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CRYOGENIC DISTRIBUTION

PRESSURE DROP DESIGN DATA

"A" Revision January 7, 1976
"B" Revision April 15, 1980

Page No.  Ref.

2  Smooth tubes, He gas, 200K, 25 atm
3  Smooth tubes, He and H2 gas, 500F, 1 atm
4  Smooth tubes, Two phase H2
5  Smooth tubes, H2 HX cooldown
6  Smooth tubes, H2 gas 2760K, 1 atm
7  Smooth tubes, H2 gas 2900K, 100 psi
8  Smooth tubes, H2 gas 3000K, 2200 psi
9  Smooth tubes, N2 gas 3000K, 0.1 atm
10  Valves and fittings, equivalent lengths
11  Smooth and flexible pipe - liquid N2
12  Smooth and flexible pipe - liquid H2
13  Smooth and flexible pipe - liquid O2
14  Smooth pipe - LN2
15  Flex. pipe - LN2
16  Flex. pipe - LN2
17  Smooth tubes, He gas, 2930K, 1 atm
18  Smooth tubes, He gas, 2930K, 3 atm
19  Smooth tubes, He gas, 2930K, 18 atm
20  Smooth tubes, H2 gas, 2900K; 100, 150, 200 psig
21  Pressure drop through 1/4" #1251-BB

Superior Line shutoff valve: for 500, 1000, 2000 psig H2 gas @ 800F

22  Two phase He 1.2 atm, 4.40K 1-20 gm/sec
23  " " 10-100 "
24  " " 10-100 "
25  " " 10-100 "
26  Baker Diagram - 2 phase flow He
   1 atm 4.20K  1-3 gm/sec
27  Same as above except 3.80K
28  Baker Diagram - N2 1 atm 770K 30-60 gm/sec

R. Byrns 6 cc

/nh
PRESSURE DROP IN SMOOTH TUBES

FOR HELIUM @ 20°C, 25 atm

\[ \frac{\Delta P}{L} = 0.06 \text{ psi/ft} \]

MULTIPLY \( \frac{\Delta P}{L} \) BY 25 \( \frac{P(\text{atm})}{25} \)

TO FIND \( \frac{\Delta P}{L} \) FOR OTHER PRESSURES.

CTH FOR 0.310" I.D.

(\( \Delta P = 15 \text{ psi} \) for 200 ft)

@ 1 atm,

FOR 30 scfm——

\[ \frac{0.315}{15} = 0.02 \text{ psi} \]

= 15.0 psi / 200

FLOW, SCFM

0.01

0.1

1.0

10.0

ES0501 R. A. Byrns 10 September 1975 DH859 B PAGE 2

R. Byrns

April 18 1972
Pressure Drop in Smooth Copper Water Tubes: H₂ and He, 1 atm, 50°F

1. Divide ΔP by P in atmospheres, absolute, to
2. Find ΔP% for densities other than 1 atm.

Diagram showing pressure drop for different diameters and flow rates.

Flow SCFM

Flow SCFM
Pressure Drop in Smooth Tubes for Two Phase Hydrogen Flow

Ref. EN-711-504245

Flow, SCFM

Two Phase Hydrogen Flow

Flow, SCFM

Pressure Drop, \( \frac{AP}{L} \) (psi/ft.)

\( \frac{AP}{L} \propto \frac{fpV}{2gD} \)

DBM Calc., \( T = 27^\circ K, D = 0.652" \)

DBM Calc., \( T = 27^\circ K, D = 0.652" \)

RAB Calc., \( T = 27.5^\circ K, D = 0.652" \)

(T2" Bubble Chamber,
Approx. 130 ft. equiv. sta. length.

254 ft. of tube = 500 ft. equiv.

\( \Delta P/500 = \Delta P/L \)

\( \sim 0.008 (H_2 \text{ gas}) \)

\( \sim 0.006 (H_2) \)

Measured points 2-26-58 on dummy heat load. \( T = 26^\circ K, D = 0.527" \)

\( H_2 \text{ gas} \)

\( 23^\circ K, D = 0.32 \)

\( \Delta P = 0.24 \text{ psi} \)

\( \Delta P = 4.8 \text{ psi} \)
HEAT EXCHANGER PRESSURE DROP

\[ \Delta P = \frac{f_0 \cdot \frac{1}{2} \cdot \rho \cdot u^2}{L} = \frac{f_0 \cdot \frac{1}{2} \cdot \rho \cdot (2u)^2}{L} = \frac{f_0 \cdot \frac{1}{2} \cdot \rho \cdot 4u^2}{L} \]

\[ \Delta P = \frac{f_0 u^2}{4 \cdot \sqrt{D}} \]

EQUILIBRIUM PRESSURE

(COOL DOWN)

CALCULATED PRESSURE DROP FOR 2000 SCFM HYDROGEN GAS FLOW

72" BUBBLE CHAMBER

FLOW = 200 SCFM = \( 1.75 \times 10^{-2} \) \( \frac{105}{\text{sec.}} \) HYDROGEN

TUBE \( \frac{3}{4} \times 0.049 \) IN. \( D = 0.652" \)

R. BURNS 3/11/58
Pressure difference in copper water line as a function of flow of hydrogen gas.

Helium

1 atm 0°C

$\frac{p}{0.114} = 2 \text{ cm H}_2$

Diagram shows pressure difference in copper water line as a function of hydrogen gas flow.
P\textsuperscript{R}ES\textsuperscript{U}RE \textsuperscript{D}RO\textsuperscript{P} - H\textsubscript{\textsuperscript{2}} G\textsuperscript{A}\textsuperscript{S}

\( P = 100 \) \( \text{psig} \), \( T = 290^\circ \text{K} \)
\( \rho = 0.0412 \) \( \text{g/cm}^2 \)

\( 1/2 \) - \text{T}U\text{P}E \text{T}Y\text{P}E 1

\( 1 \) - \text{T}U\text{P}E \text{T}Y\text{P}E 2

\( 2 \) - \text{T}U\text{P}E \text{T}Y\text{P}E 3

\( 3 \) - \text{T}U\text{P}E \text{T}Y\text{P}E 4

\( 4 \) - \text{T}U\text{P}E \text{T}Y\text{P}E 5

FLOW - \text{GPM}
Resistance of Valves and Fittings to Flow of Fluids

Chapter Three
Flow of Fluids through Valves and Fittings (Cont.)

* CRANE TECH PAPER NO. 409 MAY 1942
Pressure Drop Curves

The following curves may be helpful in determining the proper line size for your transfer requirement. These charts represent loss of pressure due to fluid flow through a pipe. Total pressure drop also includes additional loss of pressure (head) due to any increase in elevation.

Please notice that a smaller diameter rigid pipe line can accommodate the same flow capacity as a larger diameter flex line. This is significant when considering heat-leak (liquid loss) and system purchase cost.

Liquid Nitrogen
Pressure Drop Due to Fluid Flow

Rigid Piping

Flexible Piping

DATA FROM CVI CORP. COLUMBUS, OHIO - 43216
DIV. OF PENNWALT

7.0, Box 2138
314 - 276 - 7381

(1975)
Liquid Hydrogen
Pressure Drop Due to Fluid Flow

<table>
<thead>
<tr>
<th>Flow, Gal./Min. (GPM)</th>
<th>0.00001</th>
<th>0.0001</th>
<th>0.001</th>
<th>0.01</th>
<th>0.1</th>
<th>1.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>PSI/FOOT</td>
<td>1.000</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
</tbody>
</table>

Rigid Piping
Flexible Piping

---

Liquid Oxygen
Pressure Drop Due to Fluid Flow

<table>
<thead>
<tr>
<th>Flow, Gal./Min. (GPM)</th>
<th>0.00001</th>
<th>0.0001</th>
<th>0.001</th>
<th>0.01</th>
<th>0.1</th>
<th>1.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>PSI/FOOT</td>
<td>1.000</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
</tbody>
</table>

Rigid Piping
Flexible Piping

---
PRESSURE DROP - PSI/FT.

VS. FLOW - GPM.

LIQUID NITROGEN

THRU CVI "UTILITY-FLEX"

FROM CVI CORP.

COLUMBUS, OHIO

DIV. OF PENNWALT

100

(378.5 LITERS MIN)

FLOW - GPM

10

1/2 NOM. I.D.

2" NOM. I.D.

3/4" NOM. I.D.

1/2" NOM. I.D.

1/4" NOM. I.D.

1/4" NOM. I.D.

1/2" NOM. I.D.

1/2" NOM. I.D.

1/4" NOM. I.D.

1/4" NOM. I.D.

1/4" NOM. I.D.
**PRICE LIST**

**SEMI FLEXIBLE CRYOGENIC TRANSFER LINE**

<table>
<thead>
<tr>
<th>LINE SIZE</th>
<th>INNER I.D. (INCHES)</th>
<th>BASIC CHARGE WITH END TERMINALS</th>
<th>BASIC CHARGE WITH BAYONET ENDS</th>
<th>PRICE PER FOOT</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-5</td>
<td>0.65</td>
<td>$250.00</td>
<td>$320.00</td>
<td>$4.40</td>
</tr>
<tr>
<td>A-10</td>
<td>1.25</td>
<td>285.00</td>
<td>385.00</td>
<td>5.60</td>
</tr>
<tr>
<td>A-15</td>
<td>1.73</td>
<td>320.00</td>
<td>460.00</td>
<td>8.00</td>
</tr>
<tr>
<td>A-20</td>
<td>2.20</td>
<td>365.00</td>
<td>550.00</td>
<td>10.50</td>
</tr>
</tbody>
</table>

**NOTES:**
1. TOTAL LINE PRICE = OVERALL LENGTH X PRICE PER FOOT + BASIC CHARGE.
2. PACKAGING CHARGE TO BE ADDED TO ABOVE DEPENDING ON LINE LENGTH.
3. ALL LINES ARE FACTORY ASSEMBLED AND LEAK TESTED.
4. ENDS INCLUDE ONE PUMPING PORT AND ONE ANNULUS OVERPRESSURE RELIEF VALVE.
5. BAYONET ENDS INCLUDE ONE MALE AND ONE FEMALE.

**SELECTED DATA**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Inside Dia. (Inches)</td>
<td>.646</td>
<td>1.245</td>
<td>1.730</td>
<td>2.205</td>
</tr>
<tr>
<td>Outside Dia. (Inches)</td>
<td>1.565</td>
<td>2.390</td>
<td>2.990</td>
<td>3.550</td>
</tr>
<tr>
<td>Weight (Lbs/Ft)</td>
<td>.9</td>
<td>1.2</td>
<td>1.7</td>
<td>2.2</td>
</tr>
<tr>
<td>Cool-Down (BTU/FT)</td>
<td>10 - 8</td>
<td>20 - 15</td>
<td>25 - 21</td>
<td>30 - 26</td>
</tr>
<tr>
<td>Heat Leak (BTU/HR/FT)</td>
<td>1.2</td>
<td>1.8</td>
<td>2.0</td>
<td>2.4</td>
</tr>
<tr>
<td>Bend Radius (Inches)</td>
<td>20</td>
<td>32</td>
<td>40</td>
<td>48</td>
</tr>
<tr>
<td>Flow Rate (Water-GPM) *</td>
<td>.5</td>
<td>3.4</td>
<td>9.0</td>
<td>19.0</td>
</tr>
<tr>
<td>0.01 PSI/FT Pressure Drop</td>
<td>1.6</td>
<td>11.0</td>
<td>31.0</td>
<td>62.0</td>
</tr>
<tr>
<td>0.10 PSI/FT Pressure Drop</td>
<td>34.0</td>
<td>90.0</td>
<td>190.0</td>
<td></td>
</tr>
</tbody>
</table>

* IN PURE LIQUID CONDITION LN₂ HAS SIMILAR CHARACTERISTICS TO WATER.

**DESIGN PRESSURE (PSI)**

<table>
<thead>
<tr>
<th></th>
<th>175</th>
<th>150</th>
<th>125</th>
<th>85</th>
</tr>
</thead>
</table>

\[
\text{PAGE 15}
\]
PRESSURE DROP IN SMOOTH COPPER
WATER TUBES (TYPE K): He gas @ 1 atm, 20°C

\[ \Delta P = \frac{1}{2} \rho V^2 \]

\[ \frac{\Delta P}{1.4452 \text{ g/sq ft}^2} = f \]

WHERE
\[ \rho \] = density of He gas (14.1 lb/ft³)
\[ D \] = I.D. of tube (ft.)
\[ f \] = Friction factor
\[ V \] = mean flow velocity (ft/s)
\[ g \] = 32.2 ft/s²

FLOW K.A.
K. K. Iyama (1/3/76)
PRESSURE DROP IN SMOOTH COPPER
WATER TUBES (TYPE K): H₂ gas; @ 3 atm; 26°C

\[ \delta = 3.110 \times 10^{-2} \frac{\text{Lbf}}{\text{ft}^2} \]

---

CALCULATED FROM DAHER'S Eqs.

\[ \frac{\Delta P}{\mu} = \frac{2F}{L} \times \frac{V^2}{2} \]

WHERE
- \( \rho \): density of H₂ gas (kg/m³)
- \( D \): friction factor
- \( V \): mean flow velocity (ft/s)
- \( \delta \): 32.2 ft/m

---

FLOW: 500 M
Y. KAJIYAMA (6-8)
**PRESSURE DROP IN SHORT TUBES**

**WATER USE (TYPICAL)**: H. GAS installation, 50 psi

*CALCULATED FROM Darcy's Eq.*

\[
\Delta P = \frac{\gamma f V^2}{2 D g}
\]

- \( \gamma \) = density of H-gas (lb/lb)
- \( f \) = friction factor
- \( V \) = mean flow velocity (ft/sec)
- \( g \) = 32.2 ft/sec^2
- \( D \) = 1.2 ft. of BR. (ft)

\[ \delta = 1.849 \times 10^{-4} \]
CALCULATED FROM Darcy's Eq.

\[ \Delta P = \frac{\delta f \cdot v^2}{1.94 \cdot \rho} \]

\( \delta = \) density of He gas (lbm/ft^3)
\( f = \) friction factor
\( v = \) mean flow velocity (ft/sec)
\( \rho = 32.2 \cdot \rho_{\text{air}} \)
\( D = \) i.d. of tube (ft)

\( \gamma = 2.052 \times 10^{-1} \, \text{W/ft}^3 \)
REF. 7911-32 MGP I
UCID 7115
B.S. HICKMAN
8-12-57

PRESURE DROP: H₂ GAS
T = 70°F

FLOW - SCFM

50 100 150 200 250 300 350

1″ TYPE "K" TUBING
1/4″ TYPE "K" TUBING
1/2″ TYPE "K" TUBING

P = 100 PSIG
P = 150 PSIG
P = 200 PSIG
P = 250 PSIG
P = 300 PSIG

PRESSURE DROP* VS. FLOW RATE
FOR 1/4" SUPERIOR LINE SHUTOFF
VALVE - CAT. NO 1261-EB-H₂ GAS at 80°F

*CALCULATED

FLOW RATE: S.C.F.M.  H₂ GAS

LINE PRESSURE
500 PSIG

LINE PRESSURE
1000 PSIG

LINE PRESSURE
2000 PSIG

REF. ENG. NOTE
7911-40 MB P33
R. HICKMAN
UCID 786
PRESSURE DROP VS. MASS FLOW RATE FOR HELIUM FLOWING THROUGH TUBES

- 1.2 ATM.
- 4.434 °K

--- SATURATED LIQUID PHASE
--- SATURATED GAS PHASE

PRESSURE DROP

PSI/METER

MASS FLOW RATE
grams/sec

0.045" I.D.
0.126" I.D.
0.190" I.D.
0.311" I.D.
0.436" I.D.
0.600" I.D.

APRIL '80
R. Yamada
PRESSURE DROP VS. MASS FLOW RATE FOR HELIUM FLOWING THROUGH TUBES

@ 1.2 ATM
@ 4.424 °K

- SATURATED LIQUID PHASE
- SATURATED GAS PHASE

MASS FLOW RATE: grams/sec
PRESSURE DROP VS. MASS FLOW RATE FOR HELIUM FLOWING THROUGH TUBES

@ 15 ATM.
@ 4.5 °K

SATURATED GAS PHASE

MASS FLOW RATE [grams/sec]
PRESURE DROP VS MASS FLOW RATE FOR HELIUM FLOWING THROUGH TUBES

@ 15 ATM
@ 45° K

SATURATED GAS PHASE

PRESSURE DROP
PSI/INCH

MASS FLOW RATE grams/sec
Baker Diagram for Two-Phase Flow

- Helium @ 4.2°K, 1 atm
- 1.339 cm I.D. Tube
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