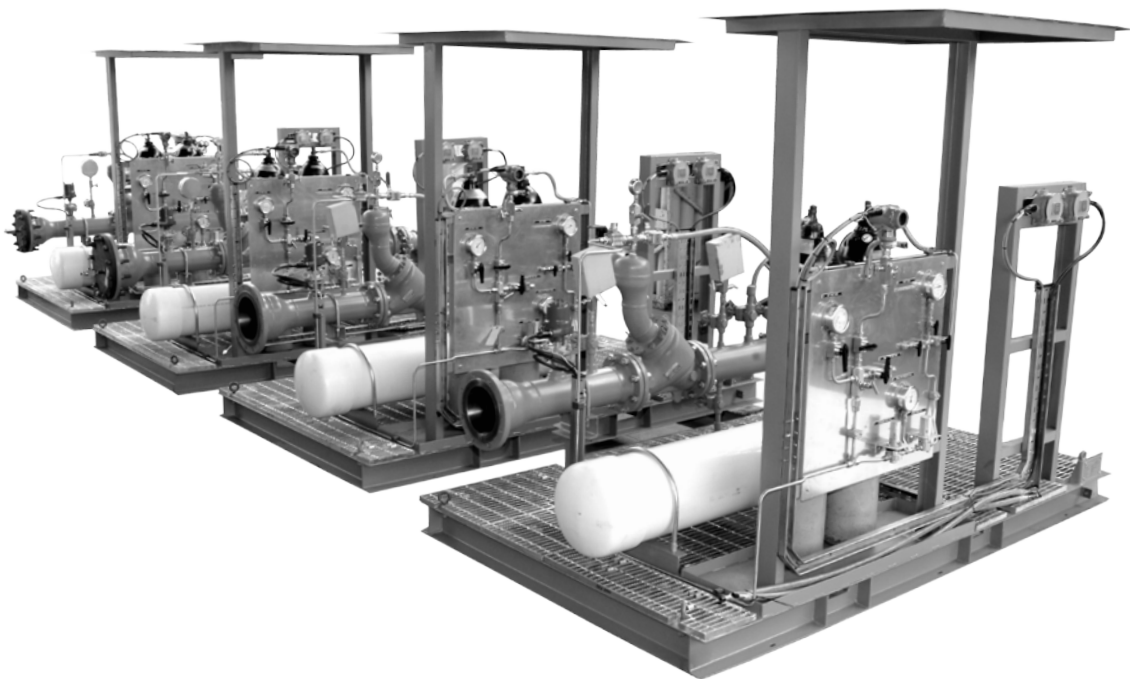


# An Introduction to Liquid Pipeline Surge Relief





## The Importance of Surge Relief

In many applications, such as pipelines, storage terminals and marine loading and unloading, it is necessary to include surge relief systems for the purpose of equipment and personnel protection. Surge pressures result from a sudden change in fluid velocity and, without surge relief, these surge pressures can damage pipes, other piping components, equipment and personnel.

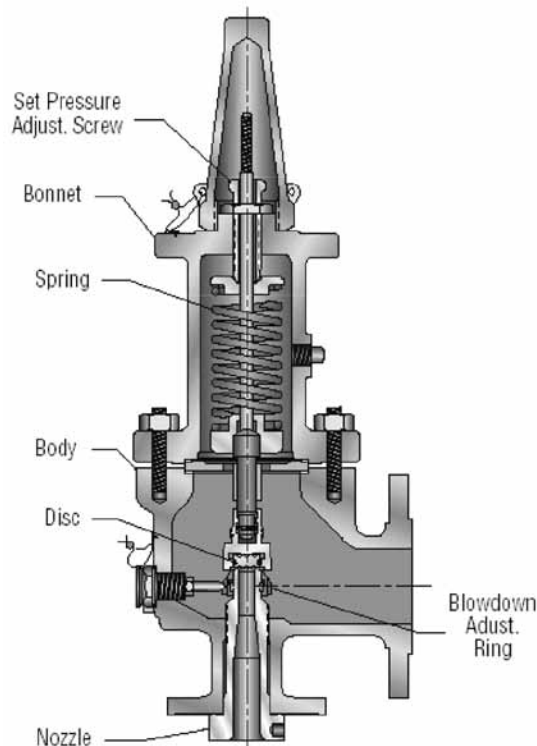
These pressure surges can be generated by anything that causes the liquid velocity in a line to change quickly (e.g., valve closure, pump trip, Emergency Shut Down (ESD) closure occurs) and subsequently packing pressure. Total surge pressure may be significantly above the maximum allowable pressure of the system, leading to serious damage to your valuable assets.

The fundamental requirements of surge relief systems include the need for fast acting, high capacity valves which can open very quickly to remove surge pressures from the line and then return to the normal (closed) state quickly but without causing additional pressure surge during closure. These valves are often required to open fully in very short periods of time, so that they may pass the entire flowing stream if conditions dictate.

Long pipelines can produce dangerous pressures when static product is shut-in between valves and thermal expansion occurs. In this situation, pressure relief will be required. Although the time of operation and valve capacities are not as crucial in such applications, they remain as key elements of safety in the system and proper regard to selection and operation is imperative.

In general, all systems where pressure is contained must have some form of pressure relief, which is often mandated and regulated by local authorities. The design of such systems is dependent on a complex range of factors including, but not limited to, the potential for pressure increases, the volumes which must be passed by the pressure relief equipment in operation and the capacity of the system to contain pressures.

Typical tank and pressure vessel systems are required to release pressure without passing large volumes of liquid. Usually these systems operate to relieve vapor from the space above the liquid using self acting pressure relief valves. An example of such a valve is shown below.



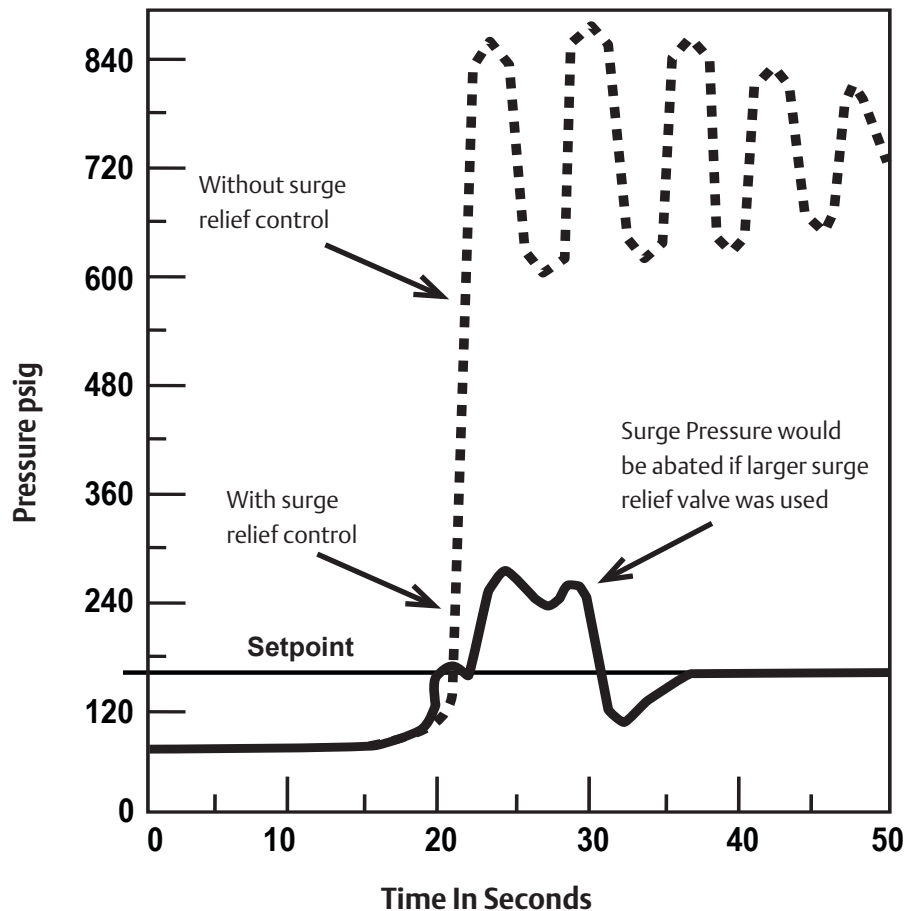
**Self Acting Pressure Relief Valve**

Although these valves are commonly used as pressure relief devices, the nozzle size is quite small and hence the capacity for passing liquids is extremely limited. Therefore, such designs are limited to tank and vessel protection, where overpressure is readily relieved without the need to pass significant quantities of liquid.

# Typical Applications for Surge Control Valves

In bulk liquid transportation, safety systems in the form of pressure control, pressure regulation and surge relief valves are required. In the United States, Department of Transportation (DOT) mandate guidelines. DOT Title 49 CFR Ch.1 Part 195.406 states: “No operator may permit the pressure in a pipeline during surges or other variations from normal operations to exceed 110% of the operating pressure limit established under paragraph (a) of this section. Each operator must provide adequate controls and protective equipment to control pressure within this limit”.

The potential for damage may be illustrated by the following graph showing the effects of the closure of an ESD valve. Without surge relief the pressure spikes to around 10 times the normal line pressure. As the pressure wave created propagates along the line, the cycling effect occurs. The effect on pressure if a surge pressure relief valve is used (shown below). The larger the capacity of the surge relief control valve, the lower the pressure spike.



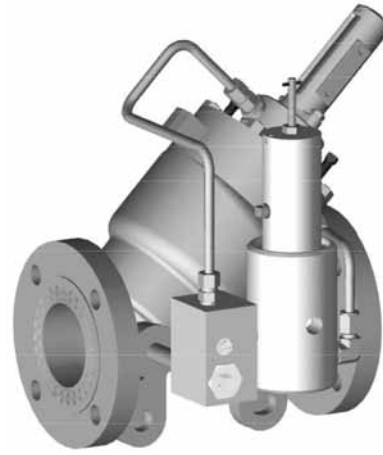
Note: Figure adapted from “Sliding-plug Surge Relief Valve Helps Meet DOT Requirements”, Pipeline Industry, January 1992.

## Types of Surge Control Valves

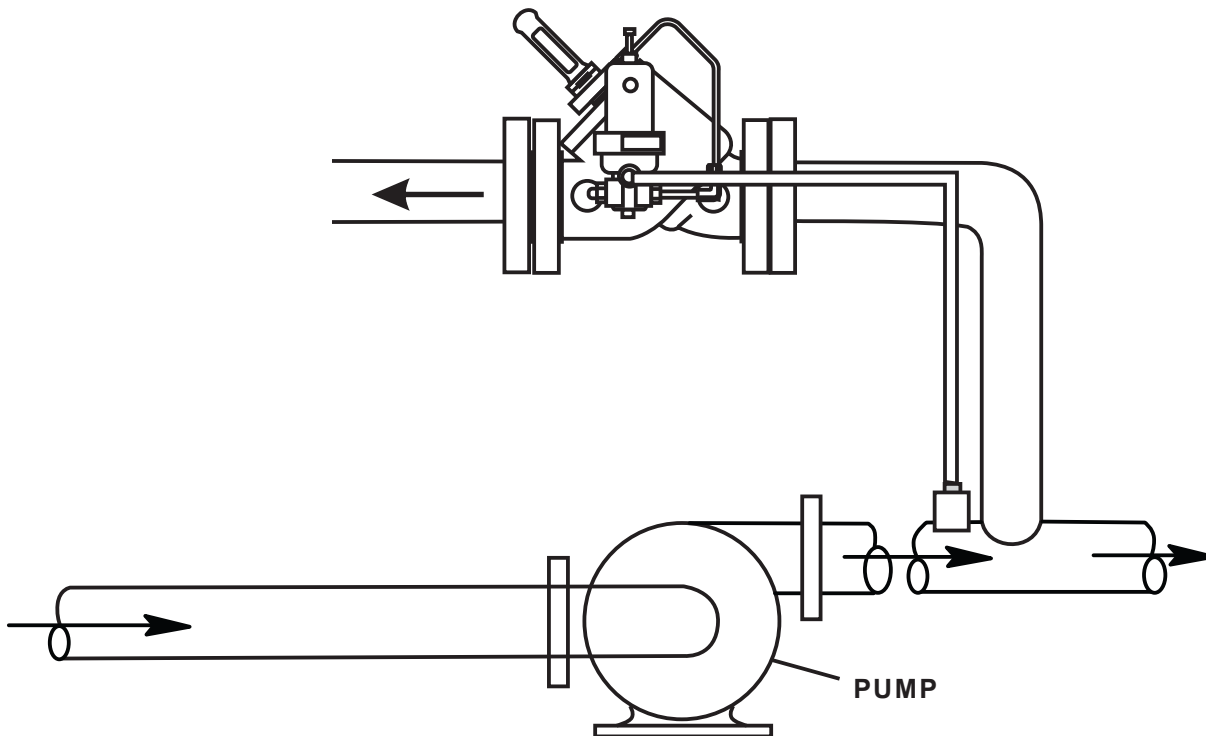
### Daniel Pilot Operated Pressure Relief Valves

The Daniel 761 Valve is a pilot operated pressure relief valve used for pump protection duty and for similar applications where pressure relief is required to maintain pressure at a given set point.

Pressure is controlled to within  $\pm 2$  psi regardless of upstream conditions. The pilot and main valve are single seated valves with high capacities. These valves protect the line against excessive pressure and surge or as a pump bypass to maintain a constant pump discharge pressure.



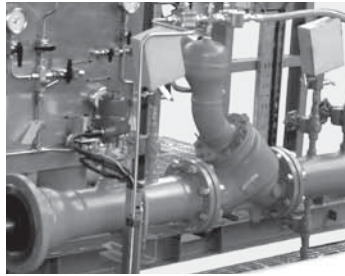
761 Pressure Relief Valve



Typical Application for the 761 Pressure Relief Valve (pump pressure relief)

## Nitrogen Loaded Surge Relief Valves

For applications where exceptionally fast response times are required, customers need to use gas loaded systems. Pipeline surge relief applications call for the minimum possible operating times and valves which can open fully when required.

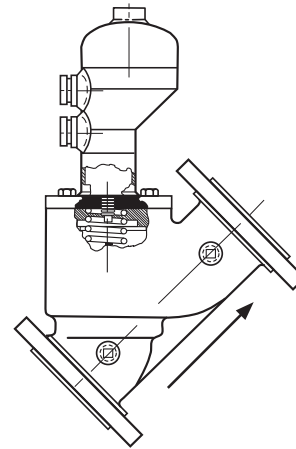


These valves are normally closed and open on increasing inlet pressure. The basic valve is the balanced piston design. Nitrogen gas is used to pressurize the valve piston to keep it in the closed position. The valve incorporates an integral oil reservoir mounted on the external surface of the cylinder head, which upon installation is partially filled with a light oil. Gas under pressure is applied to the reservoir. The pressure of the nitrogen gas, minus the 4 psi (force of the valve spring) is the effective set point of the valve. When the pipeline pressure is less than this total force, the valve will be tightly closed. As pipeline pressure increases the spring and gas pressure is overcome and the valve opens. The oil is a moveable barrier between the gas and valve piston. This should eliminate any possibility of gas permeating the piston seal which would result in gas bypassing the piston and gas consumption.

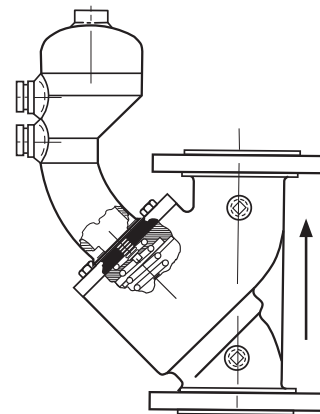
The valve may be mounted in a 45° angle position, horizontally or vertically. Whichever orientation is specified, the oil reservoir must be vertical.

The valves are capable of handling dirty and viscous products and are extremely easy to size, operate and maintain. The entire internal assembly is removable as a cartridge without the need to remove the body from the line. This is designed without any internal parts to obstruct the relief path. This further minimizes debris accumulation, which could inhibit valve operation in emergency relief responses.

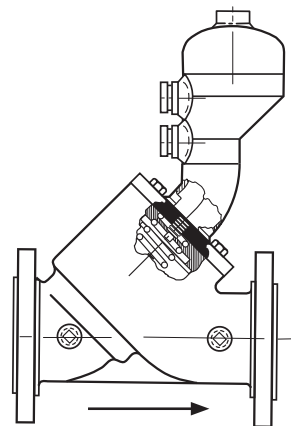
The Daniel Nitrogen Loaded Surge Relief Valve operates on a hydraulically balanced-piston principle. When pressures on both sides of the piston are equalized, a spring located on top of the piston acts as a differential force and closes the piston. When the pressure against the bottom of the piston exceeds the pressure plus the force of the spring exerted against the top of the piston, spring tension is overcome, and the valve opens. Opening and closing speed is controlled by a check valve mounted to the internal surface of the cylinder head and is relatively unrestricted. The result is fast-opening response. Closing speed is controlled by a fixed orifice in the check valve.



Daniel Surge Relief Valve for 45° installation



Daniel Surge Relief Valve for vertical installation



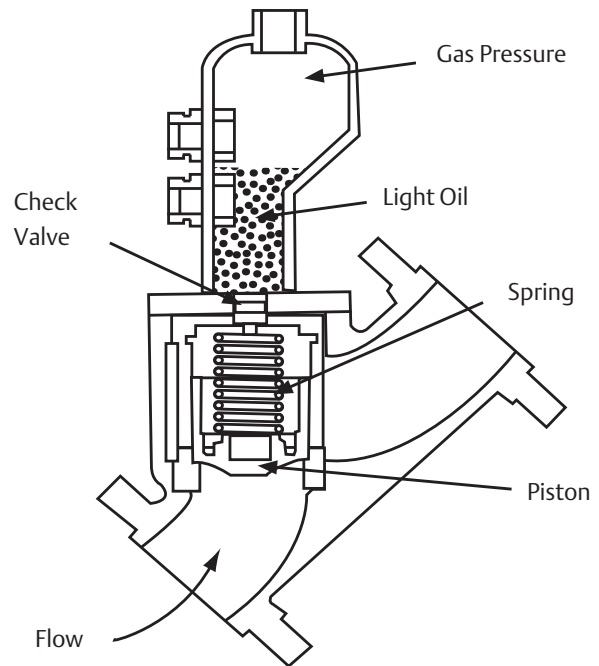
Daniel Surge Relief Valve for horizontal installation

# Valve Operation

## Surge Relief Valve Closed Position

Line pressure on the nose of the piston is equally transmitted to the spring side of the piston. When the nitrogen pressure is applied to the top of the oil, (which is in effect a moveable barrier between the piston and nitrogen) plus the spring pressure is greater than line pressure, the valve will be in the closed position.

- The oil reservoir is supplied with two sight gauges. When the valve is closed the oil level in the reservoir will show oil covering the lower sight glass only
- Oil visible in both the lower and upper sight gauges indicates that the valve is in the open position
- Absence of oil in the lower sight gauge indicates that proper oil capacity has not been reached or that reservoir oil is leaking into the product system



**Valve Closed Position**

## Surge Relief Valve Open Position

As pipeline pressure increases, the combined force of the spring and nitrogen gas pressure is overcome and the valve opens.

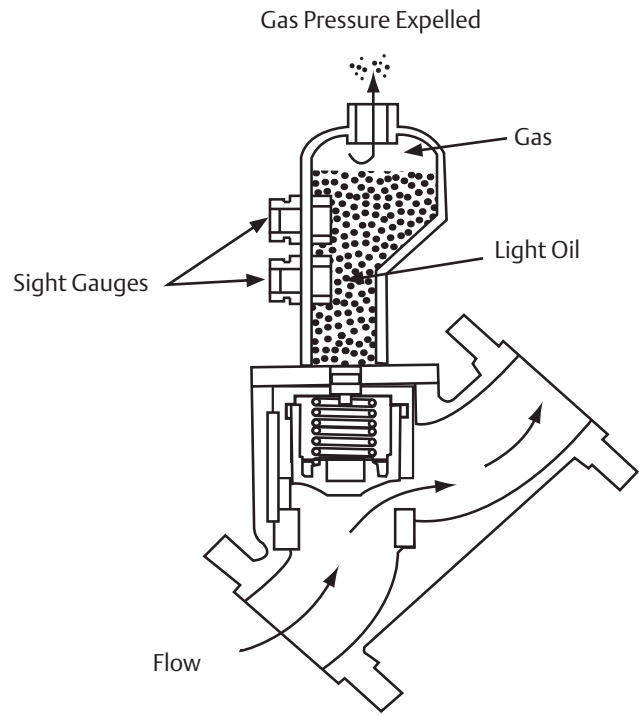
- Opening and closing speed is controlled by a unique check valve mounted to the internal surface of the cylinder head. The opening of the valve is relatively unrestricted, and response time is typically under 100 msec
- This results in an extremely fast opening response. The opening and closing speed is controlled by an orifice in the check valve

A simple routine visual check can be done to determine if the oil in the sight glass is within the recommended limits, this makes it easy for a pipeline operations team to be confident of the surge relief valves readiness.

Note 1: The spring in the Daniel Nitrogen Loaded Surge Relief Valve is for shipping purposes to insure piston movement does not cause damage during shipment. This is the only purpose of this spring.

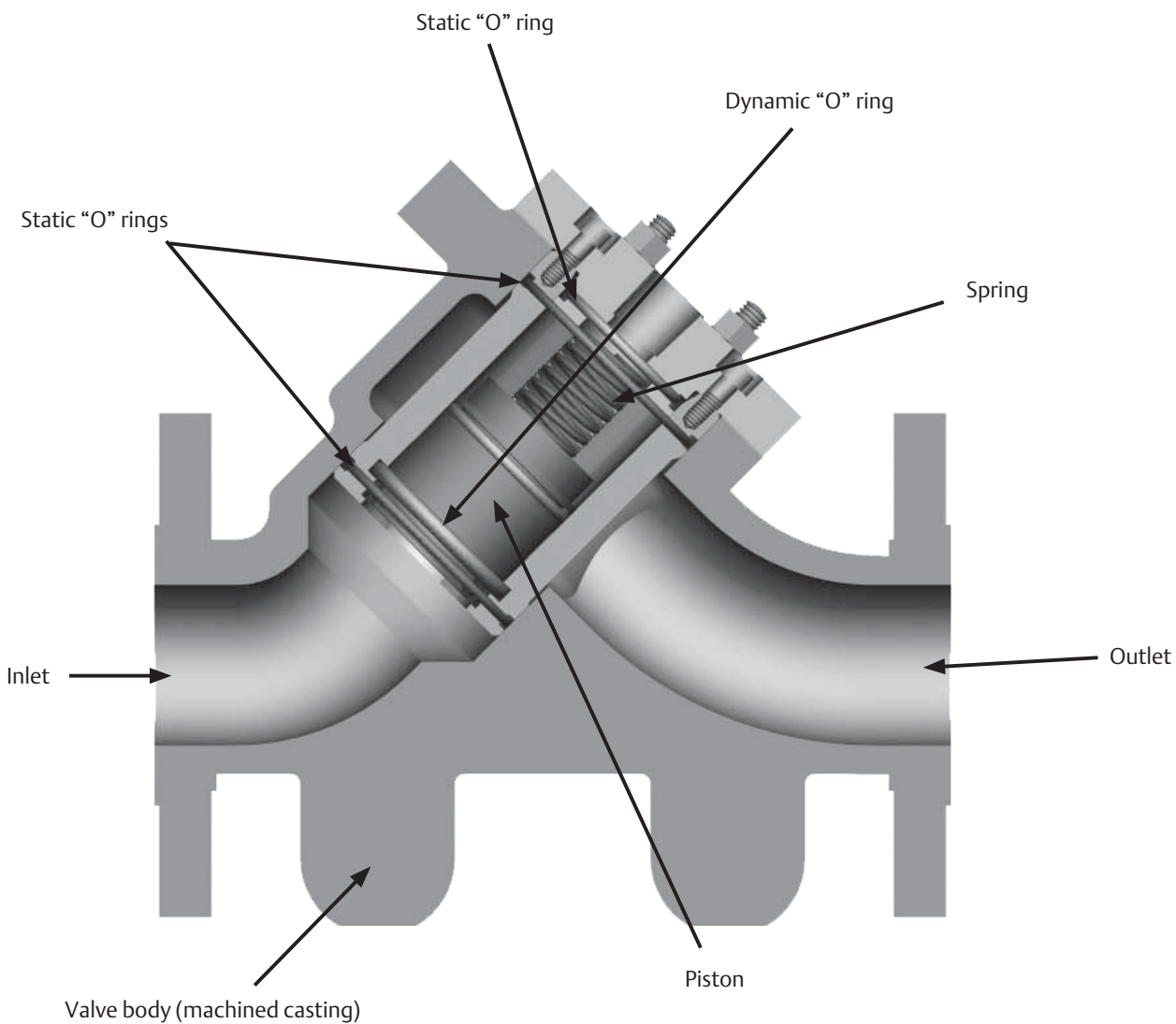
Note 2: Equal area on both sides of the piston, allow the nitrogen pressure to be set at the actual set point minus spring force rather than a calculated percentage.

Note 3: Oil in the reservoir of the Daniel Nitrogen Loaded Surge Relief Valve has many advantages. It allows the piston seals to be exposed to a clean, lubricating fluid which helps to extend the service life of the seals tremendously. In addition, it should eliminate the possibility of nitrogen gas permeating the seals which will ultimately result in a leak and nitrogen consumption.



**Valve Open Position**

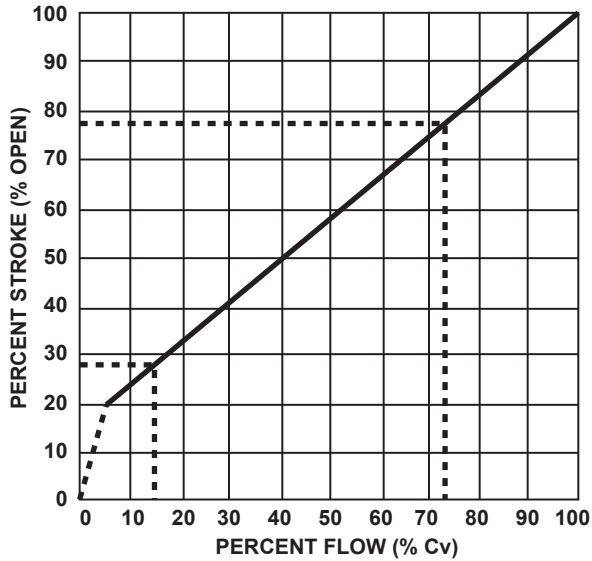
## 762 Gas Loaded Valve



**Cut away view of the Daniel 762 valve body (without the nitrogen reservoir).**

## 762 Gas Loaded Valve Characteristic Curve

For Daniel Valve Sizes from 2" to 16"



Percent Piston Stroke (% Open) versus Percent Flow ( % Cv)

### Valve Specifications

The range of surge relief valves includes two separate models, which are identified by the orientation of the valve and its application.

- 765 – Gas loaded pressure relief (horizontal)
- 766 – Gas loaded pressure relief (45° orientation)
- 767 – Gas loaded pressure relief (vertical)

Valves are available in 2-inch through 16" sizes, in 150 # ANSI to 600 # ANSI classes.

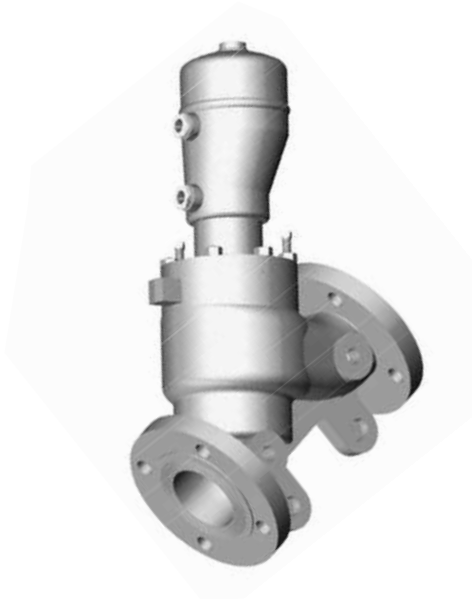
For 900# ANSI or higher consult factory.

This valve can also be used for back pressure control with the following model numbers:

- 762 – Back pressure relief (horizontal)
- 763 – Back pressure relief (45° orientation)

### Reference Document:

3-9008-562 Daniel Gas Loaded Relief / Back Pressure Control Valves (Operating and Maintenance Manual).

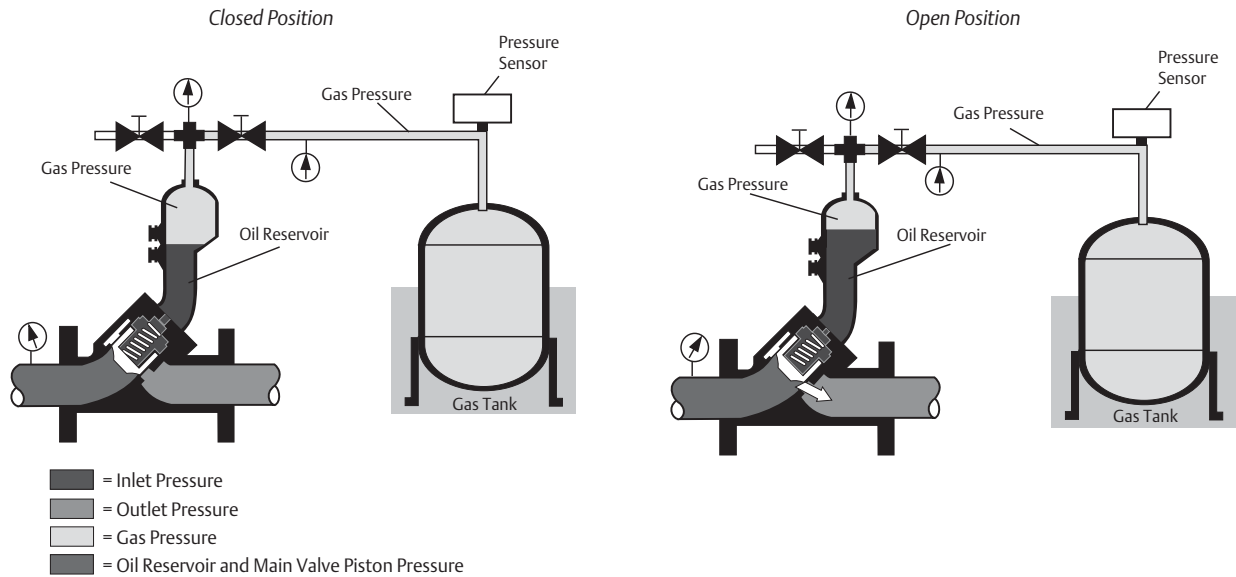


766 Gas Loaded Pressure Relief Valve for 45° installation

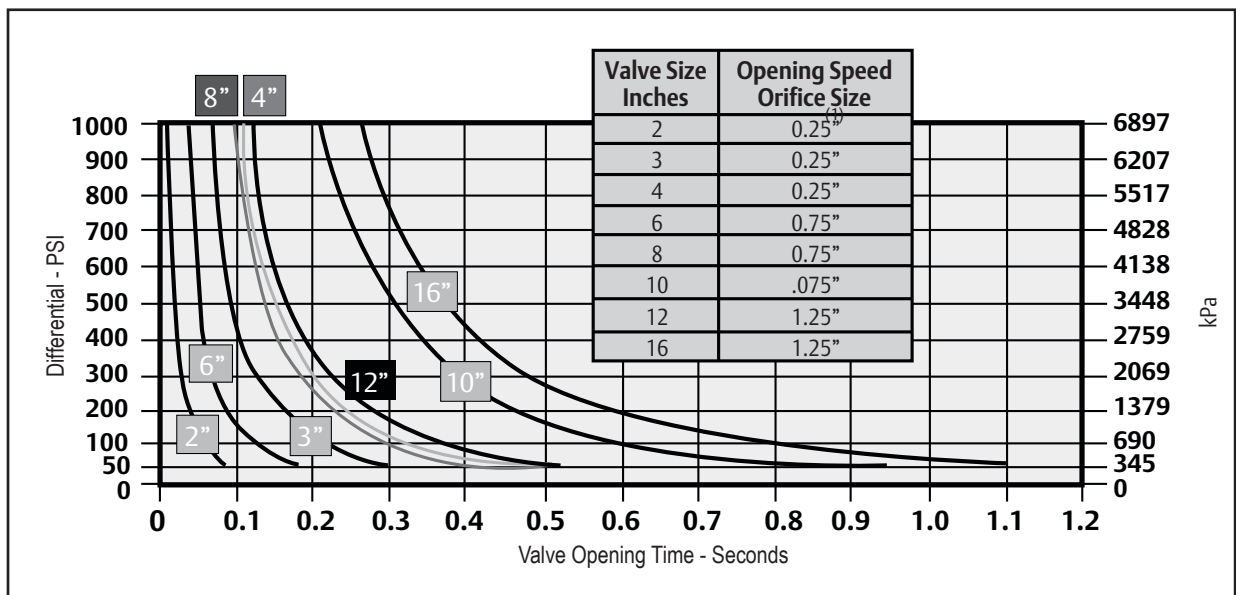
# Gas Loaded Surge Relief Systems

Gas loaded systems require design and sizing according to the conditions of the system. The required pressure of the gas loading system will depend upon the system relief pressure and the amount of fluid the valve must pass when it relieves. This will dictate the valve size.

Such systems offer flexibility in design according to what is desired, including extremely rapid opening, as illustrated in the figure below. It follows that, the higher the differential pressure (the pressure difference between the main line being relieved and the nitrogen set pressure) the faster the valve will open.



Typical System Showing Gas Plenum Tank and Instrumentation



Valve Sizing and Opening Speed

(1) For faster response time, consult factory

## Typical Installation

Although quick opening of the surge relief valve is desirable, if the valve were to shut in a similar time then further problems could occur – a valve slamming shut can produce hydraulic shock (water hammer) in the system, creating a undesirable secondary surge.

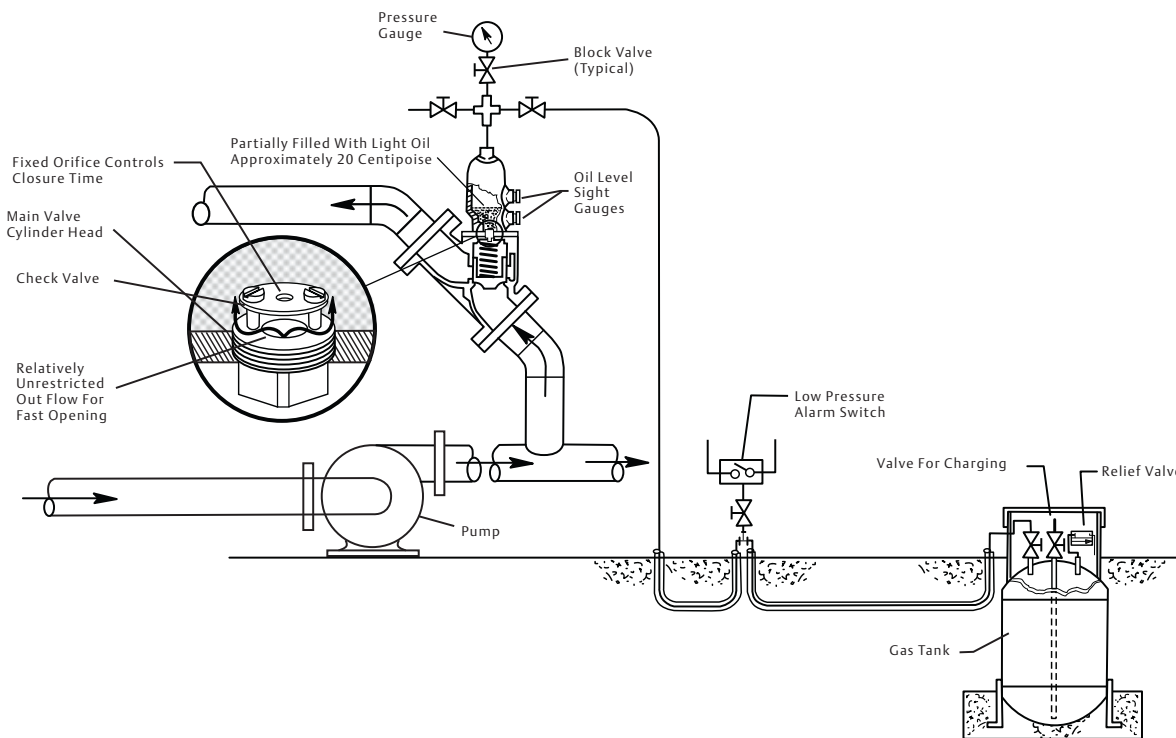
Good surge relief system design will include systems to dampen, or slow the valve, on closing. Often this requires sophisticated reverse flow pilots. However, in the case of the Daniel surge relief valve a unique check valve provides unrestricted flow when opening, and a reduced orifice to limit closing speed. This design is extremely versatile and offers the user the opportunity to determine different closing speeds as required by the system when the valve is built.

## Nitrogen System<sup>(1)</sup>

The nitrogen system must supply a constant pressure to the valve, even under conditions of varying ambient temperatures. Normally, the system will be designed to use standard gas bottles and will incorporate a control panel to regulate the nitrogen supply pressure.

Supply pressure should be set at, or close to, the relief pressure required. The valve is a hydraulically balanced piston design which means that the forces applied across the piston are proportional to the pressures. This is particularly important when setting the system up: the gas pressure set point, minus the force exerted by the spring is the relief pressure for the system.

The gas tank should be buried underground or insulated to keep the gas at a constant temperature. Thermal expansion, caused by the increases in temperature of the gas will change the relief set point.



Typical Installation - 766 Gas Loaded Pressure Relief Valve

(1) Please refer to the 3-9008-562 Daniel Gas Loaded Relief/Back Pressure Control Valves Operating and Maintenance Manual for safe use of the equipment for its intended purpose.

## Gas Plenum Tank Installation and Sizing

The effective volume of the gas plenum decreases as the valve opens by an amount equal to the piston displacement. The size of the gas plenum determines the percentage that the pressure relief set point will change as the valve opens. For example, a 12" valve piston displacement is 554 cubic inches from a closed to an open position. Thus, when fully opened, an equal amount of gas is contained in a volume that is decreased by 554 cubic inches. From Boyles Law, we can see the proportional increase in pressure as:  $P_1V_1 = P_2V_2$ . For example, a 12" valve piston displacement is 554 cubic inches from a closed to an open position.

### Before the gas tank is sized, determine:

1. Set point (PSI)
2. Valve size
3. Allowable over-pressure (PSI) (typically 10%)

Valve Size	Cubic Inches	Cubic Centimeters
2"	3.7	60.63
3"	12.6	206.48
4"	20	327.74
6"	66	1,081.55
8"	165	2,703.87
10"	347	5,686.31
12"	554	9,078.44
16"	1,207	19,779.19

### Example of Gas Plenum Tank Sizing Assuming Adiabatic Compression

$P_1$  = Value required set pressure, valve closed

$P_2$  = Maximum allowable overpressure, valve open

$V_1$  = Total Gas Volume (gas chamber and volume behind main valve position)

PD = Volume displacement of main valve piston

Exponent = .709 derived from K factor of Nitrogen (1.41)

$$V_1 = \frac{\left[ PD \left( \frac{P_2}{P_1} \right)^{0.709} \right]}{\left[ \left( \frac{P_2}{P_1} \right)^{0.709} - 1 \right]}$$

#### Example: 12 inch Valve

$P_1$  = 640 PSI set point required, minus 4 PSI spring load<sup>(1)</sup> plus 14.7 PSI (adjustment to absolute) = 650.7 PSI

$P_2$  = 680 PSI maximum allowable over-pressure, minus 6 PSI spring load<sup>(2)</sup> plus 14.7 PSI (adjustment to absolute) = 688.7 PSI

$V_1$  = Unknown

PD = 554 cubic inches

The preceding formula is used to solve for  $V_1$ :

$$V_1 = \frac{\left[ 554 \left( \frac{688.7}{650.7} \right)^{0.709} \right]}{\left[ \left( \frac{688.7}{650.7} \right)^{0.709} - 1 \right]}$$

$$V_1 = \frac{576.74779}{0.41061} = 14046.121 \text{ cubic inches}$$

$$\frac{14046.121}{231 \text{ Cubic Inches per U.S. Gallon}} = 60.80 \text{ U.S. Gallon Tank Volume}$$

(1) Valve is fitted with light piston spring which provides 4 PSI preload with valve closed. This 4 PSI preload must be subtracted from  $P_1$  to arrive at actual gas pressure.

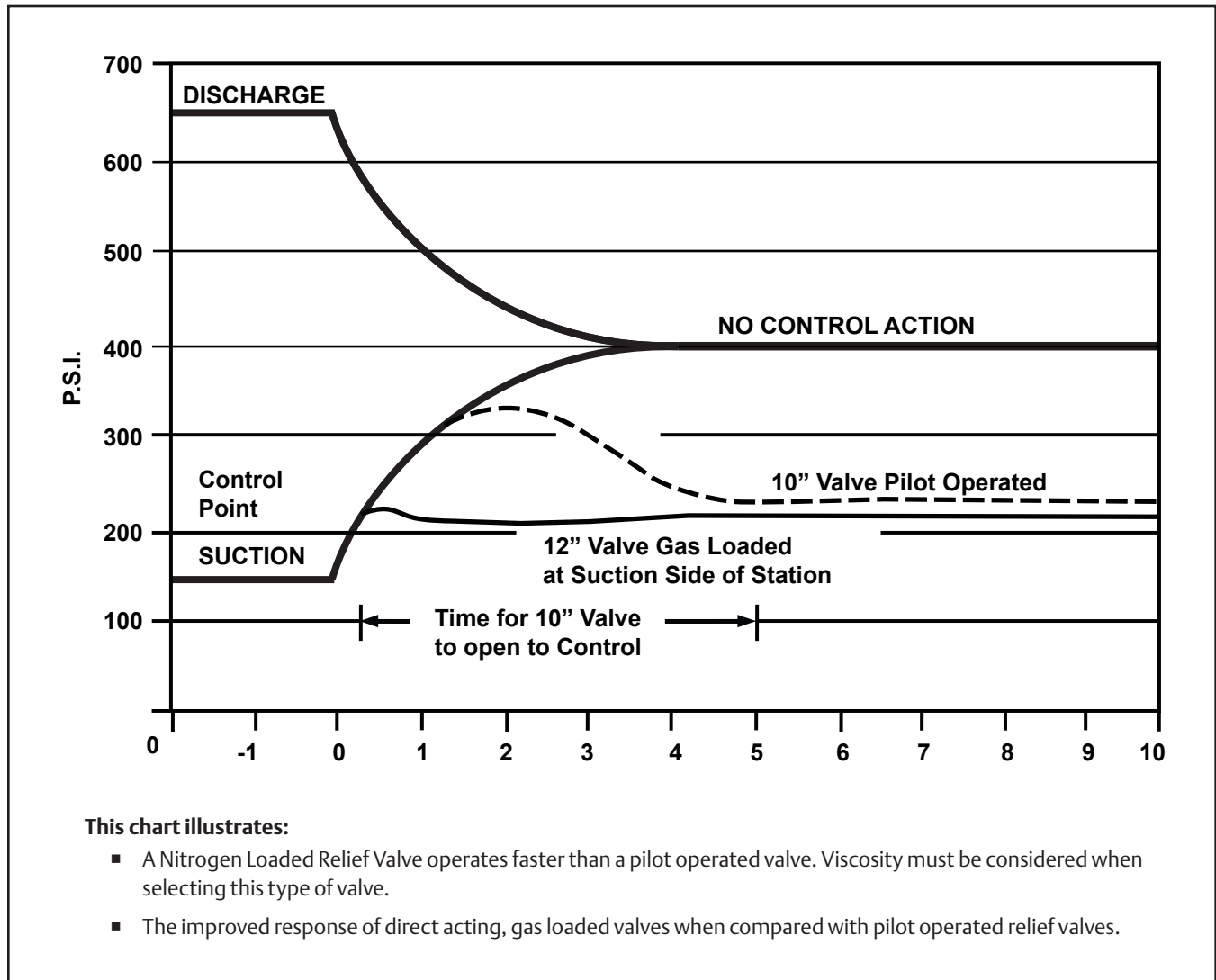
(2) Valve is fitted with light piston spring which provides 6 PSI preload with valve open. This 6 PSI preload must be subtracted from  $P_2$  to arrive at actual gas pressure.

### Pressure Switch

Daniel recommends a pressure switch be used in the gas supply line for the valve to activate an alarm should gas pressure decrease below an acceptable operating level. The valve will open any time gas pressure is less than line pressure.

### Pump Station Operation

The benefits of the gas loaded system are illustrated below. This shows a pump station where dangerously high pressures may be experienced on the suction side as the pump is stopped. The use of a surge relief valve prevents the suction pressure rising to this dangerous point.

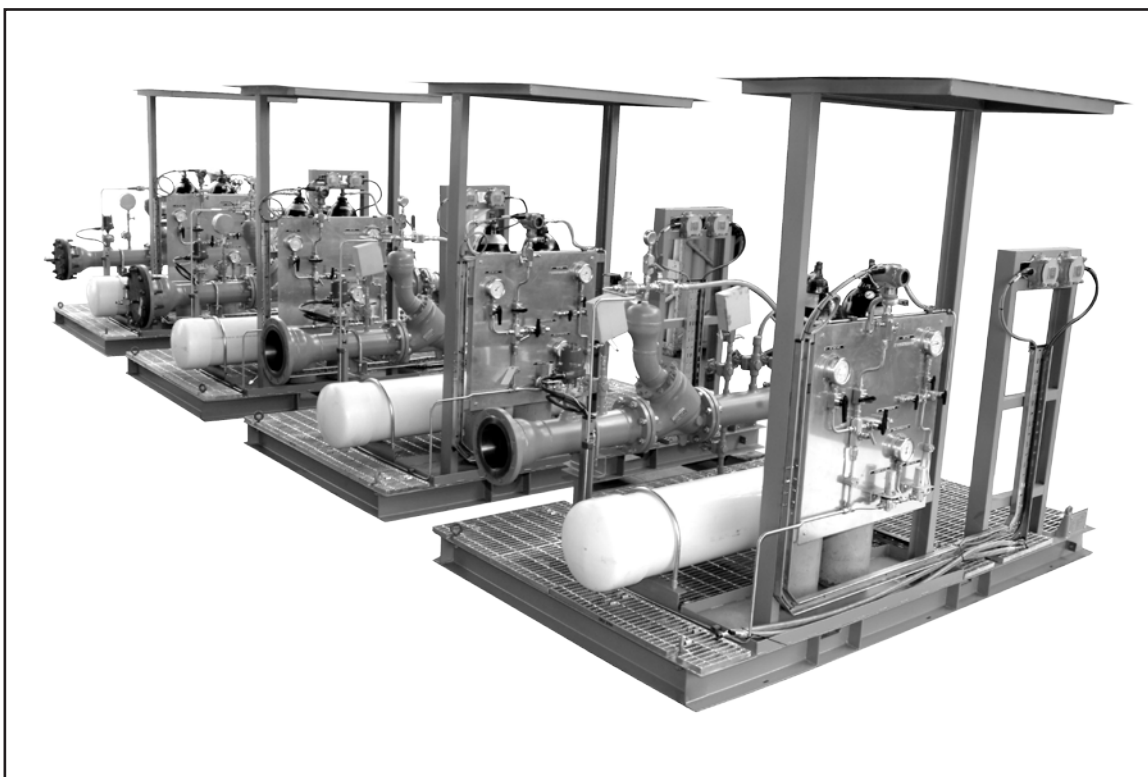


Response Time of Pilot Operated Valve Versus Gas Loaded Valve

## Complete Surge Relief Systems

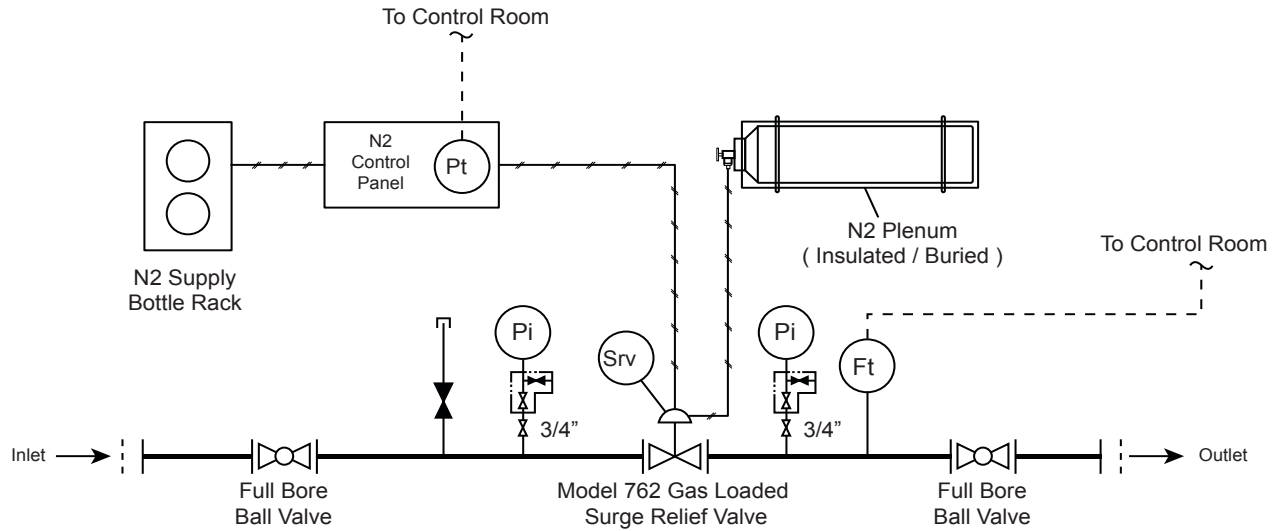
As a value added service, Daniel offers skid based surge relief systems that have significant advantages. Customers can confidently rely on Daniel to provide an integrated system with properly sized surge relief valves, manifolds and piping, as well as appropriate maintenance provision (block valves) and a nitrogen charging system.

A typical skid layout for a marine loading operation is shown below with redundant, parallel surge relief valves, inlet and outlet manifolds sized to minimize the pressure loss, and the nitrogen system completely integrated on the skid with other required equipment and instrumentation.

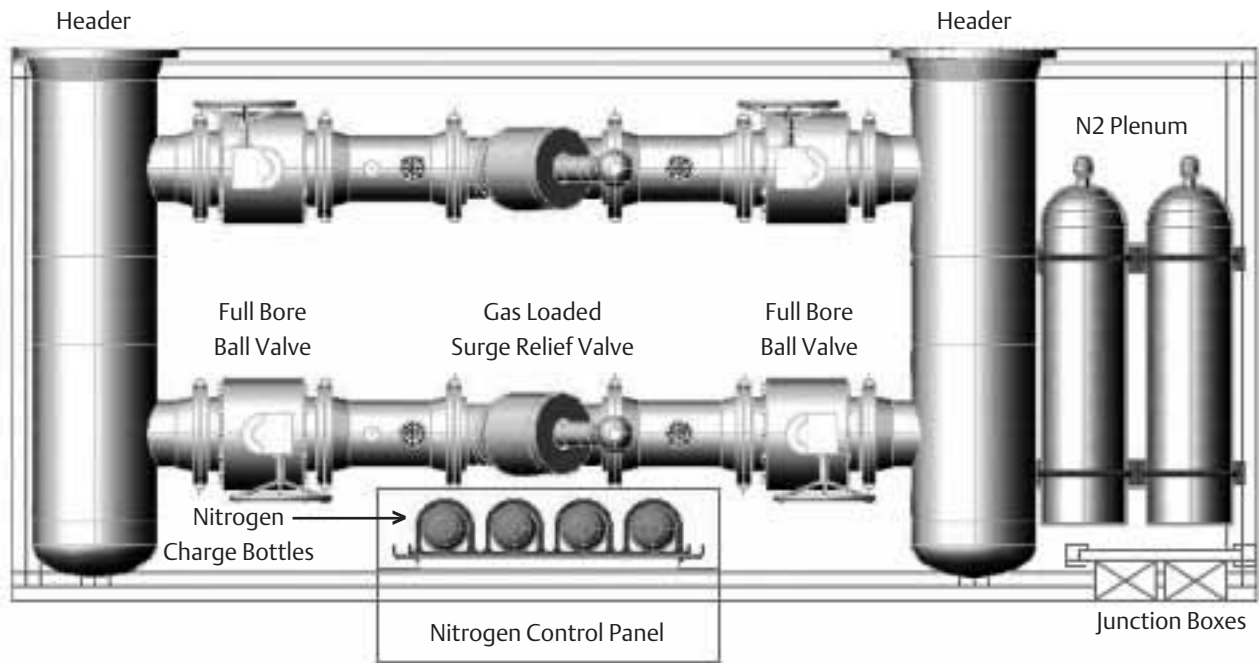


**A Typical Surge Relief System Skid**

### Typical Surge Relief System



### Surge Relief System with Nitrogen Panel and Plenum



Smart devices on the skid and the nitrogen panel can be connected to a flow computer device such as a ROC 809 to communicate directly with PlantWeb® digital architecture or other digital control systems using AMS® Suite Device Manager.

## System Description

Typical surge relief systems include correctly sized inlet and outlet manifolds with isolation valves upstream and downstream of the surge relief valves. These are normally full-port ball valves. It is possible to implement a system with an upstream isolation valve only, to save both space and cost.

A properly sized surge relief valve with the control system that supplies nitrogen timely at the established set point is critical. The system consists of the pressurized nitrogen insulated plenum and the requisite supply cylinder.

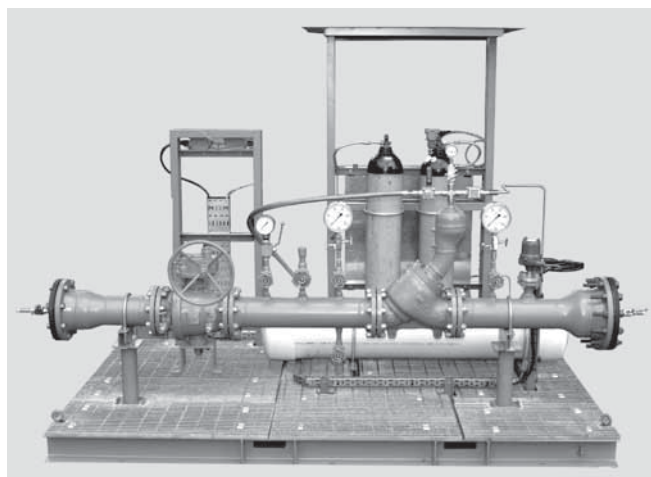
Relieving type pressure regulators employed in the nitrogen control panel reduce the nitrogen supply pressure to the desired set pressure in stages. As the set point pressure is reached, the regulator relieves the nitrogen from the top work of the surge relief valve through its relieving port and the surge relief valve opens to relieve the liquid surge pressure. There is a nitrogen plenum which is also connected to the output of the set point regulator and acts as a buffer in the nitrogen gas system to keep the system operation stable.

The nitrogen supply cylinders are filled to an initial pressure of 1800 psig (124.14 barg). The set point pressure is measured using a pressure transmitter, which can be transmitted to a remote control room. When the transmitter pressure falls below the set point, the supply cylinder must be replaced with full bottle. The system nitrogen set point is field settable by authorized personnel. The surge relief valve, inlet/outlet piping, nitrogen control panel, supply cylinders and the plenum are all designed, engineered, assembled, tubed, wired, configured and put onto a suitable structural skid with adequate lifting facility.

The piping run will include the necessary instrumentation, including pressure and temperature indicators and transmitters. Daniel offers complete design, fabrication, documentation, testing and commissioning of systems for surge relief, both as skid mounted systems and as loose integrated solutions.

## Major Benefits of Using Daniel Surge Relief Valve

- High flow capacities (Cv) means smaller and /or fewer valves to save installation costs and weight
- Fast response – rapid opening, controlled closing without slamming shut
- Oil reservoir helps extend the life of the seals and in addition eliminates the possibility of nitrogen gas permeating the seals with reduced nitrogen consumption
- Line pressure operated – no separate power source required
- 45° valve design allows for vertical operation of the piston. This ensures that the valve opening
- Does not get affected due to debris, when the valve cycles during an occasional surge
- Ratio of nitrogen pressure to set pressure is 1:1 (less force exerted by spring)
- Linear action valves are the preferred choice for surge control application







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