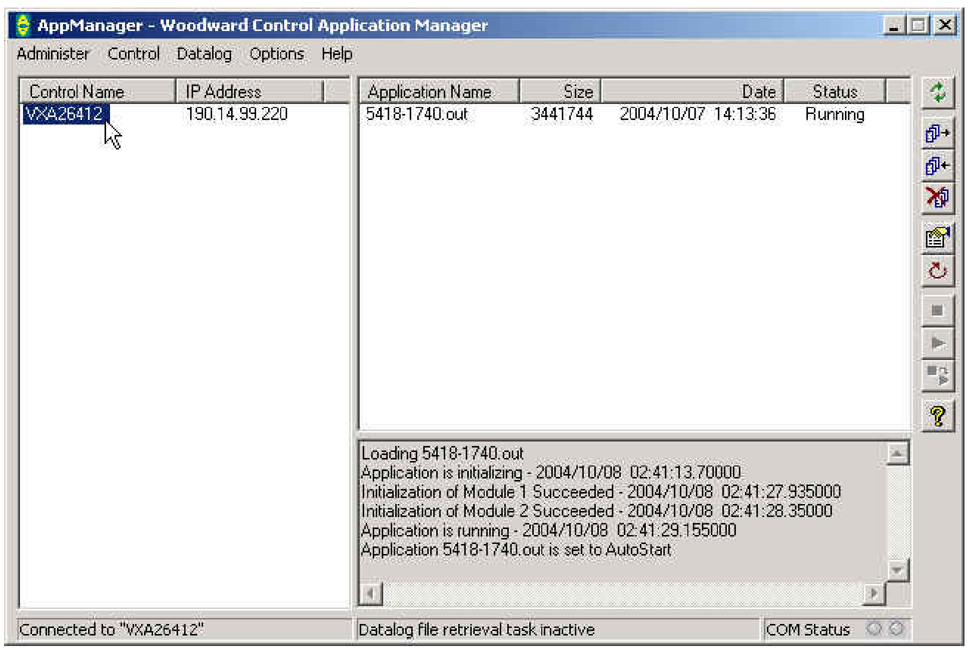
On the other hand, if the control will operate on an existing network, it may be necessary to change the IP addresses of the control and HMI, if utilized.

NOTICE	**To change the Vertex-Pro's IP address, the application software must be stopped. Therefore, this procedure can only be performed when the motor/compressor is shut down.**

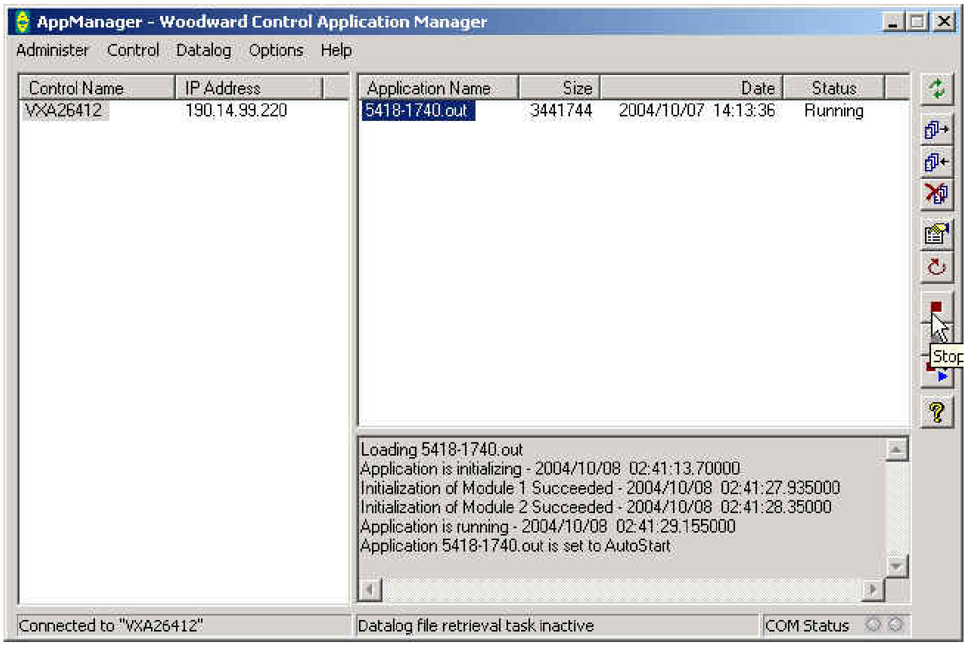
To change the control's IP address, use the provided Application Manager (AppManager) software from a laptop or other connected computer. When AppManager is launched, it will search for all connected controls, whether one connected directly by an Ethernet cable or several on an Ethernet LAN. All connected controls will be displayed by name and IP address in the left pane of the AppManager window.

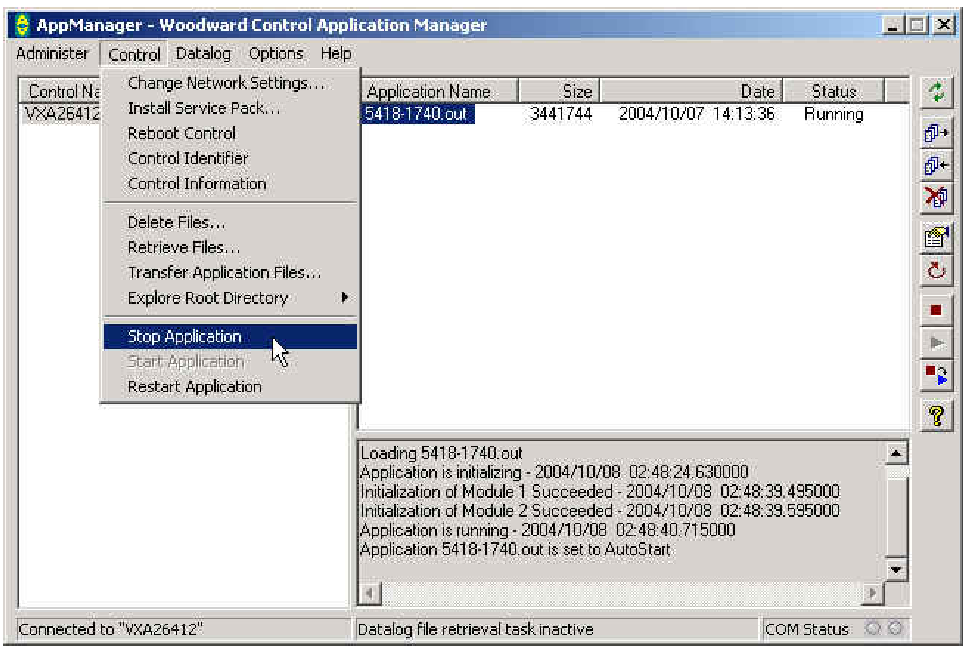


Select the control name to highlight it. The name, size, date, and status of the application software will appear in the pane to the right.



To allow changing the IP address, the application software must be stopped. Select the application name, *XXXX-XXXX.out*, in the right pane of the AppManager window. Then, click the Stop button in the toolbar, or select *Stop Application* from the *Control* menu.

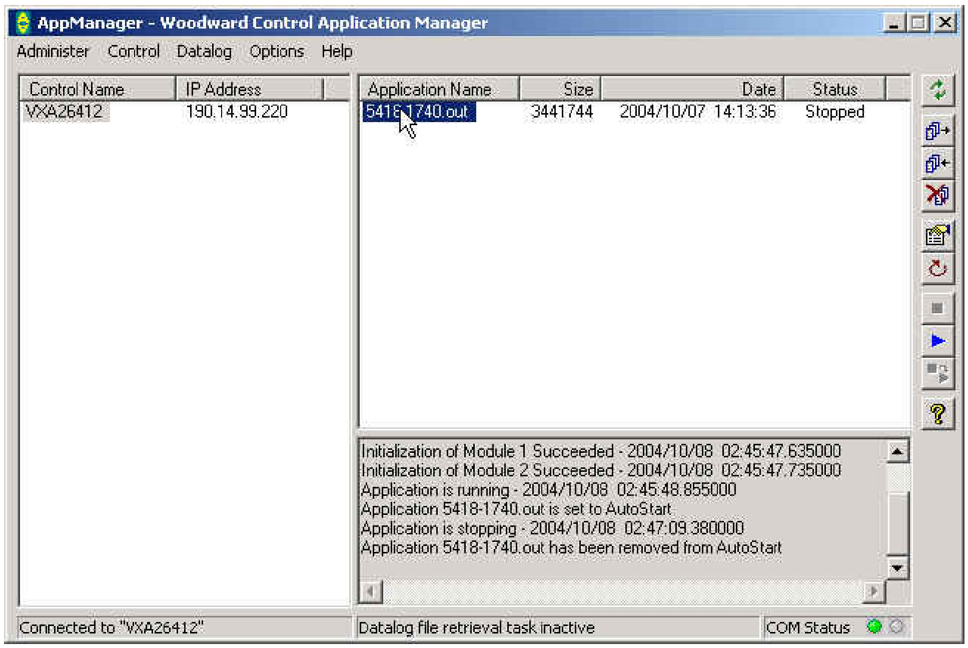




AppManager will request confirmation before stopping a running application.

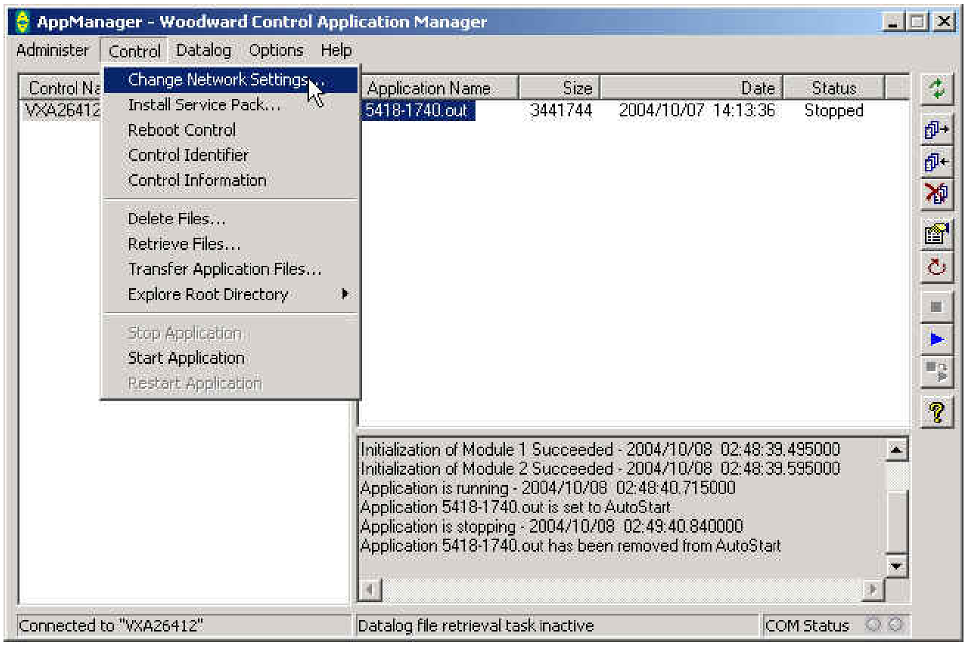
Select *Yes* and, if prompted, enter *ServiceUser* as the *Connect As:* and *Password:*.

Once the application is stopped, it will be indicated as such in the *Status* column in the right pane of the AppManager window.

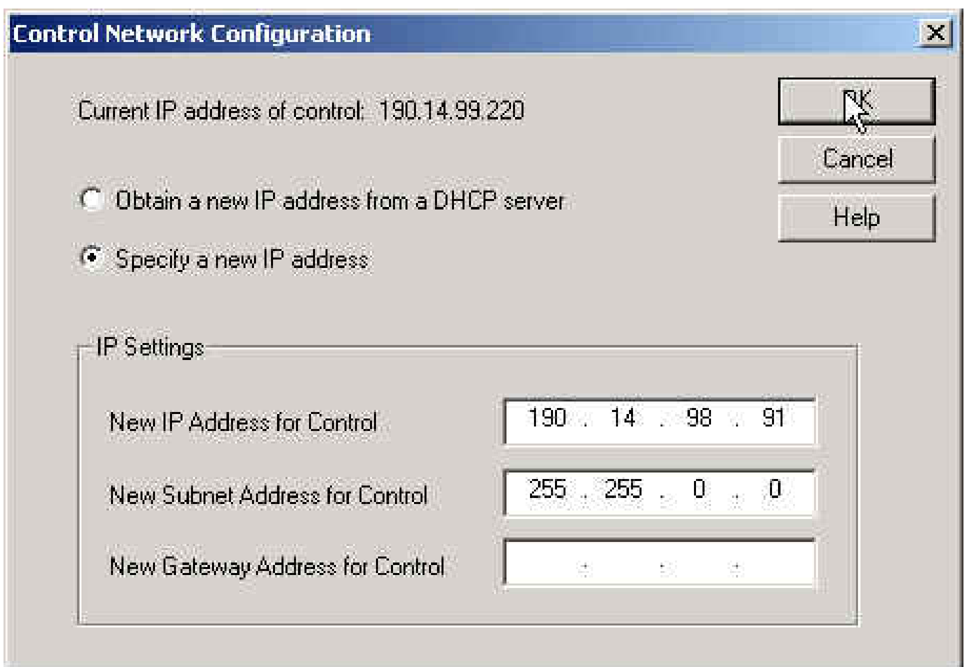


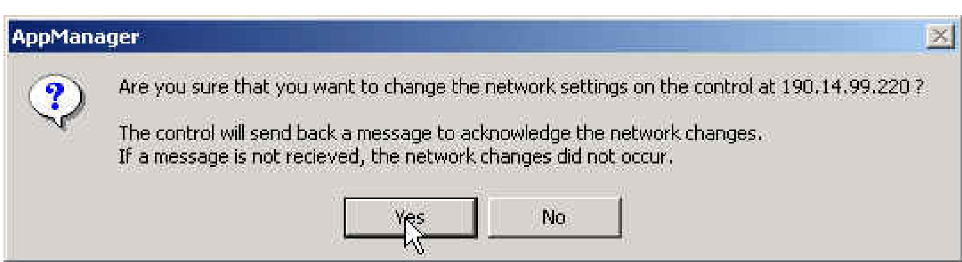
The IP address can now be changed by selecting *Change Network Settings* from the *Control* menu.

NOTICE	**If no control is selected when *Change Network Settings* is initiated, AppManager will prompt for the IP address of the control that is to be readdressed. If a valid address is entered, the readdressing process will continue as described below, but on its own, AppManager will stop the application software, if running. It is always preferred to manually stop the application as described above, thereby ensuring that the unit has been properly secured.**



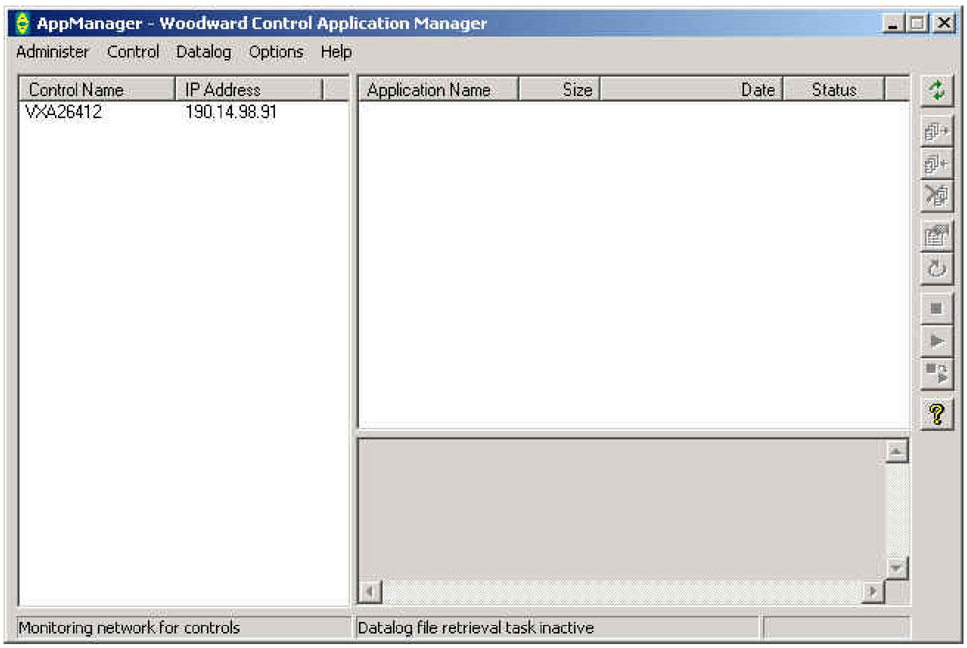
AppManager will prompt for a new IP address. If installed on an Ethernet LAN, a DHCP server can assign the address, or one may be specified directly. Select *OK*. Then, select *Yes* at the confirmation prompt to proceed with the change.



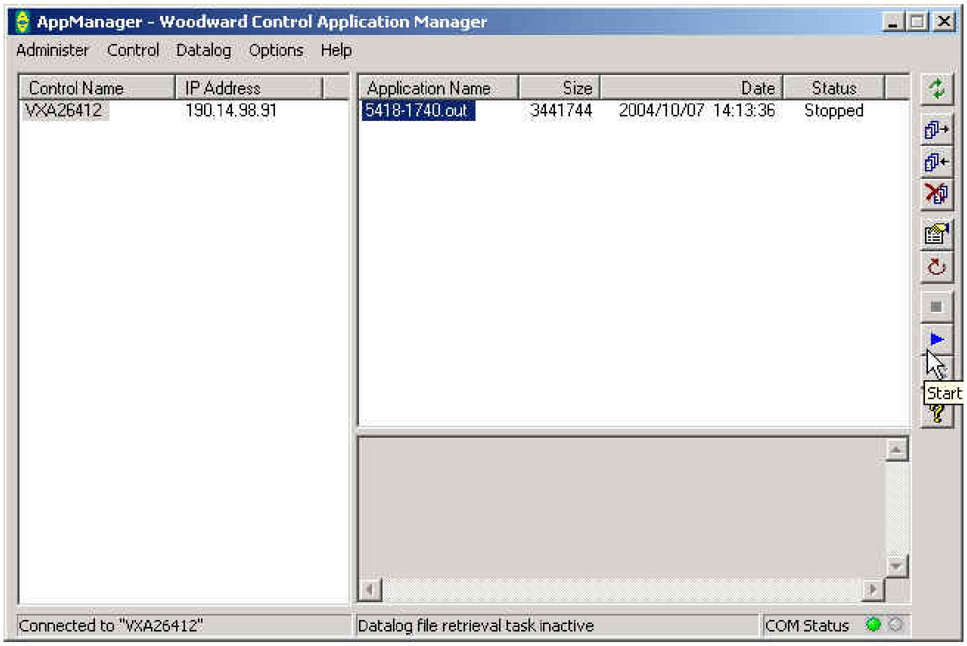


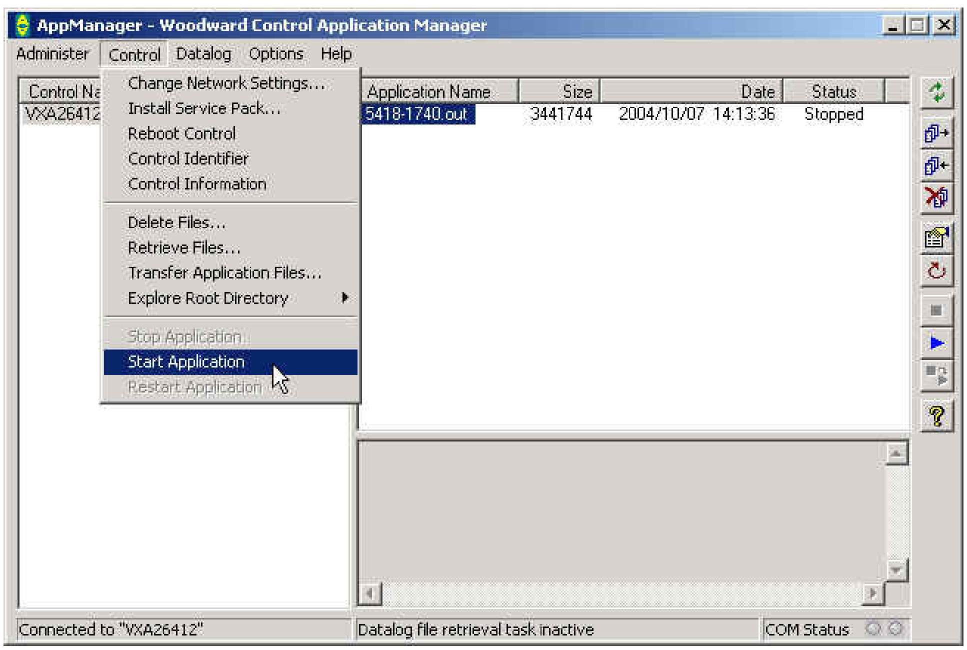
IMPORTANT	**Depending upon the version of AppManager being used, the confirmation pop-up may indicate that AppManager will display a confirmation message after successfully readdressing the control. This confirmation of completion may or may not be displayed, depending upon the versions of the control and AppManager in use. If the confirmation message does not appear, it does not necessarily mean that the readdressing failed.**

After the IP address is changed, the control will reboot and will eventually be displayed again in the AppManager control list. This process typically takes 45~60 seconds. Success of the address change can be confirmed by verifying the newly displayed IP address in AppManager's control list.

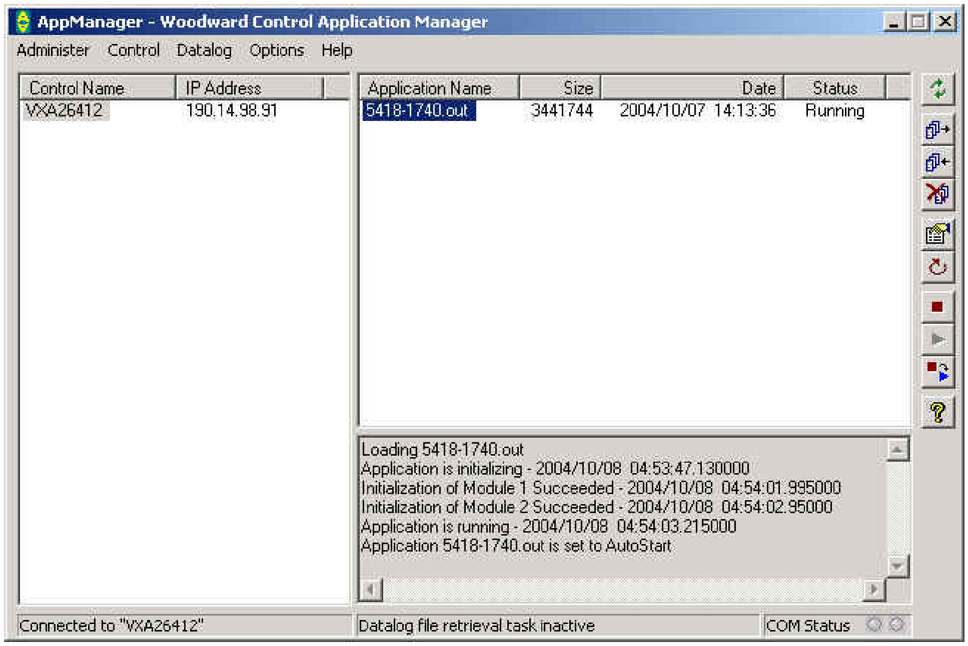


The application software must now be restarted. As before, select the control name to highlight it. Then, select the application name, *XXXX-XXXX.out*, in the right pane. Click the Start button in the toolbar, or select *Start Application* from the *Control* menu.





The application will initialize, as indicated in the *Status* column and by messages displayed in the lower right box of the AppManager window. Once complete, the *Status* column should display *Running*.



Changing the HMI's IP Address

The HMI computer is like any other Microsoft Windows computer, and its IP address can be changed as described in the earlier section, *Changing a Computer's IP Address*. Attach a standard keyboard and mouse to the HMI computer for ease of use.

Chapter 2.
System Overview

Introduction

The Vertex-Pro anti-surge control is designed for industrialized axial or centrifugal compressors with 1 to 4 recycle loops. Standard off-the-shelf models are available and field configurable for 1 and 2 recycle loop applications. .Custom models are available for 3 and 4 recycle loop applications. This controller includes specifically designed algorithms and logic to start, stop, control, and protect industrial compressors driven by stationary speed motors or variable-frequency drive motors. OEM-qualified algorithms are used within the Vertex-Pro for straight-through, iso-cooled, double-flow, single side-stream, and back-to-back compressor applications.

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

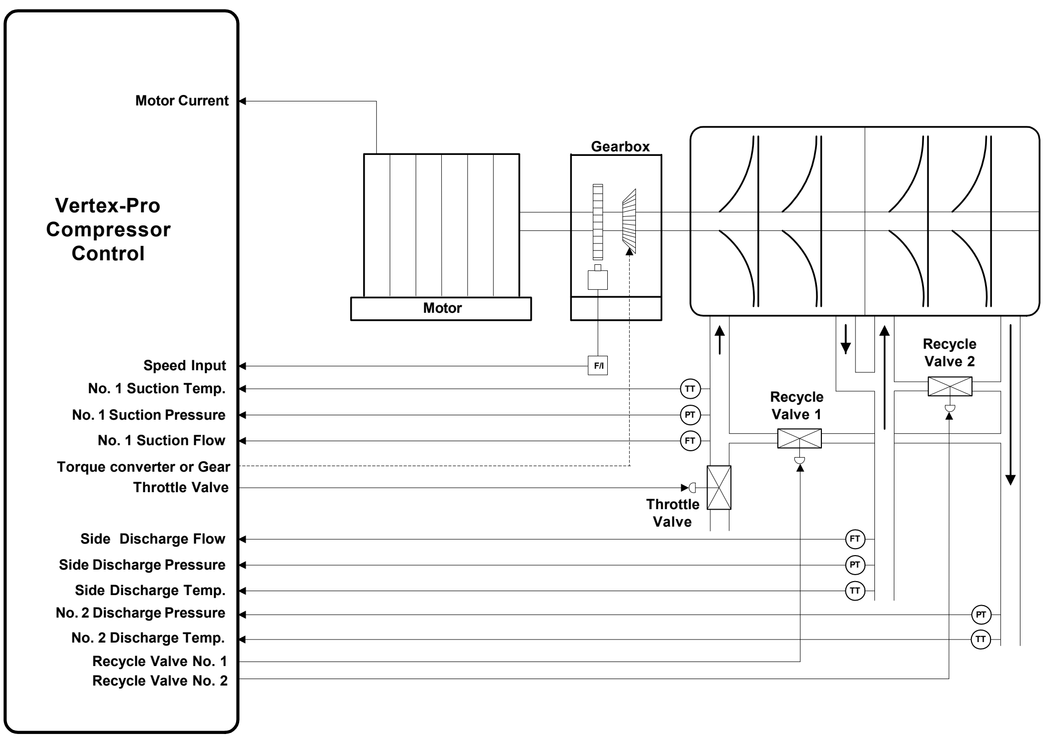


Figure 2-1. Typical Compressor Application

The Vertex-Pro controller includes the following PID control & protection functions:

- Anti-Surge PID Control
- Rate PID Control
- Boost (open-loop backup line response)
- Surge Recovery
- Surge Minimum Position
- Start, Purge, Stop, Shutdown, & Zero Speed Sequencing Positions
- Alarm & Shutdown Logic

Alternatively, the following functions can be configured, depending on the application requirements:

Motor

- Current limit PID Control
- Start Sequence Logic

Compressor

- Throttle or Inlet Guide Vane Ramp Loading (motor protection)
- Performance Control (compressor suction or discharge pressure, flow, or external signal)
- Load Sharing (parallel compressors up to three trains)

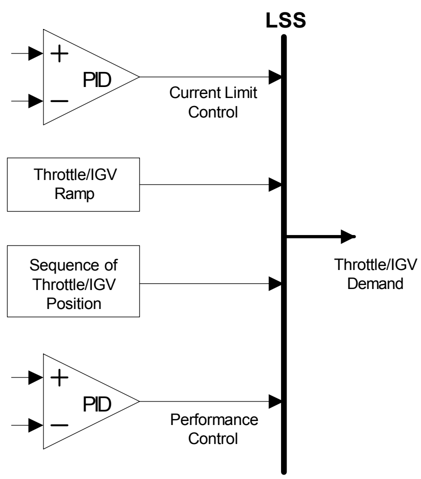


Figure 2-2. Throttle/IGV Control Logic

Motor Start-up/Shutdown

The Vertex-Pro provides three selectable start-up modes: Manual, Semi-Auto, and Sequence. In the manual mode, the throttle valve or inlet guide vane (IGV) is opened by an operator manually raising/positioning the Vertex-Pro's valve demand signal. In the semi-automatic mode, the valve/vanes are automatically opened to the user-defined position at a user-defined rate. In the sequence mode, the Vertex-Pro automatically controls valve position based on a defined sequence in order to prevent a motor over current condition.

Motor Current Limit Control

When configured, this control function senses motor current and limits compressor load to protect against motor overload conditions.

Performance Control

When configured, this control function is used to control compressor suction pressure, compressor discharge pressure, compressor flow, or any process variable related to compressor flow or load. This control function compares an analog input signal to an internal setpoint and, depending on the programmed configuration, positions the compressor throttle valve, inlet guide vanes, torque converter, and/or motor speed (VFD) to accomplish the desired control.

Load Sharing Control

When configured, this control function is used to share compressor load with up to two other identical compressors in parallel. When connected to one or two other Vertex-Pro controllers operating identical compressors in parallel, these paralleled controllers work together to maintain overall suction/discharge header pressure while controlling each compressor equidistant from their surge control lines.

Anti-Surge Control

The anti-surge PID uses compressor pressure, temperature, and flow signals to calculate each compressor stage's operating point, then compares this value to the specific surge map and surge control line to position the respective recycle valve, and keep the compressor away from surge.

Surge Protection & Recovery Functions

Quick-acting Rate and Boost functions are also available to open the recycle valve and protect the compressor should a transient process condition step the compressor towards surge. A Pre-Pack feature is also configurable to improve system response times by compensating for lag times associated with long recycle piping runs. If a surge event occurs in spite of all performed corrective actions, Surge Recovery and Surge Minimum Position functions take over to protect the unit until process stability is achieved.

Chapter 3. Compressor Control Description

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.

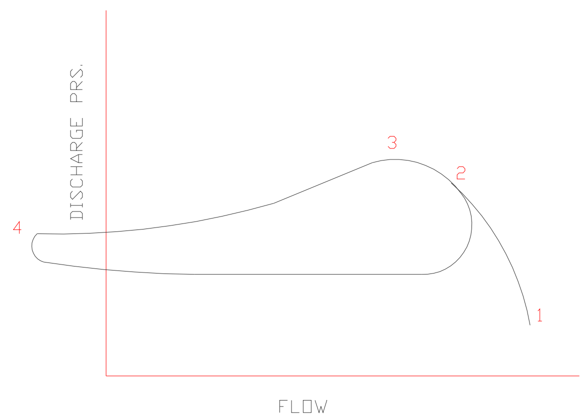


Figure 3-1. Surge Cycle

The illustration above 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.

Functional Overview

An overview of the Vertex-Pro anti-surge and capacity control functions is shown in Figures 2-2 and 3-3. Use this diagram to match the Vertex-Pro's control features to the site-specific application.

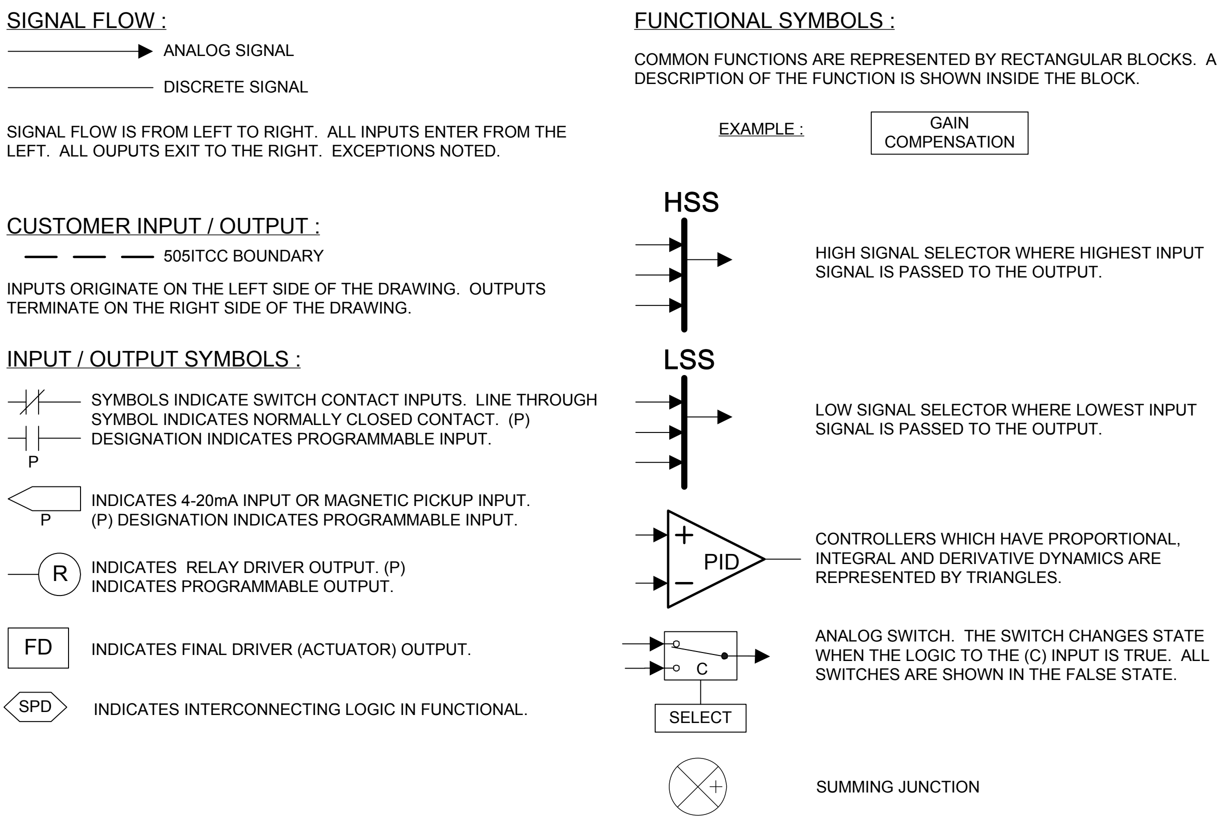


Figure 3-2. Overview of Vertex-Pro Functionality Notes

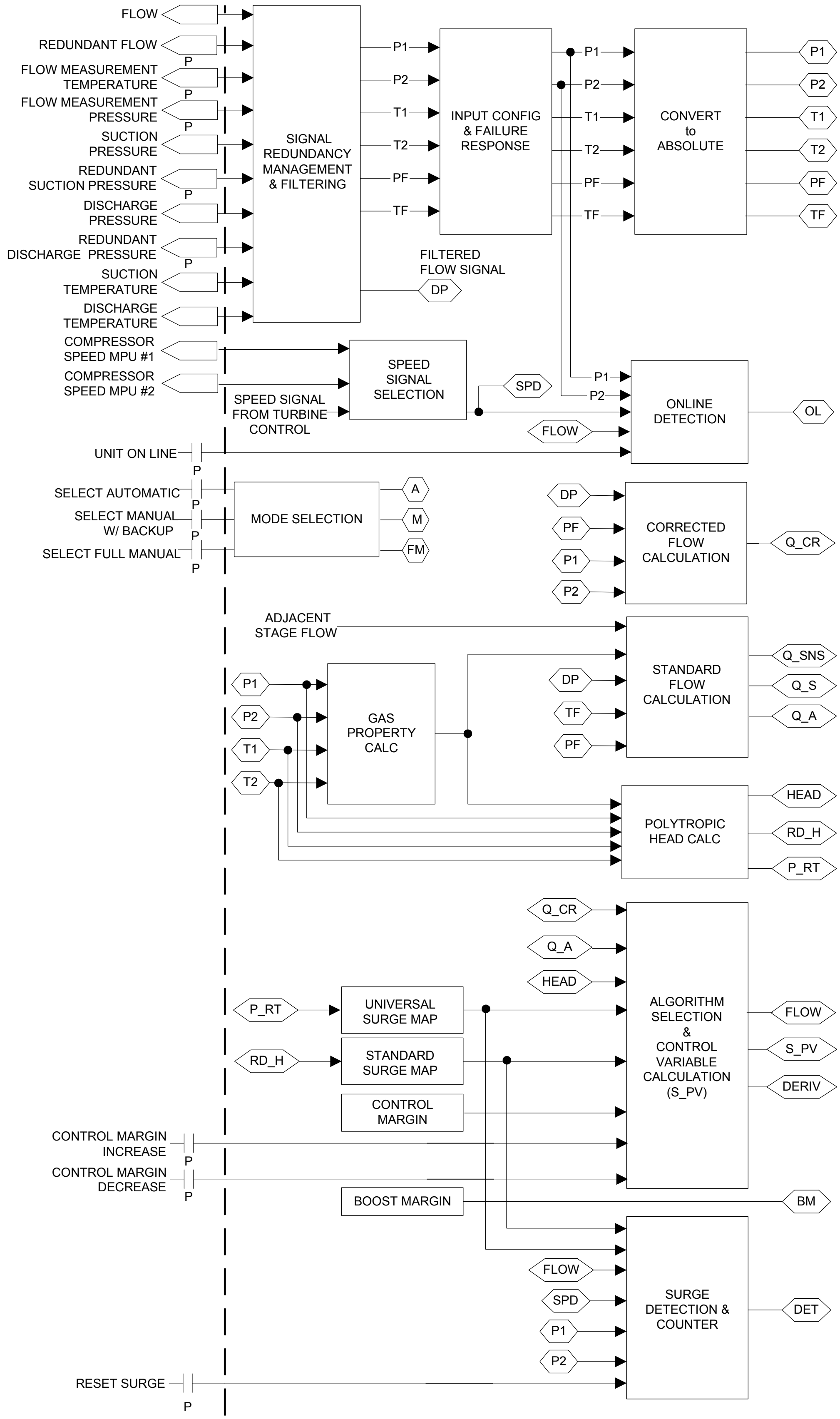


Figure 3-3a. Overview of Vertex-Pro Anti-Surge Control Functionality

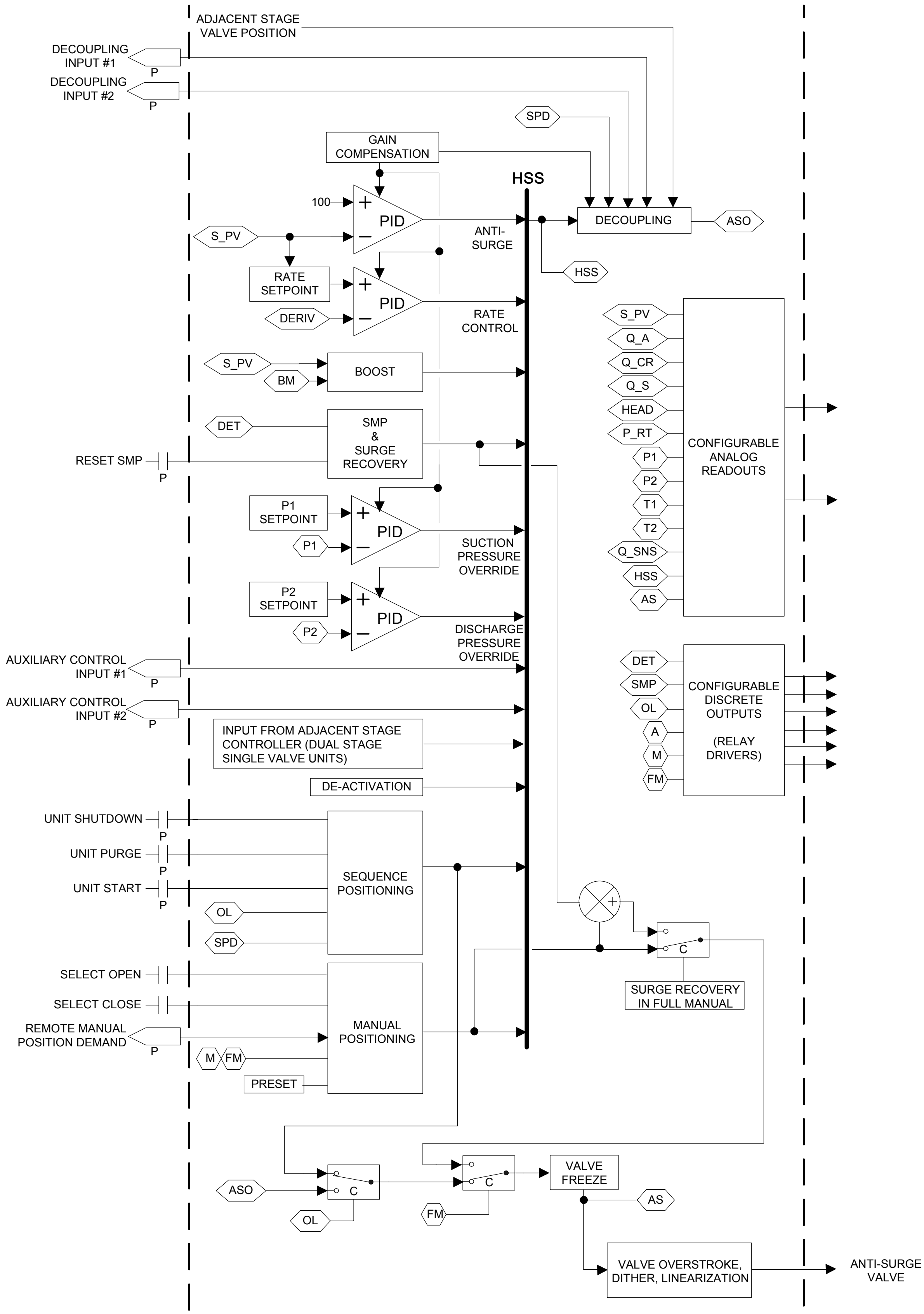


Figure 3-3b. Overview of Vertex-Pro Anti-Surge Control Functionality

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 Vertex-Pro accommodates two such compressor map definitions, Standard and Universal.

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 3-4). Depending upon the compressor configuration and instrumentation, changes in molecular weight, temperature, and compressibility are compensated for accurate representation of the compressor operation.

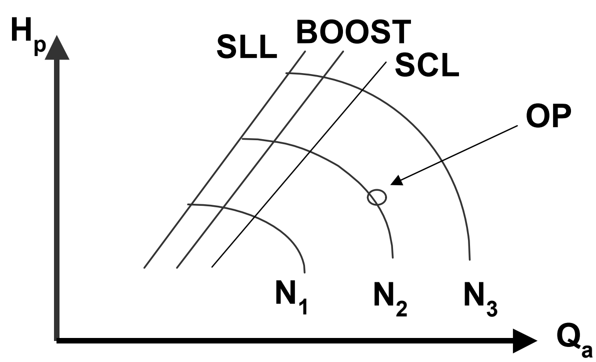


Figure 3-4. Standard Compressor Map

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 3-4). The operating point is also defined using these parameters. Simply, the operating point is defined as volumetric inlet flow squared divided by polytropic head.

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

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 3-5.

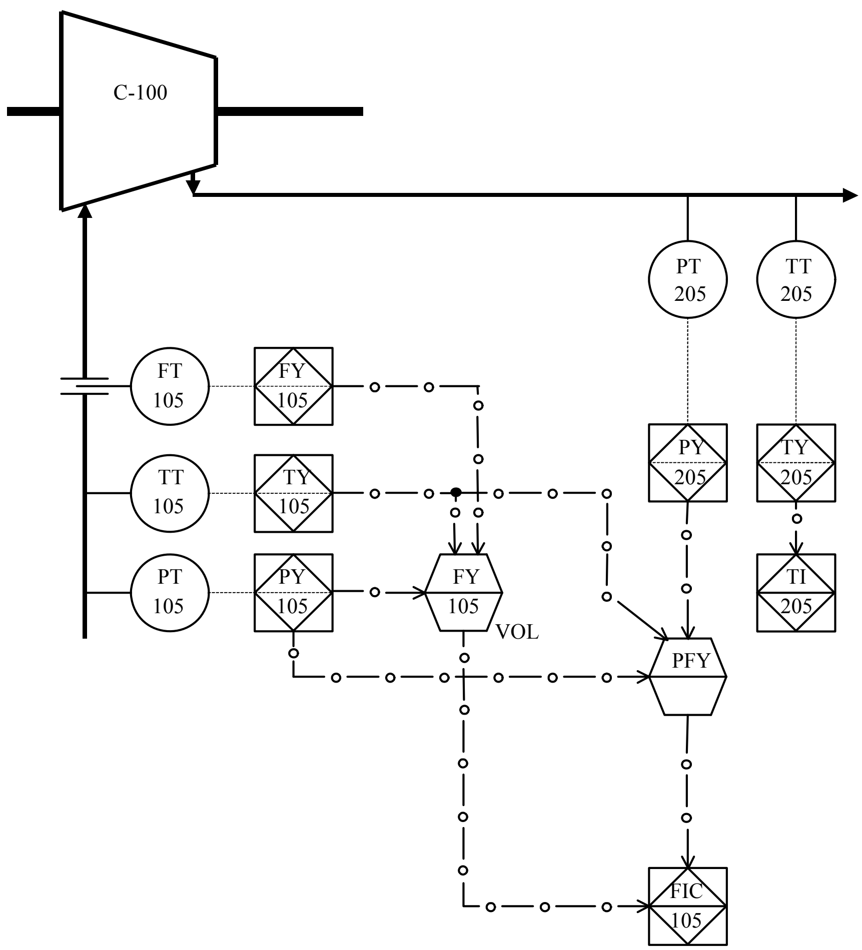


Figure 3-5. Process Control Diagram

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.

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 3-4) 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 operating points (five head-flow pairs). Occasionally, however, the given compressor map is not described in units of polytropic head and actual flow. In this case, the manufacturer's map must be converted to polytropic head and actual flow to enter the map into the control (The Vertex-Pro Configuration Tool software will assist in this task). Additionally, surge limits are commonly 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 five pairs are different and entered successively lowest to highest. Compressors typically have higher flow requirements with higher head values.

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.

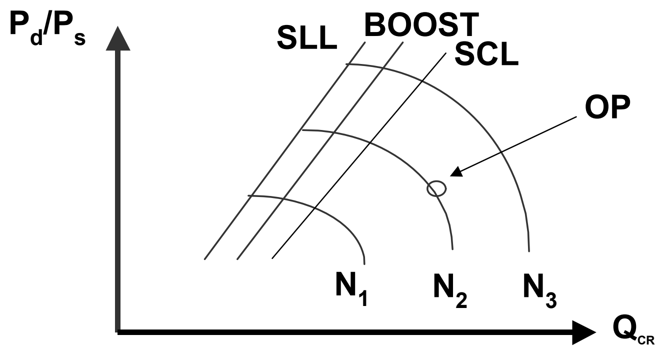


Figure 3-6. Universal Compressor Map

Universal Operating Point

The Universal Compressor Map is in terms of pressure ratio, Pd/Ps, versus corrected inlet flow, Q_{CR} (Figure 3-6). 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 3-7.

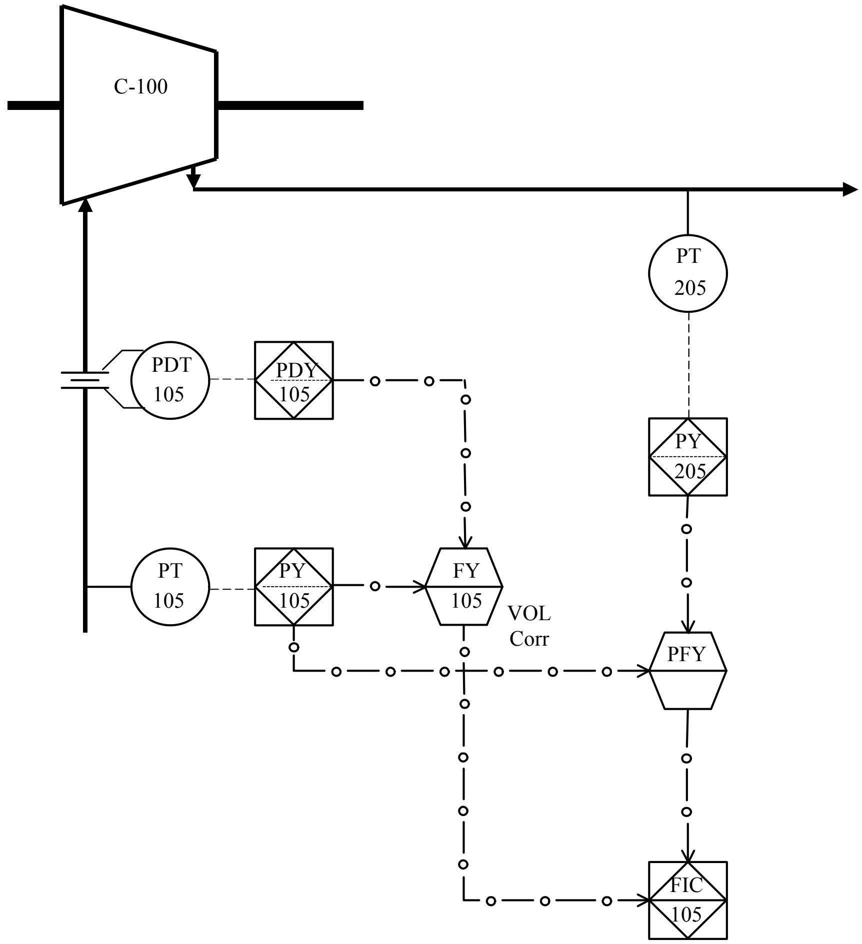


Figure 3-7. Process Control Diagram

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.

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 (Figure 3-6). 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.

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 Appendix A and the Vertex-Pro Configuration—Comp General section in Chapter 4 for supported compressor configurations.

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.

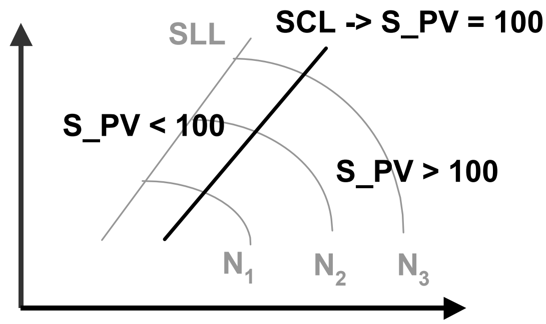


Figure 3-8. Compressor Map S_PV Regions

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.

Vertex-Pro 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.

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).

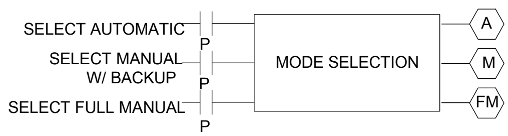


Figure 3-9. Mode Select

Automatic

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.

Manual with Backup

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.

Full Manual

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.

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.

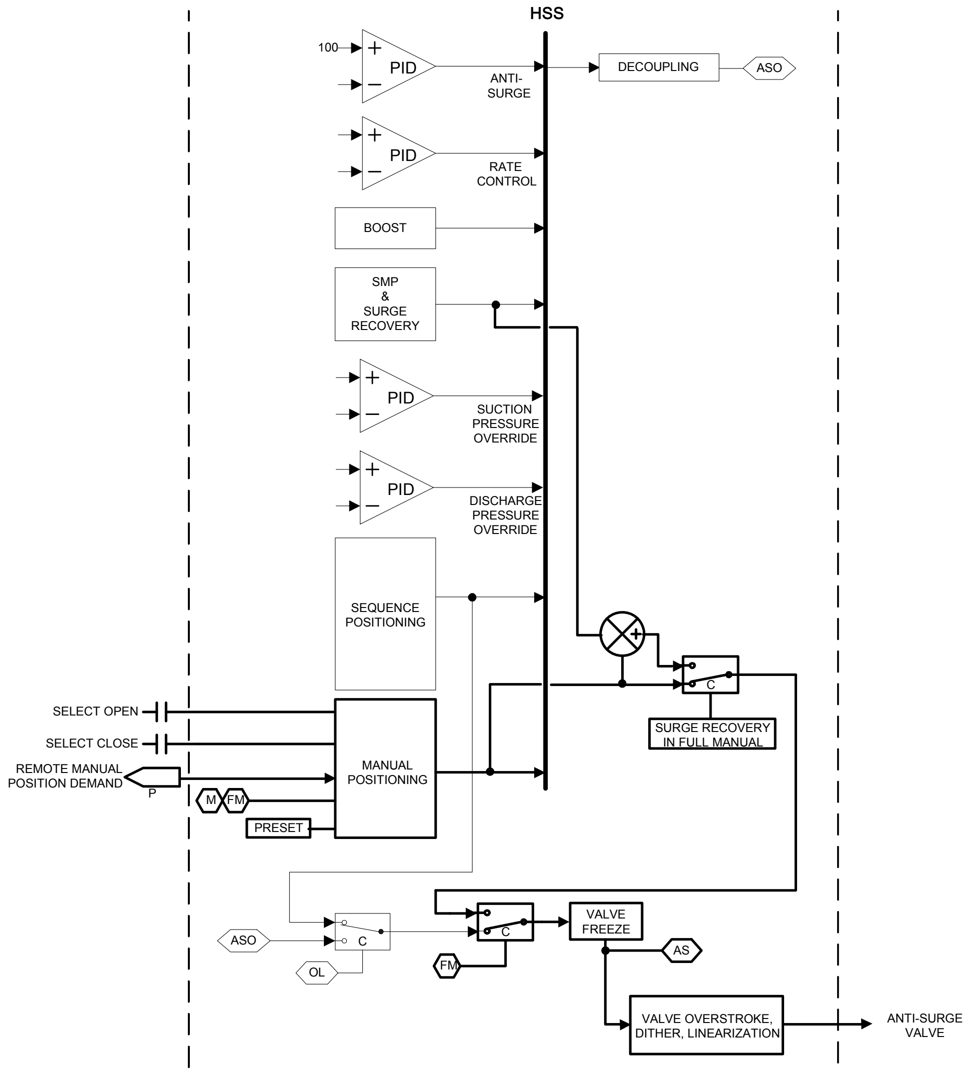


Figure 3-10. Manual Setting of Anti-surge Valve

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.

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.

Sequencing

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.

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.

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.

ON-LINE: 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.

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.

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.**

On-Line Detection

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.

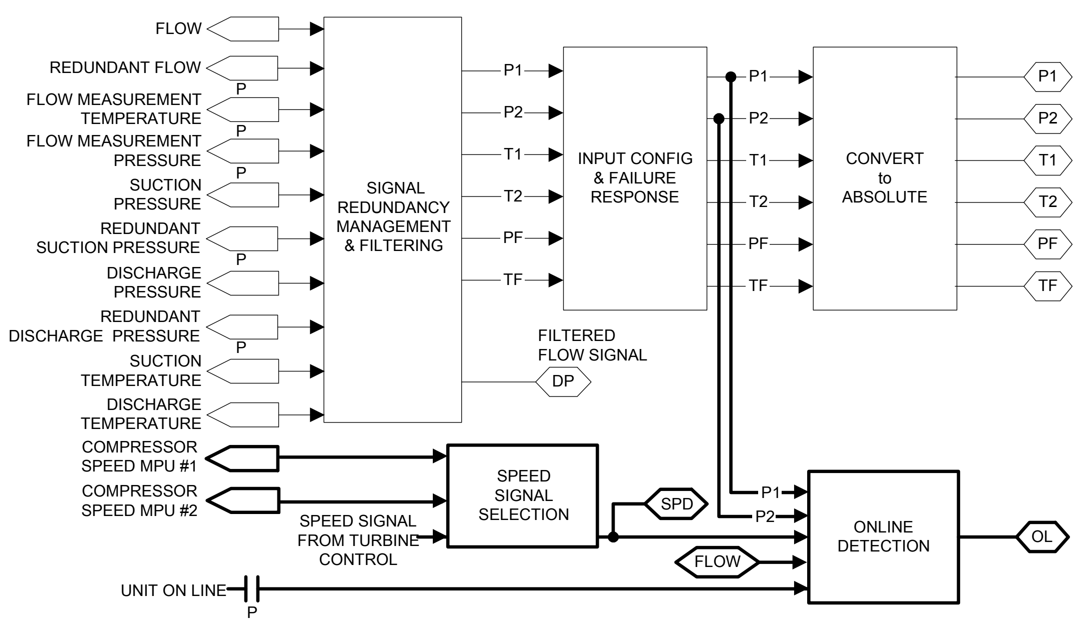


Figure 3-11. On-Line Detection

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—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 Vertex-Pro 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.**

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 (Figure 3-12).

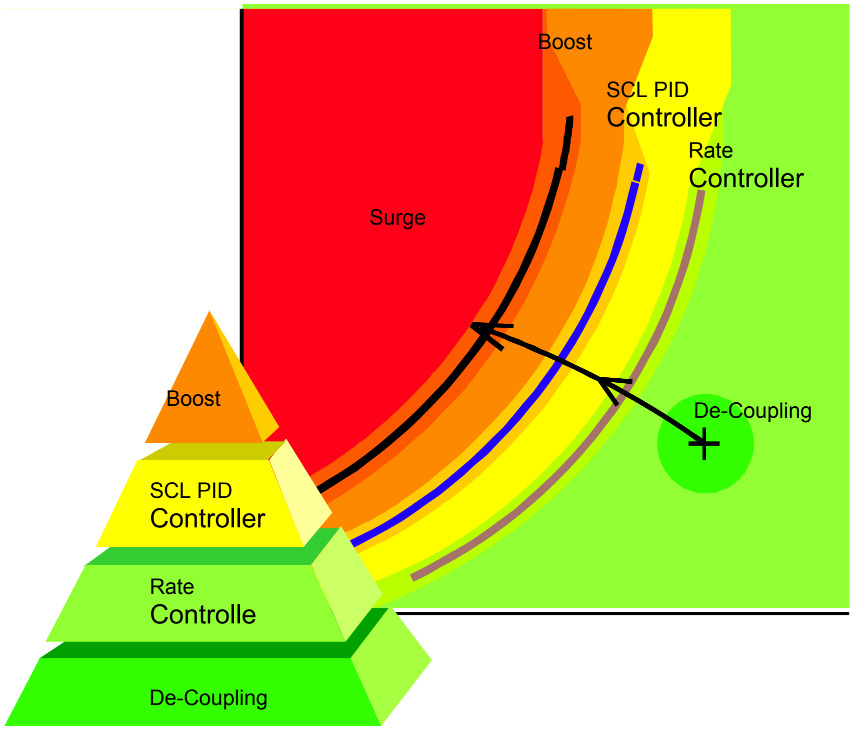


Figure 3-12. Anti-Surge Functions

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.

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

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 the 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

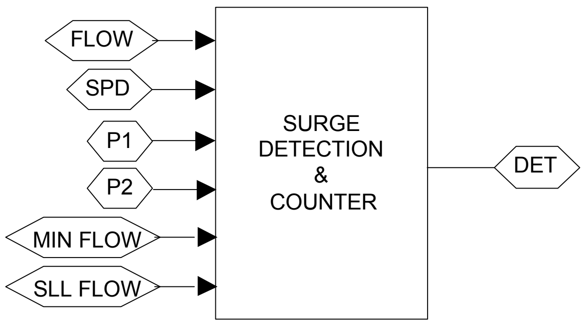


Figure 3-13. Surge Detection and Counter

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, do not actually detect a surge. They merely initiate a surge response if the calculated flow reaches the respective set-point.

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.

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.

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 3-14). 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. Surge Recovery is inhibited when the unit is not on-line.

Surge Minimum Position (SMP)

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.

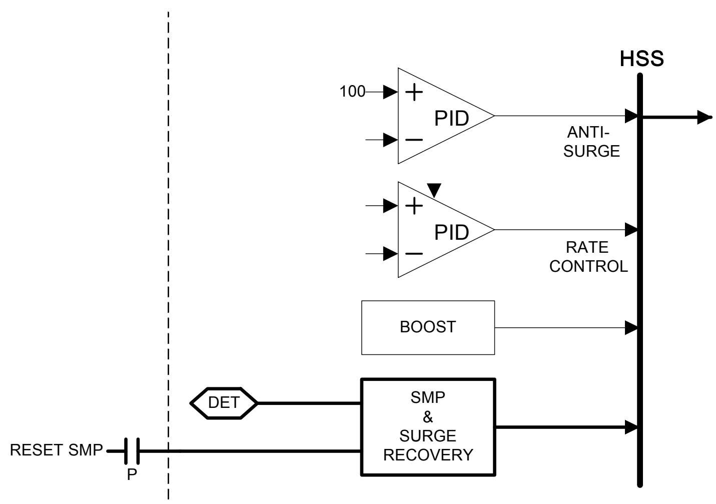


Figure 3-14. Surge Recovery and Surge Minimum Position (SMP)

For example, in Figure 3-15, 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.

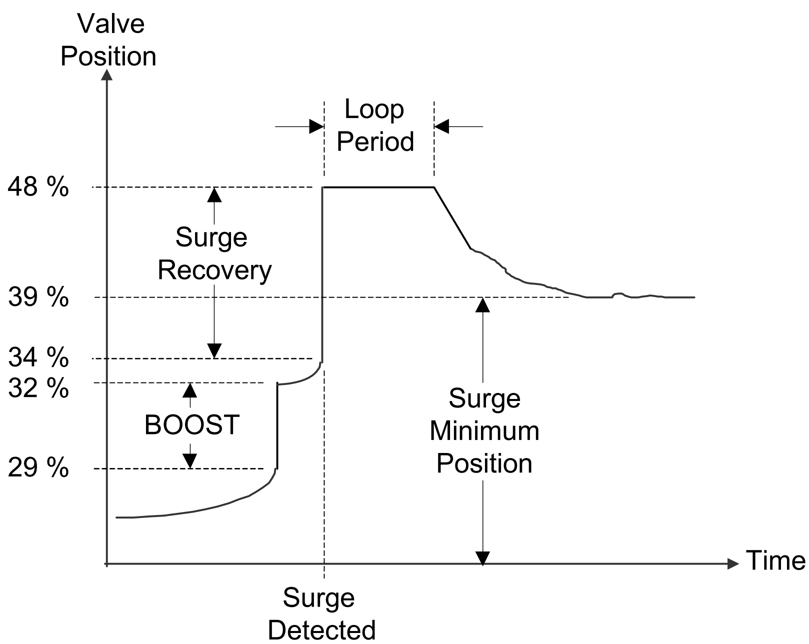


Figure 3-15. Anti-surge Valve Response to a Surge

Boost / Valve Step Opening

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, or Valve Step Opening 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 / Valve Step 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.

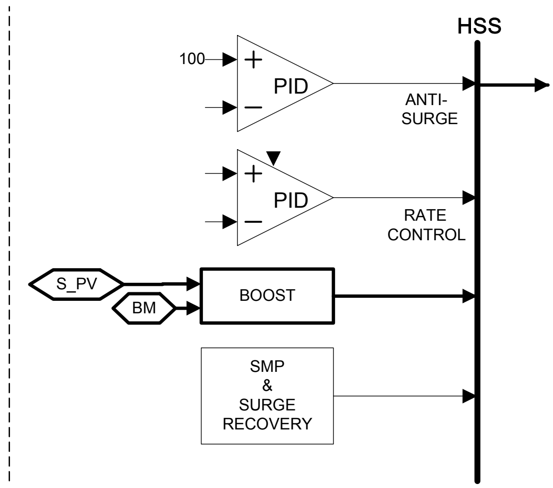


Figure 3-16. BOOST / Valve Step Opening

The BOOST action will open the anti-surge valve a configured amount above it's 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. 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.

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.

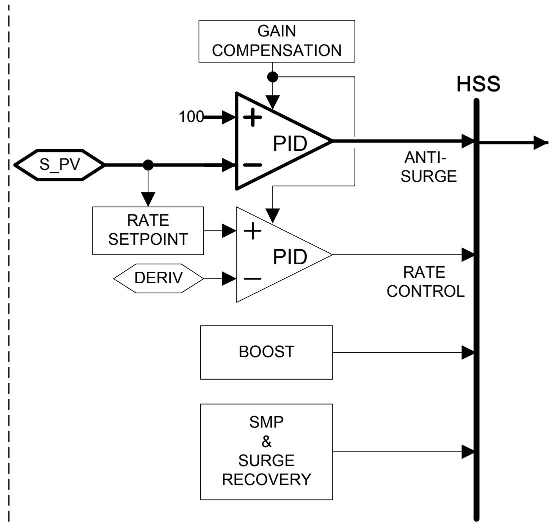


Figure 3-17. Anti-Surge PID

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.

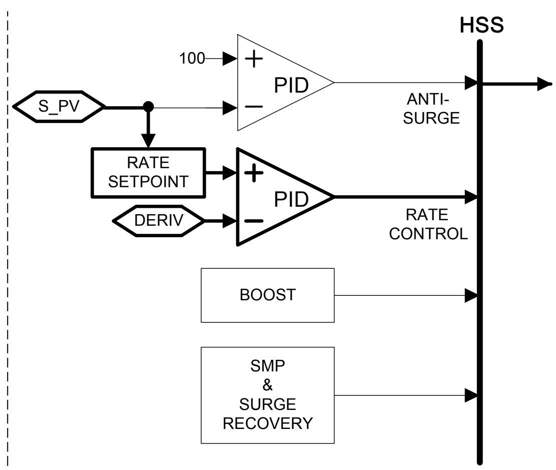


Figure 3-18. Rate Controller PID

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 key to determining the best settings.

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. See the Dynamics Adjustments section in Chapter 4 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.

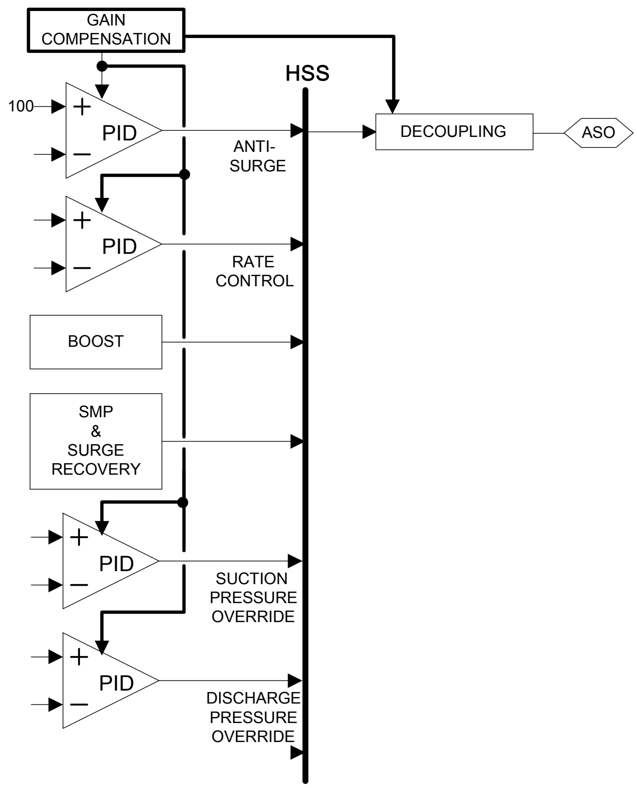


Figure 3-19. Automatic Gain Compensation

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.**

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.

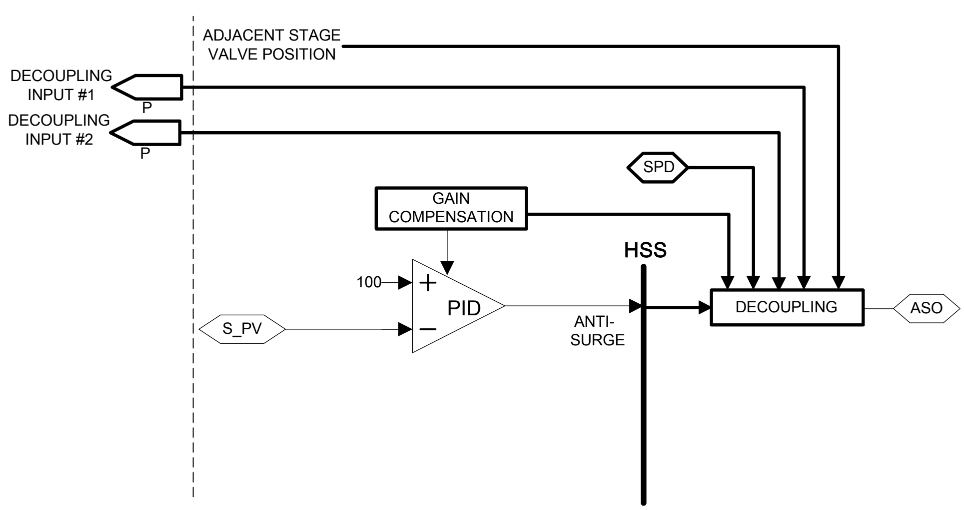


Figure 3-20. Anti-Surge Decoupling

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 modes described above are 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 3-21 for examples of Another Stage Decoupling values based upon piping arrangement.

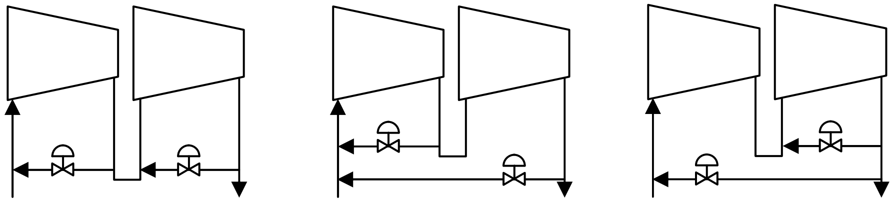


Figure 3-21. Effect of Valve Layout on Adjacent Stage Decoupling Amounts

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.

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 Vertex-Pro 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 Vertex-Pro are still active. The HSS will select the highest valve position regardless of its control source.

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.

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.

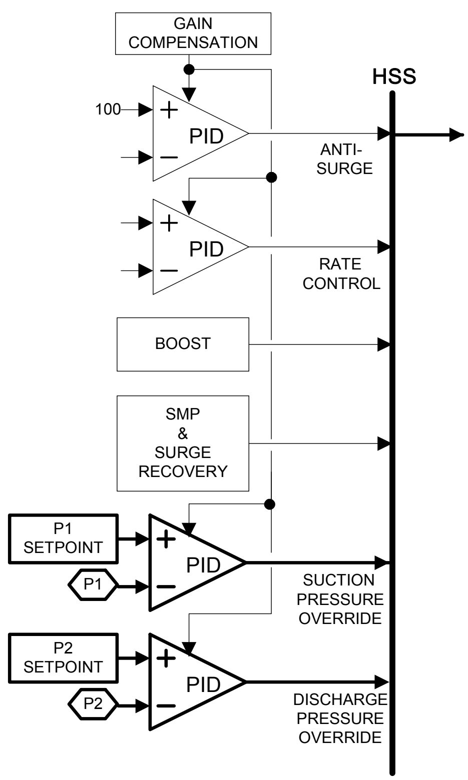


Figure 3-22. Pressure Override Control

Auxiliary Control

One or two custom controllers may be added to the High Signal Select (HSS) bus within the Vertex-Pro. 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.

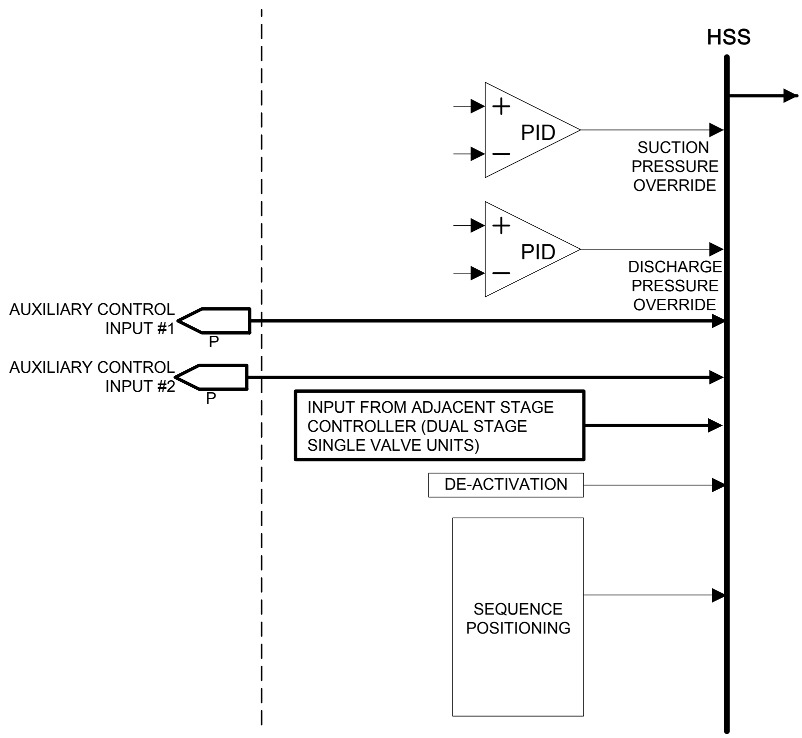


Figure 3-23. Auxiliary Control Variables

Support Functions

In addition to anti-surge control routines, there are support functions that enhance the Vertex-Pro’s 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 datalogging function is provided.

Signal Redundancy

While the Vertex-Pro 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, sidestream 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 sidestream. 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.

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.

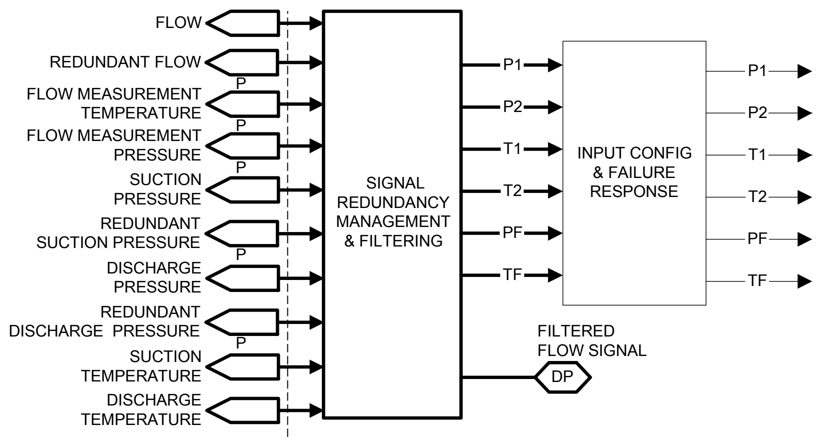


Figure 3-24. Analog 4–20 mA Input Signal Filtering and Failure Monitoring

Surge Control Line Shifting / Control Margin Bias

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 Vertex-Pro 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.

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.

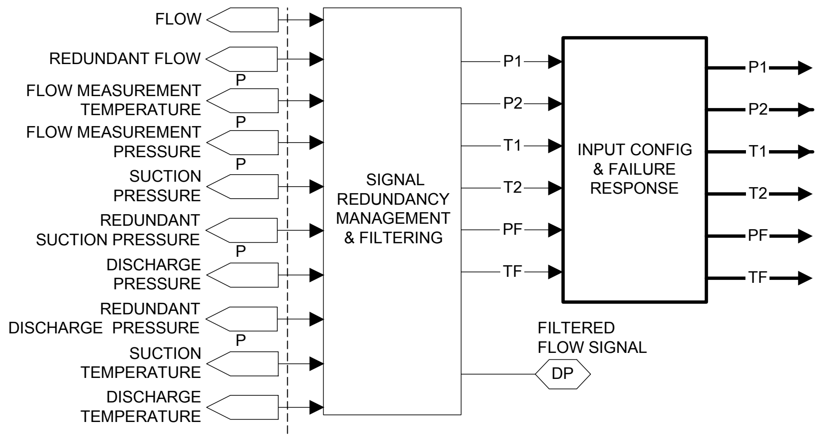


Figure 3-25. Input Signal Configure and Failure Response

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 the chart in Figure 3-26, 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 3-1. Input Signal Failure Response Sequences

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.

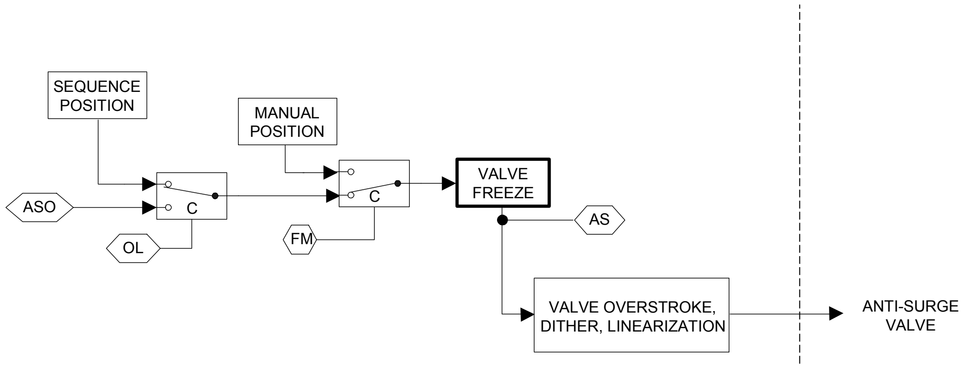


Figure 3-26. Valve Position Freeze Routine

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).

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.

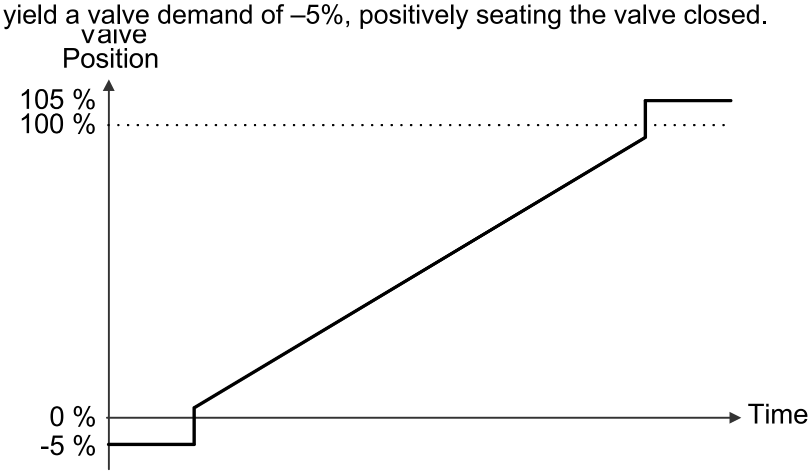


Figure 3-27. Valve Overstroke

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, and can be detrimental to good control, especially in high gain systems requiring fine valve control. For applications susceptible to this condition, the Vertex-Pro 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 3-28 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.

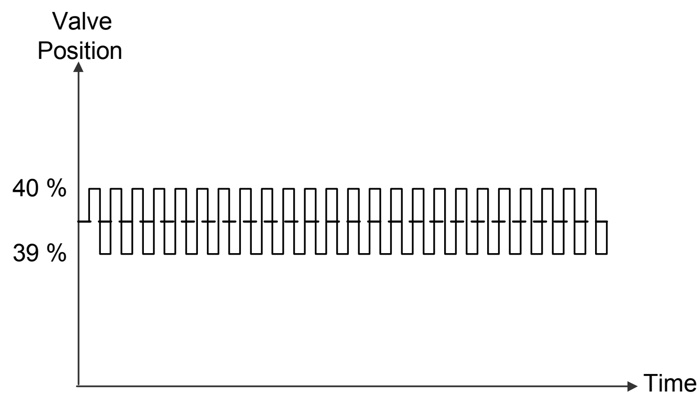


Figure 3-28. Valve Dither

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 3-29 for a sample equal percentage valve characteristic and the corresponding linearization curve that results in a linear flow characteristic.

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 Vertex-Pro 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 3-30 for a sample valve output illustrating a BOOST response with Pre-Pack enabled.

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

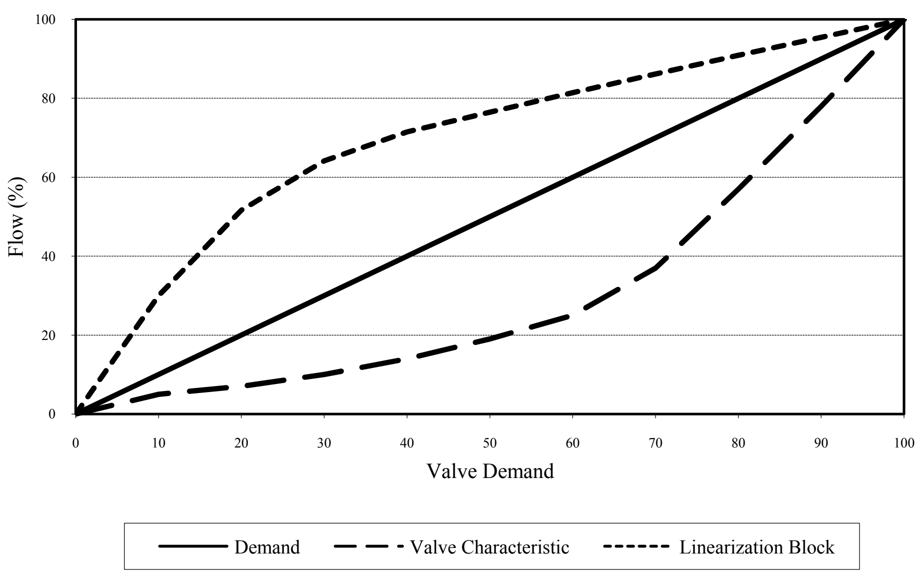


Figure 3-29. Valve Characterization

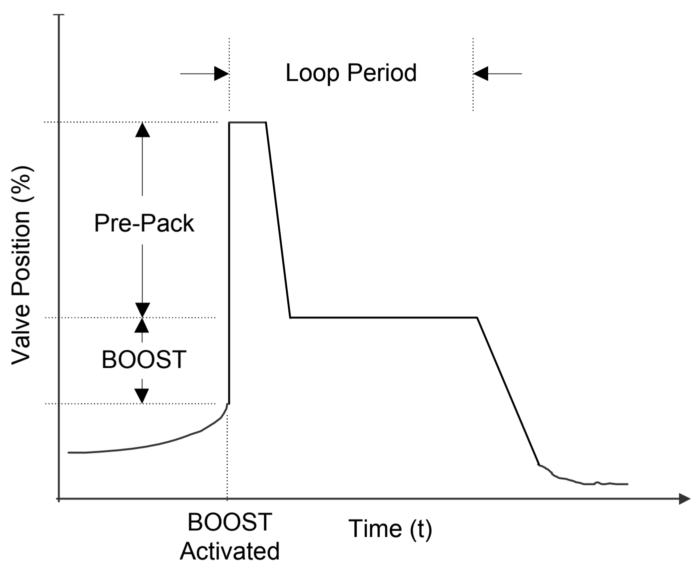


Figure 3-30. BOOST Response with Pre-Pack

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. Refer to the Loop Period Test Procedure in Chapter 4.

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.

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 (suction or discharge). In either case, the calculated average compressibility (Zavg=(Z1+Z2)/2) is used for head calculations.

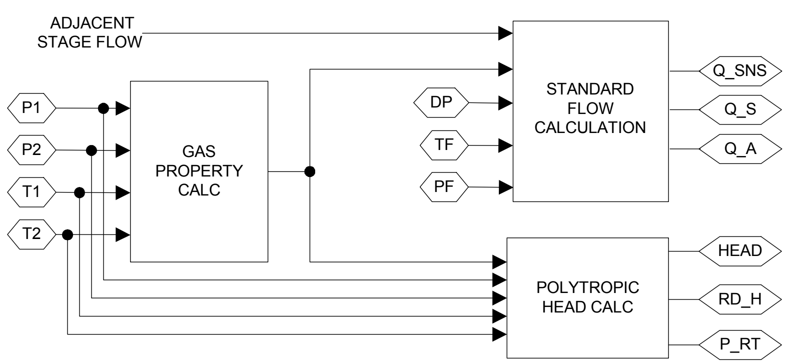


Figure 3-31. Gas Property Calculations

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.

Operating Point Calculations

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.

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

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·m³/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 Vertex-Pro 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
hf is the differential pressure across the flow element
Pf is the gas pressure at the flow element
MW is the gas molecular weight
Rg is the Universal Gas Constant
Tf is the gas temperature at the flow element
Zf 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 (hf), pressure (Pf), and temperature (Tf) are measured. As discussed previously, compressibility (Zf) 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. 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 Vertex-Pro. 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:
QA is actual volumetric suction flow
QS is total compressor stage flow (normal or mass)
ρ1 is the gas density at suction conditions
T1 is the gas temperature at suction conditions
Z1 is the gas compressibility at suction conditions
P1 is the gas pressure at suction conditions
Tnor is the normal condition gas temperature
Znor is the normal condition gas compressibility
Pnor 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 Knor), and the Universal Gas Constant (Rg) or normal condition process parameters (Tnor, Pnor, Znor)

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:
HP is polytropic head
Zavg is the average gas compressibility for the compressor
P2 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
ηp is the polytropic efficiency of the compressor
T2 is the gas temperature at discharge conditions
Z2 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:

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

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:

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

K and Rg 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.

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 antisurge 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:
QCR is the corrected volumetric suction flow
KCR is the corrected flow constant
hf is the differential pressure across the flow element
Pf 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 (KCR) 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 (KCR) and polytropic exponent (n) are calculated for the compressor performance map's rated or reference condition and configured into the control.

Chapter 4.
General Description

Introduction

The Vertex-Pro 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 and the Vertex-Pro Configuration—General configuration section in Chapter 5). The user may choose either of two compressor map implementations, the Standard Performance Map Algorithm or Universal Performance Map Algorithm, described in detail in Chapter 3. Either algorithm will accurately represent the current compressor operating point. The Vertex-Pro 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 monitoring operation are available through the provided Commissioning and Configuration Tool (CCT) software running on any connected computer, or on a standard 12.1 inch (307 mm) touch-screen Service Panel PC. Additional operational and monitoring capabilities are available over serial Modbus.

Additional Features

The Vertex-Pro 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 Vertex-Pro 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 Vertex-Pro can still provide surge protection in automatic, based upon a flow derivative surge signature. Optionally, other signal failures can initiate the same Fail to Manual backup 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 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.

Vertex-Pro Inputs and Outputs

Control Inputs

Twenty-four (24) 4–20 mA analog inputs are available. One (1) through five (5) are fixed as Flow, Suction Pressure, Discharge Pressure, Suction Temperature, and Discharge Temperature for Stage 1. Six (6) through twenty-four (24) are configurable for the following options. The numbers may be used as an index to the configuration value available in the Modbus list.

0. **Not Used**
1. **Stage 1 Raw Signal PF**—The Flow Element Pressure input may be used for a pressure transmitter at the flow element, if its location is far from the compressor suction or discharge pressure measurements.
2. **Stage 1 Raw Signal TF**—The Flow Element Temperature input may be used for a temperature transmitter at the flow element, if its location is far from the compressor suction or discharge temperature measurements.
3. **Stage 1 HSS Auxiliary #1**—Auxiliary HSS (High Signal Selector) inputs are provided for anti-surge valve positioning (0% = Closed, 100% = Open) in Full Manual Mode.
4. **Stage 1 HSS Auxiliary #2**—Auxiliary HSS (High Signal Selector) inputs are provided for anti-surge valve positioning (0% = Closed, 100% = Open) in Full Manual Mode.
5. **Stage 1 Remote Manual Valve Position**—Remote valve positioning (0% = Closed, 100% = Open) in Manual Modes.
6. **Stage 1 Redundant Flow**—Accommodates a redundant flow transmitter.
7. **Stage 1 Redundant Suction Pressure**—Accommodates a redundant suction pressure transmitter.
8. **Stage 1 Redundant Discharge Pressure**—Accommodates a redundant discharge pressure transmitter.
9. **Stage 2 Raw Signal PF**—The Flow Element Pressure input may be used for a pressure transmitter at the flow element, if its location is far from the compressor suction or discharge pressure measurements.
10. **Stage 2 Raw Signal TF**—The Flow Element Temperature input may be used for a temperature transmitter at the flow element, if its location is far from the compressor suction or discharge temperature measurements.
11. **Stage 2 HSS Auxiliary #1**—Auxiliary HSS (High Signal Select) inputs are provided for anti-surge valve positioning (0% = Closed, 100% = Open) in Full Manual Mode.
12. **Stage 2 HSS Auxiliary #2**—Auxiliary HSS (High Signal Select) inputs are provided for anti-surge valve positioning (0% = Closed, 100% = Open) in Full Manual Mode.
13. **Stage 2 Remote Manual Valve Position**—Remote valve positioning (0% = Closed, 100% = Open) in Manual Modes.
14. **Stage 2 Redundant Flow**—Accommodates a redundant flow transmitter.
15. **Stage 2 Redundant Suction Pressure**—Accommodates a redundant suction pressure transmitter.
16. **Stage 2 Redundant Discharge Pressure**—Accommodates a redundant discharge pressure transmitter.
17. **Stage 2 Flow**—Flow input is certainly required for AntiSurge control. This signal is a mass flow or a differential pressure of flow elements.
18. **Stage 2 Suction Pressure**—Inlet Pressure of the compressor section.
19. **Stage 2 Discharge Pressure**—Outlet Pressure of the compressor section.
20. **Stage 2 Suction Temperature**—Inlet Temperature of the compressor section.
21. **Stage 2 Discharge Temperature**—Outlet temperature of the compressor section.
22. **Motor Current**—Signal from motor current sensor when the Motor Current Limit is used.

23. **Remote Setpoint #1 for Load Sharing**—The load sharing setpoint is from sequence #1 controller. This signal input is only used for Load Sharing by hardwired connection. If CAN communication is used for Load Sharing, the hardwired connection will be unnecessary.
24. **Remote Setpoint #2 for Load Sharing**—The load sharing setpoint is from sequence #2 controller. This signal input is only used for Load Sharing by hardwired connection. If CAN communication is used for Load Sharing, the hardwired connection will be unnecessary.
25. **Mass/Standard Flow #1 for Load Sharing**—Mass Flow or Standard Flow is from sequence #1 controller. This signal input is only used for Load Sharing by hardwired connection. If CAN communication is used for Load Sharing, the hardwired connection will be unnecessary.
26. **Mass/Standard Flow #2 for Load Sharing**— Mass Flow or Standard Flow is from sequence #2 controller. This signal input is only used for Load Sharing by hardwired connection. If CAN communication is used for Load Sharing, the hardwired connection will be unnecessary.
27. **Header Signal for Load sharing**—The process variable which becomes the basis of the load sharing is inputted. This variable is permitted by any process signals. For example, it is from a Suction/Discharge pressure transmitter or a flow transmitter.
28. **IGV Remote Setpoint**—Remote valve positioning (0% = Closed, 100% = Open) in Manual Modes.
29. **External Speed Sensor**—The speed of a motor is inputted when performing velocity control.
30. **Remote Header Pressure Setpoint**—Remote setpoint of Load Sharing in remote control modes.
31. **Stage 1 ASV Position Feedback**—used for acting as the monitor of the position of ASV.
32. **Stage 2 ASV Position Feedback**—used for acting as the monitor of the position of ASV.
33. **Throttle/IGV Position Feedback**—used for acting as the monitor of the position of Throttle/IGV.
34. **Performance Process**—Process variable for controlling the performance of compressor train.
35. **Remote Performance Setpoint**—Remote setpoint of Load Sharing in remote control modes.

Thirty-eight (38) contact inputs are available, two (2) of which are fixed for Emergency shutdown and Alarm/Trip Reset. The thirty-six (36) remaining contact inputs are configurable for the following options:

0. **Not Used**
1. **Stage 1 Reset SMP** (momentary)—Resets the Surge Minimum Position hold on ASV position.
2. **Stage 1 Reset Surge Capture Info.** (momentary)—Resets the Surge Capture information (counter, signature values)—Does not reset the Total Surges Counter.
3. **Stage 1 Select AUTO Mode** (momentary)—Selects the Automatic control mode.
4. **Stage 1 Select MANUAL w/ BACKUP** (momentary)—Selects the Manual with Backup control mode.
5. **Stage 1 Select FULL MANUAL Mode** (momentary)—Selects the Full Manual control mode.
6. **Stage 1 Purge Position** (sustained)—Selects the anti-surge valve's Purge position during start-up.
7. **Stage 1 Online Auxiliary Input** (sustained)—Initiates the transition from sequence positioning control to automatic anti-surge control (starts the anti-surge control instead of, or in addition to, using speed, flow, or pressure setpoints).

8. **Stage 1 Add Margin – Inc** (momentary or sustained)—Increases the current Control Margin by 0.1% per second while the input is closed.
9. **Stage 1 Add Margin – Dec** (momentary or sustained)—Decreases the current Control Margin by 0.1% per second while the input is closed (cannot decrease below the configured Base Control Margin).
10. **Stage 1 AS Valve Output Fault** (sustained)—Anti-Surge Valve output fault, which will force the control into Full Manual Mode and move the valve output to the shutdown position. The control cannot detect open- or short-circuits on the 4–20 mA anti-surge valve outputs. This discrete input configuration is provided for an external circuit monitoring device to signal such a fault.
11. **Stage 1 Start Position** (momentary)—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.
12. **Stage 1 Shutdown** (momentary or sustained)—Initiates a compressor shutdown by positioning the anti-surge valve in the configured shutdown position. Restarts are inhibited if the input is sustained.
13. **Stage 2 Reset SMP** (momentary)—Resets the Surge Minimum Position hold on valve position.
14. **Stage 2 Reset Surge Capture Info.** (momentary)—Resets the Surge Capture information (counter, signature values)—Does not reset the Total Surges Counter.
15. **Stage 2 Select AUTO Mode** (momentary)—Selects the Automatic control mode.
16. **Stage 2 Select MANUAL w/ BACKUP** (momentary)—Selects the Manual with Backup control mode.
17. **Stage 2 Select FULL MANUAL Mode** (momentary)—Selects the Full Manual control mode.
18. **Stage 2 Purge Position** (sustained)—Selects the anti-surge valve’s Purge position during start-up.
19. **Stage 2 Online Auxiliary Input** (sustained)—Initiates the transition from sequence positioning control to automatic anti-surge control (starts the anti-surge control instead of, or in addition to, using speed, flow, or pressure setpoints).
20. **Stage 2 Add Margin – Inc** (momentary or sustained)—Increases the current Control Margin by 0.1% per second while the input is closed.
21. **Stage 2 Add Margin – Dec** (momentary or sustained)—Decreases the current Control Margin by 0.1% per second while the input is closed (cannot decrease below the configured Base Control Margin).
22. **Stage 2 AS Valve Output Fault** (sustained)—Anti-Surge Valve output fault, which will force the control into Full Manual Mode and move the valve output to the shutdown position. The control cannot detect open- or short-circuits on the 4–20 mA anti-surge valve outputs. This discrete input configuration is provided for an external circuit monitoring device to signal such a fault.
23. **Stage 2 Start Position** (momentary)—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.
24. **Stage 2 Shutdown** (momentary or sustained)—Initiates a compressor shutdown by positioning the anti-surge valve in the configured shutdown position. Restarts are inhibited if the input is sustained.
25. **Performance Setpoint Raise** (momentary or sustained)—Increases the performance setpoint by the configured rate while the input is closed.
26. **Performance Setpoint Lower** (momentary or sustained)—Decreases the performance setpoint by the configured rate while the input is closed.
27. **Performance Control Enable** (sustained)—If applicable, the performance control is enabled while the input is closed.
28. **Performance Remote Setpoint Enable** (sustained)—If applicable, the remote (4–20 mA) performance control is enabled while the input is closed.

29. **Current Limit Raise** (momentary or sustained)— If applicable, increases the current limit setpoint by the configured rate while the input is closed.
30. **Current Limit Lower** (momentary or sustained)— If applicable, decreases the current limit setpoint by the configured rate while the input is closed.
31. **Load Sharing Enable** (sustained)—If applicable, the load sharing control is enabled while the input is closed.
32. **Load Sharing Permissive #2** (sustained)—If applicable, the load sharing control was permitted at another parallel compressor control while the input is closed.
33. **Load Sharing Permissive #3** (sustained)—If applicable, the load sharing control was permitted at another parallel compressor control while the input is closed.
34. **Throttle/IGV Raise** (momentary or sustained)— If applicable, increases the Throttle/IGV ramp by the configured rate while the input is closed.
35. **Throttle/IGV Lowe**r (momentary or sustained)— If applicable, decreases the Throttle/IGV ramp by the configured rate while the input is closed.
36. **Throttle/IGV Remote Enable** (sustained)—If applicable, the remote (4–20 mA) Throttle/IGV ramp control is enabled while the input is closed.
37. **Stage 1 Open Anti-Surge Valve** (momentary or sustained)—The anti-surge valve of the 1st section will open 100% when the input is closed in manual modes.
38. **Stage 1 Close Anti-Surge Valve** (momentary or sustained)—The anti-surge valve of the 1st section will close when the input is closed in manual modes.
39. **Stage 2 Open Anti-Surge Valve** (momentary or sustained)—The anti-surge valve of the 2nd section will open 100% when the input is closed in manual modes.
40. **Stage 2 Close Anti-Surge Valve** (momentary or sustained)—The anti-surge valve of the 2nd section will close when the input is closed in manual modes.
41. **Additional Unit Load Sharing Enabled #1** (sustained)—In order to carry out load sharing, the master controller must know that load sharing is enabled on other Vertex-Pro controllers. This input is required only when using hardwired connection for load sharing. If CAN communication is used for Load Sharing, the hardwired connection will be unnecessary.
42. **Additional Unit Load Sharing Enabled #2** (sustained)—In order to carry out load sharing, the master controller must know that load sharing is enabled on other Vertex-Pro controllers. This input is required only when using hardwired connection for load sharing. If CAN communication is used for Load Sharing, the hardwired connection will be unnecessary.
43. **Header Pressure Remote Setpoint Enable** (sustained)—If applicable, the remote (4–20 mA) header pressure setpoint for load sharing is enabled while the input is closed.
44. **Stage 1 Remote Manual Enable** (sustained)—If applicable, the remote (4–20 mA) Manual control for the 1st stage anti-surge valve is enabled while the input is closed.
45. **Stage 2 Remote Manual Enable** (sustained)—If applicable, the remote (4–20 mA) Manual control for the 2nd stage anti-surge valve is enabled while the input is closed.

46. **Start Permissive** (sustained)—An external contact may be used as a motor startup permissive. When programmed for this functionality, the contact input must be closed in order for a 'START' command to be executed. Should the contact be open when a 'START' command is given, an alarm will be issued and the Service Panel will indicate that the start permissive was not met (Start Perm Not Met). The alarm does not need to be cleared but the contact must be closed before the Vertex-Pro will accept a 'START' command. After a 'START' command has been accepted, the start permissive contact will have no effect on operation. If used, this input is typically connected to an Inlet Throttle Valve or Inlet Guide Vane closed limit switch to verify that it is in the closed position before a motor startup is performed.
47. **Load Sharing #1 is Master** (sustained)—In order to carry out load sharing, the controllers must know which controller is the master. This input is required only when using hardwired connection for load sharing. If CAN communication is used for Load Sharing, the hardwired connection will be unnecessary.
48. **Load Sharing #2 is Master** (sustained)—In order to carry out load sharing, the controllers must know which controller is the master. This input is required only when using hardwired connection for load sharing. If CAN communication is used for Load Sharing, the hardwired connection will be unnecessary.
49. **External Trip #2** (momentary or sustained)—If applicable, a trip from other devices is inputted.
50. **External Trip #3** (momentary or sustained)—If applicable, a trip from other devices is inputted.
51. **External Trip #4** (momentary or sustained)—If applicable, a trip from other devices is inputted.
52. **External Trip #5** (momentary or sustained)—If applicable, a trip from other devices is inputted.
53. **Load Sharing #1 No Shutdown** (sustained)—In order to carry out load sharing, the controller must know which controller is healthy. This signal is not in the any control state of the controller. Other controllers will get to know that the CPU of the controller is healthy. This input is required only when using hardwired connection for load sharing. If CAN communication is used for Load Sharing, the hardwired connection will be unnecessary.
54. **Load Sharing #2 No Shutdown** (sustained)—In order to carry out load sharing, the controller must know which controller is healthy. This signal is not in the any control state of the controller. Other controllers will get to know that the CPU of the controller is healthy. This input is required only when using hardwired connection for load sharing. If CAN communication is used for Load Sharing, the hardwired connection will be unnecessary.
55. **Local / Remote** (sustained)—If applicable, the Remote control is enabled while the input is closed. The Remote control mode can use Modbus Serial/Ethernet command. The Local control mode can use hardwired contact inputs.

Control Outputs

One (1) 4–20 mA output for the 1st stage anti-surge valve is provided. Final valve demand including Decoupling and Freeze routines (includes valve overstroke, dither, and linearization). While the default valve configuration is fail-open (4 mA=Open, 20 mA=Closed), the control can be configured for a fail-closed valve. However, in this case, action must be taken by other devices to open the valve if the control fails or loses power (i.e. output current falls below 4 mA or the configured minimum). A failed actuator output, such as an open- or short-circuit, cannot be detected.

Seven (7) additional configurable analog outputs are provided for readouts of any of the following parameters for both compressor sections:

0. **Not Used**
1. **Stage 1 Surge Process Variable (S_PV)**—Surge Process Variable value.
2. **Stage 1 Actual Suction Volumetric Flow** (Standard Algorithm)—Volumetric Inlet Flow.
3. **Stage 1 Corrected Suction Volumetric Flow** (Universal Algorithm)—Corrected Volumetric Inlet Flow.
4. **Stage 1 Stage Flow** (Standard Algorithm)—Total Mass or Normal/Standard Volumetric Flow through the compressor section (Adjacent Section Flow ± Sensor Flow).
5. **Stage 1 Polytropic Head** (Standard Algorithm)—Calculated Polytropic Head.
6. **Stage 1 Press Ratio**—Pressure Ratio across the compressor section.
7. **Stage 1 P1 Control Value**—Suction Pressure value after redundancy management (if applicable), filtering, and failure routines.
8. **Stage 1 P2 Control Value**—Discharge Pressure value after redundancy management (if applicable), filtering, and failure routines.
9. **Stage 1 T1 Control Value** (Standard Algorithm)—Suction Temperature value after filtering and failure routines.
10. **Stage 1 T2 Control Value** (Standard Algorithm)—Discharge Temperature value after filtering and failure routines.
11. **Stage 1 Sensor Flow** (Standard Algorithm)—Calculated Mass or Normal/Standard Volumetric Flow through the flow sensor.
12. **Stage 1 HSS Output**—Output of the High Signal Select bus for all automatic control routines.
13. **Stage 1 Valve Percent**—Final valve demand including Decoupling and Freeze routines (excludes valve overstroke, dither, and linearization).
14. **Stage 2 Surge Process Variable (S_PV)**—Surge Process Variable value.
15. **Stage 2 Actual Suction Volumetric Flow** (Standard Algorithm)—Volumetric Inlet Flow.
16. **Stage 2 Corrected Suction Volumetric Flow** (Universal Algorithm)—Corrected Volumetric Inlet Flow.
17. **Stage 2 Stage Flow** (Standard Algorithm)—Total Mass or Normal/Standard Volumetric Flow through the compressor section (Adjacent Section Flow ± Sensor Flow).
18. **Stage 2 Polytropic Head** (Standard Algorithm)—Calculated Polytropic Head.
19. **Stage 2 Press Ratio**—Pressure Ratio across the compressor section.
20. **Stage 2 P1 Control Value**—Suction Pressure value after redundancy management (if applicable), filtering, and failure routines.
21. **Stage 2 P2 Control Value**—Discharge Pressure value after redundancy management (if applicable), filtering, and failure routines.
22. **Stage 2 T1 Control Value** (Standard Algorithm)—Suction Temperature value after filtering and failure routines.
23. **Stage 2 T2 Control Value** (Standard Algorithm)—Discharge Temperature value after filtering and failure routines.
24. **Stage 2 Sensor Flow** (Standard Algorithm)—Calculated Mass or Normal/Standard Volumetric Flow through the flow sensor.
25. **Stage 2 HSS Output**—Output of the High Signal Select bus for all automatic control routines.
26. **Stage 2 Valve Percent**—Final valve demand including Decoupling and Freeze routines (excludes valve overstroke, dither, and linearization).
27. **Stage 2 Valve Demand**—Final valve demand including Decoupling and Freeze routines (includes valve overstroke, dither, and linearization).
28. **Throttle/IGV Demand**—The demand signal to the Inlet Guide Vane or the Inlet Throttle Valve which the Vertex-Pro controls at percentage (0–100%/ 4–20 mA).

29. **Load Sharing Remote Setpoint**—In order to carry out load sharing, the header pressure setpoint from the master controller is required. This output is required only when using hardwired connection for load sharing. If CAN communication is used for Load Sharing, the hardwired connection will be unnecessary. If Load Sharing function is not used, this output is applicable also to the monitor of the header pressure setpoint, or feedback signal of remote header pressure setpoint.
30. **Stage 1 ASV Position**— The demand signal to the 1st stage anti-surge valve which the Vertex-Pro controls as a percentage (100-0%/4–20 mA or 0–100%/4–20 mA).
31. **Stage 2 ASV Position**— The demand signal to the 2nd stage anti-surge valve which the Vertex-Pro controls as a percentage (100-0%/4–20 mA or 0–100%/4–20 mA).
32. **Throttle/IGV Position**—This is used to monitor the position of the Inlet Guide Vane or the Inlet Throttle Valve.
33. **Header Pressure**—In order to carry out load sharing, the header pressure in the master controller is required. This output is required only when using hardwired connection for load sharing. If CAN communication is used for Load Sharing, the hardwired connection will be unnecessary. If Load Sharing function is not used, this output is applicable also to the monitor of the header pressure.

Twenty (20) discrete outputs are available, two (2) of which are fixed for Shutdown and Alarm. The eighteen (18) remaining contact outputs are configurable for the following options:

0. **Not Used**
1. **Off Line-Controlled SD**—The Anti-Surge control is in the controlled shutdown condition.
2. **Off Line-Emergency SD**—The Anti-Surge control is in the shutdown condition.
3. **Off Line-Zero Speed**—The Anti-Surge control is in the complete stop (zero speed) condition. This condition will appear after a SD. It will become active after the configured shutdown delay time passes.
4. **Off Line-Purge**—The Anti-Surge control is in the purge cycle during a startup.
5. **Off Line-Start**—The Anti-Surge control is in the startup condition excluding the purge cycle.
6. **On Line**—The Anti-Surge control is online and active.
7. **Stage 1 Surge Detected**—Surge has been detected.
8. **Stage 1 SMP Active**—Surge Minimum Position is active.
9. **Stage 1 AUTO Mode**—The control is in Automatic Mode.
10. **Stage 1 MANUAL /w BACKUP**—The control is in Manual w/ Backup Mode.
11. **Stage 1 FULL MANUAL**—The control is in Full Manual Mode.
12. **Stage 2 Surge Detected**—Surge has been detected.
13. **Stage 2 SMP Active**—Surge Minimum Position is active.
14. **Stage 2 AUTO Mode**—The control is in Automatic Mode.
15. **Stage 2 MANUAL /w BACKUP**—The control is in Manual w/ Backup Mode.
16. **Stage 2 FULL MANUAL**—The control is in Full Manual Mode.
17. **Load Sharing Permissive**—Execution of load sharing is permissible.
18. **Load Sharing Enabled**—Execution of load sharing is possible.
19. **Load Sharing Active**—Load sharing is active.
20. **Load Sharing Master**—Load sharing is performing in the master control.
21. **Current Limited**—The control is under current limitation.
22. **Performance Control Active**—Performance control of system is active.
23. **Ready to Start**—The control is waiting for the start command.

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 of 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 Valve—Anti-surge valves should be sized properly, capable of flowing the full capacity 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 control software. 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 5. Configuration Procedures

Introduction

The Vertex-Pro may be configured using the Control Assistant software running on a connected computer or via the standard service panel 12.1” display. See Chapter 1 for a description of system level configuration.

IMPORTANT	**The operation process in this manual is explained by using the Control Assistant version 3.8. Please use Control Assistant version 3.8 or higher.**

The default configuration values, except for those that require testing and tuning such as PID gains, Loop Period, etc., are representative of a typical compressor control application. But, virtually every feature can be enabled or disabled and tuned to allow full customization of the control. The Compressor Performance Map(s), API Data Sheet(s), Flow Element Calculation / Data Sheet(s), and a P&ID will be required to properly configure the control. Most of the configuration can be completed prior to start-up. The exceptions, which require running the compressor for testing, are as follows:

- Loop Period
- Automatic Gain Compensation
- PID Tuning (1 to 2 control loops per compressor section, depending upon configuration)
- Decoupling
- Valve Linearization

Connect to the Control

To configure the control’s settings, use the Control Assistant software. The Control Assistant is opened from the start menu of Windows. Start the Control Assistant software program by clicking on Start > Programs > Woodward > Control Assistant. The Control Assistant Menu bar will appear as shown in Figure 5-1. Click on the icon (New WinPanel) on the tool bar. An OPC Connection dialog box will automatically appear. Select Servlink OPC server and Local Server. Click on the Connect button. Refer to Figure 5-2.

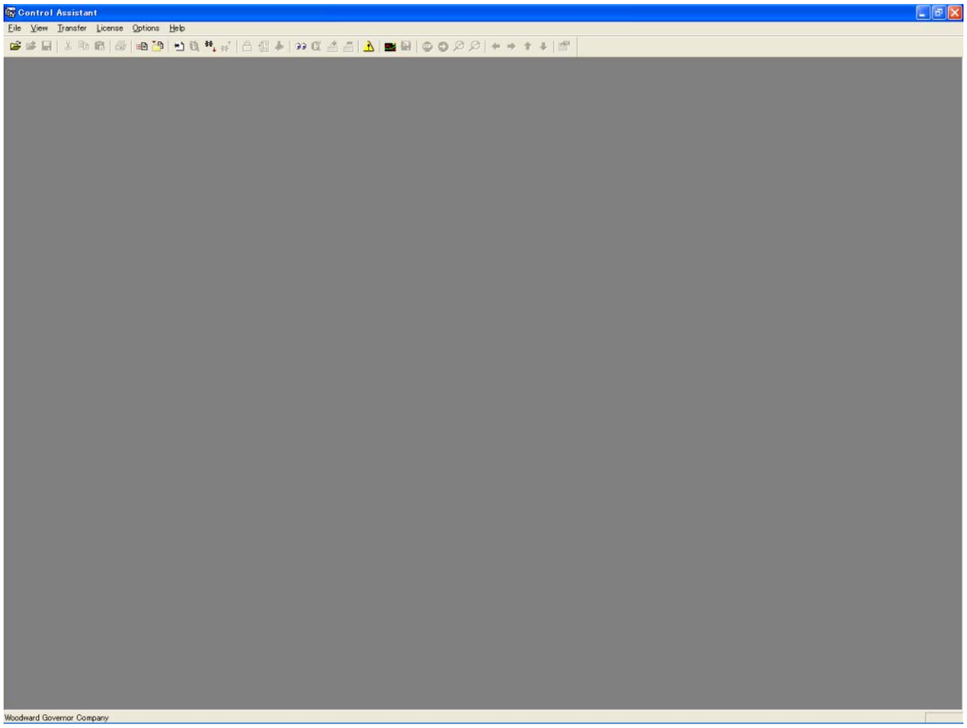


Figure 5-1. Control Assistant

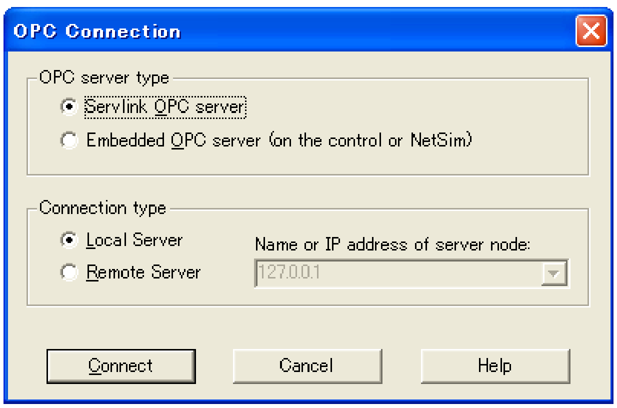


Figure 5-2. OPC Connection dialog box

With the standby message of the Control Assistant, the SOS Servlink OPC Server starts automatically.

Figure 5-3. Control Assistant waiting message

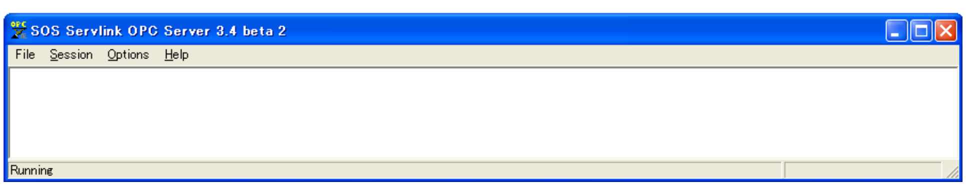


Figure 5-4. SOS Servlink OPC Server

When the SOS Servlink OPC Server starts for the first time, the session field will be a blank as shown in Figure 5-4. Click on New Session in the session menu. Refer to Figure 5-5. The Connect Servlink to control dialog box will open. Input the IP address of control into a Primary TCP IP Address field. Then, click the Connect TCP button. Refer to Figure 5-6. The status will become "Connected" when the communication between the Service Panel and the Control is established. If communication is not established, confirm the IP address of control using the AppManager software. If the session IP address of SOS is different, delete the session and try connecting again using the correct IP address.

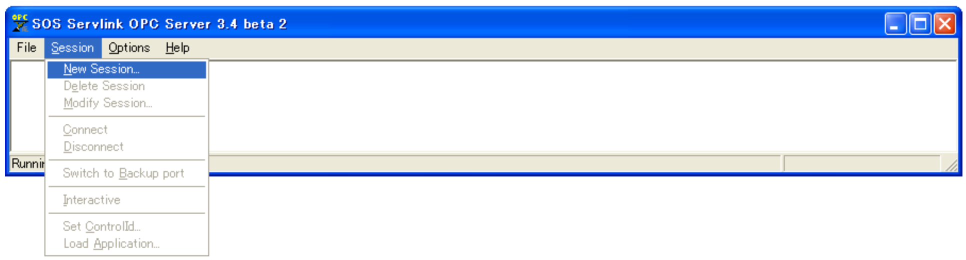


Figure 5-5. SOS Session menu

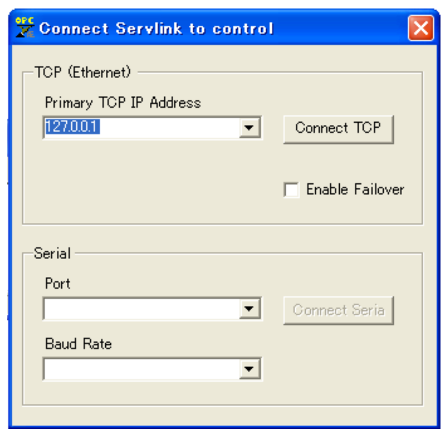


Figure 5-6. Connect Servlink to control dialog box

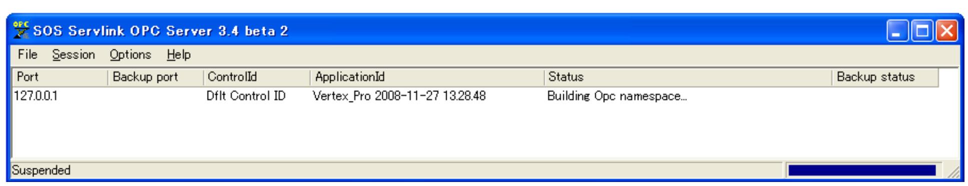


Figure 5-7. SOS Building OPC Namespace

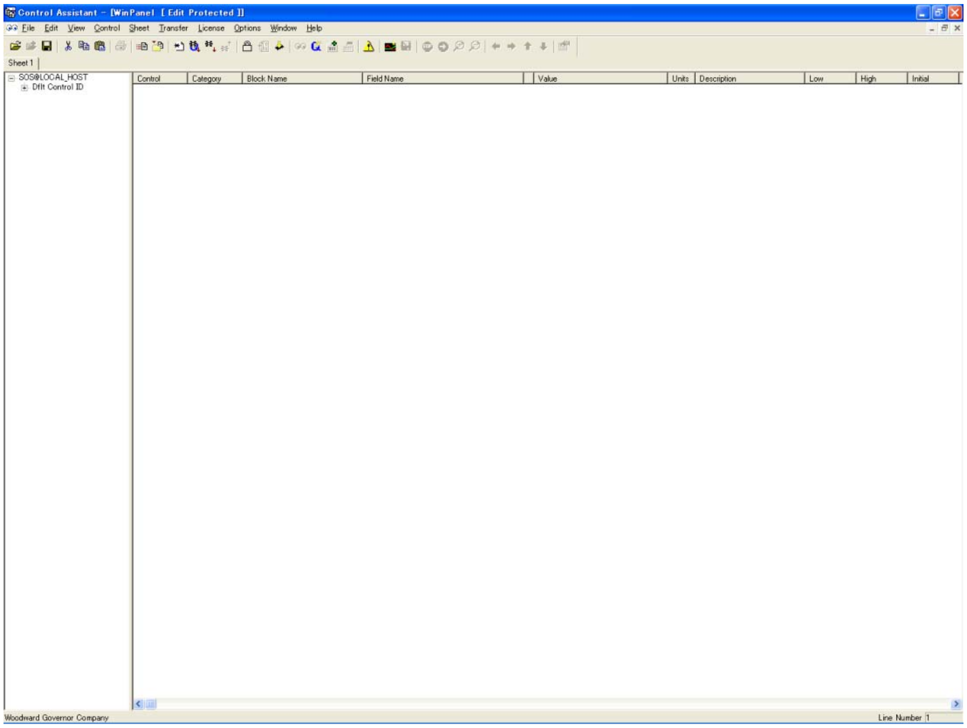


Figure 5-8. Control Assistant WinPanel

At this point, click on the icon (Quick Inspector) on the tool bar. Multiple sheets will automatically be created from each Service and Configure Header programmed into the control. Refer to Figure 5-9. Optionally, other inspectors can be created to allow viewing of more than one sheet at a time.

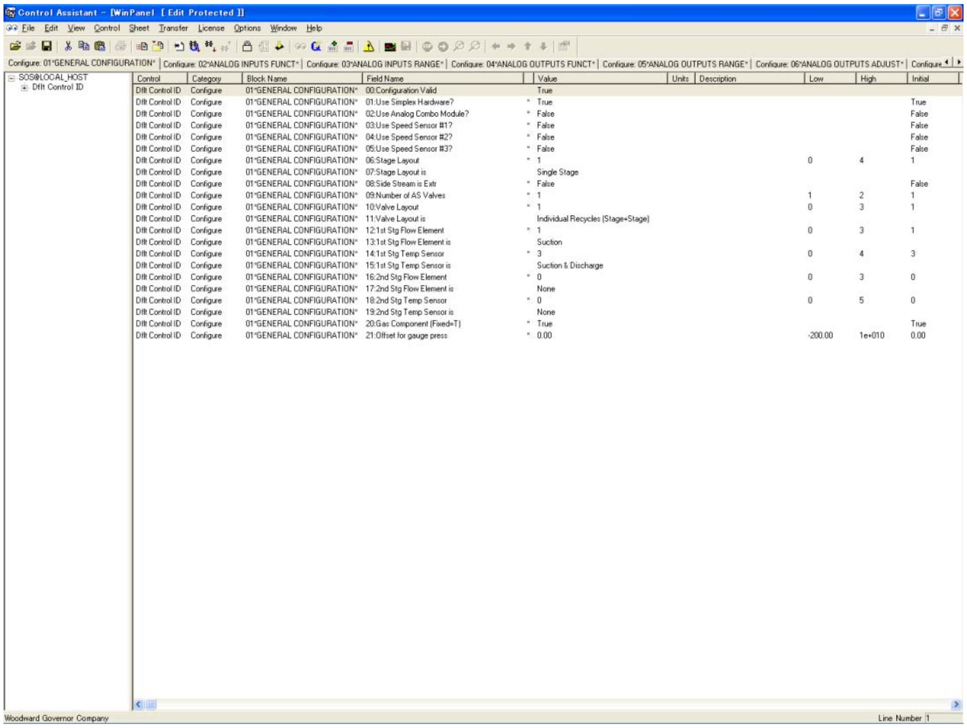


Figure 5-9. Control Assistant Service and Configure

Menu Descriptions

The Vertex-Pro has "14" Configure menus and "36" Service menus to simplify and protect control settings and their adjustments. All menus appear as pages. They are arranged alphabetically and can be located by using the inspector's arrow buttons located above the pages to scroll to the desired menu.

Operating the Configure Mode

Two Configure mode options are offered within the Control Assistant program (Configure-Change, Configure-View Only). The Configure-Change mode is used to change control settings, test control hardware, and calibrate control I/O, while the motor is not in operation or is shutdown. For security purposes, the Configure-Change mode is password protected. The Configure-View Only mode is used to only view Configure mode settings, while the prime mover or compressor is in operation or shutdown. No Configure mode settings can be changed via the View Only mode.

To enter the "Enable Tune Mode," click on the "Tunable Fields" in the program's main window. Once communications with the control has been established, the mode's "Enter Tune Password" box will appear. At this point enter the Configure mode password (reference Appendix A of this Volume).

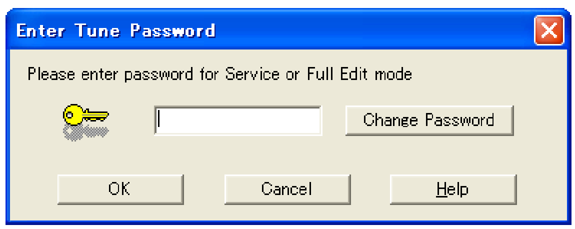


Figure 5-10. Enter Tune Password

The program's Configure menu items are protected when the control is in operation and cannot be changed. Before configuration values can be changed the control must be in its I/O Lock mode.

To enter the **I/O Lock** mode and enable configuration changes, click on the **I/O Lock** icon on the Tool Bar. Because the values set in Configure are critical to motor operation, it is not safe to operate the prime mover while these parameters are being configured. In the I/O Lock mode the control outputs will be set to their off state and the microprocessor will stop executing the application code.

In order to open the Configure-Change mode, the Vertex-Pro control must be running and the prime mover for compressors must be shutdown. The following screen will be displayed. Click "Yes" and the Vertex-Pro control will accept program changes.

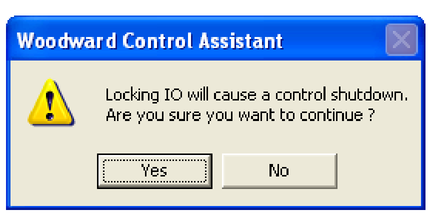
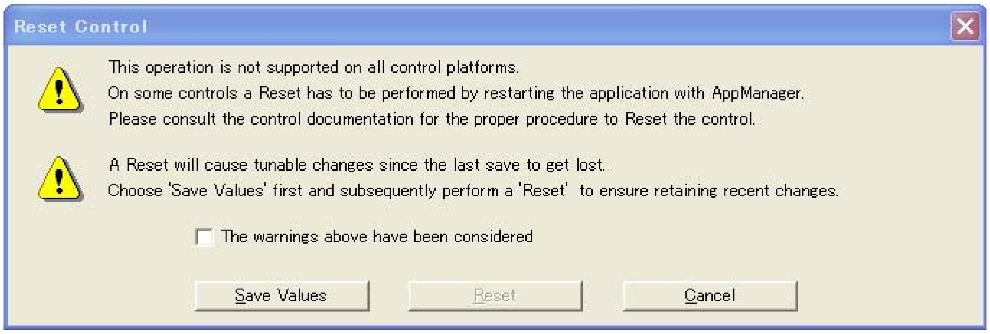
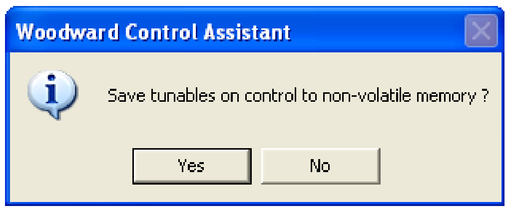


Figure 5-11. Locking IO

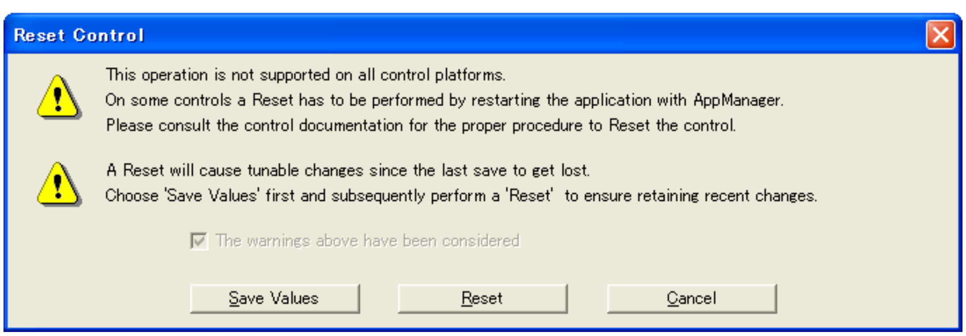
Once the configuration changes have been completed click on the **Reset** icon to allow the control to store the configured parameters, return the outputs to their active state and resume executing the application software.
The following warning message box will appear. Click "Save Values" for saving tunables on the Vertex-Pro to non-volatile memory.





Click "Yes" and the Vertex-Pro control will save program changes.

After the above message box is shown, click "OK." Check a box of "The warnings above have been considered" in the Reset Control screen. After that "Reset" button will be active. Click "Reset" for resetting the Vertex-Pro.



The Vertex-Pro control will re-start.

Configure: 01*GENERAL CONFIGURATION*

Field Name		Value	Units	Description	Low	High	Initial
00:Configuration Valid		True					
01:Use Simplex Hardware?	*	True					True
02:Use Analog Combo Module?	*	False					False
03:Use Speed Sensor #1?	*	False					False
04:Use Speed Sensor #2?	*	False					False
05:Use Speed Sensor #3?	*	False					False
06:Stage Layout	*	1			0	4	1
07:Stage Layout is		Single Stage					
08:Side Stream is Extr	*	False					False
09:Number of AS Valves	*	1			1	2	1
10:Valve Layout	*	1			0	3	1
11:Valve Layout is		Individual Recycles (Stage+Stage)					
12:1st Stg Flow Element	*	1			0	3	1
13:1st Stg Flow Element is		Suction					
14:1st Stg Temp Sensor	*	3			0	4	3
15:1st Stg Temp Sensor is		Suction & Discharge					
16:2nd Stg Flow Element	*	0			0	3	0
17:2nd Stg Flow Element is		None					
18:2nd Stg Temp Sensor	*	0			0	5	0
19:2nd Stg Temp Sensor is		None					
20:Gas Component (Fixed=T)	*	True					True
21:Offset for gauge press	*	0.00			-200.00	1e+010	0.00
22:Use Metric Measurements?	*	True					True
23:Select Pressure Units	*	2			1	9	2
24:Pressure Units is		kPa - METRIC					
25:Use Absolute Press Input	*	False					False
26:Air Comp w/o P1 Signal	*	False					False

Figure 5-12. Configure: 01*GENERAL CONFIGURATION* Menu

The selections on this menu largely determine the appearance of the subsequent configuration, as well as the internal software connections for proper control functionality. Some combinations may be invalid, in which case an error message will be displayed and further configuration inhibited. Refer to the configuration rules at the end of this list, or see Appendix B for a complete listing of valid configurations.

General Configuration Rules

1. "Dual with 1 Flow Element" layouts cannot utilize the Universal Algorithm.
2. "Dual with SideStream" layouts can only utilize the Universal Algorithm if the flow elements are in the 1st stage suction and 2nd stage discharge. Otherwise, use the Standard Algorithm and configure the flow element locations appropriately.
3. "Dual with SideStream" layouts and "Variable" gas composition cannot utilize the Standard Algorithm.
4. The Standard Algorithm requires a temperature measurement(s) in the same location as the flow element(s) (suction, discharge, side-stream) if the gas composition is "Constant." If the gas composition is "Variable," temperature measurements are required in both the suction and discharge.

00:Configuration Valid **Monitor**
TRUE is displayed when the configurations are suitable.

01:Use Simplex Hardware? **Initial=TRUE (FALSE, TRUE)**
The Vertex-Pro can be setup for Simplex type or Redundant type hardware configuration. Set TRUE, if a Simplex type is used.

02:Use Analog Combo Module? Initial=FALSE (FALSE, TRUE)
The Vertex-Pro can use an Analog Combo module as an option. Set TRUE, if an Analog Combo module is used.

IMPORTANT **The Analog Combo Module is option for the Vertex-Pro. The Vertex-Pro accepts only the following signals in the analog combo module.**
- **Three(3) Speed Inputs from MPU or proximity probe**
- **Two(2) Analog Inputs for 4–20 mA**

03:Use Speed Sensor #1? Initial=FALSE (FALSE, TRUE)
The Analog Combo module includes speed sensor inputs. Set TRUE, if speed sensor #1 is used.

04:Use Speed Sensor #2? Initial=FALSE (FALSE, TRUE)
The Analog Combo module includes speed sensor inputs. Set TRUE, if speed sensor #2 is used.

05:Use Speed Sensor #3? Initial=FALSE (FALSE, TRUE)
The Analog Combo module includes speed sensor inputs. Set TRUE, if speed sensor #3 is used.

IMPORTANT **Priority is given to speed sensors over a programmable analog input for an external speed sensor. When using direct speed sensors, an external speed sensor 4–20 mA input cannot be used.**

06:Stage Layout Initial=1 (1, 4)
Select the appropriate stage layout: “Single,” “Dual with 1 Flow Element,” “Dual with 2 Flow Elements,” or “Dual with SideStream.” “Dual with 1 Flow Element” is not an available selection with the Universal Algorithm. See Figure 5-13 for examples of each layout (instrument locations are shown as examples only).

07:Stage Layout is **Monitor**

This displays the item name selected for the stage layout.

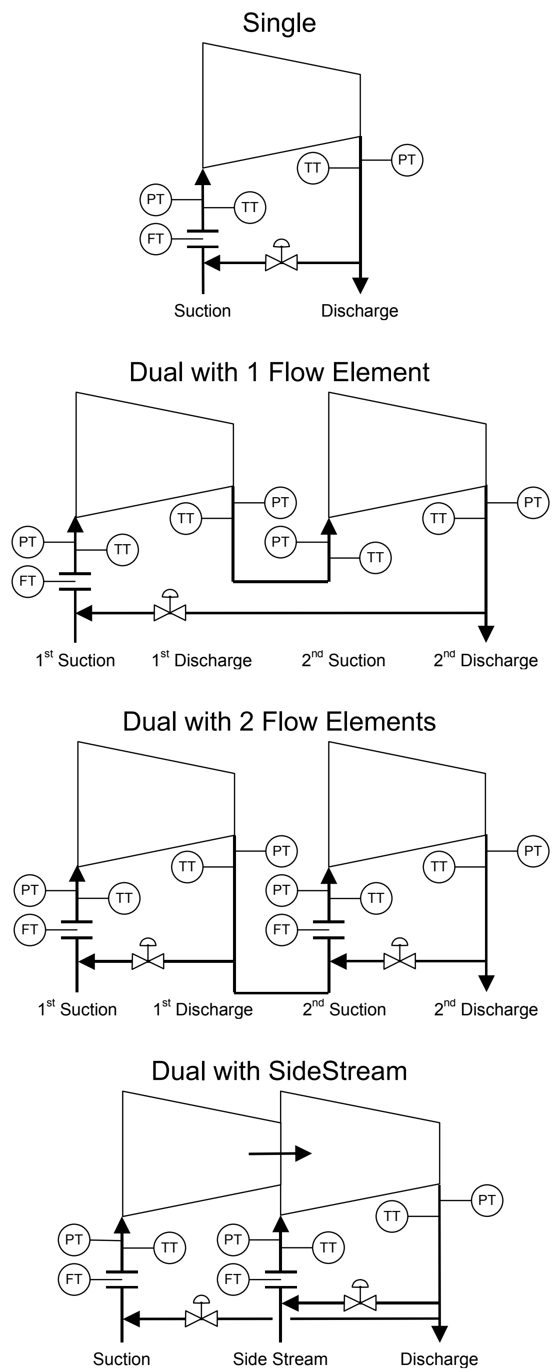


Figure 5-13. Example Compressor Layouts

08:Side Stream is Extr **Initial=FALSE (FALSE, TRUE)**

For “Dual with SideStream” layouts, select “Admission” (flow into the compressor train) or “Extraction” (flow out of the compressor train) for the SideStream direction. Set TRUE, if “Extraction” is used.

09:Number of AS Valves **Initial=1 (1, 2)**

For Dual Stage layouts, set whether the train has one or two recycle (Anti-Surge) valves. The “Dual with 1 Flow Element” layout is limited to a single valve.

10:Valve Layout **Initial=1 (1, 3)**
For "Dual with 2 Flow Element" layouts and "Two" valves, select the valve layout as "Stage + Stage" (individual recycles), "Stage + Overall" (common suction recycles), or "Overall + Stage" (common discharge recycles). These describe the piping arrangements for the first and second compressor sections' recycle valves. See Figure 5-14 and 5-15 for examples.

11:Valve Layout is **Monitor**
This displays the item name selected for the valve layout.

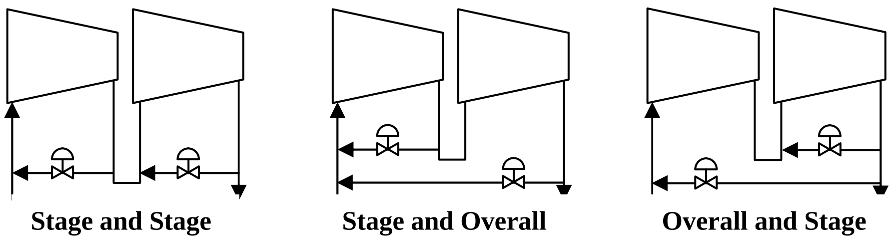


Figure 5-14. Dual with 2 Flow Element Layouts

As shown in Figure 5-15, this configuration is predetermined by the side-stream direction for "Dual with SideStream" layouts with "Two" valves.

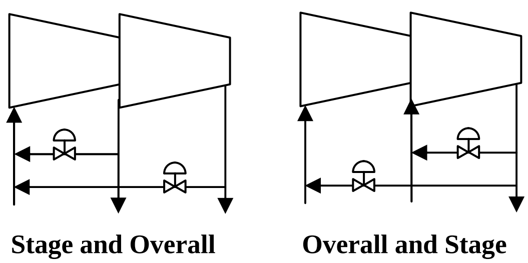


Figure 5-15. Dual with SideStream Layouts

12:1st Stg Flow Element **Initial=0 (0, 3)**
Select the location of the first compressor section flow element as "Suction," "Discharge," "SideStream," or "None." "None" applies only to "Dual with 1 Flow Element" layouts where the element corresponds to the second compressor section.

13:1st Stg Flow Element is **Monitor**
This displays the item name selected for the 1st stage flow element.

14:1st Stg Temp Sensor **Initial=0 (0, 4)**
Select the location of the first compressor section's temperature sensor(s) as "Suction," "Discharge," "Suction + Discharge," "SideStream," or "None." This selection is required only for the Standard Algorithm, or if temperatures and flow will be displayed with the Universal Algorithm. If the gas composition is "Constant," a temperature measurement is required, at a minimum, at the flow element. If "Variable," temperature measurements are required in both the suction and discharge of the compressor.

15:1st Stg Temp Sensor is **Monitor**
This displays the item name selected for 1st stage temperature sensor.

16:2nd Stg Flow Element **Initial=0 (0, 3)**
For Dual Stage layouts, select the location of the second compressor section flow element as “Suction,” “Discharge,” “SideStream,” or “None.” “None” applies only to “Dual with 1 Flow Element” layouts where the element corresponds to the first compressor section.

17:2nd Stg Flow Element is **Monitor**
This displays the item name selected for the 2^{nd} stage flow element.

18:2nd Stg Temp Sensor **Initial=0 (0, 5)**
For Dual Stage layouts, select the location of the second compressor section’s temperature sensor(s) as “Suction,” “Discharge,” “Suction + Discharge,” “SideStream,” “SideStream + Discharge,” or “None.” This selection is required only for the Standard Algorithm, or if temperatures and flow will be displayed with the Universal Algorithm. If the gas composition is “Constant,” a temperature measurement is required, at a minimum, at the flow element. If “Variable,” temperature measurements are required in both the suction and discharge of the compressor.

19:2nd Stg Temp Sensor is **Monitor**
This displays the item name selected for the 2^{nd} stage temperature sensor.

20:Gas Component (Fixed=T) **Initial=TRUE (FALSE, TRUE)**
Set whether the process gas composition (molecular weight, ratio of specific heats, etc.) is “Fixed=TRUE” or “Variable=FALSE.” For example, select “Fixed” for a closed-loop refrigeration compressor, but a hydrocarbon recycle compressor in a refinery may require “Variable.” This selection is required only for the Standard Algorithm, as the Universal Algorithm is largely immune to gas composition changes. If “Variable” is configured with the Standard Algorithm, temperature measurements are required in both the suction and discharge of the compressor.

21:Offset for gauge press **Initial=0.0 (-200.0, 1.0E+10)**
Adjust the atmospheric pressure offset from its default mean sea level value. This will be added to the gauge pressure input signals to generate absolute pressure values. See Appendix C for a chart of altitude-referenced atmospheric pressures.

22:Use Metric Measurements? **Initial=TRUE (FALSE, TRUE)**
Set TRUE for metric (SI) units or FALSE for English (Imperial) units.

23:Select Pressure Units **Initial=2 (1, 9)**
Set the appropriate engineering unit for pressure:

1 = psi (English / Imperial)
2 = kPa (Metric / SI)
3 = Feet of H_2O (English / Imperial)
4 = kg/cm^2 (Metric / SI)
5 = atm (Metric / SI)
6 = $tons/ft^2$ (English / Imperial)
7 = Torr (English / Imperial)
8 = Inches Hg (English / Imperial)
9 = bar (Metric / SI)

24:Pressure Units is **Monitor**
This displays the item name selected for the pressure units.

25:Use Absolute Press Input **Initial=FALSE (FALSE, TRUE)**
Most internal calculations use absolute pressure measurements. If the pressure inputs (P1, P2, Pf) are calibrated in absolute pressure, set this field to TRUE.

26:Air Comp w/o P1 Signal **Initial=FALSE (FALSE, TRUE)**
Often, air compressors are installed without suction pressure transmitters since the suction pressure is known to be constant atmospheric pressure, ignoring barometric fluctuations. Set TRUE to force the control to use a constant 101.325 kPaA (or other atmospheric pressure offset, if configured) instead of the 4–20 mA P1 input signal.

Configure: 02*ANALOG INPUTS FUNCT*

Field Name		Value	Units	Description	Low	High	Initial
01:Programable AI #1 Func	*	22			0	35	22
02:Programable AI #1 Msg		Motor Current					
03:Programable AI #2 Func	*	27			0	35	27
04:Programable AI #2 Msg		Header Pressure for Load sharing					
05:Programable AI #3 Func	*	25			0	35	25
06:Programable AI #3 Msg		Flow #1 for Load sharing					

Figure 5-16. Configure: 02*ANALOG INPUTS FUNCT* Menu

Five analog inputs are fixed for flow, suction pressure, discharge pressure, suction temperature, and discharge temperature for the 1st compressor section, and nineteen (19) are configurable. If the Vertex-Pro uses the optional Analog Combo module, two (2) additional configurable analog inputs are added for a total of twenty-six (26). Select the appropriate function from the following function number—Each function can only be assigned once.

01:Programmable AI #1 Func **Initial=0 (0, 35)**
Select one of the following parameters for the programmable analog input #1.

0. Not Used
1. Stage 1 Raw Input Signal PF
2. Stage 1 Raw Input Signal TF
3. Stage 1 HSS Auxiliary Input 1
4. Stage 1 HSS Auxiliary Input 2
5. Stage 1 Remote Manual Valve Pos.
6. Stage 1 Redundant Flow Input
7. Stage 1 Redund. Suct. Prs. Input
8. Stage 1 Redund. Disch. Prs. Input
9. Stage 2 Raw Input Signal PF
10. Stage 2 Raw Input Signal TF
11. Stage 2 HSS Auxiliary Input 1
12. Stage 2 HSS Auxiliary Input 2
13. Stage 2 Remote Manual Valve Pos.
14. Stage 2 Redundant Flow Input
15. Stage 2 Redund. Suct. Prs. Input
16. Stage 2 Redund. Disch Prs. Input
17. Stage 2 Flow
18. Stage 2 Suction Pressure
19. Stage 2 Discharge Pressure
20. Stage 2 Suction Temperature
21. Stage 2 Discharge Temperature
22. Motor Current
23. Remote Spt of Load sharing #1
24. Remote Spt of Load sharing #2
25. Flow #1 for Load sharing
26. Flow #2 for Load sharing
27. Header Pressure for Load sharing
28. Throttle/IGV Remote Setpoint
29. External Speed Sensor

30. Remote Header Press Setpt
31. Stage 1 ASV Feedback
32. Stage 2 ASV Feedback
33. Throttle/IGV Feedback
34. Performance Process Input
35. Remote Performance Setpt

02:Programmable AI #1 Msg **Monitor**
This displays the item name selected for the programmable analog input #1.

The Programmable Analog Inputs #2 thru #21 are entered following the same rules as described for the Programmable Analog Input #1.

IMPORTANT **The last two (#20 and #21) of programmable inputs are accepted when using the optional Analog Combo Module for Vertex-Pro.**

Configure: 03*ANALOG INPUTS RANGE*

Field Name		Value	Units	Description	Low	High	Initial
01:AI Fail Min mA	*	2.00			0.00	6.00	2.00
02:AI Fail Max mA	*	22.00			20.00	25.00	22.00
03:C1-Flow 4mA Val	*	0.00			0.00	1e+010	0.00
04:C1-Flow 20mA Val	*	100.00			0.00	1e+010	100.00
05:C1-Suct Press 4mA Val	*	0.00			-200.00	1e+010	0.00
06:C1-Suct Press 20mA Val	*	100.00			-200.00	1e+010	100.00
07:C1-Disch Press 4mA Val	*	0.00			0.00	1e+010	0.00
08:C1-Disch Press 20mA Val	*	100.00			-200.00	1e+010	100.00
09:C1-Suct Temp 4mA Val	*	0.00			-1000.00	1000.00	0.00
10:C1-Suct Temp 20mA Val	*	100.00			-1000.00	1000.00	100.00
11:C1-Disch Temp 4mA Val	*	0.00			-1000.00	1000.00	0.00
12:C1-Disch Temp 20mA Val	*	100.00			-1000.00	1000.00	100.00
13:Program AI #1 4mA Val	*	0.00			-1000.00	1e+010	0.00
14:Program AI #1 20mA Val	*	100.00			-1000.00	1e+010	100.00
15:Program AI #2 4mA Val	*	0.00			-1000.00	1e+010	0.00
16:Program AI #2 20mA Val	*	100.00			-1000.00	1e+010	100.00

Figure 5-17. Configure: 03*ANALOG INPUTS RANGE* Menu

01: AI Fail Min mA **Initial=2.0 (0.0, 6.0)**
Set the value (in mA) that corresponds to the minimum failure point of all analog inputs. This setup is common to all analog inputs.

02: AI Fail Max mA **Initial=22.0 (20.0, 25.0)**
Set the value (in mA) that corresponds to the maximum failure point of all analog inputs. This setup is common to all analog inputs.

03:C1-Flow 4mA Val **Initial=0.0 (0.0, 1.0E+10)**
Set the value (in engineering units) that corresponds to the minimum range on the flow element of the 1st stage compressor.

04:C1-Flow 20mA Val **Initial=100.0 (0.0, 1.0E+10)**
Set the value (in engineering units) that corresponds to the maximum range on the flow element of the 1st stage compressor.

05:C1-Suct Press 4mA Val **Initial=0.0 (-200.0, 1.0E+10)**
Set the value (in engineering units) that corresponds to the minimum range on the suction pressure of the 1st stage compressor.

06:C1-Suct Press 20mA Val **Initial=100.0 (-200.0, 1.0E+10)**
Set the value (in engineering units) that corresponds to the maximum range on the suction pressure of the 1st stage compressor.

07:C1-Disch Press 4mA Val **Initial=0.0 (0.0, 1.0E+10)**
Set the value (in engineering units) that corresponds to the minimum range on the discharge pressure of the 1st stage compressor.

08:C1-Disch Press 20mA Val **Initial=100.0 (0.0, 1.0E+10)**
Set the value (in engineering units) that corresponds to the maximum range on the discharge pressure of the 1st stage compressor.

09:C1-Suct Temp 4mA Val **Initial=0.0 (-1000.0, 1000.0)**
Set the value (in engineering units) that corresponds to the minimum range on the suction temperature of the 1st stage compressor.

10:C1-Suct Temp 20mA Val **Initial=100.0 (-1000.0, 1000.0)**
Set the value (in engineering units) that corresponds to the maximum range on the suction temperature of the 1st stage compressor.

11:C1-Disch Temp 4mA Val **Initial=0.0 (-1000.0, 1000.0)**
Set the value (in engineering units) that corresponds to the minimum range on the discharge temperature of the 1st stage compressor.

12:C1-Disch Temp 20mA Val **Initial=100.0 (-1000.0, 1000.0)**
Set the value (in engineering units) that corresponds to the maximum range on the discharge temperature of the 1st stage compressor.

13:Program AI #1 4mA Val **Initial=0.0 (-1000.0, 1.0E+10)**
Set the value (in engineering units) that corresponds to the minimum range on programmable analog input #1.

14:Program AI #1 20mA Val **Initial=100.0 (-1000.0, 1.0E+10)**
Set the value (in engineering units) that corresponds to the maximum range on programmable analog input #1.

The Programmable Analog Input Ranges #2 thru #21 are entered following the same rules as described for Programmable Analog Input Range #1.

Configure: 04*ANALOG OUTPUTS FUNCT*

Field Name		Value	Units	Description	Low	High	Initial
01:Programmable AO #1 Func	*	0			0	33	0
02:Programmable AO #1 Msg		Not Used					
03:Programmable AO #2 Func	*	0			0	33	0
04:Programmable AO #2 Msg		Not Used					
05:Programmable AO #3 Func	*	0			0	33	0
06:Programmable AO #3 Msg		Not Used					

Figure 5-18. Configure: 04*ANALOG OUTPUTS FUNCT* Menu

One (1) analog output is assigned for the 1st anti-surge valve, and seven (7) are configurable. Select the appropriate function from the following function number—Each function can be assigned simultaneously.

01:Programmable AO #1 Func **Initial=0 (0, 33)**

Select one of the following parameters for programmable analog output #1.

0. Not Used
1. Stage 1 Surge Process Variable (S_PV)
2. Stage 1 Actual Suction Volumetric Flow
3. Stage 1 Corrected Suction Volumetric Flow
4. Stage 1 Stage Flow
5. Stage 1 Polytropic Head
6. Stage 1 Pressure Ratio
7. Stage 1 Suction Press
8. Stage 1 Discharge Pressure
9. Stage 1 Suction Temperature
10. Stage 1 Discharge Temperature
11. Stage 1 Sensor Flow
12. Stage 1 HSS Output
13. Stage 1 Valve Percentage
14. Stage 2 Surge Process Variable (S_P)
15. Stage 2 Actual Suction Volumetric Flow
16. Stage 2 Corrected Suction Volumetric Flow
17. Stage 2 Stage Flow
18. Stage 2 Polytropic Head
19. Stage 2 Pressure Ratio
20. Stage 2 Suction Pressure
21. Stage 2 Discharge Pressure
22. Stage 2 Suction Temperature
23. Stage 2 Discharge Temperature
24. Stage 2 Sensor Flow
25. Stage 2 HSS Output
26. Stage 2 Valve Percentage
27. Stage 2 Valve Demand
28. Throttle/IGV Demand
29. Load Sharing Remote Setpoint
30. Stage 1 ASV Position Feedback
31. Stage 2 ASV Position Feedback
32. Throttle/IGV Position Feedback
33. Header Pressure

02:Programmable AO #1 Msg **Monitor**

This displays the item name selected for the programmable analog output #1.

Programmable Analog Outputs #2 thru #7 are entered following the same rules as described for Programmable Analog Output #1.

Configure: 05*ANALOG OUTPUTS RANGE*

Field Name		Value	Units	Description	Low	High	Initial
01:Stage 1 ASV 4mA Val	*	0.00			-1000.00	1e+010	0.00
02:Stage 1 ASV 20mA Val	*	100.00			-1000.00	1e+010	100.00
03:Program AO #1 4mA Val	*	400.00			-1000.00	1e+010	400.00
04:Program AO #1 20mA Val	*	1200.00			-1000.00	1e+010	1200.00
05:Program AO #2 4mA Val	*	0.00			-1000.00	1e+010	0.00
06:Program AO #2 20mA Val	*	100.00			-1000.00	1e+010	100.00
07:Program AO #3 4mA Val	*	90.00			-1000.00	1e+010	90.00
08:Program AO #3 20mA Val	*	250.00			-1000.00	1e+010	250.00

Figure 5-19. Configure: 05*ANALOG OUTPUTS RANGE* Menu

01:Stage 1 ASV 4mA Val **Initial=0.0 (-1000.0, 1.0E+10)**
Set the value (in engineering units) that corresponds to the minimum range on the ASV (anti-surge valve) of the 1st stage compressor.

02:Stage 1 ASV 20mA Val **Initial=100.0 (-1000.0, 1.0E+10)**
Set the value (in engineering units) that corresponds to the maximum range on the ASV (anti-surge valve) of the 1st stage compressor.

03:Program AO #1 4mA Val **Initial=0.0 (-1000.0, 1.0E+10)**
Set the value (in engineering units) that corresponds to the minimum range on programmable analog output #1.

04:Program AO #1 20mA Val **Initial=100.0 (-1000.0, 1.0E+10)**
Set the value (in engineering units) that corresponds to the maximum range on programmable analog output #1.

Programmable Analog Output Ranges #2 thru #7 are entered following the same rules as described for Programmable Analog Output Range #1.

Configure: 06*ANALOG OUTPUTS ADJUST*

Field Name		Value	Units	Description	Low	High	Initial
01:ASV#1 Force Enable	*	False					False
02:ASV#1 Go to Min	*	False					False
03:ASV#1 Go to Max	*	False					False
04:Stage 1 ASV Min Offset	*	4.00			0.00	6.00	4.00
05:Stage 1 ASV Max Offset	*	20.00			18.00	25.00	20.00
06:AO#1 Force Enable	*	False					False
07:AO#1 Go to Min	*	False					False
08:AO#1 Go to Max	*	False					False
09:Program AO #1 Min Offset	*	4.00			0.00	6.00	4.00
10:Program AO #1 Max Offset	*	20.00			18.00	25.00	20.00
11:AO#2 Force Enable	*	False					False
12:AO#2 Go to Min	*	False					False
13:AO#2 Go to Max	*	False					False
14:Program AO #2 Min Offset	*	4.00			0.00	6.00	4.00
15:Program AO #2 Max Offset	*	20.00			18.00	25.00	20.00

Figure 5-20. Configure: 06*ANALOG OUTPUTS ADJUST* Menu

IMPORTANT

To configure a Fail Open valve, valve action could be reversed by setting the Min Position Value to 100% and the Max Position Value to 0%. This would have the same effect as configuring the valve as Fail Open on the I/O Configuration Screen. However, it is recommended to use the latter method and leave the 4–20 mA range values at their defaults. If both methods are accidentally employed at the same time (Fail Open configured and mA calibration reversed), the valve will not operate as desired.

01:ASV#1 Force Enable **Initial=FALSE (FALSE, TRUE)**
Forcing function is provided for maintenance and testing for the 1st stage anti-surge valve. Set TRUE to enable forcing. When forcing is complete, set FALSE again to disable.

02:ASV#1 Go to Min **Initial=FALSE (FALSE, TRUE)**
By lowering the Min mA setting for the 1st stage anti-surge valve, the valve can be adjusted to be at its minimum stop setpoint (normally full recycle flow at 100%). To go to the minimum mA setpoint, set this tunable momentarily to TRUE . Once toggled, a set of 100% flow or 100% open will be reached. When forcing is complete, return “01:ASV#1 Force Enable”to FALSE to disable.

03:ASV#1 Go to Max **Initial=FALSE (FALSE, TRUE)**
By raising the Max mA setting for the 1st stage anti-surge valve, the valve can be adjusted to be at its maximum stop setpoint (normally 0 recycle flow at 0%). To go to the maximum mA setpoint, set this tunable momentarily to TRUE. Once toggled, a set of 0% flow or full close will be reached. When forcing is complete, return "01:ASV#1 Force Enable" to FALSE to disable.

04:Stage 1 ASV Min Offset **Initial=4.0 (0.0, 6.0)**
This is where to input the minimum stop (4 mA) Offset.

05:Stage 1 ASV Max Offset **Initial=20.0 (0.0, 25.0)**
This is where to input the maximum stop (20 mA) Offset.

06:AO#1 Force Enable **Initial=FALSE (FALSE, TRUE)**
Forcing function is provided for maintenance and testing of the programmable analog output #1. Set TRUE to enable forcing. When forcing is complete, set FALSE again to disable.

07:AO#1 Go to Min **Initial=FALSE (FALSE, TRUE)**
By lowering the Min mA setting of the programmable analog output #1, the valve can be adjusted to be at its minimum stop setpoint (0%). To go to the minimum mA setpoint, set this tunable momentarily to TRUE. Once toggled, a set of 0% setpoint will be reached. When forcing is complete, return "06:AO#1 Force Enable" to FALSE to disable.

08:AO#1 Go to Max **Initial=FALSE (FALSE, TRUE)**
By raising the Max mA setting of the programmable analog output #1, the valve can be adjusted to be at its maximum stop setpoint (100%). To go to the maximum mA setpoint, set this tunable momentarily to TRUE. Once toggled, a set of 100% setpoint will be reached. When forcing is completed, return "06:AO#1 Force Enable" to FALSE to disable.

09:Program AO #1 Min Offset **Initial=4.0 (0.0, 6.0)**
This is where to input the minimum stop (4 mA) Offset.

10:Program AO #1 Max Offset **Initial=20.0 (0.0, 25.0)**
This is where to input the maximum stop (20 mA) Offset.

Programmable Analog Output Calibrations #2 to #7 are entered following the same rules as described for Programmable Analog Output Calibration #1.

Configure: 07*CONTACT INPUTS FUNCT*

Field Name		Value	Units	Description	Low	High	Initial
01:Programable BI #1 Func	*	11			0	52	11
02:Programable BI #1 Msg		Stage 1 Start Position					
03:Programable BI #2 Func	*	34			0	52	34
04:Programable BI #2 Msg		Throttle/IGV Raise					
05:Programable BI #3 Func	*	35			0	52	35
06:Programable BI #3 Msg		Throttle/IGV Lower					

Figure 5-21. Configure: 07*CONTACT INPUTS FUNCT* Menu

Two (2) discrete inputs are fixed for External Trip and Alarm/Trip Reset commands. There are thirty-six (36) configurable discrete inputs available for the compressor control. Select the appropriate function from the following list—Each function can only be assigned once.

01:Programmable BI #1 Func **Initial=0 (0, 55)**

Select one of the following parameters for the programmable contact input #1.

0. Not Used
1. Stage 1 Reset SMP
2. Stage 1 Reset Surge Capture Info.
3. Stage 1 Select AUTO Mode
4. Stage 1 Select MANUAL w/ BACKUP
5. Stage 1 Select FULL MANUAL Mode
6. Stage 1 Purge Position
7. Stage 1 Online Auxiliary Input
8. Stage 1 Control Margin Increase
9. Stage 1 Control Margin Decrease
10. Stage 1 AS Valve Output Fault
11. Stage 1 Start Position
12. Stage 1 Shutdown
13. Stage 2 Reset SMP
14. Stage 2 Reset Surge Capture Info
15. Stage 2 Select AUTO Mode
16. Stage 2 Select MANUAL w/ BACKUP
17. Stage 2 Select FULL MANUAL Mode
18. Stage 2 Purge Position
19. Stage 2 Online Auxiliary Input
20. Stage 2 Control Margin Increase
21. Stage 2 Control Margin Decrease
22. Stage 2 AS Valve Output Fault
23. Stage 2 Start Position
24. Stage 2 Shutdown
25. Performance Setpoint Raise
26. Performance Setpoint Lower
27. Performance Control Enable
28. Performance Remote Setp Enable
29. Current Limit Raise
30. Current Limit Lower
31. Load Sharing Enable
32. Load Sharing Permissive #2
33. Load Sharing Permissive #3
34. Throttle/IGV Raise
35. Throttle/IGV Lower
36. Throttle/IGV Remote Enable
37. Stage 1 Open Anti-Surge Valve
38. Stage 1 Close Anti-Surge Valve
39. Stage 2 Open Anti-Surge Valve
40. Stage 2 Close Anti-Surge Valve
41. Another Load sharing Enabled #1
42. Another Load sharing Enabled #2
43. Stage 1 Remote Manual Enable
44. Stage 2 Remote Manual Enable
45. Header Press Remote Setp Enable
46. Start Permissive
47. Load Sharing #1 is Master
48. Load Sharing #2 is Master
49. External Trip #2
50. External Trip #3
51. External Trip #4
52. External Trip #5
53. Load Sharing #1 No Shutdown
54. Load Sharing #2 No Shutdown
55. Local / Remote

02:Programmable BI #1 Msg **Monitor**
This displays the item name selected for the programmable contact input #1.

Programmable Contact Inputs #2 to #36 are entered following the same rules as described for Programmable Contact Input #1.

Configure: 08*CONTACT OUTPUTS LEVEL*

Field Name		Value	Units	Description	Low	High	Initial
01:Prog BO #1 Level SW	*	0			0	33	0
02:Prog BO #1 Msg		Not Used					
03:Prog BO #1 ON Level	*	0.00			-10000.00	1e+010	0.00
04:Prog BO #1 OFF Level	*	0.00			-10000.00	1e+010	0.00
05:Prog BO #2 Level SW	*	0			0	33	0
06:Prog BO #2 Msg		Not Used					
07:Prog BO #2 ON Level	*	0.00			-10000.00	1e+010	0.00
08:Prog BO #2 OFF Level	*	0.00			-10000.00	1e+010	0.00

Figure 5-22. Configure: 08*CONTACT OUTPUTS LEVEL* Menu

Two (2) contact outputs are fixed for Shutdown and Alarm status. There are eighteen (18) configurable discrete outputs available from the compressor control.

IMPORTANT

Contact outputs can be configured as a level switch and as a status indication. Priority is given to the level switch over the status indication when both the level switch and the status indication are set to the same contact output.

There is an ON and an OFF setting for each level switch option. When configured as a level switch the relay will change state when the selected parameter reaches the programmed ON level. The relay energizes when the value is higher the ON level when the configuration is ON >= OFF. The relay energizes when the value is lower the ON level when the configuration is ON <= OFF. Select the appropriate function for the level switch from the following.

01:Prog BO #1 Level SW **Initial=0 (0, 33)**
Select one of the following parameters for the programmable level switch #1.

0. Not Used
1. Stage 1 Surge Process Variable (S_PV)
2. Stage 1 Actual Suction Volumetric Flow
3. Stage 1 Corrected Suction Volumetric Flow
4. Stage 1 Stage Flow
5. Stage 1 Polytropic Head
6. Stage 1 Pressure Ratio
7. Stage 1 Suction Pressure
8. Stage 1 Discharge Pressure
9. Stage 1 Suction Temperature
10. Stage 1 Discharge Temperature
11. Stage 1 Sensor Flow
12. Stage 1 HSS Output
13. Stage 1 Valve Percent
14. Stage 2 Surge Process Variable (S_P)
15. Stage 2 Actual Suction Volumetric Flow
16. Stage 2 Corrected Suction Volumetric Flow
17. Stage 2 Stage Flow

18. Stage 2 Polytropic Head
19. Stage 2 Pressure Ratio
20. Stage 2 Suction Pressure
21. Stage 2 Discharge Pressure
22. Stage 2 Suction Temperature
23. Stage 2 Discharge
24. Stage 2 Sensor Flow
25. Stage 2 HSS Output
26. Stage 2 Valve Percent
27. Stage 2 Valve Demand
28. Throttle/IGV Demand
29. Load sharing Remote Setpoint
30. Stage 1 ASV Position
31. Stage 2 ASV Position
32. Throttle/IGV Position
33. Header Pressure

02:Prog BO #1 Msg **Monitor**
This displays the item name selected for programmable level switch #1.

03:Prog BO #1 ON Level **Initial=0.0 (-10000.0, 1.0E+10)**
Enter the level switch ON setting in engineering units. The relay will energize once the selected parameter's level is at this setting.

04:Prog BO #1 OFF Level **Initial=0.0 (-10000.0, 1.0E+10)**
Enter the level switch OFF setting in engineering units. This allows the user to program the desired hysteresis for the function selected. The relay will remain energized until the parameter's level is at this setting.

Programmable Contact Outputs #2 to #18 are entered following the same rules as described for the Programmable Contact Output #1.

Configure: 09*CONTACT OUTPUTS FUNCT*

Field Name		Value	Units	Description	Low	High	Initial
01:Programmable BO #1 Func	*	0			0	23	0
02:Programmable BO #1 Msg		Not Used					
03:Programmable BO #2 Func	*	0			0	23	0
04:Programmable BO #2 Msg		Not Used					
05:Programmable BO #3 Func	*	0			0	23	0
06:Programmable BO #3 Msg		Not Used					

Figure 5-23. Configure: 09*CONTACT OUTPUTS FUNCT* Menu

Two (2) contact outputs are fixed for Shutdown and Alarm status. There are eighteen (18) configurable discrete outputs available from the compressor control. Select the appropriate function for the status indication from the following.

01:Programmable BO #1 Func **Initial=0 (0, 23)**
Select one of the following parameters for the programmable status indication #1.

0. Not Used
1. Off Line-Controlled SD
2. Off Line-Emergency SD
3. Off Line-Zero Speed
4. Off Line-Purge
5. Off Line-Start

6. On Line
7. Stage 1 Surge Detected
8. Stage 1 Surge Min Pos(SMP)
9. Stage 1 AUTO Mode
10. Stage 1 MANUAL /w BACKUP
11. Stage 1 FULL MANUAL
12. Stage 2 Surge Detected
13. Stage 2 Surge Min Pos(SMP)
14. Stage 2 AUTO Mode
15. Stage 2 MANUAL /w BACKUP
16. Stage 2 FULL MANUAL
17. Load Sharing Permissive
18. Load Sharing Enabled
19. Load Sharing Active
20. Load Sharing Master
21. Current Limited
22. Performance Control Active
23. Ready to Start

02:Programmable BO #1 Msg **Monitor**
This displays the item name selected for programmable current status #1.

Programmable Contact Output #2 to #18 are entered following the same rules as described for Programmable Contact Output #1.

Configure: 10*PERFORMANCE CONTROL*

Field Name		Value	Units	Description	Low	High	Initial
01:Use Performance Control?	*	False					False
02:Select Perform Source	*	0			0	7	0
03:Controled Signal is		Not Used					
04:Invert Performance Input	*	False					False
05:Use Setpoint Tracking?	*	True					True
06:Minimum Setpoint	*	0.00			-10000.00	1e+010	0.00
07:Maximum Setpoint	*	100.00			-10000.00	1e+010	100.00
08:Setpoint Initial Value	*	0.00			-10000.00	1e+010	0.00
09:Setpoint Default Rate	*	3.00			0.01	9e+020	3.00
10:Setpoint Fast Rate Delay	*	5.00			0.00	100.00	5.00
11:Setpoint Fast Rate	*	9.00			0.01	1e+010	9.00
12:Performance Droop	*	2.00			0.00	10.00	2.00
13:Proportional Gain	*	1.00			0.00	100.00	1.00
14:Integral Gain	*	0.30			0.001	10.00	0.30
15:Speed Derivative Ratio	*	100.00			0.01	100.00	100.00
16:Perform Control Deadband	*	0.00			0.00	100.00	0.00
17:Remote Setpoint Rate	*	10.00			0.01	1e+010	10.00
18:Remote Min Setpoint	*	0.00			-10000.00	1e+010	0.00
19:Remote Max Setpoint	*	100.00			-10000.00	1e+010	100.00
20:Use Perform Auto Enable?	*	False					False
21:Select Target for Auto	*	0			0	10	0
22:Target for auto is		Not Used					
23:Auto Enable Setpt(units)	*	0.00			-1e+010	1e+010	0.00
24:Auto Enbl is Less Equal?	*	False					False
25:Auto Hysteresis (units)	*	0.00			-10000.00	10000.00	0.00

Figure 5-24. Configure: 10*PERFORMANCE CONTROL* Menu

Performance control is maintained by using a throttle valve or IGV to a suction/discharge pressure or a flow value of the compressor train.

IMPORTANT **Performance control is the base control for the execution of load sharing. If load sharing control is used, configured performance controls are necessary.**

01:Use Performance Control? **Initial=FALSE (FALSE, TRUE)**
Set TRUE to configure the performance control function. Select FALSE if the performance function is not used.

02:Select Perform Source **Initial=0 (0, 7)**
Select one of the following parameters for the performance control source. When using performance control, a certain signal must be chosen.

0. Not Used
1. Configurable Analog Input
2. Train Suction Pressure
3. Train Discharge Pressure
4. Stage 1 Mass/Normal Flow
5. Stage 1 Inlet Volumetric Flow
6. Stage 2 Mass/Normal Flow
7. Stage 2 Inlet Volumetric Flow

03:Controlled Signal is **Monitor**
This displays the item name selected for the performance control source.

04:Invert Performance Input **Initial=FALSE (FALSE, TRUE)**
Set TRUE if the performance control will be reverse acting. If FALSE is set, the control will be forward acting. If TRUE is set, this option will result in the throttle valve or IG Valve decreasing, to increase the performance input parameter. An example of when the input would be inverted is when the performance control PID is being used for compressor suction pressure control

05:Use Setpoint Tracking? **Initial=TRUE (FALSE, TRUE)**
If TRUE, the setpoint will track the performance input to allow bumpless transfer to control mode. If FALSE, the setpoint will initialize to the 'Setpoint Initial Value' on power-up.

06:Minimum Setpoint **Initial=0.0 (-10000.0, 1.0E+10)**
Set the minimum performance setpoint. This value is the minimum setpoint value that the performance setpoint can be decreased/lowered to (the lower limit of performance setpoint).

07:Maximum Setpoint **Initial=100.0 (-10000.0, 1.0E+10)**
Set the maximum performance setpoint. This value is the maximum setpoint value that the performance setpoint can be increased/raised to (the upper limit of performance setpoint).
(Must be greater than the 'Minimum Setpoint' Setting)

08:Setpoint Initial Value **Initial=0.0 (-10000.0, 1.0E+10)**
Set the setpoint initialization value. When not using the Setpoint Tracking function, this is the value that the performance setpoint initializes to upon power-up or exiting the program mode.
(Must be less than or equal to the 'Maximum Setpoint' Setting)

09:Setpoint Default Rate **Initial=3.0 (0.01, 500.0)**
Set the performance setpoint slow rate. This value is the rate (in units per second) at which the performance setpoint moves when adjusted.

10:Setpoint Fast Rate Delay **Initial=5.0 (0.0, 100.0)**
This value will determine how long the Setpoint Slow Rate will have to be selected before the Setpoint Fast Rate will be engaged. The default is 5 seconds. This implies that if a Raise Performance Setpoint command is continually given, the Performance Setpoint will raise at the slow rate for 5 seconds and then raise at the fast rate after that.

11:Setpoint Fast Rate **Initial=9.0 (0.01, 1.0E+10)**
This value (in units per second) will determine how fast the performance setpoint will raise or lower when the Fast Rate is initiated.

12:Performance Droop **Initial=2.0 (0.0, 10.0)**
Enter the droop percentage. If needed, this is typically set between 2-6% and not more than 10%.

13:Proportional Gain **Initial=1.0 (0.0, 100.0)**
Enter the performance PID proportional gain value. This value is used to set the performance control response. This value can be changed in the Run Mode while the motor is operating. If unknown, a recommended starting value is 1%.

14:Integral Gain **Initial=0.3 (0.001, 10.0)**
Enter the performance PID integral gain value, in repeats-per-second (rps). This value is used to set the performance control response. This value can be changed in the Run Mode while the motor is operating. If unknown, a recommended starting value is 0.3 rps.

15:Speed Derivative Ratio **Initial=100.0 (0.01, 100.0)**
Enter the performance PID derivative ratio. This value is used to set performance control response. This value can be changed in the Service Mode while the motor is operating. If unknown, a recommended starting value is 100%.

16:Perform Control Deadband **Initial=0.0 (0.0, 100.0)**
This value will determine the deadband in the Remote Performance Setpoint input. The default value is set to zero. In the event that the input signal is noisy or drifts, a small deadband value can be added to allow stability during normal operation, and still permit movement on the Performance Setpoint when needed.

17:Remote Setpoint Rate **Initial=10.0 (0.01, 1.0E+10)**
Enter the maximum desired rate (in units per second) that the Performance Setpoint will change for a large step change in the Remote Performance Setpoint signal.

18:Remote Min Setpoint **Initial=0.0 (-10000.0, 1.0E+10)**
Set the minimum remote performance setpoint. This value is the minimum setpoint value that the remote performance setpoint can be decreased/lowered to (the lower limit of the performance setpoint).
(Must be greater than the 'Minimum Setpoint' Setting)

19:Remote Max Setpoint **Initial=100.0 (-10000.0, 1.0E+10)**
Set the maximum remote performance setpoint. This value is the maximum setpoint value that the remote performance setpoint can be increased/raised to (the upper limit of the performance setpoint).
(Must be greater than the 'Remote Minimum Setpoint' Setting)

20:Use Performance Auto Enable? **Initial=FALSE (FALSE, TRUE)**
If set TRUE, the performance control will be automatically change to enable under the programmed condition. In order to use this function, the following surveillance selection is required.

21:Select Target Input for Auto Initial=0 (0, 10)
The Vertex-Pro can enable performance control automatically. If applicable, select one of the following parameters for the automatic performance enable source.

0. Not Used
1. Configurable Analog Input
2. Header Pressure
3. Stage 1 Suction Pressure
4. Stage 1 Discharge Pressure
5. Stage 1 Mass/Normal Flow
6. Stage 1 Inlet Volumetric Flow
7. Stage 2 Suction Pressure
8. Stage 2 Discharge Pressure
9. Stage 2 Mass/Normal Flow
10. Stage 2 Inlet Volumetric Flow

22:Target for auto is Monitor
This displays the item name selected for the automatic performance enable source.

23:Auto Enable Setpoint (units) Initial=0.0 (-1.0E+10, 1.0E+10)
Enter the value which confirms performance control automatically. Performance control is automatically confirmed below or above this value.

24:Auto Enable is Smaller Equal? Initial=FALSE (FALSE, TRUE)
If TRUE is inputted, the performance control will become effective automatically below the Auto Enable Setpoint, and will become invalid automatically above Auto Enable Setpoint. If FALSE is inputted, the performance control will become effective automatically above the Auto Enable Setpoint, and will become invalid automatically below the Auto Enable Setpoint.

25:Auto Hysteresis (units) Initial=0.0 (-10000, 10000)
Enter the hysteresis (in engineering units) which determines the enable position of the performance control. Hysteresis influences the point at which this becomes effective, and the point at which this becomes invalid.

Configure: 11*Throttle/IGV Ramp*

Field Name		Value	Units	Description	Low	High	Initial
01:Use Throttle/IGV Ramp?	*	True					True
02:Shutdown Position(%)	*	0.00			0.00	100.00	0.00
03:Minimum Position(%)	*	5.00			0.00	100.00	5.00
04:Maximum Position(%)	*	100.00			0.00	100.00	100.00
05:Manual Control Rate(%/sec)	*	2.00			0.00	10000.00	2.00
06:Remote Control Rate(%/sec)	*	10.00			0.00	9e+020	10.00
07:Use automatic open?	*	False					False
08:Auto Open Start Pos(%)	*	30.00			0.00	9e+020	30.00
09:Auto Open Rate(%/sec)	*	0.20			0.00	10000.00	0.20
10:Auto Open Waiting Time(sec)	*	45.00			0.00	3600.00	45.00

Figure 5-25. Configure: 11*Throttle/IGV Ramp* Menu

The Throttle valve or Inlet Guide Vane (IGV) will adjust the compressor inlet flow. This function determines the position of the Throttle/IGV. After a motor start, the Throttle/IGV opens at the programmed valve position automatically. The valve position is manually adjusted by an open or close contact input. When a shutdown occurs, the Throttle/IGV closes immediately to the programmed shutdown position.

01:Use Throttle/IGV Ramp? **Initial=FALSE (FALSE, TRUE)**
Set TRUE to use the Throttle/IGV Ramp function. Select FALSE if the Throttle/IGV Ramp function is not used except during a shutdown state.

02:Shutdown Position(%) **Initial=0.0 (0.0, 100.0)**
Set the shutdown position for the Throttle valve or IGV. This setup is effective also when not using the Throttle/IGV Ramp function.

03:Minimum Position(%) **Initial=0.0 (0.0, 100.0)**
Set the minimum position for the Throttle valve or IGV. This value is the close limit or starting position of the Throttle valve or IGV.

04:Maximum Position(%) **Initial=100.0 (0.0, 100.0)**
Set the maximum position for the Throttle valve or IGV. This value is the open limit of the Throttle valve or IGV.

05:Manual Control Rate(%/sec) **Initial=2.0 (0.0, 10000.0)**
Set the Throttle/IGV Ramp slow rate. This value is the rate (in percent per second) at which the Throttle/IGV moves when adjusted.

06:Remote Control Rate(%/sec) **Initial=10.0 (0.0, 10000.0)**
Enter the maximum desired rate that the Throttle/IGV position will change for a large step change in the Remote Throttle/IGV Setpoint signal.

07:Use automatic open? **Initial=FALSE (FALSE, TRUE)**
Set TRUE to use the Throttle/IGV Ramp automatic open. Select FALSE if the Throttle/IGV Ramp automatic open is not used.

08:Auto Open Start Pos(%) **Initial=30.0 (0.0, 100.0)**
Set the start position in automatic opening of the Throttle/IGV Ramp. This setup is invalid when the automatic opening function is not used.

09:Auto Open Rate(%/sec) **Initial=0.2 (0.0, 10000.0)**
Set the change rate in automatic opening of the Throttle/IGV Ramp.

10:Auto Open Waiting Time(sec) **Initial=0.0 (0.0, 3600.0)**
Enter the waiting time after a motor start until the Throttle valve or IGV automatic opening function is used.

Configure: 12*Current Limit Control*

Field Name		Value	Units	Description	Low	High	Initial
01:Use Current Limit?	*	True					True
02:Invert Current Input	*	False					False
03:Initial Setpoint(units)	*	1000.00			0.00	9e+020	1000.00
04:Min Setpoint(units)	*	0.00			0.00	9e+020	0.00
05:Max Setpoint(units)	*	1200.00			0.00	9e+020	1200.00
06:Stpt Man Rate(units/sec)	*	5.00			0.00	9e+020	5.00
07:Stpt Rmt Rate(units/sec)	*	5.00			0.00	9e+020	5.00
08:Use Sequence Limit?	*	True					True
09:Current X1	*	0.00			-10.00	1e+010	0.00
10:Current X2	*	400.00			-10.00	1e+010	400.00
11:Current X3	*	600.00			-10.00	1e+010	600.00
12:Current X4	*	800.00			-10.00	1e+010	800.00
13:Current X5	*	1000.00			-10.00	1e+010	1000.00
14:Position Y1	*	100.00			-10.00	110.00	100.00
15:Position Y2	*	100.00			-10.00	110.00	100.00
16:Position Y3	*	95.00			-10.00	110.00	95.00
17:Position Y4	*	90.00			-10.00	110.00	90.00
18:Position Y5	*	70.00			-10.00	110.00	70.00
19:Sequence Opn Rate(%/sec)	*	2.00			0.00	100000.00	2.00
20:Sequence Cls Rate(%/sec)	*	2.00			0.00	100000.00	2.00

Figure 5-26. Configure: 12*Current Limit Control* Menu

Current limit control adjusts Throttle/IGV and prevents the over-current of the motor. The sequence limit to which valve position is changed can be used together with motor current. In order to use this function, the motor current analog input is required.

01:Use Current Limit? Initial=FALSE (FALSE, TRUE)
Set TRUE to use the current limitation function. Select FALSE if the current limiting function is not used.

02:Invert Current Input Initial=FALSE (FALSE, TRUE)
Set TRUE if the current limit control will be reverse acting. If FALSE is set, this will result in the throttle valve or IGV decreasing via the current limit PID control, to prevent the over-current of the motor. If TRUE is set, the control will be reverse acting. An example of when the input would be inverted is when the input signal of the motor current decreases with compressor load.

03:Initial Setpoint(units) Initial=1000.0 (0.0, 9.0E+20)
Set the setpoint initialization value. This is the value that the current limit setpoint initializes to upon power-up or exiting program mode.
(Must be more than or equal to the 'Minimum Setpoint' Setting)

04:Min Setpoint(units) Initial=0.0 (0.0, 9.0E+20)
Set the minimum current limit setpoint. This value is the minimum setpoint value that the current limit setpoint can be decreased/lowered to (lower limit of the setpoint).

05:Max Setpoint(units) Initial=1200.0 (0.0, 9.0E+20)
Set the maximum current limit setpoint. This value is the maximum setpoint value that the current limit setpoint can be increased/raised to (upper limit of the setpoint).

06:Stpt Man Rate(units/sec) Initial=5.0 (0.0, 9.0E+20)
Set the current limit setpoint manual control rate. This value is the rate (in units per second) at which the current limit setpoint moves when adjusted.

07:Stpt Rmt Rate(units/sec) Initial=5.0 (0.0, 9.0E+20)
Set the current limit setpoint remote control rate. This value is the rate (in units per second) at which the current limit setpoint moves when adjusted by an external 4–20 mA analog input.

08:Use Sequence Limit? Initial=FALSE (FALSE, TRUE)
This function will limit the Throttle/IGV position with the set-up current value. Set TRUE, if the planned sequence position is used for Throttle/IGV. Select FALSE if the planned sequence position is not used.

09:Current X1 Initial=0.0 (-10.0, 1.0E+10)
Input point #1 of the motor current value, in engineering units.
(Must be less than the 'Current X2 Value')

10:Current X2 Initial=400.0 (-10.0, 1.0E+10)
Input point #2 of the motor current value, in engineering units.
(Must be less than the 'Current X3 Value')

11:Current X3 Initial=600.0 (-10.0, 1.0E+10)
Input point #3 of the motor current value, in engineering units.
(Must be less than the 'Current X4 Value')

12:Current X4 Initial=800.0 (-10.0, 1.0E+10)
Input point #4 of the motor current value, in engineering units.
(Must be less than the 'Current X5 Value')

13:Current X5 Initial=1000.0 (-10.0, 1.0E+10)
Input point #5 of the motor current value, in engineering units.

14:Position Y1 Initial=100.0 (-10.0, 110)
Input point #1 of the Throttle valve or IGV position, in percent. This is the valve position at current X1.
(Must be less than the 'Position Y2 Value')

15:Position Y2 Initial=100.0 (-10.0, 110)
Input point #2 of the Throttle valve or IGV position, in percent. This is the valve position at current X2.
(Must be less than the 'Position Y3 Value')

16:Position Y3 Initial=95.0 (-10.0, 110)
Input point #3 of the Throttle valve or IGV position, in percent. This is the valve position at current X3.
(Must be less than the 'Position Y4 Value')

17:Position Y4 Initial=90.0 (-10.0, 110)
Input point #4 of the Throttle valve or IGV position, in percent. This is the valve position at current X4.
(Must be less than the 'Position Y5 Value')

18:Position Y5 Initial=70.0 (-10.0, 110)
Input point #5 of the Throttle valve or IGV position, in percent. This is the valve position at current X5.

19:Sequence Opn Rate(%/sec) Initial=2.0 (0.0, 10000)
Set the rate of opening the Throttle or IGV via sequence. This value is the rate (in percentage per second) at which the Throttle/IGV opens with the set-up current value.

20:Sequence Cls Rate(%/sec) Initial=2.0 (0.0, 10000)
Set the rate of closing the Throttle or IGV via sequence. This value is the rate (in percent per second) at which the Throttle/IGV closes with the set-up current value.

Configure: 13*Load Sharing Control*

Field Name		Value	Units	Description	Low	High	Initial
01:Use Load Sharing?	*	False					False
02:Use CAN Comm?	*	True					True
03:Invert Header Ctrl?	*	False					False
04:Train Sequence Number	*	1			1	3	1
05:Train 1 Load Setting	*	50.00			0.00	1000.00	50.00
06:Train 2 Load Setting	*	50.00			0.00	1000.00	50.00
07:Train 3 Load Setting	*	50.00			0.00	1000.00	50.00
08:Use Setpoint Tracking?	*	True					True
09:Initial Setpoint(units)	*	2000.00			-10000.00	1e+010	2000.00
10:Min Setpoint(units)	*	0.00			-10000.00	1e+010	0.00
11:Max Setpoint(units)	*	2000.00			-10000.00	1e+010	2000.00
12:Setpt Man Rate(units/sec)	*	5.00			0.01	9e+020	5.00
13:Setpt Rmt Rate(units/sec)	*	10.00			0.00	9e+020	10.00
14:Header Press DB(units)	*	3.00			0.00	1e+010	3.00
15:Flow Balance DB(units)	*	0.00			0.00	1e+010	0.00
16:Flow Balance Delay(sec)	*	1.00			0.00	100.00	1.00
17:Header Ctrl Rate(/sec)	*	2.00			0.00	9e+020	2.00
18:Flow Ctrl Rate(/sec)	*	0.70			0.00	9e+020	0.70

Figure 5-27. Configure: 13*Load Sharing Control* Menu

IMPORTANT **Performance control is the base control for the execution of load sharing. If load sharing control is used, configured performance controls are necessary.**

The Vertex-Pro can perform load sharing of the compressor train for three sets connected in parallel. The controller keeps the suction/discharge header pressure constant using performance control. The performance controller controls the compressor’s suction/discharge pressure at the required pressure via the throttle valve or IGV. When three compressors are working in parallel, the load sharing system keeps them equidistant from their surge control lines through communication with each sets’ performance controller. Furthermore, the controllers keep loading of each compressor train constant by making all mass flows the same. The communication of information between each controller for load sharing is selectable. This can be through direct hardwired connections or CAN communication.

For a three-set load balance, the following formulas are used.

$$LB_1 = 2 - \frac{L_1}{(L_1 + L_2 + L_3)/3}$$

$$LB_2 = 2 - \frac{L_2}{(L_1 + L_2 + L_3)/3}$$

$$LB_3 = 2 - \frac{L_3}{(L_1 + L_2 + L_3)/3}$$

$$V_1 = \left(\frac{Q_{w1} \times LB_1 + Q_{w2} \times LB_2 + Q_{w3} \times LB_3}{3} - Q_{w1} \times LB_1\right) \times \text{Gain}$$

Subscripts are the priority number of a compressor.

Where:
L is the load ratio of each compressor train.
LB is the calculated load balance of each compressor train.
Q_w is the Mass Flow of each compressor train.
V is the load differential value of each compressor train.
Gain is the rate of sharing speed to balance loading.

01:Use Load Sharing? **Initial=FALSE (FALSE, TRUE)**
Set TRUE to use the load sharing function. Select FALSE if the load sharing function is not used.

02:Use CAN Comm? **Initial=TRUE (FALSE, TRUE)**
Set TRUE to use CAN communication for load sharing. Select FALSE if the CAN communication for load sharing is not used.

03:Invert Header Ctrl? **Initial=FALSE (FALSE, TRUE)**
Set TRUE if the performance control will be reverse acting. If FALSE is set, the control will be forward acting. If TRUE is set, this option will result in the throttle valve or IGV decreasing, to increase the performance controller's input parameter. An example of when the input would be inverted is when the performance control PID is used for compressor suction pressure control.

04:Train Sequence Number **Initial=1 (1, 3)**
Set the load-sharing function's priority for each compressor train in parallel. In the initial state, the smallest number serves as the master load sharing controller .

05:Train 1 Load Setting **Initial=50 (0, 1000)**
Enter the self-load ratio for load sharing. A unit is arbitrary. In the case of similar compressor sizes, the same values will be used for all compressor trains.
For example, three 5 MW compressor trains would be configured as follows:
Train 1 Load Setting=5, Train 2 Load Setting=5, Train 3 Load Setting=5
This value is a part of the ratio which allows load to balance.

06:Train 2 Load Setting **Initial=50 (0, 1000)**
Only when the hardwired connection is used for load sharing, enter the ratio of load sharing for the next train (for Train 2). When load sharing is performed through CAN communication, this item set up in the First Train (Master control) will be read automatically.

07:Train 3 Load Setting **Initial=50 (0, 1000)**
Only when the hardwired connection is used for load sharing, enter the ratio of load sharing for the next train (for Train 3). When load sharing is performed through CAN communication, this item set up in the First Train (Master control) will be read automatically.

08:Use Setpoint Tracking? Initial=TRUE (FALSE, TRUE)
If TRUE, the header pressure setpoint will track the header pressure input to allow bumpless transfer into load sharing control mode. If FALSE, the setpoint will initialize to the 'Initial Setpoint' value on power-up or exiting program mode.

09:Initial Setpoint(units) Initial=2000.0 (-10.0, 1.0E+10)
Set the setpoint initialization value. When not using the Setpoint Tracking function, this will be the value that the header pressure setpoint initializes to upon power-up or exiting program mode.
(Must be less than or equal to the 'Maximum Setpoint' Setting)

10:Min Setpoint(units) Initial=0.0 (-10.0, 1.0E+10)
Set the minimum header pressure setpoint. This value is the minimum setpoint value that the header pressure setpoint can be decreased/lowered to (lower limit of the header pressure setpoint).

11:Max Setpoint(units) Initial=2000.0 (-10.0, 1.0E+10)
Set the maximum header pressure setpoint. This value is the maximum setpoint value that the header pressure setpoint can be increased/raised to (upper limit of the header pressure setpoint).

12:Setpt Man Rate(units/sec) Initial=5.0 (0.0, 9.0E+20)
Set the header pressure setpoint slow rate. This value is the rate (in units per second) at which the header pressure setpoint moves when adjusted.

13:Setpt Rmt Rate(units/sec) Initial=10.0 (0.0, 9.0E+20)
Set the header pressure setpoint remote control rate. This value is the rate (in units per second) at which the header pressure setpoint moves when adjusted by an external 4–20 mA analog input or through a Modbus communication input.

14:Header Press DB(units) Initial=3.0 (0.0, 1.0E+10)
Set the dead band width (in engineering units) for stopping operation of the header pressure adjustment during load sharing control.

15:Flow Balance DB(units) Initial=0.0 (0.0, 1.0E+10)
Set the dead band width (in engineering units) for stopping operation of the mass flow adjustment during load sharing control.

16:Flow Balance Delay(sec) Initial=1.0 (0.0, 100.0)
Set the filter time constant (sec) of the mass flow adjustment for load sharing.

17:Header Ctrl Rate(/sec) Initial=2.0 (0.0, 9.0E+20)
Set the load sharing execution rate for header pressure adjustment. This value specifies the header pressure adjustment rate of change (in engineering units per second) .

18:Flow Ctrl Rate(/sec) Initial=0.7 (0.0, 9.0E+20)
Set the load sharing execution rate for mass flow adjustment. This value specifies the mass flow adjustment rate of change (in engineering units per second).

Configure: 14*LEVEL ALARM*

Field Name		Value	Units	Description	Low	High	Initial
01:Level Alarm #1 is for	*	0			0	33	0
02:Level Alarm #1 Msg		Not Used					
03:Level Alarm #1 ON Level	*	0.00			-10000.00	1e+010	0.00
04:Level Alarm #1 OFF Level	*	0.00			-10000.00	1e+010	0.00
05:Level Alarm #2 is for	*	0			0	33	0
06:Level Alarm #2 Msg		Not Used					
07:Level Alarm #2 ON Level	*	0.00			-10000.00	1e+010	0.00
08:Level Alarm #2 OFF Level	*	0.00			-10000.00	1e+010	0.00
09:Level Alarm #3 is for	*	0			0	33	0
10:Level Alarm #3 Msg		Not Used					
11:Level Alarm #3 ON Level	*	0.00			-10000.00	1e+010	0.00
12:Level Alarm #3 OFF Level	*	0.00			-10000.00	1e+010	0.00
13:Level Alarm #4 is for	*	0			0	33	0
14:Level Alarm #4 Msg		Not Used					
15:Level Alarm #4 ON Level	*	0.00			-10000.00	1e+010	0.00
16:Level Alarm #4 OFF Level	*	0.00			-10000.00	1e+010	0.00

Figure 5-28. Configure: 14*LEVEL ALARM* Menu

There are four (4) configurable level alarms available from the compressor control. These alarms are not automatically reset, even if the alarm state changes to FALSE.

There is an ON and an OFF setting for each level alarm option. When configured as a level alarm, the configured point will change state when the selected parameter reaches the programmed ON level. The level alarm goes TRUE when the value is greater than or equal to the ON level when the configuration is ON >= OFF. The level alarm goes TRUE when the value is less than or equal to the ON level when the configuration is ON <= OFF. Select the appropriate function for the level alarm from the following.

01:Level Alarm #1 is for **Initial=0 (0, 33)**
Select one of the following parameters for the programmable level alarm #1.

0. Not Used
1. Stage 1 Surge Process Variable (S_PV)
2. Stage 1 Actual Suction Volumetric Flow
3. Stage 1 Corrected Suction Volumetric Flow
4. Stage 1 Stage Flow
5. Stage 1 Polytropic Head
6. Stage 1 Pressure Ratio
7. Stage 1 Suction Pressure
8. Stage 1 Discharge Pressure
9. Stage 1 Suction Temperature
10. Stage 1 Discharge Temperature
11. Stage 1 Sensor Flow
12. Stage 1 HSS Output
13. Stage 1 Valve Percentage
14. Stage 2 Surge Process Variable (S_P)
15. Stage 2 Actual Suction Volumetric Flow
16. Stage 2 Corrected Suction Volumetric Flow
17. Stage 2 Stage Flow
18. Stage 2 Polytropic Head
19. Stage 2 Pressure Ratio
20. Stage 2 Suction Pressure
21. Stage 2 Discharge Pressure
22. Stage 2 Suction Temperature

23. Stage 2 Discharge Temperature
24. Stage 2 Sensor Flow
25. Stage 2 HSS Output
26. Stage 2 Valve Percentage
27. Stage 2 Valve Demand
28. Throttle/IGV Demand
29. Load sharing Remote Setpoint
30. Stage 1 ASV Position Feedback
31. Stage 2 ASV Position Feedback
32. Throttle/IGV Position Feedback
33. Header Pressure

02:Level Alarm #1 Msg **Monitor**
This displays the item name selected for the programmable level alarm #1.

03:Level Alarm #1 ON Level **Initial=0.0 (-10000.0, 1.0E+10)**
Enter the level alarm ON setting in engineering units. The level alarm will go to TRUE once the selected parameter's level is at this setting.

04:Level Alarm #1 OFF Level **Initial=0.0 (-10000.0, 1.0E+10)**
Enter the level alarm OFF setting in engineering units. This allows the user to program the desired hysteresis for the function selected. The level alarm will remain TRUE until the parameter's level is at this setting.

Programmable Level Alarms #2 thru #4 are entered following the same rules as described for the Programmable Level Alarm #1.

Save and Reset the Vertex-Pro Control

When the tuning or setting of parameters is complete, the values must be saved in the control's non-volatile memory. Go to the Tool Bar and click the PROM icon for Save Values. The values will be saved in non-volatile memory and will be unaffected by loss of power to the control.

Once the configuration changes are complete, click on the Control Assistant program's Reset icon. This will allow the control to store the configured parameters, return the outputs to their active state, and resume executing the application software.

Chapter 6.
Service Menu Procedures

Overview

The Service mode is accessed through the PC interface and has the same easy to follow format as the Configure mode. The service mode can be used to change control settings, test control hardware, and calibrate control inputs/outputs while the unit is on-line (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 motor not shutdown. The Service Mode cannot be used to operate the motor or to perform Run Mode functions. The Service Mode is to be used for internal adjustments only.

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 this Volume's Configure mode chapter for all other page parameter descriptions.**

IMPORTANT **The operation process in this manual is explained by using the Control Assistant version 3.8. Please use Control Assistant version 3.8 or higher.**

Operating the Service Mode

Two Service mode options are offered within the Control Assistant program (Service-Change, Service-View Only). The Service-Change mode is used to change control settings, test control hardware, and calibrate control I/O, while the motor is in operation or shutdown. For security purposes, the Service-Change mode is password protected. The Service-View Only mode is used to only view Service mode settings, while the prime mover or compressor is in operation or shutdown. No Service mode settings can be changed via the View Only mode.

The Vertex-Pro control and the Service Panel computer must be connected (via an Ethernet cable) before the Control Assistant can be opened. Trying to open the Control Assistant without an Ethernet connection will result in a "Waiting for OPC server" message.

Figure 6-1. Waiting for OPC server

To enter the "Enable Tune Mode," click on the "Tunable Fields" on the program's main window. Once communications with the control has been established, the mode's "Enter Tune Password box" will appear. At this point enter the Service mode password (reference Appendix A of this Volume).

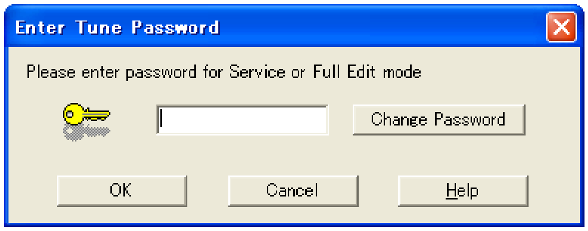


Figure 6-2. Enter Tune Password

Save Changes

The Service Mode allows the user to change values internal to the Vertex-Pro control. The Vertex-Pro has two copies of the internal values. One it keeps in SRAM and the other it keeps in Non-volatile EEPROM, both on the CPU modules. When the Vertex-Pro control is powered up or reset it transfers the values from EEPROM to the SRAM and uses the values in SRAM. When the user makes changes in the Service Mode, he is making changes to the SRAM values. If the Vertex-Pro control is powered down or reset before the new values are stored into the EEPROM on the CPU modules the changes are lost and cannot be retrieved. Go to the Tool Bar and clicking the PROM icon will store the new values into the EEPROM of the Vertex-Pro control. When the control has finished the save procedure after clicking "Yes", the display box shown below will appear.

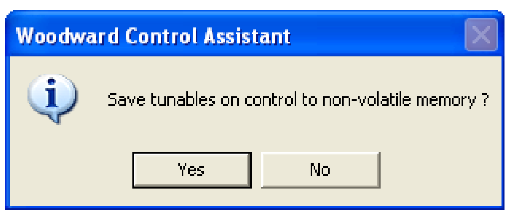


Figure 6-3. Save tunables

Figure 6-4. Save

Service: 01*C1 INPUTS*

Field Name		Value	Units	Description	Low	High	Initial
01:Default Value- P1	*	561.92			-200.00	1e+010	561.921
02:Default Value- P2	*	1159.15			-200.00	1e+010	1159.15
03:Default Value- PF	*	1159.15			-200.00	1e+010	1159.15
04:Default Value- T1	*	-74.80			-1000.00	1000.00	-74.80
05:Default Value- T2	*	-19.80			-1000.00	1000.00	-19.80
06:Default Value- TF	*	-19.80			-1000.00	1000.00	-19.80
07:LGV Enbl- P1	*	True					True
08:LGV Enbl- P2	*	True					True
09:LGV Enbl- PF	*	True					True
10:LGV Enbl- T1	*	True					True
11:LGV Enbl- T2	*	True					True
12:LGV Enbl- TF	*	True					True
13:Flow- Flow Constant	*	217.27			0.00	1e+010	217.268
14:Flow- Compensated	*	True					True
15:Flow- Differential Press	*	False					False
16:Flow- Select Mass Flow	*	True					True
17:Property- Z Calc Enbl	*	False					False
18:Proper- Z Default	*	0.91			0.00	100.00	0.907
19:Proper- Z2 Default	*	0.89			0.50	1.10	0.891
20:Proper- Crit Pres for Z	*	2.00			-101.325	1e+010	2.00425
21:Proper- Crit Temp for Z	*	0.00			-273.15	1e+010	0.00
22:Proper- Efficiency	*	0.87			0.00	100.00	0.866
23:Proper- k Default	*	1.42			0.00	100.00	1.42001
24:Proper- Mol Weight	*	28.00			-100.00	100.00	28.00
25:AS Vlv- HSS Aux #1 Enbl	*	False					False
26:AS Vlv- HSS Aux #2 Enbl	*	False					False
27:P1 Ovrd- P1 Ovrd Enbl	*	False					False
28:P1 OVRD- Spt	*	0			0	10000000	0
29:P2 Ovrd- P2 Ovrd Enbl	*	False					False
30:P2 OVRD- Spt	*	0			0	1410065408	0
31:Alarm Only on High Flow	*	False					False
32:Alarm Only on Low Flow	*	False					False

Figure 6-5. Service: 01*C1 INPUTS* Menu

01:Default Value- P1 **Initial=101.325 (-200.0, 1.0E+10)**
Enter a conservative default value for 1st stage compressor suction pressure (See Signal Failure Routines in Chapter 3). 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.

02:Default Value- P2 **Initial=101.325 (-200.0, 1.0E+10)**
Enter a conservative default value for 1st stage compressor discharge pressure (See Signal Failure Routines of Chapter 3). 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.

03:Default Value- PF **Initial=101.325 (-200.0, 1.0E+10)**
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 (See Signal Failure Routines of Chapter 3). 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.

04:Default Value- T1 **Initial=0.0 (-1000.0, 1.000)**
Enter a conservative default value for 1st stage compressor suction temperature (See Signal Failure Routines of Chapter 3). 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.

05:Default Value- T2 **Initial=0.0 (-1000.0, 1.000)**
Enter a conservative default value for 1st stage compressor discharge temperature (See Signal Failure Routines of Chapter 3). 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.

06:Default Value- TF **Initial=0.0 (-1000.0, 1.000)**
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 fails (See Signal Failure Routines of Chapter 3). 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.

07:LGV Enbl- P1 **Initial=TRUE (FALSE, TRUE)**
Set TRUE 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.

08:LGV Enbl- P2 **Initial=TRUE (FALSE, TRUE)**
Set TRUE 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.

09:LGV Enbl- PF **Initial=TRUE (FALSE, TRUE)**
Set TRUE to enable the Last Good Value failure response for the flow measurement alternate pressure signal. 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.

10:LGV Enbl- T1 **Initial=TRUE (FALSE, TRUE)**
Set TRUE to enable the Last Good Value failure response for the compressor suction temperature signal. 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.

11:LGV Enbl- T2 **Initial=TRUE (FALSE, TRUE)**
Set TRUE to enable the Last Good Value failure response for the compressor discharge temperature signal. 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.

12:LGV Enbl- TF **Initial=TRUE (FALSE, TRUE)**
Set TRUE to enable the Last Good Value failure response for the flow measurement alternate temperature signal. 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.

13:Flow- Flow Constant **Initial=3000.0 (0.0, 1.0E+10)**
Enter a flow element coefficient used to convert the measured flow element differential pressure to mass or normal/standard volumetric units (See Chapter 3 for an explanation of this constant). It is not used if the flow input is calibrated for mass or normal/standard volumetric units.

14:Flow- Compensated **Initial=FALSE (FALSE, TRUE)**
Set TRUE if the flow input is linear, calibrated in mass or normal/standard volumetric units, set FALSE for flow element differential pressure (with or without square-root compensation). The selection of this configurable will affect how the configured flow constant is used.

15:Flow- Differential Press **Initial=TRUE (FALSE, TRUE)**
Set TRUE if the flow input is raw differential pressure without square-root compensation, or FALSE if the square-root is compensated in the transmitter and its output is linear.

16:Flow- Select Mass Flow **Initial=TRUE (FALSE, TRUE)**
Set TRUE if the desired flow display units are mass, or FALSE for normal/standard volumetric display units. This configurable also applies to the calibration of the linear flow input if **Flow- Compensated** is configured TRUE. The selection of this configurable will affect the value of the configured flow constant.

17:Property- Z Calc Enbl **Initial=FALSE (FALSE, TRUE)**
Set TRUE to enable the online calculation of compressibility or FALSE to use the configured default values. The online calculation uses configured default critical pressure and temperature of the gas and measured temperatures and pressures to generate the calculated value.

18:Proper- Z Default **Initial=0.9 (0.0, 100)**
Enter the default compressibility corresponding to the process gas at compressor suction conditions. This value can usually be found on the manufacturer's compressor performance map or data sheet. For added accuracy across the range of the operating map, this input may be connected from a multi-dimensional curve or calculation instead of simply using a single default value.

19:Proper- Z2 Default **Initial=0.9 (0.5, 1.1)**
Enter the default compressibility corresponding to the process gas at compressor discharge conditions. This value can usually be found on the manufacturer's compressor performance map or data sheet. For added accuracy across the range of the operating map, this input may be connected from a multi-dimensional curve or calculation instead of simply using a single default value.

20:Proper- Crit Pres for Z **Initial=5000.0 (-101.325, 1.0E+10)**
Enter the process gas critical pressure. This value is used in a Redlich-Kwong derivation of gas compressibility if **Property- Z Calc Enbl** is configured TRUE.

21:Proper- Crit Temp for Z **Initial=100.0 (-273.15, 1.0E+10)**
Enter the process gas critical temperature. This value is used in a Redlich-Kwong derivation of gas compressibility if **Property- Z Calc Enbl** is configured TRUE.

22:Proper- Efficiency **Initial=0.85 (0.0, 100)**
Enter the default compressor efficiency. This value can usually be found on the manufacturer's compressor performance map or data sheet. It is used to calculate specific heat ratio or the polytropic exponent, depending upon the configuration of the **Gas Component**. For added accuracy across the range of the operating map, this input may be connected from a multi-dimensional curve or calculation instead of simply using a single default value.

23:Proper- k Default **Initial=1.4 (0.0, 100)**
Enter the default specific heat ratio corresponding to the process gas being compressed. This value can usually be found on the manufacturer's compressor performance map or data sheet. For added accuracy across the range of the operating map, this input may be connected from a multi-dimensional curve or calculation instead of simply using a single default value.

24:Proper- Mol Weight **Initial=28.0 (-100.0, 100)**
Enter the process gas molecular weight, used to calculate head and flow. This value can usually be found on the manufacturer's compressor performance map or data sheet.

25:AS Vlv- HSS Aux #1 Enbl **Initial=FALSE (FALSE, TRUE)**
Set TRUE 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.

26:AS Vlv- HSS Aux #2 Enbl **Initial=FALSE (FALSE, TRUE)**
Set TRUE 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.

27:P1 Ovrd- P1 Ovrd Enbl **Initial=FALSE (FALSE, TRUE)**
Set TRUE 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 motor speed, controlling suction pressure, reaches minimum governor).

28:P1 OVRD- Spt **Initial=0.0 (0.0, 1.0E+7)**
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.

29:P2 Ovrd- P2 Ovrd Enbl **Initial=FALSE (FALSE, TRUE)**
Set TRUE 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 controllers (such as when motor speed, controlling discharge pressure, reaches minimum governor).

30:P2 OVRD- Spt **Initial=1.0E+7 (0.0, 1.0E+7)**
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.

31:Alarm Only on High Flow **Initial=FALSE (FALSE, TRUE)**
Set TRUE to detect only high failure of the flow transmitter. The signal failure of the flow transmitter is not detected if it becomes 2 mA (default low failure point) or less.

32:Alarm Only on Low Flow **Initial=FALSE (FALSE, TRUE)**
Set TRUE to detect only low failure of the flow transmitter. The signal failure of the flow transmitter is not detected if it becomes 22 mA (default high failure point) or more.

Service: 02*C1 SEQUENCE*

Field Name		Value	Units	Description	Low	High	Initial
01:On-Line- Flow Spt	*	2.00			0.00	1e+010	2.00428
02:On-Line- Speed Spt	*	5913.00			0.00	50000.00	5913.00
03:On-Line- P1 Spt	*	0.00			-200.00	1e+010	0.00
04:On-Line- P2 Spt	*	0.00			-200.00	1e+010	0.00
05:On-Line- Flow Enbl	*	False					False
06:On-Line- Speed Enbl	*	False					False
07:On-Line- P1 Enbl	*	False					False
08:On-Line- P2 Enbl	*	False					False
09:On-Line- Aux Input Enbl	*	True					True
10:SEQ- Shutdown Delay	*	0.00			0.00	1000.00	0.00
11:SEQ- Shutdown Position	*	100.00			0.00	100.00	100.00
12:SEQ- Zero Speed	*	0.00			-1.00	1000.00	0.00
13:SEQ- Start Position	*	100.00			0.00	100.00	100.00
14:SEQ- Zero Speed Pos	*	100.00			0.00	100.00	100.00
15:SEQ- Purge Position	*	0.00			0.00	100.00	0.00
16:Manual- Shutdown Pos Enb	*	True					True

Figure 6-6. Service: 02*C1 SEQUENCE* Menu

01:On-Line- Flow Enbl **Initial=FALSE (FALSE, TRUE)**
Set TRUE to enable the flow detection method for the online condition. All enabled triggers 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.

02:On-Line- Flow Spt **Initial=1.0E+10 (0.0, 1.0E+10)**
Enter the required flow setpoint (in suction volumetric units) for the online condition. On startup, once flow increases beyond this setpoint, the online detection trigger is satisfied.

03:On-Line- Speed Enbl **Initial=FALSE (FALSE, TRUE)**
Set TRUE to enable the speed detection method for the online condition. All enabled triggers 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.

04:On-Line- Speed Spt **Initial=6000.0 (0.0, 50000)**
Enter the required speed setpoint (in rpm) for the online condition. On startup, once speed increases beyond this setpoint, the online detection trigger is satisfied.

05:On-Line- P1 Enbl **Initial=FALSE (FALSE, TRUE)**
Set TRUE to enable the suction pressure detection method for the online condition. All enabled triggers 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. If this compressor is not the first section in a train, the suction pressure online detection method cannot be used (suction pressure decreases with speed only on the first compressor section).

06:On-Line- P1 Spt **Initial=1000.0 (-200.0, 1.0E+10)**
Enter the required suction pressure setpoint (in engineering units) for the online condition. On startup, once suction pressure decreases below this setpoint (on Stage 1), the online detection trigger is satisfied. If this compressor is not the first section in a train (Stage 2 or later), then the suction pressure setpoint must be exceeded by the input to trigger the online condition.

07:On-Line- P2 Enbl **Initial=FALSE (FALSE, TRUE)**
Set TRUE to enable the discharge pressure detection method for the online condition. All enabled triggers 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.

08:On-Line- P2 Spt **Initial=1000.0 (-200.0, 1.0E+10)**
Enter the required discharge pressure setpoint (in engineering units) for the online condition. On startup, once discharge pressure increases beyond this setpoint, the online detection trigger is satisfied.

09:On-Line- Aux Input Enbl **Initial=FALSE (FALSE, TRUE)**
Set TRUE to enable the auxiliary discrete input for the online condition. All enabled triggers 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. The On-Line directions from the outside can be inputted from Modbus or Contact input.

10:SEQ- Purge Position **Initial=0.0 (0.0, 100.0)**
Enter the required anti-surge valve position (0–100% open) for a purge cycle during startup.

11:SEQ- Zero Speed **Initial=250.0 (-1.0, 1000.0)**
Enter the speed (in rpm) at which the compressor is considered started, and therefore, the speed at which the anti-surge valve transitions from its configured zero-speed position to the configured start position. Conversely, this is also the speed below which the unit is considered zero-speed after a shutdown. On startup from the zero-speed position, this speed switch function becomes effective after start conditions are established.

12:SEQ- Start Position **Initial=100.0 (0.0, 100.0)**
Enter the required startup position (0–100% open) for the anti-surge valve, typically 100% for full recycle. 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 force a start sequence— if none are configured, the control will skip the start sequence and transition immediately to automatic, online control (not recommended).

13:SEQ- Shutdown Position **Initial=100.0 (0.0, 100.0)**
Enter the required shutdown position (0–100% open) for the anti-surge valve, typically 100% for full recycle.

14:SEQ- Shutdown Delay **Initial=300.0 (0.0, 1000.0)**
Enter the delay time (seconds) used by the control to determine when to transition to the zero-speed sequence. During a shutdown, after speed falls below the configured startup speed (**Zero Speed**) and remains there for this delay time, the anti-surge valve is transitioned from the configured shutdown position to the zero-speed position.

15:SEQ- Zero Speed Pos **Initial=100.0 (0.0, 100.0)**
Enter the required zero-speed position (0–100% open) for the anti-surge valve. This additional shutdown sequence is sometimes used to close the anti-surge valve after a shutdown to provide process isolation, rather than leaving the valve open. If such a procedure is unnecessary, simply configure this position identically to the shutdown position (**Shutdown Position**) and the delay time (**Shutdown Delay**) to 0.

16:Manual- Shutdown Pos Enb **Initial=TRUE (FALSE, TRUE)**
Set TRUE to force the anti-surge valve to its configured shutdown position if a shutdown input is received while in full manual mode. If this is set FALSE and a shutdown is received while in full manual mode, the manual demand is not overridden, and the operator retains full control of the anti-surge valve.

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. In the Vertex-Pro, speed inputs are optional.**

Service: 03*C1 CTRL PARAMETER*

Field Name		Value	Units	Description	Low	High	Initial
01:AS PID- AGC Enbl	*	False					False
02:AS PID- Int Gain	*	0.10			0.001	10.00	0.10
03:AS PID- Prop Gain	*	0.10			0.00	100.00	0.10
04:AS PID- SDR	*	100.00			0.01	100.00	100.00
05:Rate Ctrl- Rate Ctrl Enb	*	True					True
06:Rate Ctrl- AGC Enbl	*	False					False
07:Rate Ctrl- Int Gain	*	0.10			0.001	10.00	0.10
08:Rate Ctrl- Prop Gain	*	0.10			0.00	100.00	0.10
09:Rate Ctrl- SDR	*	100.00			0.01	100.00	100.00
10:Rate Ctrl- Spt Factor	*	20.00			0.10	100.00	20.00
11:P1 Ovrd- AGC Enbl	*	False					False
12:P1 OVRD- Int Gain	*	0.10			0.001	10.00	0.10
13:P1 OVRD- Prop Gain	*	0.10			0.00	100.00	0.10
14:P1 OVRD- SDR	*	100.00			0.01	100.00	100.00
15:P2 Ovrd- AGC Enbl	*	False					False
16:P2 OVRD- Int Gain	*	0.10			0.001	10.00	0.10
17:P2 OVRD- Prop Gain	*	0.10			0.00	100.00	0.10
18:P2 OVRD- SDR	*	100.00			0.01	100.00	100.00
19:Filter Time- Flow	*	0.02			0.00	10.00	0.02
20:Filter Time- Press	*	0.20			0.00	10.00	0.20
21:Filter Time- Temp	*	3.00			0.00	10.00	3.00
22:COMPENS- AS Valve Cv	*	1000.00			0.00	100000.00	1000.00
23:COMPENS- Normal Value	*	10000.00			0.00	1e+010	10000.00
24:COMPENS- Current Factor		1.00					
25:Loop Period	*	1.00			0.10	100.00	1.00

Figure 6-7. Service: 03*C1 CTRL PARAMETER* Menu

01:AS PID- AGC Enbl **Initial= FALSE (FALSE, TRUE)**
Set TRUE 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.

02:AS PID- Int Gain **Initial=0.1 (0.001, 10.0)**
Enter the appropriate integral gain (in repeats per second) of the anti-surge PID.

03:AS PID- Prop Gain **Initial=0.1 (0.0, 100.0)**
Enter the appropriate proportional gain (in percent) of the anti-surge PID.

04:AS PID- SDR **Initial=100.0 (0.01, 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 Dynamics Adjustments section later in this chapter for more details on tuning speed derivative ratio.

05:Rate Ctrl- Rate Ctrl Enb **Initial= TRUE (FALSE, TRUE)**
Set TRUE 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.

06:Rate Ctrl- AGC Enbl **Initial= FALSE (FALSE, TRUE)**
Set TRUE to enable automatic gain compensation of the rate 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.

07:Rate Ctrl- Int Gain **Initial=0.1 (0.001, 10.0)**
Enter the appropriate integral gain (in repeats per second) of the rate PID.

08:Rate Ctrl- Prop Gain **Initial=0.1 (0.0, 100.0)**
Enter the appropriate proportional gain (in percent) of the rate PID.

09:Rate Ctrl- SDR **Initial=100.0 (0.01, 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 Dynamics Adjustments section later in this chapter for more details on tuning speed derivative ratio.

10:Rate Ctrl- Spt Factor **Initial=20.0 (0.10, 100.0)**
Enter the appropriate rate controller setpoint, in percent of maximum allowable rate (see Chapter 3 for a complete description of the rate controller and how this setpoint is implemented).

11:P1 Ovrd- AGC Enbl **Initial= FALSE (FALSE, TRUE)**
Set TRUE to enable automatic gain compensation of the suction pressure 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.

12:P1 OVRD- Int Gain **Initial=0.1 (0.001, 10.0)**
Enter the appropriate proportional gain (in percent) of the suction pressure PID.

13:P1 OVRD- Prop Gain **Initial=0.1 (0.0, 100.0)**
Enter the appropriate proportional gain (in percent) of the suction pressure PID.

14:P1 OVRD- SDR **Initial=100.0 (0.01, 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 Dynamics Adjustments section later in this chapter for more details on tuning speed derivative ratio.

15:P2 Ovrd- AGC Enbl **Initial=FALSE (FALSE, TRUE)**
Set TRUE to enable automatic gain compensation of the discharge pressure 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.

16:P2 OVRD- Int Gain **Initial=0.1 (0.001, 10.0)**
Enter the appropriate integral gain (in repeats per second) of the discharge pressure PID.

17:P2 OVRD- Prop Gain **Initial=0.1 (0.0, 100.0)**
Enter the appropriate proportional gain (in percent) of the discharge pressure PID.

18:P2 OVRD- SDR **Initial=100.0 (0.01, 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 Dynamics Adjustments section later in this chapter for more details on tuning speed derivative ratio.

19:Filter Time- Flow **Initial=0.02 (0.0, 10.0)**
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.

20:Filter Time- Press **Initial=0.2 (0.0, 10.0)**
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.

21:Filter Time- Temp **Initial=3.0 (0.0, 10.0)**
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.

22:COMPENS- AS Valve Cv **Initial=1000.0 (0.0, 1.0E+5)**
Enter the anti-surge valve's sizing coefficient (C_v). This value is used by the Automatic Gain Compensation routine to calculate full-open valve flow at current operating conditions.

23:COMPENS- Normal Value **Initial=10000.0 (0.0, 1.0E+10)**
Enter the normalizing factor for gain compensation (see Chapter 3 for a complete description of this function). If Auto Gain Compensation will be utilized, it must be tuned at the same operating conditions at which the PID controls are tuned. At this operating point, adjust this value of fully open anti-surge valve flow until the gain compensation value (**Current Factor**) equals 1.0.

24:COMPENS- Current Factor **Monitor**
This monitoring value is the current compensation factor that will be used to scale the PID controllers' proportional gain terms. It is used to assist with properly tuning the normalizing factor noted above (**Normal Value**).

25:Loop Period **Initial=1.0 (0.1, 100.0)**
Enter the appropriate system loop delay time in seconds (see Chapter 3 for a complete description of this parameter and when it is used). 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). Refer to the Loop Period Test Procedure later in this chapter.

Service: 04*C1 DECOUPLING*

Field Name		Value	Units	Description	Low	High	Initial
01:Fast Speed Amount	*	0.00			0.00	100.00	0.00
02:Fast Speed Delay	*	30.00			0.00	100.00	30.00
03:SS Speed Amount	*	0.00			0.00	1e+010	0.00
04:SS Speed Delay	*	300.00			0.00	1000.00	300.00
05:Another Stg Amount	*	0.00			-100.00	100.00	0.00
06:Another Stg Delay	*	30.00			0.00	100.00	30.00
07:Spd/Process to ASV Enbl	*	False					False
08:ASV to Spd/Capacity Enbl	*	False					False
09:DCPL Limit	*	10.00			0.00	100.00	10.00
10:DCPL Range	*	110.00			0.00	500.00	110.00

Figure 6-8. Service: 04*C1 DECOUPLING* Menu

Decoupling is enabled once for all routines. To eliminate a particular Decoupling action, configure its "Amount" to 0.0. 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.

01:Fast Speed Amount **Initial=0.0 (0.0, 100.0)**
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 separately for all routines—to disable a particular routine, configure its amount to 0.0.

02:Fast Speed Delay **Initial=30.0 (0.0, 100.0)**
Enter the appropriate delay time (in seconds) that the emergency speed decoupling routine will remain in effect. After this time delay, the bias will have been removed from the valve demand.

03:Speed Amount **Initial=0.0 (0.0, 1.0E+10)**
Enter the appropriate gain, or scalar, (in actual suction volumetric flow 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 separately for all routines—to disable a particular routine, configure its amount to 0.0.

04:SS Speed Delay **Initial=300.0 (0.0, 1000.0)**
Enter the appropriate delay time (in seconds) that the steady-state speed decoupling routine will remain in effect.

IMPORTANT **The speed-based decoupling modes described above are active only if a valid speed signal is available. In the Vertex-Pro, speed inputs are optional.**

05:Another Stg Amount **Initial=0.0 (-100.0, 100.0)**
For Dual Stage 2-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.

06:Another Stg Delay **Initial=30.0 (0.0, 100.0)**
For Dual Stage 2-valve trains, 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 have been removed from the valve demand.

07:Speed/Process to ASV Enbl **Initial=FALSE (FALSE, TRUE)**
Set TRUE to enable decoupling or feed-forward biasing of the anti-surge valve demand based upon speed or process changes. There are two speed and three configurable routines available. By default, all are enabled—configure the amounts to 0 for any routines that are not used.

08:ASV to Speed/Capacity Enbl **Initial=FALSE (FALSE, TRUE)**
Set TRUE to enable decoupling, or feed-forward biasing, of the speed or capacity control demand based upon anti-surge valve movement. For example, when the anti-surge valve opens, the unit is artificially loaded because it has reached its Surge Control Line or Surge Limit. Increasing the speed reference of a motor prime mover or opening a compressor throttling valve / IGV will improve this situation.

09:DCPL Limit **Initial=10.0 (0.0, 100.0)**
This is the maximum amount, in valve opening percent, that the sum of all decoupling routines can move the anti-surge valve.

10:DCPL Range **Initial=110.0 (0.0, 500.0)**
This is the S_PV value below which Decoupling is enabled. Above this value, Decoupling is automatically disabled as the compressor is not operating near surge.

Service: 05*C1 RECYCLE VALVE*

Field Name		Value	Units	Description	Low	High	Initial
01:AS Valve- Decay Rate	*	0.75			0.10	100.00	0.75
02:AS Valve- Invert Output	*	True					True
03:AS Valve Dither	*	0.00			0.00	10.00	0.00
04:AS Valve- Overstroke Enb	*	False					False
05:ASV Ovstrk Amount Open	*	2.00			0.00	10.00	2.00
06:ASV Ovstrk Amount Closed	*	2.00			0.00	10.00	2.00
07:Manual- Valve rate	*	2.00			0.10	100.00	2.00
08:Manual- Fast Rate Delay	*	5.00			1.00	10.00	5.00
09:Manual- Fast Rate	*	3.00			1.00	10.00	3.00
10:Manual- Input Fail Add	*	50.00			0.00	100.00	50.00
11:Enbl All Sns Fail to Man	*	False					False
12:Manual- Remote Enbl	*	False					False

Figure 6-9. Service: 05*C1 RECYCLE VALVE* Menu

01:AS Valve- Decay Rate **Initial=0.75 (0.1, 100.0)**
Enter the ramp rate value, in percent per second, to be used by the automatic open-loop routines when ramping the anti-surge valve closed.

02:AS Valve- Invert Output **Initial=TRUE (FALSE, TRUE)**
Set TRUE to invert the anti-surge valve demand signal for fail-open, or air-to-close, valve configurations typical in anti-surge control applications.

03:AS Valve Dither **Initial=0.0 (0.0, 10.0)**
Enter the valve demand peak amplitude, typically <1%, to apply to the anti-surge valve output. Dither is applied to the valve demand as a square-wave signal onto the control's current output to help decrease response time and prevent electro-mechanical "stiction" in some valve designs. The dither frequency is defaulted to 12.5 Hz but may be tuned in the core application. If utilized, dither should not be noticeable as physical valve movement. If dither is unnecessary, configure this value to 0.0.

04:AS Valve- Overstroke Enb **Initial=FALSE (FALSE, TRUE)**
Set TRUE to positively seat the anti-surge valve in the full-open and full-closed positions.

05:ASV Ovstrk Amount Open **Initial=2.0 (0.0, 10.0)**
Enter the overstroke amount for the open position. When the valve demand reaches 99.8%, this overstroke percentage is added to the output, forcing the valve fully open with a demand greater than 100%.

06:ASV Ovstrk Amount Closed **Initial=2.0 (0.0, 10.0)**
Enter the overstroke amount for the closed position. When the valve demand reaches 0.2%, this overstroke percentage is subtracted from the output, forcing the valve fully closed with a demand less than 0%.

07:Manual- Valve rate **Initial=2.0 (0.1, 100.0)**
Enter the ramp rate value, in percent per second, to be used when in the manual valve control modes. This rate is applied regardless of opening/closing direction. When a discrete open or closed command is held for 5 seconds (tunable in the **Fast Rate Delay**), the control transfers to a fast rate, calculated as 3 times (tunable in the **Fast Rate**) this default rate.

08:Manual- Fast Rate Delay **Initial=5.0 (1.0, 10.0)**
This value will determine how long the Setpoint Slow Rate will have to be selected before the Setpoint Fast Rate will be engaged. It is defaulted for 5 seconds. This implies that if a Raise Performance Setpoint command is continually given, the Performance Setpoint will increase at the slow rate for 5 seconds and then increase at the fast rate after that.

09:Manual- Fast Rate **Initial=3.0 (1.0, 10.0)**
This value will determine how fast the performance setpoint will raise or lower when the Fast Rate is initiated.

10:Manual- Input Fail Add **Initial=50.0 (0.0, 100.0)**
Enter the value in valve percent that will be added to the anti-surge valve demand when the flow measurement input fails. Without the flow input, anti-surge control is compromised, and the control will revert to Full Manual mode at the new fixed valve demand.

11:Enbl All Sns Fail to Man **Initial=FALSE (FALSE, TRUE)**
Set TRUE to enable the Fail to Manual strategy on all input failures (pressure, temperature) and not simply flow. This is the most conservative strategy for handling input signal failures but Last Good Value, if enabled, takes priority.

12:Manual- Remote Enbl **Initial=FALSE (FALSE, TRUE)**
Set TRUE to enable remote positioning of the anti-surge valve when in manual mode. This input may be a configurable, or connected from other logic as an operating permissive. The remote demand may come from any source (4–20 mA input, Modbus, other logic). If enabled, the input is not failed, and the remote demand is within 0.5% of the current manual demand (for bumpless transfer) then the remote demand will take control of the valve.

Service: 06*C1 ANTI-SURGE*

Field Name		Value	Units	Description	Low	High	Initial
01:BOOST- BOOST Enbl	*	True					True
02:BOOST- Amount	*	14.80			0.00	100.00	14.80
03:BOOST- BOOST Margin	*	5.00			-20.00	20.00	5.00
04:Srg Recov- Srg Recov Enb	*	True					True
05:Srg Recov- Amount	*	29.60			0.00	100.00	29.60
06:Srg Recov- Min Pos	*	0.00			0.00	100.00	0.00
07:Srg Recov-SR in Full Man	*	True					True
08:Srg Det- Flow Deriv Enbl	*	True					True
09:Srg Det- Min Flow Enbl	*	False					False
10:Srg Det- P1 Deriv Enbl	*	False					False
11:Srg Det- P2 Deriv Enbl	*	False					False
12:Srg Det- Speed Deriv Enb	*	False					False
13:Srg Det- Flow Deriv Spt	*	70.00			0.00	2000.00	70.00
14:Srg Det- Min Flow Spt	*	100.00			0.00	1e+010	100.00
15:Srg Det- P1 Deriv Spt	*	425.60			0.00	1e+010	425.60
16:Srg Det- P2 Deriv Spt	*	179.27			0.00	1e+010	179.268
17:Srg Det- Spd Deriv Spt	*	419.00			0.00	1000.00	419.00
18:Srg Det- Enbl at SLL	*	False					False
19:SMP- SMP Enbl	*	True					True
20:SMP- Amount	*	7.40			0.00	100.00	7.40
21:AS Valve- Freeze Enbl	*	False					False
22:AS Valve- Freeze Delay	*	0.00			0.00	1000.00	0.00
23:Pre-Pack- Pre-Pack Enbl	*	False					False
24:Pre-Pack- Amount	*	0.00			0.00	100.00	0.00

Figure 6-10. Service: 06*C1 ANTI-SURGE* Menu

01:BOOST- BOOST Enbl **Initial=TRUE (FALSE, TRUE)**
Set TRUE to enable the BOOST or Backup Line open-loop step response.

02:BOOST- Amount **Initial=10.0 (0.0, 100.0)**
Enter the value 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 **Loop Period** 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 Backup Line to the Surge Control Line.

03:BOOST- BOOST Margin **Initial=5.0 (-20.0, 20.0)**
Enter the value in percent flow, typically 3~5%, to locate the BOOST or Backup Line to the left of the configured Surge Control Line.

04:Srg Recov- Srg Recov Enb **Initial=TRUE (FALSE, TRUE)**
Set TRUE to enable the open-loop step response triggered when surge is detected by any of the configured surge detection methods.

05:Srg Recov- Amount **Initial=20.0 (0.0, 100.0)**
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 VLV_DECAY rate.

06:Srg Recov- Min Pos **Initial=50.0 (0.0, 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 **Srg Recov- Amount** value, whichever is greater.

07:Srg Recov-SR in Full Man **Initial=TRUE (FALSE, TRUE)**
Set TRUE 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.

08:Srg Det- Flow Deriv Enbl **Initial=TRUE (FALSE, TRUE)**
Set TRUE to enable the flow derivative surge detection routine. This routine detects surge by monitoring the rate of change of calculated compressor flow.

09:Srg Det- Min Flow Enbl **Initial=FALSE (FALSE, TRUE)**
Set TRUE 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.

10:Srg Det- P1 Deriv Enbl **Initial= FALSE (FALSE, TRUE)**
Set TRUE to enable the suction pressure derivative surge detection routine. This routine detects surge by monitoring the rate of change of measured compressor suction pressure.

11:Srg Det- P2 Deriv Enbl **Initial= FALSE (FALSE, TRUE)**
TRUE to enable the discharge pressure derivative surge detection routine. This routine detects surge by monitoring the rate of change of measured compressor discharge pressure.

12:Srg Det- Speed Deriv Enb **Initial= FALSE (FALSE, TRUE)**
Set TRUE to enable the speed derivative surge detection routine. This routine detects surge by monitoring the rate of change of measured compressor speed.

13:Srg Det- Flow Deriv Spt **Initial=70.0 (0.0, 2000.0)**
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.

14:Srg Det- Min Flow Spt **Initial=2500.0 (0.0, 1.0E+10)**
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.

15:Srg Det- P1 Deriv Spt **Initial=1000.0 (0.0, 1.0E+10)**
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.

16:Srg Det- P2 Deriv Spt **Initial=1000.0 (0.0, 1.0E+10)**
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.

17:Srg Det- Spd Deriv Spt **Initial=400.0 (0.0, 1000.0)**
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.

18:Srg Det- Enbl at SLL **Initial= FALSE (FALSE, TRUE)**
Set TRUE 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.

19:SMP- SMP Enbl **Initial=TRUE (FALSE, TRUE)**
Set TRUE 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.

20:SMP- Amount **Initial=5.0 (0.0, 100.0)**
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 function requires a reset input (RESET_SMP) to allow the valve to close further.

21:AS Valve- Freeze Enbl **Initial= FALSE (FALSE, TRUE)**
Set TRUE 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.

22:AS Valve- Freeze Delay **Initial=120.0 (0.0, 1000.0)**
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.

23:Pre-Pack- Pre-Pack Enbl **Initial=FALSE (FALSE, TRUE)**
Set TRUE 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 Period** attributable to large piping volumes.

24:Pre-Pack- Amount **Initial=10.0 (0.0, 100.0)**
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% (default--may be tuned in the operation) of the loop Period time.

Service: 07*C1 SURGE LINE*

Field Name		Value	Units	Description	Low	High	Initial
01:S_PV- Ctrl Margin	*	10.00			-50.00	500.00	10.00
02:Enbl SCL Shift on Surge	*	False					False
03:Ctrl Margin Shift Amount	*	2.00			0.00	10.00	2.00
04:Num of Stgs(Intcooler+1)	*	0			0	9	0
05:Standard Map- MW	*	28.00			2.00	500.00	28.00
06:Standard Map- T1	*	0.00			-1000.00	1000.00	0.00
07:Standard Map- Average Z	*	0.90			0.50	1.10	0.90
08:Actual Vol Flow 1 (X1)	*	20000.00			0.00	1e+010	20000.00
09:Actual Vol Flow 1 (X2)	*	30000.00			0.00	1e+010	30000.00
10:Actual Vol Flow 1 (X3)	*	40000.00			0.00	1e+010	40000.00
11:Actual Vol Flow 1 (X4)	*	50000.00			0.00	1e+010	50000.00
12:Actual Vol Flow 1 (X5)	*	60000.00			0.00	1e+010	60000.00
13:Polytropic Head 1 (Y1)	*	1000.00			0.00	1e+010	1000.00
14:Polytropic Head 1 (Y2)	*	1500.00			0.00	1e+010	1500.00
15:Polytropic Head 1 (Y3)	*	2000.00			0.00	1e+010	2000.00
16:Polytropic Head 1 (Y4)	*	2500.00			0.00	1e+010	2500.00
17:Polytropic Head 1 (Y5)	*	3000.00			0.00	1e+010	3000.00

Figure 6-11. Service: 07*C1 SURGE LINE* Menu

01:S_PV- Ctrl Margin **Initial=10.0 (-50.0, 500.0)**
Enter the value, typically 8~10%, used to calculate the setpoint or Surge Control Line when the Standard Algorithm is used. This margin is expressed as a percentage of flow above that (or to the right) of the configured Surge Limit Line.

02:Enbl SCL Shift on Surge **Initial=FALSE (FALSE, TRUE)**
Set TRUE to enable Surge Control Line shifting based upon the surge counter. If enabled, the Surge Control Line will be shifted a configured percentage for each detected surge. When the surge counter is reset, the shifted amount will slowly ramp back to 0, returning the SCL to its original position.

03:Ctrl Margin Shift Amount **Initial=2.0 (0.0, 10.0)**
Enter the value, in percent, to be added to the current control margin for every detected surge. For example, if configured as 1%, the control line would shift 3% if 3 surges were detected. When the surge counter is reset, this extra margin will slowly ramp back to 0, returning the SCL to its original position.

04:Num of Stgs(Intcooler+1) **Initial=0 (0, 9)**
Enter the number of compressor sections separated by intercoolers (in other words, the number of intercoolers plus one). This value is used to scale the configured compressor efficiency when calculating specific heat ratio or polytropic exponent, thereby improving the accuracy of the polytropic head calculation when intercoolers are present.

05:Standard Map- MW **Initial=28.0 (2.0, 500.0)**
Enter the process gas molecular weight from a compressor performance curve used to calculate the Standard Algorithm's Reduced Head vs. Q^2/Head curve.

06:Standard Map- T1 **Initial=0.0 (-1000.0, 1000.0)**
Enter the suction pressure from a compressor performance curve used to calculate the Standard Algorithm's Reduced Head vs. Q^2/Head curve.

07:Standard Map- Average Z **Initial=0.9 (0.5, 1.1)**
Enter the average compressibility from a compressor performance curve used to calculate the Standard Algorithm's Reduced Head vs. Q^2/Head curve.

08:Actual Vol Flow 1 (X1) **Initial=20000.0 (0.0, 1.0E+10)**
Enter the inlet volumetric flow #1 on a surge line from the compressor performance curve, in Am^3/h.
(Must be less than the 'X2 Value')

09:Actual Vol Flow 1 (X2) **Initial=30000.0 (0.0, 1.0E+10)**
Enter the inlet volumetric flow #2 on a surge line from the compressor performance curve, in Am^3/h.
(Must be less than the 'X3 Value')

10:Actual Vol Flow 1 (X3) **Initial=40000.0 (0.0, 1.0E+10)**
Enter the inlet volumetric flow #3 on a surge line from the compressor performance curve, in Am^3/h.
(Must be less than the 'X4 Value')

11:Actual Vol Flow 1 (X4) **Initial=50000.0 (0.0, 1.0E+10)**
Enter the inlet volumetric flow #4 on a surge line from the compressor performance curve, in Am^3/h.
(Must be less than the 'X5 Value')

12:Actual Vol Flow 1 (X5) **Initial=60000.0 (0.0, 1.0E+10)**
Enter the inlet volumetric flow #5 on a surge line from the compressor performance curve, in Am^3/h.

13:Polytropic Head 1 (Y1) **Initial=1000.0 (0.0, 1.0E+10)**
Enter the polytropic head #1 on a surge line from the compressor performance curve, in N-m/h.

14:Polytropic Head 1 (Y2) **Initial=1500.0 (0.0, 1.0E+10)**
Enter the polytropic head #2 on a surge line from the compressor performance curve, in N-m/h.

15:Polytropic Head 1 (Y3) Initial=2000.0 (0.0, 1.0E+10)
Enter the polytropic head #3 on a surge line from the compressor performance curve, in N-m/h.

16:Polytropic Head 1 (Y4) Initial=2500.0 (0.0, 1.0E+10)
Enter the polytropic head #4 on a surge line from the compressor performance curve, in N-m/h.

17:Polytropic Head 1 (Y5) Initial=3000.0 (0.0, 1.0E+10)
Enter the polytropic head #5 on a surge line from the compressor performance curve, in N-m/h.

IMPORTANT

Service Menus 8 thru 14 for the 2nd stage compressor (C2) are entered following the same rules as described for Service Menus 1 thru 7 for the 1st stage compressor (C1).

Service: 15*C1 INPUT SIGNALS*

Field Name		Value	Units	Description	Low	High	Initial
01:SUCT PRES (ABSOLUTE)		663.25					
02:SUCT PRES (GAUGE)		561.92					
03:SUCT PRES DEF VAL		True					
04:SUCT PRES LAST GOOD VAL		False					
05:SUCT TEMP (ABSOLUTE)		198.35					
06:SUCT TEMP (GAUGE)		-74.80					
07:SUCT TEMP DEF VAL		True					
08:SUCT TEMP LAST GOOD VAL		False					
09:DISCH PRES (ABSOLUTE)		1260.47					
10:DISCH PRES (GAUGE)		1159.15					
11:DISCH PRES DEF VAL		True					
12:DISCH PRES LAST GOOD VA		False					
13:DISCH TEMP (ABSOLUTE)		253.35					
14:DISCH TEMP (GAUGE)		-19.80					
15:DISCH TEMP DEF VAL		True					
16:DISCH TEMP LAST GOOD VAL		False					
17:FLOW PRES (ABSOLUTE)		1260.47					
18:FLOW PRES (GAUGE)		1159.15					
19:FLOW PRES DEF VAL		True					
20:FLOW PRES LAST GOOD VAL		False					
21:FLOW TEMP (ABSOLUTE)		253.35					
22:FLOW TEMP (GAUGE)		-19.80					
23:FLOW TEMP DEF VAL		True					
24:FLOW TEMP LAST GOOD VAL		False					
25:SPEED SIGNAL FILTERED		-2500.00					
26:FLOW SIGNAL FILTERED		0.00					

Figure 6-12. Service: 15*C1 INPUT SIGNALS* Menu

01:SUCT PRES (ABSOLUTE) Monitor
Suction pressure signal used for control after filtering, failure response, and conversion to absolute units (engineering units).

02:SUCT PRES (GAUGE) Monitor
Suction pressure signal used for control after filtering and failure response (engineering units).

03:SUCT PRES DEF VAL Monitor
Boolean indication that the suction pressure signal has failed and the Default Value is in use. If configured, the control may be failed to Manual mode.

04:SUCT PRES LAST GOOD VAL **Monitor**
Boolean indication that the suction pressure signal has failed and the Last Good Value is in use.

05:SUCT TEMP (ABSOLUTE) **Monitor**
Suction temperature signal used for control after filtering, failure response, and conversion to absolute units (engineering units).

06:SUCT TEMP (GAUGE) **Monitor**
Suction temperature signal used for control, after filtering and failure response (engineering units).

07:SUCT TEMP DEF VAL **Monitor**
Boolean indication that the suction temperature signal has failed and the Default Value is in use. If configured, the control may be failed to Manual mode.

08:SUCT TEMP LAST GOOD VAL **Monitor**
Boolean indication that the suction temperature signal has failed and the Last Good Value is in use.

09:DISCH PRES (ABSOLUTE) **Monitor**
Discharge pressure signal used for control after filtering, failure response, and conversion to absolute units (engineering units).

10:DISCH PRES (GAUGE) **Monitor**
Discharge pressure signal used for control after filtering and failure response (engineering units).

11:DISCH PRES DEF VAL **Monitor**
Boolean indication that the discharge pressure signal has failed and the Default Value is in use. If configured, the control may be failed to Manual mode.

12:DISCH PRES LAST GOOD VA **Monitor**
Boolean indication that the discharge pressure signal has failed and the Last Good Value is in use.

13:DISCH TEMP (ABSOLUTE) **Monitor**
Discharge temperature signal used for control, after filtering, failure response, and conversion to absolute units (engineering units).

14:DISCH TEMP (GAUGE) **Monitor**
Discharge temperature signal used for control after filtering and failure response (engineering units).

15:DISCH TEMP DEF VAL **Monitor**
Boolean indication that the discharge temperature signal has failed and the Default Value is in use. If configured, the control may be failed to Manual mode.

16:DISCH TEMP LAST GOOD VAL **Monitor**
Boolean indication that the discharge temperature signal has failed and the Last Good Value is in use.

17:FLOW PRES (ABSOLUTE) **Monitor**
Flow sensor pressure signal used for control after filtering, failure response, and conversion to absolute units (engineering units).

18:FLOW PRES (GAUGE) **Monitor**
Flow sensor pressure signal used for control after filtering and failure response (engineering units).

19:FLOW PRES DEF VAL **Monitor**
Boolean indication that the flow sensor pressure signal has failed and the Default Value is in use. If configured, the control may be failed to Manual mode.

20:FLOW PRES LAST GOOD VAL **Monitor**
Boolean indication that the flow sensor pressure signal has failed and the Last Good Value is in use.

21:FLOW TEMP (ABSOLUTE) **Monitor**
Flow sensor temperature signal used for control after filtering, failure response, and conversion to absolute units (engineering units).

22:FLOW TEMP (GAUGE) **Monitor**
Flow sensor temperature signal used for control after filtering and failure response (engineering units).

23:FLOW TEMP DEF VAL **Monitor**
Boolean indication that the flow sensor temperature signal has failed and the Default Value is in use. If configured, the control may be failed to Manual mode.

24:FLOW TEMP LAST GOOD VAL **Monitor**
Boolean indication that the flow sensor temperature signal has failed and the Last Good Value is in use.

25:SPEED SIGNAL FILTERED **Monitor**
Raw compressor speed input after filtering (rpm).

26:FLOW SIGNAL FILTERED **Monitor**
Raw flow input after filtering (engineering units).

Service: 16*C1 CALCULATE VALUES*

Field Name	Value	Units	Description	Low	High	Initial
01:FLOW THROUGH THE SENSOR	0.00					
02:MASS FLOW THROUGH STAGE	0.00					
03:ACTUAL FLOW AT SUCTION	0.00					
04:CALC FLOW THROUGH ASV	18270.83					
05:ACTUAL SETPOINT (SCL) FL	0.00					
06:POLYTROPIC HEAD	3879.15					
07:CURRENT OPERATING POINT	0.00					
08:PRIMARY CONTROLLER S_PV	0.00					
09:CONTROL MARGIN VALUE	10.00					
10:S_PV AT OR NEAR SCL	True					
11:S_PV VALUE AT SLL	90.91					
12:OPERATION STABLE	False					
13:STEADY STATE FAILED	True					
14:SHAFT HORSEPOWER	0.00					
15:SUCTION COMPRESIBILITY	0.91					
16:FLOW SENSOR COMPRESIBILI	0.90					
17:AVERAGE COMPRESIBILITY	0.75					
18:ADIABATIC EFFICENCY	1.90					
19:PRESURE RATIO	0.34					
20:SIGMA	1.42					
21:SPECIFIC HEAT RATIO	0.91					

Figure 6-13. Service: 16*C1 CALCULATE VALUES* Menu

01:FLOW THROUGH THE SENSOR **Monitor**
Calculated flow through the flow sensor (engineering units). May be mass or normal/standard volumetric units depending upon configuration.

02:MASS FLOW THROUGH STAGE **Monitor**
Calculated flow through the compressor stage (engineering units). May be mass or normal/standard volumetric units depending upon configuration.

03:ACTUAL FLOW AT SUCTION **Monitor**
Calculated volumetric flow at compressor suction conditions (engineering units).

04:CALC FLOW THROUGH ASV **Monitor**
Calculated, full-open volumetric flow through the anti-surge valve used by the Automatic Gain Compensation routine (engineering units).

05:ACTUAL SETPOINT (SCL) FL **Monitor**
Calculated setpoint flow (Surge Control Line) based upon the configured algorithm, Surge Limit Line, and control margin (engineering units). Does not apply to the Auxiliary surge control input.

06:POLYTROPIC HEAD **Monitor**
Calculated polytropic head across the compressor (engineering units).

07:CURRENT OPERATING POINT **Monitor**
Calculated compressor operating point based upon configured algorithm (engineering units).

08:PRIMARY CONTROLLER S_PV **Monitor**
Calculated surge process variable (S_PV) for the primary controller (percent).

09:CONTROL MARGIN VALUE **Monitor**
Current control margin after shifting and manual adjustments (percent).

10:S_PV AT OR NEAR SCL **Monitor**
Boolean indication that the S_PV value is at or below 100% (Surge Control Line). A 1% hysteresis is defaulted, meaning that this Boolean will go FALSE when S_PV increases beyond 101%. This parameter may be used to inhibit speed lower commands, Cascade control, etc. Setpoint and hysteresis values are tunable in the core software.

11:S_PV VALUE AT SLL **Monitor**
Calculated surge process variable (S_PV) for the primary controller at the configured Surge Limit Line (percent).

12:OPERATION STABLE **Monitor**
Boolean indication that the compressor is operating within the configured dead bands for speed, flow, suction pressure, and discharge pressure. The Last Good Value signal failure response is available.

13:STEADY STATE FAILED **Monitor**
Boolean indication of steady state status. If steady state was not achieved immediately prior to failure of a sensor, the LGV value's validity is questionable and is therefore not used.

14:SHAFT HORSEPOWER **Monitor**
Calculated compressor horsepower based upon calculated head and flow and assumed mechanical efficiency (HP).

15:SUCTION COMPRESSIBILITY **Monitor**
Calculated compressibility across the compressor used by the control (no units).

16:FLOW SENSOR COMPRESIBILI **Monitor**
Configured or calculated compressibility used by the control corresponding to the configured flow element location (no units).

17:AVERAGE COMPRESSIBILITY **Monitor**
Calculated compressibility across the compressor used by the control (no units).

18:ADIABATIC EFFICIENCY **Monitor**
Calculated compressor efficiency (decimal value).

19:PRESURE RATIO **Monitor**
Calculated compressor pressure ratio (no units).

20:SIGMA **Monitor**
Calculated Polytropic Exponent used by the control (no units).

21:SPECIFIC HEAT RATIO **Monitor**
Configured or calculated Ratio of Specific Heats or Isentropic Exponent used by the control (no units).

Service: 17*C1 OPERATING VALUES*

Field Name		Value	Units	Description	Low	High	Initial
01:VALVE PERCENT		100.00					
02:SEQUENCE MODE		Off Line - Zero Speed					
03:OPERATION MODE		Auto Mode					
04:CONTROL MODE		Sequence Position					
05:VALVE FREEZE ACTIVE		False					
06:HSS OUTPUT		100.00					
07:ANTI-SURGE PID DEMAND		100.00					
08:HSS AUXILIARY #1		-1.00					
09:HSS AUXILIARY #2		-1.00					
10:BOOST OUTPUT		-1.00					
11:DECOUPL OUTPUT		0.00					
12:HSS DEACTIVATION INPUT		-1.00					
13:MANUAL RAMP		100.00					
14:MANUAL DEMAND		-1.00					
15:SUCT PRES OVRD PID DEMAN		-1.00					
16:DISCH PRES OVRD PID DEMA		-1.00					
17:RATE CTRLLER PV		0.00					
18:RATE CTRLLER SP		0.90					
19:RATE PID DEMAND		-1.00					
20:SMP ACTIVE		False					
21:SMP OUTPUT		0.00					
22:SURGE RECOVERY ACTIVE		False					
23:SURGE RECOVERY OUTPUT		0.00					
24:SURGE COUNTER		0.00					
25:SURGE DETECTED		False					
26:SURGE DET-FLOW DERIV		False					
27:SURGE DET-MINIMUM FLOW		False					
28:SURGE DET-SUCT PRES DERI		False					
29:SURGE DET-DISCH PRES DER		False					
30:SURGE DET-SLL CROSSING		False					
31:SURGE DET-SPEED DERIV		False					
32:CAPTURED FLOW DERIV		0.00					
33:CAPTURED OP POINT		0.00					
34:CAPTURED SUCT PRES DERIV		0.00					
35:CAPTURED DISCH PRES DERI		0.00					
36:CAPTURED SPEED DERIV		0.00					

Figure 6-14. Service: 17*C1 OPERATING VALUES* Menu

01:VALVE PERCENT **Monitor**
Final output of the primary controller (percent open).

02:SEQUENCE MODE **Monitor**
This indication provides a following message corresponding to the current sequence position.

Message Number	Sequence
1	Offline – Controlled Shutdown
2	Offline – Emergency Shutdown
3	Offline – Zero Speed
4	Offline – Purge
5	Offline – Start
6	Online

Table 6-1. Sequence Messages

03:OPERATION MODE **Monitor**
This indication provides a following message corresponding to the current operating mode.

Message Number	Operating Mode
1	Automatic Mode
2	Manual with Backup Mode
3	Full Manual Mode

Table 6-2. Operating Mode Messages

04:CONTROL MODE **Monitor**
This indication provides a following message provides an integer value corresponding to the current controlling function.

Message Number	Controlling Function
1	Anti-Surge PID Controller
2	Surge Recovery
3	BOOST
4	Manual with Backup
5	Suction Pressure Override
6	Discharge Pressure Override
7	Rate PID Controller
8	Sequence Positioning
9	Auxiliary Input #1
10	Auxiliary Input #2
11	Auxiliary Input #3
12	Deactivation Routine

Table 6-3. Controlling Function Messages

05:VALVE FREEZE ACTIVE **Monitor**
Boolean indicator that the Freeze function is clamping the anti-surge valve demand at a stable operating position.

06:HSS OUTPUT **Monitor**
Output of the primary controller High Signal Select bus (percent).

07:ANTI-SURGE PID DEMAND **Monitor**
Output demand of the primary Anti-Surge PID controller (percent).

08:HSS AUXILIARY #1 **Monitor**
Output demand of the HSS Auxiliary Input #1 (percent).

09:HSS AUXILIARY #2 **Monitor**
Output demand of the HSS Auxiliary Input #2 (percent).

10:BOOST OUTPUT **Monitor**
Output demand of the Boost, or Backup Line open-loop routine (percent).

11:DECOUPL OUTPUT **Monitor**
Output demand of the five feed-forward or decoupling routines (2 speed and between stage) acting upon the anti-surge valve (percent).

12:HSS DEACTIVATION INPUT **Monitor**
Output demand of the HSS Deactivation routine (percent).

13:MANUAL RAMP **Monitor**
Output demand of the Manual mode position ramp (percent).

14:MANUAL DEMAND **Monitor**
Output demand of the Manual mode controller including Surge Recovery if enabled (percent).

15:SUCT PRES OVRD PID DEMAN **Monitor**
Output demand of the Suction Pressure Override PID controller (percent).

16:DISCH PRES OVRD PID DEMA **Monitor**
Output demand of the Discharge Pressure Override PID controller (percent).

17:RATE CTRLLER PV **Monitor**
Measured Rate PID controller process variable, or measured rate of change of the compressor operating point toward the Surge Control Line (percent per second).

18:RATE CTRLLER SP **Monitor**
Calculated Rate PID controller setpoint (percent per second) based upon the current S_PV and configured loop PERIOD and Rate Setpoint Factor.

19:RATE PID DEMAND **Monitor**
Output demand of the Rate PID controller (percent).

20:SMP ACTIVE **Monitor**
Boolean indication that the SMP limiter is active.

21:SMP OUTPUT **Monitor**
Output demand of the Surge Minimum Position open-loop routine (percent).

22:SURGE RECOVERY ACTIVE **Monitor**
Boolean indication that the Surge Recovery is active.

23:SURGE RECOVERY OUTPUT **Monitor**
Output demand of the Surge Recovery open-loop routine (percent).

24:SURGE COUNTER **Monitor**
Counter indicating the number of surges detected. This value is not reset by RESET_SURG but can be reset by a core software tunable.

25:SURGE DETECTED **Monitor**
Boolean indicator (latched) that the controller has detected a compressor surge.

26:SURGE DET-FLOW DERIV **Monitor**
Boolean indicator that the controller has detected a compressor surge based upon high rate of change of calculated flow.

27:SURGE DET-MINIMUM FLOW **Monitor**
Boolean indicator that the calculated flow through the compressor fell below the configured minimum flow setpoint.

28:SURGE DET-SUCT PRES DERI **Monitor**
Boolean indicator that the controller has detected a compressor surge based upon high rate of change of measured suction pressure.

29:SURGE DET-DISCH PRES DER **Monitor**
Boolean indicator that the controller has detected a compressor surge based upon high rate of change of measured discharge pressure.

30:SURGE DET-SLL CROSSING **Monitor**
Boolean indicator that the calculated compressor operating point crossed to the left of the configured Surge Limit Line.

31:SURGE DET-SPEED DERIV **Monitor**
Boolean indicator that the controller has detected a compressor surge based upon high rate of change of measured speed.

32:CAPTURED FLOW DERIV **Monitor**
Maximum captured flow derivative (engineering units per second).

33:CAPTURED OP POINT **Monitor**
Captured operating point at surge (engineering units).

34:CAPTURED SUCT PRES DERIV **Monitor**
Maximum captured suction pressure derivative (engineering units per second).

35:CAPTURED DISCH PRES DERI **Monitor**
Maximum captured discharge pressure derivative (engineering units per second).

36:CAPTURED SPEED DERIV **Monitor**
Maximum captured speed derivative (rpm per second).

IMPORTANT

Service Menus 18 thru 20 for the 2nd stage compressor (C2) are monitored following the same rules as described for Service Menus 15 to 17 for the 1st stage compressor (C1).

IMPORTANT

Service Menus 50 thru 54 are entered following the same rules as described for Configure Menus 10 to 14.

Service: 55*COMMUNICATION SETTINGS*

Field Name		Value	Units	Description	Low	High	Initial
01:Use Serial Modbus 1?	*	False					False
02:Use Serial Modbus 2?	*	False					False
03:Use Ethernet Modbus 1?	*	False					False
04:Use Ethernet Modbus 2?	*	False					False
05:Com#1 Transmission Mode	*	2			1	2	2
06:Com#1 Device Number	*	1			1	247	1
07:Com#2 Transmission Mode	*	2			1	2	2
08:Com#2 Device Number	*	1			1	247	1
09:Serial#1 Baud Rate	*	9			1	11	9
10:Serial#1 Stop Bits	*	1			1	3	1
11:Serial#1 Parity Bits	*	1			1	3	1
12:Serial#1 Driver	*	1			1	3	1
13:Serial#2 Baud Rate	*	9			1	11	9
14:Serial#2 Stop Bits	*	1			1	3	1
15:Serial#2 Parity Bits	*	1			1	3	1
16:Serial#2 Driver	*	1			1	3	1

Figure 6-15. Service: 55*COMMUNICATION SETTINGS* Menu

The Vertex-Pro has serial ports and Ethernet ports, in order to communicate with a DCS or an HMI. The ports are attached to the CPU module. Communications can also be performed in a redundant mode if the CPU modules are in a redundant configuration. The communication of the Vertex-Pro uses Modbus protocol. Transmission Modes ASCII or RTU are both available. The latter is generally preferred for Modbus speed and efficiency. The Device Number is defaulted to one (1) but can be tuned if the control is on a serial multi-drop network.

IMPORTANT

Each Vertex-Pro CPU has one Serial and one Ethernet communication ports for Modbus link. Redundant communication by the same medium type is possible only when the Vertex-Pro has two CPU modules. For any Modbus connection, the Vertex-Pro must have a unique device number.

The Timeout Delay is defaulted to 10 seconds and is adjustable only with special software tools. This delay defines the Modbus link dead time allowed before a link error is assumed and an alarm is generated. Select the Driver Protocol as desired: RS-232, RS-422, RS-485 (see Manual 26415 for serial port locations and wiring pin outs on the CPU board), or TCP/IP Ethernet. If a serial protocol is selected, complete the port configuration by selecting the appropriate Baud Rate, Stop Bits, and Parity to match those of the master device.

01:Use Serial Modbus 1? Initial=FALSE (FALSE, TRUE)
Set TRUE, when the Serial port on the left side CPU module is used.

02:Use Serial Modbus 2? Initial=FALSE (FALSE, TRUE)
Set TRUE, when the Serial port on the right side CPU module is used. This configuration is required in a redundant system only.

03:Use Ethernet Modbus 1? Initial=FALSE (FALSE, TRUE)
Set TRUE, when the Ethernet port on the left side CPU module is used.

04:Use Ethernet Modbus 2? Initial=FALSE (FALSE, TRUE)
Set TRUE, when the Ethernet port on the right side CPU module is used. This configuration is required in a redundant system only.

05:Com#1 Transmission Mode **Initial=2 (1, 2)**
Set the Transmission Mode, which defines the communication #1 protocol for the Modbus. This setup is similar to the Serial port on the redundant CPU module.

1. ASCII
2. RTU (Remote Terminal Unit)

06:Com#1 Device Number **Initial=1 (1, 247)**
The Network Address input defines the slave block address on the Modbus of the communication #1 network. The network address may depend on the master device's allowable addresses. This setup is similar to the Serial port on the redundant CPU module.

07:Com#2 Transmission Mode **Initial=2 (1, 2)**
Set the Transmission Mode, which defines the communication #2 protocol for the Modbus. This setup is similar to the Ethernet port on the redundant CPU module.

1. ASCII
2. RTU (Remote Terminal Unit)

08:Com#2 Device Number **Initial=1 (1, 247)**
The Network Address input defines the slave block address on the Modbus of the communication #2 network. The network address may depend on the master device's allowable addresses. This setup is similar to the Ethernet port on the redundant CPU module.

09:Serial#1 Baud Rate **Initial=9 (1, 11)**
Set the Baud rate, which defines the transfer rate for serial port #1 communications.

1. 110
2. 300
3. 600
4. 1,200
5. 1,800
6. 2,400
7. 4,800
8. 9,600
9. 19,200
10. 38,400
11. 57,600

10:Serial#1 Stop Bits **Initial=1 (1, 3)**
Set the Stop bits, which defines the number of stop bits for serial port #1 communication protocol. Stop bits specify the time that elapses between transmitted characters.

1. 1 stop bit
2. 2 stop bits
3. 1.5 stop bits

11:Serial#1 Parity Bits **Initial=1 (1, 3)**
The Parity input defines protocol for serial port #1 communications. If 8 data bits is selected, select "1" here for "OFF (none)."

1. OFF (none)
2. ODD
3. EVEN

12:Serial#1 Driver **Initial=1 (1, 3)**

The Driver input defines the type of driver output for serial port #1 communications.

1. RS-232
2. RS-422
3. RS-485

13:Serial#2 Baud Rate **Initial=9 (1, 11)**

Set the Baud rate, which defines the transfer rate for serial port #2 communications. This configuration is required in a redundant system only.

1. 110
2. 300
3. 600
4. 1,200
5. 1,800
6. 2,400
7. 4,800
8. 9,600
9. 19,200
10. 38,400
11. 57,600

14:Serial#2 Stop Bits **Initial=1 (1, 3)**

Set the Stop bits, which defines the number of stop bits for serial port #2 communication protocol. Stop bits specify the time that elapses between transmitted characters. This configuration is required in a redundant system only.

1. 1 stop bit
2. 2 stop bits
3. 1.5 stop bits

15:Serial#2 Parity Bits **Initial=1 (1, 3)**

The Parity input defines protocol for serial port #2 communications. If 8 data bits is selected, select "1" here for "OFF (none)." This configuration is required in a redundant system only.

1. OFF (none)
2. ODD
3. EVEN

16:Serial#2 Driver **Initial=1 (1, 3)**

The Driver input defines the type of driver output for serial port #2 communications. This configuration is required in a redundant system only.

1. RS-232
2. RS-422
3. RS-485

Service: 56* LOCAL REMOTE FUNCTIONS*

Field Name		Value	Units	Description	Low	High	Initial
01:Use Local/Remote?	*	False					False
02:Keep Contacts Enbld Rmt	*	False					False
03:Keep Modbus Enbld Local	*	False					False
04:Use Modbus Trip?	*	False					False
05:Use 2 Step Trip Modbus?	*	False					False
06:Always Enbl Modbus Trip?	*	False					False
07:Remote Enabled		True					
08:Contacts Enabled		True					
09:Modbus Enabled		False					

Figure 6-16. Service: 56* LOCAL REMOTE FUNCTIONS* Menu

The Local/Remote function allows an operator using the HMI/DCS to disable any remote command, discrete input, or Modbus command from a remote control room. This function is typically used during a system startup or shutdown to allow only one operator to manipulate the Vertex-Pro's control modes and settings. If Local/Remote is not configured, discrete inputs and Modbus commands which are configured, are enabled at all times. If the Local/Remote function is programmed, Local and Remote modes can be selected through a programmed contact input or Modbus command.

> **IMPORTANT**
>
> **The optional touch screen HMI, or similar HMI/DCS Modbus communication provided by the user, may be installed anywhere within communication protocol distance limitations. With regard to the Local/Remote functionality, the HMI/DCS is always considered Local, no matter where it is installed.**

When configured, the Local/Remote function provides a Local-only mode, in which the HMI/DCS is the sole control station. This Local mode can be further customized to enable discrete inputs and/or Modbus commands if necessary. Regardless of this supplemental configuration, the following inputs/commands are always enabled in the Local control mode:

- External Trip Discrete Input
- External Trip 2 Discrete Input
- External Trip 3 Discrete Input
- External Trip 4 Discrete Input
- External Trip 5 Discrete Input
- Start Permissive Discrete Input
- Local/Remote Discrete Input
- Local/Remote Modbus Command (if Modbus is configured)
- Trip/ESD Modbus Command (if Modbus is configured)

If the control mode is switched from Local to Remote, the Vertex-Pro can be operated through the HMI/DCS, and/or all Modbus commands.

When using a discrete input to select between Local and Remote modes, a closed contact, or high input, selects the Local/Remote mode and an open contact, or low input, selects the Local mode.

A configurable discrete output may be assigned to indicate (energized) when Local mode is selected. There is also an indication of the Local/Remote mode selection through Modbus (TRUE for Remote mode, FALSE for Local mode).

01:Use Local/Remote? Initial=FALSE (FALSE, TRUE)
Set TRUE if using Local/Remote control logic. If TRUE, this permits the unit to go from REMOTE (Modbus or contact inputs) control to LOCAL (contact inputs) control only. If FALSE, all programmed inputs are active at all times.

02:Keep Contacts Enbld Rmt Initial=FALSE (FALSE, TRUE)
When TRUE is selected, the contacts are always active regardless of Local/Remote selection. When FALSE is selected, the contact inputs are disabled when Remote mode is selected.

03:Keep Modbus Enbld Local Initial=FALSE (FALSE, TRUE)
When TRUE is selected, the Modbus is always active regardless of Local/Remote selection. When FALSE is selected, the Modbus inputs are disabled when Local mode is selected.

04:Use Modbus Trip? Initial=FALSE (FALSE, TRUE)
This is the option that determines how the Modbus Commands trip the Vertex-Pro control. The user must select one of the following three options:

- Not Used — Cannot initiate a trip from a Modbus port.
- One-Step — Will initiate a trip after receiving the Modbus port trip command.
- Two-Step — Will initiate a trip after receiving the Modbus port confirmed trip command.

05:Use 2 Step Trip Modbus? Initial=FALSE (FALSE, TRUE)
Select TRUE for the two-step TRIP command from Modbus. In order to issue a Trip via a Modbus Trip command, an Acknowledge input from Modbus is required.

06:Always Enbl Modbus Trip? Initial=FALSE (FALSE, TRUE)
Select TRUE for always enabling the TRIP command from Modbus, even if the Vertex-Pro is in the Local mode.

07:Remote Enabled Monitor
TRUE is displayed when Remote mode is active.

08:Contacts Enabled Monitor
TRUE is displayed when commands from contact inputs are effective.

09:Modbus Enabled Monitor
TRUE is displayed when commands from the Modbus are effective.

Service: 57*Current Ctrl Mon&Adj*

Field Name		Value	Units	Description	Low	High	Initial
01:Motor Current(units)		0.00					
02:Current Lim Setpt(units)		1000.00					
03:Cur Lim MV Rate(%/sec)	*	2.00			0.00	10000.00	2.00
04:Current Lim PID Out (%)		100.00					
05:Cur Lim PID P Gain	*	1.00			0.00	100.00	1.00
06:Cur Lim PID I Gain	*	0.10			0.001	50.00	0.10
07:Cur Lim PID SDR	*	100.00			0.01	100.00	100.00
08:Rmt Curr Lim Spt(units)		1000.00					

Figure 6-17. Service: 57*Current Ctrl Mon&Adj* Menu

01:Motor Current(units) **Monitor**
Motor Current input signal is used for control after filtering (engineering units).

02:Current Lim Setpt(units) **Monitor**
Current limiting setpoint used for control (engineering units).

03:Cur Lim MV Rate(%/sec) **Initial=2.0 (0.0, 10000.0)**
When the current input signal is failed, the current limit PID output can be changed manually. Set the current limit manual demand rate. This value is the rate (in percent per second) at which the current limit demand moves when adjusted.

04:Current Lim PID Out (%) **Monitor**
The output of the current limit PID is displayed in percent.

05:Cur Lim PID P Gain **Initial=1.0 (0.0, 100.0)**
Enter the appropriate proportional gain (in percent) of the current limit PID.

06:Cur Lim PID I Gain **Initial=0.1 (0.001, 50.0)**
Enter the appropriate integral gain (in repeats per second) of the current limit PID.

07:Cur Lim PID SDR **Initial=100.0 (0.01, 100.0)**
Enter the appropriate speed derivative ratio (in percent) of the current limit PID. Leave this value at 100% for proportional and integral control. Refer to the Dynamics Adjustments section later in this chapter for more details on tuning the speed derivative ratio.

08:Rmt Curr Lim Spt(units) **Monitor**
If used, the remote current limit setpoint is displayed in engineering units.

Service: 58*Perform Ctrl Mon&Adj*

Field Name		Value	Units	Description	Low	High	Initial
01:Perform Ctrl is		Disable					
02:Rmt Perform Ctrl is		Disable					
03:Performance Input(units)		1.52					
04:Performance Spt(units)		1.52					
05:Performance Droop (%)	*	2.00			0.00	10.00	2.00
06:Performance PID Outpt(%)		7.00649e-044					
07:Performance PID P Gain	*	0.70			0.00	100.00	1.00
08:Performance PID I Gain	*	0.50			0.001	10.00	0.30
09:Performance PID SDR	*	100.00			0.01	100.00	100.00
10:Rmt Perforance Sp(units)		0.00					

Figure 6-18. Service: 58*Perform Ctrl Mon&Adj* Menu

01:Perform Ctrl is **Monitor**
The operating mode status message for performance control is displayed.

Message Number	Operating Mode
0	Disable
1	In Control
2	Active
3	Inhibited
4	Enabled

Table 6-4. Performance Control Status Messages

02:Rmt Perform Ctrl is **Monitor**
The operating mode status message for remote performance control is displayed.

Message Number	Operating Mode
0	Disable
1	In Control
2	Active
3	Inhibited
4	Enabled

Table 6-5. Remote Performance Control Status Messages

03:Performance Input(units) **Monitor**
Performance input signal used for control, after filtering (engineering units).

04:Performance Spt(units) **Monitor**
Performance setpoint used for control (engineering units).

05:Performance Droop (%) **Initial=2.0 (0.0, 10.0)**
Enter the droop percentage. If needed, typically set between 2-6% and not more than 10%.

06:Performance PID Outpt (%) **Monitor**
Performance PID output used for control (percentage).

07:Performance PID P Gain **Initial=1.0 (0.0, 100.0)**
Enter the performance PID proportional gain value. This value is used to set performance control response. This value can be changed in the Run Mode while the motor is operating. If unknown, a recommended starting value is 1.0%.

08:Performance PID I Gain **Initial=0.3 (0.001, 10.0)**
Enter the performance PID integral gain value, in repeats-per-second (rps). This value is used to set performance control response. This value can be changed in the Run Mode while the motor is operating. If unknown, a recommended starting value is **0.3** rps.

09:Performance PID SDR **Initial=100.0 (0.01, 100.0)**
Enter the performance PID derivative ratio. This value is used to set performance control response. This value can be changed in the Service Mode while the motor is operating. If unknown, a recommended starting value is 100%.

10:Rmt Performance Sp(units) **Monitor**
If used, the remote performance setpoint is displayed in engineering units.

Service: 59*Load Share Ctl Mon&Adj*

Field Name		Value	Units	Description	Low	High	Initial
01:LS Control is		Disable					
02:Rmt LS Control is		Inhibited					
03:Master Control of LS		False					
04:Header Press(units)		0.93					
05:Header Press Spt(units)		0.93					
06:LoadShare Rmt Spt(units)		0.93					
07:Flow Monitor		-0.01					
08:Flow #1 Input Monitor		-0.01					
09:Flow #2 Input Monitor		-0.01					
10:Flow Differece(%)		100.00					
11:Header Press DB(units)	*	3.00			0.00	1e+010	3.00
12:Flow Balance DB(units)	*	0.00			0.00	1e+010	0.00
13:Flow Balance Delay(sec)	*	1.00			0.00	100.00	1.00
14:Header Ctrl Rate(/sec)	*	2.00			0.00	9e+020	2.00
15:Flow Ctrl Rate(/sec)	*	0.70			0.00	9e+020	0.70

Figure 6-19. Service: 59*Load Share Ctl Mon&Adj* Menu

01:LS Control is **Monitor**

The operating mode status message for load sharing control is displayed.

Message Number	Operating Mode
0	Disable
1	Configuration Error
2	Active
3	Inhibited
4	Enabled
5	Permissive

Table 6-6. Load Sharing Status Messages

02:Rmt LS Control is **Monitor**

The operating mode status message for remote load sharing control is displayed.

Message Number	Operating Mode
0	Disable
1	Control
2	Active
3	Inhibited
4	Enabled

Table 6-7. Remote Load Sharing Status Messages

03:Master Control of LS **Monitor**

TRUE is displayed when this controller is bearing the master controller for load sharing. In the case of a slave, FALSE is displayed.

04:Header Press(units) **Monitor**

Header pressure input signal used for control, after filtering (engineering units).

05:Header Press Spt(units) **Monitor**

Header pressure setpoint used for control (engineering units).

06:LoadShare Rmt Spt(units) **Monitor**
If used, the remote header pressure setpoint is displayed (engineering units).

07:Flow Monitor **Monitor**
The current controller's mass flow is displayed (engineering units).

08:Flow #1 Input Monitor **Monitor**
The mass flow of other controllers which perform load sharing is displayed (engineering units).

09:Flow #2 Input Monitor **Monitor**
The mass flow of other controllers which perform load sharing is displayed (engineering units).

10:Flow Difference(%) **Monitor**
The difference between the mass flow of the current controller and an average mass flow is displayed in percent.

11:Header Press DB(units) **Initial=3.0 (0.0, 1.0E+10)**
Set the dead band width (in engineering units) for stopping the operation of the header pressure adjustment during load sharing control.

12:Flow Balance DB(units) **Initial=0.0 (0.0, 1.0E+10)**
Set the dead band width (in engineering units) for stopping the operation of the mass flow adjustment during load sharing control.

13:Flow Balance Delay(sec) **Initial=1.0 (0.0, 100.0)**
Set the filter time constant (sec) of the mass flow adjustment used for load sharing.

14:Header Ctrl Rate(/sec) **Initial=2.0 (0.0, 9.0E+20)**
Set the load sharing execution rate for header pressure adjustment. This value specifies the header pressure adjustment rate of change (in engineering units per second).

15:Flow Ctrl Rate(/sec) **Initial=0.7 (0.0, 9.0E+20)**
Set the load-sharing execution rate for mass flow adjustment. This value specifies the mass flow adjustment rate of change (in engineering units per second).

Service: 60*Throttle/IGV Ctrl Mon*

Field Name		Value	Units	Description	Low	High	Initial
01:Throttle/IGV Low Limit		True					
02:Throttle/IGV High Limit		False					
03:Throttle/IGV control is		Valve Ramp in Control					
04:Throttle/IGV Demand (%)		0.00					
05:Valve Ramp Stpt(%)		0.00					
06:Rmt Valve Ramp Stpt(%)		0.00					
07:Sequence Position(%)		100.00					

Figure 6-20. Service: 60*Throttle/IGV Ctrl Mon* Menu

01:Throttle/IGV Low Limit **Monitor**
TRUE is displayed when the throttle valve or IGV is at minimum position.

02:Throttle/IGV High Limit **Monitor**
TRUE is displayed when the throttle valve or IGV is at maximum position.

03:Throttle/IGV control is **Monitor**
Status indication of which mode is in control of the throttle valve or IGV.

Message Number	Operating Mode
0	No Selection
1	Current Limit in Control
2	Valve Ramp in Control
3	Sequence in Control
4	Load Sharing in Control
5	Performance in Control

Table 6-8. Throttle/IGV Control Messages

04:Throttle/IGV Demand (%) **Monitor**
The Throttle/IGV demand is displayed in percent.

05:Valve Ramp Stpt(%) **Monitor**
The Throttle/IGV Ramp setpoint is displayed in percent.

06:Rmt Valve Ramp Stpt(%) **Monitor**
If used, the Remote Throttle/IGV Ramp setpoint is displayed in percent.

07:Sequence Position(%) **Monitor**
The Sequence position of the Throttle/IGV is displayed in percent.

Service: 61*COMMON ALARMS*

Field Name	Value	Units	Description	Low	High	Initial
01:FIRST ALARM	Motor Current Failed					
02:PS1 Fault	False					
03:PS2 Fault	False					
04:Main Chassis Temp High	False					
05:Top Left Fan Fault	False					
06:Top Right Fan Fault	False					
07:Bottom Left Fan Fault	False					
08:Bottom Right Fan Fault	False					
09:Left CPU Fault	False					
10:Right CPU Fault	False					
11:A2 HD Analog Fault	False					
12:A3 HD Analog Fault	False					
13:A4 Analog Combo Fault	False					
14:A5 Analog Combo Fault	False					
15:A6 Discrete I/O Fault	False					
16:A7 Discrete I/O Fault	False					
17:Serial Modbus #1 Fault	False					
18:Serial Modbus #2 Fault	False					
19:Ether Modbus #1 Fault	False					
20:Ether Modbus #2 Fault	False					
21:Discrete Input Mismatch	False					
22:Start Permissive Not Met	False					
23:Trip as Alarm	False					
24:Speed Sensor 1 Failed	False					
25:Speed Sensor 2 Failed	False					
26:Speed Sensor 3 Failed	False					
27:Performance Input Fault	False					
28:Performance Rmt Sp Fault	False					
29:Motor Current Failed	True					
30:Remote Spt LS #1 Faile	True					
31:Remote Spt LS #2 Faile	True					
32:Flow #1 for LS Failed	True					
33:Flow #2 for LS Failed	True					
34:Header Pressure Failed	True					
35:Throttle/IGV Rmt Sp Fail	False					
36:Ext Speed Sensor Failed	True					
37:Rmt Header Prs Sp Failed	False					
38:Stage 1 ASV Pos Failed	False					
39:Stage 2 ASV Pos Failed	False					
40:Throttle/IGV Pos Failed	False					
41:spare	False					
42:spare	False					
43:HD Analog Output #1	False					
44:HD Analog Output #2	False					
45:HD Analog Output #3	False					
46:HD Analog Output #4	False					
47:HD Analog Output #5	False					
48:HD Analog Output #6	False					

49:HD Analog Output #7	False
50:HD Analog Output #8	False
51:Combo Analog Output #1	False
52:Combo Analog Output #2	False
53:Combo Analog Output #3	False
54:Combo Analog Output #4	False
55:Combo Act Output #1	False
56:Combo Act Output #2	False
57:HD Analog Input #1	True
58:HD Analog Input #2	True
59:HD Analog Input #3	True
60:HD Analog Input #4	True
61:HD Analog Input #5	True
62:HD Analog Input #6	True
63:HD Analog Input #7	True
64:HD Analog Input #8	True
65:HD Analog Input #9	True
66:HD Analog Input #10	True
67:HD Analog Input #11	True
68:HD Analog Input #12	True
69:HD Analog Input #13	True
70:HD Analog Input #14	True
71:HD Analog Input #15	True
72:HD Analog Input #16	True
73:HD Analog Input #17	True
74:HD Analog Input #18	False
75:HD Analog Input #19	False
76:HD Analog Input #20	False
77:HD Analog Input #21	False
78:HD Analog Input #22	False
79:HD Analog Input #23	False
80:HD Analog Input #24	False
81:Combo Analog Input #1	False
82:Combo Analog Input #2	False
83:Combo Analog Input #3	False
84:Combo Analog Input #4	False
85:Combo Analog Input #5	False
86:Combo Analog Input #6	False
87:Combo Analog Input #7	False
88:Combo Analog Input #8	False
89:Can Network #1 Error	False
90:Can Network #2 Error	False
91:in the Forc/Calib Mode	False
92:Level Alarm #1	False
93:Level Alarm #2	False
94:Level Alarm #3	False
95:Level Alarm #4	False

Figure 6-21. Service: 61*COMMON ALARMS* Menu

Alarms related to the hardware of Vertex-Pro are displayed. Alarms are generated from the control and represent a condition that the Vertex-Pro application considers to be wrong but not dangerous enough to initiate an emergency shutdown.

01:FIRST ALARM **Monitor**
The alarm for the hardware generated first is displayed.

02~95: (Alarm Items) **Monitor**
TRUE is displayed in the Value field of the item in which an alarm was generated.
Refer to Chapter 7 Alarms/Trips for details.

IMPORTANT **All the hardware alarms of Vertex-Pro containing options are displayed in this field. For example, Redundant CPUs and Power Supplies, or Analog Combo Modules.**

Service: 62*STAGE 1 ALARMS*

Field Name	Value	Units	Description	Low	High	Initial
01:FIRST ALARM	Primary Flow Signal Failed					
02:Primary Flow Sig Fld	True					
03:Primary Suct Prs Sig Fld	True					
04:Primary Disch Prs Sig Fl	True					
05:Suct Temp Sig Fld	True					
06:Disch Temp Sig Fld	True					
07:Flow Element Press Sig F	False					
08:Flow Element Temp Sig F	False					
09:Aux HSS Input 1 Sig Fld	False					
10:Aux HSS Input 2 Sig Fld	False					
11:Man Vlv Pos Input Sig Fl	False					
12:Redun Flow Input Sig Fld	False					
13:Redun Suct Press Sig Fld	False					
14:Redun Disch Prs Sig Fld	False					
15:spare	False					
16:spare	False					
17:Redun Flow Input Diff	False					
18:Redun P1 Input Diff	False					
19:Redun P2 Input Diff	False					
20:Not in Auto - Started	False					
21:Full Man-Srg Recv Disbld	False					
22:Steady State Cond Fld	False					
23:spare	False					
24:Surge Min Pos Active	False					
25:Anti-Surge Vlv Out Fld	False					

Figure 6-22. Service: 62*STAGE 1 ALARMS* Menu

Alarms related to the 1st stage compressor are displayed. Alarms are generated from the control and represent a condition that the Vertex-Pro application considers to be wrong but not dangerous enough to initiate an emergency shutdown.

01:FIRST ALARM **Monitor**
The alarm for the 1st stage compressor generated first is displayed.

02~25: (Alarm Items) **Monitor**
TRUE is displayed in the Value field of the item in which an alarm was generated.
Refer to Chapter 7 Alarms/Trips for details.

Service: 63*STAGE 2 ALARMS*

Field Name	Value	Units	Description	Low	High	Initial
01:FIRST ALARM	No Alarm					
02:Primary Flow Sig Fld	False					
03:Primary Suct Prs Sig Fld	False					
04:Primary Disch Prs Sig Fl	False					
05:Suct Temp Sig Fld	False					
06:Disch Temp Sig Fld	False					
07:Flow Element Press Sig F	False					
08:Flow Element Temp Sig F	False					
09:Aux HSS Input 1 Sig Fld	False					
10:Aux HSS Input 2 Sig Fld	False					
11:Man Vlv Pos Input Sig Fl	False					
12:Redun Flow Input Sig Fld	False					
13:Redun Suct Press Sig Fld	False					
14:Redun Disch Prs Sig Fld	False					
15:spare	False					
16:spare	False					
17:Redun Flow Input Diff	False					
18:Redun P1 Input Diff	False					
19:Redun P2 Input Diff	False					
20:Not in Auto - Started	False					
21:Full Man-Srg Recv Disbld	False					
22:Steady State Cond Fld	False					
23:spare	False					
24:Surge Min Pos Active	False					
25:Anti-Surge Vlv Out Fld	False					

Figure 6-23. Service: 63*STAGE 2 ALARMS* Menu

Alarms related to the 2nd stage compressor are displayed. Alarms are generated from the control and represent a condition that the Vertex-Pro application considers to be wrong but not dangerous enough to initiate an emergency shutdown.

01:FIRST ALARM **Monitor**
The alarm for the 2nd stage compressor generated first is displayed.

02~25: (Alarm Items) **Monitor**
TRUE is displayed in the Value field of the item in which an alarm was generated.
Refer to Chapter 7 Alarms/Trips for details.

Service: 64*TRIPS*

Field Name		Value	Units	Description	Low	High	Initial
01:FIRST TRIP		Power Up Shutdown					
02:Power Up Shutdown		True					
03:Emrg SD from OPC		False					
04:Overspeed		False					
05:spare		False					
06:spare		False					
07:spare		False					
08:spare		False					
09:External Trip 2		False					
10:External Trip 3		False					
11:Comm Link #1 Trip		False					
12:spare		False					
13:spare		False					
14:spare		False					
15:External Trip Input		True					
16:Controled Shutdown		False					
17:External Trip 4		False					
18:External Trip 5		False					
19:spare		False					
20:HD ANA Module Fault		False					
21:COMBO Module Fault		False					
22:DIO Module Fault		False					
23:Invalid Comp Config		False					

Figure 6-24. Service: 64*TRIPS* Menu

The above folder shows trip condition indications. A trip is considered to be any condition that causes the Vertex-Pro control to immediately take the motor to a failed safe condition (Emergency Shutdown).

01:FIRST TRIP **Monitor**
The trip condition generated first is displayed.

02~23: (Trip Items) **Monitor**
TRUE is displayed in the Value field of the item in which a trip was generated. Refer to Chapter 7 Alarms/Trips for details.

Service: 65*Hardware Alarm Ovrd*

Field Name		Value	Units	Description	Low	High	Initial
01:Power Supply	*	False					False
02:Top Left Fan	*	False					False
03:Top Right Fan	*	False					False
04:Bottom Left Fan	*	False					False
05:Bottom Right Fan	*	False					False
06:CPU Module	*	False					False
07:HD Analog Module	*	False					False
08:Analog Combo Module	*	False					False
09:DIO Module	*	False					False

Figure 6-25. Service: 65*Hardware Alarm Ovrd* Menu

Whenever a hardware alarm is generated, the alarm is displayed until maintenance is complete and the alarm condition no longer exists. The alarm may disrupt normal control. The Vertex-Pro can override these hardware alarms. To clear, an Alarm Reset command is required after overriding hardware alarms.

01:Power Supply **Initial=FALSE (FALSE, TRUE)**
Set TRUE, to override the power supply alarm. This override is effective for both power supply modules on the right (PS1) and the left (PS2).

02:Top Left Fan **Initial=FALSE (FALSE, TRUE)**
Set TRUE, to override the top left fan alarm.

03:Top Right Fan **Initial=FALSE (FALSE, TRUE)**
Set TRUE, to override the top right fan alarm.

04:Bottom Left Fan **Initial=FALSE (FALSE, TRUE)**
Set TRUE, to override the bottom left fan alarm.

05:Bottom Right Fan **Initial=FALSE (FALSE, TRUE)**
Set TRUE, to override the bottom right fan alarm.

06:CPU Module **Initial=FALSE (FALSE, TRUE)**
Set TRUE, to override the CPU module alarm. This override is effective for both CPU modules on the right (slot A1) and the left (slot A8).

07:HD Analog Module **Initial=FALSE (FALSE, TRUE)**
Set TRUE, to override the 24/8 Analog Module alarm. This override is effective for both 24/8 Analog Modules in slot A2 and slot A3.

08:Analog Combo Module **Initial=TRUE (FALSE, TRUE)**
Set TRUE, to override the optional Analog Combo Module alarm. This override is effective for both optional Analog Combo Modules in slot A4 and slot A5.

09:DIO Module **Initial=FALSE (FALSE, TRUE)**
Set TRUE, to override the 48/24 Discrete Combo Module alarm. This override is effective for both 48/24 Discrete Combo Modules in slot A6 and slot A7.

Chapter 7. Alarms/Trips

General

The Vertex-Pro Control System monitors all alarms and trips and sends them to the PC Interface program and Modbus. This chapter includes a list of all alarms, shutdowns, and possible causes of the alarm/trip.

Alarms

See Table 7-1 for a list of the Vertex-Pro's alarms. This list is duplicated for each compressor section. 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.

Number	Description	Explanation
0	No Alarm	The Vertex-Pro has no hardware alarms.
1	MicroNet Plus PS1 Fault	Failure of the Power Supply module in slot PS1 (left side). Verify that the module is inserted and the Fault lights are off. Check input voltages of the supply.
2	MicroNet Plus PS2 Fault (Redundant Only)	Failure of the Power Supply module in slot PS2 (right side). Verify that the module is inserted and the Fault lights are off. Check input voltages of the supply.
3	MicroNet Plus Temp High	Chassis over temperature is detected.
4	Top Left Fan Fault	Chassis Top Left Fan Fault is detected.
5	Top Right Fan Fault	Chassis Top Right Fan Fault is detected.
6	Bottom Left Fan Fault	Chassis Bottom Left Fan Fault is detected.
7	Bottom Right Fan Fault	Chassis Bottom Right Fan Fault is detected.
8	Left CPU Fault	Failure of the CPU module in slot A1. Verify that the module is inserted and the Fault lights are off.
9	Right CPU Fault (Redundant Only)	Failure of the CPU module in slot A8. Verify that the module is inserted and the Fault lights are off.
10	A2 HD Analog Fault	Failure of the 24/8 Analog module in slot A2. Verify that the module is inserted and the Fault lights are off.
11	A3 HD Analog Fault (Redundant Only)	Failure of the 24/8 Analog module in slot A3. Verify that the module is inserted and the Fault lights are off.
12	A4 Analog Combo Fault (Option)	Failure of the Analog Combo module in slot A4. Verify that the module is inserted and the Fault lights are off.
13	A5 Analog Combo Fault (Option)	Failure of the Analog Combo module in slot A5. Verify that the module is inserted and the Fault lights are off.
14	A6 Discrete I/O Fault	Failure of the 48/24 Discrete Combo module in slot A6. Verify that the module is inserted and the Fault lights are off.
15	A7 Discrete I/O Fault (Redundant Only)	Failure of the 48/24 Discrete Combo module in slot A7. Verify that the module is inserted and the Fault lights are off.

Number	Description	Explanation
16	Serial Modbus Port 1 Fault	Serial port on the left side CPU Fault is detected.
17	Serial Modbus Port 2 Fault (Redundant Only)	Serial port on the right side CPU Fault is detected.
18	Ether Modbus Port 1 Fault	Ethernet port on the left side CPU Fault is detected.
19	Ether Modbus Port 2 Fault (Redundant Only)	Ethernet port on the right side CPU Fault is detected.
20	Discrete Input Mismatch (Redundant Only)	Miss match of discrete input is detected.
21	Start Permissive Not Met	Start was selected while the Start Permissible contact input was not closed.
22	Trip as Alarm	The Vertex-Pro has a trip(s).
23	Speed Sensor 1 Failed (Option)	Speed probe #1 input failed.
24	Speed Sensor 2 Failed (Option)	Speed probe #2 input failed.
25	Speed Sensor 3 Failed (Option)	Speed probe #3 input failed.
26	Performance Input Fault	Analog input for performance control failed.
27	Performance Remote Ref Fault	Analog input for remote performance control failed.
28	Motor Current Failed	Analog input for motor current control failed.
29	Remote Spt of Load Sharing #1 Failed	Analog input for remote header setpoint #1 for load sharing failed.
30	Remote Spt of Load Sharing #2 Failed	Analog input for remote header setpoint #2 for load sharing failed.
31	Mass/Normal Flow #1 for Load sharing Failed	Analog input for Mass/Normal Flow #1 for load sharing failed.
32	Mass/Normal Flow #2 for Load sharing Failed	Analog input for Mass/Normal Flow #2 for load sharing failed.
33	Header Pressure Failed	Analog input for header pressure for load sharing control failed.
34	Throttle/IGV Remote Setpt Failed	Analog input for remote Throttle/IGV ramp setpoint failed.
35	External Speed Sensor Failed	Analog input for external speed sensor failed.
36	Remote Header Press Setpt Failed	Analog input for remote header pressure setpoint for load sharing control failed.
37	Stage 1 ASV Pos Feedback Failed	Analog input of 1st anti-surge valve position feedback failed.
38	Stage 2 ASV Pos Feedback Failed	Analog input of 2nd anti-surge valve position feedback failed.
39	Throttle/IGV Pos Feedback Failed	Analog input of Throttle valve or IGV position feedback failed.
40	spare	
41	spare	
42	HD Analog Output #1	AO#1 in 24/8 Analog Module failed.
43	HD Analog Output #2	AO#2 in 24/8 Analog Module failed.
44	HD Analog Output #3	AO#3 in 24/8 Analog Module failed.
45	HD Analog Output #4	AO#4 in 24/8 Analog Module failed.
46	HD Analog Output #5	AO#5 in 24/8 Analog Module failed.
47	HD Analog Output #6	AO#6 in 24/8 Analog Module failed.
48	HD Analog Output #7	AO#7 in 24/8 Analog Module failed.
49	HD Analog Output #8	AO#8 in 24/8 Analog Module failed.
50	Combo Analog Output #1 (Option)	AO#1 in Analog Combo Module failed.
51	Combo Analog Output #2 (Option)	AO#2 in Analog Combo Module failed.
52	Combo Analog Output #3 (Option)	AO#3 in Analog Combo Module failed.
53	Combo Analog Output #4 (Option)	AO#4 in Analog Combo Module failed.
54	Combo Act Output #1 (Option)	ACT#1 in Analog Combo Module failed.
55	Combo Act Output #2 (Option)	ACT#2 in Analog Combo Module failed.
56	HD Analog Input #1	AI#1 in 24/8 Analog Module failed.
57	HD Analog Input #2	AI#2 in 24/8 Analog Module failed.
58	HD Analog Input #3	AI#3 in 24/8 Analog Module failed.
59	HD Analog Input #4	AI#4 in 24/8 Analog Module failed.
60	HD Analog Input #5	AI#5 in 24/8 Analog Module failed.
61	HD Analog Input #6	AI#6 in 24/8 Analog Module failed.
62	HD Analog Input #7	AI#7 in 24/8 Analog Module failed.
63	HD Analog Input #8	AI#8 in 24/8 Analog Module failed.
64	HD Analog Input #9	AI#9 in 24/8 Analog Module failed.

Number	Description	Explanation
65	HD Analog Input #10	AI#10 in 24/8 Analog Module failed.
66	HD Analog Input #11	AI#11 in 24/8 Analog Module failed.
67	HD Analog Input #12	AI#12 in 24/8 Analog Module failed.
68	HD Analog Input #13	AI#13 in 24/8 Analog Module failed.
69	HD Analog Input #14	AI#14 in 24/8 Analog Module failed.
70	HD Analog Input #15	AI#15 in 24/8 Analog Module failed.
71	HD Analog Input #16	AI#16 in 24/8 Analog Module failed.
72	HD Analog Input #17	AI#17 in 24/8 Analog Module failed.
73	HD Analog Input #18	AI#18 in 24/8 Analog Module failed.
74	HD Analog Input #19	AI#19 in 24/8 Analog Module failed.
75	HD Analog Input #20	AI#20 in 24/8 Analog Module failed.
76	HD Analog Input #21	AI#21 in 24/8 Analog Module failed.
77	HD Analog Input #22	AI#22 in 24/8 Analog Module failed.
78	HD Analog Input #23	AI#23 in 24/8 Analog Module failed.
79	HD Analog Input #24	AI#24 in 24/8 Analog Module failed.
80	Combo Analog Input #1 (Option)	AI#1 in Analog Combo Module failed.
81	Combo Analog Input #2 (Option)	AI#2 in Analog Combo Module failed.
82	Combo Analog Input #3 (Option)	AI#3 in Analog Combo Module failed.
83	Combo Analog Input #4 (Option)	AI#4 in Analog Combo Module failed.
84	Combo Analog Input #5 (Option)	AI#5 in Analog Combo Module failed.
85	Combo Analog Input #6 (Option)	AI#6 in Analog Combo Module failed.
86	Combo Analog Input #7 (Option)	AI#7 in Analog Combo Module failed.
87	Combo Analog Input #8 (Option)	AI#8 in Analog Combo Module failed.
88	Can Network #1 Error	CAN network #1 by using CAN port 1 on both CPU is detected.
89	Can Network #2 Error (Redundant Only)	CAN network #2 by using CAN port 2 on both CPU is detected.
90	In Forcing or Calibrating Mode	The forcing mode or calibration mode for I/O test is confirmed.
91	Level Alarm #1	Level alarm #1 which the user set up is detected.
92	Level Alarm #2	Level alarm #2 which the user set up is detected.
93	Level Alarm #3	Level alarm #3 which the user set up is detected.
94	Level Alarm #4	Level alarm #4 which the user set up is detected.

Table 7-1a. Common Alarm List

Number	Description	Explanation
0	No Alarm	The Vertex-Pro has no compressor alarms.
1	Flow Input Signal Failed	Flow input signal failed.
2	Suction Pressure Input Signal Failed	Suction Pressure input signal failed.
3	Discharge Pressure Input Signal Failed	Discharge Pressure input signal failed.
4	Suction Temperature Input Signal Failed	Suction Temperature input signal failed.
5	Discharge Temperature Input Signal Failed	Discharge Temperature input signal failed.
6	Flow Element Pressure Input Signal Failed	Flow Element Pressure input signal Failed.
7	Flow Element Temperature Input Signal Failed	Flow Element Temperature input signal Failed.
8	HSS Auxiliary Input #1 Signal Failed	HSS Auxiliary Input #1 Signal Failed.
9	HSS Auxiliary Input #2 Signal Failed	HSS Auxiliary Input #2 Signal Failed.
10	Remote Manual Valve Position Input Signal Failed	Remote Manual Valve Position input signal Failed.
11	Redundant Flow Input Signal Failed	Redundant Flow input signal Failed.
12	Redundant Suction Pressure Input Signal Failed	Redundant Suction Pressure input signal Failed.
13	Redundant Discharge Pressure Input Signal Failed	Redundant Discharge Pressure input signal Failed.
14	Spare	
15	Spare	
16	Redundant Flow Inputs Difference Alarm	Difference is detected between the redundant flow inputs.
17	Redundant Suction Pressure Inputs Difference Alarm	Difference is detected between the redundant suction pressure inputs.

Number	Description	Explanation
18	Redundant Discharge Pressure Inputs Difference Alarm	Difference is detected between the redundant discharge pressure inputs.
19	Start Sequence Initiated while in Manual Mode	Start Sequence has been initiated while in Full Manual Mode.
20	Full Manual Mode Selected without Surge Recovery Enabled	Full Manual Mode is selected without Surge Recovery Enabled.
21	Steady State Condition Failed	Steady State Condition has failed.
22	Spare	
23	Surge Minimum Position Active	Surge Minimum Position is active.
24	Anti-surge Valve Output Fault	Anti-surge Valve output signal has failed.

Table 7-1b. Compressor Alarm List

IMPORTANT **The contents of the compressor alarms are common to each stage. These alarms are available on every stage.**

Trips

See Table 7-2 for a list of the Vertex-Pro's trips. The numerical reference can be used as an index to determine the first trip received via the first trip number in the Datalog or Modbus.

Number	Description	Explanation
0	No Trip	The Vertex-Pro has no trip.
1	Power up Shutdown	Issued only immediately after a power up of the Vertex-Pro.
2	Shutdown Initiated from PC	Issued from the Control Assistant during debugging mode.
3	Spare	
4	Speed Sensor Failure	Loss of all speed probes or an external speed sensor input (4–20 mA) was sensed.
5	Spare	
6	Spare	
7	Spare	
8	External Trip Input #2	External Trip #2 contact input was opened.
9	External Trip Input #3	External Trip #3 contact input was opened.
10	Shutdown Initiated from Modbus 1	A Shutdown command was issued from Modbus #1.
11	System Fault	The operating system in the Vertex-Pro detects an alarm. I/O Lock is initiated by the Control Assistant.
12	Spare	
13	Spare	
14	Main Trip Contact Input	External Trip contact input was opened.
15	Spare	
16	External Trip Input #4	External Trip #4 contact input was opened.
17	External Trip Input #5	External Trip #5 contact input was opened.
18	Spare	
19	All 24/8 Analog Modules Fault	24/8 Analog Module Fault was detected.
20	All Analog Combo Modules Fault (Option)	Analog Combo Module Fault was detected.
21	All 48/24 Discrete Combo Modules Fault	48/24 Discrete Combo Module Fault was detected.
22	Invalid Compressor Configuration	The configuration of the Vertex-Pro is invalid.

Table 7-2. Trip List

High-Speed Datalog

The Vertex-Pro includes a high-speed data logging capability 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 is recorded is fixed. The sample rate can be changed but only with special software tools.

The datalog is a circular buffer that is stored in the CPU's memory. As shown in Table 7-3, it records 40 discrete values (TRUE/FALSE) and 51 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 complete datalog files already exist, the older of the two will be overwritten by the next datalog file.

AppManager and Control Assistant software, included in the Service Panel, can be used to retrieve and view the datalogs. (AppManager and Control Assistant 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.

Discrete Values (TRUE/FALSE = 1/0)	Analog Values
Suction Pressure LGV Active	Compressor Speed
Suction Pressure Default Value Active	Filtered Flow Signal
Disch. Pressure LGV Active	Filtered Suction Pressure Signal
Disch. Pressure Default Value Active	Filtered Discharge Pressure Signal
Flow Pressure LGV Active	Filtered Flow Pressure Signal
Flow Pressure Default Value Active	Filtered Suction Temperature Signal
Suction Temperature LGV Active	Filtered Discharge Temperature Signal
Suction Temperature Default Value Active	Filtered Flow Temperature Signal
Discharge Temperature LGV Active	Suction Pressure Value used for Control
Disch. Temperature Default Value Active	Discharge Pressure Value used for Control
Flow Temperature LGV Active	Flow Pressure Value used for Control
Flow Temperature Default Value Active	Suction Temperature Value used for Control
Surge Detected	Discharge Temperature Value used for Control
Surge Detected by Flow Derivative	Flow Temperature Value used for Control
Surge Detected by Suction Pressure Derivative	Ratio of Specific Heats (k)
Surge Detected by Discharge Pressure Derivative	Calculated Sigma Value
Surge Detected by Speed Derivative	Suction Compressibility (Z1)
Surge Detected by Minimum Flow	Flow Compressibility (Zf)
Surge Detected by Surge Limit Line	Calculated Average Compressibility (Zavg)
Surge Minimum Position (SMP) Active	Calculated Flow at Sensor (Qsns)
Sequence – Purge	Calculated Flow thru Stage (Qs)
Sequence – Start	Calculated Actual Inlet Flow (Qa)
Sequence – OnLine	Calculated Corrected Inlet Flow (Q_{CR})
Sequence – Controlled Shutdown	Calculated Polytropic Head (Hp)
Sequence – Emergency Shutdown	Calculated Reduced Head (Hred)
Sequence - Zero Speed	Calculated Pressure Ratio (PR)
Automatic Mode Selected	S_PV Value
Manual w/ Backup Selected	Control Margin Percentage
Full Manual Mode Selected	Gain Compensation Value
AntiSurge Valve Freeze Active	Rate PID Process Value
AntiSurge PID In Control	Rate PID Setpoint Value
Rate PID In Control	Flow Derivative Value Captured at Surge
BOOST In Control	Speed Derivative Value Captured at Surge
Surge Recovery In Control	Suction Pressure Derivative Value Captured at Surge
Manual w/ Backup In Control	Discharge Pressure Derivative Value Captured at Surge
Suction Pressure Override In Control	Operating Point Value Captured at Surge
Discharge Pressure Override In Control	Surge Counter
Auxiliary Input #1 In Control	Decoupling Output
Auxiliary Input #2 In Control	AntiSurge PID Output
Auxiliary Input #3 In Control	Suction Pressure Override Output
	Discharge Pressure Override Output
	Boost Output
	Surge Recovery Output
	SMP Output
	Manual Output
	Auxiliary Input #1 Output
	Auxiliary Input #2 Output
	Auxiliary Input #3 Output
	AntiSurge Valve HSS Output
	AntiSurge Valve Demand
	Alarm First-Out Indicator

Table 7-3. Vertex-Pro Compressor Datalog

Chapter 8.
Modbus

Modbus Communications

The Vertex-Pro control can communicate with plant distributed control systems and/or CRT based operator control panels through up to four Modbus communication ports. These ports support ASCII or RTU MODBUS transmission protocols. The CPU of Vertex-Pro has one serial port and one Ethernet port for Modbus communications. The CPU's SIO port utilizes Modbus based ports that can communicate via RS-232, RS-422, or RS-485 communications.
Serial/Ethernet Modbus utilizes a master/slave protocol. This protocol determines how a communication network's master and slave devices establish and break contact, how a sender is identified, how messages are exchanged, and how errors are detected. The Vertex-Pro control is always the slave device, the DCS or operator interface will act as the master and initiate communication transactions.

Monitor Only

The Modbus communication ports are defaulted from the factory to communicate with any device which communicates through Modbus and has the same port settings. Alternatively each port can be configured to only output data and ignore any input commands. This allows the control to be monitored but not controlled from an external device. By simply connecting a monitoring device, configured to communicate through Modbus, this device can be used to monitor all control parameters, modes, etc. without effecting control of the turbine. To use a Modbus port for monitoring only (Boolean and analog write commands are ignored), program the 'Use Modbus Port' setting to 'Not Used'.

Monitor and Control

Once a Modbus port is configured for Modbus communications, the control will accept Run mode commands from an external network master device (DCS, HMI, etc.). This allows a Modbus compatible device to monitor and perform all Vertex-Pro Control Run mode parameters and commands. Modbus ports are independent of each other, and can be used simultaneously. The last command given between the ports has priority. To use a Modbus port to monitor and operate the Vertex-Pro Control, program the desired port(s) 'Use Modbus Port' setting to 'TRUE'.

Modbus Communication

The Vertex-Pro Control supports two Modbus transmission modes (ASCII & RTU). A mode defines the individual units of information within a message and the numbering system used to transmit the data. Only one mode per Modbus network is allowed. The supported modes are ASCII (American Standard Code for Information Interchange), and RTU (Remote Terminal Unit). These modes are defined in the following table.

CHARACTERISTIC	ASCII	RTU
Coding System	hexadecimal (uses ASCII printable binary characters: 0-9, A-F)	8-bit binary
Start Bits	1	1
Data Bits per Char	7	8
Parity	even, odd, or none	even, odd, or none
Stop Bits	1, 1.5, or 2	1, 1.5, or 2
Baud Rate	110, 300, 600, 1200, 1800, 2400, 4800, 9600, 19200, 38400 or 57600	110, 300, 600, 1200, 1800, 2400, 4800, 9600, 19200, 38400 or 57600
Error Checking	LRC (Longitudinal Redundancy Check)	CRC (Cyclical Redundancy Check)

Table 8-1. ASCII vs. RTU Modbus

In the RTU mode, data is sent in 8-bit binary characters and transmitted in a continuous stream. In the ASCII mode, each binary character is divided into two 4-bit parts (high order and low order), changed to be represented by a hexadecimal equivalent, then transmitted, with breaks of up to 1 second. Because of these differences, data transmission with the ASCII mode is typically slower (see Figure 8-1 below).

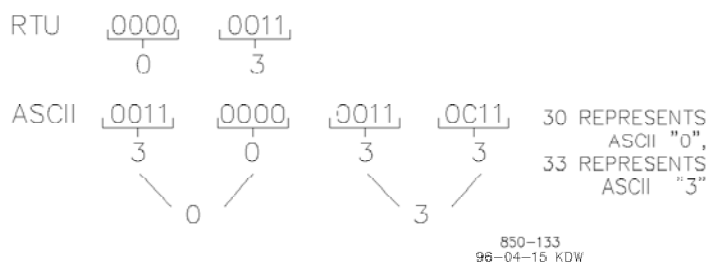


Figure 8-1. ASCII/RTU Representation of 3

The Modbus protocol allows one master and up to 247 slaves on a common network. Each slave is assigned a fixed, unique device address in the range of 1 to 247. With the Modbus protocol, only the network master can initiate a transaction. A transaction consists of a request from the master to a slave unit and the slave's response. The protocol and Modbus device number are set in the Program Mode and can be adjusted in the Service Mode, if required.

Volume 1 shows the required RS-232, RS-422, RS-485 or Ethernet communication connections. The transmit data (TXD), receive data (RXD), and signal ground (SIG GND) must be properly connected as shown. In addition the shield (SHLD) should be connected in at least one location.

In serial communication cases where a device which is being interfaced to is located a distance of greater than 15.24 meters (50 feet) from the control, it is recommended that a RS-422 or RS-485 be used. Each CPU module has three ports, with one port dedicated for Serial Modbus communications and configurable for RS-232, RS-422, or RS-485 communications. With the use of RS-422 or RS-485 communications the control can interface with a device through serial communications up to 1219.2 meters (4000 feet) from the control. In Ethernet communication cases, the length of a cable is limited to 30.48 meters (100 feet). Alternatively one or two CPU modules may be installed within the control's chassis.

This control functions as a slave unit only. As a slave unit, the control will only respond to a transaction request by a master device. The control can directly communicate with a DCS or other Modbus supported device on a single communications link. If multi-dropping is used (via RS-422, RS-485 or Ethernet communications), up to 246 devices (Vertex-Pro units or other customer devices) can be connected to one Master device on a single network. The device number for each port can be set in the Program or Service modes.

Each message to or from a master has a defined structure called the message "frame". A frame consists of the slave device address, a code defining the requested data, and error checking information. See Figure 8-2.

	BEGINNING OF FRAME	SLAVE ADDRESS	FUNCTION CODE	DATA	ERROR CHECK CODE	END OF FRAME
ASCII	:	2 CHARS 8 BITS	2 CHARS 8 BITS	4 BITS DATA PER CHAR	2 CHAR 8 BITS	CR LF
RTU	3-CHAR DEAD TIME	1 CHAR 8 BITS	1 CHAR 8 BITS	8 BITS DATA PER CHAR	2 CHAR 16 BITS	3 CHAR DEAD TIME

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93-09-27 DAR

Figure 8-2. Modbus Frame Definition

The Modbus function code tells the addressed slaves what function to perform. The following table lists the function codes supported by this control.

CODE	ADDRESS RANGE	TYPE	FUNCTION
01	00001-0FFFF	Input Coil	Read Boolean written to control (Raise/Lower and Enable/Disable Commands)
02	10001-1FFFF	Input Status	Read Boolean from control (Status Indications / Alarms and Trips)
03	40001-4FFFF	Holding Register	Read Analog written to control
04	30001-3FFFF	Input Register	Read Analog from control (Pressure, Setpt, etc.)
05	00001-0FFFF	Input Coil	Write Boolean to control (Raise/Lower and Enable/Disable Commands)
06	40001-4FFFF	Holding Register	Write Analog to control (Enter Setpt Directly)
08	0000	Diagnostic Code 0 Only	Loopback Test
15	00001-0FFFF	Input Coils	Write block of Boolean to control
16	40001-4FFFF	Holding Registers	Write block of Analog to control

Table 8-2. Modbus Function Codes

When a Modbus message is received, it is checked for any errors or invalid data. If there is invalid data in the message, an error code is sent back to the master and the control issues an alarm message. The error codes are defined in the following table. The exception error status and respective error codes can be viewed in the Service Mode under PORT # SETTINGS, where # is the number of the port (1 or 2).

If the control has not received a message for the configured time-out period, the control will alarm with an error message, but no message is sent to the master. This time-out is defaulted to 2 seconds and only applies to units using both monitor and control (adjustable in the Service Mode).

Modbus Slave Exception Error Codes

CODE	ERROR MESSAGE	TO MASTER	MEANING
0	No Error	0	Error free
1	Bad Modbus function	1	Message function received is not an allowable action for addressed slave. (Unsupported or illegal function code).
2	Bad Modbus data address	2	Address referenced in data field is not an allowable address for the addressed slave location. (Master requested data which is not configured from slave).
3	Bad Modbus data value	3	Amount of data requested from slave was too large for slave to return in a single response. Woodward maximum is 118 registers.
9	Bad Modbus checksum	None	Error in the checksum. Can indicate link quality and/or noise problems.
10	Bad Modbus message	None	Data received by the slave, but it is too short to be a valid Modbus message/command.
n/a	Lost Modbus link	None	No message received for the configured time-out period.

Table 8-3. Modbus Error Codes

Port Adjustments

Before the Vertex-Pro Control will communicate with the master device, the communication parameters must be verified. These values are set in the Program Mode and can be adjusted, if required, from the Service Mode.

Modbus Communication Port Adjustments

PARAMETER	ADJUSTMENT RANGE
Baud Rate	110 TO 57600
Parity	NONE, ODD, or EVEN
Stop Bits	1 TO 2

Control Modbus Addresses

The Modbus communication ports in the Vertex-Pro Control are programmed for unique Modbus addresses. A complete listing of these addresses for your application is located at the end of this section. The Modbus address listing consists of Boolean Writes, Boolean Reads, Analog Reads, and Analog Writes. The Boolean reads and writes are also referred to as input and holding coils. The analog reads and writes are also referred to as input registers and holding registers.

All values that can be addressed by Modbus are considered to be discrete and numeric. The discretes are a 1 bit binary, on or off value and the numerics are 16 bit values. Discretes are sometimes referred to as coils or digitals and numerics are referred to as registers or analogs. All read/write registers are interpreted by the Vertex-Pro Control as signed 16 bit integer values. Since Modbus can only handle integers, values that require a decimal point in the Modbus Master Device are multiplied by a scaling constant before being sent by the Vertex-Pro Control. See Tables 7-7 & 7-8 (Analog Reads and Analog Writes) under the MULTIPLIER column for defaulted communication constants and ranges.

The maximum number of discretes and registers that can be transmitted in one packet is dependent on each implementation of Modbus. The following table defines these limits.

MODE OF TRANSMISSION	MAX DISCRETES	MAX REGISTERS
ASCII	944	59
RTU	1188	118

Table 8-4. Maximum Modbus Discrete and Analog Values

Boolean Writes (Holding Coils)

Holding coils are logical signals that are both readable from and writable to the Vertex-Pro Control. An example of a Boolean write value would be raise or lower commands. A logical true denoted by the value 1 will cause the command listed in the description to be executed. For example, if a 1 is written to address 0:0010 and this corresponded to a speed raise command, the speed setpoint will increase until a 0 is written to address 0:0010. The Vertex-Pro Control supports function codes 1, 5, and 15. These correspond to reading selected holding coils, writing to a single holding coil, and writing to multiple holding coils, respectively. The holding coils available are listed in Table 8-5, under Boolean Writes.

Boolean Reads (Input Coils)

Input coils are logical signals that are readable from, but not writable to, the Vertex-Pro Control. An example of a Boolean read value would be a turbine trip status indication. The input coil will have the value 1 if the statement in the description column is true and a 0 if false. The ‘1:’ term in the address identifies an input coil. The Vertex-Pro Control supports Modbus function code 2, which involves reading selected input coils. The input coils available are listed in Table 8-6, under Boolean Reads.

Analog Reads (Input Registers)

Input registers are analog values that are readable from, but not writable to, the Vertex-Pro Control. An example of an analog read value would be turbine speed. The values of the input registers are stored internal to the control as floating point numbers representing engineering units (i.e. KPA or RPM). The values that are transmitted are integer values ranging from -32767 to +32767. Since Modbus can only handle integers, values that require a decimal point must be multiplied by a scaling constant in the Vertex-Pro Control before being sent across the Modbus link. For example, these input registers may be listed as the Modbus value 'x100' or 'cascade scale factor' under the description heading to denote the value is multiplied by a scaling constant (refer to Modbus Scale Factors later in this section). This will allow transmission of decimal parts of a number if this is necessary for better resolution.

See the Vertex-Pro Control Service Mode for default communication constants and ranges. The control supports Modbus function code 4, which involves reading selected input registers. The input registers available are listed in Table 8-7, under Analog Reads.

Analog Writes (Holding Registers)

Holding registers are analog values that are writable to the Vertex-Pro Control. These values can also be read from a device performing error checking. An example of an analog write value would be a direct speed setpoint value as opposed to raise and lower setpoint commands. The values of the holding registers are also stored in the control as numbers representing engineering units (i.e. PSI (kPa) or RPM). Once again, if decimal points are required, a scaling factor must be used (refer to Modbus Scale Factors later in this section). The Vertex-Pro Control supports Modbus function codes 3, 6, and 16. These correspond to reading selected holding registers, writing to a single holding register, and writing to multiple holding registers, respectively. The holding registers available are listed in Table 8-8, under Analog Writes. The following tables give the address and description of all Boolean and analog, reads and writes.

IMPORTANT	**The field filled with the gray of subsequent address tables is not applied to the Vertex_Pro.**

Boolean Writes (writes from the master device to the Vertex-Pro)

Addr	Description
0:0001	Emergency Shutdown
0:0002	Emergency Shutdown Acknowledge
0:0003	Controlled Shutdown
0:0004	Abort Controlled Shutdown
0:0005	System Reset
0:0006	Start / Run
0:0007	Open HP Valve Limiter
0:0008	Close HP Valve Limiter
0:0009	Lower Speed Setpoint
0:0010	Raise Speed Setpoint
0:0011	Go To Rated (Idle / Rated)
0:0012	Go To Idle (Idle / Rated)
0:0013	Halt Auto Start Seq
0:0014	Continue Auto Start Seq
0:0015	Enable Remote Speed Setpoint Control
0:0016	Disable Remote Speed Setpoint Control
0:0017	Go To Modbus Entered Speed Setpt
0:0018	Spare
0:0019	Arm Frequency Control (Not Used)
0:0020	Disarm Frequency Control (Not Used)
0:0021	Sync Enable (Not Used)
0:0022	Sync Disable (Not Used)
0:0023	Enable Cascade Control
0:0024	Disable Cascade Control
0:0025	Lower Cascade Setpoint
0:0026	Raise Cascade Setpoint
0:0027	Enable Remote Cascade Setpoint Control
0:0028	Disable Remote Cascade Setpoint Contro
0:0029	Go to Modbus Entered Cascade Setpoint
0:0030	Spare
0:0031	Enable Current Control
0:0032	Disable Current Control
0:0033	Lower Current Setpoint
0:0034	Raise Current Setpoint
0:0035	Enbl Rmt Current Stpnt Control
0:0036	Dsbl Rmt Current Stpnt Control
0:0037	Go To Modbus Entrd Current Setpt
0:0038	Spare
0:0039	Select Remote Ctrl (Remote/Local)
0:0040	Select Local Ctrl (Remote/Local)
0:0041	Spare
0:0042	Modbus Alarm Acknowledge
0:0043	Energize Relay 1 (Not Used)
0:0044	De-Energize Relay 1 (Not Used)
0:0045	Energize Relay 2 (Not Used)
0:0046	De-Energize Relay 2 (Not Used)
0:0047	Energize Relay 3 (Not Used)
0:0048	De-Energize Relay 3 (Not Used)
0:0049	Energize Relay 4 (Not Used)
0:0050	De-Energize Relay 4 (Not Used)
0:0051	Energize Relay 5 (Not Used)
0:0052	De-Energize Relay 5 (Not Used)
0:0053	Energize Relay 6 (Not Used)
0:0054	De-Energize Relay 6 (Not Used)
0:0055	Spare
0:0056	Spare
0:0057	Enable Extraction Control
0:0058	Disable Extraction Control
0:0059	Lower Extraction Setpoint
0:0060	Raise Extraction Setpoint
0:0061	Enable Remote Extr Setpoint Control
0:0062	Disable Remote Extr Setpoint Control
0:0063	Go To Modbus Entered Extraction Setpt
0:0064	Open LP Valve Limiter
0:0065	Close LP Valve Limiter
0:0066	Decrease Extr/Adm Demand
0:0067	Increase Extr/Adm Demand
0:0068	Enable Extr/Adm Priority
0:0069	Disable Extr/Adm Priority
0:0070	Spare
0:0071	Enbl Forcing of Turb Rly 1 (Not Used)
0:0072	Enbl Forcing of Turb Rly 2 (Not Used)
0:0073	Enbl Forcing of Turb Rly 3 (Not Used)
0:0074	Enbl Forcing of Turb Rly 4 (Not Used)
0:0075	Momentarily Energize Relay 1 (Not Used
0:0076	Momentarily Energize Relay 2 (Not Used

Addr	Description
0:0077	Momentarily Energize Relay 3 (Not Used
0:0078	Momentarily Energize Relay 4 (Not Used
0:0079	Momentarily Energize Relay 5 (Not Used
0:0080	Momentarily Energize Relay 6 (Not Used
0:0081	Spare
0:0082	Enable Inlet/Exhaust Dcpl (Not Used)
0:0083	Disable Inlet/Exhaust Dcpl (Not Used)
0:0084	Lower Inlet/Exhaust Dcpl Setpoint
0:0085	Raise Inlet/Exhaust Dcpl Setpoint
0:0086	Enable Remote Inlet/Exhaust Setpoint
0:0087	Disable Remote Inlet/Exhaust Setpoint
0:0088	Go To Modbus Entered Inl/Exh Setpoint
0:0089	Spare
0:0090	Enable Manual E/A Pressure Control
0:0091	Disable Manual E/A Pressure Control
0:0092	Lower Manual E/A Press Dmnd (Not Used)
0:0093	Raise Manual E/A Press Dmnd (Not Used)
0:0094	Enable Remote E/A Pressure Demand
0:0095	Disable Remote E/A Pressure Demand
0:0096	Go To Modbus Entered E/A Pressure Dmnd
0:0097	Spare
0:0098	HP/V1 Valve Go To Manual
0:0099	HP/V1 Valve Revert to Automatic
0:0100	Close HP/V1 Valve in Manual
0:0101	Open HP/V1 Valve in Manual
0:0102	Enable Rmt HP/V1 Position (Not Used)
0:0103	Disable Rmt HP/V1 Position (Not Used)
0:0104	Goto MB Entered HP/V1 Pos. (Not Used)
0:0105	Spare
0:0106	LP/V2 Valve Go To Manual
0:0107	LP/V2 Valve Revert To Automatic
0:0108	Close LP/V2 Valve in Manual
0:0109	Open LP/V2 Valve in Manual
0:0110	Enable Rmt LP/V2 Position (Not Used
0:0111	Disable Rmt LP/V2 Position (Not Used)
0:0112	Goto MB Entered LP/V2 Pos. (Not Used)
0:0113	Spare
0:0114	Spare
0:0115	Stage 1 - Lower Surge Control Margin
0:0116	Stage 1 - Raise Surge Control Margin
0:0117	Stage 1 - Auxiliary OnLine Input
0:0118	Stage 1 - Initiate Purge Sequence
0:0119	Stage 1 - Reset Surge Minimum Position
0:0120	Stage 1 - Reset Surge Information
0:0121	Stage 1 - Emergency Compressor Trip
0:0122	Stage 1 - Controlled Compressor Trip
0:0123	Stage 1 - Select AUTO Mode
0:0124	Stage 1 - Select MANUAL W/ BACKUP Mode
0:0125	Stage 1 - Select FULL MANUAL Mode
0:0126	Stage 1 - Close AntiSurge Valve
0:0127	Stage 1 - Open AntiSurge Valve
0:0128	Stage 1 - Go To MB Entered Valve Pos.
0:0129	Stage 1 - Initiate Start Sequence
0:0130	Stage 1 - Enable Suction Press. Ovrd.
0:0131	Stage 1 - Goto MB P1 Ovrd. Setpoint
0:0132	Stage 1 - Enable Disch. Press. Ovrd.
0:0133	Stage 1 - Goto MB P2 Ovrd. Setpoint
0:0134	Lower Throttle/IG Valve Ramp
0:0135	Raise Throttle/IG Valve Ramp
0:0136	Enable Remote Throttle/IGV Setpoint
0:0137	Disable Remote Throttle/IGV Setpoint
0:0138	Go to Modbus Entered Throttle/IGV Setp
0:0139	Spare
0:0140	Stage 2 - Lower Surge Control Margin
0:0141	Stage 2 - Raise Surge Control Margin
0:0142	Stage 2 - Auxiliary OnLine Input
0:0143	Stage 2 - Initiate Purge Sequence
0:0144	Stage 2 - Reset Surge Minimum Position
0:0145	Stage 2 - Reset Surge Information
0:0146	Stage 2 - Emergency Compressor Trip
0:0147	Stage 2 - Controlled Compressor Trip
0:0148	Stage 2 - Select AUTO Mode
0:0149	Stage 2 - Select MANUAL W/ BACKUP Mode
0:0150	Stage 2 - Select FULL MANUAL Mode
0:0151	Stage 2 - Close AntiSurge Valve
0:0152	Stage 2 - Open AntiSurge Valve

Addr	Description
0:0153	Stage 2 - Go To MB Entered Valve Pos.
0:0154	Stage 2 - Initiate Start Sequence
0:0155	Stage 2 - Enable Suction Press. Ovrd.
0:0156	Stage 2 - Goto MB P1 Ovrd. Setpoint
0:0157	Stage 2 - Enable Disch. Press. Ovrd.
0:0158	Stage 2 - Goto MB P2 Ovrd. Setpoint
0:0159	Enable Remote Header Press Setpt
0:0160	Disable Remote Header Press Setpt
0:0161	Go to Modbus Entered Header Press Setp
0:0162	Load sharing Enable
0:0163	Load sharing Disable
0:0164	Stage 1 - Go To MB Entered Add Margin
0:0165	Stage 1 - Halt MB Entered Add Margin
0:0166	Stage 2 - Go To MB Entered Add Margin
0:0167	Stage 2 - Halt MB Entered Add Margin
0:0168	Spare
0:0169	Spare

Table 8-5. Boolean Writes

Boolean Reads (reads from the Vertex-Pro by the master device)

Addr	Description
1:0001	Alarm - MPU #1 Failed
1:0002	Alarm - MPU #2 Failed
1:0003	Alarm - Cascade Input Failed
1:0004	Alarm - Aux Input Failed
1:0005	Alarm - KW Input Failed
1:0006	Alarm - Sync Input Failed
1:0007	Alarm - First Stage Press Input Failed
1:0008	Alarm - Remote Speed Input Failed
1:0009	Alarm - Remote Cascade Input Failed
1:0010	Alarm - Remote Aux Input Failed
1:0011	Alarm - Loadshare Input Failed
1:0012	Alarm - Actuator #1 Failed
1:0013	Alarm - Actuator #2 Failed
1:0014	Alarm - Start Permissive Not Met
1:0015	Alarm - Communication Link #1 Failed
1:0016	Alarm - Communication LInk #2 Failed
1:0017	Alarm - Generator Breaker Open
1:0018	Alarm - Turbine Trip
1:0019	Alarm - Tie Breaker Open
1:0020	Alarm - Overspeed Alarm
1:0021	Alarm - Tie Breaker Open / No Aux
1:0022	Alarm - Gen Breaker Open / No Aux
1:0023	Alarm - Tie Breaker Open / No Casc
1:0024	Alarm - Gen Breaker Open / No Casc
1:0025	Alarm - Tie Breaker Open / No Remote
1:0026	Alarm - Gen Breaker Open / No Remote
1:0027	Alarm - Stuck in Critical Alarm
1:0028	Alarm - Extr Input Failed
1:0029	Alarm - Remote Extr Input Failed
1:0030	Alarm - HP Pressure Comp. Input Failed
1:0031	Alarm - LP Pressure Comp. Input Failed
1:0032	Alarm - Speed Setpoint Config. Error
1:0033	Alarm - Steam Map Configuration Error
1:0034	Alarm - Speed Stpnt. in Critical Band
1:0035	Alarm - Remote Inlet/Exh Input Failed
1:0036	Alarm - Ext. Speed Bias Input Failed
1:0037	Alarm - Remote Man E/A Dmnd Input Fld
1:0038	Alarm Not Acknowledged
1:0039	Alarm Acknowledge
1:0040	Alarm Exists (Common Alarm Indication)
1:0041	Trip - Power up
1:0042	Trip - HMI ESD Button
1:0043	Trip - Overspeed Trip
1:0044	Trip - Spare
1:0045	Trip - Spare
1:0046	Trip - Spare
1:0047	Trip - Spare
1:0048	Trip - External Trip 2
1:0049	Trip - External Trip 3
1:0050	Trip - Modbus Link #1 Trip
1:0051	Trip - Spare
1:0052	Trip - Spare
1:0053	Trip - Spare
1:0054	Trip - Spare
1:0055	Trip - External Trip (BI_01)
1:0056	Trip - Controlled Shutdown Complete
1:0057	Trip - External Trip 4
1:0058	Trip - External Trip 5
1:0059	Trip - Extraction Input Failed
1:0060	Trip - Dual HD Analog Fault
1:0061	Trip - Dual Analog Combo Fault
1:0062	Trip - Dual Discrete I/O Fault
1:0063	Trip - Invalid Compressor Config
1:0064	Shutdown Exists (Trip Indication)
1:0065	ESD Acknowledge Enable
1:0066	Moving to Min Setpoint
1:0067	Ramping to Idle (Idle / Rated)
1:0068	Idle / Rated at Idle
1:0069	Ramping to Rated (Idle / Rated)
1:0070	Idle Rated At Rated (Idle / Rated)
1:0071	Auto Seq - Setpt at Lo Idle
1:0072	Auto Seq - Ramping to High Idle
1:0073	Auto Seq - Setpt at High Idle
1:0074	Auto Seq - Ramping to Rated
1:0075	Auto Seq - At Rated
1:0076	Speed PID In Control of LSS (not aux)
1:0077	Speed Sensor 1 Failed Overide ON
1:0078	Spare
1:0079	Overspeed Test Permissive
1:0080	Overspeed Test In Progress
1:0081	Speed At or above Min Gov
1:0082	Turbine In Critical Speed Band
1:0083	Remote Speed Setpt Is Enabled
1:0084	Remote Speed Setpt Is Active
1:0085	Remote Speed Setpt Is In Control
1:0086	Remote Speed Setpt Is Inhibited
1:0087	Speed PID In Control (not being lmted)
1:0088	Spare
1:0089	Spare
1:0090	Generator Breaker Closed (Not Used)
1:0091	Utility Tie Breaker Closed (Not Used)
1:0092	Synchronizing Rate Selected (Not Used)
1:0093	Synchronizing Is Enabled (Not Used)
1:0094	Sync / Load Share In Control (Not Used
1:0095	Sync / Load Share Inhibited (Not Used
1:0096	Spare
1:0097	Frequency Control Armed (Not Used)
1:0098	Frequency Control Active (Not Used)
1:0099	Spare
1:0100	Cascade Is Enabled
1:0101	Cascade Is Active
1:0102	Cascade Is In Control
1:0103	Cascade Is Inhibited
1:0104	Rmt Cascade Is Enabled
1:0105	Rmt Cascade Is Active
1:0106	Rmt Cascade Is In Control
1:0107	Rmt Cascade Is Inhibited
1:0108	Spare
1:0109	Auxiliary Is Enabled (Not Used)
1:0110	Auxiliary Is Active (Not Used)
1:0111	Auxiliary Is In Control (Not Used)
1:0112	Aux Active / Not Limiting (Not Used)
1:0113	Aux Active / Not In Control (Not Used)
1:0114	Auxiliary is Inhibited (Not Used)
1:0115	Remote Aux Is Enabled (Not Used)
1:0116	Remote Aux Is Active (Not Used)
1:0117	Rmt Aux Is In Control (Not Used)
1:0118	Rmt Aux Is Inhibited (Not Used)
1:0119	Spare
1:0120	Extraction Is Enabled

Addr	Description
1:0121	Extraction Is Active
1:0122	Extraction Is In Control (not lmted)
1:0123	Extraction is Inhibited
1:0124	Remote Extr Is Enabled
1:0125	Remote Extr Is Active
1:0126	Rmt Extr Is In Control
1:0127	Rmt Extr Is Inhibited
1:0128	Pressure Priority Enabled
1:0129	Pressure Priority Active
1:0130	Speed Priority Active
1:0131	Priority Transfer Permiss. (Not Used)
1:0132	Spare
1:0133	Controlled Stop In Progress
1:0134	LP Valve Limiter Is Open
1:0135	LP Valve Limiter Is Closed
1:0136	LP Valve Limiter In Control
1:0137	HP Valve Limiter Is Open
1:0138	HP Valve Limiter Is Closed
1:0139	HP Valve Limiter In Control
1:0140	Remote/Local Remote Selected
1:0141	MODBUS Boolean Write Active
1:0142	Ready to Start (Met Start Permissive)
1:0143	At Steam Map Limit
1:0144	At Min Press Limit (Not Used)
1:0145	At HP MAX Limit
1:0146	At HP MIN Limit
1:0147	At LP MAX Limit
1:0148	At LP MIN Limit
1:0149	At Max Power Limit (Not Used)
1:0150	At Max Press Limit (Not Used)
1:0151	Shutdown Relay Energized
1:0152	Alarm Relay Energized
1:0153	Programmable Relay 1 Energized
1:0154	Programmable Relay 2 Energized
1:0155	Programmable Relay 3 Energized
1:0156	Programmable Relay 4 Energized
1:0157	Programmable Relay 5 Energized
1:0158	Programmable Relay 6 Energized
1:0159	ESD Contact Input Closed
1:0160	Reset Contact Input Closed
1:0161	Programmable DI#1 Closed
1:0162	Programmable DI#2 Closed
1:0163	Programmable DI#3 Closed
1:0164	Programmable DI#4 Closed
1:0165	Programmable DI#5 Closed
1:0166	Programmable DI#6 Closed
1:0167	Programmable DI#7 Closed
1:0168	Programmable DI#8 Closed
1:0169	Programmable DI#9 Closed
1:0170	Programmable DI#10 Closed
1:0171	Programmable DI#11 Closed
1:0172	Programmable DI#12 Closed
1:0173	Programmable DI#13 Closed
1:0174	Programmable DI#14 Closed
1:0175	Programmable DI#15 Closed
1:0176	Programmable DI#16 Closed
1:0177	2-Step ESD Configured
1:0178	Manual Start Configured
1:0179	Auto Start Configured
1:0180	Semi-Auto Start Configured
1:0181	Idle/Rated Start Configured
1:0182	Auto Start Sequence Configured
1:0183	1st Stage Press. Configured (Not Used)
1:0184	Remote Speed Control Configured
1:0185	Loadsharing Configured (Not Used)
1:0186	ESD (Trip) Configured
1:0187	Gen Set Configured (Not Used)
1:0188	Cascade Control Configured
1:0189	Remote Cascade Configured
1:0190	Aux Control Configured (Not Used)
1:0191	Remote Aux Configured (Not Used)
1:0192	Modbus Local/Remote Active Configured
1:0193	Start Permissive Configured
1:0194	Freq. Arm/Disarm Configured (Not Used)
1:0195	Freq. Control Configured (Not Used)
1:0196	MPU 2 Configured
1:0197	Local/Remote Configured
1:0198	Local/Remote ESD Always Active
1:0199	Casc Setpt Tracking Config'd

Addr	Description
1:0200	KW Input Cfgd & Not Fld (Not Used)
1:0201	Extr/Adm Configured
1:0202	Admission-only Configured
1:0203	Extr Enable/Disable Config.
1:0204	Priority Selection Config. (Not Used)
1:0205	Remote Extr/Adm Setpt Configured
1:0206	E/A Setpt Tracking Config'd
1:0207	Spare
1:0208	T for 505E/ F for 505D (Not Used)
1:0209	Alarm - PS1 Fault
1:0210	Alarm - PS2 Fault
1:0211	Alarm - Main Chassis Temp High
1:0212	Alarm - Top Left Fan Fault
1:0213	Alarm - Top Right Fan Fault
1:0214	Alarm - Bottom Left Fan Fault
1:0215	Alarm - Bottom Right Fan Fault
1:0216	Alarm - Left CPU Fault
1:0217	Alarm - Right CPU Fault
1:0218	Alarm - A2 HD Analog Fault
1:0219	Alarm - A3 HD Analog Fault
1:0220	Alarm - A4 Analog Combo Fault (Option)
1:0221	Alarm - A5 Analog Combo Fault (Option)
1:0222	Alarm - A6 Discrete I/O Fault
1:0223	Alarm - A7 Discrete I/O Fault
1:0224	Alarm - Serial Modbus Port 1 Fault
1:0225	Alarm - Serial Modbus Port 2 Fault
1:0226	Alarm - Ether Modbus Port 1 Fault
1:0227	Alarm - Ether Modbus Port 2 Fault
1:0228	Alarm - Discrete Input Mismatch
1:0229	Alarm - Start Permissives Not Met
1:0230	Alarm - Trip as Alarm
1:0231	Alarm - Speed Sensor 1 Failed (Option)
1:0232	Alarm - Speed Sensor 2 Failed (Option)
1:0233	Alarm - Speed Sensor 3 Failed (Option)
1:0234	Alarm - Performance Input Fault
1:0235	Alarm - Perform Remote Ref Fault
1:0236	Alarm - Motor Current Failed
1:0237	Alarm - Rmt Spt of LS #1 Failed
1:0238	Alarm - Rmt Spt of LS #2 Failed
1:0239	Alarm - S_PV #1 for LS Failed
1:0240	Alarm - S_PV #2 for LS Failed
1:0241	Alarm - Header Pressure Failed
1:0242	Alarm - Throttle/IGV Rmt Failed
1:0243	Alarm - External Speed Sig Fld
1:0244	Alarm - Rmt Header Prs Stpt Fld
1:0245	Alarm - Stage 1 ASV Fdbk Failed
1:0246	Alarm - Stage 2 ASV Fdbk Failed
1:0247	Alarm - Throttle/IGV Fdbk Failed
1:0248	Alarm - spare
1:0249	Alarm - spare
1:0250	Alarm - HD Analog Output #1
1:0251	Alarm - HD Analog Output #2
1:0252	Alarm - HD Analog Output #3
1:0253	Alarm - HD Analog Output #4
1:0254	Alarm - HD Analog Output #5
1:0255	Alarm - HD Analog Output #6
1:0256	Alarm - HD Analog Output #7
1:0257	Alarm - HD Analog Output #8
1:0258	Alarm - Combo Analog Output #1
1:0259	Alarm - Combo Analog Output #2
1:0260	Alarm - Combo Analog Output #3
1:0261	Alarm - Combo Analog Output #4
1:0262	Alarm - Combo Act Output #1
1:0263	Alarm - Combo Act Output #2
1:0264	Alarm - HD Analog Input #1
1:0265	Alarm - HD Analog Input #2
1:0266	Alarm - HD Analog Input #3
1:0267	Alarm - HD Analog Input #4
1:0268	Alarm - HD Analog Input #5
1:0269	Alarm - HD Analog Input #6
1:0270	Alarm - HD Analog Input #7
1:0271	Alarm - HD Analog Input #8
1:0272	Alarm - HD Analog Input #9
1:0273	Alarm - HD Analog Input #10
1:0274	Alarm - HD Analog Input #11
1:0275	Alarm - HD Analog Input #12
1:0276	Alarm - HD Analog Input #13
1:0277	Alarm - HD Analog Input #14
1:0278	Alarm - HD Analog Input #15

Addr	Description
1:0279	Alarm - HD Analog Input #16
1:0280	Alarm - HD Analog Input #17
1:0281	Alarm - HD Analog Input #18
1:0282	Alarm - HD Analog Input #19
1:0283	Alarm - HD Analog Input #20
1:0284	Alarm - HD Analog Input #21
1:0285	Alarm - HD Analog Input #22
1:0286	Alarm - HD Analog Input #23
1:0287	Alarm - HD Analog Input #24
1:0288	Alarm - Combo Analog Input #1 (Option)
1:0289	Alarm - Combo Analog Input #2 (Option)
1:0290	Alarm - Combo Analog Input #3
1:0291	Alarm - Combo Analog Input #4
1:0292	Alarm - Combo Analog Input #5
1:0293	Alarm - Combo Analog Input #6
1:0294	Alarm - Combo Analog Input #7
1:0295	Alarm - Combo Analog Input #8
1:0296	Alarm - Can Network #1 Error
1:0297	Alarm - Can Network #2 Error
1:0298	Alarm - At the Forcing or Calibrating
1:0299	Spare
1:0300	Alarm - Stage 1 Primary Flow Sig Fld
1:0301	Alarm - Stage 1 Primary Suct Prs Sig Fl
1:0302	Alarm - Stage 1 Primary Disch Prs Sig F
1:0303	Alarm - Stage 1 Suct Temp Sig Fld
1:0304	Alarm - Stage 1 Disch Temp Sig Fld
1:0305	Alarm - Stage 1 Flow Element Press Sig
1:0306	Alarm - Stage 1 Flow Element Temp Sig F
1:0307	Alarm - Stage 1 Aux HSS Input 1 Sig Fld
1:0308	Alarm - Stage 1 Aux HSS Input 2 Sig Fld
1:0309	Alarm - Stage 1 Man Vlv Pos Input Sig F
1:0310	Alarm - Stage 1 Redun Flow Input Sig Fl
1:0311	Alarm - Stage 1 Redun Suct Press Sig Fl
1:0312	Alarm - Stage 1 Redun Disch Prs Sig Fld
1:0313	Alarm - Stage 1 spare
1:0314	Alarm - Stage 1 spare
1:0315	Alarm - Stage 1 Redun Flow Input Diff
1:0316	Alarm - Stage 1 Redun P1 Input Diff
1:0317	Alarm - Stage 1 Redun P2 Input Diff
1:0318	Alarm - Stage 1 Not in Auto - Started
1:0319	Alarm - Stage 1 Full Man-Srg Recv Disbl
1:0320	Alarm - Stage 1 Steady State Cond Fld
1:0321	Alarm - Stage 1 spare
1:0322	Alarm - Stage 1 Surge Min Pos Active
1:0323	Alarm - Stage 1 Anti-Surge Vlv Out Fld
1:0324	Spare
1:0325	Spare
1:0326	Spare
1:0327	Spare
1:0328	Spare
1:0329	Spare
1:0330	Stage 1 - AntiSurge PID In Control
1:0331	Stage 1 - HSS Aux. Input 1 In Control
1:0332	Stage 1 - HSS Aux. Input 2 In Control
1:0333	Stage 1 - HSS Aux. Input 3 In Control
1:0334	Stage 1 - BOOST In Control
1:0335	Stage 1 - Deactivation In Control
1:0336	Stage 1 - Manual w/ Backup In Control
1:0337	Stage 1 - P1 Override In Control
1:0338	Stage 1 - P2 Override In Control
1:0339	Stage 1 - Rate PID In Control
1:0340	Stage 1 - Seq. Positioning In Control
1:0341	Stage 1 - Surge Recovery In Control
1:0342	Stage 1 - Valve Freeze Active
1:0343	Stage 1 - Auto Mode
1:0344	Stage 1 - Manual with Backup Mode
1:0345	Stage 1 - Full Manual Mode
1:0346	Stage 1 - Online
1:0347	Stage 1 - P1 Default Value in Use
1:0348	Stage 1 - P1 Last Good Value in Use
1:0349	Stage 1 - P2 Default Value in Use
1:0350	Stage 1 - P2 Last Good Value in Use
1:0351	Stage 1 - PF Default Value in Use
1:0352	Stage 1 - PF Last Good Value in Use
1:0353	Stage 1 - Surge Detected
1:0354	Stage 1 - Surged by Flow Derivative
1:0355	Stage 1 - Surged by Minimum Flow
1:0356	Stage 1 - Surged by P1 Derivative
1:0357	Stage 1 - Surged by P2 Derivative

Addr	Description
1:0358	Stage 1 - Surged by Speed Derivative
1:0359	Stage 1 - Surge Limit Line Crossed
1:0360	Stage 1 - SMP Active
1:0361	Stage 1 - Purge Active
1:0362	Stage 1 - Emergency Shutdown Active
1:0363	Stage 1 - Controlled Shutdown Active
1:0364	Stage 1 - Start Active
1:0365	Stage 1 - Zero Speed
1:0366	Stage 1 - T1 Default Value in Use
1:0367	Stage 1 - T1 Last Good Value in Use
1:0368	Stage 1 - T2 Default Value in Use
1:0369	Stage 1 - T2 Last Good Value in Use
1:0370	Stage 1 - TF Default Value in Use
1:0371	Stage 1 - TF Last Good Value in Use
1:0372	Stage 1 - Steady State Condition Fld.
1:0373	Spare
1:0374	Spare
1:0375	Spare
1:0376	Spare
1:0377	Spare
1:0378	Spare
1:0379	Spare
1:0380	Load Sharing Enabled
1:0381	Lasd Sharing Active
1:0382	Load Sharing Master
1:0383	Load Sharing Slave
1:0384	Rmt Current Limit Setpt Enabled
1:0385	Rmt Throttle/IGV Setpt Enabled
1:0386	Rmt Header Press Setpt Enabled
1:0387	Spare
1:0388	Spare
1:0389	Spare
1:0390	Spare
1:0391	Spare
1:0392	Spare
1:0393	Spare
1:0394	Spare
1:0395	Spare
1:0396	Spare
1:0397	Spare
1:0398	Spare
1:0399	Spare
1:0400	Alarm - Stage 2 Primary Flow Sig Fld
1:0401	Alarm - Stage 2 Primary Suct Prs Sig Fl
1:0402	Alarm - Stage 2 Primary Disch Prs Sig F
1:0403	Alarm - Stage 2 Suct Temp Sig Fld
1:0404	Alarm - Stage 2 Disch Temp Sig Fld
1:0405	Alarm - Stage 2 Flow Element Press Sig
1:0406	Alarm - Stage 2 Flow Element Temp Sig F
1:0407	Alarm - Stage 2 Aux HSS Input 1 Sig Fld
1:0408	Alarm - Stage 2 Aux HSS Input 2 Sig Fld
1:0409	Alarm - Stage 2 Man Vlv Pos Input Sig F
1:0410	Alarm - Stage 2 Redun Flow Input Sig Fl
1:0411	Alarm - Stage 2 Redun Suct Press Sig Fl
1:0412	Alarm - Stage 2 Redun Disch Prs Sig Fld
1:0413	Alarm - Stage 2 spare
1:0414	Alarm - Stage 2 spare
1:0415	Alarm - Stage 2 Redun Flow Input Diff
1:0416	Alarm - Stage 2 Redun P1 Input Diff
1:0417	Alarm - Stage 2 Redun P2 Input Diff
1:0418	Alarm - Stage 2 Not in Auto - Started
1:0419	Alarm - Stage 2 Full Man-Srg Recv Disbl
1:0420	Alarm - Stage 2 Steady State Cond Fld
1:0421	Alarm - Stage 2 spare
1:0422	Alarm - Stage 2 Surge Min Pos Active
1:0423	Alarm - Stage 2 Anti-Surge Vlv Out Fld
1:0424	Spare
1:0425	Spare
1:0426	Spare
1:0427	Spare
1:0428	Spare
1:0429	Spare
1:0430	Stage 2 - AntiSurge PID In Control
1:0431	Stage 2 - HSS Aux. Input 1 In Control
1:0432	Stage 2 - HSS Aux. Input 2 In Control
1:0433	Stage 2 - HSS Aux. Input 3 In Control
1:0434	Stage 2 - BOOST In Control
1:0435	Stage 2 - Deactivation In Control
1:0436	Stage 2 - Manual w/ Backup In Control

Addr	Description
1:0437	Stage 2 - P1 Override In Control
1:0438	Stage 2 - P2 Override In Control
1:0439	Stage 2 - Rate PID In Control
1:0440	Stage 2 - Seq. Positioning In Control
1:0441	Stage 2 - Surge Recovery In Control
1:0442	Stage 2 - Valve Freeze Active
1:0443	Stage 2 - Auto Mode
1:0444	Stage 2 - Manual with Backup Mode
1:0445	Stage 2 - Full Manual Mode
1:0446	Stage 2 - Online
1:0447	Stage 2 - P1 Default Value in Use
1:0448	Stage 2 - P1 Last Good Value in Use
1:0449	Stage 2 - P2 Default Value in Use
1:0450	Stage 2 - P2 Last Good Value in Use
1:0451	Stage 2 - PF Default Value in Use
1:0452	Stage 2 - PF Last Good Value in Use
1:0453	Stage 2 - Surge Detected
1:0454	Stage 2 - Surged by Flow Derivative
1:0455	Stage 2 - Surged by Minimum Flow
1:0456	Stage 2 - Surged by P1 Derivative
1:0457	Stage 2 - Surged by P2 Derivative
1:0458	Stage 2 - Surged by Speed Derivative
1:0459	Stage 2 - Surge Limit Line Crossed
1:0460	Stage 2 - SMP Active
1:0461	Stage 2 - Purge Active
1:0462	Stage 2 - Emergency Shutdown Active
1:0463	Stage 2 - Controlled Shutdown Active
1:0464	Stage 2 - Start Active
1:0465	Stage 2 - Zero Speed
1:0466	Stage 2 - T1 Default Value in Use
1:0467	Stage 2 - T1 Last Good Value in Use
1:0468	Stage 2 - T2 Default Value in Use
1:0469	Stage 2 - T2 Last Good Value in Use
1:0470	Stage 2 - TF Default Value in Use
1:0471	Stage 2 - TF Last Good Value in Use
1:0472	Stage 2 - Steady State Condition Fld.
1:0473	Spare
1:0474	Spare
1:0475	Spare
1:0476	Spare
1:0477	Spare
1:0478	Spare
1:0479	Spare
1:0480	Alarm - Level Alarm #1
1:0481	Alarm - Level Alarm #2
1:0482	Alarm - Level Alarm #3
1:0483	Alarm - Level Alarm #4
1:0484	Spare
1:0485	Spare
1:0486	Spare
1:0487	Spare
1:0488	Spare
1:0489	Spare
1:0490	Programmable Relay 7 Energized
1:0491	Programmable Relay 8 Energized
1:0492	Programmable Relay 9 Energized
1:0493	Programmable Relay 10 Energized
1:0494	Programmable Relay 11 Energized
1:0495	Programmable Relay 12 Energized
1:0496	Programmable Relay 13 Energized
1:0497	Programmable Relay 14 Energized
1:0498	Programmable Relay 15 Energized
1:0499	Programmable Relay 16 Energized
1:0500	Programmable Relay 17 Energized
1:0501	Programmable Relay 18 Energized
1:0502	Programmable Relay 19 Energized
1:0503	Programmable Relay 20 Energized
1:0504	Programmable Relay 21 Energized
1:0505	Programmable Relay 22 Energized
1:0506	Programmable DI#17 Closed
1:0507	Programmable DI#18 Closed
1:0508	Programmable DI#19 Closed
1:0509	Programmable DI#20 Closed
1:0510	Programmable DI#21 Closed
1:0511	Programmable DI#22 Closed
1:0512	Programmable DI#23 Closed
1:0513	Programmable DI#24 Closed
1:0514	Programmable DI#25 Closed
1:0515	Programmable DI#26 Closed
1:0516	Programmable DI#27 Closed
1:0517	Programmable DI#28 Closed
1:0518	Programmable DI#29 Closed
1:0519	Programmable DI#30 Closed
1:0520	Programmable DI#31 Closed
1:0521	Programmable DI#32 Closed
1:0522	Programmable DI#33 Closed
1:0523	Programmable DI#34 Closed
1:0524	Programmable DI#35 Closed
1:0525	Programmable DI#36 Closed
1:0526	Programmable DI#37 Closed
1:0527	Programmable DI#38 Closed
1:0528	Programmable DI#39 Closed
1:0529	Programmable DI#40 Closed
1:0530	Programmable DI#41 Closed
1:0531	Programmable DI#42 Closed
1:0532	Programmable DI#43 Closed
1:0533	Programmable DI#44 Closed
1:0534	Programmable DI#45 Closed
1:0535	Programmable DI#46 Closed

Table 8-6. Boolean Reads

Analog Reads (reads from the Vertex-Pro by the master device)

Address	Description	Multiplier	Units
3:0001	Cause of last trip	1	
3:0002	Speed Sensor #1 Input (RPM)	1	rpm
3:0003	Speed Sensor #2 Input (RPM)	1	rpm
3:0004	Actual Prime Mover's Speed (RPM) (Option)	1	rpm
3:0005	Actual Speed (%) x 100 (Option)	100	%
3:0006	Speed Setpoint (%) x 100	100	%
3:0007	Speed Setpoint (RPM)	1	rpm
3:0008	Speed Droop Setpoint (%)	100	%
3:0009	Speed Sensor #3 Input (RPM)	1	rpm
3:0010	Speed PID Output (%) x 100	100	%
3:0011	Min Governor Speed Setpoint (RPM)	1	rpm
3:0012	Highest Speed Reached (RPM)	1	rpm
3:0013	Idle / Rated - Idle Speed (RPM)	1	rpm
3:0014	Idle / Rated - Rated Speed (RPM)	1	rpm
3:0015	Auto Seq - Low Idle Speed Setpt (RPM)	1	rpm
3:0016	Auto Seq - Low Idle Delay (MIN*100)	1.66666667	mins

Address	Description	Multiplier	Units
3:0017	Auto Seq - Mins Left At Low Idle x 100	1.66666667	mins
3:0018	Auto Seq-Low to High Idle Rate RPM/SEC	1	rpm/s
3:0019	Auto Seq - High Idle Speed Setpt (RPM)	1	rpm
3:0020	Auto Seq - High Idle Delay (MIN*100)	1.66666667	mins
3:0021	Auto Seq - Mins Left At High Idle x100	1.66666667	mins
3:0022	Auto Seq-Hi Idle to Rated Rate RPM/SEC	1	rpm/s
3:0023	Auto Seq - Rated Speed Setpt (RPM)	1	rpm
3:0024	Auto Seq - Run Time Hours	1	hrs
3:0025	Auto Seq - Hours Since Trip	1	hrs
3:0026	Cascade Setpoint (Scaled)	1	
3:0027	Cascade PID Output (%) x 100	100	%
3:0028	Cascade Input (%) x 100	100	%
3:0029	Cascade Setpoint (%) x 100	100	%
3:0030	Cascade Scale Factor	1	
3:0031	Cascade Input (Scaled)	1	
3:0032	Remote Cascade Input (Scaled)	1	
3:0033	Current Lim Setpoint (Scaled)	1	
3:0034	Current Lim PID Output (%) x 100	100	%
3:0035	Current Lim Input (%) x 100	100	%
3:0036	Current Lim Setpoint (%) x 100	100	%
3:0037	Current Lim Scale Factor	1	
3:0038	Current Lim Input (Scaled)	1	
3:0039	Remote Current Lim Input (Scaled)	1	
3:0040	Remote Speed Setpoint Input	1	rpm
3:0041	FSP Scale Factor (Not Used)	1	
3:0042	FSP Input (Scaled) (Not Used)	1	
3:0043	Loadshare Scale Factor (Not Used)	1	
3:0044	Sync / Ldshr Input (Scaled) (Not Used)	1	
3:0045	KW Scale Factor (Not Used)	1	
3:0046	KW Input (Scaled) (Not Used)	1	
3:0047	HP Valve Limiter Output	100	%
3:0048	LP Valve Limiter Output	100	%
3:0049	Actuator 1 Demand (%) x100	100	%
3:0050	Actuator 2 Demand (%) x100	100	%
3:0051	Extr/Adm Manual Demand	100	%
3:0052	Extraction Setpoint (Scaled)	1	
3:0053	Extraction PID Output (%) x 100	100	%
3:0054	Extraction Input (%) x 100	100	%
3:0055	Extraction Setpoint (%) x 100	100	%
3:0056	Extraction Scale Factor	1	
3:0057	Extraction Input (Scaled)	1	
3:0058	Remote Extr Input (Scaled)	1	
3:0059	Spare	1	
3:0060	Modbus Entered Speed Setpoint (fdbk)	1	rpm
3:0061	Modbus Entered Cascade Setpoint (fdbk)	1	
3:0062	Mdbs Entrd Current Limit (fdbk)	1	
3:0063	Modbus Entered Extr Setpoint (fdbk)	1	
3:0064	S-demand Limited (from ratio/lmtr)	100	%
3:0065	P-demand Limited (from ratio/lmtr)	100	%
3:0066	HP Map Demand (from ratio/lmtr)	100	%
3:0067	LP Map Demand (from ratio/lmtr)	100	%
3:0068	S-term (from LSS to ratio/lmtr)	100	%
3:0069	P-term (from LSS to ratio/lmtr)	100	%
3:0070	Control Parameter (Line 1) (Not Used)	1	
3:0071	Control Parameter (Line 2) (Not Used)	1	
3:0072	Turbine Analog Input 1 (% x 100)	100	%
3:0073	Turbine Analog Input 2 (% x 100)	100	%
3:0074	Turbine Analog Input 3 (% x 100)	100	%
3:0075	Turbine Analog Input 4 (% x 100)	100	%
3:0076	Turbine Analog Input 5 (% x 100)	100	%
3:0077	Turbine Analog Input 6 (% x 100)	100	%
3:0078	Turbine Analog Output 1 (mA x 100)	100	mA
3:0079	Turbine Analog Output 2 (mA x 100)	100	mA
3:0080	Turbine Analog Output 3 (mA x 100)	100	mA
3:0081	Turbine Analog Output 4 (mA x 100)	100	mA
3:0082	Analog Output 5 (mA x 100) (Not Used)	1	
3:0083	Analog Output 6 (mA x 100) (Not Used)	1	
3:0084	Turbine Actuator #1 Output (mA x 100)	100	mA
3:0085	Turbine Actuator #2 Output (mA x 100)	100	mA
3:0086	Spare	1	
3:0087	KW Units (3=MW 4=KW) (Not Used)	1	
3:0088	Spare	1	
3:0089	Turbine Analog Input 1 Configuration	1	
3:0090	Turbine Analog Input 2 Configuration	1	
3:0091	Turbine Analog Input 3 Configuration	1	
3:0092	Turbine Analog Input 4 Configuration	1	
3:0093	Turbine Analog Input 5 Configuration	1	
3:0094	Turbine Analog Output 1 Configuration	1	
3:0095	Turbine Analog Output 2 Configuration	1	

Address	Description	Multiplier	Units
3:0096	Turbine Analog Output 3 Configuration	1	
3:0097	Turbine Analog Output 4 Configuration	1	
3:0098	Analog Output 5 Config. (Not Used)	1	
3:0099	Analog Output 6 Config. (Not Used)	1	
3:0100	Turbine Relay 1 Configuration	1	
3:0101	Turbine Relay 2 Configuration	1	
3:0102	Turbine Relay 3 Configuration	1	
3:0103	Turbine Relay 4 Configuration	1	
3:0104	Relay 5 Configuration (Not Used)	1	
3:0105	Relay 6 Configuration (Not Used)	1	
3:0106	Turbine Contact Input 1 Configuration	1	
3:0107	Turbine Contact Input 2 Configuration	1	
3:0108	Turbine Contact Input 3 Configuration	1	
3:0109	Turbine Contact Input 4 Configuration	1	
3:0110	Turbine Contact Input 5 Configuration	1	
3:0111	Turbine Contact Input 6 Configuration	1	
3:0112	Turbine Contact Input 7 Configuration	1	
3:0113	Turbine Contact Input 8 Configuration	1	
3:0114	Contact Input 9 Config. (Not Used)	1	
3:0115	Contact Input 10 Config. (Not Used)	1	
3:0116	Contact Input 11 Config. (Not Used)	1	
3:0117	Contact Input 12 Config. (Not Used)	1	
3:0118	Aux Units Configured (Not Used)	1	
3:0119	Cascade Units Configured	1	
3:0120	Extraction Units Configured	1	
3:0121	Spare	1	
3:0122	Inlet/Exhaust Setpoint (Scaled)	1	
3:0123	Inlet/Exhaust PID Output (%) x 100	100	%
3:0124	Inlet/Exhaust Input (%) x 100	100	%
3:0125	Inlet/Exhaust Setpoint (%) x 100	100	%
3:0126	Inlet/Exhaust Scale Factor	1	
3:0127	Inlet/Exhaust Input (Scaled)	1	
3:0128	Remote Inlet/Exhaust Input (Scaled)	1	
3:0129	Modbus Entered Inlet/Exh Stpnt (fdbk)	1	
3:0130	Turbine Alarm -- First-out	1	
3:0131	Header Press Setpoint (Scaled)	1	
3:0132	Header Press PID Output (%) (Not Used)	100	%
3:0133	Header Press Input (%) x 100	100	%
3:0134	Header Press Setpoint (%) x 100	100	%
3:0135	Header Press Scale Factor	1	
3:0136	Header Press Input (Scaled)	1	
3:0137	Remote Header Press Input (Scaled)	1	
3:0138	Throttle/IGV Setpoint (Scaled)	100	%
3:0139	Throttle/IGV Sequence	100	%
3:0140	Throttle/IGV Control No	1	
3:0141	Throttle/IGV Demand	100	%
3:0142	Remote Throttle/IGV Input	100	%
3:0143	Mdbs Entrd Header Press Setpt (fdbk)	1	
3:0144	Spare	1	
3:0145	Spare	1	
3:0146	Spare	1	
3:0147	Load Sharing Status Message	1	
3:0148	Common Alarm First Out	1	
3:0149	Spare	1	
3:0150	Spare	1	
3:0151	Spare	1	
3:0152	Spare	1	
3:0153	Spare	1	
3:0154	Spare	1	
3:0155	Spare	1	
3:0156	Spare	1	
3:0157	Spare	1	
3:0158	Spare	1	
3:0159	Spare	1	
3:0160	Spare	1	
3:0161	Spare	1	
3:0162	Spare	1	
3:0163	Spare	1	
3:0164	Spare	1	
3:0165	Spare	1	
3:0166	Spare	1	
3:0167	Spare	1	
3:0168	Spare	1	
3:0169	Spare	1	
3:0170	Spare	1	
3:0171	Spare	1	
3:0172	Spare	1	
3:0173	Spare	1	
3:0174	Spare	1	

Address	Description	Multiplier	Units
3:0175	Spare	1	
3:0176	Spare	1	
3:0177	Spare	1	
3:0178	Spare	1	
3:0179	Spare	1	
3:0180	Spare	1	
3:0181	Spare	1	
3:0182	Spare	1	
3:0183	Spare	1	
3:0184	Spare	1	
3:0185	Spare	1	
3:0186	Spare	1	
3:0187	Spare	1	
3:0188	Spare	1	
3:0189	Spare	1	
3:0190	Spare	1	
3:0191	Spare	1	
3:0192	Stage 1 - AntiSurge PID Output	1	%
3:0193	Stage 1 - BOOST Output	1	%
3:0194	Stage 1 - AS Valve Decoupling Output	1	%
3:0195	Stage 1 - Spd Cntrl Decoupling Output	1	%
3:0196	Stage 1 - Flow Filtered Input Signal	1	kg/hr, Nm3/hr, kPaD
3:0197	Stage 1 - Gain Compensation Factor	1	
3:0198	Stage 1 - Calculated Polytropic Head	1	N-m/kg
3:0199	Stage 1 - Calculated Reduced Head	1	
3:0200	Stage 1 - Calculated Spec. Heat Ratio	1	
3:0201	Stage 1 - Manual Valve Position	1	%
3:0202	Stage 1 - Manual Position Ramp	1	%
3:0203	Stage 1 - Surge Control Line Margin	1	%
3:0204	Stage 1 - P1 Override PID Output	1	%
3:0205	Stage 1 - P2 Override PID Output	1	%
3:0206	Stage 1 - Calculated Pressure Ratio	1	
3:0207	Stage 1 - P1 Value Used for Control	1	kPaG, kPaA
3:0208	Stage 1 - P1 Filtered Input Signal	1	kPaG, kPaA
3:0209	Stage 1 - P2 Value Used for Control	1	kPaG, kPaA
3:0210	Stage 1 - P2 Filtered Input Signal	1	kPaG, kPaA
3:0211	Stage 1 - PF Value Used for Control	1	kPaG, kPaA
3:0212	Stage 1 - PF Filtered Input Signal	1	kPaG, kPaA
3:0213	Stage 1 - "Corrected" Suction Flow	1	Am3/hr
3:0214	Stage 1 - Sensor Flow	1	kg/hr,Nm3/hr
3:0215	Stage 1 - Surge Control Line Flow	1	Am3/hr
3:0216	Stage 1 - Actual Suction Flow	1	Am3/hr
3:0217	Stage 1 - Stage Flow	1	kg/hr,Nm3/hr
3:0218	Stage 1 - Rate PID Output	1	%
3:0219	Stage 1 - Surge Event Counter	1	
3:0220	Stage 1 - Total Number of Surges	1	
3:0221	Stage 1 - S_PV Surge Process Variable	1	%
3:0222	Stage 1 - Surge Capture Flow Deriv.	1	Am3/hr/s
3:0223	Stage 1 - Surge Capture P1 Derivative	1	kPa/s
3:0224	Stage 1 - Surge Capture P2 Derivative	1	kPa/s
3:0225	Stage 1 - Surge Capture Speed Deriv.	1	rpm/s
3:0226	Stage 1 - Calculated Sigma	1	
3:0227	Stage 1 - Surge Minimum Position	1	%
3:0228	Stage 1 - Sequencing Position Output	1	%
3:0229	Stage 1 - Surge Recovery Output	1	%
3:0230	Stage 1 - T1 Value Used for Control	1	DegC
3:0231	Stage 1 - T1 Filtered Input Signal	1	DegC
3:0232	Stage 1 - T2 Value Used for Control	1	DegC
3:0233	Stage 1 - T2 Filtered Input Signal	1	DegC
3:0234	Stage 1 - TF Value Used for Control	1	DegC
3:0235	Stage 1 - TF Filtered Input Signal	1	DegC
3:0236	Stage 1 - HSS Output	1	%
3:0237	Stage 1 - Valve Final Output	1	%
3:0238	Stage 1 - Valve Demand Percent	1	%
3:0239	Stage 1 - Calc. Avg Compressibility	1	
3:0240	Stage 1 - Calc. Suct. Compressibility	1	
3:0241	Stage 1 - Calc. Flow Compressibility	1	
3:0242	Stage 1 - HSS Auxiliary Input #1	1	%
3:0243	Stage 1 - HSS Auxiliary Input #2	1	%
3:0244	Stage 1 - HSS Auxiliary Input #3	1	%
3:0245	Stage 1 - Surge Capture Operating Pnt.	1	
3:0246	Stage 1 - Deactivation Output	1	%
3:0247	Stage 1 - Operating Point Rate	1	
3:0248	Stage 1 - Rate PID Setpoint	1	
3:0249	Stage 1 - Opr. Pnt. (Map X-axis Value)	1	Am3/hr
3:0250	Stage 1 - Opr. Pnt. (Map Y-axis Value)	1	N-m/kg, Press Ratio
3:0251	Stage 1 - Mode Selected	1	
3:0252	Stage 1 - Status	1	
3:0253	Stage 1 - Active Control Routine	1	

Address	Description	Multiplier	Units
3:0254	Stage 1 - Mode and Routine Active	1	
3:0255	Stage 1 - Alarm First-out	1	
3:0256	Spare	1	
3:0257	Spare	1	
3:0258	Spare	1	
3:0259	Spare	1	
3:0260	Spare	1	
3:0261	Spare	1	
3:0262	Spare	1	
3:0263	Stage 2 - AntiSurge PID Output	1	%
3:0264	Stage 2 - BOOST Output	1	%
3:0265	Stage 2 - AS Valve Decoupling Output	1	%
3:0266	Stage 2 - Spd Cntrl Decoupling Output	1	%
3:0267	Stage 2 - Flow Filtered Input Signal	1	kg/hr, Nm3/hr, kPaD
3:0268	Stage 2 - Gain Compensation Factor	1	
3:0269	Stage 2 - Calculated Polytropic Head	1	N-m/kg
3:0270	Stage 2 - Calculated Reduced Head	1	
3:0271	Stage 2 - Calculated Spec. Heat Ratio	1	
3:0272	Stage 2 - Manual Valve Position	1	%
3:0273	Stage 2 - Manual Position Ramp	1	%
3:0274	Stage 2 - Surge Control Line Margin	1	%
3:0275	Stage 2 - P1 Override PID Output	1	%
3:0276	Stage 2 - P2 Override PID Output	1	%
3:0277	Stage 2 - Calculated Pressure Ratio	1	
3:0278	Stage 2 - P1 Value Used for Control	1	kPaG, kPaA
3:0279	Stage 2 - P1 Filtered Input Signal	1	kPaG, kPaA
3:0280	Stage 2 - P2 Value Used for Control	1	kPaG, kPaA
3:0281	Stage 2 - P2 Filtered Input Signal	1	kPaG, kPaA
3:0282	Stage 2 - PF Value Used for Control	1	kPaG, kPaA
3:0283	Stage 2 - PF Filtered Input Signal	1	kPaG, kPaA
3:0284	Stage 2 - "Corrected" Suction Flow	1	Am3/hr
3:0285	Stage 2 - Sensor Flow	1	kg/hr,Nm3/hr
3:0286	Stage 2 - Surge Control Line Flow	1	Am3/hr
3:0287	Stage 2 - Actual Suction Flow	1	Am3/hr
3:0288	Stage 2 - Stage Flow	1	kg/hr,Nm3/hr
3:0289	Stage 2 - Rate PID Output	1	%
3:0290	Stage 2 - Surge Event Counter	1	
3:0291	Stage 2 - Total Number of Surges	1	
3:0292	Stage 2 - S_PV Surge Process Variable	1	%
3:0293	Stage 2 - Surge Capture Flow Deriv.	1	Am3/hr/s
3:0294	Stage 2 - Surge Capture P1 Derivative	1	kPa/s
3:0295	Stage 2 - Surge Capture P2 Derivative	1	kPa/s
3:0296	Stage 2 - Surge Capture Speed Deriv.	1	rpm/s
3:0297	Stage 2 - Calculated Sigma	1	
3:0298	Stage 2 - Surge Minimum Position	1	%
3:0299	Stage 2 - Sequencing Position Output	1	%
3:0300	Stage 2 - Surge Recovery Output	1	%
3:0301	Stage 2 - T1 Value Used for Control	1	DegC
3:0302	Stage 2 - T1 Filtered Input Signal	1	DegC
3:0303	Stage 2 - T2 Value Used for Control	1	DegC
3:0304	Stage 2 - T2 Filtered Input Signal	1	DegC
3:0305	Stage 2 - TF Value Used for Control	1	DegC
3:0306	Stage 2 - TF Filtered Input Signal	1	DegC
3:0307	Stage 2 - HSS Output	1	%
3:0308	Stage 2 - Valve Final Output	1	%
3:0309	Stage 2 - Valve Demand Percent	1	%
3:0310	Stage 2 - Calc. Avg Compressibility	1	
3:0311	Stage 2 - Calc. Suct. Compressibility	1	
3:0312	Stage 2 - Calc. Flow Compressibility	1	
3:0313	Stage 2 - HSS Auxiliary Input #1	1	%
3:0314	Stage 2 - HSS Auxiliary Input #2	1	%
3:0315	Stage 2 - HSS Auxiliary Input #3	1	%
3:0316	Stage 2 - Surge Capture Operating Pnt.	1	
3:0317	Stage 2 - Deactivation Output	1	%
3:0318	Stage 2 - Operating Point Rate	1	
3:0319	Stage 2 - Rate PID Setpoint	1	
3:0320	Stage 2 - Opr. Pnt. (Map X-axis Value)	1	Am3/hr
3:0321	Stage 2 - Opr. Pnt. (Map Y-axis Value)	1	N-m/kg, Press Ratio
3:0322	Stage 2 - Mode Selected	1	
3:0323	Stage 2 - Status	1	
3:0324	Stage 2 - Active Control Routine	1	
3:0325	Stage 2 - Mode and Routine Active	1	
3:0326	Stage 2 - Alarm First-out	1	
3:0327	Spare	1	
3:0328	Spare	1	
3:0329	Spare	1	
3:0330	Spare	1	
3:0331	Spare	1	
3:0332	Spare	1	

Address	Description	Multiplier	Units
3:0333	Spare	1	
3:0334	Stage 1 Flow Input (% x 100)	100	%
3:0335	Stage 1 Suction Press. Input (% x 100)	100	%
3:0336	Stage 1 Disch. Press. Input (% x 100)	100	%
3:0337	Stage 1 Suction Temp. Input (% x 100)	100	%
3:0338	Stage 1 Disch. Temp. Input (% x 100)	100	%
3:0339	Comp. Config. Analog Input 1 (% x 100)	100	%
3:0340	Comp. Config. Analog Input 2 (% x 100)	100	%
3:0341	Comp. Config. Analog Input 3 (% x 100)	100	%
3:0342	Comp. Config. Analog Input 4 (% x 100)	100	%
3:0343	Comp. Config. Analog Input 5 (% x 100)	100	%
3:0344	Comp. Config. Analog Input 6 (% x 100)	100	%
3:0345	Comp. Config. Analog Input 7 (% x 100)	100	%
3:0346	Comp. Config. Analog Input 8 (% x 100)	100	%
3:0347	Comp. Config. Analog Input 9 (% x 100)	100	%
3:0348	Comp. Config. Analog Input 10 (% x 100	100	%
3:0349	Comp. Config. Analog Input 11 (% x 100	100	%
3:0350	Comp. Config. Analog Input 12 (% x 100	100	%
3:0351	Comp. Config. Analog Input 13 (% x 100	100	%
3:0352	Comp. Config. Analog Input 14 (% x 100	100	%
3:0353	Comp. Config. Analog Input 15 (% x 100	100	%
3:0354	Comp. Config. Analog Input 16 (% x 100	100	%
3:0355	Comp. Config. Analog Input 17 (% x 100	100	%
3:0356	Comp. Config. Analog Input 18 (% x 100	100	%
3:0357	Comp. Config. Analog Input 19 (% x 100	100	%
3:0358	Comp. Config. Analog Input 20 (% x 100	100	%
3:0359	Comp. Config. Analog Input 21 (% x 100	100	%
3:0360	Stage 1 AS Valve Output (mA x 100)	100	mA
3:0361	Comp. Config. Analog Out 1 (mA x 100)	100	mA
3:0362	Comp. Config. Analog Out 2 (mA x 100)	100	mA
3:0363	Comp. Config. Analog Out 3 (mA x 100)	100	mA
3:0364	Comp. Config. Analog Out 4 (mA x 100)	100	mA
3:0365	Comp. Config. Analog Out 5 (mA x 100)	100	mA
3:0366	Comp. Config. Analog Out 6 (mA x 100)	100	mA
3:0367	Comp. Config. Analog Out 7 (mA x 100)	100	mA
3:0368	Comp. Analog Input 1 Configuration	1	
3:0369	Comp. Analog Input 2 Configuration	1	
3:0370	Comp. Analog Input 3 Configuration	1	
3:0371	Comp. Analog Input 4 Configuration	1	
3:0372	Comp. Analog Input 5 Configuration	1	
3:0373	Comp. Analog Input 6 Configuration	1	
3:0374	Comp. Analog Input 7 Configuration	1	
3:0375	Comp. Analog Input 8 Configuration	1	
3:0376	Comp. Analog Input 9 Configuration	1	
3:0377	Comp. Analog Input 10 Configuration	1	
3:0378	Comp. Analog Input 11 Configuration	1	
3:0379	Comp. Analog Input 12 Configuration	1	
3:0380	Comp. Analog Input 13 Configuration	1	
3:0381	Comp. Analog Input 14 Configuration	1	
3:0382	Comp. Analog Input 15 Configuration	1	
3:0383	Comp. Analog Input 16 Configuration	1	
3:0384	Comp. Analog Input 17 Configuration	1	
3:0385	Comp. Analog Input 18 Configuration	1	
3:0386	Comp. Analog Input 19 Configuration	1	
3:0387	Comp. Analog Input 20 Configuration	1	
3:0388	Comp. Analog Input 21 Configuration	1	
3:0389	Comp. Analog Output 1 Configuration	1	
3:0390	Comp. Analog Output 2 Configuration	1	
3:0391	Comp. Analog Output 3 Configuration	1	
3:0392	Comp. Analog Output 4 Configuration	1	
3:0393	Comp. Analog Output 5 Configuration	1	
3:0394	Comp. Analog Output 6 Configuration	1	
3:0395	Comp. Analog Output 7 Configuration	1	
3:0396	Comp. Relay 1 Configuration	1	
3:0397	Comp. Relay 2 Configuration	1	
3:0398	Comp. Relay 3 Configuration	1	
3:0399	Comp. Relay 4 Configuration	1	
3:0400	Comp. Relay 5 Configuration	1	
3:0401	Comp. Relay 6 Configuration	1	
3:0402	Comp. Relay 7 Configuration	1	
3:0403	Comp. Relay 8 Configuration	1	
3:0404	Comp. Relay 9 Configuration	1	
3:0405	Comp. Relay 10 Configuration	1	
3:0406	Comp. Relay 11 Configuration	1	
3:0407	Comp. Relay 12 Configuration	1	
3:0408	Comp. Relay 13 Configuration	1	
3:0409	Comp. Relay 14 Configuration	1	
3:0410	Comp. Relay 15 Configuration	1	
3:0411	Comp. Relay 16 Configuration	1	

Address	Description	Multiplier	Units
3:0412	Comp. Relay 17 Configuration	1	
3:0413	Comp. Relay 18 Configuration	1	
3:0414	Comp. Contact Input 1 Configuration	1	
3:0415	Comp. Contact Input 2 Configuration	1	
3:0416	Comp. Contact Input 3 Configuration	1	
3:0417	Comp. Contact Input 4 Configuration	1	
3:0418	Comp. Contact Input 5 Configuration	1	
3:0419	Comp. Contact Input 6 Configuration	1	
3:0420	Comp. Contact Input 7 Configuration	1	
3:0421	Comp. Contact Input 8 Configuration	1	
3:0422	Comp. Contact Input 9 Configuration	1	
3:0423	Comp. Contact Input 10 Configuration	1	
3:0424	Comp. Contact Input 11 Configuration	1	
3:0425	Comp. Contact Input 12 Configuration	1	
3:0426	Comp. Contact Input 13 Configuration	1	
3:0427	Comp. Contact Input 14 Configuration	1	
3:0428	Comp. Contact Input 15 Configuration	1	
3:0429	Comp. Contact Input 16 Configuration	1	
3:0430	Comp. Contact Input 17 Configuration	1	
3:0431	Comp. Contact Input 18 Configuration	1	
3:0432	Comp. Contact Input 19 Configuration	1	
3:0433	Comp. Contact Input 20 Configuration	1	
3:0434	Comp. Contact Input 21 Configuration	1	
3:0435	Comp. Contact Input 22 Configuration	1	
3:0436	Comp. Contact Input 23 Configuration	1	
3:0437	Comp. Contact Input 24 Configuration	1	
3:0438	Comp. Contact Input 25 Configuration	1	
3:0439	Comp. Contact Input 26 Configuration	1	
3:0440	Comp. Contact Input 27 Configuration	1	
3:0441	Comp. Contact Input 28 Configuration	1	
3:0442	Comp. Contact Input 29 Configuration	1	
3:0443	Comp. Contact Input 30 Configuration	1	
3:0444	Comp. Contact Input 31 Configuration	1	
3:0445	Comp. Contact Input 32 Configuration	1	
3:0446	Comp. Contact Input 33 Configuration	1	
3:0447	Comp. Contact Input 34 Configuration	1	
3:0448	Comp. Contact Input 35 Configuration	1	
3:0449	Comp. Contact Input 36 Configuration	1	

Table 8-7. Analog Reads

Analog Writes (writes from the master device to the Vertex-Pro)

Address	Description	Multiplier	Units
4:0001	Modbus Entered Speed Setpoint	1	rpm
4:0002	Modbus Entered Casc Setpoint	Configurable	
4:0003	Modbus Entered Aux Setpoint (Not Used)	1	
4:0004	Modbus Entered Extr Setpoint	Configurable	
4:0005	Modbus Entered Inlet/Exhaust Setpoint	Configurable	
4:0006	Modbus Entered Manual E/A Press Demand	100	%
4:0007	Modbus Entered Manual HP/V1 Setpoint	100	
4:0008	Modbus Entered Manual LP/V2 Setpoint	100	
4:0009	Modbus Entered Current Limit Setpt	Configurable	
4:0010	Stage 1 - MB Entered P1 Override Stpt.	Configurable	KPa
4:0011	Stage 1 - MB Entered P2 Override Stpt.	Configurable	kPa
4:0012	Stage 1 - MB Entered Manual Valve Pos.	100	%
4:0013	Stage 1 - MB Entered Add Margin	10	
4:0014	Stage 2 - MB Entered P1 Override Stpt.	Configurable	KPa
4:0015	Stage 2 - MB Entered P2 Override Stpt.	Configurable	KPa
4:0016	Stage 2 - MB Entered Manual Valve Pos.	100	%
4:0017	Stage 2 - MB Entered Add Margin	10	
4:0018	Modbus Entered Throttle/IGV Setpt	100	
4:0019	Modbus Entered Header Press Setpt	Configurable	
4:0020	Spare	1	
4:0021	Spare	1	
4:0022	Spare	1	

Table 8-8. Analog Writes

Analog Lookup Table

Some of the analog reads shown in the Modbus list are reference values, such as first out alarms or I/O configuration indicators. To interpret such values Reference Table 8-9.

3:0001 Cause of Last Trip	0 - No Shutdowns
	1 - Power-up / CPU Reset
	2 - Shutdown Initiated from HMI
	3 - Turbine Overspeed Trip
	4 - External Speed Sensor Failure (Option)
	5 - Turbine HP/V1 Actuator Output Failure
	6 - Turbine LP/V2 Actuator Output Failure
	7 - Speed in Critical Band Too Long
	8 - External Trip Input #2
	9 - External Trip Input #3
	10 - Shutdown Initiated from Modbus 1
	11 - Shutdown Initiated from Modbus 2
	12 - Tie-Breaker Opened
	13 - Generator Breaker Opened
	14 - Main Trip Contact Input
	15 - Controlled Shutdown Complete
	16 - External Trip Input #4
	17 - External Trip Input #5
	18 - Extraction / Admission Pressure Input
	19 - All 24/8 Analog Modules Fault
	20 - All Analog Combo Modules Fault (Option)
	21 - All 48/24 Discrete Combo Modules Fault
	22 - Invalid Compressor Configuration
3:0148 Comp Common Alarm First Out	0 - No Alarms
	1 - PS1 Fault
	2 - PS2 Fault
	3 - Temp High
	4 - Top Left Fault
	5 - Top Right Fault
	6 - Bottom Left Fault
	7 - Bottom Right Fault
	8 - Left CPU Fault
	9 - Right CPU Fault
	10 - A2 HD Analog Fault
	11 - A3 HD Analog Fault
	12 - A4 Analog Combo Fault (Option)
	13 - A5 Analog Combo Fault (Option)
	14 - A6 Discrete I/O Fault
	15 - A7 Discrete I/O Fault
	16 - Serial Modbus Port 1 Fault
	17 - Serial Modbus Port 2 Fault
	18 - Ether Modbus Port 1 Fault
	19 - Ether Modbus Port 2 Fault
	20 - Discrete Input Mismatch
	21 - Start Permissive Not Met
	22 - Trip as Alarm
	23 - Speed Sensor 1 Failed (Option)
	24 - Speed Sensor 2 Failed (Option)
	25 - Speed Sensor 3 Failed (Option)
	26 - Performance Input Fault
	27 - Performance Remote Ref Fault
	28 - Motor Current Failed
	29 - Remote Setpoint of Load Sharing #1 Failed
	30 - Remote Setpoint of Load Sharing #2 Failed
	31 - S_PV #1 for Load sharing Failed
	32 - S_PV #2 for Load sharing Failed
	33 - Header Pressure Failed
	34 - Throttle/IGV Remote Setpoint Failed
	35 - External Speed Sensor Failed (Option)
	36 - Remote Header Press Setpoint Failed
	37 - Stage 1 ASV Pos Feedback Failed
	38 - Stage 2 ASV Pos Feedback Failed
	39 - Throttle/IGV Pos Feedback Failed
	40 – spare
	41 – spare
	42 - HD Analog Output #1
	43 - HD Analog Output #2
	44 - HD Analog Output #3
	45 - HD Analog Output #4
	46 - HD Analog Output #5
	47 - HD Analog Output #6
	48 - HD Analog Output #7

	49 - HD Analog Output #8
	50 - Combo Analog Output #1 (Option)
	51 - Combo Analog Output #2 (Option)
	52 - Combo Analog Output #3 (Option)
	53 - Combo Analog Output #4 (Option)
	54 - Combo Act Output #1 (Option)
	55 - Combo Act Output #2 (Option)
	56 - HD Analog Input #1
	57 - HD Analog Input #2
	58 - HD Analog Input #3
	59 - HD Analog Input #4
	60 - HD Analog Input #5
	61 - HD Analog Input #6
	62 - HD Analog Input #7
	63 - HD Analog Input #8
	64 - HD Analog Input #9
	65 - HD Analog Input #10
	66 - HD Analog Input #11
	67 - HD Analog Input #12
	68 - HD Analog Input #13
	69 - HD Analog Input #14
	70 - HD Analog Input #15
	71 - HD Analog Input #16
	72 - HD Analog Input #17
	73 - HD Analog Input #18
	74 - HD Analog Input #19
	75 - HD Analog Input #20
	76 - HD Analog Input #21
	77 - HD Analog Input #22
	78 - HD Analog Input #23
	79 - HD Analog Input #24
	80 - Combo Analog Input #1
	81 - Combo Analog Input #2
	82 - Combo Analog Input #3
	83 - Combo Analog Input #4
	84 - Combo Analog Input #5
	85 - Combo Analog Input #6
	86 - Combo Analog Input #7
	87 - Combo Analog Input #8
	88 - Can Network #1 Error
	89 - Can Network #2 Error
	90 - In Forcing or Calibrating Mode
	91 - Level Alarm #1
	92 - Level Alarm #2
	93 - Level Alarm #3
	94 - Level Alarm #4
3:0251, 3:0322 Stage 1 (251) and Stage 2 (322) Mode Selected	0 – No Selection
	1 – AUTO Mode Selected
	2 – MANUAL w/ BACKUP Mode Selected
	3 – FULL MANUAL Mode Selected
3:0252, 3:0323 Stage 1 (252) and Stage 2 (323) Status	0 – No Selection
	1 – Offline - Controlled Shutdown
	2 – Offline - Emergency Shutdown
	3 – Offline - Zero Speed
	4 – Offline - Purge
	5 – Offline - Start
	6 – On Line
3:0253, 3:0324 Stage 1 (253) and Stage 2 (324) Active Control Routine	0 – No Selection
	1 – Anti-Surge PID
	2 – Surge Recovery
	3 – BOOST (Valve Step Opening)
	4 – MANUAL (with BACKUP)
	5 – Suct Press Override
	6 – Dsch Press Override
	7 – Rate Control
	8 – Sequence Position
	9 – Aux Input #1
	10 – Aux Input #2
	11 – Aux Input #3
	12 – Deactivation Routine
	13 – FULL MANUAL
3:0254, 3:0325 Stage 1 (254) and Stage 2 (325) Active Mode and Control Routine	0 – No Selection
	1 – AUTO / Shutdown Positioning
	2 – AUTO / Zero Speed Positioning
	3 – AUTO / Purge Positioning
	4 – AUTO / Start Positioning
	5 – AUTO / Anti-Surge PID
	6 – AUTO / Rate PID
	7 – AUTO / Surge Recovery
	8 – AUTO / BOOST (Valve Step Opening)

	9 – AUTO / Manual with Backup
	10 – AUTO / Suction Pressure Override
	11 – AUTO / Discharge Pressure Override
	12 – AUTO / Sequence Positioning
	13 – AUTO / Auxiliary HSS Input 1
	14 – AUTO / Auxiliary HSS Input 2
	15 – AUTO / Auxiliary HSS Input 3
	16 – AUTO / Deactivation Routine
	17 – MANUAL w/BACKUP / Shutdown Position
	18 – MANUAL w/BACKUP / Zero Speed Position
	19 – MANUAL w/BACKUP / Purge Position
	20 – MANUAL w/BACKUP / Start Position
	21 – MANUAL w/BACKUP / Anti-Surge PID
	22 – MANUAL w/BACKUP / Rate PID
	23 – MANUAL w/BACKUP / Surge Recovery
	24 – MANUAL w/BACKUP / BOOST / Valve Step Opening
	25 – MANUAL w/BACKUP / Manual with Backup
	26 – MANUAL w/BACKUP / Suction Pressure Override
	27 – MANUAL w/BACKUP / Discharge Pressure Override
	28 – MANUAL w/BACKUP / Sequence Positioning
	29 – MANUAL w/BACKUP / Auxiliary HSS Input 1
	30 – MANUAL w/BACKUP / Auxiliary HSS Input 2
	31 – MANUAL w/BACKUP / Auxiliary HSS Input 3
	32 – MANUAL w/BACKUP / Deactivation Routine
	33 – FULL MANUAL / Surge Recovery
	34 – FULL MANUAL / On Line
	35 – FULL MANUAL / Off Line
3:0255, 3:0326 Stage 1 (255) and Stage 2 (326) Alarm First Out	0 - No Alarms
	1 - Primary Flow Signal Failed
	2 - Primary Suction Press. Signal Failed
	3 - Primary Discharge Press. Signal Failed
	4 - Suction Temperature Signal Failed
	5 - Discharge Temperature Signal Failed
	6 - Flow Element Pressure Signal Failed
	7 - Flow Element Temperature Signal Failed
	8 - Auxiliary HSS Input 1 Signal Failed
	9 - Auxiliary HSS Input 2 Signal Failed
	10 - Manual Valve Position Input Signal Failed
	11 - Redundant Flow Input Signal Failed
	12 - Redundant Suction Press. Signal Failed
	13 - Redundant Discharge Press. Signal Fail
	14 - Not used
	15 - Not used
	16 - Redundant Flow Difference Alarm
	17 - Redundant P1 Difference Alarm
	18 - Redundant P2 Difference Alarm
	19 - Not in Automatic -- Start Initiated
	20 - Full Manual -- Surge Recovery Disabled
	21 - Steady State Condition Failed
	22 - Surge Detected
	23 - Surge Minimum Position Active
	24 - Anti-Surge Valve Output Circuit Fault
3:0368 – 3:0388 Compressor Analog Input Configuration	0 – Not Used
	1 - Stage 1 Raw Input Signal PF
	2 - Stage 1 Raw Input Signal TF
	3 - Stage 1 HSS Auxiliary Input 1
	4 - Stage 1 HSS Auxiliary Input 2
	5 - Stage 1 Remote Manual Valve Pos.
	6 - Stage 1 Redundant Flow Input
	7 - Stage 1 Redundant Suction Pressure Input
	8 - Stage 1 Redundant Discharge Pressure Input
	9 - Stage 2 Raw Input Signal PF
	10 - Stage 2 Raw Input Signal TF
	11 - Stage 2 HSS Auxiliary Input 1
	12 - Stage 2 HSS Auxiliary Input 2
	13 - Stage 2 Remote Manual Valve Pos.
	14 - Stage 2 Redundant Flow Input
	15 - Stage 2 Redundant Suction Pressure Input
	16 - Stage 2 Redundant Discharge Pressure Input
	17 - Stage 2 Flow
	18 - Stage 2 Suction Pressure
	19 - Stage 2 Discharge Pressure
	20 - Stage 2 Suction Temperature
	21 - Stage 2 Discharge Temperature
	22 - Motor Current
	23 - Remote Setpoint of Load Sharing #1
	24 - Remote Setpoint of Load Sharing #2
	25 - Flow #1 for Load sharing
	26 - Flow #2 for Load sharing
	27 - Header Pressure for Load sharing

	28 - Throttle/IGV Remote Setpoint
	29 - External Speed Sensor
	30 - Remote Header Press Setpoint
	31 - Stage 1 ASV Pos Feedback
	32 - Stage 2 ASV Pos Feedback
	33 - Throttle/IGV Pos Feedback
	34 - Performance Process Input
	35 - Remote Performance Setpoint
3:0389 – 3:0395 Compressor Analog Output Configuration	1 - Not Used
	2 - Stage 1 Surge Process Variable (S_PV)
	3 - Stage 1 Actual Suction Volumetric Flow
	4 - Stage 1 Corrected Suction Volume Flow
	5 - Stage 1 Compressor Flow
	6 - Stage 1 Polytropic Head
	7 - Stage 1 Pressure Ratio
	8 - Stage 1 Suction Pressure
	9 - Stage 1 Discharge Pressure
	10 - Stage 1 Suction Temperature
	11 - Stage 1 Discharge Temperature
	12 - Stage 1 Sensor Flow
	13 - Stage 1 HSS Output
	14 - Stage 1 Valve Percentage
	15 - Stage 2 Surge Process Variable (S_PV)
	16 - Stage 2 Actual Suction Volumetric Flow
	17 - Stage 2 Corrected Suction Volume Flow
	18 - Stage 2 Compressor Flow
	19 - Stage 2 Polytropic Head
	20 - Stage 2 Pressure Ratio
	21 - Stage 2 Suction Pressure
	22 - Stage 2 Discharge Pressure
	23 - Stage 2 Suction Temperature
	24 - Stage 2 Discharge Temperature
	25 - Stage 2 Sensor Flow
	26 - Stage 2 HSS Output
	27 - Stage 2 Valve Percentage
	28 - Stage 2 Valve Demand
	29 - Throttle/IGV Demand
	30 - Load sharing Remote Setpoint
	31 - Stage 1 ASV Position Feedback
	32 - Stage 2 ASV Position Feedback
	33 - Throttle/IGV Position Feedback
	34 - Header Pressure
3:0396 – 3:0413 Compressor Discrete Output Configuration	1 - Not Used
	2 - Off Line-Controlled SD
	3 - Off Line-Emergency SD
	4 - Off Line-Zero Speed
	5 - Off Line-Purge
	6 - Off Line-Start
	7 - On Line
	8 - Stage 1 Surge Detected
	9 - Stage 1 Surge Min Pos(SMP)
	10 - Stage 1 AUTO Mode
	11 - Stage 1 MANUAL /w BACKUP
	12 - Stage 1 FULL MANUAL
	13 - Stage 2 Surge Detected
	14 - Stage 2 Surge Min Pos(SMP)
	15 - Stage 2 AUTO Mode
	16 - Stage 2 MANUAL /w BACKUP
	17 - Stage 2 FULL MANUAL
	18 - Load Sharing Permissived
	19 - Load Sharing Enabled
	20 - Load Sharing Active
	21 - Load Sharing Master
	22 - Current Limited
	23 - Performance Control Active
	24 - Ready to Start
	25 - Level Switch - Stage 1 Surge Process Variable (S_PV)
	26 - Level Switch - Stage 1 Actual Suction Volumetric Flow
	27 - Level Switch - Stage 1 Corrected Suction Volume Flow
	28 - Level Switch - Stage 1 Compressor Flow
	29 - Level Switch - Stage 1 Polytropic Head
	30 - Level Switch - Stage 1 Pressure Ratio
	31 - Level Switch - Stage 1 Suction Pressure
	32 - Level Switch - Stage 1 Discharge Pressure
	33 - Level Switch - Stage 1 Suction Temperature
	34 - Level Switch - Stage 1 Discharge Temperature
	35 - Level Switch - Stage 1 Sensor Flow
	36 - Level Switch - Stage 1 HSS Output
	37 - Level Switch - Stage 1 Valve Percentage
	38 - Level Switch - Stage 2 Surge Process Variable (S_PV)

	39 - Level Switch - Stage 2 Actual Suction Volumetric Flow
	40 - Level Switch - Stage 2 Corrected Suction Volume Flow
	41 - Level Switch - Stage 2 Compressor Flow
	42 - Level Switch - Stage 2 Polytropic Head
	43 - Level Switch - Stage 2 Pressure Ratio
	44 - Level Switch - Stage 2 Suction Pressure
	45 - Level Switch - Stage 2 Discharge Pressure
	46 - Level Switch - Stage 2 Suction Temperature
	47 - Level Switch - Stage 2 Discharge Temperature
	48 - Level Switch - Stage 2 Sensor Flow
	49 - Level Switch - Stage 2 HSS Output
	50 - Level Switch - Stage 2 Valve Percentage
	51 - Level Switch - Stage 2 Valve Demand
	52 - Level Switch - Throttle/IGV Demand
	53 - Level Switch - Load sharing Remote Setpoint
	54 - Level Switch - Stage 1 ASV Position Feedback
	55 - Level Switch - Stage 2 ASV Position Feedback
	56 - Level Switch - Throttle/IGV Position Feedback
	57 - Level Switch - Header Pressure
3:0414 – 3:0449 Compressor Discrete Input Configuration	0 – Not Used
	1 - Stage 1 Reset SMP
	2 - Stage 1 Reset Surge Capture Info.
	3 - Stage 1 Select AUTO Mode
	4 - Stage 1 Select MANUAL w/ BACKUP
	5 - Stage 1 Select FULL MANUAL Mode
	6 - Stage 1 Purge Position
	7 - Stage 1 Online Auxiliary Input
	8 - Stage 1 Control Margin Increase
	9 - Stage 1 Control Margin Decrease
	10 - Stage 1 AS Valve Output Fault
	11 - Stage 1 Start Position
	12 - Stage 1 Shutdown
	13 - Stage 2 Reset SMP
	14 - Stage 2 Reset Surge Capture Info
	15 - Stage 2 Select AUTO Mode
	16 - Stage 2 Select MANUAL w/ BACKUP
	17 - Stage 2 Select FULL MANUAL Mode
	18 - Stage 2 Purge Position
	19 - Stage 2 Online Auxiliary Input
	20 - Stage 2 Control Margin Increase
	21 - Stage 2 Control Margin Decrease
	22 - Stage 2 AS Valve Output Fault
	23 - Stage 2 Start Position
	24 - Stage 2 Shutdown
	25 - Performance Setpoint Raise
	26 - Performance Setpoint Lower
	27 - Performance Control Enable
	28 - Performance Remote Setpoint Enable
	29 - Current Limit Raise
	30 - Current Limit Lower
	31 - Load Sharing Enable/Disable
	32 - Load Sharing Permissive #1
	33 - Load Sharing Permissive #2
	34 - Throttle/IGV Raise
	35 - Throttle/IGV Lower
	36 - Throttle/IGV Remote Enable
	37 - Stage 1 Open Anti-Surge Valve
	38 - Stage 1 Close Anti-Surge Valve
	39 - Stage 2 Open Anti-Surge Valve
	40 - Stage 2 Close Anti-Surge Valve
	41 - Another Control LS Enabled #1
	42 - Another Control LS Enabled #2
	43 - Remote Header Press Setpoint E/D
	44 - Stage 1 Remote ASV Enable
	45 - Stage 2 Remote ASV Enable
	46 - Start Permissive
	47 - Load Sharing #1 is Master
	48 - Load Sharing #2 is Master
	49 - External Trip #2
	50 - External Trip #3
	51 - External Trip #4
	52 - External Trip #5
	53 - Load Sharing #1 No Shutdown
	54 - Load Sharing #2 No Shutdown
	55 - Local / Remote

Table 8-9. Modbus Analog Read Lookup Table

Chapter 9.
Field Set-up

Loop Period Test Procedure

The system response time for the Vertex-Pro 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 Stage I/O configuration screen, 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.

After this test is completed compare the loop period times. If the numbers are the same or similar (i.e. 5,6,7) then the system is lag time limited and Pre-pack will speed up open-loop step response. Select the lower time or an average to configure the Loop Period on the Open Loop Configuration Screen. If the numbers are proportional (i.e. 3,6,9) then the system is rate limited (or valve limited) and the Pre-pack function will not help. In this case, select the lower time to configure the Loop Period on the Open Loop Configuration Screen. If only step 1 of the test is done and the loop period is greater than 10 seconds, enable the Pre-pack function.

If the test was unsuccessful, then possibly the compressor was choked or flow limited. To correct this problem, reduce the flow through the compressor and repeat the test.

The configured Loop Period time is used by the control in calculating the Rate PID setpoint, in determining how long to apply the BOOST and Surge Recovery routines, and in determining how long to wait for the system to respond to these actions before resuming surge detection. In the cases of the open-loop responses, the shorter the configured loop period time, the more conservative or aggressive the control response, but the more likely it is for unnecessary or excessive recycling.

But, for the Rate PID controller, a shorter loop period actually "detunes" the control by increasing the allowable operating point rate of movement (Rate PID setpoint). In other words, adjusting the Loop Period time my help one control routine but hurt another. Since a conservative or aggressive strategy is generally preferred to ultimately protect the compressor, even at the expense of excessive but temporary recycling, it is usually best to err on the side of a shorter Loop Period time if the test described above does not produce a definitive value. In this case however, the Rate PID Setpoint, if enabled, should be reduced to compensate for the shorter Loop Period.

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 Stage Closed Loop configuration screen. These are the adjustable and interacting parameters used to match the response of the control loop with the response of the system. They correspond to the P (proportional), I (integral), and D (derivative) terms, and are displayed by the Vertex-Pro as follows:

- P = Prop Gain (% output per unit error)
- I = Int Gain (repeats per minute)
- D = Deriv Ratio

Refer to the sections below for general tuning theory and procedures. See Chapter 5 for specific features of the Vertex-Pro's compressor control tuning screens.

Tuning P & I Gains

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

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

For best response, the proportional gain and integral gain should be as high as possible. To obtain a faster transient response, slowly increase the proportional gain setting until the actuator 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 Vertex-Pro's adjustable gains. If the accumulated mechanical gain (actuators, valves, valve linkage, etc.) is very high, the Vertex-Pro's adjustable gains must be very low to result in a system gain that affords stability.

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

Tuning Derivative

The value of the 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 Vertex-Pro, 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 Vertex-Pro'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 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 9-1 shows the typical response to a load change when the dynamics are optimally adjusted.

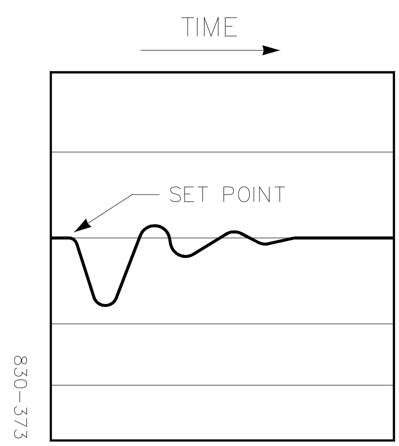


Figure 9-1. Typical Response to Load Change

Chapter 10. Compressor Operation Overview

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 Vertex-Pro's functionality only. For more complete, process-specific compressor or plant operating instructions, contact the plant-equipment manufacturer.

Screens are shown below as configured for ITCC Mode (See 26489V1 for Control Mode Configuration options)—In Turbine-Only or Compressor-Only Modes, there will be some variation in screen appearance from those shown below.

Compressor Operation

The HMI/DCS's common screen footer displays status messages and pertinent data for the compressor (both stages if applicable) at the bottom of every screen. To the right side of the footer, the S_PV process variable and anti-surge valve demand are shown. The former will blink red when S_PV falls below 98% while the unit is online as an immediate visual indication that the compressor is operating to the left of the Surge Control Line. To the left side of the footer is a status message that will indicate the compressor's current control mode (Auto, Manual with Backup, Full Manual) and controlling function.

Once configured, the Vertex-Pro 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 operating screens, available from Figure 10-1, provide access to all pertinent data used by the control to position the anti-surge valves. The sections below describe typical start-up, online operation, and shutdown scenarios, as well as how to use the available screens and data to interpret compressor operation and intervene as required.

Start-up

When shutdown and at zero speed (0 rpm), the unit is off-line, and the Vertex-Pro maintains the compressor anti-surge valve at the "Zero Speed Position." Typical compressor start-ups are on full recycle during a steam motor warm-up, which may last several hours. As steam is initially admitted to the motor and speed increases past the compressor's configured "Zero Speed" setpoint, the control ramps the anti-surge valve to the "Start Position." This start sequence may also be triggered by a configurable discrete input or Modbus command.

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.**

The control will remain off-line, in the start sequence, with the valve at the "Start Position" until an on-line condition is triggered. All enabled on-line triggers (speed, suction pressure, discharge pressure, flow, auxiliary input) must be satisfied to go on-line and transfer from sequencing to automatic control. If a shutdown (i.e. motor trip, ESD, configurable discrete input, Modbus command) is received at any time during start-up, the control will sequence the valve to the "Shutdown Position" and await a restart (configurable discrete input, Modbus command) or slow to zero speed.

On-Line / Normal Operation

After the unit goes on-line, as determined by the Vertex-Pro'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 Vertex-Pro will monitor operation and position the valve as determined by the various control routines:

- Anti-Surge PID
- Rate PID
- BOOST / Valve Step Opening
- Surge Recovery
- Surge Minimum Position
- Decoupling
- Suction Pressure Override
- Discharge Pressure Override
- Auxiliary Control Inputs (2)
- Manual Control (Manual with Backup, Full Manual)

Removal of an on-line trigger (speed, suction pressure, discharge pressure, flow, auxiliary input) will revert control to the start sequence and ramp the valve to the "Start Position." The control will remain as such until the on-line trigger is restored.

If a shutdown (motor trip, ESD, configurable discrete input, Modbus command) is received, the control will sequence the valve to the "Shutdown Position" and await a restart (configurable discrete input, Modbus command) or slow to zero speed.

Emergency Shutdown

When a shutdown is received, the anti-surge valve is immediately moved to the configured "Shutdown Position." The 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 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 Vertex-Pro transfers to automatic Anti-Surge control.

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.

Vertex-Pro Compressor Operating Screens

Depending on the compressor configuration as single, dual, triple or quadruple stage (one, two, three or four sections), several compressor operating screens will be available in the HMI/DCS. This chapter will explain the operation method using sample screens. Figures shown by the following explanation are sample

Compressor Operation Screen (Sample of Dual Stage)

This screen, shown in Figure 10-1, provides all relevant data for both compressor sections in a tabular format, without graphics. Information presented includes all filtered input values, control values (inputs after filtering and failure routines), surge capture, calculated performance data, and control outputs. Messages are displayed to indicate the routine and sequence that are in control. Control mode (Auto, Manual with Backup, Full Manual) selections are also available. This screen is available only for two-stage configurations and is intended to provide a single screen for operation of the entire compressor train. Reference the following screen descriptions for details on the data and controls presented.

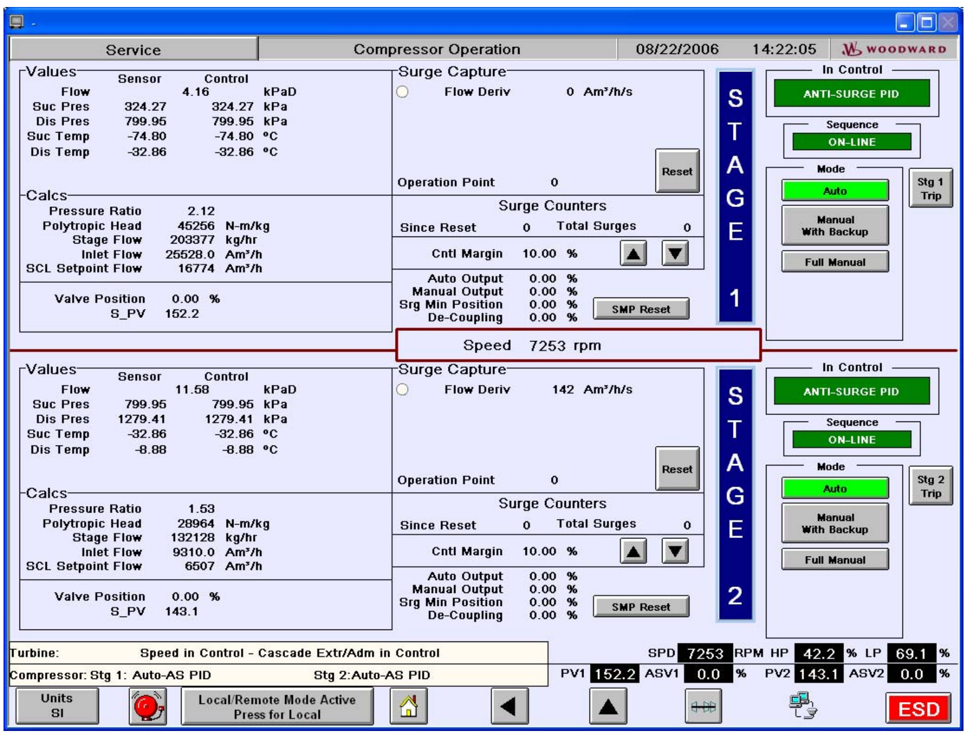


Figure 10-1. Sample Compressor Operation Screen

Compressor Stage Operation Screen

The primary operating screen for an individual compressor section is shown in Figure 10-2. The compressor and field instruments are displayed graphically at the top of the screen. The instrument boxes indicate the filtered input values in engineering units. The motor and compressor body schematics are outlined in either blue or white. The latter indicates which piece of equipment is monitored by the current screen. Selecting another piece of equipment, outlined in blue, will jump to that equipment's operating screen.

The Stage Trip button provides an immediate method of placing the compressor on full recycle, instead of ramping opening the anti-surge valve in either of the Manual control modes, which could take several seconds. In other words, it initiates a compressor shutdown, without affecting the motor control. However, Performance Control, if enabled, will be inhibited. When the compressor is in its shutdown sequence, the button acts to put the unit back online in automatic control.

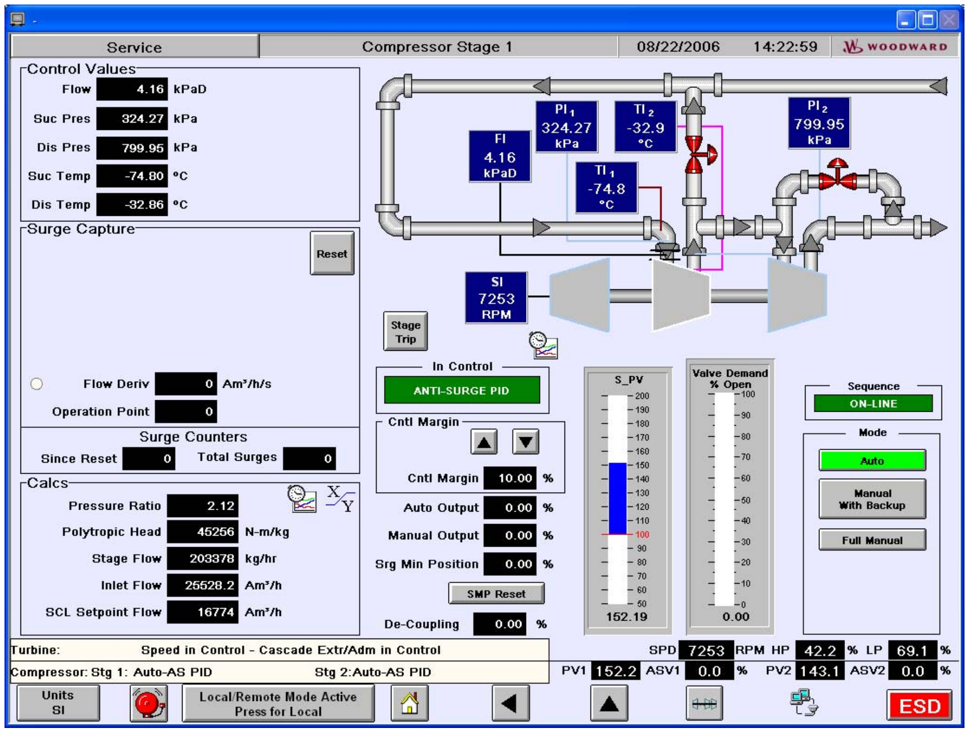


Figure 10-2. Sample Compressor Stage Operation Screen

The "In Control" status message will indicate which of the Vertex-Pro's control routines listed below is positioning the anti-surge valve at a given time.

- Anti-Surge PID
- Rate PID
- BOOST / Valve Step Opening
- Surge Recovery / Surge Minimum Position
- Suction Pressure Override
- Discharge Pressure Override
- Auxiliary Control Input #1
- Auxiliary Control Input #2
- Adjacent Stage Controller (for Dual Stage, Single-Valve configurations)
- Manual with Backup
- Full Manual
- Sequence Positioning
- Deactivation Routine

The current control margin is displayed with adjustment buttons to allow increasing and decreasing the value. The value cannot be decreased below the Base Control Margin configured on the I/O Configuration Screen.

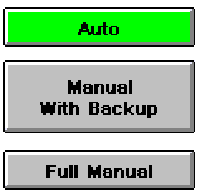
Control demands are indicated for Auto, Manual, Surge Minimum Position (SMP), and Decoupling routines. If enabled, SMP is indicated when active—

Select the SMP Reset button to reset SMP and allow the anti-surge valve to close after a surge event.

Two bar graphs provide visual indication of S_PV and valve demand. If enabled, the Valve Freeze function is indicated above the valve demand bar graph when active.

The "Sequence" status message will indicate which sequence the Vertex-Pro is in at a given time.

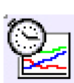
- On-Line
- Off-Line – Start
- Off-Line – Purge
- Off-Line – Zero Speed
- Off-Line – Emergency Shutdown
- Off-Line – Controlled Shutdown



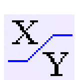
Auto/Manual switching is available with the buttons provided. The active control mode is indicated by a highlighted button. In either Manual control mode, adjustment buttons are provided to manually open or close the Anti-Surge Valve. The manual valve demand may also be entered directly as an analog value.

IMPORTANT **The Auto/Manual mode buttons operate on a command/feedback principle. When selected, they command the Vertex-Pro to the appropriate mode, but they await feedback before changing colors. Communications errors or timing problems can sometimes result in a feedback mismatch, indicated by a white colored button that appears "stuck in transition." To clear this situation and resynchronize the buttons, reselect the original mode button. Then attempt the mode switch again.**

To the left, control values (inputs after filtering and failure routines) are displayed with indicators if last good values, default values, or the Fail to Manual function are active. The surge capture is displayed below, including indicators of which routines detected the surge. The surge counter and capture values can be reset, but the Total Surges counter will remain.



To the bottom left, calculated performance values are displayed with a link to a trend page. Similar buttons elsewhere on the screen will jump to trend screens of other pertinent data. Refer to Volume 1 of this manual for more information about trend screens.



Select the X-Y Plot button to jump to the Operating Map Screen.

Compressor Stage Logic Diagram Screen

The Logic Diagram Screen, shown in Figure 10-3, provides a flow diagram view of the Vertex-Pro's compressor control functionality. It is particularly useful in illustrating the HSS bus operation. Inputs are shown to the upper left of the diagram. If enabled and active, input failure backup strategies are indicated in the respective box. The In Control and Sequence messages are duplicated to the upper right.

All control functions are shown with their individual demands to the HSS. The active function is highlighted in green. Any routine that is not configured is shown disabled in gray. Downstream logic shows the addition of the decoupling demand, if enabled, and the Full Manual mode switch, which bypasses the HSS.

Select one of the four PID amplifier symbols, outlined in blue, to jump to a tuning screen for that loop. The dynamics tuning screens are detailed below. Similarly, select the Valve Characterizer box, also outlined in blue, to jump to the Manual Stroke/Linearization screen, also detailed below.

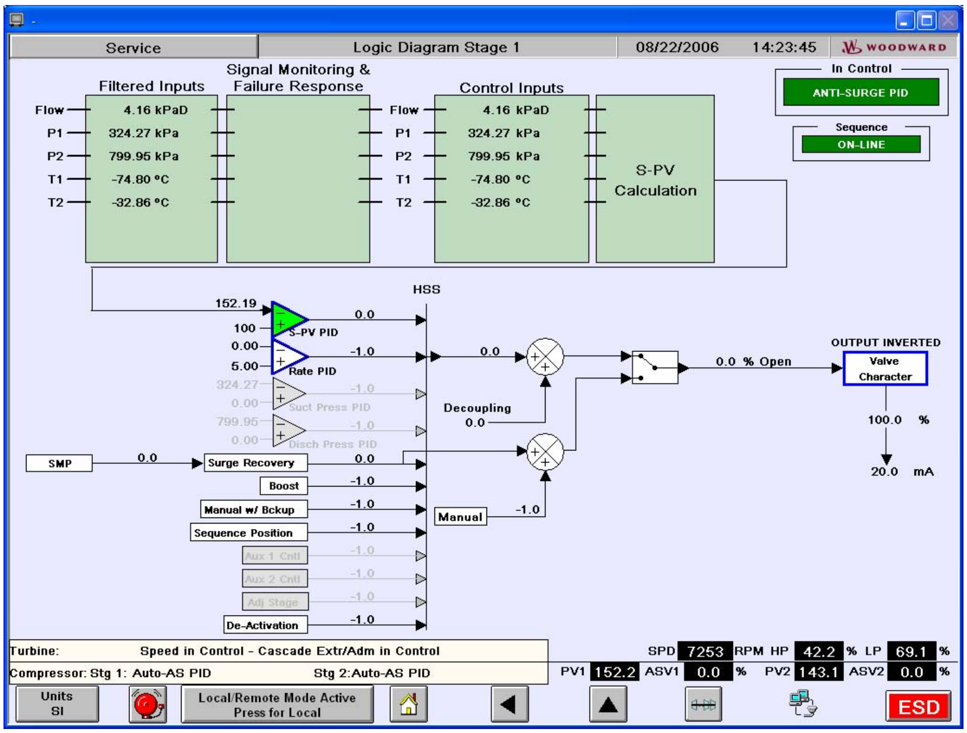


Figure 10-3. Sample Compressor Logic Diagram Screen

Compressor Dynamics Tuning Screens

Tuning of the various controllers is available via individual dynamics tuning screens accessible from the Logic Diagram screen shown in Figure 10-3. Select the desired PID amplifier, outlined in blue, to access the respective tuning screen. The Anti-Surge Dynamics tuning screen is shown in Figure 10-4. Similar screens are available for the Rate, Suction Pressure Override, and Discharge Pressure Override controllers.

The trend is configured with pens for the process variable, setpoint, and PID demand output. The trend window can be expanded or contracted in one-minute increments and the number of horizontal lines adjusted as desired. The crosshair, or cursor, can be moved to any location within the trend to verify pen values at that point. Below the trend, the minimum and maximum Y-axis limits for each pen can also be adjusted. The cursor values and current values are shown for each pen.

If the process cannot be manipulated, such as with a discharge block valve, the demand value to the right, in this case the base control margin, can be adjusted to introduce disturbances. Tune the proportional (P), integral (I), and derivative (SDR) values as necessary to achieve the desired control response (See the Dynamics Adjustments section in Chapter 4 for details on P-I-D settings and general tuning procedures).

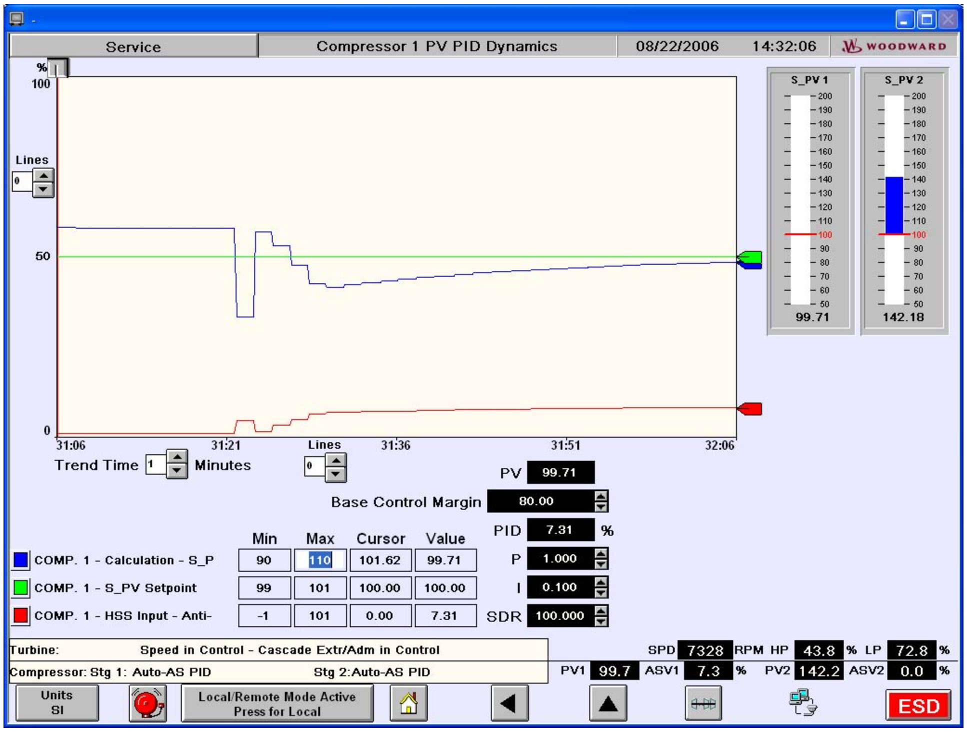


Figure 10-4. Sample Compressor Anti-Surge PID Tuning Screen

Compressor Stage Map Screen

The Compressor Map Screen is shown in Figure 10-5. The current compressor operation is reflected in the position of the dynamic operating point on the map. Pertinent operating data are shown to the right of the map. Adjust the number of horizontal and vertical lines as desired, perhaps to mimic the original compressor map from the manufacturer.

If the compressor has been surge-tested, or field-mapped, the original Surge Limit Line points may be found to be incorrect. Both the head and flow values for each of the five (5) points may be adjusted. Exercise caution if these points are to be modified on a running unit.

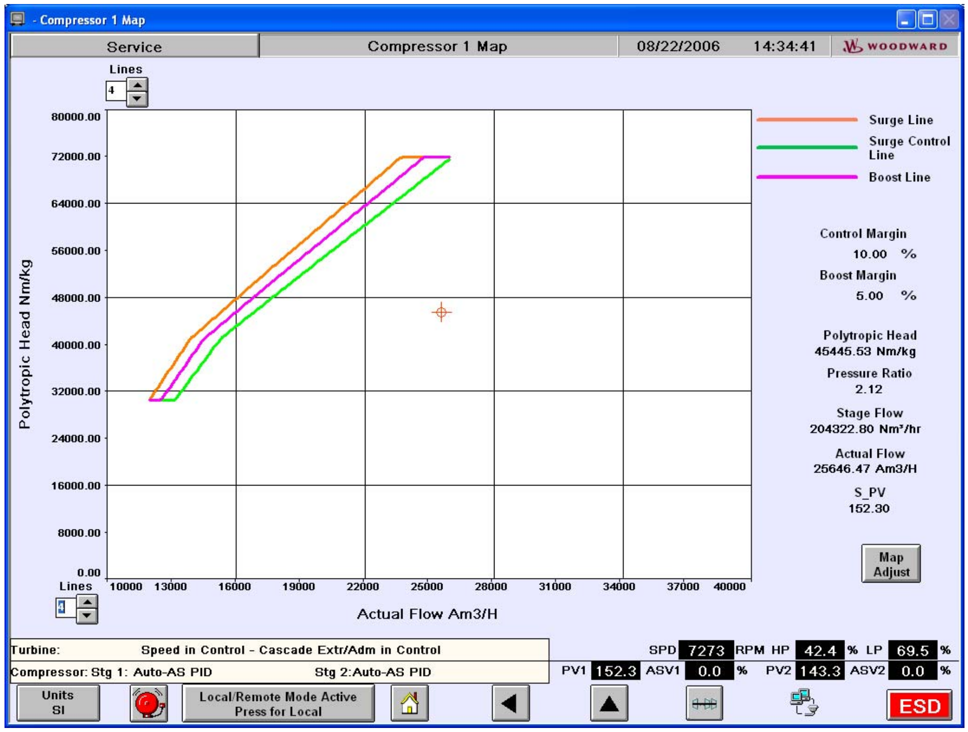


Figure 10-5. Sample Compressor Map Screen

If the Vertex-Pro's calculated flow is inaccurate, the flow constant (and polytropic exponent for the Universal Algorithm) may be adjusted here as well. If a known flow point exists, by comparison with another calibrated flow measurement, or by using compressor speed and head to reference flow on the original compressor map, the flow constant can be modified proportionally. For example, if the Vertex-Pro's calculated flow is 10% higher than a different, but known accurate measurement, reduce the flow constant by 9.09%.

Compressor AS Valve Manual Stroke/Linearization Screen

Due to the broad range of typical compressor operation, linear valves are preferred for anti-surge control. However, accurate linear characterizations are rare in all but premium sliding stem globe control valves. And, as line sizes increase, these valves quickly become cost and size prohibitive. As a result, less accurate rotary valves are common in anti-surge applications, especially as unit size increases. Regardless of the valve design, the Vertex-Pro provides a linearization utility to characterize the control's demand output with the valve design to produce as linear a flow profile as possible.

The Anti-surge Valve Linearization Screen is shown in Figure 10-6. The security login must be Engineering or higher to permit valve stroking via this screen. In addition, functionality is limited to shutdown (zero speed) and normal, online operating conditions. In case of the former, enabling the linearization stroke will put the compressor control into Full Manual mode to allow stroking the valve for maintenance or testing purposes. If online, the mode is instead switched to Manual with Backup, and with flow, the linearization function is feasible, provided that the process and compressor operation is stable. If the unit is in a start-up or shutdown condition, as speed is ramping between minimum (zero) and online, valve stroking via this screen is inhibited. When enabled, adjustment buttons are provided to open and close the valve, as well as single-button commands to go fully open or fully closed.

The current, calculated stage flow is displayed for reference. While this flow measurement is that through the compressor, not through the valve, it is nonetheless related, and recycle flow can be inferred. With the unit online and at a stable operating point, and the anti-surge valve fully closed, note the calculated stage flow. Enable the linearization stroke, and open the valve fully. Again, once stable, note the compressor flow. The difference between these two flow values is the maximum anti-surge valve flow at the current operating conditions. Divide this value by ten (10) to yield a targeted flow rate per ten percent (10%) valve position increment. Position the valve at ten percent (10%) increments and adjust the linearization curve's corresponding Y-values to achieve the targeted flow increment. Disable the linearization stroke when complete.

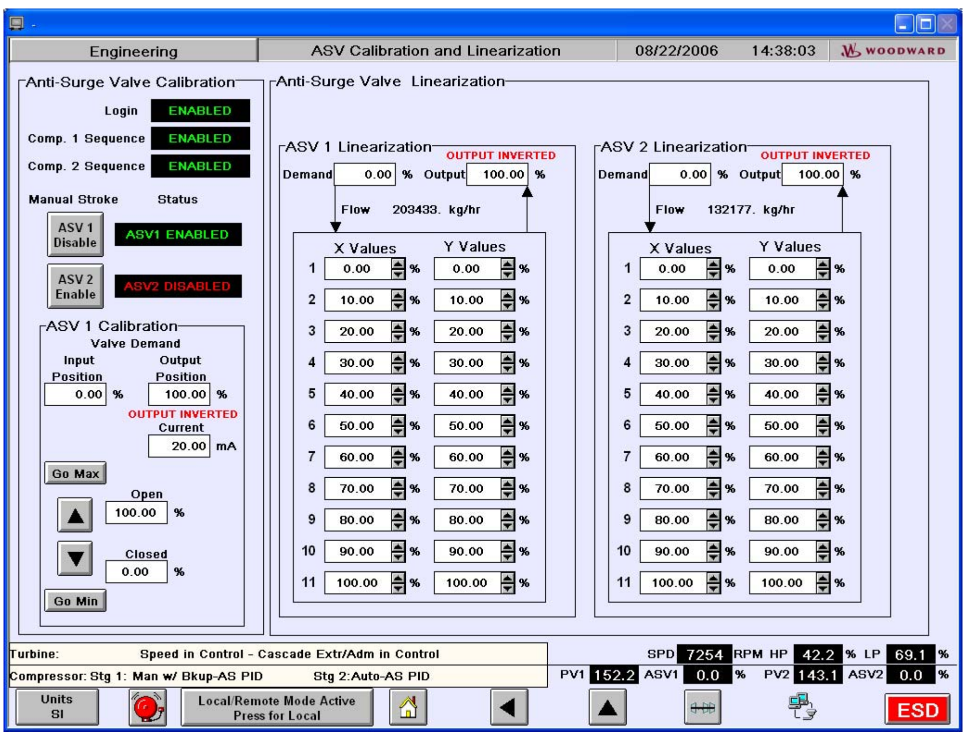


Figure 10-6. Sample Compressor Anti-surge Valve Linearization Screen

Appendix A. Default Login/Security Level Passwords

The following passwords are the defaults for the Vertex-Pro's various login levels.

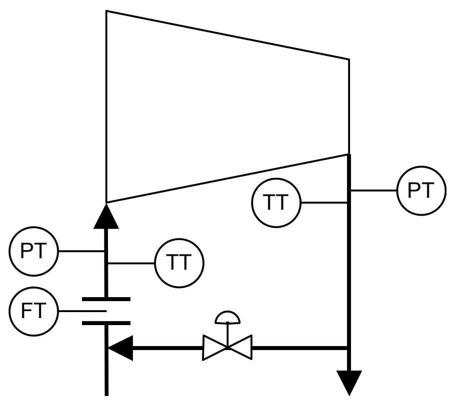
Monitor	No Password
Service	1111
Debug	1112
Configure	1113

Appendix B. Valid Compressor Configurations

Introduction

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 Vertex-Pro will generate an error message for invalid configurations but will not automatically correct or pinpoint the problem.

Standard Algorithm / Single Stage

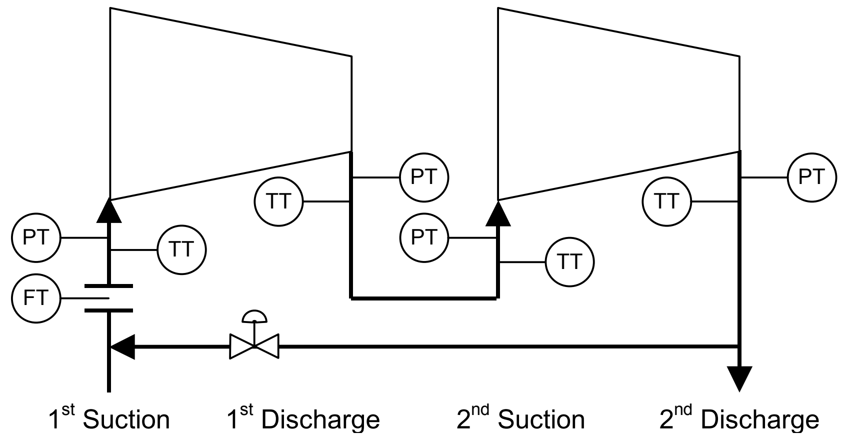


Gas Component	Flow Element	Temperature Sensor	Number of Valves	Config.
Constant	Suction	Suct. + Disch.	1	Valid
		Suct.	1	Valid
		Disch.	1	-
	Discharge	Suct. + Disch.	1	Valid
		Suct.	1	-
		Disch.	1	Valid

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



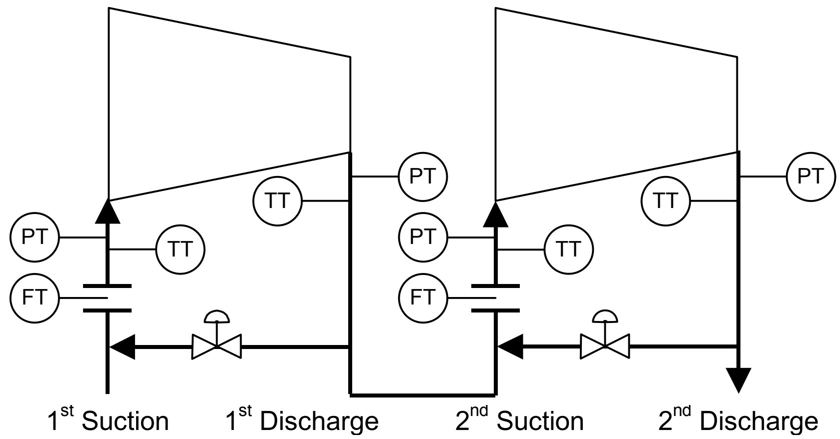
Gas Component	Flow Element	Temperature Sensor	Number of Valve	Config.
Constant	1st Suct.	(Suct. + Disch.) + (Suct. + Disch.)	1	Valid
		(Suct. + Disch.) + (Suct.)	1	Valid
		(Suct. + Disch.) + (Disch.)	1	Valid
		(Suct.) + (Suct. + Disch.)	1	Valid
		(Disch.) + (Suct. + Disch.)	1	-
		(Suct.) + (Suct.)	1	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-2a. 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-2b. Standard Algorithm, Dual with 1 Flow Element Configurations

Standard Algorithm / Dual with 2 Flow Elements



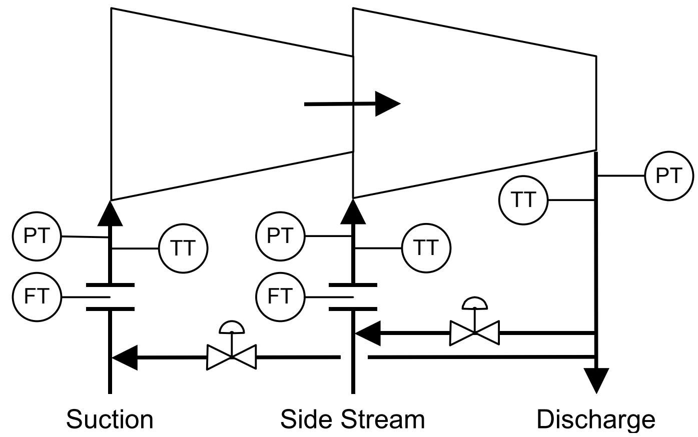
Gas Component	Flow Element	Temperature Sensor	Number of Valve	Config.
Constant	1st Suct. + 2nd Suct.	(Suct. + Disch.) + (Suct. + Disch.)	2 or 1	Valid
		(Suct. + Disch.) + (Suct.)	2 or 1	Valid
		(Suct. + Disch.) + (Disch.)	2 or 1	-
		(Suct.) + (Suct. + Disch.)	2 or 1	Valid
		(Disch.) + (Suct. + Disch.)	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-3a. 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-3b. Standard Algorithm, Dual with 2 Flow Element Configurations

Standard Algorithm / Dual with Sidestream

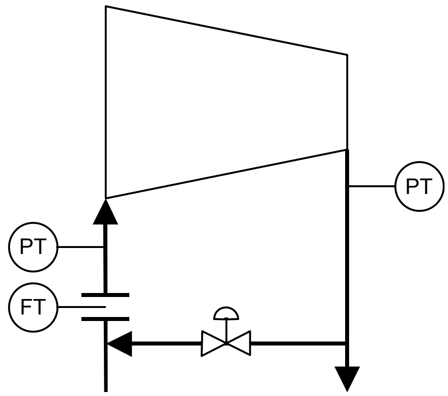


Gas Component	S.S. Direction	Flow Element	Temperature Sensor	Number of Valve	Config.
Constant	Admission	Suct. + S.S.	(Suct.) + (S.S. + Disch.)	2 or 1	Valid
			(Suct.) + (S.S.)	2 or 1	Valid
			(Suct.) + (Disch.)	2 or 1	-
		Suct. + Disch.	(Suct.) + (S.S. + Disch.)	2 or 1	Valid
			(Suct.) + (S.S.)	2 or 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-4. Standard Algorithm, Dual with SideStream Configurations

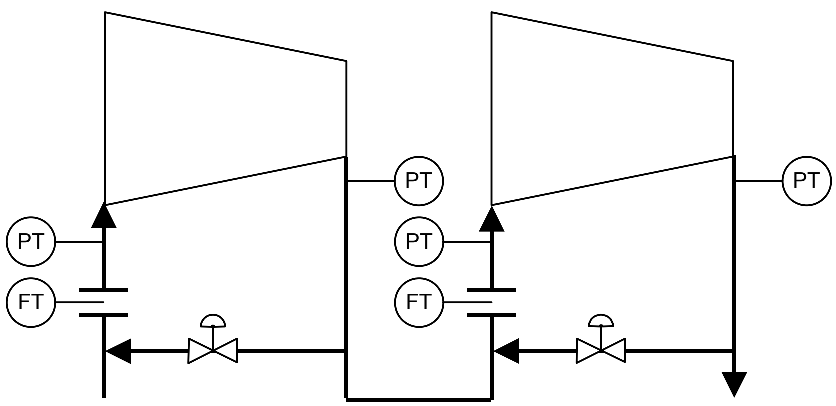
Universal Algorithm / Single Stage



Flow Element	Number of Valve	Config.
Suction	1	Valid
Discharge	1	Valid

Figure B-5. Universal Algorithm, Single Stage Configurations

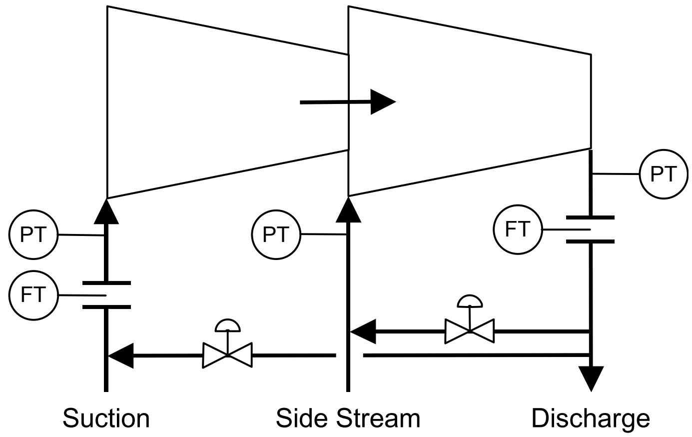
Universal Algorithm / Dual with 2 Flow Elements



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-6. 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-7. Universal Algorithm, Dual with SideStream Configurations

Appendix C.
Atmospheric Pressure Chart

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 C-1. Atmospheric Pressure Chart

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WOODWARD

PO Box 1519, Fort Collins CO 80522-1519, USA
1000 East Drake Road, Fort Collins CO 80525, USA
Phone +1 (970) 482-5811 • Fax +1 (970) 498-3058

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