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Westinghouse Astronuclear Laboratory

EMERGENCY COOLING LINE RELIEF VALVE REQUIREMENTS

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PREPARED BY:

F. T. Johnson
F. T. Johnson
Test Systems Design

REVIEWED BY:

D. J. McDonald
D. J. McDonald
Test Systems Design

APPROVED BY:

W B Henderson
W. B. Henderson, Manager
Equipment & Facilities Engineering

Westinghouse Electric Corporation

Astronuclear Laboratory

Pittsburgh, Pennsylvania 15236

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EMERGENCY COOLING LINE RELIEF VALVE REQUIREMENTSI. INTRODUCTION

The normal flow path for both the propellant and coolant fluids used in NRX testing is through a single line routed to the engine nozzle. However, a second line directly to the reactor pressure vessel dome provides a path for an emergency purge, in the event of a failure in the normal flow path. The Test Cell design permits either gaseous hydrogen, gaseous nitrogen, gaseous helium or liquid nitrogen to be supplied to the reactor through the emergency purge line. A single pressure control valve PCV-18 is provided in the branch line through which both gaseous hydrogen and nitrogen flow. This valve is closed during normal reactor operation, with the possibility of full tank farm bank pressure of 3500 psi on its upstream side. Since this line has recently been increased in size, it has been necessary to evaluate the need to protect the core from excessive pressures in the event PCV-18 would fail wide open. This document defines the need for a relief valve and describes the manner in which both its setting and the capacity were determined.

II. SUMMARY

The most restrictive situation involving relief valve operation was

determined to be one in which 25 lb/sec of ambient gaseous hydrogen is required to maintain the tie-rod temperatures below 1600°R during emergency cooling conditions. The relief valve set pressure was established as the pressure required to drive this flow rate to the reactor vessel dome, with the pressure there being 140 psia. This latter pressure was established to be compatible with the maximum allowable core pressure drop of 150 psi. The relief valve capacity was determined to be the difference between the maximum available flow from the tank farm at 3500 psig (76 lb/sec) and the 25 lb/sec required coolant flow rate, or 51 lb/sec. To provide this capability, a relief valve, such as an Anderson-Greenwood pilot operated valve (Part No. 2312R68) is considered acceptable. This valve has a 6" inlet connection and 8" outlet. It will contain an "R" size orifice with an area of 16.00 sq. in. At the herein specified set pressure of 850 psig, the valve capacity is 976,700 SCFM of gaseous hydrogen. This is equivalent to a flow rate of 84.5 lb/sec.

III. DISCUSSION

A schematic diagram of the piping systems associated with PCV-18

is attached. (Figure 1) During normal reactor tests PCV-18 is closed, JBV-11 is open and JBV-10 is closed. JBV-18 is also closed. Thus, the full pressure of a gaseous hydrogen tank farm bank is applied to the upstream side of PCV-18. If, during the performance of a test PCV-18 were to fail open, a large gaseous hydrogen flow rate would be directed to the reactor vessel dome. The resulting excessive pressure drop through the reactor vessel could result in the ejection of the core. To prevent such an occurrence, it is necessary to install a relief valve in the reactor dome inlet line downstream of PCV-18. This relief valve, SV-79, must be capable of diverting sufficient flow away from the reactor dome to prevent a core pressure drop greater than 150 psi. Several operating situations have been analyzed to determine the required relief valve setting and capacity.

A. Requirements

Three sources of data have been used to establish the criteria for calculating the required capacity and set pressure for the safety valve.

1. Reference (1) indicates that a flow of 46 lb/sec of ambient gaseous hydrogen would produce a pressure drop of 150 psi through an ambient core and will result in a dome pressure of 298 psia.

2. Reference (2) indicates that, for the abnormal emergency purge condition, an ambient gaseous hydrogen flow of 25 lb/sec is required to maintain the tie-rod temperatures below 1600°R. The dome pressure at this flow rate is 140 psia per Reference (5).

It was decided to base the relief valve set pressure and capacity on the second of these requirements because the 25 lb/sec cooling rate requirement is sufficient to adequately cool the core during emergency conditions and this flow rate results in the lowest core pressure drop.

B. Relief Pressure Determination

The set pressure of relief valve SV-79 was established as the pressure required to drive 25 lb/sec of gaseous hydrogen from the junction of the relief valve line and the PCV-18 line to the dome. The dome pressure at this flow rate is 140 psia. The set pressure was then calculated by using equation 1-6 from Reference (3), and test data from Reference (8).

$$W^2 = \frac{144 g D A^2}{\bar{v} f l} \left[\frac{(P_1')^2 - (P_2')^2}{(P_1')} \right]$$

Where W = Flow rate, lb/sec.

D = Inside pipe diameter, ft.

A = Cross-sectional flow area, ft².

$\bar{v}$ = Specific volume of fluid, ft³/lb.

f = Friction factor for complete turbulence, dimensionless.

l = Equivalent length of pipe, ft.

(P_1') = Upstream pressure, (absolute) lb/in².

(P_2') = Downstream pressure, (absolute) lb/in².

At the specified conditions, the upstream pressure (P_1) was calculated to be 850 psig. This was, therefore, established as the relief valve set point. (See calculations attached)

C. Flow Capacity Determination

The capacity of relief valve SV-79 must be sufficient to divert all of the gaseous hydrogen flowing from the tank farm at 3500 psig in excess of the 25 lb/sec that must be directed to the reactor vessel dome. The maximum flow rate from the tank farm to the point at which the SV-79 line is joined to the PCV-18 line was calculated by using the above equation and the following equation 3.86 from Reference (7).

$$W = C_d g A \sqrt{\frac{2k}{R(k-1)}} \frac{P_o}{\sqrt{T_o}} \left(\frac{P_d}{P_o}\right)^{1/k} \sqrt{1 - \left(\frac{P_d}{P_o}\right)^{\frac{(k-1)}{k}}}$$

where g = Acceleration of gravity $\left(\frac{\text{lb}_m \text{ in}}{\text{lb}_f \text{ sec}^2}\right)$

k - Ratio of specific heats of fluid

R = Fluid gas constant, $\left(\frac{\text{in}^2}{\text{sec}^2 \text{ } ^\circ R}\right)$

T_o = Temperature, $^\circ R$

P_o = lb/in^2 upstream stagnation pressure

P_d = Downstream pressure lb/in^2

A = Cross-sectional flow area, in^2

C_d = Coefficient of discharge

Flow was found to be sub-sonic in PCV-18 and the maximum flow rate with the tank farm at 3500 psi and the relief valve set at 850 psi was calculated to be approximately 76 lb/sec. (See calculations attached) Since 25 lb/sec of this total flow must be permitted to pass directly to the core, the relief valve capacity must provide for the remainder of the total flow or 51 lb/sec. A representative relief valve satisfying the required capabilities is an Anderson-Greenwood pilot operated valve, Part No. 2312R68. This valve has a 6" inlet and an 8" outlet and must be provided with an "R" size orifice having a flow area of 16.00 sq. in. At the specified set pressure of 850 psig, the valve capacity is 976,700 SCFM of gaseous hydrogen. (See Figure 2 attached) This is equivalent to a flow rate of 84.6 lb/sec.

D. Adequacy During Alternate Operating Conditions

The PCV-18 valve could possibly fail open during any phase of the reactor test operation and thereby cause an over-pressurization of the core. Four operational conditions were investigated to determine the adequacy of the safety valve SV-79 in protecting the core from excessive drops should PCV-18 fail wide open.

Condition No. 1

PCV-18 fails open with the reactor at ambient temperatures and no flow being injected through the nozzle torus.

This condition would have no adverse effect on the core. As mentioned above, Reference (1) shows that a flow of 46 lb/sec through an ambient core is required to produce a core pressure drop of 150 psi. Since the relief valve limits the reactor flow to 25 lb/sec, the core pressure drop will be less than the limiting 150 psi.

Condition No. 2

PCV-18 fails open when required to supply emergency cooling to the dome with no flow now being injected through the nozzle torus.

This is the condition for which the relief valve was sized. Since the valve limits the core flow to 25 lb/sec, the core pressure drop will be less than 150 psi. This failure, however, would be postulating a double failure.

Condition No. 3

PCV-18 fails open during normal reactor cooling operation after a full power run with gaseous hydrogen being injected into the core through the nozzle torus via PCV-41.

The proposed shutdown for NRX-A3 is to ramp the LH₂ from 71.3 lb/sec to 26 lb/sec. At this point either the flow shutdown chain or power scram would be activated. If the flow shutdown were actuated PCV-41 would maintain a pressure of 60% of nozzle torus pressure. The corresponding GH₂ flow rate is approximately 4.2 lb/sec GH₂. The test operator, however, may be required to manually increase this flow rate to as much as 9 or 10 lb/sec in order to keep the tie-rod temperatures below 1200°R. If PCV-18 were to fail wide open during this normal retreat, an additional flow of 25 lb/sec would be injected into the dome. The total flow rate would therefore be a maximum of 35 lb/sec of GH₂.

The maximum allowable total flow rate that can be injected into the reactor via the nozzle torus and the dome penetration is the minimum flow rate which would create a pressure drop across the core of 150 psi. This flow rate is 46 lb/sec of gaseous hydrogen through an ambient core as given in Reference (1).

Due to the fact that the fuel element orifices are choked with the core at ambient temperatures, the pressure drop across the core will be larger for this case than for the case of the core at an elevated temperature. A hot reactor will, therefore, require a higher flow rate for a given core ΔP , as compared to an ambient reactor.

If the flow shutdown chain were activated to scram the reactor when the reactor was at full power, PCV-41 would maintain a nozzle torus pressure of 532 psia. A corresponding flow rate of 21 lb/sec would be supplied to the nozzle. If PCV-18 were to fail wide open at this point and inject 25 lb/sec of GH_2 into the dome, the total flow rate would be 46 lb/sec. This, however, would be postulating a double failure.

Condition No. 4

PCV-18 fails open while the reactor is in a full power run with 70 lb/sec of liquid hydrogen being pumped through the core.

Reference (6) shows the dome pressure at 698 psia for a reactor at full power with 71.3 lb/sec of liquid hydrogen flowing through the core. Calculations were made to determine the amount of ambient gaseous hydrogen that would be injected into the dome if the pressure relief valve were set at 850 psig and if PCV-18 were to fail open. In calculating this flow rate, test results given

in Reference (8) were used in conjunction with equation 1-6 from Reference (3). Also, equation 3.86 from Reference (7) was used for sub-sonic flow across the Bobrick check valves which are located in the three dome penetrations.

The amount of hydrogen that would be injected into the dome if PCV-18 failed open during a full power run was found to be approximately 17.3 lb/sec of ambient GH_2 . (See calculations attached)

Reference (6) shows the core pressure drop to be 125 psi for 71.3 lb/sec of 200°R hydrogen during a 100% power run. A thirty percent (30%) increase in flow at this power level would only increase the core pressure drop to 140 psi. On this basis, the Reactor Analysis group has advised that an additional flow of 17.3 lb/sec of ambient GH_2 injected into the dome at 698 psia is not excessive. If steady state conditions were achieved with this added flow rate, the dome end pressure would increase about 100 psi. This, in turn, would reduce the flow rate being injected into the dome.

E. General

The primary purpose of the SV-79 relief valve is to protect the core from overpressurization in the event PCV-18 were to be inadvertently opened to a greater degree than required during any phase of reactor operation. This condition could occur as a result of a malfunction

of PCV-18 or an operator's error. It should be pointed out that if this condition did occur, the SV-79 relief valve would vent a substantial amount of GH_2 to atmosphere unless the situation was quickly corrected. This could seriously reduce the available GH_2 held in reserve for emergency cooling requirements.

REFERENCES

1. WANL-TME-1050 - "NRX-A3 Test Prediction Report", January, 1965.
2. WANL-TNR-148 - "Safety Analysis Report - NRX Testing", April 27, 1964.
3. Crane Company Technical Paper No. 410, Flow of Fluids, 1957.
4. Shapiro, A.H., "The Dynamics and Thermodynamics of Compressible Fluid Flow", Volume I, 1953.
5. WANL-TE-1263 - "Emergency Cooling with H₂ or He Through the Normal or Dome Flow Path", August 13, 1964.
6. WANL-TME-840A - "Reactor Analysis Data Book", July 31, 1964.
7. "Fluid Power Control"; Blackburn, Reethof, and Shearer, 1960.
8. WANL-TSD-226 - "Emergency Purge Manifold Assembly Flow Test", April 6, 1965.

FIGURE 1

FIGURE 2

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1. CALCULATION OF RELIEF VALVE SET POINT

FROM TSD-226 THE PRESSURE REQUIRED UPSTREAM OF THE 6" MISSION CHECK VALVE TO DRIVE 25 lb/sec of GH_2 INTO THE DOME WAS CALCULATED TO BE 791 PSIA.

USING EQUATION 1-7 CRANE TECH. PAPER NO. 410. SIMPLIFIED COMPRESSIBLE FLOW, COMPLETE ISOTHERMAL EQUATION.

$$W^2 = \frac{144 g D A^2}{V_1 f L} \left[\frac{(P_1')^2 - (P_2')^2}{P_1'} \right]$$

W = FLOW RATE, lb/SEC

D = DIAMETER, FEET

A = AREA, SQUARE FEET

g = ACCELERATION OF GRAVITY, $\frac{\text{lb}_m \text{ft}}{\text{lb}_f \text{sec}^2}$

V_1 = SPECIFIC VOLUME, ft^3/lb

f = FRICTION FACTOR

L = EQUIVALENT LENGTH, FEET

P_1' = UPSTREAM PRESSURE, PSIA

P_2' = DOWNSTREAM PRESSURE, PSIA

KNOWN:

$$W = 25 \text{ lb/sec}$$

$$P_2 = 791 \text{ PSIA}$$

$$f = .0152$$

$$g = 32.2 \text{ ft/sec}^2$$

$$D = .4324 \text{ ft}$$

$$A = .1469 \text{ ft}^2$$

$$L_e = 148 \text{ ft}$$

} 6" SCH 160

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SOLVE FOR P_1 :

EQUIV. LENGTH TAKEN
BETWEEN THE MISSION CHECK
AND THE RELIEF VALVE.

$$\left[\frac{(P_1')^2 - (P_2')^2}{P_1} \right] = \frac{\omega^2 \bar{V}_1 f L}{144 g D A^2} = \frac{\omega^2 \bar{V}_1 L (0.0152)}{144 (32.2)(.4324)(.1469)^2}$$

$$\left[\frac{(P_1')^2 - (P_2')^2}{P_1} \right] = \frac{\omega^2 \bar{V}_1 L}{2840}$$

ASSUME $P_1 = 850$

$$\bar{V} = \frac{ZRT}{144P} = \frac{1.037 (766.6) (523)}{144 (850)}$$

$$\left[\frac{(P_1')^2 - (P_2')^2}{P_1} \right] = \frac{(25)^2 (3.39) (148)}{2840}$$

$$\bar{V} = 3.39 \pm \frac{3}{16}$$

$$(P_1')^2 - 110 P_1 - (791)^2 = 0$$

$$P_1 = \frac{110 + \sqrt{(110)^2 + 4(791)^2}}{2}$$

$$P_1 = \frac{110 + 1585}{2} = \frac{1695}{2} = 847.5 \text{ PSIA}$$

$$847.5 - 13.0 = 834.5 \text{ PSIG}$$

RELIEF VALVE SET POINT THEREFORE WAS
SPECIFIED AT 850 PSIG

2. CALCULATION OF MAXIMUM FLOW RATE FROM THE TANK FARM AT 3500 PSIG TO THE RELIEF VALVE SET AT 850 PSIG, USING AN ITERATIVE TECHNIQUE.

a) ASSUME FLOW RATE $\dot{W} = 76$ lb/SEC
 CALCULATE PRESSURE UPSTREAM OF PCV-18, I.E. ΔP FROM TANK FARM TO PCV-18.

USE EQUATION 1-7 CRANE TECH. PAPER NO. 410.

$$\dot{W}^2 = \frac{144 g_c D A^2}{\bar{V} f L} \left[\frac{(P_1')^2 - (P_2')^2}{P_1} \right]$$

$$\left[\frac{(P_1')^2 - (P_2')^2}{P_1} \right] = \frac{\dot{W}^2 \bar{V}_1 L}{2840} = \frac{(76)^2 (.94)(1300)}{2840} = 2490$$

KNOWN:

$$\begin{aligned} \dot{W} &= 76 \text{ lb/SEC} \\ L_e &= 1300 \text{ feet } 6" \text{ SCH } 160 \\ P_1 &= 3513 \text{ PSIA} \\ \bar{V}_1 &= .94 \text{ ft}^3/\text{lb} \end{aligned}$$

$$\bar{V}_1 = \frac{ZRT}{144 P}$$

$$\bar{V}_1 = \frac{1.15(2875)}{3500}$$

$$\bar{V}_1 = .94 \text{ ft}^3/\text{lb}$$

SOLVE FOR P_2 :

$$(P_1')^2 - (P_2')^2 = 2490 P_1$$

$$P_2^2 = (3513)^2 - 2490(3513)$$

$$P_2 = \sqrt{3.57 \times 10^6}$$

$$P_2 = 1890 \text{ PSIA}$$

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2. (b) ASSUME FLOW RATE $\dot{W} = 76 \text{ lb/sec}$
 CALCULATE PRESSURE DOWNSTREAM
 OF PCV-18, I.E. ΔP FROM PCV-18 TO SV-79.

USE EQUATION 1-7 CRANE TECH. PAPER
 NO. 410

$$\left[\frac{(P_1')^2 - (P_2')^2}{P_1} \right] = \frac{W^2 \bar{V}_1 L f}{144 g D A^2} = \frac{W^2 \bar{V}_1 L}{2840}$$

KNOWN:

$$W = 76 \text{ lb/sec}$$

$$L_e = 64 \text{ feet } 6'' \text{ SCH } 160$$

$$P_2 = 850 + 13 = 863 \text{ PSIA}$$

SOLVE FOR P_1 :

$$\left[\frac{(P_1')^2 - (P_2')^2}{P_1} \right] = \frac{(76)^2 (2.81) (64)}{2840} = 366$$

$$P_1^2 - 366 P_1 - (863)^2 = 0$$

$$P_1 = \frac{366 + \sqrt{(366)^2 + 4(863)^2}}{2}$$

$$P_1 = \frac{366 + 1790}{2} = \frac{2156}{2}$$

$P_1 = 1078 \text{ PSIA}$

$$\text{ASSUME } P_1 = 1070$$

$$\bar{V} = \frac{ZRT}{144P}$$

$$\bar{V} = \frac{1.045 (2875)}{1070}$$

$$\bar{V} = 2.81 \text{ ft}^3/\text{lb}$$

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- 2 (c) ASSUME STATIC PRESSURE UPSTREAM OF PCV-18 IS 1890 PSIA. CALCULATE STAGNATION PRESSURE, ASSUMING $\dot{W} = 76$ lb/sec.

$$P_{\text{STAGNATION}} = P_{\text{STATIC}} + P_{\text{VELOCITY}}$$

$$P_0 = 1890 + \frac{v^2}{2g} \frac{\rho}{144} \quad A = .1469 \text{ ft}^2 \text{ 6" SCH 160}$$

$$P_0 = 1890 + \frac{\dot{W}^2}{\rho^2 A^2} \left(\frac{\rho}{144} \right) \frac{1}{2g}$$

$$P_0 = 1890 + \frac{\dot{W}^2 \bar{V}_1}{A^2 9260}$$

$$P_0 = 1890 + \frac{(76)^2 (1.60)}{199.5}$$

$$P_0 = 1890 + 46.3$$

$P_0 = 1936.3 \text{ PSIA}$

ASSUME $P_0 = 1950$

$$\bar{V} = \frac{ZRT}{144 P}$$

$$\bar{V} = \frac{1.082(2875)}{1950}$$

$$\bar{V} = 1.60 \text{ ft}^3/\text{lb}$$

- (d) DETERMINE IF FLOW WOULD THEN BE CHOKED ACROSS PCV-18

$$\frac{P_D}{P_0} = \frac{1080}{1936} = 0.558$$

$$\left(\frac{P^*}{P_0} \right)_{\text{CRITICAL}} = 0.5282 \quad \therefore \text{FLOW IS NOT CHOKED}$$

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2. (c) ASSUME PRESSURE DOWNSTREAM OF PCV-18 IS 1080 PSIA. ASSUME STAGNATION PRESS. UPSTREAM OF PCV-18 IS 1936 PSIA. CALCULATE FLOW RATE $\dot{W}$.

USE EQUATION 3.86, FLUID POWER CONTROL
PAGE 67 AND 216.

$$\frac{\dot{W}}{C_D A_0} = g \sqrt{\frac{2k}{R(k-1)}} \frac{P_0}{\sqrt{T_0}} \left(\frac{P_d}{P_0}\right)^{\frac{1}{k}} \sqrt{1 - \left(\frac{P_d}{P_0}\right)^{\frac{(k-1)}{k}}}$$

$\dot{W}$ = FLOW RATE, lb/SEC

C_D = COEFFICIENT OF DISCHARGE

g = ACCELERATION OF GRAVITY, $\frac{\text{lbm IN}}{\text{lb}_f \text{ SEC}^2}$

A_0 = AREA, SQUARE FEET

k = RATIO OF SPECIFIC HEATS

R = GAS CONSTANT, $\frac{\text{IN}^2}{\text{SEC}^2 \text{ } ^\circ\text{R}}$

P_0 = UPSTREAM STAGNATION PRESSURE, PSIA

P_d = DOWNSTREAM PRESSURE

T_0 = TEMPERATURE, $^\circ\text{R}$

KNOWN:

$A = 9.65 \text{ IN}^2$

$P_0 = 1936 \text{ PSIA}$

$P_d = 1080 \text{ PSIA}$

$k = 1.4$

$g = 386 \text{ IN/SEC}^2$

$R = 3,545,000 \text{ IN}^2/\text{SEC}^2 \text{ } ^\circ\text{R}$

$T_0 = 530 \text{ } ^\circ\text{R}$

$C_D = .65$

F.T.S.

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2. (e) CONTINUED

$$\frac{W}{C_D A_0} = .0235 P_0 \left(\frac{P_d}{P_0} \right)^{.715} \sqrt{1 - \left(\frac{P_d}{P_0} \right)^{.286}}$$

$$\frac{W}{C_D A_0} = .0235 (1936) (.558)^{.715} \sqrt{1 - (.558)^{.286}}$$

$$\frac{W}{C_D A_0} = .0235 (1936) (.659) (.392) = 11.72$$

$$W = 11.72 C_D A_0 = 11.72 (9.65)(.65)$$

$W = 73.6 \text{ lb/sec}$

THIS CALCULATED FLOW AGREES WITH THE FLOW RATE INITIALLY ASSUMED, WITHIN THE ACCURACY OF THESE CALCULATIONS. THE MAXIMUM FLOW RATE WILL BE ASSUMED TO BE 76 lb/sec.

3/26/65

3. CALCULATION TO DETERMINE THE GH_2 FLOW RATE THAT WOULD BE INJECTED INTO THE DOME WHEN REACTOR IS RECEIVING 71.3 lb/SEC OF LH_2 VIA THE NORMAL FLOW PATH, USING AN ITERATIVE TECHNIQUE.

a) PRESSURE DROP FROM SV-79 TO MISSION CHECK VALVE
 ASSUME: (1) SV-79 SET PRESS OF 850 PSIG
 (2) DOME FLOW IS 17.0 lb/SEC
 CALCULATE:

PRESSURE UPSTREAM OF 6 INCH MISSION CHECK VALVE.

USE EQUATION 1-7 CRANE'S TECH. PAPER NO. 410

$$\left[\frac{(P_1')^2 - (P_2')^2}{P_1} \right] = \frac{W^2 \bar{V}_1 L f}{144 g D A^2} = \frac{W^2 \bar{V}_1 L}{2840}$$

KNOWN:

$$W = 17.5 \text{ lb/SEC}$$

$$L_e = 148 \text{ feet of 6" SCH 160 BETWEEN THE MISSION CHECK VALVE AND SV-79}$$

$$P_1 = 850 + 13 = 863 \text{ PSIA}$$

$$\bar{V}_1 = \frac{ZRT}{144P} = \frac{1.035(2875)}{863} = 3.44 \text{ ft}^3/\text{lb}$$

SOLVE FOR P_2 :

$$\left[\frac{(P_1')^2 - (P_2')^2}{P_1} \right] = \frac{(17)^2 (3.44)(148)}{2840} = 51.6$$

$$P_2^2 = P_1^2 - 51.6 P_1 = (863)^2 - 51.6(863)$$

$$P_2 = \sqrt{745,000 - 44,500}$$

$$P_2 = 835 \text{ PSIA}$$

3/26/65

3. b) ASSUME: PRESSURE UPSTREAM of MISSION
CHECK VALVE IS 835 PSIA
FLOW RATE of 17.0 lb/sec

CALCULATE: PRESSURE UPSTREAM of 2 INCH
BOBRICK CHECK VALVES

USE EQUATION 1-7 CRANE'S TECH. PAPER
NO. 410.

$$\left[\frac{(P_1')^2 - (P_2')^2}{P_1} \right] = \frac{W^2 \nabla + L}{144 g D A^2} = W^2 \nabla C_1$$

$$\text{WHERE } C_1 = \frac{+L}{144 g D A^2} = .14$$

THIS CONSTANT WAS CALCULATED FROM
EXPERIMENTAL DATA OBTAINED DURING
FLOW TEST ON EMERGENCY PURGE
MANIFOLD ASSEMBLY. SEE TSD-226.

KNOWN:

$$W = 17.0 \text{ lb/SEC}$$

$$P_1 = 835 \text{ PSIA}$$

$$C_1 = .14$$

$$\nabla = \frac{ZRT}{144 P} = \frac{1.034(2875)}{835} = 3.56 \text{ ft}^3/\text{lb}$$

SOLVE FOR P_2 :

$$(P_1')^2 - (P_2')^2 = (17)^2 (3.56) (.14) P_1$$

$$P_2^2 = (835)^2 - 144(835)$$

$$P_2 = \sqrt{697,000 - 120,000}$$

$$P_2 = 759 \text{ PSIA}$$

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3. c) ASSUME PRESS. UPSTREAM OF 2 INCH BOBRICK CHECK VALVE IS 759 PSIA

CALCULATE UPSTREAM STAGNATION PRESS.

ASSUME $\dot{W} = \frac{17.0}{3} \text{ lb/SEC.} = 5.66 \text{ lb/sec}$

$$P_{\text{STAGNATION}} = P_{\text{STATIC}} + P_{\text{VELOCITY}}$$

$$P_0 = 759 + \frac{V^2 \rho}{2g} \frac{e}{144}$$

$$P_0 = 759 + \frac{W^2 \bar{V}_1}{A^2 9260}$$

$$P_0 = 759 + \frac{(5.66)^2 (3.76)}{(.02330)^2 9260}$$

$$P_0 = 759 + 23.9$$

$$\boxed{P_0 = 783 \text{ PSIA}}$$

$$A = .02330 \text{ ft}^2$$

(2" SCH 40 PIPE)

ASSUME $P_0 = 790$

$$\bar{V}_1 = \frac{ZRT}{144P}$$

$$\bar{V} = \frac{1.032(2875)}{790}$$

$$\bar{V} = 3.76 \text{ ft}^3/\text{lb}$$

- d) DETERMINE IF FLOW IS CHOKED ACROSS THE BOBRICK CHECK VALVES.

$$\frac{P_D}{P_0} = \frac{700}{783} = .895 \quad \left(\frac{P_1^*}{P_0} \right)_{\text{CRITICAL}} = 0.5282$$

∴ FLOW IS NOT CHOKED

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3. e) ASSUME UPSTREAM STAGNATION PRESSURE OF BOBRICK CHECK VALVE IS 783 PSIA.
ASSUME DOWNSTREAM PRESSURE IS 700 PSIA

CALCULATE FLOW RATE ACROSS BOBRICK CHECK VALVE.

USE EQ. 3.86, FLUID POWER CONTROL

$$\frac{W}{C_D A_0} = .0235 P_0 \left(\frac{P_d}{P_0} \right)^{.715} \sqrt{1 - \left(\frac{P_d}{P_0} \right)^{.286}}$$

$$\frac{W}{C_D A_0} = .0235 (783) (.895)^{.715} \sqrt{1 - (.895)^{.286}}$$

$$\frac{W}{C_D A_0} = 1.695 (.1735) = 2.94$$

THE VALUE OF $C_D A_0$ WAS CALCULATED TO BE 2.00 IN² FROM EXPERIMENTAL DATA OBTAINED DURING FLOW TEST ON EMERGENCY PURGE MANIFOLD ASSEMBLY, SEE TSD-226

$$W = 2.94 C_D A_0 = 2.94(2) = 5.88 \text{ lb/sec}$$

$$\text{TOTAL } \dot{W} = 5.88(3) = 17.64 \text{ lb/sec}$$

THIS INITIALLY ASSUMED FLOW RATE OF 17.0 lb/sec APPEARS TO BE LOW. THE FLOW RATE THEREFORE SHOULD ACTUALLY WORK OUT TO BE APPROXIMATELY 17.3 lb/sec.