Released

Product Manual 35245
(Revision -, 3/2025)
Original Instructions

Woodward Anti-surge Control (Enhanced) ASCE

Software P/N 10-031-139GAP through 10-031-143GAP
GAP4

User Manual

Released

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

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

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

WARNING

Overspeed / Overtemperature / Overpressure

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

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

WARNING

Personal Protective Equipment

The products described in this publication may present risks that could lead to personal injury, loss of life, or property damage. Always wear the appropriate personal protective equipment (PPE) for the job at hand. Equipment that should be considered includes but is not limited to:

- **Eye Protection**
- **Hearing Protection**
- **Hard Hat**
- **Gloves**
- **Safety Boots**
- **Respirator**

Always read the proper Material Safety Data Sheet (MSDS) for any working fluid(s) and comply with recommended safety equipment.

WARNING

Start-up

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

NOTICE

Battery Charging Device

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

Chapter 1.
General Information

Introduction

The ASCE (Anti-surge Control Enhanced) is Woodward standard control software designed for preventing a surge in dynamic (axial and centrifugal) compressors and for providing additional control functions that keep compressor operation within safe limits and at maximum process efficiency. Figure 1-1 shows an example of a typical compressor application with two stages and two valves. The primary function of the ASCE is to protect the compressor from surge by automatically positioning the anti-surge valves. The ASCE has secondary functions that position anti-choke valves and quench valves.

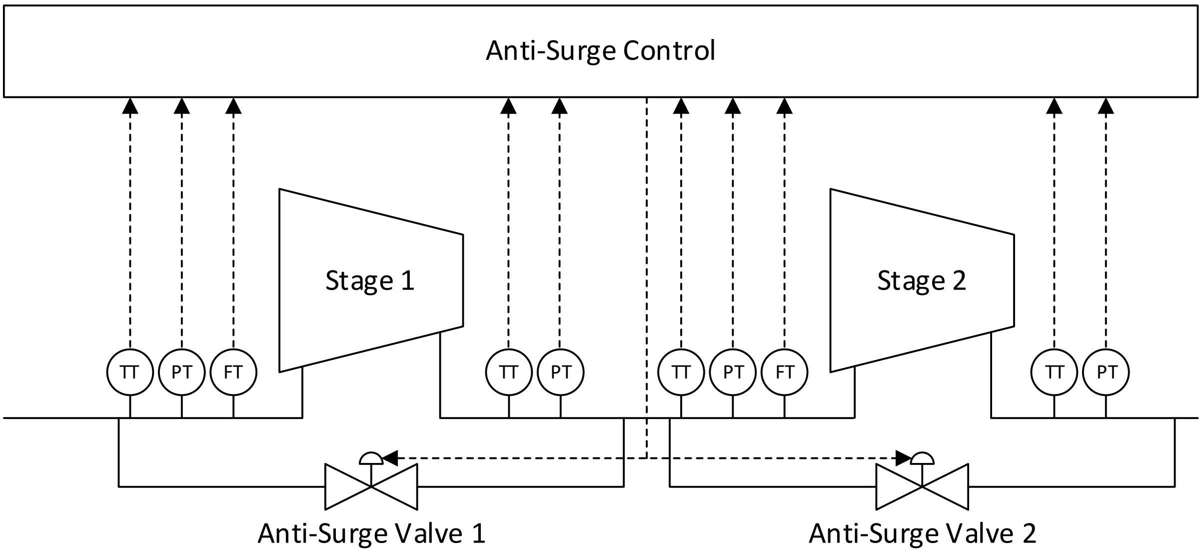

Figure 1-1. Typical Compressor Application

Table 1-1. Abbreviations, Acronyms, and Symbols

a	Acoustic Velocity
AGC	Automatic Gain Compensation
ASC	Anti-surge Control
ASCE	Anti-surge Control Enhanced
ASV	Anti-surge Valve
BL	Boost Line
CLL	Choke Limit Line
DCS	Distributed Control System
FT	Flow Transmitter
GAP	Graphical Application Programmer
Hp	Polytropic Head
HSS	High Signal Select
IF	Invariant Flow
IH	Invariant Head
IP	Invariant Power
k	Isentropic Exponent
LGV	Last Good Value
mA	Milliamp
N	Speed
N%	Percent of Rated Speed
OP	Operating Point
P1	Suction Pressure
P2	Discharge Pressure
PID	Proportional / Integral / Derivative
PT	Pressure Transmitter
Qa	Actual Volumetric Flow
SCL	Surge Control Line
SLL	Surge Limit Line
SMP	Surge Minimum Position
T1	Suction Temperature
T2	Discharge Temperature
TCV	Temperature Control Valve
TT	Temperature Transmitter
WSPV	Woodward Surge Process Variable

Compressor Surge

Definition

Surge in a dynamic compressor is a dangerous operating phenomenon and must be avoided. Surge occurs at a low flow rate when the compressor cannot further increase its head to overcome resistance in the downstream process. Stable operation cannot be sustained at flows below the surge flow limit. Surge is characterized by a reversal of the flow direction through the compressor. In other words, gas flows from the discharge side to the suction side during a surge event. A surge cycle is a repeating process of reverse and forward flow patterns. Surge can be observed in rapid oscillations of flow and pressure, as well as rising discharge and sometimes suction temperature. It is usually accompanied by an audible boom and piping or machine vibration. Violent surging may result in serious damage to the compressor equipment:

- Increased clearances at the impeller seals (leads to higher internal recycling and reduced capacity)
- Damage to balance piston seals
- Damage to compressor shaft end seals
- Damage to compressor thrust bearings
- Damage to compressor radial bearings
- Damage to impellers
- Possible shearing of the drive shaft

Along with possible compressor damage, the unstable flows and pressures contribute to upstream and downstream process upsets.

The Surge Cycle

Figure 1-2 shows a typical surge cycle. The figure tracks the operating point of the compressor in flow and discharge pressure coordinates.

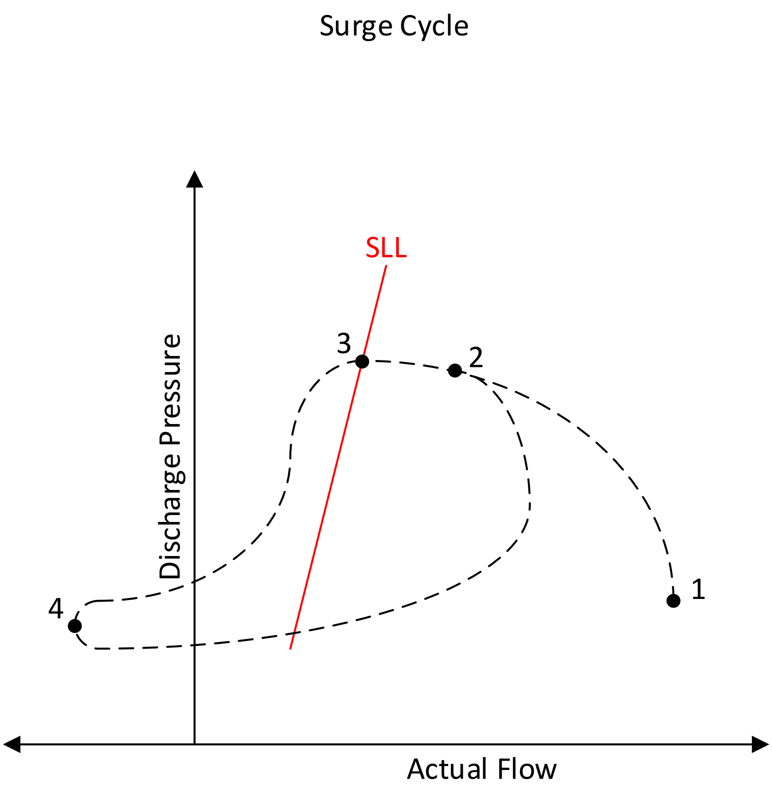

Figure 1-2. Surge Cycle

At operating point 1, the compressor has low discharge pressure, and the output flow is at its maximum value. As the system resistance increases, compressor flow decreases, and discharge pressure increases. The system resistance increase could be caused by many factors: discharge valve closure, downstream process shutdown or flow reduction, series compressor shutdown, or parallel compressor start up. 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. This limit is the surge limit line (SLL), shown at operating point 3. If the system resistance increases further, the discharge pressure exceeds the machine's capability. This condition initiates a surge that spans between operating points 3 and 4. Flow may reverse through the compressor, as shown at operating point 4. A now reduced system resistance will allow increased forward flow that brings the compressor back to operating point 2. This surge cycle (moving between operating points 2, 3, and 4) will continue until the initial cause is resolved or other action is taken to protect the compressor.

Maintaining flow above the compressor's surge limit prevents these surge conditions. The ASCE 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 ASCE responds by opening the anti-surge valve(s). This action simultaneously causes the flow to increase and discharge pressure and polytropic head to decrease, moving the operating point away from the surge limit.

Anti-surge Control

By modulating the anti-surge valve, the ASCE regulates the operating point of the compressor to achieve these objectives:

- 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 system efficiency.

Compressor manufacturers create compressor performance maps to describe the capability and safe operation limits of the compressor. The y-axis of the map is typically discharged pressure, pressure ratio, or polytropic head. The x-axis of the map is typically actual flow, standard flow, or mass flow. The surge limit is shown on the compressor performance map as a Surge Limit Line (SLL). Operation to the left of the SLL is unstable and can result in surge. The SLL is configured in the ASCE based on the compressor manufacture's performance map. For an additional margin of safety, the ASCE uses a Surge Control Line (SCL) that is shifted to the right of the SLL. The ASCE monitors the parameters of the compressor to determine the location of the current operating point. Based on the location of the operating point relative to the SCL, the ASCE will determine if opening of the anti-surge valve is necessary. Opening the anti-surge valve moves the operating point away from the conditions where surge can occur.

Compressor Choke

Definition

In most operating conditions, decreasing discharge pressure will increase flow. Choking of a centrifugal compressor occurs when the velocity of gas in the compressor reaches sonic velocity. Further reduction of discharge pressure can no longer increase flow through the compressor. This condition is sometimes called stonewall. Choke is an undesirable operating condition for centrifugal compressors. Prolonged operation at the choke limit can lead to damage of compressor components. The potential for damage is greater in multistage centrifugal compressors and axial compressors.

Anti-Choke Control

Compressor choke is prevented by increasing discharge pressure and thereby decreasing flow. Discharge pressure can be controlled by installing a throttle valve (anti-choke valve) downstream of the compressor, as shown in Figure 1-3. Normally this valve will remain fully open.

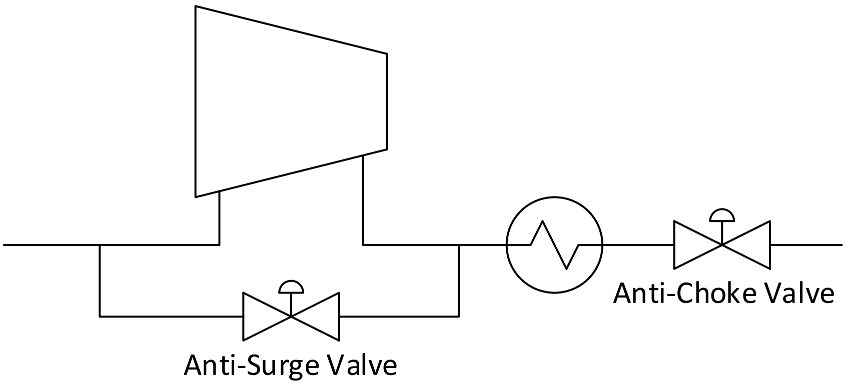

Figure 1-3. Typical Anti-Choke Valve Location

The choke limit is shown on the compressor performance map as a Choke Limit Line (CLL). Operation on the CLL will result in choke conditions. The CLL is configured in the ASCE based on the compressor manufacture's compressor performance map. Based on the location of the operating point relative to the CLL, the ASCE will determine if closing of the anti-choke valve is necessary. Closing the anti-choke valve moves the operating point away from the conditions where choke can occur.

Quench

Definition

Quench is a process used in closed-loop refrigeration applications. Hot recycle gas is cooled by injecting liquid in the recycle line. The liquid used for quenching is produced as part of the refrigeration process. The liquid phase is converted to gas phase when it is injected in the hot recycle line. The phase conversion absorbs heat from the hot recycle gas, which lowers its temperature. Quench prevents the compressor suction temperature from exceeding operational limits. A typical piping schematic for a system with quench is shown in Figure 1-4.

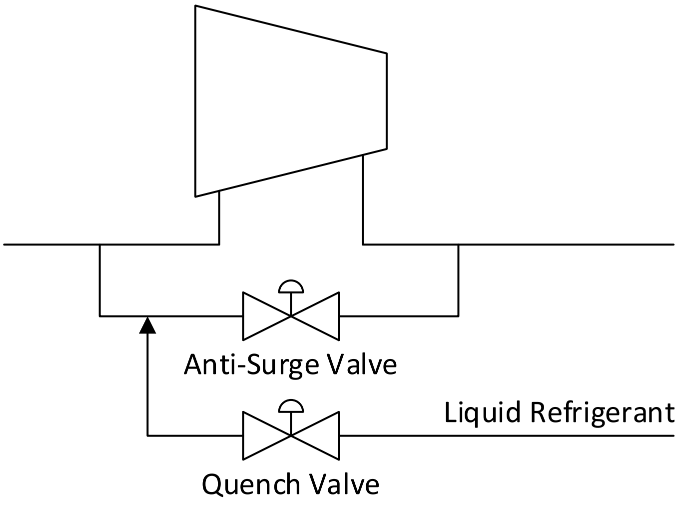

Figure 1-4. Anti-Surge and Quench Valves

Quench Control

The quench valve regulates the amount of liquid injected in the recycle line. If too much liquid is injected, a trip may be triggered as the liquid level in the suction knockout drum exceeds safe limits. If too little liquid is injected, the suction temperature may exceed safe limits. In its simplest form, a quench controller is a standard PID loop that maintains the suction temperature at a setpoint by positioning the quench valve.

Chapter 2.
Control Functions

Introduction

An overview of the ASCE anti-surge control functions is shown in Figure 2-1. This diagram is helpful for understanding how the main control functions and the support functions are related to each other.

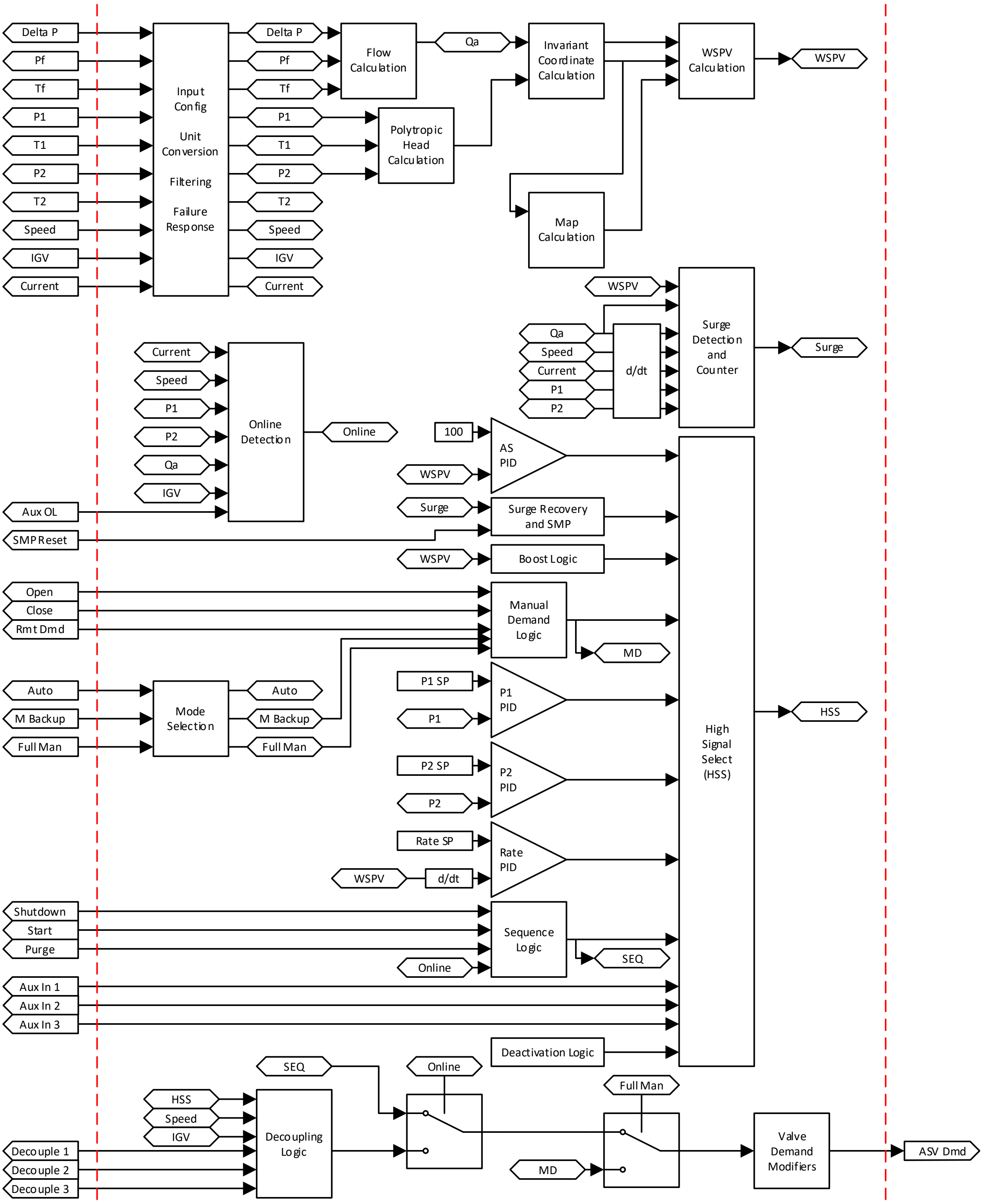

Figure 2-1. ASCE High-Level Function Block Diagram

Compressor Performance Map

Understanding the compressor performance map is key to understanding the function of the ASCE. A typical compressor performance map is shown in Figure 2-2. This map shows coordinates of polytropic head and actual volumetric suction flow, but other coordinate systems are commonly used.

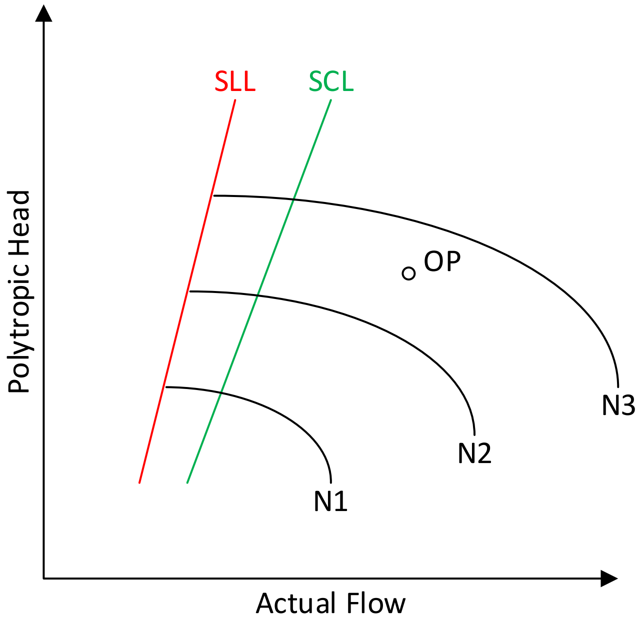

Figure 2-2. Typical Compressor Performance Map

The map includes these important features:

- SLL – the Surge Limit Line which divides the regions of stable and unstable operation.
- SCL – the Surge Control Line which is used by the ASCE to position the anti-surge valve. Note that the SCL is typically not shown on the manufacturer's map.
- OP – the location of the operating point.
- N – lines of constant compressor speed.

Some maps will also include a CLL for choke control. Many applications do not require choke control.

Compressor manufacturers often provide maps for multiple compressor suction conditions. The suction condition is defined by the suction pressure, the suction temperature, the suction isentropic exponent, the suction compressibility factor, and the molecular weight. The compressor manufacturer plots the SLL and CLL in coordinate systems that show the polytropic head, pressure ratio, or discharge pressure as a function of flow. Flow may be presented as actual flow, standard flow, or mass flow. In these coordinate systems, the plotted limit lines are only valid for one suction condition. For example, an SLL drawn for a particular suction pressure will not be valid for a different suction pressure. The original map coordinates can be converted to a different set of coordinates that are not sensitive to changes in the suction conditions. These coordinates are referred to as invariant coordinates. The ASCE uses three invariant coordinates: invariant head (IH), invariant flow (IF), and invariant power (IP).

Operating Point

The main anti-surge controller in the ASCE is a PID loop. The PID loop process value is a number that represents the location of the operating point relative to a point on the SCL. The ASCE includes three methods for calculating operating point values: the legacy method, the invariant flow method, and the invariant power method.

Earlier versions of the Woodward anti-surge software (ASC) calculated the operating point using polytropic head and actual flow.

$$OP = \sqrt{\frac{(Q_a)^2}{H_p}}$$

The ASCE also uses this operating point calculation (legacy method) for compressor performance maps entered as discharge pressure, pressure ratio, or polytropic head as a function of flow (actual, standard, or mass).

The ASCE includes the ability to enter the compressor performance map using invariant head as a function of invariant flow and invariant head as a function of invariant power. Typically, the calculation based on invariant flow is used. For the special case in which a flow measurement is not available, the calculation based on invariant power may be used. The equations shown below are used when the compressor performance map is entered with invariant head and invariant flow.

$$OP_{IF} = \sqrt{\frac{IF^2}{IH}}$$

Where:

$$IF = \frac{Q_a}{a}$$

$$IH = \frac{H_p}{a^2}$$

In the above equations, a is acoustic velocity.

For the special case of an invariant power map, the following equations are used.

$$OP_{IP} = \frac{IP}{IH}$$

Where:

$$IP = \frac{Power}{a^2 \times \rho_1 \times N\%}$$

The legacy operating point and the invariant operating point are both insensitive to changes in suction conditions. In fact, substituting IF and IH into the OP_{IF} equation and canceling terms reveals that the OP and OP_{IF} calculations are equivalent. Even though the operating point values are equivalent, the invariant coordinate system is preferred because maps entered in these coordinates are better at predicting the SLL location in off-design conditions. Invariant coordinate maps are also better able to handle compressor performance maps that cover a wide range of suction conditions.

The result of the operating point calculation is a single number that describes the operating point location. A similar calculation can be performed for points on the SCL. Comparing the operating point with a corresponding point on the SCL gives the distance from surge for the current conditions.

The operating point calculation can be expanded to show that it is invariant to changes in the gas composition. The independent variables in this equation can be measured, estimated, or assumed constant. For a simplified view of the measurements necessary to determine the operating point, refer to the process control diagram in Figure 2-3.

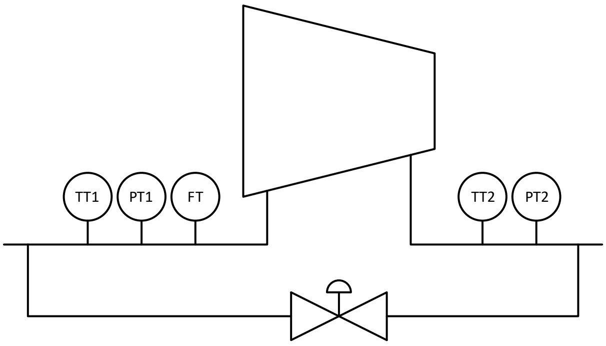

Figure 2-3. Process Control Diagram with Operating Point Measurements

The volumetric flow calculation is carried out using three measurements:

- PT1 – compressor suction pressure
- TT1 – compressor suction temperature
- FT – differential pressure across the flow element

Polytropic head also requires three measurements:

- PT1 – compressor suction pressure
- PT2 – compressor discharge pressure
- TT1 – compressor suction temperature

This example assumes a suction flow element; discharge flow elements are handled in a similar fashion.

Temperature transmitters are not strictly required when the suction invariant flow operating point or the invariant power operating point are used. However, even though the operating point calculation will be accurate, the polytropic head and flow calculations will not be accurate. To provide the best possible information to operators, it is always recommended to include suction and discharge pressure transmitters.

Surge Control Line

Data points from the SLL are collected from the compressor performance map and configured in the ASCE. Combining the SLL and a safety margin defines the SCL. The SCL is the point at which the ASCE will protect the compressor by modulating the anti-surge valve.

The Boost Line provides additional anti-surge protection. When the operating point reaches this line, an open-loop step response is triggered to prevent a surge. The Boost Line is defined as a percentage of flow behind (to the left of) the SCL.

The SLL is configured in the ASCE as a series of X-Y points (with a maximum of twelve points). Compressor performance maps can be defined in different coordinates. The ASCE supports the following map coordinates:

- Discharge pressure versus flow, P2=f(flow)
- Pressure ratio versus flow, P2/P1=f(flow)
- Polytropic head versus flow, Hp=f(flow)
- Invariant head versus invariant flow, IH=f(IF)
- Invariant head versus invariant power, IH=f(IP)

For the first three options, the flow coordinate can be entered as actual flow, standard flow, or mass flow. If necessary, any compressor manufacturer coordinate system can be converted to invariant head versus invariant flow using external engineering tools. The invariant head versus invariant flow map is the recommended coordinate system for most applications. If a flow measurement is not available, the invariant power map is the recommended coordinate system. A compressor manufacturer coordinate system can be converted to invariant head versus invariant power using external engineering tools.

It is recommended that at least six SLL points are entered. Points must be entered in ascending order, meaning that the point with the lowest flow will be entered as the first point. Compressors typically have increasing head values with increasing flow values.

Woodward Surge Process Variable (WSPV)

Regardless of the configured map coordinates, the ASCE generates a surge process variable (WSPV) that represents the distance between the current operating point and the corresponding operating point on the SCL. WSPV gives the operator and the anti-surge PID one number that reflects how close the compressor is to surging.

Once the operating point and its corresponding SCL point are calculated, the ratio of these two numbers is multiplied by 100 to find WSPV.

$$WSPV = \frac{OP}{OP_{SCL}} \times 100$$

By normalizing the operating point with respect to the SCL, the value of WSPV will always be 100 when the operating point is on the SCL. The safety margin, or surge control margin, is a multiplier applied to the SLL points. The surge control margin sets the offset between the SCL and SLL. A typical surge control margin is 10%, which is achievable on most applications with properly sized anti-surge valves and responsive valve actuation systems. However, if these conditions are not optimal, the surge control margin may need to be increased to protect the compressor.

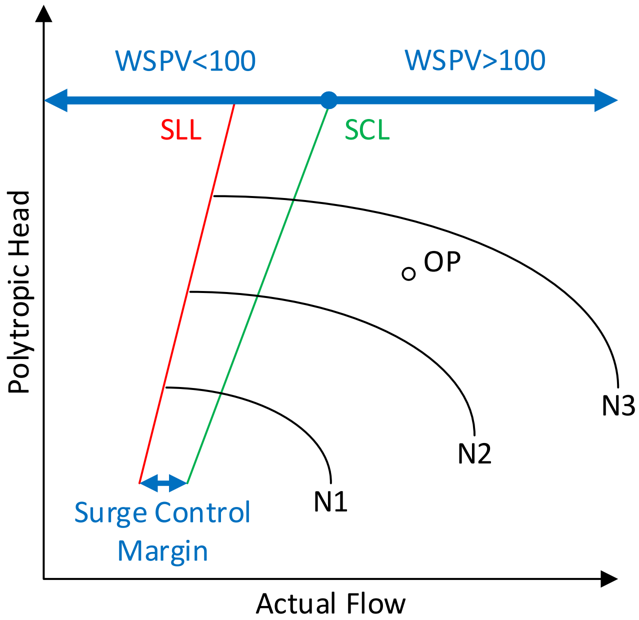

Figure 2-4. Surge Control Margin and WSPV Regions

If WSPV is greater than 100, the compressor is operating in a safe region of the map. In this condition the ASCE can close the anti-surge valve. When the WSPV value is equal to or less than 100, the ASCE will modulate the anti-surge valve such that the operating point stays on the SCL. To an operator, WSPV is an indication of how far away the compressor is operating from the SCL. The PID loop setpoint is always 100, regardless of the surge control margin. The operator can use WSPV to judge if the anti-surge valve will open when performing a process function. For example, a value of 180 indicates that the operating point is 80% of flow beyond the SCL. In other words, the compressor is operating far from surge and the ASCE should maintain the anti-surge valve in the closed position.

Anti-surge Control Description

The ASCE provides all necessary functions from manual control to sequencing to closed-loop PID control. In addition to compressor protection, there are other supporting functions that reduce upsets, increase accuracy, and simplify configuration.

When the ASCE is in the Automatic mode or Manual with Backup mode, there are several controllers that can position the anti-surge valve. The output of each routine is 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.

Control Modes

While online, the ASCE operates 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. These modes can be configured to operate when the is compressor offline as well.

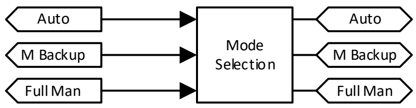

Figure 2-5. Mode Selection

Automatic Mode

The anti-surge valve position demand is modulated automatically based on compressor proximity to the SCL. Valve position cannot be controlled manually in this mode. The ASCE monitors WSPV and then determines the position of the anti-surge valve. While the ASCE is in Automatic mode, the Manual demand will track the current valve position demand for a bumpless transfer to Manual.

Manual with Backup

In this mode, the operator is allowed to open and close 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 demand or the automatic demand.

Full Manual

In this mode, the operator manually moves the anti-surge valve. The automatic controllers are bypassed and cannot influence the anti-surge valve, no matter where the operating point is on the compressor performance map. Decoupling is not active while in this mode. If enabled, Surge Recovery in Full Manual will allow the open-loop surge recovery routine to activate in Full Manual mode. The valve will automatically step open according to the surge recovery demand. After surge detection, the operator maintains full control of the anti-surge valve demand. In Full Manual mode, Surge Minimum Position is inactive.

Manual Valve Positioning

There are binary commands available for opening and closing the anti-surge valve when in either Manual with Backup mode or Full Manual mode. When the input is closed, the valve is ramped at the configured Manual Raise / Lower Slow Rate. If the input is held closed for the configured Delay for Fast Rate time, the ramp speed will increase to the configured Manual Raise / Lower Fast 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 target value can be entered. The valve will ramp to the target position at the configured rate. Each of these positioning commands is disabled if Remote Positioning is active.

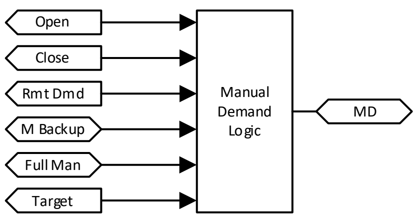

Figure 2-6. Anti-surge Valve Positioning Logic

Remote Manual Valve Positioning

The manual position can also be controlled via an analog signal. An external control, such as a DCS, can position the anti-surge valve with this analog signal. 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%. Use Remote Manual must be selected in the compressor configuration.

If manual mode is triggered by a sensor failure while the remote manual signal is enabled, the remote manual demand will only be used if it is within 0.5% of the current manual demand. This logic prevents an abrupt change in the anti-surge valve position. The remote manual demand has to be brought with 0.5% of the current demand before it can take control of the valve position.

Regardless of the rate of change of the remote input, the valve will ramp at the configured Manual Raise / Lower Slow Rate. Remote Manual Valve Positioning is automatically disabled on failure of the analog input. Other manual mode controls, such as the open/close binary inputs and target command, are disabled when remote positioning is active.

Sequencing Functions

During startup and shutdown of the compressor, the flow is fluctuating, and the process is unstable. The time between a start and stable automatic control is termed "offline." A separate routine detects when "online" operation is allowable.

During the offline period when automatic control is not available, sequencing provides fixed valve positioning. There are four programmable positions:

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

Speed thresholds, binary inputs, or combinations of both determine when to select the purge, start, shutdown, and zero speed positions. Using speed thresholds can simplify sequencing by allowing software speed switches to determine what state the prime mover is in. Motor current thresholds are also available for motor-driven compressors. Alternatively, binary inputs or Modbus commands can signal a start or shutdown.

Purge Position

A purge sequence is required during the startup of some processes. In the purge sequence, the anti-surge valve is partially or fully closed to send process gas downstream of the compressor. There are five configurable options for enabling and disabling the purge position.

With the Purge Disabled at Start option, the anti-surge valve goes to the purge position when the ASCE is in the controlled shutdown state and the purge request command is received. The purge position is deactivated when the ASCE leaves the controlled shutdown state, typically due to a transition to the start state. The purge position can also be deactivated with the purge quit command.

With the Purge Disabled at Online option, the anti-surge valve goes to the purge position when the ASCE is in the start state and the purge request command is received. The purge position is deactivated when the ASCE transitions from the offline condition to the online condition. The purge position can also be deactivated with the purge quit command.

With the Purge Disabled on Speed Level option, the anti-surge valve goes to the purge position when the speed is less than the configured speed level during startup and the purge request command is received. The purge position is deactivated when the speed is greater than the configured speed level. The purge position can also be deactivated with the purge quit command.

With the Purge Disabled on Current Level option, the anti-surge valve goes to the purge position when the motor current is less than the configured motor current level during startup and the purge request command is received. The purge position is deactivated when the motor current is greater than the configured motor current level. The purge position can also be deactivated with the purge quit command.

With the Purge on Request Only option, the anti-surge valve goes to the position when the ASCE is in the start state, or the controlled shutdown state and the purge request command is received. The anti-surge valve will leave the purge position when the ASCE transitions to any other state, but the purge position will remain activated for the next time the ASCE enters the controlled shutdown state or the start state. The purge position will only be deactivated by the purge quit command.

Start Position

When the ASCE is in the start state or the controlled shutdown state, the anti-surge valve will ramp to the configured Position During Startup at the configured Opening Rate at Start. If the purge position is active, the anti-surge valve will instead go to the configured Purge Position. The anti-surge valve will remain in this position until the ASCE transitions to another state, typically due to detection of the online condition.

Shutdown Position

At any time, the compressor can be shutdown from an internal condition or by a dedicated trip input. The anti-surge valve is immediately positioned and held at the configured Shutdown Position if this feature has been selected. After the shutdown is cleared, the ASCE can transition to another configured sequence position based on current conditions.

Zero Speed (or Current) Position

The anti-surge valve will remain in the shutdown position until the unit is re-started or the speed drops below the configured Zero Speed Level for a configured Time After Shutdown. 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 Time After Shutdown to 0 seconds.
If a motor current analog signal is used, then motor current can be used in place of speed for this feature.

IMPORTANT	**The zero speed / zero motor current sequencing described above is active only if a valid speed signal or a valid motor current signal is available. If not, the unit will sequence to and from the shutdown position only. In this case, a start signal must be used to sequence the compressor online.**

Online Detection

Once any one of the online triggers are satisfied for the configurable delay time, the ASCE will slowly close the anti-surge valve until the automatic anti-surge routines take control. If any online trigger is deactivated while in normal operation, the ASCE returns to the start sequence.

Online detection is an important determination made by the anti-surge controller. Once the compressor is determined to be online, the surge detection and automatic control routines are activated. Suction pressure, discharge pressure, flow, speed, motor current, pressure ratio, IGV position, and an auxiliary input may be used together or independently to determine when the compressor is online.

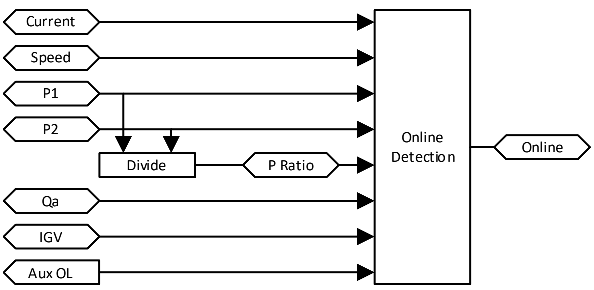

Figure 2-7. Online Detection Logic

Each online detection method may be enabled or disabled independently. The auxiliary input (configurable discrete input or Modbus command) is most often driven by a compressor safety system or sequencer. If Modbus is used, separated signals for online and offline status should be used, and the signals should be pulsed. If a hardwired signal is used, a single input should be maintained (not pulsed) to indicate the online status. Speed, discharge pressure, motor current, IGV position, pressure ratio, and flow must exceed their respective online levels. Conversely, suction pressure must drop below its online level. It is not recommended to use suction pressure as an online detection method for any stage other than the first stage because suction pressure of a downstream stage will increase when the compressor is started. If more than one method is enabled, all must be satisfied before the compressor is considered online. If none are enabled, the unit will transfer directly to automatic, online control during startup. In other words, 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 startup.

IMPORTANT	**If utilized, the online contact input must be maintained closed the entire time the compressor is operating. If the contact is opened, the ASC will assume the compressor is offline and revert to the start sequence and position the anti-surge valve at its start position.**

Speed or the auxiliary input are the recommended online detection methods. If other parameters are used, exercise care in selecting their online levels so as not to interfere with normal startup procedures. Some startup valve sequencing may inadvertently trigger the online status if online levels are configured too low (flow, discharge pressure). There is a configurable delay time for online detection to avoid frequent on-off transitions.

IMPORTANT	**The speed-based online detection is active only if a valid speed signal is available. The current-based online detection is active only if a valid motor current signal is available.**

Anti-surge Control Map Regions

Each anti-surge routine is designed to operate in a certain region of the compressor performance map. In total, these routines encompass the entire operating region, as shown in Figure 2-8.

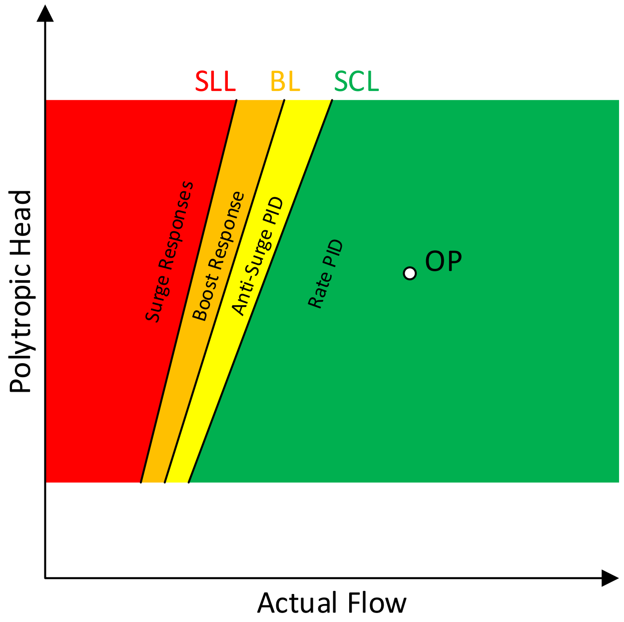

Figure 2-8. Protection Regions on the Compressor Performance Map

There are two routines dedicated to 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 ASCE. These routines operate in the red region in Figure 2-8.

There are four routines that act to prevent surge while maintaining stable process conditions. Starting from the SLL and working to the right, the first routine is Boost. This routine monitors the operating point with respect to the Boost Line (BL). If the operating point crosses the line, it initiates a momentary small step increase in the anti-surge valve position to prevent further movement toward the SLL. The Boost routine operates in the orange region in Figure 2-8.

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 SCL, the anti-surge main PID loop is active. If the operating point is away from the SCL but approaching the SCL rapidly, the rate controller PID loop anticipates the need for action, opening the anti-surge valve earlier in order to slow the operating point's progression toward the SCL. The main PID operates in the yellow region and the rate PID operates in the green region in Figure 2-8.

Even when the operating point is not on the SCL, the decoupling routines act to stabilize the process by minimizing the interaction of the anti-surge routines and other controllers (for example, performance controllers). The decoupling routines operating in the green region in Figure 2-8.

Anti-surge Control Routines

Anti-surge PID

This is the main anti-surge control routine. The anti-surge PID compares the process variable, WSPV, to 100 to determine the proper position of the anti-surge valve. If WSPV is greater than 100, the operating point is on the right side of the SCL. The PID output will move toward zero (closing the anti-surge valve). When WSPV is less than 100, the operating point is on the left side of the SCL. The PID output will increase until the flow through the anti-surge valve restores WSPV to the setpoint of 100. When WSPV is 100, the operating point is on the SCL.

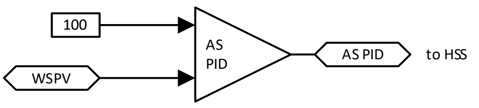

Figure 2-9. Anti-surge PID

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 WSPV, or the rate at which the operating point is approaching the SCL. If this rate is too fast, the rate controller PID will open the anti-surge valve before the operating point reaches the SCL. The Rate PID is automatically disabled if any input signal is failed.

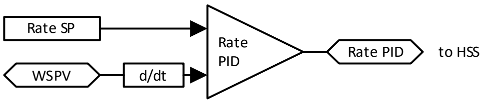

Figure 2-10. Rate Controller PID

The setpoint for the Rate Controller PID is a percentage of the maximum safe rate of approach to the Surge Control Line. The maximum rate of approach to the SCL is dynamically calculated from the current distance to the SCL and the configured P and I gains of the Rate Controller PID.

The further the operating point is from the SCL (WSPV > 100), the greater the allowable rate. As the operating point moves closer to the SCL, the rate setpoint is reduced. This ensures that operation is not disturbed 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 ensure the controller has time to react, the actual rate setpoint is a percentage, typically 20-40%, of this maximum allowed rate. If the system dynamics require that the Rate Controller act sooner, reduce this Rate Setpoint percentage. As the Rate Setpoint percentage approaches 100%, the Rate Controller setpoint approaches the calculated maximum allowable rate.

Gain Compensation

The Anti-surge, Rate Controller, and Pressure Override PID dynamics include proportional, integral, and derivative action. These dynamics can be compensated (adjusted) by the Automatic Gain Compensation (AGC) routine as the compressor operating conditions change. With AGC, the PIDs can be tuned once at a normal operating condition. As the process conditions change, the PIDs will remain stable over the entire operating region as AGC adjusts the gains. 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.

The gain compensation routine constantly calculates the theoretical full-open anti-surge valve flow under the current process conditions. The current full-open flow is compared to the full-open flow at a normal operating condition. The full-open flow at the normal operating condition is referred to as the normal flow. The 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 and lower head), the calculated anti-surge valve flow will decrease. This increases the gain compensation value and results in more aggressive proportional gains. 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 and higher head), the anti-surge valve flow calculation will lower the gain compensation value and reduce the proportional gains. This reduction in proportional gains compensates for the increase in valve gain from the new process conditions.

AGC must be properly 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. The gain compensation factor is limited to a range of 0.2 to 5.0. Gain Compensation is inhibited when any input signal is failed and when the unit is not online.

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 online, and it is preferable to have the ASCE in Manual with Backup mode to prevent disruptions during this procedure. The anti-surge valve’s full-open Cv value must be configured correctly before performing this procedure. The Normal Value is anti-surge valve flow (in actual cubic meters per hour) at this normal operating point. Tune the Normal Value until the gain compensation factor equals 1.0. The Normal Value is the flow through the anti-surge valve if it were 100% open at the normal operating point conditions.

AGC is now configured at the normal operating point. The gain compensation factor will move above and below 1.0 as the compressor deviates 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. Both PID tuning and AGC configuration should be done with the compressor at the same, or similar, operating conditions.

Decoupling

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 movement of the anti-surge valve. For instance, a pressure setpoint change will usually require a speed change, and this usually results in a compressor operating point change. By changing speed, WSPV changes and the anti-surge PID may respond. The decoupling routines are designed to anticipate the anti-surge PID change and adjust the anti-surge valve demand 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 dynamics, and the two systems may fight. Decoupling will also reduce the unwanted interactions between controllers.

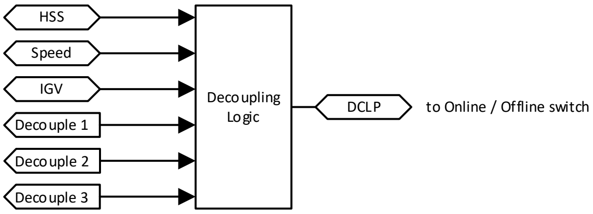

Figure 2-11. Anti-surge Decoupling

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. The decoupling routines are enabled and disabled together. Disabling any of the five routines individually is done by configuring its respective amount to 0.0. In addition, the decoupling action is not allowed to influence the anti-surge valve until the compressor is online 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 WSPV value is greater than the configured WSPV Range to Activate value. The Decoupling output is limited by the configured Maximum Decoupling Level and Minimum Decoupling Level. Decoupling mode is deactivated in Full Manual mode and in Manual with Backup mode if the manual demand is controlling the anti-surge valve.

Speed decoupling can be performed in two cases, one to prevent a surge and the other to stabilize the process. 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 to avoid surge. It is configured as the Fast Speed Amount in percent per RPM. Usually, the relationship of speed to WSPV is direct so this value is set greater than zero. The time constant is configured as Fast Speed Delay Time. 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. This slower acting decoupling is configured as Slow Speed Amount and is usually greater than zero. The time constant is set as 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.

If the Map Pointer is set to Head from IGV Position or Head with IGV Shift, the ASCE assumes that the compressor uses variable inlet guide vanes and does not use variable speed. In this case, the speed decoupling features described above act as IGV decoupling features. Changes in IGV position will affect the anti-surge valve position through the decoupling routines.

IMPORTANT	**The speed-based decoupling is active only if a valid speed signal is available. IGV-based decoupling is active only if a valid IGV signal is available.**

The position of the anti-surge valve can be adjusted based on the movement of the anti-surge valve from an adjacent stage. 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 determining the sign of 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 Other Stage Amount would be a positive value. If, however, the second compressor section recycles to the first stage suction piping, the first stage flow would increase, moving away from surge. This situation would require a negative Amount. Similar relationships exist relative to decoupling the second compressor section from the first stage anti-surge valve. See Figure 2-12 for examples of Other Stage Decoupling values based upon piping arrangement.

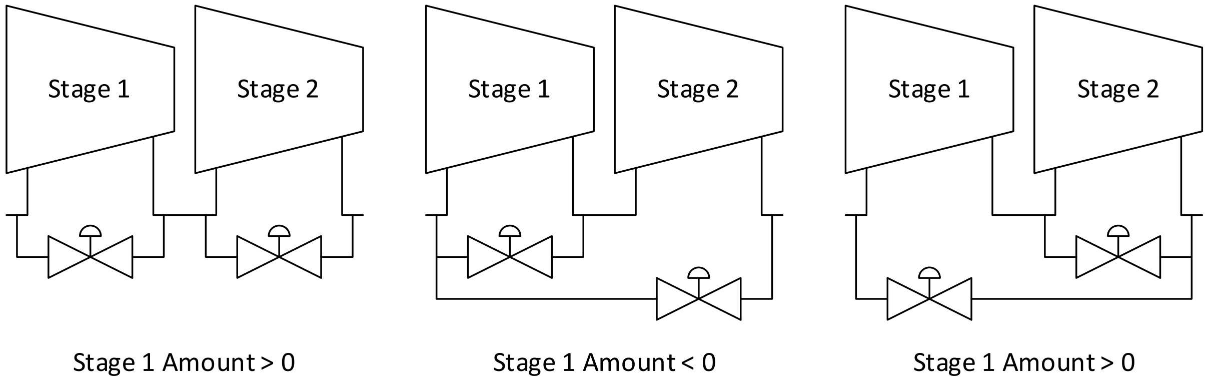

Figure 2-12. Effect of Valve Layout on Adjacent Stage Decoupling Amounts

There are two configurable Decoupling inputs. 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 compensating change in the anti-surge valve position. Each decoupling input has a Delay Time and an Amount to configure. 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. 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.

Boost Routine

The Boost Line (BL) is established between the SLL and the SCL as a backup surge prevention. Boost operates when the main PID loop and rate PID loop actions do not produce enough effect to keep the operating point to the right of the SCL. When the operating point crosses the BL, the Boost response immediately steps the valve open from its current position by a preconfigured amount.

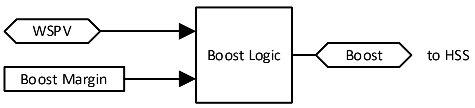

Figure 2-13. Boost Routine

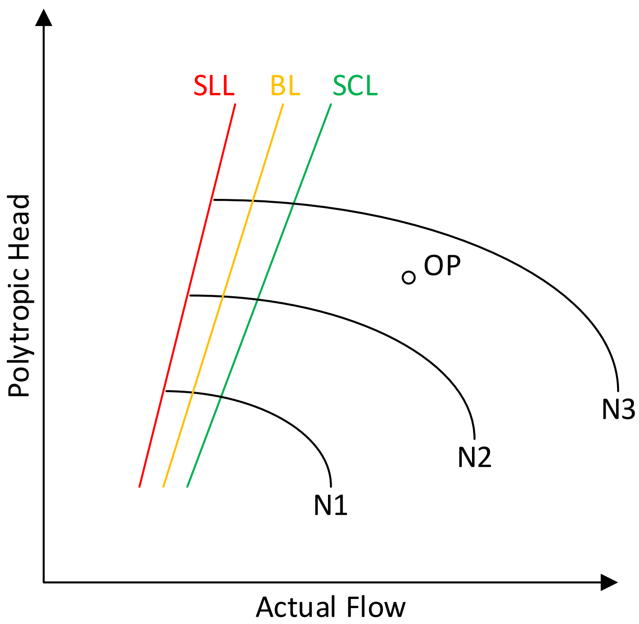

Figure 2-14. Compressor Performance Map Showing SLL, BL, and SCL

The valve demand will remain constant for a fixed amount of time (the loop period) following the step opening. During this time, a second boost response cannot be triggered, even if the operating point remains to the left of the Boost line. If the operating point is to the right of the Boost line when the timer expires, the Boost action will begin to decrease, allowing the anti-surge PID to regain control. However, if the operating point is still left of the Boost line, another Boost response will be triggered, and the sequence will repeat until the operating point is to the right of the Boost line. The Boost routine is inhibited when the unit is not online.

The location of the Boost line is determined by the Boost Margin, a percentage of flow to the left of the SCL. If the surge margin is 15% and the Boost Margin is 5%, then the SCL is 15% from the SLL and the Boost Line is 10% from the SLL. 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.

Surge Detection and Response

Surge Detection Routines

The Surge Detection routines determine when a surge event has occurred, capture the surge signature, and maintain a surge counter. The surge signature is a collection of values indicating how parameters change when a surge occurs. These routines are available for surge detection:

- Flow derivative
- Suction pressure derivative
- Discharge pressure derivative
- Speed derivative
- Minimum flow
- Surge limit line crossed
- Motor current derivative
- External surge detection contact

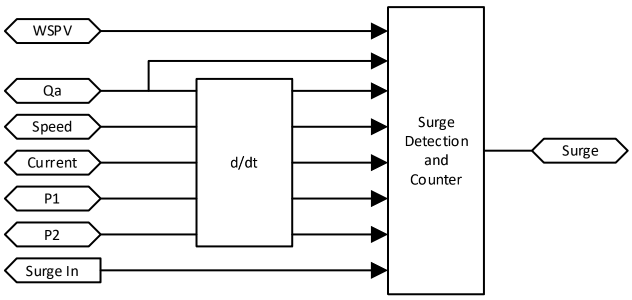

Figure 2-15. Surge Detection and Counter

IMPORTANT **The speed-based surge detection described above is active only if a valid speed signal is available.**

Note that two routines, Minimum Flow and Surge Limit Line Crossed, do not actually detect a surge. They merely initiate a surge response if the calculated operating point reaches the predicted surge limit.

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 test of the compressor). One of the most reliable detection routines is flow derivative. This routine is typically enabled before any surge data is available. The remaining routines are enabled as setpoints and are found during surge 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 online, 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. The Surge Limit Line Crossed routine will be disabled if an input for suction pressure, discharge pressure, pressure at flow, or flow has an active fault condition or an active maintenance override. If flow is calculated from a side-stream flow meter and flow through an adjacent stage, a failure in either the side-stream flow meter or the adjacent stage flow meter will disable surge detection routines that rely on flow.

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

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

Surge Counters

The Surge Counters record the number of surges detected by the anti-surge controller. The Surge Counter and the Total Surge Counter increment for each detection. A Reset Counter command will reset the Surge Counter. To reset the Total Surge Counter, issue the Reset Counter once, then a second time within 3 seconds, then a third time within 3 seconds.

Surge Recovery

Under certain process conditions the anti-surge control may not be able to prevent a surge from occurring. The Surge Recovery response breaks the surge cycle. Whenever surge is detected the Surge Recovery response immediately opens the anti-surge valve by a fixed amount above the current position demand. The minimum amount that the valve must be opened during Surge Recovery can also be configured. The resulting Surge Recovery response will be the greater of the two values. Following the Surge Recovery response, the valve demand will remain constant for the loop period time (see the Loop Period section) and then begin ramping closed as far as permitted by process conditions.

Surge Minimum Position

During the closing phase of the Surge Recovery response the anti-surge valve cannot be allowed to close beyond its position at the surge event. The anti-surge valve position demand is then limited by the Surge Minimum Position (SMP). The SMP routine captures the valve position demand at the onset of the first surge cycle and then adds a configurable bias to that. Once process conditions are stabilized and the cause of the surge has been investigated and addressed, the operator can reset the SMP function. The valve will then close as far as permitted by process conditions. The SMP is not enforced when the ASCE is in Full Manual mode.

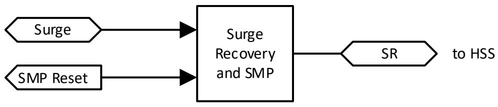

Figure 2-16. Surge Recovery and Surge Minimum Position (SMP)

For example, in Figure 2-17, the anti-surge PID and a single 3% boost response were not sufficient to prevent a surge. 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 corrected. Now, the operator can reset the SMP function, allowing the anti-surge routines to close the valve further and move the operating point to the SCL. In any surge event, the cause of the surge needs to be investigated before resetting SMP. Resetting SMP may cause the compressor to surge again if the conditions that created the surge have not been corrected.

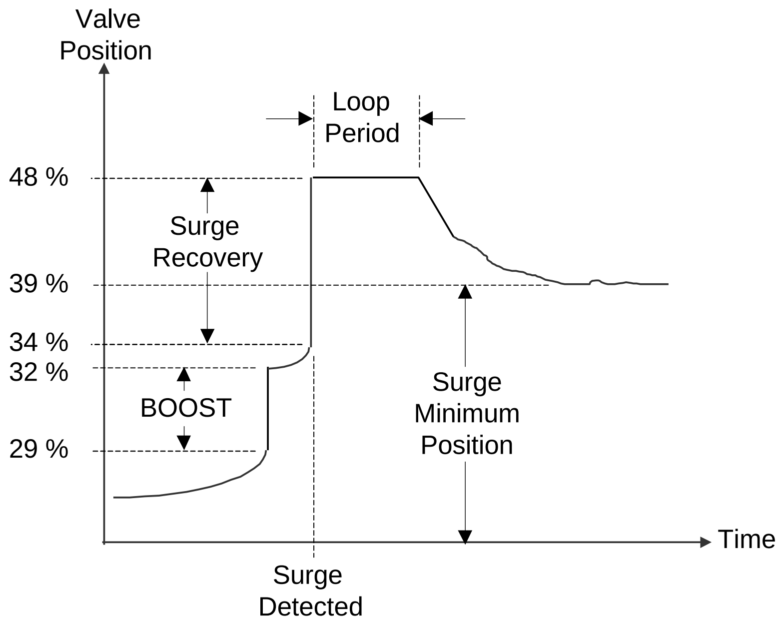

Figure 2-17. Anti-surge Valve Response to a Surge

Consecutive Surge Response and Surge Time Response

As an additional protection, it is possible to generate an alarm or a shutdown based on the number of detected surges within a configured time. Also, an external hardwired multi-surge detection option is available. If enabled, the anti-surge valve will go to the 100% open position if the consecutive surge alarm is triggered.

The ASCE tracks the amount of time that the operating point remains on the left side of the SLL. If the timer exceeds a configured threshold and the feature is enabled, a shutdown will be triggered.

Process Control Routines

The following routines can operate the anti-surge valve to control a process condition other than anti-surge control. Process conditions can drive suction pressure below a safe level and discharge pressure above a safe level. In these cases, the ASCE pressure override controllers will modulate the anti-surge valve to control pressure and assist in avoiding pressure related trips. Both Suction Pressure Override and Discharge Pressure Override may be simultaneously enabled. 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 both anti-surge valves connected to the first stage suction header. 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 (interstage pressure). The Stage 2 Suction Pressure Override controller can act on the unit suction pressure, not the interstage pressure. Since both Suction Overrides act on the same process variable, enable only one override or stagger their setpoints 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 compressor operation is on the SCL. 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 valve position. This scenario 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 will be effective only when the compressor is loaded sufficiently for the anti-surge PID to keep the valve closed.

To allow external control of the anti-surge valve, three 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 ASC 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 setpoint and the compressor suction pressure. If enabled, the override controller will open the valve to increase the suction pressure as needed. The anti-surge valve cannot be used to decrease suction pressure. The suction pressure override can be configured to use the actual suction pressure or an external signal.

Discharge Pressure Override

The Discharge Pressure Override routine monitors the difference between the compressor discharge pressure and the discharge pressure setpoint. The override controller will open the valve to decrease the discharge pressure. The anti-surge valve cannot be used to increase discharge pressure. The discharge pressure override can be configured to use the actual discharge pressure or an external signal.

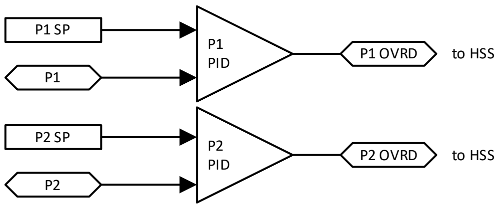

Figure 2-18. Pressure Override Controls

Auxiliary Control

Up to three custom controllers may be added to the High Signal Select (HSS) bus within the ASCE. These are configurable analog inputs that must be calibrated for 0–100% open on the anti-surge valve. If necessary, a first-order filter time constant may be configured. If any input signal fails, it is ignored by the HSS.

Support Functions

In addition to anti-surge control routines, there are support functions that enhance the ASCE capabilities:

- 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.
- Choke and quench PID control.

Signal Filtering

The field signals that are input into the ASCE may be filtered for noise reduction. Filtering can prevent false surge detections and unnecessary PID response to noise. If process measurements are clean enough to provide adequate control without filtering, configure filter time constants of 0 seconds to optimize the controller's speed of response. If filtering is deemed necessary, it is recommended to enable it in the ASCE, 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, with the lag time constant configured in seconds. A higher value time constant 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 cannot be excessively filtered. As a result, the anti-surge controller employs a more elaborate filtering scheme. A moving average filter provides a highly correlated signal without excessive delay times. A time constant is configured similarly to the other inputs but is used in a fourth-order filter scheme that weights the lagged signals according to their respective ages. The most recent value is given the largest weighting, while the oldest value has the lowest weighting. Flow signals require much faster filtering than do pressures and temperatures. Lag time constants are typically less than 100 milliseconds.

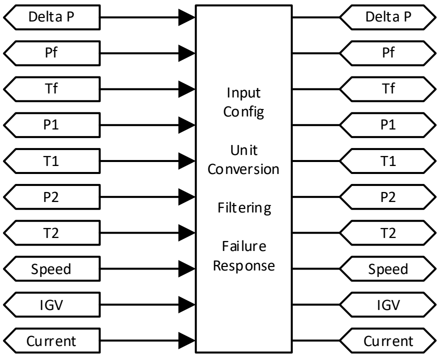

Figure 2-19. Analog Input Signal Filtering

Control Line Shift

Changing process and machine conditions can move a compressor's normal operation toward its surge limit. Consider an aging compressor in 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 ASCE offers automatic biasing of the control margin to shift the SCL when surges are detected. This feature is a temporary solution to a surge event. If enabled, the control margin will shift to the right by a configured amount for each surge detected. For example, if the control margin is at 10% and surge detection logic records 3 individual surges, a configured SCL shift amount of 1% would bias the control margin to 13%. When the surge counter is reset, the shift amount ramps slowly back to 0, gradually returning the SCL to its original location. 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.

Signal Failure Routines

When a field sensor (or both sensors, if redundant) used for surge protection fails, three actions are possible to replace the failed sensor value:

- Last Good Value
- Configured Default Value
- Calculated Default Value (for some inputs)

If enabled, Last Good Value (LGV) verifies steady state operation and uses the value for a 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.

Operational stability is determined by monitoring speed, IGV position, flow, suction pressure, discharge pressure, and motor current. If each input is stable for approximately one minute, the compressor is in a steady state condition, and the last good value selections would be valid. If the compressor were to move from this operating point, at least two of these inputs would 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 milliamp 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 and IGV-based stability monitoring described above is active only if a valid signal is available.**

If the system steady state condition changes or a second signal failure occurs while using the last good value, last good value is disabled and a default value is used. The default value is also used if LGV is not enabled. When any signal failure occurs, the values of speed, IGV position, flow, suction pressure, discharge pressure, and motor current are captured. If the values of these sensors change, 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 fallback signal will transfer to the default value. These default values should be chosen to generate a conservative WSPV.

Pressure signals can use a calculated default value based on pressure ratio. This option can be enabled independently for suction pressure and discharge pressure. If either pressure sensor fails, the alternate default value is calculated from the remaining healthy pressure sensor and the last good value or default value of pressure ratio. If process instability is detected or if pressure ratio last good value has been disabled, the last good value for pressure ratio will be replaced by the configured default value for pressure ratio.

Temperature signals can use a calculated default value based on polytropic exponent relationships. This is referred to as the Smart method for temperature fallback. If a temperature sensor fails, the alternate default value is calculated from the remaining healthy temperature and pressure sensors. This approach suits applications where efficiency and gas property variations are limited.

An additional signal failure option is to switch the mode to Full Manual and increase the anti-surge valve opening by a preconfigured amount. When this option is enabled, it can be configured to trigger on any sensor failure or just on flow sensor failure. For compressors with side-streams, side-stream flow meter failure and adjacent stage flow meter failure will both trigger the configured flow failure responses. When the IH = f(IP) map is used, failures in motor current, speed, or suction pressure can be configured to trigger a switch to Full Manual mode. These inputs are critical for calculating invariant power (IP).

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 protect the machine when important process data is unavailable.

The Minimum Valve Position option provides additional protection by ramping the anti-surge valve to a configured value when the flow sensor fails or when the pressure at the flow sensor fails. The anti-surge valve cannot be closed beyond this position unless Full Manual mode is selected. Automatic mode is not available when Minimum Valve Position is active. The Minimum Valve Position limit will automatically ramp back to zero when the failed sensor is restored. When the IH = f(IP) map is used, failures in motor current, speed, or suction pressure can be configured to trigger Minimum Valve Position. These inputs are critical for calculating invariant power (IP).

There is a No Speed Measurement option for constant speed compressors. When this option is enabled, the speed value used in the ASCE will always be the configured default value. It is important to set this default value correctly when the IH = f(IP) map is used without a speed measurement.

The tables below summarize the fallback routines for pressure, temperature, and flow failures. For compressors with side-streams, the flow failure response will be triggered by both side-stream flow meter failure and adjacent stage flow meter failure.

Table 2-1. Temperature Fallback Strategy

Last Good Value Enabled	Smart Settings Enabled	Fallback Value in Stable Operation	Fallback Value If Not Stable	Fallback Value on Multiple Failures
NO	NO	Default	Default	Default
YES	NO	Last Good	Default	Default
YES	YES	Last Good	Calculated	Last Good Calculated Value
NO	YES	Calculated	Calculated	Last Good Calculated Value

Table 2-2. Discharge Pressure Fallback Strategy

Last Good Value Enabled	Use Ratio for P2	Fallback Value in Stable Operation	Fallback Value if Not Stable	Fallback Value on Multiple Failures or P1 Fault
NO	NO	Default P2	Default P2	Default P2
YES	NO	Last Good P2	Default P2	Default P2
YES	YES	Last Good P2	Default Ratio*P1	Default Ratio*P1_DFLT
NO	YES	Default Ratio*P1	Default Ratio*P1	Default Ratio*P1_DFLT
NO	YES with Use Ratio LGV	LGV Ratio*P1	Default Ratio*P1	Default Ratio*P1_DFLT

Table 2-3. Suction Pressure Fallback Strategy

Last Good Value Enabled	Use Ratio for P1	Fallback Value in Stable Operation	Fallback Value if Not Stable	Fallback Value on Multiple Failures or P2 Fault
NO	NO	Default P1	Default P1	Default P1
YES	NO	Last Good P1	Default P1	Default P1
YES	YES	Last Good P1	P2/Default Ratio	P2_DFLT/Default Ratio
NO	YES	P2/Default Ratio	P2/Default Ratio	P2_DFLT/Default Ratio
NO	YES with Use Ratio LGV	P2/LGV Ratio	P2/Default Ratio	P2_DFLT/Default Ratio

Table 2-4. Flow, Speed, and Motor Current Fallback Strategy

Last Good Value Enabled	Fallback Value in Stable Operation	Fallback Value if Not Stable	Fallback Value on Multiple Failures
NO	Default	Default	Default
YES	Last Good Value	Default	Default

Table 2-5. Critical Signal Fallback Actions

Full Manual	Min Recycle Flow	Transition on Failure	Operation Modes Available	Valve Demand
YES	NO	Full Manual Mode	Full Manual Mode	Last Good Position + Added Manual Amount
YES	YES	Full Manual Mode	Full Manual Mode	Last Good Position + Added Manual Amount (with Minimum Limit)
NO	NO	Manual with Backup Mode	Full Manual Mode or Manual with Backup Mode	Last Good Position + Added Manual Amount
NO	YES	Manual with Backup Mode	Full Manual Mode or Manual with Backup Mode	Last Good Position + Added Manual Amount (with Minimum Limit)

Valve Freeze Mode
Under some operating conditions, the anti-surge valve may be continuously modulated at a partially open position. To eliminate unnecessary movements of the valve, the Valve Freeze Mode is used. When this mode is enabled, the valve will be held in a fixed position until a significant change in the process occurs. This feature can prevent over-reaction of the anti-surge valve and help stabilize minor process swings.

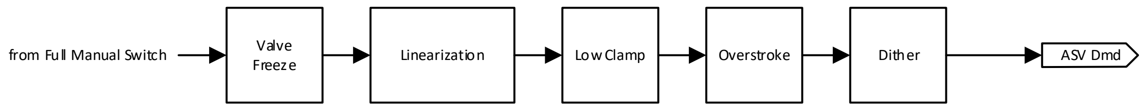

Figure 2-20. Valve Demand Modifiers

The Freeze Delay Time defines the time interval at which the Freeze function is enabled. After this time delay, the Freeze routine is initiated if two conditions are met. First, the valve demand must be moving less than the configured Window on Valve Demand. Second, WSPV must stay within the configured Window on WSPV. If both 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 startup 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 (WSPV > 115).

Valve Over Stroke
To ensure full seating of the anti-surge valve in the fully open and closed positions, the Valve Overstroke function is used. This function adds a configured Overstroke Open Amount to the valve position once its position demand reaches 99.8% open. If, for example, the overstroke amount is set at 5%, the valve demand will step to 105% once the controller output reaches 99.8%. Conversely, the Overstroke Closed Amount value is subtracted from the control output once it reaches 0.2% open. If the same 5% overstroke were set for the closed position, a control output of 0.2% would yield a valve demand of –5%, positively seating the valve closed.

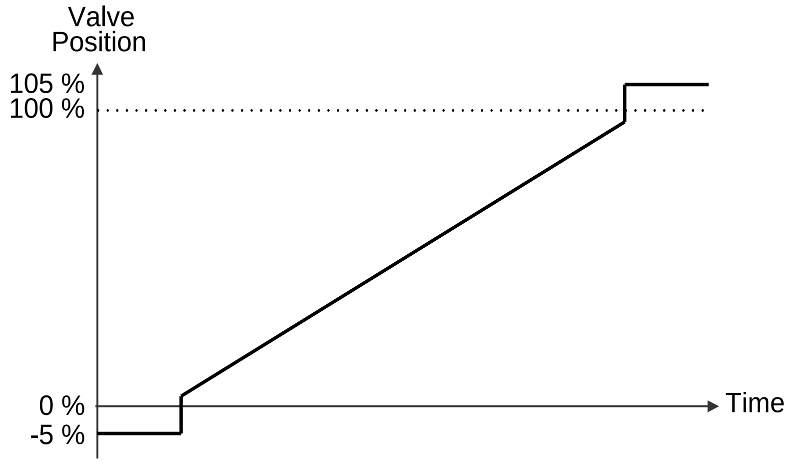

Figure 2-21. Valve Overstroke

Valve Dither

Many valve designs can develop memory if their position remains 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 converters (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 can be detrimental to good control, especially in high gain systems requiring fine valve control. For applications susceptible to this condition, the ASCE offers a dither function added to the valve demand output. Dither applies a 12.5 Hz signal of configurable amplitude onto the valve demand. Figure 2-22 shows a 0.5% dither applied to a constant 39.5% valve output. Dither, if applied, should not be visible as movement in the valve. The dither function is always active. Configure the amount to 0.0% for no dither.

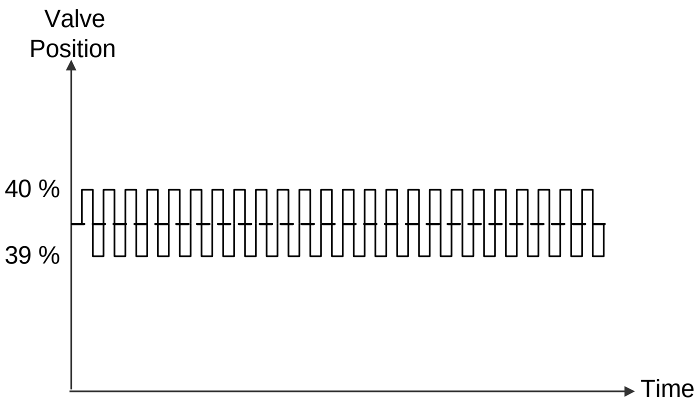

Figure 2-22. Valve Dither

Valve Linearization

Valve linearization plays an important role in compressor control applications. To ensure adequate tuning within a wide valve position range, the linear anti-surge valve characteristic is generally preferred. However, valves with quick opening, equal-percentage, and modified equal percentage characteristics are used in some applications. The ASCE incorporates a valve linearizing function that converts control output to flow in a linear fashion, regardless of the valve's characteristic. An eleven-point linearization table is provided to characterize the demand output to the anti-surge valve's flow characteristics. Figure 2-23 shows a sample equal percentage valve characteristic and the corresponding linearization curve that results in a linear flow characteristic.

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

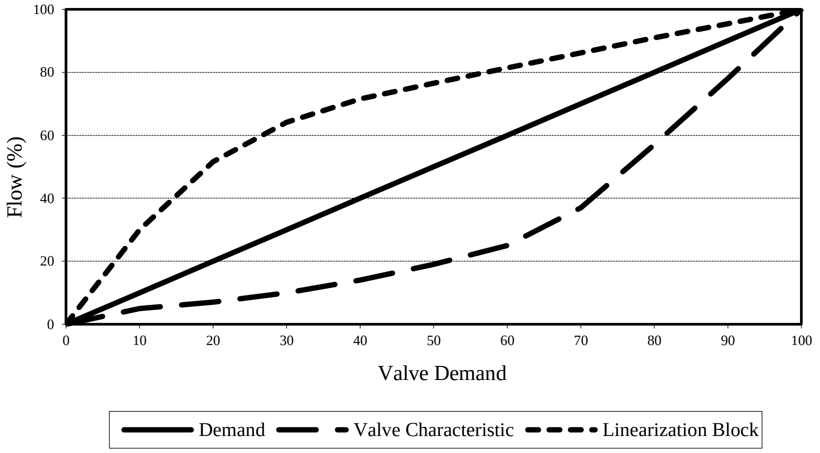

Figure 2-23. Valve Characterization

Pre-Pack

The Pre-Pack feature is used on applications where long piping runs and / or large volumes create a significant system lag. The ASCE can compensate for this time lag 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 a response is measured.

To help overcome this lag, the Pre-Pack routine will overstroke the anti-surge valve momentarily at the beginning of the Boost and Surge Recovery responses. This temporary overreaction can reduce the total response time of the system. See Figure 2-24 for a sample valve output illustrating a Boost response with Pre-Pack enabled.

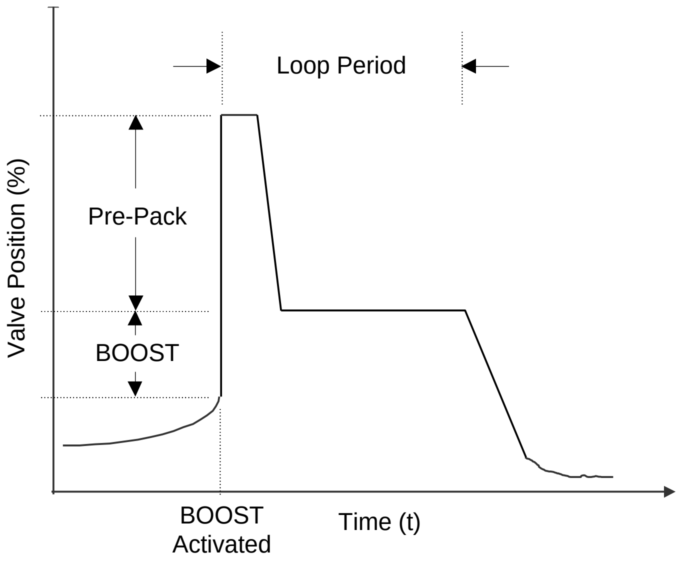

Figure 2-24. Boost Response with Pre-Pack

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 favorably. In some cases, the anti-surge valve or other components in the system are the limiting factors, and the Pre-Pack feature cannot overcome these limitations. A Pre-Pack value between 0% and 50% is tunable, depending on the system's ability to react and process stability required.

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 a smooth transition in the valve demand output. Deactivation is an internal function and cannot be modified.

Compressibility Calculation
Calculations of flow and head require the gas compressibility factor, Z. There are two ways to input gas compressibility at suction (Z1)— discharge (Z2), and flow meter (Zf) conditions:

- Input constant values provided by the compressor performance map or compressor data sheet.
- Enable real-time calculation of Z1, Z2, and Zf.

In the latter case it is required to input gas critical temperature and pressure. If the constant Z values are used, compressibility at the flow meter (Zf) is selected based upon the configured flow element location. Polytropic head calculations can use either the suction compressibility or the average compressibility.

Isentropic Exponent Calculation
The isentropic exponent for the process gas must be known for polytropic head calculation. A common simplifying assumption is to use specific heat ratio as the isentropic exponent. Default values for isentropic exponent and efficiency are configured in the software and used in the polytropic head calculation. However, the software will calculate the isentropic exponent from temperature and pressure measurements if the calculated gas properties option is enabled. This calculation is disabled when the unit is offline, when operation is not steady state with healthy inputs, or if the calculated value exceeds the configured default by ± 0.25.

Maintenance Override
The maintenance override function gives technicians a predictable and controlled method for taking sensors out of service. This function is accessible from the Configuration Toolkit. When maintenance override is activated for a sensor, the sensor is treated as failed by the ASCE. All configured failure responses for that sensor will be triggered. However, the standard fallback response is not used. Instead, the sensor value is replaced by a Maintenance Override Value. The Maintenance Override Value is initially set to the current value used in the control, ensuring a bumpless transfer to the

Maintenance Override Value. The Maintenance Override Value can then be adjusted as needed by the technician in Toolkit.

IMPORTANT

The maintenance override function should only be used by trained personnel. Enabling a maintenance override will trigger any fault responses associated with the sensor. The ability of the anti-surge control to react to process conditions will be diminished while maintenance overrides are active. Carefully observe process conditions and be prepared to manually position the anti-surge valve to protect the compressor.

While the maintenance override is active, the technician can observe the sensor value in Toolkit and confirm that it is correct. When maintenance is complete and the maintenance override is deactivated, the value used in the ASCE will transition from the Maintenance Override Value to the sensor value.

There are multiple protections for the maintenance override function. The Toolkit user must be logged in at the level 3 security level or higher to access this function. Before enabling the maintenance override for any sensor, a Maintenance Override Inhibit must be removed in Toolkit. Maintenance overrides are also inhibited if WSPV is less than 105. The WSPV inhibit threshold is adjustable in Toolkit, but it is automatically returned to the default value when the maintenance override is complete. If WSPV drops below the threshold after an override has been enabled, the override will remain active. Suction pressure and discharge pressure cannot be overridden at the same time.

Be sure to consider configured sensor failure responses when enabling a maintenance override. In many applications, a flow failure will trigger a switch to full manual mode and an automatic opening of the anti-surge valve to a configured position. If these options are configured, they will be triggered by maintenance override just as they are triggered by a real sensor fault. Surge detection routines associated with a sensor input will also be overridden while a maintenance override is active.

Additional Valve Controls

Choke Control

Choke (also known as stonewall) is a condition at which further decrease of head across the compressor does not result in an increase of flow. Compressor curves in the choke region are characterized by vertical slope. This condition is usually determined by the gas flow reaching sonic velocity or another aerodynamic limitation within the compressor. Choke is an undesirable operating condition which may damage the compressor. Anti-choke control is provided in the ASCE.

The anti-choke function is an additional PID controller. The PID output typically controls a downstream flow limiting valve, but an upstream valve can be used in some applications. Closing the valve reduces flow and moves the compressor away from the choke condition The operating point is compared to a corresponding point on the configured choke limit line (CLL). The PID output is based on that comparison. As with anti-surge control, the flow squared over polytropic head value (Q^2/H) is used for the process value calculation, but the CLL is used in the calculation instead of the SCL.

Quench Control

Quench temperature control is employed in refrigeration compressors to provide cooling of the anti-surge recycle line. Temperature control is achieved by injecting liquid process fluid in the recycle line. Fluid from the main condenser flashes from liquid to gas when it enters the recycle line. The recycle line temperature is reduced as the phase change process absorbs heat from the hot recycle gas.

The quench temperature control valve is driven by the Quench PID, an exhaust temperature limiter PID, or an external signal. These three signals are high signal selected to determine which signal controls the quench valve. By default, the quench valve is held closed while the anti-surge valve is closed, but this feature can be overridden. Manual operation of the quench valve is allowed.

The temperature measurement for the Quench PID can come from one of three sources:

- Suction temperature
- Temperature at the flow meter
- Dedicated quench temperature measurement

Three options are available for the Quench PID setpoint:

- Fixed Setpoint – A setpoint adjusted by the operator.
- Variable Setpoint from Dew Point Curve – A setpoint calculated from the dew point temperature. The dew point temperature is constantly updated as suction pressure changes. The setpoint includes a configurable offset from the dew point temperature.
- Limited Fixed Setpoint – The setpoint is a combination of the first two options. The operator chooses the setpoint, but the setpoint is limited by the dew point temperature to prevent over-quenching.

Secondary Loop

A secondary PID loop for anti-surge purposes is available. The secondary loop will drive an additional anti-surge valve located in parallel to the primary valve. This loop is not intended to control quench valves or on / off valves like a Hot Gas Bypass. The secondary loop can be configured as one of these options:

- Cold recycle based on operating point – The valve opening is based on the operating point location relative to an additional control line defined by the secondary anti-surge margin.
- Cold recycle proportional to anti-surge valve – The valve opening is dependent on the position of the primary anti-surge valve.
- Cold recycle with external signal – The valve opening is based on external setpoint and process value signals.

The secondary valve can be positioned manually and by sequencing logic as well.

Sensor Flow Calculations

Compressor flow is a critical measured parameter in the ASCE. Flow can be input to the ASCE using various methods: flow element differential pressure (with or without square root extraction) or mass flow. The mass flow input requires an external flow computer or transmitter calibration using process data. While these methods are suitable for simple flow measurement and display, they are not ideal for anti-surge control because of accuracy limitations and response time delays. For these reasons, the preferred flow measurement for surge prevention is raw flow element differential pressure without square root extraction. The calculations described below assume this configuration. Mass flow is calculated using the measurement of differential pressure, pressure at the flow sensor, and temperature at the flow sensor.

$$\dot{m} = C \times Y \times \frac{\pi d^2}{4} \sqrt{\frac{2 \times h_f \times \rho}{(1-\beta^4)}}$$

Where:
$\dot{m}$ is the mass flow rate
C is the discharge coefficient
Y is the expansion factor
d is the flow element bore
h_f is the differential pressure across the flow element
ρ is the density
β is the ratio of flow element bore and pipe internal diameter

By combining constant terms, the mass flow equation can be re-written:

$$\dot{m} = K_M \times \sqrt{\frac{h_f \times P_f \times MW}{T_f \times Z_f}}$$

The flow constant, K_M, is calculated during configuration by inputting C, Y, d, and β from the flow meter data sheet. Molecular weight is also input during initial configuration. The flow element differential pressure, the pressure at the flow element, and the temperature at the flow element are measured while the compressor is running. Compressibility at the flow element is either configured as a constant or calculated based on measurements.

A second method for calculating the flow constant is available in the ASCE: the calibration data method. In this method, operating data for a calibration point is input to the ASCE. Note that the calibration data is often captured from a maximum flow condition (maximum differential pressure of the flow transmitter). In this case, the calibration data may not be relevant to normal compressor operation. If possible, use calibration data generated from a compressor's normal operating condition. Ideally, the flow constant can be cross-checked by using geometry data and calibration data from multiple operating conditions.

The expansion factor (Y) is usually assumed to be constant in the operating range of the compressor. The expansion factor is a function of the differential pressure, the pressure at the flow element, the beta ratio, and the isentropic exponent. When necessary, the expansion factor can be calculated using measurements of pressure and differential pressure to increase flow meter accuracy.

The calculated mass flow through the flow element can then be combined with any side-stream or adjacent stage flows to find the total mass flow through the compressor stage. Mass flow units are always used whenever it is necessary to add flow values.

Chapter 3.
Incorporating ASCE in an Application

Introduction

The ASCE consists of two GAP software modules—the interface module and the core module. All critical logic is contained in the core module. The interface module provides defined input points for external signals (both field signals and signals from external logic). External tools such as OPC clients should be connected to blocks in the interface module whenever possible. The core module is locked and can only be edited by Woodward engineers. The interface module is not locked, but Woodward recommends avoiding modifications to this module as well.

Woodward maintains five instances of the ASCE, supporting compressors with up to five stages of anti-surge control. The following part numbers are actively maintained by Woodward. Each part number includes a core module and an interface module.

- 10-031-139GAP
- 10-031-140GAP
- 10-031-141GAP
- 10-031-142GAP
- 10-031-143GAP

The ASCE can be configured entirely through setting tunable values in GAP. However, to make configuration more intuitive, Woodward provides a Configuration Toolkit for each of the five ASCE instances:

- 10-031-139TLKT
- 10-031-140TLKT
- 10-031-141TLKT
- 10-031-142TLKT
- 10-031-143TLKT

Control Outputs

The primary function of the ASCE is to generate four control outputs such that a compressor is protected, and the surrounding process is optimized:

- Anti-surge valve demand
- Anti-choke valve demand
- Quench valve demand
- Secondary anti-surge valve demand

Additional Features

In addition to the control outputs, the ASCE also provides the following features:

- The calculation of gas properties such as isentropic exponent (k) and compressibility (Z) are available for additional accuracy.
- Seven robust surge detection routines detect a surge within 50 milliseconds. These user-configurable surge detection routines are:
  - Flow derivative (rate of change)
  - Minimum flow level
  - Speed derivative (rate of change)
  - Suction pressure derivative (rate of change)
  - Discharge pressure derivative (rate of change)
  - Motor current derivative (rate of change)
  - Cross surge limit line
- Transmitter failures automatically initiate fallback routines to avoid process disruptions. Upon a signal failure, the ASCE analyzes the compressor operation for stability to determine if the last good value is viable. If the last good value is not viable, default values are used. Even if every transmitter except flow fails, the ASCE can still provide surge protection in automatic

mode, based upon a flow derivative surge signature. Optionally, other signal failures can initiate the same fail to Full Manual routine as a flow failure, providing the most conservative protection strategy.

- Bumpless transfer between three control modes is provided:
  - Automatic
  - Manual with Backup
  - Full Manual
- To stabilize interrelated processes, decoupling routines are provided between the anti-surge valve and speed, as well as from a second anti-surge valve. Two additional decoupling routines can be configured from external sources.
- Startup and shutdown sequencing of the anti-surge valve, including an optional purge position, provide complete compressor control from zero speed to full loading.
- Maintenance override on critical analog inputs. This feature provides a controlled and predictable method for taking transmitters out of service and returning them to service.

ASCE Inputs

Analog Input Features

The following analog inputs are available for each compressor loop:

- Flowmeter
  - Differential pressure from the flow element at suction or discharge
- Redundant Flowmeter
  - Accommodates a second flow transmitter for redundancy
- Suction Pressure
  - Compressor inlet pressure
- Redundant Suction Pressure
  - Accommodates a second inlet pressure transmitter for redundancy
- Discharge Pressure
  - Compressor outlet pressure
- Redundant Discharge Pressure
  - Accommodates a second outlet pressure transmitter for redundancy
- Pressure at Flow Element
  - The Flow Element Pressure input may be used for calculating flow using a value from a pressure transmitter at the flow element, especially if its location is far from the compressor suction or discharge pressure measurements.
- Suction Temperature
  - Compressor inlet temperature
- Discharge Temperature
  - Compressor outlet temperature
- Temperature at Flow Element
  - The Flow Element Temperature input may be used for calculating flow using a value from a temperature transmitter at the flow element, especially if its location is far from the compressor suction or discharge temperature measurements
- Side-stream Temperature
  - Temperature measured on a side-stream (admission or extraction)
- HSS1 Demand Input
- HSS2 Demand Input
- HSS3 Demand Input
- Decoupling #1 Demand, Decoupling #2 Demand, Decoupling #3 Demand
  - Auxiliary Decoupling inputs are provided for limited feed-forward biasing of the anti-surge valve, based upon a separate process change.
- Remote Manual Valve Position
  - Remote valve positioning (0% = Closed, 100% = Open) in Manual Mode
- Pressure Upstream Anti-surge Valve
  - This can be utilized for anti-surge valve flow estimation and is needed if gain compensation is used.
- Pressure Downstream Anti-surge Valve
  - This can be utilized for Anti-surge valve flow estimation and is needed if gain compensation is used.
- Temperature at Anti-surge Valve

This can be utilized for anti-surge valve flow estimation and is needed if gain compensation is used.

- Alternate Suction Pressure Override
  - A dedicated suction pressure transmitter for suction pressure override control.
- Alternate Discharge Pressure Override
  - A dedicated discharge pressure transmitter for discharge pressure override control.
- Anti-surge Valve Position Feedback
  - This is provided for anti-surge valve position feedback (0% = Closed, 100% = Open).
- Quench Temperature Input
  - Dedicated suction temperature transmitter for quench control.
- IGV Position Feedback
  - Inlet guide vane position feedback (0% = minimum flow position, 100% = maximum flow position).
- Motor Current
  - For motor-driven compressors, current can be used for online detection and sequencing. This input is required when the invariant head versus invariant power compressor map is used. Either a motor current or a driver power input can be routed to this input. When the invariant head versus invariant power compressor map is used, a current input must be in Amps and a power input must be in kW.
- Speed
  - For variable speed compressors, speed can be used for online detection and sequencing. This input is required when the invariant head versus invariant power compressor map is used.

In addition to these inputs, the following analog inputs can be configured on compressors with side-streams. These signals usually come from another instance of the ASCE in the same application. When these inputs are used, it is critical that their fault conditions are also passed into the ASCE.

- Mass flow from an upstream stage
- Discharge temperature from an upstream stage
- Mass flow from a downstream stage
- Suction temperature from a downstream stage

Binary Inputs Features

The following binary inputs are available for each compressor loop:

- Close Anti-surge Valve
  - Closing the anti-surge valve when in Manual with Backup or Full Manual
- Open Anti-surge Valve
  - Opening the anti-surge valve when in Manual with Backup or Full Manual
- Reset SMP
  - Resets the Surge Minimum Position hold on valve position (pulse)
- Reset Capture Info
  - Resets the Surge Capture information (counter, signature values). Does not reset the Total Surges Counter (pulse).
- Select Auto Mode
  - Selects the Automatic control mode (pulse)
- Select Manual with Backup Mode
  - Selects the Manual with Backup control mode (pulse)
- Select Full Manual Mode
  - Selects the Full Manual control mode (pulse)
- Purge Request
  - Selects the anti-surge valve's purge position (pulse).
- Quit Purge Request
  - Cancels the request for the anti-surge valve's purge position (pulse).
- Suction Pressure Override Enable/Disable
  - To enable/disable P1 (Suction Pressure) Override PID
- Discharge Pressure Override Enable/Disable
  - To enable/disable P2 (Discharge Pressure) Override PID
- Send P1 Override Setpoint
  - To send an override P1 setpoint It can be configured to use the actual P1 or use dedicated P1 override input.
- Send P2 Override Setpoint
  - To send an override P2 setpoint. It can be configured to use the actual P2 or use dedicated P2 override input.

- Online/Offline Auxiliary Input
  - Initiates the transition from offline to online automatic anti-surge control, i.e. starts the anti-surge control instead of, or in addition to, other detection methods (sustained).
- Control Margin Increase/Decrease
  - Increases/Decreases the current Control Margin by 0.2% per second while the input is closed.
- Raise/Lower Choke Control Demand
  - Increases/decreases the current Choke Control Demand at a configurable rate while the input is closed.
- Choke Auto/Manual Mode Request
  - Auto/Manual mode for Choke
- Raise/Lower Quench Setpoint
  - Increases/decreases the current Quench Setpoint at configured “setpoint rate of change” while the input is closed.
- Raise/Lower Quench Control Demand
  - Increases/decreases the Quench Demand at configured “manual rate of change” while the input is closed.
- Quench Auto/Manual Mode Request
  - Auto/Manual Mode for Quench
- Send Quench T Offset
  - To send the Quench T offset for quench setpoint calculation.
  - This value will be added to the temperature value from dew curve
- Send Valve Target
  - To manually send the Manual Position Demand
- External Surge Detection
- External Excessive Surge Detection

Anti-surge Control Recommendations

Compressor control systems are but one element in the entire anti-surge control loop. 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.

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 electronic transmitters with time constants from about 250 milliseconds. As a comparison, pneumatic transmitters can have time constants of several seconds, which obviously eliminates their use in surge protection. As digital transmitters have become more prominent, it is becoming increasingly more difficult to procure their analog predecessors. The extra signal processing in these transmitters adds 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. Straight upstream pipe runs and the use of flow conditioners not only improve accuracy but also reduce signal noise.

Anti-surge Valves

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

Chapter 4.
Configuring the ASCE

This chapter provides detailed information on configuration of the ASCE using the Configuration Toolkit. The Configuration Toolkit is a wtool file built in Woodward's Toolkit software. Using a series of pages, it guides the user through the configuration process. There is a unique Configuration Toolkit file for each instance of the ASCE. The Configuration Toolkit is divided into these pages:

- Home
- Main Configuration
- Gas Characteristics
- Flow Element
- Anti-surge Valve Settings
- Mapping
- Sequence
- Protection
- Surge Detection
- PIDs
- Sensor Handling
- Decoupling
- Auxiliary Controls

Compressor Configuration Screens

Communication

Before configuring the ASCE, the Configuration Toolkit must be connected to either control hardware or a simulated control running on a computer. Open the Configuration Toolkit and press the Connect button.

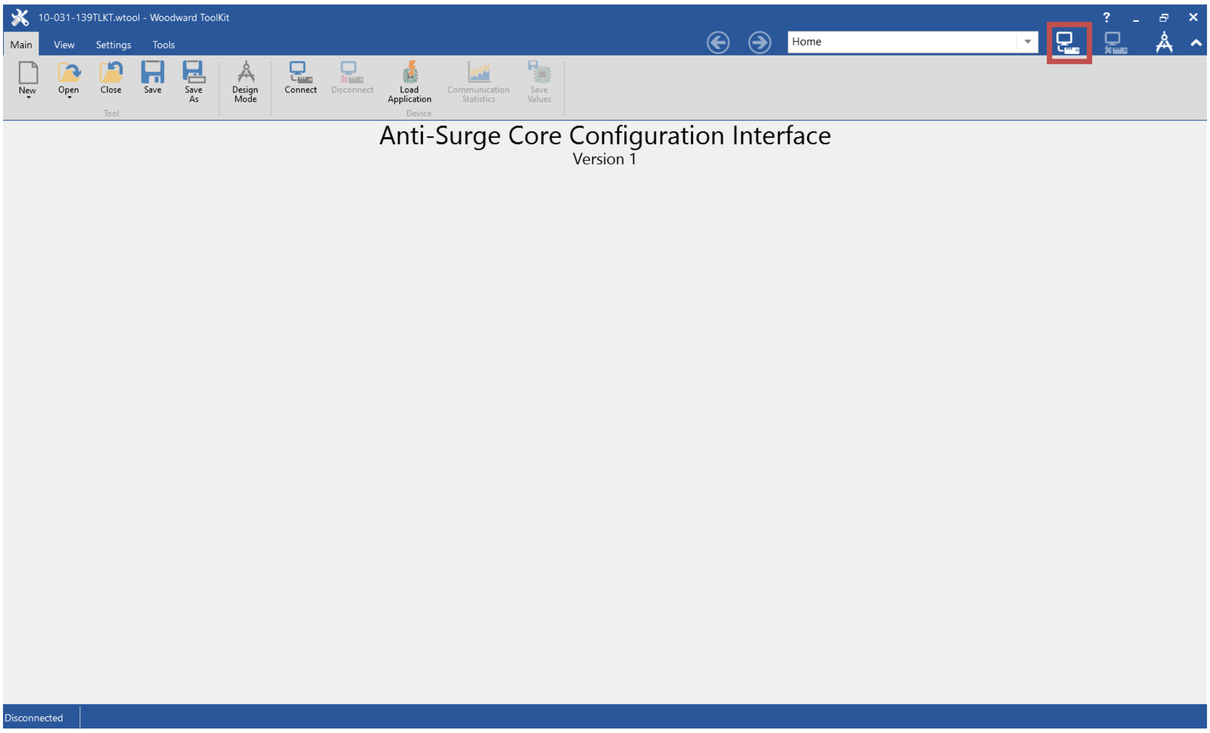

Figure 4-1. Home Page Showing Connect Button

The Configure Connection window will open. Ensure that TCP/IP is selected for the network. The Protocol is Servlink. Check the box for the appropriate IP address or add the IP address if needed. When all settings are correct, press Connect.

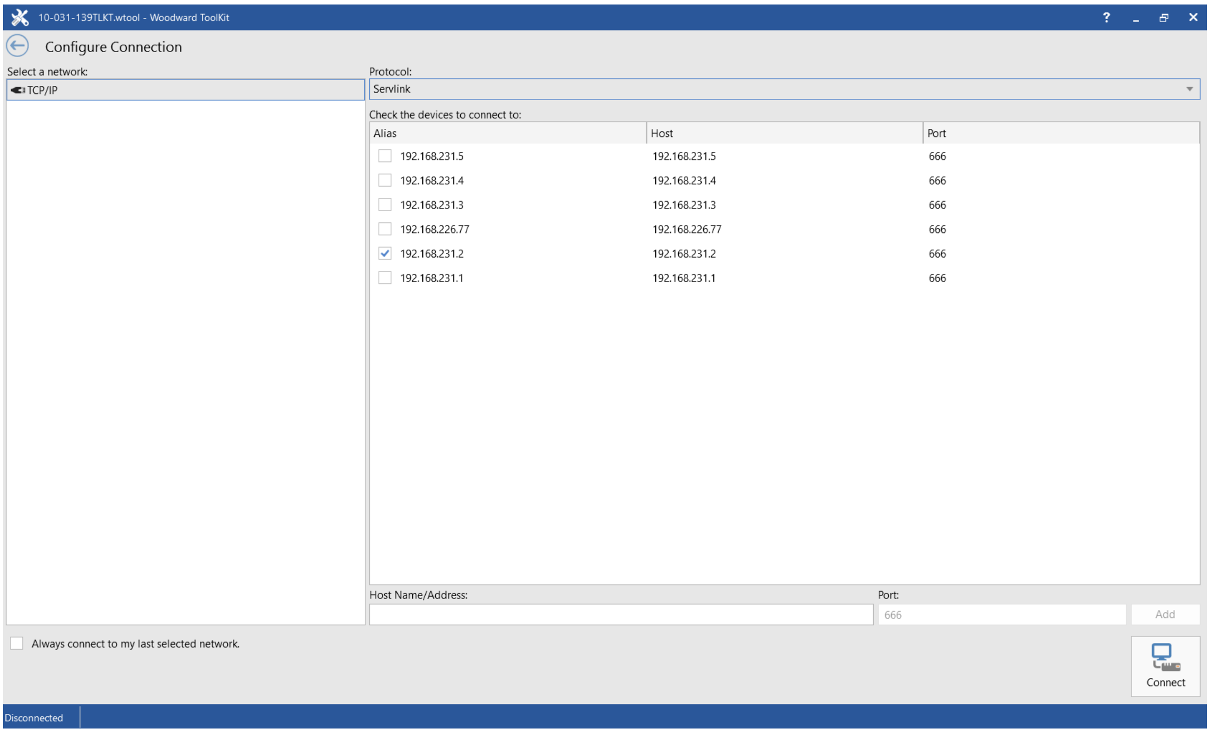

Figure 4-2. Configure Connection Window

After the connection is complete, the Security Login window will open. There are three security levels: Operator, Service, and Configuration. The configuration of the ASCE requires the user to login at the Configuration level (or at a higher level). If the user is logged in at a lower security level, some configuration settings will not be accessible or will not be visible.

Enter the username and password and click the Log In button.

IMPORTANT **Usernames and passwords are set on each CPU and can be changed by the end-user. If default values are changed, be sure they are recorded for future use. Refer to project-specific documentation for default usernames and passwords.**

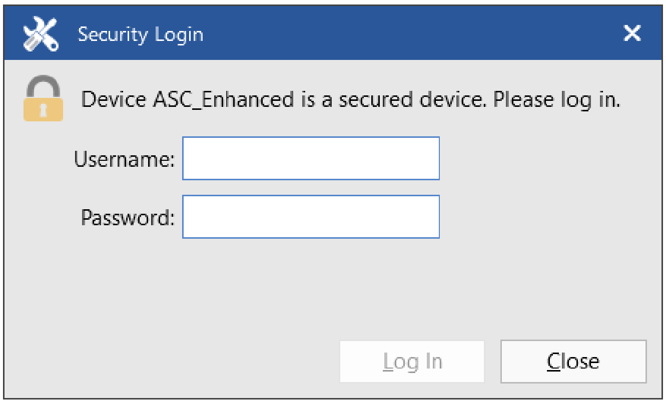

Figure 4-3. Toolkit Security Login Window

IMPORTANT **The control system should be in a shutdown condition before making configuration changes to the ASCE.**

Home Page

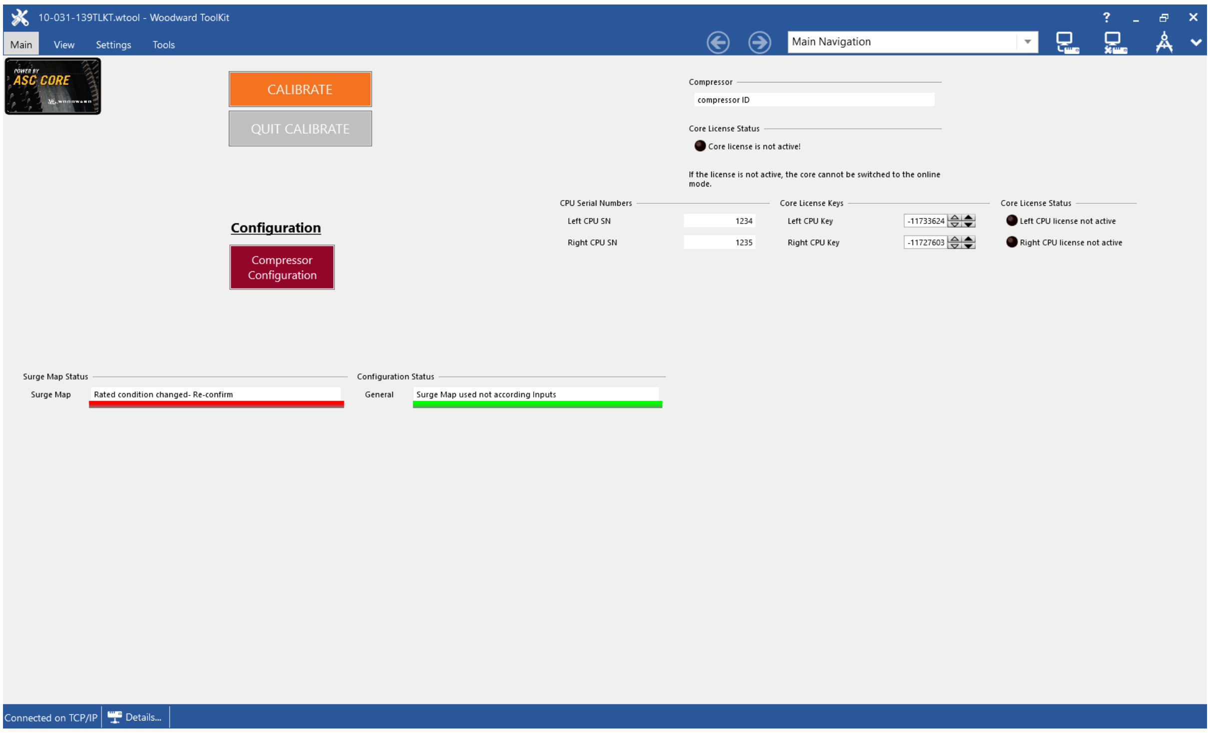

Figure 4-4. Home Page

Calibration

The Home Page contains a Calibrate button and a Quit Calibrate button. To access all configuration options, calibration mode must be activated. Calibration mode will be blocked if the ASCE is not in a shutdown state.

Compressor Configuration

The Compressor Configuration button navigates to the Main Configuration Page. All other pages include a navigation button to return to the Home Page.

Core License Status

The LED will be illuminated red if the core license is not active. If the core license is not active, it will not be possible to trigger the online condition and close the anti-surge valve. Each instance of the ASCE core in an application must be licensed with a license key number that is tied to the CPUs that are running the application. In applications with redundant hardware, the ASCE will be considered licensed if either CPU module has a correct license key number configured. This section will only be displayed in Toolkit if the licensing feature has been enabled in GAP. By default, the licensing feature is disabled.

CPU Serial Numbers

The Left CPU and Right CPU serial numbers are displayed here. These serial numbers are used to generate core license keys. This section will only be displayed in Toolkit if the licensing feature has been enabled in GAP. By default, the licensing feature is disabled.

Core License Keys

The Left CPU and Right CPU core license key numbers are entered here. These license key numbers are generated from the CPU serial numbers. If the core license key number is correct for the CPU serial number, the CPU's license will be activated. The CPU's active license status is indicated by the red LED located to the right of the key number. An illuminated LED means that the CPU does not have an active license. This section will only be displayed in Toolkit if the licensing feature has been enabled in GAP. By default, the licensing feature is disabled.

Main Configuration Page

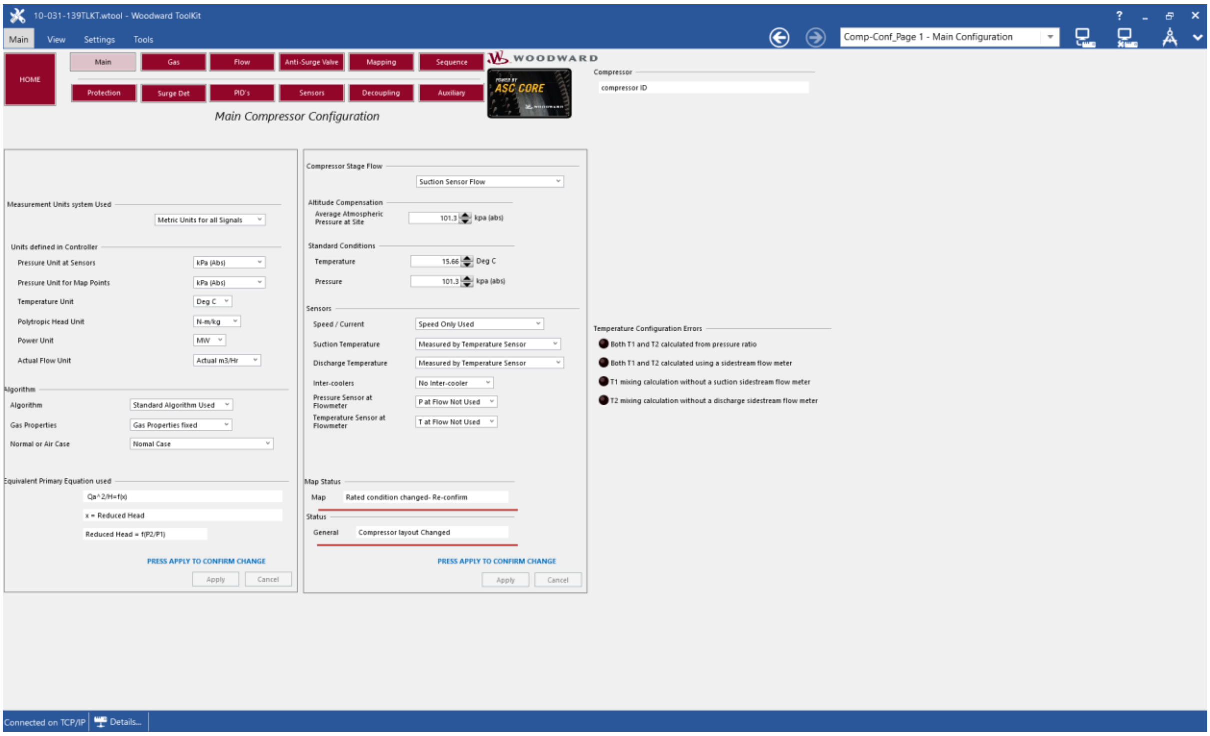

Figure 4-5. Main Configuration Page

Measurement Unit System Used

Select the measurement unit system from the following list:

- Metric Units for all Signals
- Imperial Units for all Signals

This parameter controls the options displayed in other unit configuration settings. This setting is critical and must be set before other configuration settings.

Pressure Unit at Sensors

Select the pressure sensor units from the list. The options displayed depend on the Measurement Units System Used setting.

Table 4-1. Pressure Sensor Unit Options

Metric Options	Imperial Options
kPa (absolute)	psi (absolute)
MPa (absolute)	Ft of H_2O (absolute)
Bar (absolute)	Atm (absolute)
kg/cm² (absolute)	Torr (absolute)
kPa (gauge)	Tons-force/ft2 (absolute)
MPa (gauge)	Inches of Hg (absolute)
Bar (gauge)	psi (gauge)
kg/cm² (gauge)	Ft of H_2O (gauge)
	Atm (gauge)
	Torr (gauge)
	Tons-force/ft2 (gauge)
	Inches of Hg (gauge)

Pressure Unit for Map Points
Select the pressure units that will be used for configuring and displaying map points. The options displayed depend on the Measurement Units System Used setting.

Table 4-2. Pressure Map Point Unit Options

Metric Options	Imperial Options
kPa (absolute)	psi (absolute)
MPa (absolute)	Ft of H2O (absolute)
Bar (absolute)	Atm (absolute)
kg/cm² (absolute)	Torr (absolute)
kPa (gauge)	Tons-force/ft2 (absolute)
MPa (gauge)	Inches of Hg (absolute)
Bar (gauge)	psi (gauge)
kg/cm² (gauge)	Ft of H2O (gauge)
	Atm (gauge)
	Torr (gauge)
	Tons-force/ft2 (gauge)
	Inches of Hg (gauge)

Temperature Unit
Select the temperature sensor units from the list. The options displayed depend on the Measurement Units System Used setting.

Table 4-3. Temperature Sensor Unit Options

Metric Options	Imperial Options
°C	°F
°K	°R

Polytropic Head Unit
Polytropic head units are selectable in the metric unit system. In the imperial unit system, the units are always the same.

Table 4-4. Polytropic Head Unit Options

Metric Options	Imperial Options
N-m/kg	ft-lbf/lbm
Kg-m/kg	
kJ/kg	

Power Unit
Power units are selectable in the metric unit system. In the imperial unit system, the units are always the same.

Table 4-5. Power Unit Options

Metric Options	Imperial Options
MW	HP
kW	

Actual Flow Unit
Select actual flow units from the list. These units are used for entering and displaying map points.

Table 4-6. Actual Flow Unit Options

Metric Options	Imperial Options
actual m³/hr	actual ft³/hr
actual m³/min	actual ft³/min

Algorithm
- Not Used
- Standard Algorithm Used

If Not Used is selected, many blocks in the ASCE are disabled to reduce CPU load.

Gas Properties
- Gas Properties Fixed
- Gas Properties Calculated

If Gas Properties Calculated is selected, the sigma value and the isentropic exponent value will be calculated while the compressor is running based on pressure and temperature measurements. All temperature sensors are needed to utilize this functionality.

Normal or Air Case
- Normal Case
- Air Compressor with Suction Pressure
- Air Compressor without Suction Pressure

This selection defines a distinction between air compressors and all other gases. In the case of an air compressor, the user can specify whether suction pressure is available or not.

Normal Case should be selected for all gases other than air. If the compressed gas is air, select one of the two air compressor options. The molecular weight and isentropic exponent gas properties are assumed for the air case. If a suction pressure transmitter is used with an air compressor, select Air Compressor with Suction Pressure. If an air compressor does not have a suction pressure transmitter, select Air Compressor without Suction Pressure. In this case, the atmospheric pressure is used in place of a suction pressure transmitter.

Compressor Stage Flow
- Suction Sensor Flow
- Discharge Sensor Flow
- Upstream Stage Flow + Sensor Flow
- Upstream Stage Flow – Sensor Flow
- Downstream Stage Flow + Sensor Flow
- Downstream Stage Flow – Sensor Flow

Suction Sensor Flow and Discharge Sensor Flow are the most common cases. If the system includes a flow meter that can measure the total flow through the stage (no addition or subtraction of flow from side-streams), one of these cases should be selected. For the other cases that calculate compressor stage flow from a sensor measurement and an adjacent stage flow, failures in the adjacent stage flow will trigger the same responses that are triggered by the sensor flow failure.

For Upstream Stage Flow + Sensor Flow, the total stage flow through the configured stage is the sum of the sensor mass flow and the mass flow through the previous stage. The flow meter is located on an admission side-stream.

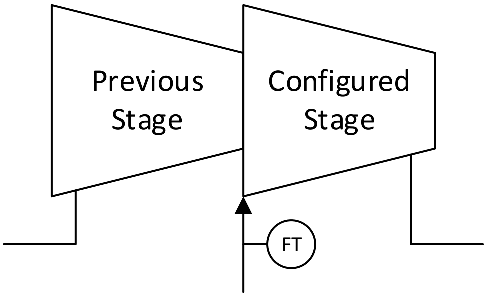

Figure 4-6. Upstream Stage Flow + Sensor Flow

For Upstream Stage Flow – Sensor Flow, the total stage flow through the configured stage is the difference between the mass flow through the previous stage and the sensor mass flow. The flow meter is located on an extraction side-stream.

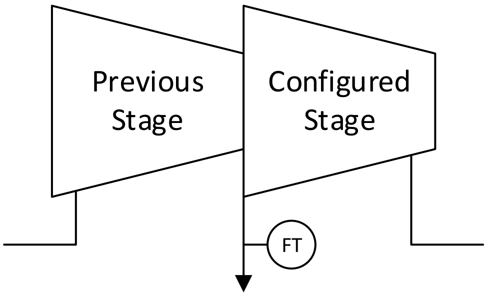

Figure 4-7. Upstream Stage Flow – Sensor Flow

For Downstream Stage Flow – Sensor Flow, the total stage flow through the configured stage is the difference between the mass flow through the next stage and the sensor mass flow. The flow meter is located on an admission side-stream.

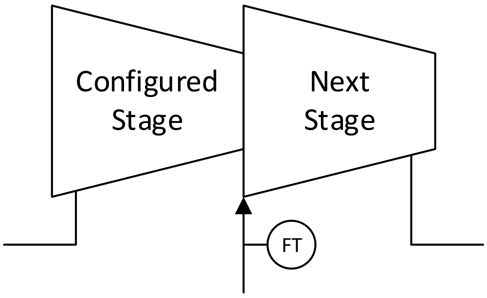

Figure 4-8. Downstream Stage Flow – Sensor Flow

For Downstream Stage Flow + Sensor Flow, the total stage flow through the configured stage is the sum of the sensor mass flow and the mass flow through the next stage. The flow meter is located on an extraction side-stream.

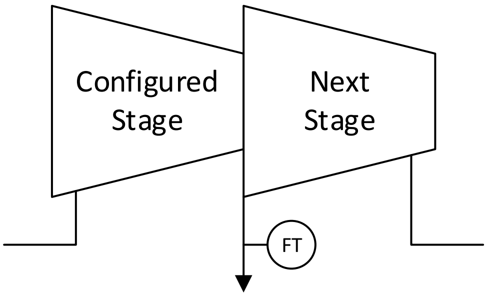

Figure 4-9. Downstream Stage Flow + Sensor Flow

Average Atmospheric Pressure at Site
Enter the atmospheric pressure at the site. This setting is used to compensate for altitude when converting gauge pressure units to absolute pressure units. If SI units are used, the atmospheric pressure is always entered in kPa. The default value is 101.3 kPa. If imperial units are used, the atmospheric pressure is always entered in psi. The default value is 14.73 psi.

Standard Temperature
The standard temperature is used in calculation of density and flow at standard conditions. Enter this value in ° C when SI units are used (default = 15.66 ° C) and in ° F when imperial units are used (default = 60 ° F).

Standard Pressure
The standard pressure is used in calculation of density and flow at standard conditions. Enter this value in kPa when SI units are used (default = 101.3 kPa) and in psi when imperial units are used (default = 14.73 psi).

Speed / Current Sensors
- Speed Only Used
- Speed and Motor Power (or current) Used
- Motor Power (or current) Only Used
- No Speed / No Motor Power (or current) Used

Select the combination of speed and motor current inputs that are available. This setting impacts sequencing, online detection, and surge detection logic.

Suction Temperature
- Measured by Temperature Sensor
- Calculated from T2 and Pressure Ratio
- Calculated from Upstream/Side-stream Mix
- Default Value Used

The most common selection is Measured by Temperature Sensor; this option will yield the most accurate anti-surge control. If a suction temperature sensor is not available, suction temperature can be calculated from the discharge temperature and the pressure ratio. In compressors with side-streams, suction temperature can be calculated using the discharge temperature of the upstream stage and the suction side-stream temperature (mixing calculation). The suction temperature from the mixing calculation may be more accurate than the suction temperature from the pressure ratio calculation. If a sensor is not available and neither calculation method is feasible, a default suction temperature can be configured.

Discharge Temperature
- Measured by Temperature Sensor
- Calculated from T1 and Pressure Ratio
- Calculated from Downstream/Side-stream Mix
- Default Value Used

The most common selection is Measured by Temperature Sensor; this option will yield the most accurate anti-surge control. If a discharge temperature sensor is not available, discharge temperature can be calculated from the suction temperature and the pressure ratio. In compressors with side-streams, discharge temperature can be calculated using the suction temperature of the downstream stage and the discharge side-stream temperature (mixing calculation). The discharge temperature from the mixing calculation may be more accurate than the discharge temperature from the pressure ratio calculation. If a sensor is not available and neither calculation method is feasible, a default discharge temperature can be configured.

Inter-coolers

Select the number of inter-coolers that are included within the stage. If there are heat exchangers before or after the compressor stage, leave this setting at the default, No inter-cooler. This setting only applies to heat exchangers that are located within a compressor stage. In other words, use this setting when pressure and temperature are not measured at the inlet and outlet of the heat exchanger. This setting must be correct to ensure proper calculation of the sigma parameter when inter-coolers are used.

- No inter-cooler
- One inter-cooler
- Two inter-coolers
- Three inter-coolers

An example of inter-cooler use is shown in Figure 4-10. In the example, there are two impellers with a heat exchanger between them. The two impellers are treated as a single stage for anti-surge control purposes. Pressure and temperature are only measured at the suction of the first impeller and at the discharge of the second impeller. In this example, the inter-coolers setting would be set to one inter-cooler.

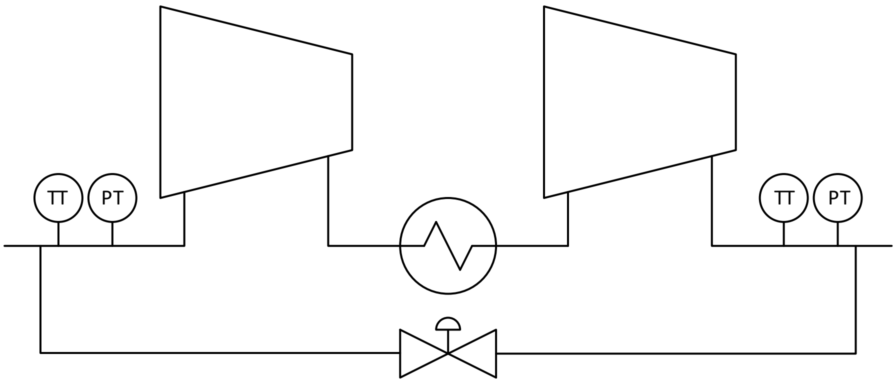

Figure 4-10. Compressor Stage with One Inter-Cooler

The calculation used to account for intercoolers is based on the assumptions that each impeller has the same pressure ratio and that the discharge gas from each stage is cooled to the first impeller's suction temperature before entering the following impeller. If there are significant deviations from these assumptions, this feature should not be used. Instead, a customized solution is required for the application.

Pressure Sensor at Flowmeter

- P at Flow Not Used
- P at Flow Used

Use this setting to indicate that a dedicated pressure sensor at the flowmeter is used. The dedicated pressure sensor is used in the flow compensation calculation. If this setting is set to P at Flow Not Used and the Compressor Stage Flow setting is set to Suction Sensor Flow, Upstream Stage Flow + Sensor Flow, or Upstream Stage Flow – Sensor Flow, the pressure at the flow meter is assumed to be the P1 value. If this setting is set to P at Flow Not Used and the Compressor Stage Flow setting is set to Discharge Sensor Flow, Downstream Stage Flow + Sensor Flow, or Downstream Stage Flow – Sensor Flow, the pressure at the flow meter is assumed to be the P2 value.

Temperature Sensor at Flowmeter

- T at Flow Not Used
- T at Flow Used

Use this setting to indicate that a dedicated temperature sensor at the flowmeter is used. The dedicated temperature sensor is used in the flow compensation calculation. If this setting is set to T at Flow Not Used and the Compressor Stage Flow setting is set to Suction Sensor Flow, the temperature at the flow meter is assumed to be the T1 value. If this setting is set to T at Flow Not Used and the Compressor Stage Flow setting is set to Discharge Sensor Flow, the temperature at the flow meter is assumed to be the T2 value. If this setting is set to T at Flow Not Used and the

Compressor Stage Flow setting is set to Upstream Stage Flow + Sensor Flow, Upstream Stage Flow – Sensor Flow, Downstream Stage Flow + Sensor Flow, or Downstream Stage Flow – Sensor Flow, the temperature at the flow meter is assumed to be the side-stream temperature value.

Gas Characteristics Page

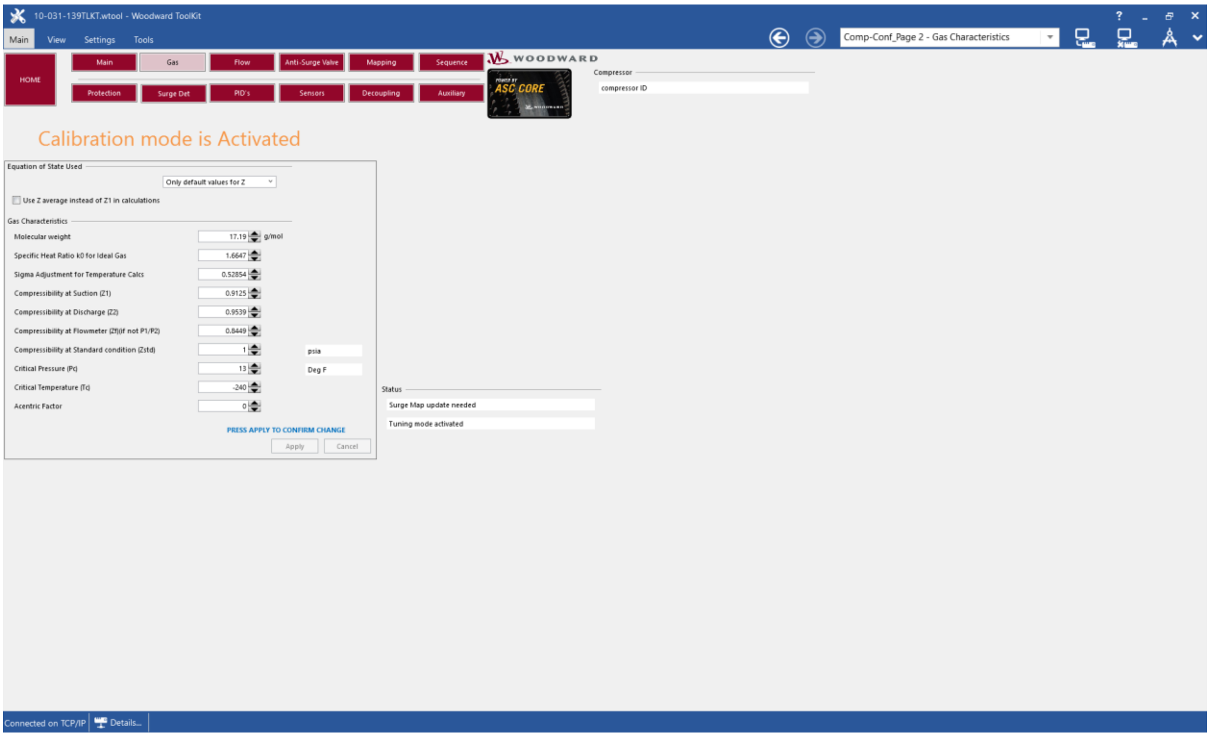

Figure 4-11. Gas Characteristics Page

Equation of State Used

- Only Default Values for Z
- Redlich Kwong (RK)
- Redlich Kwong Soaves (RKS)
- Peng Robinson (PR)
- Peng Robinson Gasem (PRG)
- Lee Kesler Plocker (LKP)

An equation of state (EOS) must be selected if it is required to calculate compressibility values based on measured pressures and temperatures. In most cases, it is acceptable to use default values for compressibility.

The RSK EOS is recommended for hydrogen and chlorine. The PR EOS is recommended for CO2. The PRG EOS is recommended for heavy hydrocarbons. The LKP EOS is recommended for air, light hydrocarbons, and ammonia.

IMPORTANT	**When an EOS has been selected, it is required to know the critical pressure (PC) and the critical temperature (TC) of the gas. Except for RK, the acentric factor is also required. Do not select an EOS if these values are not known.**

When an EOS is selected, a panel appears on the right side of the screen. This panel contains the EOS HELP TOOL. This tool will calculate the expected compressibility factor, and the expected isentropic exponent based on pressure, temperature, TC, PC, and the acentric factor. It can be used to confirm the compressibility default values provided by the compressor manufacturer. It can also be used to confirm that the selected EOS is appropriate for the application.

EOS HELP TOOL Pressure
Enter the pressure in the units defined by the Pressure Unit at Sensors setting. This pressure is used to calculate the displayed Actual Compressibility Factor and the Real Gas Specific Heat Ratio (or isentropic exponent).

EOS HELP TOOL Temperature
Enter the temperature in the units defined by the Temperature Unit setting. This temperature is used to calculate the displayed Actual Compressibility Factor and the Real Gas Specific Heat Ratio (or isentropic exponent).

Use Z Average Instead of Z1 in Calculations
By default, polytropic head calculations in the ASCE use suction compressibility. In some cases, compressor manufacturers use the average of suction and discharge compressibility. This option can be enabled to replace suction compressibility with average compressibility in polytropic head calculations.

Molecular Weight
Enter the gas molecular weight in units of g/mol. Deviations smaller than 15% from the entered value are generally acceptable and will not affect the accuracy of the anti-surge controller. This input should be set according to the compressor performance map and datasheet.

Specific Heat Ratio for Ideal Gas
The specific heat ratio is also known as the isentropic exponent. For an ideal gas, the isentropic exponent is the ratio of specific heat at constant pressure to specific heat at constant volume. This value is used in the calculation of the sigma parameter.

Sigma Adjustment for Temperature Calculations
The compressor manufacturer typically provides an isentropic exponent (k) value that produces an accurate polytropic head estimate. In some applications, the isentropic exponent is also used to calculate suction or discharge temperature, depending on the available sensors. For real gasses, the isentropic exponent that results in an accurate polytropic head calculation might not result in an accurate temperature calculation. When the calculated temperature differs significantly from the manufacturer's estimate, this input can be used to adjust sigma (a function of k) and compensate for differences in the isentropic exponent.

Compressibility at Suction
Enter the gas compressibility at suction conditions. Although the ASCE can calculate compressibility factors while running, it is mandatory to set the default value based on the compressor performance map and datasheet. This value is used in surge limit line calculations.

Compressibility at Discharge
Enter the gas compressibility at discharge conditions. Although the ASCE can calculate compressibility factors while running, it is mandatory to set the default value based on the compressor performance map and datasheet. This value is used in surge limit line calculations.

Compressibility at Flow Meter
Enter the gas compressibility at the conditions found at the flow meter location. If Compressor Stage Flow is set to Suction Sensor Flow or Discharge Sensor Flow, this value is not used. Instead, Compressibility at Suction or Compressibility at Discharge is used in the flow compensation calculation.

Compressibility at Standard Conditions
Enter the gas compressibility at the standard pressure and temperature conditions.

Critical Pressure (Pc)
Enter the critical pressure in the units defined with the Pressure Unit at Sensors setting. This value is only required if an equation of state is used to calculate compressibility.

Critical Temperature (Tc)
Enter the critical temperature in the units defined with the Temperature Unit setting. This value is only required if an equation of state is used to calculate compressibility.

Acentric Factor
Enter the acentric factor. This value is only required if an equation of state is used to calculate compressibility (except for RK method).

Flow Element Page

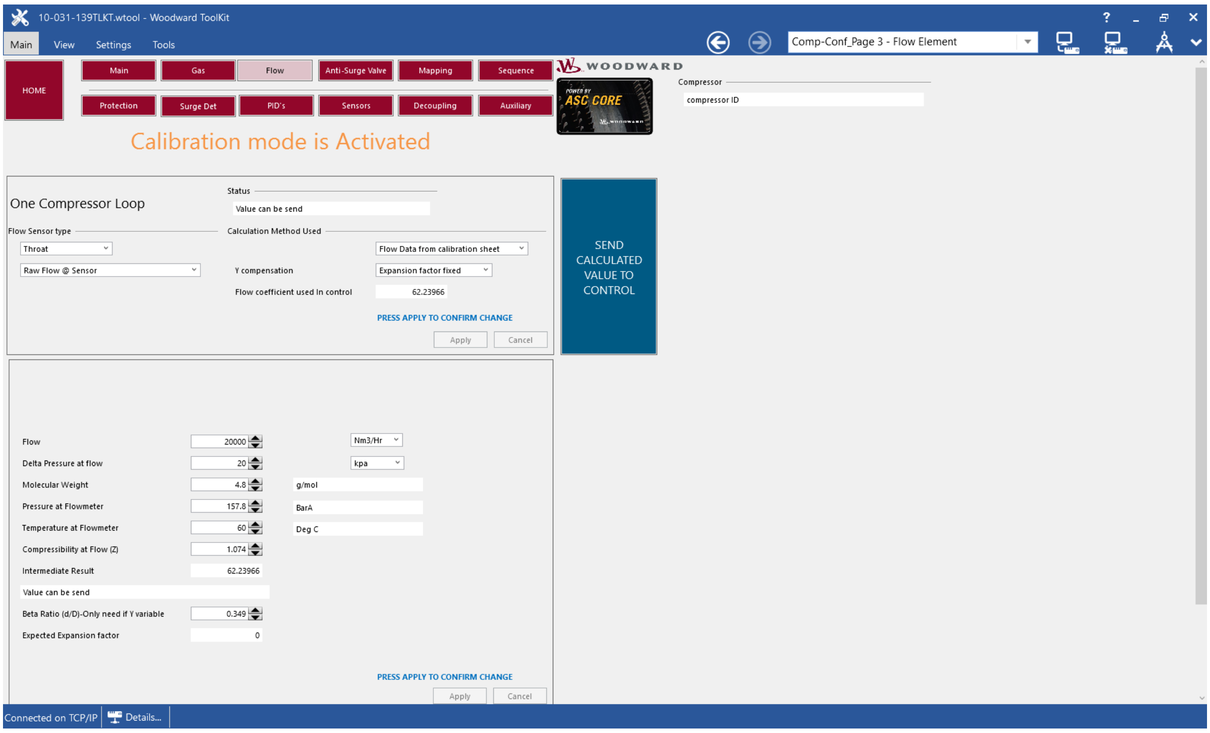

Figure 4-12. Flow Element Page

This page is used to calculate the flow element coefficient. This parameter is critical for anti-surge control. There are three methods for flow element coefficient calculation. Based on the selected method, the configuration options presented on this page will change.

Flow Element Type
- Orifice Plate
- Throat
- Long Radius Nozzle
- Venturi Nozzle
- Venturi Tube
- Annubar
- V-Cone
- Other

The flow element type setting is only used by the variable expansion factor logic.

Flow Signal Type
- Raw Flow at Sensor
- Square Root at Sensor
- Square Root and Compensation at Sensor

Select Raw Flow at Sensor if the transmitter signal is in pressure differential units. This is the preferred flow signal type due to its minimal latency.

Select Square Root at Sensor if the transmitter takes the square root of the differential pressure before sending the signal to the control system. This method is not preferred because the square root calculation in the transmitter can add significant delay to the signal.

Select Square Root and Compensation at Sensor if the transmitter does full pressure and temperature compensation before sending the signal to the control system. The signal from the transmitter could be standard flow or mass flow units. The signal MUST be converted to kg/s units in the software before it is input to the ASCE.

Calculation Method Used

- Flow Data from Calibration Sheet
- Flow Data from Geometry
- Manual Setting of Flow Coefficient

This setting controls the display of other configuration parameters on this page. Select Flow Data from Calibration Sheet to enter calibration data from a known flow and differential pressure condition. Select Flow Data from Geometry to calculate the flow coefficient using the flow meter geometry. Select Manual Setting of Flow Coefficient if the flow coefficient is calculated outside of the ASCE instead of using the ASCE flow coefficient calculation logic.

Flow Coefficient Used in Control

This display shows the coefficient currently being used by the ASCE to calculate flow. This value might not match the value displayed as the Intermediate Result of each calculation method. Any time a change is made to the calculation inputs, the Intermediate Result is immediately updated. The new calculation shown in Intermediate Result is not used in the flow calculation until the SEND CALCULATED VALUE TO CONTROL button is pressed. This multi-step process prevents accidental changes to the flow calculation. In addition, the ASCE includes logic that will prevent excessive changes to the flow calculation while the compressor is running. If the new coefficient is within 5% of the current coefficient, the flow calculation can be updated with the new coefficient. The 5% protection is overridden when the compressor is in a safe state for larger changes (for example, when the compressor is shutdown).

Y Compensation

- Expansion Factor Fixed
- Variable Expansion Factor

When the ratio (Pressure - Delta Pressure) / Pressure is less than 0.98 or when the expected expansion factor value is below 0.96, the variation of the expansion factor might have a significant impact on the accuracy of the flow calculation. In that case an option is available to correct for the expansion factor variation.

When Expansion Factor Fixed is selected, the flow coefficient will only use the data sheet parameters. When Variable Expansion Factor is selected, the flow coefficient will be continuously updated based on the measured pressure at the flow meter and measured flow element pressure differential. To use the variable expansion factor function, the beta ratio is needed even if the geometry method is not used for the flow coefficient calculation. If the flow coefficient is entered manually, the Variable Expansion Factor cannot be used.

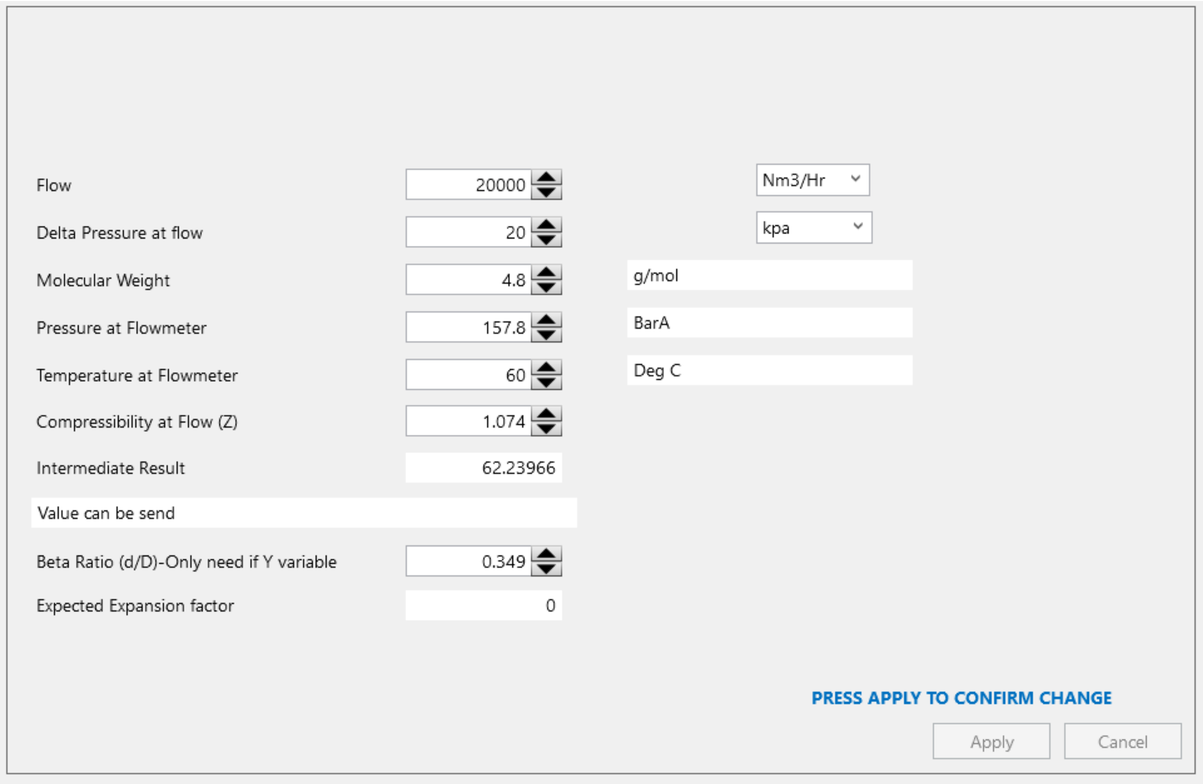

Figure 4-13. Flow Data from Calibration

Flow (in Flow Data from Calibration method)
Enter the flow value from the data sheet and select the flow units. Flow can be entered as standard flow or mass flow.

Table 4-7. Flow Unit Options

Metric Options	Imperial Options
Nm^3/h	SCFM x 1000
kg/h	lb/h

Delta Pressure at Flow (in Flow Data from Calibration method)
Enter the flow element differential pressure corresponding to the flow value entered in the previous setting and select the differential pressure units.

Table 4-8. Differential Pressure Unit Options

Metric Options	Imperial Options
kPa	psi
mbar	inch H_2O
mm H_2O	inch Hg
mm Hg	

Molecular Weight (in Flow Data from Calibration method)
Enter the molecular weight from the data sheet. The units are always g/mol. The calibration gas may be different than the actual process gas.

Pressure at Flow Meter (in Flow Data from Calibration method)
Enter the pressure at the flow meter shown on the data sheet. The units must match the units selected with the Pressure Unit at Sensors setting.

Temperature at Flow Meter (in Flow Data from Calibration method)
Enter the temperature at the flow meter shown on the data sheet. The units must match the units selected with the Temperature Unit setting.

Compressibility at Flow (in Flow Data from Calibration method)
Enter the compressibility factor at the flow meter shown on the data sheet.

Intermediate Result (in Flow Data from Calibration method)
The intermediate result displays the flow coefficient calculated from the above inputs. The button SEND CALCULATED VALUE TO CONTROL will save this value for use in the flow calculation. A status display below the intermediate result will indicate if conditions have been met to permit the flow coefficient to be updated.

Beta Ratio (in Flow Data from Calibration method)
Enter the beta ratio (d/D). The value is only needed in the Flow Calibration from Data Sheet method if a variable expansion factor is used.

Expected Expansion Factor (in Flow Data from Calibration method)
The expected expansion factor displays the expansion factor calculated from the above inputs. This output can be used to evaluate the need for a variable expansion factor by checking multiple calibration points across the operating range of the compressor.

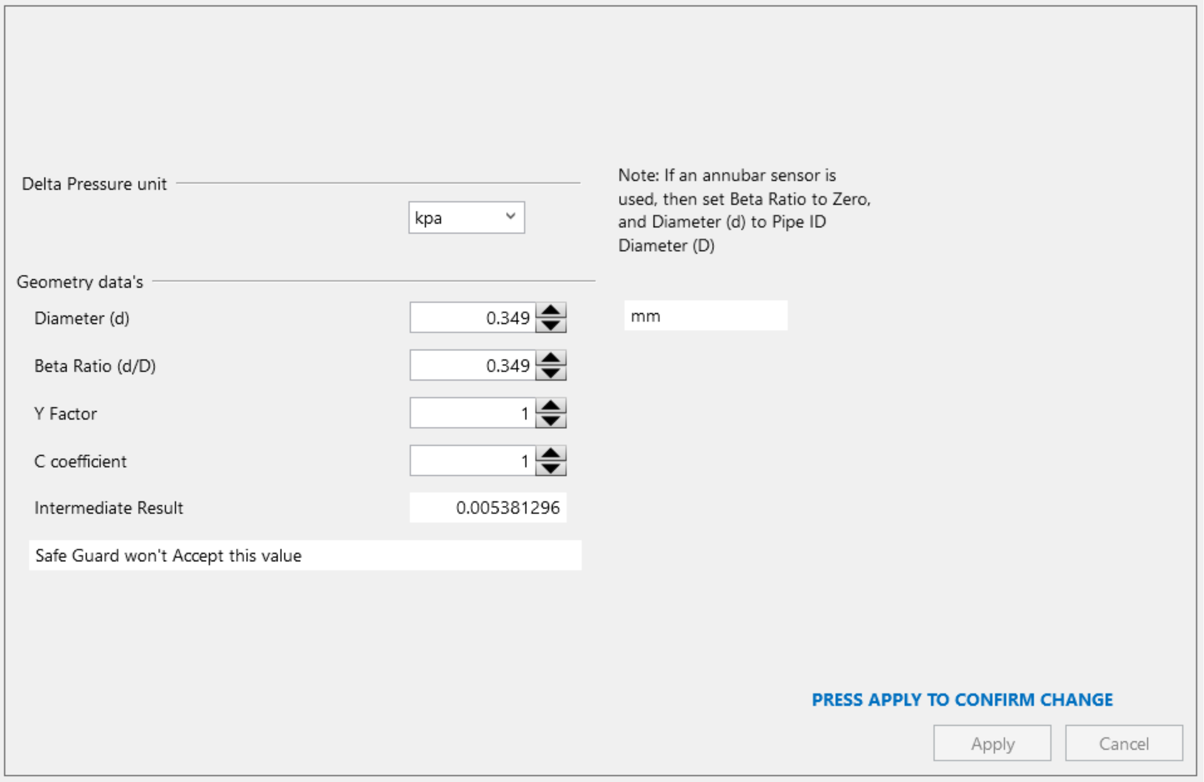

Figure 4-14. Flow Data from Geometry

Delta Pressure Unit (in Flow Data from Geometry method)
Select the differential pressure option that matches the units of the signal received from the transmitter.

Diameter (in Flow Data from Geometry method)
Enter the diameter of the flow element. The units will be inches or millimeters, depending on the unit system.

Beta Ratio (in Flow Data from Geometry method)
Enter the beta ratio (d/D).

Factor (in Flow Data from Geometry method)
Enter the expansion factor of the flow element.

C Coefficient (in Flow Data from Geometry method)
Enter the discharge coefficient of the flow element.

Intermediate Result (in Flow Data from Geometry method)
The intermediate result displays the flow coefficient calculated from the above inputs. The button SEND CALCULATED VALUE TO CONTROL will save this value for use in the flow calculation. A status display below the intermediate result will indicate if conditions have been met to permit the flow coefficient to be updated.

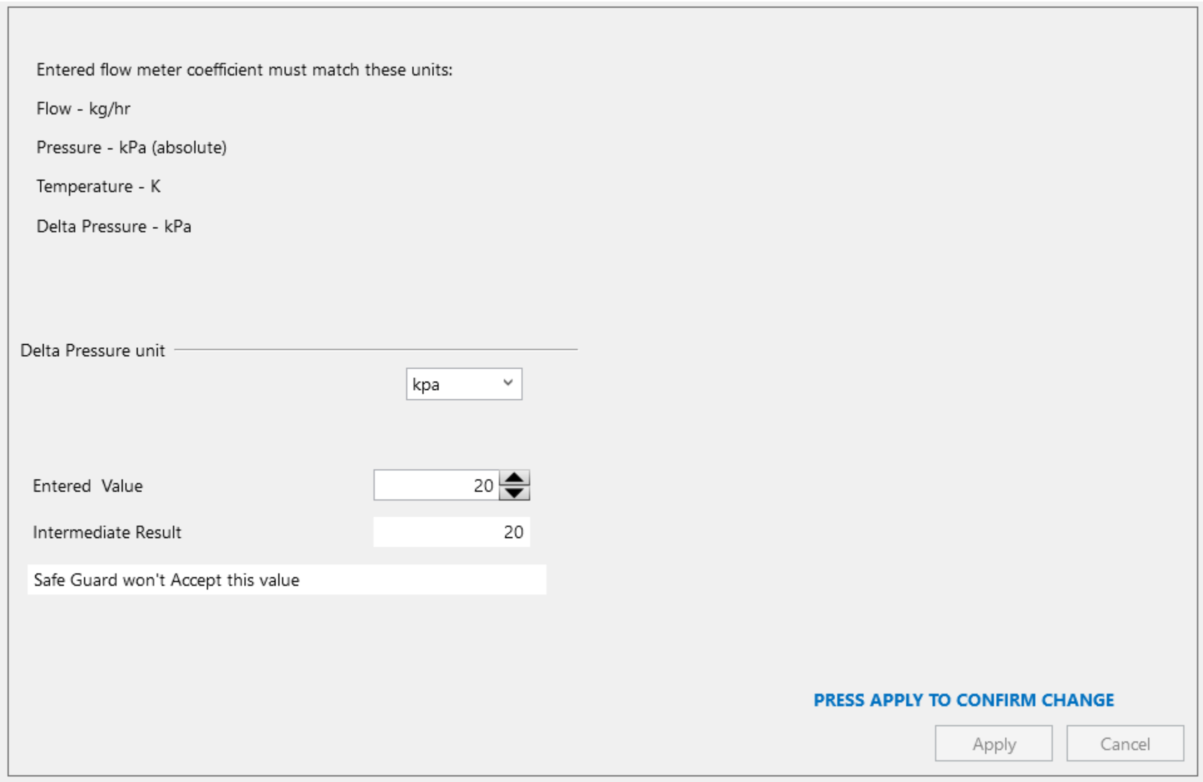

Figure 4-15. Manual Setting of Flow Coefficient

Delta Pressure Unit (in Manual Setting of Flow Coefficient method)
Select the differential pressure option that matches the units of the signal received from the transmitter.

Entered Value (in Manual Setting of Flow Coefficient method)
Enter a flow coefficient that has been calculated outside of the ASCE.

IMPORTANT	**If the flow coefficient is calculated outside of the ASCE and entered manually, the coefficient must be calculated using these units:** **Flow – kg/hr** **Pressure – kPa (absolute)** **Temperature – K** **Differential Pressure - kPa**

Intermediate Result (in Manual Setting of Flow Coefficient method)
The intermediate result displays the flow coefficient from the Entered Value setting. The button SEND CALCULATED VALUE TO CONTROL will save this value for use in the flow calculation. A status display below the intermediate result will indicate if conditions have been met to permit the flow coefficient to be updated.

Anti-surge Valve Settings Page

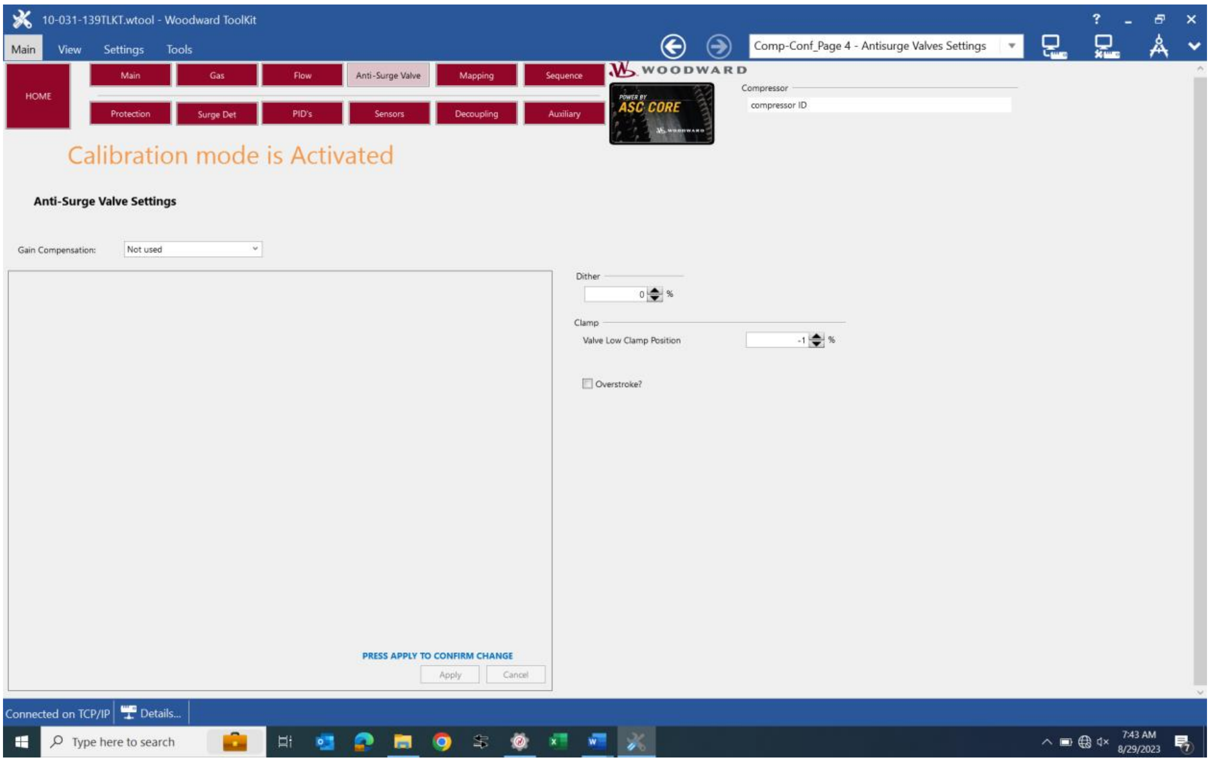

Figure 4-16. Anti-surge Valve Settings Page

Gain Compensation

There are three options for gain compensation. This setting will determine which additional settings are displayed on the page.

- Not Used
- Linearization Curve Used
- Compensation Based on Cv

Linearization Curve

If this option is selected for gain compensation, a 13 point curve table is displayed. This table can be used to linearize the demand-to-flow relationship for a valve that does not have a linear characteristic.

Normal Flow Value (in Compensation Based on Cv method)

Enter the typical full-open actual volumetric flow through the anti-surge valve in the displayed units. The units are determined by the Actual Flow Unit selection on the Main Configuration Page and by the Multiply Factor on Actual Flow selection on the Mapping Page. This value is tuned during commissioning as described in the Gain Compensation section of Chapter 2.

Anti-surge Valve Cv (in Compensation Based on Cv method)

Enter the Cv of the anti-surge valve.

If Kv is known instead of Cv, convert the Kv value with this equation: Cv = Kv / 0.865.

Dither

The dither function which will generate a pulsation signal at high frequency. Enter the amount (in %) to be added to the original valve demand by the dither function.

Valve Low Clamp Position

If it is necessary to limit the minimum position of the anti-surge valve, enter a value (in %) greater than zero here.

Overstroke

The overstroke function can be used to ensure that the valve is fully seated in the open and closed position. Check the box to enable this function. Overstroke Open and Overstroke Closed settings will be shown. Enter a value (in %) in each setting. When the valve is nearly closed, the negative value in Overstroke Closed will be added to the valve demand to drive the valve fully closed. When the valve is nearly open, the positive value in Overstroke Open will be added to the valve demand to drive the valve fully open.

Mapping Page

The Mapping Page is used for configuring the surge limit line and the choke limit line. The various sections of the Mapping Page (Rate Conditions, Surge Map, Surge Display, X-Y Curves, Choke Map, Choke Display) are accessed using the navigation buttons on the left side of the page. The Rated Conditions must be configured before the other sections are used.

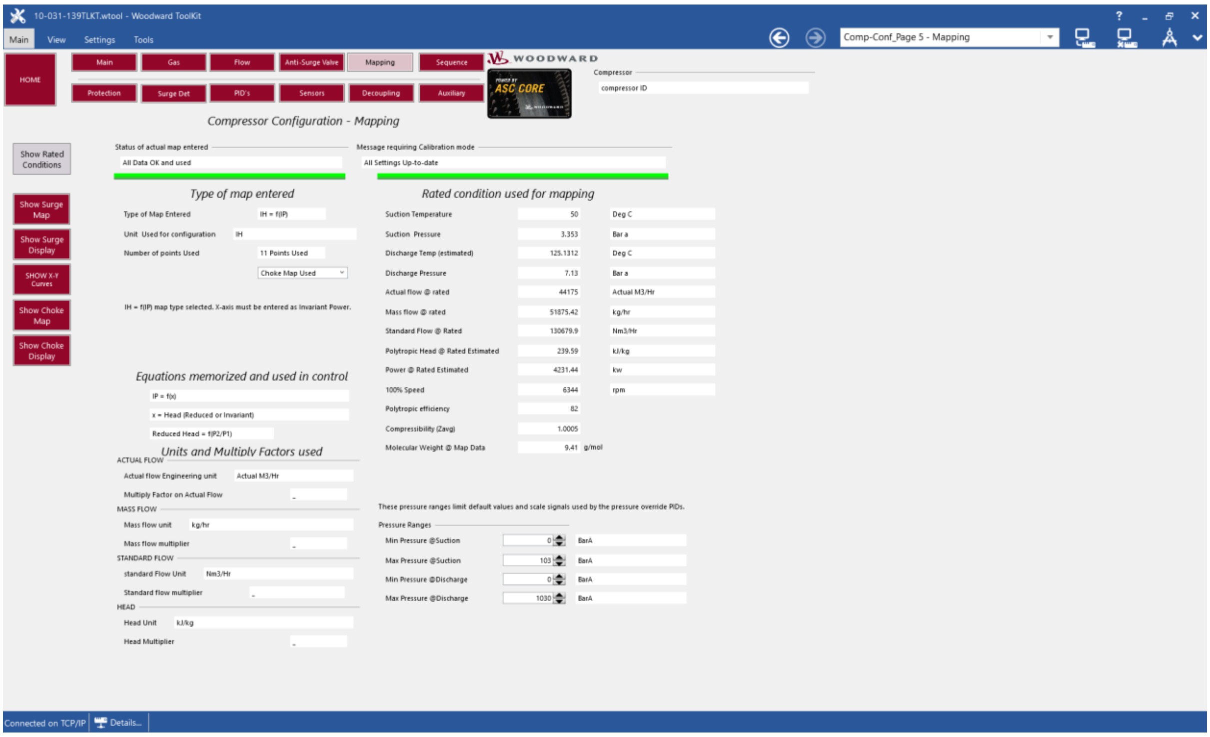

Figure 4-17. Mapping Page (Rated Conditions Section)

Type of Map Entered (in Rated Conditions section)

- P2 = f(flow) [default]
- P2/P1 = f(flow)
- H = f(flow)
- IH = f(IF)
- IH = f(IP)

Select one of the five map types to configure. The map type selection is often based on the maps provided by the compressor manufacturer. If the compressor manufacturer provides maps for multiple suction conditions and gas compositions, IH = f(IF) is the recommended map type. The P2, P2/P1, and H options are considered non-invariant map types because the surge limit line associated with configured points will depend on the suction conditions. Both IH map types are considered invariant maps because the configured surge limit line will not depend on suction conditions. If a flow measurement is not available, the IH=f(IP) map may be used. This map requires a motor current or driver power input, as well as a compressor speed input for variable speed compressors.

If P2 = f(flow) is selected, the y-axis of the map will be discharge pressure. The x-axis will be the flow selected with the Type of Flow for Mapping setting. The ASCE will convert the entered points to Reduced Head = f(Q^2/H) points using the configurated rated conditions.

If P2/P1 = f(flow) is selected, the y-axis of the map will be the pressure ratio. The x-axis will be the flow selected with the Type of Flow for Mapping setting. The ASCE will convert the entered points to Reduced Head = f(Q^2/H) points using the configurated rated conditions.

If H = f(flow) is selected, the y-axis of the map will be polytropic head. The x-axis will be the flow selected with the Type of Flow for Mapping setting. The ASCE will convert the entered points to Reduced Head = f(Q^2/H) points using the configurated rated conditions.

If IH = f(IF) is selected, the y-axis of the map will be the invariant head. The x-axis will be the invariant flow. For this map type, the ASCE does not need to convert to another coordinate system using the rated conditions.

If IH = f(IP) is selected, the y-axis of the map will be the invariant head. The x-axis will be the invariant power. For this map type, the ASCE does not need to convert to another coordinate system using the rated conditions.

Number of Points Used (in Rated Conditions section)
Select the number of points to configure on the surge limit line. The minimum is 1 and the maximum is 12.

Choke Map (in Rated Conditions section)

- Choke Map Not
- Choke Map Used

Select a choke map option. In many cases, the choke limit line is not configured. If the application includes an output driving an anti-choke valve, the choke limit line must be configured. The number of points in the choke limit line will follow the selection for number of points in the surge limit line. However, the maximum number of points in the choke limit line is 6. If more than 6 points are configured in the surge limit line, the choke limit line will only have 6 points to configure.

Map Pointer (in Rated Conditions section)

- Head (Reduced or Invariant)
- Head from Speed
- Head from IGV Position
- Head from IGV Shift

This setting determines the method used to find an equivalent point on the surge limit line for a given operating point. The distance between the operating point and the equivalent point on the surge limit line is the distance from surge parameter (WSPV).

The default option is Head (Reduced or Invariant). For the non-invariant map input types (P2, P2/P1, H), the map pointer is reduced head. Distance from surge is determined by finding a point on the surge limit line that has the same reduced head as the operating point's reduced head. For the invariant map types (IH), the map pointer is invariant head. Distance from surge is determined by finding a point on the surge limit line that has the same invariant head as the operating point's invariant head.

If Head from Speed is selected, the equivalent point on the surge limit line will be selected based on the speed at the current operating point. If Head from IGV Position is selected, the equivalent point on the surge limit line will be selected based on the IGV position at the current operating point.

IMPORTANT	**Head from Speed should not be selected if gas composition is not constant or nearly constant, or if specific heat ratio changes significantly due to large suction condition variations.**

Head from IGV Shift is the recommended option when the compressor has variable position IGVs and the compressor manufacturer provides maps for multiple suction conditions and gas compositions. If this option is selected, the surge limit line must be configured for a single IGV position. Surge Limit Line Shift and Choke Limit Line Shift curve points will be displayed on the right side of the page. This option should only be used with the invariant map types, IH = f(IF) and IH = f(IP). An IGV position feedback input or an IGV demand output must be configured in the ASCE.

Surge Limit Line Shift (in Rated Conditions section)
The Surge Limit Line Shift tables are only displayed if the map pointer is set to Head from IGV Shift. The first table is IGV position (x-axis) vs. IH shift factor (y-axis). The base surge limit line IH values are multiplied by the output of the table as IGV position changes. The second table is IGV position (x-axis) vs. IF or IP shift factor (y-axis). The base surge limit line IF or IP values are multiplied by the output of the table as IGV position changes. Each table contains 12 points. The first point and the last point should be used to limit the min and max table output and avoid extrapolation errors in case the IGV position goes outside of the expected range. The remaining 10 points can be used to provide unique shift factors for up to 10 IGV positions on a map.

Choke Limit Line Shift (in Rated Conditions section)
The Choke Limit Line Shift tables are only displayed if the map pointer is set to Head from IGV Shift. The first table is IGV position (x-axis) vs. IH shift factor (y-axis). The base choke limit line IH values are multiplied by the output of the table as IGV position changes. The second table is IGV position (x-axis) vs. IF or IP shift factor (y-axis). The base choke limit line IF or IP values are multiplied by the output of the table as IGV position changes. Each table contains 12 points. The first point and the last point should be used to limit the min and max table output and avoid extrapolation errors in case the IGV position goes outside of the expected range. The remaining 10 points can be used to provide unique shift factors for up to 10 IGV positions on a map.

Type of Flow for Mapping (in Rated Conditions section)
Choose the flow type that will be used to configure map points.

- Actual Flow
- Mass Flow
- Standard Flow

Note that this setting is not used if Type of Map Entered is set to IH = f(IF) or IH = f(IP). For these map types, invariant flow or invariant power are always used.

Multiply Factor on Actual Flow (in Rated Conditions section)
If actual flow values on the map are very large, a multiply factor can be applied to the entered map points. For example, if actual flow for a point is 120000 and the multiply factor is set to E+04, the map point would be entered as 12 instead of 120000 (12 * 10^4 = 120000).

- -
- X10
- X100
- E+03
- E+04
- E+05
- E+06
- E+07
- E+08

Multiply Factor on Mass Flow (in Rated Conditions section)
If mass flow values on the map are very large, a multiply factor can be applied to the entered map points. For example, if mass flow for a point is 120000 and the multiply factor is set to E+04, the map point would be entered as 12 instead of 120000 (12 * 10^4 = 120000).

- - [default]
- X10
- X100
- E+03
- E+04
- E+05
- E+06
- E+07
- E+08

Multiply Factor on Standard Flow (in Rated Conditions section)
If standard flow values on the map are very large, a multiply factor can be applied to the entered map points. For example, if standard flow for a point is 120000 and the multiply factor is set to E+04, the map point would be entered as 12 instead of 120000 (12 * 10^4 = 120000). There is also an option to

enter points in millions of standard cubic feet per day (MMSCFD) or millions of standard cubic meters per day (MMSCMD).

- - [default]
- X10
- X100
- E+03
- E+04
- E+05
- E+06
- E+07
- E+08
- MMSCFD or MMSCMD

Multiply Factor on Head (in Rated Conditions section)
If head values on the map are very large, a multiply factor can be applied to the entered map points. For example, if head for a point is 120000 and the multiple factor is set to E+04, the map point would be entered as 12 instead of 120000 (12 * 10^4 = 120000).

- - [default]
- X10
- X100
- E+03
- E+04
- E+05
- E+06
- E+07
- E+08

Suction Temperature (in Rated Conditions section)
Enter the suction temperature from the configured map. If the invariant map input option is used, enter the suction temperature from the most typical (rated or normal) suction condition.

Suction Pressure (in Rated Conditions section)
Enter the suction pressure from the configured map. If the invariant map input option is used, enter the suction pressure from the most typical (rated or normal) suction condition.

Discharge Temperature Estimate (in Rated Conditions section)
The discharge temperature calculated from other inputs is displayed here. Check this value against the predicted discharge temperature from the map or datasheet.

Actual Flow at Rated (in Rated Conditions section)
Enter the actual flow at the rated operating condition from the configured map. If the invariant map input option is used, enter the actual flow from the most typical (rated or normal) suction condition.

Mass Flow at Rated (in Rated Conditions section)
The mass flow calculated from other inputs is displayed here. Check this value against the rated mass flow from the map or datasheet.

Standard Flow at Rated (in Rated Conditions section)
The standard flow calculated from other inputs is displayed here. Check this value against the rated standard flow from the map or datasheet.

Polytropic Head at Rated (in Rated Conditions section)
The polytropic head calculated from other inputs is displayed here. Check this value against the rated polytropic head from the map or datasheet.

Power at Rated (in Rated Conditions section)
The required power calculated from other inputs is displayed here. Check this value against the rated power from the map or datasheet.

100% Speed (in Rated Conditions section)
Enter the 100% compressor speed in RPM from the configured map.

Polytropic Efficiency (in Rated Conditions section)
Enter the polytropic efficiency at the rated operating conditions from the configured map.

Pressure Ranges (in Rated Conditions section)
Enter the min and max values for suction pressure and discharge pressure. These settings are used to limit pressure default values and to scale the pressure values used by the pressure override controllers. Typically, these values are set to match the range of the pressure transmitters.

CONFIRM RATED CONDITIONS (in Rated Conditions section)
Click this button after all updates in the Rated Conditions section are complete. The ASCE will check the changes to determine if updates to the surge map are needed. The map status display at the top of the page will display a message indicating the need for map updates.

Power Source (in Rated Conditions section)
If the IH = f(IP) map type is used, the compressor stage power must be known for calculation of invariant power (IP). The ASCE includes an analog input for this purpose. The Power Source configuration specifies the type of signal used in the invariant power calculation.

- Power calculated from current
- Power direct input

In either case, the analog input MUST represent the power consumed by the compressor stage or stages that are protected by the anti-surge valve driven by the ASCE. If motor current is used, the analog input MUST be in Amps. If a direct power input is used, the analog input MUST be in kW. If motor current is used, *Motor Rated Current* and *Motor Rated Voltage* must be set correctly. These settings are not needed with a direct power input.

Motor Rated Current (in Rated Conditions section)
This setting must be correct if *Power Source* is set to Power calculated from current. The rated current is used in calculation of the load percent, which is used to find motor power factor and efficiency. Enter the value in Amps.

Motor Rated Voltage (in Rated Conditions section)
This setting must be correct if *Power Source* is set to Power calculated from current. The rated voltage is used in calculation of power from measured motor current. Enter the value in kW.

Mechanical Loss (in Rated Conditions section)
This setting applies to both *Power Source* options. Enter a percentage value that represents all mechanical losses between the driver output shaft and the compressor input shaft (for example, gear boxes).

Load vs Power Factor Table (in Rated Conditions section)
This table must be filled in correctly if the *Power Source* is Power calculated from current. The motor manufacturer should provide a chart or table showing the power factor as a function of load percent. Load percent is measured current divided by *Motor Rated Current*. The power factor is needed to calculate power from motor current.

Load vs Motor Efficiency Table (in Rated Conditions section)
This table must be filled in correctly if the *Power Source* is Power calculated from current. The motor manufacturer should provide a chart or table showing the motor efficiency as a function of load percent. Load percent is measured current divided by *Motor Rated Current*. The motor efficiency is needed to calculate power from motor current.

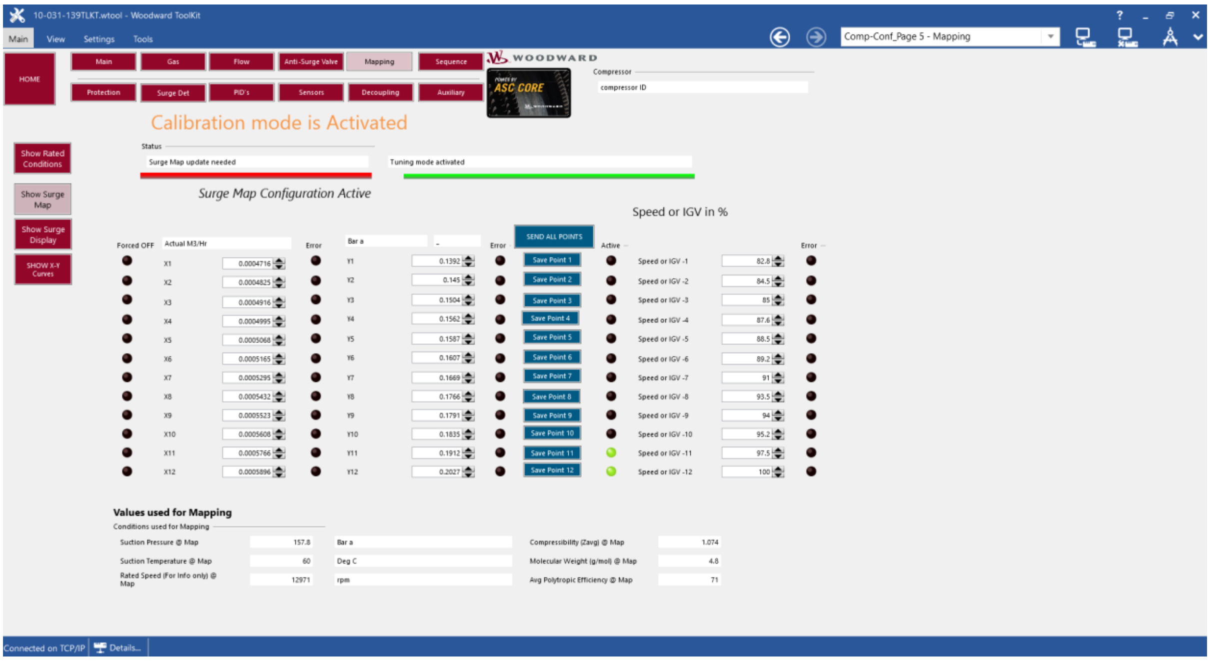

Figure 4-18. Mapping Page (Surge Map Section)

Surge Map Table (in Surge Map section)
The surge map table is used to configure the points on the surge limit line. Enter flow, invariant flow, or invariant power (depending on map type selected) in the first column of the table. The required units are displayed at the top of the column. Enter P2, P2/P1, H, or invariant head in the second column of the table (depending on map type selected). The required units are displayed at top of the column. Be sure to take into account any multipliers configured in the Rated Conditions section. Multipliers will be included in the unit displays. The points entered in the surge map table must be taken from the map that was used to specify the rated condition. There is an exception to this rule if an invariant map type is selected. Invariant map points are independent of the suction condition.

The Forced OFF lights will turn on (red) if an error in the configuration is forcing the point to be removed from the surge limit line or if the point is not needed due to the number of points configured. For example, if the configured number of points is 6, the Forced OFF light will be on for points 7 through 12.

The third data entry column in the table is used for speed or IGV position corresponding to each point. If the map type is P2, P2/P1, or H, and the compressor operates at multiple speeds, the speed is entered in the third column as a percentage of the 100% speed configured in the Rated Conditions section. For example, if the configured 100% speed is 12000 RPM and the map point in the second row corresponds to a speed of 9000 RPM, 75 would be entered in the third column of the second row (9000 / 12000 * 100 = 75%). If an invariant map type is selected, the speed values must be entered as reduced speed (%RPM / acoustic velocity) instead of %RPM.

If the map type is P2, P2/P1, or H, and the compressor operates at multiple IGV positions, the IGV position is entered in the third column as a percentage. The IGV positions on the map should be scaled such that 0% corresponds to the minimum flow position and 100% corresponds to the maximum flow position. Therefore, the first row in the table would have an IGV position of 0% and the last row in the table would have an IGV position of 100%.

Each data entry column has an error light displayed on the right side the column. Each entered point must be greater than the previous point. For example, X2 must be greater than X1, Y2 must be greater than Y1, and Speed 2 must be greater than Speed 1. If this rule is violated, the error light will turn on and it will not be possible to save the point. There is an exception to this rule if Head with IGV Shift is chosen for the map pointer. In this case, a surge limit line is configured for a single IGV position. The IGV position entered in the third column of the surge map table will be the same for every point, typically 0% for the minimum flow position.

The Active column contains lights that indicate which points are currently being used in the WSPV calculation. These lights will update as the operating point's reduced head value changes.

Save Points (in Surge Map section)
Each point has a Save Point button associated with it. The data entered for the point will not be used by the ASCE until it has been saved using this button. The SEND ALL POINTS button will save every point. These buttons will be hidden if there is an error in any configured points.

Values Used for Mapping (in Surge Map section)
The values displayed in this area show the suction conditions that were configured in the Rated Conditions section. For the non-invariant map types, the points configured in the surge map table must be taken from a map that corresponds to these suction conditions.

NOTICE	**Entry of surge map data is critical and must match the actual surge map data from a surge test or the data delivered by the compressor manufacturer.**

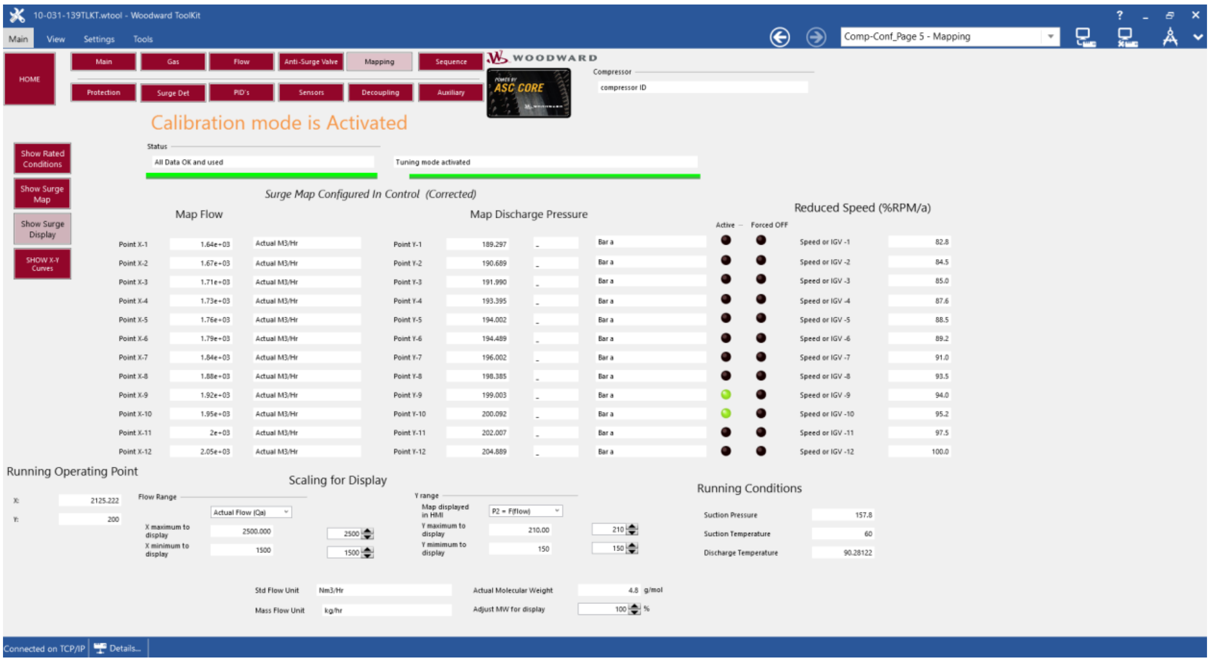

Figure 4-19. Mapping Page (Surge Display Section)

Surge Map Display Table (in Surge Display section)
The surge map display table shows the x and y points adjusted for deviations from the rated suction condition. If the current operating conditions do not match the rated conditions and an invariant map type is not used, the values in this section will not match the values configured in the Surge Map section. The Active and Forced OFF lights have the same function as those described in the Surge Map section above.

Flow Displayed (in Surge Display section)
- Actual Flow (Qa)
- Mass Flow (Qm)
- Standard Flow (Qs)

Select the flow to display in the X-Y Curves section. This setting also determines the flow displayed in the HMI, if applicable. The x-axis column of the table and the visible min / max settings will update based on this selection. This setting is not used with the invariant map types.

X Maximum to Display (in Surge Display section)
Enter the maximum value for the x-axis of the X-Y Curves. A unique maximum value can be set for each flow type.

X Minimum to Display (in Surge Display section)

Enter the minimum value for the x-axis of the X-Y Curves. A unique minimum value can be set for each flow type.

Map Type Displayed (in Surge Display section)

- P2 = f(flow)
- P2/P1 = f(flow)
- H = f(flow)
- IH = f(IF or IP)
- Hr = f(Q^2/H)

Select the map type to display in the X-Y Curves section. This setting also determines the map type displayed in the HMI, if applicable. The y-axis column of the table and the visible min / max settings will update based on this selection. Note that an additional map type is available for display that is not a map type used for configuration, Hr = f(Q^2/H). This map type is the coordinate system that all non-invariant input map types are converted to for internal calculations.

Y Maximum to Display (in Surge Display section)

Enter the maximum value for the y-axis of the X-Y Curves. A unique maximum value can be set for each map type.

Y Minimum to Display (in Surge Display section)

Enter the minimum value for the y-axis of the X-Y Curves. A unique minimum value can be set for each map type.

Running Operating Point (in Surge Display section)

The X and Y value of the current operating point are displayed here. The displayed values will change based on the Map Type Displayed and the Flow Displayed settings. For example, if the Map Type Displayed is P2 = f(flow) and the Flow Displayed is Actual Flow (Qa), the displayed X value will be the current actual flow and the displayed Y value will be the current discharge pressure.

Adjust MW for Display (in Surge Display section)

This setting can be used to adjust the molecular weight to match the actual gas composition. Molecular weight adjustments are needed for accurate display of map points, but they are not necessary for accurate anti-surge control. In most cases, the molecular weight is not adjusted, and the rated condition molecular weight is used for all internal calculations.

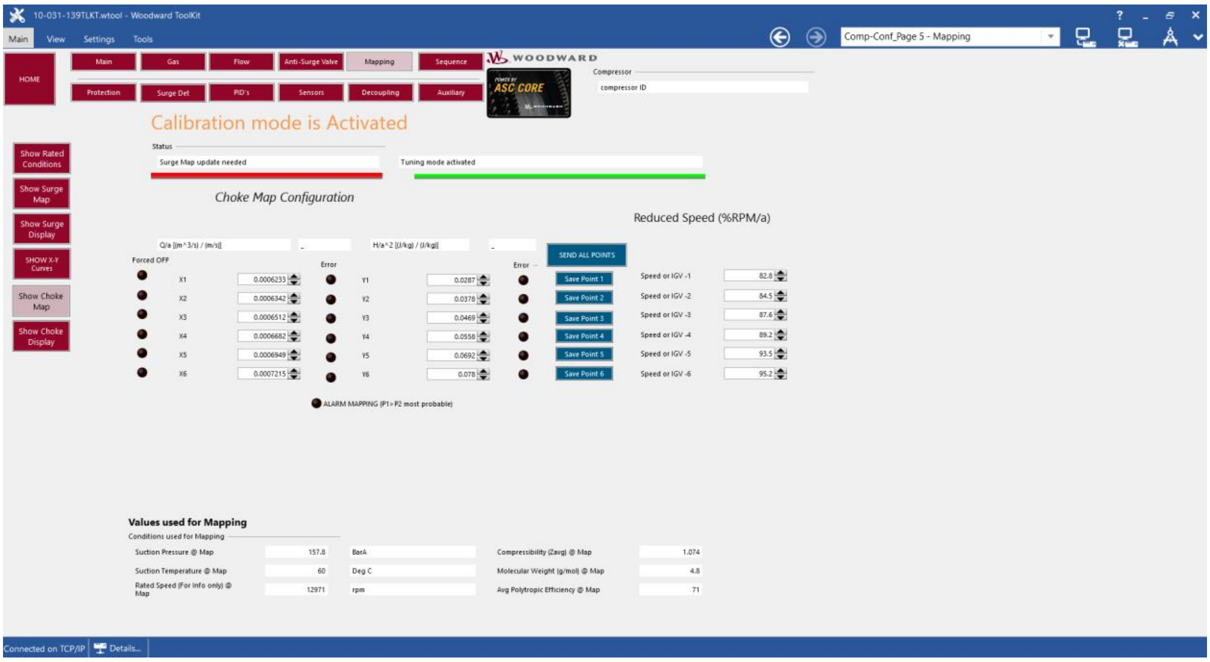

Figure 4-20. Mapping Page (Choke Map Section)

Choke Map Table (in Choke Map section)

The choke limit line is configured in this section. Configuration of the choke limit line follows the same procedures as those used for the surge limit line. Refer to the Surge Map Table section for additional details.

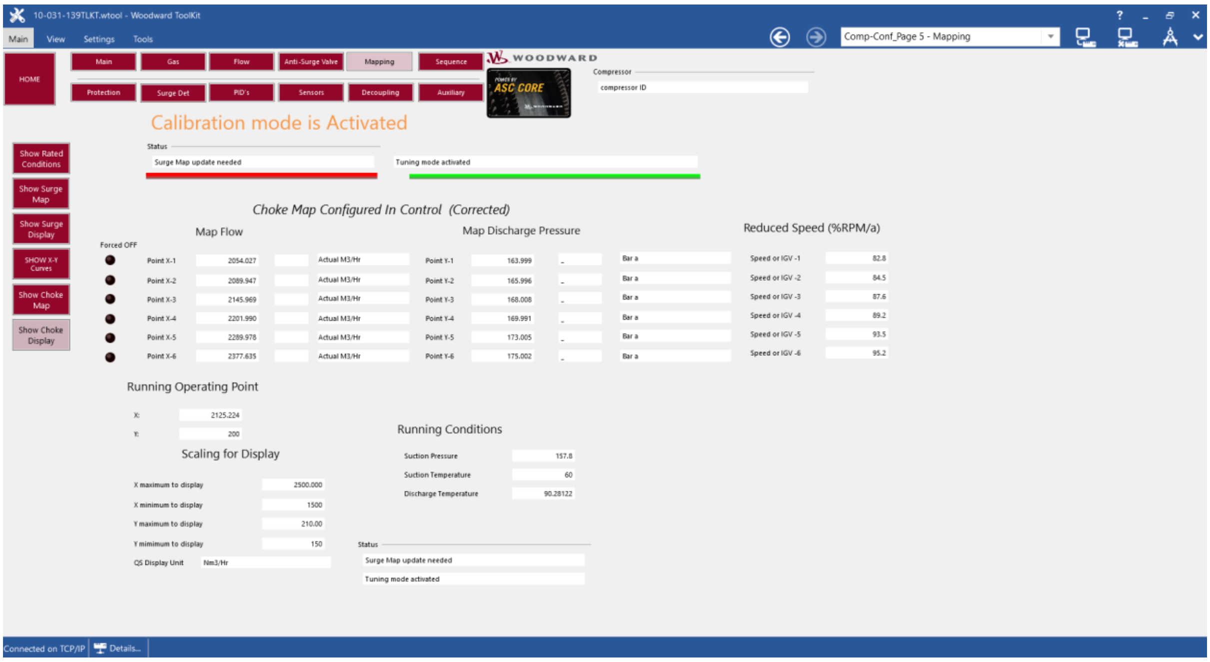

Figure 4-21. Mapping Page (Choke Display Section)

Choke Map Display Table (in Choke Display section)

The choke map display table has the same function as the surge map display table, except that it shows choke limit line display points. There are no settings to change in this section. Refer to the description of the surge map display table for details.

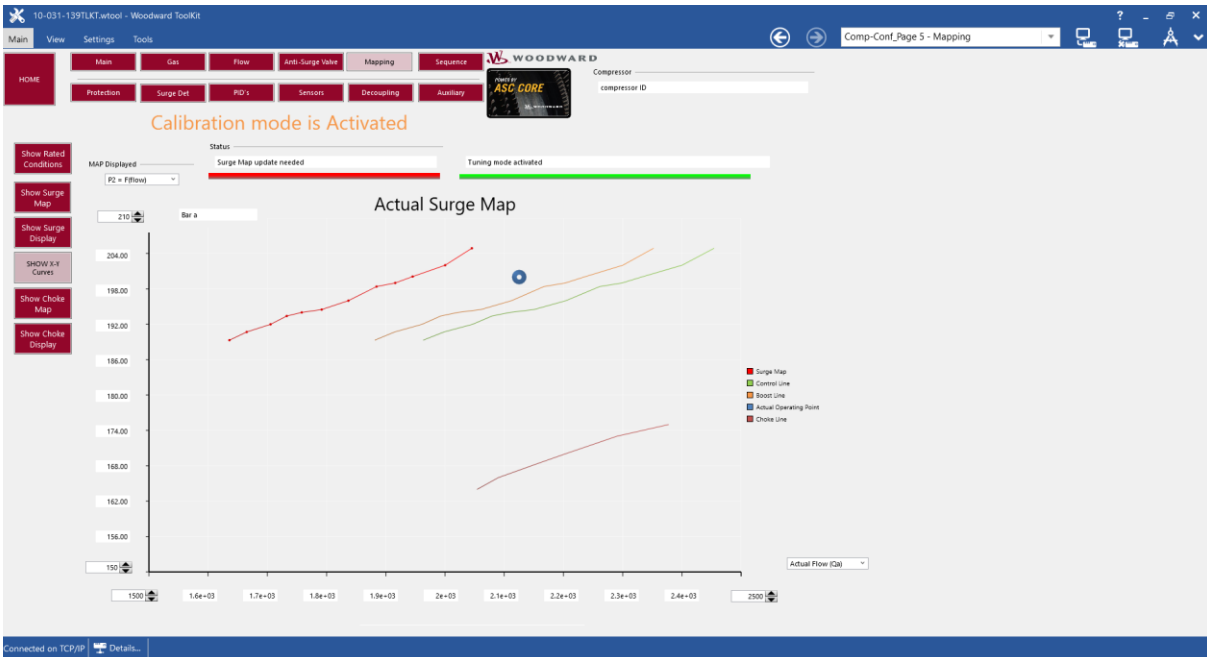

Figure 4-22. Mapping Page (X-Y Curve Section)

X-Y Curves

This section displays the surge limit line, boost line, surge control line, and choke limit line with the points adjusted for the current suction conditions. Map display type and flow type can be selected in this section, and axis limits can be adjusted as well. The operating point is also displayed.

Sequence Page

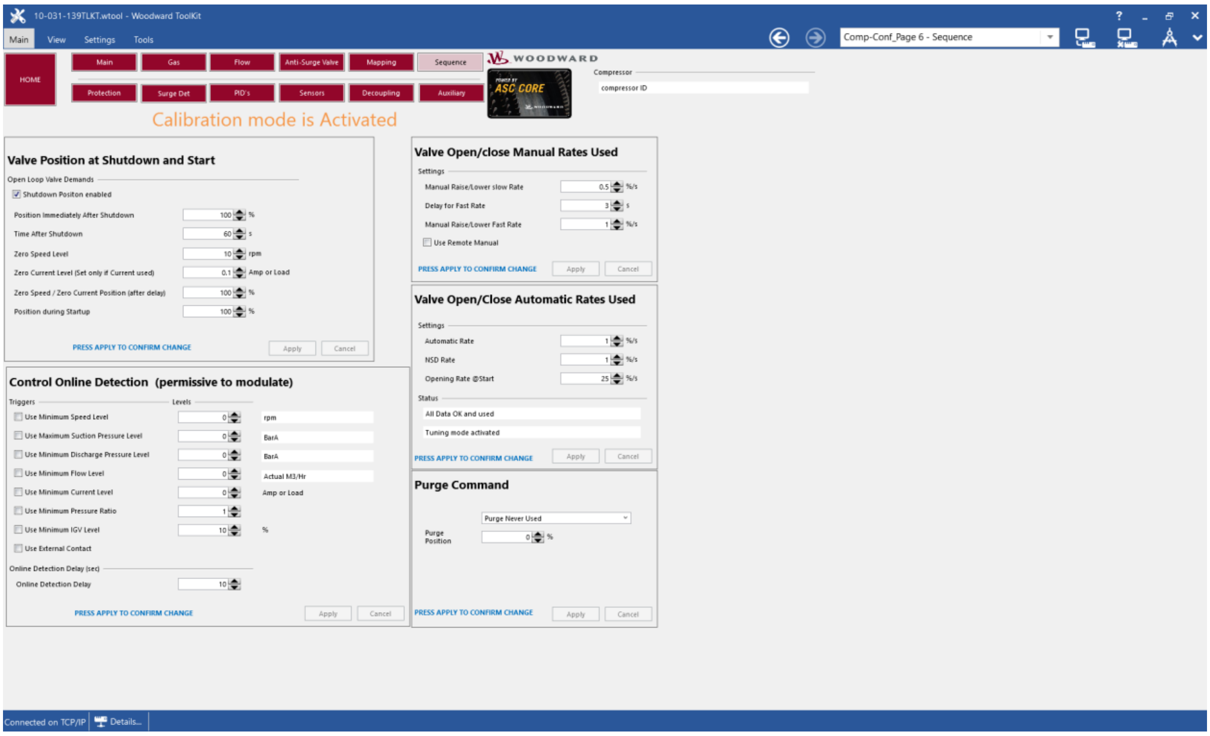

Figure 4-23. Sequence Page

Shutdown Position Enabled
Check the box to force the anti-surge valve to a configured position when the control system is shutdown. If unchecked, the anti-surge valve will remain at the same position prior to the shutdown.

Position Immediately After Shutdown
Enter the required shutdown position of the anti-surge valve (0% to 100%). Typically, this is set to 100%, resulting in a fully open anti-surge valve.

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

Zero Speed Level
Enter the speed level in RPM at which the compressor is considered started. This is the speed at which the anti-surge valve transitions from its configured zero-speed / zero-current position to the configured start position.

This is also the speed at which the unit is considered zero-speed after a shutdown. The zero speed level switching will only come into effect when other conditions have been fulfilled.

Zero Current Level
Enter the current level in amps at which the compressor is considered started. This is the current at which the anti-surge valve transitions from its configured zero-speed / zero-current position to the configured start position.

This is also the current at which the unit is considered zero-current after a shutdown. The zero current level switching will only come into effect when other start conditions have been fulfilled.

IMPORTANT	The zero speed functionality is only active if a valid speed signal is available. The zero current functionality is only active if a valid current signal is available. If neither signal available, the sequence will go to the shutdown position after the configured Time After Shutdown. In this case a start signal is required to sequence the compressor online.

Zero Speed / Zero Current Position
Enter the required anti-surge valve position when the configured time after shutdown has passed. If configured, the zero-speed level and / or the zero current level conditions must be satisfied before the shutdown timer will start.

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

Position During Startup
Enter the required startup position for the anti-surge valve. Typically, this is set to 100%, and the anti-surge valve is fully open during startup. The valve will transition to this position on startup and remain there until the configured online conditions are met. The startup condition can be triggered by speed level, by current level, or by an external command.

At least one online trigger must be enabled to use this start sequence. The ASCE will skip the start sequence and transition immediately to online control if no online triggers are configured (not recommended).

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

Online Detection – Use Minimum Speed Level
Check this box to enable the speed detection method for the online condition. Enter the required speed setpoint in RPM. The online trigger is satisfied during startup once speed increases above this setpoint.

Online Detection – Use Maximum Suction Pressure Level
Check to enable the suction pressure detection method for the online condition. Enter the required suction pressure setpoint in the unit shown. Once suction pressure decreases below this setpoint, the online detection trigger is satisfied.

Online Detection – Use Minimum Discharge Pressure Level
Check to enable the discharge pressure detection method for the online condition. Enter the required discharge pressure setpoint in the unit shown. Once discharge pressure increases above this setpoint, the online detection trigger is satisfied.

Online Detection – Use Minimum Flow Level
Check to enable the flow detection method for the online condition. Enter the required flow setpoint at suction in the unit shown. Once flow increases above this setpoint, the online detection trigger is satisfied.

Online Detection – Use Minimum Current Level
Check to enable the motor current detection method for the online condition. Enter the required current level. Once the motor current increases above this setpoint, the online detection trigger is satisfied. If the motor current input is used with a power signal instead of a current signal, enter the minimum power level in kW.

Online Detection – Use Minimum Pressure Ratio
Check to enable the pressure ratio detection method for the online condition. Enter the required pressure ratio. Once the ratio of discharge pressure (P2) to suction pressure (P1) increases above this setpoint, the online detection trigger is satisfied.

Online Detection – Use Minimum IGV Level
Check to enable the IGV detection method for the online condition. Enter the required IGV level for the online condition. Once the IGV position increases above this setpoint, the online detection trigger is satisfied.

Online Detection – Use External Contact
Check to enable the auxiliary binary input for the online condition. This auxiliary input can be through Modbus or hardwired.

Online Detection Delay
Enter the online detection delay in seconds. After all configured online conditions are satisfied, the delay timer is started. When the delay time is complete, the ASCE will transition to the online state.

Manual Raise / Lower Slow Rate
Enter the slow ramp rate in percent per second. This is the rate at which the manual anti-surge position demand will change when a raise or lower command is received.

Delay for Fast Rate
Enter the value in seconds required to activate the fast rate. If a raise or lower command is maintained for the configured time, the manual demand rate will increase to the fast rate.

Manual Raise / Lower Fast Rate
Enter the fast ramp rate in percent per second. This is the rate at which the manual anti-surge position demand will change when a raise or lower command is maintained for longer than the delay for fast rate setting.

Use Remote Manual
Check this box to enable the remote manual demand. Use this feature when an analog input from another system is used to manually position the anti-surge valve.

Automatic Rate
Enter the automatic rate in percent per second. This is the rate used by the automatic open-loop protection routines when ramping the anti-surge valve closed.

NSD Rate
Enter the normal shutdown rate in percent per second. This is the rate used when the anti-surge valve is ramped to the start position during a normal shutdown.

Opening Rate at Start
Enter the opening rate in percent per second. This the rate used when the anti-surge valve is ramped to the start position during startup.

Purge Usage
- Purge Never Used
- Purge Disabled at Start
- Purge Disabled at Online
- Purge Disabled on Speed Level
- Purge Disabled on Motor Current Level
- Purge on Request Only

This option controls the enabling and disabling of the purge position. For all options, an emergency shutdown will override the purge position and drive the valve to the shutdown position.

Table 4-9. Purge Options

Purge Never Used	The anti-surge valve never goes to a purge position.
Purge Disabled at Start	The purge position can be activated when the ASCE is in the controlled shutdown state. The purge position is deactivated when the start sequence is initiated.
Purge Disabled at Online	The purge position can be activated in the controlled shutdown state and during startup before the ASCE is online. The purge position is deactivated when the ASCE is online.
Purge Disabled on Speed Level	The purge position can be activated in the controlled shutdown state during startup when the speed is less than the configured trigger off level. The purge position is deactivated when the speed is greater than the configured trigger off level.
Purge Disabled on Motor Current Level	The purge position can be activated in the controlled shutdown state and during startup when the motor current is less than the configured trigger off level. The purge position is deactivated when the motor current is greater than the configured trigger off level.
Purge on Request Only	The purge position is activated and deactivated using external commands. There is no condition that will automatically disable the purge position.

Purge Position
Enter the anti-surge valve position used during compressor purge.

Trigger Off Level
Enter the speed or motor current level that will deactivate the purge position when it is exceeded. This setting only applies when Purge Disabled on Speed Level or Purge Disabled on Motor Current Level is selected.

Protection Page

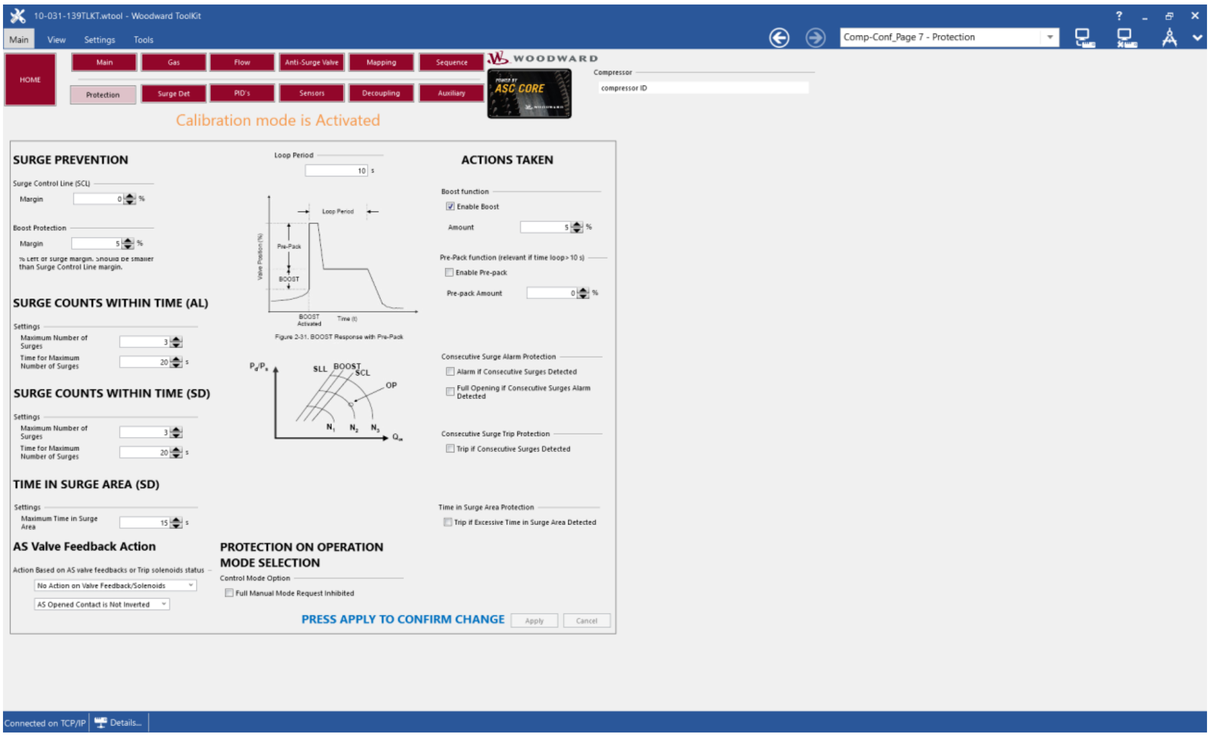

Figure 4-24. Protection Page

Surge Control Line Margin
Enter the margin used to define the position of the surge control line. Values of 8-15% are typical. The margin offsets the surge control line from surge limit line by a percentage of actual flow.

Boost Protection Margin
Enter the margin used to define the position of the boost line. The margin offsets the boost line from the surge control line by a percentage of actual flow.

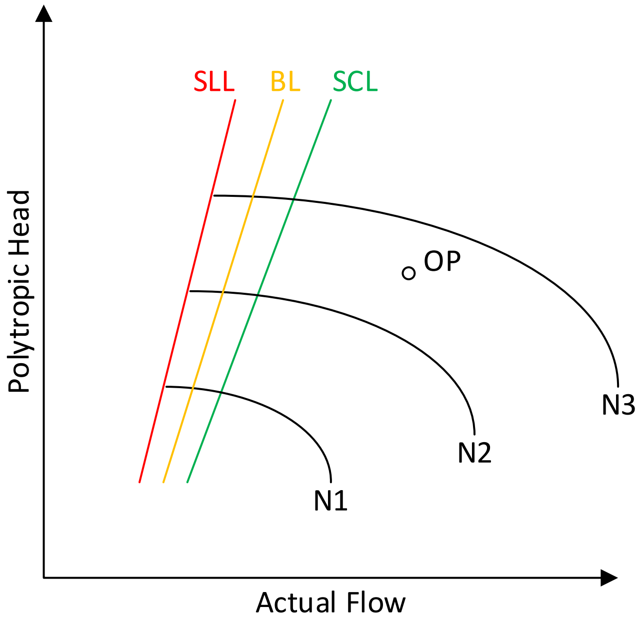

Figure 4-25. Surge Prevention Lines

Surge Counts within Time – Alarm
Enter the maximum number of surges and the time for maximum number of surges. If the maximum number of surges are counted within the configured time, an alarm output can be activated. See *Alarm if Consecutive Surges Detected* setting.

Surge Counts within Time – Shutdown
Enter the maximum number of surges and the time for maximum number of surges. If the maximum number of surges are counted within the configured time, a shutdown output can be activated. See *Trip if Consecutive Surges Detected* setting.

Time in Surge Area – Shutdown
Enter the maximum time that the operating point can remain in the surge area (to the left of the SLL). If the time threshold is exceeded, a shutdown can be activated. See *Trip if Excessive Time in Surge Area Detected* setting.

Action Based on ASV Feedback or Solenoid Status
- No Action on Valve Feedback / Solenoids
- Force Open if Deviation Demand / ASV Opened Contact
- Force Open – ASV Contact is Trip Solenoid
- Force Open if Deviation Demand / ASV Analog Feedback

These options are used to detect when the anti-surge valve demand is not in control of the valve, and the valve should be held at 100% until the situation is resolved. The not-in-control condition can be detected with a limit switch, with a trip solenoid status input, or with an analog position feedback.

Table 4-10. Loss of Anti-surge Valve Control Actions

No Action on Valve Feedback / Solenoids	The anti-surge valve demand is not affected by position feedback.
Force Open if Deviation Demand / ASV Opened Contact	The anti-surge valve demand is forced to 100% when the demand is less than 90%, the valve feedback discrete input is wired to a limit switch, and the limit switch indicates that the valve is still open.
Force Open – ASV Contact is Trip Solenoid	The anti-surge valve demand is forced to 100% when the valve feedback discrete input is wired to a trip solenoid, and the solenoid state is forcing the valve to open.
Force Open if Deviation Demand / ASV Analog Feedback	The anti-surge valve demand is forced to 100% when the analog position feedback is greater than 88% and the deviation between the demand and the feedback is greater than 10%

ASV Open Contact Inversion

- ASV Opened Contact is Not Inverted
- ASV Opened Contact is Inverted

Use this option to set the inversion of the opened limit switch input. If the input is not inverted, a closed contact indicates that the anti-surge valve is fully open. Note that this input can also be wired to a trip solenoid status signal. If the input is not inverted, a closed contact indicates that the solenoid is forcing the valve to open.

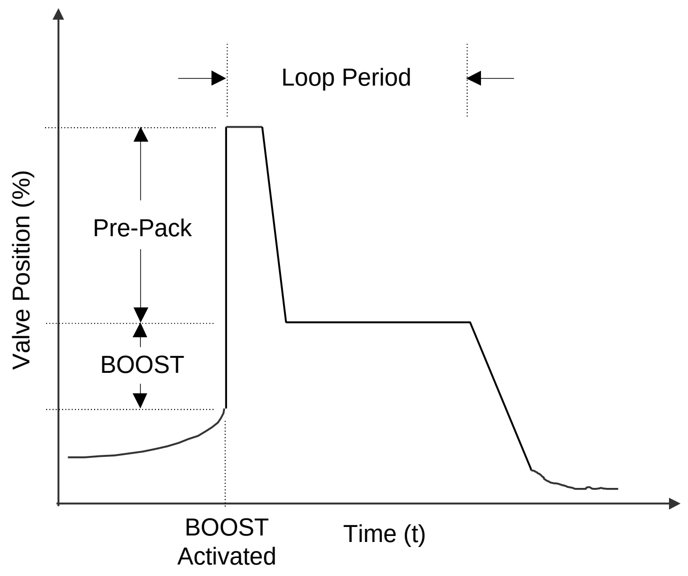

Figure 4-26. Protection Actions

Loop Period
Following a change in anti-surge valve position, there will be a time delay before the effect of the position change is seen in the flow measurement. This delay is the loop period. Enter the value in seconds. This setting also appears on the Surge Detection page.

Enable Boost
Check the box to enable the boost open-loop step response. In enabled, the boost response will be triggered when the operating point crosses the boost line.

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

the boost amount is set such that the increased valve demand will move the operating point to the right side of the boost line when the boost response is triggered.

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

Pre-Pack Amount
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.

Alarm if Consecutive Surges Detected
Enable this option to generate an alarm output when consecutive surges are detected (see Surge Counts within Time – Alarm section).

Full Opening on Consecutive Surge Alarm
Enable this option to fully open the anti-surge valve when consecutive surges are detected (see Surge Counts within Time – Alarm setting).

Trip if Consecutive Surges Detected
Enable this option to generate a shutdown output if consecutive surges are detected (see Surge Counts within Time – Shutdown setting).

Trip if Excessive Time in Surge Area Detected
Enable this option to generate a shutdown output if the operating point remains in the surge area for longer than the configured maximum time (see *Maximum Time in Surge Area* setting).

Full Manual Mode Request Inhibited
Check the boss to inhibit full manual mode selection by the operator.

Surge Detection Page

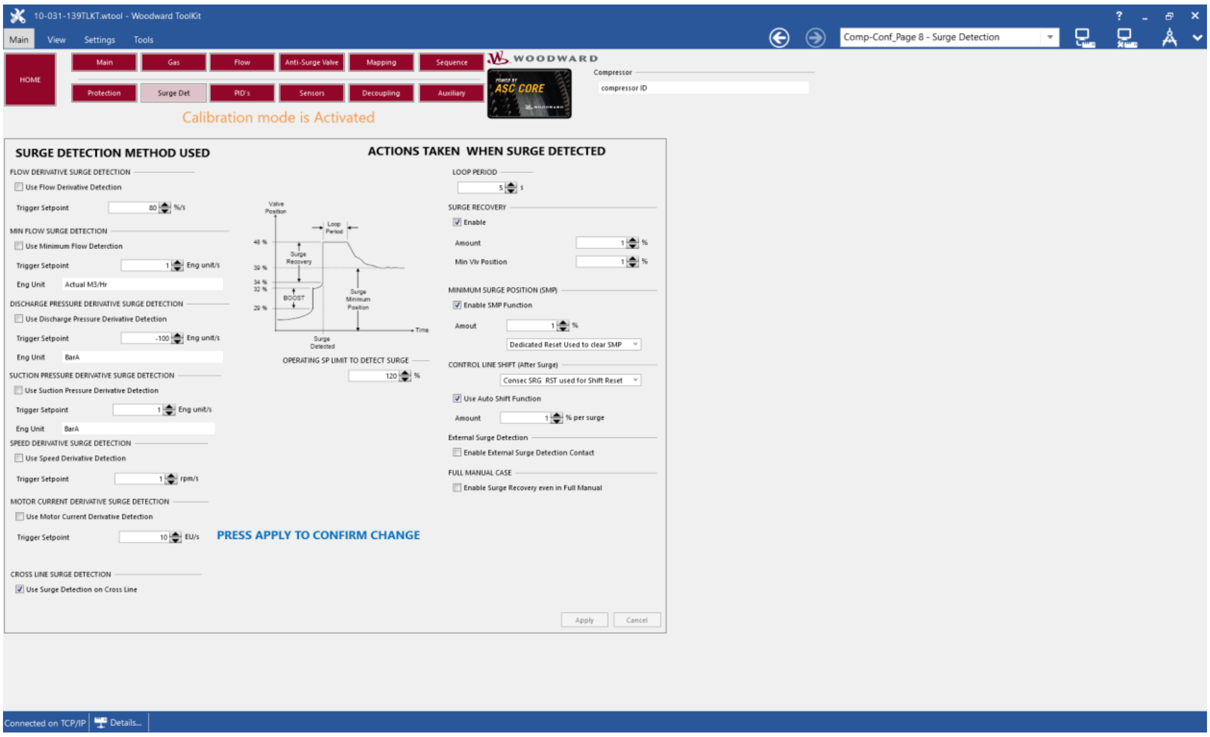

Figure 4-27. Surge Detection Page

The surge detection methods and actions are configured on this screen.

Flow Derivative Surge Detection
Check to enable the flow derivative surge detection routine. This routine detects surge by monitoring the rate of change of compressor flow.

Enter the flow derivative value, in percent of suction volumetric flow units per second, above which the Surge Recovery and Surge Minimum Position routines, if enabled, are to be triggered. The setpoint is configured in percent to account for the wide range of most compression processes and to eliminate false triggers on noise at low flow levels. For example, if the current operating flow is 10,000 m3/hr and this set point is configured as 50%, a surge will be detected if the rate of flow change exceeds 5,000 m3/hr. However, the same flow change at a nominal flow rate of 50,000 m3/hr is only 10%, and could be caused by a noisy signal, not surge. At higher flows, larger flow changes are tolerated without detecting surge. Surge will only be detected when flow is decreasing, not when it is increasing.

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

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

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

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

Enter the discharge pressure derivative value, in engineering units per second, above which the Surge Recovery and Surge Minimum Position routines, if enabled, are to be triggered. If a negative threshold is configured, surge will only be detected when pressure is decreasing. If a positive threshold is configured, surge will only be detected when pressure is increasing.

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

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

Enter the suction pressure derivative value, in engineering units per second, above which the Surge Recovery and Surge Minimum Position routines, if enabled, are to be triggered. If a negative threshold is configured, surge will only be detected when pressure is decreasing. If a positive threshold is configured, surge will only be detected when pressure is increasing.

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

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

Enter the speed derivative value, in engineering units per second, above which the Surge Recovery and Surge Minimum Position routines, if enabled, are to be triggered. The configured threshold must be positive. Surge is detected when speed is increasing faster than the configured rate.

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

Motor Current Derivative Surge Detection

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

Enter the motor current derivative value, in engineering units per second, above which the Surge Recovery and Surge Minimum Position routines, if enabled, are to be triggered. The configured threshold must be negative. Surge is detected when motor current is decreasing faster than the configured rate.

Cross Line Surge Detection
Check to enable the surge limit line crossing surge detection routine.

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

Operating SP Limit to Detect Surge
Enter the limit for operating setpoint in percent to detect surge. When measured WSPV is lower than the entered value, surge can be detected and counted, and anti-surge action can be activated.

Loop Period
Following a change in anti-surge valve position, there will be a time delay before the effect of the position change is seen in the flow measurement. This delay is the loop period. Enter the value in seconds. This setting also appears on the Protection page.

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

Surge Recovery Amount
Enter the value in valve percent that will be added to the anti-surge valve demand when surge is detected. After the loop period time, the Surge Recovery response ramps to the Surge Minimum Position if that feature is enabled. If Surge Minimum Position is not enabled, the Surge Recovery response ramps to zero.

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

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

Surge Minimum Position Amount
Enter the value in valve percent that will be added to the anti-surge valve demand when surge is detected to establish the SMP valve limit. After the open-loop Surge Recovery response ramps out, the valve will not be allowed to close below the SMP limit until SMP has been reset.

Surge Minimum Position Reset
The Surge Minimum Position requires a dedicated or normal reset input prior to allowing the valve to close further:
- Dedicated reset used to clear SMP
- Normal reset used to clear SMP

Control Line Shift Enable
Check to enable Surge Control Line auto-shifting based upon the surge counter.

Control Line Shift Amount
The Surge Control Line will be shifted to the right by the configured amount for each detected surge.

Control Line Shift Reset
When the surge counter is reset, the shifted amount will slowly ramp back to 0, returning the SCL to its original position. Available reset possibilities are given below:
- Consecutive Surge Reset used for Shift Reset
- SMP Reset used for Shift Reset
- Total Surge Reset used for Shift Reset
- Dedicated Reset used for Shift Reset

External Surge Detection
Check to enable the surge detection on an external hardwired signal.

This routine initiates the surge detection as well as multi surge detection response when an external hardwired command is detected. This is required when surge detection is also done by a third-party system.

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

PID Page

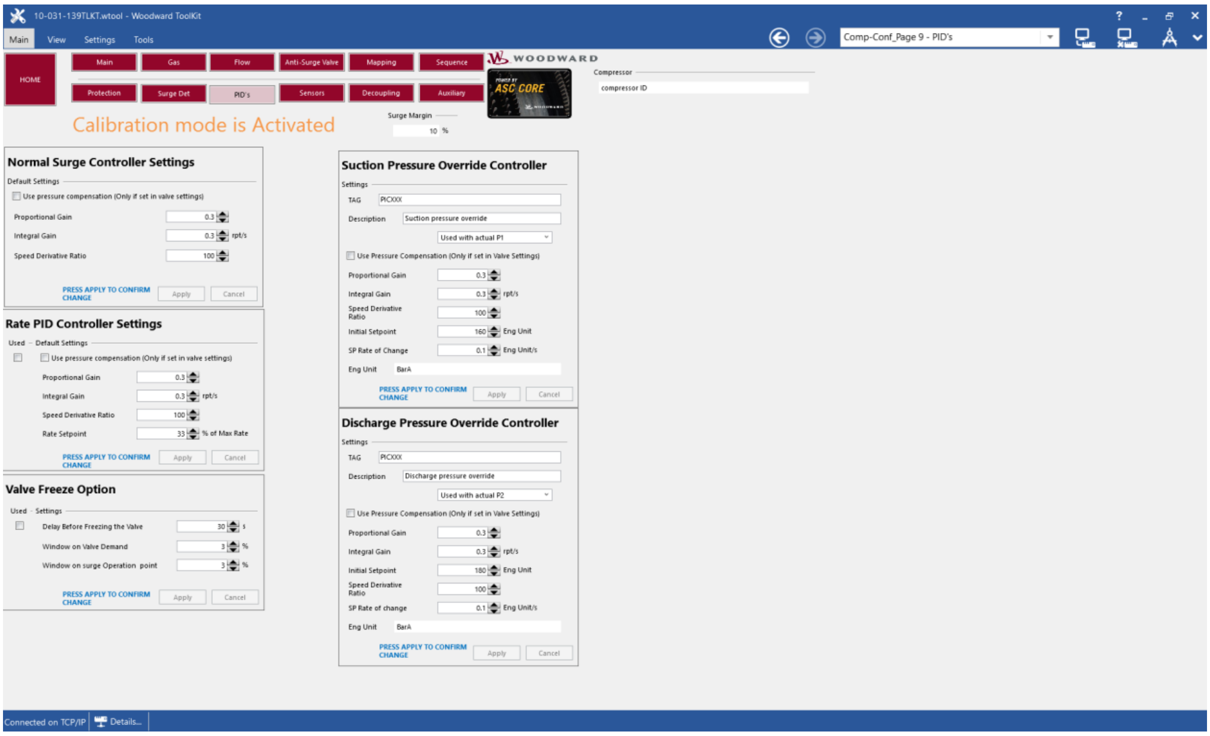

Figure 4-28. PID Page

Normal Surge Control Pressure Compensation
Check this checkbox to enable automatic gain compensation of the anti-surge PID's proportional gain. If enabled, gain compensation will scale the proportional gain relative to the compressor's current operating conditions. This feature should only be used when anti-surge valve Cv gain compensation has been configured.

Normal Surge Control Proportional Gain
Enter the proportional gain of the anti-surge PID.

Normal Surge Control Integral Gain
Enter the integral gain of the anti-surge PID.

Normal Surge Control Speed Derivative Ratio
Enter the speed derivative ratio of the anti-surge PID. Leave this value at 100 for proportional and integral control (recommended).

Rate Control Used
Check to enable the Rate Controller, which limits the rate of movement of the compressor operating point toward the Surge Control Line. As the operating point moves closer to the Surge Control Line, its speed of approach becomes more critical. If the rate 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.

Rate Control Pressure Compensation
Check to enable automatic gain compensation of the rate PID's proportional gain. If enabled, gain compensation will scale the proportional gain relative to the compressor's current operating conditions. This feature should only be used when anti-surge valve Cv gain compensation has been configured.

Rate Control Proportional Gain
Enter the proportional gain of the rate PID.

Rate Control Integral Gain
Enter the integral gain of the rate PID.

Rate Control Speed Derivative Ratio
Enter the speed derivative ratio of the rate PID. Leave this value at 100 for proportional and integral control.

Rate Control Rate Setpoint
Enter the rate controller setpoint, in percent of maximum allowable rate.

Valve Freeze Used
Check to enable the anti-surge valve freeze function. This routine will clamp the valve demand at a fixed output when the process is stable. Stability is checked by measuring the variation is valve demand and WSPV. This feature may aid in settling an unnecessarily swinging process.

Delay Before Freezing the Valve
Enter the time delay, in seconds, after which the freeze function is enabled when process stability is detected. In other words, after this time delay the freeze routine is initiated provided that the valve demand and WSPV criteria are satisfied.

Valve Freeze Demand Window
Enter the value of internal valve demand, in %, at which the freeze function remains active.

Valve Freeze Surge Operating Point Window
Enter the value WSPV, in %, at which the Freeze function remains active.

Suction Pressure Override Usage
- Not Used
- Used with Actual P1
- Used with Dedicated Channel

This auxiliary controller will modulate the anti-surge valve when suction pressure falls below an established limiting setpoint. This control loop is usually used to help maintain suction pressure within the process limits. The actual P1 or another dedicated channel can be selected as the process value for suction pressure override controller.

Suction Pressure Override Pressure Compensation
Check to enable automatic gain compensation of the suction pressure PID's proportional gain. If enabled, gain compensation will scale the proportional gain relative to the compressor's current operating conditions. This feature should only be used when anti-surge valve Cv gain compensation has been configured.

Suction Pressure Override Proportional Gain
Enter the proportional gain of the suction pressure PID.

Suction Pressure Override Integral Gain
Enter the integral gain of the suction pressure PID.

Suction Pressure Override Speed Derivative Ratio
Enter the speed derivative ratio of the suction pressure PID. Leave this value at 100 for proportional and integral control.

Suction Pressure Override Initial Setpoint
Enter a pressure override setpoint initial value. This setpoint should be chosen carefully if other devices or logic will be controlling the same process parameter.

Suction Pressure Override SP Rate of Change
This setting defines the rate of change when the setpoint is raised or lowered during operation.

Discharge Pressure Override Usage

- Not Used
- Used with Actual P2
- Used with Dedicated Channel

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. The actual P2 or another dedicated channel can be selected as the process value for discharge pressure override controller.

Discharge Pressure Override Pressure Compensation
Check to enable automatic gain compensation of the discharge pressure PID's proportional gain. If enabled, gain compensation will scale the proportional gain relative to the compressor's current operating conditions. This feature should only be used when anti-surge valve Cv gain compensation has been configured.

Discharge Pressure Override Proportional Gain
Enter the proportional gain of the discharge pressure PID.

Discharge Pressure Override Integral Gain
Enter the integral gain of the discharge pressure PID.

Discharge Pressure Override Speed Derivative Ratio
Enter the speed derivative ratio of the discharge pressure PID. Leave this value at 100 for proportional and integral control.

Discharge Pressure Override Initial Setpoint
Enter a pressure override setpoint initial value. This setpoint should be chosen carefully if other devices or logic will be controlling the same process parameter.

Discharge Pressure Override SP Rate of Change
This setting defines the rate of change when the setpoint is raised or lowered during operation.

Sensor Handling Page

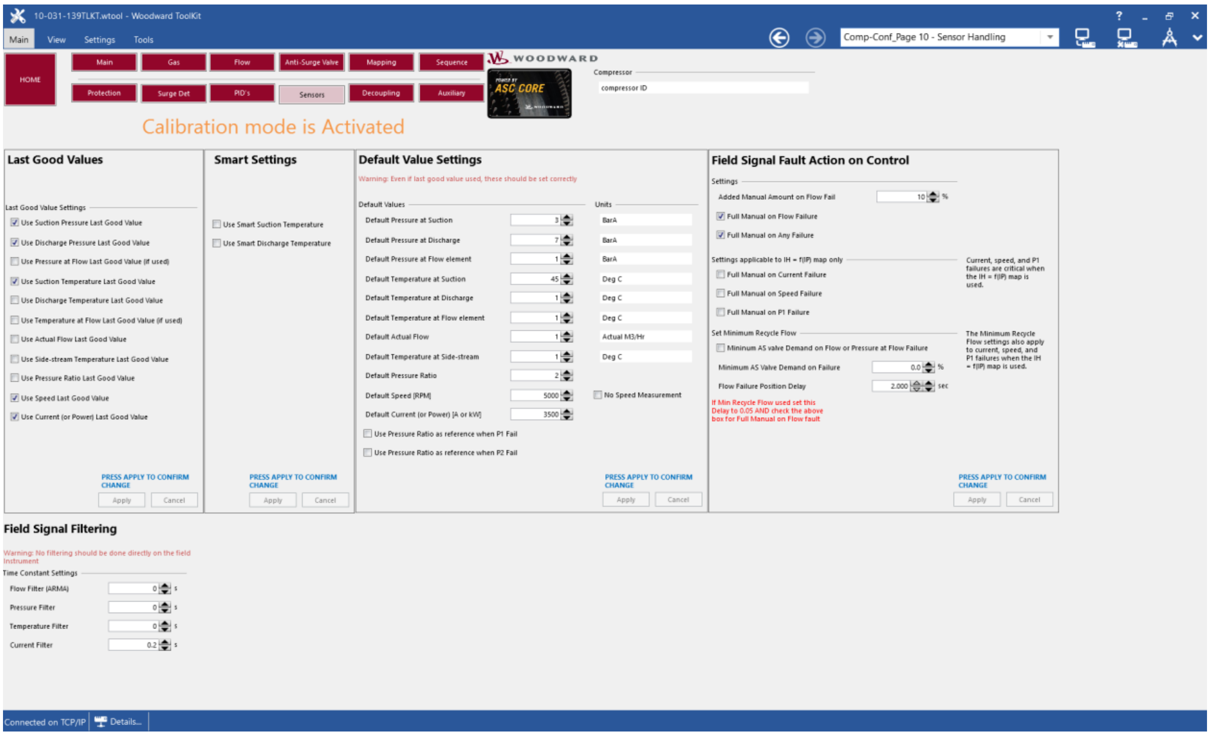

Figure 4-29. Sensor Handling Page

This page contains settings related to sensor inputs. Responses to sensor failures are configured here (last good value, smart settings, default value) as well as signal filtering and control actions.

Use Suction Pressure Last Good Value

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

Use Discharge Pressure Last Good Value

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

Use Pressure at Flow Last Good Value

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

Use Suction Temperature Last Good Value

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

Use Discharge Temperature Last Good Value

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

Use Temperature at Flow Last Good Value

Check to enable the last good value failure response for the temperature at flow measurement when the alternate temperature signal is used. If the signal fails, and compressor operation has been stable for approximately one minute, the stable alternate temperature value will be retained for control.

IMPORTANT **The Last Good Value configuration should be set correctly for Pressure at Flow and Temperature at Flow even if dedicated inputs are not used for these signals.**

Use Actual Flow Last Good Value
Check to enable the last good value failure response for the compressor actual flow. If the signal fails, and compressor operation has been stable for approximately one minute, the stable actual flow value will be retained for control.

Use Pressure Ratio Last Good Value
Check to enable the last good value failure response for the compressor pressure ratio. If the signal fails, and compressor operation has been stable for approximately one minute, the stable pressure ratio will be retained for control.

Use Speed Last Good Value
Check to enable the last good value failure response for the compressor speed. If the signal fails, and compressor operation has been stable for approximately one minute, the stable speed value will be retained for control.

Use Current (or Power) Last Good Value
Check to enable the last good value failure response for motor current. If the signal fails, and compressor operation has been stable for approximately one minute, the stable motor current value will be retained for control. Note that a driver power input may be used in place of a motor current input. In that case, the last good value of driver power is used.

Use Smart Suction Temperature
Check to enable the smart setting failure response for the compressor suction temperature. This option will be active in the online condition when P1, P2 and T2 sensors are healthy. If any of the other sensors are failed, Default Value for suction temperature will be used.

Use Smart Discharge Temperature
Check to enable the smart setting failure response for the compressor discharge temperature. This option will be active in the online condition when P1, P2 and T1 sensors are healthy. If any of the other sensors are failed, Default Value for discharge temperature will be used.

Default Pressure at Suction
Enter a conservative default value for the compressor suction pressure. This value will be used for control after a signal failure if last good value is not enabled or not suitable because of unstable operation, or if compressor operation becomes unstable while the last good value is in use. Generally, this default value should be chosen to generate a conservative calculation of compressor operation in the case of a signal failure. A typical value is 10% less than the rated suction pressure.

Default Pressure at Discharge
Enter a conservative default value for compressor discharge pressure. This value will be used for control after a signal failure if last good value is not enabled or not suitable because of unstable operation, or if compressor operation becomes unstable while the last good value is in use. Generally, this default value should be chosen to generate a conservative calculation of compressor operation in the case of a signal failure. A typical value is 10% more than the rated discharge pressure.

Default Pressure at Flow Element
If an alternate pressure signal is used for the flow measurement, enter a conservative default value to be used in the event that the alternate pressure signal fails This value will be used for control after a signal failure if last good value is not enabled or not suitable because of unstable operation, or if compressor operation becomes unstable while the last good value is in use. Generally, this default value should be chosen to generate a conservative calculation of compressor operation in the case of a signal failure. A typical value is 10% less than the rated pressure at the flow element.

Default Temperature at Suction
Enter a conservative default value for compressor suction temperature. This value will be used for control after a signal failure if last good value is not enabled or not suitable because of unstable operation, or if compressor operation becomes unstable while the last good value is in use. Generally,

this default value should be chosen to generate a conservative calculation of compressor operation in the case of a signal failure.

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

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

Default Actual Flow
Enter a conservative default value for the actual suction flow. 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. A typical value is 10% less than the rated actual flow.

Default Pressure Ratio
Enter a conservative default value for pressure ratio. Generally, this default value should be chosen to generate a conservative calculation of compressor operation in the case of a signal failure.

Default Speed
Enter a conservative value for compressor speed in RPM. 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.

No Speed Measurement
Check to force the control to always use the configured default value for compressor speed. This option is needed when the invariant power map is used with a fixed-speed motor. In most fixed-speed compressors, the speed is not measured. The invariant power calculation requires speed. Use this option to send a default value for speed to the invariant power calculation.

Default Current (or Power)
Enter a conservative value for motor current in Amps. 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. If a driver power signal is used instead of a motor current signal, enter a conservative value for driver power in kW.

Use Pressure Ratio as Reference when P1 Fails
When checked, the last good pressure ratio or default pressure ratio will be used to calculate P1 when the P1 sensor fails.

Use Pressure Ratio as Reference when P2 Fails
When checked, the last good pressure ratio or default pressure ratio will be used to calculate P2 when the P2 sensor fails.

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

Pressure Filter Time Constant
Enter the appropriate filter time constant, in seconds, to be used with the pressure signal filters. Filtering should be minimized, if possible, but this value can be adjusted as necessary to provide clean, noise-free pressure signals. Because pressure signals generally have low noise and moderate response times, the filter time constant is typically between zero and a few hundred milliseconds.

Temperature Filter Time Constant
Enter the appropriate filter time constant, in seconds, to be used with the temperature signal filters. Filtering should be minimized, if possible, but this value can be adjusted as necessary to provide clean, noise-free temperature signals. Because pressure signals generally have low noise and moderate response times, the filter time constant is typically between zero and a few hundred milliseconds.

Motor Current Filter Time Constant
Enter the appropriate filter time constant, in seconds, to be used with the motor current signal filter. Adjust the value as necessary to provide a noise-free signal that is still responsive to rapid changes in the process. If a driver power signal is used instead of a motor current signal, this time constant will be used with the driver power signal filter.

Added Manual Amount on Flow Failure
If a flow signal failure triggers a transition to a manual mode, the initial manual demand will be the valve position at time of failure plus this configured additional demand.

Full Manual on Flow Failure
Check to enable the fail to full manual strategy on flow sensor input failures.

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

Full Manual on Current Failure
Check to enable the fail to full manual strategy on motor current (or driver power, if applicable) sensor input failure. This setting is only used when the IH = f(IP) map type has been selected. Motor current (or driver power) is a critical input to the calculation of invariant power.

Full Manual on Speed Failure
Check to enable the fail to full manual strategy on speed sensor input failure. This setting is only used when the IH = f(IP) map type has been selected. Compressor speed is a critical input to the calculation of invariant power.

Full Manual on P1 Failure
Check to enable the fail to full manual strategy on suction pressure input failure. This setting is only used when the IH = f(IP) map type has been selected. Suction pressure is a critical input to the calculation of invariant power.

Minimum Anti-surge Valve Demand on Flow or Pressure at Flow Failure
Check to enable the minimum anti-surge valve demand on flow or pressure input failure. When the IH = f(IP) map type has been selected, this setting also enables the minimum anti-surge valve demand when motor current, speed, or suction pressure fail. These inputs are critical to the calculation of invariant power.

Minimum Anti-surge Valve Demand on Failure
Specify the minimum anti-surge valve demand limit that is enforced when flow or pressure fails. When the IH = f(IP) map type has been selected, this setting also determines the minimum anti-surge valve demand when motor current, speed, or suction pressure fail. These inputs are critical to the calculation of invariant power.

Flow Failure Position Delay
After a flow failure, the transition to the manual demand with the configured added amount will not occur until after this delay time is complete.

IMPORTANT	If Minimum Recycle Flow is used, set the Flow Failure Position Delay to 0.05 AND check the Full Manual on Flow Sensor Fault

Decoupling Page

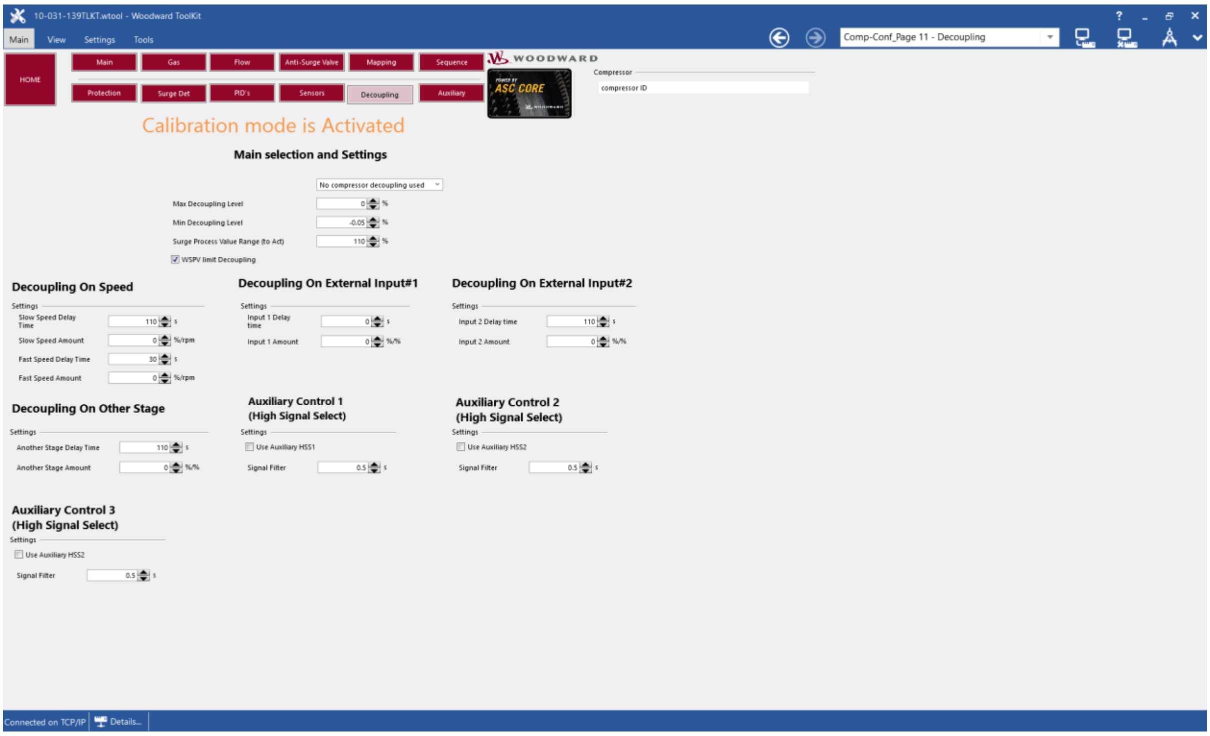

Figure 4-30. Decoupling Page

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.

Decoupling Usage

- No Compressor Decoupling Used
- Compressor Decoupling Used

Select decoupling usage from the menu. All decoupling methods are enabled together. To disable a specific decoupling method, set its amount to zero.

Maximum Decoupling Level

Maximum value that can be added to or subtracted from the anti-surge valve demand by the decoupling action. The configured value is multiplied by -1 to create the minimum value that can be subtracted from the anti-surge valve demand.

Minimum Decoupling Level

If asymmetric limits on decoupling are required, this setting can be used to specify a minimum decoupling demand that is not the same as the minimum value that is calculated from the Maximum Decoupling Level.

WSPV Range to Activate

WSPV must be less than this value for decoupling to be active.

WSPV Limit Decoupling

If this setting is enabled, rate limits are enforced on the decoupling signals.

Slow Speed Delay Time

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

Slow Speed Amount
Enter the gain (in percent valve demand per RPM) applied from a change in speed to generate a decoupling signal to the anti-surge valve demand.

Fast Speed Delay Time
Enter the delay time (in seconds) that the fast speed decoupling routine will remain in effect.

Fast Speed Amount
Enter the gain (in percent valve demand per RPM) applied from a change in speed to generate a decoupling signal to the anti-surge valve demand.

IMPORTANT

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

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

Other Stage Delay Time
For a multistage compressor, this is the delay time (in seconds) that a decoupling signal from the adjacent stage valve position will remain in effect.

Other Stage Amount
Enter the gain (in percent per percent valve demand of the adjacent stage valve) applied from a change in adjacent valve position to generate a decoupling signal to the anti-surge valve. The amount may be positive or negative depending upon the adjacent valve's effect on compressor flow.

Input 1 Delay Time
This is the delay time (in seconds) that a decoupling signal from the first external input will remain in effect.

Input 1 Amount
Enter the gain (in percent per change in external signal) applied from a change in external input 1 to generate a decoupling signal to the anti-surge valve demand.

Input 2 Delay Time
This is the delay time (in seconds) that a decoupling signal from the second external input will remain in effect.

Input 2 Amount
Enter the gain (in percent per change in external signal) applied from a change in external input 2 to generate a decoupling signal to the anti-surge valve demand.

Use Auxiliary HSS1
Check to enable the High Signal Select (HSS) bus input for auxiliary input #1. The auxiliary input comes 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.

Auxiliary HSS1 Filter Time Constant
Filter applied to the auxiliary input 1 signal.

Use Auxiliary HSS2
Check to enable the High Signal Select (HSS) bus input for auxiliary input #2. The auxiliary input comes 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.

Auxiliary HSS2 Filter Time Constant
Filter applied to the auxiliary input 2 signal.

Use Auxiliary HSS3
Check to enable the High Signal Select (HSS) bus input for auxiliary input #3. The auxiliary input comes 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.

Auxiliary HSS3 Filter Time Constant
Filter applied to the auxiliary input 3 signal.

Auxiliary Controls Page

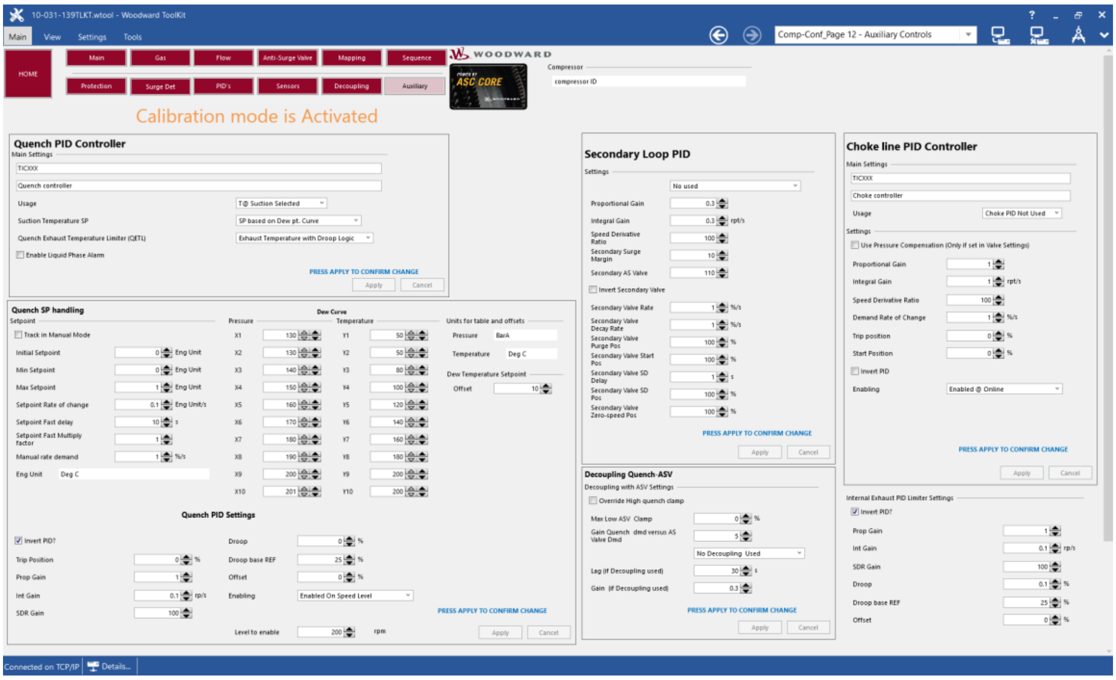

Figure 4-31. Auxiliary Controls Page

This page is used for configuration of the quench control, the secondary control, and the choke control.

Quench Usage
- Not Used
- External Sensor
- Temperature at Flow Meter
- Temperature at Suction

Select the source for the temperature process value controlled by the quench PID. If the application does not include quench, select Not Used.

Quench Suction Temperature Setpoint
- Fixed Setpoint
- Fixed Setpoint with Dew Point Limiter
- Setpoint Based On Dew Point Curve

Select the method used for determining the quench PID temperature setpoint. The Fixed Setpoint is controlled by the operator (raise / lower commands) or by a remote setpoint analog input. The Fixed Setpoint with Dew Point Limiter is the same as the Fixed Setpoint, but the setpoint cannot be lowered below the setpoint calculated from the dew point curve. The Setpoint Based On Dew Point Curve uses a setpoint calculated from the dew point with a configurable offset. Because the dew point varies with pressure, this setpoint will change as the suction pressure changes.

Quench Exhaust Temperature Limiter
- Exhaust Temperature Limiter Not Used
- Exhaust Temperature with Droop Logic

- Exhaust Temperature with Shared Logic

Select the method used for limiting the exhaust temperature (final discharge temperature in the compressor train). The exhaust temperature limiter demand is high signal selected with the suction temperature quench control demand. Exhaust Temperature with Droop Logic is the standard selection when exhaust temperature limiting is required. Droop Logic is included in this controller to prevent adverse interactions in applications with multiple quench controllers that are working together to limit exhaust temperature. If alternate exhaust temperature limiter logic is required, select Exhaust Temperature with Shared Logic. This selection routes a signal from external logic to the quench output high signal select bus.

Enable Liquid Phase Alarm
Check the box to enable the liquid phase alarm. The liquid phase alarm indicates that the temperature controlled by the quench PID has dropped below the level at which liquid phase fluid can form. The dew point curve must be configured correctly if the alarm is enabled.

Track in Manual Mode
If this option is selected, the quench setpoint will track the process value while the quench controller is in manual mode.

Initial Setpoint
Configure an initial setpoint that will be set at power up.

Minimum Setpoint
Minimum value for the quench setpoint.

Maximum Setpoint
Maximum value for the quench setpoint.

Setpoint Rate of Change
Default rate of change of the quench setpoint.

Setpoint Fast Delay
If a raise / lower command is maintained for longer than this delay time, the Setpoint Fast Multiplier will be active.

Setpoint Fast Multiplier
Setpoint Rate of Change will be multiplied by Setpoint Fast Multiplier to cause the setpoint to change more quickly when raise / lower commands are maintained for longer than the Setpoint Fast Delay.

Manual Demand Rate
Rate of change of the quench valve manual demand in %/sec.

Dew Point Curve
The dew point curve is defined with 10 points (pressure vs. temperature). The dew point curve must be entered correctly if the setpoint setting is Fixed Setpoint with Dew Point Limiter or Setpoint Based On Dew Point Curve. The curve is also required if the liquid phase alarm is enabled. Enter the points in the same units that were selected for the pressure and temperature inputs.

Dew Point Temperature Setpoint Offset
Enter a temperature offset which is added to the output of the dew point calculation. The offset provides a safety margin to reduce the likelihood of introducing liquid phase fluid to the compressor suction. Enter the offset in the same units that were selected for the temperature inputs.

Invert Quench PID?
The quench PID is typically inverted. If an increase in demand (in other words, an increase in quench valve opening) will lower the suction temperature, the PID should be inverted. This is usually the case for a quench valve.

Trip Position
When the quench actuator fails, or when the compressor is shutdown, the quench valve will go to the trip position with a rate of 50 percent per second.

Proportional Gain
Enter the proportional gain of the quench PID.

Integral Gain
Enter the integral gain of the quench PID.

SDR
Enter the speed derivative ratio of the quench PID. Leave this value at 100 for proportional and integral control.

Droop
Droop logic may be needed if multiple quench valves are controlling the same suction temperature. If droop logic is not needed, set this value to 0.0.

Droop Base Ref
The droop logic will attempt to hold the quench valve at this reference position. When the suction temperature deviates from the setpoint, the quench valve demand will deviate from this reference position to restore the suction temperature to the setpoint value.

Offset
The offset acts as a deadband on the quench PID error. If the absolute value of the error is less than the offset, the error is set to 0.0 and the PID holds its current value.

Enabling

- Enable at Start
- Enable at Online
- Enable at Speed Level
- Enable at Motor Current Level
- Always Active

Select the sequence logic used to enable the quench controller. When the controller is enabled, it will modulate the quench valve to control the suction temperature.

Level to Enable
Enter the level that must be exceeded to enable the quench controller. This setting is only applicable when Enable at Speed Level or Enable at Motor Current Level is selected for the Enabling option. Enter the value in RPM or amps.

Override High Quench Clamp
If this option is selected, there is no upper limit on the quench valve position. If this option is not selected, there is an upper limit on the quench valve position based on the anti-surge valve position. This option is generally not selected so that the quench valve is forced closed when the anti-surge valve is closed.

Quench Demand vs. Anti-surge Demand Gain
If the Override High Quench Clamp option is not selected, there is an upper limit on the quench valve position based on the anti-surge valve position. The upper limit is found by multiplying the anti-surge valve position by this gain setting.

Max Low Anti-surge Valve Clamp
The quench logic calculates a lower limit on the anti-surge valve position based on the quench demand. The lower limit is the quench demand divided by the Quench Demand vs. anti-surge Demand Gain. The calculated lower limit can itself be limited by this Max Low Anti-surge Valve Clamp setting. For example, if no anti-surge valve lower limit is needed, set Max Low Anti-surge Valve Clamp to 0.0.

Decoupling Signal

- No Decoupling Used
- Decoupling on Anti-surge Valve demand
- Decoupling on External Signal

Choose the decoupling signal source. The most common source is the anti-surge valve position, but an external signal is available as well. The decoupling logic attempts to proactively adjust the quench valve position based on changes in the anti-surge valve position.

Decoupling Lag
This setting is the first-order time constant, or lag, applied to the decoupling input.

Decoupling Gain
This setting is the gain applied to the decoupling input.

Invert Exhaust Limiter PID?
The exhaust limiter PID is typically inverted. If an increase in demand (in other words, an increase in quench valve opening) will lower the exhaust temperature, the PID should be inverted. This is usually the case for a quench valve.

Exhaust Limiter Proportional Gain
Enter the proportional gain of the exhaust limiter PID.

Exhaust Limiter Integral Gain
Enter the integral gain of the exhaust limiter PID.

Exhaust Limiter SDR
Enter the speed derivative ratio of the exhaust limiter PID. Leave this value at 100 for proportional and integral control.

Exhaust Limiter Droop
Droop logic may be needed if multiple quench valves are controlling the same exhaust temperature. If droop logic is not needed, set this value to 0.0.

Exhaust Limiter Droop Base Ref
The droop logic will attempt to hold the quench valve at this reference position. When the exhaust temperature deviates from the setpoint, the quench valve demand will deviate from this reference position to restore the exhaust temperature to the setpoint value.

Exhaust Limiter Offset
The offset acts as a deadband on the exhaust limiter PID error. If the absolute value of the error is less than the offset, the error is set to 0.0 and the PID holds its current value.

Use Pressure Compensation for Choke
If the box is checked, gain compensation will be applied to the proportional gain.

Choke Proportional Gain
Enter the proportional gain of the choke PID.

Choke Integral Gain
Enter the integral gain of the choke PID.

Choke SDR
Enter the speed derivative ratio of the choke PID. Leave this value at 100 for proportional and integral control.

Choke Demand Rate of Change
Enter the rate of change (in % per second) for manual changes in the choke valve demand.

Choke Trip Position
Enter the trip position (in %) of the choke valve. When the ASCE is in the shutdown state or when the choke valve driver fails, the choke valve demand is set to the configured trip position.

Choke Start Position
Enter the start position (in %) of the choke valve. When the ASCE is in the start state or the controlled shutdown state, the choke valve demand is set to the configured start position.

Invert Choke PID?
The choke PID is typically not inverted with this setting. Inversion is already accounted for in the structure of the PID logic. Carefully analyze the system before enabling this option.

Choke Enabling
- Enable at Start
- Enable at Online
- Enable at Speed Level
- Enable at Motor Current Level
- Always Active

Select the sequence logic used to enable the choke controller (transition from manual operation to automatic operation).

Choke Level to Enable
Enter the level that must be exceeded to enable the choke controller. This setting is only applicable when Enable at Speed Level or Enable at Motor Current Level is selected for the Enabling option. Enter the value in RPM or amps.

Secondary PID Usage
- Not Used
- Cold Recycling Based on Operating Point
- Cold Recycling Proportional to Anti-surge Valve
- Cold Recycling with External Signal

Select the usage of the Secondary PID. Cold Recycling Based on Operating Point positions the secondary valve based on the operating point location relative to an additional control line defined by the secondary anti-surge margin. Cold Recycling Proportional to Anti-surge Valve positions the secondary valve based on the position of the primary anti-surge valve. Cold Recycling with External Signal positions the secondary valve based on an external setpoint and process value signals.

Secondary PID Proportional Gain
Enter the proportional gain of the secondary loop PID.

Secondary PID Integral Gain
Enter the integral gain of the secondary loop PID.

Secondary PID SDR
Enter the speed derivative ratio of the secondary loop PID. Leave this value at 100 for proportional and integral control.

Secondary PID Surge Margin
Enter the surge margin for secondary loop. This surge margin defines the position of an additional control line and is only applicable when the usage is Cold Recycling Based on Operating Point or Cold Recycling with External Signal.

Percentage of Primary ASV Demand
This setting is only applicable if the usage is Cold Recycling Proportional to Anti-surge Valve. The secondary valve demand is determined by multiplying the primary anti-surge valve demand by this percentage setting.

Invert Secondary PID?
Check to invert the output signal to the secondary valve.

Secondary PID Valve Rate
Enter the default rate of change for the secondary valve (in % per second) when the secondary loop is in manual mode.

Secondary PID Valve Decay Rate
Enter the default rate of change for the secondary valve (in % per second) when the valve is transitioning between sequence positions.

Secondary PID Valve Purge Position
Enter the secondary valve position during purge.

Secondary PID Valve Start Position
Enter the secondary valve position during startup.

Secondary PID Valve Shutdown Delay
Enter the required delay time (in seconds) before the secondary valve goes to the shutdown position.

Secondary PID Valve Shutdown Position
Enter the secondary valve position during shutdown.

Secondary PID Valve Zero Position
Enter the secondary valve position during zero-speed condition.

Chapter 5.
Product Support and Service Options

Product Support Options

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

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

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

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

- A **Full Service Distributor** has the primary responsibility for sales, service, system integration solutions, technical desk support, and aftermarket marketing of standard Woodward products within a specific geographic area and market segment.

- An **Authorized Independent Service Facility (AISF)** provides authorized service that includes repairs, repair parts, and warranty service on Woodward's behalf. Service (not new unit sales) is an AISF's primary mission.

A current list of Woodward Business Partners is available at:
https://www.woodward.com/en/support/industrial/service-and-spare-parts/find-a-local-partner

Product Service Options

The following factory options for servicing Woodward products are available through your local Full-Service Distributor or the OEM or Packager of the equipment system, based on the standard Woodward Product and Service Warranty (Woodward North American Terms and Conditions of Sale 5-09-0690) that is in effect at the time the product is originally shipped from Woodward or a service is performed:

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

Replacement/Exchange: Replacement/Exchange is a premium program designed for the user who is in need of immediate service. It allows you to request and receive a like-new replacement unit in minimum time (usually within 24 hours of the request), providing a suitable unit is available at the time of the request, thereby minimizing costly downtime. This is a flat-rate program and includes the full standard Woodward product warranty (Woodward North American Terms and Conditions of Sale 5-09-0690).

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

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

Flat Rate Repair: Flat Rate Repair is available for the majority of standard products in the field. This program offers you repair service for your products with the advantage of knowing in advance what the cost will be. All repair work carries the standard Woodward service warranty (Woodward North American Terms and Conditions of Sale 5-09-0690) on replaced parts and labor.

Flat Rate Remanufacture: Flat Rate Remanufacture is very similar to the Flat Rate Repair option with the exception that the unit will be returned to you in “like-new” condition and carry with it the full standard Woodward product warranty (Woodward North American Terms and Conditions of Sale 5-09-0690). This option is applicable to mechanical products only.

Returning Equipment for Repair

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

When shipping the item(s), attach a tag with the following information:
- Return authorization number
- Name and location where the control is installed
- Name and phone number of contact person
- Complete Woodward part number(s) and serial number(s)
- Description of the problem
- Instructions describing the desired type of repair

Packing a Control

Use the following materials when returning a complete control:
- Protective caps on any connectors
- Antistatic protective bags on all electronic modules
- Packing materials that will not damage the surface of the unit
- At least 100 mm (4 inches) of tightly packed, industry-approved packing material
- A packing carton with double walls
- A strong tape around the outside of the carton for increased strength

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

Replacement Parts

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

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

Engineering Services

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

- Technical Support
- Product Training
- Field Service

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

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

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

For information on these services, please contact one of the Full-Service Distributors listed at **https://www.woodward.com/en/support/industrial/service-and-spare-parts/find-a-local-partner**

Contacting Woodward's Support Organization

For the name of your nearest Woodward Full-Service Distributor or service facility, please consult our worldwide directory at **https://www.woodward.com/support**, which also contains the most current product support and contact information.

You can also contact the Woodward Customer Service Department at one of the following Woodward facilities to obtain the address and phone number of the nearest facility at which you can obtain information and service.

Products Used in Electrical Power Systems

Facility	Phone Number
Brazil	+55 (19) 3708 4800
China	+86 (512) 8818 5515
Germany	+49 (711) 78954-510
India	+91 (124) 4399500
Japan	+81 (43) 213-2191
Korea	+82 (51) 636-7080
Poland	+48 (12) 295 13 00
United States	+1 (970) 482-5811

Products Used in Engine Systems

Facility	Phone Number
Brazil	+55 (19) 3708 4800
China	+86 (512) 8818 5515
Germany	+49 (711) 78954-510
India	+91 (124) 4399500
Japan	+81 (43) 213-2191
Korea	+82 (51) 636-7080
The Netherlands	+31 (23) 5661111
United States	+1 (970) 482-5811

Products Used in Industrial Turbomachinery Systems

Facility	Phone Number
Brazil	+55 (19) 3708 4800
China	+86 (512) 8818 5515
India	+91 (124) 4399500
Japan	+81 (43) 213-2191
Korea	+ 82 (51) 636-7080
The Netherlands	+31 (23) 5661111
Poland	+48 (12) 295 13 00
United States	+1 (970) 482-5811

Revision History

Revision –
- New manual

Released

We appreciate your comments about the content of our publications.

Send comments to: industrial.support@woodward.com

Please reference publication **35225**.

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Email and Website—www.woodward.com

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

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