

SURGE CONTROL SYSTEMS FOR CENTRIFUGAL COMPRESSORS

AN APPLICATION GUIDELINE: PART I

BY KLAUS BRUN, MARYBETH MCBAIN, AND RAINER KURZ

First published in 2008, in cooperation with the Gas Machinery Research Council (GMRC),¹ the “Application Guideline for Centrifugal Compressor Surge Control Systems” has been revised and updated by the original authors and will be presented in sections in upcoming issues of *Gas Compression Magazine*.

This guideline is a reference for users, designers, and operators who need to understand surge control system functionality in different operating environments, as well as methods of evaluating surge control system performance against design criteria. A better understanding of surge control system design will enable enhanced protection of the compressor, permit cost-effective selection of components, and allow operators to determine if the existing or future surge control system will meet expectations. Evaluation against design criteria can help operators avoid unexpected costs arising from design changes or unexpected surges of the compressor.

The surge control system is an integral part of the compressor station controls. Competing factors in the design of the compressor station means that it is not always possible to choose the optimum piping arrangement, check valve, recycle valve, or control algorithm. Different centrifugal compressors and various piping layouts perform differently under surge. In addition, the surge control system designer may not have decision-making authority for the compressor station layout and component selection. To overcome these challenges, they must design against the limitations of the compressor station. Operating companies, in cooperation with the compressor manufacturer, can apply the concepts presented in this guideline to design a risk-based approach to compressor station design and evaluation to reduce the possibility of unexpected surge, which could reduce mechanical integrity, reduce operational flexibility, and/or cause the compressor to fail.

Surge control systems are an integral part of centrifugal compressor station controls. There are various approaches to surge control system design, including designing for surge prevention, limited surge occurrence under specific conditions, and risk-based evaluation of surge control systems. Each of these approaches has distinct advantages and disadvantages. This series of articles will provide a reference for surge control system functionality; selection, installation, and operation of surge control systems; surge control system components; their impact on the performance of surge control systems; and methods of evaluating and optimizing surge control system performance, regardless of the selected design approach.

I SURGE CONTROL SYSTEM DESIGN

Surge control systems protect the compressor over a range of high-risk conditions, which may encompass the entire operating range of the compressor, or only a subset of the operating range. System functionality develops from its operating environment, of which there are three: startup, normal process control, and emergency shutdown.

Methods of evaluating surge control system performance vary depending on the system design philosophy selected by the operating company in collaboration with the compressor manufacturer. The following design philosophies will be discussed:

- **Surge Avoidance:** A calculated allowable discharge volume dictates the design in this philosophy. Simple or more complex transient models of the compressor system are used to determine the discharge piping volume.
- **Permit Surge Under Specified Conditions:** This design philosophy is based on the idea that the compressor may not be fully protected because of operational changes or cost-based decisions. However, the surge control system will still guard against surge at “high-risk” or “high-energy” conditions. A simple transient model is used to evaluate and assess the occurrence of surge against the surge control system design criteria.
- **Risk Assessment:** This design philosophy uses custom-

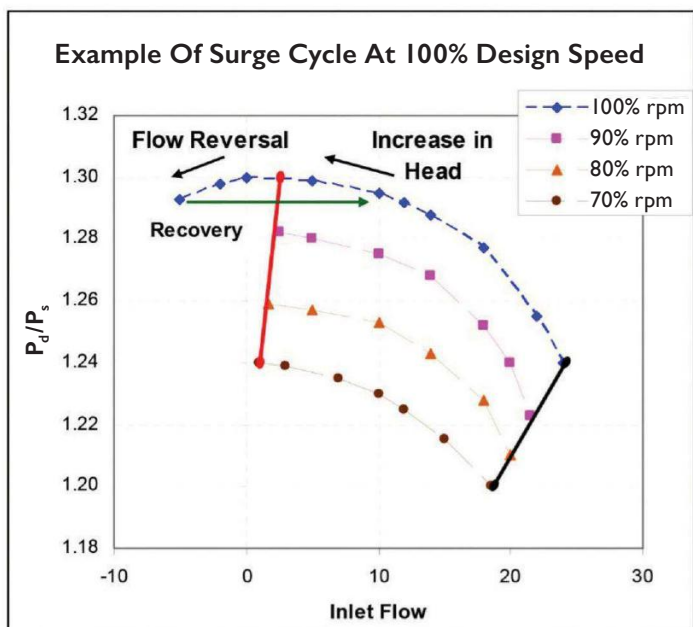


Figure 1. Typical compressor surge line is displayed on a performance map. P_d is total (stagnation) pressure of gas at discharge side; P_s is total (stagnation) pressure of gas at discharge side at suction.

ized economic- and risk-based analysis models to evaluate the surge control system in relation to a set of risk factors for a particular compressor. In this case, dynamic simulation is not required. Economic- and risk-based analysis models are based on known risk probabilities, safety requirements, and equipment repair/replacement costs to determine the overall design and operational risks associated with the surge control system.

1.1 DESCRIPTION OF SURGE

Surge is defined as the operating point at which the compressor peak head capability and the minimum flow limit are reached. When surge occurs, the compressor cannot maintain the peak head, and the system becomes unstable. Under normal conditions, the compressor operates to the right of the surge line. However, as the flow rate fluctuates, or under startup/emergency shutdown, the operating point moves closer to the surge line because of reduced flow. If the operating point approaches the surge line, the impeller and diffuser begin to operate in stall, and flow recirculation occurs. Flow separation eventually causes a decrease in the discharge pressure and flow from suction to discharge resumes. This is known as the compressor's surge cycle, as shown in Figure 1.

The surge cycle will continue to repeat unless control systems are installed or operational changes are made to bring the compressor out of the surge cycle. Depending on the discharge gas volume and the pressure ratio, the surge cycle may cause a small or large flow reversal period. Chronic surge is characterized by intermittent periods of small flow reversal that may not

cause severe damage to the compressor. Acute surge is more pronounced, usually due to a rapid transition across the surge line. Any surge event can cause severe damage to the thrust bearings, seals, and impellers. The extent of the damage caused by surge occurrence is related to the compressor design.

A surge control system continuously monitors compressor operation. When it detects the approach to surge, it opens the recycle valve, providing more flow to the compressor to avoid the potentially damaging flow reversal period and surge cycling. The surge control system should be designed for the three surge environments (which may have competing demands), the compressor operating parameters, and the manufacturer's specifications.

1.2 FUNCTION OF SURGE CONTROL SYSTEMS

Surge is a relatively common yet costly phenomenon in centrifugal compressors. The surge control system protects the compressor from surge over the range of compressor operations. Investment in a surge control system is necessary to avoid more costly compressor repairs or overhauls resulting from damaging surge conditions. While there are a variety of methods and

Continued on page 30

HFW INDUSTRIES

INCORPORATED

**Single source manufacturing and repairing
for the gas compression industry.**



www.hfwindustries.com

HFW Industries, Inc.
196 Philadelphia St.
Buffalo, NY 14207-0008

sales@hfwindustries.com
Ph: 716-875-3380 / Fax: 716-875-3385

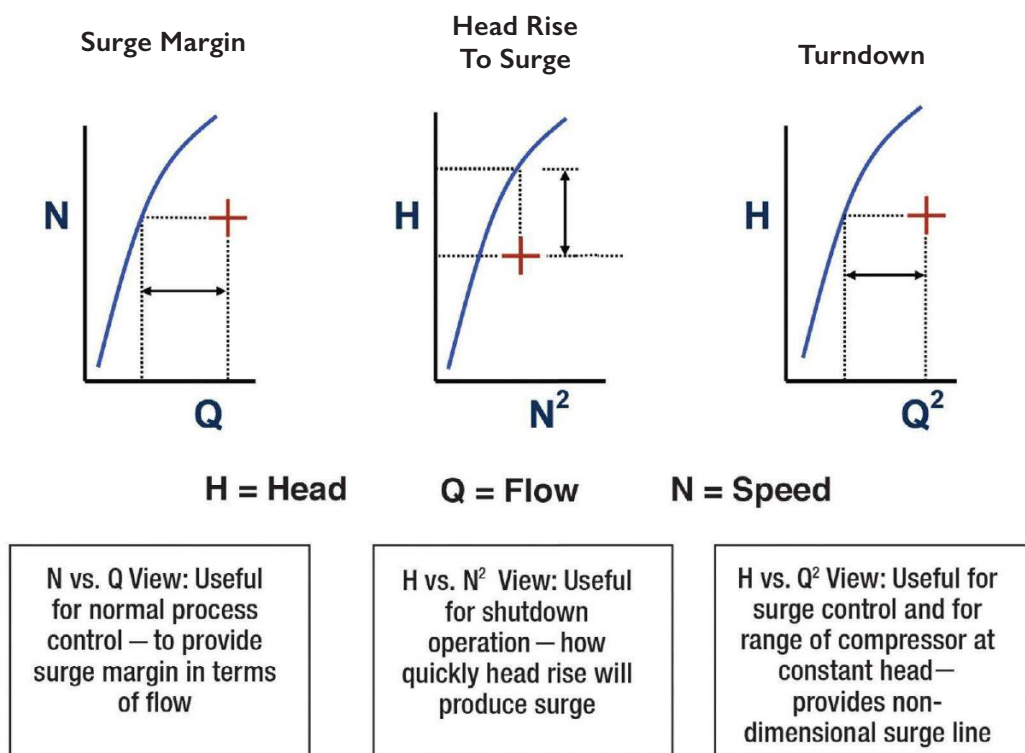


Figure 2. Depictions Of Surge In Terms Of Compressor Head, Flow, And Speed

philosophies for implementing a surge control system, the primary objective is to predict and prevent the occurrence of surge to reduce the risk of damage to the compressor and to assure a safe working environment.

The main function of a centrifugal compressor control system is to maintain flow through the compressor at or above a minimum flow limit at a specific head. The most common surge control techniques restrict compressor operation to flow rates above a defined surge control line, based on the surge margin for a particular compressor. However, restricting the compressor operating window to avoid surge due to mistakes in surge control system design should be avoided. A properly designed surge control system can enable an extended compressor operational range based on the response of the surge control system.

At a minimum, the surge control system should actively measure the compressor head and flow through the compressor system controls to determine the resulting operating point. The recycle valve should open in a specified time to a valve set point determined by the surge control system. The signal to the valve is based on the compressor operation and its proximity and movement (rate) relevant to the surge control line. When the recycle valve opens in the surge control system, it increases flow and reduces compressor head to move the compressor away from its surge point, effectively avoiding surge.

1.3 VIEWS OF SURGE

There are three ways to view the surge region of an operating centrifugal compressor: flow, head, or speed. These three views illustrate how the surge region responds to changes in gas composition. If the surge line is represented by variables that are calculated based on gas properties (enthalpy, density, or entropy), the surge

line will change based on gas composition. Each of these views is advantageous to particular operating environments.

Three views of the surge line are shown in Figure 2. Viewing the surge line in terms of speed versus flow rate provides an estimate of proximity to surge within a flow rate range or surge margin. As the compressor speed increases, the surge margin may be reduced. Flow rate changes based on changes in the gas composition (density effects) affect the surge margin and surge line in this view. The surge margin is useful during normal process operation when the flow must be reduced because of pipeline requirements.

Viewing the surge line in terms of compressor head versus speed provides an estimate of the head rise to surge. The head rise to surge tells the operator how quickly surge will occur during shutdown operation. If the surge line is flatter, the head rise to surge will be smaller and surge can occur more quickly in an emergency shutdown event.

Viewing the surge line in terms of head versus flow illustrates the compressor turndown or operational window. At a constant head, the compressor will operate within the operational region to the right of the surge line. The allowable operational flow range determines the turndown of the compressor. The surge

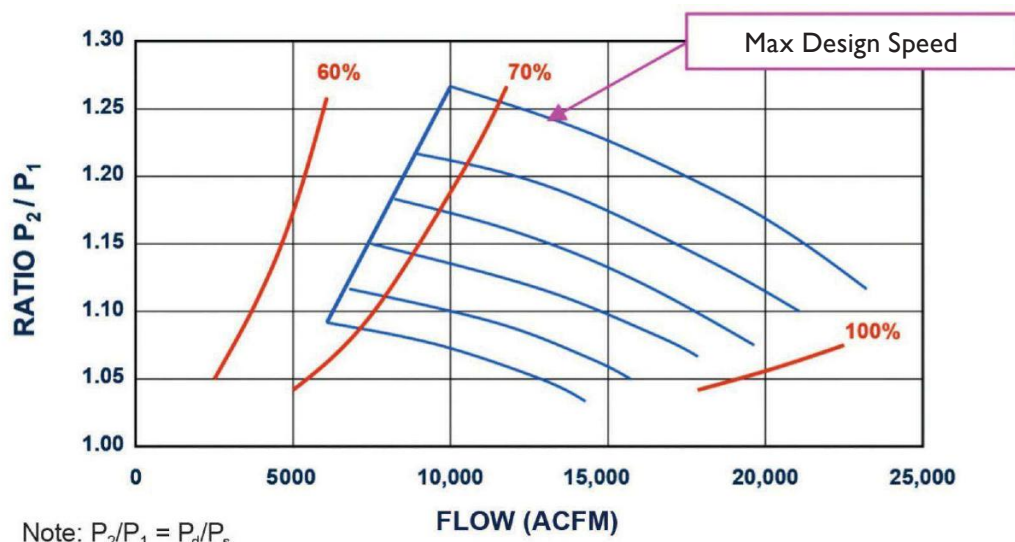


Figure 3. Example Of Recycle Valve Characteristic Curves At Various Opening Percentages

limit model is best shown on a head versus flow map because this representation normalizes the surge line. The compressor head for the performance map is calculated using the measured temperature, pressure ratio, and flow across the compressor, as well as the gas properties.

$$(I-1) \quad H_p = \frac{\left(\frac{P_d}{P_s}\right)^{np} - 1}{np} \times T \times SG \times Z$$

where H_p is compressor head, polytropic condition; P_d is total (stagnation) pressure of gas at discharge; P_s is total (stagnation) pressure of gas at suction; $np = (n-1)/n$, where n is the polytropic exponent; T is temperature of gas; SG is specific gravity; and Z is compressibility of gas.

The reduced head versus reduced flow equation should be used to simplify the equations because the temperature, specific gravity, and compressibility cancel out in both the head and flow equations. The reduced head is only a function of pressure ratio and flow, calculated as follows:

$$(I-2) \quad H_{\text{REDUCED}} = \frac{\left(\frac{P_d}{P_s}\right)^{np} - 1}{np}$$

where H_{REDUCED} is reduced head.

Reducing the head and flow to these variables allows the surge limit model to be used at all speeds and gas compositional variations, with minimal shifts in the surge line location on the performance map. The reduced head view is the best representation for the surge control system because the density effects cannot affect the uncertainty in the surge control

line. This provides more precision in the surge prediction within the control system algorithm.

I.4 SURGE CONTROL SYSTEM ENVIRONMENTS

Surge control system design is more challenging than other station control systems because of the high speed of distur-

Continued on page 32

KIENE Indicator Valves for Gas Engine/Power Cylinder Analysis

- Models available for all common gas engines.
- Rugged, compact, proven design.
- Dual port versions for continuous monitoring and auto-balance systems.

ASK US ABOUT SPECIALS TO MEET YOUR REQUIREMENTS. WE DO THEM ALL OF THE TIME - ANY QUANTITY!



SMV Dual-port Sensor Mounting Indicator Valve



Contact us now for information!

KIENE
DIESEL ACCESSORIES, INC.

1-800-264-5950
info@kienediesel.com
www.kienediesel.com

Surge Control System Environment	Surge Limit Model	Control Algorithm	Recycle Valve System	Instrumentation	Piping System
Compressor Startup	Used to develop fixed valve opening in design. See Section 3.3.4.	Not Applicable	Fixed valve opening used. See Section 3.3.4.	Not Applicable	Larger piping volume will help to avoid overheating compressor. See Sections 1.4.1 and 3.5.1.
Process Control	Nonlinear surge line will help to extend operational region of compressor. Accurate line is required to avoid surge. See Sections 3.1.3 and 8.1.	Use of lower gain signals is necessary to assure valve control is precise and allows for gradual recycle valve opening and closing. See Section 3.2.3.	Precision in controlling recycle valve position and minimizing overshoot are required. Nonlinear response of valve will affect control and resulting operation. See Section 3.3.3.	For instrumentation requirements, see Sections 3.4 and 4.1.	Larger piping volumes will affect control, and response will lag in proportion to size of piping volume. See Section 3.5.2.
Emergency Shutdown	Not Applicable	Not Applicable	Recycle valve size and characteristic (time vs % open) will affect surge avoidance ability of control system. Must assure size of valve and opening time are met. See Section 3.3.5.	Not Applicable	Minimizing downstream piping volume is critical to maintaining fast response time. Modeling of ESD event should result in a piping volume requirement. See Sections 6.1 and 3.5.3.

Table 1. Summary Of Surge Control Environments And Component Functionality Requirements

bances and the dynamic nature of surge. Required control system responses vary depending on the operating environment and the selected system components. The three primary operating environments, startup, normal process control, and emergency shutdown, are described subsequently.

1.4.1 STARTUP ENVIRONMENT

In the startup environment, the challenge for the surge control system is to bring the compressor up to design speed quickly, without overheating the discharge gas. For steam turbine or single-shaft gas turbines, the startup period is longer and the recycle gas may need to be cooled. Typically, the gas is continually recycled in startup mode to bring the compressor online. However, operating in continuous recycle will cause the temperature of the process gas to increase until new gas is supplied from upstream. When the recycle valve is fully open and the downstream check valve is closed, all compression horsepower serves as heat input to the recycled gas.

Compressor startup is initiated by equalizing compressor pressure with the pipeline. This is accomplished by opening the upstream loading (charge) valve. Once the pressure equalizes, the upstream and downstream isolation valves open, causing the downstream check valve to close. The isolation prevents flow from entering from the discharge side. Upon startup, the recycle valve is fully open. As the compressor begins to gain speed and flow increases, the recycle valve gradually closes. At this point, the compressor downstream check valve may be opened.

If the compressor cannot reach design speed in sufficient time, in the worst case, the process gas will cause the compressor to shut down due to high discharge temperature. The surge control system must function to

gradually close the recycle valve according to the startup controls. Three strategies to avoid overheating are used in the design of the compressor station:

1. Minimize recycle time for startup.
2. Increase the mass of gas in the recycle loop to allow for more heat storage. (This will have adverse effects on the surge protection for emergency shutdown.)
3. Add cooling to recycled gas.
 - Use a discharge system cooler or add a suction gas cooler on the downstream side of the recycle valve. (Layout options will be discussed in Section 2, Alternative System Layouts.)

Since the second and third strategies may increase discharge piping volume by reducing the surge control system response time in the shutdown environment, the first strategy is preferred. The surge control system should gradually close the recycle valve as the compressor speed increases.

If the recycle valve is not closed to some extent, the compressor will not be capable of coming up to full design speed (Figure 3). This relationship between the recycle valve characteristics and the compressor operating map is typical. The surge control system must act to close the recycle valve in sufficient time and with sufficient precision to attain the full design speed of the compressor. Control signal precision is required because closing the recycle valve should not cause the compressor to surge from a corresponding decrease in flow.

Note: Figure 3 provides an example of a 70% valve opening percentage used for the maximum design speed. However, more conservative criteria may be used at 40% to 50% valve opening to provide additional valve capacity at the surge line.

Continued on page 34

Typically, the response time for the compressor to come online is designed for normal ambient temperatures. At higher ambient temperatures, however, the process gas heats up more quickly, reducing the available recycle time. To avoid this, the allowable recycle time should have a sufficient safety margin to permit compressor startup at higher ambient temperatures.

This also applies to restarting the compressor after shutdown. Restart may involve higher operating temperatures, especially if the compressor is shut down because of high discharge temperature. An additional starter motor should be considered for compressors with severely limited startup capability. The motor can also provide additional power for the compressor under normal process control operation. Adding a discharge cooler to the recycle loop is another viable alternative; although, this may have other implications for the surge control system in the shutdown environment due to the added discharge volume that must be relieved through the recycle valve.

1.4.2 NORMAL PROCESS CONTROL ENVIRONMENT

Surge control system operation is distinctly different under normal process operation. In this environment, the surge control system should not limit the operational range of the compressor; that is, the surge control system should function over the entire operating range. The shape of the surge control line determines the response characteristics of the surge control system. A relatively flat surge line equates to higher surge sensitivity to changes in compressor head. A steeper surge line indicates that the compressor is more sensitive to flow rate changes or uncertainties near the surge line. The surge control system must provide for smooth operation of the compressor in either case.

The challenge for the surge control system in process control is to match the transition into surge (across the surge margin). This transition is typically gradual during normal process control, with a gradual increase in flow through the recycle valve. This requires precision control of the valve motion.

Because the control signal and recycle valve response for normal process control differs from the shutdown environment, different control system gains are used for the different surge operating environments. The control algorithm must be capable of distinguishing between start-up operation, normal process control operation, and an emergency shutdown operation. During normal process control operation, lower gain signals should be used to adjust the flow by opening or closing the valve in a controlled manner.

The allowable response time for the recycle valve in the process control environment is longer and typically not critical. Both functionalities are required to provide adequate process control during normal operation and quick response during an emergency shutdown.

Controlled shutdown of the compressor also falls un-

der the process control environment. In a controlled shutdown, the surge control system maintains a steady flow to the compressor as power is removed from the unit. As the compressor gradually decelerates, the surge control system maintains flow in proportion to the surge control line so the surge margin is not crossed.

In the controlled shutdown environment, the challenge is to prevent the compressor from overheating due to operating in continuous recycle. This would happen only if a discharge or suction cooler is not present, or if the aftercooler cannot sufficiently cool the recycled gas (due to improper sizing).

1.4.3 EMERGENCY SHUTDOWN ENVIRONMENT

The two types of compressor shutdown are defined as follows:

Controlled Shutdown – The compressor is shut down under controlled conditions in which speed and power are gradually decreased. Surge control system functionality for controlled shutdown falls under the requirements for the normal process control environment, previously discussed.

Emergency Shutdown (ESD) – The compressor suddenly shuts down and driver power is removed. Surge control system functionality for this environment is designed to protect the compressor.

During an ESD event, delaying shutdown or slowly decreasing speed is not possible because ESDs provide immediate shutdown of the compressor for safety reasons. The surge control system must function quickly to open the recycle valve fully because the station operator does not control the coastdown path. In this scenario, the coastdown path is controlled only by the deceleration of the compressor based on the power train inertia and any residual power in the system. The emergency shutdown requires more demanding control system response and may alter the surge control system design because a single recycle valve may not provide sufficient flow quickly enough. Additional system evaluation may also be required.

The worst-case ESD scenario occurs when the compressor is operating at maximum head at the lowest allowable surge margin. This is the operating point that should govern the design of the surge control system, as the maximum possible differential that must be overcome by the recycle valve flow.

Further discussion of the evaluation of the surge control system is provided in Section 6, System Design Criteria. The three surge control system environments present differing demands on the control system components. The requirements for surge control system components are discussed in Section 3 (Surge Control System Components) and in the operational description in Section 5 (Operation of Surge Control System).

1.5 SUMMARY OF SURGE CONTROL SYSTEM ENVIRONMENTS

Table I summarizes the requirements for each of the primary surge control system components in the various surge

operations, based on the differences in the surge control environments. This summary serves as the guideline reference for further discussion of component requirements. 

REFERENCE

¹Brun, K. and M.B. Nored, "Application Guideline for Centrifugal Compressor Surge Control Systems," release version 4.3 (Dallas, TX: Gas Machinery Research Council [GMRC]; San Antonio, TX: Southwest Research Institute [SWRI], 2008).

ABOUT THE AUTHORS

Klaus Brun, PhD, is the director of Research & Development at Elliott Group. He leads a group of over 60 professionals in the development of turbomachinery and related systems for the energy industry. His experience includes positions in product development, engineering, project management, and executive management at Southwest Research Institute, Solar Turbines, General Electric, and Alstom. He holds nine patents, has written more than 350 papers, and has published three textbooks on energy systems and turbomachinery. Brun is a Fellow of ASME and won an R&D 100 award in 2007 for his Semi-Active Valve invention, as well as the ASME Industrial Gas Turbine Award in 2016.

Marybeth McBain works as a senior engineer/senior project manager in the Kinder Morgan Midstream group. Her primary functions involve evaluating new compression projects for gas transmission, gas storage, and gas processing plants as well as recommending upgrades and compressor modifications to suit changing pipeline needs. McBain previously worked at Southwest Research Institute for 10 years in the pulsation analysis and turbomachinery groups as well as Apache Corporation for four years as a senior facility engineer. She holds four patents and has published more than 30 publications related to natural gas machinery. Her career is supported by a BSME from the University of Texas at Austin and an MSME from Georgia Tech.

Rainer Kurz, PhD, is the manager, Systems Analysis, at Solar Turbines Incorporated in San Diego, California. His organization is responsible for analyzing compression requirements, predicting compressor and gas turbine performance, conducting application studies, and field performance testing. Kurz attended the Universitaet der Bundeswehr in Hamburg, Germany, where he received the degree of a Dr. Ing. in 1991. He has written numerous publications about turbomachinery-related topics, is an ASME Fellow, holds two patents, and is a member of the Turbomachinery Symposium Advisory Committee.



LEGACY COMPRESSOR PARTS

Samco Enterprises, Inc. is one of the largest suppliers of natural gas compressor parts, valves and equipment in the nation. Founded in 1972, we stock over 13,000-part numbers between our five facilities and over 100,000 square feet and 25 acres of inventory. We stock new, used, and remanufactured compressor and engine parts for Cooper Bessemer, Ingersoll/Dresser Rand, Clark, Worthington, PPC, Gemini, Chicago Pneumatic, White Superior, Ariel, Joy, and other legacy manufacturers:

Cylinders • Frames • Crankshafts • Distance Pieces / Guides
Connecting Rods & Crossheads • Pins, Bushings and Bearings
Valves, Cages & Valve Internals • Gears, Sprockets & Pumps



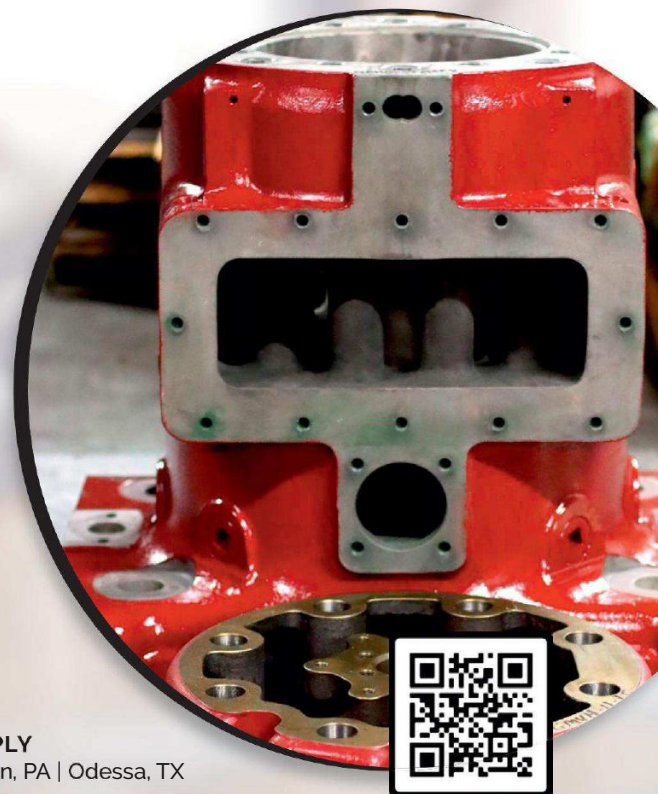
MANUFACTURING | REPAIR | SUPPLY

Houston, TX | Tyler, TX | Oklahoma City, OK | Uniontown, PA | Odessa, TX

(800) 231-0649

sales@samcoenterprises.com | www.samcoenterprises.com

Have old, used or obsolete compressor inventory? Call us. We purchase compressor parts



SCAN HERE TO CHECK
OUT OUR INVENTORY

SURGE CONTROL SYSTEMS FOR CENTRIFUGAL COMPRESSORS

AN APPLICATION GUIDELINE: PART 2

BY KLAUS BRUN, MARYBETH MCBAIN, AND RAINER KURZ

EDITOR'S NOTE: First published in 2008 in cooperation with the Gas Machinery Research Council (GMRC), the "Application Guideline for Centrifugal Compressor Surge Control Systems" has been revised and updated by the original authors and will be presented in sections in upcoming issues of Gas Compression Magazine. Part 1 is published in the September 2021 issue of Gas Compression Magazine, p. 28. Figures and references follow consecutively from Part 1.

2 SURGE CONTROL SYSTEM APPLICATIONS AND LAYOUTS

To better understand surge control system operating environments, descriptions of typical applications requiring the use of surge control systems are summarized in this section. The primary factors to consider in layout design provide the background for decisions concerning piping volume and placement of key elements in the compressor station. A typical surge control system layout is outlined in Section 2.2. Alternative layout options are provided in Section 2.3. Due to competing operational demands on the surge control systems, with any choice of piping layout, some disadvantages arise.

2.1 SURGE CONTROL APPLICATIONS

A number of applications exist for surge control systems. A brief description of functionality and variations in the primary applications is provided below.

2.1.1 Pipeline Compression Application

Pipeline compression is a typical application for centrifugal compressor surge systems. These installations have a fluctuating pressure ratio across the compressor based on the pipeline. In pipeline applications, surge events will occur due to flow reductions governed by the pipeline. These will occur over the entire surge line (i.e., over the range of the compressor's given pressure ratio). Changes in the gas composition and operating temperature will affect when surge occurs. The surge margin should take these uncertainties into account.

Gas temperature is fairly steady for a given daily period, but fluctuations can occur on a seasonal basis. The gas compositions in this type of application are predominately methane (75% to 95%) with additional heavier hydrocarbons and diluents such as nitrogen and carbon dioxide. Variations in pressure and composition occur more slowly, over a period

of several hours or more, due to the large volume of gas in the pipeline system, unless multiple machines are used in parallel.

2.1.2 Re-Injection Application

In re-injection applications, the compressor injects gas back into a potential production field. These applications require a varying discharge pressure based on the gas field pressure requirements (with field pressure changes over time). The composition of the gas can vary widely due to many sources of gas, which requires a representation of the surge line in reduced head and flow (composition independent) form. Liquid slugs of gas that would cause flow disturbances may be common – and surge control systems may be used to mitigate the disturbances. The pressure ratio is significantly larger in this type of application because the discharge gas pressure can be excessively high (greater than 3000 psig [206.8 bar]) and typically involves multiple bodies. Excessive temperature fluctuations are not as common in this type of application but can vary on a seasonal basis as well. Suction flow changes can be sudden due to required valve operations and process disturbances at certain conditions.

2.1.3 Storage And Withdrawal Application

In storage and withdrawal applications, the compressor injects or withdraws gas from a storage field or reservoir. The pressure of the suction gas varies with time (initially fairly high but declining quickly over time for withdrawal applications, or initially fairly low and increasing gradually in injection applications). Pressure ratio is also based on the storage field initial pressure. The gas composition variations are due to changes in the storage gas. These applications can be particularly challenging for a surge control system, requiring fast response for the normal process control operation, but a more gradual response as the pressure ratio falls. For this reason, the control signals for the recycle valve may need to be more diverse than a typical pipeline application.

Continued on page 40

2.1.4 Gas Gathering Application

Gas gathering installations collect production-type gas mixtures to prepare the gas for processing or transmission pipeline applications. This application may have wide swings in gas composition caused by the types of gas being treated and the level of dehydration, separation, and filtration used at one particular installation. These installations may require more extensive modeling or design efforts to minimize piping volumes. Gas mixture variations due to various production fields will cause changes in the characteristic head vs. speed curves for the compressor. The pressure ratios are typically lower than re-injection and storage applications, with discharge pressures maintained below 3000 psig because the discharge gas is typically fed into a pipeline system. Gas temperatures are fairly stable in this application.

2.1.5 High-Pressure/Process Compression Application

High-pressure compressors vary broadly in the pressure ratios and gas compositions used, depending on the specific application. Higher pressures are typically on the order of 3000 to 5000 psi (344.7 bar) in these applications. The processing plant compressor will experience changes in pressure, head, and operating conditions, depending on the type of process (liquefied natural gas [LNG] facilities, refineries, hydrocarbon processing, and natural gas liquid [NGL] removal processes). Gas composition and temperature will vary based on the process requirements as well. Surge control systems should be designed to completely avoid surge during normal operation since the higher pressures will introduce additional risk of compressor damage due to surge.

2.2 SURGE CONTROL SYSTEM LAYOUT

The basic elements of a compressor surge control system are the flow measurement (typically on the suction side of the compressor), the pressure measurement, the discharge check valve, the recycle valve and its actuation system, and the surge control system controller. The recycle line should be connected immediately upstream of the discharge check valve and upstream of the compressor flow measurement device on the suction side. The recycle line will typically be upstream of the compressor suction scrubber if the recycle loop is cooled to avoid condensed liquids in the recycle flow. The boundaries for the discharge gas volume are set by the discharge check valve (downstream of the recycle line take off point), the compressor, and the recycle valve.

Key issues to address in designing the surge control system layout are as follows:

a. Minimize downstream piping volume: The volume of gas contained between the compressor discharge flange, the downstream check valve, and the recycle valve should be minimized as much as possible. This volume is the mass inventory of the system. The volume determines the rate of relief of the downstream pressure and

the requirements for the recycle valve (size, speed, and characteristic). The downstream piping volume directly relates to surge control system performance in the shutdown environment.

b. Use multiple recycle loops as needed: Compressor trains or compressor systems with multiple sections may require independent or separate recycle loops. The surge controller for each compressor section should ensure that adequate surge control is provided for every operating scenario (shutdown of individual units and station as a whole).

c. Downstream check valve placement near the compressor discharge flange: Proximity of the downstream check valve to the compressor outlet will limit the downstream volume and increase the required system response time of the surge control system. Placement of the downstream check valves for each compressor section, return lines, and recycle take-off lines must be carefully reviewed to ensure that separate compression loops operate independently.

d. Use of independent check valves: Parallel compressor units should have check valves installed to ensure effective surge control of each compressor. Isolation valves are also recommended.

e. If the startup period requires considerable time to bring the compressor up to speed, consider adding cooling of recycle gas: The recycle gas, or a portion of the gas in the recycle loop, should be cooled to facilitate operation in continuous recycle. Incorporation of hot and cool gas recycle loops will help to reduce the possibility of overheating upon startup or controlled shutdown. Upstream pre-coolers (downstream of the recycle valve) are an option to consider that helps keep discharge system volumes small (see Item a). Installation of the system should consider where the cooler is to be placed and how much flow will be required to be cooled. Suction coolers will minimize discharge piping volume, but the hydrocarbon and water dew points should be a design parameter for the suction pressure and cooling expected to avoid two-phase flow.

f. Keep separation vessels upstream: Liquid separation vessels should be located upstream of the compressor and downstream of cooling elements in the system. Placing these on the suction side will also help minimize discharge system volume (see Item a).

g. Ensure recycled flow reaches the compressor quickly: Recycle piping should enter the suction flow downstream of any throttling valves to ensure that the flow reaches the compressor entrance quickly. Pressure relief systems should be limited on the compressor suction side because suction-mounted relief systems can cause substantial flow reduction. Alternatively, recycle lines that return upstream of the throttling valve may be considered to help unload the motor upon startup of the compressor.

ANTI-SURGE VALVE

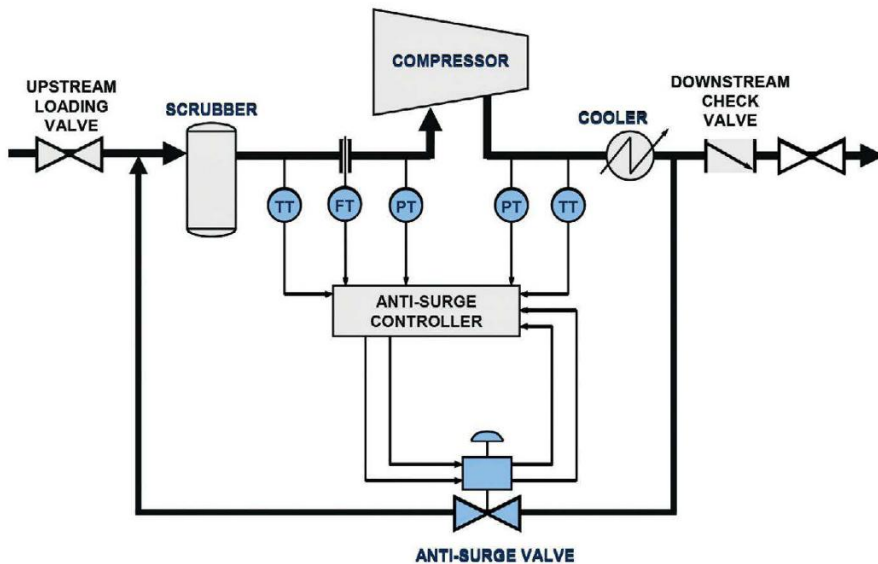


Figure 4. Typical Compressor Surge Control System Layout With Single Recycle Valve

2.3 ALTERNATIVE SYSTEM LAYOUTS

The basic cooled recycle loop (Figure 4) provides a large operating range for the compressor. However, use of a non-cooled recycle loop has some advantages over other arrangements because it minimizes the system discharge volume and allows for a faster response time dur-

ing shutdown, as shown in Figure 5. Other common arrangements that may be used for more than one compressor unit or for providing more flexibility in operation are given subsequently. These layouts may be necessary due to the operation of other units at the station or the need to increase the recycle valve flow capacity.

Multiple valves may be used in the surge control system to meet the demands of both the process control operation and the emergency shutdown event because the valve characteristic curves/control signals can differ. This will allow for both gradual and rapid changes in the valve coefficient. Multiple valves will add complexity to the control system and any transient modeling efforts, but are often required based on the necessary response time or the flow rate requirements for system discharge pressure relief.

2.3.1 HOT GAS BYPASS WITH SECONDARY COOLED LOOP

One alternative design to the basic cooled recycle loop is the hot gas bypass with a secondary cooled loop as shown in Figure 6.

Continued on page 42

COMPRESSION SERVICES

MAJOR ENGINE & COMPRESSOR COMPONENTS

- Engine and Compressor Overhauls and Repair
- Component Manufacturing and Repairs
- Trouble Shooting
- Engine and Compressor Parts
- Maintenance
- In Field Machining
- Field and Shop Retrofits
- Optic and Laser Alignment
- Commision and Initial Installation



Gas Compression Services Since 1872
(800) 255-0111 | www.exline-inc.com

Quality & Service are our #1 Priority

BASIC HOT GAS RECYCLE LOOP

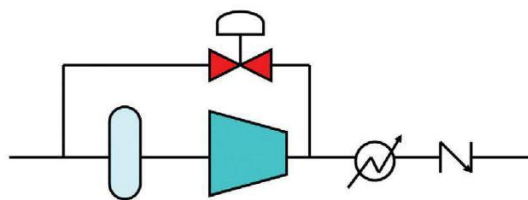


Figure 5. Single Recycle Loop With Minimal Discharge Volume

HOT AND COOLED RECYCLE VALVES

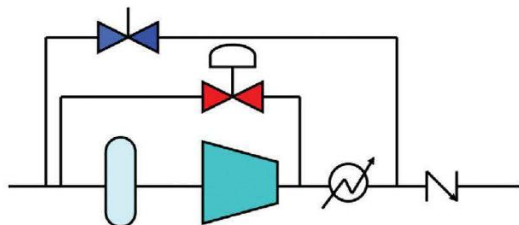


Figure 6. Hot And Cool Recycle Valves In Surge Control System

SUCTION-COOLED RECYCLE LOOP

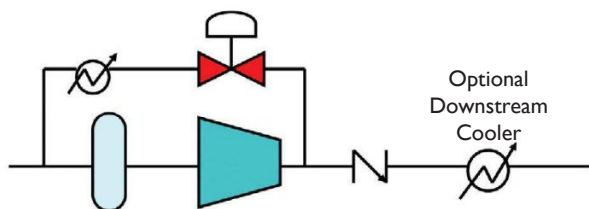


Figure 7. Recycle Loop With Suction Gas Cooling

Without an overall cooling loop, the compressor cannot run in the recycle mode for a lengthy period. The hot gas bypass and secondary cooled loop arrangement provides a means to operate in hot gas recycle with a cooled gas recycle loop as a backup. The suction temperature can help adjust the operation if inlet suction temperatures are low enough. By removing the cooler from the inner recycle loop, the surge control system can more quickly respond to operational changes.

For the hot and cool two-valve arrangement, the cooled outer loop valve is typically a modulating type, while the hot inner loop valve is a quick opening type of valve. The cooled valve in the outer loop can be sized independently of the hot valve. In addition, the capacity of the cooled valve can be considered with the shutdown valve, allowing the shutdown valve downstream of the compressor to be smaller.

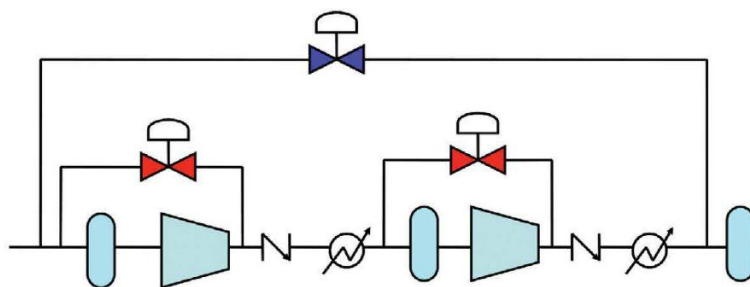


Figure 8. Hot Recycle Loops With Added Valve On Cooled Surge Control Loop

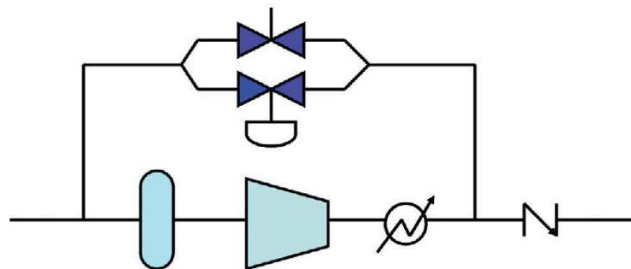


Figure 9. Use Of Multiple Valves In Parallel Arrangement

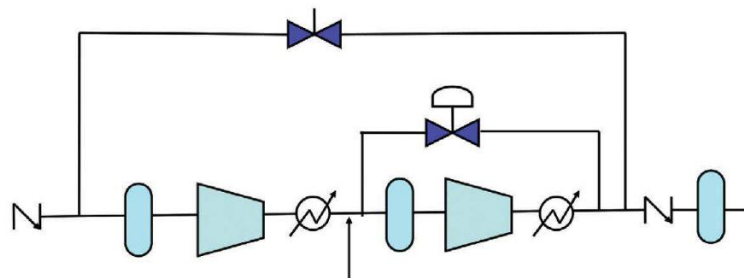


Figure 10. Recycle Valve For Second Compressor With Overall System Surge Control Valve

2.3.2 SUCTION GAS COOLER FOR COOLED RECYCLE

Another alternative configuration utilizes a suction gas cooler downstream of the recycle valve to cool the recycled gas only, as shown in Figure 7. For installations where the delivered gas must be cooled, this configuration may require two coolers, with a larger secondary cooler downstream of the check valve. However, the recycle gas cooler can be sized fairly small to only cool the bypass loop gas. The advantage of this layout is in its small discharge volume and ability to operate continuously in recycle because of the added cooler.

2.3.3 OVERALL COOLED RECYCLE WITH HOT GAS RECYCLE LOOPS

A modification that is possible for multiple units in series is the layout shown in Figure 8 in which individual hot gas bypass loops are used inside of an overall cooled loop. This configuration alternative provides good modulating surge control and fast shutdown of the units through the check valve proximity to the discharge

side of the compressor. Some redundancy is built into this design to provide secondary surge control in the event of a valve failure, but not necessarily at the same flow capacity. The additional components will increase the overall system cost.

Using multiple hot and cool recycle loops is advantageous to the startup operation of the surge control system by adding cooling to the recycle gas. The hot gas loop has advantages for the emergency shutdown operation because the recycle valve (if sized properly) can quickly open to relieve discharge pressure.

2.3.4 PARALLEL VALVE ARRANGEMENT

An alternative arrangement of multiple valves is to use the valves in parallel in the recycle loop as shown in Figure 9. The two valves can be set up in the surge control system to open at different surge margins (the first with a higher surge margin setpoint than the second). If the progression into surge is slow, only the first valve will open. If the progression into surge occurs suddenly, both valves will open. The parallel arrangement may provide redundancy in the event that one valve becomes fouled or its actuator is not functioning correctly. This requires that both valves can individually relieve the system discharge pressure, which may mean collectively that they are oversized.

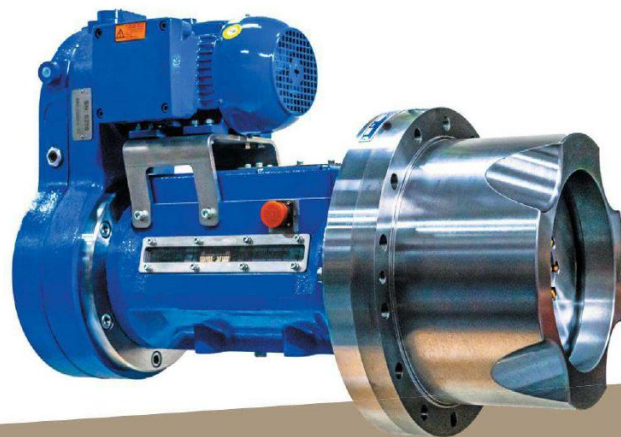
The parallel valve arrangement allows for one valve to be a linear characteristic type and one to be a quick opening characteristic (globe or ball valve) type. This provides versatility to the surge control system, enabling it to respond to both operating environments—controlled recycling for normal process control or surge avoidance for quick shutdown. When two valves are used for throttling, the valves are typically operated in cascade or split range.

2.3.5 MULTIPLE SURGE CONTROL VALVES

Additional surge valves are necessary for multiple compressor units. Using an overall recycle valve with specific valves for each unit may provide more redundancy for the control system. Another alternative for multiple units is to use one overall recycle loop and a second recycle loop for a larger downstream unit. This configuration, shown in Figure 10, provides less redundancy but allows for a large second compressor to be controlled independently of the smaller first compressor.

The configuration poses some additional risks to consider in the surge control. If both units are operating near the surge line, the discharge pressure will not be sufficiently reduced downstream of the first unit in this arrangement. The 2nd-stage compressor will introduce an additional pressure and flow requirement. The arrangement should only be applied if the outer recycle loop can sufficiently provide recycled gas quickly and if the first unit is much smaller than the second. 

THE HOERBIGER PIONEER CLASS EXCITE



eVCP
Sell more gas with
automated capacity control

Customers report an additional 10% capacity gain with eVCP. How? With automated variable volume pocket control, you can adjust to fluctuating field pressures and capture the capacity that stepped systems leave behind.

evcp.hoerbiger.com




HOERBIGER
because performance counts

SURGE CONTROL SYSTEMS FOR CENTRIFUGAL COMPRESSORS

AN APPLICATION GUIDELINE: PART 3

BY KLAUS BRUN, MARYBETH MCBAIN, AND RAINER KURZ

EDITOR'S NOTE: First published in 2008 in cooperation with the Gas Machinery Research Council (GMRC), the "Application Guideline for Centrifugal Compressor Surge Control Systems" has been revised and updated by the original authors and will be presented in sections in upcoming issues of Gas Compression Magazine. Part 1 is published in the September 2021 issue of Gas Compression Magazine, p. 28. Part 2 is published in the October 2021 issue, p. 38. Figures, references, and tables follow in consecutive order from Part 1.

3 SURGE CONTROL SYSTEM COMPONENTS

Surge control systems are typically sold as separate, dedicated control systems that either operate within the overall station control system or are used with a dedicated compressor system controller. The recommended essential components of the surge control system are described in this chapter. The accuracy of the system's ability to define the surge line, and the location of the operating point relative to that line, defines how well the surge control system monitors for surge. Accurately monitoring the operation and the method of controlling compressor operation (recycle valve opening point, actuation speed, signal gain, etc.) determines how effectively the surge control system protects the compressor from surge. Required surge control system components are:

- **Surge Limit Model:** Typically provided in the form of a performance map, this model is a description of the surge control line for the compressor. The surge limit model should be based on experimental testing, either in the factory test or from site verification.

- **System Control Algorithm:** The algorithm implemented in the surge control system is used to determine the signal sent to the recycle valve actuation system based on the measured operating point of the compressor relative to the surge limit line.

- **Recycle Valve And Actuation System:** The valve and its actuation system are controlled by the algorithm and must be selected to quickly respond to the controller signal. The valve will increase the flow of gas to the compressor suction side and reduce the downstream discharge pressure.

- **Compressor System Instrumentation (Pressure, Temperature, And Flow):** This is required instrumentation for the measurement of the compressor operating point. The flow must be measured in addition to the compressor head to determine the operation proximity to the surge line.

- **Piping System (Including Suction And Discharge Volumes And Recycle Loop Piping):** The compressor system piping will determine the response requirement for the recycle valve and the amount of gas mass available in starting up the compressor. Piping volume will also influence the process control operation (speed of response and precision of control).

3.1 SURGE LIMIT MODEL (SURGE CONTROL LINE)

The surge limit model is required to accurately predict when compressor surge will occur. The surge limit model is essentially a look-up table or performance map showing the actual surge line and the surge safety margin. The surge limit model defines the compressor's operation in relation to the surge line, using any two of the following three parameters: compressor head, flow, and speed.

3.1.1 Implementation Of The Surge Limit Model

The surge limit model should be implemented in the control system in a reduced head (or pressure ratio) against reduced flow representation, because this view provides more accuracy in the surge prediction (see Section 1.3, Views Of Surge, September 2021 *Gas Compression Magazine*, p. 30). This method also simplifies the instrumentation required to measure surge and the data reduction effort. The view of surge under the compressor head vs. flow squared (H vs. Q^2) representation will detect small changes in the compressor operation until surge is reached. Gas composition, which is not typically updated in the compressor

Continued on page 18

control system, will affect the flow representations of the surge line. Gas composition effects will influence the surge control line shape and position. Using the surge limit model with reduced head and flow variables will help to minimize the gas composition effects. The non-dimensional head versus flow map allows the operation and proximity to the surge line to be characterized independent of compositional changes.

Different manufacturers have different approaches for determining the actual surge line. The use of a nonlinear surge control line is an option to provide an expanded operation of the compressor within an allowable region. The nonlinear surge line should be implemented after confirmation of the actual surge points in a factory test. For best results, the actual surge line can be verified by a site surge test (see Section 3.1.5).

3.1.2 Choice Of Surge Margin

The surge limit model is used in the surge control system to determine the distance between the operating point of the compressor and the surge limit. The model should define a surge control line, which determines the protection margin between the actual surge line (when the compressor will surge) and the point at which the control system should act to open the recycle valve. The protection margin should be as accurate as possible to minimize unnecessary recycle time and maximize operating flexibility and compressor efficiency. The margin allowed between the actual surge line and the surge control line is based on operating company preference, the operating range of the compressor, and the uncertainty of the surge line measurement. The recommended margin is 6% to 10% of the actual flow surge limit.

Other characteristics of an installed system will affect the selected surge margin. A system with large time constants (slow overall response) may require additional margin to ensure the machine is protected. Faster systems with small time constants will operate satisfactorily with margins even less than 6% to 10%.

The surge margin choice should consider the amount of uncertainty in the detection of surge within the control system. This includes the uncertainty in the pressure, temperature, and flow rate measurements (see Section 4.0). The margin should also consider the imprecision of the transmitters and the dynamic response of the controller and actuator in the recycle valve.

Other parameters besides the direct head or flow measurement may also be used to control the response of the valve. The rate of change in flow is often used as an additional control within the algorithm to determine when the surge limit will be reached.

The model provided by a manufacturer should consider the range of possible operating conditions and gas compositions. The model should be provided to the compressor user in normalized variables as a head versus flow characterization. If speed is used in conjunction with head or flow to predict the surge line, the prediction will be

dependent on the gas composition used to generate the surge line. This approach will cause the surge limit model to be more uncertain at other gas compositions.

3.1.3 Use Of Nonlinear Surge Line In Multistage Compressors

Multistage compressors may have a surge line that corresponds to the product of the individual stage surge lines. Use of a compensated surge line results in a nonlinear surge limit model, which may be necessary to match the changes in the surge operating point for each stage. Typically, the 1st-stage surge dominates the surge control line because surge will occur earlier in Stage 1 (at higher flow rates). When a later stage surges earlier than the 1st stage (Figure 11), the surge line should be adjusted to compensate for the later stage. This will also prevent surge from occurring unexpectedly due to one stage driving another into surge.

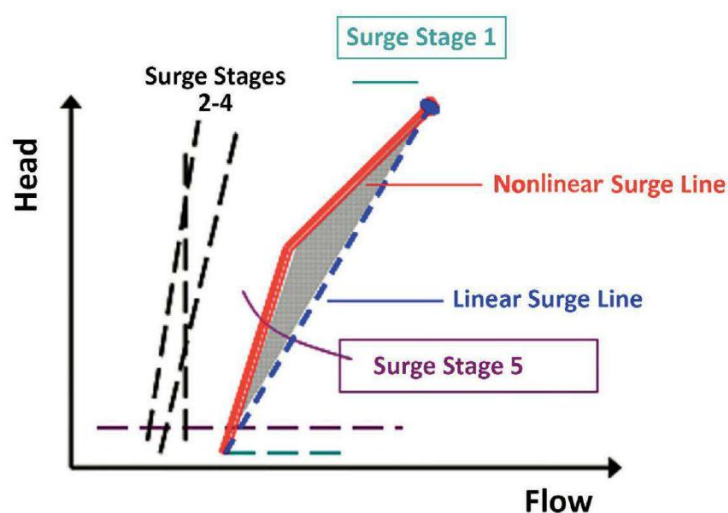


Figure 11. Surge Line Developed For A Multistage Compressor

3.1.4 Experimental Determination Of Surge Line

A factory test is often used to determine the actual surge line, especially for the manufacturer's purposes of verifying the location of the surge line. The factory test can use natural gas or air. In some cases, controlled hydrocarbon blends (mixed gases) are used as an alternative to provide a close approximation to the gas properties expected in the field. Sometimes, air is chosen because the surge condition is less risky in terms of possible damage to the machine if the surge limit model is underpredicting the occurrence of surge or if the control system fails to adequately prevent surge. Any factory test performed on a nonrepresentative gas mixture (i.e., a mixture that does not closely mirror the field setting gas) should be viewed with additional uncertainty because of the variation in the surge control line caused by gas composition changes. Representing the surge control line in terms of reduced head versus reduced flow will reduce gas composition uncertainties.

The factory test will provide a good measure of the surge line for the compressor, but the installed field site condition may affect the surge limit because of changes to system impedance at the field site. Upstream and downstream piping, coolers, valves,

and other equipment (e.g., scrubbers, auxiliary coolers, added volumes, etc.) will influence the measured surge limit. The natural gas mixture will also change the surge control line location (for gas composition-dependent surge lines) on the performance map if the factory test was performed on air. In this case, the reduced head and flow variables should be used to eliminate the probable shift in the surge control line due to gas composition.

3.1.5 Field Site Verification Of Surge Limit

The limit model can be verified using an actual test of the compressor as the operating point moves toward the surge condition. For certain compressors with sufficient operating data, the performance map is well known, and field testing is not warranted.

Verification at the field site allows the surge limit model to be tested in its true operating environment and in its installed configuration. As recommended in the GMRC *Guideline for Field Testing of Gas Turbine and Centrifugal Compressor Performance*, the surge limit model should be verified by testing for the compressor surge point with extreme caution. For the first test, it is best to select relatively low-pressure differential and operating pressure (i.e., “low-energy”) conditions. If later tests must be performed at high-head conditions to verify the surge limit model over the entire head/flow range, these tests should be preceded by tests at low-energy conditions to characterize the compressor behavior and instru-

ment outputs of incipient surge. Verification in the field entails inherently more risk, and the decision on how to verify the model should consider the possible consequences of damage to the compressor.

The other purpose in surge site testing is to verify the actual surge line using the field instrumentation (with its unique uncertainties). The testing should be performed by slowly reducing the flow when the compressor is at or near the design operating speed. The test should be stopped at the expected surge flow or incipient surge point when the flow signal becomes unstable or when the vibrations increase considerably. At this point, the recycle valve should be immediately opened to 100%. For the initial test of the recycle valve, redundancy (such as a surge detection system) is recommended to ensure the safety of the field personnel.

Surge site testing is a decision left to the operator, based on experience with a particular machine and its ability to withstand “low-energy” surge conditions. Benefits of surge testing in the field include:

- Verification that the instrumentation is installed and operating correctly
- Verification of control system function
- Verification and calibration of surge detection systems
- Determination that the surge point is not to the right of the predicted surge point
- Determination if subsynchronous vibration levels exist to the right of the surge limit. 



ULTIMATECHEMICALS.COM



COOLING SYSTEM FLUSHES

PMF – Preventive Maintenance Flush

Restore Entire Cooling System To Zero Hour

CWPMF – Cold Weather Preventive Maintenance Flush

PMF For Cold Weather & Where Water Not Available

RRF – Rust Removal Flush

Dissolve & Remove Rust

CRI – Corrosion Rust Inhibitor

99% Effective Cooling System Protection

HDF – Heavy Duty Flush

Dissolve & Remove Burnt Glycol



EXTERNAL CLEANING SERVICES

Cooler Cleaning — De-Scaling — Fin Straightening

INTERNAL CHEMICAL CIRCULATIONS

Gas Cooling Sections — Dehy Contactors

Re-Boilers — Stabilizers — Amine Processes

Plate-And-Frame Heat Exchangers

Shell-And-Tube Heat Exchangers

OTHER ULTIMATE SERVICES

Slug Catcher Cleaning - Skid Cleaning

Fire Tube Cleaning - External Vessels

Hydro-Lancing & Shotgunning

5,000 PSI – 20,000 PSI (40,000 PSI Available)

Hazardous Spill Cleanup – Hydrocarbon Remediation

Containment Clean Out – Pipeline Corrosion

“WE’VE UPPED OUR STANDARDS, SO UP YOURS”

SURGE CONTROL SYSTEMS FOR CENTRIFUGAL COMPRESSORS

AN APPLICATION GUIDELINE: PART 4

BY KLAUS BRUN, MARYBETH MCBAIN, AND RAINER KURZ

EDITOR'S NOTE: First published in 2008 in cooperation with the Gas Machinery Research Council (GMRC), the "Application Guide for Centrifugal Compressor Surge Control Systems" has been revised and updated by the original authors and will be presented in sections in upcoming issues of Gas Compression Magazine. Part 1 is published in the September 2021 issue of Gas Compression Magazine, p. 28. Part 2 is published in the October 2021 issue, p. 38. Part 3 is published in the December 2021 issue, p. 16. Figures, references, and tables follow in consecutive order from Part 1.

3.2 CONTROL ALGORITHM

The control algorithm is needed to relate the surge limit model predictions of the compressor operation to the measured data from the compressor. The algorithm develops the control signal to send to the recycle valve. The value of the control signal is based on the measured operating point of the compressor and the surge limit (based on the model predictions). Typically, the pressure and temperature instrumentation is used in combination with a flow meter to determine the operating point (Figure 12).

The recycle valve opening/closing speed and its position (amount of opening or closing) are provided by the control signal from the algorithm. When the compressor flow rate is below the flow specified for the protection margin at a given pressure ratio, the algorithm should send a control signal to the valve to open. The rate of opening (or closing) should be based on the speed required to protect the compressor. The rate of change in the surge margin over time can be used to adjust the amount of gain needed (i.e., a faster rate of change requires a higher gain signal from the controller).

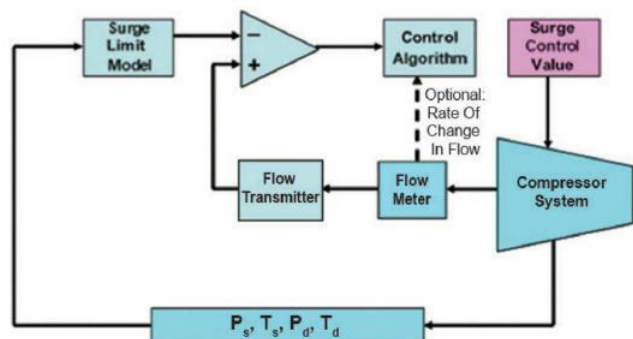


Figure 12. Surge Control Algorithm – Typical Signal Flow

Various algorithms have been successfully developed by manufacturers and surge control system design companies. The provided representation in Figure 12 is only one example of a viable option that may be considered for the algorithm.

The control algorithm response rate will be much faster than equipment response. Equipment, such as the actuation system and recycle valve, used in the compressor surge control system is often not selected by the control system engineer and will typically not provide the optimal response. The recycle valve is often chosen to match the system design of the pressure and temperature transmitters and may not be the ideal choice for the valve characteristics needed. In addition, the piping layout has a large impact on performance and the response time of the control system.

VARIATION IN CONTROL SYSTEM GAIN

The amount of gain on a control signal determines the speed of the response as well as system stability. Various responses based on different gain levels are shown in Figure 13. A sudden change in the control system is illustrated under gain levels — a low gain system, a high gain system, and a critically damped (optimum gain) system. The critically damped system produces an initially aggressive response, but the response is reduced in time to maintain stability.

Different control system gains should be used for the different surge operating environments. The control algorithm should be capable of distinguishing between startup operation, normal process control operation, and an emergency shutdown operation. A control system, which can use single- and two-gain signals (high gain to open the valve plus low gain to close the valve), will be a better choice for shutdown operation.

To effectively avoid surge, the control system must use variable gain to handle the different performance demands for the valve system. The variation in gain will help to overcome many unknowns in design for unknown volumes, instrumentation, etc.

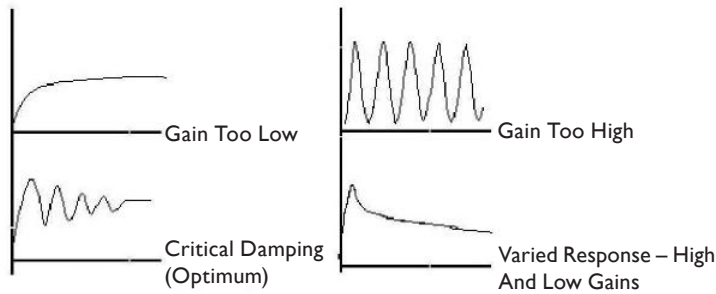


Figure 13. Various Signal Responses For Control System

CONTROL ALGORITHM DURING STARTUP AND NORMAL PROCESS OPERATION

During normal process control operation, lower gain signals should be used for adjusting the flow by opening or closing the valve in a controlled manner. The speed of opening and closing the valve is not a necessary requirement for this operation. The same control signals may be used for controlling the recycle valve in the startup operation. Consideration for this environment requires changing the gain used by the control algorithm for the process operation. The control algorithm must also consider the reaction of the recycle valve system. The recycle valve will have a certain amount of overshoot — which should be factored into the control signal in the normal process operation.

The combination of high and low gains is recommended to provide an initially fast reaction of the recycle valve (for

opening) and more gradual response to move the system away from surge (for closing). Once surge has been avoided and the compressor again crosses into the protected operation region, the gain should be reduced to offset the inherent instability of a constant high gain system.

3.2.3 RESPONSE TIME VARIATIONS

Different surge events will require different response times from the surge control system. It is difficult to provide exact values of required response times because of the many differences in compressor applications, compressor station design, discharge system volumes, and control system design. By far, the emergency shutdown situation will require the fastest response time from the control system, and this event should be used to determine required minimum response time. In determining the type of programmable logic controller (PLC) and recycle valve in the surge control system, the manufacturers should be asked for an estimated response time requirement or minimum discharge system volume based on the actual compressor model and installation configuration.

Note: During an emergency shutdown event, the recycle valve should be opened as quickly as possible to provide a quick response and protect the compressor. The shutdown operation does not affect the surge control algorithm because the sole function of the controller under the shutdown operation is to fully open the valve as quickly as possible. Signal gain levels for opening and closing the valve do not influence this operation. 



International Headquarters
2 Eagle Industrial Drive, Troy, MO

Gulf Region Office
1034 Wall Road, Broussard, LA

Permian Region Office
411 South Grandview, Odessa, TX

MECHANICAL, MILLWRIGHT, OR COOLER ISSUES?
We Can Help • Call us today! (573) 384-5060



Foundations • Mechanical • Millwright • Cooler Services

PROUD MEMBERS OF



www.eaglecompression.com

INDUSTRIAL MACHINERY SOLUTIONS