HENRY
TECHNOLOGIES

Components for Transcritical CO_2 Systems

OIL MANAGEMENT CONTROLS | **SAFETY DEVICES**

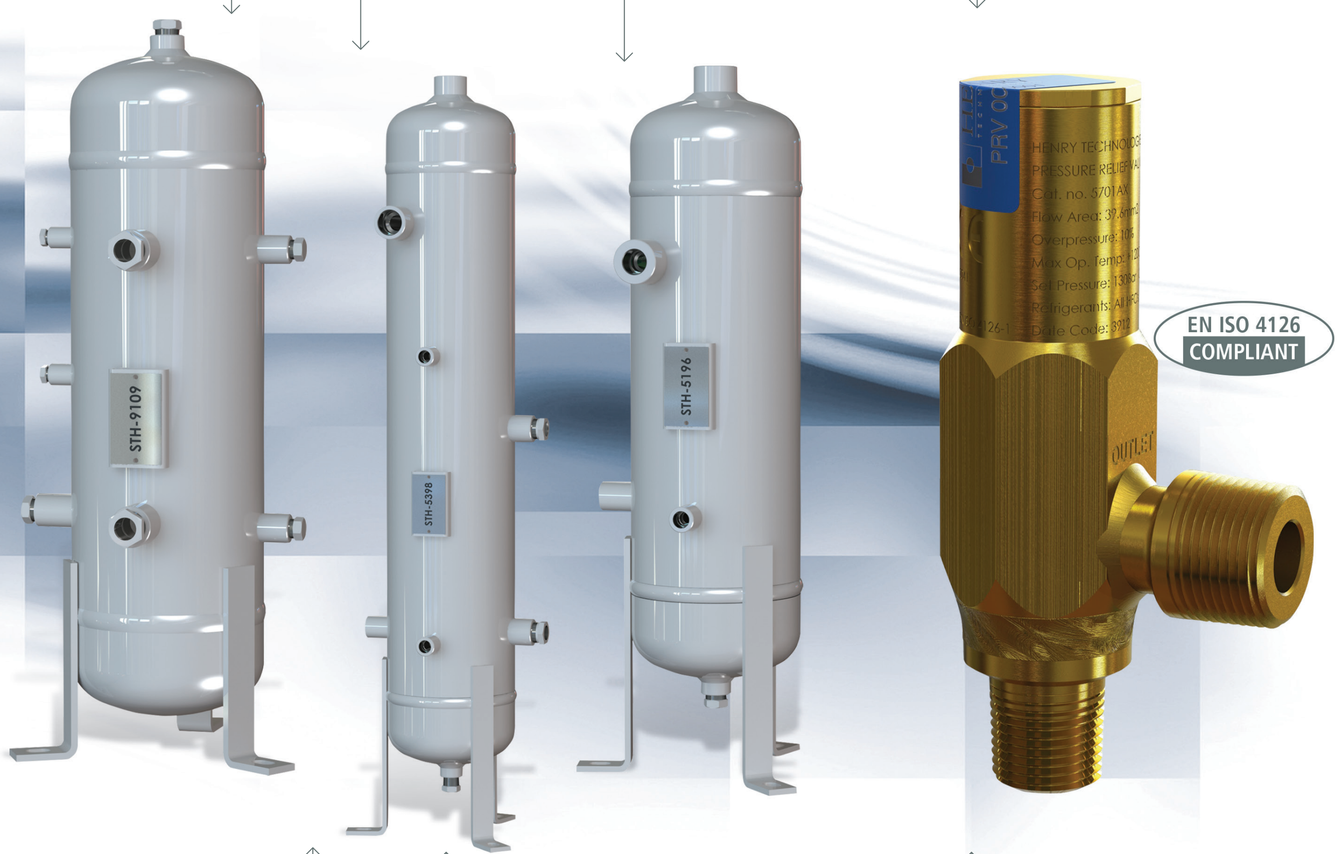
FEATURES

OIL RESERVOIR

OIL SEPARATOR-RESERVOIR

OIL SEPARATOR

HIGH PRESSURE RELIEF VALVE



Maximum Working Pressure of 130 Barg

Oil Separation Efficiency up to 97%

Max pressure setting of 130 Barg

AC&R COMPONENTS

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DESIGNED FOR PERFORMANCE

OIL MANAGEMENT CONTROLS

The function of a helical oil separator is to efficiently remove oil from the discharge gas and return it to the compressor, either directly or indirectly. This helps maintain the compressor crankcase oil level and raises the efficiency of the system by preventing excessive oil circulation.

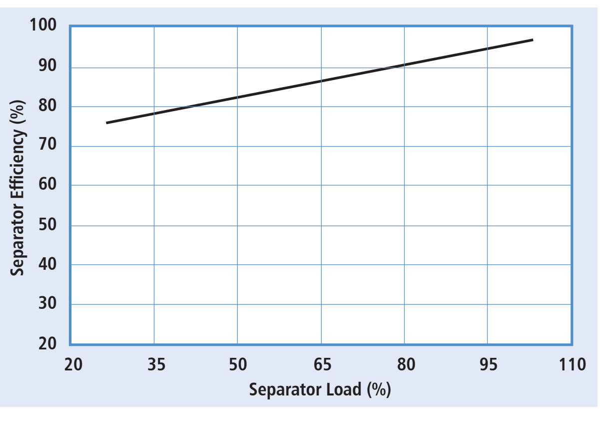
The function of an Oil Reservoir is to provide a holding charge of oil. The amount of oil circulating in a system varies depending on the operating conditions and the oil reservoir caters for these fluctuations by providing additional storage capacity.

Efficiency

To establish the oil separator efficiency when used on transcritical CO_2 applications Henry Technologies commissioned independent testing. The chart shows the resultant oil separator efficiency at capacities of 25% to 103%. Efficiency levels of up to 97% were recorded. The tests utilised a semi-hermetic compressor with a variable speed drive motor to enable the capacity to be adjusted.

There are many factors that affect oil separator efficiency such as; discharge gas temperature and pressure; compressor oil carry-over and the density of the discharge gas and oil. Consequently oil separator efficiency varies on each system.

Separation Efficiency



Main Features

Separator/Separator-Reservoir

- High oil separation efficiency - up to 97%
- Consistent low pressure drop
- No clogging elements due to excessive oil in the system
- No oil blow-out at start up from oil left in a coalescing element
- Maintenance-free
- Oil level sensor port (except STH-5392)

Oil Reservoir

- Two sizes available; 6.0 litres and 11.0 litres
- Clear sight glasses
- Oil level sensor port

Materials of Construction

The main components; shell, end caps and connections are made from carbon steel.

Technical Specification

Allowable operating temperature = 0°C to + 140°C

Allowable operating pressure = 0 to 130 barg

Oil Separator

Part No	Conn Size (Inch)	Dimensions (mm)								Mounting details	Drawing reference	Pre-charge qty (l)	Weight (kg)	CE Cat
		ØA	B	C	D	ØE	F	G	H					
STH-5193	1/2 NPT	168.3	638	191	202	231	202	N/A	45	3 x 14mm slots	fig.1	0.6	31.0	Cat III
STH-5196	3/4 NPT	168.3	697	191	261	231	261	N/A	45	3 x 14mm slots	fig.1	0.6	31.0	Cat III
STH-5198	1 NPT	168.3	747	191	261	231	261	N/A	45	3 x 14mm slots	fig.1	0.6	34.0	Cat III
STH-5410	1 1/4 NPT	168.3	752	196	261	231	261	N/A	39	3 x 14mm slots	fig.1	0.6	34.5	Cat III
STH-5411	1 1/2 NPT	219.1	821	204	261	283	261	N/A	60	3 x 14mm slots	fig.1	0.6	57.0	Cat III
STH-5412	2 NPT	219.1	901	210	261	283	261	N/A	55	3 x 14mm slots	fig.1	0.6	64.0	Cat III

Oil Separator-Reservoir

Part No	Conn Size (Inch)	Dimensions (mm)								Mounting details	Drawing reference	Capacity (l)	Weight (kg)	CE Cat
		ØA	B	C	D	ØE	F	G	H					
STH-5392	1/4 NPT	73	695	605	137	N/A	N/A	N/A	N/A	2 x 14mm slots	fig.2	1.1*	6.2	Cat II
STH-5398	1 NPT	168.3	992	191	261	231	271	265	45	3 x 14mm slots	fig.3	6.7*	45.2	Cat III

*Indicates reservoir capacity

Oil Reservoir

Part No	Conn Size (Inch)	Dimensions (mm)								Mounting details	Drawing reference	Capacity (l)	Weight (kg)	CE Cat
		ØA	B	C	D	ØE	F	G	H					
STH-9109	3/8 NPT	168.3	623	199	240	231	209	120	120	3 x 14mm slots	fig.4	6.0*	28.0	Cat III
STH-9108	3/8 NPT	168.3	930	199	547	231	209	269	278	3 x 14mm slots	fig.4	11.0*	41.5	Cat III

*Indicates reservoir capacity

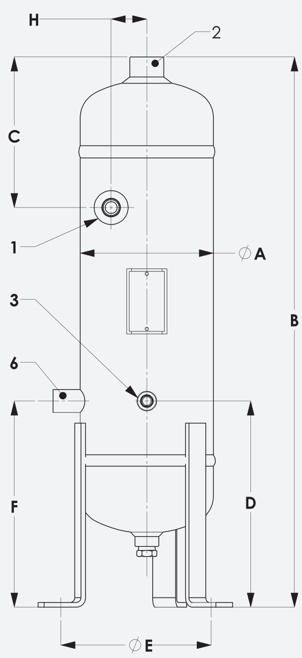


Fig.1

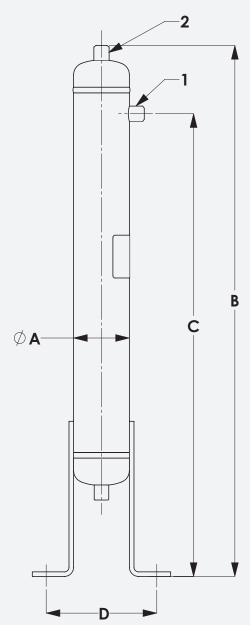


Fig.2

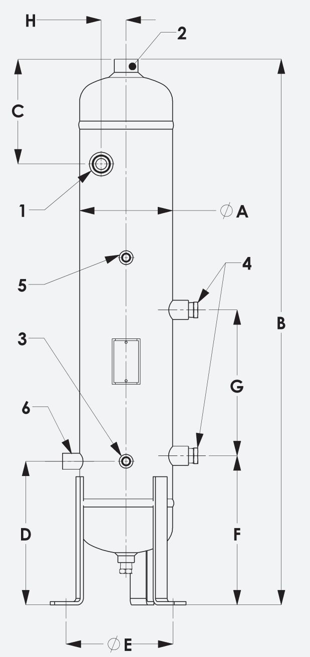


Fig.3

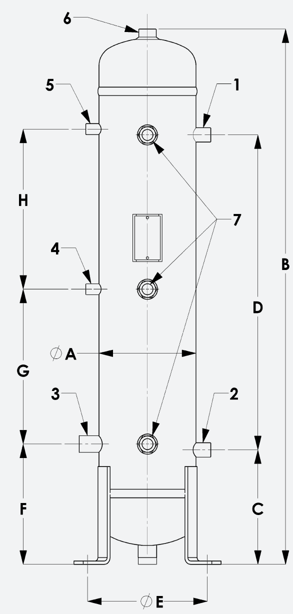


Fig.4

1. Inlet
2. Outlet
3. Oil return, 3/8 NPT
4. Sight glass
5. Port, 3/8 NPT
6. Level control conn, 1/2 NPT (except STH-5392)

1. Inlet
2. Outlet
3. Level control conn, 1/2 NPT
4. Charging conn, 1/4 NPT
5. Vent valve conn, 1/4 NPT
6. Relief valve conn, 1/2 NPT
7. Sight glass (centre sight glass on STH-9108 only)

Performance Data

This table provides a summary of the kW capacity of each separator for fixed evaporating and condensing temperatures. The table can be used as a quick reference guide. However, the Selection Guidelines are recommended for helical separator sizing.

Separator performance data

Part No	Capacity in kW of refrigeration at nominal evaporator temperature (°C)						Vol discharge (m^3/h)
	-30	-20	-10	0	10	15	
STH-5193	14	15.3	16.6	17.9	19.1	19.7	2.6
STH-5196	36.6	39.9	43.4	46.7	49.9	51.4	6.8
STH-5198	54.9	59.9	65.1	70.1	74.9	77.1	10.2
STH-5410	128	140	152	163	175	180	23.8
STH-5411	201	219	239	257	274	283	37.4
STH-5412	265	289	315	339	362	373	49.3
All data is based on 90 bar high pressure, 35°C gas cooler, 8K suction gas superheat and 5K useful superheat							

Separator-Reservoir performance data

Part No	Capacity in kW of refrigeration at nominal evaporator temperature (°C)						Vol discharge (m^3/h)
	-30	-20	-10	0	10	15	
STH-5392	9.2	10	10.9	11.7	12.5	12.9	1.7
STH-5398	54.9	59.9	65.1	70.1	74.9	77.1	10.2
All data is based on 90 bar high pressure, 35°C gas cooler, 8K suction gas superheat and 5K useful superheat							

Selection Guidelines

The most important parameter for selection is the discharge volumetric flow rate, expressed in m^3/hr. This is the calculated volume flow rate at entry to the oil separator. It is not to be confused with the compressor displacement or swept volume.

To calculate the discharge volumetric flow rate, the maximum and minimum system mass flow rates are required along with the density of the gas at the inlet to the separator.

These mass flow rates can either be calculated from first principles or by using refrigeration cycle analysis software. In this way, superheating (useful and un-useful) can be accounted for in the mass flow rate calculation.

The gas density at inlet to the separator is a function of both pressure and temperature. The inlet gas temperature is dictated by a number of system design factors including compressor performance. The gas will be in a superheated state.

Example:-

Refrigerant CO_2 (R744)
Maximum refrigeration capacity = 42 kW
Minimum refrigeration capacity = 26 kW
Evaporating temperature = -10 °C
Gas cooler outlet = 35 °C
High pressure = 90barg (a)
Suction gas superheat = 5K
Useful superheat = 5K

From analysis software:-

Maximum mass flow rate = 1052 kg/hr
Minimum mass flow rate = 651 kg/hr
Gas density, superheated, at inlet to separator = 162 kg/m^3

Note: Mass flow rate = [(kW refrigeration/ refrigerating effect) x 3600]

Use the equation:-

$$\text{Discharge volume flow rate} = \frac{\text{Mass flow rate}}{\text{Gas density}}$$

Hence for this example:-

$$\text{Calculated maximum discharge volume flow rate} = \frac{1052}{162} = 6.5\ m^3/hr$$

$$\text{Calculated minimum discharge volume flow rate} = \frac{651}{162} = 4.0\ m^3/hr$$

Using these m^3/hr figures, the recommended helical separator selection is model STH-5196 (reference additional note 3 for guidance on minimal under-sizing).

Additional notes on selection:-

1. It is recommended that the separator is **not** operated below 25% of its rated maximum capacity. This is to optimise efficiency. On systems with extreme unloading conditions, one separator per compressor should be used rather than one separator for a common discharge line.
2. Understanding the system refrigeration capacity and the percentage of full and low load run times can also be helpful in selecting the separator.
3. In cases where the maximum discharge has been exceeded by only a minimal amount and the system has unloading characteristics, select the smaller separator. It is not recommended to oversize.

Installation – Main Issues

1. Oil separators are not 100% efficient, so installing an oil separator should not be viewed as a replacement for oil traps, suction line accumulators or good oil return piping practices.
2. An initial oil pre-charge of 0.6l is required.
3. Install the oil separator/separator-reservoir vertically and reasonably close to the compressor. Proper piping practice should be adopted to prevent excessive loads or vibration at the inlet and outlet connections. The separator/separator-reservoir must be properly supported at the bottom mounting feet interface.
4. A check valve should be located downstream of the separator/ separator-reservoir outlet connection. This check valve is to prevent liquid refrigerant migrating from the condenser/gas cooler.

PRESSURE RELIEF VALVES

EN ISO 4126 COMPLIANT

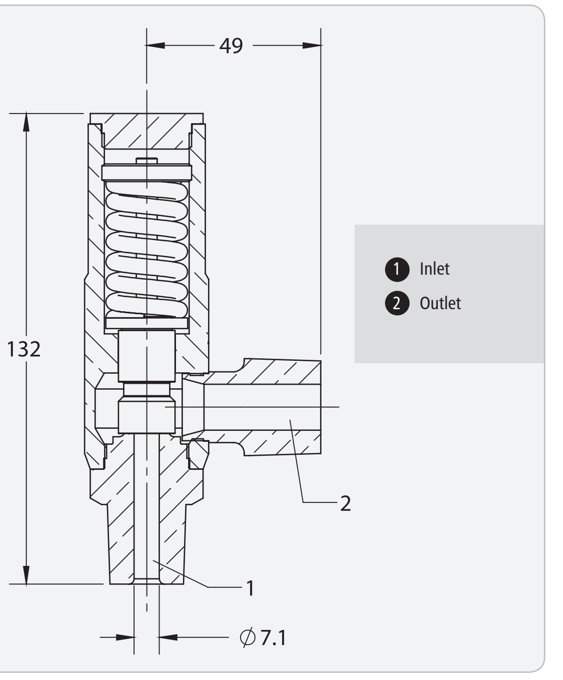
The function of a Pressure Relief Valve is to protect against over-pressure. For safety reasons, excessive over-pressure in any part of a refrigeration system must be avoided.

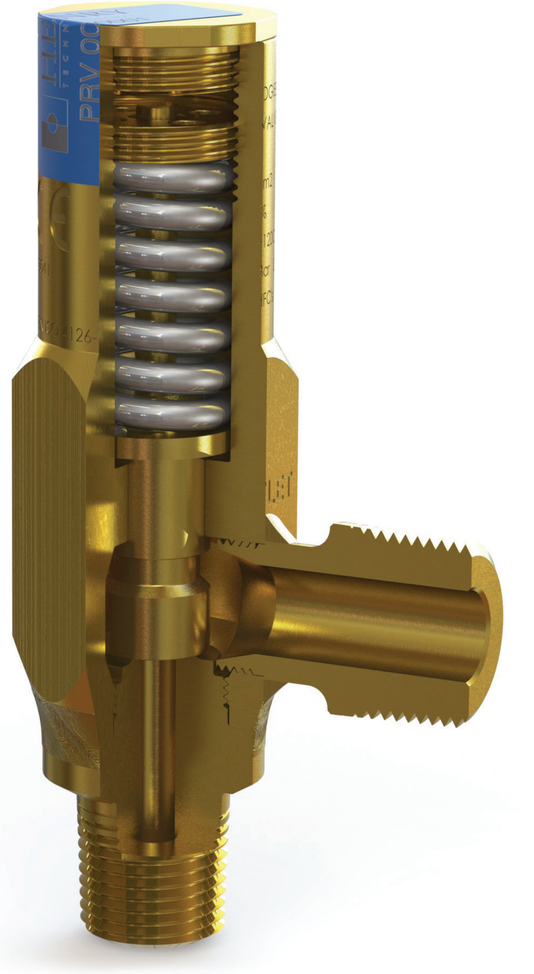
The 5701AX pressure relief valve is specifically designed for high pressure applications from 46 bar up to 130 bar and in particular, transcritical CO_2 systems. The valves are manufactured from Brass.

Main Features

- Maximum pressure setting of 130 bar
- In accordance with EN ISO 4126, the valve reseats within 15% of set pressure following a discharge
- High flow capacity
- Fluoroelastomer soft seat material provides excellent sealing characteristics
- Allowable operating temperature = -40°C to +120°C
- Suitable for HFC, HCFC and CO_2 refrigerant gases

Standard pressure settings (barg): 46, 60, 80, 100, 120, 130





Part No.	Valve Capacity Ratings (kg Air/min) @ 20°C					
	Standard Pressure Setting					
	46.0	60.0	80.0	100.0	120.0	130.0
5701AX	20.4	26.6	35.5	44.4	53.2	57.7

Part No.	High Pressure Angle Relief Valve - Brass					
	Conn Size (inch)		Flow Area (mm²)	K_{dr}	Weight (kg)	CE Cat
	Inlet	Outlet				
5701AX	1/2 NPTF	3/4 NPTF	39.59	0.71	0.82	Cat IV

Note: High pressure rupture disc (with pressure settings up to 130 barg) available on request.

Selection Guidelines

For safety reasons, relief valve selection should only be carried out by suitably qualified engineers.

Henry Technologies pressure relief valves are designed to discharge refrigerant vapour and are not recommended for liquid use.

The European Standards EN378 (reference 1) and EN13136 (reference 2) are recommended for PRV selection.

Example

A liquid receiver is to be protected from over-pressure due to fire.

Receiver dimensions = 2.016m long (L) x 0.841m outside diameter (D)
Refrigerant = R744 (CO_2)
Pressure Setting = 50.0 barg

$$Q_{md} = \frac{3600 \times \varphi \times A_{surf}}{h_{vap}}$$

Q_{md} = Minimum required discharge capacity, of refrigerant, of the pressure relief valve (kg/hour)

φ = Density of heat flow rate (kW/m²). The standards assume a value to 10 kW/m² but state that a higher value can be used if necessary. This figure relates to an un-lagged vessel.

A_{surf} = External surface area of the vessel (m²)

h_{vap} = Heat of vaporisation calculated at 1.1 times the set pressure, in bar a, of the pressure relief valve (kJ/kg)

Note:
When the relief valve setting is close to the critical pressure of the refrigerant, this sizing method may not be applicable.

$$A_{surf} = (\pi \times D \times L) + 2\left(D^2 \times \frac{\pi}{4}\right)$$

$$A_{surf} = (\pi \times 0.841 \times 2.016) + 2\left(0.841^2 \times \frac{\pi}{4}\right) = 6.44\ m^2$$

Calculate the heat of vaporisation, h_{vap}, taken at 1.1 times set pressure:

$$P_O = (P_{set} \times 1.1) + P_{atmos} = (50.0 \times 1.1) + 1.013 = 56.01\ \text{bar a}$$

From refrigerant property tables, use saturated vapour and liquid enthalpies at P_O.

Vapour = 410.59 kJ/kg
Liquid = 252.44 kJ/kg
h_{vap}=410.59-252.44 = 158.15 kJ/kg

The minimum required discharge rate of R744 can now be calculated for this vessel and set pressure:

$$Q_{md} = \frac{3600 \times \varphi \times A_{surf}}{h_{vap}} = \frac{3600 \times 10 \times 6.44}{158.15} = \underline{1465.95\ \text{kg/hr, R744}}$$

For relief valve discharge capacity, Q_m:

$$Q_m = 0.2883 \times C \times A \times K_{dr} \times K_b \times \sqrt{\frac{P_O}{V_O}}$$

Q_m = Discharge capacity, of refrigerant, of the pressure relief valve (kg/hr)

C = Function of the isentropic exponent

A = Flow area of PRV (mm²)

K_{dr} = De-rated coefficient of discharge of PRV

K_b = Theoretical capacity correction factor for sub-critical flow. A value of 1 is used for critical flow.

P_O = Actual relieving pressure of PRV (bar a)

V_O = Specific volume of saturated vapour at P_O (m³/kg)

Refrigerant data should be referenced for values of C and V_O.

The objective is to select a PRV which results in $Q_m > Q_{md}$. In this way, the relieving capacity of the PRV is greater than required thus avoiding excessive vessel pressure.

For this example, a 5701AX has been selected:

A = 39.59 mm²
K_{dr} = 0.71

$$Q_m = 0.2883 \times 2.63 \times 39.59 \times 0.71 \times 1 \times \sqrt{\frac{56.01}{0.0054}} = \underline{2{,}170.6\ \text{kg/hr, R744}}$$

$Q_m > Q_{md}$, therefore the 5701AX would be suitable for this system.

Important selection notes:

1. It is important not to grossly over-size a PRV so that Q_m is many times greater than Q_{md} as the performance of the PRV can be affected. Contact Henry Technologies for further guidance.
2. Henry Technologies recommends inlet and outlet piping for all PRVs are sized in accordance with EN13136 (reference 2) to avoid excessive pressure losses which can affect valve performance.
3. If a Henry Technologies rupture disc is used in conjunction with a Henry Technologies PRV, the PRV capacity should be de-rated by 10%. In the above example, the PRV capacity would be de-rated to 1,953.5 kg/hr (2,170.6 x 0.9).

References:

1. BS EN 378-2:2008+A2:2012* 2. BS EN 13136:2013*

*Latest revisions at the time of publication. The user should ensure the latest revisions are referenced.

Installation – Main issues

1. Connect the relief valve at a location above the liquid refrigerant level, in the vapour space. Stop valves should not be located between the vessel and the relief valve except the three-way type.
2. Do not discharge the relief valve prior to installation or when pressure testing the system.
3. Pressure relief valves should be mounted vertically.
4. Relief valves should be changed out after discharge. Most systems are subject to accumulations of debris and particles of metal and dirt are generally blown onto relief valve seats during discharge. This can inhibit the relief valve from re-sealing at the original set pressure. A valve can also relieve at a lower pressure than the stamped setting due to the force of the re-closing action.
5. The pipe-work must not impose loads on the relief valve. Loads can occur due to misalignment, thermal expansion, discharge gas thrust, etc.
6. Transcritical CO_2 systems should generally be sized with the shortest length and largest bore outlet pipe work practical to avoid solids forming downstream of the PRV during a discharge.

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