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PRESSURE DROP DESIGN DATA

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Author

Byrns, Roscoe A.

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1980-06-01



Lawrence Berkeley Laboratory

UNIVERSITY OF CALIFORNIA

Engineering & Technical Services Division

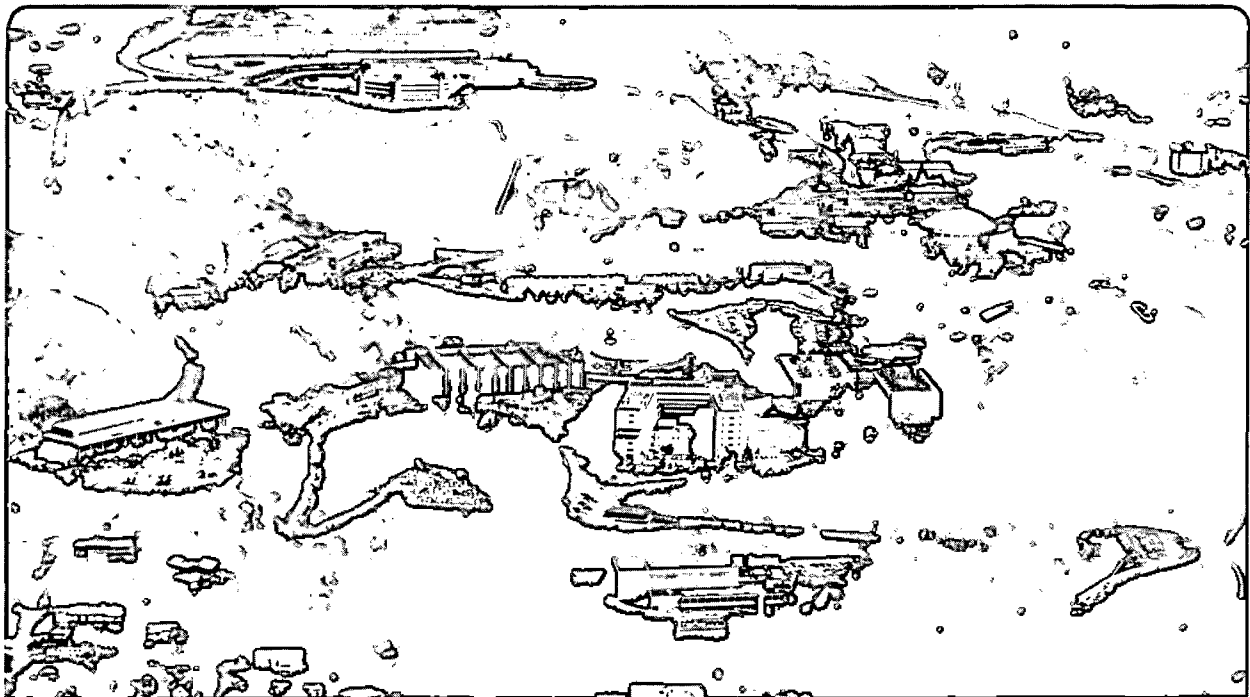
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ENGINEERING NOTE

ES0501

M4859B

1 OF 28

AUTHOR

DEPARTMENT

LOCATION

DATE

R. A. Byrns

Mechanical Engineering

Berkeley

September 1975

PROGRAM - PROJECT - JOB

ESCAR HELIUM REFRIGERATOR FACILITY

CRYOGENIC DISTRIBUTION

TITLE

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 H ₂ gas 50°F, 1 atm	
4	Smooth tubes, Two phase H ₂	(72" H ₂ B.C.)
5	Smooth tubes, H ₂ HX cooldown	" " "
6.	Smooth tubes, H ₂ gas 276°K, 1 atm	(Cryo. Data Book)
7.	Smooth tubes, H ₂ gas 290°K, 100 psi	" " "
8.	Smooth tubes, H ₂ gas 300°K, 2200 psi	" " "
9	Smooth tubes, N ₂ gas 300°K, 0.1 atm	" " "
10.	Valves and fittings, equivalent lengths	(Crane Co.)
11.	Smooth and flexible pipe - liquid N ₂	(CVI Corp.)
12	Smooth and flexible pipe - liquid H ₂	" " "
12.	Smooth and flexible pipe - liquid O ₂	" " "
13.	Smooth pipe - LN ₂	" " "
14.	Flex. pipe - LN ₂	" " "
15.	Flex. pipe - LN ₂	(Vacuum Barrier Corp.)
16.	Smooth tubes, He gas, 293°K, 1 atm	(M4908, Y. Kajiyama)
17	Smooth tubes, He gas, 293°K, 3 atm	" "
18.	Smooth tubes, He gas, 293°K, 18 atm	" "
19.	Smooth tubes, H ₂ gas, 293°K, 20 atm	" "
20.	Smooth tubes, H ₂ gas, 290°K; 100, 150, 200 psig	(7911-32 M6)
21.	Pressure drop through 1/4" #1251-BB	(7911-40 M8)
	Superior Line shutoff valve: for 500, 1000, 2000 psig H ₂ gas @ 80°F	
22.	Two phase He 1.2 atm, 4.4°K 1-20 gm/sec	(M5507, R. Yamamoto)
23	" " " 10-100 "	" "
24.	Supercritical He 15 atm, 4.5°K 1-20 "	" "
25.	" " " 10-100 "	" "
26.	Baker Diagram - 2 phase flow He 1 atm 4.2°K 1-3 gm/sec	(M5497, R. Yamamoto)
27.	Same as above except 3.8°K " "	" "
28	Baker Diagram - N ₂ 1 atm 77°K 30-60 gm/sec	" "

R. Byrns 6 cc

/nh

10.0

PRESSURE DROP IN SMOOTH TUBES FOR HELIUM @ 20°K, 25atm

$$\rho = .06 \frac{\text{gm}}{\text{cc}}$$

MULTIPLY $\frac{\Delta P}{L}$ BY $\frac{25}{P(\text{atm})}$
TO FIND $\Delta P/L$ FOR OTHER
PRESSURES.

10.0
1.0
0.1
0.01
 $\frac{\Delta P}{L}, \text{Psi}/100\text{FT}$

SINGLAPRESS
H. S. WYK
(25atm helium)
LN 7911-90
1143

0.652 I.D.

0.500 I.D.

0.375 I.D.

0.500 I.D.

0.625 I.D.

0.750 I.D.

CTA FOR 0.310 I.D.
($\Delta P = 15 \text{psi}$ for 200 ft)
@ 1 atm
FOR 30 CFM
 $3(15) = 45 \text{psi}$
 $\frac{45}{100 \text{ft}} = 0.45 \text{psi}/100 \text{ft}$
 $= 15.0 \text{psi}/200'$

* (KIM DATA FROM
FED MILK)

FLOW, SCFM

480

240

120

60

30

0.01

400

200

100

59m

R. Byrns
April 18
1972

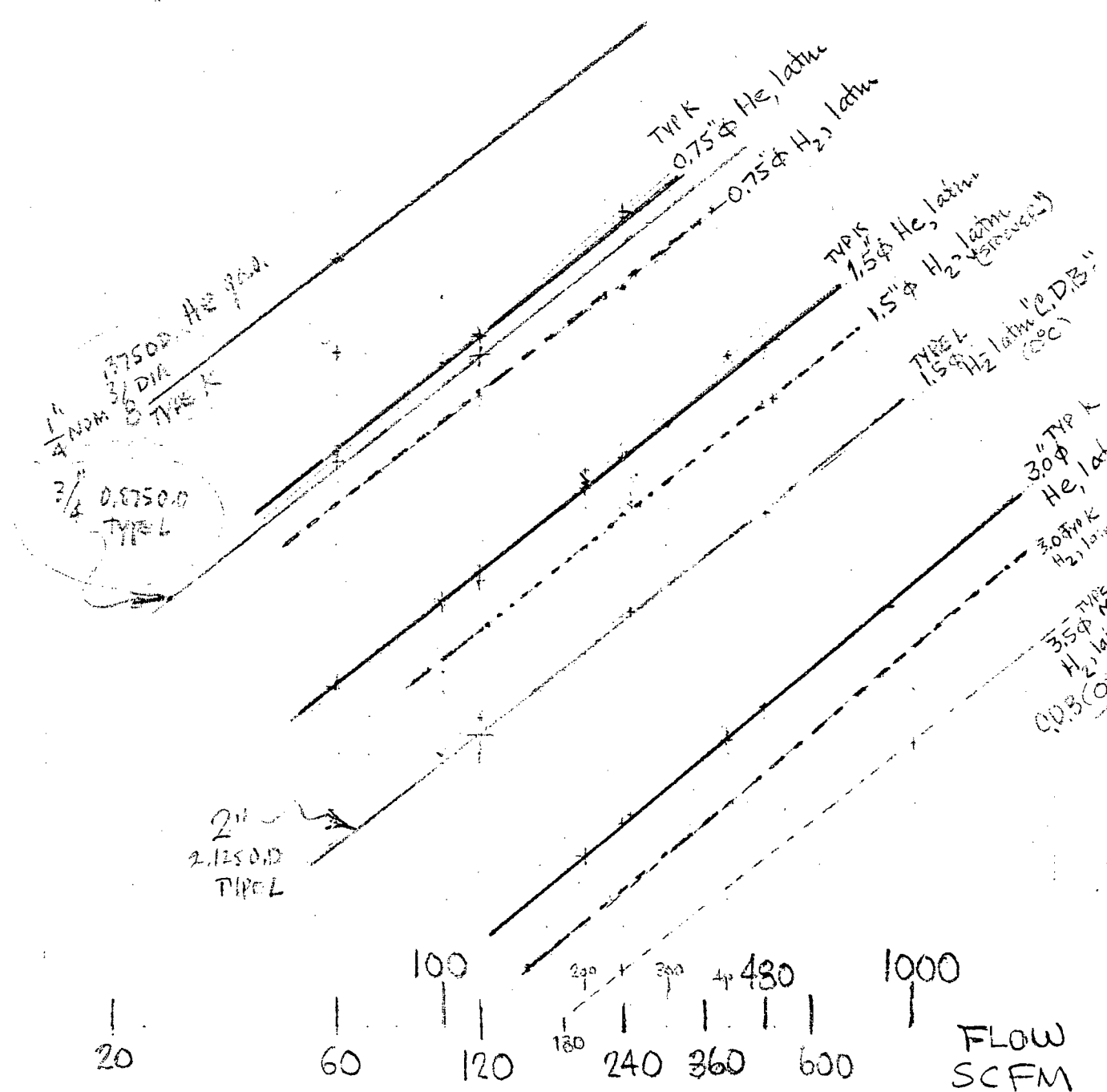
REF. APPLIED HEAT TRANSMISSION
 STOEVER, page 128
 CRYO. DATA BOOK
 page 106

R. Byrns
 18 April 1972

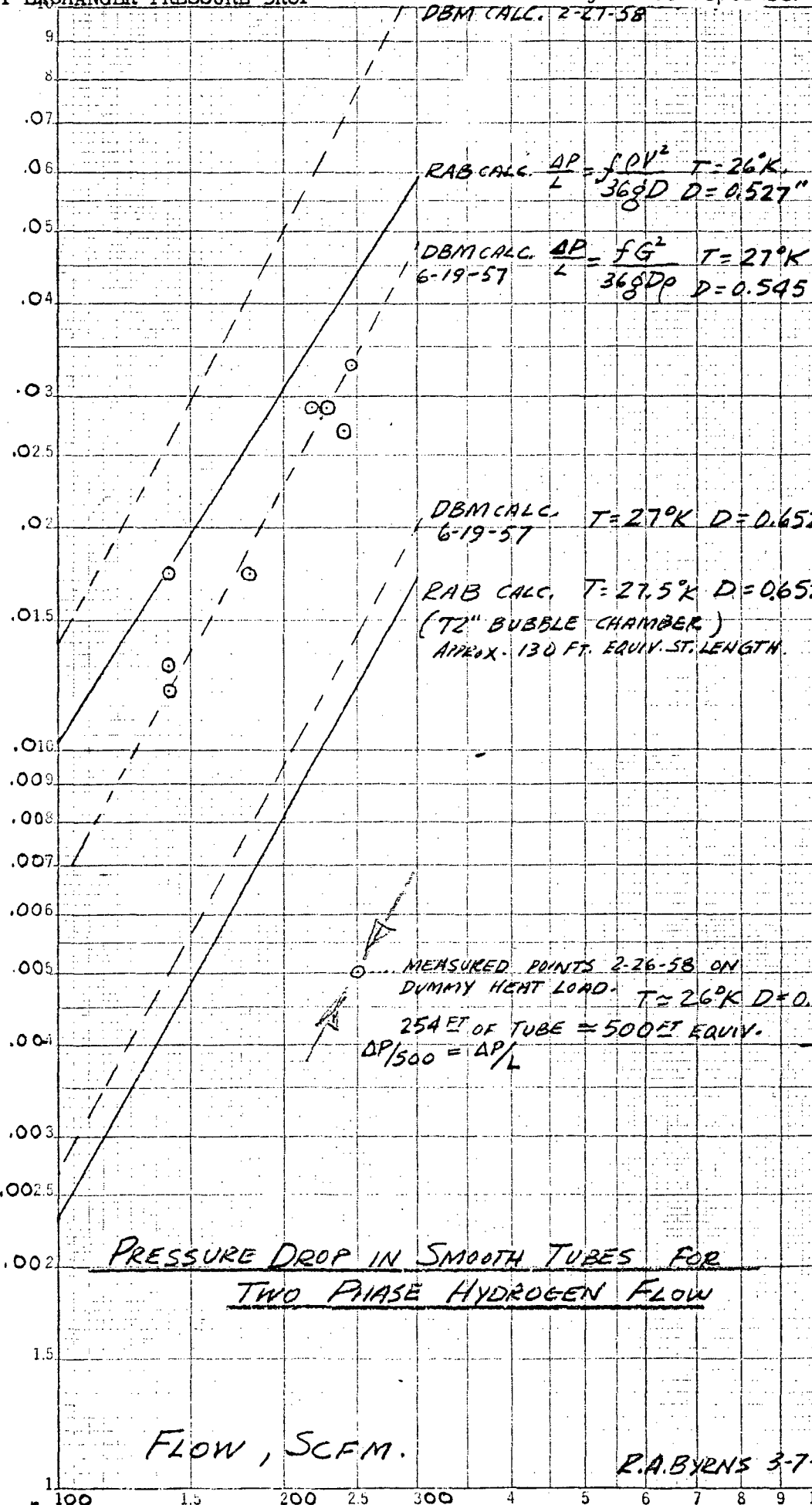
PRESSURE DROP IN SMOOTH COPPER
WATER TUBES. H₂ & He, 1 atm, 50°F

(DIVIDE $\frac{\Delta P}{L}$ BY P in atmospheres, absolute, to
 FIND $\Delta P/L$ FOR DENSITIES OTHER THAN 1 ATM.)

Pressure Drop
 $\Delta P / L$
 PSI/100 FT.



PRESSURE DROP, $\frac{\Delta P}{L}$ (PSI/FT.)



$$\frac{\Delta P}{L} \propto \frac{f V^2}{2 g D}$$

PRESSURE DROP IN SMOOTH TUBES FOR TWO PHASE HYDROGEN FLOW

~.008 (He-est)
 ~.006 (He)*
 ~.004 (He?)

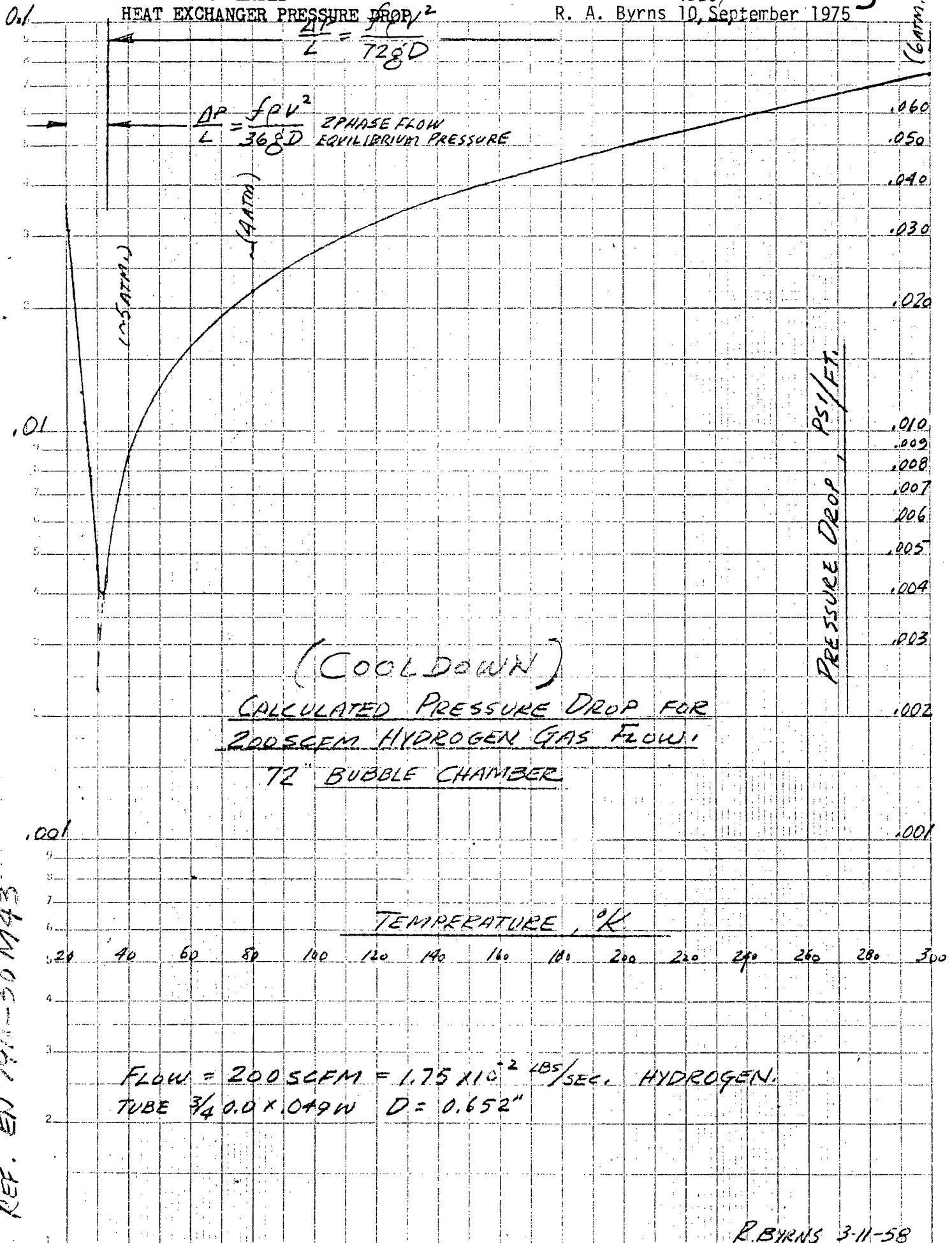
* He GAS @ 23°K - D=0.32"
 $\Delta p = .024 \frac{\rho V^2}{2}$
 $\Delta p = 4.8 \text{ psi}$

REF EN. 7911-50 M45
 72" H.B.C.

FLOW, SCFM.

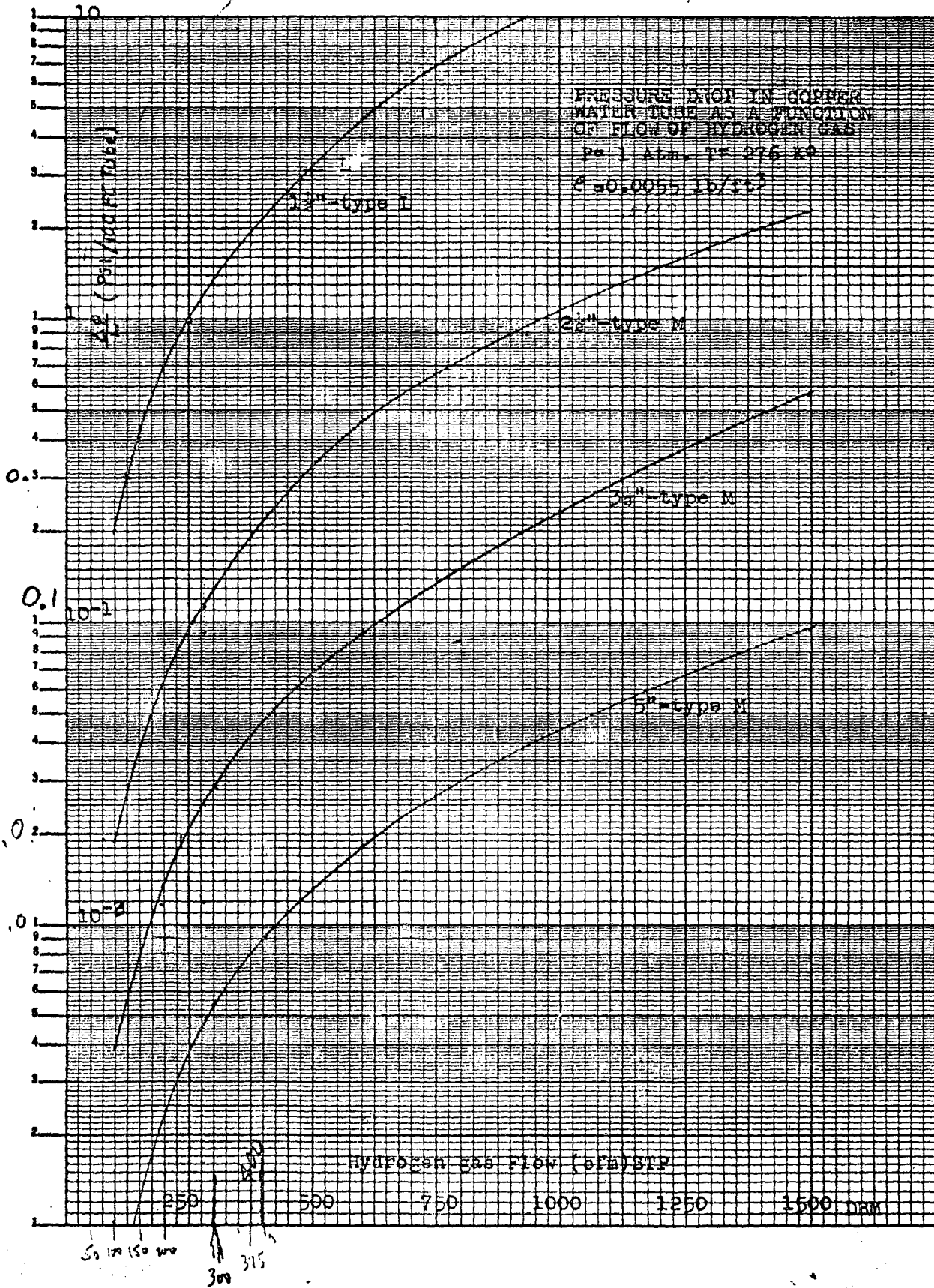
R.A. BYRNS 3-7-58

100 1.5 200 2.5 300 4 5 6 7 8 9 10

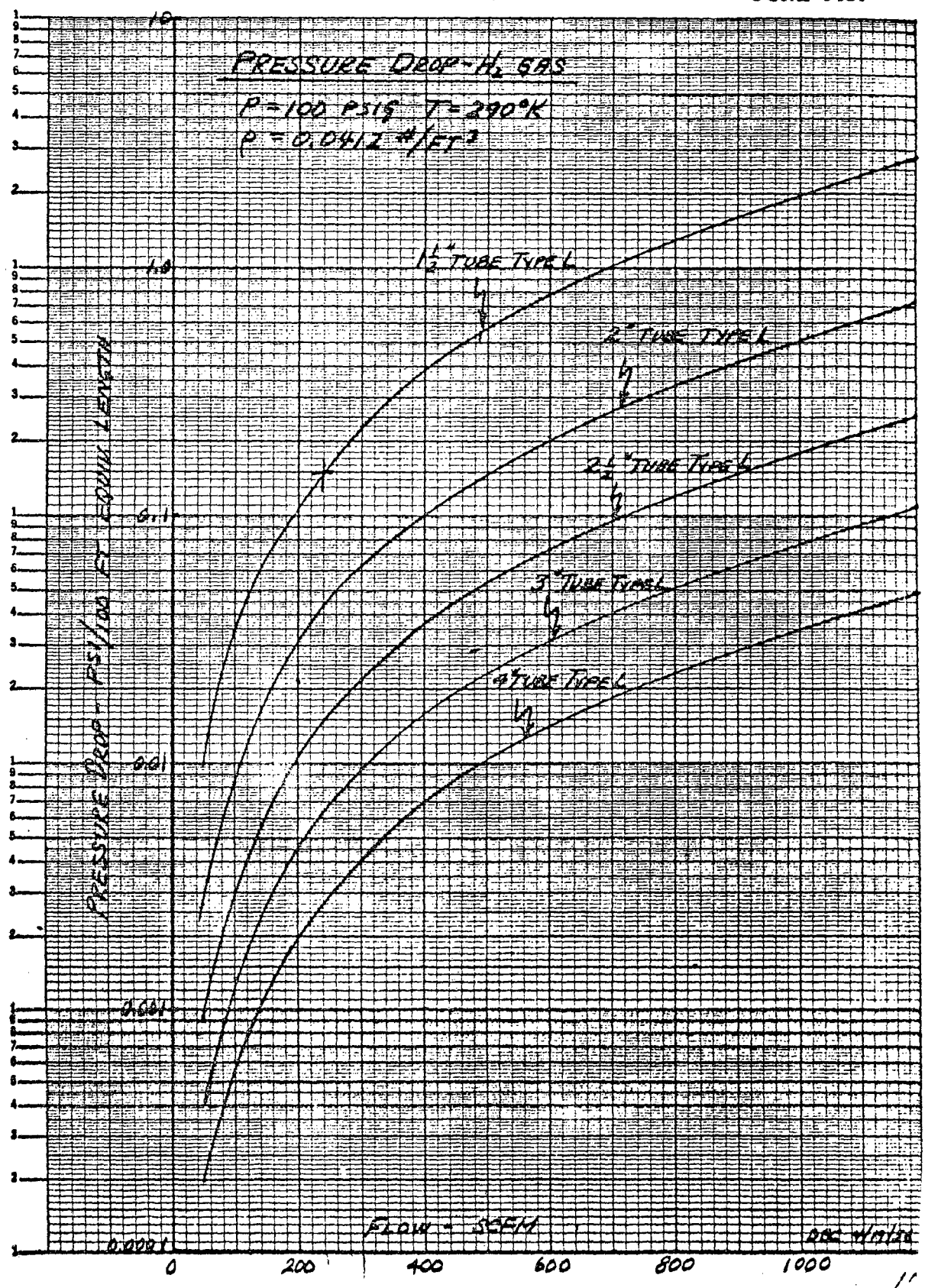


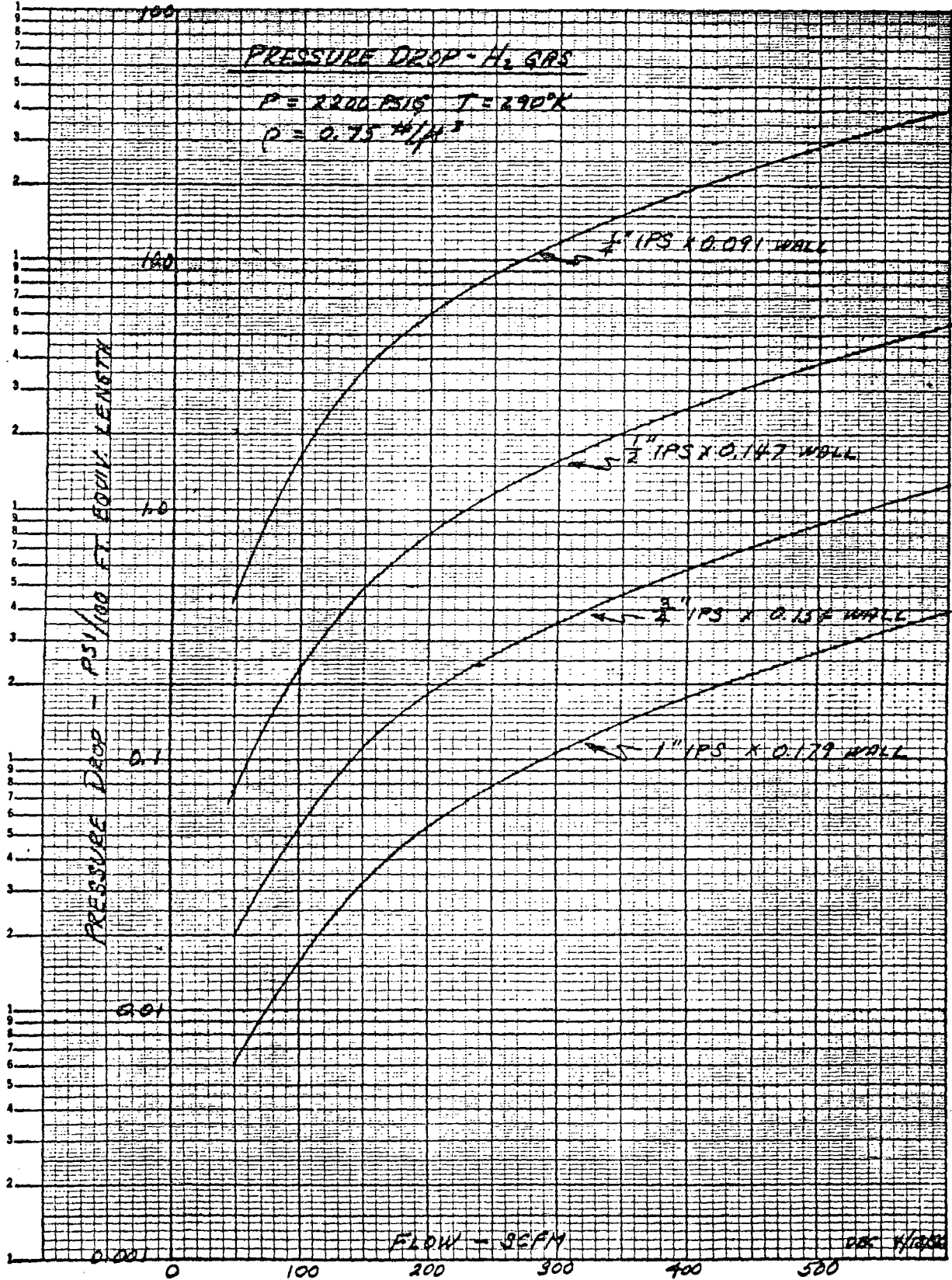
REF. EN 7911-30 M43

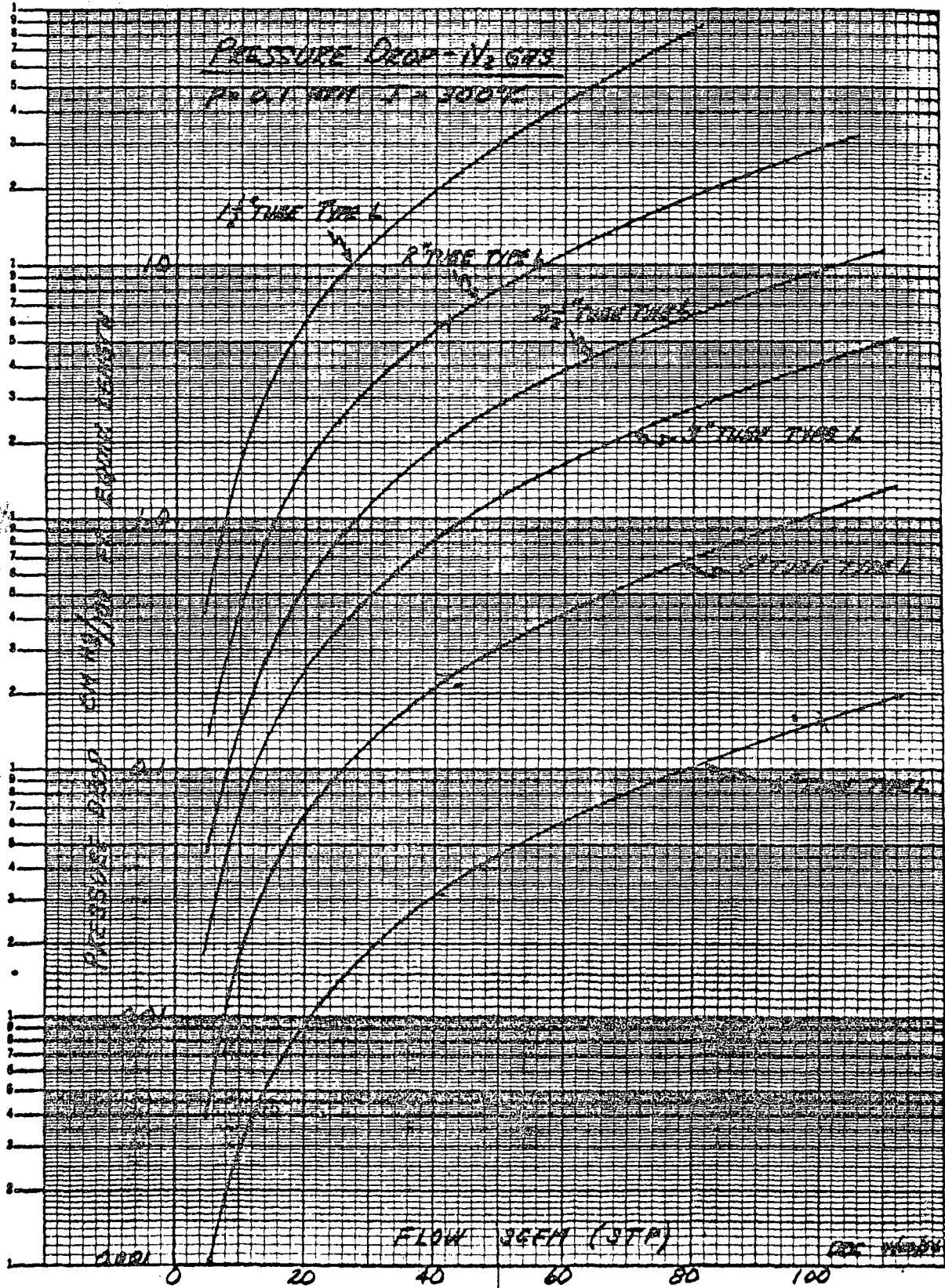
R. BYRNS 3-11-58



50 100 150 200
 250 300 315







Resistance of Valves and Fittings to Flow of Fluids

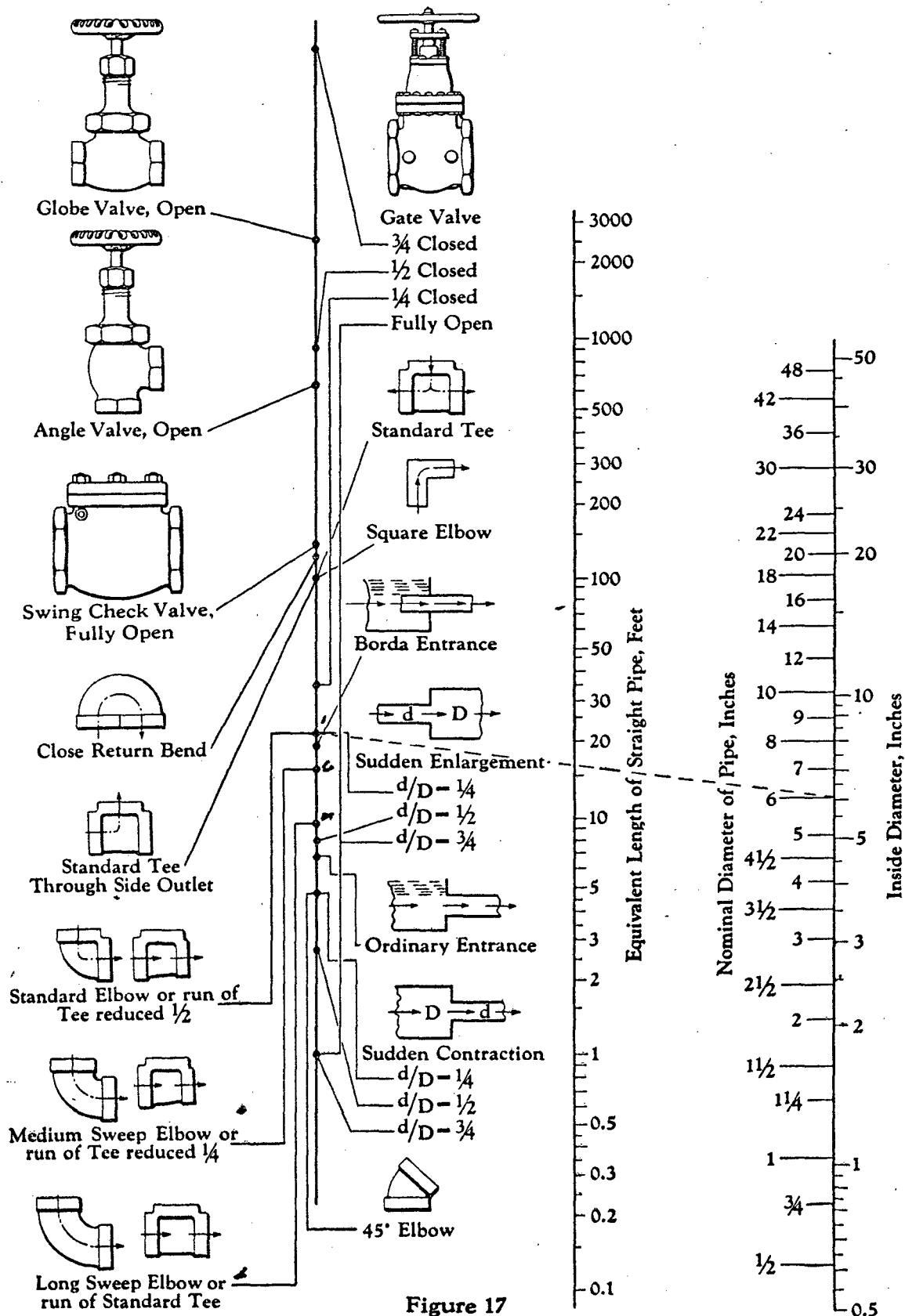


Figure 17

* CRANE TECH PAPER NO. 409 MAY 1942

Pressure Drop Curves

6

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.

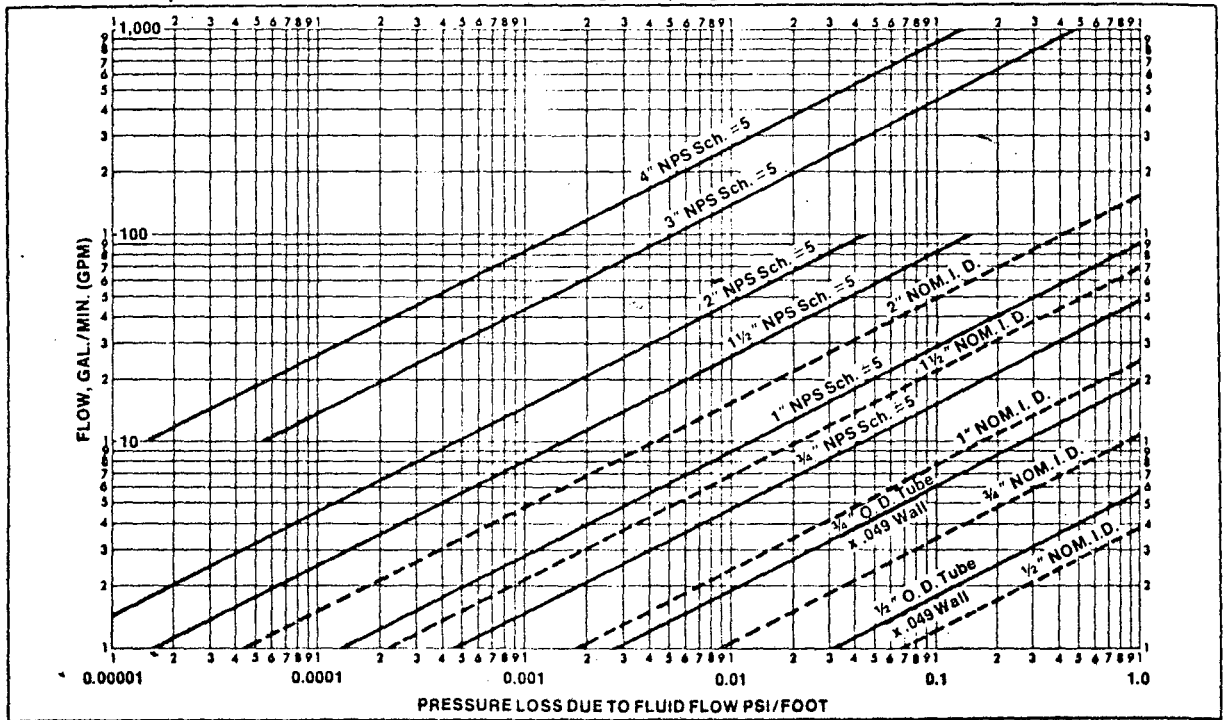
Please notice that a smaller diameter rigid pipe line can accommodate the same flow capacity as a larger diameter flex line. This is significant when considering heat-leak (liquid loss) and system purchase cost.

Liquid Nitrogen

Pressure Drop Due to Fluid Flow

Rigid Piping ———

Flexible Piping - - - - -

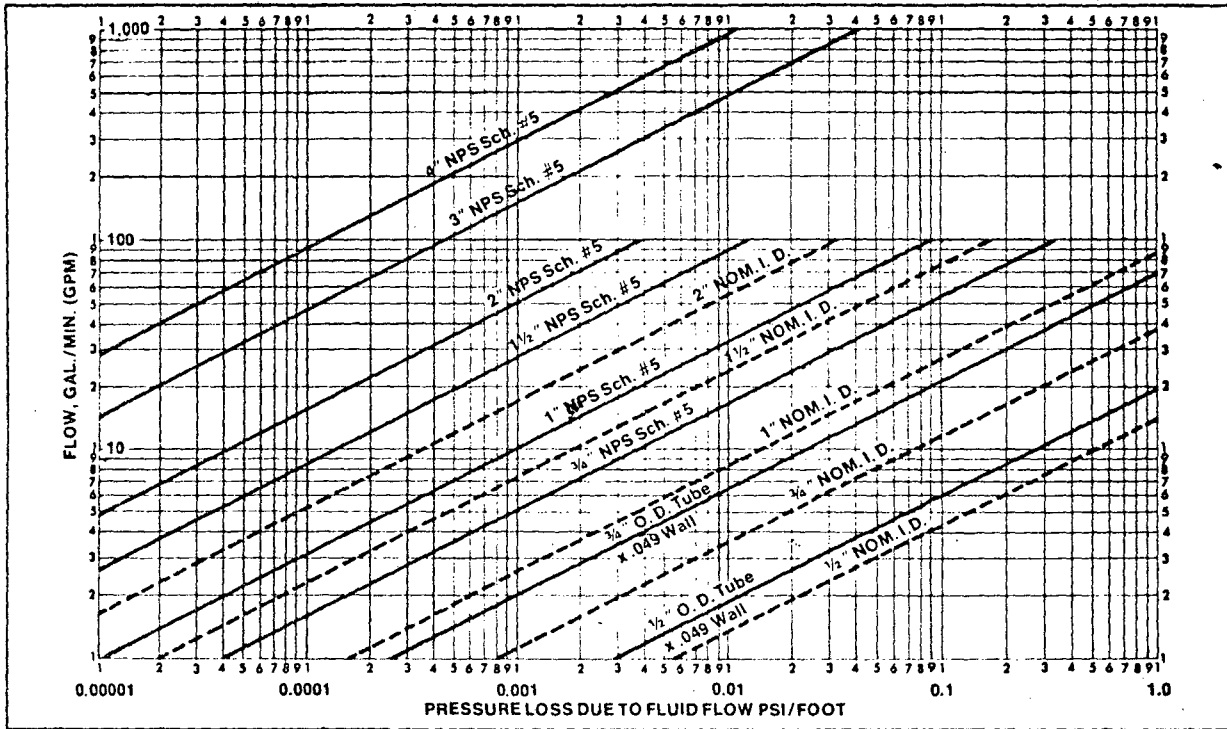


DATA FROM CVI CORP. T.O. Box 2138
(1975) DIV. OF PENNWALT COLUMBUS - OHIO - 43216
614-876-7381

7

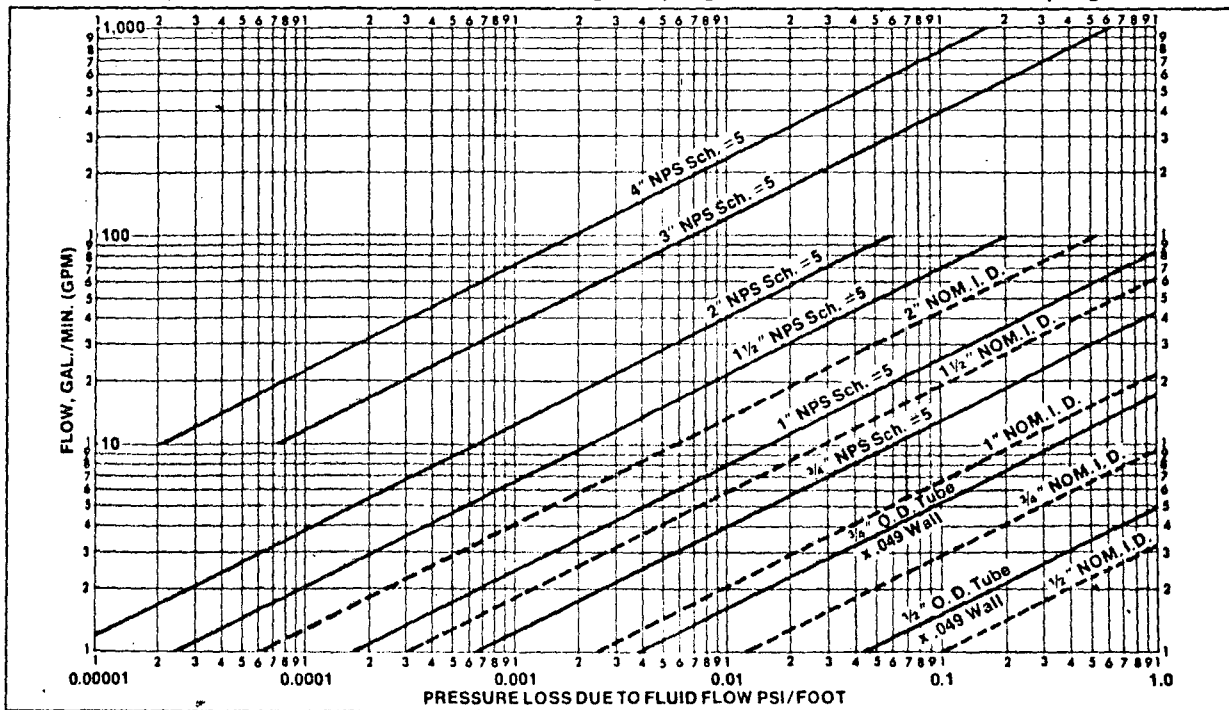
Liquid Hydrogen Pressure Drop Due to Fluid Flow

Rigid Piping ——— Flexible Piping - - - - -



Liquid Oxygen Pressure Drop Due to Fluid Flow

Rigid Piping ——— Flexible Piping - - - - -



CVI
DATA

0.001

0.01

0.1

1.0

4" NPS SCH 5

3" NPS SCH 5

2" NPS SCH 5

1 1/2" NPS SCH 5

1" NPS - SCH 5

3/4" NPS SCH 5

3/4" O.D. TUBE W/.049 WALL

1/2" O.D. TUBE W/.049 WALL

PRESSURE DROP - PSI/FT.
VS. FLOW - GPM.

FOR LIQUID NITROGEN
THRU COMMON PIPE

From CVI CORP.
COLUMBUS - OHIO
DIV. OF PENNVALT
~ (1965)

Flow - GPM

10

(378.5 LITERS)
MIN

PRESSURE DROP - PSI/FT.
VS. FLOW - GPM.

LIQUID NITROGEN,
THRU CVI "UTILITY-FLEX"

FROM CVI CORP.
COLUMBUS, OHIO
DIV. OF PENNWALT

PRESSURE DROP - PSI/FT.

2 1/2" NOM. I.D.

1 1/2" NOM. I.D.

1" NOM. I.D.

1/2" NOM. I.D.

2" NOM. I.D.

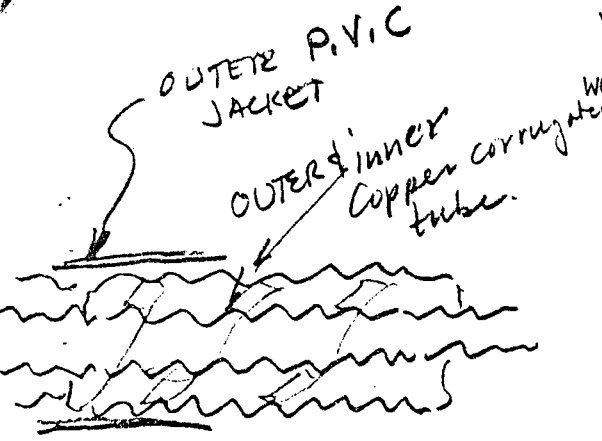
FLOW - GPM

(378.5 LITERS / MIN)

10

100

VACUUM BARRIER CORPORATION
 4 BARTEN LANE
 WOBURN, MASSACHUSETTS 01801
 (617) 933-3570



NOTE OBSOLETE DATE FOR PRICE
 BULLETIN NO. SFA-100-1
 1 FEBRUARY 1968

PRICE LIST

SEMIFLEX "A"
 SEMI FLEXIBLE CRYOGENIC
 TRANSFER LINE

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

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

SEMIFLEX A SIZE NUMBER:	A-5	A-10	A-15	A-20
Inside Dia. (Inches)	.646	1.245	1.730	2.205
Outside Dia. (Inches)	1.565	2.390	2.990	3.550
Weight (Lbs/Ft)	.9	1.2	1.7	2.2
Cool-Down (BTU/FT)	10 - 8	20 - 15	25 - 21	30 - 28
Heat Leak (BTU/HR/FT) (measured)	1.2	1.8	2.0	2.4
Bend Radius (Inches)	20	32	40	48
Flow Rate (Water-GPM) *				
0.01 PSI/FT Pressure Drop	.5	3.4	9.0	19.0
0.10 PSI/FT Pressure Drop	1.6	11.0	31.0	62.0
1.00 PSI/FT Pressure Drop	5.0	34.0	90.0	190.0

* IN PURE LIQUID CONDITION LN₂ HAS SIMILAR CHARACTERISTICS TO WATER

DESIGN-PRESSURE (PSI)	175	150	125	85
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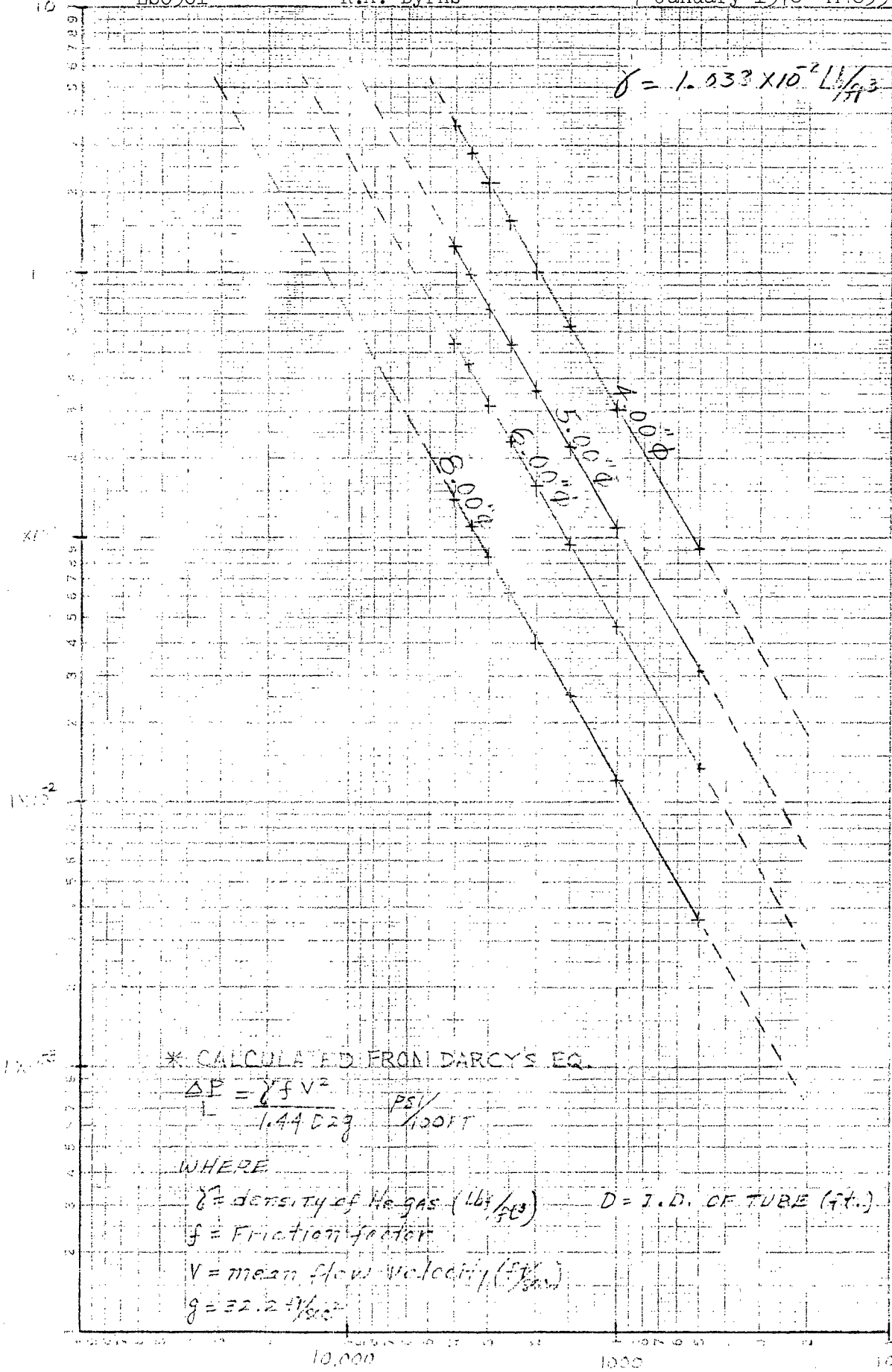
PRESSURE DROP IN SMOOTH COPPER
WATER TUBES (TYPE K): He gas @ 1 atm. 20°C

ESO501

R.A. Byrns

7 January 1976 M4859 B Page 16

ΔP PRESSURE DROP PSI, IN. H₂O



* CALCULATED FROM DARCY'S EQ.

$$\Delta P = \frac{\rho f V^2 L}{1.44 D^2 g} \quad \frac{\text{PSI}}{100 \text{ FT}}$$

WHERE

- ρ = density of He gas (lb_m/ft³)
- f = Friction factor
- V = mean flow velocity (ft³/sec)
- $g = 32.2 \text{ ft/sec}^2$
- $D = \text{I.D. OF TUBE (ft.)}$

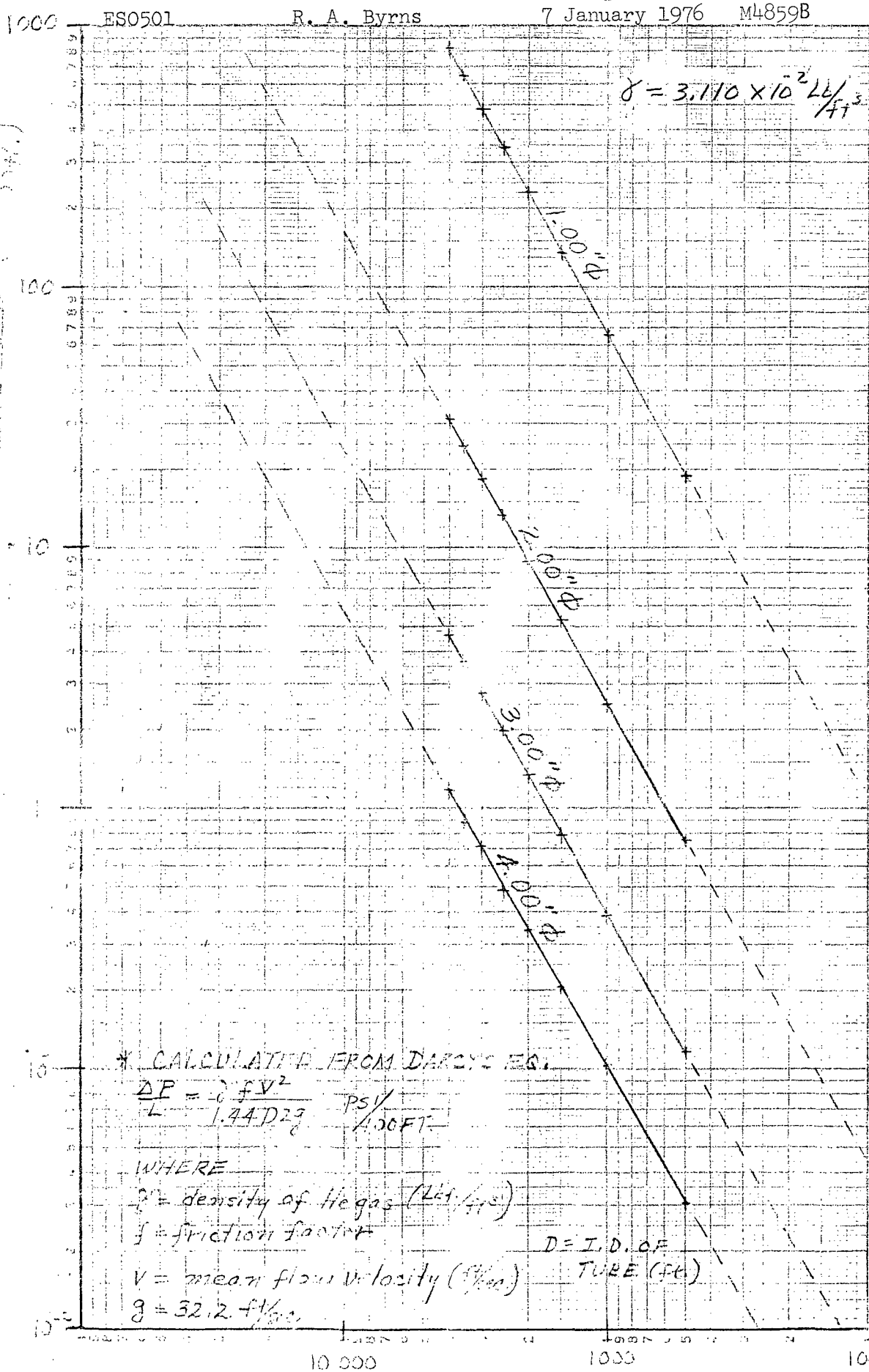
FLOW GPM

Y. K. YAMA (1/5/76)

PRESSURE DROP IN SMOOTH COPPER
WATER TUBES (TYPE K): H₂ gas; @ 3 atm; 20°C

ES0501 R. A. Byrns 7 January 1976 M4859B Page 17

$\frac{\Delta P}{L}$ PRESSURE DROP (PSI/FOOT)



* CALCULATED FROM DARCY'S EQ.

$$\frac{\Delta P}{L} = \frac{f V^2}{1.44 D^5} \quad \frac{PSI}{FOOT}$$

WHERE

ρ = density of H₂ gas (lb/ft³)

f = friction factor

V = mean flow velocity (ft/sec)

g = 32.2 ft/sec²

D = I. D. OF TUBE (FT)

FLOW - SCFM

Y. KAJIYAMA (1-6-76)

PRESSURE DROP IN CEMENT PIPE

WATER FILLS (TYPE-K) H. GAS @ 15 ft/min, 200°

9 January 1976

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ES0501

R. A. Byrns

* CALCULATED FROM DARCY'S EQ.

$$\gamma = 1.849 \times 10^{-16} \frac{Lb}{ft^3}$$

$$\frac{\Delta P}{L} = \frac{\gamma f V^2}{1.44 D^2 g}$$

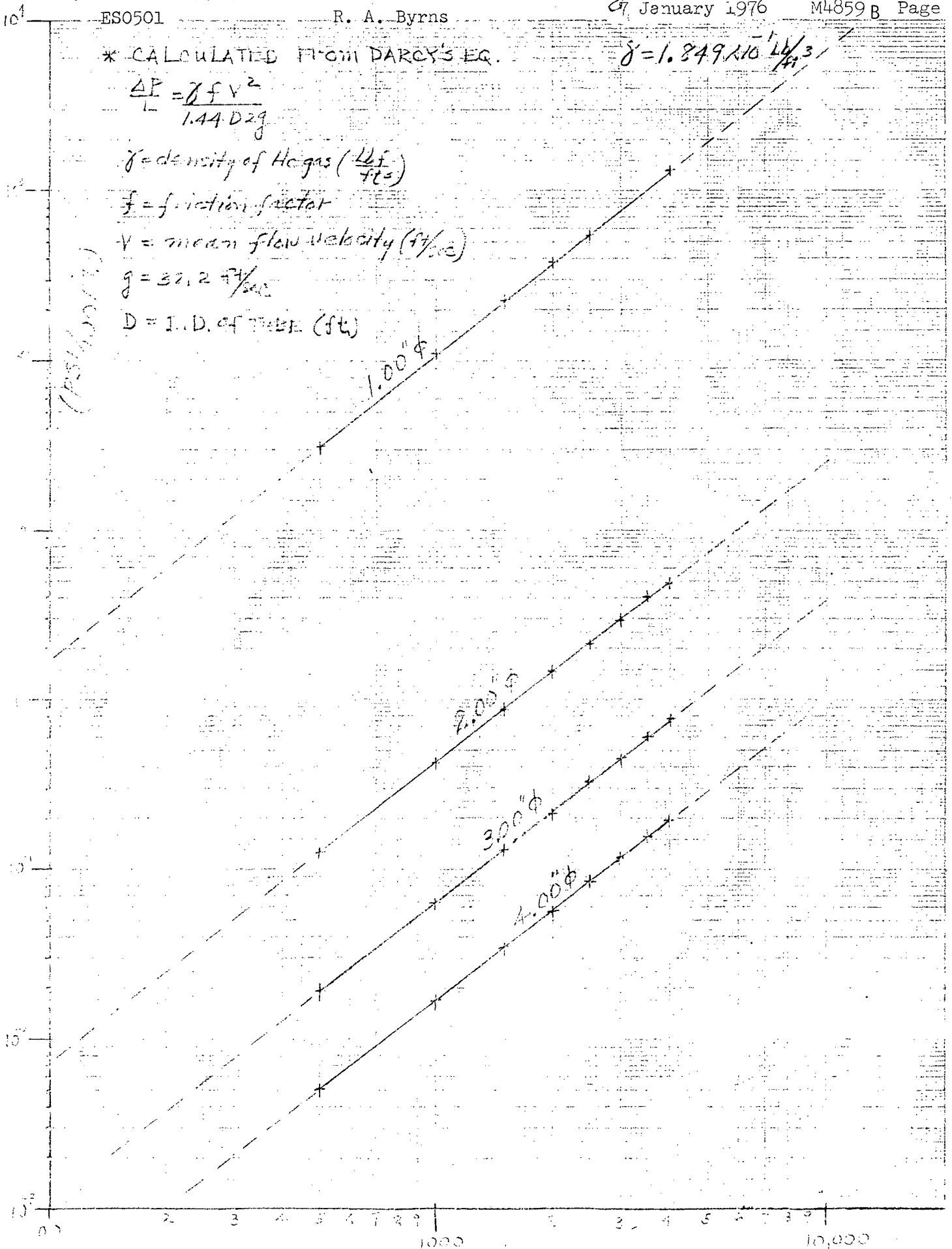
γ = density of H. gas ($\frac{Lb}{ft^3}$)

f = friction factor

V = mean flow velocity (ft/sec)

$g = 32.2 \frac{ft}{sec^2}$

D = I. D. of pipe (ft)



FLOW - SCFM

Y. KAJIYAMA

PRESSURE DROP IN SMOOTH COPPER
WATER TUBES (TYPE K) - He gas @ 20 atm, 20°C

ES0501

R. A. Byrns

7 January 1976

M4859B

Page 19

* CALCULATED FROM DARCY'S EQ.

$$\frac{\Delta P}{L} = \frac{\gamma f V^2}{1.44 D^2 g}$$

$$\gamma = 2.052 \times 10^{-1} \frac{\text{lb}}{\text{ft}^3}$$

γ = density of He gas ($\frac{\text{lb}}{\text{ft}^3}$)

f = friction factor

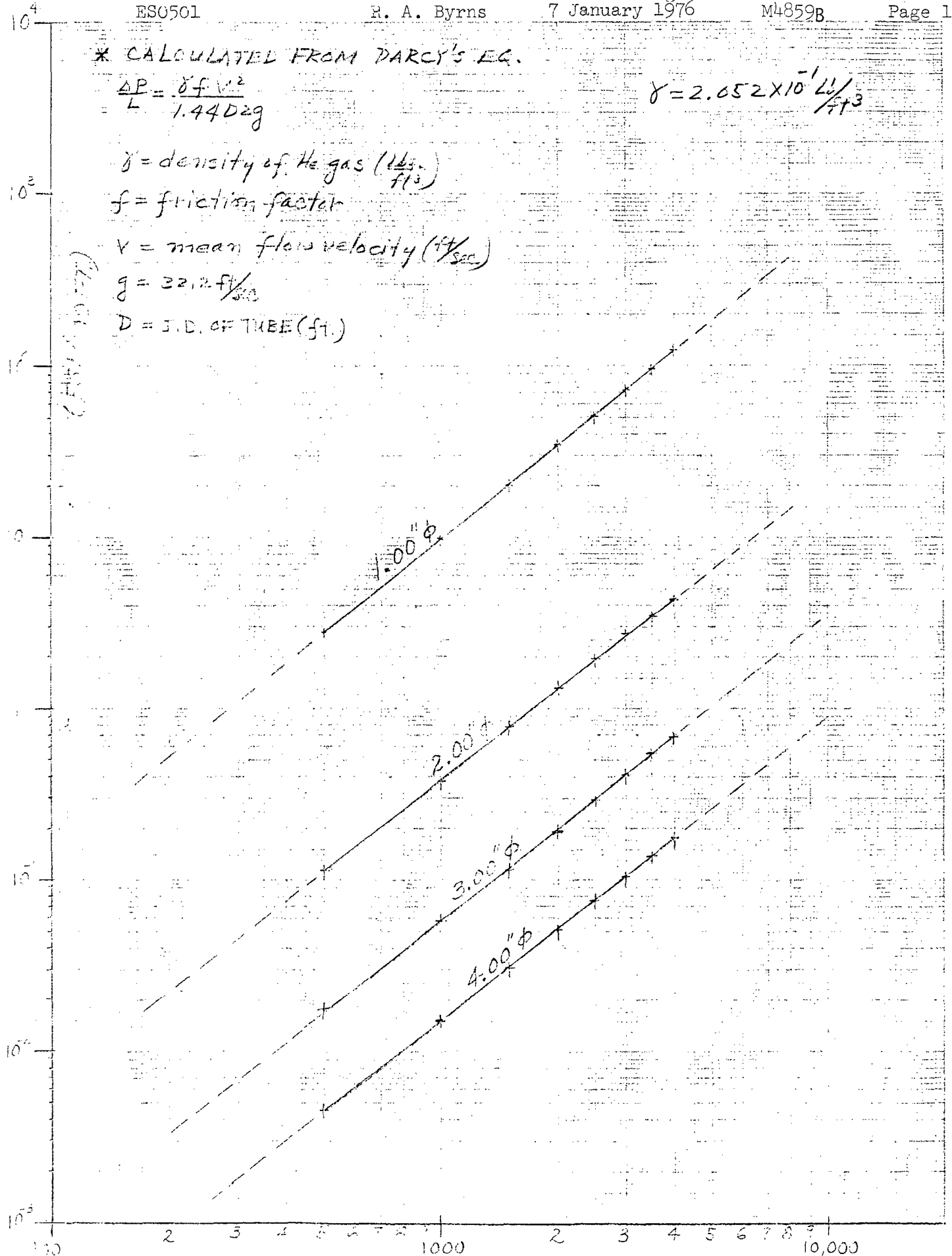
V = mean flow velocity ($\frac{\text{ft}}{\text{sec}}$)

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

D = I.D. OF TUBE (ft.)

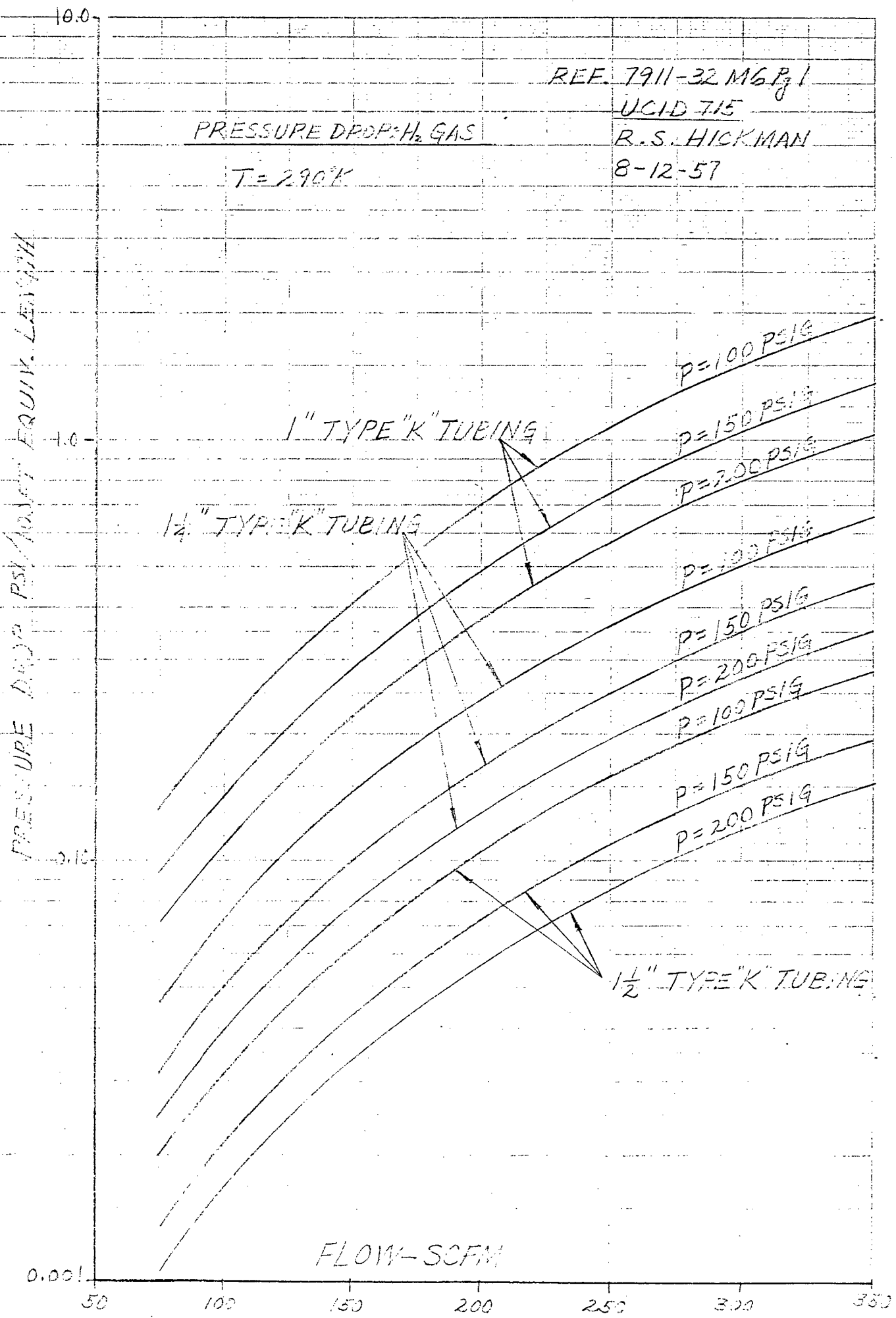
$\frac{\Delta P}{L}$ (PSI/FT)

Flow (ft³/min)



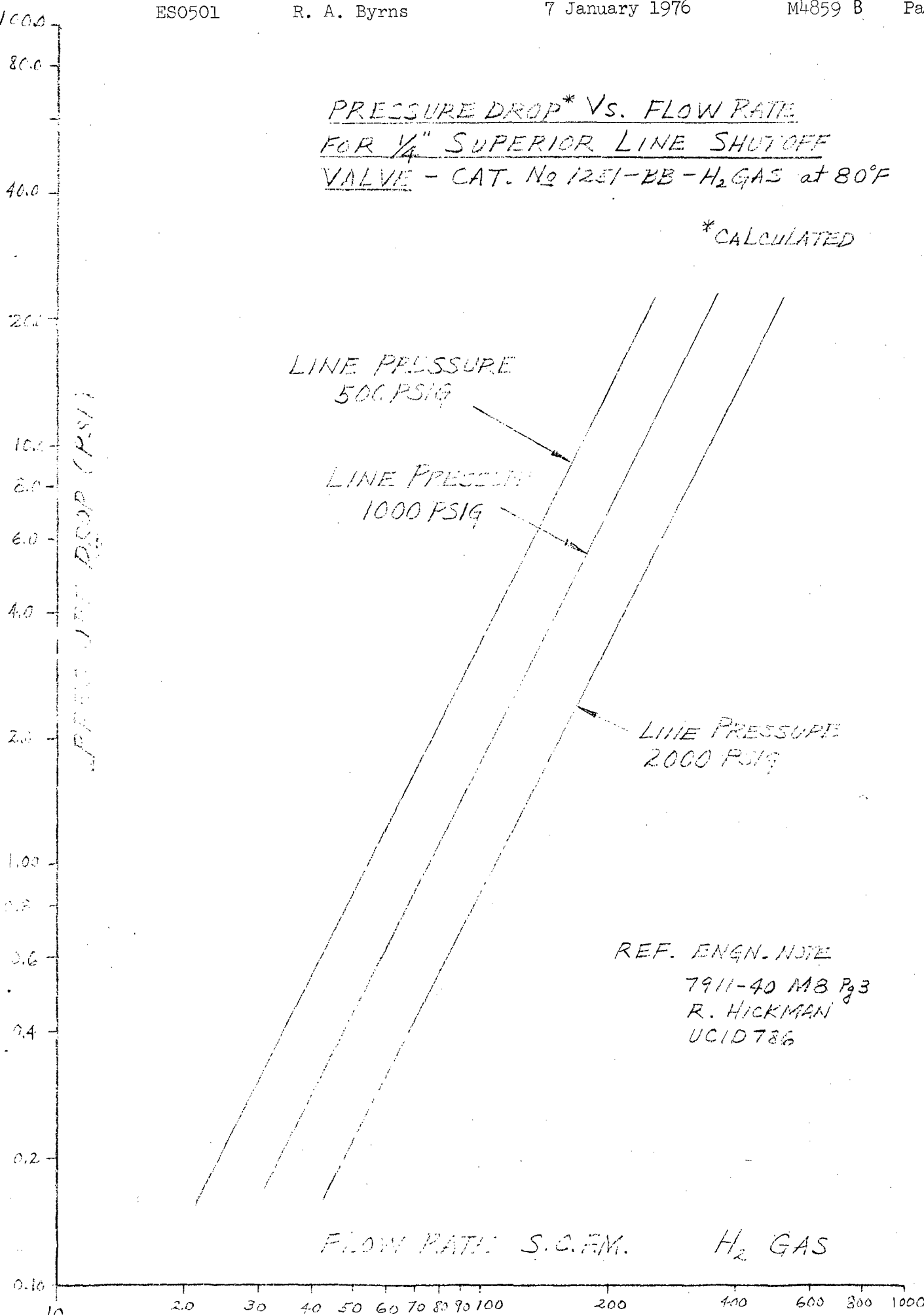
FLOW - SCALING

Y. KALININ (1-6-76)



PRESSURE DROP* VS. FLOW RATE
FOR 1/4" SUPERIOR LINE SHUTOFF
VALVE - CAT. No 1251-BB - H₂ GAS at 80°F

*CALCULATED



PRESSURE DROP VS. MASS
FLOW RATE FOR HELIUM FLOWING
THROUGH TUBES

① 1.2 ATM.
② 4.424 °K

PRESSURE DROP
PSI/METER

--- SATURATED LIQUID PHASE
— SATURATED GAS PHASE

0.065" I.D.

0.1275" I.D.

0.190" I.D.

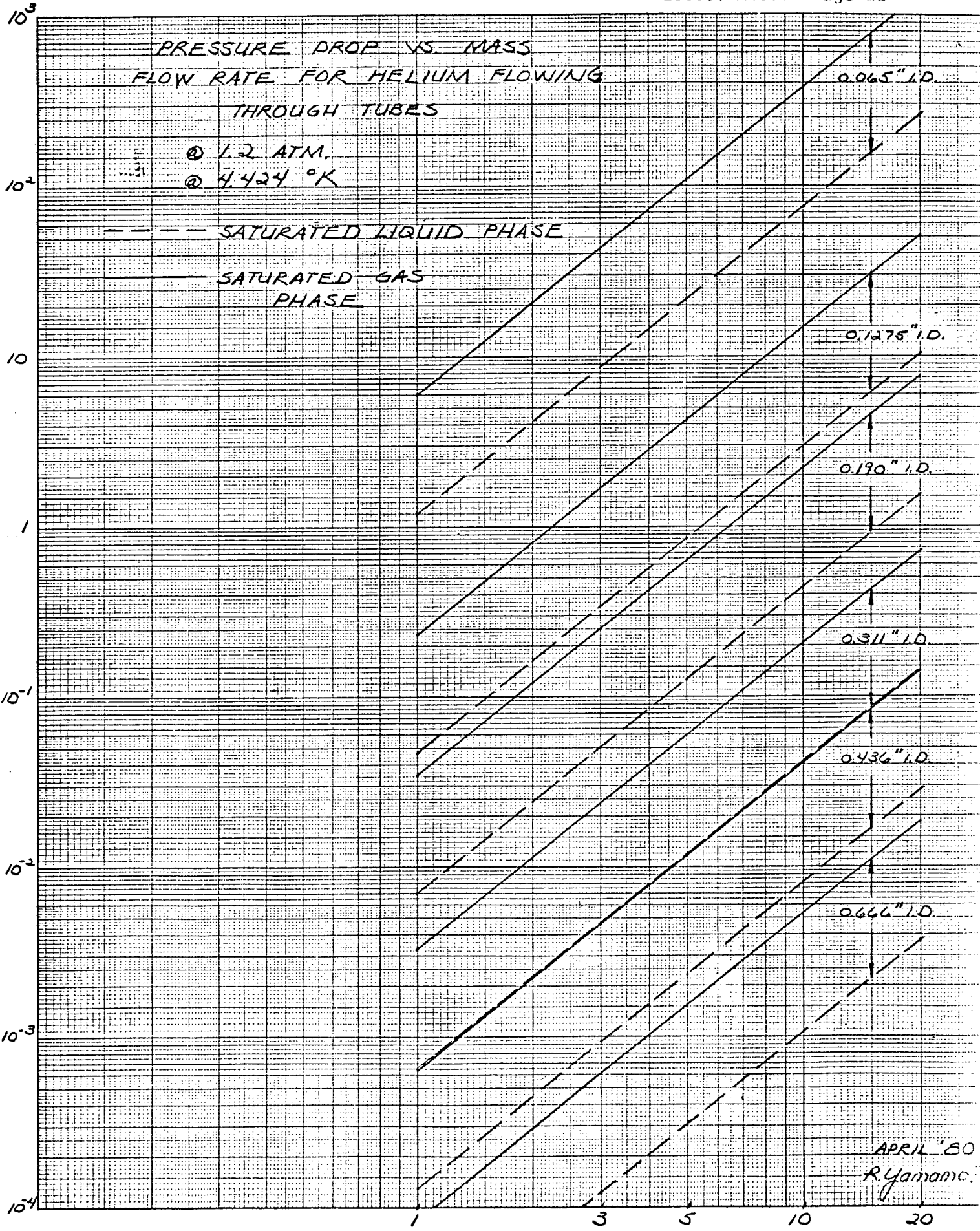
0.311" I.D.

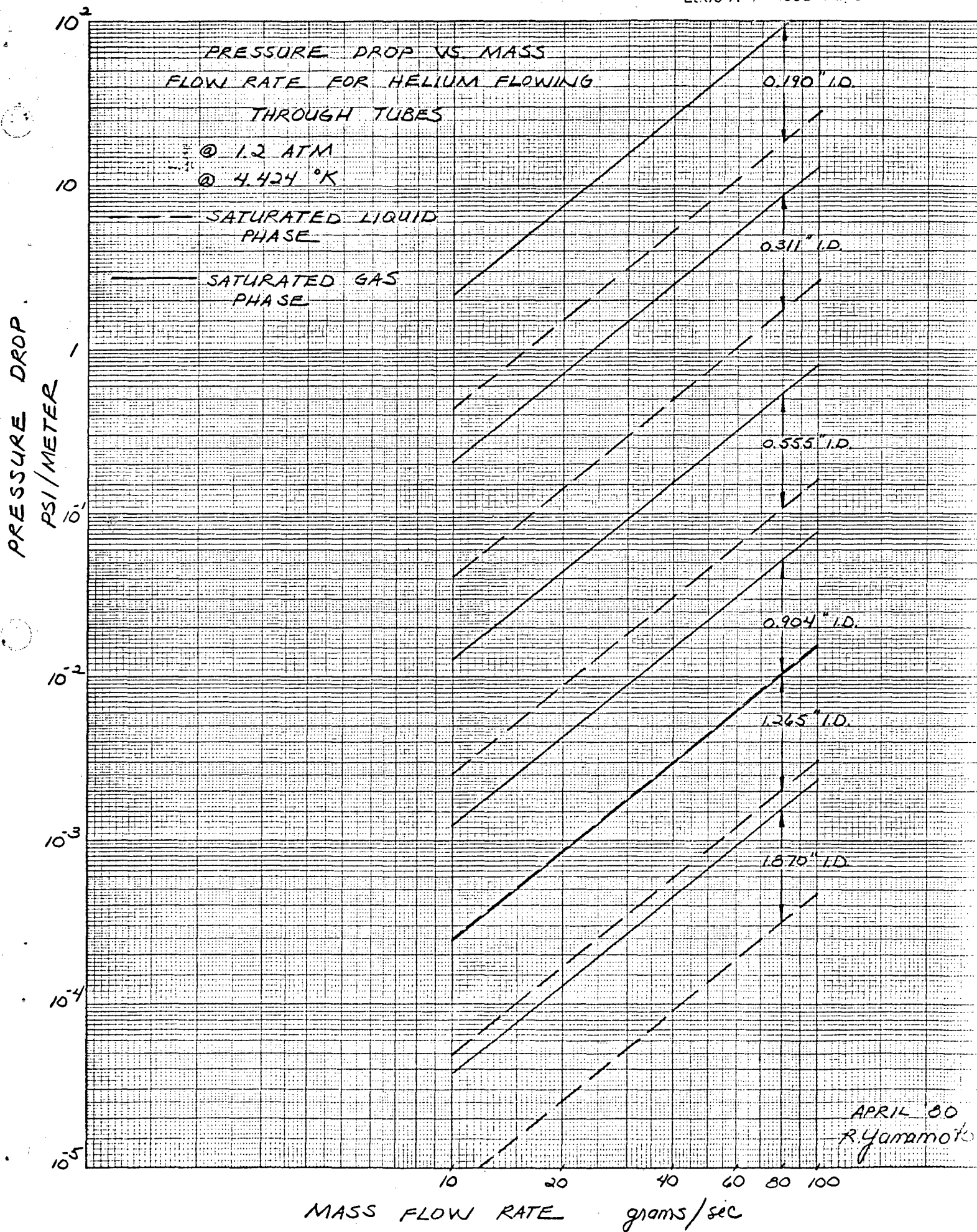
0.436" I.D.

0.666" I.D.

APRIL '80
R. Yamamoto

MASS FLOW RATE grams/sec





PRESSURE DROP VS. MASS FLOW RATE FOR HELIUM FLOWING THROUGH TUBES

@ 15 ATM.

@ 4.5°K

--- SATURATED GAS PHASE

PRESSURE DROP
PSI/METER

10³
10²
10
1
10⁻¹
10⁻²
10⁻³
10⁻⁴

1 3 5 10 20

MASS FLOW RATE grams/sec

0.065" I.D.

0.1275" I.D.

0.190" I.D.

0.2485" I.D.

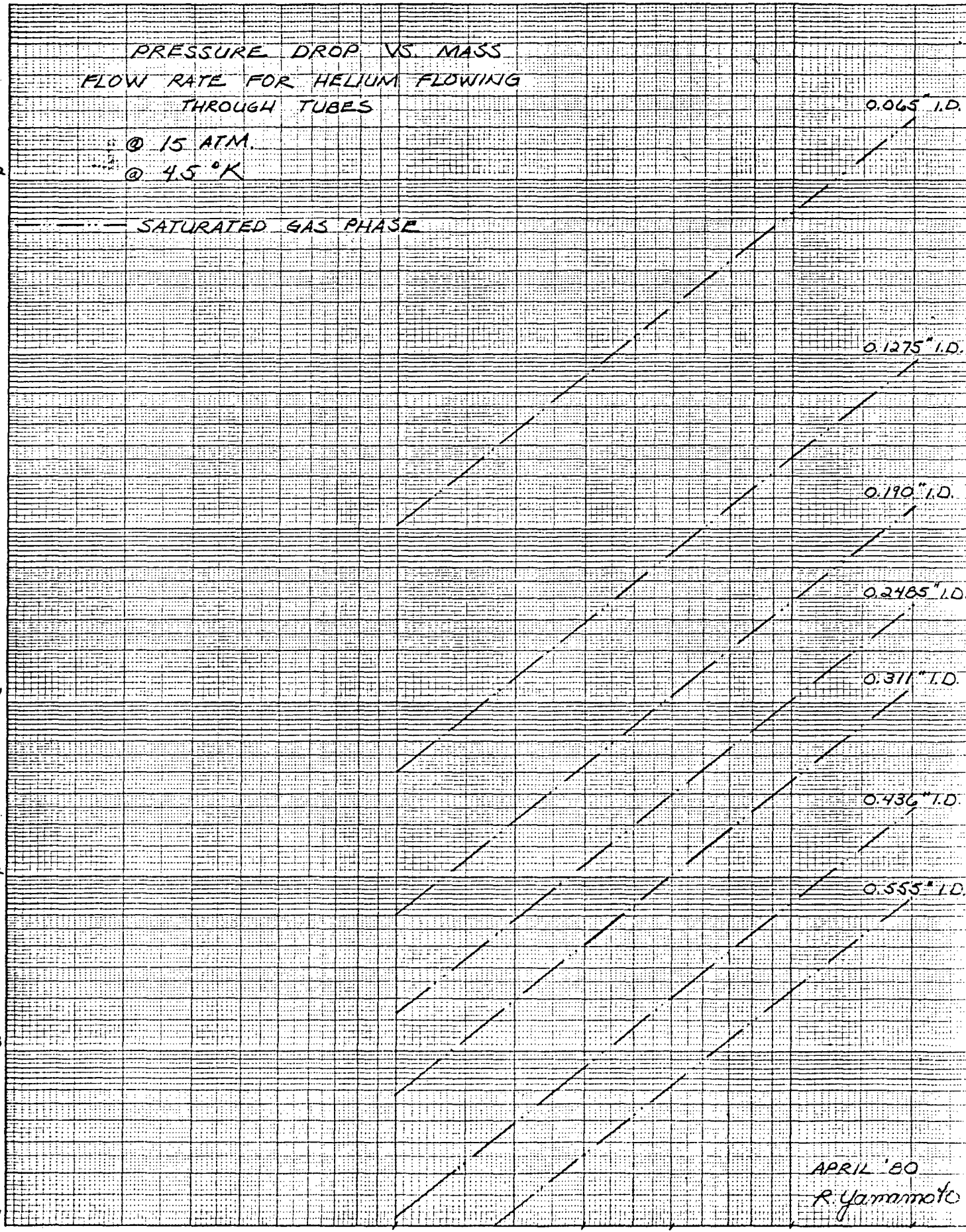
0.311" I.D.

0.436" I.D.

0.555" I.D.

APRIL '80

R. Yamamoto



PRESSURE DROP VS. MASS
FLOW RATE FOR HELIUM FLOWING
THROUGH TUBES

@ 15 ATM
@ 4.5° K

----- SATURATED GAS PHASE

PRESSURE DROP
PSI/METER

10²
10
1
10⁻¹
10⁻²
10⁻³
10⁻⁴
10⁻⁵

10 20 40 60 80 100

MASS FLOW RATE grams/sec

0.110" I.D.

0.2485" I.D.

0.311" I.D.

0.436" I.D.

0.555" I.D.

0.666" I.D.

0.785" I.D.

0.904" I.D.

1.025" I.D.

1.146" I.D.

1.265" I.D.

1.370" I.D.

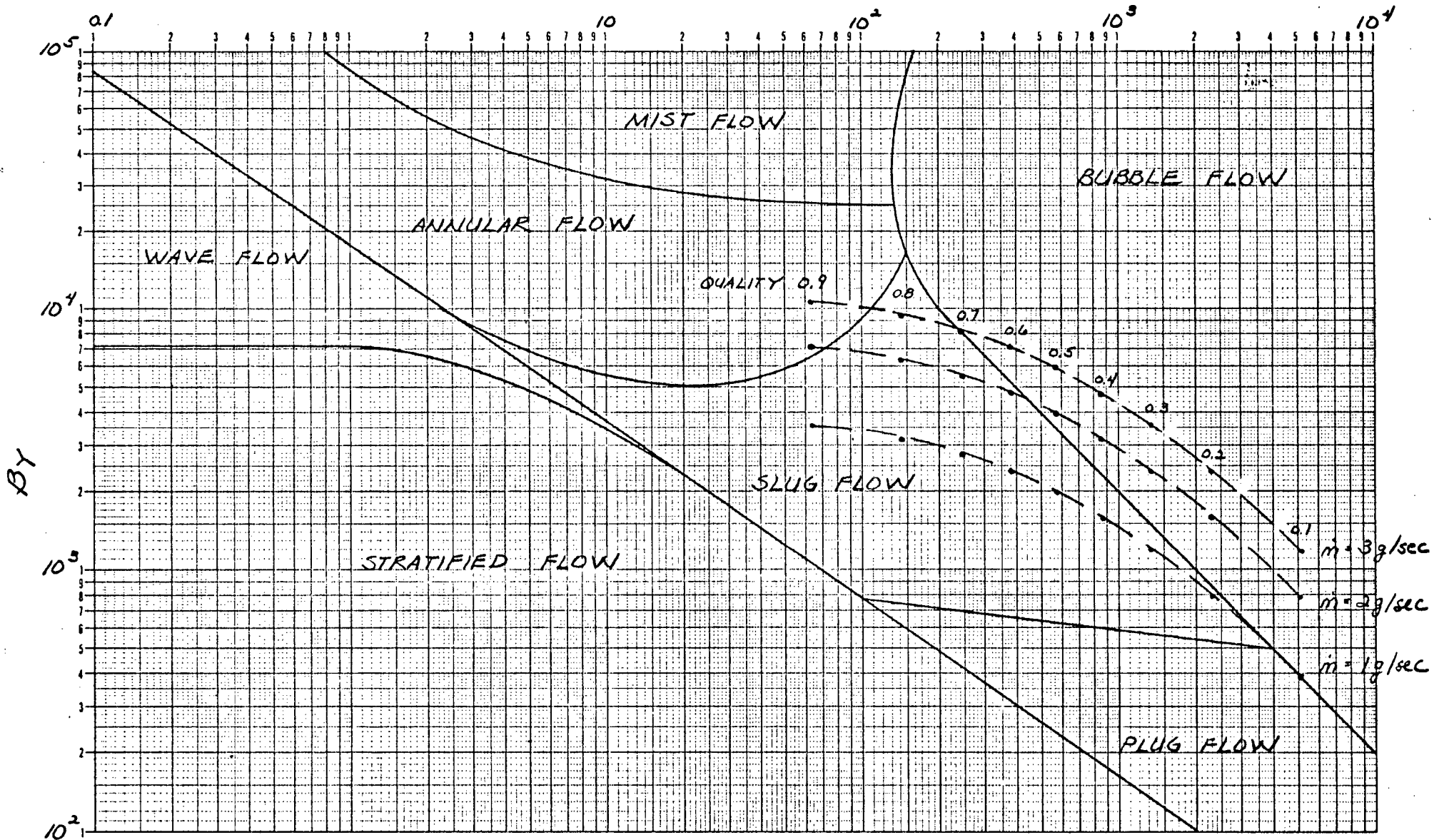
1.520" I.D.

1.870" I.D.

2.370" I.D.

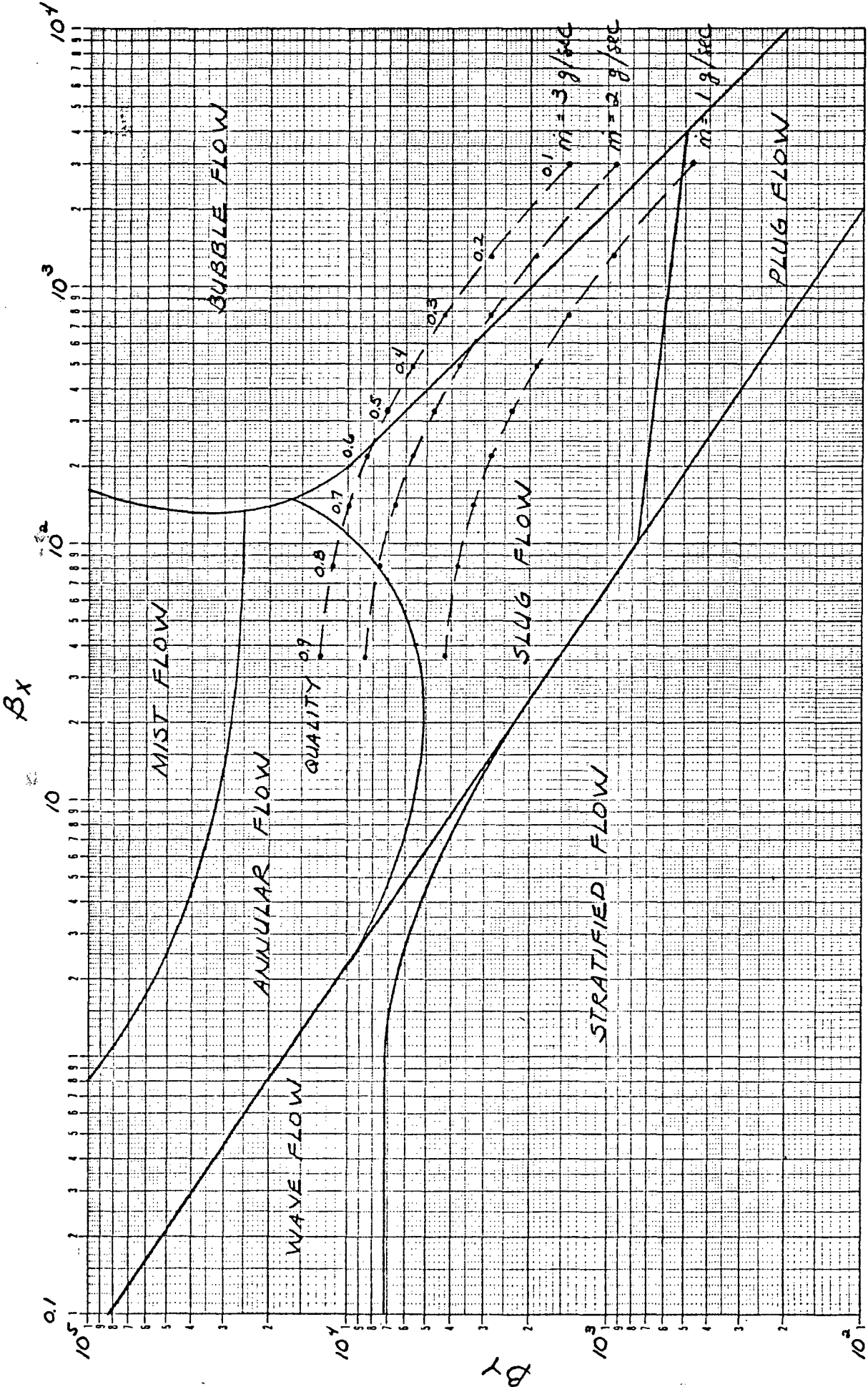
APRIL '80
R. Yamamoto

B_x



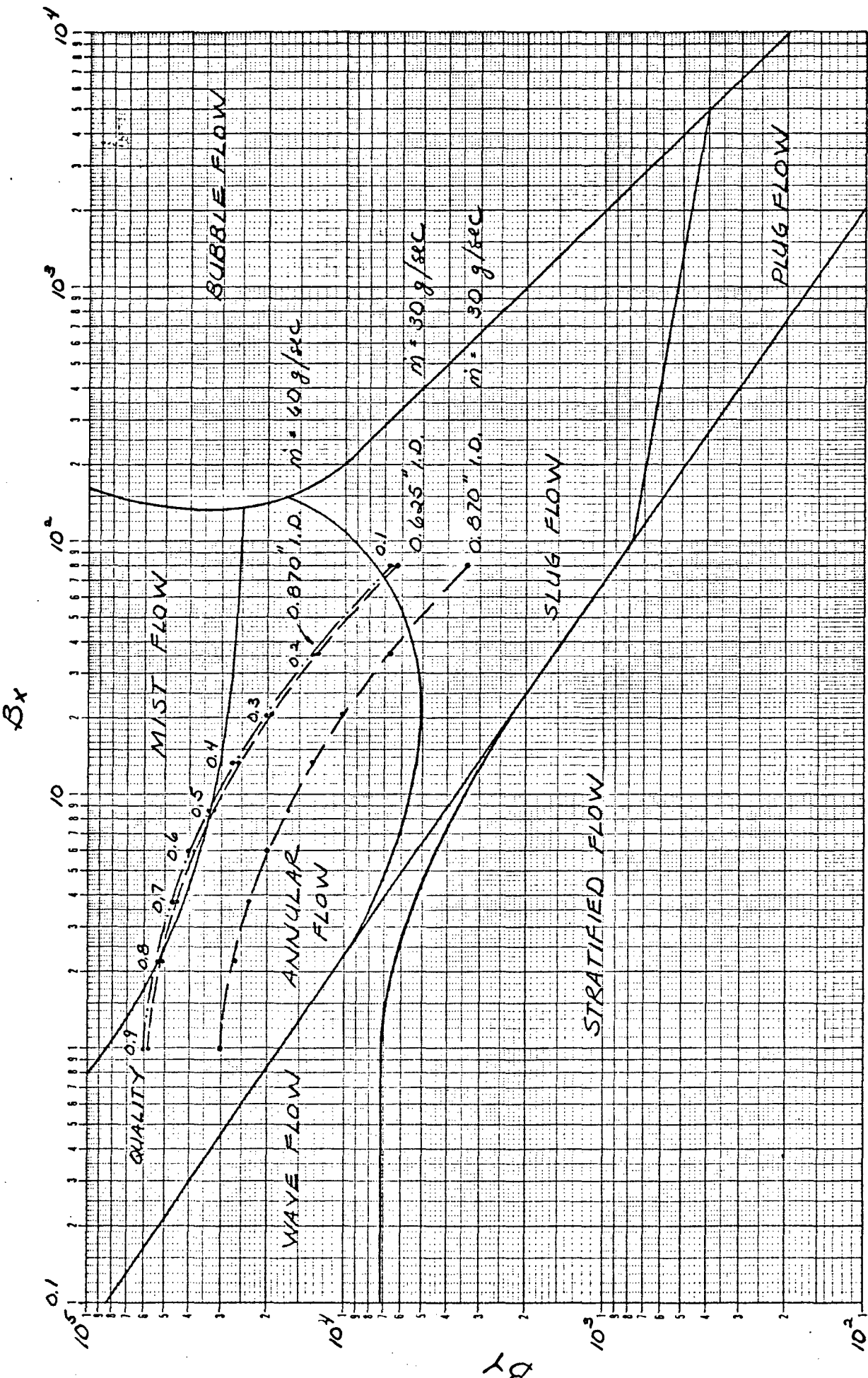
BAKER DIAGRAM FOR TWO-PHASE FLOW

— HELIUM @ 4.2°K, 1 ATM —
1.339 cm I.D. TUBE



BAKER DIAGRAM FOR TWO-PHASE FLOW

— HELIUM @ 3.8°K, 1 ATM —
1.339 cm I.D. TUBE



BAKER DIAGRAM FOR TWO-PHASE FLOW

— NITROGEN @ 77°K, 1 ATM —

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