Project: Hall D Cryogenic Target

Tittle: Relief through main line to tank (non-code)

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Code(s) of Record:

ASME B31.3 2010
ASME B31.12 2011
ASME BPVC VIII D1 2010

Reference Codes

API 520
API 521
NFPA 2,55,497
CGA 5

Reference Drawings

TGT-401-0001-1000

Description:

Hall D target relief though main line to tank. TGT-CALC-401-001 gives mass flow estimate from worst case failure mode. Ideally the event would be contained by the normal target supply/return system. For spacial reasons 1" tube has been selected at the gas panel. All return flow must pass through a check valve to reach the storage tank. Assume gas as it leaves the target is at 300K. The Weymouth friction factor will be used as it is conservative for all pipe sizes less than 20 inch NPS. Calculation indicates that the ASME relief valves should not activate for a IV loss incident.

Design assumptions limits and set points for pressures

$P_{atm} := 14.7 \cdot psi$ atm pressure absolute

$P_{op} := 18 \cdot psi$ assumed cold operating pressure absolute

Fluid Properties for H2:

$M_{H2} := 2 \cdot \frac{gm}{mol}$ Moler masse of H2

$R_{H2} := 4124.3 \cdot \frac{J}{kg \cdot K}$ gas constant

$\rho_{H2}(T, P) := \frac{P}{(R_{H2} \cdot T)}$ density of H2 and from ideal gas law

$T_{room} := 300 \cdot K$ room temperature

Specific heats of H2

$c_{pH2} := 0.143 \cdot 10^5 \cdot \frac{J}{kg \cdot K}$ $c_{vH2} := 0.102 \cdot 10^5 \cdot \frac{J}{kg \cdot K}$

$k_{H2} := \frac{c_{pH2}}{c_{vH2}} = 1.402$ Ratio of specific heat for H2

$\mu_{H2300} := 0.8959 \cdot 10^{-5} \cdot Pa \cdot s$ visc of H2 at 300K and 30 psi

$v_{soundH2} := 1321 \cdot \frac{m}{s}$ speed of sound for H2 at 300K and 30 psi

Critical flow pressure ratios for H2 determined using the ideal gas assumptions similar to API 520 eq 3.1

$$Rc_{H2} := \left(\frac{2}{k_{H2} + 1}\right)^{\frac{k_{H2}}{k_{H2} - 1}}$$

from TGT-CALC-401-001

$$dm := 7.82 \cdot \frac{gm}{s}$$ mass flow from IV loss.

Flow Path:

The main line to the tank from the hall is 1.25" NPS Sch 5s with an assumed length of 200 ft. 8 elbows are assumed to be in this path. There are 3 ball valves in this path as well. From the main header in the hall to the gas panel check valve there is ~20ft of 1.5" nom flex line and 2 ft of 1" tube. There is an enlargement from the 1" tube to the 1.5" nom flex. We will work from the tank to the check in the hall.

$$L_{cl} := (200 \cdot ft) + 3 \cdot 20 \cdot ft$$ effective length line from tank to hall gas panel

$$ID_{cl} := 1.53 \cdot in$$ ID of flex lines

$$A_{cl} := \pi \cdot \frac{ID_{cl}^{\ 2}}{4}$$ cross area of flex

$$f_{cl} := \frac{0.032 \cdot in^{\frac{1}{3}}}{ID_{cl}^{\ \frac{1}{3}}} = 0.028$$ Weymouth friction factor

$$dV_{H2} := \frac{dm}{\rho_{H2}\left(T_{room}, P_{op}\right)} = 0.078 \ \frac{m^3}{s}$$ volumetric flow of H2

$$v_{cl} := \frac{dV_{H2}}{A_{cl}} = 65.727 \ \frac{m}{s}$$ velocity in flex line

$$K_{cl} := f_{cl} \cdot \frac{L_{cl}}{ID_{cl}} = 56.63$$ resistance coef for line

$$K_{bnd} := 30 \cdot f_{cl}$$ resistance coef for nom bend

$$K_{bv} := 3 \cdot f_{cl}$$ resistance coef for ball valve

$K_{ent} := 1.0$ resistance coef for tank entrance

pressure loss main line

$$\Delta P_{cl} := \left(K_{cl} + 8 \cdot K_{bnd} + 3 \cdot K_{bv} + K_{ent}\right) \cdot \rho_{H2}\left(T_{room}, P_{op}\right) \cdot \frac{{v_{cl}}^2}{2} = 2.028 \ psi$$

Gas panel:

$L_{gp} := (2 \cdot ft)$ estimated length of gas panel tubing to valve

$t_{wall} := 0.035 \cdot in$

$OD := 1 \cdot in$

$ID_{gp} := OD - 2 \cdot t_{wall}$ ID of gas panel return tube

$A_{gp} := \pi \cdot \frac{{ID_{gp}}^2}{4}$ cross area of return tube

$f_{gp} := \frac{0.032 \cdot in^{\frac{1}{3}}}{{ID_{gp}}^{\frac{1}{3}}} = 0.033$ Weymouth friction factor

$P := \Delta P_{cl} + P_{op} = 20.028 \ psi$ pressure in lines

$dV_{H2} := \frac{dm}{\rho_{H2}\left(T_{room}, P\right)}$ vol flow in gas panel

$v_{gp} := \frac{dV_{H2}}{A_{gp}} = 159.879 \ \frac{m}{s}$ velocity in return tube

$K_{gp} := f_{gp} \cdot \frac{L_{gp}}{ID_{gp}} = 0.846$ resistance coef return line

$K_{elbow} := 30 \cdot f_{gp}$ resistance of elbow at tgt top

$\beta := \frac{ID_{gp}}{ID_{cl}}$

$K_{en} := \frac{\left(1 - \beta^2\right)}{\beta^4} = 4.619$ resistance coef for enlargement

Pressure drop on gas panel

$$\Delta P_{gp} := \left(K_{gp} + 2 \cdot K_{elbow} + K_{en}\right) \cdot \rho_{H2}\left(T_{room}, P\right) \cdot \frac{{v_{gp}}^2}{2} = 1.538\ \mathbf{psi}$$

The total pressure at the exit of the check valve is then

$$P_{exit} := P_{op} + \Delta P_{gp} + \Delta P_{cl} = 21.566\ \mathbf{psi}$$

the check valve is a cirlcle seal H249T1-6PP-1

$$Cv := 10.3$$

$$K := 891 \cdot \frac{1}{\mathbf{in}^4} \cdot \frac{{ID_{gp}}^4}{Cv^2} = 6.283$$

$$\Delta P := K \cdot \rho_{H2}\left(T_{room}, P\right) \cdot \frac{{v_{gp}}^2}{2} = 1.3\ \mathbf{psi}$$

Pressure at entrance to check valve is

$$P_{ent} := P_{exit} + \Delta P = 22.866\ \mathbf{psi}$$