

GENERAL SPECIFICATION

ROTATING MACHINERY

GS EP MEC 253

Anti Surge System for Centrifugal and Axial Compressors
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1. Scope

1.1 Purpose of the specification

The intention of this document is to provide an overview of how the compressor anti-surge system should work, with the following points:

- Function and minimum requirement definition
- Responsibility of the Vendor for the whole system, as defined in this document.

1.2 Limits of application

This specification applies to the following driven machines, whether or not covered by a standard, a professional document or a code:

- Centrifugal compressors as per [API Std 617](#) or [API Std 672](#)
- Axial compressors

applicable for either process gas or air.

1.3 Responsibility

The compressor Manufacturer shall assume the full responsibility for the design, the supply and the tuning of the Anti Surge System. In addition, compressor Manufacturer shall review and comment the sizing of the complete anti surge loop.

The equipment including all auxiliaries shall be suitable for operation under the environmental conditions specified by the Company.

2. Reference documents

The reference documents listed below form an integral part of this General Specification.

External Documents

Unless otherwise stipulated, the applicable version of these documents, including relevant appendices and supplements, is the latest revision published at the effective date of this document.

Reference	Title
API Std 617	Axial and Centrifugal Compressors and Expander-compressors for Petroleum, Chemical and Gas Industry Services
API Std 672	Package Integrally Geared Centrifugal air Compressor for Petroleum, Chemical and Gas Industry Services
ASME PTC 10	Performance Test Code on Compressors and Exhausters
FCI 70-2	Control Valve Seat Leakage

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Reference	Title
ISA Guide	Control Valves, Practical Guide for Measurement and Control
ISO 5167 (All parts)	Measurement of fluid flow by means of pressure differential devices - All parts

Total General Specifications

Unless otherwise stipulated, the applicable version of these documents, including relevant appendices and supplements, is the latest revision published in the applicable yearly collection.

Reference	Title
GS EP INS 101	Instrumentation engineering, supply and construction general requirements
GS EP INS 120	Control and Choke Valves
GS EP INS 137	On/off valve control panels and actuators functional and construction requirements
GS EP INS 900	Instrument hook-up diagrams
GS EP MEC 292	Rotating Machines Packages Installation Requirements
GS EP PVV 102	Piping Hook-up Standards
GS EP PVV 112	Piping material classes
GS EP PVV 142	Valves

3. Definitions

- **Surge Flow:** The volume flow capacity below which a dynamic compressor starts to surge.
- **Surge Line:** A line composed of dedicated points where for each speed, the actual surge occurs when the flow is reduced.
- **Surge Control Line:** A parallel line to the surge line where the anti surge valve is operated to keep minimum flow through the compressor without surging.
- **Surge Protection Line:** Called also Safety Line, a line between the surge line and the control line where the anti-surge valve is ordered to be fully open.

4. System Overview

A dynamic compressor requires a recycle loop to control the flow and avoid surge by keeping a specified minimum flow through the compressor. Surge is a non-steady state condition with flow reversal inside the impellers and can cause severe damages to the machine, particularly to the impellers, the thrust bearings and the seals. It can also affect the suction and discharge piping.

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To prevent surge conditions, an anti-surge system is employed. This system continuously checks the process conditions and adjusts the flow through the anti-surge valve in order that at least the minimum flow is maintained. It attempts to anticipate surge through the field instruments and takes pre-emptive action, by opening the anti-surge valve before any surge occurs. If surge is detected then the anti-surge valve trips open and the compressor is tripped.

The anti-surge system is designed for control and asset protection. It is not designed as a safety system.

The compressor anti surge protection loop(s) shall be free of any isolation or check valve.

The flow measurement shall be installed on the suction line.

The anti-surge system shall consist as a minimum of:

- Compressor suction flow measuring device
- Compressor suction flow transmitter
- Compressor suction and discharge pressure transmitters
- Compressor suction temperature transmitter if required for flow compensation
- Anti-surge valve and associated accessories (refer below)
- Anti surge control system based on PLC technology.

In case of side stream, such as for refrigeration compressors, each compressor section shall have its own anti-surge protection system including dedicated anti surge valve, instrumentation and controller.

In case of a multistage compressor with or without intermediate gas refrigeration, each compressor section shall have its own anti-surge protection system including dedicated anti surge valve, instrumentation and controller.

4.1 Field Instrumentation

Refer to the anti-surge control system schematic attached in Appendix 1. Anti Surge instrumentation shall be fully dedicated to the anti-surge system and provided by compressor Manufacturer. The instruments are installed on the suction and discharge pipe work of the compressor by Contractor. These field instruments to be provided by compressor Manufacturer include:

- 1 x suction flow differential pressure transmitter coupled to a flow nozzle measuring device located at the compressor suction side and installed according to [ISO 5167](#) with all necessary straight lengths of upstream and downstream pipe. If the rangeability of the Anti Surge control PDT is not enough to measure the maximum flow of the compressor, a second PDT, called "wide range PDT", shall be supplied and wired to the PLC. The information shall also be sent to the DCS.
- 1 x suction pressure transmitter
- 1 x suction temperature transmitter, if required for flow compensation

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- 1 x discharge pressure transmitter
- 1 x discharge temperature transmitter, although not used for anti-surge protection purpose. This transmitter is used to protect the compressor against high discharge temperature, and shall be located as close as possible to the discharge main flange connection.

Flow measuring devices shall be based on orifice plates (or venturi) with flange taps designed according to [ISO 5167](#). The flow is calculated by the anti-surge controller, based on the differential pressure across the nozzle flow element, and may be compensated by the pressure and temperature.

These instruments shall be installed for gas service, insulated and heat traced depending on the process and environmental conditions.

All signal inputs have a noise filter configured on the Anti Surge Controller to ensure that signal noise will not affect control action.

All instrumentation shall be installed on the main process line. Dedicated manifolds are strictly prohibited.

Above field instruments design shall comply with [GS EP INS 101](#), and shall be installed in accordance with [GS EP PVV 102](#) and [GS EP INS 900](#). Thermowell design shall comply with [GS EP INS 900](#).

All field transmitters shall have built-in indicator displaying the measured value in metric engineering units (barg, °C, mbar, ...). Field transmitters shall be able to be configured to transmit rapidly and raw (unfiltered) data to the PLC, as defined by the anti surge system Vendor.

Anti-surge system transmitters and valve accessories shall be powered from the package unit control panel.

4.2 Anti-Surge Controller

The controller is configured to operate on a single suction flow measurement and the differential pressure measurement on each section of the compressor.

In all cases, the anti-surge controller shall be either integrated in the package PLC or added and installed within the package control panel. If a dedicated controller is used, it shall communicate with the package PLC.

The various signals of the surge control (e.g. anti surge valve regulator input signal, set point and output, FT output, suction and discharge pressure signals) shall be transmitted to the plant ICSS (Integrated Control and Safety Systems) through the UCP PLC for regular analysis, mainly during the starting, stopping and unsteady operation phases.

4.3 Anti-Surge Valve

Anti-surge valve shall be provided with instrument air operated actuator and fitted as a minimum with the following accessories:

- Electro-pneumatic positioner
- Position recopy transmitter

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- Fully open and close position limit switches
- Boosters
- Quick exhausts, solenoid valves, instrument air pressure regulators.

This valve shall be selected by the compressor Manufacturer and be suitable for permanent control from minimum flow to any specified operating flow conditions, and in any case the selected Cv of the valve shall be at least 1.1 times the calculated Cv at the maximum specified flow conditions. The valve shall be operated by a pneumatic actuator with an associated pneumatic control panel being able to operate at a minimum plant air supply pressure of 5 barg.

These valves shall be always selected for continuous operation.

All anti-surge valves and dedicated recycle valves when anti-surge valves are used for compressor protection only shall be classified as operating in severe service conditions if one or more of the following conditions is fulfilled:

- Critical pressure drop ratio: $(P_1 - P_2) / P_1 > 0.5$ for any specified conditions
- Pressure drop > 50 bar for any specified conditions
- High rangeability ratio: max. calculated Cv / min. calculated Cv > 70
- $(P_1 - P_2) \times Q_m > 10000000$ (bar.kg/h) for any specified conditions

Where:

P_1 = Valve upstream absolute pressure (bara)

P_2 = Valve downstream absolute pressure (bara)

Q_m = Weight flow (kg/h).

All valves identified as severe service shall be designed providing a sufficient number of discrete pressure drop stages to maintain the trim exit fluid velocity head (V_h), or dynamic pressure (KE), below 480 kPa for continuous and intermittent service. Valve trim exit fluid velocity head shall be calculated based on the [ISA Guide](#) as follows:

$$V_h = \text{Dynamic Pressure (KE)} = \frac{\rho_0 V_0^2}{2M_2}$$

Where:

KE = Exit Dynamic Pressure (kPa)

ρ_0 = Valve trim exit fluid density (kg/m³)

V_0 = Valve trim exit fluid velocity (m/s)

M_2 = 1000 Constant value (no dimension)

The valve Manufacturer shall also supply a calculation note demonstrating that the trim outlet dynamic pressure criterion of 480 kPa is fully respected.

For any specified operating conditions, the maximum Mach number at valve inlet and outlet flange location shall not exceed 0.25.

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For anti surge valve the valve Manufacturer shall clearly indicate the minimum controllable flow and the corresponding valve stroke. The actual valve range ability shall meet all specified flow conditions, and the minimum flow conditions shall be fully controllable.

The valve seat leakage shall be class IV which corresponds to a seat contact linear pressure of 5.5 kgf/mm (300 pounds force/linear inch as per [FCI 70-2](#)).

The valve shall be flow to open type.

The valve shall be operated either in automatic control mode or quick open mode or manual mode.

The control mode shall be via an integral I/P converter with a digital positioner. This signal shall be driven by the anti surge controller. A valve position feedback shall be transmitted to the controller. The pneumatic control to the actuator shall be via a booster.

The closure rate of the valve shall be controlled by the Anti Surge Controller output signal and shall be adjustable between 15 to 100 seconds.

The valve, the associated pneumatic panel and the solenoid shall be fail-safe. The Anti Surge valve shall be failed open.

The valve shall be capable to fully open within 1 second maximum.

The anti-surge valve actuator shall be single-acting spring-return design. The use of double acting actuators shall be subject to Company review and approval. If double acting actuators are approved, a dedicated air tank shall be provided to ensure the fail-safe function.

Metallurgy of the anti-surge valve shall be in accordance with applicable Company piping class project specifications ([GS EP PVV 112](#)).

In any case, anti surge valves shall be globe type which shall comply with design requirements for globe valves as per [GS EP INS 120](#), § 8 (Control Valve Body), equipped with a cage-guided type trim. Anti surge valves may be angle-type valves for RTJ-type flanges. For low rating services such as LNG applications, angle valves with non RTJ-type flanges may be used.

The valve flow characteristic shall be linear, modified linear or equal percentage type. Compressor Manufacturer shall supply the characteristic curves of the valve showing the minimum controllable flow.

The valve marking, painting, preservation and packaging shall comply with requirements of [GS EP INS 120](#).

The valve installation shall comply with requirements of [GS EP MEC 292](#) § 5.

5. Principle of Operation

In automatic mode, it shall not be possible to manually open or close the anti-surge valve.

Refer to Anti Surge System schematic in Appendix 1.

The anti-surge controller shall be designed to accept remote manual control signal.

The anti-surge protection system algorithm shall be based, as a minimum, on three lines, and checked for all specified gas compositions (normal operation, operational tests during commissioning (air, N2, sweet gas, sour gas...)).

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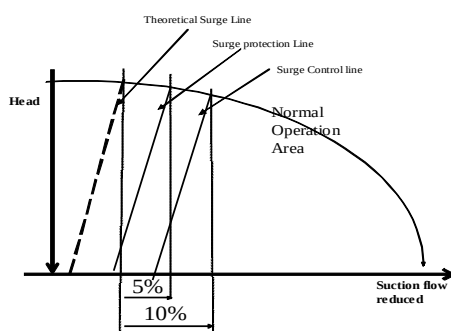
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- The surge line
- The surge protection line
- The surge control line.

The anti-surge system divides the compressor characteristic curves into zones, splitted up by the different lines. Each zone is subject to a different response of the anti-surge controller.



Compressor Characteristic Curves

For large molecular weight variations, the compressor Manufacturer shall super-imposed the performance curves (from minimum to maximum molecular weights) showing the location of the operating points as well as the surge and the surge control lines. The compressor Manufacturer shall also clearly indicate the control strategy implemented.

5.1 Start-up

The anti surge controller shall keep the Anti Surge Valve fully open up to the minimum compressor operating speed.

5.2 Surge Line

The surge line position as defined on the expected performance curves shall be checked during the shop tests and shall be verified during the field tests as part of the commissioning acceptance tests.

5.3 Surge Control Line

For normal operation, the Anti Surge Valve shall be controlled by the Anti Surge Controller, in order to keep the operating point close to the Surge Control Line.

The surge control line shall be parallel to the surge line and set with an adjustable margin initially set at 10%.

5.4 Surge Protection Line

If the flow reaches this line then the AS Control will fire open the Anti Surge Valve.

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In addition to that, the anti surge control system shall initiate the shutdown of the compressor in the following cases:

- If the operating point remains more than 5 seconds on the left of the SPL
- If the operating point crosses the SPL more than 6 time within a short period of time.

The surge protection line shall be parallel to the surge line and set with an adjustable margin initially set at 5%.

An alarm shall be initiated when the operating point reaches the Surge Protection line.

5.5 Shutdown

For normal stop, the Anti Surge Valve is fully controlled by the Anti Surge Controller down to minimum operating speed. Then the Anti Surge Valve is fully open during the rundown sequence.

For Emergency shutdown, the Anti Surge Valve is fired open.

5.6 Alarm & Trip

If there is a discrepancy of 2% or more between the Anti Surge valve positioner and the command from the Anti Surge Controller, an alarm shall be initiated.

Upon failure of any anti-surge system transmitter, the Anti Surge Controller shall fire open the Anti Surge Valve and run the compressor down to minimum operating speed.

The following events shall be recorded within the package Unit Control Panel:

- Surge Protection Line
- Transmitter failure
- Valve discrepancy
- Manual mode
- Automatic mode
- Surge Count.

5.7 Manual control

A HIC override function of the AS valve shall be provided to operate the Anti Surge Valve from 0 to 100% associated to a low signal selector that will always ensure full protection of compressor against surge.

6. Dynamic Simulation Study

The aims of the dynamic simulation are to confirm the design of the Anti Surge Valve, including the trim characteristic, and to evaluate the need of hot gas bypass valve. Compressor Manufacturer shall perform a dynamic simulation, based on actual process volumes that shall be provided by the EPC Contractor. This dynamic simulation shall also detect potential reverse rotation of the compressor and the associated sole need for bi-directional dry gas seals.

The hot gas bypass valve shall be on-off type.

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A numeric model shall be created to represent the dynamic process during transient operations. In that way, the dynamic simulation shall be split in two parts:

Part one dedicated and limited to (each) compressor section in order:

- To verify the sizing of the surge valve protection
- To set the anti surge controller parameters
- To assess the need or not of hot bypass.

The model is limited from the upstream isolation valve to the discharge isolating valve. The model shall include all volumes (scrubber, cooler, valves, compressor and piping) and the compressor characteristics (head, flow, efficiency and speeds) with gas composition.

The results shall show the motion of the operating points in the head/flow diagram during transients operation and presents any compressor surging conditions.

Part two dedicated to simulate the whole compression process, in order to confirm the part one conclusion and to evaluate the compressor behavior during transients (start up and shutdown, speed variation,) and in upset conditions.

This part shall be covered by a specific document, issued during the course of the project and shall include:

- The boundary of the systems to be modeled.
- The characteristics of:
 - The process equipment involved with their respective data (PID, volume).
 - The compressors characteristics (head, flow, speed) and the driver performance (speed rate, output power, limitations).
 - The upstream and downstream process (separator, scrubber, heat exchanger): This process will have to be modeled with behaviors based on agreed assumptions (by both parties).
 - The controllers characteristic (PID coefficient) of any control valves.
- The transient situation and upset conditions are as a minimum defined as following:
 - Quick closure of isolation discharge valves.
 - Quick closure of control valves located at intermediate positions.
 - Emergency shutdown of one of the compressor and impact on the other equipment. At least two scenarii shall be considered: Emergency shut down from the certified operating point and emergency shutdown from operation on the surge control line at maximum continuous speed, maximum specified suction pressure and maximum specified molecular weight.
 - Change in gas composition if any, by closing or opening wells.
 - Start up conditions, in normal and at the settle out pressure.
 - Quick liquid variation in the upstream separator.

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- The results shall show:
 - The motions of compressor operating points in the respective head/curves diagrams associated to speed and power variations.
 - The pressure and temperature profile at various defined locations of the process.
 - A recommendation for anti surge sizing, anti surge setting parameters and hot gas by pass valve sizing if it is required.

The Compressor Manufacturer shall clearly indicate the criteria used to identify the need or not for a hot gas by pass loop.

If confirmed by the dynamic simulation, the hot gas by-pass valve shall be provided shipped loose by the Compressor Manufacturer. The hot gas return line tie-in connection point shall be taken as close as possible from the compressor discharge flange directly back to the compressor suction, as close as possible to the compressor suction flange and in any case downstream the compressor suction scrubber outlet flange using as short piping as possible.

Hot gas by-pass valves shall be actuated on-off ball or globe valves, for which the body shall be in compliance with [GS EP PVV 142](#), and for which the actuator and associated control components shall be in compliance [GS EP INS 137](#) or equivalent project specification. Hot gas by-pass valves are not permitted as a substitute for anti-surge or regulation purposes, which shall be in compliance with [GS EP INS 120](#).

Compressor Manufacturer and Company shall mutually agree on the list and content of scenarii to be analyzed.

7. Testing

7.1 Testing in compressor Manufacturer facilities

The surge line position, as defined in the expected performance curves, must be checked during the performance test in Manufacturer facilities.

During the [ASME PTC 10](#) Type 2 test, the actual surge location shall be determined by observing suction flow instabilities, including reverse flow.

If an [ASME PTC 10](#) Type 1 test is carried out, the compressor performance curve shall be explored up to surge flow measured during the Type 2 test.

Compressor Manufacturer and Company shall jointly define the surge limit inception, based on the following phenomena:

- Typical associated low frequency sub synchronous vibration noise
- Suction flow instability
- Axial displacement
- Noise.

The surge control line and the surge protection line shall be based on surge measured during Type 2 test or Type 1 test if performed. In any case the surge control line and the surge protection line shall not be based on the left extremity of the predicted performance curve.

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7.2 Testing on site during commissioning and start-up

During on site commissioning and start-up, it is mandatory to check again the actual surge line position. This test is part of the commissioning acceptance test procedure. It must be carried out under the responsibility of the Vendor in presence of the Company mechanical representative. Only field instrumentation will be used for this test.

The mandatory way to perform this test is to operate the compressor in closed loop using the anti surge valve. Before the test, the control line must be inhibited or moved inside the surge area and the surge protection line set a few % ahead the surge line as defined in § 7.1. By using the anti surge valve in automatic mode, the flow will be reduced down to the surge protection line, where the anti surge valve will jump to full open position. At this time, with trends analysis of vibration and discharge pressure stability, it is possible to state if surge inception occurs or not. Depending on the results, the surge protection line can be moved closer to the surge line as defined in § 7.1, as long as the surge phenomenon is not identified at each speed.

The Vendor shall provide the FTT analyzer to detect rotating stall and surge inception.

After these tests the respective position of the protection line and the control line shall be adjusted accordingly (5% for protection line and 10% for control line ahead actual surge line position).

In addition to the above, the discharge valve (ESDV) closure test shall be carried out with the unit in operation.

Compressor Manufacturer shall submit the field test procedures to Company including FAT results showing the actual measured position of the surge line.

The required temporary monitoring equipment to carry out the above tests shall be provided by Compressor Manufacturer.

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Appendix 1

Appendix 1 Anti Surge System Schematic (typical)

