

PETRONAS TECHNICAL STANDARDS

DESIGN AND ENGINEERING PRACTICE

TECHNICAL, PROCEDURAL AND SPECIFICATIONS

GUIDELINES FOR COMPRESSOR ANTISURGE CONTROL SYSTEMS

PTS 32.30.40.44

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This new PTS **32.30.40.44 – Guidelines for Antisurge Compressor Control Systems** has been developed to provide a standard guideline for the Design, Implementation, Testing and Commissioning and Maintenance for Compressor Antisurge Control Systems.

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1 INTRODUCTION

1.1 OBJECTIVE

The objective of this document is to provide a standard guideline for the design, implementation, testing, commissioning and maintenance for Compressor Antisurge Control Systems. It is intended for use by PETRONAS and Vendor while developing and also during the operation and maintenance of the system.

1.2 DISTRIBUTION, INTENDED USE AND REGULATORY CONSIDERATIONS

Unless otherwise authorised by PETRONAS, the distribution of this document is confined to companies forming part of or managed by PETRONAS, and to Contractors and Manufacturers/Suppliers nominated by them.

This PTS is intended for use in oil refineries, gas plants, chemical plants and, where applicable, in exploration and production facilities and supply/marketing installations. If national and/or local regulations exist in which some of the requirements may be more stringent than in this PTS, the Contractor shall determine by careful scrutiny which of the requirements are the more stringent and which combination of requirements will be acceptable as regards safety, environmental, economic and legal aspects. In all cases the Contractor shall inform the Principal of any deviation from the requirements of this PTS which is considered to be necessary in order to comply with national and/or local regulations. The Principal may then negotiate with the authorities concerned with the object of obtaining agreement to follow this PTS as closely as possible.

1.3 DEFINITIONS

1.3.1 General Definitions

The **Contractor** is the party which carries out all or part of the design, engineering, procurement, construction, commissioning or management of a project or operation of a facility. The Principal may undertake all or part of the duties of the Contractor.

The **Manufacturer/Supplier/Vendor** is the party which manufactures or supplies equipment and services to perform the duties specified by the Contractor.

The **Principal** is the party which initiates the project and ultimately pays for its design and construction. The Principal will generally specify the technical requirements. The Principal may also include an agent or consultant authorised to act for, and on behalf of, the Principal.

The word “**shall**” indicates a requirement.

The word “**should**” indicates a recommendation.

1.3.2 Abbreviations

DCS	Distributed Control System
ASC	Antisurge Controls
AS	Antisurge
ECA	Equipment Criticality Analysis
IPF	Instrumented Protective System
HAZOP	Hazard and Operability Studies

HMI	Human Machine Interface
FAT	Factory Acceptance Test
SIT	Systems Integration Test
SAT	Site Acceptance Test

1.4 BACKGROUND

1.4.1 Scope of Coverage

This document covers antisurge control on aerodynamic compressors (centrifugal and axial compressors). In addition, it covers both single and multi-stage compressor configurations with either fixed or variable speed drivers.

1.4.2 Antisurge Controls

The objective of the antisurge control is to prevent a machine from approaching its surge region. Surge is defined as the point in the compressor operating map where the machine loses its forward flow and head, resulting in a cyclic flow reversal. The event is cyclical, rapid and detrimental to the machine's performance and integrity. The cycle speed is directly dependant on volumes within the downstream pipes, the compressor itself and its operating point. The cycle speeds are typically less than a second.

Due to its inherent robust design, centrifugal compressors are less susceptible to surge damage as compared to axial compressors. Additional precautions are mandated for the design of surge controls around axial compressors.

The antisurge control shall be designed to provide optimum efficiency and stability of the compressor throughout its operating envelope while safeguarding the compressor from surge.

1.4.3 Phases of Development of Antisurge Control Systems

This document covers four distinct phases of the development:

1. Design
 - Covering elements of measuring instruments, controllers, final control element, control schemes (including performance, decoupling, limiting and other types of controls), compressor curves, speed of response, user interfaces, alarm and trip configuration, failure handling, power supply
2. Implementation
 - Covering instrument installation guidelines, interfacing with other systems and sub-systems
3. Testing and Commissioning
 - Covering factory acceptance testing (FAT), systems integration test (SIT), site acceptance testing (SAT) and compressor surge testing and tuning
4. Maintenance
 - Covering spares, training and recommended proactive preventive maintenance

2 DESIGN OF ANTISURGE CONTROL SYSTEMS

The design for antisurge control systems can be divided into two phases, of data identification and instrument specification.

2.1 DATA IDENTIFICATION

The following documents shall be made available prior to antisurge control design:

1. Process Flow Scheme
2. Machine specifications, including Compressor Performance Maps

These documents shall be utilised to develop the initial surge point/line. This then provides the basis of the sizing for the antisurge control valve.

2.2 INSTRUMENT SPECIFICATION

2.2.1 Control Loop Configuration Selection

A number of options are available for control loops configuration for antisurge control. Configuration decision includes:

1. Type of antisurge algorithm used

There are various options available for antisurge algorithm. The simplest algorithm tend to use flow/head computations, others include reduced flow/compression ratio and reduced flow/polytropic head. The increase in complexity of the algorithm results in more instrumentation. For instance, the reduced flow/polytropic head computation requires five transmitters as opposed to two transmitters for a simple flow/head computation. An increase in the number of transmitters equates to a decrease in reliability.

Selection of the antisurge algorithm shall be based on any of the following conditions:

1. optimising the compressor performance and efficiency
2. variability of the plant and the process load
3. size of the compressor
4. compressor criticality
5. compressor driver

2. Redundancy requirements

Depending on the criticality of the machine, options are available to provide redundancy for field transmitters and controllers. This requirement necessitates the inclusion of failure detection and switching mechanisms. Decisions on the redundancy shall be based on the Equipment Criticality Analysis (ECA) and/or Instrument Protective Function (IPF) studies.

3. Tripping requirements
- 4.

In event the antisurge valve is required to trip, the time taken from trip signal initiation to the antisurge valve to be fully open shall be less than 2s, complying fully to compressor manufacturer's requirement.

2.2.2 Measurement Instrumentation

Due to the high speed cyclical nature of the surge event, measurement instrumentation shall be designed to detect high frequency process fluctuations. Pressure and differential pressure (flow) transmitters' response time shall be less than 200ms.

Volume bottles shall not be utilized in instrument impulse lines to avoid time delays. Damping and/or filtering shall not be allowed in transmitters. Should damping be required due to noise, the minimum possible damping shall be applied in the controllers.

For temperature elements used in surge control algorithm, head-mounted temperature transmitters shall not be used.

Location of the transmitters shall be as close as possible to the compressor nozzle (suction and discharge).

For flow meters, only differential pressure type, e.g. venturi or orifice-plate meters shall be utilised. The use of flow nozzle shall be avoided.

Instrument installation practices shall comply with PTS 32.37.10.11.

2.2.3 Controller

A dedicated single loop controller is preferred for antisurge control. For small compressors (less than 3 MW) and/or low complexity algorithm, a DCS/PLC-based system may be chosen. In this case, the control module shall run at a maximum scan time of 250ms.

For controllers, considerations shall be made on the need for redundancy based on ECA studies.

All necessary information (process and controller) for stand-alone controllers' should be made available to the DCS system. The control outputs shall be hardwired directly from the controller to the antisurge control valve.

Antisurge controller shall never be operated in Manual. A low limit selector, between the hand-control (HIC) and the Anti Surge Control shall be provided in the controller to open the antisurge valve. In the event of a trip the hand-controller shall be forced to full open position automatically.

2.2.4 Control Valve

The opening speed of the antisurge control valve shall be limited to a maximum of 2s. As a general rule, the antisurge valve should be sized twice the flow with ten percent tolerance at maximum surge point.

Pneumatic actuators shall be utilised.

Valve positioners with online diagnostic capabilities shall be utilised. Dedicated position feedback from the antisurge valve shall be made available.

Antisurge valves shall be installed close to the discharge line (near the cooler). Antisurge valves shall be fail-open. Quick-opening valves shall not be utilised. There shall be no hand-wheel installed.

An automated on-off bypass valve should be provided if the antisurge valve C_v cannot cater for start-up or shutdown modes. If the bypass valve is provided, it shall be provided with an open/close limit switch. The bypass valve sizing shall be verified to ensure that there is no possibility of choked flow through the compressor, in event of spurious opening during normal operation.

Refer to PTS 32.36.01.17 for details on antisurge control valve requirements.

2.2.5 Isolation Valves

There shall be no isolation valves installed in the anti surge line.

2.2.6 Alarm and Trip Requirements

HAZOP and IPF studies of the antisurge loop will define the need to incorporate surge trip. If a surge trip is required, the trip signal shall be wired directly to the machine shutdown system and antisurge control valve. Alarms shall be configured as a minimum for the following:

1. Pre-surge alarm
2. Surge alarm
3. System failure alarms (for single loop controllers)
4. Communication failure alarm

2.2.7 Transmitter Failure Handling

Transmitter failure handling is an option to consider in order preventing unnecessary trips. There are two (2) requirements in order to achieve this functionality, i.e. failure detection and transmitter failure handling.

Transmitter failure detection can be configured to detect if the transmitter signal drops below 3.6mA or goes above 20.8mA.

Upon flow transmitter failure, the antisurge control valve shall be configured to fully open. Upon suction or discharge pressure transmitter failure, the maximum compression ratio shall be selected in the surge calculations.

Alarms shall be generated under transmitter failure condition or deviation between redundant transmitters.

2.2.8 Interfacing with other systems

For vendor-based controllers, standard communication protocols (modbus or OPC) shall be made available to the DCS systems in order to allow communication of process values, calculated values, status and system health parameters. Critical signals such as start/stop shall be hardwired.

2.2.9 Human Machine Interface (HMI)

For vendor-based controllers, human machine interface should be made available in the vicinity of the controller for maintenance purposes. These should be installed in a dedicated PC/server. This application shall include an event-triggered high-speed historian with minimum scan time of 1s or better.

The ASC system shall be configured to minimise operator action. Permissible actions include opening of the control valve, closing the control valve to the point limited by the ASC, resetting any surge events (through next-level password access) and system alarms. Operator shall not be allowed to place the controller to Manual, change setpoints/safety margins or modifying other fixed controller configuration parameters. All configurations shall be limited by password access.

Remote controllers shall have output tracking in the DCS.

2.2.10 Other Design Considerations

There are areas where additional design considerations should be utilised to improve the design.

1. Activation/deactivation of antisurge control

A decision shall be made on the conditions that will cause activation or deactivation of the antisurge control. This decision shall be based on:

- Speed of the machine
- Trip/healthy condition

NOTE:

Deactivation implies antisurge valve is fully open and surge trip is not active.

2. Interaction for multi-stage or compressors in series

For multi-stage or compressors in series, control strategies should be configured to avoid interaction between compressor stages. This can be in the form of control loop decoupling.

3. Dynamic simulation

Dynamic simulation shall be carried out for start-up and shutdown scenarios prior to design of antisurge control systems.

4. Integration with compressor performance control system.

Antisurge control shall take precedence over performance control.

6. Location of performance valves

Location of the performance valve shall not be within the antisurge loop.

7. Capacity recycle

Any capacity recycle shall be done through the antisurge valve.

8. Hardwire interface between surge controller and other systems

Contact outputs between systems shall be potential-free contact (dry contact). Interface requirements shall be verified during FAT.

3 IMPLEMENTATION

3.1 INSTRUMENT INSTALLATION GUIDELINES

Refer to PTS 32.37.10.11 and PTS 32.37.20.10 for generic installation requirements.

3.2 OTHER IMPLEMENTATION GUIDELINES

All differential pressure flow meters shall not be configured with square-rooting in the transmitter.

Earthing connections shall be in accordance to PTS 33.64.10.10

All connections to the safeguarding system shall be hardwire connections.

4 TESTING AND COMMISSIONING

There are 3 phases at this stage:

1. Factory Acceptance Test and Systems Integration Test
2. Site Acceptance Test
3. Surge test

4.1 FACTORY ACCEPTANCE TEST AND SYSTEMS INTEGRATION TEST OF THE ANTISURGE CONTROL SYSTEM

The personnel involved during FAT shall be comprised of instrumentation and control personnel. The scope of the FAT shall include but not be limited to:

1. Hardware set-up within control cabinets
2. Wiring
3. Earthing
4. Ventilation
5. Relays
6. Fuse terminals
7. Functionality of power supply
8. Cable taggings
9. Terminal tightness checks
10. Transmitter input checks
11. Controller output checks
12. Failure handling of controller, if redundancy is present
13. Failure handling of transmitter, if configured
14. Failure handling of power supply
15. Software communication connections
16. Trip outputs
17. Hardwire connections to other systems
18. Antisurge simulation to verify controller surge lines versus actual compressor performance maps
19. Software configurations and settings

The scope of the Systems Integration Test during FAT shall include but not be limited to:

1. Communication interface to DCS and all subsystems
2. Simulated functional test

4.2 SITE ACCEPTANCE TEST OF ANTISURGE CONTROL SYSTEM

The SAT of the ASC begins upon completion of all connections of the ASC to all its systems and sub-systems. The SAT should incorporate random elements of the FAT and shall be further enhanced by incorporating live test to transmitters, control valve, systems and sub-systems.

4.3 SURGE TEST

Surge test is carried out by applying process conditions close to or at the surge limit of the compressor. It is typically stopped once incipient surge condition is detected.

Surge test shall be carried out under the following conditions:

1. New compressor installation.
2. Mechanical modifications to the compressor internals, e.g. restaging of compressors.
3. Major changes in process operating conditions outside original surge test envelope.
4. Based on manufacturer's recommendation, e.g. for compressors in severe service application, such as oxygen service, surge verification testing shall be carried out on a scheduled basis.

The preparation for the surge test involves the following elements:

1. Field instrumentation checks
2. Antisurge valve response checks
3. Verification of ASC parameters against design
4. Vendor/DCS system checks
5. Surge Test Procedure with agreed test gas
6. Agreed on minimum number of test points
7. Surge test preparation
8. Discussion with Operations/Engineering
9. Surge test proper
10. Surge test final setup

The final tuning parameters for the ASC shall take into consideration the overall process system stability.

Upon completion of the surge test, all parameters shall be updated into the ASC and verified.

The detailed requirement of the above is presented as a checklist in Appendix 1.

5 MAINTENANCE

The following elements shall be made available for the maintenance team:

1. Configuration tool for vendor-based systems
2. Spares
3. Procedures for configuration and maintenance
4. System documentation, e.g. system manuals, wiring diagrams
5. Controller configuration

5.1 CONFIGURATION TOOL

For vendor-supplied systems, both software and hardware shall be made available to allow for analysis (diagnostics) and configuration to the system. Dedicated hardware and software system may be made available for a series of antisurge control system in a particular location. If economics do not justify this, the site shall maintain a dedicated laptop with the associated communication cables for this purpose.

5.2 SPARES

Spares requirement shall be dictated by ECA.

5.3 PROCEDURES FOR CONFIGURATION

Vendor shall provide configuration procedures for the Antisurge Control system.

5.4 SYSTEM DOCUMENTATION

Vendor shall provide complete system documentation in both softcopy and hardcopy for the Antisurge Control system. These shall include but not be limited to:

1. Compressor performance maps
2. Selected surge line against compressor performance map
3. Wiring diagrams
4. System manuals
5. Control schemes and control narrative
6. Configuration parameters including PID tuning parameters
7. All calibration & test records
8. Instrument Datasheets

5.5 BACKUPS

Site shall retain a complete backup of all configurations in 2 separate locations; one of these may include a backup laptop. The other should be burned onto a disc. Magnetic media (flash drives, etc) shall not be utilised as a key backup.

6 REFERENCES

In this PTS, reference is made to the following publications:

NOTE:

Unless specifically designated by date, the latest edition of each publication shall be used, together with any amendments / supplements / revisions thereto.

PETRONAS STANDARDS

Control Valves: Selection sizing and specification	PTS 32.36.01.17
Instrument Signal Lines	PTS 32.37.20.10
Installation of online instruments	PTS 32.37.10.11
Instruments for Measurement and Control	PTS 32.31.00.32
Compressors – Selection, Testing and Installation	PTS 31.29.40.10
Design Engineering Management Manual	Draft Stage
Control valve engineering guide	Draft Stage
Actuated valve management strategy	PTS 32.36.01.19

APPENDIX 1: SURGE TEST CHECKLIST

No.	Checklist	Y / N
	Field Instrumentation	
1	All flow transmitters shall not have square-rooting applied	
2	Noise filters in the transmitters should as a principle not be applied	
3	Verify all valves on the transmitter manifolds are in the appropriate positions	
4	Loop checks of all transmitters should be carried out to the Vendor ASC panel	
5	Validate that all ranges of the transmitters in the field correspond with Vendor ASC configured ranges	
6	All control valve stroke times shall be less than 2 seconds	
7	Validate that for split range outputs from the Vendor ASC controller, that the output from OUTPUT1 and OUTPUT2 of the Vendor ASC controllers are manipulating the correct valve in the field.	
	Vendor ASC System Checks	
8	Both redundant power systems are healthy	
9	Communications are healthy between Controllers and DCS and Vendor Monitoring System respectively and Vendor Monitoring System screens are active.	
10	Analogue input from the DCS hand-stations for the remote low clamps (manual opening of the ASCV) are functional	
11	Cabinet fans are running	
12	Validate that connections to PLC are functional	
	Surge Test - Preparations	
13	Ensure that personnel (typically Rotating Engineer from Owner and manufacturer) is available for machine monitoring on vibration and axial measurements. Personnel shall be provided with a radio and shall highlight if there are any excessive movements on the rotor or if the general direction of the axial and vibration variables is in the direction to trip the machine (or in the absence of a trip, to a point considered to be detrimental to the machine). Under this condition, any further movement into surge is to be stopped.	
14	All necessary safeguarding trips for testing the surge to be overridden under documented procedures. All start permissive shall not be overridden.	
15	All Vendor ASC controllers to be reset from any alarm/trip condition. All Vendor ASC controllers to be placed on Main control	
16	All Vendor ASC controllers shall be placed in Manual with outputs at 100%.	
17	Vendor ASC controllers shall typically be configured to disallow operation by hand-station from the DCS.	
18	All Performance controllers to be placed on manual and output shall be set to zero	
19	During machine start, all process parameters associated with the machine to be checked, flow1, flow2 , Pd, Ps, Td, Ts, Speed to be operating normally (i.e. no excessive fluctuations and values are realistic).	
20	Vendor ASC high speed monitoring shall be connected and all measurements shall be verified to be recorded.	

No.	Checklist	Y / N
	Discussions with Operations	
21	Agreement shall be obtained with operations to either isolate the machine fully or partially during the period of surge testing. This is to allow the machine to operate near to surge. Work permit shall be issued to execute the surge test.	
22	If the machine is to be placed in isolation, care shall be taken to ensure that the coolers on the bypass line are running and shall be monitored by operations to ensure that increases in the temperature are not substantial.	
23	If the machine is placed in a non-isolated or partially isolated condition, operations shall be informed to minimize any actions taken on the process loop associated with the compressor discharge or suction, as this will directly impact the surge test. If there is a necessity for operations to manipulate the process, operations focal point shall inform the test crew, the test should be stopped temporarily, the change implemented and the test resumed.	
24	Ideally at least three surge points are required although more are ideal. Agreement shall be obtained from operations as to the process conditions at which these tests will be carried out	
25	It shall be noted that each surge test shall be carried out at a different speed. Discussions shall be held with operations to determine the possible speed points. The first speed point may be just above minimum governor. Agreement shall be made for the maximum speed for the surge test, ideally this should be at the normal operating speed of the machine. An intermediate speed is then selected in between the first and the max speed.	
26	Discussions shall be held with operations for them to understand the impact of the surge test especially the impact resulting from potential rapid opening of the surge valve during the test.	
27	If the composition of the gas during the surge test is not expected to be identical to normal operation, a request shall be made to laboratory to take a sample. Further, if the gas composition is expected to change during the test, more sampling shall be carried out.	
	Surge test proper	
28	Vendor ASC vendor shall set up the controller so as to automatically close the valve in a very slow manner.	
29	Vendor ASC vendor shall ensure that protection shall be provided in the event that the machine does move into surge to rapidly open the valve	
30	As the machine approaches surge, the Vendor ASC vendor shall close the valve at a slower rate. This is to ensure sufficient process stabilization time in between the valve movements as the surge point is approached	
31	Validate that the machine monitoring functions are still healthy	
32	As the valve is further closed, the vendor may begin to see early signs of surge (incipient surge)	
33	If incipient surge is detected, the vendor shall stop the surge test and make the necessary recordings of the parameters associated with this point.	
34	In the rare circumstance that the machine does not indicate the incipient (or pre-surge) condition, the machine may move into a surge condition at which point the vendor would immediately (or via an automated action) push the valve to a full open or a predetermined large opening	
35	In the event of a surge incident, feedback shall be obtained from the machine monitoring personnel as to the magnitude of the surge on the machine (as can normally be seen on the axial movements)	

No.	Checklist	Y / N
36	Once the parameters are recorded for the incipient surge (or true surge) condition and the recycle valve is fully opened, the speed of the machine can be raised to the next agreed point and the surge test is then repeated.	
	Surge Test – Final Setup	
37	The vendor shall carry out the following tasks which will have minimal impact on the process: i) PID tuning of the controller ii) Surge trip test and setting of Surge Reference line iii) Other tests	
38	The vendor shall decide on an appropriate safety margin taking into consideration of the dynamic performance of the control valve in moving away from surge. The Vendor ASC vendor shall record / provide his reasons for the final selection in his service visit report.	
39	For machines in series or multiple stages, the vendor shall configure loop decoupling	
40	Vendor shall configure the trip counts and the reset time	
41	Vendor shall configure the fallback strategy in compliance to Owner's requirements. Fallback strategies are utilized in the event of transmitter failure.	
42	Vendor upon completion of all tuning parameters shall upload final parameters into the backup controller	
43	Final checksum shall be checked and recorded by site personnel.	
44	Upon completion of this test, the machine can be handed over to operations to proceed with start-up and surge testing may begin on the next machine.	
45	The vendor shall prepare a report highlighting all changes carried out on the controller with respect to PID tuning and other specific configuration parameters. Vendor shall provide explanations for his/her choice.	
46	The site personnel shall have the soft copies of the following (as a minimum): i) soft copy of the parameters ii) soft copy of the template files, if applicable iii) soft copy of the configuration software The final parameter and template files shall be tested by site personnel before the vendor leaves the site. It is recommended that a soft copy of these files are kept in a safe location (as this would represent a master backup in the event of any failure at site)	