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Relief Valve Test Panel: System Review

T. Schaus, 8/5/92

The RD/Cryo section currently operates a Relief Valve Test Panel for setting and testing relief valve set pressures (see drawing #MD-194470). A relief valve is mounted on a volume chamber and the chamber's pressure is slowly increased in a controlled manner using 2000 psig air bottles as pressure sources. Through gauges on the panel, the operator can measure the set pressures of the relief valves and adjust them as necessary. All tubing is 304 stainless steel with a minimum pressure rating of 3768 psig and connected via welds or Swagelok fittings. Five relief valves protect the system from over-pressurization and 'Relief Valve Sizing' (included in rear) proves that their flow capacities are adequate. Also see the 'Piping , Valve, and Instrument List' (also included) for further information. An operating procedure is not required for safe use of the Test Panel since the relief valves can handle all situations that may arise. See relief valve sizing.

Fermilab's ES&H manual chapter 5031.1, 'Pressure Piping Systems,' defines procedures for designing, building, and testing most pressurized systems under six inches in inside diameter. This encompasses the entire Test Panel, including the two volume chambers. The 'Policy' section requires a review of sections of the system which rise above 150 psig, and this entails a pressure test as per chapter 5034. 'Pressure Test' outlines a procedure for testing the required sections, and the Test Panel's documentation will be submitted for review by a qualified engineer, thus fulfilling all of chapter 5031 requirements

Relief Valve Test Panel: Relief Valve Sizing

T. Schaus, F. Renken ~~9/29/92~~
10/20/92

Five relief valves exist on the RD/Cryo Relief Valve Test Panel. (Refer to drawing #MD-194470 and 'Piping, Valve, and Instrument List' for information.) To be effective, these relief valves must be able to handle the maximum flow rates supplied by all feasible sources, and will be shown to do so below. Three relief valves are Circle Seal 5100 series valves and two are Anderson / Greenwood 81MS44 valves. More information on them may be found in their catalogs.

Relief Valve SV-121 (set at 450 psig) protects a 0-500 psig gauge (PI-116) and must be able to handle the maximum flow through regulator RV-126 or regulator RV-127, depending on the positions of ball valves MV-104, 105, and 106. If valves MV-104 and 105 are closed and regulator RV-126 is set at 750 psig, a maximum flow rate of <u>62 SCFM</u> air must be expelled (this number was supplied by a Grove engineer, assuming a 2000 psig input). If MV-104, 105, & 106 are open, regulator RV-127 may supply air. RV-127's manufacturer, Fairchild, offers this flow rate formula:

Max. Flow = (.13)(inlet pressure), max. inlet pressure = 2000 psig
= (.13)(2000 psig) = <u>260 SCFM air</u>

The flow capacity of relief valve SV-121 is approximately <u>450 SCFM</u> of air at 10% overpressure (from Circle Seal catalog, 5100 series specifications), and therefore is capable of protecting PI-116 from either source.

Relief valves SV-122 (Circle Seal) and SV-124 (AGCO 81MS44-2) control the pressure in the 0-100 psig and 0-500/0-2000 psig volume chambers, respectively. They are sized using the accepted Compressed Gas Association formula for an un-insulated container holding a non-liquefied gas (CGA S-1.3-1980, p8):

SV-124: Q = .029W, Q = minimum flow rate required
W = weight of water which could fill the chamber

Q = 0.029(.2292 cubic feet)(62.45 lbm per cu. foot)
= <u>0.4150 SCFM air</u>

According to Anderson / Greenwood catalog sizing formula and information, SV-124 ,which is -2 orifice valve, the flow rate capacity can be found using the following formula:

(V is flow rate in SCFM, A is the orifice area, C is the gas constant, K is the valve coefficient of discharge, P_1 is the 110% cracking pressure absolute, M is the molecular weight, T is the temperature in R, and Z is the compression factor. All values in AGCO catalog.)

$$V = \frac{A(6.32)CKP_1}{\sqrt{MTZ}}$$

$$V = \frac{(.012)(6.32)(356)(.816)(2160)}{\sqrt{(29)(530)(1)}}$$

$$V = 384 \text{ SCFM}$$

Clearly 384 SCFM is sufficient for the volume chamber relief valve SV-124.

SV-122: $Q = 0.029(.7292 \text{ cubic feet})(62.45 \text{ lbm per cu. foot})$
$= \underline{1.321 \text{ SCFM air}}$

SV-122 cracks at 103 psig and has a capacity of 100 SCFM at 10% overpressure, also more than enough.

Relief valve SV-123 must limit the pressure of the manifold at 110 psig. Again, the maximum flow rate through the Grove regulator (RV-125) is 62 SCFM of air, as model number 15LG differs from model 15L only in the hand wheel. For SV-123, the Circle Seal catalog gives a maximum flow capacity of 100 SCFM of air at 10% overpressure, a satisfactory rate.

Finally, SV-128 (AGCO 81MS44-4) must restrict the gas supply hose pressure to 2300 psig. The highest bottle pressure connected to the panel in the last eight years was 2600 psig, but most fall near 2000 psig. As the bottle's manual valve is opened, the gas supply line pressurizes to the bottle pressure. If this pressure rises above 2300 psi, SV-128 must start releasing air at the rate it enters. Assuming a flow rate of 1862 SCFM air leaving through the relief valve (SV-128 releases air at approximately 1862 SCFM at 10% overpressure - AGCO catalog relief capacity charts), the time required to reduce the pressure from 2600 to 2300 psig will give good indication of the performance of the valve. At the high pressure involved the ideal gas law may not be accurate so the specific volume will be calculated using the compressibility factors of Nitrogen and Oxygen. This is necessary since a critical point doesn't exist for air. Nitrogen and Oxygen will be accounted for by 79% and 21% mass respectively.

Compressibility factors are obtained using reduced pressure and temperature and the Nelson-Orbert generalized compressibility charts.

Mass of Nitrogen at 2600 psig:

$$P_R = \frac{P}{P_{CR}} = \frac{(2600 + 14.7) \text{ psia}}{492 \text{ psia}} = 5.3$$

$$T_R = \frac{T}{T_{CR}} = \frac{530 \text{ R}}{227.1 \text{ R}} = 2.33$$

Which from the charts yields Z = 1.03.

From Wylen and Sonntag $R = 0.3830 \dfrac{\text{psia} \cdot \text{ft}^3}{\text{lbm} \cdot \text{R}}$ for nitrogen.

Specific Volume:

$$v_{N_2} = \frac{ZRT}{P} = \frac{\text{psia} \cdot \text{ft}^3 \cdot \text{R}}{\text{lbm} \cdot \text{R} \cdot \text{psia}} = \frac{1.03(.3830)(530)}{2614.7} = 0.0799 \frac{\text{ft}^3}{\text{lbm}}$$

Mass of Nitrogen:

$$m_{1N_2} = \frac{V}{v_{N_2}}(\%) = \frac{1.55 \text{ ft}^3}{.0799 \frac{\text{ft}^3}{\text{lbm}}}(.79) = 15.3 \text{ lbm}$$

Mass of Oxygen at 2600 psig:

$$P_R = \frac{P}{P_{CR}} = \frac{(2600 + 14.7)\text{ psia}}{736\text{ psia}} = 3.5$$

$$T_R = \frac{T}{T_{CR}} = \frac{530\text{ R}}{278.6\text{ R}} = 1.9$$

Which from the charts yields Z = 0.94.

From Wylen and Sonntag $R = 0.3353\ \frac{\text{psia}\cdot\text{ft}^3}{\text{lbm}\cdot\text{R}}$ for oxygen.

Specific Volume:

$$v_{O_2} = \frac{ZRT}{P} = \frac{\text{psia}\cdot\text{ft}^3\cdot\text{R}}{\text{lbm}\cdot\text{R}\cdot\text{psia}} = \frac{0.94(.3353)(530)}{2614.7} = 0.0639\ \frac{\text{ft}^3}{\text{lbm}}$$

Mass of Oxygen:

$$m_{1O_2} = \frac{V}{v_{N_2}}(\%) = \frac{1.55\text{ ft}^3}{0.0639\frac{\text{ft}^3}{\text{lbm}}}(.21) = 5.09\text{ lbm}$$

Total mass at 2600 psig = 15.3 + 5.09 = 20.39 lbm.

To calculate the mass at 2300 psig the same procedure is followed yielding the following results:

Mass of Nitrogen: 13.76 lbm.
Mass of Oxygen: 4.52 lbm.
Total mass: 18.28 lbm.

Therefore the change in mass to be accounted for is 2.11 lbm. (m_1-m_2)

At standard temperature and pressure:

R = 0.3704 for air.

$$V = \frac{mRT}{P} = \frac{\text{lbm}\cdot\text{psia}\cdot\text{ft}^3\cdot\text{R}}{\text{lbm}\cdot\text{R}\cdot\text{psia}} = \frac{2.11(0.3704)(530)}{14.7} = 28.2\text{ SCF}$$

With a flow capacity of 1862 SCFM

$$\text{time} = \frac{V}{\text{flow capacity}} = \frac{28.2\text{ SCF}}{1862\text{ SCFM}} = 0.0151\text{ min} = 0.91\text{ seconds.}$$

Since the time is less than one second the valve can sufficiently relieve the incoming flow, especially since the operator takes a few seconds to open the bottle's valve manually. Although two bottles are connected to the source line the probability of both bottles being above 2300 psig is minimal. Furthermore, the probability that both would be opened at exactly the same time is even less. In this incredibly unlikely circumstance it would merely take the valve about 2 seconds to relieve the pressure. Therefore, the relief is sufficient to handle any condition in this system.

Relief Valve Test Panel: Pressure Test

T. Schaus, F. Renken ~~9/29/92~~ 10/27/92

As noted in the ASME Boiler and Pressure Vessel Code (section VIII, U-1(c)), 'Vessels having an inside diameter, width, height, or cross section diagonal not exceeding 6 in. .... are not considered to be within the scope [of the pressure vessel division].' All of the pressurized equipment in the Relief Valve Test Panel has an inside diameter of 6 inches or less, including the two volume chambers, and therefore falls under the Fermilab ES&H 'Pressure Piping Systems' standard (chapter 5031.1). Following this standard, 'All pressure piping systems shall be pressure tested as described per Fermilab ES&H manual chapter 5034.' Thus, the Relief Valve Test Panel will be tested in this manner. Although hydrostatic testing is safer, a pneumatic test, in conformance with sec VIII UG-100, will be performed since the system is not easily dried. Refer to the ASME code and the Fermi ES&H manual for more information.

A Pressure Testing Permit was obtained (copy at rear) and the system will be reviewed by the division/section safety officer. The system is divided into a high pressure section (0-500/0-2000 psig) and a pre-regulator section (to 2300 psig) for the purpose of this test. A low pressure sub-system also exists, but ES&H chapter 5031 dictates that reviews must occur only when '... the operating pressure is above 150 psig for gas ...,' and the low pressure section only reaches 110 psig. The high pressure and pre-regulator sections shall be tested separately as per ASME section VIII, UG-100. This requires a test pressure at least equal to '1.25 times the maximum allowable working pressure ....' Refer to drawing # MD-194470, 'Piping, Valve & Instrument List' (located in rear), and the testing procedure outlined below.

A. <u>Pre-regulator Section Test</u>

1. Close the manual valves on the two source bottles if they are in place.
2. Relieve all pressure in the gas source line (connected to the bottles):
   i. Close MV-104 and 105.
   ii. Open MV-103 and, if applicable, the manual valve on the end of the vent line (outside the portakamp).
   iii. Open RV-127 as much as necessary to relieve the pressure.
   iv. Open MV-115 to relieve the pressure retained by the check valve.
3. Close RV-125, 126, and 127 to isolate the high and low pressure sections.
4. Remove the source bottle from the system by detaching the gas source lines.
5. Attach the testing apparatus diagrammed in Fig. 1 to one gas source line and cap the other. The funcion of SV-203 will be performed by valve SV-128 reset to the testing pressure as per step 6.
6. Replace or install SV-128 with a valve as described by SV-203 set at 3000 psig with a -4 orifice.
7. During most of the test, all unnecessary personnel shall leave the room but may stand as close as outside the next door. Those remaining in the room will stand behind the test panel (gauge side). Any persons in the room must have safety glasses on. Following UG-100:
   i. Determine the test pressure:
      Test Press. = 1.25(MAWP)(S)
      = 1.25(2300)(1) = 2875 psig
   ii. Close vent MV-204 on the testing apparatus.
   iii. Turn on the compressor and let it run for about fifteen minutes.
   iv. Using regulator RV-201, gradually increase the test pressure until one half of the test pressure is reached:
      0.5(T.P.) = 0.5(2875) = 1438 psig

v. Hold at this pressure for 5 minutes. Any leak will be evident by a slight decrease in pressure. No inspection of pipes should occur at this high pressure until after full test pressure has been reached.

vi. If a leak is suspected, reduce the pressure to 200 psig; pinpoint the leak using Snoop, and depressurize all lines before repairs are attempted.

vii. The pressure should now be increased by steps of one tenth of the test pressure until the test pressure is reached:
0.1(T.P.) = 0.1(2875) = 288 psig
At each step hold the pressure as above and only check if decrease is observed.

viii. The test pressure shall be held for five minutes. The pressure will then be reduced to four fifths of the test pressure (through RV-201), at which time personnel may again enter the room.
0.8(T.P.) = 0.8(2875) = 2300 psig

ix. Visually inspect the system and carefully check for leaks using a rag in addition to Snoop to protect one's hands from the high pressure. Any leaks should have been detected before visual inspection by loss of pressure. This inspection is necessary to fulfill UG-100 requirements.

x. When the inspection is complete, shut off the compressor and close the regulator, thereby slowly relieving the pressure. If necessary, use MV-204 to speed the release of air.

xi. Refer to the Fermilab ES&H manual chapter 5034TA p. 1-2 and ASME UG-100 for further guidelines.

8. Reset relief valve SV-128 to normal operating cracking pressure (2300 psig; the MAWP of the pre-regulator section) before operating the panel for any use other than this pressure test.

B. <u>High Pressure Test</u>

1. Close the manual valves on the two source bottles. Relieve all pressure in the system by opening valves MV-103, 104, 105, and 106, along with regulator RV-127 (just enough to relieve the pressure in the gas source line). If a manual valve was installed on the vent line outside the portakamp, open it. Then, open MV-115 to vent the small pressure retained due to venting through a check valve.
2. If this step wasn't done previously, attach a manual valve to the venting pipe on the end outside the portakamp. Close this valve.
3. Remove the 0-500 psig gauge (PI-116) and cap the line. The pressure in this test will run over 500 psig and may damage this gauge otherwise.
4. Remove the high pressure regulators RV-126 and 127 and cap the output lines on both regulators. Removal is necessary because the test pressure will exceed the maximum output pressures of both regulators.
5. Cap relief valve SV-121.
6. Cap the relief valve test opening in volume chamber A (located on top of the volume chamber).
7. Check to make sure MV-103, 104, 105, and 106 are still open.
8. Connect the test apparatus shown in Fig. 1 to MV-115 and open MV-115.
9. Replace SV-124 with relief valve SV-303 as described for the test set at 2475 psig. SV-124 will be used to provide the relief for the test.
10. During most of the test, all unnecessary personnel shall leave the room but may stand as close as outside the next door. Those remaining in the room will stand behind the test panel (gauge side). Any persons in the room must have safety glasses on. Following UG-100:

i. Determine the test pressure:
Test Press.= 1.25(MAWP)(S)
= 1.25(1950(1) = 2438 psig

ii. Close vent MV-304 on the testing apparatus.
iii. Turn on the compressor and let it run for about fifteen minutes.
iv. Using regulator RV-201, gradually increase the test pressure until one half of the test pressure is reached:
0.5(T.P.) = 0.5(2438) = 1219 psig
v. Hold at this pressure for 5 minutes. Any leak will be evident by a slight decrease in pressure. No inspection of pipes should occur at this high pressure until after full test pressure has been reached.
vi. If a leak is suspected, reduce the pressure to 200 psig; pinpoint the leak using Snoop, and depressurize all lines before repairs are attempted.
vii. The pressure should now be increased by steps of one tenth of the test pressure until the test pressure is reached:
0.1(T.P.) = 0.1(2438) = 244 psig
At each step hold the pressure as above and only check if decrease is observed.
viii. The test pressure shall be held for five minutes. The pressure will then be reduced to four fifths of the test pressure (through RV-301), at which time personnel may again enter the room.
0.8(T.P.) = 0.8(2438) = 1950 psig
ix. Visually inspect the system and carefully check for leaks using a rag in addition to Snoop to protect one's hands from the high pressure. Any leaks should have been detected before visual inspection by loss of pressure. This inspection is necessary to fulfill UG-100 requirements.
x. When the inspection is complete, shut off the compressor and close the regulator, thereby slowly relieving the pressure. If necessary, use MV-204 to speed the release of air.
xi. Refer to the Fermilab ES&H manual chapter 5034TA p. 1-2 and ASME UG-100 for further guidelines.

11. Uncap relief valve SV-121 immediately following the test.
12. Before any use of the panel after this test, reset SV-124 to normal operating cracking pressure of 1950.

Upon completion of this test, the Pressure Testing Permit 'Results' section will be filled in. Reports 'System Review,' 'Relief Valve Sizing,' 'Pressure Test,' and 'Sizing for Test Relief Valves' will be filed in the ES&H Section Pressure Vessel Master File (MS 119) and a copy kept by the RD/Cryo department.

Relief Valve Test Panel: Sizing For Test Relief Valves

T. Schaus ~~8/5/92~~ 9/29/92

In order to comply with the Fermilab ES&H manual chapter 5031.1, the RD/Cryo Relief Valve Test Panel will require separate pressure tests on two sections: 1. High pressure system to 2438 psig. 2. Pre regulator system to 2875 psig. Each test will require a relief valve (SV-203 & 303) set at an appropriate pressure (see Fig 1). In order for these relief valves to ensure safety, their flow capacity must meet or exceed the flow capacity of the regulator preceding them (RV-201 & 301). In all three cases, this regulator will be a Grove high pressure, low volume unit with model number 15KX. The highest input pressure that the regulator would be provided with is 3000 psig, the highest pressure attainable with the upstream compressor. Through a phone call, the manufacturer provided us with the flow capacity of the regulator for these conditions:

<u>max. flow = 38.1 SCFM air,</u> input = 3000 psig

The valves and their flow capacities are as follows:

System	Test press.	Relief	Cracking pressure	Flow capacity
1. High P.	2438 psig	Anderson / Green. 81MS44-2	2475 psig	<u>486 SCFM</u> @ 110% C.P.
2. Pre-reg.	2875 psig	Anderson / Green. 81MS44-4	3000 psig	<u>2425 SCFM</u> @ 110% C.P.

Both relief valves have considerably higher capacities than 38.1 SCFM and will easily be able to limit their respective systems to a safe pressure.

plus 3 psi, whichever is greater. The valve shall be tested for proper operation prior to conducting the test.

e) The gaskets, O-rings, plugs, etc. may be reused if inspected and found to be acceptable by the engineer.

f) Test equipment should be used exclusively for pressure testing to avoid damage and contamination and should be placed in a secured storage area when not in use.

3. PRESSURE TEST GUIDELINES

a) Pressure testing should be conducted as per ASME sec. III, UG-99 or UG-100.

b) All seams, connections of fittings, manways, plugs, couplings and welds made to the outside surface shall be visually examined in hydrostatic tests and soap-bubble checked in pneumatic tests. Helium leak testing may alternatively be used in pneumatic tests.

c) If a leak is detected at any pressure level reading during the test, the pressure shall be immediately reduced to one-half that pressure level reading while locating the leak.

d) If a leak is detected, the vessel and lines shall be depressurized before attempting any repairs or adjustments.

e) If a pressure test is allowed to exceed the test pressure such that visible permanent distortion is encountered, or if visible permanent distortion in excess of the expected design amount is encountered without exceeding the maximum test pressure, the vessel shall be reviewed by the engineer and safety personnel. Based on their recommendation, the vessel may be repaired, derated or scrapped.

f) If a pressure test is allowed to exceed the test pressure but the vessel shows no measurable permanent deformation, the maximum allowable working pressure of that vessel need not be reduced. When this situation occurs, an engineering review shall be required before the vessel is accepted.

g) After inspection, the vessel shall be relieved of its pressure gradually through a valve at the test stand.

h) For hydrostatic tests, the vents at the top of the vessel shall be opened after pressurization, the liquid media drained and the vessel dried to preclude excessive corrosion.