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(1) For a very extensive compilation of cryogenic properties, see Cryogenic Materials Data Handbook Report No. AFML-TDR-64-280 (Rev. 1970) published by Air Forced Materials Lab., Wright-Patterson A.F.B. (in LBL Engineering Library).

(2) For an extensive reference on elastomer seals, see Engineering Note M5109 by E. J. Bely.

/nh

General: Pressure-deflection relations for a few rubber and synthetic gaskets of different proportions are summarized on the attached graphs. These data provide a basis for estimating the static loads required to deform gaskets of the same cross-section and durometer hardness as those tested.

Testing Procedure: The tests were made on a 60,000 lb. Riehle compression machine in the Engineering Materials Laboratory on the campus, using the 0-3000 lb. scale. The gasket material was placed on the compression plates, which are heavy steel discs 10 inches in diameter. There was no constraint imposed on the gaskets, except for the frictional forces on the load-bearing surfaces.

Some of the data were obtained at a deformation rate of 0.03 inches per minute. Other data were recorded by a "static" procedure, the load being read after the gasket had remained at a given deformation for 30 seconds.

Remarks:

(a) Speed of deformation had a marked effect on the test results, as will be noted from curve "C" for 1/16 X 1/2 Hycar strips. The data obtained by the "static" loading procedure can be used to estimate forces required to maintain a given deflection for a short time. Cold flow of the loaded gasket will relieve the force after a time, but no data were taken on the magnitude of this effect. The data taken at a .03 inches per minute loading rate will give high values of the load required for a static deformation.

(b) To estimate the effect of end constraint--e.g., a continuous gasket as is generally used--different lengths of gasket were tested, both dry and lubricated with Lubriseal. The results show that there is a considerable effect, which increases as the deformation increases. If these results are applied to continuous gaskets, the loads taken from the attached curves should be increased. The amount of the increase is not known definitely without further tests.

(c) The effect of gasket grooves was not investigated. It is obvious that grooves, or any additional constraint in general, will increase the load required for a given deflection.

(d) For the attached curves, pressures are based on the undeformed load area and deflections on per cent of undeformed thickness in the direction of the load.

Example: 1/4" square gasket, 8" long

Load area = 1/4 X 8 = 2 in.^{2}

Pressure = $\frac{\text{Load}}{2}$ in p.s.i.

Deflection of 0.10" = $\frac{0.10}{0.25}$ X 100 = 40%

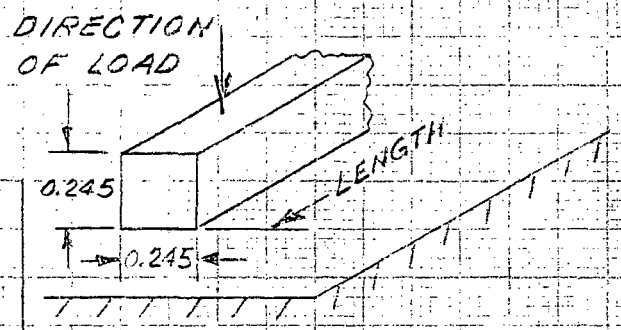
E.D.Kane

EDK:E/ah

PRESSURE-DEFLECTION CURES FOR RUBBER GASKETS

Design Data No. 1
E. D. Kane
5-20-46
Redrawn: 11-17-50

1/4" SQUARE GASKET

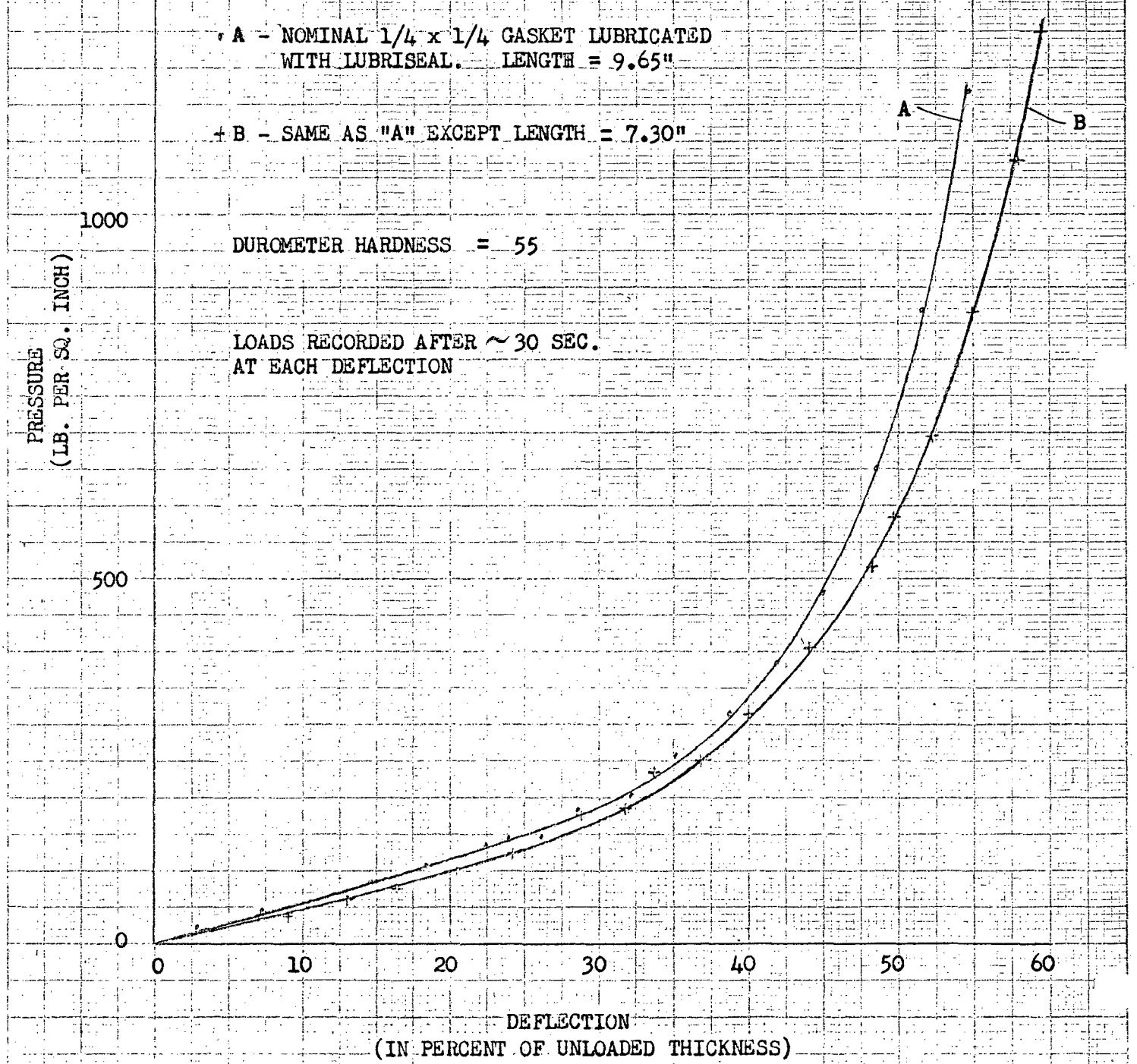


• A - NOMINAL 1/4 x 1/4 GASKET LUBRICATED WITH LUBRISEAL. LENGTH = 9.65"

+ B - SAME AS "A" EXCEPT LENGTH = 7.30"

DUROMETER HARDNESS = 55

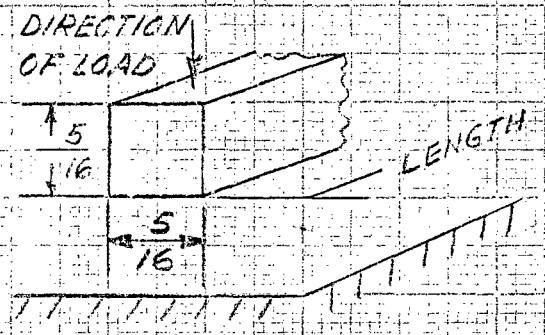
LOADS RECORDED AFTER ~30 SEC. AT EACH DEFLECTION



EK 5-46

PRESSURE-DEFLECTION CURVES FOR RUBBER GASKETS

5/16 SQUARE GASKET

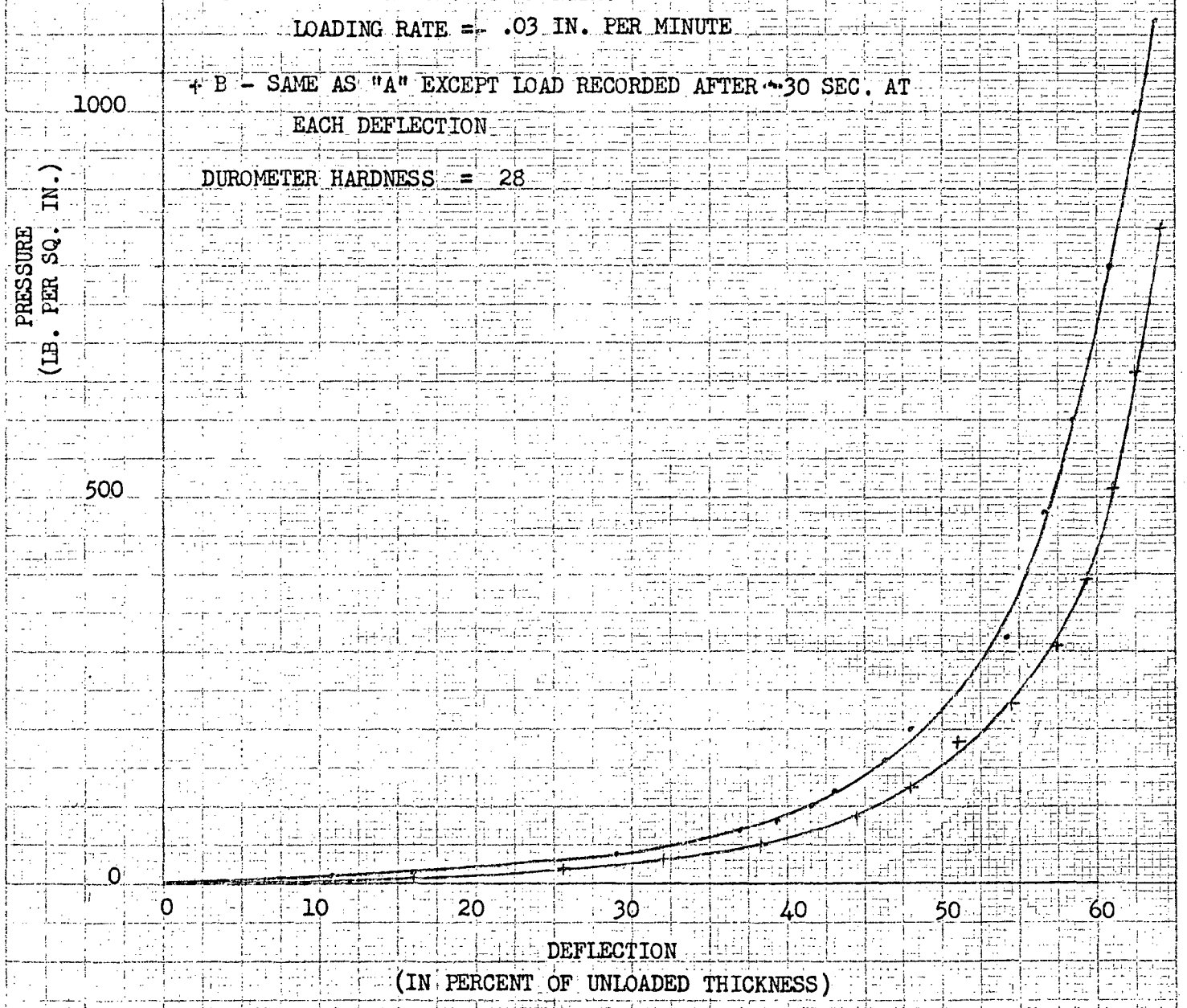


MATERIAL - SILICONE RUBBER

•A - NO LUBRICATION. 8" LENGTH.
LOADING RATE = .03 IN. PER MINUTE

+ B - SAME AS "A" EXCEPT LOAD RECORDED AFTER ~30 SEC. AT EACH DEFLECTION

DUROMETER HARDNESS = 28



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PRESSURE-DEFLECTION CURVES FOR RUBBER GASKETS

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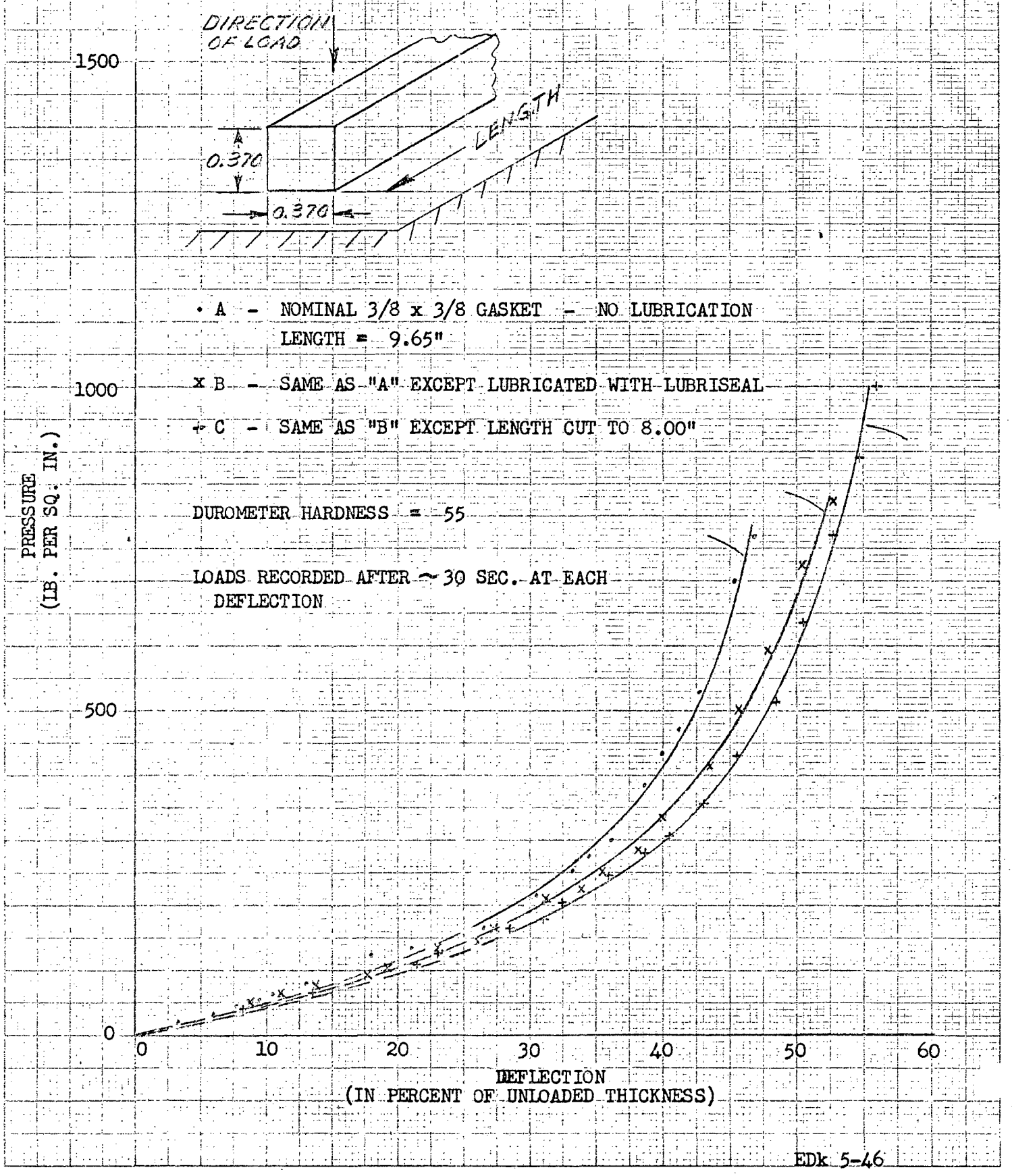
3/8" SQUARE GASKET



• A - NOMINAL 3/8 x 3/8 GASKET - NO LUBRICATION
LENGTH = 9.65"

x B - SAME AS "A" EXCEPT LUBRICATED WITH LUBRISEAL

+ C - SAME AS "B" EXCEPT LENGTH CUT TO 8.00"

DUROMETER HARDNESS = 55

LOADS RECORDED AFTER ~ 30 SEC. AT EACH DEFLECTION

EDk 5-46

PRESSURE-DEFLECTION CURVES FOR RUBBER GASKETS

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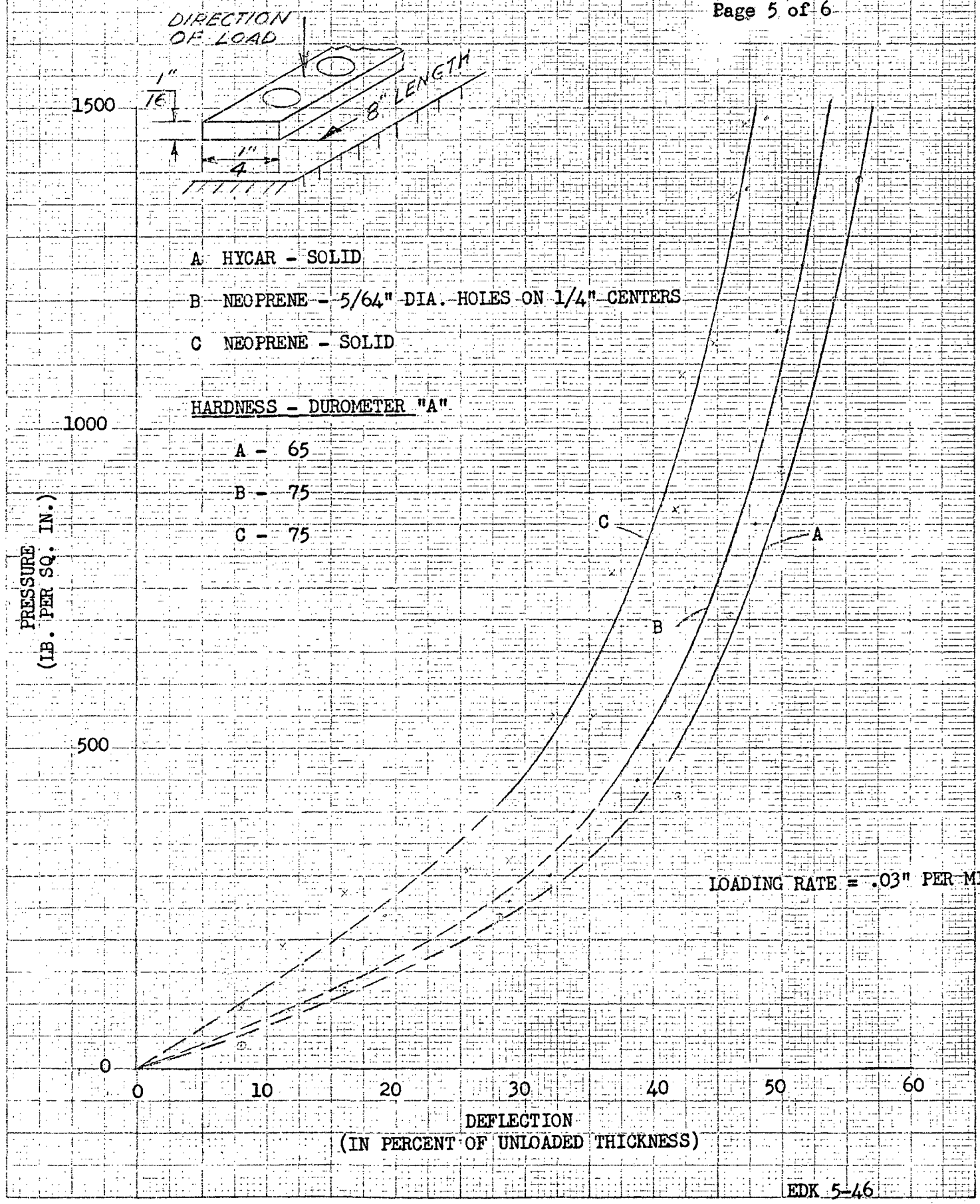
THIN GASKETS



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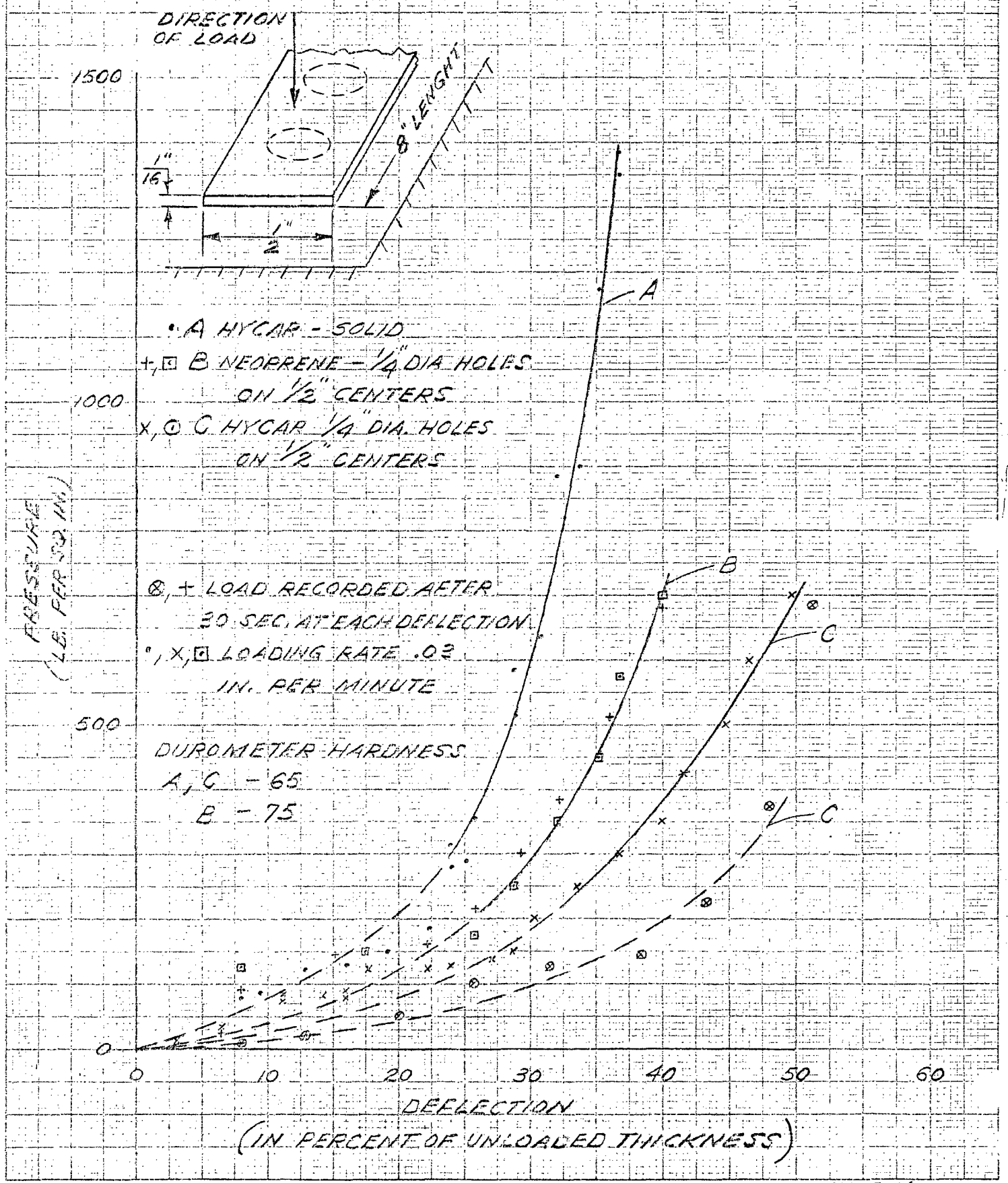
PRESSURE - DEFLECTION CURVES FOR THIN GASKETS



Note: Accuracy of better than ±20% cannot be expected.

1. Natural Convection (Reference: McAdams, "Heat Transmission," 1933, p.244)

M = Heat transfer rate $\frac{\text{watts}}{\text{in}^2}$ θ = temperature rise °C

$$M = 0.0013 \quad \theta^{1.25}$$

This formula applies to vertical plane surfaces over a foot high. Heat transfer rate is increased about 30% for horizontal surfaces facing upward and decreased about 30% for horizontal surfaces facing downward.

This formula applies to horizontal cylinders of 4 ft. diameter. Heat transfer rate varies inversely with fourth root of diameter down to 1/2" diameter.

Transfer from natural convection may be affected considerably by obstructions to circulation such as ledges, offsets, etc.

2. Radiation

For a body small compared to its surroundings:

$$M = 36.7 \quad P \left[\left(\frac{T_1}{1000}\right)^4 - \left(\frac{T_2}{1000}\right)^4\right] \approx 0.147 \quad P \left(\frac{T_{av}}{1000}\right)^3 \theta$$

Approximate form is correct to a few per cent between 0 and 100 C.
P is emissivity of body, M is watts/in.^{2} for body, T is degrees K (°C+273)

$$P = \frac{1}{\frac{1}{P_1} + \frac{1}{P_2} - 1}$$ if body is large compared to enclosure or for close parallel surfaces.

3. Forced Convection (Reference: McAdams, "Heat Transmission," 1933, p.237)

Below V = 16 ft./sec. $\frac{M}{\theta} = 0.0037\ (1+0.2V)\ \frac{\text{watts}}{\text{in.}^2\ {}^\circ\text{C}}$

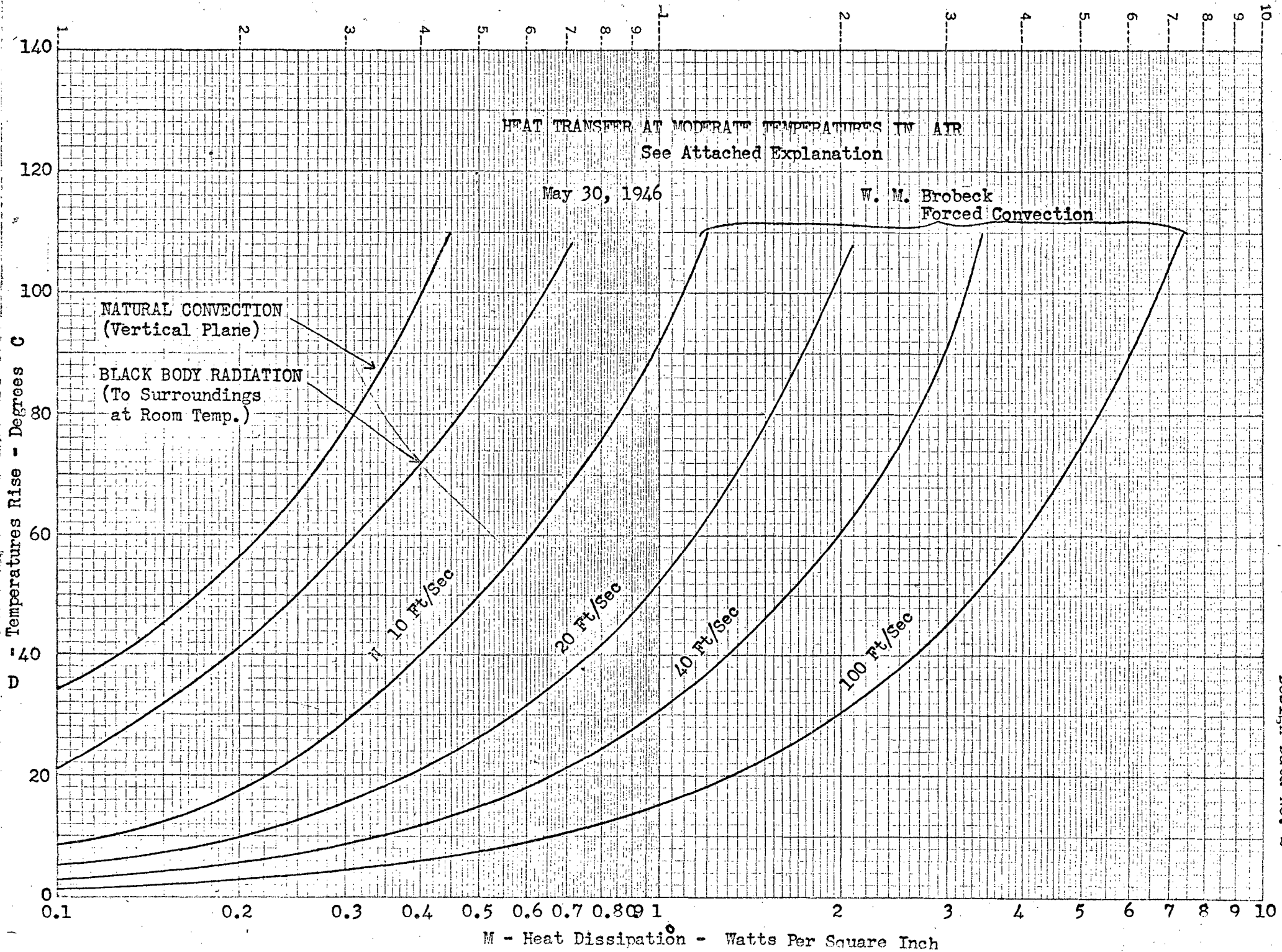
Above V = 16 ft./sec. $\frac{M}{\theta} = 0.0018\ V^{0.78}\ \frac{\text{watts}}{\text{in.}^2\ {}^\circ\text{C}}$

"Rough" surfaces increase transfer about 10%.

Increasing velocity above 100 ft./sec. (where velocity head = $2\frac{1}{4}$ inches of water) will usually be found uneconomical.

WMB:E:ah W. M. Brobeck

KEUFFEL & ESSER CO., N. Y. NO. 359-61
Semi-Logarithmic. 2 cycles × 10 to the inch. 5th lines accented.
MADE IN U. S. A.



RADIATION LABORATORY - UNIVERSITY OF CALIFORNIA - BERKELEY

DESIGN DATA

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ORIGINAL 9-10-46 REDRAWN 3-3-52	5	1

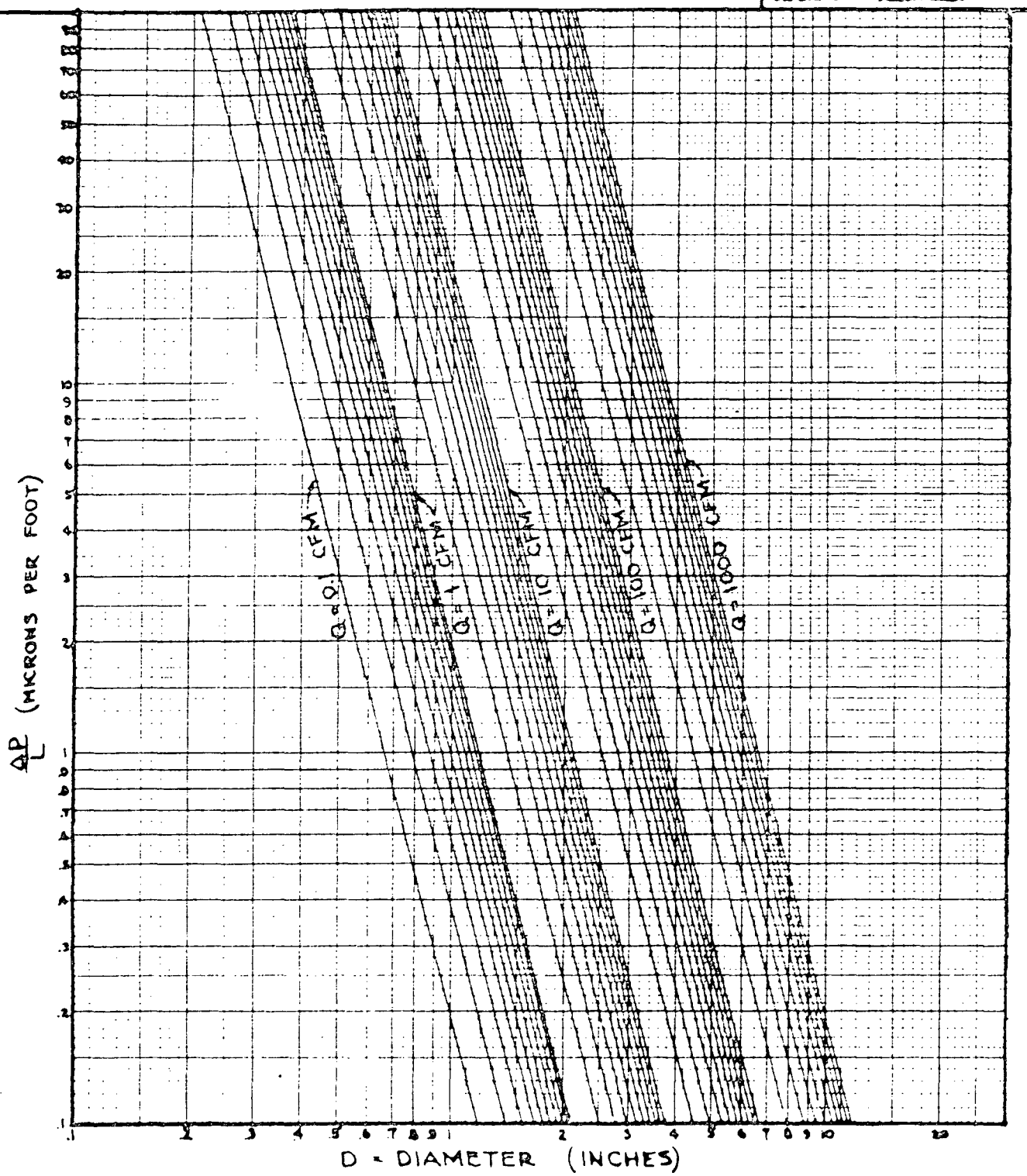
SUBJECT

PRESSURE DROP IN FOREVACUUM PIPES FOR STREAMLINE FLOW

PREPARED W. M. BROOCCK

CHECKED BY

DRAWN BY SERGMILLER



CURVES ARE BASED ON FOLLOWING FORMULA:

$$\frac{\Delta P}{L} = 1.93 \frac{Q}{D^4}$$ FOR AIR AT 20°C & UNITS USED HEREIN

FOR OTHER GASES OR TEMPERATURES, MULTIPLY THE ABOVE $\frac{\Delta P}{L}$ BY THE RATIO OF THE ABSOLUTE VISCOSITY OF THE GAS

CONDITIONS FOR STREAMLINE FLOW:
(ALSO CALLED VISCOUS FLOW)

1 REYNOLDS NO < 2000

2 $P > \frac{200}{D}$ (P IN MICRONS) (D IN INCHES)

SUBJECT

PROPERTIES OF SELECTED CERAMIC MATERIALS

PREPARED R. Reimers

CHECKED BY

I. Introduction: Most properties in this paper were taken from brochures, catalogs, and handbooks. These values will often be different from those found in scientific literature because the commercial ceramics have various purities which affect the properties. Scientific literature is usually concerned with the properties of high purity materials. This paper is written primarily for designers and is only as accurate as the catalogs themselves. Some catalog data have been multiplied by conversion factors.

II. References:

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4. Chart #651, Mechanical and Elect. Prop. of Alsimag Ceramics, American Lava Corp.
5. Bulletin 951, Coors Porcelain Co., Golden, Colorado, (circa 1965).
6. Brochure, National Beryllia Corp., Haskell, N. J., (dated Nov. 1964).
7. Brochure, "Boron Nitride", Carborundum Corp., Latrobe, Pa.
8. J. Doar (Union Carbide, Parma, Ohio), letter to R. Reimers, Jan. 25, 1966.
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10. ---
11. Catalog H-8745, National Carbon Co., Division of Union Carbide (1963).
12. Bulletin 112DB, National Carbon Co., N. Y.
13. Bulletin #106EB, National Carbon Co., N. Y.
14. Letter, dated April 30, 1963, W. Redanz to R. Reimers (Vapor Pressure of BN).
15. W. Kohl, Handbook of Materials and Techniques for Vacuum Devices (Reinhold Pub., New York, 3rd Ed., 1967), pp. 61-117.
16. W. D. Kingery, Introduction to Ceramics, (Wiley, N. Y., 1960).
17. J. Fredrickson and W. Redanz, Boron Nitride for Aerospace Applications, Union Carbide Corp., paper presented before ASM, Orlando, Florida, (April 1964).
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23. Fused Quartz Catalog, General Electric, Willoughby, Ohio, (Received 1-65).
24. Brochure, Engineering with Glass, Corning Glass Works, pp. 26-27, (Received 4-19-66).
25. Brochure, U. S. Fused Quartz Co., Date Unknown, (Received 2-66).
26. Catalog, Thermal American Fused Quartz Co., Date Unknown, (Received 5-66).
27. R. B. Scott, Cryogenic Engineering, Van Nostrand, 1959, pp. 343-345.
28. Bulletin #F917C, Linde Co., "Synthetic Sapphire".
29. R. Reimers, "Thermal Conductivity of Sapphire", LRL Engr. Note M3738B, Rev. 11-3-66.
30. R. Reimers, "Thermal Conductivity of Hot Pressed BN at Low Temperature", LRL Engr. Note M3691A, Rev. 1-68.
31. Wright Air Development Div. Report TR 60-56, part II, p. 3.112-1, "Thermal Conductivity of Copper".
32. LRL M. E. Dept. Design Data Sheet #63, R. Nickerson, 11/52.
33. Thermophysical Prop. of High Temp. Matls., Vol. 6, Part II, MacMillan, 1967, U.C. Cat. TA407G.

Alumina Ceramic -- Commercially Available

See Footnote								
	% Purity	85	94	95	96	97.6	98	99.5
(1)	Company	AM,C	AM,C,W	AL,NB	AM,C	W	AM,C	AM,C,NB,W
(2)	Reference	4,5	3,4,5	1,6	4,5	3	4,5	3,4,5,6
	Density (gm per cc)	3.40-3.42	3.58-3.67	3.5-3.69	3.70-3.72	3.76	3.72-3.78	3.84-3.9
	% Water Absorption	0	0	0	0	0	0	.02 Max (NB)
(3)	Tensile Strength (psi)	17,000(20°C) 8,000(1093°C)	20,000(20°C) 9,000(1093°C)	31,000 -	25,000(20°C) 13,000(1093°C)	- -	20,000 -	28,000 -
(3)	Compressive (psi)	240,000	300,000	250,000	375,000	250,000	325,000	300,000
(4)	Flexural Strength (psi)	35,000	46,000(20°C)	45,000	47,000(20°C)	43,000	35,000(20°C)	43,000(20°C)
(3)	Young's Mod. (psi)	33×10^6	41×10^6	41×10^6	44×10^6	-	49×10^6	52×10^6
	Hardness (mohs)	9	9	9	9	9	9	9
	Hardness (Rockwell 45N)	72-75	74-78	-	78	-	73-74	81
(5)	Coeff. Expansion (in./in°C) (See Design Data #78 and American Lava (ref. 3 and Coors Bulletin 951 for more detail.)	7.5×10^{-6}	8.0×10^{-6}	-	8.2×10^{-6}		8.3×10^{-6}	8.4×10^{-6}
(8)	Thermal Conductivity (watts $cm^{-1}°C^{-1}$ @ 25°C)	.15-.23	.18-.305	.208-.295	.180-.352	-	.257-.352	.294-.369
	Melting Point (°C)	-	-	1699	-	-	-	2038
	Max. Working Temp. (°C)	1100-1400	1500-1700	1482-1593	1550-1700	1650	1600-1700	1650-1750
	Specific Heat (cal/gm°C)	.22(100°C)	.21(100°C)	.19	.21(100°C)	.21(100°C)	.21(100°C)	.21(100°C)
	(watt sec/lb°C)	418	399	361	399	399	399	399
(6)	Dielectric Const.	8.2-8.3(25°C)	8.9(25°C)	8.84-9.3	9.0-9.1(25°C)	9.53(25°C)	9.2-9.4(25°C)	9.4-9.7(25°C)
	@ 1 Mc unless noted)	15.3(800°C)	24.(800°C)	-	22.4(800°C)	@ 10 Mc	15.8(800°C)	10.7(800°C)
(6,7)	Dielectric Strength (volts/mil)	230 rms 60 cps	230 rms 60 cps	180-340 .125 thk. spec.	230 rms 60 cps	-	230	220-340 various spec. thkn.
(6,3)	Resistivity 25°C	10^{14}	10^{14}	10^{14}(25°C)	10^{14}	10^{14}	10^{14}	10^{14} - 10^{15}
	(Ohm cm) 900°C	4×10^5	$.35 \times 10^7$-3.2×10^7	-	6.8×10^5	5×10^8	7.1×10^7	$.25 \times 10^7$-4.7×10^7
	Loss Factor 25°C	.0033-.007	.001-0018	-	.001-.0027	-	.001-.0018	.0009-.001
(6)	@ 1 Mc	(Strongly dependent on frequency and temperature.)						

Footnotes:

(1) AM = American Lava; C = Coors Porcelain; W = Western Gold & Platinum; AL = Alberox; NB = National Beryllia.

(2) References are given on page 1.

(3) Values are minima found in catalogs.

(4) Defined as maximum stress in extreme fiber under bending load ends supported; see ref 15, p 62.

(5) Expansion values from Coors Bulletin 951.

(6) Electrical properties may depend upon both frequency and temperature. The following references (see p 1) contain graphs and charts which show the temperature and frequency dependence of various electrical properties: 4, 5, 6.

(7) Thickness of test specimen affects values obtained. Specimen .250 inches thick, unless noted.

(8) See page 5 for temperature dependence.

BORON NITRIDE---COMMERCIALLY AVAILABLE

Grade	A (Std)	M	HP (High Purity) No SiO_2
% Composition	93.5 BN; 4-6 O_2; 5-8 B_2O_3 No Silica	40 BN; ≈60 SiO_2; other <.3; No Detectable O_2	95.5 BN; 1.5-2.5 O_2; <.1 B_2O_3
Manufacturer	Carborundum Co.		
References (See pg 1 of this paper)	1	1	1
May be metallized?	?	Yes	?
Density (gm/cc) avg	2.08	2.12	1.90
Water absorption (% weight gain @ 90% R.H.	1.1 in 168 hrs	0.04 in 168 hrs	0.16 in 168 hrs
Toxicity	Nontoxic	Nontoxic	Nontoxic
Tensile strength (psi) @ 25°C, Dir. A	5750	-	-
" " " " Dir. B Unless noted	9000	-	-
Compressive strength (psi) @ 25°C to press'g. direction	45000	46,000	16,000
" " " " to press'g. direction	34000	42,000	15,000
Flexural strength (psi)	11705 ∥ to press'g direction 13940 ⊥ to press'g. direction	14200 ∥ to press'g. direction 15400 ⊥ to press'g. direction 25°C	7665 ∥ to press'g. direction 6350 ⊥ to press'g. direction
Young's modulus (millions of psi) @ 25°C to press'g. direct.	9.4	13.6	6.2
" " " " " "	6.0	15.4	11.4
Hardness (on scale indicated)	385 (Knoop 100); 2 (MOHS)	89.5 (Rockwell 15T)	205 (Knoop 100)
Coeff. of expansion (°C-1) to press'g. direction	75-500°C, 2.3×10^{-6}, 75-2000°C, 6.2×10^{-6}	75-500°C, 1.80×10^{-6}; 75-1000°C, 2.50×10^{-6}	75-1000°C, 0; 75-2000°C, 0.7×10^{3}
" " " " "	1.1×10^{-6} " 2.0×10^{-6}	" $.20 \times 10^{-6}$; " $.40 \times 10^{-6}$	" 0; " 1.3×10^{3}
Machining comments	Machines easily	Use carbide tool	Machines easily but is soft
Has been used at LRL?	Yes - taps well	Maybe	Yes
Thermal conductivity (cal $sec^{-1}cm^{-1}°C^{-1}$	∥ .055, ⊥ .105 (100°C)	∥ .023, ⊥ .060; (100°C)	∥ .145, ⊥ .095; (100°C)
" " (watt $cm^{-1}°C^{-1}$)	∥ .230 ⊥ .440 (100°C)	∥ .0964, ⊥ .252; (100°C)	∥ .609, ⊥ .398; (100°C)
Melting point (°C)	-	-	-
Max working temp (°C)	2775 (inert or reducing atm) 985 ox. atm.	1400 (oxidizing or inert)	2775 (inert atm)
Specific heat (cal/gm°C)	.278 (182°C)	-	-
" " (watt sec/lb°C)	528	-	-
Dielectric constant (@ 25°C, 1 Mc unless noted)	4.08 (ASTM D150)	3.7 (ASTM D150)	4.1 @ 1 Kc (Astm D150)
Dielectric strength (volts/mil)	950 (ASTM D257)	986 (ASTM D149)	790 (ASTM D149)
Volume resistivity (@ 20°C, in Ohm cm)	(23°C) > 2×10^{14} (ASTM D257)	> 2.5×10^{14} (25°C)(ASTM D257)	1.6×10^{12} (ASTM D257)
Loss factor (@ 1 Mc unless noted)	.00139 (ASTM D150)	.006	.0045 @ 1 Kc (ASTM D150)

Notes:

Available sizes: Types HBR, HBN: round, .125 to 14 dia; 6, 12 or 18 in. long; rectangular, .125 x .125 to 10 x 10; plate 1/4 x 10 to 1 x 10; also wafers. Pyrolytic: crucibles, boats, dishes in catalog. Also disks 1-3 in. dia x .062 - .500 thick and rectangular pieces up to 2 x 4 x 2.5 or 2 x 3 x .5
Grades A, HP: round, .125 to 14 dia; 6, 12 or 18 in. long; rectangular, .125 sq to 10 sq; plate .5 x 3 x 1 x 10;
Grade M: round, .125 to 9 dia, 5 in. long; .125 sq to 6 sq, 5 in. long

Vapor Pressure: Carborundum Co. (believed to be GradeA material): 1.45×10^{-4} torr (2031°K); 1.51×10^{-6} (1777°K): 8.86×10^{-7} (1465°K), date believed to be Jan. 1964. More and better data needed. W. Redanz (Union Carbide) said that at 2000°C, vapor pressure is > 10^{-2} torr. Author feels this may be questionable data. See page 6.

Prices: About $8.00 per cubic inch in diameter > 1 in.; costs up to $100.00 per cu in. for small diameters and down to ≈ $5/in^3 for 10" diameters.

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5 of 5

BORON NITRIDE---COMMERCIALLY AVAILABLE

Grade	HBN (Std Grade)	HBR (Premium Grade)
% Composition	95.5-97 BN; 3.9 max O_2; 0.4 max Carbon	
Manufacturer	National Carbon Co., Division of Union Carbide	
References (See pg 1 of this paper)	11,17	17
May be metallized?	?	?
Density (GM/CC) avg	2.0	1.85
Water absorption (% weight gain @ 90% R.H.	3.3 max	.4 in 312 hrs
Toxicity	Nontoxic	Nontoxic
Tensile strength (psi @ 25°C, Dir. A	6500	-
" " Dir. B, unless noted	8000	-
Compressive strength (psi) @ 25°C ∥ to press'g. direction	27,500 Dir. A	-
" " " ⊥ to press'g. direction	26,500 Dir. B	-
Flexural strength (psi)	16,000(0°C); 4000(800-1500°C) 10,000(2000°C)	16,000(0°C); 5000(900-1500°C) 10,000(2000°C)
Young's modulus (millions of psi) @ 25°C ∥ press'g. direction	11- Dir. A	-
" " " " ⊥ " "	9- Dir. B	-
Hardness (on scale indicated)	-	-
Coeff. of expansion (°C^{-1}) ∥ to press'g. direction	$\Delta L/L$ = .0082 from 0°C-1800°C	$\Delta L/L$ = .0028 from 0°-1800°C
" " " ⊥ to press'g. direction	$\Delta L/L$ = .0150 " "	$\Delta L/L$ = .0058 " "
	has hysteresis - see ref. 17	has hysteresis - see ref. 17
Machining comments	Machinable	Machinable
Has been used at LRL?	Maybe	Yes
Thermal conductivity (cal sec^{-1}cm^{-1}°C	-	-
" " (watt cm^{-1}°C^{-1})	⊥ to press'g. dir.: .109(1649°C)	-
Melting point (°C)	-	-
Max. working temp.(°C)	2400	-
Specific heat (cal/gm°C)	-	-
" " (watt sec/lb°C)		
Dielectric constant (@ 25°C, 1 Mc unless noted)	4.39-4.52 (0-500°C) Dir. A & B same	-
Dielectric strength (volts/mil)		-
Volume resistivity (@ 20°C, in Ohm cm)	-	-
Loss factor (@ 1 Mc unless noted)	-	-

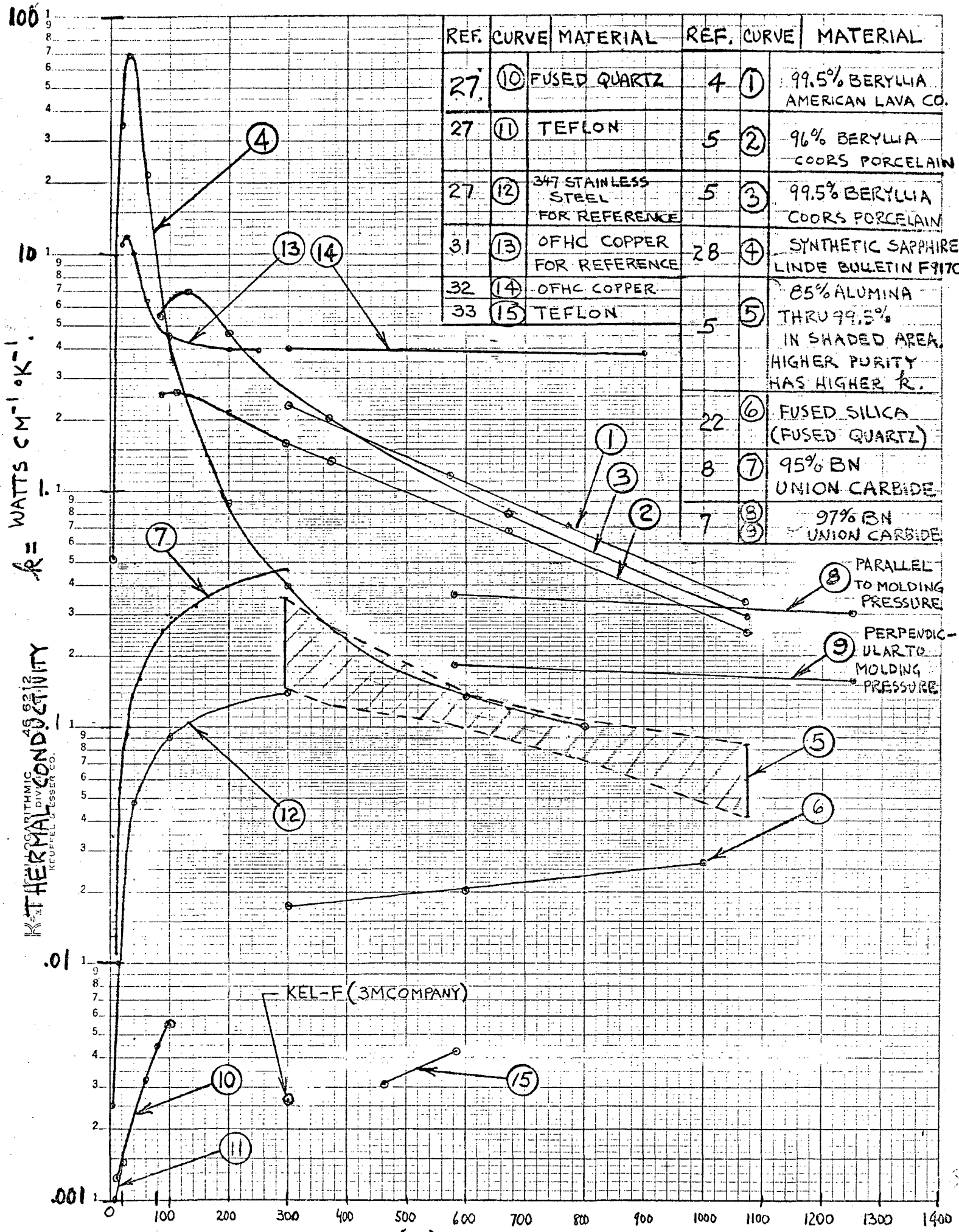
81 0/2

BERYLLIA, FUSED QUARTZ AND SYNTHETIC SAPPHIRE---COMMERCIALLY AVAILABLE

	Composition - % by weight	96% Beryllia	98% Beryllia	99% Beryllia	99.5% Beryllia	99.5% Beryllia	>99.9% Alumina Synthetic Sapphire	(Fused Silica) Fused Quartz ≈99.8% (ref 25)
(1)	Manufacturer	C	C	NB	AM	C	UC	GE,E,US,TA,CO
(2)	Reference Number	5	5	6	4	5	15(p 86), 20	22,23,24,25,26
	Density (gm/cc typical)	2.85	2.85	2.85	2.88	2.85	3.98	2.2
(9,3)	Tensile Strength (psi)	N.M.	N.M.	-	-	N.M.	58,000(20°C);40,000(500°C)	800-7000 (refs 23,25,26)
(3)	Compressive Strength (psi)	225,000	225,000	200,000	185,000 min	225,000	300,000	>160,000 (ref 23)
(4)	Flexural Strength (psi)	20,000(20°C); 9000(2000°F)	25,000(20°C) 13,000(2000°F)	30,000	25,000	25,000(20°C); 13,000(2000°F)	*	-
(3)	Young's Modulus (psi)	44×10^6	45×10^6	45×10^6	-	51×10^6	50×10^6 - 56×10^6	9.7×10^6 - 10.5×10^6
	Hardness	64(Rockwell 45N)	64(Rockwell 45N)	9 (mohs)	65(Rockwell 45N)	64(Rockwell 45N)	9(mohs)	4.9-7 (refs 22,26)
(5)	Coeff. expansion (in./in°C) Avg over range 25-1000°C unless noted)	10.1×10^{-6}	9.2×10^{-6}	9×10^{-6}	8.5×10^{-6}	9.2×10^{-6}	8.4×10^{-6} (60° orientation to crystal axis)	5.4×10^{-7} (ref 25); 9.57×10^{-6} (20°C)
(8)	Thermal Conductivity (cal (sec cm°C)/@ 20°C)	.38	.49	-	.55	.60	0.11(0°C)	.0033 - .0041
(8)	Thermal Conductivity (watts/cm°C @ 20°C)	1.60	2.06	2.43 (25°C)	2.30	2.52	.461	.0138 - .0172
	Melting point (°C)	-	-	2566	-	-	2040	Anneals 1070-1140 (refs 23-26)
	Max. work. temp. (°C)	1700	1800	2204	1600	1850	*	900 (ref 24)
	Specific heat (cal/gm°C	.30 (100°C)	.30(100°C)	.24(20°C)	-	.31(100°C)		.08(115°K); .29(1000°K)
	Specific heat (watt sec/lb°C)	570(100°C)	570(100°C)	455(20°C)	-	588(100°C)	.18	152(115°K); 551(1000°K)
(6)	Dielectric Constant @ 1 Mc, R.T.	6.6	6.5	6.4	6.4	6.7	See references	3.75 (ref 23)
(6) (7)	Dielectric Strength (volts/mil)	240 rms	250 rms	300 (.125 thk. spec.)	240	250 rms	1240	400-410(20°C), (1 Mc, ref 23)
(6)	Resistivity (ohm cm)	$>10^{17}$(25°C)	$>10^{17}$(25°C)	10^{16}(R.T.)	$>10^{14}$	$>10^{17}$	$\approx 10^{11}$(500°C) $\approx 10^{3}$(200°C)	2.5×10^{12}(183°C) ref 22; 6×10^{5}(677°C)
(6)	Loss Factor @ 1 Mc, 25°C	.001	.001	-	.0006	.002	See references	<.0004, 20°C, ref 23

Footnotes:

(1) C = Coors, UC = Union Carbide, NB = National Beryllia, AM = American Lava, E = Englehard, GE = General Electric, US = U.S. Fused Quartz Co., TA = Thermal American Fused Quartz Co. CO = Corning Glass.
(2) References are given on page 1 of this paper.
(3) Values are minima found in catalogs.
(4) Defined as maximum stress in extreme fiber under central point load, ends supported. See page 62, ref. 15. These values are typical.
(5) Expansion values from Coors bulletin 951. See also LRL Design Data 78 and reference 4.
(6) Electrical properties may depend upon both frequency and temperature.
(7) Thickness of test specimen affects value obtained. Specimen .250 thick unless noted.
(8) See page 5 for temperature dependence.
(9) N.M. means Not Measured by manufacturer.
(10) Pyrolytic boron nitride is sold by Union Carbide and its properties which are unusual and anistropic are listed in reference 19. It has a dielectric strength of 4000 volts/mil at 20°C.


k = WATTS CM⁻¹ °K⁻¹
THERMAL CONDUCTIVITY
100
10
1.
.01
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0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
REF. CURVE MATERIAL
27 10 FUSED QUARTZ
27 11 TEFLON
27 12 347 STAINLESS STEEL FOR REFERENCE
31 13 OFHC COPPER FOR REFERENCE
32 14 OFHC COPPER
33 15 TEFLON
REF. CURVE MATERIAL
4 1 99.5% BERYLLIA AMERICAN LAVA CO.
5 2 96% BERYLLIA COORS PORCELAIN
5 3 99.5% BERYLLIA COORS PORCELAIN
28 4 SYNTHETIC SAPPHIRE LINDE BULLETIN F917C.
5 5 85% ALUMINA THRU 99.5% IN SHADED AREA. HIGHER PURITY HAS HIGHER k.
22 6 FUSED SILICA (FUSED QUARTZ)
8 7 95% BN UNION CARBIDE
7 8 9 97% BN UNION CARBIDE
PARALLEL TO MOLDING PRESSURE
PERPENDICULAR TO MOLDING PRESSURE
KEL-F (3M COMPANY)

TITLE	PREPARED BY	DATE
FRICTION LOSS IN PIPES, TUBES AND WATER PASSAGES FOR WATER AT 15.6°C---60°F	R. Peters	47,49,57
	REVISED BY L. E. Brown J. O. Turner	DATE 8/79
(SUPERSEDES D/D 10, 10.1A AND 10.2)	REVISED BY	DATE

Based on information contained in "Cameron Hydraulic Data", 15th Edition, published by Ingersoll Rand Co., 1977.

Values for friction head loss were calculated from the Darcy-Weisbach equation (modified to yield head loss in PSI):-

$$h_f = 0.433 \times \frac{fLV^2}{D2g}$$

where h_f = head loss due to friction, in PSI.

L = length of pipe, in feet.

D = average I.D. of pipe, in feet.

V = fluid velocity in ft/sec.

g = gravitational constant: 32.174 ft/sec^2.

f = friction factor, which is determined as follows:

For laminar flow (R<2000):-

$$f = 64/R$$

where R = Reynolds Number = $\frac{VD}{v}$

v = Kinematic Viscosity for water @ 60°F = 1.216×10^{-5} ft^2/sec.*

Values for f under turbulent flow (R>4000) were calculated from the Colebrook equation:-

$$\frac{1}{\sqrt{f}} = -2 \log_{10} \left(\frac{\epsilon}{3.7D} + \frac{2.51}{R\sqrt{f}} \right)$$

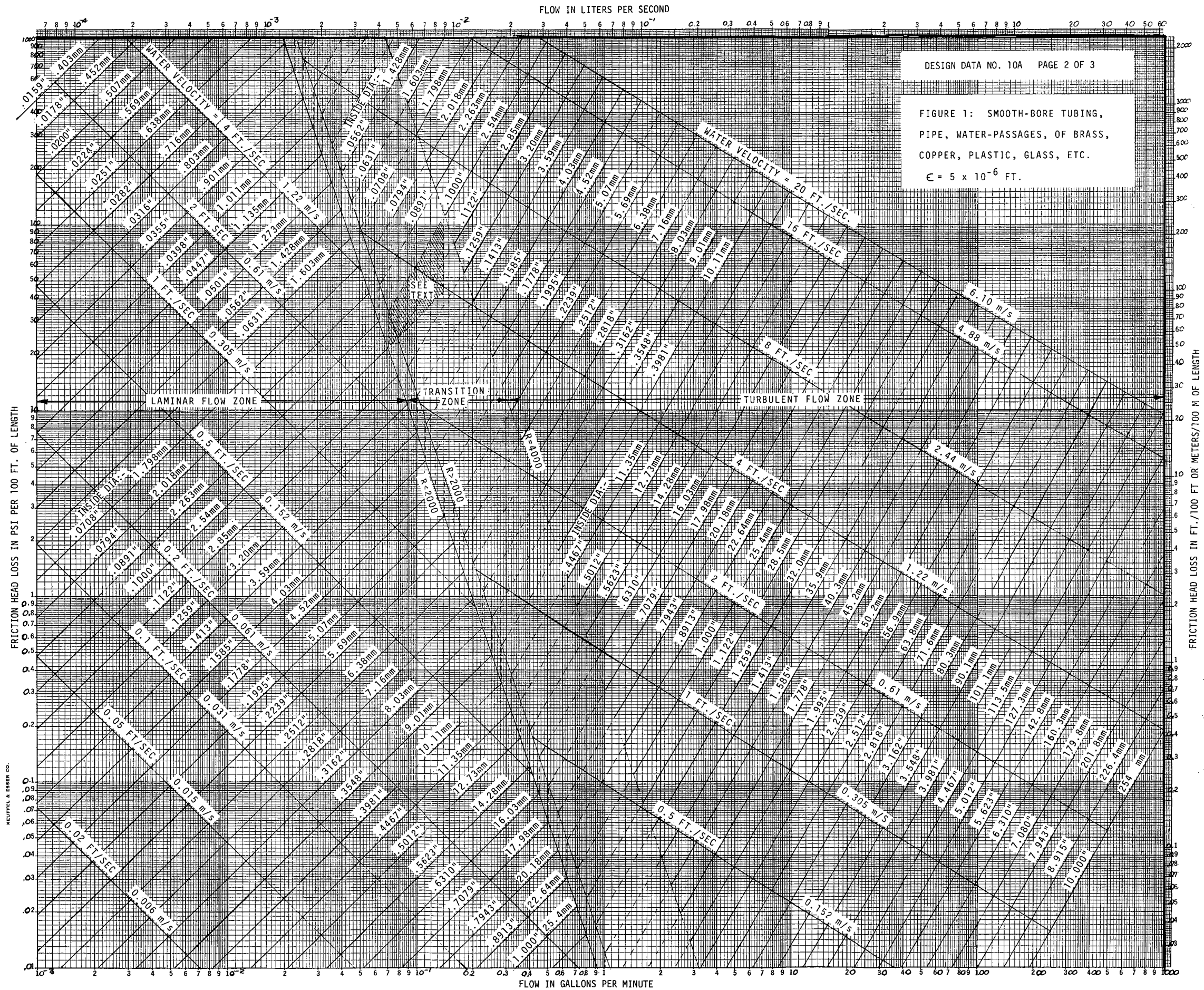
where: ϵ = absolute roughness in feet (for smooth tubes: 5×10^{-6}, for commercial steel pipe: 1.5×10^{-4}.)

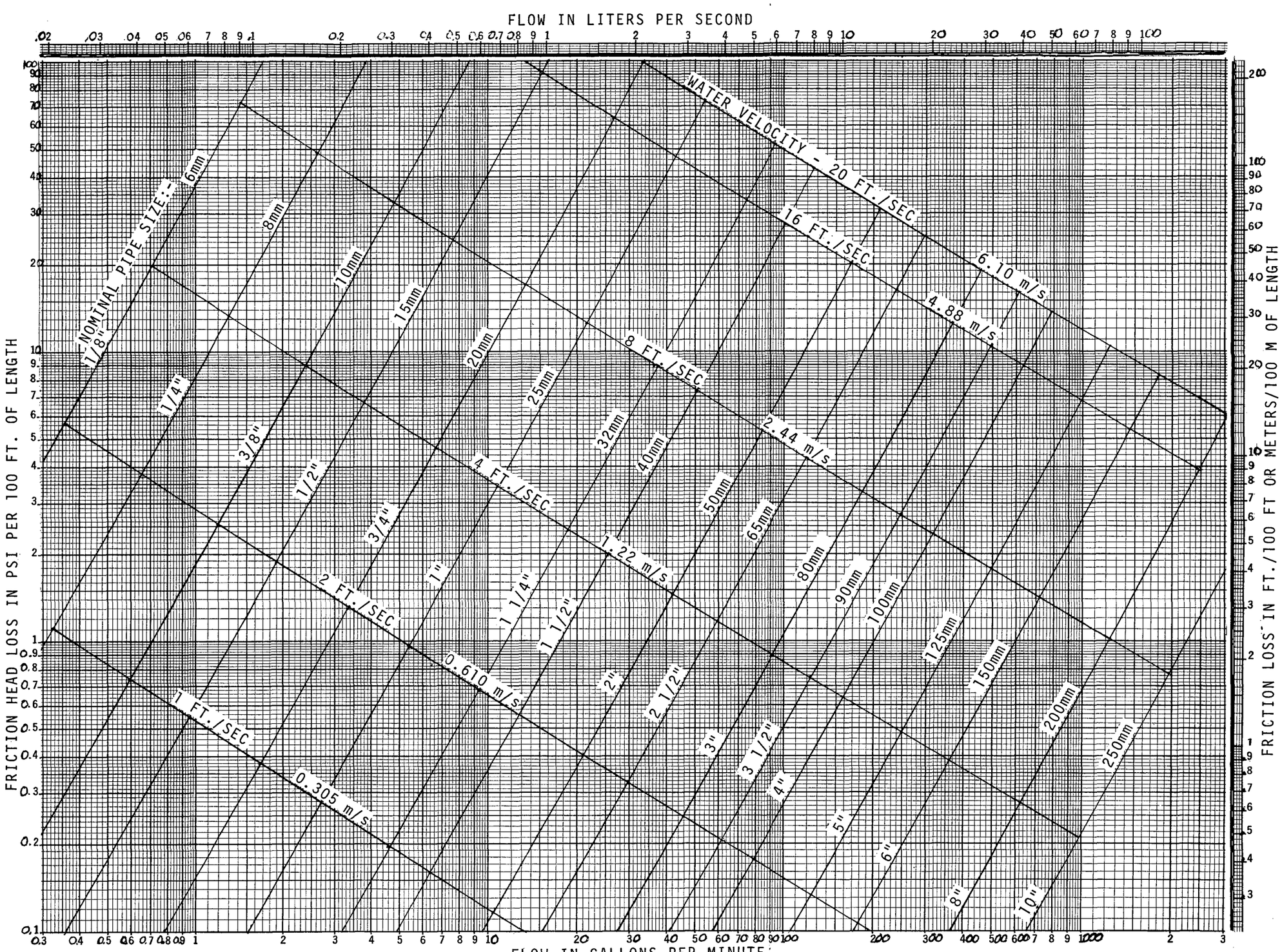
For the transition zone on figure 1, from R<2000 to R>4000 where flow is unpredictable between laminar and turbulent, the conservative design position is to consider it turbulent. All the curves are plotted on this basis except the 0.1000 in.I.D., for which the complete area of unpredictability is shown. This is typical for all diameters. Figure 2 is all turbulent flow.

Diameters for plotting figure 1 were selected to give twenty equal-ratio increments in each decade, for clarity and simplicity.

Velocity above 20 ft/sec is not recommended because of noise, constriction due to cavitation, and damage to valves and fittings.

*Procedures, data and charts for determining friction head losses for liquids of other viscosities are given in "Liquid Viscosity Effects on Pumping Systems" by G. F. Carlson in Heating/Piping/Air Conditioning, July, 1979.


FLOW IN LITERS PER SECOND
FLOW IN GALLONS PER MINUTE
FRICTION HEAD LOSS IN PSI PER 100 FT. OF LENGTH
FRICTION HEAD LOSS IN FT./100 FT OR METERS/100 M OF LENGTH
DESIGN DATA NO. 10A PAGE 2 OF 3
FIGURE 1: SMOOTH-BORE TUBING, PIPE, WATER-PASSAGES, OF BRASS, COPPER, PLASTIC, GLASS, ETC.
ε = 5 x 10^-6 FT.
WATER VELOCITY = 20 FT./SEC.
WATER VELOCITY = 4 FT./SEC
LAMINAR FLOW ZONE
TRANSITION ZONE
TURBULENT FLOW ZONE
R=4000
R=2000
SEE TEXT
INSIDE DIA.
KEUFFEL & ESSER CO.



DESIGN DATA NO. 10A

PAGE 3 OF 3

FIGURE 2:

NEW COMMERCIAL STEEL PIPE
SCHEDULE 40
STANDARD WEIGHT

ALL TURBULENT FLOW

$\epsilon = 1.5 \times 10^{-4}$ FT.

RADIATION LABORATORY - UNIVERSITY OF CALIFORNIA - BERKELEY

DESIGN DATA

DATE	D.D.NO.	PAGE 1 OF 2 PAGES
11/2/49	10.1A	

SUBJECT

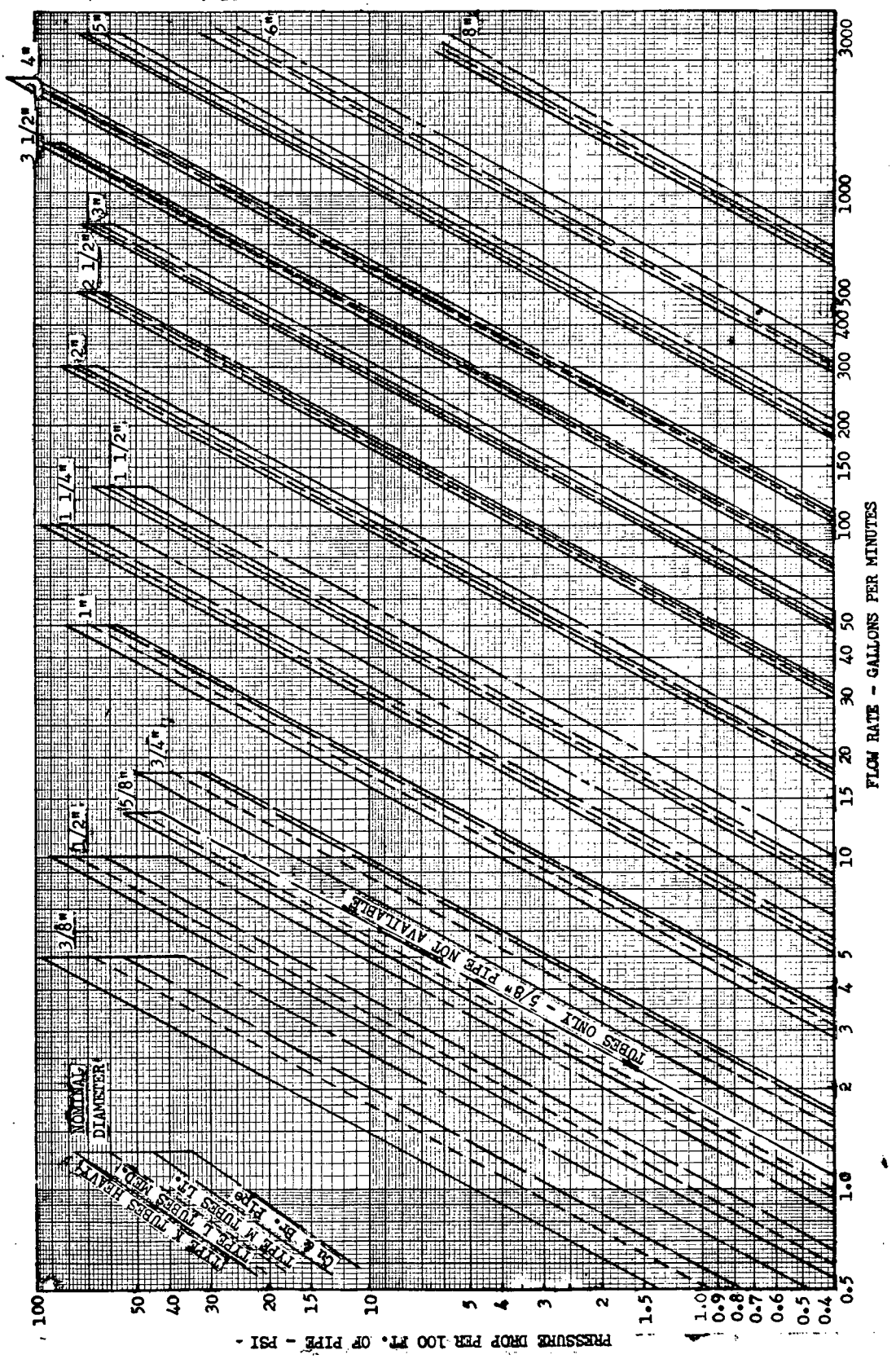
WATER FLOW IN COPPER AND BRASS TUBES AND PIPE*

PREPARED R. Peters

CHECKED BY

From "Cameron Hydraulic Data"

Redrawn: 11/7/57
Revised 11/3/60



EL-019-a

CU TUBE AND PIPE DIMENSIONS

NOMINAL TUBE OR PIPE SIZE		3/8	1/2	5/8	3/4	1	1 1/4	1 1/2	2	2 1/2	3	3 1/2	4	5	6	8
TUBE O. D.		1/2	5/8	3/4	7/8	1 1/8	1 3/8	1 5/8	2 1/8	2 5/8	3 1/8	3 5/8	4 1/8	5 1/8	6 1/8	8 1/8
TYPE K TUBING	I.D.	.402	.527	.652	.745	.995	1.245	1.481	1.959	2.435	2.907	3.385	3.857	4.805	5.741	7.583
	WALL	.049	.049	.049	.065	.065	.065	.072	.083	.095	.109	.120	.134	.160	.192	.271
TYPE L TUBING	I.D.	.430	.545	.666	.785	1.025	1.265	1.505	1.985	2.465	2.945	3.425	3.905	4.875	5.845	7.725
	WALL	.035	.040	.042	.045	.050	.055	.060	.070	.080	.090	.100	.110	.125	.140	.200
TYPE M TUBING	I.D.	.450	.569	.690	.811	1.055	1.291	1.527	2.009	2.495	2.981	3.459	3.935	4.907	5.881	7.785
	WALL	.025	.028	.030	.032	.035	.042	.049	.058	.065	.072	.083	.095	.109	.122	.170
PIPE	I.D.	.494	.625		.822	1.062	1.368	1.600	2.062	2.500	3.062	3.500	4.000	5.063	6.125	8.000
	WALL	.0905	.1075		.114	.1265	.146	.150	.1565	.1875	.219	.250	.250	.250	.250	.3125
	O. D.	.675	.84		1.050	1.315	1.660	1.900	2.375	2.875	3.500	4.000	4.500	5.563	6.625	8.625

1 Cu. Ft. = 7.48051 gals.

Feet of Water X .433 = p s i

RP/plc

RADIATION LABORATORY · UNIVERSITY OF CALIFORNIA · BERKELEY

DESIGN DATA

SUBJECT: CU TUBE AND PIPE DIMENSIONS

PREPARED: Ralph Peters

CHECKED BY: Retyped: 9-10-51

DATE: 7-25-51

D. D. NO.: 10.1A

RADIATION LABORATORY - UNIVERSITY OF CALIFORNIA - BERKELEY

DESIGN DATA

DATE	D.D.NO.	PAGE 1 OF 1 PAGES
11/3/49	10.2	

SUBJECT

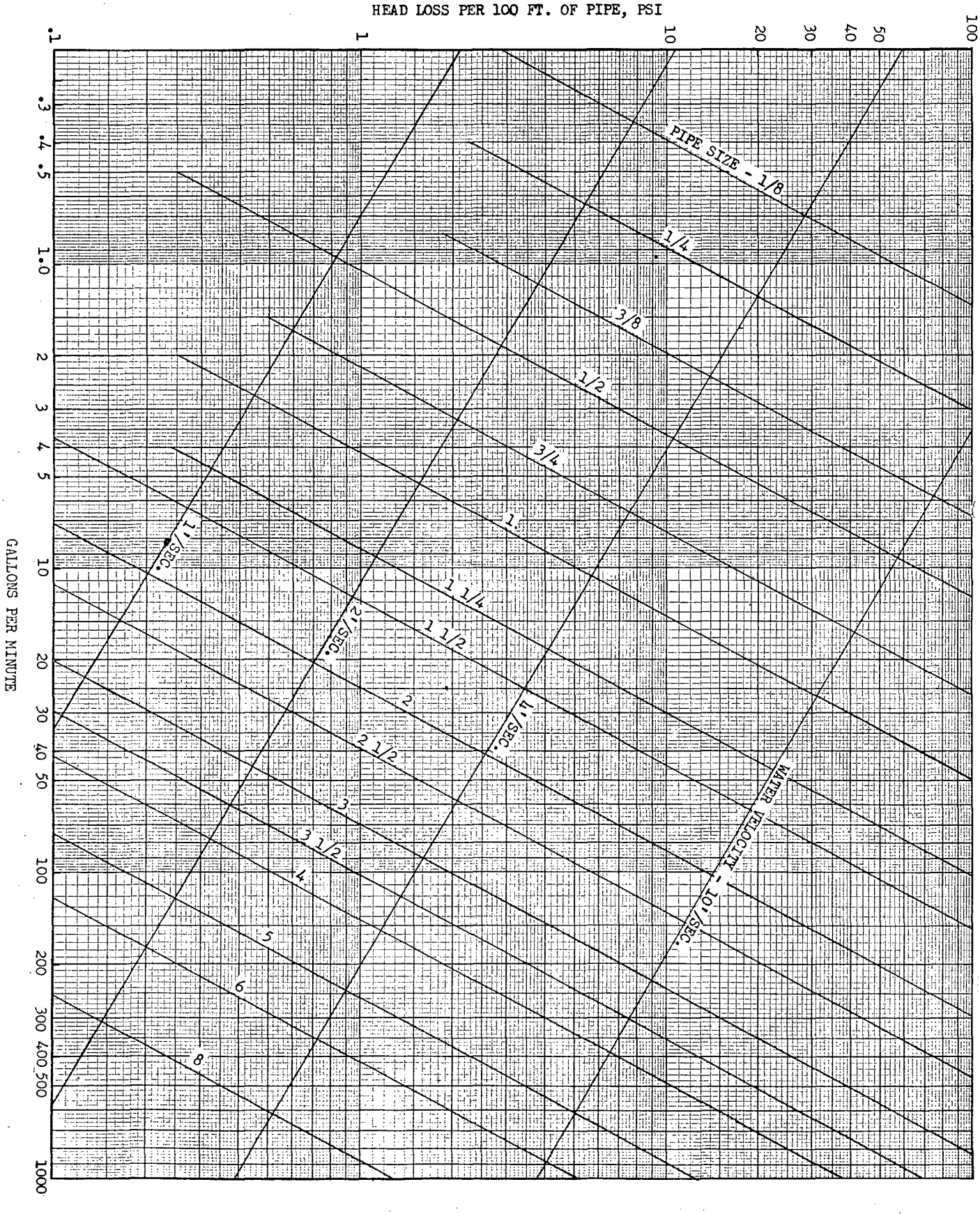
WATER FLOW IN STANDARD WEIGHT STEEL PIPE (SCHED. 40)*

PREPARED: R. Peters

CHECKED BY:

*Taken from Cameron Hydraulic Data

Redrawn: 11/8/57



RL-10-8

Although Webster lists eight distinct varieties of mica, only two are suitable as electrical insulators. These two varieties are "Moscovite," (sometimes known as "White" or "Potash" mica), and "Philogopite," (sometimes known as "Amber" or "Magnesia" mica).

Properties

The composition and physical properties of these two micas, as reported by the Mica Insulator Company, are listed in the table below:

	Moscovite	Philogopite
Chemical Composition (by analysis)--		
Silica ($Si\ O_2$)	45.2	40.8
Alumina ($Al_2\ O_3$)	38.4	26.9
Potash ($K_2\ O$)	11.8	12.7
Magnesia ($Mg\ O$)	--	7.6
Ferric Oxide	--	12.0
Water ($H_2\ O$)	4.6	
Specific Gravity	2.76-3.0	2.78-2.85
Hardness, Moh's Scale	2.8-3.2	2.5-2.7
Max. Temperature at which employable	535 C.	1000 C.
Permittivity (S.I.C.)	4.2-5.0	2.9-3.0
Spec. Resist. Megohms x 10^6	7-133	0.45-22
Electric strength at 20C in volts per mil	3250-6250	3700-4200

In addition, Standard Handbook for Electrical Engineers, by Knowleton, lists a further electrical difference between the two micas (Sec. 4, p. 569 and 570):

Power Factor at 60-1000 Kilocycles, 25°C

Moscovite .0001 to .0008 (R. H. Spry)
.04 to .01 (Lewis, Hall and Caldwell)

Philogopite .003 to .09 (R. H. Spry)
7.12 to .38 (Lewis, Hall and Caldwell)

(The values are greatly influenced by the presence of stains and inclusions)

Philogopite mica is superior for high temperature service, but inferior for high frequency service. It is therefore highly desirable to be able to distinguish between the two types.

Moscovite mica is translucent, and colored ruby, green, or brown of various shades. Philogopite mica is more or less opaque with coloring ranging from pale yellow and silver to dark copper and brown. However, physical appearance overlaps between the two types of mica to a considerable extent, and is not a reliable means of identification for laboratory purposes.

Specification

Trade and regional names do not differentiate reliably between the two types of mica. Thus, Mica Insulator Company's "Micanite" can be either Moscovite or Philogopite, depending on the temperature service to be encountered. "India" or "Indian" mica is used loosely as a synonym for Moscovite mica, since most of the mica exported by India is Moscovite. However, Philogopite mica is also exported as "Indian" mica. Similarly, "Madagascar" or "Canadian" is much used as a synonym for Philogopite, since the principal mica exports of these countries are of this variety.

Grade and quality numbers are also of little help in differentiating between micas; in fact, it is hard to determine whether the number refers to grade (the size of the sheet) or the quality (purity, coloring, lack of impurities). This confusion is emphasized by the table below:

Number	Grade	Number	Quality
1	25" x 35-3/4" sheet or larger	1	Clear and slightly stained
2	15" x 23-3/4" " " "	2	Fair stained
3	10" x 14-3/4" " " "	3	Stained
4	6" x 9-3/4" " " "	4	Heavily stained
5	3" x 5-3/4" " " "	5	Black stained

In view of the confusion in trade terminology, all mica should be ordered and called for on drawings as Moscovite or Philogopite. Grade and quality numbers should always be followed by their description in size or color as:

Mica-Moscovite, Grade 5 (6" x 9-3/4" or larger),
Quality 1 (clear or slightly stained).

Grade and quality specifications are not generally required on drawings where small quantities are involved--the best quality being assumed.

Identification

As it appears that commercial mica designations should not be relied on when attempting to distinguish between Philogopite and Moscovite, the following simple test is recommended where positive identification is required:

Place a small (1/2" sq.) sample of the unknown mica under a piece of 1/8" copper plate. Heat the copper with an oxyacetylene torch in a concentrated region over the mica sample until the upper surface of the copper puddles. Do not allow the flame to reach the mica. If the mica is Philogopite, little change will be noted after this test; if it is Moscovite, the surface under the puddled copper will have an opaque silvery metallic appearance and the surface will become cracked and brittle. For a more positive test, place a sample known to be Philogopite along side the unknown sample, and puddle the copper directly above the junction of the two sheets, thus insuring that each sample was exposed to the same degree of heat.

Mechanical designers are requested to call for mica as either Philogopite or Moscovite, depending on the requirements, and not by trade or regional names.

W. W. Salsig, Jr.

WWS:E/ah

TITLE	PREPARED BY	DATE
GUIDELINES FOR MAKING GRAPHS	W. M. Brobeck	3-14-47
	REVISED BY: J. O. Turner	DATE: 5-78
	REVISED BY	DATE

In order for a graph to be clear and easily understood, and to serve as a useful permanent record, the author's observance of the following points is strongly urged.

1. Axes and scales must be clearly shown.

2. Label each scale with both the name of the quantity and its unit. A unit such as "seconds x 10^{-3}" or "gauss x 10^{3}" is ambiguous, and must never be used. Use a definitive unit such as milliseconds or kilogauss.

3. The abscissa should be the independent variable unless it represents height or altitude. Avoid the use of more than one abscissa scale.

4. Show the value at the origin of each scale, whether zero or some other quantity.

5. If a change in scale or a discontinuity is unavoidable, it must be clearly indicated.

6. Show the value at each cycle boundary on logarithmic scales.

7. Always show plotted points if they are from test data or from calculations so difficult that only a few are made. Points on simple mathematical curves should not be shown.

8. Doubtful portions of curves should be dashed or dotted.

9. Each curve in a multiple set must be clearly labeled. Use different types of lines and/or points for curves close enough to be confused with each other. Do not use different colors, since they are impractical to reproduce.

10. The title must be clear, accurate, and complete, so that a reader can know quickly if the graph is useful to him. It should include any special information needed to understand or use the graph, and the date and author's name.

11. A file retrieval number must be shown.

12. Relevant supplemental information such as the following should be clearly shown on the graph if possible without overcrowding. If not, it should be carried in accompanying text:

    a. Full identification of equipment concerned.

    b. All relevant conditions.

    c. References to data sources.

d. Date of test and name of observer.

e. A graph of statistical data should indicate if probable error, standard deviation, etc. apply.

f. If formal curve-fitting procedures are used, the method should be stated (e.g. least squares, linear regression, etc.).

13. The following additional information is frequently helpful in understanding and using a graph:

a. The least count of instruments from which the test data are plotted.

b. The equation from which an analytic function plot is made.

14. Leave margins clear for printing control and binding.

(Many of these points are illustrated on page 3.)

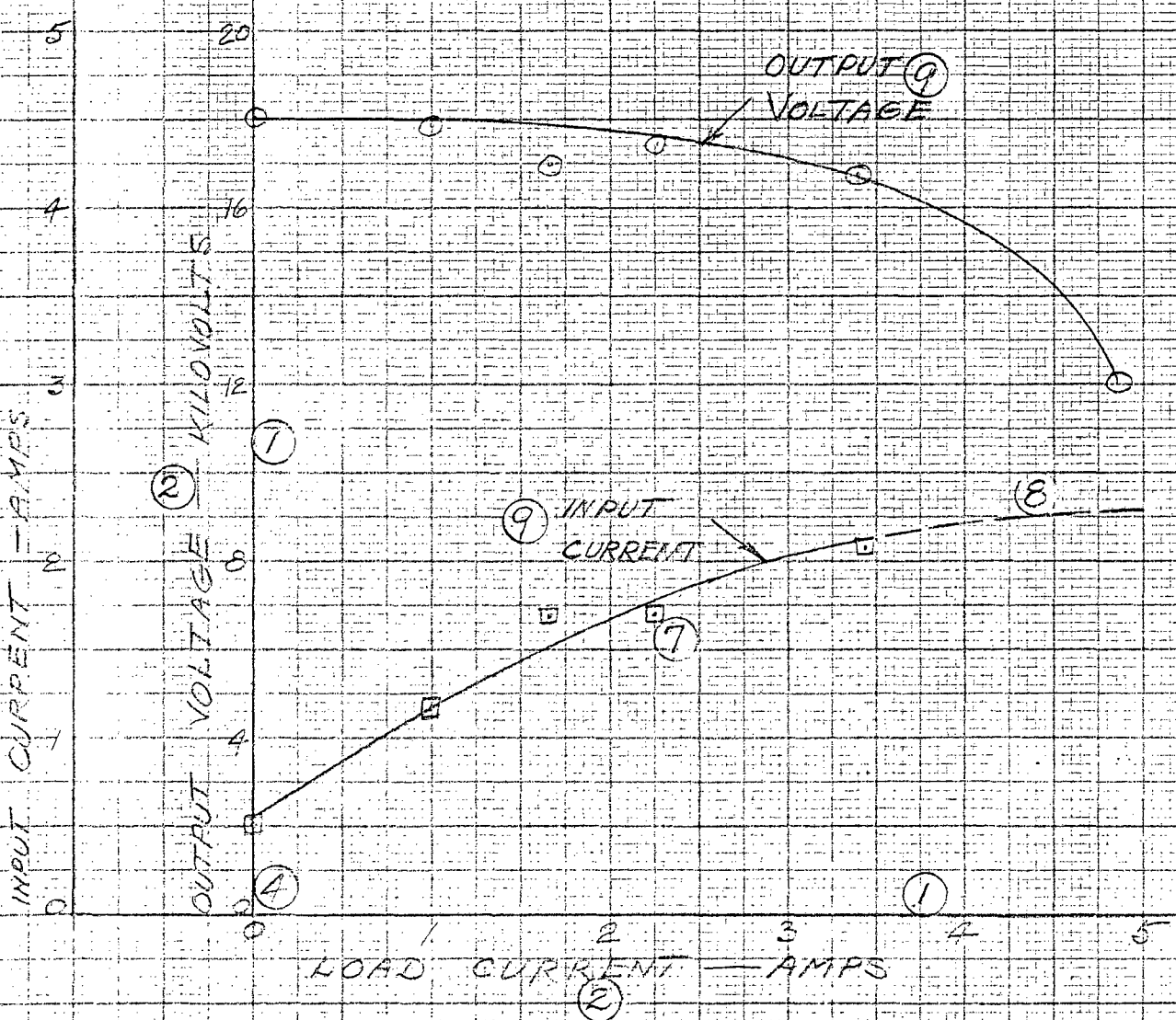
LAWRENCE BERKELEY LABORATORY – UNIVERSITY OF CALIFORNIA

DESIGN DATA

NUMBER 12A | PAGE 3 OF 3

11

CHARACTERISTICS OF 10
50 KW DC POWER SUPPLY
ASSEMBLY DRE. 241239
SERIAL NO. 314159245 12
INPUT: 115 V. 60 HERTZ
TRANSFORMER TAP NO. 3



TEST: 2-30-36 BY J. DEAKE 12
ELECTRONICS LOG BOOK 23 P. 91

H = magnetic field strength at right angles to shaft - kilogauss

F = speed of shaft - revolutions per minute

K = resistivity of shaft material - microhm inches*

D_1 = inside diameter of shaft - inches

D_2 = outside diameter of shaft - inches

P = power required - watts

L = length of shaft in inches

L is assumed large compared with D_2---error is less than 10% if $\frac{L}{D}$ is greater than 5.

$$P = 2.24 \times 10^{-6} \frac{H^2F^2L}{K} (D_2^4 - D_1^4)$$

*Note that the dimensions of resistivity are ohms x inches. This is numerically equal to the resistance across an inch cube.

E. M. McMillan
per W. M. B.

WMB:E/ah

TITLE	PREPARED BY	DATE
PREFERRED AND ALLOWED UNITS	W.M. Brobeck	3/47 9/50
	REVISED BY R. Reimers, R. Avery, J. Turner	DATE 6/78
	REVISED BY	DATE

The whole matter of units is in a state of flux, and the Mechanical Department of LBL, in accordance with DOE policy, is slowly moving toward conversion to the SI units of the metric system. In general, the metric units(1) listed below are to be considered as first preference, subject to the availability of hardware, tools, machine scales, stock materials, etc., in SI units.

This list is not intended to cover units for all quantities, but only for those that have been called into question at one time or another.

For the metric policy established for PEP-4, see Engineering Note M-5084, by Gene Miner.

For a treatise on the International System of Units (SI), with complete definitions of base, supplementary, and derived units and conversion factors, see ANSI Z210.1-1976 "A.N. Standard for Metric Practice."

Footnotes appear on Page 2.

Quantity	Metric Preferred	Conventional Preferred	Allowed
length(2)	meter, millimeter	inch	foot
volume	cubic meter	cubic inch	cubic foot
mass	kilogram	pound	metric ton
time	second	second	minute, hour
temperature	degree kelvin	degree Celsius	
force	newton	pound-force	
torque, moment	newton meter	pound inch	
pressure, stress	pascal	torr, pound-force/sq. inch	micron
energy	joule (watt second)	joule (watt second)	BTU(3)
power	watt	watt	horsepower(4)
magnetic flux	weber	maxwell (line)	
magnetic flux density	tesla	gauss (line sq.cm)	
magnetic field strength	ampere-turn/meter	oersted	
magnetomotive force	ampere turn	ampere turn	
gas flow	cu. meter/second	cu. ft./second, minute or hour	liter/second
liquid flow	cu. meter/second	gallon/minute	liter/second

cont.

Quantity	Metric Preferred	Conventional Preferred	Allowed
heat conductivity	watt/meter kelvin	watt/deg. C inch	
heat transfer factor	watt/sq. meter kelvin	watt/deg. C sq. in.	
specific heat	joule/kilogram kelvin	watt second/deg. C pound	
specific mass	kilogram/cubic meter	pound/cubic inch	gram/cu. centimeter
electrical resistivity	ohm meter	ohm inch	ohm centimeter

(1) Whenever appropriate, these prefixes should be used to apply multiples of ten:

Prefix	Multiple	Symbol	Prefix	Multiple	Symbol
pico-	10^{-12}	p	deka-	10	da
nano-	10^{-9}	n	hecto-	10^{2}	h
micro-	10^{-6}	μ	kilo-	10^{3}	k
milli-	10^{-3}	m	mega-	10^{6}	M
centi-	10^{-2}	c	giga-	10^{9}	G
deci-	10^{-1}	d	tera-	10^{12}	T

(2) The millimeter or inch is preferred on all mechanical drawings.

(3) BTU should be used for describing commercial appliances only.

(4) Horsepower should be used for describing commercial motive power units only.

bl

SUBJECT

RADIO FREQUENCY POWER LOSS IN SHEET CONDUCTORS

PREPARED

W. M. Brobeck

CHECKED BY

Retyped 12/16/57

i = RMS amperes per inch perimeter

d = skin depth - inches (i.e., thickness of sheet that would have same power loss with DC current = i)

p = resistivity = 1 for annealed copper (0.68 microhm inches at 20C)

f = frequency in megacycles/second

w = power loss in watts/square inch

μ = magnetic permeability of sheet = 1 for non-magnetic materials

$$d = 0.00260 \sqrt{\frac{p}{\mu f}} = \frac{0.00260}{\sqrt{f}} \quad \text{for copper}$$

$$w = 0.68 \times 10^{-6} \frac{i^2 p}{d}$$

$$= 2.62 \times 10^{-4}\, i^2 \sqrt{f} \quad \text{for copper}$$

The following graph gives d and w as a function of i and f for copper sheets.

Notes:

$d = \sqrt{\frac{p}{\pi f \mu}}$ in consistent units (cf. Ramo & Whinnery, Fields and Waves in Modern Radio, 1944, p. 205 et seq.)

d is assumed small compared to the radius of curvature of the conductor.

W. M. Brobeck

WMB/nh

RADIATION LABORATORY - UNIVERSITY OF CALIFORNIA - BERKELEY

DESIGN DATA

DATE	D.D.NO.	PAGE OF PAGES
3/17/47	15	2

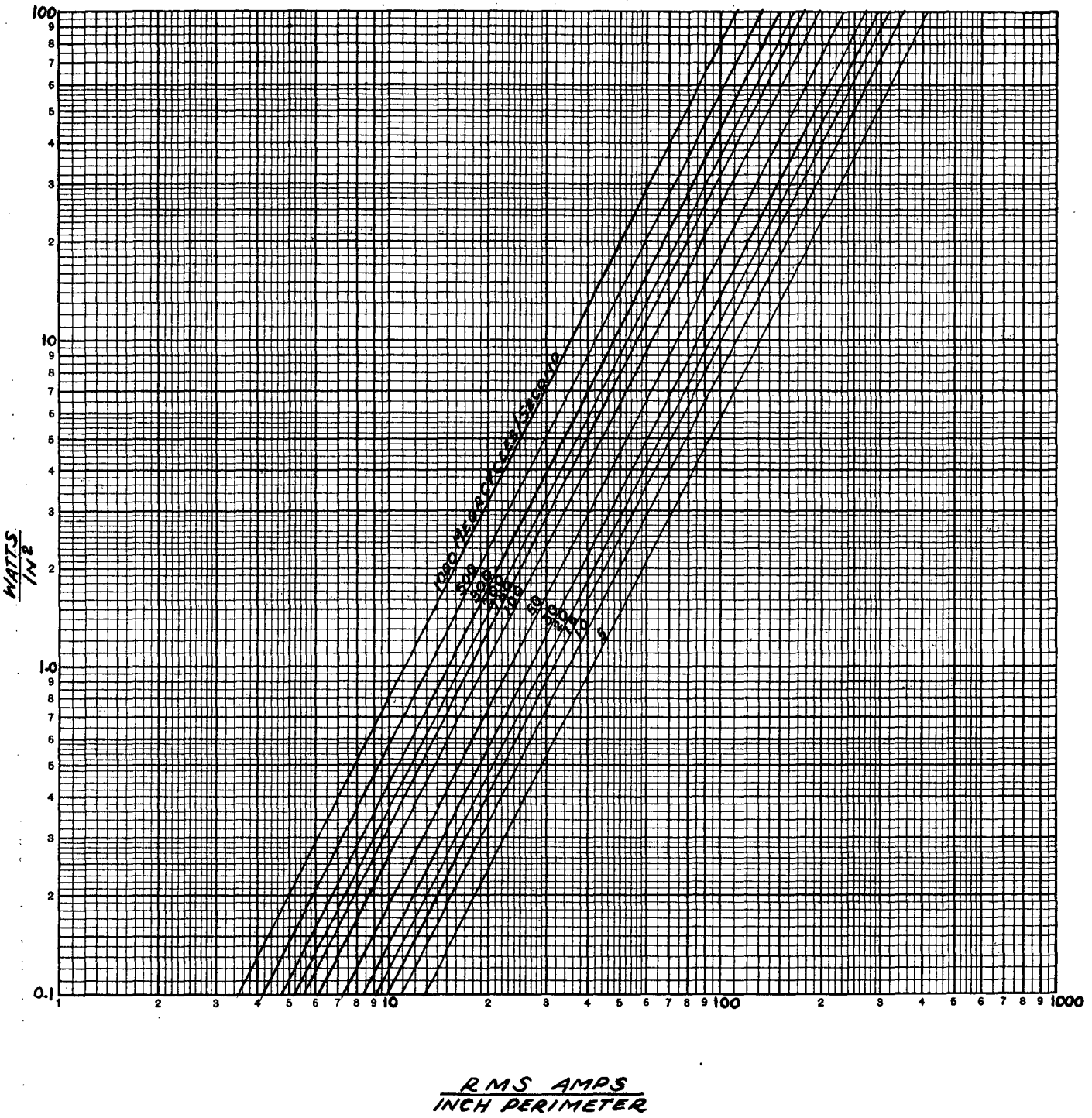
SUBJECT

RADIO FREQUENCY POWER LOSS IN SHEET CONDUCTORS

PREPARED W. M. Brobeck

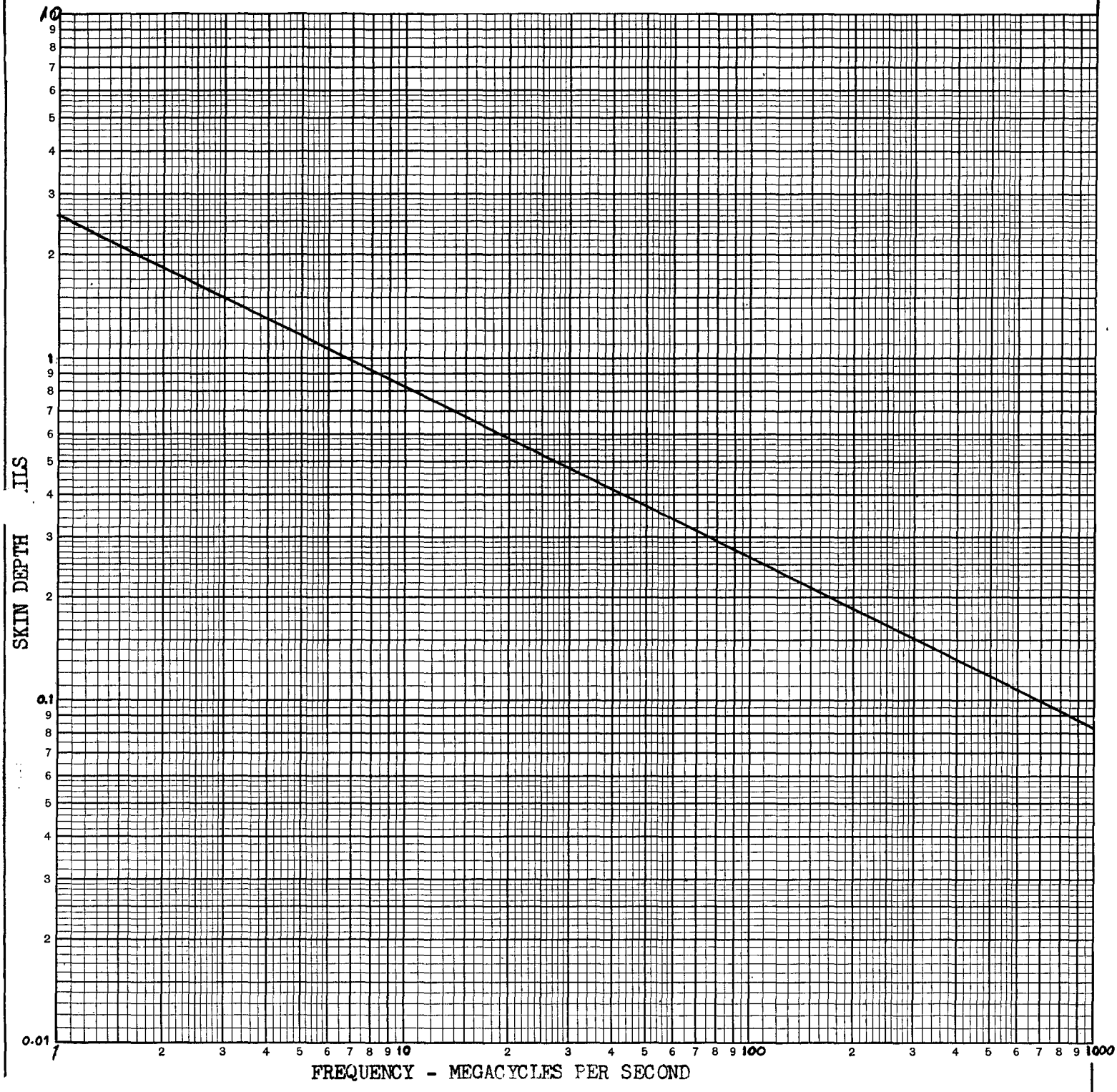
CHECKED BY

Copied 12/5/57 by K. Connelly



DL-610-a

RADIATION LABORATORY - UNIV. OF CALIFORNIA - BERKELEY DESIGN DATA	Date 3-17-47	D.D. 15	page 3
Subject SKIN DEPTH* OF RADIO FREQUENCY CURRENT	Prepared W. M. Brobeck		
	Copied K. Connelly 10-15-57		



*Thickness of DC conductor that would have same resistance.

(3-24-47)

RADIATION LABORATORY - UNIVERSITY OF CALIFORNIA - BERKELEY DESIGN DATA	DATE	D.D. NO.	PAGE
	6-20-47	16	1 of

SUBJECT

VIBRATION ISOLATION

PREPARED Marvin Martin

CHECKED BY Retyped 9-7-51

The isolation of mechanical vibrations to prevent transmission of vibratory forces to parts of the adjacent structure requires careful selection of suitable flexible mountings. An incorrect choice of the mountings will result in a magnification of the vibration instead of the desired attenuation.

The mass of the vibrating parts and the spring constant (pounds load required for one inch deflection) of the flexible mounts determine a natural frequency of vibration for the system. If the disturbing frequency is near this natural frequency, resonance will occur which will magnify the vibration. If the disturbing frequency is small compared to the natural frequency, the vibration force will be transmitted unchanged through the mounting. If the disturbing frequency is large compared to the natural frequency, the vibration forces will be attenuated and only a small fraction transmitted through the mounting. This is the desired condition.

The fraction of the vibration forces transmitted is called the transmissibility and is defined by the following equation:

$$T = \frac{1}{\left(\frac{f}{f_n}\right)^2 - 1}$$

where f = disturbing frequency
f_n = natural frequency

$$f_n = \frac{1}{2\pi}\sqrt{\frac{Kg}{W}}$$

where K = spring constant
W = weight supported by flexible mounts.
g = acceleration of gravity

Noting that $\frac{W}{K}$ = static deflection of system = d

$$T = \frac{1}{\left(\frac{N}{188}\right)^2 d - 1}$$

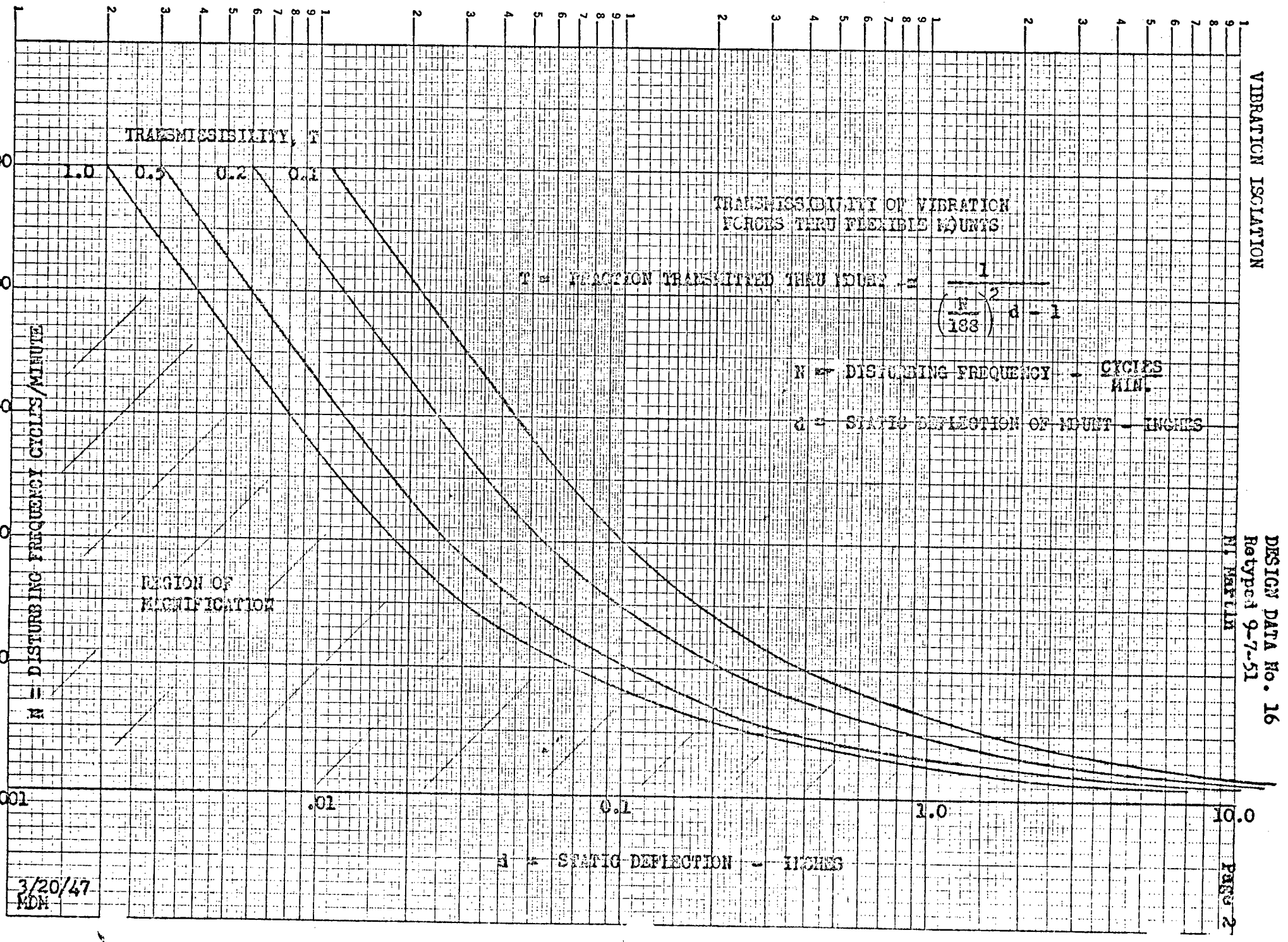
where N = disturbing frequency in cycles/minute
d = static deflection, inches

The accompanying curves show disturbing frequency vs. static deflection for various degrees of transmissibility.

Marvin Martin

MM:FP

KEUFFEL & ESSER CO., N. Y. NO. 359-81G
Semi-Logarithmic, 4 Cycles × 10 to the inch.
MADE IN U.S.A.



DESIGN DATA No. 16
Retyped 9-7-51
H. Martin

3/20/47
MDH

The basic equation for molecular flow** through pipes and orifices is:

(1) $G = C\,(P_1 - P_2)$ where G is mass rate of flow
P_1 and P_2 are upstream & downstream pressures
*C is proportionality constant for the gas, temperature, area and length of pipe.

Most vacuum flow calculations use a factor which is related to mass rate of flow by the following equation:

(2) $Q = \dfrac{GP}{\rho}$ where ρ is the mass density of the gas at pressure P.

Here Q has the dimensions of $\dfrac{\text{Pressure x Volume}}{\text{Time}}$ and is usually expressed in micron liters per second.

A useful equation for calculation of the flow of air is:

(3) $Q = 75\,K\,A\,(P_1 - P_2)$

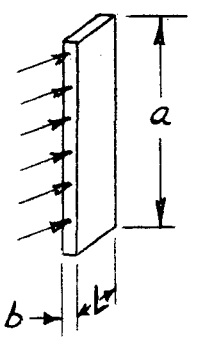
Q is in micron liters/sec.
A is cross sectional area in square inches.
P_1 and P_2 are in microns.
K is a factor whose value depends on the geometry of the pipe.
($K = 1$ for an orifice in a thin diaphragm)

Values of K in equation (3):
(Taken from Loeb, Kinetic Theory of Gases. See also Clausing Physik, 66, 471, 1930; Ann. Physik 12, 961, 1932; Physica 9, 65, 1929)

1. Orifice in a thin diaphragm $K = 1$

2. A long cylindrical tube of length L and radius R where $L \gg R$ $K = \frac{8}{3}\frac{R}{L}$

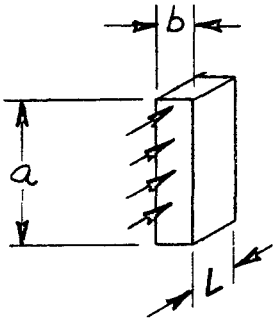
3. A slit like tube as shown where $a \gg L \gg b$ $K = \frac{b}{L}\log_e \frac{b}{L}$



4. A long rectangular tube where $L \gg a$ and $L \gg b$
See Pg. 4

5. A short cylindrical tube of length L and radius R:
Find K as a function of L/R from Curve I.

6. A short slit like tube as shown where $a \gg b$ and $a \gg L$
Find K as a function of $\frac{L}{b}$ from Curve II.



Marvin Martin

MM:bw/ah

Note: Notation used differs from that of Loeb, ref. 1.

* C in equation (1) for an orifice is $A\sqrt{\frac{\rho}{2\pi p}}$

** Molecular flow occurs when the mean free path is greater than the linear dimensions of the system.

PUMPING SPEED OF PIPES & ORIFICES AT HIGH VACUUM

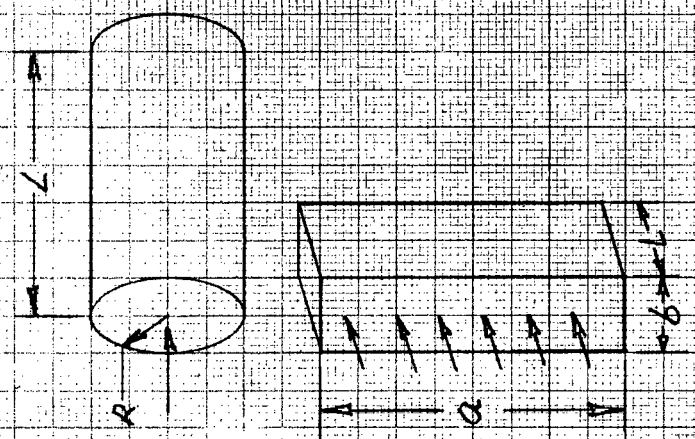
Marvin Martin

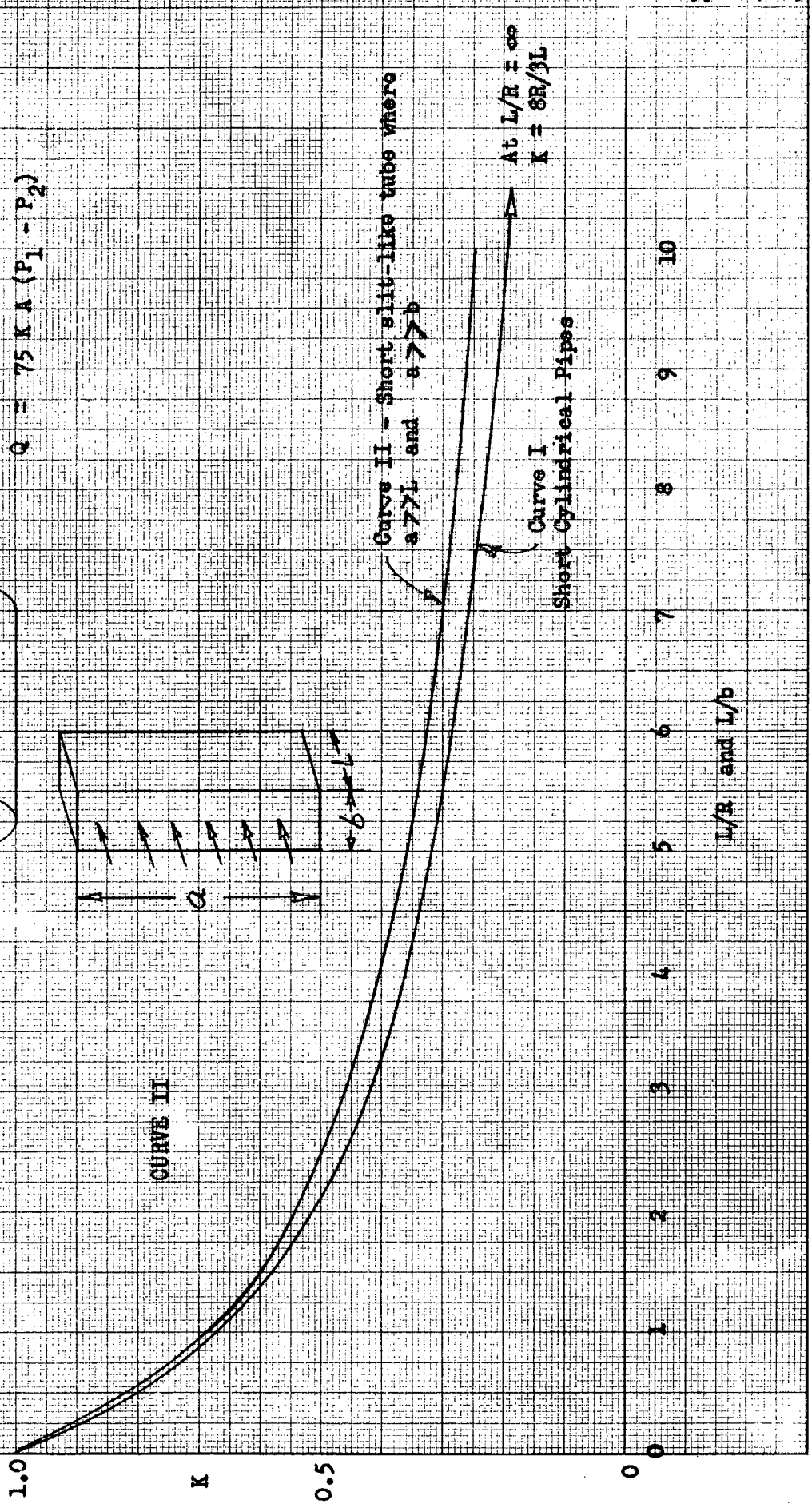
Rev: 9-22-47 Retyped 9-15-50

Values of K

To be used in computing conductance of pipes.

$Q = 75\ K\ A\ (P_1 - P_2)$

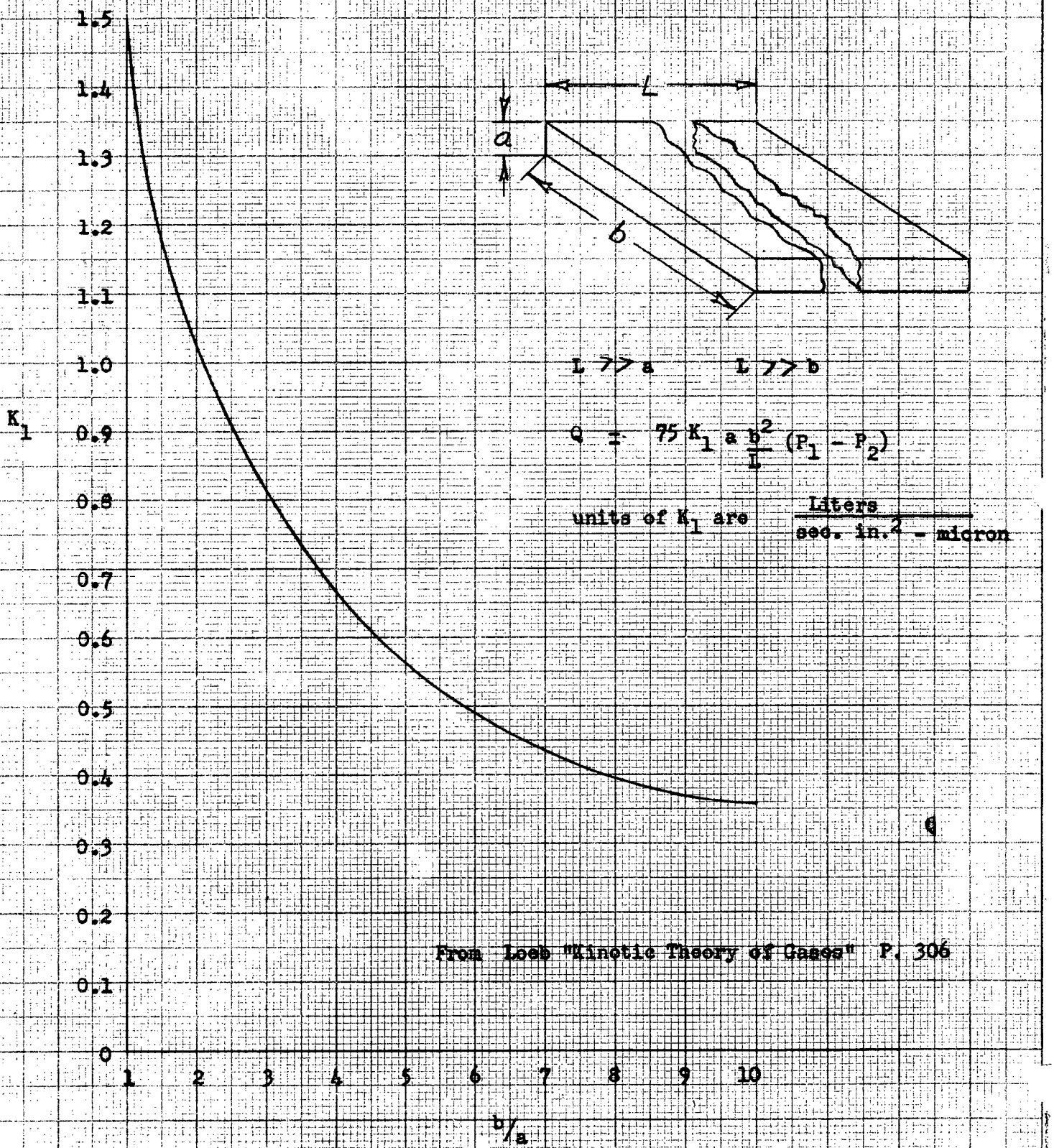




PUMPING SPEED OF PIPES AND ORIFICES AT HIGH VACUUM

W.H. Brobeck

CONDUCTANCE OF RECTANGULAR TUBES



From Loeb "Kinetic Theory of Gases" P. 306

LAWRENCE BERKELEY LABORATORY – UNIVERSITY OF CALIFORNIA

DESIGN DATA

NUMBER 18B | PAGE 1 OF 2

TITLE: TENSILE PROPERTIES AT ROOM TEMPERATURE OF FREQUENTLY-USED UNWELDED AND WELDED ALUMINUM ALLOY SHEET AND PLATE

PREPARED BY: J. E. Cullen | DATE: 12/67

REVISED BY: J. E. Cullen | DATE: 5/80

REVISED BY: | DATE:

Alloy and temper	Unwelded: Minimum tensile properties(1) Ultimate (ksi)	Unwelded: Minimum tensile properties(1) Yield (ksi)	Welded(2) GMAW or GTAW: Typical transverse tensile properties: Filler metal alloy (ksi)	Welded(2) GMAW or GTAW: Typical transverse tensile properties: Ultimate (ksi)	Welded(2) GMAW or GTAW: Typical transverse tensile properties: Yield (ksi)	Max allowable design stress in tension, as welded, room temp. to 200°F. (Table UNF 23.1 ASME Code Sect. VIII-Div. 1) (ksi)
Heat-treatable group:						
2014-0	37	16	4043	29	14	(Not for welding. Bars forging rods, & shapes only. See SB-211, SB221 & SB247, ASME Sect II, Part B.)
2014-T6	67	59	4043	35	20	
2024-T4	60	36	5356	42	28	
2219-T62	54	36	2319	35	26	(non-code)
6061-0	22	12	4043	18	9	6
6061-T4	30	16	4043	27	18	6
6061-T6	42	35	4043	27	18	6
6061-T6	42	35	5356	30	20	6
6061-T6	42	35	4043(2.2)	32(2.2)	18(2.2)	6
7075-T62	78	67	5356	44	25	(non-code)
7178-T6	84	73	5556	54	41	
Non-heat-treatable group:						
1100-0	11	3.5	1100	13	6	2.3
1100-H14	16	14	1100	13	6	2.3
3003-0	14	5	1100	13	7	3.3
3003-0			5356	14	8	3.3
3003-H14	20	17	1100	16	8.5	3.3
3004-0	22	8.5	4043	24	11	5.5
3004-H32	28	21	5356	27	12	5.5
3004-H34	32	25	5356	30	15	5.5
5052-0	25	9.5	5556	28	13	6.3
5052-H32	31	23	5556	30	14	6.3

Alloy and temper	Unwelded: Minimum tensile properties(1) Ultimate (ksi)	Unwelded: Minimum tensile properties(1) Yield (ksi	Welded(2) GMAW or GTAW: Typical transverse tensile properties: Filler metal alloy (ksi)	Welded(2) GMAW or GTAW: Typical transverse tensile properties: Ultimate (ksi)	Welded(2) GMAW or GTAW: Typical transverse tensile properties: Yield (ksi)	Welded(2) GMAW or GTAW: Max allowable design stress in tension as welded, room temp. to 200°F. (Table UNF 23.1 ASME Code Sect. VIII-Div.1) (ksi)
Non-heat-treatable group (cont'd):						
5083-0(1)	40	18	5356	41	21	10.0(1)
5083-H321	44	31	5356	40	21	10.0(1)
5083-H321	44	31	5556	43	21	10.0(1)
5086-0	35	14	5356	37	17	8.8
5086-H32	40	28	5556	39	18	8.8
5456	42	19	5556	46	22	10.5
5456-H321	46	33	5356	45	21	10.5

NOTES

1. Minimum vales as specified under ASTM B209-78. Thickness range is 0.050" to 1.5". Temperature not to exceed 150°F for Alloy 5083.

2. For welded joints in which fusion of base metal is complete from root to face of weld metal (i.e., full penetration). No post-weld treatment performed. Except as noted below, data is derived from AWS Welding Handbook Section 4, 6th Edition, published 1972.

   2.1 Alloy group 2XXX (Al + Cu) from Vol. 3 DOD Aerospace Struct'l Metals Handbook, 1977 Rev. weldability ratings: Alloy 2219--good; 2014 and 2024--fair.

   2.2 Alloy 6061 (Al + Mg + Si) values for 6061-T6 as noted were developed by application of UCLBL Spec. M408 using GTAW (TIG), DCSP/75% Helium 25% Argon.

   2.3 Alloy group 7XXX (Al + Zn + Mg) from Vol. 3 DOD Aerospace Struct'l Metals Handbook, 1977 Rev., and Paper No 3--Selection of Aluminum Alloys & Fillers for Welding I. B. Robinson, Aluminum Welding Seminar May 18, 1978. Weldability rating--fair.

   2.4 Alloy group 5XXX (Al + Mg) from papers based on tests made by Rice, Campbell and Simmons of Battelle Memorial Institute, published 1961 and 1962, and Paper No 8--Designing for Welding, P. B. Dickerson, Aluminum Welding Seminary May 18, 1978. Weldability of alloys listed is very good.

nh

SUBJECT

FOR
U. C. R. L. COLOR CODE/IDENTIFICATION AND SAFETY

PREPARED W. Carpender/ E. Steele

CHECKED BY

"B" Rev.: 7/21/53

This color code is intended as a guide to contractors doing work for the University of California Radiation Laboratory, for the Laboratory's own construction projects, and for miscellaneous and maintenance painting. Any part of it may be deleted or invoked as required by the situation. With this in mind, the code has been broken down into the following sections:

I. Piping and Distribution Systems
II. Special Hazards
III. Accelerators and Associated Equipment
IV. General
V. Signs
VI. Schedule of Suggested Paints and Thinners

This code is based on the following:

Scheme for Identification of Piping Systems A.S.A. A 13-1928, Reaffirmed 1947.
University of California Std. Pipe and Conduit Identification Symbols, Dwg. 6676.
Bevatron, Colors To Be Used For Identification of Major Assemblies, Eng. Notes 175-1-M66A

References:

U. C. R. L. Std. (Electrical) Phase Colors Dwg. 10 Z 1161B

This Design Data supersedes Dwgs. 21-510, 215-11, and 3D6353 (D.D. #19)

SUBJECT: U. C. R. L. COLOR CODE FOR IDENTIFICATION AND SAFETY

PREPARED: W. Carpender/E. Steele

CHECKED BY:

I. PIPING AND DISTRIBUTION SYSTEMS

IDENTIFICATION SYMBOLS	SYSTEM	A.S.A. CLASS	BASIC COLOR	LETTERING OR BAND COLOR	REMARKS
	AIR:				
BAIR	Breathing Air System	S	L. Blue	Aqua	
AIR #	Compressed Air System	S	Aqua	Black	
	ELECTRICAL:				Western Litho Co."E-Z"Labels:
E #	115 Volt AC Conduit	D	(Labels)		CCP2
E #	220 Volt AC Conduit	D	(Labels)		CCP3
E #	440 Volt AC Conduit	D	(Labels)		CCP5
Mark voltage on line	Hi Voltage Conduit (above 600 V) (See Special Hazards "II")	D	Yellow	Black	CCP8
TEL	Telephone Conduit		None	White or Black	CCP11
FA #	Fire Alarm Conduit (120 V D.C.)	F	None	Red	
COM #	Public Address System Specials, etc.	S			CCP10 CCP12
	FIRE:				
FIRE #	Fire Main or Wet Standpipe System	F	Red	White	
DSP #	Dry Standpipe	F	Red	White	
CO_2	Carbon Dioxide Systems	F	Red	*Aluminum & *Orange	
SPR #	Sprinkler System	F	Red	White	
	GAS:				
HPG	Natural (City) Gas Distribution Lines 3 psig and above	D	Yellow	D.Brown & Red	"High Pressure Gas"
MPG	Medium Pressure Natural Gas 1/2 to 3 psig	D	Yellow	D.Brown	
GAS	Natural Gas House Lines 6 to 7 in. W.G.	D	Yellow	D.Brown	
LPG	Liquified Petroleum Gas 3 psig and above	D	Aluminum	D.Blue & Yellow	
BUT or PROP	Butane or Propane LPG House Lines 6 to 7 in. W.G.	D	Aluminum	D.Blue	
	GASSES, BOTTLED AND SYSTEMS:				
ACET	Acetylene	D	Yellow	*Red	
AIR #	Air (In cylinders)	D	*Yellow	*D.Blue & *D.Green	

SUBJECT: U. C. R. L. COLOR CODE FOR IDENTIFICATION AND SAFETY

PREPARED: W. Carpender/E. Steele

CHECKED BY:

I. PIPING AND DISTRIBUTION SYSTEMS (CON'T.)

IDENTIFICATION SYMBOLS	SYSTEM	A.S.A. CLASS	BASIC COLOR	LETTERING OR BAND COLOR	REMARKS
	GASSES, BOTTLED AND SYSTEMS: (CON'T.)				
AMG #	Ammonia (Anydrous)	D	Yellow	*Aluminum and *Black	
ARGON	Argon	S	Green	*D. Brown	
CO_2	Carbon Dioxide	D	*Aluminum	*Orange	
CL	Chlorine	D	Yellow	*Aqua	
ETHYL	Ethylene	D	*Orange	*D. Blue	
	Freon (See Refrigeration)	S	*White	Black	
HE	Helium	S	*Grey	*Orange	
H2	Hydrogen	D	Yellow	*Red and White	
BUT	Butane	D	*Aluminum	D. Blue	(See "Gas")
METH	Methane	D	*Aluminum	*Red and *Green	
N	Nitrogen	S	*Black	White	
OX #	Oxygen	D	Yellow	*D. Green	
SO_2	Sulfur Dioxide	D	Yellow	Aluminum and D. Green	
PROP	Propane	D	Aluminum	D. Blue	(See "Gas")
	OIL:				
OILS	Cooling Oil Supply (Cold)	D	L. Brown	D. Green	
OILR	Cooling Oil Return (Warm)	D	L. Brown	Black	
OILD	Oil Drain System (Inc. Vac. Oil Drain)	D	L. Brown	Grey	
VO	Vacuum Oil Distribution	D	L. Brown	D. Blue	
LOS	Lube Oil Supply	D	D. Brown	D. Green	
LOR	Lube Oil Return	D	D. Brown	Black	
FO	Fuel Oil	D	D. Brown	Yellow	
	PROCESS:				
	Acid	D	Yellow	Orange	
	Caustic	D	Yellow	D. Blue	
	Solvents	D	Yellow	L. Blue	
	REFRIGERATION:				
AML #	Ammonia Liquid	D	Yellow	*Aluminum and *Black	
AMS #	Ammonia Suction	D	Yellow	*Aluminum and *Black	
AMG #	Ammonia Hot Gas	D	Yellow	*Aluminum and *Black	
FL #	Freon Liquid	S	*White	Yellow	
FS #	Freon Suction	S	*White	Black	
FG #	Freon Hot Gas	S	*White	Black	
	SEWERS AND DRAINS:				
AS #	Acid Sewer	D	Yellow	Grey	
D #	Drains (Inc. Roof Leaders)	S	Grey	D. Green	
SS #	Sanitary Sewer	S	Grey	Aqua	
PS	Pressure Sewer	S	Grey	Yellow	

D-42B(M)

SUBJECT: U. C. R. L. COLOR CODE FOR IDENTIFICATION AND SAFETY

PREPARED: W. Carpender/E. Steele

CHECKED BY:

I. PIPING AND DISTRIBUTION SYSTEMS (CON'T.)

IDENTIFICATION SYMBOLS	SYSTEM	A.S.A. CLASS	BASIC COLOR	LETTERING OR BAND COLOR	REMARKS
	STEAM:				
HPS #	High Pressure Steam 41 psig. & over	D	Orange	White	
MPS #	Medium Pressure Steam 16 to 40 psig.	D	Orange	White	
LPS #	Low Pressure Steam up to 15 psig.	D	Orange	White	
R #	Condensate Return	S	D. Green	Orange	
	VACUUM:				
FVAC	Fore Vacuum	S	D. Blue	Grey	
HVAC	Hi Vacuum	S	D. Blue	White	
HOUSE	House Fore-Vacuum	S	D. Blue	Aqua	
VAC #	Lab Utility Vac Systems	S	Grey	D. Blue	
FVAC or HVAC	Vacuum Systems using Mercury	D	D. Blue	Orange	
	VENTS AND EXHAUSTS:				
VENT	Vents and Exhausts, Inc.				
	San. Sewer Vents	S	Grey	White	
	Vents for Mercury	D	Orange	Black	
	WATER:				
CW #	(Cold) Water, Domestic, City	S	D. Green	Grey	
CHWS #	Chilled Water Supply (Cooled by Refrigeration)	S	Paint with basic color of water being used	Add Aqua Band to Band Color of water being used	(Cold)
CHWR #	Chilled Water Return (Cooled by Refrigeration)	S			(Warm)
TWS	Tower Water Supply	S	D. Green	Yellow	(Cold)
TWR	Tower Water Return	S	D. Green	White	(Warm)
CALS	Calgon Water Supply	S	D. Green	Yellow	(Cold)
CALR	Calgon Water Return	S	D. Green	White	(Warm)
DW #	Distilled Water and Demineralized Water	S	Aluminum	D. Green	
HW #	Hot City Water (Domestic and Process)	D	Orange	D. Green	
HWS #	Hot(Heating) Water Supply	D	Orange	D. Green & Yellow	(Hot)
HWR #	Hot(Heating) Water Return	D	Orange	D. Green & Black	(Cold)
LCWS	Low Conductivity Water (Illco) Supply	S	Aluminum	Yellow	(Cold)
LCWR	Low Conductivity Water (Illco) Return	S	Aluminum	Black	(Warm)

Note: * In front of a color indicates cylinder color code as normally used by suppliers to U.C.R.L.
Following an Identification Symbol indicates that it was taken from U.C. Standard Dwg. 6676.

D-42C(M)

I. PIPING AND DISTRIBUTION SYSTEMS (CON'T.)

SWITCHES AND VALVES

Important switches and valves shall be clearly marked by means of signs or stickers bearing one of the following texts:

OPEN - FIRE - OPEN

RED LETTERS ON WHITE BACKGROUND, or

CLOSE - FIRE - CLOSE

GREEN LETTERS ON WHITE BACKGROUND. Stickers for this use are available at the Electric Shop.

IMPORTANT NOTE:

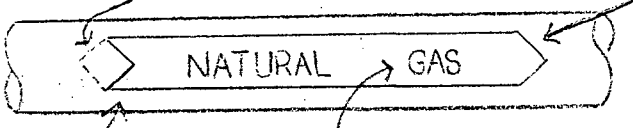
The marking of valves shall be done only after clearing through Safety Engineer (C. R. Wintersteen) and marking of Switches or Circuit Breakers shall be done only after clearing through Power Engineer (C. T. Grauer) or those designated by them.

LABELING PIPING AND CONDUITS (Preferred Method):

In general, identification and instructions should be stenciled in the "band" color on pipe. Such markings should be near valves and branches. Wherever possible or advisable, the W. H. Brady Co. "Quick Labels," or the Western Lithograph Co. "E-Z-Code System" labels should be used. These are obtainable at the Plant Engr. Office, the Electric Shop, and the Maintenance Mechanics Shop. These labels have not proven too successful for outdoor applications, however.

If Flow Is In Either Or Both Directions

Indicate Direction Of Flow



Arrow:
- *If on unpainted pipe or pipe painted to match room, paint arrow "basic" color.
- *If on pipe painted "basic" color, outline arrow in "band" color.
- *Use Brady "Quick-Labels" or equal, cut to arrow shape wherever possible.

Information:
Stenciled in "band" color. Use U. C. Standard "Identification Symbols" wherever possible.

I. PIPING AND DISTRIBUTION SYSTEMS (CON'T.)

NOTE: Where 3-color system (2 band colors) is used, the following can be done:

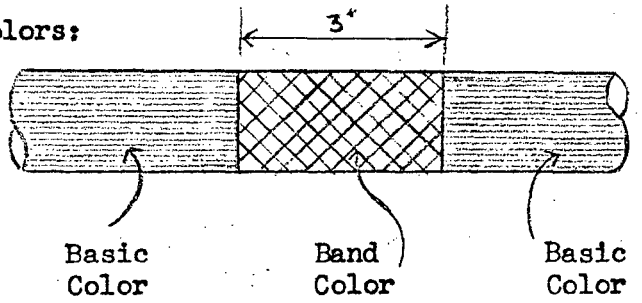
a. Letters may be alternated in the two band colors.
b. The arrow outline may be painted in one band color and the information in the other.
c. The information may be painted in one band color and underlined with the other.

BANDING PIPING

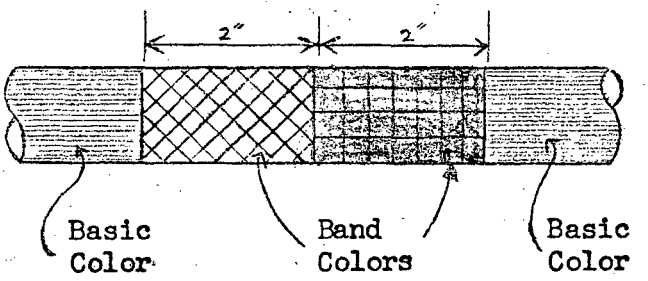
Where pipe is too small for practical lettering, or where it is not desired to repeat the lettering, pipe may be banded as follows:

(A) Pipe painted with the basic colors:

2-color Systems
(One Band Color)



3-color System
(Two Band Colors)



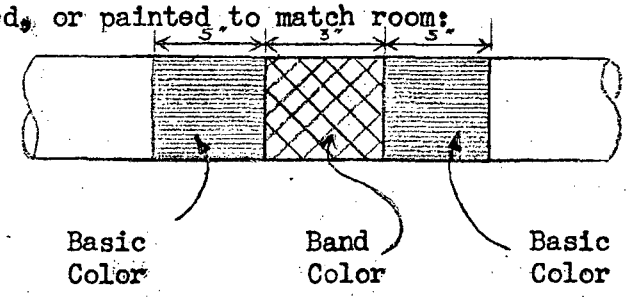
(Con't.)

I. PIPING AND DISTRIBUTION SYSTEMS (CON'T.)

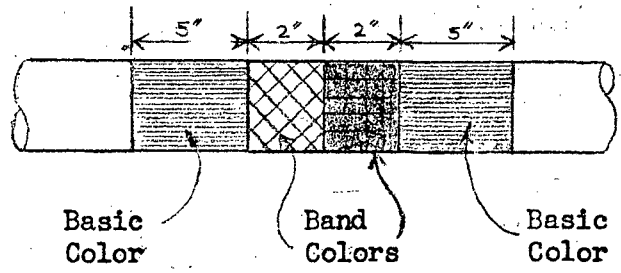
BANDING PIPING (Con't.)

(B) Pipe unpainted, already painted, or painted to match room:

2-color Systems
(One Band Color)



3-color Systems
(Two Band Colors)



GENERAL NOTES:

On equipment (pumps, etc.) which is directly associated with the system being coded, paint main part basic color and trim with band color. On piping, paint unions, edges of flanges, valve hand wheels, etc., with band color.

Supply Lines are defined as follows:
Cooling systems, from the cooling device to the device being cooled.
Heating systems, from the heating device to the device being heated.

Return Lines are of course the converse.

Location of Bands and Labels:
In general bands and/or labels should be placed as follows:

a. 15 to 20 ft. apart on straight runs of pipe,
b. On each side of partitions and floors within 6 ft. of said partition or floor,
c. Within 6 ft. of all valves and branches.

II. SPECIAL HAZARDS

HAZARD	A.S.A. CLASS	BASIC COLOR (BACKGROUND)	LETTERING OR BAND COLOR	REMARKS
HI VOLTAGE: (Above 600V) Conduits, Junction boxes, etc., containing high voltage cables, where these are routed through areas in which general work is done. Not to apply to Switchgear or equipment inside enclosures. Mark voltage on equipment as deemed necessary for safety. (See Piping, etc., I)	D	Yellow	Black	
RADIATION:	D & V	L. Blue	Violet	See Signs under "V"
MERCURY:	D	Orange	Black	

III. ACCELERATORS AND ASSOCIATED EQUIPMENT*

	BASIC COLOR	SECONDARY COLOR	REMARKS
MAGNET PARTS	Aluminum		
MAGNET COIL PARTS	Buff		
COOLING EQUIPMENT (Other than water)	L. Grey		
POWER SUPPLIES: Ground Potential	Grey		
VACUUM SYSTEM EQUIPMENT (See Vacuum system piping under I)	D. Blue		
INJECTORS	Olive Green		
ACCELERATING SYSTEM	Bronze		
MISCELLANEOUS COMPONENTS	Aluminum		
STRUCTURAL STEEL	L. Grey		

* Refer to Engineering Note 175-1-M66A

IV. GENERAL

	BASIC COLOR	LETTERING OR HIGHLIGHT COLOR	REMARKS
SHOPS AND OFFICES: Color scheme as applied to Machine Shop by Messrs. Barton and Harvie.			
Machine Tools:			
Frame, Bed, etc.	Horizon Grey		
Moving Parts, Guards, Handles Control Wheels, etc.		"Spotlight Buff"	
Dados, workbenches, tables, miscellaneous furniture, fixtures	Aqua (Dado Enamel)		
Walls (Mix to suit room)	L. Green		No Standard Paint
Ceilings (Mix to suit room)	Flat White		No Standard Paint
FENCES AND ROADWAYS:			
Danger and Attention Areas, Barricades	Yellow	Black	See Signs "V"
Road Markings, Lines, etc.	White		See Signs "V"
NOTE: USE RED ONLY FOR FIRE			
VEHICLES:			
Lift Trucks, Busses, Trucks,	Yellow	Black	
Truck Cranes	Yellow	Black	
FLAMMABLE LIQUIDS:			
Labels for identifying contents of containers are obtainable at the Safety Office	Yellow	Black	Usual Colors - See ASA #A13 for exact combination
CRANES:			
Hooks, Loadblocks, Control Pendants, cabs(where advisable)	Yellow Yellow	Black Black	
Bridge, Trolley, etc.	L. Grey		Or to match room

D-421(M)

SUBJECT

U. C. R. L. COLOR CODE FOR IDENTIFICATION AND SAFETY

PREPARED W. Carpender/E. Steele

CHECKED BY

V. SIGNS

FIRE PROTECTION SIGNS:

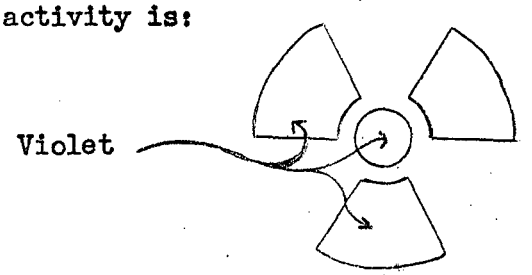
Signs must be Red on White, or as Underwriter Standards, White on Red.

HAZARD SIGNS:

Signs must be Black on Yellow. Hazards include mechanical, electrical, fences, road areas.

RADIATION SIGNS:

Lettering and symbol must be of Violet on a Pale Blue background. The standard A. E. C. symbol for Radiation activity is:



DIRECTIONAL OR INSTRUCTIONAL SIGNS:

All kinds shall be Black letters on White background, or the reverse, if desired.

VI. SCHEDULE OF SUGGESTED PAINTS

COLOR	MANUFACTURER	FINISH	RECOM-MENDED THINNER	PRIMER, WOOD OR RUSTY SURFACES	PRIMER, ON CLEAN SUR-FACES	MAX. TEMP.	REMARKS
Red	Rustoleum	H-2	633	769	960	250°	
Orange	Rustoleum (Flambeau-Red)	H-6	633	769	960	250°	
Yellow	Rustoleum - SO	659					
	Rustoleum (M-H Yellow)	H-18	633	769	960	250°	
	Pittsburg Lavax Focal Yellow	23-78		Fuller 4080			
Aqua	Rustoleum	Mix "A"	633	769	960	250°	See page 13
	DuPont Dado Enamel	#8 Medium					
D. Green	Rustoleum (Oliver Green)	H-12	633	769	960	250°	
	Olo Rust - Sele (Rust 782)	1696					
L. Blue	Rustoleum	Mix "B"	633	769	960	250°	See page 13
	Glidden Japalac	#1215					
D. Blue	Rustoleum (Internat. Blue)	H-8	633	769	960	250°	
	Pittsburg Lavax Mach. Enamel	2387					
Violet	Martin Senours	2225					Radiation only
White	Amercoat	#33 White					
White	Rustoleum SO	2766	540	769 & 850	960	250°	
Black	Rustoleum	H-5	633	769	960	250°	
D. Brown	Rustoleum SO	745	633				
L. Brown	Rustoleum Hull Finish (Marine)	358	363	769	960	250°	
Buff	Dupont Mach. Enamel	Spotlight Buff					
Grey	Rustoleum LO	583	785	769	960	250°	
	Rustoleum (For Machinery)	A201	633	769	(Not Usually req.)		
L. Grey	DuPont Mach. Enamel	Horizon Grey					
Bronze	Make up as needed						
Aluminum	Rustoleum	500	(None req.)	769	960	500°	
Olive Green	Pittsburg Mach. Enam. Vista Green	23-76		Fuller 4080			
Thinners	Rustoleum (Slight Amber Color)	633				250°	
	Rustoleum (Clear)	540				250°	
	Rustoleum	363					
Sealer	Rustoleum "Clear-Sele" for Wood and Fabric	717					
Primers	Rustoleum (Oxide) Inside & Outside	769	633			250°	
	Rustoleum SO (Zinc Cr.) Inside Only	960	633			250°	
	Fuller Zinc Cromate	4080					
"Pale Blue"	Martin Seymour Nu Hu Dark Blue	40					Radiation Only

SUBJECT: U. C. R. L. COLOR CODE FOR IDENTIFICATION AND SAFETY
Revised: 3/12/53

RADIATION LABORATORY - UNIVERSITY OF CALIFORNIA - BERKELEY
DESIGN DATA
Revised:

DATE	D.D. NO.	PAGE
6/17/52	19 B	12 A

PREPARED: W. Carpender/E. Steele
CHECKED BY:

VI. SCHEDULE OF SUGGESTED PAINTS (Continued).

MIX "A" -- AQUA:

Add dark green (Rustoleum #H-12) to white (Rustoleum #2766) to match standard panel. Use care; not much green is required.

MIX "B" -- LIGHT BLUE:

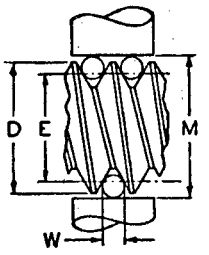
Add dark blue (Rustoleum # H-8) to white (Rustoleum #2766) to match standard panel. Use care; not much blue is required.

TITLE

FACTORS FOR CALCULATING, SPECIFYING AND MEASURING THREAD DIMENSIONS BY THE THREE-WIRE METHOD---60-DEGREE FORMS

PREPARED BY	DATE
W. M. BROBECK	9/47
REVISED BY	DATE
J. O. Turner	4/80
REVISED BY	DATE

For a detailed discussion of this procedure, see "MACHINERY'S HANDBOOK", 20th edition, p. 1406.



M: dimension over wires
D: major or outside diameter
E: pitch diameter
P: pitch
W: wire diamenter

E = D - X.
X = 0.6495P

M = E + Y
Y = 3 W - 0.86603P

ISO METRIC (dimensions in millimeters):-

P	W	X	Y
0.3	0.173	0.195	0.260
0.35	0.202	0.227	0.303
0.4	0.231	0.260	0.346
0.45	0.260	0.292	0.390
0.5	0.289	0.325	0.433
0.6	0.346	0.390	0.520
0.7	0.404	0.455	0.606
0.75	0.433	0.487	0.650
0.8	0.462	0.520	0.693
0.9	0.520	0.585	0.779
1.0	0.578	0.650	0.866
1.25	0.722	0.812	1.083
1.5	0.866	0.974	1.299
1.75	1.011	1.137	1.516
2.0	1.155	1.299	1.732
2.5	1.443	1.624	2.165
3.0	1.732	1.949	2.598
3.5	2.021	2.273	3.031
4.0	2.310	2.598	3.464
4.5	2.598	2.923	3.897
5.0	2.887	3.248	4.330
5.5	3.176	3.572	4.763
6	3.464	3.897	5.196

AMERICAN NATIONAL THREADS (dimensions in inches):-

Threads per Inch	P	W	X	Y
28	.0357	.029	.0232	.0561
24	.0417	.029	.0271	.0509
20	.0500	.032	.0325	.0527
18	.0556	.0395	.0361	.0704
16	.0625	.0395	.0406	.0644
14	.0714	.045	.0464	.0731
13	.0769	.045	.0500	.0684
12	.0833	.055	.0541	.0928
11	.0909	.055	.0591	.0863
10	.1000	.063	.0650	.1024
9	.1111	.072	.0722	.1198
8	.1250	.081	.0812	.1348
7	.1429	.092	.0928	.1523
6	.1667	.108	.1083	.1797
5-1/2	.1818	.120	.1181	.2026
5	.2000	.127	.1299	.2078
4-1/2	.2222	.143	.1444	.2366
4	.2500	.143	.1624	.2125
3-1/2	.2857	.185	.1856	.3076

Wires are available in LBL Machine Shop.
Tolerance on Pitch or Major Dia. and on Dimension over Wires must be the same.
No tolerance required on wire diameter.

EXAMPLE: (dimensions in inches)

Dimension a screw and nut with 2-1/8 diameter and - 8 NS (National Special) threads/inch, .0010 tolerance on the external thread, .0020 trolerance on the internal thread and .0005 minimum clearance.

Basic E (Pitch dia.) = 2.1250 - .0812 = 2.0438

For Nut:

E (min.) = Basic E = 2.0438
E (max.) = 2.0438 + .002 = 2.0458
M (Min.) (for go gage) = 2.0438 + 0.1348 = 2.1786
M (max.) (for no-go gage) 2.1786 + .002 = 2.1806

For Screw:

E (max.) = 2.0438 - .0005 = 2.0433
E (min.) = 2.0433 - .0010 = 2.0423
M (max.) = 2.1786 - .0005 = 2.1781
M (min.) - 2.1786 - .0010 = 2.1776

Wire size, .081

ISO METRIC procedure the same except specifying everything, including pitch, in millimeters.

/nh

RADIATION LABORATORY - UNIVERSITY OF CALIFORNIA - BERKELEY

DESIGN DATA

DATE	D.D. NO.	PAGE 1 OF 3 PAGES
7/21/70	23B	

SUBJECT

CHEVRON SEALS INTERNAL PARTS

PREPARED: J. Dols

CHECKED BY: P. Bean

"B" Revision, April 23, 1971

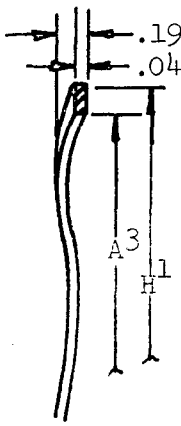


FIG 1
MARCEL SPRING

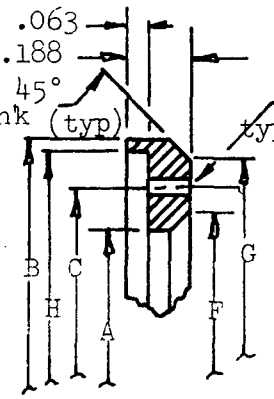


FIG 2
PRESSURE RING

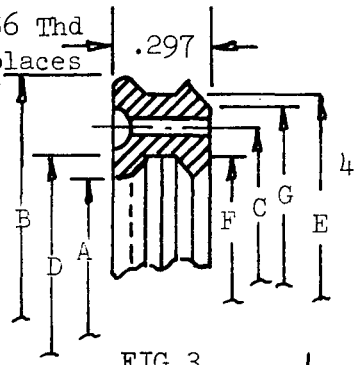


FIG 3
LANTERN RING

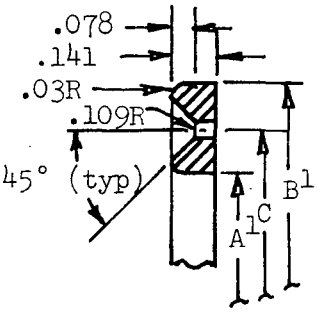
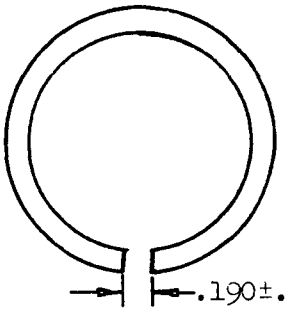


FIG 4
SEAT RING



MARCEL SPRING
GAP

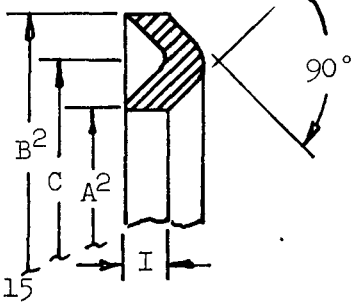


FIG 5
GASKET

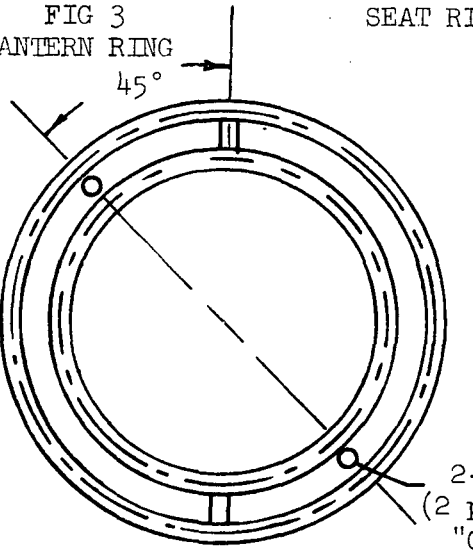


FIG 3 LANTERN RING

DIMENSIONAL DATA

Nom ID	Fig 2 & 3 A Dia +0.002 -0.000	Fig 4 A1 Dia +0.002 -0.000	Fig 5 A2 Dia	Fig 1 A3 Dia ±0.005	Fig 2 & 3 B Dia +0.000 -0.002	Fig 4 B1 Dia +0.000 -0.002	Fig 5 B2 Dia	B.C. C Dia ±0.005	D Dia ±0.005	E Dia ±0.005	F Dia ±0.005	G Dia ±0.005	Fig 2 H Dia ±0.002	Fig 1 H1 Dia ±0.005	I	J Rad Min
3/8	0.395	0.377	0.368	0.520	0.855	0.873	0.882	0.625	0.500	0.750	0.500	0.750	0.780	0.795	0.083	0.063
1/2	0.520	0.502	0.493	0.645	1.105	1.123	1.132	0.813	0.625	1.000	0.688	0.938	1.030	1.045	0.083	0.063
3/4	0.770	0.752	0.743	0.895	1.355	1.373	1.382	1.063	0.875	1.250	0.938	1.188	1.280	1.295	0.083	0.063
1	1.020	1.002	0.993	1.145	1.605	1.623	1.632	1.313	1.125	1.500	1.187	1.438	1.530	1.545	0.083	0.063
1 1/4	1.270	1.252	1.240	1.395	1.855	1.873	1.885	1.563	1.375	1.750	1.406	1.719	1.780	1.795	0.140	0.109
1 1/2	1.520	1.502	1.490	1.645	2.105	2.123	2.135	1.813	1.625	2.000	1.657	1.969	2.030	2.045	0.140	0.109
1 3/4	1.770	1.752	1.740	1.895	2.230	2.248	2.260	2.000	1.875	2.125	1.844	2.156	2.155	2.170	0.140	0.109
2	2.020	2.002	1.990	2.145	2.605	2.623	2.635	2.313	2.125	2.500	2.156	2.469	2.530	2.545	0.140	0.109
2 1/2	2.520	2.502	2.490	2.645	3.105	3.123	3.135	2.813	2.625	3.000	2.656	2.969	3.030	3.045	0.140	0.109
3	3.020	3.003	2.988	3.145	3.730	3.747	3.762	3.375	3.125	3.625	3.188	3.563	3.655	3.670	0.156	0.125

D-1(M)

RADIATION LABORATORY - UNIVERSITY OF CALIFORNIA - BERKELEY

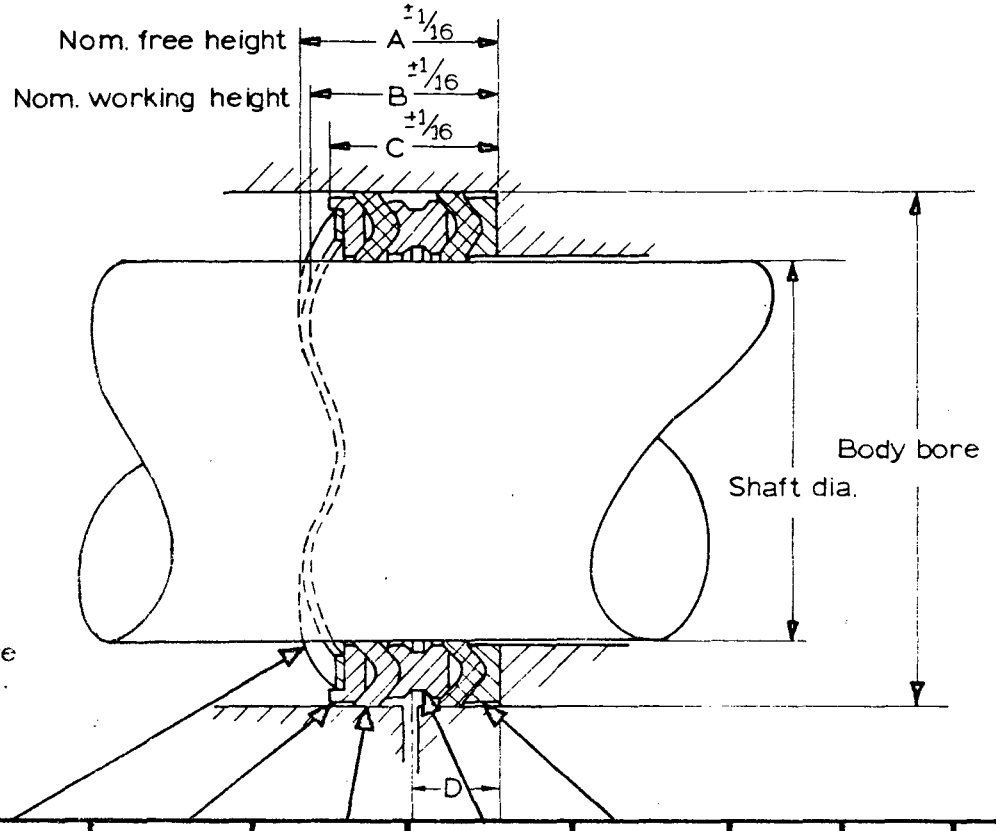
DESIGN DATA

DATE	D.D. NO.	PAGE 2 OF 3 PAGES
7/21/70	23B	

SUBJECT: CHEVRON SEALS INTERNAL PARTS

PREPARED: J. Dols

CHECKED BY: P. Bean



Notes:
1. Shaft should be polished.
2. Oil lubrication desirable where use is frequent.

Shaft Dia.	Body Bore	Spring Washer Part no.	Pressure Ring Part no.	Gasket Part no.	Lantern Ring Part no.	Seat Ring Part no.	A	B	C	D
3/8	.875 .878	4730-40895	4730-40875	4730-40855	4730-40865	4730-40885	.812	.719	.688	.375
1/2	1.125 1.127	4730-40896	4730-40876	4730-40856	4730-40866	4730-40886	1.000	.938	.875	.438
3/4	1.362 1.366	4730-40897	4730-40877	4730-40857	4730-40867	4730-40887	1.000	.938	.875	.438
1	1.625 1.627	4730-40898	4730-40878	4730-40858	4730-40868	4730-40888	1.078	1.015	.938	.500
1 1/4	1.875 1.877	4730-40899	4730-40879	4730-40859	4730-40869	4730-40889	1.000	.938	.875	.437
1 1/2	2.111 2.115	4730-40900	4730-40880	4730-40860	4730-40870	4730-40890	1.000	.938	.875	.437
1 3/4	2.250 2.253	4730-40901	4730-40881	4730-40861	4730-40871	4730-40891	.812	.750	.687	.376
2	2.625 2.627	4730-40902	4730-40882	4730-40862	4730-40872	4730-40892	1.000	.938	.875	.437
2 1/2	3.125 3.127	4730-40903	4730-40883	4730-40863	4730-40873	4730-40893	1.000	.938	.875	.437
3	3.750 3.753	4730-40904	4730-40884	4730-40864	4730-40874	4730-40894	1.031	.968	.906	.500

D-1 (M)

RADIATION LABORATORY - UNIVERSITY OF CALIFORNIA - BERKELEY

DESIGN DATA

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4/23/71	23B	3 of 3

SUBJECT: CHEVRON SEALS INTERNAL PARTS

PREPARED: J. Dols

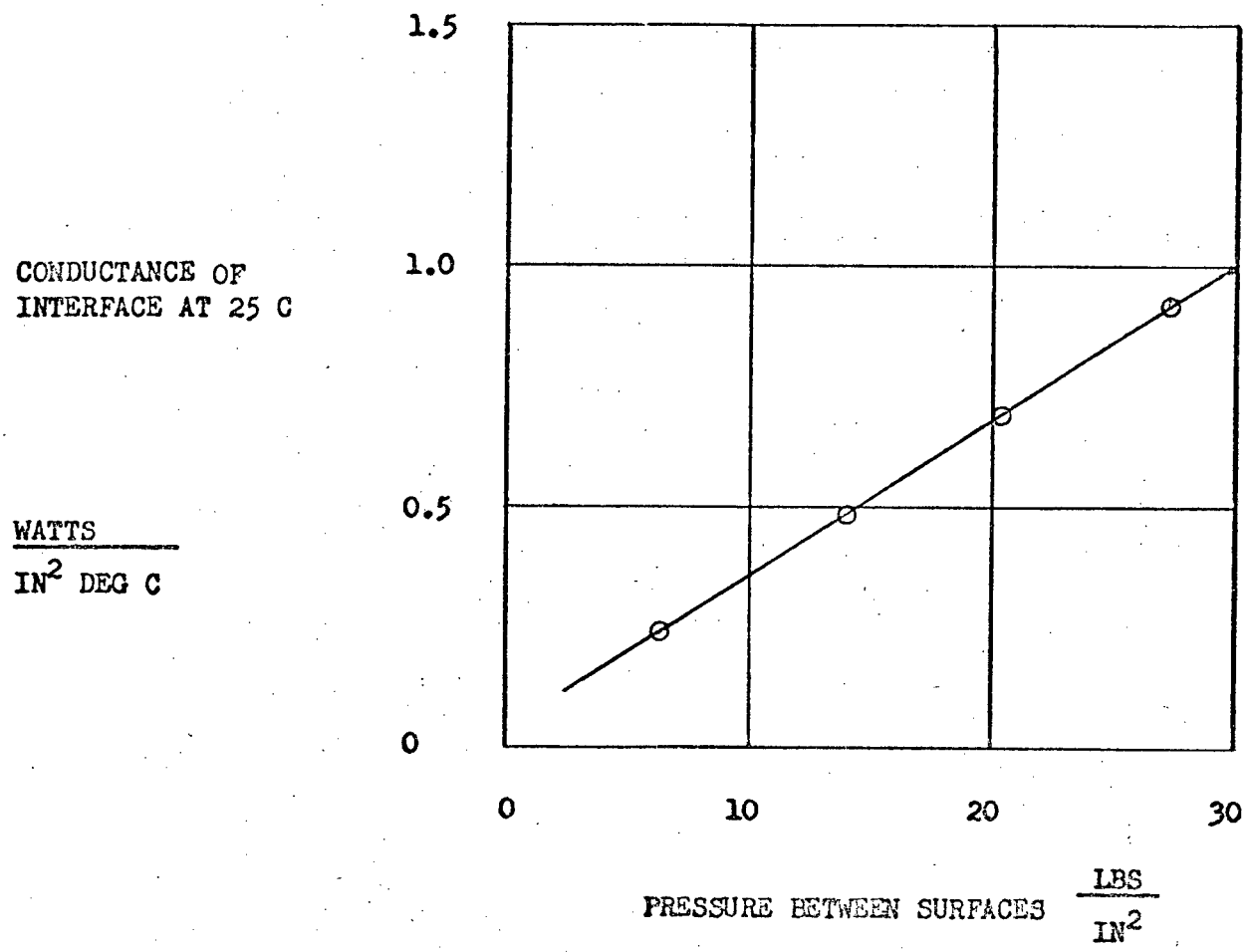
CHECKED BY: R.L. Erickson

Note: For your cross reference listed below are stock numbers, 10A drawings and old LRL Berkeley drawings.

	Size	LRL Stock No.	Old No.	10A Series
Gasket	3/8	4730-40855	3G 6001	10A 1591-1
	1/2	4730-40856	3G 6011	10A 1591-2
	3/4	4730-40857	3G 6021	10A 1591-3
	1	4730-40858	2N 4711A	10A 1591-4
	1 1/4	4730-40859	4E 4001	10A 1591-5
	1 1/2	4730-40860	3G 6031	10A 1591-6
	1 3/4	4730-40861	3G 6041	10A 1591-7
	2	4730-40862	2N 5301	10A 1591-8
	2 1/2	4730-40863	4E 4311	10A 1591-9
	3	4730-40864	2N 4241	10A 1591-10
Lantern Ring	3/8	4730-40865	1K 7111	10A 1601-1
	1/2	4730-40866	3G 1131	10A 1601-2
	3/4	4730-40867	1G 1291A	10A 1601-3
	1	4730-40868	9881A	10A 1601-4
	1 1/4	4730-40869	4E 3981	10A 1601-5
	1 1/2	4730-40870	1G 1311A	10A 1601-6
	1 3/4	4730-40871	1G 1331A	10A 1601-7
	2	4730-40872	2Q 2972	10A 1601-8
	2 1/2	4730-40873	4E 4322	10A 1601-9
	3	4730-40874	2Q 3392	10A 1601-10
Pressure Ring	3/8	4730-40875	1K 7101	10A 1581-1
	1/2	4730-40876	3G 1141	10A 1581-2
	3/4	4730-40877	1G 1351B	10A 1581-3
	1	4730-40878	9901	10A 1581-4
	1 1/4	4730-40879	4E 4011	10A 1581-5
	1 1/2	4730-40880	1G 1361B	10A 1581-6
	1 3/4	4730-40881	1G 1371B	10A 1581-7
	2	4730-40882	2Q 2982	10A 1581-8
	2 1/2	4730-40883	4E 4342	10A 1581-9
	3	4730-40884	2Q 3402A	10A 1581-10
Seat Ring	3/8	4730-40885	1K 7121	10A 1611-1
	1/2	4730-40886	3G 1121	10A 1611-2
	3/4	4730-40887	1G 1381A	10A 1611-3
	1	4730-40888	9891	10A 1611-4
	1 1/4	4730-40889	4E 4021	10A 1611-5
	1 1/2	4730-40890	1G 1391A	10A 1611-6
	1 3/4	4730-40891	1G 1401A	10A 1611-7
	2	4730-40892	2Q 2992	10A 1611-8
	2 1/2	4730-40893	4E 4332	10A 1611-9
	3	4730-40894	2Q 3382	10A 1611-10.
Spring Washer	3/8	4730-40895	4E 4352-1	10A 1571-1
	1/2	4730-40896	4E 4352-2	10A 1571-2
	3/4	4730-40897	4E 4352-3	10A 1571-3
	1	4730-40898	4E 4352-4	10A 1571-4
	1 1/4	4730-40899	4E 4352-5	10A 1571-5
	1 1/2	4730-40900	4E 4352-6	10A 1571-6
	1 3/4	4730-40901	4E 4352-7	10A 1571-7
	2	4730-40902	4E 4352-8	10A 1571-8
	2 1/2	4730-40903	4E 4352-9	10A 1571-9
	3	4730-40904	4E 4352-10	10A 1571-10

MATERIAL COPPER - SURFACES OPTICALLY FLAT

From Jacobs & Starr, Review of Scientific Instruments, Vol. 10, p. 140



Note: Radiation Transfer between black body surfaces at 20C = Approx. .004 Watts/In^2 Deg C.

Therefore radiation can play no appreciable part in transfer under above conditions.

Note added September 20, 1948:

Data on heat resistance between cold-rolled steel blocks tested in air by Brunot and Buckland of the General Electric Co. (Design News, Sept. 1948) show contact resistance varying from 6 inches equivalent length of steel with rough machined rusted surfaces at zero pressure to 1/4 inch for clean lapped surfaces at 300 psi. In general increase from zero to 300 psi cut the resistance to 1/2 to 1/3.

WMB/RE/FP

DESIGN DATA

DATE	D.D.NO.	PAGE
8-14-64	25A	1 OF 4 PAGES

SUBJECT

BRAZE FILLER METALS AND BRAZING PRACTICE
(HARD SOLDERS, SILVER SOLDERS)

PREPARED Ralph Peters (3-19-48)

CHECKED BY R.P. & J.T.

A Revision: Revised & retyped, August 14, 1964, R. Reimers RR

BRAZE FILLER METAL	MELTING POINT F°	MELTING POINT C°	FLOW POINT F°	FLOW POINT C°	COMPOSITION	CONDUCTIVITY % OF COPPER	TENSILE STRENGTH KIPS/IN²	USES (See Comments also)
Handy & Harman Easy Flo	1160	627	1175	635	50% Ag 15.5 Cu 16.5 Zn 18 Cd	18% LRL 1948 23.9% H & H '64	35 Cu. joint 35 - 45 brass joint > 50 stl. joints	Most Metals
Handy & Harman Sil-Fos	1185	641	1300	704	15% Ag 80 Cu 5 P	14% LRL 1948	40 - 60	Cu-to-Cu Only
Westing-house Phos-Cu	1310	710	1350	732	92.75% Cu. 7.25% P	4% LRL 1948	20 - 40	Cu-to-Cu Not for brass, bronze
Handy & Harman Braze Easy	1240	671	1325	720	65% Ag 20% Cu 15% Zn	23% LRL 1948	64.8	Silver & Others
Handy & Harman Easy Flo #3	1170	632	1270	628	15.5 Zn 50% Ag 15.5 Cu 16.0 Cd 3.0 Ni	18% H & H 1964	30 - 35 cu joint 35 - 45 brass " > 50 stl. joint	Tungsten Carbide to Steel Al bronze to Stl. Others

GENERAL

Braze films should be between .001 and .010 thick favoring the small clearance. Too tight a fit causes bare spots. Too large gives poor capillary flow and weaker joints. A film .0015 thick is twice as strong as one .015 thick.

Handy & Harman flux is always used except on Phos-copper and Sil-Fos copper-to-copper joints. This flux can be used on any filler metal with a melting point between 1100° F (593° C) to 1600° F (871° C).

For additional information see: Design Data 68 and 71; Brazing Manual, American Welding Society.

RL-610-a

Locating shoulders are useful in brazing assemblies. Provide locating screws, clips, etc., to hold assemblies while brazing.

Use soft solder on brass bellows whenever possible.

Specify if machining is to be done before or after brazing. It should almost always be done after.

Electrical conductivity data are not conclusive. Those values given above which were measured at LRL are the conductivity of the wire filler metal before using in a joint, which may or may not be related to the actual joint resistance. Westinghouse claims conductivity of a thin film of Phos-copper is 98% that of copper. Butt joints with Easy-Flo and Sil-Fos are claimed to have conductivities 85% to 96% that of copper.

Brazing always anneals metals.

EASY-FLO melts at a lower temperature than any other filler metal. (AWS Class. BAg-la)

Flux is always used with all Easy-Flo's. This is a basic weakness because occasionally flux is occluded in a joint. For this reason Easy-Flo is not recommended for vacuum tight joints. Try to make vacuum joints copper-to-copper, brazed with copper or Sil-Fos. If the use of Easy-Flo on vacuum joints cannot be avoided try to design the assembly so that the Easy-Flo joint is made in the shop and all field assembly joints are copper. Special attention should be given to inspection and testing of Easy-Flo vacuum joints including thorough flushing with boiling water.

Easy-Flo is definitely the best filler metal for furnace brazing most materials. It can be used on most metals. Do not use where fillets are needed (it is very fluid and has only a very short plastic range). Do not use as the first filler metal on a two-step assembly where the first filler is not to remelt when the second is done. It is good for the second filler on such an assembly. Use everywhere, except on the exceptions just indicated. Service temp. 400° F. max. Film thk. .002/.005. Do not use on Al, Mg.

SIL-FOS - AWS Class. BCuP-5

Use Sil-Fos, without flux, on vacuum tight copper-to-copper joints that will need to be remade. Never use it on anything but copper-to-copper. Handy & Harman recommend it for use on brass and bronze with flux, but Laboratory technicians, while admitting that it can be used on these materials even without flux, nevertheless seldom use it on brass and bronze. In general, use it on copper assemblies—especially if large fillets are required. It has a wide plastic range. It is never as fluid as Phos-copper or Easy-Flo. It does not embrittle copper as much as Phos-copper does on repeated reheating. Do not use Sil-Fos on furnace brazing jobs. It will not flow properly. Brazing range: 1300 - 1500° F. Film thickness .001 to .005. Service temperature 300° F maximum.

PHOS-COPPER - AWS Class. BCuP-2

Phos-copper makes practically a foolproof joint on copper-to-copper tubing. No flux is required. Cleaning is not critical; nor is heat control. Always use Phos-copper on copper-to-copper joints unless the joint will need to be remade. Phos-copper embrittles copper and should not be used on an assembly where the joint will be subject to vibration or flexing. Westinghouse recommends it for use on brass and bronze with flux. Laboratory technicians, admitting that it can be used on these materials even without flux, nevertheless never use it on brass and bronze. The melting temperature is too high for these alloys. Phos-copper is perhaps the most fluid of all filler metals and flows very well by capillary action. Do not use in furnace brazing jobs. Never use on ferrous parts. (Phos-copper not purchased anymore. Used infrequently as of June 1964.) Film thk. .001/.003 svc. temp. 300°F max

BRAZE EASY (Formerly called Easy Silver Solder) Svc. Temp. 400° F Max.

This filler metal has approximately the same characteristics as Easy-Flo, but has a higher melting point. Use it as the first filler in two-step assemblies, possibly excepting copper two-step assemblies where Phos-copper or Sil-Fos could be used. Use it even on copper two-step assemblies if it is a furnace brazing job. Braze Easy works well in the furnace. Phos-copper and Sil-Fos do not.

EASY-FLO #3 - AWS Class. BAg-3

This filler metal has a wider plastic range than Easy-Flo. Use it on all applications where heavy fillets are required except copper-to-copper. Use Sil-Fos for fillets on copper-to-copper. Use with B-1 flux on stainless steel if stainless steel is subject to chloride corrosion.

SUMMARY

Use Sil-Fos on copper joints to be remade or requiring fillets.
Use Phos-copper on permanent unflexed copper joints.
Use Braze Easy on two-step assemblies.
Use Easy-Flo everywhere else except in some ultrahigh vacuum systems.

Note added, June 6, 1957: EN 7911-11 M8

The 72-inch Bubble Chamber magnet coils were fabricated using internal sleeves and Easy Flo. The 184-inch modification magnet auxiliary coils had similar joints made with Sil-Fos. The hollow copper conductor was 1 3/16" square. The following are probably true: (1) Sil-Fos joints are harder to bend and more likely to fracture than Easy-Flo joints. (2) Easy-Flo penetrates more easily into a joint than Sil-Fos. (3) Flux occlusions have not been a problem with Easy-Flo.

Note added, R. Reimers, August 1964: References, Handy & Harman literature and correspondence, American Welding Society Brazing Manual.

A. Ultrahigh Vacuum Filler Metals

Some systems must be free of outgassing and contamination from cadmium, zinc, phosphorus, carbon and high vapor pressure impurities. In general, Easy Flo, Sil-Fos and Braze RT are not acceptable for these systems. Vacuum tube grade low vapor pressure filler metals such as the following--Handy & Harman BT VTG, Braze 603 VTG, Premabraze 615 VTG, Premabraze 630 VTG, Premabraze 715 VTG and other similar filler metals, all of which are composed of silver, copper, nickel, indium, and tin should be used. Their flow points are in the 705° C to 795° C region. They are items 42, 45, 48, and 46 of Design Data 71, respectively. Premabraze 715 is corrosion resistant BT and is not in Design Data 71. BT is specifically for ceramic joints. Premabraze 130 (82% Au, 18% Ni) excellent for UHV bakeable systems, wets 304, 316, 321, 347 stainless steel. Avoid use of flux.

B. Braze Filler Metals for 300-Series S. S. (For 200 and 400 series, see refs.)

Torch, furnace, induction, resistance, and dip brazing processes used. Furnace brazing temperature should be controlled ± 10° F. Vacuum brazing pressure of .01 to 100 microns used. Proper stress relieving at a temperature below solidus temperature of base metal helps avoid stress-corrosion cracking during brazing. Always degrease immediately prior to brazing. Carbide precipitation occuring during brazing of unstabilized stainless steel (302, 304) above 800° F can be lessened by use of 304L, 321, 347. Following brazes can be used: Easy Flo, Easy Flo #3, Premabraze alloys, Brazes 603, 630, and others. Each braze requires specific flux, atmosphere and temperature. See Handy & Harman literature, AWS Brazing Manual, DD #71. Clearances .0005 to .0035 depending on coefficients of expansion, heating rate and filler used.

C. Handy & Harman Fluxes

1. Handy Flux: all-purpose; suitable for most silver brazing; used on steel, copper, bronze, brass, nickel and others; Starts dissolving oxides at 800° F. Liquid at 1100° F. Working range: 1100° F - 1600° F.

2. Handy Flux Type B-1 is for brazing high chromium stainless steels, tungsten and chromium carbides and molybdenum alloys. Range: 1100° F to 1700° F.

3. Handy Flux Type A-1 is for brazing aluminum-bronze and other alloys containing small amounts of aluminum and titanium, but is not recommended for use with aluminum- or titanium-base alloys.

One-half x 1/2 x 2" bars of Tough Pitch Copper at 95% ACS were butt-joined the following methods:

1. Easy Flo, Easy Solder 657, Sil Fos, and Phos Copper brazes by Heliarc in spaced bars at .002" spacing.

2. Heliarc fusion welds following common heliarc practice using pure Silver, Tough Pitch Copper, OFHC copper, 372, and 939 filler rods.

Excess brazing and welding beads were ground off to give a 1/2 x 1/2 section at the weld.

D.C. electrical resistance through 2 cm of the bar including the joint was measured and the data is reported as an increase in length of unjoined copper path normal to the joint for each such joint, to give equal D.C. resistance.

Method	Joint Material	Equivalent Copper Path Increase per joint - inches
Solder	Easy Flo	.037
	Easy Solder 657	.048
	Sil Fos	.055
	Phos Copper	.121
Weld	Silver	.123
	T.P. Copper	.138
	OFHC Copper	.135
	Anaconda 372 Rod (Silcon Deoxidized)	.154
	Anaconda 939 Rod (Phosphorous Deoxidized)	.180

RN/mh

RADIATION LABORATORY - UNIVERSITY OF CALIFORNIA - BERKELEY

DESIGN DATA

DATE	D.D. NO.	PAGE 1 OF PAGES
10/28/48	27A	

SUBJECT: RECOMMENDED STANDARD BOLT HOLE LAYOUTS FOR LIGHTWEIGHT FLANGES

PREPARED: W. M. Brobeck

CHECKED: *Corrected 12/13/57 by E. Chuck

These sizes are suggested for use on light equipment where ASA flanges are not applicable. However, ASA flanges should be considered the basic standard for piping on permanent installations. The ASA sizes are included for reference.

A reasonable effort should be made in future designs to use these light standard dimensions where applicable so that vacuum pump systems, test set ups, blank flanges, drill jigs, etc. will become interchangeable and the salvage value of parts increased.

ASA Standard - 150 lbs.				Recommended Light Standard		
Pipe Size	Bolt Circle	No. of Bolts	Size of Bolts	Bolt Circle	No. of Bolts	Size of Bolts
1	3 1/8	4	1/2	2	4	5/16
1 1/4	3 1/2	4	1/2	2 1/4	4	5/16
1 1/2	3 7/8	4	1/2	2 1/2	4	5/16
2	4 3/4	4	5/8	2 3/4	4	3/8
2 1/2	5 1/2	4	5/8	3	4	3/8
3	6	* 4	5/8	3 1/4	4	3/8
3 1/2	7	8	5/8	3 1/2	4	3/8
4	7 1/2	8	5/8	3 3/4	8	3/8
5	8 1/2	8	3/4	4	8	3/8
6	9 1/2	8	3/4	4 1/4	8	3/8
8	11 3/4	8	3/4	4 1/2	8	3/8
				4 3/4	8	1/2
				5	8	1/2
				5 1/2	8	1/2
				6	8	1/2
				6 1/2	12	1/2
				7	12	1/2
				7 1/2	12	1/2
				8	12	1/2
				8 1/2	12	1/2
	Hole diameters are 1/8" larger than bolt diameters.			Hole diameters to be 1/16" larger than bolt diameters.		

WMB:nw

D-1(M)

TITLE: FACTORS FOR USE IN COOLING CALCULATIONS

PREPARED BY: W. M. Brobeck — DATE: 2-49

REVISED BY: J. O. Turner — DATE: 7-79

REVISED BY: — DATE:

I RESISTANCE LOSS IN ELECTRICAL CONDUCTORS AT VARIOUS TEMPERATURES

(Based on information from National Bureau of Standards Handbooks 100 and 109)

Temperature °C	Watts/kg at 1 A/mm^2 current density		kW/ton* at 1000 A/in^2 current density	
	Aluminum-61% IACS	Copper-IACS	Aluminum-61% IACS	Copper-IACS
20	10.45	1.939	22.78	4.226
40	11.29	2.091	24.61	4.557
60	12.13	2.244	26.44	4.891
80	12.98	2.396	28.29	5.222
100	13.82	2.549	30.12	5.555

II COOLANT FLOW REQUIRED FOR 1°C TEMPERATURE RISE

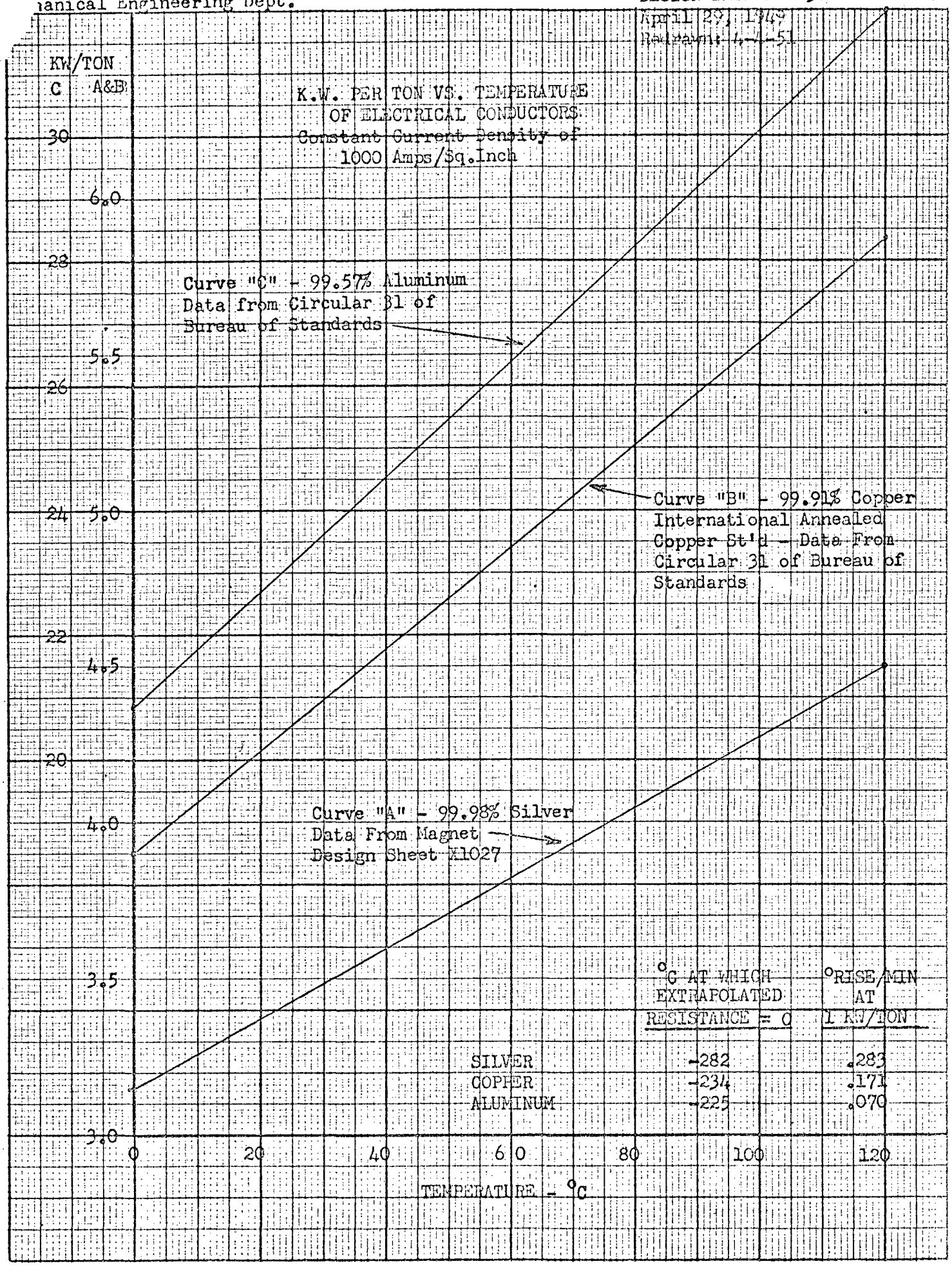
Coolant @25°C	Liters/second per kW	GPM per kW	CFM per kW
Water	0.239	3.79	-------
Transformer oil	0.607	9.62	-------
Air	850	-----	1800

III THEORETICAL POWER REQUIRED TO PUMP COOLANTS

Rate of flow	Pressure	Watts	Horsepower
1 Liter/second	1 k Pa	1.000	-------
1000 GPM	1 psi	434	0.582
1000 CFM	1 in. water	118	0.158

*U.S. or "short" ton, 2000-lb.

DESIGN DATA NO. 30
April 29, 1949
Reapproved: 4-1-51



Calculation and Graph 6-8-48 AW

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RADIATION LABORATORY - UNIVERSITY OF CALIFORNIA - BERKELEY

DESIGN DATA

DATE	D.D. NO.	PAGE
8-15-49	32	1 of 1

SUBJECT

FORMULAS FOR PARTICLE ACCELERATOR CALCULATIONS USING "ELECTRON VOLT" UNITS

PREPARED: W. M. Brobeck

CHECKED BY: Retyped: 9-19-50

E_T = total energy)
E_k = kinetic energy) electron volts
E_o = rest energy)

X = voltage gradient - volts/cm

e = charge in electrons

B = magnetic flux density - gauss

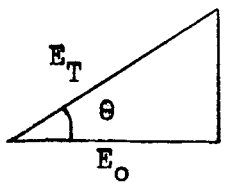
c = velocity of light = 3×10^{10} cm/sec

β = velocity/velocity of light

R = radius in cm

f = rotation frequency in cycles/sec

centimeter units are retained to simplify the formulas

FIELD ACTING	RELATIVISTIC FORMULA FOR ANY ENERGY	NON-RELATIVISTIC FORMULAS FOR LOW ENERGIES*	ELECTRONS	PROTONS	DEUTERONS	ALPHA PARTICLES
ANY	$\beta = \sqrt{\frac{E_T^2 - E_o^2}{E_T^2}}$	$\beta = \sqrt{\frac{2E_k}{E_o}}$	$1.978 \times 10^{-3} \sqrt{E_k}$	$46.17 \times 10^{-6} \sqrt{E_k}$	$32.67 \times 10^{-6} \sqrt{E_k}$	$2316 \times 10^{-6} \sqrt{E_k}$
MAGNETIC	$R_{mag} = \frac{\sqrt{E_T^2 - E_o^2}}{300\ Be}$	$R_{mag} = \frac{\sqrt{2E_oE_k}}{300\ Be}$	$\frac{3.370 \sqrt{E_k}}{B}$	$\frac{144.4 \sqrt{E_k}}{B}$	$\frac{204.0 \sqrt{E_k}}{B}$	$\frac{143.9 \sqrt{E_k}}{B}$
	$f = \frac{300\ Bec}{2\pi E_T}$	$f = \frac{300\ Bec}{2\pi E_o}$	$2.80 \times 10^6 B$	$1526B$	$764B$	$768B$
RADIAL ELECTRIC	$R_{elec} = \frac{E_T \beta^2}{Xe}$	$R_{elec} = \frac{2E_k}{Xe}$ E_o →	0.511×10^6	938×10^6	1874×10^6	3729×10^6
BOTH	Fields acting in opposite directions $\frac{R}{R_{mag}} = \frac{1}{1 - \frac{X}{300B\beta}}$ $R = \infty$ when $X = 300\ B\beta$	RELATIONS IN MAGNETIC FIELD FOR ANY ENERGY  300 BeR $\sin\theta = \beta$				

*Error does not exceed 1% if E_k is below 1% of E_o

WMB:FP/ah checked by: R.P.

W.M. Brobeck

TITLE

PROPERTIES OF NON-MAGNETIC MANGANESE STEELS FROM JESSOP STEEL COMPANY

PREPARED BY	DATE
W. C. Twichell	11/49
REVISED BY	DATE
J. O. Turner	3/80*
REVISED BY	DATE

Properties		Jessop Type #9 Super High Tensile	E-200
Chemical:	C	.35/.45	.25/.45
	Mn	12/12.75	10.50/12.50
	Si	.40/.60	.60 max.
	S	.040 max.	(.040 max.)
	P	.090 max	(.090 max.)
	Ni	3.10/3.40	7.50/8.50
	Cr	4.00/4.75	(.20/.30)
	Mo	.40/.60	.50 max
Physical: (Average)	TS	115-130,000 PSI	80-100,000 PSI
	YP (.2% offset)	85-100,000 PSI	30-60,000 PSI
	El-2"	35-45%	25-50%
	Red. Area	40-50%	30-60%
	Hardness	B.H.N. 217 to 300	-----
	Izod impact	85-90 ft. lbs. (68°F)	80 (68°F)
	Charpy impact	37-43 ft. lbs. (-50°F)	30 ft. lbs. (-70°F)
	Bend	180° around a pin equal to the thickness of material being bent	180° around a 3/4" pin for 3/8" plate.
	Endurance limit (R.R Moore rotating beam)	64,000 PSI	----
Miscellaneous:	Permeability: (-20° to 100°C)	Mu = 1.003 to 1.008 (H = 300) (as-rolled condition)	1.003 to 1.006 (H = 1000)
	Specific Gravity	7.9	7.9
	Resistivity: (Microhm cm.)	67.8 at 25.1°C	69 to 71
	Coefficient of Expansion (0°-1000°C)	22.2 x 10^{-6}/degree C.	20 x 10^{-6}/degree C

Fabrication data (#9SHT and E-200):

Working properties: Drawing, bending and forming - good. Flame - cutting - good. Machining and drilling - fair. (Harder to machine than Type 304. Stainless, but good finishes can be obtained).

Welding properties (General Electric Co. recommendations):

"Regarding.....the welding technique which we recommend for welding non-magnetic manganese-nickel steel, our Works Laboratory at Schenectady informs me that practically all welding on this type of steel within our company is done with the metallic arc process using a chromo-nickel flux coated electrode. The electrode most commonly used is Type 316 stainless (19% chromium, 13% nickel, 2-1/2% molybdenum).....

"Manganese nickel non-magnetic steel has thermal characteristics similar to stainless steel and since it is welded with stainless steel electrodes the recommended welding technique, joint preparation, etc. is similar to that recommended for stainless steel. This same welding electrode and welding procedure may be used for joining manganese-nickel non-magnetic steel to plain low carbon steel.....

"Welded joints in manganese-nickel non-magnetic steel do not have the same physical properties as the base metal manganese-nickel steel. However, the welded joints are non-magnetic so that the welds serve the purpose for which the material is usually intended.

"Managanese-nickel steels do not readily lend themselves to other methods of welding. However, it is possible to use some of the other methods of welding on special applications....."

Quoted from letter to W. M. Brobeck, signed R. O. Brosemer, dated November 7, 1945. This applies to Jessop Type E-200. Type #9 can be welded with the same techniques using Type 304 rod.

Stress relieving and forming (Jessop Steel Co. recommendations for E-200):

".....Stress relieving is desirable and in the case of the non-magnetic (steel) can be accomplished by heating of 900°F to 1100°F..... Time allowed for heating is usually 1 hour per inch of thickness. This stress relieving temperature is satisfactory for combinations of non-magnetic to mild steel, non magnetic to non-magnetic or non-magnetic to stabilized austenite. In the case of non-magnetic to austenite subject to carbide precipitation (i.e., greater than .83 C) full annealing must be resorted to.

"Peening of welds for local stress relieving can be done on non-magnetic to non-magnetic welds but on dissimilar alloys where dilution, etc. take place, the disadvantages are readily apparent in that deposits resembling casting can and do exist and the resulting effect on magnetic permeability on the austenites that respond to cold working may be undesirable. ....."

"The (E200) non-magnetic steel can be cold bent to a 90° angle on a 3" radius, however the sheared edges within the area of the bend should be ground to assure against cracking. This steel responds to cold working in that the hardness, yield point and ultimate strength is raised as in 18-8 stainless but not as rapidly. Also it differs from the 18-8 stainless types in that magnetic permeability is not affected.

"For hot forming the material should be heated to 1300 to 1400°F and formed. Subsequent reannealing will not be necessary since no metallurgical changes take place in this operation."

Quoted from letter to W. D. Douglass, signed I. B. Anderson, dated October 20, 1945.

Availability

Jessop steels are available from the mill as plates, sheets, and bars. The maximum plate size at 1" thickness is 48" x 120".

*The 3/80 revisions are based on a private communication from R. A. Hahn, Staff Metallurgist, Jessop Steel Co., Washington, PA

JOT/nh

RADIATION LABORATORY - UNIVERSITY OF CALIFORNIA - BERKELEY

DESIGN DATA

DATE	D.Q. NO.	PAGE
11-11-49	35	1

SUBJECT: CONVERSION CHART FOR U.C.R.L. PREFERRED HEAT TRANSFER UNITS

PREPARED: H. Gordon, M. Martin, D. Theodore Scalise.

CHECKED BY: Retyped 7-10-50

Symbol	Quantity	Multiple Quantity Expressed in → Conventional Units	by →	To Obtain Quantity Expressed in → Preferred Unit
L	Length	cm	0.3937	in.
		cm	0.0328	ft.
A	Area	cm^2	0.1550	$in.^2$
		cm^2	1.076×10^{-3}	$ft.^2$
V	Volume	cm^3	0.0610	$in.^3$
		cm^3	3.531×10^{-5}	$ft.^3$
C_p	Specific Heat	$\frac{B.T.U.}{lb.\ ^oF}$	1899	$\frac{watt\ sec.}{lb.\ ^oC}$
		$\frac{cal}{gm\ ^oC}$	1899	$\frac{watt\ sec.}{lb.\ ^oC}$
μ	Absolute Viscosity	centipoise*	6.72×10^{-4}	$\frac{lb.(mass)}{sec.\ ft.}$
		centipoise	2.42	$\frac{lb.(mass)}{hr.\ ft.}$
		centipoise	2.09×10^{-5}	$\frac{lb.\ (force)\ sec.}{ft.^2}$
k	Heat Conductivity	$\frac{cal}{sec.cm^2\ (^oC/cm)}$	10.632	$\frac{watts}{^oC\ in.}$
		$\frac{B.T.U.}{hr.ft.^2\ (^oF/ft.}$	0.04394	$\frac{watts}{^oC\ in.}$
		$\frac{watts}{cm\ ^oC}$	2.54	$\frac{watts}{^oC\ in.}$

*1 poise = 1 dyne sec/cm^2 = 1 gram/sec. cm.

Symbol	Quantity	Multiply Quantity Expressed in → Conventional Units	by →	To Obtain Quantity Expressed in → Preferred Unit
H	Unit of Heat	Calories*	4.187	watt sec. (Joules)
		B.T.U.	1055	watt sec. (Joules)
q	Rate of Heat Flow	$\frac{\text{B.T.U.}}{\text{hr.}}$	.293	watt
		$\frac{\text{B.T.U.}}{\text{sec.}}$	1.055	kilowatts
		$\frac{\text{cal}}{\text{sec.}}$	4.186	watt
		h.p.	746	watt
q/A	Heat Flux	$\frac{\text{cal}}{\text{cm}^2\ \text{sec.}}$	27.006	$\frac{\text{watts}}{\text{in.}^2}$
		$\frac{\text{B.T.U.}}{\text{hr.ft.}^2}$	2.035×10^{-3}	$\frac{\text{watts}}{\text{in.}^2}$
h,U	Heat Transfer Factor	$\frac{\text{B.T.U.}}{\text{hr.ft.}^2\ {}^\circ\text{F}}$	3.663×10^{-3}	$\frac{\text{watts}}{{}^\circ\text{C in.}^2}$
		$\frac{\text{cal}}{\text{sec. cm}^2\ {}^\circ\text{C}}$	27.006	$\frac{\text{watts}}{{}^\circ\text{C in.}^2}$

* 1 calorie = heat to raise 1 gram of water 1°C.

Convenient Factors for Use in Fluid Flow Calculations

For air and water at 21°C and 29.92 in. Hg barometric pressure

A. Velocity Head $= \frac{V^2}{2g}$

1. Air

$$\left[\frac{V\ (\text{f.p.m.})}{4005}\right]^2 = \text{in. water (vel. head).}$$

$$\left[\frac{V\ (\text{f.p.m.})}{2.11 \times 10^4}\right]^2 = \text{p.s.i. (vel. head)}$$

2. Water

$$\left[\frac{V\ (\text{f.p.m.})}{732}\right]^2 = \text{p.s.i. (vel. head)}$$

$$\left[\frac{V\ (\text{f.p.s.})}{12.2}\right]^2 = \text{p.s.i. (vel. head)}$$

B. Reynolds No. $= Re = \frac{VDP}{\mu}$

1. Air

$Re = 512.5\ VD$

V = vel. in $\frac{\text{ft.}}{\text{sec.}}$

D = dia. in inches of round tube

$= \frac{4 \times \text{cross sectional area}}{\text{wetted perimeter}}$ for other shapes

2. Water

$Re = 7.93 \times 10^3\ VD$

V = vel. in $\frac{\text{ft.}}{\text{sec.}}$

D = dia. in inches of round tube

$= \frac{4 \times \text{cross sectional area}}{\text{wetted perimeter}}$ for other shapes

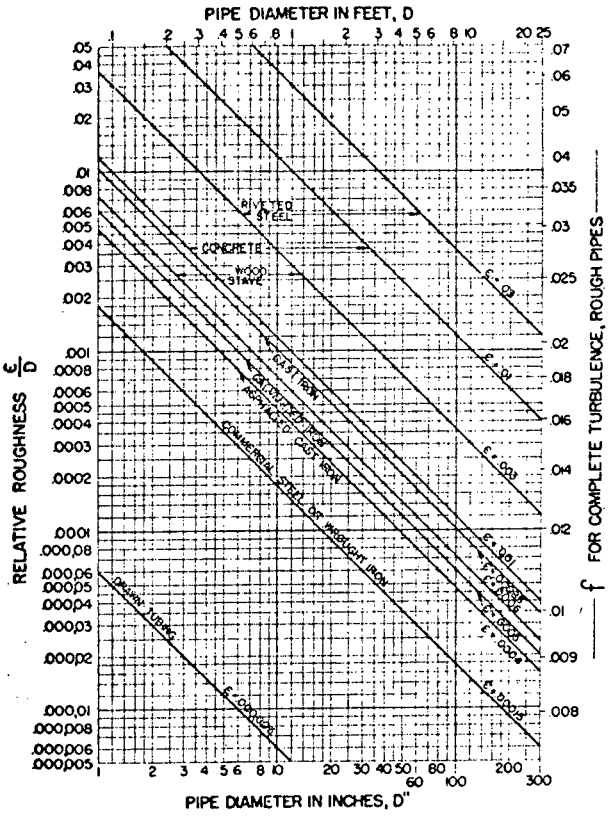
DESIGN DATA

PREPARED: L. E. Brown

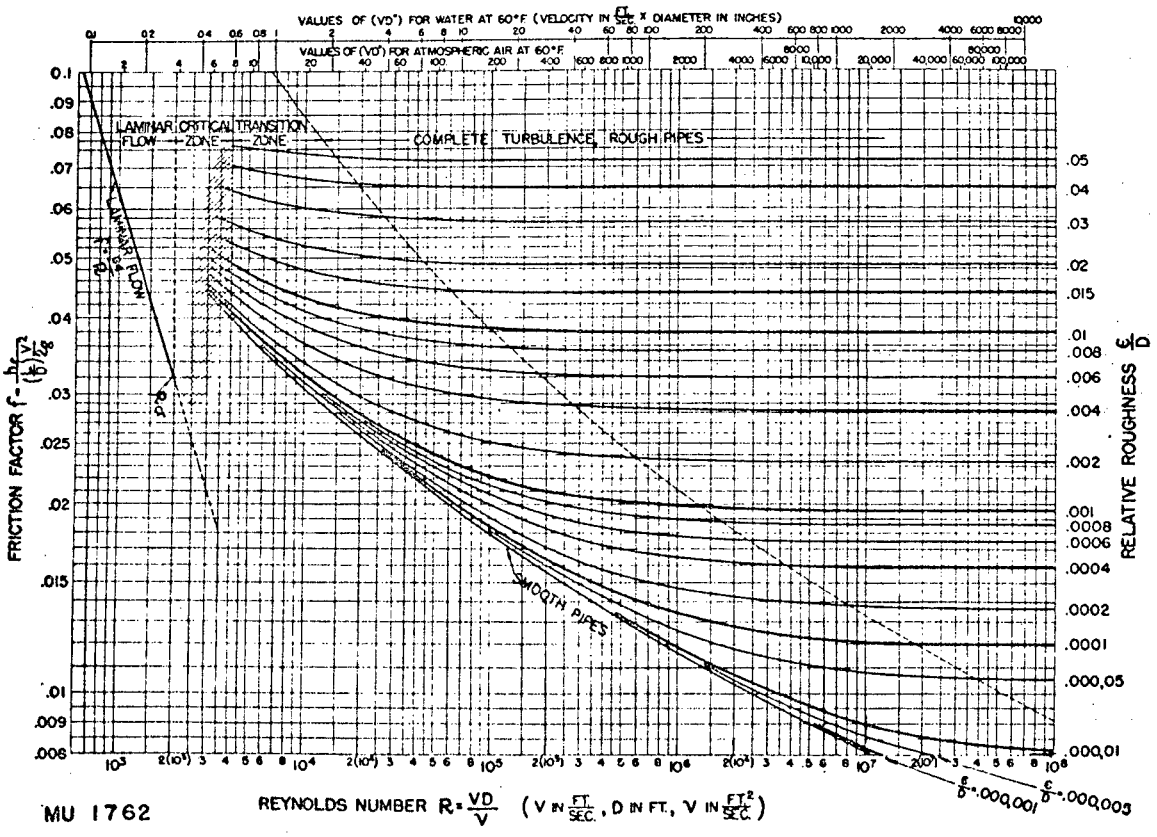
CHECKED BY: W. Brobeck

FRICTION FACTORS FOR PIPE FLOW

Reference: Transactions of the A.S.M.E. November, 1944



MU 1763



MU 1762

ALLOY & COMPOSITION	To C	Y.S. 1000 psi	T.S. 1000 psi	Elong %	R.A.	Impact	Remarks
ALUMINUM & ALLOYS: - (This data typical of that for all Al. alloys)							
2SO	20	4.15	13.2	41.5		19 Iz	Note: All Aluminum Alloys retain their toughness & ductility to -300°F. Room temperature data applicable down to liquid Air temperatures.
	-80	4.15	15.2	47.5		20 Iz	
	-180					27 Iz	
17-ST	20	45.5	68.0	15		15 C-V	
	-80	46.5	70.0	16		18 C-V	
24-ST	20	43.7	70.1	23.3		12 C-V	
	-80	46.4	74.1	25.3		12 C-V	
61-ST	20	39.2	46.0	21			
	-80	41.7	50.4	22.5			
COPPER & ALLOYS:							
Pure Copper - 99.98% Soft	20	8.6	31.4	48	76	43 Iz	62 C-V
	-80	10.1	38.5	47	74	44 Iz	
	-180	18.3	50.8	58	77	50 Iz	69 C-V
Pure Copper -99.9% Rolled	20	43.3	45.8	16	55.9		>20% Reduction
	-180	50.4	53.0	19	55.4		
Cartridge Brass 70-30 Cu-Zn Annealed	20	28	51	49	78	66 Iz	Typical of behavior of brasses at low temperatures
	-80	27	58	60	79	69 Iz	
	-180	30	74	75	73	79 Iz	
Naval Brass 60 Cu, 39.25 Zn, .75Sn	20	28.8	57.1	49.4	50.5		Annealed
	-180	37.2	81.1	48.3	48.4		
Beryllium Copper 2.56 Be (Solution Treated)	20	24.9	76.2	36	50	41 Iz	Typical example of property changes in precipitation hardenable alloys
	-80	29.1	86.7	38	54	40 Iz	
	-180	50.0	112	41	57	40 Iz	
(Aged)	20	125	187	2.6	5	2 Iz	
	-80	147	202	4	5	3 Iz	
	-180	155	214	3	6	3 Iz	
Manganese Bronze 38.85 Zn, 1.43 Mn, 1.25 Pb, .9 Sn	20	24	72.4	28	44	20 Iz	Annealed
	-80	27	75.5	31	43	22 Iz	
	-180	28.8	94.8	37	41	20 Iz	

Iz, Standard Izod V notch; C, Charpy; V, Charpy V notch

SUBJECT

PROPERTIES OF METALS AT LOW TEMPERATURES

PREPARED R. A. Nickerson

CHECKED BY

ALLOY & COMPOSITION	To C	Y.S. 1000 psi	T. S. 1000 psi	Elong %	R.A.	Impact	Remarks
NICKEL & ALLOYS							
"A" Nickel 99.4 Ni, .1 Cu, .15 Fe, .2 Mn, .05 Si, .1 C, .005 S	24		62	23.5	75	216 C V	Annealed
	-80					235 C V	
	-190		86	22	58	234 C V	
	24		133	1.06	58	185 C V	Cold Drawn
	-80					205 C V	
	-190		155	3.12	54	210 C V	
	24	54.4	93.4	32.7	45.5	195 C V	Hot Rolled
	-80					236 C V	
	-190	81.8	122.5	46.7	57.2	227 C V	
Monel 671 Vi, 30 Cu, 1.4 Fe, 1 Mn, .1 Si, .15 C, .01 S	21	31.3	78.7	57.5	75	189 C V	100 Iz) Annealed
	-183	49.5	115.3	49.5	72	184 C V	119 Iz)
	24	93.7	103.8	19	72	216 C V	Cold Drawn
	-80	100.9	117.45	21.8	71	219 C V	
	-190					212 C V	
	21	67	92	31	70.6	216 C V	Forged
	-183	91.5	128	44.5		216 C V	
	-253	96.4	142	38.5			
"K" Monel 66 Ni, 29 Cu, 2.75 Al, .9 Fe, .25 Mn, .15 C, .5 Si	24		94			130 C K	Quench 1750°F
	-80					133 C K	
Magnetic Transformation <-135°C Soft Quench <-101°C Aged	24	125.9	157.3	15.5	37.4	27 C K	Quench & Age (See note on Be-Cu)
	-80	134.6	171.6	17.3	41.1	28 C K	
Inconel 78.5 Ni, 14 Cr, 6.5 Fe, .25 Mn, .2 Cu, .25 Si, .08 C, .008 S	24	36	94	31	65	130 C K	Quench 1750°F
	-80	42.5	106	40	64	133 C K	
	24	147	132	70	49	58 C V	Quench & Age 525°F. No appreciable de-drease in properties of unaged
	-80	155	164	10	51	63 C V	

C, Charpy; V, Charpy V notch; K, Charpy Keyhole notch; Iz, Izod inconel to -315°F -193°C

ALLOY & COMPOSITION	To c	Y.S. 1000 psi	T.S. 1000 psi	Elong %	R.A. %	Impact	Remarks
STAINLESS STEELS							
302 .11 C, 16.2 Cr, 11.5 Ni	20	44.8	93	48	52	118 Iz	Water Quench
	-180	118	220	55	75	118 Iz	2010°F
304 .06 C, 18,25 Cr, 9.7 Ni	20	32	87.2	69	81	119 Iz	Annealed
	-185	87.6	225	44	63	119 Iz	Annealed & Cold Drawn (-180°C,-65 Iz)
	20	91.5	152	22	64	66 Iz	
	-76	103	196	29	67	68 Iz	
316 .07 C, 18.41 Cr, 9.88 Ni, 2.8 Mo	20	119	133	23	73	89 Iz	A & CD (-180°C, 80 Iz)
	-76	135	186	31	60	77 Iz	
321 .05 C, 19.04 Cr, 9.15 Ni, Ti 8 x %C	20	36	86	45	79	178 C V	Water Quenched 1900°F
	-76	38	143	46	74	161 C V	
	20	85	131	22	69	89 C V	Annealed & Cold Drawn
	-76	89	174	32	67	75 C V	
347 .07 C, 18.97 Cr, 10.29 Ni, .95 Cb	20	50	92	41	76	123 C V	W. Q. 2000°F (-180°C, 115 CV)
	-76	52	146	40	69	115 C V	
	20	128	145	14	60	31 C V	Annealed & Cold Drawn
	-76	135	165	33	63	36 C V	

Ferritic & Martensitic Stainlesses of the type 403, 410, 416, 420, 430, 440 C, 446 should be avoided for low temperature service.

References:

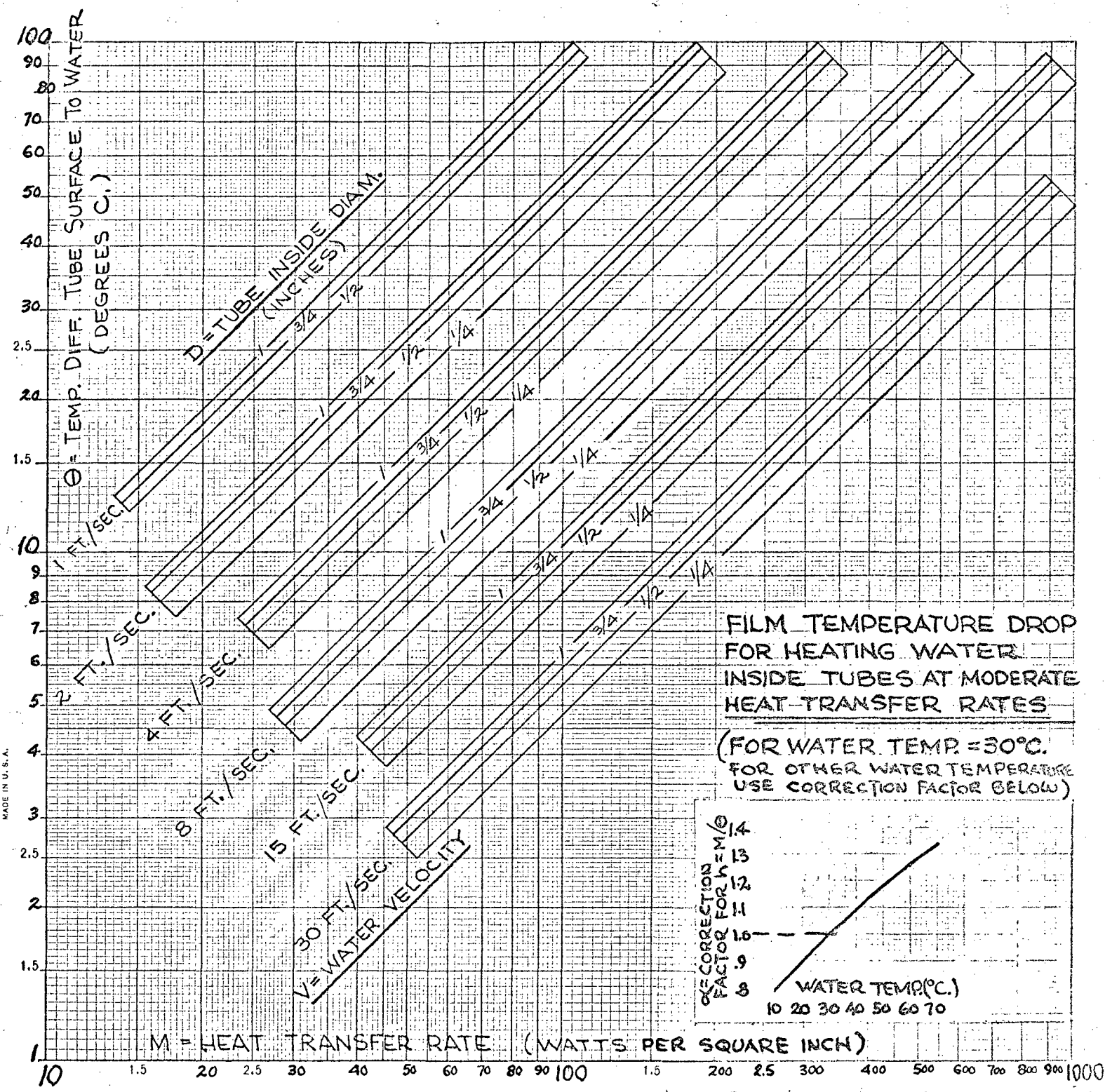
American Society For Metals Handbook & references therein on Low Temperature properties. ASME, ASTM Symposium on "Effect of Temperature on Metals", June 23, 1931.

U.S. Dept. of Commerce - Bureau of Standards Research Paper 1882, 40, 1948 "Influence of Low Temperature on Mechanical Properties of 18.8"

International Nickel Co. Technical Bulletins

RN:ah

T. Scalise
9-25-50



359-110G KEUFFEL & ESSER CO.
Logarithmic, 2 X 2 Cycles.
MADE IN U.S.A.

DERIVED FROM McADAMS "HEAT TRANSMISSION" 1942, P.168:—

$$h = \frac{M}{\Theta} = 1.07\,\alpha\,\frac{V^{.8}}{D^{.2}}$$

(SYMBOLS & UNITS FOR ABOVE EQN. DEFINED ON THIS PAGE)

(1) $$P_\infty = bF + \frac{L}{S} + \sum \frac{A_v}{A_v + A_t + \frac{S}{160}} P_v$$ (Expressed in different units from those used in original article)

P_∞ = Press. @ infinite time (ultimate press.) (μ)

F = Fore pressure (μ)

b = Constant involving back diffusion through diffusion pump
  b = 0.001 for most diffusion pumps pumping air
  b = 0.1 to 0.8 for H_2 and H_e

L = Leakage rate (μ Ft^3/min.)

S = Pump speed (Ft^3/min.)

A_v = Exposed area of volatile material (in^2)

A_t = Cold trap area (in^2)

P_v = Saturation vapor pressure of volatile material (μ) (see curves)

P_o = Pressure at time t_o (μ)

$\sum$ = Indicates summation of similar terms for other volatile materials.

The formula for pressure vs. time including outgassing effects is:

(2) $$P = P_o e^{-\frac{S}{v}(t-t_o)} + P_\infty \left(1 - e^{-\frac{S}{v}(t-t_o)}\right)$$

v = Volume of system (Ft^3)

$t-t_o$ = Pumping time (minutes)

P_v is usually taken from curve @ 24 to 36 hours.

Further reduction of P with time is attributed to impoverishment of surface in volatile constituents.

The preceding relations, recommended by Distillation Products, Inc. to calculate the ultimate pressure in systems containing volatile materials, are based on the assumption that the volatile material exhibits a constant vapor pressure at its surface. This usually results in a pessimistic estimate of pressure due to surface impoverishment with time.

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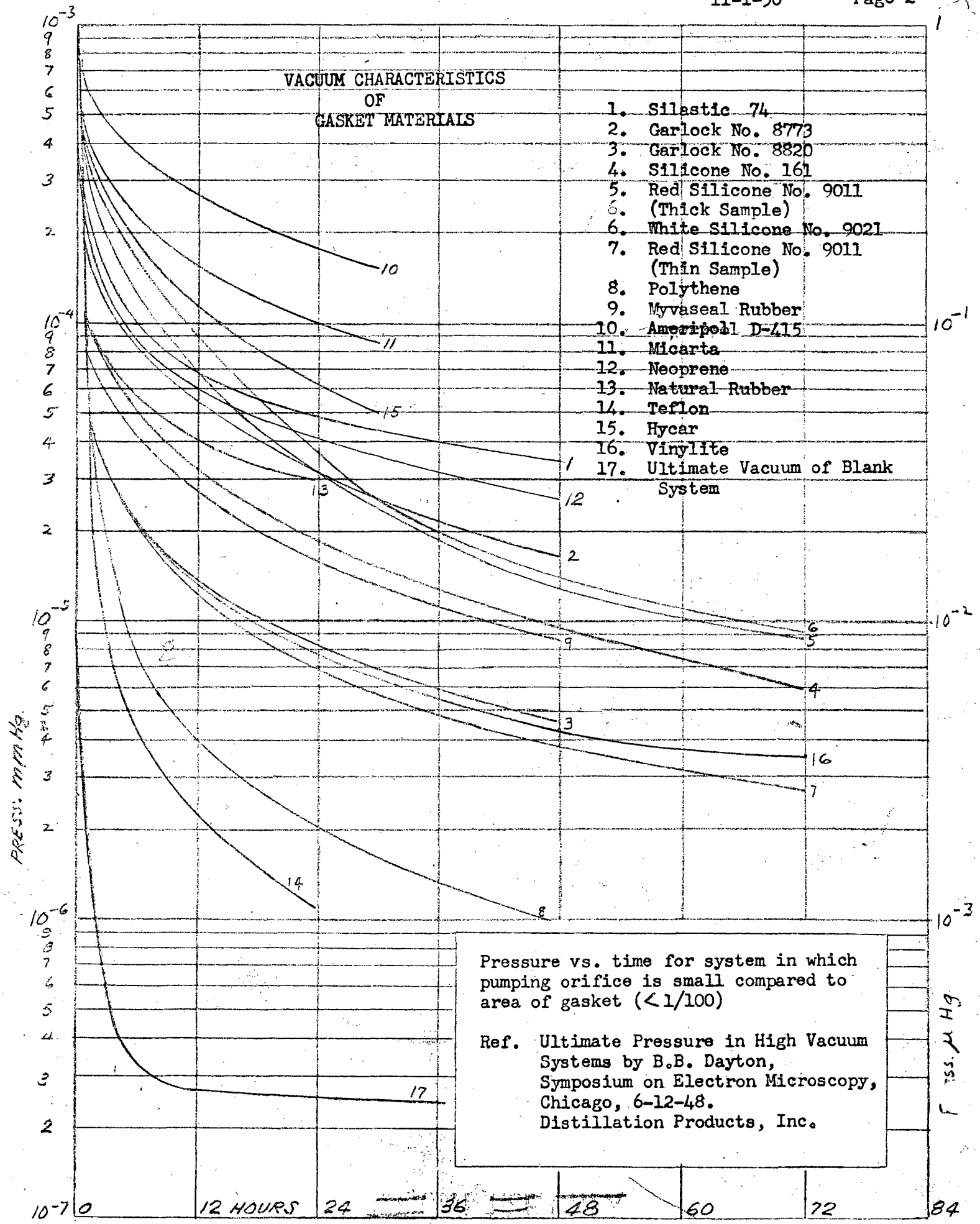
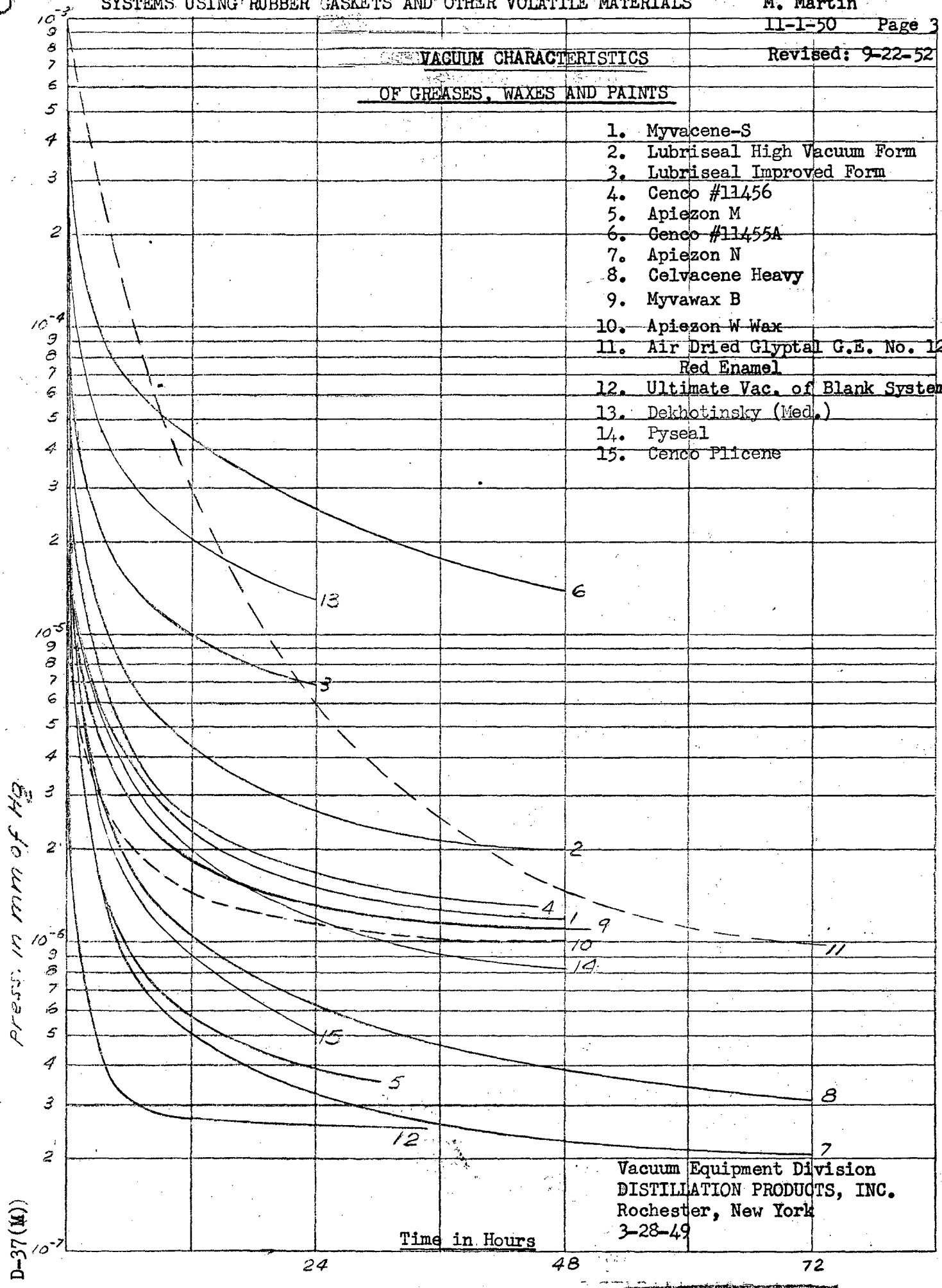
*From: Ultimate Pressure in High Vacuum Systems by B.B. Dayton, Symposium on Electron Microscopy, Chicago, 6-12-48. Distillation Products, Inc.

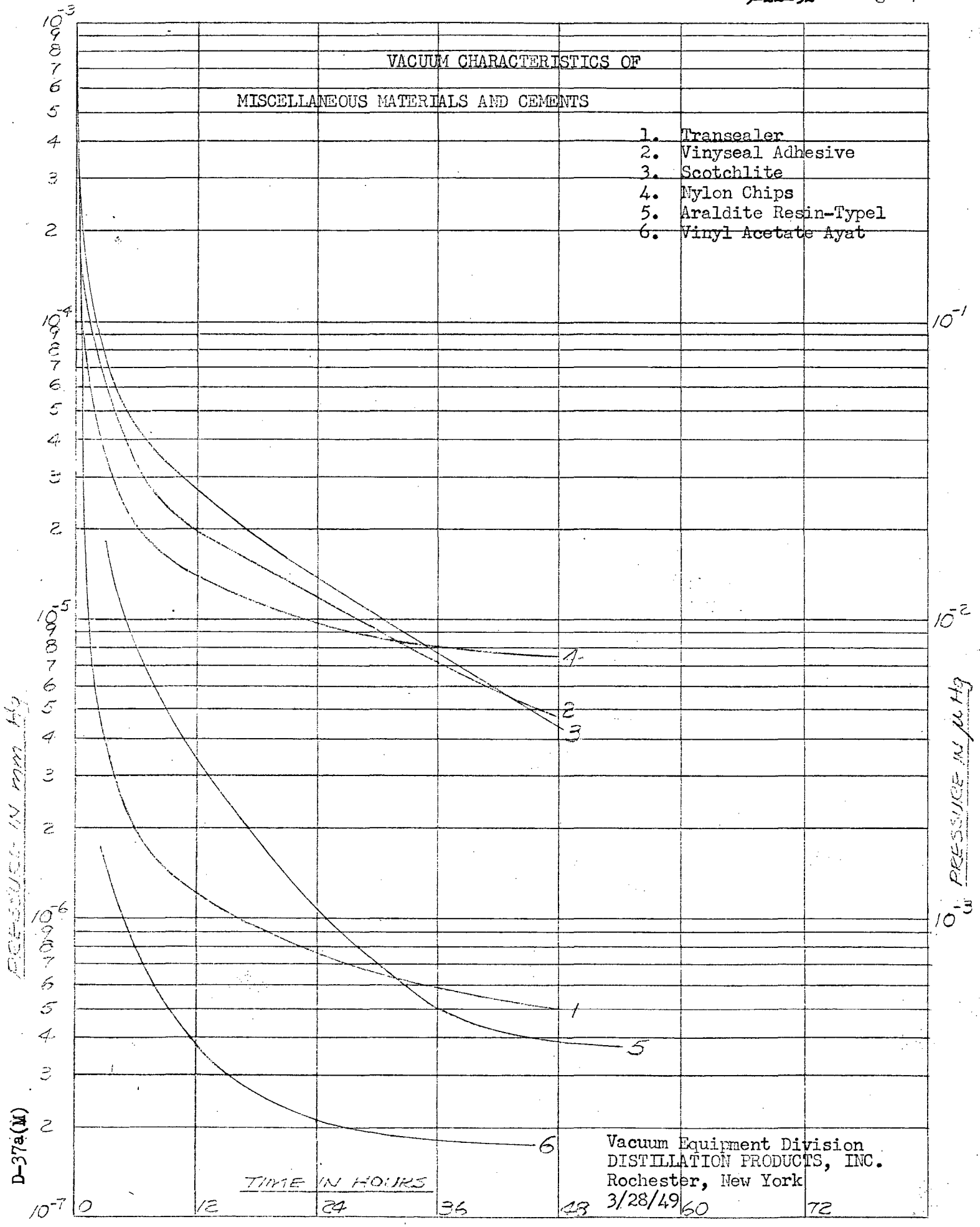


Pressure vs. time for system in which pumping orifice is small compared to area of gasket (< 1/100)

Ref. Ultimate Pressure in High Vacuum Systems by B.B. Dayton, Symposium on Electron Microscopy, Chicago, 6-12-48. Distillation Products, Inc.

VACUUM CHARACTERISTICS OF GREASES, WAXES AND PAINTS





Vacuum Equipment Division
DISTILLATION PRODUCTS, INC.
Rochester, New York
3/28/49

TITLE

PIPE, CONDUIT, AND TUBING BENDERS AVAILABLE IN LBL SHOPS

PREPARED BY D. Vorkoeper — DATE 12/50
REVISED BY J. O. Turner, C. Haines — DATE 7/67
REVISED BY J. O. Turner, C. Haines — DATE 4/80

TUBING BENDERS:

TYPE	MAKE	TUBE SIZE O.D. Inches	BEND RADIUS TO CENTERLINE mm	BEND RADIUS TO CENTERLINE Inches	LOCATION
Hand	Greenlee*	1/4	19.1	3/4	Sheet Metal Shop
"	"	5/16	19.1	3/4	"
"	"	3/8	25.4	1	"
"	"	1/2	31.8	1-1/4	"
"	"	5/8	41.3	1-5/8	"
"	"	3/4	47.6	1-7/8	"
"	"	7/8	57.2	2-1/4	"
"	"	1	69.9	2-3/4	"

*This Greenlee bender will handle 1/16" wall tubing.

Hand	Parker Model H624	1/2	38.1	1-1/2	"
"	"	5/8	47.6	1-7/8	"
"	"	3/4	57.2	2-1/4	"
"	"	7/8	66.7	2-5/8	"
"	"	1	76.2	3	"
"	"	1-1/8	85.7	3-3/8	"
"	"	1-1/4	95.3	3-3/4	"
"	"	1-1/2	114.3	4-1/2	"
Hand	Parker-Exactol Model 412	1/4	14.3	9/16	"
"	"	1/4	19.1	3/4	"
"	"	5/16	17.5	11/16	"
"	"	5/16	25.4	1	"
"	"	3/8	23.8	15/16	"
"	"	3/8	31.8	1-1/4	"
"	"	1/2	31.8	1-1/4	"
"	"	1/2	50.8	2	"
"	"	1/2	63.5	2-1/2	"
"	"	5/8	38.1	1-1/2	"
"	"	5/8	63.5	2-1/2	"
"	"	3/4	44.5	1-3/4	"
"	"	3/4	76.2	3	"

TUBING BENDERS, CONT'D:

TYPE	MAKE	TUBE SIZE O.D. Inches	BEND RADIUS TO CENTERLINE mm	BEND RADIUS TO CENTERLINE Inches	LOCATION
Hand	Parker-Imperial**	1/8	9.53	3/8	Assembly, Sheet Metal
"	" "	3/16	11.1	7/16	Machine Shop Tool Crib
"	" "	1/4	14.3	9/16	"
"	" "	5/16	17.5	11/16	"
"	" "	3/8	23.8	15/16	"
"	" "	7/16	34.9	1-3/8	"
"	" "	1/2	38.1	1-1/2	"
"	" "	5/8	57.2	2-1/4	"
"	" "	3/4	76.2	3	Assembly
"	" "	7/8	76.2	3	Machine Shop Tool Crib
"	" "	1	88.9	3-1/2	Assembly, Sheet Metal

**These Parker-Imperial benders are made primarily for refrigeration tubing.

PIPE AND RIGID CONDUIT BENDER:

TYPE	MAKE	NORMINAL PIPE SIZE Inches	BEND RADIUS TO CENTERLINE mm	BEND RADIUS TO CENTERLINE Inches	LOCATION
Hydraulic	Black Hawk Model S-130	1/2	82.6	3-1/4	Machine Shop
"	"	3/4	114.3	4-1/2	"
"	"	1	146.1	5-3/4	"
"	"	1-1/4	184.2	7-1/4	"
"	"	1-1/2	209.6	8-1/4	"
"	"	2	241.3	9-1/2	"

Maximum size for this bender is 2" Schedule 40 Pipe. It is primarily for bends up to 90° or offsets. Additional shoes can be made to bend tubing sizes or special bend radii.

ROLLS:

The bending rolls in the Welding Shop can be adapted to roll large radii tubes. The following rollers are on hand:

Tube Size
3/4" O.D.
1" O.D.

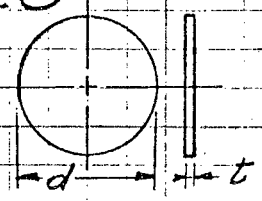
/nh

BASED ON MAX. STRESS OF 12,000 PSI
& POISSON'S RATIO = 0.3
FOR OTHER STRESSES & PRESSURES:

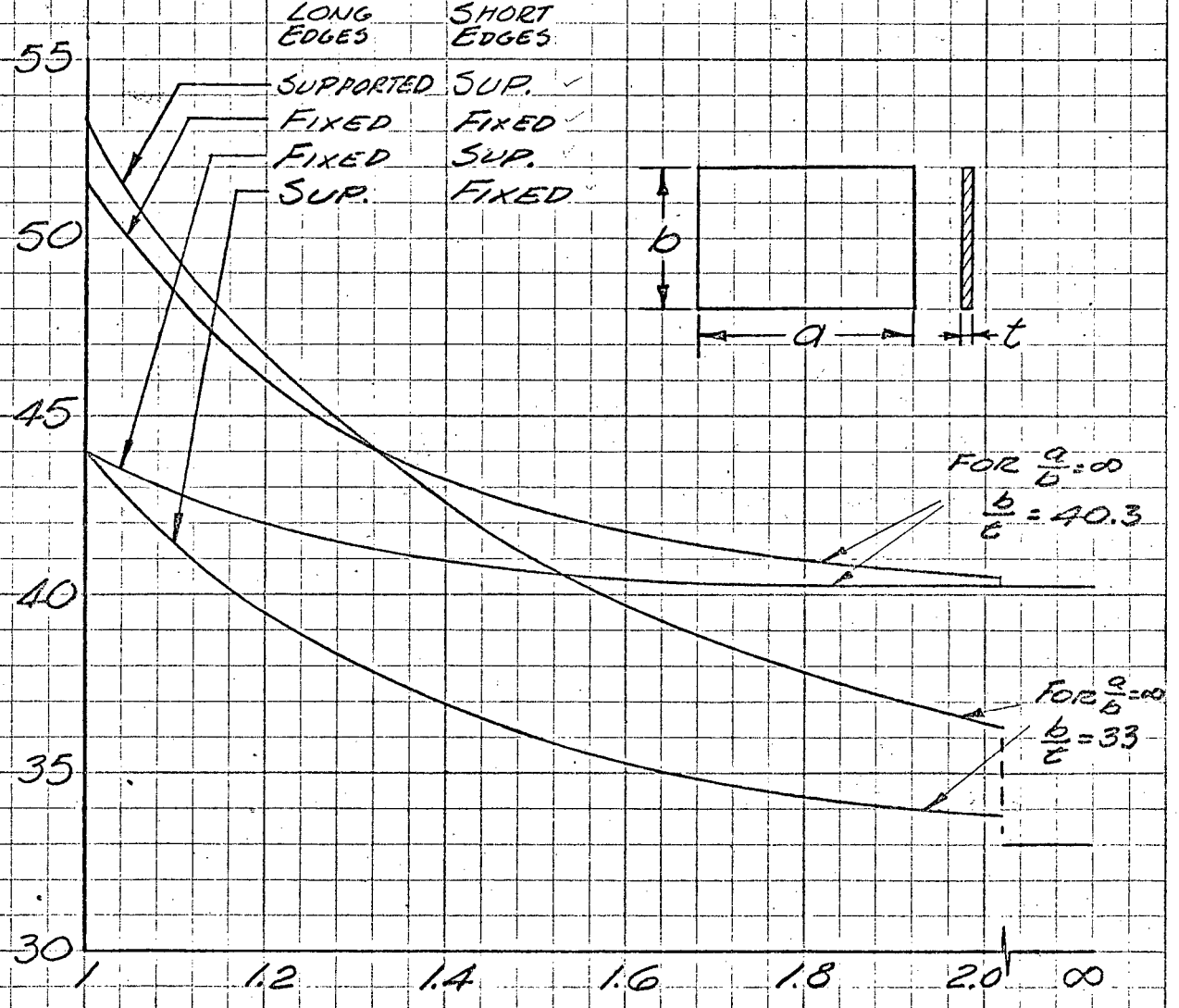
$$\frac{t_2}{t_1} = \sqrt{\frac{12000}{S_2} \times \frac{p_2}{14.7}}$$

CIRCULAR PLATES

	d/t
CLAMPED EDGES	66.0
SUPPORTED	51.4



RECTANGULAR PLATES



REF: ROARK, "FORMULAS FOR STRESS & STRAIN" 2ND ED. 1943 CH. 10.

R. MEUSER 3-7-51

KEUFFEL & ESSER CO., N. Y. NO. 359-2
5 X 5 to the inch.
MADE IN U.S.A.

*Corrected 7-24-51

The R.F. power required to produce a given voltage on the capacitor which terminates a fore-shortened quarter wave transmission line depends upon:

Capacity ——— C, Farads

Frequency ——— f, Cycles/sec

Outer and Inner Conductor Diameter ——— D and d, inches

Resistivity of the Conductor Material ——— International Annealed Copper Standard is assumed in these formulas.

These factors are related by the following formula:

$$(1) \quad P = \frac{78.5}{\sqrt{f}} \left[\frac{1}{D} + \frac{1}{d}\right] \left(\frac{V}{Z_o}\right)^2 \left[\frac{\frac{\theta}{2} + \frac{\sin 2\theta}{4}}{\sin^2 \theta}\right] \text{ ——— Watts}$$

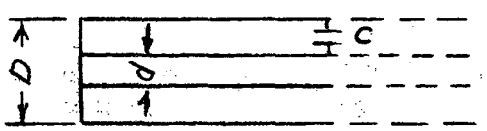
Where Z_o = Characteristic impedance of line = $138 \log_{10} \frac{D}{d}$

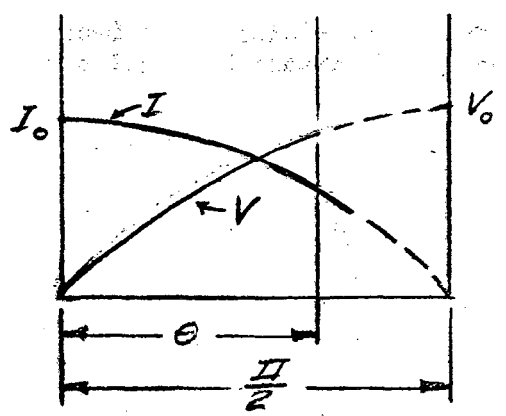
* θ = Length of line, radians = $\tan^{-1} \frac{X_c}{Z_o} = \frac{2\pi L}{\lambda}$

X_c = Capacitive Reactance $\frac{1}{2\pi f C}$

L and λ are length of line and wavelength corresponding to frequency, f, in consistent units

The above formula may be used to calculate the power in any line, but neglects end losses in the shorted end of the line and losses which occur in the terminating capacity.





Current and voltage variation with length

In design problems it is desirable to find an optimum geometry, i.e., one which will require the least power to produce a given voltage on the capacitor. The attached curves show the variation of $\frac{P}{V^2}$ (proportional to shunt admittance) with respect to the other parameters.

There are two cases which may be encountered in design. The frequency is assumed fixed by other considerations in both cases.

<u>CASE I</u> Capacity fixed, length variable, Z_o variable (This is the usual case in cyclotron design where C is the Dee ~~capacity~~ capacity).

Design Procedure:

1. Calculate X_c ($\frac{1}{2\pi fC}$)
2. Select D/d from Figure 1.
3. Make D as large as space and mechanical considerations permit.
4. Calculate $\theta = \tan^{-1} \frac{X_c}{Z_o}$
5. Calculate power from equation (1)
6. If optimum D/d cannot be used, the sensitivity to values different from the optimum can be seen in Figure 2.

<u>CASE II</u>

Length Fixed, capacity variable, Z_o variable. (This case may be encountered where for mechanical reasons the maximum length is determined and it is permissible to vary dimensions or add extra capacity to the dee)

Design Procedure:

1. Make D/d = 9.1 (Z_o = 132.5)
2. Choose D as large as possible as in Case I.
3. Calculate power from equation (1)
4. If optimum D/d (9.1) cannot be used the sensitivity to values different from optimum can be seen in Figure 3.

Figure 4 is a curve of $\frac{\frac{\theta}{2} + \frac{\sin 2\theta}{4}}{\sin^2\theta}$ against θ for convenience in calculating powers.

If the outer conductor is non-circular in shape, a value of D_{equiv} may be used which corresponds to the actual Z_o of the line. For Z_o of miscellaneous shapes see "Reference Data for Radio Engineers" - Federal Telephone and Radio Corporation.

Marvin Martin
4/11/51
Page 3

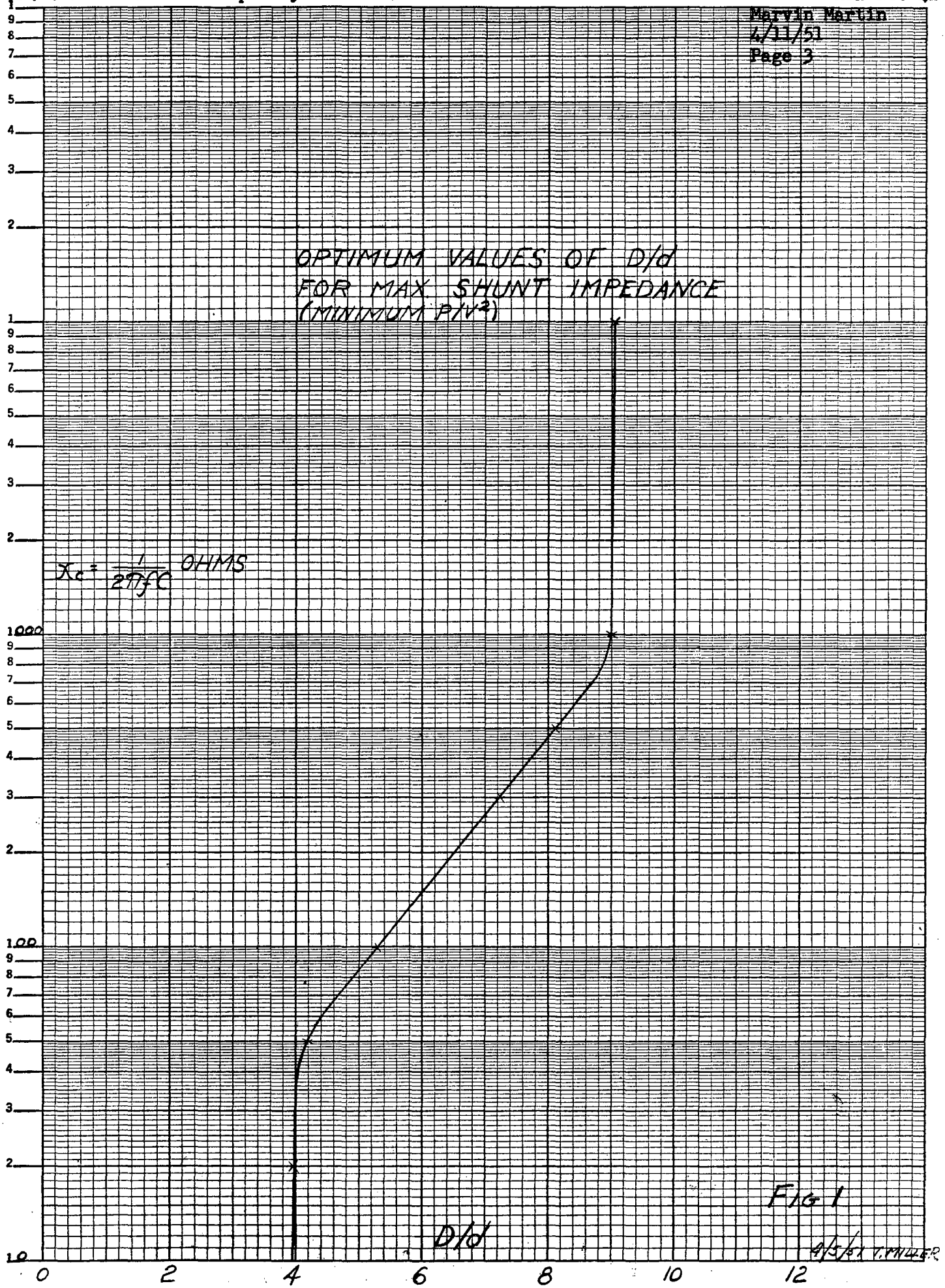


FIG 1

4/5/51 T. MILLER

KEUFFEL & ESSER CO., N. Y. NO. 359-61d
Semi-Logarithmic, 4 Cycles X 10 to the Inch.
MADE IN U.S.A.

R.F. Power Loss in Capacity Loaded Quarter Wave Transmission Lines

DESIGN DATA NO. 42

Marvin Martin
4/11/51
Page 4

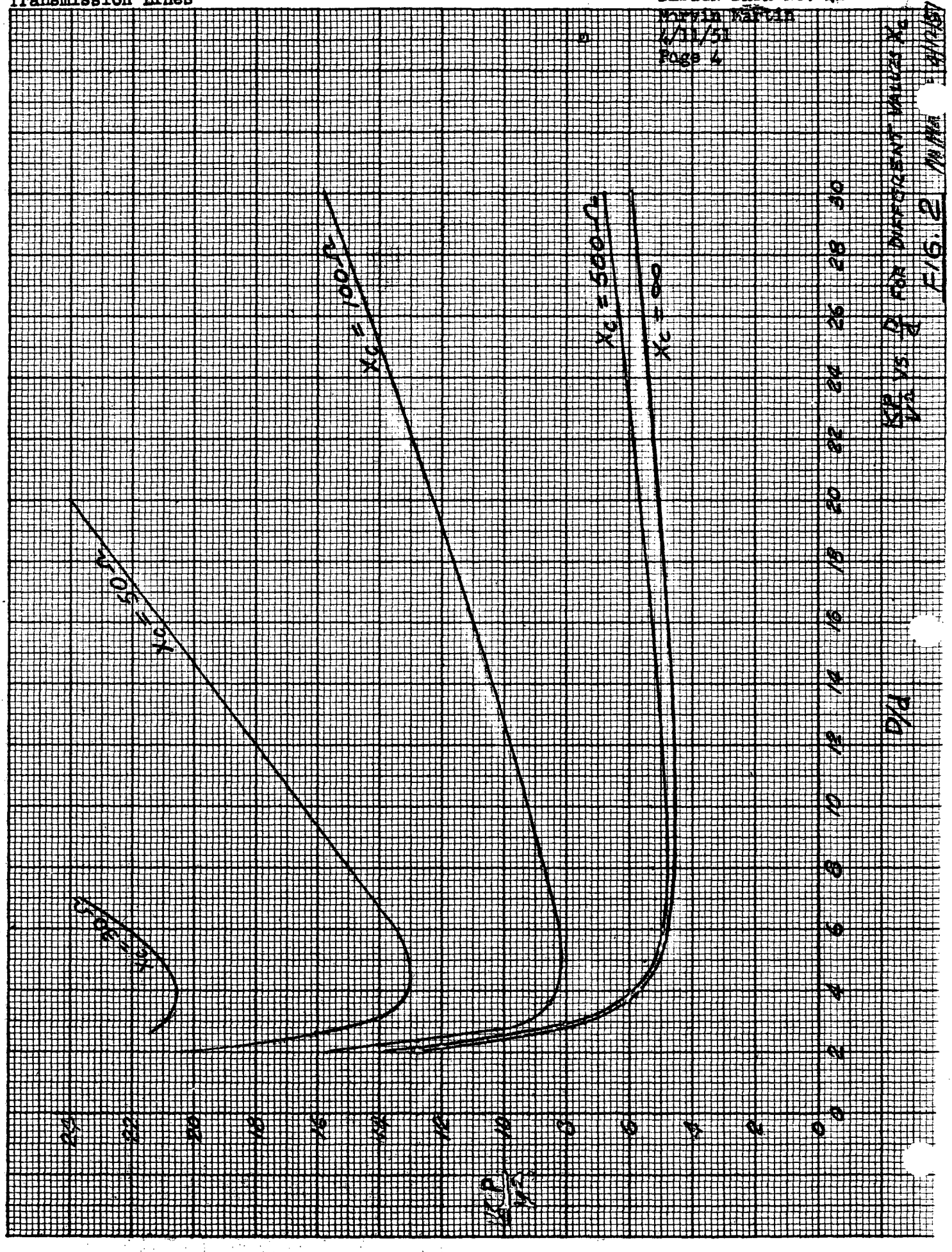


FIG. 2

PRINTED IN U.S.A. ON CLEARPRINT TECHNICAL PAPER NO. 1000H
TECHNICHART
CLEARPRINT PAPER CO. 730 20 X 20 DIVISIONS PER INCH 180 X 200 DIVISIONS

Harvin Marvin
4/11/51

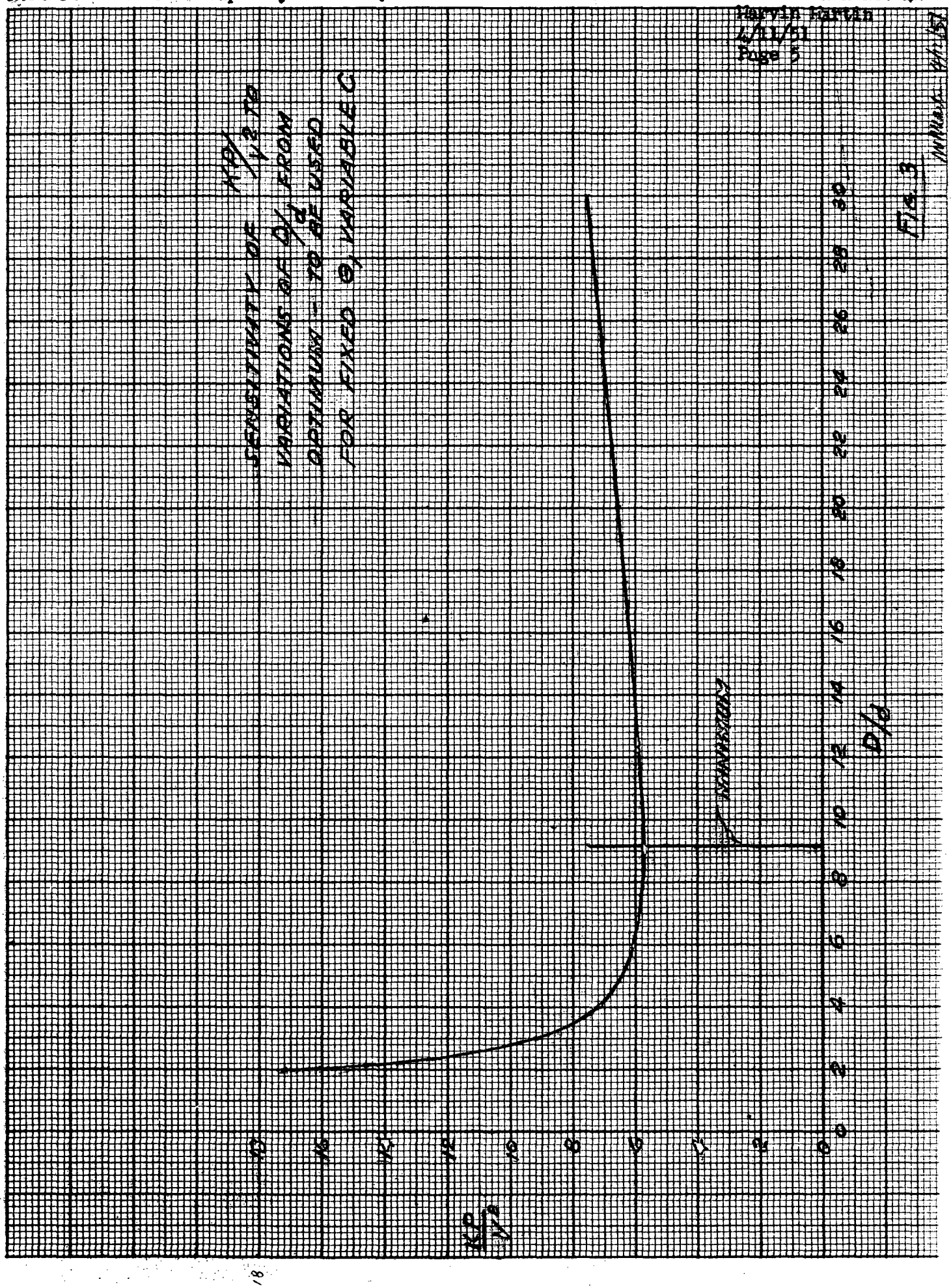


FIG. 3

CLEARPRINT PAPER CO. T30 20 X 20 DIVISIONS PER INCH 150 X 200 DIVISIONS PRINTED IN U.S.A. ON CLEARPRINT TECHNICAL PAPER NO. 1000H
TECHNICHART

R.F. POWER LOSS IN CAPACITY LOADED QUARTER WAVE TRANSMISSION LINES

VALUES OF $\dfrac{\frac{\theta}{2} + \frac{\sin 2\theta}{4}}{\sin^2\theta}$ IN THE FOLLOWING FORMULA:

$$P = \frac{78.5}{\sqrt{f}}\left[\frac{1}{d} + \frac{1}{D}\right]\left(\frac{V}{Z_0}\right)^2\left[\frac{\frac{\theta}{2} + \frac{\sin 2\theta}{4}}{\sin^2\theta}\right]$$

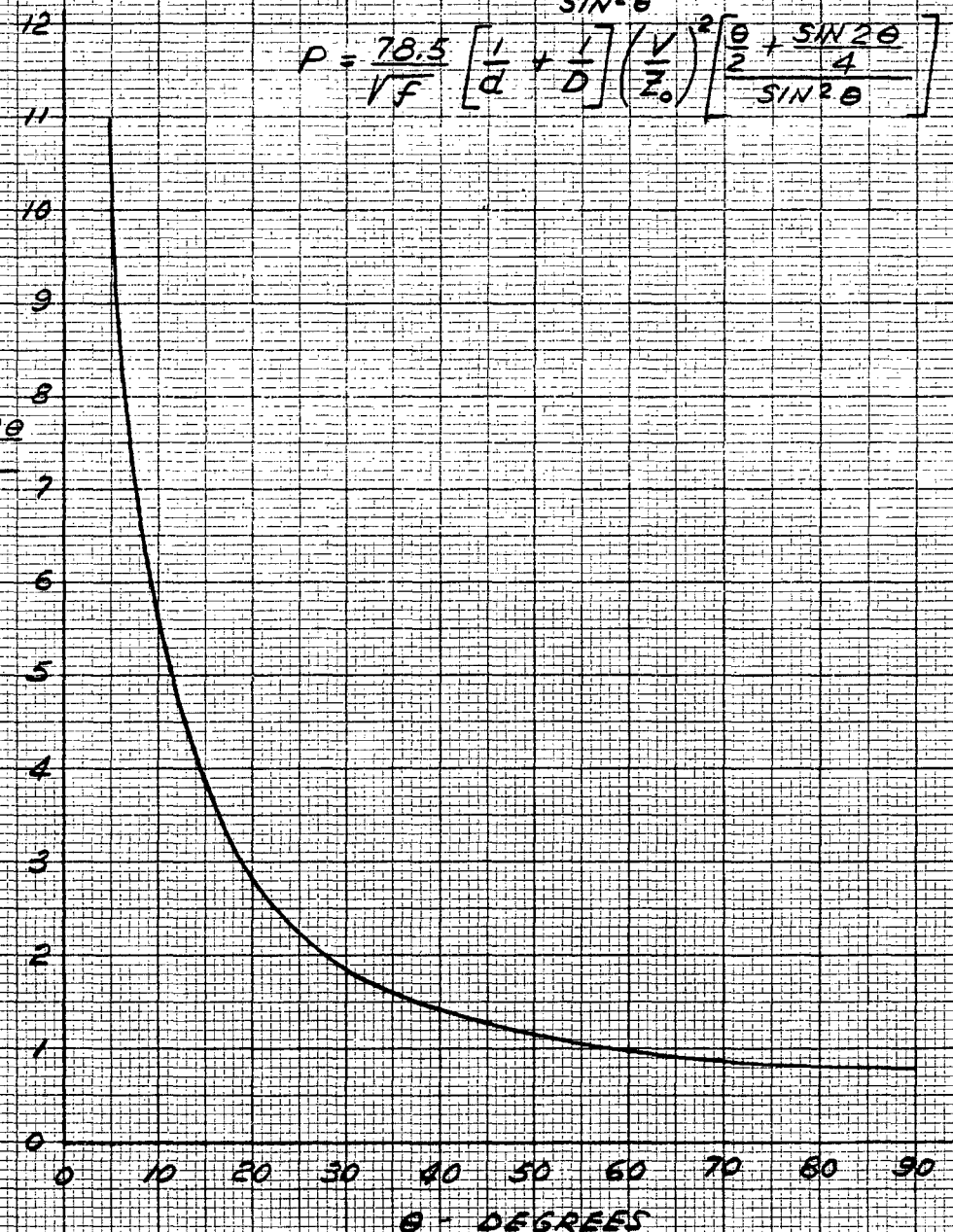


FIG 4

KMartin 4/12/51

KEUFFEL & ESSER CO
NO. 359-11 10 × 10 to the half inch, 5th lines accented.
Engraving, 7 × 10 in.
MADE IN U.S.A.

1. DEFINITIONS:

$$Q = \frac{2\pi(\text{energy stored})}{\text{energy lost/cycle}} = \frac{\omega U}{P} = \frac{\omega L}{R}$$

where $\omega = 2\pi f$

U = energy stored at voltage V

P = power required to obtain voltage V

L = inductance/unit length of line

R = resistance/unit length of line
(See D. D. #42 for other Symbols)

Shunt Impedance:

$$Z_s = \frac{V^2}{2P}$$

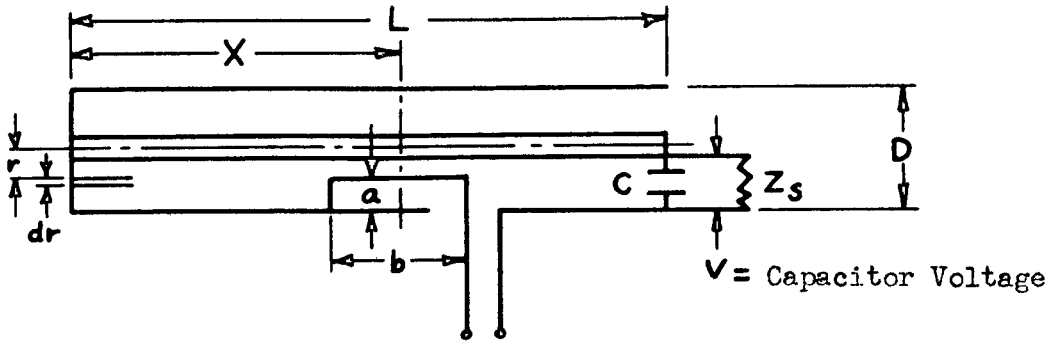
2. RELATION BETWEEN Q AND Z_s (Follows from 1. above)

$$Q = \frac{Z_s}{Z_o}\left(\frac{\frac{\theta}{2} + \frac{\sin 2\theta}{4}}{\sin^2\theta}\right)$$

for $\theta = \pi/2$ (Zero Capacity)

$$Q = \left(\frac{Z_s}{Z_o}\right)\left(\frac{\pi}{4}\right)$$

MM:plc



V_ℓ, Z_ℓ = Loop Voltage and Impedance

$$H_\phi = \frac{I}{2\pi r} = -j\,\frac{V\cos\beta x}{2\pi r Z_o \sin\beta L} \quad \text{where } \beta = \frac{2\pi}{\lambda}$$

$$V_\ell = \oint \vec{E}\cdot\vec{d\ell} = \int_s \nabla \times \vec{E}\cdot\vec{ds} = -j\omega\mu\int_s \vec{H}\cdot\vec{ds}$$

Assume $\frac{b}{\lambda} \ll 1/4$

$$V_\ell = \frac{-\omega\mu V\cos\beta x}{2\pi Z_o \sin\beta L}\int_{\frac{D}{2}-a}^{\frac{D}{2}} \frac{b\,dr}{r} = b\mu\,\frac{fV\cos\beta x}{Z_o\sin\beta L}\,\mathrm{Ln}\left(\frac{D}{D-2a}\right)$$

$$\frac{V_\ell^2}{Z_\ell} = \frac{V^2}{Z_s}$$

$$Z_\ell = \frac{R_s b^2\mu^2 f^2\cos^2\beta x}{Z_o^2\sin^2\beta L}\,\mathrm{Ln}^2\left(\frac{D}{D-2a}\right)$$

Converting to Inches, Megacycles/sec., and Volts

$$V_\ell = \frac{.014\,bfV\cos\beta x}{Z_o\sin\beta L}\,\mathrm{Log}_{10}\left(\frac{1}{1-\frac{2a}{D}}\right)\text{Volts}$$

$$Z_\ell = \frac{1.96\times10^{-4}\,Z_s b^2 f^2\cos^2\beta x}{Z_o^2\sin^2\beta L}\,\mathrm{Log}_{10}^2\left(\frac{1}{1-\frac{2a}{D}}\right)\ \text{OHMS}$$

The 300 Series Stainless steel alloys are low carbon iron alloys with nickel and chromium added to retain the austenite (the high temperature, non-magnetic, form of iron) at room temperature. The austenite so retained is not completely stable--the strain energy or thermal energy necessary to cause it's transformation to the low temperature magnetic ferrite is a stability measure of the austenite and magnetic permeability is a sensitive measure of the amount of transformation occurring.

The accompanying graphs on pages 5 and 6 report the results of magnetic permeability studies of a group of stainless steels representative of each of the AISI 300 series classes which have been cold worked by rolling. The data is representative only of rolling and will vary for other forms of cold working such as bending or wire drawing. (e.g. 18-8 Stainless wire is used in magnetic wire recorders as the recording element)

Hardness and tensile strength as a function of cold rolling is shown on the graphs on page 3 and 4. These curves permit relating, in a general way, the mechanical state of fabricated sheet or plate with permeability.

USE OF THE DATA:

For steels of composition other than those shown on the graphs, it is possible to estimate the permeability in the following manner: From the chemical composition of the stainless steel, stability factor Δ may be computed:

$$\Delta = \%\,Ni - \left[\frac{(\%Cr + 1.5\%\,Mo - 20)^2}{12} - \frac{\%Mn}{2} - 35 \times \%\,C + 15\right]$$

The % C of the stainless is carbon in solution and not carbides precipitated as CrC, CbC, or TiC. The results of these calculations for the steels shown on pages 5 and 6 are given in the table on page 3.

The steel of the unknown permeability can be expected to have a BH curve corresponding to that shown on the graphs for a similar value of Δ. From the permeability curves, it may be seen that the permeability increases rapidly with cold work for Δ values which are negative, and less rapidly, the greater the value of Δ.

This data applies to stainless steels in the composition range.

C	.03 - .20	Cr	14 - 25
Mn	0.4 - 4.0	Ni	7.5 - 21
Si	.3 - .5	Mo	0 - 3.0

AISI	C	Mn	Si	P	S	Cr	Ni	Other	T.S.	%Cold Wk	Hard	△
301	.074	.88	.34			17.55	7.76	.15Mo	less than 100,000	less than 5%	R_B80-82	-7.92
321(1)	.056	1.58	.48			18.23	10.36	.24Ti	95,000-100,000	3-6	R_B82-85	-3.40/3.60
321(2)	.064	1.61	.47			18.31	10.26	.68Ti	95,000-100,000	3-6	R_B82-85	-4.40/4.60
304	.043	.92	.42	.011	.007	19.00	10.66		95,000-100,000	5-8	R_B85-90	-2.45
347	.055	1.78	.58	.014	.015	18.36	10.67	.95Cb	105,000-115,000	8-12	R_C21-25	-1.90/-2.20
302	.126	.63	.40	.015	.008	18.40	8.99		120,000-130,000	12-16	R_B93-96	-1.49
308	.068	.89	.43	.016	.006	17.90	11.74		125,000-140,000	20-25	R_C25-28	- .80
307	.154	3.92	.49			20.65	9.61					+1.93
316	.054	1.67	.31			17.52	13.37	2.39Mo				+1.00
310	.198	2.27	.90	.021	.005	24.33	20.65					+12.12

RADIATION LABORATORY - UNIVERSITY OF CALIFORNIA - BERKELEY

DESIGN DATA

SUBJECT: PERMEABILITY OF COLD WORKED 18-8 STAINLESS STEELS

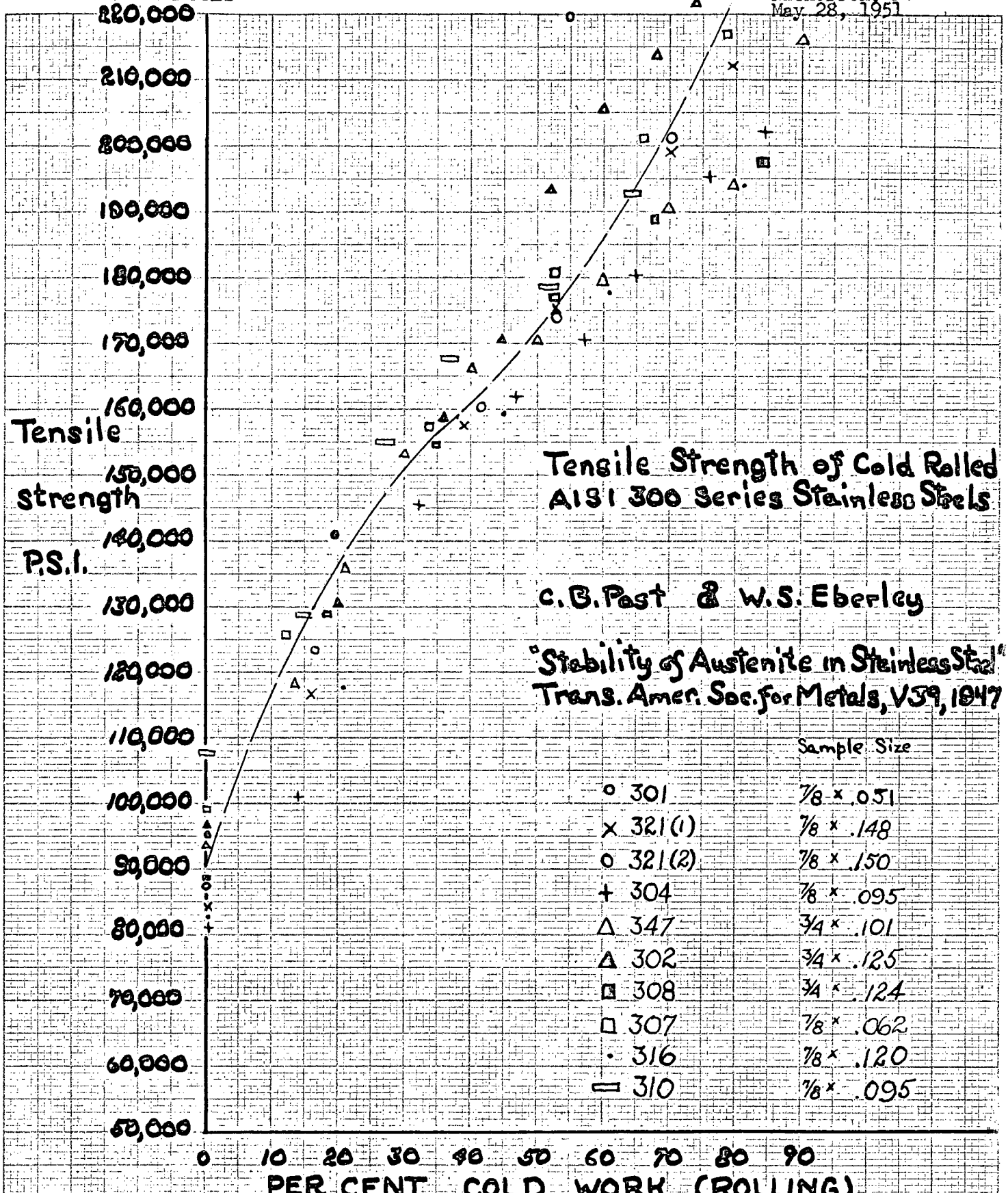
PREPARED: Nickerson, R.

CHECKED BY:

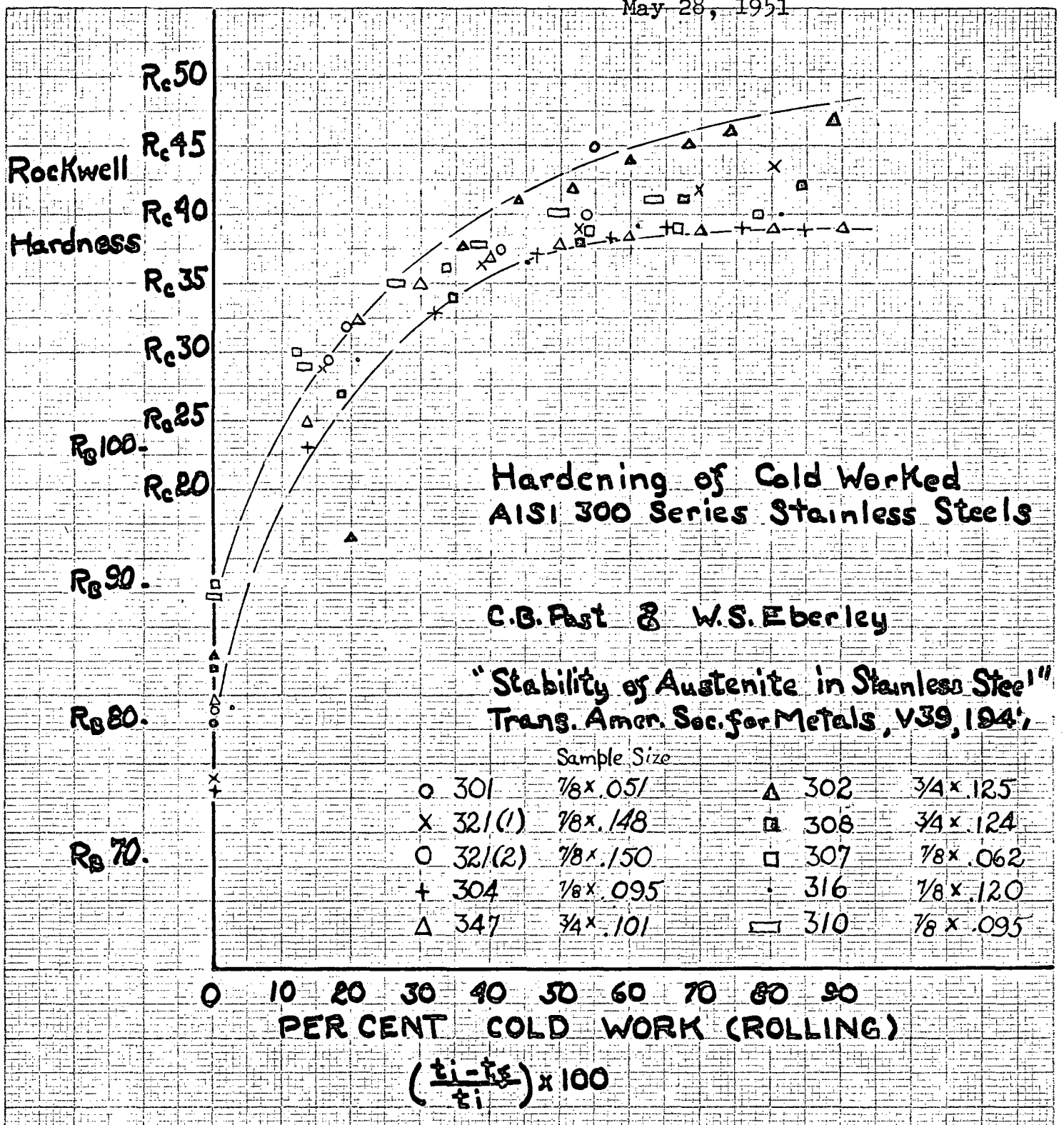
DATE: 5-28-51

D.R. NO.: 44

PAGE: 2



KEUFFEL & ESSER CO., N. Y. NO. 359-126
10 X 10 to the ½ inch, 5th lines accented
MADE IN U.S.A.

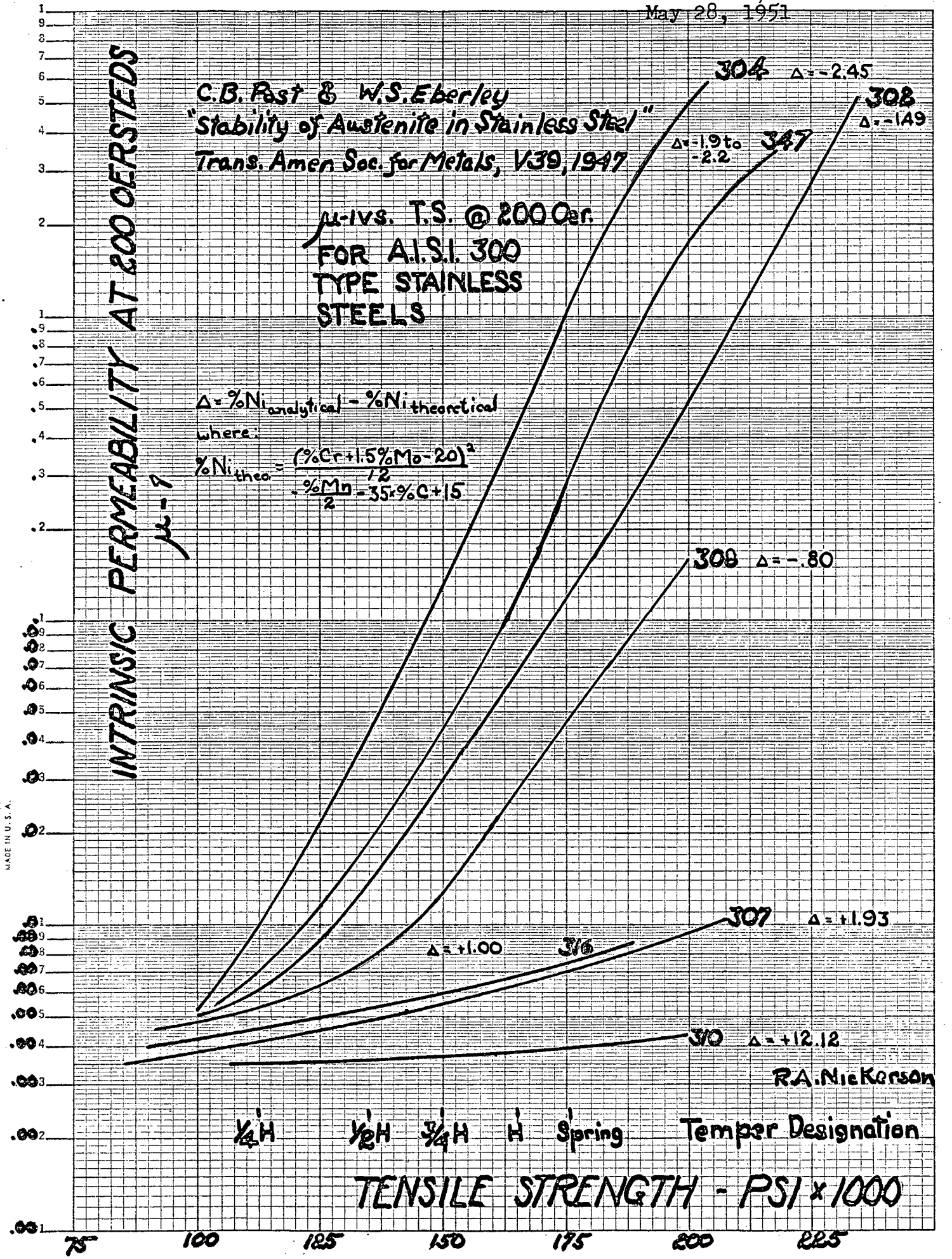


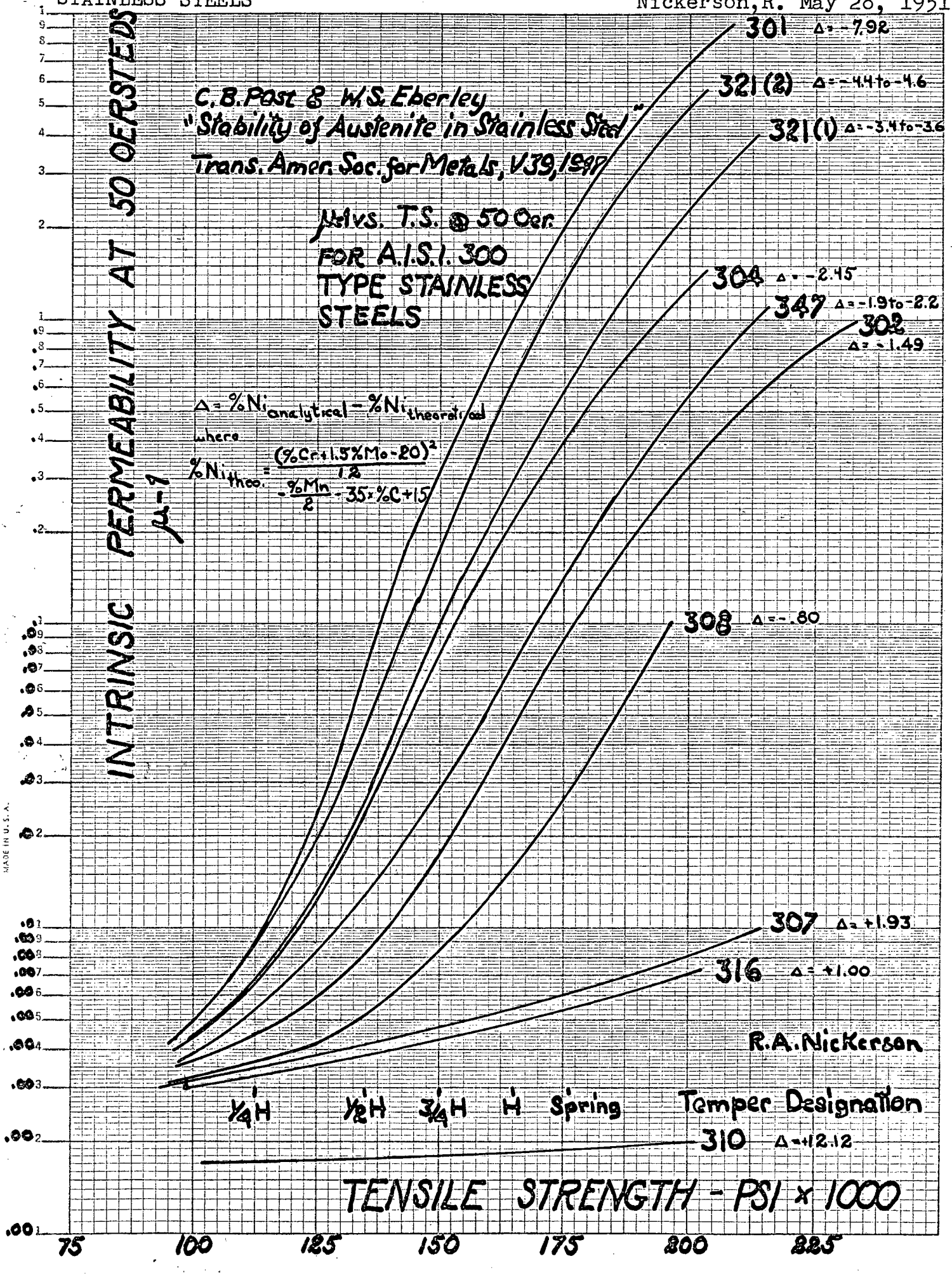
R.A. Nickerson

KEUFFEL & ESSER CO., N. Y. NO. 359-120
10 X 10 to the ½ inch, 5th lines accented.
MADE IN U.S.A.

MAGNETIC PERMEABILITY OF COLD WORKED 18-8 STAINLESS STEELS

DESIGN DATA NO. 44 Pg.5
Nickerson, R.
May 28, 1951




C.B. Post & W.S. Eberley
"Stability of Austenite in Stainless Steel"
Trans. Amer. Soc. for Metals, V39, 1947
μ vs. T.S. @ 50 Oer.
FOR A.I.S.I. 300 TYPE STAINLESS STEELS
INTRINSIC PERMEABILITY AT 50 OERSTEDS
μ-1
Δ = %Ni analytical − %Ni theoretical
where
%Ni theo. = (%Cr + 1.5%Mo − 20)²/12 − %Mn/2 − 35 × %C + 15
301 Δ = −7.92
321 (2) Δ = −4.4 to −4.6
321 (1) Δ = −3.4 to −3.6
304 Δ = −2.45
347 Δ = −1.9 to −2.2
302 Δ = −1.49
308 Δ = −.80
307 Δ = +1.93
316 Δ = +1.00
310 Δ = +12.12
R.A. Nickerson
1/4 H
1/2 H
3/4 H
H
Spring
Temper Designation
TENSILE STRENGTH - PSI × 1000
75
100
125
150
175
200
225

RADIATION LABORATORY - UNIVERSITY OF CALIFORNIA - BERKELEY

DESIGN DATA

DATE	D.D. NO.	PAGE
8/17/51	45	1 of 2

SUBJECT: ELECTRON WORK FUNCTIONS OF THE ELEMENTS

PREPARED: H. P. Hernandez

CHECKED BY:

ELEMENT	WORK FUNCTION Øm, VOLTS	ELEMENT	WORK FUNCTION Øm, VOLTS
Ag	4.28	Li	2.39
Al	3.74	Mg	3.46
As	5.11	Mn	3.95
Au	4.58	Mo	4.27
B	4.5	Na	2.27
Ba	2.29	Nd	3.3
Be	3.37	Ni	4.84
Bi	4.28	Os	4.55
C	4.39	Pb	4.02
Ca	2.76	Pd	4.82
Cb	3.99	Pr	2.7
Cd	3.92	Pt	5.29
Ce	2.7	Rb	2.13
Co	4.18	Re	5.1
Cr	4.51	Rh	4.65
Cs	1.89	Ru	4.52
Cu	4.47	Sb	4.08
Fe	4.36	Se	4.72
Ga	3.96	Si	4.1
Ge	4.56	Sm	3.2
Hf	3.53	Sn	4.11
Hg	4.52	Sr	2.35
Ir	4.57	Ta	4.12
K	2.15	Te	4.73
La	3.3	Th	3.41

ELEMENT	WORK FUNCTION ϕm, VOLTS
Ti	4.09
Tl	3.76
U	3.74
V	4.11
W	4.50
Zn	3.74
Zr	3.84

The data for work functions is taken from the article "Electron Work Functions of the Elements", Journal of Applied Physics, June 1950, which lists measurements published during the period 1924 -- 1949.

For most of the elements values obtained by thermionic, photoelectric, or contact potential methods are about the same, and, to obtain representative values of work function, the unweighted mean ϕm of all data for each element is tabulated.

The reference article also contains a curve which shows the comparison of the first ionization potential, Ei; electron work function, ϕm; and the standard electrode potential E^o versus atomic number. From this curve a hypothetical value of work function may be predicted for elements on which no data has yet appeared in literature.

HPH:ah

RADIATION LABORATORY-UNIVERSITY OF CALIFORNIA-BERKELEY
DESIGN DATA

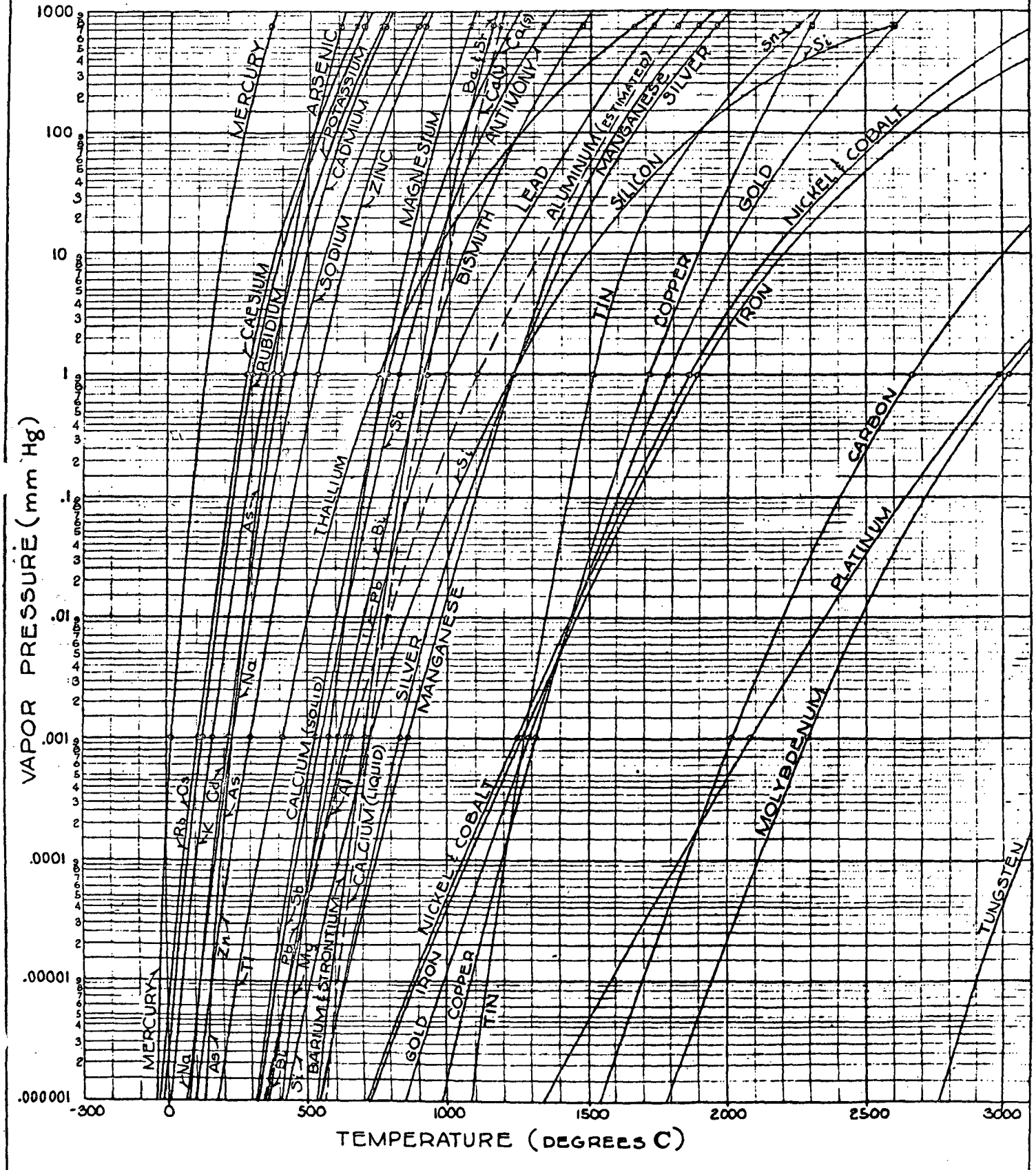
DATE	D.D. No.	PAGE
9-12-51	46	1 of 1

PREPARED

CHECKED BY V. McClain

VAPOR PRESSURE vs. TEMPERATURE

CURVES PLOTTED THRU VALUES AT CIRCLED POINTS TAKEN FROM INTERNATIONAL CRITICAL TABLES



DWG. 5E8983

SUBJECT

SURFACE FINISHES,
TYPICAL APPLICATIONS AND RELATIVE COSTS

PREPARED Ralph Frey

CHECKED BY J.C.Turner /s/

Revised 2/17/60

Although relative costs will vary with part design and available shop facilities, finer finishes cost more money. This should be kept in mind when drawings and specifications are made. It should be especially remembered by both designers and shop men when considering finishing for appearance only.

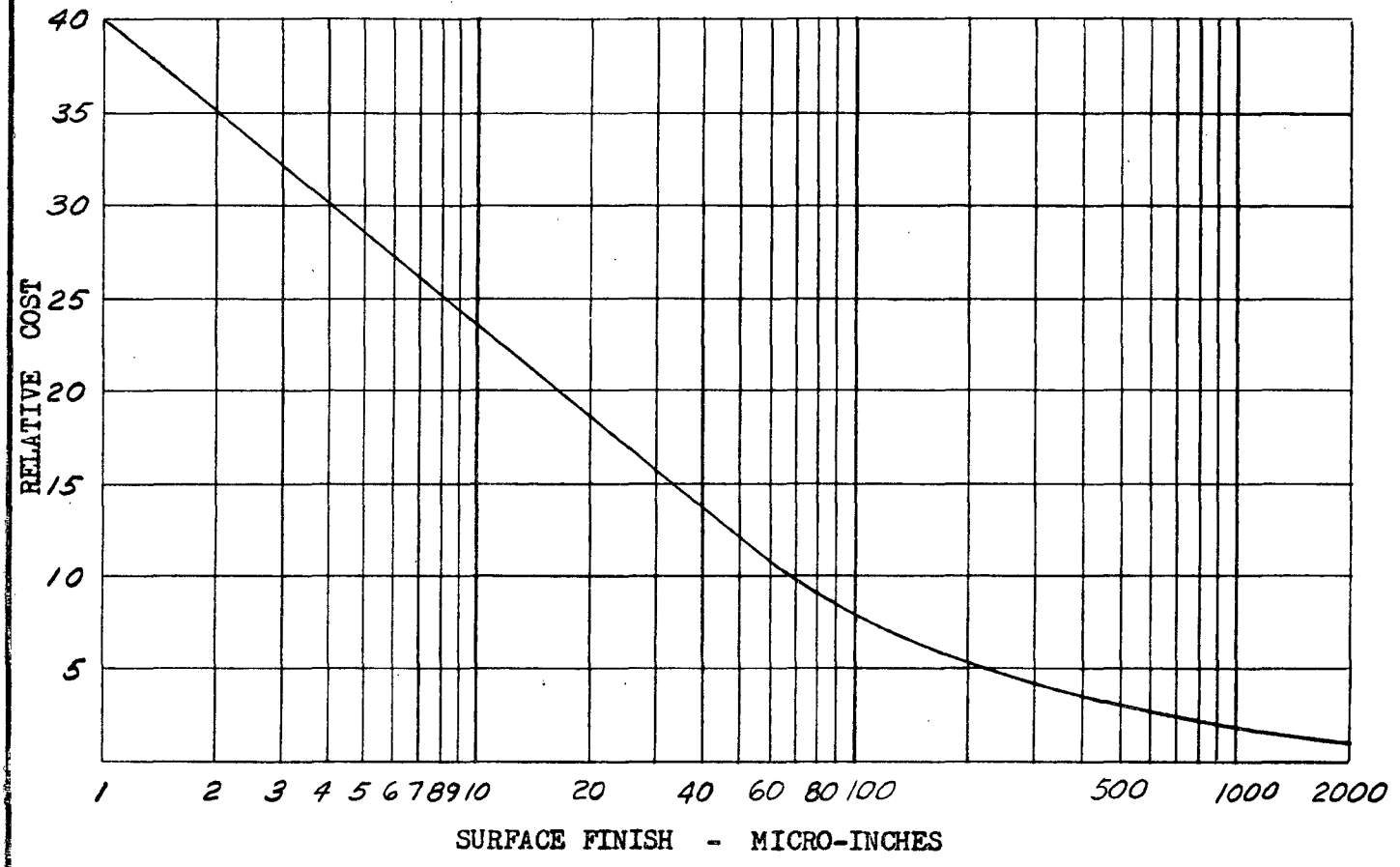
The table below shows typical applications and relative cost of the various surface finishes. This relationship is graphically illustrated on the next page.

Visual comparison gauges are available in the Mechanical Engineering Department. The shops have profilometers for actual measurement when this is necessary.

ROUGHNESS HEIGHT VALUE (MICROINCHES)	TYPICAL APPLICATIONS	TYPICAL METHODS OF PRODUCING FINISH	APPROX. RELATIVE COST
1	Micrometer anvils, mirrors, high grade gages	Lapping, polishing, superfinishing	40
2	Shop gages, comparator anvils, metal to metal faces	Lapping, polishing, superfinishing, micro-honing	35
4	Vernier caliper faces, sliding contact under heavy loads, precision roller and ball bearings, seal faces moving relative to flexible seals retaining gases	Grinding, micro-honing, lapping superfinishing, burnishing, polishing, etc.	30
8	Sliding contact under high load such as cam faces and journal bearings, good grade ball and roller bearings, seal faces moving relative to flexible seals retaining liquids and greases	Grinding, honing, lapping, rolling, polishing, burnishing, etc.	26
16	High speed shaft journals under moderate load, commercial grade ball and roller bearings, ball and roller bearing seats, "O" ring grooves for static seals, valve plugs and seats, cylinder bores, gear teeth	Grinding, rolling, lapping, honing, some moulding and extruding, etc.	20
32	Sliding contact under light loads, splined shafts, key seats, facing for friction clutches and brakes, solid metal gaskets, mating faces of precision parts, gear teeth, highly stressed parts, piston O.D.s	Grinding, turning, milling, broaching, reaming, honing, extruding, moulding, boring, etc.	15
63	Mating faces of machine parts (no motion), for appearance on outside faces, to obtain size dimensions to decimal tolerances	Shaping, grinding, broaching, turning, milling, extruding, permanent mould casting, drilling, boring, etc.	10
125	For a great variety of non-critical assemblies, such as housing parts, facings on pipe flanges trueing up and stock removal, sizing to decimal tolerance	Shaping, turning, milling, grinding, boring, forging, rolling, extruding, drilling, permanent mould casting	7
250	Flange facing using soft gaskets, clearance dimensions (airfits), for rough machine parts, for stock removal, for trueing up or to obtain size to fractional tolerances	Shaping, turning, milling, rough grinding, shearing, forging, boring	5
500	Primarily for stock removal only	Shaping, turning, milling, sand casting, sawing, planing	3.0
1000	For stock removal prior to finishing cuts	Rough turning, planing, milling torch cutting, sawing, etc.	1.5
2000	For stock removal prior to finishing	Very rough turning, planing, milling, torch cutting, sawing	1

The above table is copied from Oak Ridge National Laboratory report ORNL-1051.

The following curve graphically illustrates the relationship between cost and surface finish.



RADIATION LABORATORY - UNIVERSITY OF CALIFORNIA - BERKELEY

DESIGN DATA

SUBJECT

THREADS - LOADS AND STRESSES PER UNIT TORQUE

A Revision. Supersedes D. D. 48, 11-26-51

THE INFORMATION IN THIS TABLE RELATES THE TORQUE APPLIED TO BOLTS AND SCREWS TO THE AXIAL LOAD AND TENSILE STRESS AREA AVERAGE STRESS. DESIGN CONSIDERATIONS, SUCH AS THE DESIGN STRESS, FACTOR OF SAFETY, MATERIAL, LOADING, ETC., MUST NECESSARILY BE DETERMINED BY THE DESIGNER.

Size	Dia	Thds per inch UNC	Thds per inch UNF	Root area sq in.	Tensile stress area sq in.	Tensile stress lbs/sq in. with torque of 1 in.-lb	Axial load lbs with torque of 1 in.-lb
0	.0600		80	.00151	.00180	46,296	83.3
1	.073	64		.00218	.00263	26,043	68.5
1	"		72	.00237	.00278	24,638	
2	.086	56		.00310	.00370	15,713	58.1
2	"		64	.00339	.00394	14,756	
3	.099	48		.00406	.00487	10,371	50.5
3	"		56	.00451	.00523	9,657	
4	.112	40		.00496	.00604	7,391	44.6
4	"		48	.00566	.00661	6,754	
5	.125	40		.00672	.00796	5,025	40.0
5	"		44	.00716	.00830	4,819	
6	.138	32		.00745	.00909	3,986	36.2
6	"		40	.00874	.01015	3,570	
8	.164	32		.01196	.0140	2,178	30.5
8	"		36	.01285	.01474	2,068	
10	.190	24		.0145	.0175	1,504	26.3
10	"		32	.0175	.0200	1,316	
12	.216	24		.0206	.0242	957	23.2
12	"		28	.0226	.0258	897	
1/4	.250	20		.0269	.0318	629	20.0
1/4	"		28	.0326	.0364	549	
5/16	.3125	18		.0454	.0524	305	16.0
5/16	"		24	.0524	.0580	276	
3/8	.375	16		.0678	.0775	172	13.3
3/8	"		24	.0809	.0878	152	
7/16	.4375	14		.0933	.1063	108	11.4
7/16	"		20	.1090	.1187	96	

Note. See page 2 for data source and other pertinent information.

Size	Dia	Thds per inch UNC	Thds per inch UNF	Root area sq in.	Tensile stress area sq in.	Tensile stress lbs/sq in. with torque of 1 in.-lb	Axial load lbs with torque of 1 in.-lb
1/2	.500	13		.1257	.1419	70.5	10.0
1/2	"		20	.1486	.1599	62.5	
9/16	.5625	12		.162	.182	48.8	8.89
9/16	"		18	.189	.203	43.8	
5/8	.625	11		.202	.226	35.4	8.00
5/8	"		18	.240	.256	31.25	
3/4	.750	10		.302	.334	20.0	6.67
3/4	"		16	.351	.373	17.9	
7/8	.875	9		.419	.462	12.4	5.71
7/8	"		14	.480	.509	11.23	
1	1.000	8		.551	.606	8.25	5.00
1	"		12	.625	.663	7.54	
1 1/8	1.125	7		.693	.763	5.82	4.44
1 1/8	"		12	.812	.856	5.19	
1 1/4	1.250	7		.890	.969	4.13	4.00
1 1/4	"		12	1.024	1.073	3.73	
1 3/8	1.375	6		1.054	1.155	3.15	3.64
1 3/8	"		12	1.260	1.315	2.77	
1 1/2	1.500	6		1.294	1.405	2.37	3.33
1 1/2	"		12	1.521	1.581	2.11	
1 3/4	1.750	5		1.74	1.90	1.50	2.86
1 3/4	"		12	2.12	2.19	1.305	
2	2.000	4.5		2.30	2.50	1.00	2.50
2	"		12	2.81	2.89	.865	
2 1/4	2.250	4.5		3.02	3.25	.684	2.22
2 1/4	"		12	3.60	3.69	.602	
2 1/2	2.500	4		3.72	4.00	.500	2.00
2 1/2	"		12	4.49	4.60	.435	

PREPARED Lee R. Glasgow

CHECKED BY Lee R. Glasgow

DATE 1-23-73

D.D. NO. 48A

1. The tabulated values for stress per unit torque (S/T) and load per unit torque (P/T) were derived from the following formula which came from Machine Design Magazine, Reference Issue, "Fastening and Joining", 5th ed, chapter 4, 11 Sept 1969.

   T = KDP
   T = applied torque-inch-lbs
   K = torque coefficient which is made up of three components:

   $$K = K_1 + K_2 + K_3$$

   K_1 represents unit torque wasted by friction on the bearing face of a nut or bolt. ≈ 50% of total.

   K_2 represents unit torque wasted by friction on contact flanks of the threads. ≈40% of total.

   K_3 represents the useful unit torque that produces bolt tension. ≈10% of total.

   D = nominal screw or bolt diameter-inches
   P = bolt tension or clamping load - lbs

   The table is based upon a torque coefficient of K = .2, which is an average value for components as normally obtained from stock. If lubrication is applied then an average value of .15 should be used for K and the table values of S/T and P/T should be multiplied by .2/.15 = 1.33. The same torque creates higher stresses and loads under lubricated conditions. If a more exact value of K for a specific requirement is desired, it can be computed from the formula given in the Machine Design reference above.

2. Only one value is given in load per unit torque column for both fine and coarse threads. Theoretically there is a slight difference, due to the difference in helix angle and pitch radius, that would show up in the derivation of K, but the difference is so small relative to the effect of friction that its significance is lost.

3. These data should be more realistic than the previous D. D. 48. The old data were based upon the theoretical maximum resultant tensile stress obtained when the torsional shear stress and tensile stress components are mathematically combined (see Bolts, Nuts, and Screws, Lamson and Session Company, pg 151, LBL Engineering Library, TJ1330, L241, 1944.) The data presented in this note were determined from actual tests which showed that design can be based upon the tensile component alone.

4. Table data in this note were checked against data from several other tables and corresponds quite well. A very good torque value chart for screws and bolts of various materials and tensile strengths is available in the P. R. Sturtevant Co.'s "Torque Manual", 7th ed, pgs 38 thru 41. This manual is in the Engineering Library Catalog Section.

LG:er

This table shows stud spacing (inches) based on 8000 psi on root diameter of stud and 330 psi gasket pressure (based on area of undeformed gasket).

This 330 psi pressure has proved satisfactory for vacuum joints using square gaskets of 55 to 65 durometer hardness installed in grooves designed to permit 33% deflection of the unrestrained portion of the gasket.

Deflection of cover plate may require a closer spacing.

	STUD SPACING - INCHES					
GASKETS / STUDS	Single 1/8 Sq.	Double 1/8 Sq. & Single 1/4 Sq.	Single 3/16 Sq.	Double 3/16 Sq. & Single 3/8 Sq.	Double 1/4 Sq.	Double 3/8 Sq.
1/4 - 20	5.2	2.6	3.5	1.7	1.3	0.87
5/16 - 18	8.7	4.4	5.8	2.9	2.2	1.4
3/8 - 16	13.2	6.6	8.8	4.4	3.3	2.2
7/16 - 14	18.0	9.0	12.0	6.0	4.5	3.0
1/2 - 13	24.4	12.2	16.3	8.1	6.1	4.1
9/16 - 12	31.4	15.7	20.9	10.5	7.8	5.2
5/8 - 11	39.2	19.6	26.1	13.1	9.8	6.5
3/4 - 10	58.6	29.3	39.0	19.5	14.6	9.8
7/8 - 9	81.3	40.6	54.2	27.1	20.3	13.5
1 - 8	107	53.4	71.2	35.6	26.7	17.8

RADIATION LABORATORY - UNIVERSITY OF CALIFORNIA - BERKELEY

DESIGN DATA

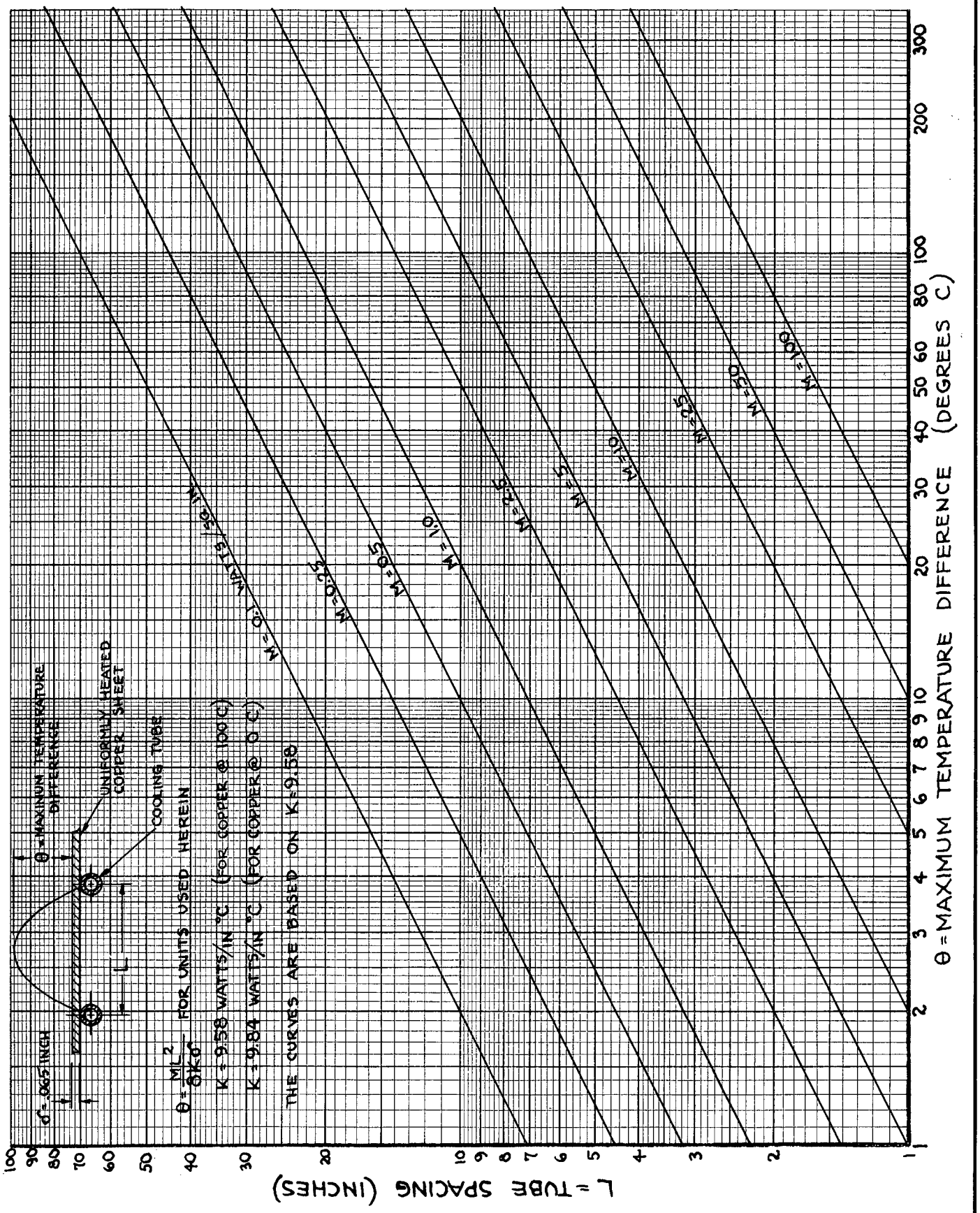
DATE	D.D. NO.	PAGE
2-27-52	52	1 OF 1

SUBJECT: COOLING TUBE SPACING VS. MAXIMUM TEMPERATURE DIFFERENCE ON UNIFORMLY HEATED 16 GAGE (.065) COPPER SHEET

PREPARED: D. VANCE

CHECKED BY: SCALISE

DRAWN BY: SEEGMILLER



RADIATION LABORATORY - UNIVERSITY OF CALIFORNIA - BERKELEY

DESIGN DATA

DATE	D.D. NO.	PAGE
10/14/44	54	1

SUBJECT

CHARACTERISTICS OF PURE TUNGSTEN FILAMENTS

PREPARED: T. W. Macomber

CHECKED BY:

Pure Tungsten Filament at 2500°K
(Assumes no heat conducted away by end clamps)

d	A	v	w	i	i/v	i/w	Life
DIAMETER (INCHES)	HEATING CURRENT (AMPERES)	VOLTAGE DROP (VOLTS/INCH)	INPUT (WATTS/INCH)	EMISSION CURRENT (MA/INCH)	(MA/VOLT)	(MA/WATT)	HOURS TO EVAPORATE 10% OF WT.
VARIATION PER:	$d^{3/2}$	$d^{-1/2}$	d	d	$d^{3/2}$		d
.0006	.0908	9.35	.848	3.62	.387	.426	101.2
.001	.1953	7.24	1.415	6.03	.833	"	168.6
.002	.552	5.12	2.830	12.06	2.36	"	337.2
.003	1.015	4.18	4.245	18.09	4.33	"	506.
.004	1.562	3.62	5.660	24.1	6.67	"	675.
.005	2.184	3.24	7.075	30.2	9.31	"	843.
.006	2.870	2.96	8.49	36.2	12.24	"	1,012.
.007	3.62	2.74	9.90	42.2	15.42	"	1,180.
.008	4.42	2.56	11.32	48.2	18.85	"	1,350.
.0085	4.84	2.48	12.02	51.2	20.6	"	1,434.
.009	5.27	2.41	12.74	54.3	22.5	"	1,518.
.010	6.18	2.29	14.15	60.3	26.3	"	1,686.
.012	8.12	2.09	16.98	72.4	34.6	"	2,020.
.014	10.23	1.936	19.81	84.4	43.6	"	2,360.
.015	11.35	1.870	21.22	90.5	48.4	"	2,530.
.016	12.50	1.810	22.64	96.5	53.3	"	2,700.
.018	14.92	1.708	25.48	108.5	63.6	"	3,040.
.020	17.47	1.620	28.30	120.6	74.5	"	3,370.
.025	24.41	1.448	35.4	150.8	104.1	"	4,220.
.030	32.1	1.322	42.5	180.9	136.9	"	5,060.
.034	38.7	1.242	48.1	205.	165.2	"	5,740.
.035	40.4	1.224	49.5	211.	172.5	"	5,900.
.040	49.4	1.145	56.6	241.	211.	"	6,750.
.050	69.1	1.024	70.8	302.	294.	"	8,430.
.060	90.8	.935	84.9	362.	387.	"	10,120.
.070	114.4	.866	99.0	422.	488.	"	11,800.
.080	139.8	.810	113.2	482.	596.	"	13,500.
.090	165.8	.763	127.4	543.	711.	"	15,180.
.100	195.3	.724	141.5	603.	834.	"	16,860.
.110	225.3	.690	155.6	664.	961.	"	18,600.
.120	256.8	.661	169.8	724.	1,095.	"	20,200.
.125	272.9	.648	176.9	754.	1,164.	"	21,100.
.130	289.5	.635	184.0	784.	1,235.	"	21,900.
.140	323.5	.612	198.1	844.	1,380.	"	23,600.
.145	341.	.601	205.2	875.	1,450.	"	24,500.
.150	359.	.591	212.2	905.	1,530.	"	25,300.
.200	552.	.512	283.0	1,206.	2,360.	"	33,700.
.250	772.	.458	354.0	1,508.	3,290.	"	42,200.

NOTE: The heat carried away by end clamps is proportional to current only. F Ta or W filaments it is 0.23 watts per ampere.

Pure Tungsten Filament at Various Temperatures

The following constants give characteristics at lower and higher temperatures than 2500 K, taking characteristics on Page 1 as unity.

°K	A	v	w	i	i/v	i/w	Life
	AMPERES	VOLTS/INCH	WATTS/INCH	MA/INCH	MA/VOLT	MA/WATT	
800	.097	.0250	2.42×10^{-3}				
900	.126	.0376	4.75×10^{-3}				
1000	.161	.0540	8.64×10^{-3}				
1200	.232	.099	2.38×10^{-2}				
1800	.548	.371	.2035	1.50×10^{-4}	4.04×10^{-4}	7.33×10^{-4}	2.32×10^{6}
1900	.608	.439	.267	*7.65×10^{-4}	*1.74×10^{-3}	*2.87×10^{-3}	1.45×10^{5}
2000	.671	.514	.344	3.37×10^{-3}	6.56×10^{-3}	9.80×10^{-3}	1.17×10^{4}
2100	.733	.597	.437	1.32×10^{-2}	2.21×10^{-2}	3.02×10^{-2}	1.23×10^{3}
2200	.798	.686	.545	4.46×10^{-2}	6.70×10^{-2}	8.18×10^{-2}	1.64×10^{2}
2300	.864	.784	.677	1.37×10^{-1}	1.75×10^{-1}	2.02×10^{-1}	25.6
2400	.933	.888	.826	.389	.438	.471	4.82
2500	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2600	1.060	1.123	1.202	2.41	2.15	2.000	.244
2700	1.12	1.25	1.42	5.38	4.30	3.79	.077
2800	1.17	1.38					

* For thorium multiply by 10,000.

REFERENCES: Applied Electronics, M. I. T. Staff, 1943, p. 86.
"The Characteristics of Tungsten Filaments as Functions of Temperature", by Drs. H. A. Jones & Irving Langmuir, General Electric Review, June, 1927, pp. 310 - 319. This design data was copied from UCRL Chart X-1161.

RADIATION LABORATORY • UNIVERSITY OF CALIFORNIA • BERKELEY

DESIGN DATA

DATE	D.D. NO.	PAGE 1 OF 1 PAGES
6/5/52	56 C	

SUBJECT: MAGNET DESIGN INFORMATION

PREPARED: A. Schmidt, D. T. Scalise

CHECKED BY: E. Kane, L. E. Brown

A REVISION 1-5-55 (SCALISE)
B " 10-21-55 "
C " 2-26-64 "

CONDUCTOR PROPERTIES

CONDUCTOR	Specific Weight $\frac{\text{Lbs.}}{\text{Cu. In.}}$	RESISTIVITY = ρ (Michrohm inches) at 20C.	at 40C.	$0C \le t \le 120C$	Heat Conductivity at 20 C. $\left(\frac{\text{Watts}}{\text{in. }^{\circ}C}\right)$	Specific Heat at 20 C. $\left(\frac{\text{Watt Sec.}}{\text{Lbs. }^{\circ}C}\right)$	Linear Coef. of Thermal Expansion. per $^{\circ}C$.
ALUMINUM Internat'l Al. Std. (99.58% Al)	.098	1.11	1.20	$\rho = .00453(t+225)$	5.4	430	23.9×10^{-6}
COPPER Internat'l Annealed Cu. Std. (99.91% Cu)	.321	.679	.732	$\rho = .00267(t+234)$	9.76	175	16.8×10^{-6}
SILVER (99.98% Ag)	.380	.64	.69	$\rho = .0025(t+236)$	10.52	106	18.8×10^{-6}

FORMULAS INDEPENDENT OF MATERIAL

Ampere turnes for gap = 2.02 x (gauss) x (inches gap)

B Joules/Cu.In. stored energy of Magnetic field in air = (1/15.35) x (kilogauss)^2

Pounds force on conductor = (1/1750) x (kilogauss) x (amperes) x (inches length)

A Pounds force between long parallel conductors = 4.496×10^{-8} x (amps. in one cond.) x (amps in other cond.) x (inches length cond. / inches between cond.)

Pounds forces between pole faces = (1/1.735) x (kilogauss)^2 x (sq. inches area)

CONDUCTOR FORMULAS DEPENDING ON MATERIAL AND TEMPERATURE

	Coefficients at 40 C.			Coef. at any temperature proportional to
C (kilowatts) x (tons) =	(.059)	Al.	(Megamp-turns)^2 x (inches mean turn length)^2	ρw
	(.118)	Cu		
	(.131)	Ag		
(Amperes) / (sq. inch) =	(202)	Al	$\sqrt{\frac{\text{(kilowatts)}}{\text{(tons)}}}$	$\sqrt{\frac{w}{\rho}}$
	(469)	Cu		
	(525)	Ag		
(Sq. inches Cross Section) =	(4.95)	Al	$\sqrt{\frac{\text{(kilowatts) x (tons)}}{\text{(volts) x (parallel paths)}}}$	$\sqrt{\frac{\rho}{w}}$
	(2.13)	Cu		
	(1.90)	Ag		
(Sq. inches Cross Section) =	(1.20)	Al	$\frac{\text{(Megamp-turns) x (inches mean turn length)}}{\text{(volts) x (parallel paths)}}$	ρ
	(.732)	Cu		
	(.69)	Ag		

FOR RECTANGULAR CONDUCTOR LOSING HEAT FROM TWO EDGES

(Degrees C. rise at center) =	(.028)	Al	(10^{-6}) x (inches width)^2 x $\left(\frac{\text{amperes}}{\text{sq. in.}}\right)^2$	$\frac{\rho}{k}$
	(.0094)	Cu		
	(.0082)	Ag		
(watts) / (sq. in. edge surface) =	(.60)	Al	(10^{-6}) x (inches width) x $\left(\frac{\text{amperes}}{\text{sq. in.}}\right)^2$	ρ
	(.366)	Cu		
	(.345)	Ag		

SYMBOLS: ρ = resistivity; w = specific weight; k = heat conductivity

REFERENCES: UCRL Chart X-1027; Chem. Physics Handbook, Circular 31 Bureau of Standards

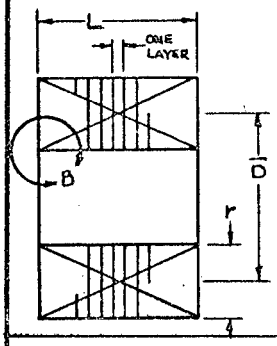
SUBJECT

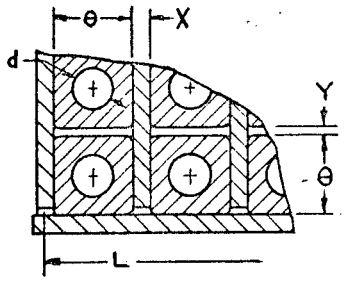
CALCULATION GUIDE FOR INTERNALLY COOLED MAGNET COILS

PREPARED
L. E. Brown

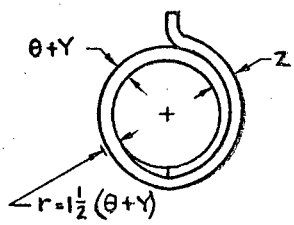
CHECKED BY
SCALISE

This Design Data applies to coils wound with square hollow conductors; layers connected electrically in series and hydraulically in parallel.

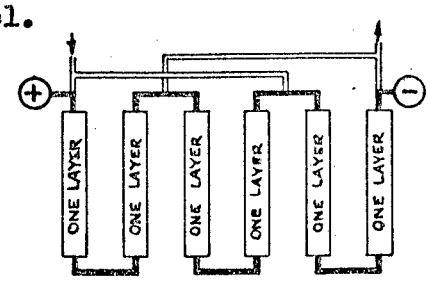




VIEW B



ONE LAYER OF 1½ TURNS



SCHEMATIC:
SERIES ELECTRICAL CIRCUIT n=6
PARALLEL HYDRAULIC CIRCUIT m=2

EQUATIONS

$$\theta = \left(\frac{L}{n} - X\right)$$

$$r = t(\theta + y) \leq Z$$

$$I = \frac{NI}{N} = \frac{NI}{nt}$$

$$P = 10^{-3}\,(EI) = 10^{-3}\,(I^2R) = 10^{-6}\left(\frac{I}{A}\right)^2 WK$$

$$F = \frac{5\pi}{10^{10}}\left(\frac{K\bar{D}w}{Lr}\right)\frac{(NI)^2}{P} = \frac{AN}{Lr}$$

$$d^2 = \frac{4}{\pi}\left(\theta^2 - \frac{Lr}{N}F\right)$$

$$A = \theta^2 - \frac{\pi}{4}d^2$$

$$Q = \frac{3.8P}{\Delta T}\ \text{(for water)} = \frac{qn}{m}$$

$$T = T_i + \frac{\Delta T}{2} \leq \text{mean cond. temp.}$$

$$S = \frac{1}{12}\pi \bar{D} tm$$

$$R = \rho\,\frac{\pi \bar{D} N}{A}$$

$$W = \frac{\pi \bar{D} rLwF}{2000}$$

K from Design Data #30
H, q, and d from Design Data #10
For Coolant other than water, see Design Data #29
For UCRL Stock Conductors see Design Data #58
For resistivity, see Design Data #56.

LEB:plc

LIST OF SYMBOLS

	UNITS
A = conductor cross sectional area	Sq. In.
$\bar{D}$ = mean diameter of coil	In.
d = conductor hole diameter	In.
E = magnet voltage	Volts
F = space factor (not including space for clamping terminals or protecting enclosure.)	-
H = head loss to coolant	psi
I = magnet current	Amps
K = power per ton of cond. at 1000 Amps/in.^{2}, see D.D. #30	KW/ton
L = axial length of coil assembly	In.
m = number of layers hydraulically in series	-
N = number of turns	-
NI = number of ampere turns	Amp turns
n = number of layers	-
P = magnet power	KW
Q = total flow rate of coolant	GPM
q = flow rate per cooling circuit	GPM
R = coil resistance	Ohms
r = effective radial depth of coil	In.
S = cooling circuit length	Ft.
T = average coolant temp.	°C.
T_i = initial temp. of coolant	°C.
ΔT = coolant temp. rise	°C.
t = number of turns per layer	-
W = total weight of conductor	Tons
w = specific weight of cond. mat'l.	lbs/cu in
X = unit axial cond. tol. & allow + insulator thickness	In.
Y = unit radial cond. tol. & allow + insulator thickness	In.
Z = Max. radial depth of winding	In.
θ = conductor size	In.
ρ = resistivity of conductor mat'l. at mean temp.	ohm in.

Outside Dimensions[a]	Hole Diameter	Corner Radius	Effective Area	Space Factor[b]	Electrical Resistance[b] 20°C	Electrical Resistance[b] 40°C	Mass/ Unit Length[b]	Cat. No: 6145-
HOLLOW SQUARE:-								
.255±.005 in. (6.48±0.13mm)	.124 ±.004 in. (3.15±.10mm)	.030±.010 in. (.762±.254mm)	.052±.004 in.^{2} (33.55±2.58mm^2)	.80	160[c] 525[d]	172[c] 564[d]	.201[e] .299[f]	24179
.340±.005 in. (8.64±.13mm)	.184±.004 in (4.67±.10mm)	.030±.010 in. (.762±.254mm)	.088±.005 in.^{2} (56.77±3.23mm^2)	.76	94.4[c] 310[d]	102[c] 335[d]	.340[e] .506[f]	24180
.467±.005 in. (11.86±.13mm)	.275±.005 in. (6.99±.13mm)	.047±.016 in. (1.19±.40 mm)	.157±.008 in^2 (101.3±5.16mm^2)	.72	52.9[c] 174[d]	57.1[c] 187[d]	.607[e] .903[f]	24181
.640±.005 in. (16.26±.13mm)	.402±.005 in (10.21±.13mm)	.047±.016 in. (1.19±.40mm)	.281±.011 in.^{2} (181.3±7.09mm^2)	.69	29.6[c] 97.1[d]	31.9[c] 105[d]	1.09[e] 1.62[f]	----
SOLID RECTANGULAR:-								
1/16 x 1/2 in. (1.59x12.7mm)			.031 in^2 (20.0mm^2)		268[c] 879[d]	289[c] 948[d]	.120[e] .179[f]	----
1/8 x 1 in. (3.18x25.4mm)			.125 in^2 (80.6mm^2)		66.5[c] 218[d]	71.7[c] 235[d]	.483[e] .719[f]	----

a. The recommended standard sizes of square conductor were selected such that (1) maxium utilization is made of existing sizes and (2) the ratio of areas for successively smaller conductors is approximately constant (1.64 to 1.79).

b. The tabulated space factor, resistance, and mass/unit length are based on nominal dimensions. The conductivity used was 98% of the International Annealed Copper Standard. Space factor = Effective area ÷ (O.D.)^2.

c. Micro-ohms per foot

d. Micro-ohms per meter.

e. Pounds per foot.

f. Kilograms per meter.

REFERENCES: For square conductor specifications: Eng. Notes 203-16 M3A, 303-30 M3, Specification M 13

nh

LAWRENCE BERKELEY LABORATORY – UNIVERSITY OF CALIFORNIA

DESIGN DATA

TITLE: COPPER CONDUCTORS FOR MAGNETS RECOMMENDED STANDARD SIZES

PREPARED BY: H. Gordon/T. Scalise — DATE: 5/52

REVISED BY: R. Frey — DATE: 1/58

REVISED BY: J. O. Turner — DATE: 3/80

NUMBER: 58B

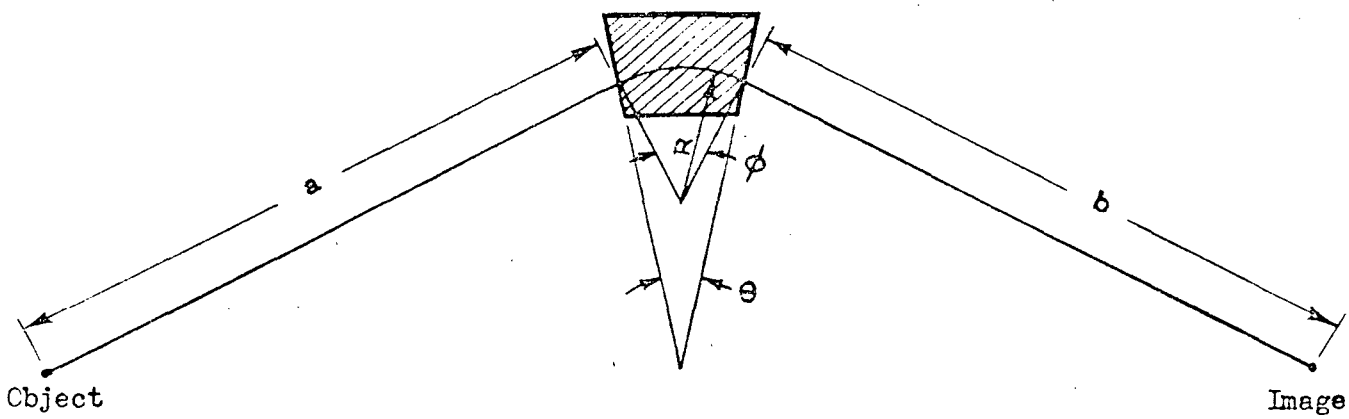
PAGE 1 OF 1

PROPERTIES OF NITROGEN

Boiling Point	-195.8	deg. C.
Latent Heat of Vaporization	90,500 161,000	watt sec./lb. watt sec./liter
Heat of Gas from Boiling Point to room temperature (20 C.) at constant pressure	100,000	watt sec./lb.
Density of Liquid	.0292 50.4 1.78 .808	lbs./cu. in. lbs./cu. ft. lbs./liter gms./cc.
Specific Volume of Gas at 20 C., 14.7 psia.	13.8 695	cu. ft./lb. cu. ft. gas / cu. ft. liquid

LIQUID NITROGEN CONSUMPTION

BASIS	CONSUMPTION
Calculated evaporation rate for unshielded trap, with emissivity = 1.0, radiantly heated by a large enclosure at 20 C., stem conduction neglected.	0.37 cu. in./hr. / sq. in. rad. surface = 0.87 liters/hr. / sq. ft. rad. surface
Observed evaporation rate for several types of unshielded traps	0.43 cu. in./hr. / sq. in. rad. surface = 1.0 liters/hr. / sq. ft. rad. surface
Calculated evaporation to cool stainless steel from 20 C. to -195.8 C.	5 cu. in. liq. Nitrogen / cu.in.stainless steel



Assumptions: 1. Focal length is long compared to path length through field (i.e. greater than ten times as large)

2. Field is effective over angle ϕ (about one-half gap distance should be allowed beyond the edge of the magnet for fringing field)

R = radius in magnetic field
ϕ = angle through which beam turns
θ = angle between edges of magnet
F = focal length $= \dfrac{1}{\dfrac{1}{a} + \dfrac{1}{b}}$

Horizontal focal length (in plane of paper) $= \dfrac{R}{\theta}$

Vertical focal length $= \dfrac{R}{\phi - \theta}$

Note that the two focal length are equal if $\phi = 2\theta$

For derivation see Engineering Note 3320-01 M-52

For focal length when path through magnet is not small compared to focal length see W. G. Cross RSI Vol. 22, No. 10, p. 717, October, 1951.

WMB:fg

RADIATION LABORATORY - UNIVERSITY OF CALIFORNIA - BERKELEY

DESIGN DATA

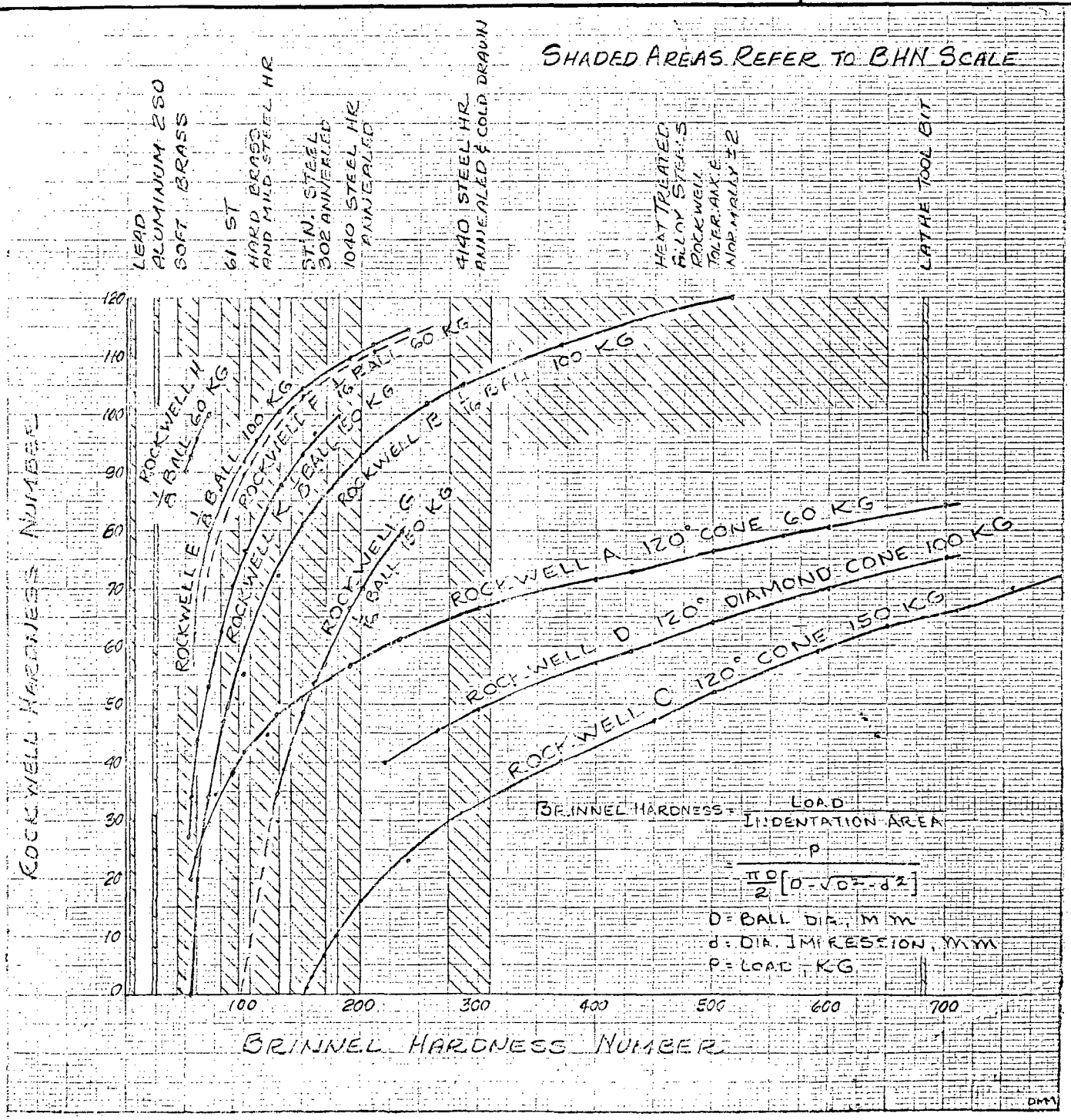
DATE	D.D. NO.	PAGE
10/3/52	61	1

SUBJECT

ROCKWELL HARDNESS SCALES COMPARED WITH BRINNEL HARDNESS NUMBERS AND WITH THE BRINNEL HARDNESS RANGES OF SOME COMMON METALS

PREPARED H. Paul Hernandez

CHECKED BY



This chart can be used to:

1. Select Rockwell scales for hardness testing.
2. Convert tolerance of a Rockwell hardness number to BHN tolerance.
3. Give the relationship of an unknown metal when given its hardness.
4. Reduce catalog and handbook data to a common reference so that they can be compared.

The metal Brinnel hardness ranges, as shown in the shaded areas, are approximate and are shown to indicate relative hardness.

These Rockwell scales are applicable where the metal thickness or the metal hard case depth is greater than ten times the depth of the ball indentation. Where the metal or hard case thickness is less than ten times the depth of ball indentation, use the Rockwell superficial scales which are not given here.

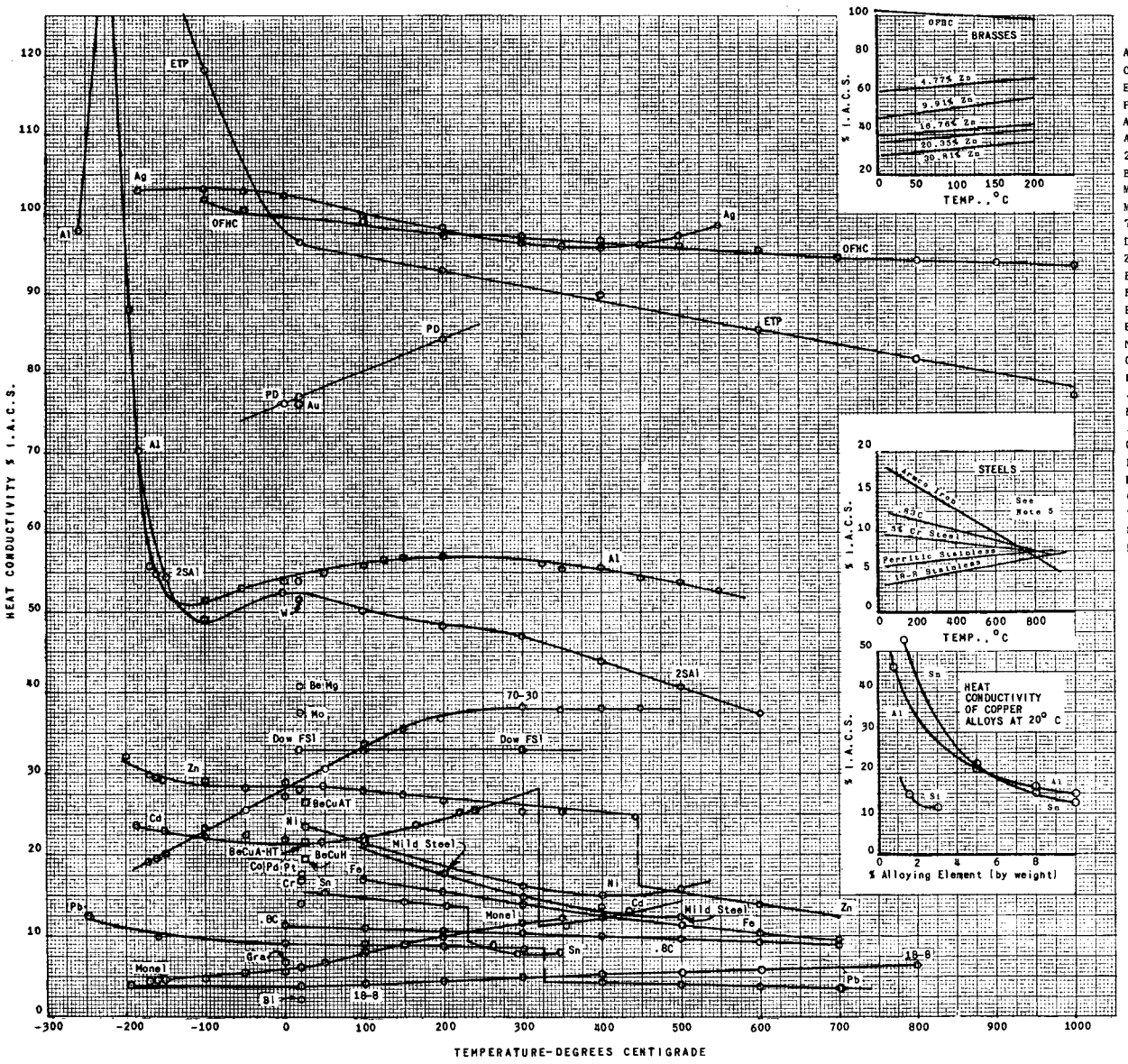
D-9(M)

Heat Conductivity of Metals and Alloys Found On The Accompanying Graph.

Ag. High Purity Silver
OPHC Oxygen Free High Conductivity Copper
ETP Electrolytic Tough Pitch Copper
Pd. Phosphorus Deoxidized Copper
Au. High Purity Gold
Al. High Purity Aluminum
2SAl. Alcoa 2S Aluminum
Be. Beryllium
Mg. Magnesium
Mo. Molybdenum
70-30 70-Copper, 30-Zinc Brass
Dow FSI 3-Al, IZn,0.3Mn, Magnesium Alloy
Zn. High Purity Zinc
Be. Cu.AT Beryllium Copper Solution Heat Treated & Aged
" " A " " Solution Heat Treated
" " HT " " Cold Worked, S.H.T. & Aged
" " H " " Cold Worked, S.H.T.
Ni. High Purity Nickel
Cd. High Purity Cadmium
Fe. Electrolytic Iron
8C Steel AISI 1080
Monel 67Ni, 30Cu, Fe,Mn,C,Si,S
I8-8 AISI 304 Stainless Steel
Co. Cobalt
Pd. Palledium
Pt. Platinum
Cr. Chromium
Ta. Tantalum
Sn. Tin
Pb. Lead
Graphite
Bi. Bismuth
W Tungsten

Note:
I. Almost all aluminum alloys (and states of work hardening and aging) have heat conductivities at 20C of 35 to 49% IACS
2. Most Lead alloys are from 7-12% IACS
3. Most Nickel alloys are from 3-7% IACS
4. Most Magnesium alloys 20-35% IACS

RL-610-a



LEGEND

Ag	High Purity Silver
OFHC	Oxygen Free High Conductivity Copper
ETP	Electrolytic Tough Pitch Copper
PD	Phosphorus Deoxidized Copper
Au	High Purity Gold
Al	High Purity Aluminum
2SAl	Alcoa 2S Aluminum
Be	Beryllium
Mg	Magnesium
Mo	Molybdenum
70-30	70 Copper 30 Zinc Brass
Dow FS1	3-Al,1Zn, 0.3Mn, Magnesium Alloy
Zn	High Purity Zinc
BeCuAT	Beryllium Copper, Solution Heat Treated & Aged
BeCuA	Beryllium Copper, Solution Heat Treated
BeCuHT	Beryllium Copper, Cold Worked, S.H.T. & Aged
BeCuH	Beryllium Copper, Cold Worked, S.H.T.
Ni	High Purity Nickel
Cd	High Purity Cadmium
Fe	Electrolytic Iron
.8C	AISI 1080 Steel
Monel	67Ni, 30Cu, & Fe, Mn, C, Si, S
18-8	AISI 304 Stainless Steel
Co	Cobalt
Pd	Palladium
Pt	Platinum
Cr	Chromium
Ta	Tantalum
Sn	Tin
Pb	Lead
Gra	Graphite
Bi	Bismuth
W	Tungsten

NOTES

1. Almost all Aluminum alloys (& states of work hardening & aging) have heat conductivities of 35 to 49% I.A.C.S. at 20°C.
2. Most Lead alloys are from 7-12% I.A.C.S.
3. Most Nickel alloys are from 3-7% I.A.C.S.
4. Most Magnesium alloys 20-35% I.A.C.S.
5. Most Iron-base alloys pass by 7.5% at 930°C.

*Expressed as Percentage of Copper (International Annealed Copper Standard) at 20°C.

$$1.A.C.S. = .93\% \frac{cal}{sec.\ cm^2 (^\circ C/cm)} = 9.94 \frac{Watts}{^\circ C\ in} = 3.91 \frac{Watts}{^\circ C\ cm}$$

Copy 11/15/57 K. Connelly

RADIATION LABORATORY · UNIVERSITY OF CALIFORNIA · BERKELEY

DESIGN DATA

SUBJECT: HEAT CONDUCTIVITY OF METALS AND ALLOYS*

DATE: 11/24/52

PREPARED: R. A. Nickerson

CHECKED BY:

D.D. NO. 63

PAGE 2 OF 2 PAGES

RADIATION LABORATORY - UNIVERSITY OF CALIFORNIA - BERKELEY

DESIGN DATA

DATE	D.D. NO.	PAGE
11/28/52	64A	1

SUBJECT: TAP DRILL DEPTHS

PREPARED D. Vorkoeper
W. M. Brobeck

~~CHECKED BY~~

Revision 2/18/54

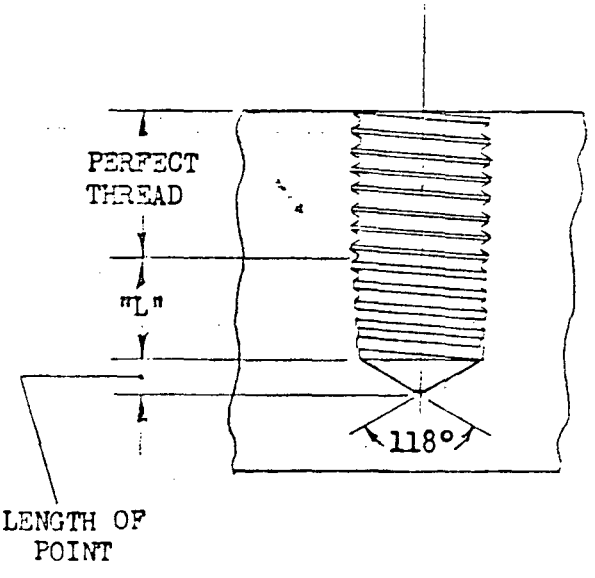
FOR AMERICAN STANDARD TAPER PIPE THREADS

Nominal Pipe Size	Threads Per Inch	Tap Drill Size	Normal Depth of Tap Drill	Minimum Depth of Tap Drill	Normal Thread Engagement for Tight Joints
1/8	27	11/32	1/2	5/16	1/4
1/4	18	7/16	3/4	7/16	3/8
3/8	18	19/32	3/4	7/16	3/8
1/2	14	23/32	15/16	9/16	1/2
3/4	14	15/16	15/16	5/8	9/16
1	11-1/2	1-5/32	1-1/4	3/4	11/16
1-1/4	11-1/2	1-1/2	1-1/4	3/4	11/16
1-1/2	11-1/2	1-23/32	1-1/4	3/4	11/16
2	11-1/2	2-3/16	1-1/4	13/16	3/4

Depths less than normal should be avoided as special taps are required.

FOR AMERICAN STANDARD SCREW THREADS

	TAP STYLE			
	Starting	Plug (Preferred)	Bottom *	
	No. of Incomplete Threads			
	7-9	2 1/2-5	1-1 1/2	
Screw Size	Additional Tap Drill Depth Required "L" or			Tap Drill Length of Point
6-32	5/16	5/32	1/16	.033
10-32	5/16	5/32	1/16	.048
1/4-20	1/2	1/4	1/8	.060
5/16-18	1/2	1/4	1/8	.082
3/8-16	5/8	5/16	1/8	.094
1/2-13	5/8	5/16	1/8	.127
5/8-11	1	1/2	1/4	.160
3/4-10	1	1/2	1/4	.197
1-8	1- 1/4	5/8	1/4	.262



Always drill through if possible.

Tap 1/2 deep means 1/2" of perfect threads.

*This number of incomplete threads can be reduced by grinding taps.

RADIATION LABORATORY - UNIVERSITY OF CALIFORNIA - BERKELEY

DESIGN DATA

DATE	D.D. NO.	PAGE
2/1/54	64.1A	1

SUBJECT

TAP DRILL DIAMETERS FOR AMERICAN STANDARD SCREW THREADS IN VARIOUS MATERIALS

PREPARED: L. Brown

CHECKED BY: LEB

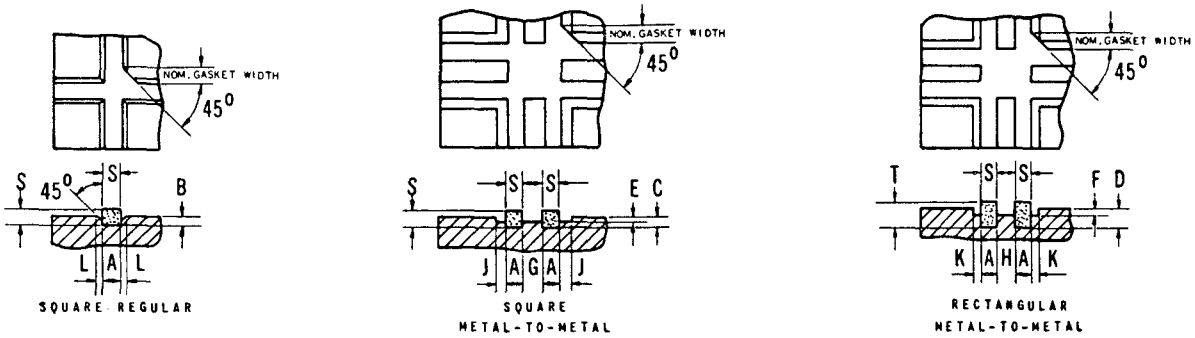
Screw Sizes \ Materials				Monel, High Speed Steel		Bronze, Carbon Cast Steel, Copper, Drop Forged Steel, Stainless Steel, Tool Steel		Aluminum Cast Brass Cast Iron Mild Steel		Babbitt, Dural, Fibre, Bakelite, Hard Rubber Sheet Brass Sheet Nickel White Metal	
Size of Screw	Threads Per Inch NC	Threads Per Inch NF	Basic Major Dia.	TAP DRILL FOR PERCENT OF FULL THREAD 50-60 Percent	Decim. Equiv.	60-70 Percent	Decim. Equiv.	70-75 Percent	Decim. Equiv.	75-80 Percent	Decim. Equiv.
0	—	80	.0600	55	.0520	3/64	.0469	3/64	.0469	56	.0465
1	64	—	.0730	1/16	.0625	53	.0595	53	.0595	54	.0550
1	—	72	.0730	52	.0635	1/16	.0625	53	.0595	53	.0595
2	56	—	.0860	49	.0730	50	.0700	51	.0670	51	.0670
2	—	64	.0860	48	.0760	49	.0730	50	.0700	50	.0700
3	48	—	.0990	45	.0820	46	.0810	47	.0786	47	.0785
3	—	56	.0990	44	.0860	45	.0820	45	.0820	46	.0810
4	40	—	.1120	42	.0935	43	.0890	43	.0890	44	.0860
4	—	48	.1120	40	.0980	42	.0935	42	.0935	43	.0890
5	40	—	.1250	36	.1065	37	.1040	38	.1015	39	.0995
5	—	44	.1250	35	.1100	36	.1065	37	.1040	38	.1015
6	32	—	.1380	32	.1160	34	.1110	35	.1100	36	.1065
6	—	40	.1380	31	.1200	32	.1160	33	.1130	33	.1130
8	32	—	.1640	28	.1405	29	.1360	29	.1360	30	.1285
8	—	36	.1640	27	.1440	28	.1405	29	.1360	29	.1360
10	24	—	.1900	21	.1590	23	.1540	25	.1495	26	.1470
10	—	32	.1900	18	.1695	19	.1660	20	.1610	21	.1590
12	24	—	.2160	13	.1850	15	.1800	16	.1770	17	.1730
12	—	28	.2160	12	.1890	13	.1850	14	.1820	15	.1800
1/4	20	—	.2500	3	.2130	5	.2055	7	.2010	8	.1990
1/4	—	28	.2500	2	.2210	7/32	.2188	7/32	.2188	3	.2130
5/16	18	—	.3125	I	.2720	H	.2660	G	.2610	F	.2570
5/16	—	24	.3125	K	.2810	J	.2770	I	.2720	I	.2720
3/8	16	—	.3750	21/64	.3281	P	.3230	O	.3160	5/16	.3125
3/8	—	24	.3750	11/32	.3437	R	.3390	Q	.3320	Q	.3320
7/16	14	—	.4375	W	.3860	3/8	.3750	U	.3680	23/64	.3594
7/16	—	20	.4375	Y	.4040	X	.3970	25/64	.3906	W	.3860
1/2	13	—	.5000	7/16	.4375	7/16	.4375	27/64	.4219	27/64	.4219
1/2	—	20	.5000	15/32	.4687	29/64	.4531	29/64	.4531	29/64	.4531
9/16	12	—	.5625	1/2	.5000	31/64	.4844	31/64	.4844	15/32	.4687
9/16	—	18	.5625	17/32	.5312	33/64	.5156	33/64	.5156	1/2	.5000
5/8	11	—	.6250	9/16	.5625	35/64	.5469	17/32	.5313	17/32	.5313
5/8	—	18	.6250	37/64	.5781	37/64	.5781	37/64	.5781	9/16	.5625
3/4	10	—	.7500	43/64	.6719	43/64	.6719	21/32	.6562	41/64	.6406
3/4	—	16	.7500	45/64	.7031	45/64	.7031	11/16	.6875	11/16	.6875
7/8	9	—	.8750	51/64	.7969	25/32	.7812	49/64	.7656	49/64	.7656
7/8	—	14	.8750	53/64	.8281	13/16	.8125	13/16	.8125	51/64	.7969
1	8	—	1.0000	29/32	.9062	57/64	.8906	7/8	.8750	7/8	.8750
1	—	12	1.0000	15/16	.9375	15/16	.9375	59/64	.9219	59/64	.9219

1. Tap drills for materials listed are given as a general guide but are not intended to apply in all cases.
2. For tap drill sizes to give 77% thread (National thd. shape) for any screw size subtract one divided by the pitch from the O.D., i.e. 2½-8N tap drill is (2½) - (1/8) = 2 3/8.
3. Drills never cut undersize.

RL-609

SUBJECT RECTANGULAR AND O-RING RUBBER GASKET GROOVES FOR STATIC VACUUM SEALS ONLY
(For Dynamic and Pressure Applications, See Parker Seal Co. Literature)

PREPARED F. REINATH
CHECKED F. BIERLEIN



Note: Unless otherwise shown, internal corners to be 1/64 radius max, and external corners to be broken.

Table I: Square & Rectangular Gaskets (Listed under "Packing" in LBL Stores Book)

Gasket Dimensions				Groove Dimensions										
	Nominal	Actual												
Sq.	Rectangular Width X Ht.	S	T	A	B	C	D	E	F	G*	H*	J*	K*	L**
	1/8 x 3/16▲	.145 .130	.208 .193	.125 .130			.155 .161		.075 .081		1/8		1/16	
3/16	3/16 x 9/32	.208 .193	.301 .286	.188 .193	.108 .113	.140 .146	.233 .239	.071 .077	.103 .109	1/4	3/16	1/8	3/32	3/64
1/4	1/4 x 3/8	.270 .255	.395 .380	.250 .255	.146 .151	.186 .193	.311 .318	.093 .100	.137 .144	5/16	1/4	5/32	1/8	1/16
3/8	3/8 x 9/16	.395 .380	.582 .567	.375 .380	.221 .226	.279 .287	.466 .474	.140 .148	.199 .207	3/8	5/16	3/16	5/32	3/32
1/2▲	1/2 x 3/4▲	.520 .505	.770 .755	.500 .505	.295 .305	.370 .380	.620 .630	.188 .198	.268 .278	1/2	3/8	1/4	3/16	1/8

▲These 3 Sizes Not In Regular Stock. ** Tolerance ±1/64 * Tolerance + 1/64 -0

CONSIDERATIONS IN THE CHOICE OF GASKETS

To be regarded only as general comments, not as hard and fast rules.

A. REGULAR VS. METAL-TO-METAL GASKETS. Regular (non-metal-to-metal) gasket grooves are cheaper to machine and the gaskets may be further compressed if found to be leaking. Metal-to-metal gaskets are used where alignment of parts is essential, where it is desirable to hide the gasket from the vacuum, or where electrical contact is required.

B. SQUARE VS. RECTANGULAR GASKETS. Rectangular metal-to-metal gaskets are easier to install and are better retained in the grooves than the square metal-to-metal gaskets. Square metal-to-metal gaskets are used only where required by space limitations.

C. O-RINGS VS. SQUARE OR RECTANGULAR GASKETS. Within the range of LRL stock sizes and where metal-to-metal gaskets are required, O-rings may be preferable, as the grooves are cheaper to machine than grooves for square or rectangular gaskets and no shop time is needed for making the gaskets. The dimensions shown in Table II (X dia.) provide a small interference between the side of the groove and the inside diameter of the O-ring to insure self-retention. NORMALLY A RECTANGULAR O-RING GROOVE IS SATISFACTORY; WHERE ADDITIONAL SELF-RETENTION IS DESIRABLE THE OPTIONAL UNDERCUT GROOVE CAN BE USED. O-rings may be used on rectangular cover plates, provided, of course, that the peripheral length is properly selected and that the inside corner at each intersection of the grooves is chamfered. The O-rings listed in Table II in bold-faced type are LRL stock sizes, but stock should be checked for a particular size before incorporating it in a design. O-rings made up by the vulcanizing of round stock by the shop should be avoided.

D. SINGLE VS. DOUBLE GASKETS. As opinions vary widely, the prospective operators of a new piece of equipment should be consulted regarding the use of single or double gaskets. Double gaskets with pumpouts are frequently used on large and medium sized cover plates, and, where access to gaskets is difficult, double gaskets are less likely to leak, and if leaks occur the space between the gaskets may be pumped out to minimize the leak. On the other hand, if the inner gasket leaks and there is no pumpout between the gaskets, or the pumpout is closed, the result is a slow leak. Double gaskets on, say, a cover plate on a tank permit vacuum testing of the gaskets, without vacuum in the tank, by pumping on the space between the gaskets. It is highly desirable, therefore, when double gaskets are used, to provide at least one pumpout and preferably more on large cover plates. Single gasket grooves, of course, are cheaper to machine and occupy less space.

NOTES

1. Cutters for machining grooves for square and rectangular gaskets to dimensions shown in Table I are on hand in the Machine Shop.
2. All gasket contact surfaces should be 63, or better, finish.
3. Rectangular gaskets 1/8 x 3/16 are to be used only where space will not permit a larger size. (1/8 sq. gaskets are no longer stocked.)
4. When placing a stretched O-ring in the groove, the ring should be given a twist between thumb and forefinger such that the ring will not roll out of the groove.
5. The square and rectangular gaskets are procured under LRL Standard Specification No. M9B. The hardness range of this HYCAR material is 55-65 durometer.
6. Depths of grooves for metal-to-metal contact allow about 34 ±4 percent compression of unrestricted portion of gasket for rectangular gaskets and about 42 ±3 percent for the square gaskets. Based on the area of the gasket face before clamping, this results in about 300 psi for the rectangular gasket and about 500 psi for the square gasket. Depths of O-ring grooves allow about 30 ±5 percent compression with a resulting pressure based on the projected area of about 350 psi.
7. The O-ring grooves are for external pressure only.

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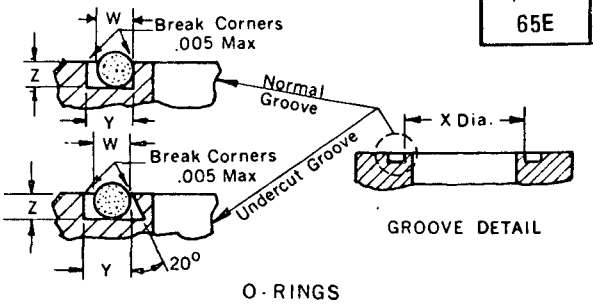

O-RINGS

LBL stock shown by dot in margin. For stock no's & other additional information see laboratory Engineering Standard Reference no's 396-398

TABLE II: O-RINGS

STANDARD SERIES

AN NO.	Actual Size ID	±	W	±	Nom. Size ID	OD	W	Groove Dimensions XDia.	±	Y	±	Z	±
● AN6227B-1	.114	.005	.070	.003	1/8	1/4	1/16	.128	.004	.113	+.015 −.000	.048	+.004 −.000
AN6227B-2	.145				5/32	9/32	1/16	.159					
● AN6227B-3	.176				3/16	3/16	1/16	.191					
AN6227B-4	.208				7/32	11/32	1/16	.223					
● AN6227B-5	.239				1/4	3/8	1/16	.254					
● AN6227B-6	.301	.005	.070	.003	5/16	7/16	1/16	.317	.004	.113	+.015 −.000	.048	+.004 −.000
● AN6227B-7	.364		.070		3/8	1/2	1/16	.380		.113		.048	
● AN6227B-8	.362		.103		3/8	9/16	3/32	.378	±.010	.151		.069	+.006 −.000
● AN6227B-9	.424				7/16	5/8	3/32	.447	.010				
● AN6227B-10	.487				1/2	11/16	3/32	.510	.010				
● AN6227B-11	.549	.005	.103	.003	9/16	3/4	3/32	.573	.010	.151	+.015 −.000	.069	+.006 −.000
● AN6227B-12	.612				5/8	13/16	3/32	.637					
● AN6227B-13	.674				11/16	7/8	3/32	.699					
● AN6227B-14	.737				3/4	15/16	3/32	.763					+.009 −.000
● AN6227B-15	.734	.006	.139	.004	3/4	1	1/8	.761		.205		.093	
AN6227B-16	.796	.006	.139	.004	13/16	1 1/16	1/8	.824	.010	.205	+.015 −.000	.093	+.009 −.000
● AN6227B-17	.859				7/8	1 1/8	1/8	.887					
AN6227B-18	.921				15/16	1 3/16	1/8	.950					
● AN6227B-19	.984				1	1 1/4	1/8	1.013					
AN6227B-20	1.046				1 1/16	1 5/16	1/8	1.076					
● AN6227B-21	1.109	.006	.139	.004	1 1/8	1 3/8	1/8	1.140	.010	.205	+.015 −.000	.093	+.009 −.000
AN6227B-22	1.171				1 3/16	1 3/16	1/8	1.202					
● AN6227B-23	1.234				1 1/4	1 1/2	1/8	1.266					
AN6227B-24	1.296				1 5/16	1 9/16	1/8	1.329					
● AN6227B-25	1.359				1 3/8	1 5/8	1/8	1.392					
AN6227B-26	1.421	.006	.139	.004	1 7/16	1 11/16	1/8	1.455	.010	.205	+.015 −.000	.093	+.009 −.000
● AN6227B-27	1.484	.006	.139	.004	1 1/2	1 3/4	1/8	1.518		.205		.093	
AN6227B-28	1.475	.010	.210	.005	1 1/2	1 7/8	3/16	1.513		.297		.144	+.010 −.000
● AN6227B-29	1.600				1 5/8	2	3/16	1.639					
AN6227B-30	1.725				1 3/4	2 1/8	3/16	1.765					
● AN6227B-31	1.850	.010	.210	.005	1 7/8	2 1/4	3/16	1.892	.010	.297	+.015 −.000	.144	+.010 −.000
AN6227B-32	1.975				2	2 3/8	3/16	2.018					
● AN6227B-33	2.100				2 1/8	2 1/2	3/16	2.144					
● AN6227B-34	2.225				2 1/4	2 5/8	3/16	2.270					
● AN6227B-35	2.350				2 3/8	2 3/4	3/16	2.397					
AN6227B-36	2.475	.010	.210	.005	2 1/2	2 7/8	3/16	2.523	.010	.297	+.015 −.000	.144	+.010 −.000
● AN6227B-37	2.600	.010			2 5/8	3	3/16	2.649					
AN6227B-38	2.725	.015			2 3/4	3 1/8	3/16	2.780					
● AN6227B-39	2.850				2 7/8	3 1/4	3/16	2.906					
AN6227B-40	2.975				3	3 3/8	3/16	3.032					
● AN6227B-41	3.100	.015	.210	.005	3 1/8	3 1/2	3/16	3.159	.010	.297	+.015 −.000	.144	+.010 −.000
AN6227B-42	3.225				3 1/4	3 5/8	3/16	3.285					
● AN6227B-43	3.350				3 3/8	3 3/4	3/16	3.411					
AN6227B-44	3.475				3 1/2	3 7/8	3/16	3.537					
● AN6227B-45	3.600				3 5/8	4	3/16	3.664					
AN6227B-46	3.725	.015	.210	.005	3 3/4	4 1/8	3/16	3.790	.010	.297	+.015 −.000	.144	+.010 −.000
● AN6227B-47	3.850				3 7/8	4 1/4	3/16	3.916					
AN6227B-48	3.975				4	4 3/8	3/16	4.042					
● AN6227B-49	4.100				4 1/8	4 1/2	3/16	4.168					
AN6227B-50	4.225				4 1/4	4 5/8	3/16	4.295					
AN6227B-51	4.350	.015	.210	.005	4 3/8	4 3/4	3/16	4.421	.010	.297	+.015 −.000	.144	+.010 −.000
● AN6227B-52	4.475		.210	.005	4 1/2	4 7/8	3/16	4.547		.297		.144	
AN6227B-88	4.475		.275	.006	4 1/2	5	1/4	4.547		.385		.191	+.012 −.000
AN6227B-53	4.600				4 5/8	5 1/8	1/4	4.673					
AN6227B-54	4.725				4 3/4	5 1/4	1/4	4.800					
AN6227B-55	4.850				4 7/8	5 3/8	1/4	4.926					
● AN6227B-56	4.975	.015	.275	.006	5	5 1/2	1/4	5.052	.010	.385	+.015 −.000	.191	+.012 −.000
● AN6227B-57	5.100	.023			5 1/8	5 5/8	1/4	5.186					
AN6227B-58	5.225				5 1/4	5 3/4	1/4	5.312					
AN6227B-59	5.350				5 3/8	5 7/8	1/4	5.439					
● AN6227B-60	5.475				5 1/2	6	1/4	5.565					

STANDARD SERIES Con't.

AN NO.	Actual Size ID	±	W	±	Nom. Size ID	OD	W	Groove Dimensions XDia.	±	Y	±	Z	±
AN6227B-61	5.600	.023	.275	.006	5 5/8	6 1/8	1/4	5.691	.010	.385	+.015 −.000	.191	+.012 −.000
AN6227B-62	5.725				5 3/4	6 1/4	1/4	5.817					
AN6227B-63	5.850				5 7/8	6 3/8	1/4	5.944					
● AN6227B-64	5.975				6	6 1/2	1/4	6.070					
● AN6227B-65	6.225				6 1/4	6 3/4	1/4	6.322					
● AN6227B-66	6.475	.023	.275	.006	6 1/2	7	1/4	6.575	.010	.385	+.015 −.000	.191	+.012 −.000
AN6227B-67	6.725				6 3/4	7 1/4	1/4	6.827					
● AN6227B-68	6.975				7	7 1/2	1/4	7.080					
AN6227B-69	7.225	.030			7 1/4	7 3/4	1/4	7.332					
● AN6227B-70	7.475	.030			7 1/2	8	1/4	7.591					
AN6227B-71	7.725	.030	.275	.006	7 3/4	8 1/4	1/4	7.843	.010	.385	+.015 −.000	.191	+.012 −.000
● AN6227B-72	7.975				8	8 1/2	1/4	8.096					
AN6227B-73	8.475				8 1/2	9	1/4	8.501					
● AN6227B-74	8.975				9	9 1/2	1/4	9.106					
AN6227B-75	9.475				9 1/2	10	1/4	9.611					
● AN6227B-76	9.975	.030	.275	.006	10	10 1/2	1/4	10.116	.010	.385	+.015 −.000	.191	+.012 −.000
AN6227B-77	10.475				10 1/2	11	1/4	10.620					
● AN6227B-78	10.975				11	11 1/2	1/4	11.125					
AN6227B-79	11.475				11 1/2	12	1/4	11.630					
● AN6227B-80	11.975				12	12 1/2	1/4	12.135					
AN6227B-81	12.475	.030	.275	.006	12 1/2	13	1/4	12.640	.010	.385	+.015 −.000	.191	+.012 −.000
● AN6227B-82	12.975				13	13 1/2	1/4	13.145					
AN6227B-83	13.475				13 1/2	14	1/4	13.650					
● AN6227B-84	13.975				14	14 1/2	1/4	14.155					
AN6227B-85	14.475				14 1/2	15	1/4	14.660					
● AN6227B-86	14.975	.030	.275	.006	15	15 1/2	1/4	15.165	.010	.385	+.015 −.000	.191	+.012 −.000
AN6227B-87	15.475				15 1/2	16	1/4	15.670	.010	.385		.191	

LIGHT SERIES

AN NO.	Actual Size ID	±	W	±	Nom. Size ID	OD	W	Groove Dimensions XDia.	±	Y	±	Z	±
AN6230B-1	1.609	.010	.139	.004	1 5/8	1 7/8	1/8	1.647	.010	.205	+.015 −.000	.093	+.009 −.000
● AN6230B-2	1.734				1 3/4	2	1/8	1.772					
AN6230B-3	1.859				1 7/8	2 1/8	1/8	1.898					
● AN6230B-4	1.984				2	2 1/4	1/8	2.023					
AN6230B-5	2.109				2 1/8	2 3/8	1/8	2.148					
● AN6230B-6	2.234	.010	.139	.004	2 1/4	2 1/2	1/8	2.274	.010	.205	+.015 −.000	.093	+.009 −.000
AN6230B-7	2.359				2 3/8	2 5/8	1/8	2.399					
● AN6230B-8	2.484				2 1/2	2 3/4	1/8	2.524					
AN6230B-9	2.609				2 5/8	2 7/8	1/8	2.650					
● AN6230B-10	2.734	±.015			2 3/4	3	1/8	2.780					
AN6230B-11	2.859	.015	.139	.004	2 7/8	3 1/8	1/8	2.905	.010	.205	+.015 −.000	.093	+.009 −.000
● AN6230B-12	2.984				3	3 1/4	1/8	3.030					
AN6230B-13	3.109				3 1/8	3 3/8	1/8	3.156					
● AN6230B-14	3.234				3 1/4	3 1/2	1/8	3.281					
AN6230B-15	3.359				3 3/8	3 5/8	1/8	3.406					
● AN6230B-16	3.484	.015	.139	.004	3 1/2	3 3/4	1/8	3.532	.010	.205	+.015 −.000	.093	+.009 −.000
AN6230B-17	3.609				3 5/8	3 7/8	1/8	3.657					
● AN6230B-18	3.734				3 3/4	4	1/8	3.782					
AN6230B-19	3.859				3 7/8	4 1/8	1/8	3.908					
● AN6230B-20	3.984				4	4 1/4	1/8	4.033					
AN6230B-21	4.109	.015	.139	.004	4 1/8	4 3/8	1/8	4.158	.010	.205	+.015 −.000	.093	+.009 −.000
● AN6230B-22	4.234				4 1/4	4 1/2	1/8	4.284					
AN6230B-23	4.359				4 3/8	4 5/8	1/8	4.409					
● AN6230B-24	4.484				4 1/2	4 3/4	1/8	4.534					
AN6230B-25	4.609				4 5/8	4 7/8	1/8	4.660					
● AN6230B-26	4.734	.015	.139	.004	4 3/4	5	1/8	4.785	.010	.205	+.015 −.000	.093	+.009 −.000
AN6230B-27	4.859				4 7/8	5 1/8	1/8	4.910					
● AN6230B-28	4.984				5	5 1/4	1/8	5.036					
AN6230B-29	5.109	.023			5 1/8	5 3/8	1/8	5.169					
● AN6230B-30	5.234	.023			5 1/4	5 1/2	1/8	5.294					
AN6230B-31	5.359	.023	.139	.004	5 3/8	5 5/8	1/8	5.419	.010	.205	+.015 −.000	.093	+.009 −.000
● AN6230B-32	5.484				5 1/2	5 3/4	1/8	5.545					
AN6230B-33	5.609				5 5/8	5 7/8	1/8	5.670					
● AN6230B-34	5.734				5 3/4	6	1/8	5.796					
AN6230B-35	5.859				5 7/8	6 1/8	1/8	5.921					
● AN6230B-36	5.984	.023	.139	.004	6	6 1/4	1/8	6.046	.010	.205	+.015 −.000	.093	+.009 −.000
AN6230B-37	6.234				6 1/4	6 1/2	1/8	6.297					
● AN6230B-38	6.484				6 1/2	6 3/4	1/8	6.548					
AN6230B-39	6.734				6 3/4	7	1/8	6.798					
● AN6230B-40	6.984				7	7 1/4	1/8	7.049					
AN6230B-41	7.234	.030	.139	.004	7 1/4	7 1/2	1/8	7.307	.010	.205	+.015 −.000	.093	-.000 −.000
● AN6230B-42	7.484				7 1/2	7 3/4	1/8	7.557					
AN6230B-43	7.734				7 3/4	8	1/8	7.808					
● AN6230B-44	7.984				8	8 1/4	1/8	8.059					
AN6230B-45	8.234				8 1/4	8 1/2	1/8	8.309					
● AN6230B-46	8.484	.030	.139	.004	8 1/2	8 3/4	1/8	8.560	.010	.205	+.015 −.000	.093	+.009 −.000
AN6230B-47	8.734				8 3/4	9	1/8	8.811					
● AN6230B-48	8.984				9	9 1/4	1/8	9.062					
AN6230B-49	9.234				9 1/4	9 1/2	1/8	9.312					
● AN6230B-50	9.484				9 1/2	9 3/4	1/8	9.563					
AN6230B-51	9.734	.030	.139	.004	9 3/4	10	1/4	9.814	.010	.205	+.015 −.000	.093	+.009 −.000
● AN6230B-52	9.984	.030	.139	.004	10	10 1/4	1/4	10.064	.010	.205		.093	

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For resistivities of hard solders, see Design Data 25 and 25.1

Notes (numbers refer to sub-script numbers in table)

(1) This is the value ordinarily taken from the reference. Where the information given in the reference was different the resistivity at 20° C. (68°F.) has been calculated and is shown in parentheses.

(2) The Resistivity ρ is the specific resistance and in c g s units

$$\rho = \frac{R\,A}{\ell} = \frac{\text{ohm x cm}^2}{\text{cm}} = \text{ohm - cm} \qquad \text{(Ref. 3)}$$

or, multipled by 10^{-6}, microhm-cm.
The tabulated values for microhm-inches were obtained by dividing the values in microhm-cm by 2.54 with slide-rule accuracy.

(3) The value for 100 percent conductivity at 20° C. for the International Annealed Copper Standard is 0.5800 microhm^{-1} cm^{-1} (Ref. 10)
The values in this column = 1.724/R where R is in microhm-cm.

Also called "volume conductivity" referred to standard copper.

(4) The resistance R at a temperature, t° C., can be calculated from the relationship--

$$R = R_o \left[1 + \alpha t\right]$$

where R_o = resist. at 0° C.
t = ° C.
α = temp. Coef.

(Ref. 4)

It should be noted that the tabulated value of α is strictly valid only for the temperature(s) specified.

(5) at 0° C.

(6) at 19.6° C.

(7) at 18° C.

(8) at 50° C.

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D-1(M)

Material	Resistivity at 20° C. Microhm-cm (1)	Resistivity at 20° C. Microhm-in (2)	Conductance Per-cent IACS (3)	Temp. Coeff. of Elect. Resist. per °C. (4) α	Temp. Coeff. of Elect. Resist. per °C. (4) Temp. C	Reference
ELEMENTS						
Aluminum(99.996 Al)	2.655	1.05	64.94	.00429	20	1
Antimony(fully annealed)	(39.8)	15.7	4.3	.00515	0 to 100	2
Arsenic	(37.9)	14.9	4.6	.0042	20	5
Barium	9.8	3.9	18	.0033	20	5
Beryllium	(6.66)	2.6	26	.00667	20	2
Bismuth	(120)	47	1.4	.004	20	5
Cadmium(99.9 fully annealed)	(7.42)	2.9	23	.0043	0 to 100	2
Calcium	(3.74)	1.5	46	.00457		2
Carbon(graphite)	1375(5)	542(5)	0.1(5)			2
Cerium	78	31	2.2			5
Cesium	(20.8)	8.2	8.3	.00478	-80 - +25	5
Chromium(electro-chromium)	14.1	5.6	12.2			2
Cobalt (99.91)	(6.22)	2.5	28	.00551	0 to 100	2
Copper ("pure")	1.6730	.66	103			1
Gallium	53.4(5)	21(5)	3.2(5)			1
Gold	(2.35)	.93	73	.00365	-80 - 1000	2
Indium	(9.03)	3.6	19	.00394		2
Iridium	5.3	2.1	33	.00392	0 to 100	2
Iron	9.71	3.8	18			2
Lead	20.65	8.1	8.3			2
Magnesium	4.46	1.8	39	.0040	20	5
Mercury	95.783	38	18	.00089	20	5
Molybdenum	5.7	2.2	30	.0050	0 to 140	2
Nickel	6.84	2.7	25			2
Osmium	9.5	3.7	18	.0042	0 to 100	2
Palladium (annealed)	10.8	4.3	16	.00377	0 to 100	2
Platinum	(10.58)	4.2	16	.00392	0 to 100	2
Rhodium	(4.7)	1.9	37	.00457	0 to 100	2
Rubidium	12.5	4.9	14			2
Silicon	85×10^3	33×10^3	—			2
Silver(extremeley pure, melted and annealed in Vacuo)	1.59	.63	108	.0041	0 to 100	1
Sodium	(4.8)	1.9	36	.0054	20	5
Strontium	22.76	8.9	7.6			2
Sulphur(rhombic)	2×10^{23}	7.9×10^{22}	—			2
Tantalum	(13.52)	5.3	13	.00382	0 to 100	2
Tellurium	2×10^5(6)	7.9×10^4	—			1

SUBJECT: Approximate Electrical Resistivities of Metals and Alloys

DESIGN DATA — PROPERTIES OF MATERIALS

PREPARED: L. Polentz — DATE: 2-17-53

CHECKED BY: — PAGE: 66 OF 14 PAGES

Material	Resistivity at 20° C. Microhm-cm (1)	Resistivity at 20° C. Microhm-in (2)	Conductance Per-cent IACS (3)	Temp. Coeff. of Elect. Resist. (4) per °C. α	Temp. Coeff. of Elect. Resist. (4) per °C. Temp. C.	Reference
ELEMENTS						
Tin	11.5	4.5	15	.0042	20	5
Titanium	(88)	35	2.0	.00469		2
Tungsten	5.5	2.2	31	.00510	0 to 170	2
Uranium	60 (7)	24 (7)	2.9			1
Vanadium	26	10	6.6			1
Zinc (Polycrystalline)	5.916	2.3	29			1
Zirconium	(44.6)	18	3.9	.00438		2
MISCELLANEOUS METALS						
Advance (See Constantan)						
Alumel	33.3	13	5.2			10
Brass	4-7	2-3	29			10
Bronze	13-18	5-7	11			10
Cast Iron	57-114	22-45	3-1.5			10
Chromel	70-110	28-43	2.5-1.6			10
Constantan	47-51	18-20	3.5			10
Ferrite	9.5	3.7	18			10
Hadfield Manganese Steel	29-67	11-26	6-2.6			10
Invar	75	30	2.3			10
Monel	42.5-45	17-18	3.9			10
Wood's Metal	51.7	20	3.3			10
ALUMINUM ALLOYS						
(99.996 Al)	2.6548	1.04	65	.00429	20	1
2S (99.0 + Al) condition 0	2.922	1.15	59	.0115	10 to 30	1
2S condition H-18	3.025	1.19	57			1
3S condition 0	3.448	1.36	50			1
condition H-12	4.105	1.61	-42			1
condition H-14	4.205	1.65	-41			1
condition H-18	4.310	1.70	40			1
11S condition T-3	4.310	1.70	40			1
14S condition 0	3.448	1.36	50			1
condition T-6	4.310	1.70	40			1
17S condition 0	3.831	1.51	45			1
condition T-4	5.747	2.26	30			1

Material		Resistivity at 20° C. Microhm-cm (1)	Resistivity at 20° C. Microhm-in (2)	Conductance Percent IACS (3)	Temp. Coeff. of Elect. Resist. per °C. (4) α	Temp. Coeff. of Elect. Resist. per °C. (4) Temp. C.	Reference
ALUMINUM ALLOYS							
18S	condition 0	3.448	1.36	50			1
	condition T-61	4.310	1.70	40			1
24S	condition 0	3.448	1.36	50			1
	condition T-4	5.747	2.26	30			1
25S	condition T-6	4.310	1.70	40			1
32S	condition 0	4.310	1.70	40			1
	condition T-6	4.926	1.94	35			1
A-51-S	condition 0	3.135	1.23	55			1
	condition T-4	3.831	1.51	45			1
	condition T-6	3.831	1.51	45			1
52S	condition 0	4.926	1.94	35			1
	condition H-38	4.926	1.94	35			1
53S	condition 0	3.831	1.51	45			1
	condition T-4	4.310	1.70	40			1
	condition T-6	4.310	1.70	40			1
56S	condition 0	5.945	2.34	29			1
	condition H-38	6.386	2.52	27			1
61S	condition 0	3.831	1.51	45			1
	condition T-4	4.310	1.70	40			1
	condition T-6	4.310	1.70	40			1
75S	condition T-6	5.747	2.26	30			1
13 Alloy DC		4.421	1.74	39			1
43 Alloy SC,PM.DC,	(As Cast)	4.660	1.84	37			1
SC,PM	(Annealed)	4.105	1.61	42			1
85 Alloy DC		6.158	2.43	28			1
108 Alloy SC		5.562	2.19	31			1
Allcast SC, PM	(As Cast)	(6.39)	2.52	27			1
	(Stress Relieved)	(5.75)	2.26	30			1
Sol'n heat treated and aged		(5.75	2.26	30			1
Sol'n heat treated and stress relieved		(4.79)	1.89	36			1
A-108 Alloy PM		4.660	1.84	37			1
113 Alloy SC		5.747	2.26	30			1
C-113 Alloy PM		6.386	2.52	27			1
122 Alloy SC	condition T-2	4.205	1.66	41			1
SC	condition T-61	5.225	2.06	33			1
PM	(As Cast)	5.071	2.00	34			1

D-1(M)

Material	Resistivity at 20° C. Microhm-cm (1)	Resistivity at 20° C. Microhm-in (2)	Conductance Percent IACS (3)	Temp. Coeff. of Elect. Resist. per °C. (4) α	Temp. Coeff. of Elect. Resist. per °C. (4) Temp. C.	Reference
ALUMINUM ALLOYS						
A-132 Alloy condition T-551	5.945	2.34	29			1
142 Alloy SC condition T-21	3.918	1.54	44			1
SC condition T-571	5.071	2.00	34			1
SC condition T-77	4.660	1.84	37			1
PM condition T-61	5.388	2.12	32			1
195 Alloy SC condition T-4	4.926	1.94	35			1
SC condition T-62	4.660	1.84	37			1
B-195 Alloy PM condition T-4	4.926	1.94	35			1
PM condition T-6	4.789	1.89	36			1
214 Alloy SC	4.926	1.94	35			1
A-214 Alloy PM	5.225	2.06	33			1
218 Alloy DC	7.184	2.83	24			1
220 Alloy SC condition T-4	8.210	3.24	21			1
319 Alloy SC	6.386	2.52	27			1
PM	6.158	2.42	28			1
355 Alloy SC condition T-51	4.010	1.58	43			1
SC condition T-6	4.789	1.89	36			1
SC condition T-61	4.660	1.84	37			1
SC condition T-7	4.105	1.61	42			1
PM condition T-6	4.421	1.74	39			1
365 Alloy SC condition T-51	4.010	1.58	43			1
SC condition T-6	4.421	1.74	39			1
SC condition T-7	4.310	1.70	40			1
PM condition T-6	4.205	1.66	41			1
Red X-8 SC,PM (As cast)	(6.53)	2.57	26			1
(Stress Relieved)	(5.95)	2.34	29			1
360 Alloy DC	4.660	1.84	37			1
380 Alloy, 4-9 Alloy DC	6.386	2.52	27			1
750 Alloy PM	3.831	1.51	45			1
40 E Alloy SC	4.926	1.94	35			1
SC - Sand Cast	PM - Permanent Mold		DC - Die Cast			
COPPER ALLOYS						
"Pure" Copper (spectographically pure)	1.6730	.66	103.06	.0068	20	1

RADIATION LABORATORY - UNIVERSITY OF CALIFORNIA - BERKELEY

DESIGN DATA

SUBJECT: PROPERTIES OF MATERIALS
Approximate Electrical Resistivities of Metals and Alloys

PREPARED: L. Polentz

CHECKED BY:

DATE: 2-17-53

D.D. NO. 66

Material	Resistivity at 20° C. Microhm-cm (1)	Resistivity at 20° C. Microhm-in (2)	Conductance Percent IACS (3)	Temp. Coeff. of Elect. Resist. (4) per °C. α	Temp. Coeff. of Elect. Resist. (4) per °C. Temp. C.	Reference
COPPER ALLOYS						
OFHC(Oxygen-Free Hard Copper) Copper (Annealed)	(1.70)	(.67-)	101.7			15
Electrolytic Tough Pitch Copper (99.92 Cu - 0.04 O)	1.71	.67	101	.00392	20	1
Deoxidized Copper(99.94 Cu - 0.02 P) Annealed	2.03	.80	85			1
Gilding Metal(95 Cu - 5 Zn) Annealed	3.1	1.2	56	.00231	20	1
Commercial Bronze(90 Cu - 10 Zn) Annealed	3.9	1.5	44	.00186	20	1
Red Brass(85 Cu - 15 Zn)annealed	4.7	1.9	37	.0016	20	1
Low Brass annealed	5.4	2.1	32	.00154	20	1
Cartridge Brass annealed	6.2	2.4	28	.001484	20	1
Yellow Brass annealed	6.4	2.5	27			1
Muntz Metal annealed	6.2	2.4	28			1
Leaded Commercial Bronze annealed	4.1	1.6	42			1
Low Leaded Brass annealed	6.6	2.6	26			1
Low Leaded Brass Tube(annealed)	6.6	2.6	26			1
Medium Leaded Brass(annealed)	6.6	2.6	26			1
High Leaded Brass (annealed)	6.6	2.6	26			1
Extra-high Leaded Brass(annealed)	6.6	2.6	26			1
Free Cutting Brass(annealed)	6.6	2.6	26			1
Leaded Muntz Metal (annealed)	6.2	2.4	28			1
Free Cutting Muntz Metal(annealed)	6.4	2.5	27			1
Forging Brass (annealed)	6.4	2.5	27			1
Architectural Bronze(annealed)	6.2	2.4	28			1
Admiralty Metal (annealed	(7.0)	2.8	24.65			1
Naval Brass (annealed)	(6.8)	2.7	26			1
Leaded Naval Brass (annealed)	(6.6)	2.6	26			1
Manganese Bronze (annealed)	(7.1)	2.8	24			1
Aluminum Brass (annealed)	(7.5)	3.0	23			1
Phosphor Bronze 5 percent Grade A	9.6	3.8	18			1
Phosphor Bronze 8 percent Grade C	13	5.1	13			1
Phosphor Bronze 10 percent Grade D	16	6.3	11			1
Phosphor Bronze 1.25 percent Grade E	3.6	1.4	48			1

D-1(M)

Material	Resistivity at 20° C. Microhm-cm (1)	Resistivity at 20° C. Microhm-in (2)	Conductance Percent IACS (3)	Temp. Coeff. of Elect. Resist. per °C. (4) α	Temp. Coeff. of Elect. Resist. per °C. (4) Temp. C	Reference
COPPER ALLOYS						
Cupro-Nickel, 30 percent	37	14.6	4.6			1
Nickel Silver 18 percent Alloy A	29	11.4	6			1
Nickel Silver 18 percent Alloy B	31	12.2	5.5			1
Silicon Bronze, Type A Annealed	(25)	9.8	7			1
Silicon Bronze, Type B Annealed	(14)	5.5	12			1
5 Percent Aluminum Bronze Annealed	9.8	3.9	17.5			1
10 Percent Aluminum Bronze Annealed	13.67	5.4	12.6			1
Beryllium Copper Sol'n treated, quenched	10	3.9	17			1
Beryllium Copper Sol'n treated, quenched and precip. hard.	6.8-9.8	2.7-3.9	21			1
Leaded Tin Bronze	(12)	4.8	14			1
Leaded Tin Bearing Bronze	(16)	6.2	11			1
Leaded Semi-red Brass	(9.6)	3.8	18			1
Leaded Yellow Brass	(6.6-9.6)	2.6-3.8	18-26			1
High Strength Yellow Brass	(9.6-14)	3.8-5.7	12-18			1
Nickel Silver	(34-43)	14-17	4-5			1
Aluminum Bronze	(12)	4.8	14			1
*Hitenso BB-961 (99.00 Cu 1.00 Cd)	1.98	0.78	87.0			Anaconda
*Hitenso C-965 (98.60 Cu 0.60 Sn, 0.80 Cd.)	2.88	1.13	60.0			Publication B-28
LEAD ALLOYS						
Corroding lead (99.73 percent + Pb.)	20.648	8.1	8.3	.00336	20 to 40	1
1 Percent Antimonial Lead, heat treated, quenched, and aged 150 days.	22.0	8.7	7.88			1
Hard Lead, Heat treated, quenched and aged 150 days	24.0	9.5	7.2			1
3 Percent Antimonial Lead, heat treated, quenched, and aged 150 days	26.5	10.4	6.5			1
50-50 Soft solder	15.6	6.1	11			1
Lead base babbits	28.2-28.7	11.1-11.3	6-6.1			1

* These are cadmium bronzes with good machinability and high conductivity. Conductivity values are for soft annealed metal.

* Revised 5/14/53

RADIATION LABORATORY - UNIVERSITY OF CALIFORNIA - BERKELEY

DESIGN DATA

SUBJECT: PROPERTIES OF MATERIALS
Approximate Electrical Resistivities of Metals and Alloys

PREPARED: L. Polentz

CHECKED BY:

DATE: 2-17-53*

D.D. NO. 66

Material	Resistivity at 20° C. Microhm-cm (1)	Microhm-in (2)	Conductance Percent IACS (3)	Temp. Coeff. of Elect. Resist. per °C. (4) α	Temp. C	Reference
MAGNESIUM ALLOYS						
(99.80 Mg)(polycrystalline)	4.46	1.76	38.6	.01784	20	1
Mazlo AM-C59S Wrought	18.0	7.1	9.7			1
Mazlo AM-265, Dowmetal H(As Cast)	11.5	4.5	15.0			1
Heat treated	14.0	5.5	12.3			1
Heat treated and aged	12.5	4.9	13.8			1
Mazlo AM-260, Dowmetal C	14-16.5	5.5-6.5	10.5-12.3			1
Mazlo AM-263, Dowmetal R	17.0	6.7	10.1			1
Dowmetal M, Mazlo AM-403, AM-3S	5.0-6.7	2.0-2.6	25.7-34.5			1
Mazlo AM-C52S, Dowmetal FS-1	9.3	3.7	18.5			1
Dowmetal JS-1	13.5	5.3	12.8			1
Mazlo AM-C57S, Dowmetal J-1	14.9	5.9	11.6			1
Dowmetal O-1, Mazlo AM-C58S	11.8-16.2	4.6-6.4	10.6-14.6			1
Mazlo AM-65S, Dowmetal D	13.8	5.4	12.5			1
NICKEL ALLOYS						
"Pure" nickel(99.95 Ni + Co)	6.84	2.7	25.2	.0069	0 to 100	1
"A" Nickel(99.4 Ni + Co)	9.5	3.7	18	.00474	20 to 100	1
"D" Nickel (95 Ni - 4.5 Mn)	14	5.5	12			1
"Z" Nickel (94 Ni - 4.5 Al)	43.3	17.0	4.0			1
Cast Nickel	21	8.3	8.2			1
Monel	48.2	19.0	3.6	.0011	20 to 100	1
Cast Monel	53.3	21.0	3.2			1
"K" Monel	58.3	22.9	3.0	.00018	20 to 100	1
"S" Monel	63.3	24.9	2.7			1
Hastelloy A	126.7	49.8	1.4	Zero	20 to 800	1
Hastelloy B	135	53	1.3			1
Hastelloy C	133	52	1.3	Zero	20 to 800	1
Hastelloy D	113	44	1.5	Almost 0	20 to 800	1
Inconel	98.1	38.6	1.8	.000125	20 to 500	1
Inconel X	124 (8)	49	1.4			13
Incalloy	(97)	38	1.8			14
Nichrome (60 Ni 24 Fe 16 Cr)	112	44	1.5	.00017	20 to 100	1
Nichrome IV (80 Ni 20 Cr)	107.9	42.4	1.6	.000219	20 to 100	1
Ni Resist. Type 1	(175) (5)	69 (5)	.98 (5)			12
Ni Resist. Type 2	(175) (5)	69 (5)	.98 (5)			12

SUBJECT: Approximate Electrical Resistivities of Metals and Alloys

PROPERTIES OF MATERIALS

RADIATION LABORATORY - UNIVERSITY OF CALIFORNIA - BERKELEY

DESIGN DATA

PREPARED: L. Polentz

CHECKED BY:

DATE: 2-17-53

D.D. NO. 66

D-1(M)

Material	Resistivity at 20° C. Microhm-cm (1)	Microhm-in (2)	Conductance Per-cent IACS (3)	Temp. Coeff. of Elect. Resist. per °C. (4) α	Temp. C	Reference
NICKEL ALLOYS						
(35 Ni - 50 Fe - 15 Cr)	100	39	1.7	.00031	20 to 500	1
Constantan (Wrought)	49	19	3.5	±.000025	20 to 500	1
Very high Permeability Alloys						
78.5 Permalloy 78.5 Ni	16	6.3	11			6
Modified 79 Permalloy 79 Ni + 4 Mo	58	23	3.0			6
Mumetal 77 Ni + 5 Cu + 1.5 Cr	60	24	2.9			6
Supermalloy 79 + 5 Mo	65	26	2.7			6
High Permeability Alloys for higher field strengths						
50 Percent Ni type alloys	45	18	3.8			6
Monimax	79	31	2.2			6
Sinimax	89	35	1.9			6
Constant Permeability Alloys						
45-25 Perminvar	19	7.5	9.1			6
7-45-25 Perminvar	80	31	2.2			6
Conpernik	45	18	3.8			6
Temperature Compensation Alloys						
30 Percent Ni Type	80	31	2.2			6
32.5 Percent Ni Type	80	31	2.2			6
Rectangular Hysteresis Alloys						
50 Percent Ni Type Alloys	50	20	3.4			6
65 Permalloy	25	9.8	6.9			6
Magnetostrictive Alloys "A" Nickel	8	3.1	22			6
Insulated Powder Alloy 2-81 Permalloy	10^6	3.9×10^5				6
TIN ALLOYS						
"Pure" Tin(99.8 +)(polycrystalline)	11.5	4.5	15.0	.00447	0 to 100	1
Antimonial Tin Solder(95 Sn - 5 Sb)	14.5	5.7	12			1
Tin-Silver Solder(95 Sn - 5 Ag)	10.4	4.1	17	.00423	0 to 100	1
Eutectic Solder(63 Sn - 37 Pb)	14.5	5.7	12			1
Tin Foil	12.1	4.8	14			1
White Metal	15.48	6.1	11			1

SUBJECT: PROPERTIES OF MATERIALS
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ZINC ALLOYS						
"Pure" Zinc	5.916	2.32	29	.00419	0 to 100	1
Zamak - 3	6.3694	2.50	27	.003774	0 to 100	1
Zamak - 5	6.5359	2.57	26	.003527	0 to 100	1
Zamak - 2	6.8493	2.69	25	.		1
Commercial Rolled Zinc	6.06-6.10	2.39	28			1
Zilloy 40	6.22	2.45	28			1
Zilloy 15	6.31	2.48	27			1
PLATINUM ALLOYS						
Platinum Type A(99.99 Percent Pt)	10.6	4.2	16	.00364	20 to 100	1
Platinum Type B(99.9 Percent Pt)	10.8	4.2	16	.0036	20 to 100	1
Platinum Type C(99.5 Percent Pt)	11.4	4.5	15	.0035	20 to 100	1
Platinum Type D(99.0 Percent Pt)	14.9	5.9	12	.0034	20 to 100	1
Platinum-5 Percent Iridium	19	7.5	9.1	.0020	0 to 100	1
Platinum-10 Percent Iridium	25	9.8	6.9	.0013	0 to 100	1
Platinum-25 Percent Iridium	33	13	5.2	.00065	0 to 100	1
Platinum-5 Percent Ruthenium	31.5	12.4	5.5	.0009	0 to 1000	1
Platinum-10 Percent Ruthenium	43.0	16.9	4.0	.0008	0 to 1000	1
Platinum-1 Percent Nickel	12.7	5.0	14	.0033	0 to 100	1
Platinum-2 Percent Nickel	15.0	5.9	11	.003	0 to 100	1
Platinum-5 Percent Nickel	23.3	9.2	7.4	.002	0 to 100	1
96 Percent Pt-4 Percent W	36.9	14.5	4.7			
PALLADIUM ALLOYS						
Palladium	10.8	4.2	16	.00377	0 to 100	1
60 Pd - 40 Ag	42	17	4.1	.00002	20 to 100	1
60 Pd - 40 Cu(Annealed and quenched)	35	14	4.9	.00032	20 to 100	1
60 Pd - 40 Cu Cold worked and heated to 300° C.	3.5	1.4	49	.00224	20 to 100	1
IRON ALLOYS						
Carbon Steels 0.06 C.,0.38 Mn (1006 range)	13.0	5.1	13			1

SUBJECT: PROPERTIES OF MATERIALS
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RADIATION LABORATORY - UNIVERSITY OF CALIFORNIA - BERKELEY
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D-1(M)

Material	Resistivity at 20° C. Microhm-cm (1)	Resistivity at 20° C. Microhm-in (2)	Conductance Percent IACS (3)	Temp. Coeff. of Elect. Resist. per °C. (4) α	Temp. Coeff. of Elect. Resist. per °C. (4) Temp. C	Reference
IRON ALLOYS						
Carbon Steels (cont.)						
0.08 C.,0.31 Mn(1010 range)	14.2	5.6	12			1
0.23 C.,0.635 Mn(1020 range)	16.9	6.6	10			1
0.415 C.,0.643 Mn(1040 range)	17.1	6.7	10			1
0.80 C.,0.32 Mn(1078 range)	18.0	7.1	9.6			1
1.22 C., 0.35 Mn	19.6	7.7	8.8			1
Alloy Steels						
0.23 C,1.51 Mn,0.105 Cu	20.8	8.2	8.3			1
0.325 C,0.55 Mn,0.17 Cr,3.47 Ni	27.1	10.6	6.4			
0.33 C,0.53 Mn,0.80 Cr,3.38 Ni	26.8	10.5	6.4			1
0.325 C,0.55 Mn,0.71 Cr,3.41 Ni	28.0	11.0	6.2			1
0.34 C,0.55 Mn,0.78 Cr,3.53 Ni, 0.39 Mo	28.9	11.4	6.0			1
0.315 C,0.69 Mn,1.09 Cr,0.073 Ni	21.0	8.3	8.2			1
0.35 C,0.59 Mn,0.88 Cr,0.26 Ni 0.20 Mo	22.3	8.8	7.7			1
0.485 C,0.90 Mn,1.98 Si,0.637 Cu	42.9	16.9	4.0			1
High Alloy Steels						
1.22 C,13.0 Mn,0.22 Si	68.3	26.9	2.5			1
0.28 C,0.89 Mn,28.37 Ni	84.2	33.1	2.0			1
0.08 C,0.37 Mn,19.11 Cr, 8.14 Ni,0.60 W	71.0	27.9	2.4			1
0.13 C,0.25 Mn,12.95 Cr	50.6	19.9	3.4			1
0.27 C,0.28 Mn,13.69 Cr	52.2	20.5	3.3			1
0.715 C,0.25 Mn,4.26 Cr,18.45 W, 1.075 V	41.9	16.5	4.1			1
Iron Manganese Alloys(Values taken from graph)						
26 Percent Mn	67	26	2.6			9
30 Percent Mn	68	27	2.5			9
35 Percent Mn	68.5	27	2.5			9
40 Percent Mn	69.5	27	2.5			9
42 Percent Mn	70	28	2.5			9
45 Percent Mn	71	28	2.4			9
48 Percent Mn	72	28	2.4			9

D-1(M)

Material	Resistivity at 20° C. Microhm-cm (1)	Microhm-in (2)	Conductance Percent IACS (3)	Temp. Coeff. of Elect. Resist. per °C. (4) α	Temp. C	Reference
IRON ALLOYS (Cont.)						
Malleable Iron						
ASTM Spec A47-33 Grade 35018	30	12	5.7			8
ASTM Spec A47-33 Grade 32510	32	13	5.4			8
Annealed Carbon Steel Castings						
0.07 - 0.20 Percent C	13-14	5.1-5.5	13			7
0.20 - 0.45 Percent C	14-16	5.5-6.3	11			7
0.45 - 1.50 Percent C	16-20	6.3-7.9	9.6			7
Low Carbon "Ingot" Iron	10.7	4.2	16			11
Bessemer Steel	14.0	5.5	12			11
Cast (Carbon) Steel	15.0	5.9	11			11
Malleable Iron	32.0	12.6	5.4			11
Cast Iron	100.0	39.4	1.7			
Nickel Steels						
AISI 301	72	28	2.4			6
AISI 302	72	28	2.4			6
AISI 302 B	72	28	2.4			6
AISI 303	72	28	2.4			6
AISI 304	72	28	2.4			6
AISI 308	72	28	2.4			6
AISI 309	72	28	2.4			6
AISI 310	72	28	2.4			6
AISI 316	74	29	2.3			6
AISI 321	72	28	2.4			6
AISI 347	73	29	2.4			6
36 Percent Ni (Invar)	81	32	2.1			6
42 Percent Ni	70	28	2.5			6
50 Percent Ni	48	19	3.6			6
4 Percent Silicon Iron	60	24	2.9			6,1

LP:fg

SUBJECT: Approximate Electrical Resistivities of Metals and Alloys

PROPERTIES OF MATERIALS

RADIATION LABORATORY - UNIVERSITY OF CALIFORNIA - BERKELEY

DESIGN DATA

PREPARED: L. Polentz

CHECKED BY:

DATE: 2-17-53

D.D. NO. 66

PAGE 14 OF PAGES 14

RADIATION LABORATORY · UNIVERSITY OF CALIFORNIA · BERKELEY

DESIGN DATA

DATE	D.Q. NO.	PAGE
2-28-53	67	1 of 1

SUBJECT

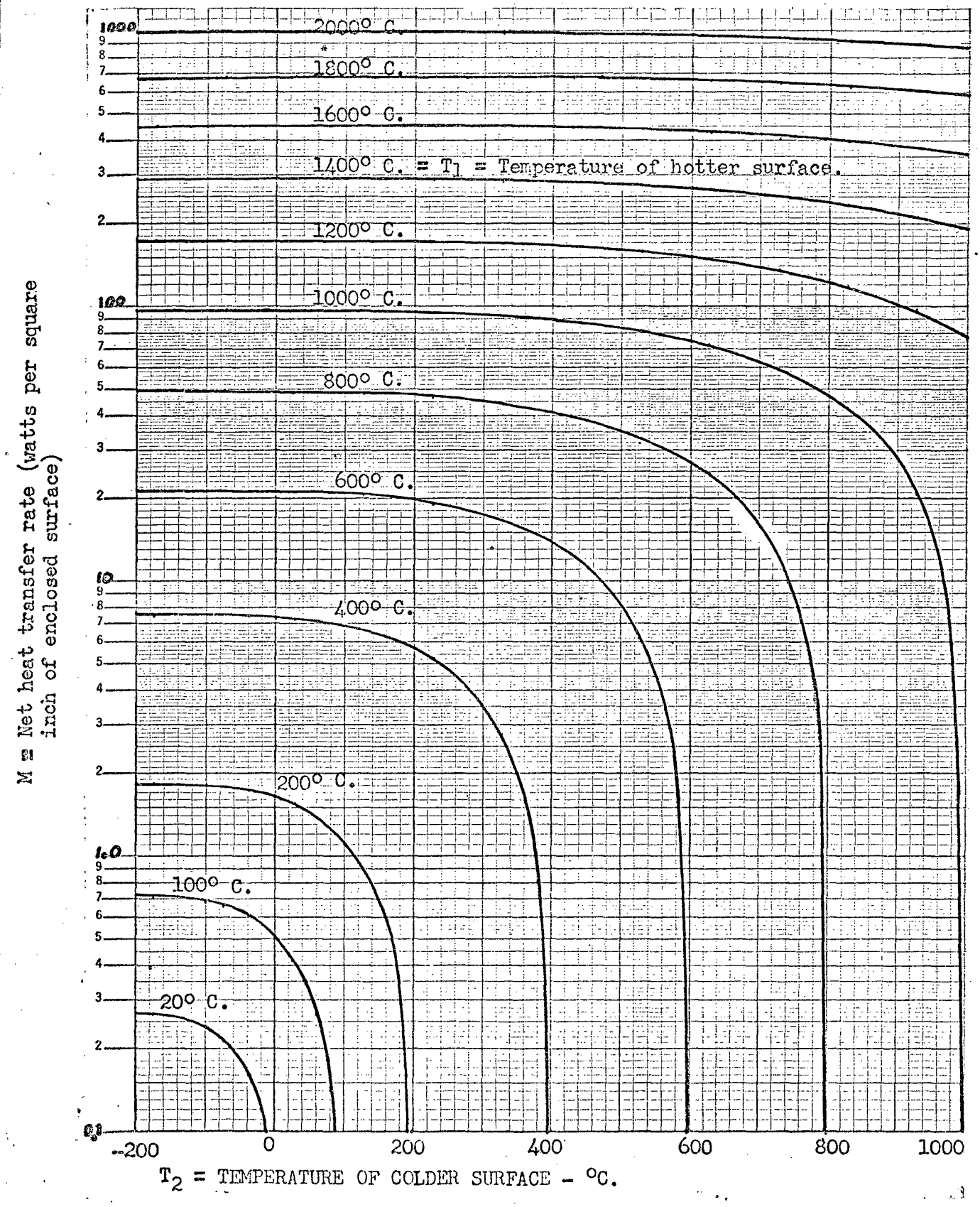
HEAT TRANSFER BY RADIATION FOR A SMALL BODY IN A LARGE ENCLOSURE.

PREPARED: L. Polentz

CHECKED BY: L. Brown, D. T. Scalise

$$M = 36.8\ \epsilon\left[\left(\frac{T_1 + 273}{1000}\right)^4 - \left(\frac{T_2 + 273}{1000}\right)^4\right]$$ for units used herein

ϵ = emissivity of small body = 1.0 for curves below.



D-34(M)

RECOMMENDED FILLER METALS FOR JOINING SIMILAR AND DISSIMILAR METALS

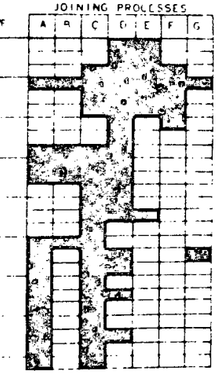
	STEEL	CAST IRON	Ni RESIST	DEOXIDIZED COPPER	RED BRASS	YELLOW BRASS	SILICON BRONZE	12 Cr STEEL	17 Cr STEEL	18-8 STAINLESS	MONEL	NICKEL	INCONEL	HASTELLOY	ALUMINUM	LEAD
LEAD	LEAD SOLDER	NOT RECOMMENDED	NOT RECOMMENDED	SOLDER	SOLDER	SOLDER	SOLDER (2)	SOLDER	SOLDER	SOLDER	SOLDER	SOLDER	SOLDER	SOLDER	NOT RECOMMENDED	LEAD SOLDER
ALUMINUM	ALUMINUM SOLDER (1)	NOT RECOMMENDED	NOT RECOMMENDED	ALUMINUM SOLDER (1)	NOT RECOMMENDED										ALUMINUM ALUMINUM SOLDER (1)	
HASTELLOY	BRAZING SOLDER EASY FLO 45 HASTELLOY B 25 Cr-20 Ni STEEL SOLDER	BRAZING SOLDER EASY FLO 45 HASTELLOY D SOLDER	BRAZING SOLDER EASY FLO 45 SOLDER	BRAZING SOLDER EASY FLO 45 SOLDER	BRAZING SOLDER EASY FLO 45 SOLDER	BRAZING SOLDER EASY FLO 45 SOLDER	BRAZING SOLDER EASY FLO 45 SOLDER	BRAZING SOLDER EASY FLO 45 HASTELLOY B 25 Cr-20 Ni STEEL SOLDER	BRAZING SOLDER EASY FLO 45 HASTELLOY B 25 Cr-20 Ni STEEL SOLDER	BRAZING SOLDER EASY FLO 45 HASTELLOY B 25 Cr-20 Ni STEEL SOLDER	BRAZING SOLDER EASY FLO 45 HASTELLOY B MONEL SOLDER	BRAZING SOLDER EASY FLO 45 HASTELLOY B MONEL NICKEL ELECTRODES SOLDER	BRAZING SOLDER EASY FLO 45 HASTELLOY B INCONEL SOLDER	BRAZING SOLDER EASY FLO 45 HASTELLOY B NICKEL ELECTRODES 25 Cr-20 Ni STEEL SOLDER		
INCONEL	EASY FLO 45 INCONEL NICKEL ELECTRODES SOLDER 18-8 STAINLESS 80 Ni-20 Cr	EASY FLO 45 NICKEL ELECTRODES WELDING BRONZE (3)	EASY FLO 45 NICKEL ELECTRODES	EASY FLO 45 PHOSPHOR COPPER SIL-FOS SOLDER WELDING BRONZE (3)	EASY FLO 45 SOLDER WELDING BRONZE (3)	EASY FLO 45 SOLDER WELDING BRONZE (3)	EASY FLO 45 WELDING BRONZE (3)	EASY FLO 45 SOLDER	EASY FLO 45 SOLDER	EASY FLO 45 INCONEL SOLDER 80 Ni-20 Cr	EASY FLO 45 INCONEL MONEL NICKEL ELECTRODES SOLDER	EASY FLO 45 INCONEL NICKEL ELECTRODES SOLDER 80 Ni-20 Cr	EASY FLO 45 INCONEL SOLDER		
NICKEL	EASY FLO 45 INCONEL NICKEL ELECTRODES SOLDER 80 Ni-20 Cr	EASY FLO 45 NICKEL ELECTRODES WELDING BRONZE (3)	EASY FLO 45 NICKEL ELECTRODES	EASY FLO 45 SOLDER WELDING BRONZE (3)	EASY FLO 45 PHOSPHOR BRONZE SOLDER WELDING BRONZE (3)	EASY FLO 45 SOLDER WELDING BRONZE (3)	EASY FLO 45 WELDING BRONZE (3)	EASY FLO 45 SOLDER	EASY FLO 45 SOLDER	EASY FLO 45 INCONEL SOLDER 18-8 STAINLESS 80 Ni-20 Cr	EASY FLO 45 MONEL NICKEL ELECTRODES	EASY FLO 45 NICKEL ELECTRODES SOLDER				
MONEL	ALUMINUM BRONZE EASY FLO 45 NICKEL ELECTRODES SOLDER WELDING BRONZE (3) MONEL 140	ALUMINUM BRONZE EASY FLO 45 NICKEL ELECTRODES WELDING BRONZE (3)	EASY FLO 45 NICKEL ELECTRODES	EASY FLO 45 SOLDER WELDING BRONZE (3)	EASY FLO 45 PHOSPHOR BRONZE SOLDER WELDING BRONZE (3)	ALUMINUM BRONZE EASY FLO 45 SOLDER WELDING BRONZE (3)	EASY FLO 45 PHOSPHOR BRONZE SILICON BRONZE WELDING BRONZE (3)	EASY FLO 45 SOLDER WELDING NOT RECOMMENDED	EASY FLO 45 SOLDER WELDING NOT RECOMMENDED	EASY FLO 45 MONEL (ARC) SOLDER	COPPER NICKEL EASY FLO 45 MONEL SOLDER					
18-8 STAINLESS	EASY FLO 45 SOLDER 18-8 STAINLESS 25 Cr-12 Ni STEEL 25 Cr-20 Ni STEEL	ALUMINUM BRONZE EASY FLO 45 NICKEL ELECTRODES	EASY FLO 45 NICKEL ELECTRODES	EASY FLO 45 PHOSPHOR BRONZE SOLDER 18-8 STAINLESS	EASY FLO 45 PHOSPHOR BRONZE SOLDER	EASY FLO 45 PHOSPHOR BRONZE SOLDER	ALUMINUM BRONZE EASY FLO 45	EASY FLO 45 SOLDER 18-8 STAINLESS 25 Cr-12 Ni STEEL 25 Cr-20 Ni STEEL	EASY FLO 45 SOLDER 25 Cr-12 Ni STEEL 25 Cr-20 Ni STEEL	EASY FLO 45 NICKEL ELECTRODES SOLDER 18-8 STAINLESS 25 Cr-12 Ni STEEL 25 Cr-20 Ni STEEL						
17 Cr STEEL	EASY FLO 45 SOLDER STEEL 25 Cr-12 Ni STEEL 25 Cr-20 Ni STEEL	ALUMINUM BRONZE EASY FLO 45	EASY FLO 45	EASY FLO 45 PHOSPHOR BRONZE SOLDER	EASY FLO 45 PHOSPHOR BRONZE SOLDER	EASY FLO 45 PHOSPHOR BRONZE SOLDER	ALUMINUM BRONZE EASY FLO 45	BRAZING SOLDER EASY FLO 45 SOLDER 25 Cr-12 Ni STEEL 25 Cr-20 Ni STEEL	BRAZING SOLDER EASY FLO 45 SOLDER STEEL 25 Cr-12 Ni STEEL 25 Cr-20 Ni STEEL							
12 Cr STEEL	EASY FLO 45 SOLDER 18-8 STAINLESS 25 Cr-12 Ni STEEL 25 Cr-20 Ni STEEL	ALUMINUM BRONZE EASY FLO 45	EASY FLO 45	EASY FLO 45 SOLDER	EASY FLO 45 SOLDER	EASY FLO 45 SOLDER	EASY FLO 45	EASY FLO 45 SOLDER 12 Cr STEEL 18-8 STAINLESS 25 Cr-12 Ni STEEL 25 Cr-20 Ni STEEL								
SILICON BRONZE	ALUMINUM BRONZE EASY FLO 45 PHOSPHOR BRONZE SILICON BRONZE WELDING BRONZE (3)	ALUMINUM BRONZE EASY FLO 45 PHOSPHOR BRONZE SILICON BRONZE WELDING BRONZE (3)	EASY FLO 45	ALUMINUM BRONZE BRAZING SOLDER EASY FLO 45 PHOSPHOR BRONZE PHOSPHOR COPPER SILICON BRONZE SIL-FOS WELDING BRONZE (3)	ALUMINUM BRONZE EASY FLO 45 PHOSPHOR COPPER SILICON BRONZE SIL-FOS WELDING BRONZE (3)	ALUMINUM BRONZE BRAZING SOLDER EASY FLO 45 PHOSPHOR COPPER SILICON BRONZE SIL-FOS WELDING BRONZE (3)	ALUMINUM BRONZE BRAZING SOLDER EASY FLO 45 PHOSPHOR BRONZE SILICON BRONZE WELDING BRONZE (3)								
YELLOW BRASS	ALUMINUM BRONZE BRAZING SOLDER EASY FLO 45 PHOSPHOR BRONZE SILICON BRONZE SOLDER	ALUMINUM BRONZE BRAZING SOLDER EASY FLO 45 PHOSPHOR BRONZE SILICON BRONZE WELDING BRONZE (3)	EASY FLO 45	BRAZING SOLDER EASY FLO 45 PHOSPHOR COPPER SILICON BRONZE SIL-FOS SOLDER WELDING BRONZE (3)	BRAZING SOLDER EASY FLO 45 PHOSPHOR BRONZE PHOSPHOR COPPER SILICON BRONZE SIL-FOS SOLDER WELDING BRONZE (3)	ALUMINUM BRONZE BRAZING SOLDER EASY FLO 45 PHOSPHOR COPPER SILICON BRONZE SIL-FOS SOLDER WELDING BRONZE (3)										
RED BRASS	BRAZING SOLDER EASY FLO 45 PHOSPHOR BRONZE SILICON BRONZE SOLDER	BRAZING SOLDER EASY FLO 45 PHOSPHOR BRONZE SILICON BRONZE WELDING BRONZE (3)	EASY FLO 45	BRAZING SOLDER EASY FLO 45 MONEL PHOSPHOR BRONZE PHOSPHOR COPPER SILICON BRONZE SIL-FOS SOLDER WELDING BRONZE (3)	EASY FLO 45 MONEL PHOSPHOR BRONZE PHOSPHOR COPPER SILICON BRONZE SIL-FOS SOLDER WELDING BRONZE (3)										
DEOXIDIZED COPPER	BRAZING SOLDER COPPER EASY FLO 45 PHOSPHOR BRONZE SILICON BRONZE SOLDER WELDING BRONZE (3)	BRAZING SOLDER EASY FLO 45 PHOSPHOR BRONZE SILICON BRONZE SOLDER WELDING BRONZE (3)	EASY FLO 45	BRAZING SOLDER COPPER EASY FLO 45 PHOSPHOR BRONZE PHOSPHOR COPPER SILICON BRONZE SIL-FOS SOLDER WELDING BRONZE (3)											
Ni RESIST	EASY FLO 45 NICKEL ELECTRODES NICKEL SILVER	EASY FLO 45 NICKEL ELECTRODES	EASY FLO 45 MONEL NICKEL ELECTRODES Ni RESIST													
CAST IRON	ALUMINUM BRONZE BRAZING SOLDER EASY FLO 45 NICKEL ELECTRODES PHOSPHOR BRONZE WELDING BRONZE (3)	ALUMINUM BRONZE BRAZING SOLDER CAST IRON EASY FLO 45 NICKEL ELECTRODES PHOSPHOR BRONZE SILICON BRONZE WELDING BRONZE (3)														
STEEL	ALUMINUM BRONZE BRAZING SOLDER EASY FLO 45 SILICON BRONZE SOLDER STEEL WELDING BRONZE (3)															

NOTE: THE FILLER METALS SHOWN IN THE RECTANGLES ARE USED TO JOIN THE BASE MATERIALS SHOWN IN THE COLUMN HEADS BY THE FOLLOWING PROCESS:

A-METAL ARC WELDING (5)
B-CARBON ARC WELDING
C-INERT GAS SHIELDED ARC WELDING
D-OXY-ACETYLENE WELDING OR BRAZING
E-GAS WELDING OR SOLDERING
F-FURNACE BRAZING
G-ATOMIC HYDROGEN WELDING

PROCESS OR METAL PREFERENCE CANNOT BE SHOWN ON THE CHART SINCE THIS DEPENDS ON THE APPLICATION.

FILLER METAL	COMPOSITION	APPROXIMATE MELTING POINT, °F
SOLDER	Pb-50, Sn-50	420
LEAD	Pb-100	620
EASY FLO 45	Ag-45, Cu-15, Zn-16, Cd-24	1125
ALUMINUM	Al-100	1200
SIL-FOS (4)	Cu-80, Ag-15, P-5	1300
PHOSPHOR COPPER (4)	Cu-93, P-7	1300
BRAZING SOLDER	Cu-50, Zn-50	1650
NICKEL SILVER	Cu-46.5, Ni-10, Si-0.1, Zn-43.4, P-.02	1700
PHOSPHOR BRONZE	Sn-5 to 10, P-.25, Cu-Bal	1830
SILICON BRONZE	Cu-97, Si-3	1870
ALUMINUM BRONZE	Cu-89, Al-10, Fe-1	1950
COPPER	Cu-100	1980
HASTELLOY D	Ni-85, Cu-3, Si-10	2050
CAST IRON	C-3, Fe-97	2100
Ni RESIST	C-2.90, Cr-2.0, Cu-5.5, Ni-14, Fe-75.6	2250
COPPER NICKEL	Cu-70, Ni-30	2300
HASTELLOY B	Ni-65, Mo-30, Fe-5	2400
INCONEL	Ni-80, Cr-14, Fe-6	2400
25 Cr-20 Ni STEEL	Cr-25, Ni-20, Fe-55	2450
MONEL	Ni-67, Cu-30, Fe-1	2480
25 Cr-12 Ni STEEL	Cr-25, Ni-12, Fe-63	2500
18-8 STAINLESS	Cr-18, Ni-8, Fe-74	2600
NICKEL	Ni-99	2650
STEEL	Fe-99.7	2680
80 Ni-20 Cr	Ni-80, Cr-20	2700



(1) RODS REQUIRE SPECIAL COATING OR FLUX.

(2) BRIGHTEN SURFACE OF SILICON BRONZE WITH EMERY AND COAT WITH FLUX BEFORE SOLDERING.

(3) WELDING BRONZE (FOR BRAZING) DEFINITION FROM AWS HANDBOOK (1942) "A GROUP OF METAL JOINING PROCESSES WHEREIN THE FILLER METAL IS A NON-FERROUS METAL OR ALLOY WHOSE MELTING POINT IS HIGHER THAN 1000°F, BUT LOWER THAN THOSE OF THE METALS BEING JOINED." THERE ARE SEVERAL VARIETIES OF BRONZE WELDING RODS. LOW FUMING, MANGANESE BRONZE, NAVAL BRASS AND BRAZING ROD. THE COPPER CONTENT VARIES FROM 57 TO 61, ZINC FROM 39 TO 41 AND THE BALANCE CONSISTS OF IRON, TIN, MANGANESE AND SILICON.

(4) DO NOT USE SIL-FOS OR PHOSPHOR COPPER FOR JOINING IRON OR NICKEL BASE METAL.

(5) WHEN METAL ARC IS INDICATED, RODS ARE FLUX COATED.

SHELL DEVELOPMENT COMPANY
Engineering Department
JUNE 1951 VGM-GAN

ZT-207A
SUPERSEDES ZT-195A

Permission to reproduce of Shell Development Company

DESIGN DATA

PREPARED BY Richard Reimers
CHECKED BY J.O. Turner

SUBJECT

PRECIOUS BRAZE FILLER METALS

NUMBER	SOLIDUS (1) (2)		LIQUIDUS (1) (2)		COMPOSITION (% by wt.)	SUPPLIERS		TRADE NAMES
	°F	°C	°F	°C		Std. Grades (3)	VTG Grades (4)	
1 (5)	3571	1966	3571	1966	Rh (100)	B,G		
2 (5)	3225	1774	3225	1774	Pt (100)	B,D,G	B,D,G	
3 (5)	2993	1645	3083	1695	Pt (75) Pd (20) Au (5)	D	D	205
4	2827	1553	2827	1553	Pd(100)	B,D,G	B,G	
5 (5)	2651	1455	2651	1455	Ni (100)	G,H,L,J, M,K,N		
6	2516	1380	2570	1410	Au (75) Pd (25)	D	D	201
7	2300	1260	2381	1305	Au (87) Pd (13)	D	D	210
8	2192	1200	2264	1240	Au (92) Pd (8)	G	G	Paloro
9	2260	1238	2260	1238	Pd (60) Ni (40)	B	B	PM129
10	2246	1230	2255	1235	Pd (65) Co (35)	G	G	Palco
11	2120	1160	2250	1232	Ag (70) Pd (30)	B		PM485
12	2165	1185	2221	1216	Cu (60) Pt (40)	G		Cuplat
13	2100	1149	2190	1199	Ag (64) Pd (33) Mn (3)	B		PM441
14	1960	1071	2150	1177	Ag (80) Pd (20)	B	B	PM447
15	2075	1135	2136	1169	Ni (36) Pd (34) Au (30)	G		Palniro 4
16	2016	1102	2050	1121	Au (50) Pd (25) Ni (25)	G	G	Palniro 1
17 (5)	1981	1083	1981	1083	Cu (100)	H,L		
18	1769	965	1967	1075	Au (65) Ni (35)	D	D	131
19	1846 1830	1008 999	2050 1962	1121 1072	Ag (75) Pd (20) Mn (5)	B,D		PM440, Palmasil 5
20	1835 1785	1002 974	1950 1835	1066 1002	Ag (90) Pd (10)	B	B	PM431
21	1945	1063	1945	1063	Au (100)	B,D,G	B,D	
23	1846	1008	1927	1053	Ag (89.5) Pd (10) Ni (.5)	G		Palnisil 10
24	1787 1785	975 974	1904 1900	1040 1038	Au (72) Ni (22) Cr (6)	B,D,G		PM265,128
25	1841	1005	1899	1037	Au (70) Ni (22) Pd (8)	G		Palniro 7

* Distributed January 1966

SUBJECT

PRECIOUS BRAZE FILLER METALS

PREPARED BY Richard Reimers
CHECKED BY J.O. Turner

NUMBER	SOLIDUS (1) (2) °F	SOLIDUS (1) (2) °C	LIQUIDUS (1) (2) °F	LIQUIDUS (1) (2) °C	COMPOSITION (% by wt.)	SUPPLIERS Std.Grades (3)	SUPPLIERS VTG Grades (4)	TRADE NAMES
26	1787	975	1886	1030	Cu (62) Au (35) Ni (3)	B,D,G		PM243, 129,Nicoro
27	1787	975	1877	1025	Cu (78) Au (20) In (2)	G		Incuro 20
28	1832 1814	1000 990	1868 1850	1020 1010	Cu (65) Au (35)	B,D,G	B,D	PM260, 406, -
29	1814 1805	990 985	1859 1841	1015 1005	Cu (62.5) Au (37.5)	B,D,G		PM242, 401, -
30	1425	774	1850	1010	Ag (62.5) Cu (32.5) Ni (5)	B,D		T50, 624
31	1780	971	1850	1010	Ag (95) Pd (5)	B	B	PM428
32	1796	980	1832	1000	Cu (60) Au (40)	G		
33	1832 1742	1000 950	1787 1778	975 970	Au (50) Cu (50)	D,G	D	402,-
34	1508	820	1769	965	Cu(87.75) Ge (12) Ni (.25)	G	B,D,G	Gemco
35	1762	961	1762	961	Ag (100)	B,D,G		
36	1778 1745	970 952	1760	960	Ag (85) Mn (15)	B,C, D,G		850, 185, 852,SIL85M
37	1742	950	1742	950	Au (82) Ni (18)	B,D,G		PM255, 130 Nioro
38	1652 1650	900 899	1742 1740	950 949	Ag (54) Pd (25) Cu (21)	B,G		PM492 Palcusil 25
39	1670	910	1697	925	Au (81.5) Cu(16.5) Ni (2)		G	Nicoro 80
40	1652	900	1670	910	Au (81.5) Cu(15.5) Ni (3)	D		409
41	1580	860	1652	900	Au (60) Cu (37) In (3)	G		Incuro 60
42	1565	852	1650	899	Ag (65) Cu (20) Pd (15)	B		PM490
43	1615	879	1650	899	Ag (52) Cu (28) Pd (20)	B		PM443
44	1625	885	1643 1640	895 893	Au (75) Cu (20) Ag (5)	B,D,G		PM261, 050 Silcoro 75
45	1666 1630	908 888	1670 1630	910 888	Au (80) Cu (20)	B,D,G		PM238,403,-
46	1450 1225	788 663	1805 1565	985 852	Cu (85) Sn (8) Ag (7)	C,D,F		7,071,SIL7T
47	1520 1515	827 824	1566	852	Ag (58) Cu (32) Pd (10)	B,G		PM491, Palcusil 10
48	1535	835	1553	845	Au (60) Cu (20) Ag (20)	D,G		408, Silcoro 60
49	1485	807	1490	810	Ag (68) Cu (27) Pd (5)	B,G		PM478, Palcusil 5
50	1275	691	1475	802	Ag (63) Cu (28.5) Sn (6), Ni (2.5)	D		630

* Distributed January 1966

SUBJECT

PRECIOUS BRAZE FILLER METALS

PREPARED BY Richard Reimers
CHECKED BY J.O. Turner

NUMBER	SOLIDUS (1) (2)		LIQUIDUS (1) (2)		COMPOSITION (% by wt.)	SUPPLIERS		TRADE NAMES
	°F	°C	°F	°C		Std. Grades (3)	VTG Grades (4)	
51	1436	780	1463	795	Ag(71.15) Cu(28.1) Ni(0.75)	G		Nicusil 3
52	1436	780	1463	795	Ag(71.5) Cu (28), Ni (.5)	D		715
53	1385	752	1445	785	Mn (5) Ni (2) Ag (65) Cu (28)	C,D		165,655
54	1436	780	1436	780	Ag (72) Cu (28)	B,D,F,G		301, BT, SIL72,Cusil
55	1265 1220	685 660	1436 1346	780 730	Ag (63) Cu (27) In (10)	D,G		630, Incusil 10
56	1120	604	1345	729	Ag (57) Cu (33) Sn (7) Mn (3)	C		57
57	1115 1095	602 591	1326	719	Ag (60) Cu (30) Sn (10)	B,C,D,F		60, 160, 603,SIL60T
58	1125	607	1310	710	Ag (60) Cu (27) In (13)	C		260
59	1166	630	1301	705	Ag (61.5) Cu (24) In (14.5)	D,G		615, Incusil 15
60 (6)	450	232	450	232	Sn (100)	A,L,J		
61 (6)	313	156	313	156	In (100)	A,E,H,L,J		

NOTES:

(1) Listing is arranged in order of decreasing liquidus temperatures. Above liquidus temperature no solid exists; below solidus temp., no liquid exists. For elements and eutectics, liquidus temperature = solidus temperature.

(2) Suppliers disagree on solidus and liquidus temperatures. Come companies list °F, others °C, some list both. All temperatures listed by suppliers are given to show the variation.

(3) Letters in this column refer to the list of suppliers below.

(4) VTG means vacuum tube grade. Suppliers in this column have very pure braze filler metals in the alloys indicated. The trade names for regular grade and VTG are the same. If VTG is desired, specify it when ordering.

(5) These filler metals wet molybdenum and tungsten.

(6) Brazing is performed at or above 800°F by definition. Tin and indium are not braze filler metals.

LIST OF SUPPLIERS: **

A - Consolidated Mining & Smelting
B - Engelhard Industries
C - Goldsmith Brothers
D - Handy & Harman
E - Indium Corporation of America
F - United Wire & Supply
G - Western Gold & Platinum
H - American Smelting & Refining Co.
J - Belmont Smelting & Refining
K - Cohn Corporation
L - A.D. Mackey
M - Pacific Metals
N - International Nickel

** Wall Colmonoy Corporation, 19345 John R St., Detroit makes thirteen types of Nicrobraz, a nickel-base braze alloy containing various combinations of: chromium; boron; iron; carbon; silicon; phosphorus; manganese; tungsten; tungsten carbide. These alloys have high abrasion and corrosion resistance and high temperature strength, a brazing range of 1700 - 2200°F, and are especially suited for furnace brazing of stainless steels.

* Distributed January 1966

The accompanying chart shows graphically the comparative strengths of commonly used structural sections together with their corresponding weights. The data shown are the allowable bending moments, and, for circular sections only, the allowable torsional moments, both in inch-pounds.

The values of these moments are given by the vertical location of the dots preceeding the description of each section. The moments are for loads which pass through the section centroids. The direction of loading for non-symmetrical sections is shown in their respective column headings.

The moments shown on the chart produce stresses of 15,000 psi in bending and 7,500 psi in torsion giving safety factors of 2(based on yield point) for mild steel. Use of these allowable stresses does not imply that they are suitable for all design situations. Neither does it relieve the designer of his responsibility for the safe design of structural elements.

SIMPLE BENDING Enter the chart at the bending moment which the section must resist and select the desired section.

SIMPLE TORSION This chart is applicable in torsion only to circular sections. Enter the chart at the torque which the section must resist and select the desired circular section.

DIFFERENT ALLOWABLE STRESSES Specific applications may require a different allowable bending stress S' or torsional stress S_s'. Multiply the actual bending moment M by $\frac{15000}{S'}$ or the actual torsional moment by $\frac{7500}{S_s'}$ to obtain a moment M'. Then enter the chart at M' and select the desired section.

The allowable moments shown on the chart were computed from:

$$M = SZ$$

Where:

S = Arbitrary allowable bending stress 15,000 psi

Z = appropriate section modulus of the section

The allowable moments shown on the chart are applicable to torsion of circular sections only since for such sections the polar moment of inertia is equal to twice the area moment of inertia and since the allowable torsional stress is frequently taken as one half the allowable bending stress.

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RADIATION LABORATORY - UNIVERSITY OF CALIFORNIA - BERKELEY

DESIGN DATA

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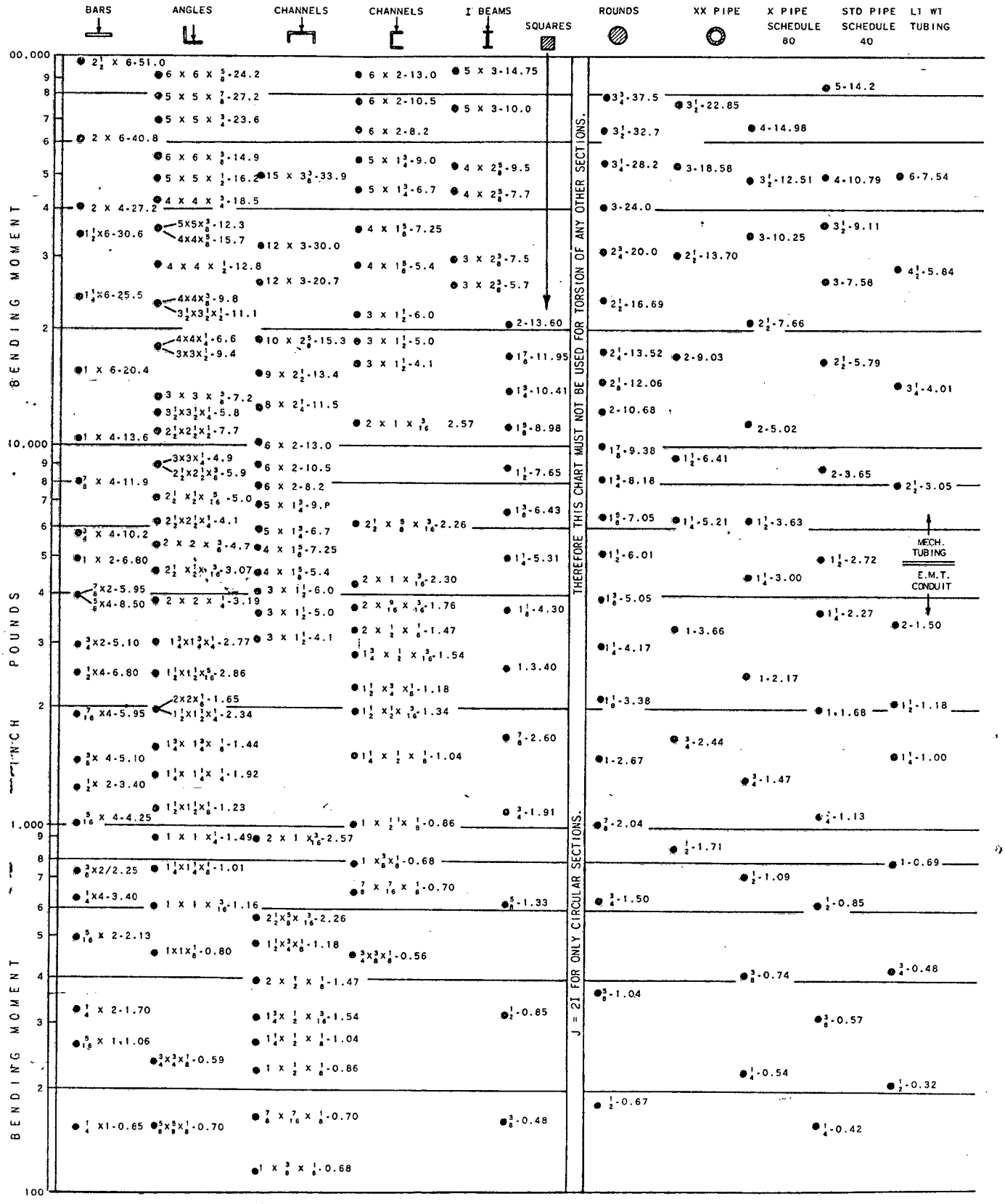
SUBJECT

ALLOWABLE BENDING MOMENTS OF COMMONLY USED SECTIONS

PREPARED: Jack Gunn

CHECKED BY: L. Freisen



RADIATION LABORATORY - UNIVERSITY OF CALIFORNIA - BERKELEY

DESIGN DATA

DATE	D.D. NO.	PAGE
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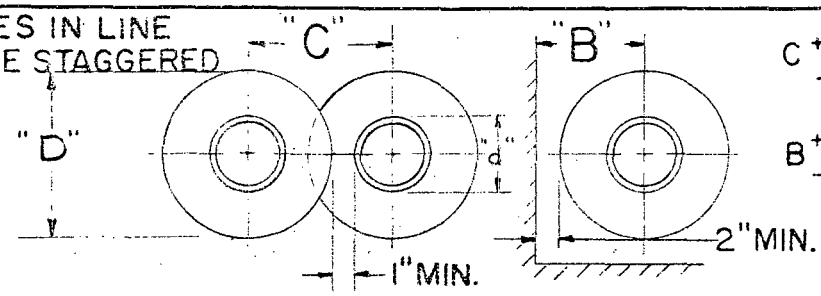
SUBJECT

SPACING FOR BARE I.P.S.(Iron pipe size) PIPE WITH FLANGES

PREPARED KELLER & GANNON
W E BARRUS

CHECKED BY 3-26-59
W.P. Carpender

FLANGES IN LINE MUST BE STAGGERED



$$C^{+\frac{1}{4}}_{-0} = \frac{D}{2} + \frac{d}{2} + 1$$

$$B^{+\frac{1}{4}}_{-0} = \frac{D}{2} + 2$$

150# MSS BRASS & BRONZE FLANGES
150# ASA FORGED STEEL FLANGES
125# ASA CAST IRON FLANGES

PIPE SIZE	"C" 1/2	3/4	1	1 1/4	1 1/2	2	2 1/2	3	4	6	8	10	12	14	16	"B"	d O.D. OF PIPE	D DIA. OF FLGE	NO. OF HOLES	BOLT DIA.
1/2	3 1/2	3 1/2	3 3/4	3 3/4	4	4 1/2	5	5 1/4	6	7	8 1/4	9 1/2	11	12	13 1/4	3 3/4	.840	3 1/2	4	1/2
3/4		3 1/2	3 3/4	4	4 1/4	4 3/4	5 1/4	5 1/2	6 1/4	7 1/4	8 1/2	9 3/4	11 1/4	12 1/4	13 1/2	4	1.05	3 7/8	4	1/2
1			4	4	4 1/4	4 3/4	5 1/4	5 1/2	6 1/4	7 1/4	8 1/2	9 3/4	11 1/4	12 1/4	13 1/2	4 1/4	1.312	4 1/4	4	1/2
1-1/4				4 1/4	4 1/2	5	5 1/2	5 3/4	6 1/2	7 1/2	8 3/4	10	11 1/2	12 1/2	13 3/4	4 1/2	1.66	4 5/8	4	1/2
1-1/2					4 1/2	5	5 1/2	5 3/4	6 1/2	7 1/2	8 3/4	10	11 1/2	12 1/2	13 3/4	4 1/2	1.906	5	4	1/2
2						5 1/4	5 3/4	6	6 3/4	7 3/4	9	10 1/4	11 3/4	12 3/4	14	5	2.375	6	4	5/8
2-1/2							6	6 1/4	7	8	9 1/4	10 1/2	12	13	14 1/4	5 1/2	2.875	7	4	5/8
3								6 1/2	7 1/4	8 1/4	9 1/2	10 3/4	12 1/4	13 1/4	14 1/2	5 3/4	3.50	7 1/2	4	5/8
4									7 3/4	8 3/4	10	11 1/4	12 3/4	13 3/4	15	6 1/2	4.50	9	8	5/8
6										10	11 1/4	12 1/2	14	15	16 1/4	7 1/2	6.62	11	8	3/4
8											12 1/4	13 1/2	15	16	17 1/4	8 3/4	8.62	13 1/2	8	3/4
10												14 1/2	16	17	18 1/4	10	10.75	16	12	7/8
12													17	18	19 1/4	11 1/2	12.75	19	12	7/8
14														18 1/2	19 3/4	12 1/2	14.0	21	12	1
16															20 3/4	13 3/4	16.0	23 1/2	16	1

300# MSS BRASS & BRONZE FLANGES. (TO 3" ONLY)
300# ASA FORGED STEEL FLANGES
250# ASA CAST IRON FLANGES

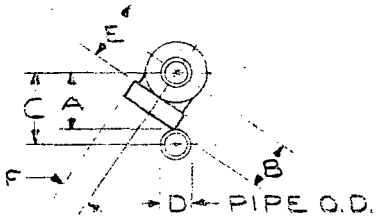
PIPE SIZE	"C" 1/2	3/4	1	1 1/4	1 1/2	2	2 1/2	3	4	6	8	10	12	14	16	"B"	d O.D. OF PIPE	D DIA. OF FLGE	NO. OF HOLES	BOLT DIA.
1/2	3 1/2	3 3/4	4	4 1/4	4 1/2	4 3/4	5 1/4	5 3/4	6 1/2	7 3/4	9	10 1/4	11 3/4	13	14 1/4	3 7/8	.840	3 3/4	4	1/2
3/4		4	4	4 1/4	4 3/4	5	5 1/2	5 3/4	6 3/4	8	9 1/4	10 1/2	12	13 1/4	14 1/2	4 1/2	1.05	4 5/8	4	5/8
1			4 1/4	4 1/2	4 3/4	5	5 1/2	6	6 3/4	8	9 1/4	10 1/2	12	13 1/4	14 1/2	4 1/2	1.312	4 7/8	4	5/8
1 1/4				4 1/2	5	5 1/4	5 3/4	6	7	8 1/4	9 1/2	10 3/4	12 1/4	13 1/2	14 3/4	4 3/4	1.66	5 1/4	4	5/8
1 1/2					5 1/4	5 1/4	5 3/4	6 1/4	7	8 1/4	9 1/2	10 3/4	12 1/4	13 1/2	14 3/4	5 1/4	1.906	6 1/8	4	3/4
2						5 1/2	6	6 1/2	7 1/4	8 1/2	9 3/4	11	12 1/2	13 3/4	15	5 1/4	2.375	6 1/2	8	5/8
2 1/2							6 1/4	6 3/4	7 1/2	8 3/4	10	11 1/4	12 3/4	14	15 1/4	5 3/4	2.875	7 1/2	8	3/4
3								7	7 3/4	9	10 1/4	11 1/2	13	14 1/4	15 1/2	6 1/4	3.50	8 1/4	8	3/4
4									8 1/4	9 1/2	10 3/4	12	13 1/2	14 3/4	16	7	4.50	10	8	3/4
6										10 3/4	12	13 1/4	14 3/4	16	17 1/4	8 1/4	6.62	12 1/2	12	3/4
8											13	14 1/4	15 3/4	17	18 1/4	9 1/2	8.62	15	12	7/8
10												15 1/4	16 3/4	18	19 1/4	10 3/4	10.75	17 1/2	16	1
12													17 3/4	19	20 1/4	12 1/4	12.75	20 1/2	16	1 1/8
14														19 1/2	20 3/4	13 1/2	14.0	23	20	1 1/8
16															21 3/4	14 3/4	16.0	25 1/2	20	1 1/4

D-1(M)

SUBJECT
SPACING FOR CAST IRON, BRASS & BRONZE FITTINGS & BARE IPS (Iron pipe size) PIPE

PREPARED KELLER & GANNON
WE BARRUS

CHECKED BY 3-26-59
W.P. Carpender



$C = \frac{D}{2} + A \qquad F = \frac{E}{2}$

$A = \sqrt{F^2 + B^2}$

FOR ELBOWS TEES & CROSSES, SCREWED TYPE

FITTING PIPE SIZE ↓

125 LB CAST IRON ASA STD.
250 LB BRASS & BRONZE ASA STD

PIPE SIZE →	"C": (CENTER TO CENTER) 1/4	3/8	1/2	3/4	1	1 1/4	1 1/2	2	2 1/2	3	A	D	D/2	E	B
1/4	1 1/4	1 5/16	1 13/32	1 1/2	1 5/8	1 13/16	1 15/16	2 5/32	2 13/32	2 23/32	.968	.540	.270	.93	.81
3/8	1 13/32	1 15/32	1 9/16	1 21/32	1 13/16	1 31/32	2 3/32	2 5/16	2 9/16	2 7/8	1.125	.675	.337	1.12	.95
1/2	1 5/8	1 11/16	1 25/32	1 7/8	2	2 3/16	2 5/16	2 17/32	2 25/32	3 3/32	1.343	.840	.420	1.34	1.125
3/4	1 27/32	1 29/32	2	2 3/32	2 1/4	2 13/32	2 17/32	2 3/4	3	3 5/16	1.562	1.05	.525	1.63	1.31
1	2 3/32	2 5/32	2 1/4	2 11/32	2 1/2	2 21/32	2 25/32	3	3 1/4	3 9/16	1.812	1.315	.656	1.95	1.50
1 1/4	2 15/32	2 17/32	2 9/16	2 21/32	2 23/32	2 31/32	3 3/32	3 5/16	3 9/16	3 7/8	2.125	1.66	.83	2.39	1.75
1 1/2	2 21/32	2 3/4	2 15/16	2 29/32	3 1/32	3 7/32	3 11/32	3 9/16	3 13/32	4 1/8	2.375	1.906	.953	2.68	1.94
2	3 1/16	3 1/8	3 1/32	3 5/16	3 1/16	3 5/8	3 3/4	3 31/32	4 7/32	4 17/32	2.781	2.375	1.187	3.28	2.25
2 1/2	3 5/8	3 11/16	3 25/32	3 7/8	4	4 3/16	4 5/16	4 17/32	4 25/32	5 1/8	3.34	2.87	1.437	3.86	2.70
3	4 5/32	4 7/32	4 5/16	4 7/16	4 11/32	4 23/32	4 21/32	5 1/16	5 5/16	5 5/8	3.87	3.50	1.75	4.62	3.08

250 LB CAST IRON ASA STD

	"C": (CENTER TO CENTER) 1/4	3/8	1/2	3/4	1	1 1/4	1 1/2	2	2 1/2	3	A	D	D/2	E	B
1/4	1 7/16	1 1/2	1 9/16	1 11/16	1 13/16	2	2 1/8	2 11/32	2 19/32	2 29/32	1.140	.540	.270	1.17	.94
3/8	1 17/32	1 5/8	1 11/16	1 25/32	1 15/16	2 3/32	2 7/32	2 7/16	2 11/16	3	1.250	.675	.337	1.36	1.06
1/2	1 25/32	1 27/32	1 15/16	2 1/32	2 3/16	2 11/32	2 15/32	2 11/16	2 15/16	3 1/4	1.50	.840	.420	1.59	1.25
3/4	2	2 1/16	2 5/32	2 1/4	2 3/8	2 9/16	2 11/16	2 29/32	3 5/32	3 15/32	1.718	1.05	.525	1.88	1.44
1	2 9/32	2 11/32	2 7/16	2 17/32	2 11/16	2 27/32	2 31/32	3 3/16	3 7/16	3 3/4	2	1.315	.657	2.24	1.63
1 1/4	2 21/32	2 23/32	2 13/16	2 29/32	3 1/16	3 1/32	3 11/32	3 9/16	3 13/16	4 1/8	2.375	1.66	.83	2.73	1.94
1 1/2	2 15/16	3	3 3/32	3 7/32	3 11/32	3 1/2	3 5/8	3 27/32	4 5/32	4 13/32	2.656	1.906	.953	3.07	2.13
2	3 15/32	3 15/32	3 9/16	3 21/32	3 13/16	3 31/32	4 5/32	4 5/16	4 9/16	4 7/8	3.125	2.375	1.187	3.74	2.50
2 1/2	4 1/32	4 3/32	4 3/16	4 9/32	4 7/16	4 19/32	4 23/32	4 15/16	5 3/16	5 1/2	3.75	2.87	1.437	4.60	2.94
3	4 5/8	4 11/16	4 25/32	4 7/8	5 1/32	5 3/16	5 5/16	5 17/32	5 23/32	6 3/32	4.343	3.5	1.75	5.36	3.38

RADIATION LABORATORY • UNIVERSITY OF CALIFORNIA • BERKELEY

DESIGN DATA

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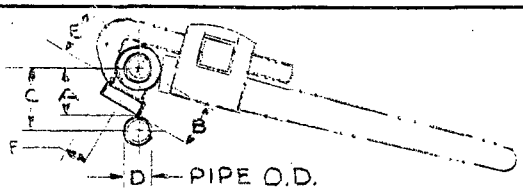
SUBJECT

SPACING FOR MALLABLE IRON FITTINGS AND BARE IRON PIPE

PREPARED BY KELLER & GANNON
W E BARRUS

CHECKED BY 3-26-59
W.P. Carpender



$C = \frac{D}{2} + A$ $\quad F = \frac{E}{2}$

$A = \sqrt{F^2 + B^2}$

FOR ELBOWS TEES & CROSSES, SCREWED TYPE

FITTING PIPE SIZE

150 LBS. ASA STD

PIPE SIZE	"C": (CENTER TO CENTER) 3/8	1/2	3/4	1	1 1/4	1 1/2	2	2 1/2	3	A	D	D/2	E	B
3/8														
1/2		1 23/32	1 13/16	1 15/16	2 1/8	2 1/4	2 15/32	2 23/32	3 1/32	1.28	.840	.420	1.197	1.12
3/4		1 15/16	2 1/32	2 3/32	2 11/32	2 15/32	2 11/16	2 15/16	3 1/4	1.5	1.05	.525	1.458	1.31
1		2 3/16	2 9/32	2 13/32	2 19/32	2 23/32	2 15/16	3 3/16	3 1/2	1.75	1.312	.656	1.771	1.50
1 1/4		2 1/2	2 19/32	2 23/32	2 29/32	3 1/32	3 1/4	3 1/2	3 13/16	2.062	1.66	.83	2.153	1.75
1 1/2		2 3/4	2 27/32	2 31/32	3 5/32	3 9/32	3 1/2	3 3/4	4 1/16	2.312	1.906	.953	2.427	1.94
2		3 1/8	3 1/32	3 11/32	3 17/32	3 21/32	3 7/8	4 1/8	4 7/16	2.687	2.375	1.187	2.96	2.25
2 1/2		3 11/16	3 25/32	3 29/32	4 3/32	4 7/32	4 1/16	4 11/16	5	3.25	2.87	1.437	3.58	2.70
3		4 1/32	4 3/16	4 7/16	4 5/8	4 3/4	4 31/32	5 1/32	5 17/32	3.78	3.50	1.75	4.28	3.08

300 LBS AAR STD

	"C": (CENTER TO CENTER) 3/8	1/2	3/4	1	1 1/4	1 1/2	2	2 1/2	3	A	D	D/2	E	B
3/8														
1/2		1 29/32	2	2 1/8	2 5/16	2 7/16	2 21/32	2 29/32	3 7/32	1.468	.840	.420	1.437	1.25
3/4		2 1/8	2 1/32	2 11/32	2 17/32	2 21/32	2 7/8	3 1/8	3 7/16	1.68	1.05	.525	1.75	1.437
1		2 3/8	2 15/32	2 19/32	2 25/32	2 29/32	3 1/8	3 3/8	3 11/16	1.937	1.312	.656	2	1.625
1 1/4		2 3/4	2 27/32	2 31/32	3 5/32	3 9/32	3 1/2	3 3/4	4 1/16	2.312	1.66	.830	2.43	1.937
1 1/2		3 1/16	3 5/32	3 9/32	3 15/32	3 19/32	3 13/16	4 1/16	4 3/8	2.62	1.90	.953	2.93	2.125
2		3 1/16	3 17/32	3 21/32	3 27/32	3 31/32	4 3/16	4 1/16	4 3/4	3	2.37	1.187	3.312	2.50
2 1/2		3 15/16	4 1/32	4 5/32	4 11/32	4 15/32	4 11/16	4 15/16	5 1/4	3.5	2.87	1.437	3.62	2.93
3		4 5/8	4 15/32	4 19/32	4 25/32	4 29/32	5 1/8	5 3/8	5 11/16	3.93	3.50	1.750	3.937	3.375

D-1(M)

RADIATION LABORATORY - UNIVERSITY OF CALIFORNIA - BERKELEY

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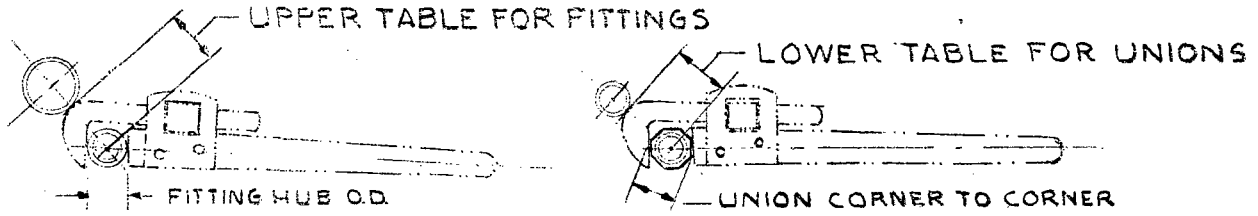
SUBJECT

SPACING BETWEEN PIPES FOR PIPE WRENCH CLEARANCES

PREPARED KELLER & GANNON W.E. BARRUS

CHECKED BY 3-26-59 W.P. Carpender



WRENCH SIZE	8"				14"				18"				24"				36"			
FITTING SIZE / PIPE SIZE	150 MI	300 MI	125 CI	250 CI	150 MI	300 MI	125 CI	250 CI	150 MI	300 MI	125 CI	250 CI	150 MI	300 MI	125 CI	250 CI	150 MI	300 MI	125 CI	250 CI
1/4	1 11/32	1 1/2	1 7/16	1 5/8	1 11/16	1 13/16	1 3/4	1 15/16	1 13/16	1 7/8	1 7/8	2	2	2 3/16	2 1/16	2 1/4	2 3/8	2 1/2	2 7/16	2 5/8
3/8	1 1/2	1 9/16	1 9/16	1 3/4	1 13/16	1 7/8	1 7/8	2 1/16	1 7/8	1 15/16	1 15/16	2 1/8	2 1/8	2 3/16	2 3/16	2 3/8	2 1/2	2 9/16	2 9/16	2 3/4
1/2	1 5/8		1 11/16		1 15/16	2 1/8	2	2 1/4	2	2 3/16	2 1/8	2 5/16	2 1/4	2 7/16	2 5/8	2 9/16	2 5/8	2 3/4	2 11/16	2 15/16
3/4					2 1/8	2 5/16	2 1/4	2 7/16	2 3/16	2 3/8	2 5/16	2 1/2	2 7/16	2 5/8	2 9/16	2 3/4	2 13/16	3	2 15/16	3 1/8
1					2 5/16	2 1/2	2 1/2	2 11/16	2 3/8	2 9/16	2 9/16	2 3/4	2 11/16	2 13/16	2 13/16	3	3	3 3/16	3 3/16	3 3/8
1 1/4					2 5/8				2 11/16	2 7/8	2 13/16	3 1/16	2 15/16	3 1/8	3 1/8	3 3/8	3 5/16	3 1/2	3 7/16	3 11/16
1 1/2					2 13/16				2 7/8	3 1/4	3 1/16	3 3/8	3 1/8	3 1/2	3 5/16	3 5/8	3 1/2	3 13/16	3 11/16	4
2									3 1/4	3 1/2	3 1/2	3 13/16	3 1/2	3 3/4	3 3/4	4 1/16	3 7/8	4 1/8	4 1/8	4 7/16
2 1/2									3 11/16	3 11/16	3 7/8	4 7/16	3 15/16	3 15/16	4 3/16	4 11/16	4 5/16	4 5/16	4 1/2	5 1/16
3									4 3/16	4 15/16	4 1/16		4 1/16	4 9/16	4 11/16	5 1/4	4 13/16	5 1/8	5 1/16	5 9/16
4																	5 9/16			

THE SIZES SHOWN BELOW WERE OBTAINED FROM UNIONS IN STOCK
TABLE FOR UNIONS APPLIES TO 150 LB. MALLABLE IRON ONLY.
MFGRS. STD'S MAY VARY BETWEEN LARGE & SMALL SIZES

	8"		14"		18"		24"		36"	
	SMALL	LARGE	SMALL	LARGE	SMALL	LARGE	SMALL	LARGE	SMALL	LARGE
1/8	1 1/2	1 9/16	1 13/16	1 15/16	1 15/16	2	2 3/16	2 1/4	2 1/2	2 5/8
1/4	1 9/16	1 5/8	1 15/16	2	2	2 1/16	2 1/4	2 5/16	2 5/8	2 5/8
3/8	1 11/16	1 3/4	2	2 1/8	2 1/16	2 3/16	2 5/16	2 7/16	2 11/16	2 3/4
1/2			2 3/16	2 5/16	2 5/16	2 3/8	2 1/2	2 5/8	2 7/8	2 15/16
3/4			2 3/8	2 7/16	2 7/16	2 1/2	2 11/16	2 3/4	3 1/16	3 1/8
1			2 5/8	2 11/16	2 11/16	2 3/4	2 15/16	3	3 5/16	3 3/8
1 1/4					3	3 1/8	3 1/4	3 3/8	3 5/8	3 11/16
1 1/2					3 5/16	3 5/16	3 9/16	3 9/16	3 15/16	3 15/16
2					3 3/4		4		4 3/8	
2 1/2					4 5/16		4 9/16		4 15/16	
3							5 1/16		5 7/16	

D-1(M)

D-1(M)

RADIATION LABORATORY - UNIVERSITY OF CALIFORNIA - BERKELEY

DESIGN DATA

SUBJECT: "HIPERCO" AND "PERMENDUR" HIGH COBALT, HIGH MAGNETIC SATURATION ALLOYS, PROPERTIES, FABRICATION, ESTIMATING COSTS

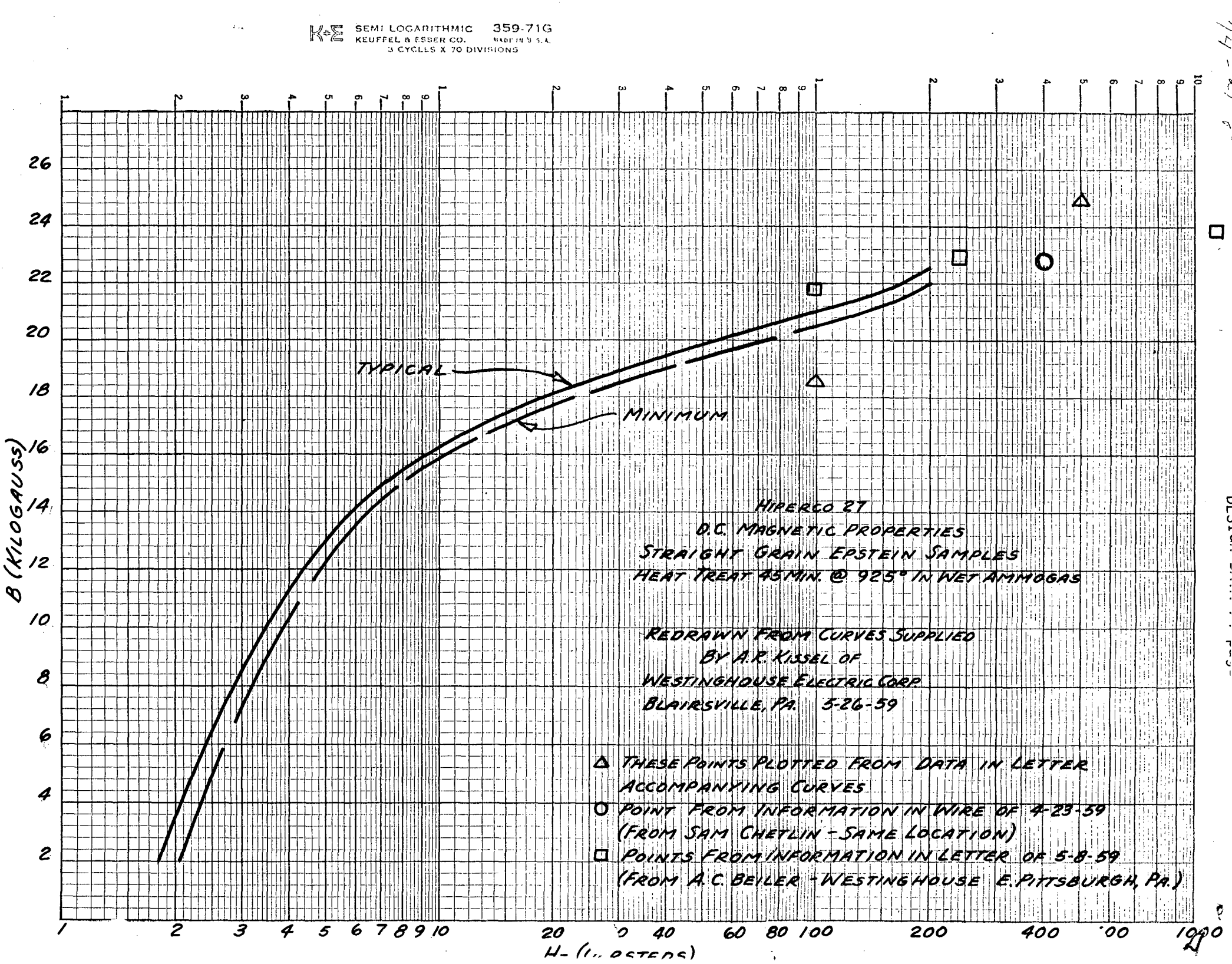
DATE: 10/9/59 | D.D. NO. 74 | PAGE 1 OF 5 PAGES

PREPARED: J. O. Turner | CHECKED BY: C. G. L.

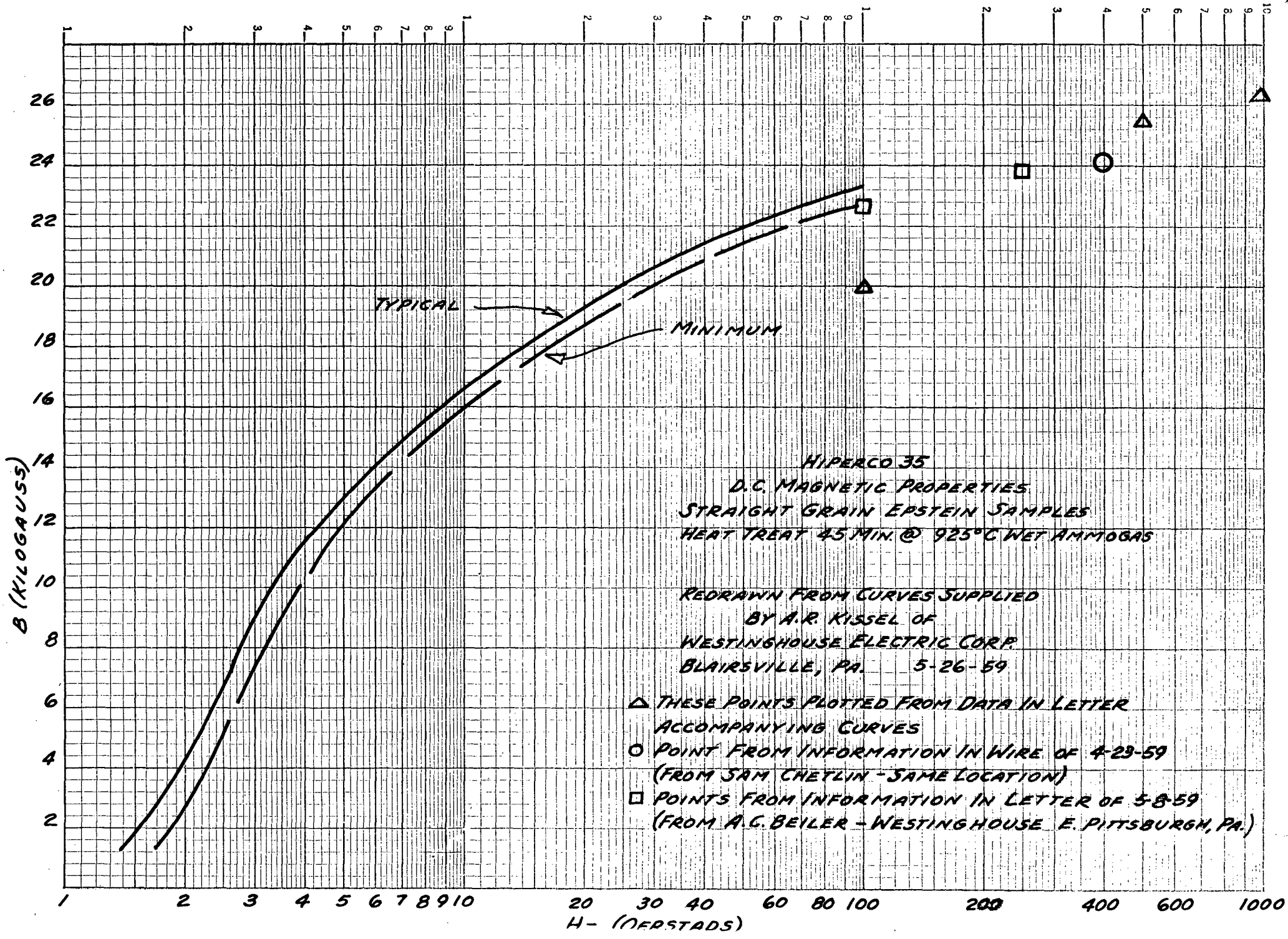
COMPARISON OF INFORMATION RECEIVED FROM MANUFACTURERS

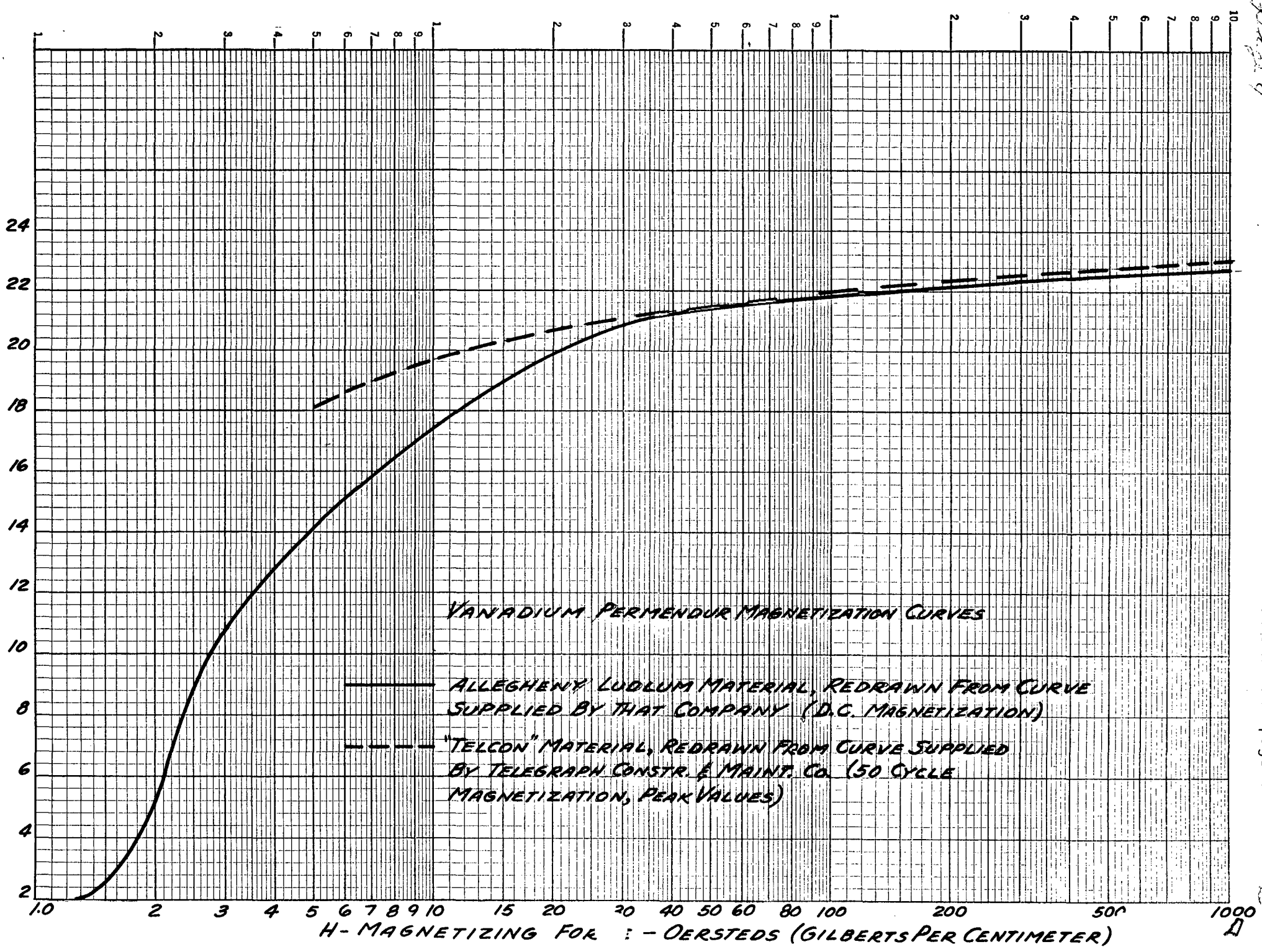
Alloy Name	Hiperco 27	Hiperco 35	Vanadium Permendur — or — 2 V. Permendur			
Composition	Co - 27% Fe - 73%	Co - 35% Fe - 65%	Co - 49%; V - 2%; Fe - 49%			
Manufacturer	Westinghouse	Electric Corp.	Allegheny-Ludlum	Arnold Eng'g.	Simonds Saw & Steel Co.	Telegraph Constr. & Maintenance Co. England
Handling and machining characteristics before final anneal	About like brittle cast iron	Very fragile, brittle, and crumbly; hard to machine: sometimes breaks from light shocks in handling	About like brittle cast iron			
Final anneal after machining	Hold at 1697°F for six hours in wet H_2 or ammogas. Cooling rate not critical.		Hold at 1350°-1450°F for four hours in dry H_2 (-60°F dew point) Cool at 100°F/hr to 600°F*	-----	-----	Hold at 1450°F for six hours in dry H_2. Cool at 9°F/min.*
Maximum Size Melt	----------		2500 lb.	900 lb.	350 lb.	900 lb.
Maximum variation magnetic properties between melts	By telegram - 2% By telephone - 5% Disagreement among different W sources - 10%		Insignificant	Insignificant	Insignificant	Insignificant
Approximate price FOB plant	$4.00/lb.		$6.00/lb.	$6.00/lb.	$4-$4.50/lb.	$2.80/lb.
Normal shipment	8 - 10 weeks		—	12-14 weeks	12 weeks	10 weeks

*Bozorth (R.M.Bozorth - "Ferromagnetism" - McGraw Hill, pages 203-204) states that maximum permeability is only slightly sensitive to cooling rate, with a slight edge in favor of the faster rate.


K+E SEMI LOGARITHMIC 359-71G
KEUFFEL & ESSER CO. MADE IN U.S.A.
3 CYCLES X 70 DIVISIONS
B (KILOGAUSS)
H- (LL OSTEDS)
TYPICAL
MINIMUM
HIPERCO 27
D.C. MAGNETIC PROPERTIES
STRAIGHT GRAIN EPSTEIN SAMPLES
HEAT TREAT 45 MIN. @ 925° IN WET AMMOGAS
REDRAWN FROM CURVES SUPPLIED
BY A.R. KISSEL OF
WESTINGHOUSE ELECTRIC CORP.
BLAIRSVILLE, PA. 5-26-59
△ THESE POINTS PLOTTED FROM DATA IN LETTER ACCOMPANYING CURVES
○ POINT FROM INFORMATION IN WIRE OF 4-23-59 (FROM SAM CHETLIN - SAME LOCATION)
□ POINTS FROM INFORMATION IN LETTER OF 5-8-59 (FROM A.C. BEILER - WESTINGHOUSE E. PITTSBURGH, PA.)

K+E SEMI-LOGARITHMIC 359 71G
KEUFFEL & ESSER CO.
3 CYCLES X 70 DIVISIONS




K+E SEMI-LOGARITHMIC 359-71G
KEUFFEL & ESSER CO. MADE IN U.S.A.
3 CYCLES X 70 DIVISIONS
VANADIUM PERMENDUR MAGNETIZATION CURVES
ALLEGHENY LUDLUM MATERIAL, REDRAWN FROM CURVE SUPPLIED BY THAT COMPANY (D.C. MAGNETIZATION)
"TELCON" MATERIAL, REDRAWN FROM CURVE SUPPLIED BY TELEGRAPH CONSTR. & MAINT. CO. (50 CYCLE MAGNETIZATION, PEAK VALUES)
H - MAGNETIZING FOR : - OERSTEDS (GILBERTS PER CENTIMETER)
1.0 2 3 4 5 6 7 8 9 10 15 20 30 40 50 60 80 100 200 500 1000
2 4 6 8 10 12 14 16 18 20 22 24

Forming

Parts are normally produced of these alloys by hot rolling, machining to shape, and annealing. Forging is uncertain and should be used only as a last resort.

Machining

Permendur and Hiperco 27 may be machined using a similar procedure to that for a good quality cast iron. The following points may be found useful. Coolant and lubricant should be of thin lubricating oil consistency. Tool tapping should be done with a carbide tool. If possible tap rough formed part before it has been reduced to final dimensions. For turning and milling a fairly flat topped tool is used but the angle is not critical. The important point is to avoid running off square edges in milling, or turning the end of the piece; and hence use a large radius piece for milling and for turning, turn from either end to meet in the middle. A fairly high finish may be obtained. It is advisable to machine on slow speeds and use fairly coarse feeds.

Hiperco 35 is much more fragile than the other two alloys and must be machined and handled with extreme care.

General

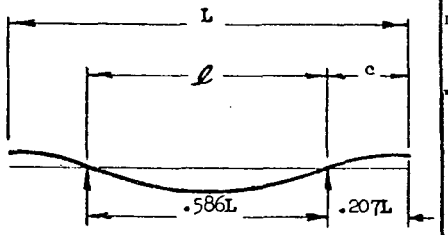
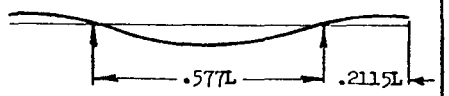
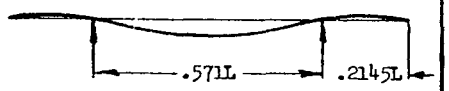
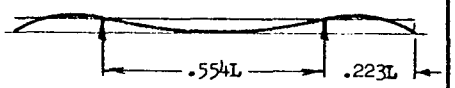
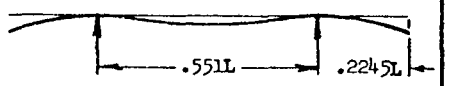
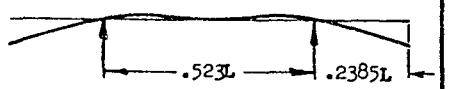
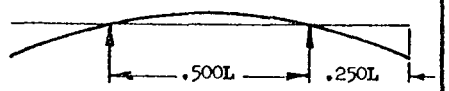
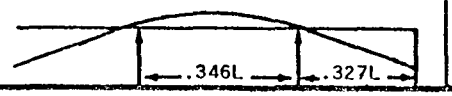
All machining or working of any kind must be done before final anneal except light surface grinding of not more than 2-3 mils per pass.

Warpage during anneal will be slight - not more than a few mils which can be removed by grinding.

After final anneal, the alloys are quite fragile and must be handled with care to avoid breakage.

hr

*From "Machinery's Handbook", pages 412-413, 20th edition.

	SPECIAL CASE		distance each way from center to inflection point = point of zero moment * $=\sqrt{\frac{\ell^2}{4}-c^2}$	moment at center $=\frac{w(c^2-\frac{\ell^2}{4})}{2}$	moment at supports $=\frac{wc^2}{2}$ = max. moment	deflection at ends * $=\frac{wc}{24EI}[3c^2(c+2\ell)-\ell^3]$ plus = down minus = up	deflection at center * $=\frac{w\ell^2}{384EI}[5\ell^2-24c^2]$ plus = down minus = up
1.	EQUAL MOMENTS AT SUPPORTS AND CENTER. LEAST STRESS		.207L	$.0214\ wL^2$	$.0214\ wL^2$	$-.000206\ \frac{wL^4}{EI}$	$.000615\ \frac{wL^4}{EI}$
2.	ZERO SLOPE AT ENDS		.196L	$.0192\ wL^2$	$.0223\ wL^2$	$-.0000780\ \frac{wL^4}{EI}$	$.000512\ \frac{wL^4}{EI}$
3.	NO END DEFLECTION		.183L	$.0177\ wL^2$	$.0230\ wL^2$	0	$.000446\ \frac{wL^4}{EI}$
4.	END AND CENTER DEFLECTIONS EQUAL. MINIMUM OVERALL DEFLECTION		.164L	$.0135\ wL^2$	$.0248\ wL^2$	$.000268\ \frac{wL^4}{EI}$	$.000268\ \frac{wL^4}{EI}$
5.	ZERO SLOPE AT SUPPORTS		.159L	$.0126\ wL^2$	$.0252\ wL^2$	$.000317\ \frac{wL^4}{EI}$	$.000237\ \frac{wL^4}{EI}$
6.	NO CENTER DEFLECTION		.106L	$.0057\ wL^2$	$.0284\ wL^2$	$.000759\ \frac{wL^4}{EI}$	0
7.	INFLECTION POINT AT CENTER. ZERO MOMENT AT CENTER		0	0	$.0312\ wL^2$	$.00113\ \frac{wL^4}{EI}$	$-.000162\ \frac{wL^4}{EI}$
8.	CENTER AT MAXIMUM HEIGHT ABOVE SUPPORTS		NONE	$.0383\ wL^2$	$.0533\ wL^2$	$.00387\ \frac{wL^4}{EI}$	$-.000613\ \frac{wL^4}{EI}$

Revised: 3/78 by Roger West

SUBJECT

BEAM CALCULATIONS
SPECIAL CASES OF SYMMETRICAL OVERHANGING BEAMS
WITH UNIFORM LOAD w lbs/in., DIMENSIONS IN INCHES

RADIATION LABORATORY - UNIVERSITY OF CALIFORNIA - BERKELEY

DESIGN DATA

PREPARED D. Vorkoeper

CHECKED BY

DATE 10-4-60

D.D. NO. 75A

PAGE 1/1

RADIATION LABORATORY · UNIVERSITY OF CALIFORNIA · BERKELEY

DESIGN DATA

SUBJECT: D. C. MAGNET COILS
TEMPERATURE RISE TIME OF NON-COOLED COPPER CONDUCTOR

DATE 2-19-62 | D.D.NO. 77 | PAGE 1 OF 1 PAGES

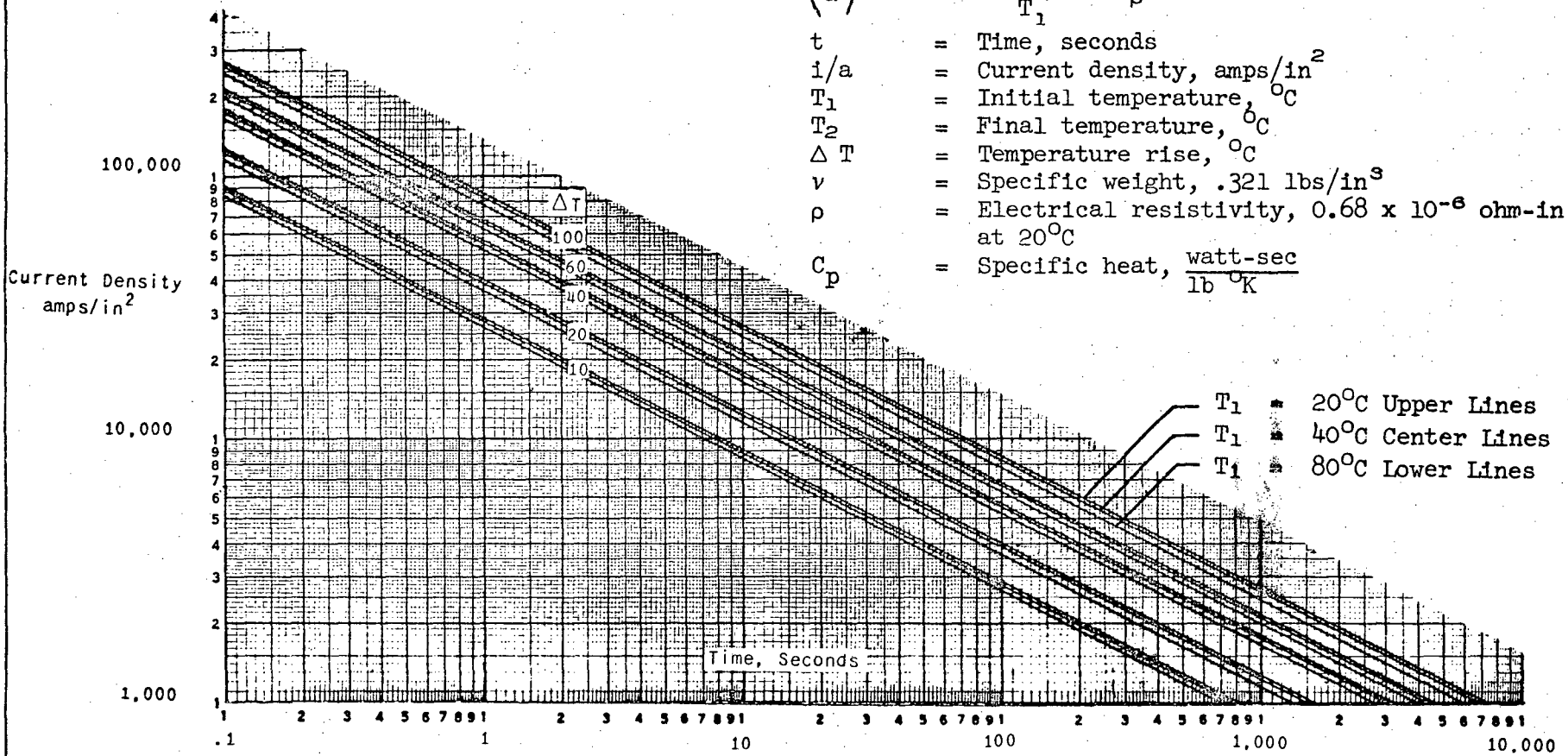
PREPARED H. Paul Hernandez

CHECKED BY D. T. Scalise

Specific electrical energy in the coil is equated to the copper specific heat energy and the following expression derived:

$$\left(\frac{i}{a}\right)^2 t = \nu \int_{T_1}^{T_2} \frac{C_p}{\rho}\, dT$$

t	=	Time, seconds
i/a	=	Current density, amps/in^2
T_1	=	Initial temperature, ^oC
T_2	=	Final temperature, ^oC
ΔT	=	Temperature rise, ^oC
ν	=	Specific weight, .321 lbs/in^3
ρ	=	Electrical resistivity, 0.68 x 10^{-6} ohm-in at 20^oC
C_p	=	Specific heat, $\frac{\text{watt-sec}}{\text{lb } ^oK}$



Example: A d. c. magnet wound with copper conductor is operating at a current density of 10,000 amp/in^2 and at a temperature of 40°C. If all cooling is removed, how soon must the electrical current stop flowing to prevent the conductor from exceeding 100°C if the heat capacity of the cooling medium is neglected. The temperature will rise 60°C from 40°C to 100°C in 44 seconds.

C_p and ρ are functions of temperature. These curves are based on linear extrapolations between C_p/ρ values of 260 x 10^6 at 20°C to 181 x 10^6 at 140°C.

LAWRENCE BERKELEY LABORATORY – UNIVERSITY OF CALIFORNIA

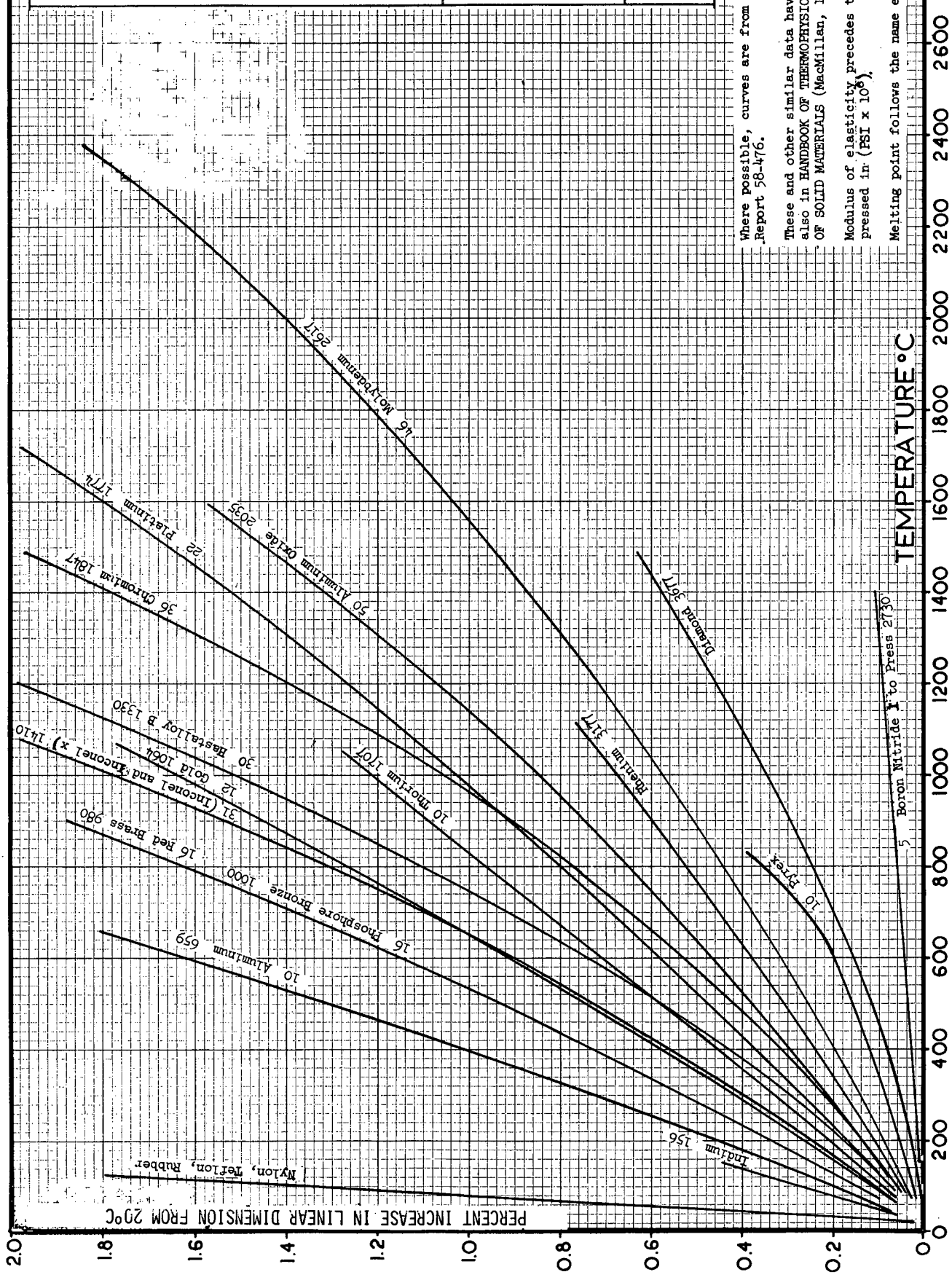
DESIGN DATA

NUMBER	PAGE
78A	1 OF 3

TITLE

THERMAL EXPANSION OF VARIOUS MATERIALS

PREPARED BY	DATE
W. H. Chamberlain	March 1964
REVISED BY	DATE
J. O. Turner	June 1979
REVISED BY	DATE

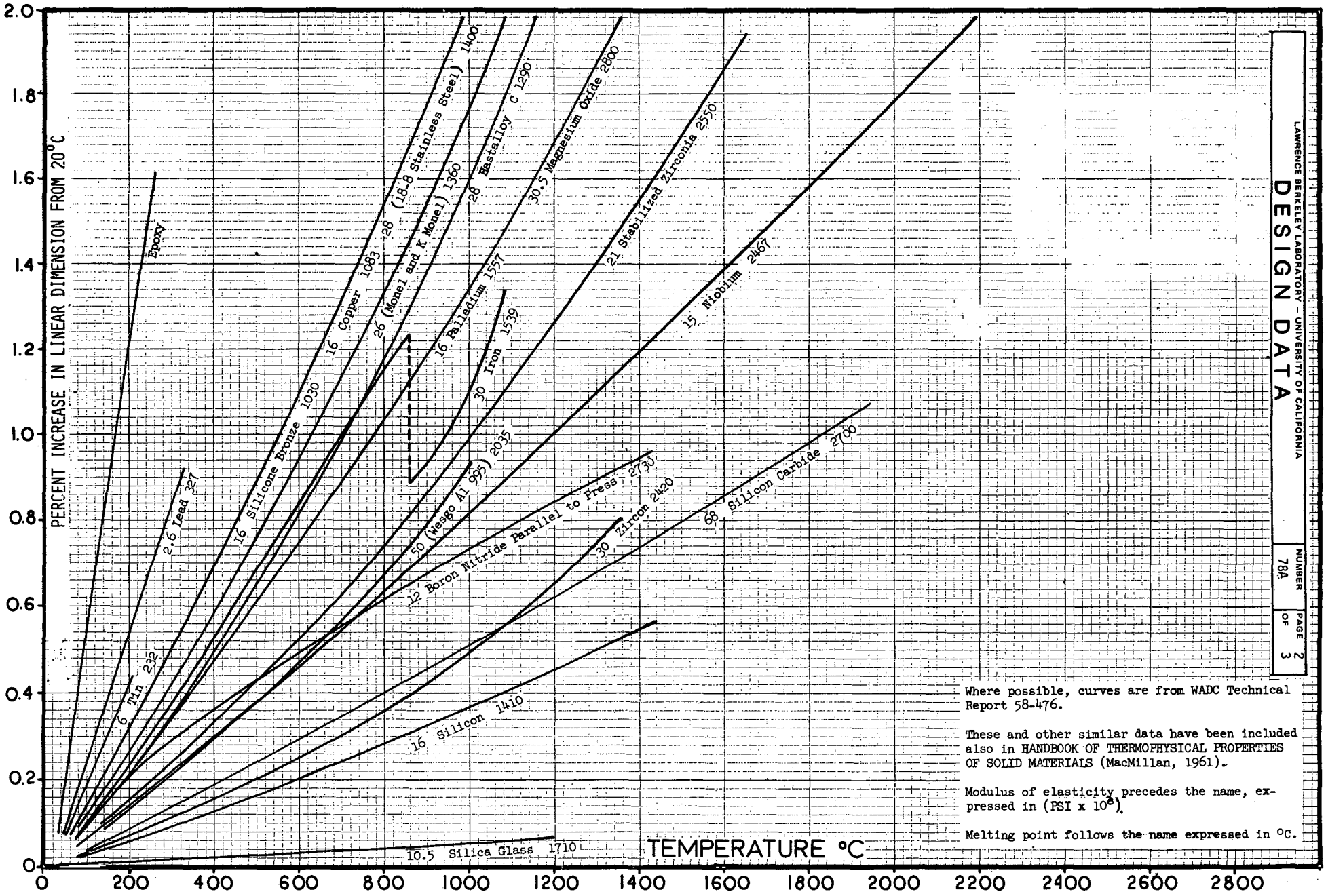


Where possible, curves are from WADC Technical Report 58-476.

These and other similar data have been included also in HANDBOOK OF THERMOPHYSICAL PROPERTIES OF SOLID MATERIALS (MacMillan, 1961).

Modulus of elasticity precedes the name, expressed in (PSI x 10^6).

Melting point follows the name expressed in °C.



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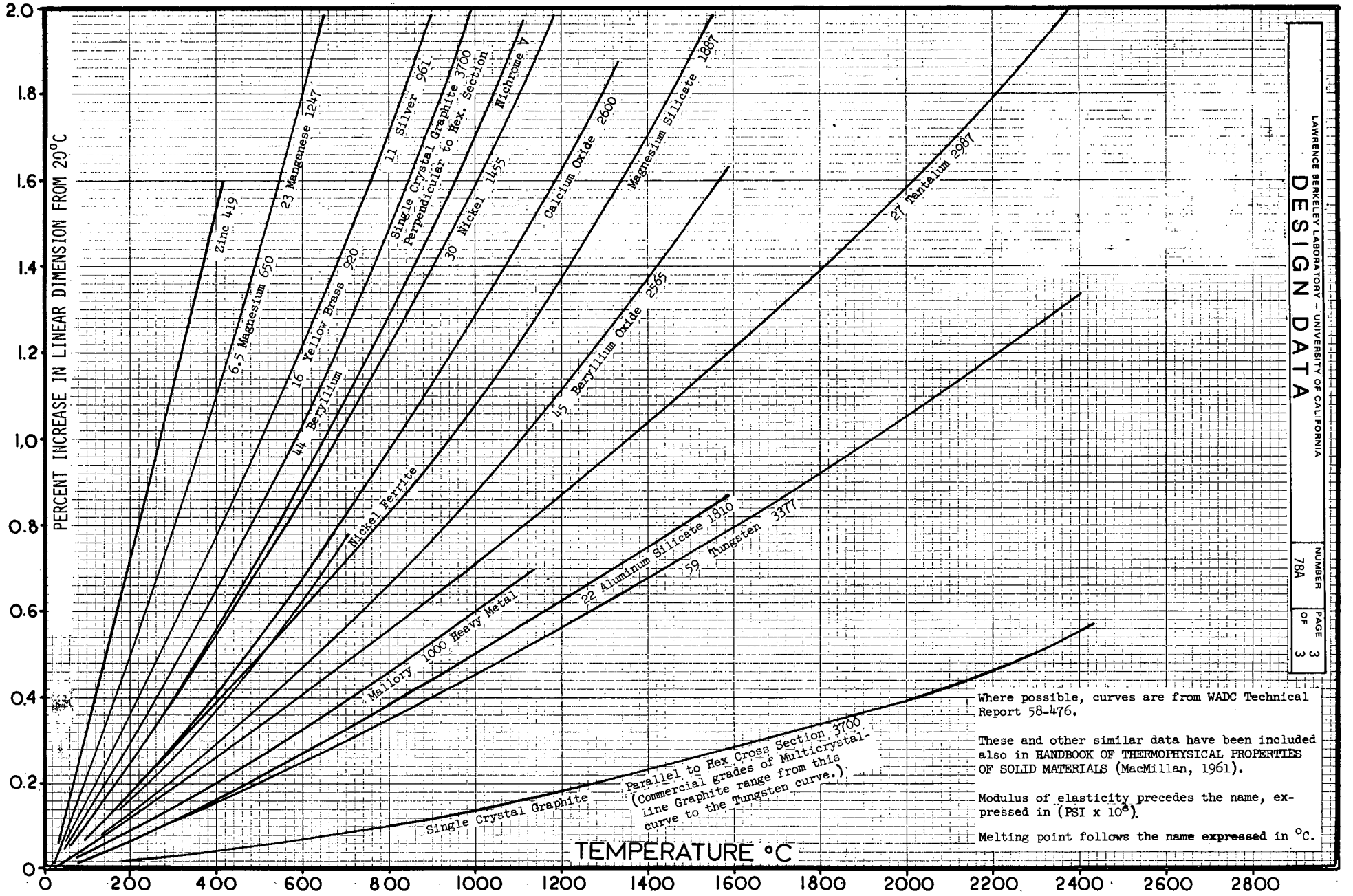
Melting point follows the name expressed in °C.

LAWRENCE BERKELEY LABORATORY – UNIVERSITY OF CALIFORNIA

DESIGN DATA

NUMBER 78A

PAGE 2 OF 3



Where possible, curves are from WADC Technical Report 58-476.

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Modulus of elasticity precedes the name, expressed in (PSI x 10^6).

Melting point follows the name expressed in °C.

LAWRENCE BERKELEY LABORATORY – UNIVERSITY OF CALIFORNIA

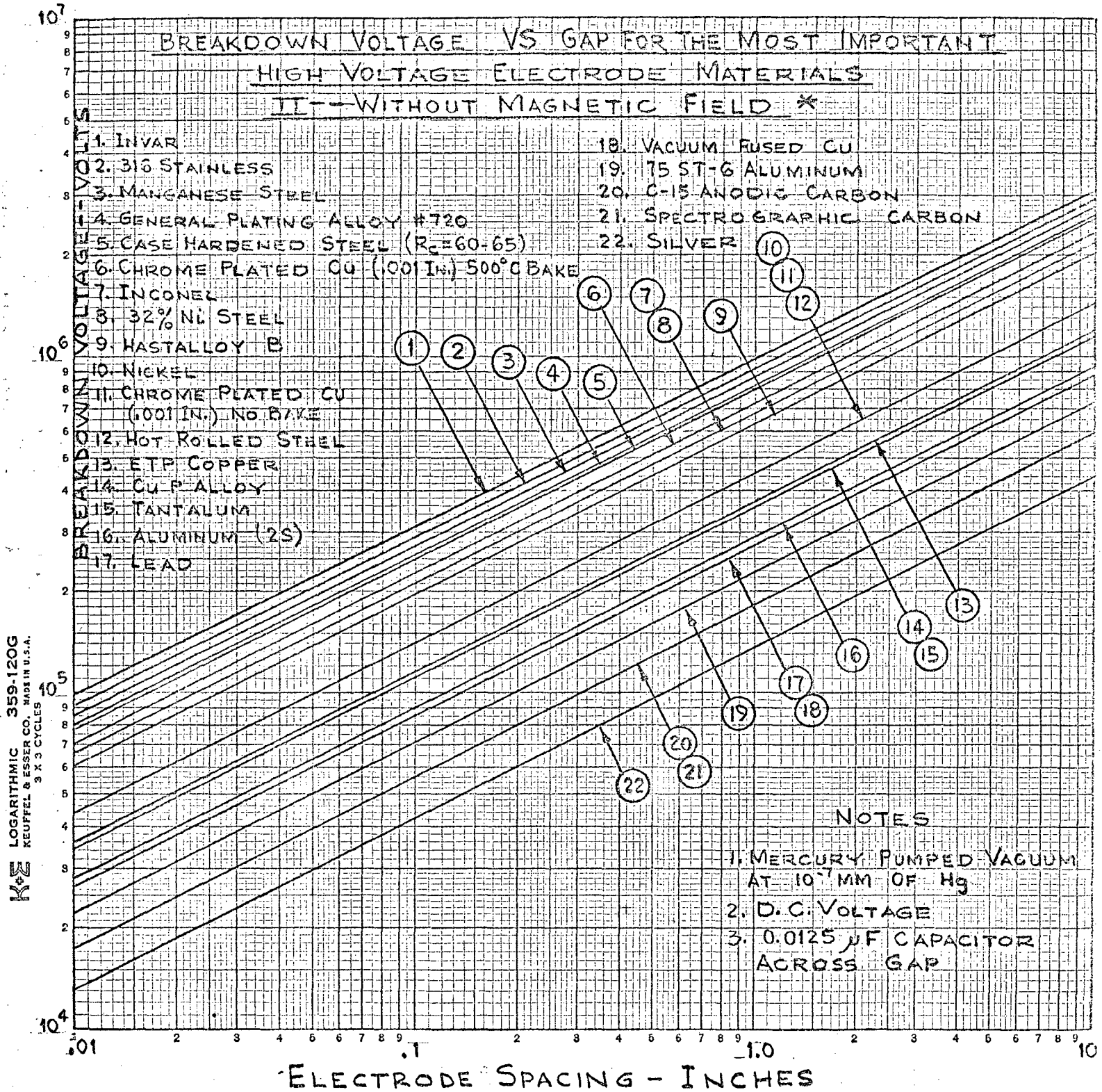
DESIGN DATA

NUMBER 78A

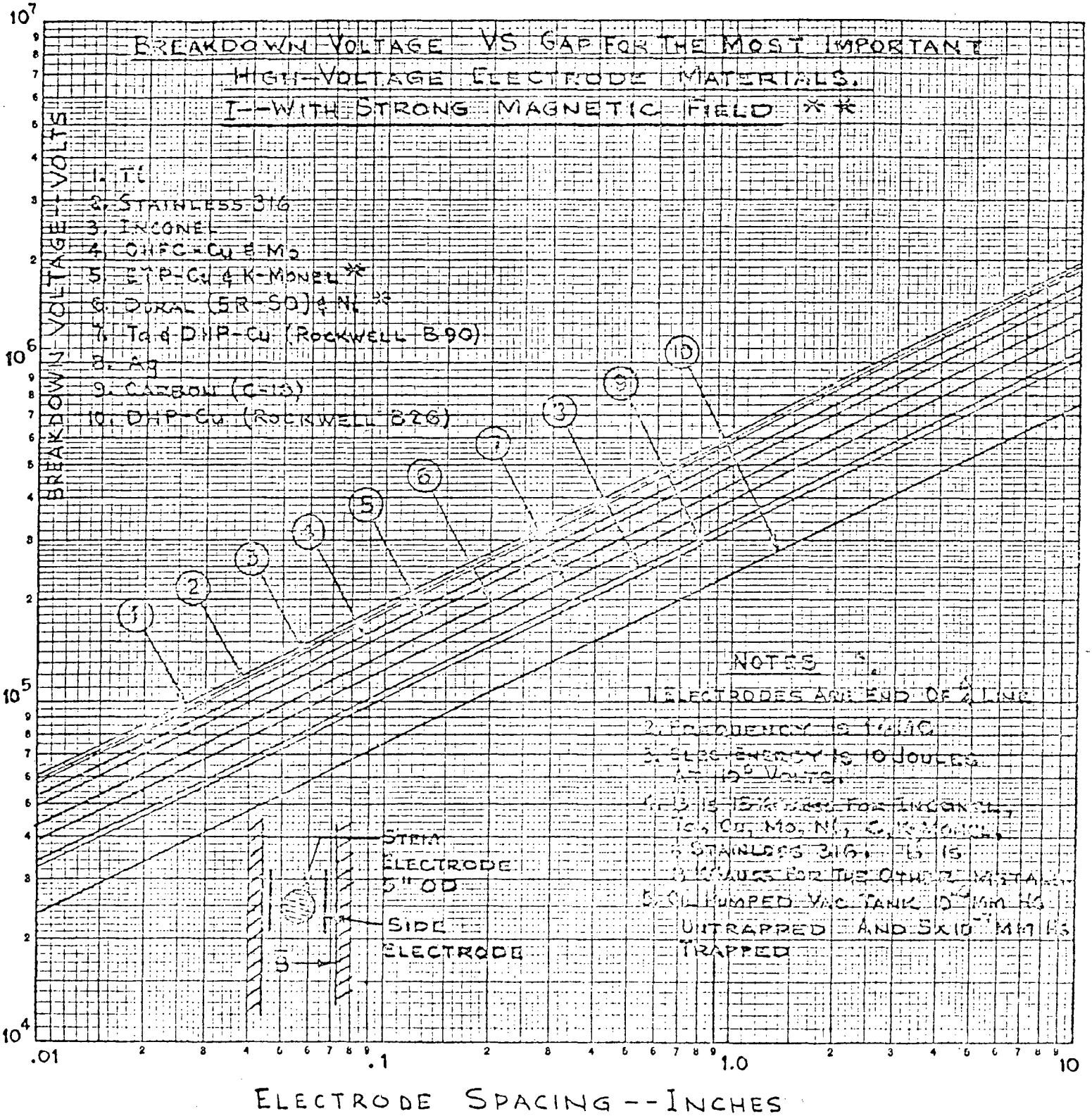
PAGE 3 OF 3

Lawrence Radiation Laboratory

DESIGN DATA NO. 79
Bob H. Smith
May 1964



* DATA FROM UCRL-2252 BY H. HEARD - JUNE 29, 1953

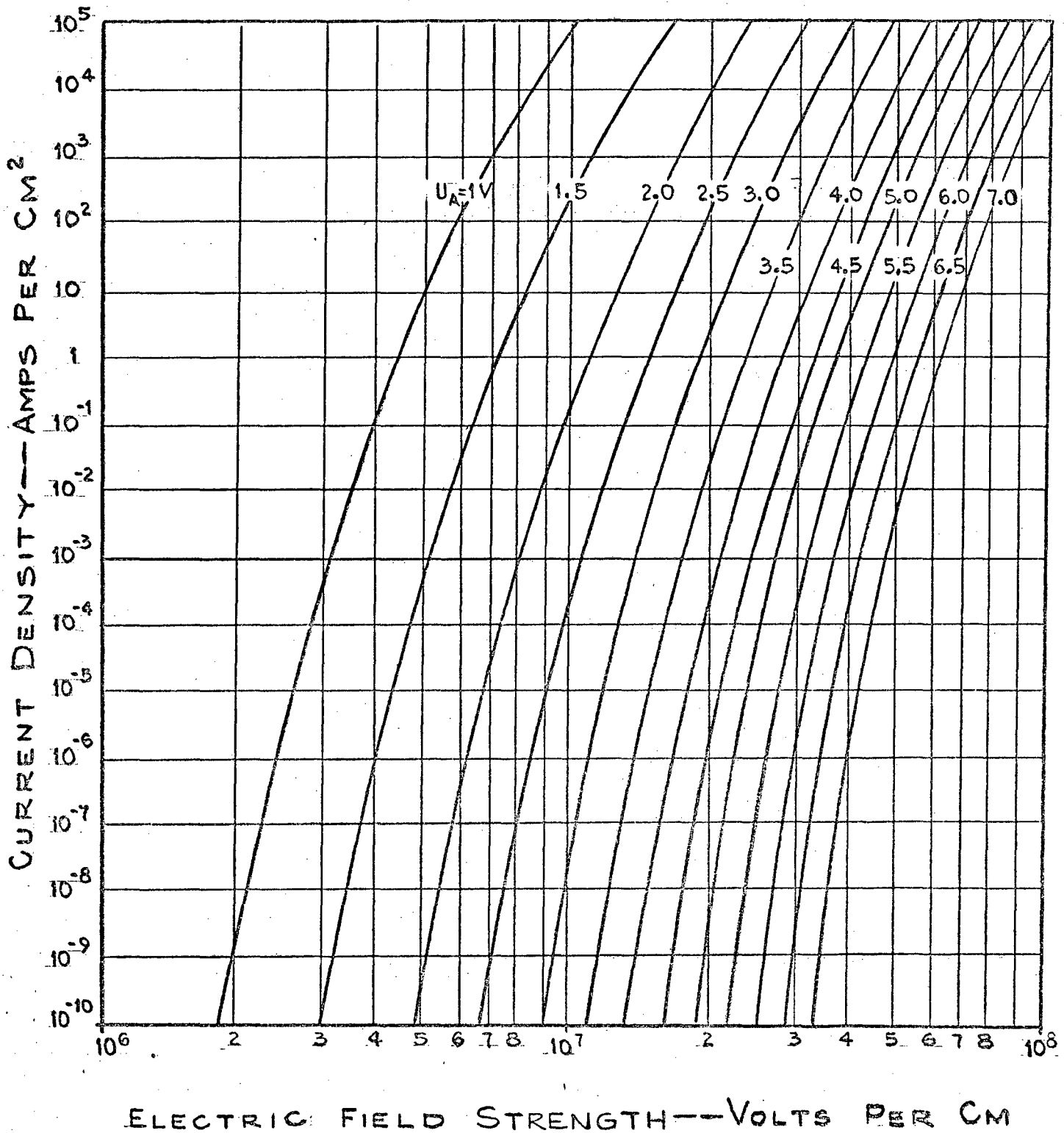


* TEST LIMITED BY RF POWER. VE COEFFICIENT MAY BE HIGHER

** DATA FROM UCRL 1962 - W. CHAPP & H. HEARD (9-24-52) & UCRL-2053

UNIVERSAL FIELD EMISSION CHART

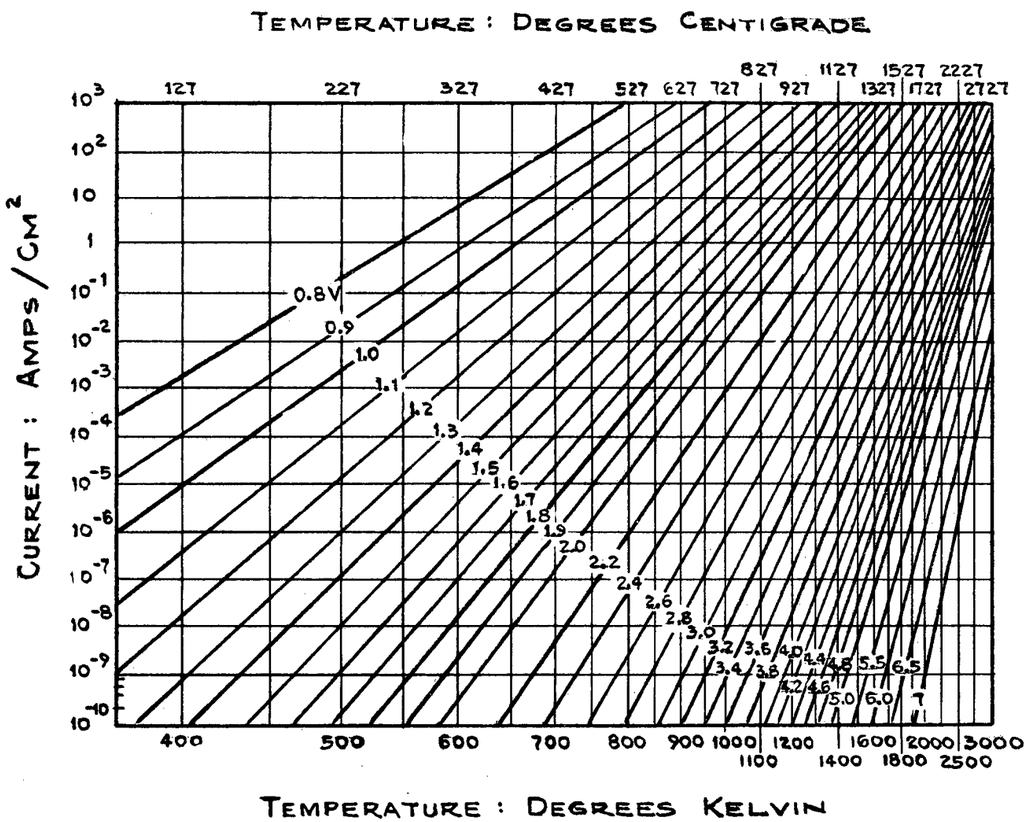
U_A = WORK FUNCTION OF SURFACE MATERIAL *



* FROM: TABELLEN DER ELEKTROMENPHYSIK
IONENPHYSIK AND ÜBERMIKROSKOPIE
MANFRED VON ARDENNE

UNIVERSAL EMISSION CHART *

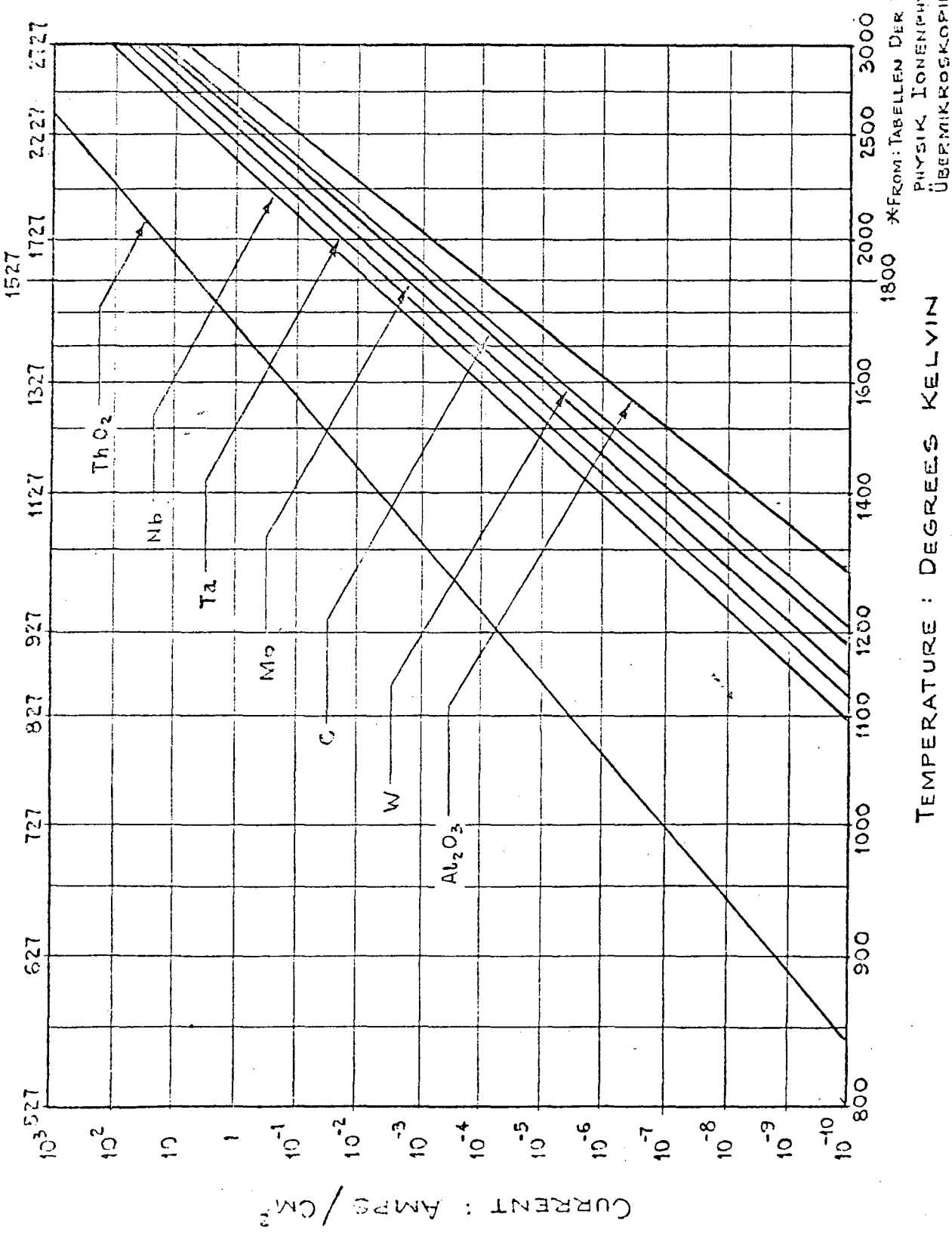
THERMIONIC EMISSION AS A FUNCTION OF TEMPERATURE AND WORK FUNCTION



MATERIAL	WORK FUNCTION (VOLTS)	MATERIAL	WORK FUNCTION (VOLTS)	MATERIAL	WORK FUNCTION (VOLTS)
Cs	1.94	Cr	4.45	Cs_2O	1.08
		Cu	4.48	Ni Cs	1.36
Rb	2.13				
K	2.25			Ba O	1.57
Na	2.28	Ru	4.52	Sb Cs	1.84
Li	2.46	W	4.53		
Ba	2.52	Hg	4.53	Sr O	2.03
Pr	2.70	Os	4.55	Ca O	2.34
Sr	2.74	Sb	4.56		
		Ir	4.57	$Ce B_6$ [2]	2.59
Ce	2.88	B	4.60	$La B_6$	2.66
Sm	3.20	Ge	4.62	$Sr B_6$	2.67
Ca	3.20	Fe	4.63	NH_4-AMALGAM	2.83
La	3.30	Rh	4.65	$Ca B_6$	2.86
U	3.45	Ag	4.70	$Th B_6$	2.92
Th	3.47	Au	4.71	$Th O_2$	2.96
		Te	4.73		
Si	3.59	As	4.79	$Pr B_6$	3.12
Mg	3.70	Se	4.87	$Y_2 O_3$	3.30
Be	3.92	Ni	4.91	$Ba B_6$	3.45
Zr	3.93	Re	4.97		
Mn	3.95	Pd	4.98	$Ag_2 S$	~3.82
Nb	3.99			Ag Br	~3.9
				Ag J	~3.96
Cd	4.04	Pt I	5.36	$Zr O_2$	4.20
Pb	4.04			Na Cl	4.2
Tl	4.05			Mg O	4.4
V	4.11				
Ta	4.13			$Nd B_6$	4.57
Ti	4.16			Ag Cl	~4.6
Ga	4.16			$Ti O_2$	4.7
Al	4.20			$Al_2 O_3$	4.7
Mo	4.24			Be O	4.7
Co	4.25				
Zn	4.27			$Si O_2$	5.0
Bi	4.34			Cu_2O	5.15
C	4.36			Cu O	5.34
Sn	4.39				

* FROM : TABELLEN DER ELECTRONENPHYSIK IONENPHYSIK AND ÜBERMIKROSKOPIE MANFRED VON ARDENNE

THERMIONIC EMISSION FOR MOST USUAL HIGH TEMPERATURE MATERIALS*



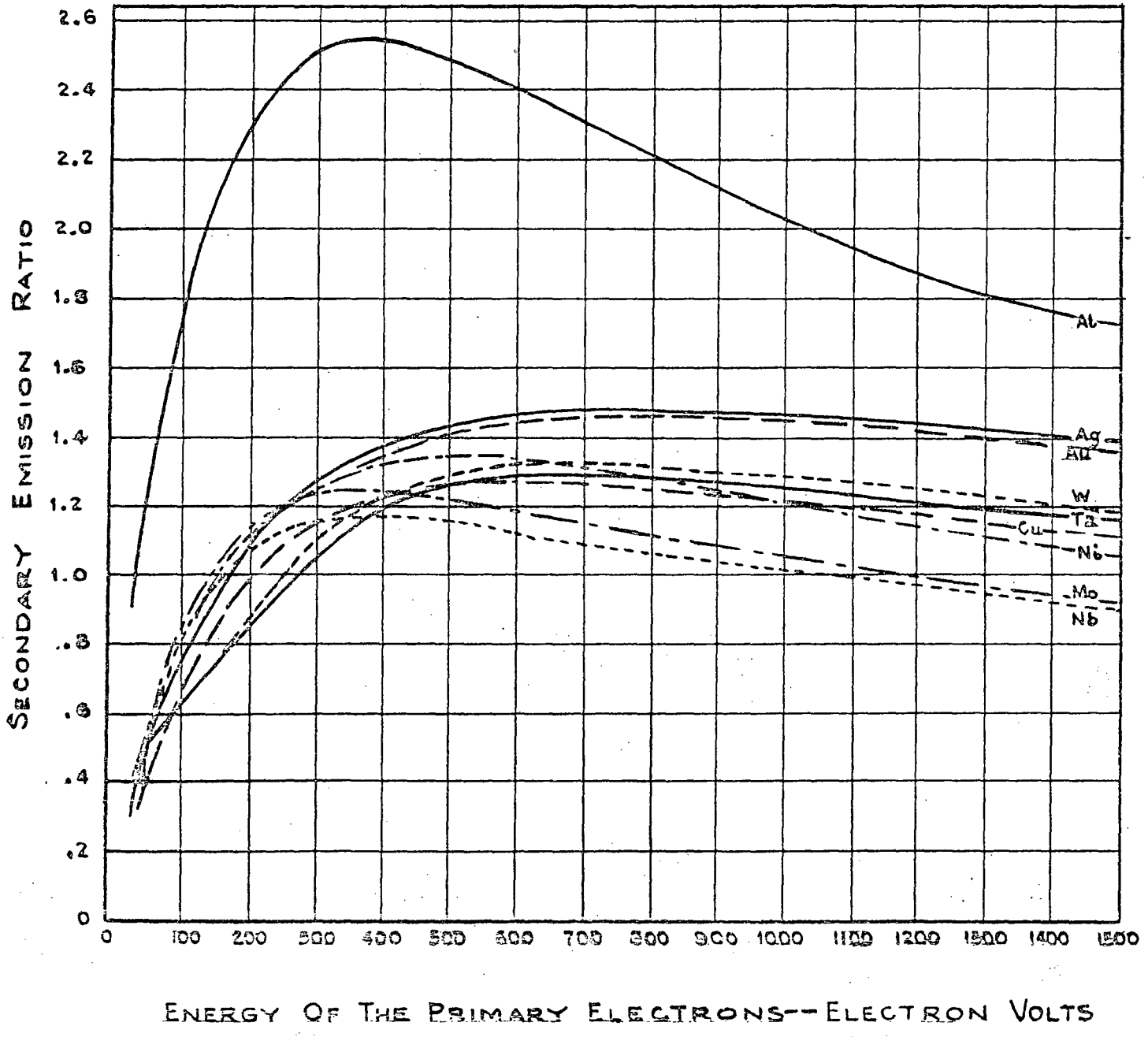
*FROM: TABELLEN DER ELEKTRONEN-PHYSIK IONENPHYSIK AND ÜBERMIKROSKOPIE MANFRED VON ARDENNE

MATERIAL CONSTANTS WHICH DETERMINE ELECTRON EMISSION*

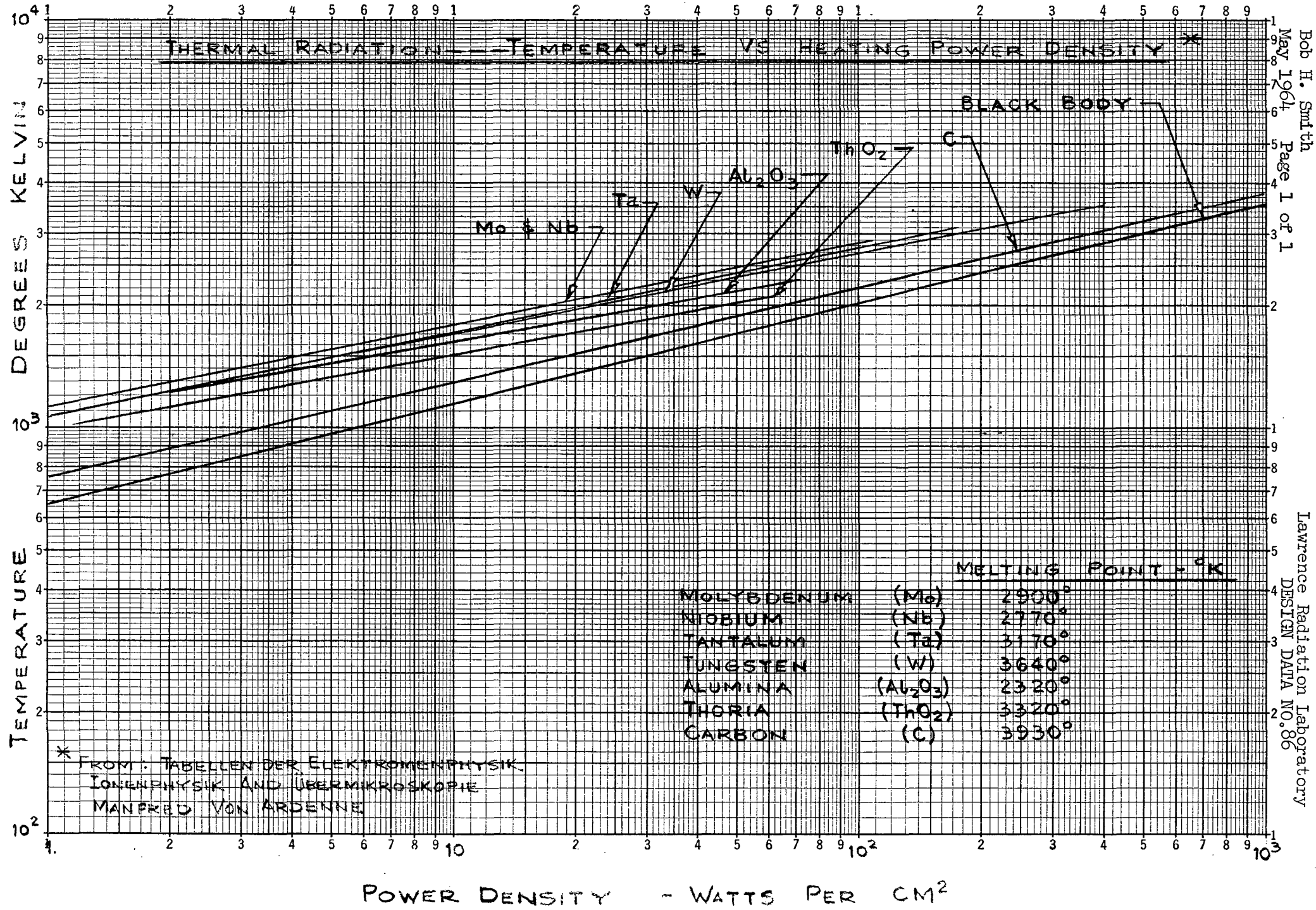
Material	Work Function	Maximum Secondary Emission Ratio	Maximum Secondary Emission Voltage	Maximum Wave Length Photoemission (Angstroms)
Ag	4.7	1.47	800	2640
Al	4.2	.97	300	2950
As	4.79			2590
Au	4.71	1.47	700	2630
B	4.60	1.20	150	2690
Ba	2.52	.90	400	4920
Be	3.92	0.6-0.9	200	3160
Bi	4.34	1.35	500	2850
C (smooth)	4.36	1.02	300	2840
C (rough)	4.36	.45	460	2840
Ca	3.2			3870
Cd	4.04	1.10	400	3070
Ce	2.88			4300
Co	4.25			2920
Cr	4.45			2780
Cs	1.94	.76-.90	400	6390
Cu	4.48	1.35	500	2770
Fe	4.63	1.32	400	2675
Ge	4.62	1.20	400	2680
Hg	4.53	1.05	600	2730
Ir	4.57			2710
K	2.25	.69	300	5510
Li	2.46	.55	100	5040
Mg	3.70	.95	300	3350
Mn	3.95			3140
Mo	4.24	1.23	400	2920
Na	2.28			5430
Nb	3.99	1.18	400	3110
Ni	4.91	1.27	500	2520
Pb	4.04	1.08	500	3070
Pd	4.98			2490
Pt	5.36	1.78	700	2320
Rb	2.13	0.85	400	5820
Re	4.97	1.30	800	2490
Rh	4.65			2660
Ru	4.52			2740
Sb	4.56			2715
Se	4.87			2540
Si	3.59	1.10	250	3450
Sn	4.39	1.35	500	2820
Sr	2.74			4520
Ta	4.13	1.1-1.35	500	3000
Te	4.73			2620
Th	3.47	1.10	800	3570
Ti	4.16	.85	280	2980
U	3.45			3590
W	4.53	1.43	700	2730
Zn	4.27			2900
Zr	3.93	1.1	300	3150
Ag_2O		.88	500	
Al_2O_3	4.7	2.60	250	2630
Ba O		4.5-12	500-800	
Be O	4.7	3.5-10	400-800	2630
Ca O	2.34	5.0	600	5200
Cu_2O	5.15	1.2	500	2400
Mg O	4.4	4-9	600	2808
Mo O		1.1	450	
Zn O		2.0		
Cs_2O-Cs	1.08	8-10	600-800	11400
Th O_2	2.96			4180
Ti O_2	4.7			2630
NaCl-Cs		23.0	1400	
NaCl	4.2	6.8		2940
Zn S		1.5	500	
Ag_2S	3.82			3100

*FROM: TABELLEN DER ELEKTROMENPHYSIK IONENPHYSIK AND ÜBERMIKROSKOPIE
MANFRED VON ARDENNE

SECONDARY EMISSION OF VARIOUS METALS *



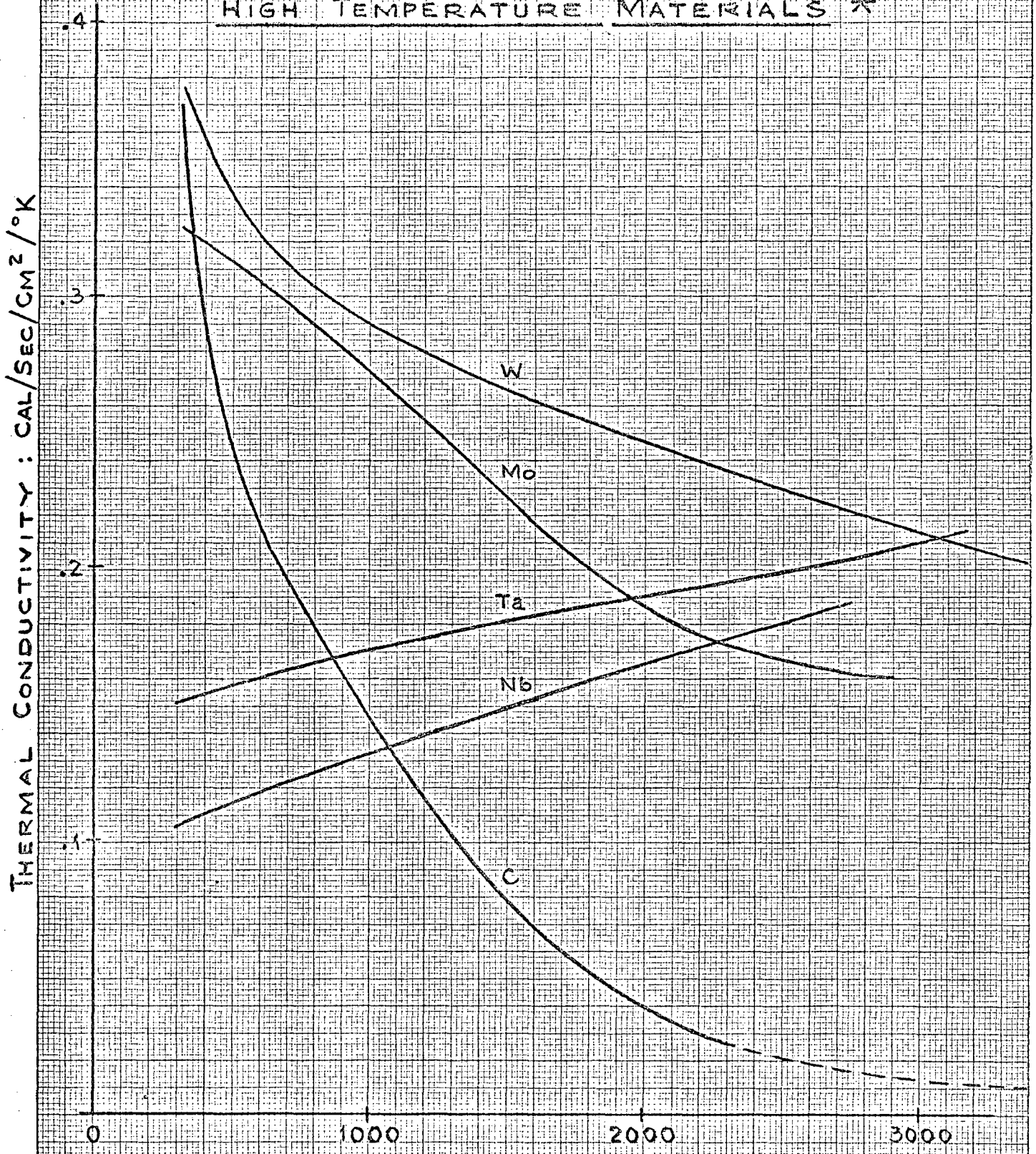
* FROM : TABELLEN DER ELEKTROMENPHYSIK
IONENPHYSIK AND ÜBERMIKROSKOPIE
MANFRED VON ARDENNE



Bob H. Smith
May 1964
Page 1 of 1

Lawrence Radiation Laboratory
DESIGN DATA NO. 86

THERMAL CONDUCTIVITY VS TEMPERATURE FOR THE MOST IMPORTANT HIGH TEMPERATURE MATERIALS *



* HANDBOOK OF THERMOLPHYSICAL PROPERTIES OF SOLID MATERIALS – GOLDSMITH, WATERMAN, HIRSCHHORN VOL. 1 – MACMILLAN CO. 1961

359-14G KEUFFEL & ESSER CO.
Millimeters, 5 mm. lines accented, cm. lines heavy.
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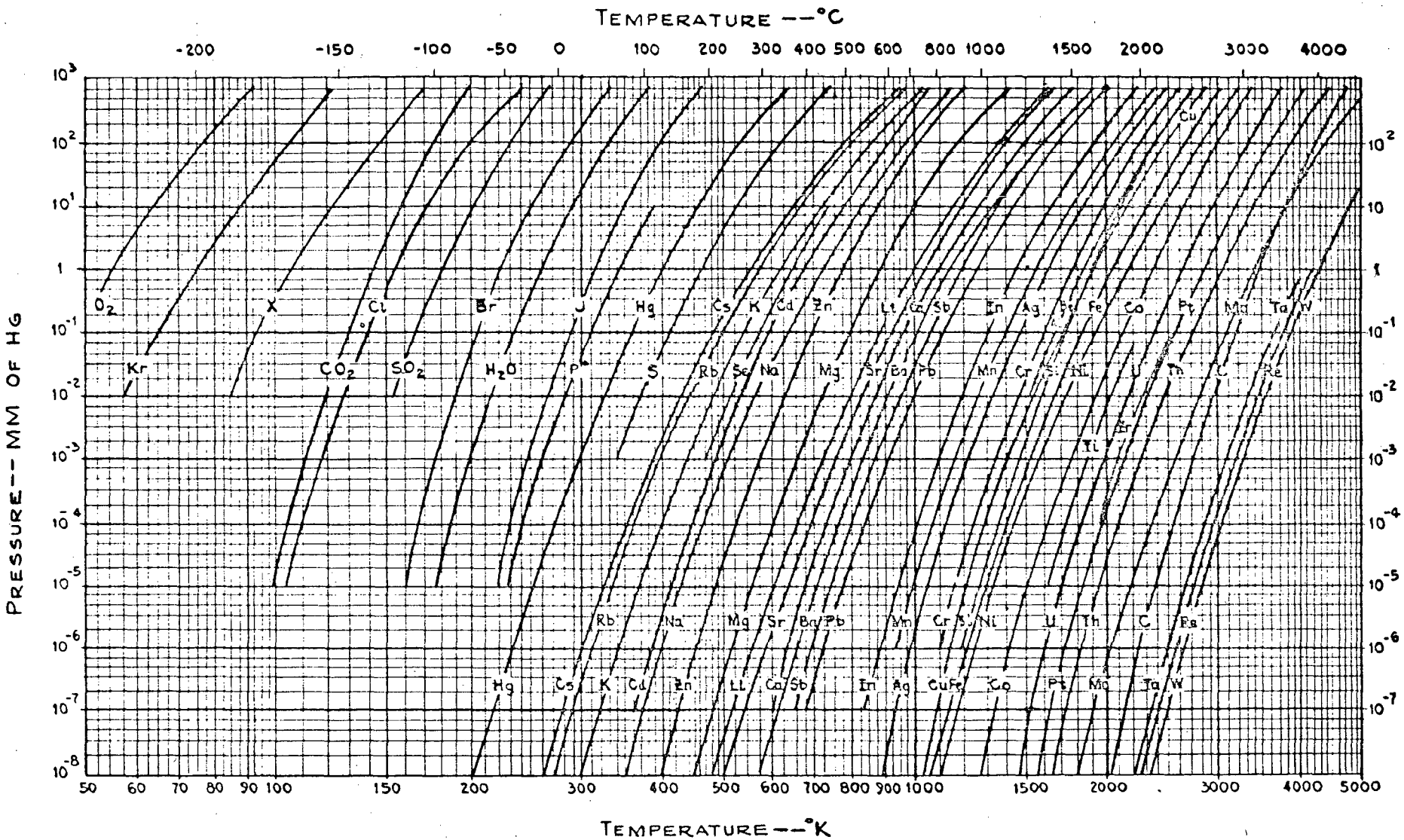
Lawrence Radiation Laboratory

THE SATURATION VAPOR PRESSURE AS A FUNCTION OF TEMPERATURE FOR THE MOST IMPORTANT ELEMENTS OF HIGH VACUUM TECHNIQUE *



* FROM: TABELLEN DER ELEKTRONENPHYSIK IONENPHYSIK AND ÜBERMIKROSKOPIE MANFRED VON ARDENNE

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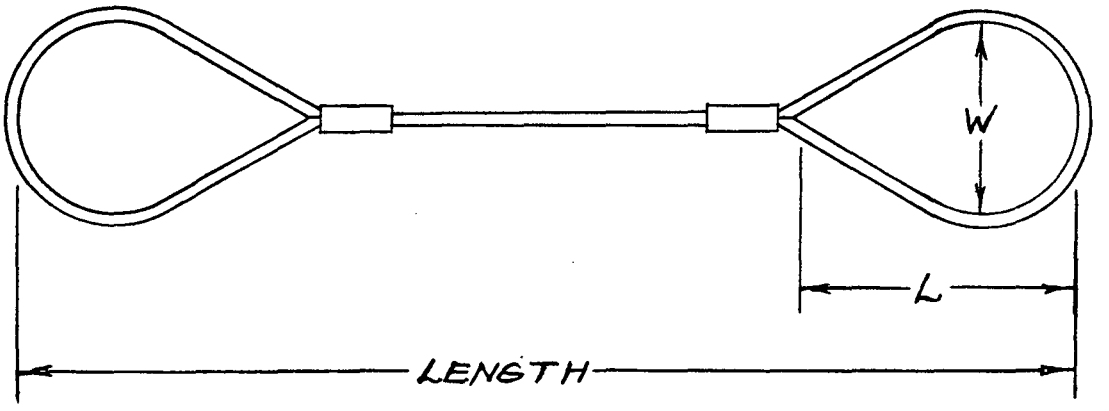
DESIGN DATA

NUMBER	PAGE 1 OF 1
90A	

TITLE	PREPARED BY	DATE
STANDARD WIRE ROPE SLING SINGLE LEG WITH END LOOPS UCLBL STANDARD CRANE LIFTING EQUIPMENT	I. Halpern	12/8/64
	REVISED BY P. Bringham	DATE 4/78
	REVISED BY	DATE



ROPE Diameter Inches	IWRC Construction	Rated Capacity Pounds	W Inches	L Inches	STOCK LENGTHS Ft. +1/4", -0
1/4	6 x 19	1100	4 1/2	9	3, 4, 6, 8, 10, 12
3/8	6 x 19	2400	5 1/2	11	3, 4, 6, 8, 10, 12
1/2	6 x 19	4400	7	14	4, 6, 8, 10, 12
5/8	6 x 19	6800	8	16	4, 6
3/4	6 x 19	9800	9	18	6, 8, 10

NOTES

1 - Material to be Plow Steel or better
2 - Non-galvanized IWRC Construction Wire Rope
3 - Stainless steel cast sleeves or UCLBL approved
4 - 5/1 Safety factor (Breaking strength to rated capacity)
5 - Loop formed by rope end opened up into two groups of 3 strands each and laid back together at junction such that each group encircles through rope in opposite direction
6 - LBL use of wire rope slings restricted to those constructed per LBL Specification M464

(From "American Institute of Physics Handbook" Second Edition, D. E. Gray, Ed. Copyright 1957, 1963, by permission of McGraw-Hill Book Co.)

Gas or N_2 vapor mixture saturated at 23°C and 760 mm Hg total pressure	Pressure of vapor, mm Hg	Relative dielectric strength
Fluorotrichloromethane, CCl_3F	725	3.0
Tetrafluorodichloroethane, $C_2Cl_2F_4$	760	2.8
Trifluorotrichloroethane, $C_2Cl_3F_3$	306	2.6
Sulfur hexafluoride, SF_6	760	2.41†
Difluorodichloromethane, CCl_2F_2	760	2.4
Boron trichloride, BCl_3	760	2.3
Methyl iodide, CH_3I	370	2.2
Sulfur dioxide, SO_2	760	1.9
Phosphorus trichloride, PCl_3	113	1.9
Thionyl chloride, $SOCl_2$	110	1.65
Carbon tetrachloride, CCl_4	105	1.65
Chloroform, $CHCl_3$	180	1.58
Sulfuryl chloride, SO_2Cl_2	...	1.56
Chlorine, Cl_2	760	1.55
Carbon disulfide, CS_2	330	1.50
Fluorodichloromethane, $CHCl_2F$	760	1.33
Hydrogen sulfide, H_2S	760	1.30
Ethylene, C_2H_4	760	1.21
Titanium tetrachloride, $TiCl_4$	12	1.17
Methyl formate, $HCOOCH_3$	570	1.16
Trichloroethylene, $CHCl{:}CCl_2$	65	1.15
Nitrous oxide, N_2O	760	1.14
Phosphoryl chloride, $POCl_3$	34	1.11
Dichloromethane, CH_2Cl_2	400	1.11
Acetylene, C_2H_2	760	1.10
Trichloroethane, $CH_2ClCHCl_2$	...	1.08
Ethyl amine, $C_2H_5NH_2$	760	1.06
Chloromethane, CH_3Cl	760	1.06
Dimethyl amine, $(CH_3)_2NH$	760	1.04
Acetaldehyde, CH_3CHO	760	1.03
Fluorochloromethane, CH_2ClF	...	1.03
Carbon monoxide, CO	760	1.02
Tetrachloroethane, $CHCl_2CHCl_2$	6.8	1.02
Sulfur dichloride, S_2Cl_2	12.5	1.02
Nitrobenzene, $C_6H_5NO_2$	0.3	1.02
Methyl bromide, CH_3Br	760	1.02
Ethyl ether, $(C_2H_5)_2O$	495	1.00

*The relative dielectric strength is defined as the ratio of dielectric strength of the gas or nitrogen-vapor mixture to that of nitrogen at atmospheric pressure and room temperature, when measured in the same gap. Taken from Charlton and Cooper, Gen. Elec. Rev. 40,438 (1937).

†Hochberg and Sandberg, J. Tech. Phys.(U.S.S.R.) 12,65 (1942).

‡Landolt-Börnstein, "Physikalisch-Chemischen Tabellen," vol. III, p. 1264.

SUBJECT

RELATIVE DIELECTRIC STRENGTHS OF VARIOUS GASES AND NITROGEN-VAPOR MIXTURES*

PREPARED Bob H. Smith

CHECKED BY

(From "American Institute of Physics Handbook" Second Edition, D. E. Gray, Ed. Copyright 1957, 1963, by permission of McGraw-Hill Book Co.)

Gas or N_2 vapor mixture saturated at 23°C and 760 mm Hg total pressure	Pressure of vapor, mm Hg	Relative dielectric strength
Methane, CH_4	760	1.00
Ethyl alcohol, C_2H_5OH	52	1.00
Dichloroethane, CH_2ClCH_2Cl	70	1.00
Ethyl chloride, C_2H_5Cl	760	1.00
Nitromethane, CH_3NO_2	34	1.00
Benzoyl chloride, C_6H_5COCl	est. 0.2	1.00
Thioacetic acid, CH_3COSH	...	1.00
Acetone, CH_3COCH_3	210	0.98
Dibromoethane, CH_2BrCH_2Br	12.5	0.98
Air	760	0.97‡
Methyl acetate, CH_3COOCH_3	195	0.95
Ethylene oxide, $\underset{\underset{O}{\llcorner\!\lrcorner}}{CH_2\ CH_2}$	760	0.95
Benzaldehyde, C_6H_5CHO	0.6	0.95
Acetic acid, CH_3COOH	14	0.94
Methyl alcohol, CH_3OH	110	0.94
Formaldehyde, CH_2O	760	0.93
Bromobenzene, C_6H_5Br	ca. 4	0.93
Ethyl acetate, $CH_3COOC_2H_5$	86	0.91
Tetrachloroethylene, $CCl_2{:}CCl_2$	ca. 18	0.90
Carbon dioxide, CO_2	760	0.88
Aniline, $C_6H_5NH_2$	ca. 0.3	0.87
Oxygen, O_2	760	0.86‡
Toluene, $C_6H_5CH_3$	25	0.86
Benzene, C_6H_6	85	0.84
Ammonia, NH_3(over NH_4OH)	...	0.82
Chlorobenzene, C_6H_5Cl	10.5	0.81
Methylamine, CH_3NH_2	760	0.81
Diethyl amine, $(C_2H_5)_2NH$	215	0.78
Difluoromethane, CH_2F_2	...	0.69
Hydrogen, H_2	760	0.54‡

*The relative dielectric strength is defined as the ratio of dielectric strength of the gas or nitrogen-vapor mixture to that of nitrogen at atmospheric pressure and room temperature, when measured in the same gap. Taken from Charlton and Cooper, Ge. Elec. Rev. 40,438 (1937).

†Hochberg and Sandberg, J. Tech. Phys.(U.S.S.R.) 12,65 (1942).

‡Landolt-Börnstein, "Physikalisch-Chemischen Tabellen," vol. III, p. 1264.

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TABLE OF IONIZATION POTENTIALS OF THE ELEMENTS

ROM Finkelnburg-Humbach, Ionization energies of atoms and atom ions. Naturwiss. 42, 35, 1955, and Lisitzin, Soc. Sci. fenn. Comment. physico-math. 10, vol 4, 1938.

EGEND Z = Atomic number of the element. W_{I_1} = Ionization potential for the neutral unexcited atom in Joules/Kilomole $\times 10^4$.

eU_{I_1} = Ionization potential of the neutral unexcited atom in eV. eU_{I_2} = Ionization potential of the singly unexcited atom in eV.

eU_{I_3} = Ionization potential of the doubly unexcited atom in eV, etc.

Figures in italics are measured values. Figures in [ ] are values measured approximately. Figures in straight type are extrapolated values. Figures in ( ) are by Lisitzin with approximation formula to about ± 3% of calculated values.

Z	Element	W_{I_1}	eU_{I_1}	eU_{I_2}	eU_{I_3}	eU_{I_4}	eU_{I_5}	eU_{I_6}	eU_{I_7}	eU_{I_8}	eU_{I_9}	$eU_{I_{10}}$	$eU_{I_{11}}$	$eU_{I_{12}}$	$eU_{I_{13}}$	$eU_{I_{14}}$	$eU_{I_{15}}$	$eU_{I_{16}}$	$eU_{I_{17}}$	$eU_{I_{18}}$	$eU_{I_{19}}$	$eU_{I_{20}}$
1	H	1311.3	*13.5976*	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
2	He	2371.0	*24.580*	*54.400*	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
3	Li	520.0	*5,390*	*75,62*	*122,42*	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
4	Be	898.9	*9.320*	*18.21*	*153.85*	*217.66*	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
5	B	800.1	*8.296*	*25.15*	*37.92*	*259.30*	*340,13*	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
6	C	1086.5	*11.264*	*24,376*	*47.86*	*64,48*	*391,99*	*489.84*	—	—	—	—	—	—	—	—	—	—	—	—	—	—
7	N	1402.6	*14.54*	*29.60*	*47.426*	*77.45*	*97.86*	*551,93*	*666.83*	—	—	—	—	—	—	—	—	—	—	—	—	—
8	O	1313.4	*13.614*	*35.15*	*54.93*	*77.39*	*113.87*	*138.08*	*739.11*	*871.12*	—	—	—	—	—	—	—	—	—	—	—	—
9	F	1680.2	*17.418*	*34.98*	*62.65*	*87.23*	*114.21*	*157.12*	*185.14*	935.8 ± 0.3	1101,8	—	—	—	—	—	—	—	—	—	—	—
10	Ne	2079,6	*21,559*	*41,07*	63,5 ± 0.1	*97.16*	*126,4*	*157.9*	207,2 ± 0,1	239,1 ± 0.1	1195,4 ± 0,3	1360.2	—	—	—	—	—	—	—	—	—	—
11	Na	495.7	*5.138*	*47.29*	71.8 ± 0.1	*98.88*	*138.6*	*172.4*	*208,44*	264,2 ± 0,1	299.7 ± 0,1	1464,7 ± 0,3	1645,9	—	—	—	—	—	—	—	—	—
12	Mg	737.3	*7.644*	*15,03*	78,2 ± 0.1	*109.3*	*141,23*	186.8 ± 0.1	*225,3*	*265,84*	328,0 ± 0.1	367,2 ± 0.1	1761,2 ± 0.3	1958,7	—	—	—	—	—	—	—	—
13	Al	577.4	*5.984*	*18.82*	*28.44*	*119.96*	*153.8*	*190.42*	241,8 ± 0.1	*285.13*	*330,1*	398.6 ± 0.1	441.5 ± 0.1	2071.3 ± 0.6	2298.8	—	—	—	—	—	—	—
14	Si	786.3	*8.149*	*16.34*	*33,46*	*45.13*	*166.73*	*205,1*	*246,41*	304,0 ± 0.1	*351,8*	*401.3*	475.9 ± 0.2	522.8 ± 0.2	2436.0 ± 0.9	2666.0	—	—	—	—	—	—
15	P	1017.8	*10.55*	*19.65*	*30.16*	*51.35*	*65.01*	*220.41*	*263,3*	309.3 ± 0,1	*372.8* ± 0.2	*425.4*	476 ± 3	560.0 ± 0.2	610.7 ± 0,3	2815 ± 1	3060.5	—	—	—	—	—
16	S	999.0	*0.357*	*23.4*	*34.8*	*47,29*	72,5 ± 0.1	88.0 ± 0,1	*280.99*	328.4 ± 0.1	*278.9*	448.5 ± 0,2	505,6 ± 0,2	567 ± 4	651.4 ± 0,2	705.5 ± 0.4	3220 ± 2	3482.2	—	—	—	—
17	Cl	1255.2	*13.01*	*23.80*	*39.9*	*53,3*	67.8 ± 0.2	96,6 ± 0,3	114.2 ± 0,1	*348,5*	400,3 ± 0,1	*455.3*	530.9 ± 0.2	592.9 ± 0.3	667 ± 4	749,3 ± 0,2	806.9 ± 0.5	3654 ± 2	3931,0	—	—	—
18	Ar	1519.8	*15.755*	*27.6*	*40.90*	*59,79*	75.0 ± 0.1	91.3 ± 0.3	123.9 ± 0.4	143,4 ± 0.1	422,6 ± 0.2	479.0 ± 0.2	538.6 ± 0.2	620.4 ± 0.2	687.0 ± 0.4	754 ± 10	854.0 ± 0.3	915.7 ± 0.6	4115 ± 2	4407.1	—	—
19	K	418.7	*4.339*	*31.81*	*45.9*	*61,1*	82.6 ± 0.4	99,4 ± 0,4	117,9 ± 0,4	154.3 ± 0.6	476.0 ± 0.1	503.8 ± 0.3	562.7 ± 0,2	628.7 ± 0.2	716.7 ± 0.3	787.8 ± 0.5	878 ± 13	965.7 ± 0.3	1031 ± 1	4603 ± 3	4910.4	—
20	Ca	589.5	*6.111*	*11.87*	*51.21*	*67.3*	84 ± 1	109 ± 1	127.9 ± 0 5	143.3 ± 0.4	187,9 ± 0.7	211.3 ± 0.1	591.6 ± 0.3	656.9 ± 0.2	725.7 ± 0.3	819.8 ± 0.4	895.5 ± 0.6	990 ± 20	1084,3 ± 0,3	1153 ± 1	5119 ± 4	5440.9
21	Sc	632.6	*6.56*	*12.89*	*24.75*	*73.9*	91,8	111 ± 1	139 ± 1	159.2 ± 0.5	180,2 ± 0,5	224.9 ± 0,8	249.7 ± 0.2	686,4 ± 0,3	756.2 ± 0.2	829.5 ± 0.4	929.6 ± 0.5	1010,2 ± 0,6	1115 ± 20	1209,5 ± 0.4	1282 ± 1	5662 ± 5
22	Ti	658.6	*6.83*	*13.57*	*28.14*	*43,24*	*99.8*	119	141 ± 1	172 ± 1	193.1 ± 0,5	216.9 ± 0.6	265 ± 1	291.4 ± 0,2	788.1 ± 0.4	862,3 ± 0.3	940.0 ± 0,5	1046,5 ± 0,6	1132 ± 1	1245 ± 30	1341,5 ± 0,4	1418 ± 2
23	V	650.2	*6.74*	*14.2*	*29.7*	*46.0*	*65,2*	*128.9*	151	174 ± 1	206 ± 2	230.2 ± 0.6	260 ± 1	308 ± 1	336.1 ± 0.2	869.5 ± 0.5	975.1 ± 0.3	1057.3 ± 0.7	1170.3 ± 0.6	1260 ± 1	1380 ± 30	1440.6 ± 0.5

SUBJECT
EXCITATION AND IONIZATION POTENTIALS
(From "TABELLEN ZUR ANGEWANDTEN PHYSIK"
-- Manfred von Ardenne 1962)

LAWRENCE RADIATION LABORATORY
UNIVERSITY OF CALIFORNIA
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NO. 92

DATE 4-24-67

PAGE 1 OF 4

REQUESTED BY Bob H. Smith

CHECKED BY

TABLE OF IONIZATION POTENTIALS OF THE ELEMENTS (continued)

Z	Element	W_{I_1}	eV_{I_1}	eV_{I_2}	eV_{I_3}	eV_{I_4}	eV_{I_5}	eV_{I_6}	eV_{I_7}	eV_{I_8}	eV_{I_9}	$eV_{I_{10}}$	$eV_{I_{11}}$	$eV_{I_{12}}$	$eV_{I_{13}}$	$eV_{I_{14}}$	$eV_{I_{15}}$	$eV_{I_{16}}$	$eV_{I_{17}}$	$eV_{I_{18}}$	$eV_{I_{19}}$	$eV_{I_{20}}$
24	Cr	652.3	6.764	16.49	31	(51)	73	90.6	161.1	185	209 ± 1	246 ± 2	272 ± 1	299 ± 1	354 ± 1	383.9 ± 0.2	1011.8 ± 0.6	1094.8 ± 0.3	1181.9 ± 1.0	1301 ± 1	1395 ± 1	1525 ± 35
25	Mn	710.8	7.432	15.64	33.69	(53)	(76)	100 ± 1	190.24	196.4	221 ± 1	249 ± 1	288 ± 2	315 ± 1	244 ± 1	403 ± 1	434.7 ± 0.3	1134.0 ± 0.7	1221.7 ± 0.4	1313.0 ± 1	1438 ± 1	1537 ± 1
26	Fe	762.0	7.90	16.18	30.64	(56)	(79)	103 ± 1	130 ± 3	151	234.4 ± 0.5	262 ± 1	291 ± 1	333 ± 2	362 ± 1	392 ± 1	455 ± 1	488.4 ± 0.6	1263 ± 1	1354.8 ± 0.4	1450.5 ± 1.5	1582 ± 1
27	Co	758.2	7.86	17.05	33.49	(53)	(82)	(109)	133 ± 1	163 ± 5	185.9 ± 0.1	276.9 ± 0.6	306 ± 1	337 ± 1	381 ± 2	412 ± 1	444 ± 1	510 ± 2	545.5 ± 0.7	1399 ± 1	1494.7 ± 0.4	1595 ± 1.5
28	Ni	736.5	7.633	18.15	36.16	(56)	(79)	(113)	(143)	168 ± 2	200 ± 6	224 ± 1	321.0 ± 0.7	352 ± 1	385 ± 1	432 ± 2	465 ± 1	498 ± 2	529 ± 2	605 ± 1	1541 ± 1.0	1589.3 ± 0.5
29	Cu	745.3	7.724	20.29	36.83	(59)	(83)	(109)	(148)	(182)	206 ± 4	241 ± 8	265 ± 1	370 ± 1	401 ± 1	436 ± 1	486 ± 2	520 ± 1	557 ± 2	630 ± 2	669 ± 1	1691 ± 1
30	Zn	906.0	9.391	17.96	39.70	(62)	(86)	(114)	(144)	(188)	(224)	247 ± 6	—	311 ± 1	421 ± 1	451 ± 2	491 ± 1	543 ± 3	580 ± 1	619 ± 2	695 ± 2	735 ± 1
31	Ga	578.6	6.00	20.51	30.70	64.2	(90)	(118)	(149)	(183)	(231)	(271)	—	—	—	—	—	—	—	—	—	—
32	Ge	760.3	7.88	15.93	34.21	45.7	93.4	(123)	(155)	(189)	(226)	(280)	—	—	—	—	—	—	—	—	—	—
33	As	946.2	9.81	18.7 ± 0.1	28.3	50.1	62.9 ± 0.1	127.5	(160)	(196)	(234)	(274)	—	—	—	—	—	—	—	—	—	—
34	Se	940.4	9.75	21.5	32.0	42.9	68.3 ± 0.1	82.1 ± 0.2	155	(202)	(241)	(282)	—	—	—	—	—	—	—	—	—	—
35	Br	1142.2	11.84	21.6	35.9	47.3	59.7 ± 0.1	88.6 ± 0.2	103.0 ± 0.4	193	(248)	(291)	—	—	—	—	—	—	—	—	—	—
36	Kr	1350.3	13.996	24.56	36.9	52.5	64.7	78.5 ± 0.1	111.0 ± 0.4	126 ± 0.1	234	(300)	—	—	—	—	—	—	—	—	—	—
37	Rb	402.8	4.176	27.56	40	52.6	71.0	84.4	99.2 ± 0.1	136 ± 1	150 ± 2	277	—	—	—	—	—	—	—	—	—	—
38	Sr	548.9	5.692	11.026	43.6	57.1	71.6	90.8	106	122.3 ± 0.1	162 ± 1	177 ± 2	324	—	—	—	—	—	—	—	—	—
39	Y	615.5	6.38	12.23	20.5	61.8	77.0	93.0	116	129	146.2 ± 0.2	191 ± 1	206 ± 3	374	—	—	—	—	—	—	—	—
40	Zr	659.4	6.835	12.92	24.8	33.97	82.3	99.4	116	139	154	173.0 ± 0.2	222 ± 2	—	—	—	—	—	—	—	—	—
41	Nb	663.6	6.88	13.90	28.1	38.3	50	110.4	124	141	165	186	203.4 ± 0.2	—	—	—	—	—	—	—	—	—
42	Mo	687.9	7.131	15.72	29.6	46.4	61.2	67	131	153	167	194	210	—	—	—	—	—	—	—	—	—
43	Tc	697.5	7.32	14.87	31.9	(43)	(59)	(76)	(94)	161	183	195	224	—	—	—	—	—	—	—	—	—
44	Ru	710.1	7.36	16.60	30.3	(47)	(63)	(81)	(100)	(119)	192	216	225	—	—	—	—	—	—	—	—	—
45	Rh	719.7	7.46	15.92	32.8	(46)	(67)	(85)	(105)	(126)	(147)	225	250	—	—	—	—	—	—	—	—	—
46	Pd	803.5	8.33	19.42	(33)	(49)	(66)	(90)	(111)	(132)	(155)	(178)	261	—	—	—	—	—	—	—	—	—
47	Ag	730.6	7.574	21.48	36.10	(52)	(70)	(89)	(116)	(139)	(162)	(187)	—	—	—	—	—	—	—	—	—	—
48	Cd	867.5	8.991	16.904	44.5	(55)	(73)	(94)	(115)	(146)	(170)	(195)	—	—	—	—	—	—	—	—	—	—
49	In	858.1	5.785	18.86	28.0	58	(77)	(98)	(121)	(144)	(178)	(204)	—	—	—	—	—	—	—	—	—	—
50	Sn	707.2	7.332	14.6	30.7	46.4 ± 0.1	91	(103)	(126)	(151)	(176)	(213)	—	—	—	—	—	—	—	—	—	—

LAWRENCE RADIATION LABORATORY
UNIVERSITY OF CALIFORNIA
BERKELEY

DESIGN DATA

SUBJECT: EXCITATION AND IONIZATION POTENTIALS (From "TABELLEN ZUR ANGEWANDTEN PHYSIK" - - Manfred von Ardenne 1962)

REQUESTED BY: Bob H. Smith

CHECKED BY:

NO. 92

DATE 4-24-67

TABLE OF IONIZATION POTENTIALS OF THE ELEMENTS (continued)

Z	Element	WI_1	eU_{I_1}	eU_{I_2}	eU_{I_3}	eU_{I_4}	eU_{I_5}	eU_{I_6}	eU_{I_7}	eU_{I_8}	eU_{I_9}	$eU_{I_{10}}$	$eU_{I_{11}}$	$eU_{I_{12}}$	$eU_{I_{13}}$	$eU_{I_{14}}$	$eU_{I_{15}}$	$eU_{I_{16}}$	$eU_{I_{17}}$	$eU_{I_{18}}$	$eU_{I_{19}}$	$Ue_{I_{20}}$
51	Sb	833.6	*8.64*	16.7 ±0.5	*24.8*	*44.1*	63.8 ±0.5	119	(132)	(157)	(184)	(211)	—	—	—	—	—	—	—	—	—	—
52	Te	869.2	*9.01*	18.8 ±0.5	*31*	*38*	66 ±1	83 ±2	149	(164)	(192)	(220)	—	—	—	—	—	—	—	—	—	—
53	J	1006.9	*10.44*	*19.0*	*33*	(42)	71	83 ±2	104 ±3	182	(200)	(229)	—	—	—	—	—	—	—	—	—	—
54	Xe	1169.8	*12.127*	*21.2*	*32.1*	(45)	(57)	89	102 ±3	126 ±3	218	(238)	—	—	—	—	—	—	—	—	—	—
55	Cs	375.6	*3.893*	*25.1*	34.6 ±0.7	(46)	(62)	(74)	108	122 ±3	150 ±4	256	—	—	—	—	—	—	—	—	—	—
56	Ba	560.6	*5.810*	*10.00*	37 ±1	(49)	(62)	(80)	(93)	127	144 ±4	158 ±5	—	—	—	—	—	—	—	—	—	—
57	La	541.4	*5.61*	*11.43*	*19.17*	(52)	(66)	(80)	(100)	(114)	151	165 ±5	204 ±6	—	—	—	—	—	—	—	—	—
58	Ce	[666.5]	[*6.91*]	*12.3*	*19.5*	*36.7*	(70)	(85)	(100)	(122)	(137)	172	189 ±6	—	—	—	—	—	—	—	—	—
59	Pr	[555.6]	[*5.76*]	—	—	—	—	(89)	(106)	(122)	(146)	(162)	197	—	—	—	—	—	—	—	—	—
60	Nd	[608.8]	[*6.31*]	—	—	—	—	—	(111)	(129)	(147)	(171)	—	—	—	—	—	—	—	—	—	—
61	Pm	—	—	—	—	—	—	—	—	(135)	(154)	(173)	—	—	—	—	—	—	—	—	—	—
62	Sm	540.1	*5.6*	[*11.2*]	—	—	—	—	—	—	(161)	(181)	—	—	—	—	—	—	—	—	—	—
63	Eu	546.8	*5.67*	*11.24*	—	—	—	—	—	—	—	(187)	—	—	—	—	—	—	—	—	—	—
64	Gd	594.1	*6.16*	[*12*]	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
65	Tb	[650.2]	[*6.74*]	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
66	Dy	[657.8]	[*6.82*]	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
67	Ho	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
68	Er	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
69	Tm	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
70	Yb	597.9	*6.2*	*12.10*	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
71	Lu	593.3	*6.15*	*14.7*	(19)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
72	Hf	530.5	*5.5*	*14.9*	(21)	(31)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
73	Ta	742.7	*7.7*	16.2 ±0.5	(22)	(33)	(45)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
74	W	770.0	*7.98*	17.7 ±0.5	(24)	(35)	(48)	(61)	—	—	—	—	—	—	—	—	—	—	—	—	—	—
75	Re	759.1	*7.87*	16.6 ±0.5	(26)	(38)	(51)	(65)	(79)	—	—	—	—	—	—	—	—	—	—	—	—	—
76	Os	839.0	*8.7*	17 ±1	(25)	(40)	(54)	(68)	(83)	(99)	—	—	—	—	—	—	—	—	—	—	—	—
77	Ir	887.6	*9.2*	17.0 ±0.3	(27)	(39)	(57)	(72)	(88)	(104)	(121)	—	—	—	—	—	—	—	—	—	—	—

LAWRENCE RADIATION LABORATORY
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REQUESTED BY: Rob H. Smith

CHECKED BY:

NO. 92

DATE 4-24-67

TABLE OF IONIZATION POTENTIALS OF THE ELEMENTS (continued)

Z	Element	eU_{I_1}	eU_{I_2}	eU_{I_3}	eU_{I_4}	eU_{I_5}	eU_{I_6}	eU_{I_7}	eU_{I_8}	eU_{I_9}	$eU_{I_{10}}$	$eU_{I_{11}}$	$eU_{I_{12}}$	$eU_{I_{13}}$	$eU_{I_{14}}$	$eU_{I_{15}}$	$eU_{I_{16}}$	$eU_{I_{17}}$	$eU_{I_{18}}$	$eU_{I_{19}}$	$eU_{I_{20}}$
78	Pt	864.2	8.96	18.54	(29)	(41)	(55)	(75)	(92)	(109)	(127)	(146)	—	—	—	—	—	—	—	—	—
79	Au	889.7	9.223	20.5	(30)	(44)	(58)	(73)	(96)	(114)	(133)	(153)	—	—	—	—	—	—	—	—	—
80	Hg	1006.5	10.434	18.751	34.2	(46)	(61)	(77)	(94)	(120)	(139)	(159)	—	—	—	—	—	—	—	—	—
81	Tl	589.1	6.106	20.42	29.8	50	(64)	(81)	(98)	(117)	(145)	(166)	—	—	—	—	—	—	—	—	—
82	Pb	715.1	7.415	15.03	31.93	39.0	69.7	(84)	(103)	(122)	(142)	(173)	—	—	—	—	—	—	—	—	—
83	Bi	703.0	7.287	19.3	25.6	45.3	56.0	94.4	(107)	(127)	(148)	(169)	—	—	—	—	—	—	—	—	—
84	Po	790.9	8.2 ± 0.4	19.4 ± 1.7	27.3 ± 0.8	(38)	(61)	(73)	(112)	(132)	(154)	(176)	—	—	—	—	—	—	—	—	—
85	At	887.6	9.2 ± 0.4	20.1 ± 1.7	29.3 ± 0.9	(41)	(51)	(78)	(91)	(138)	(160)	(183)	—	—	—	—	—	—	—	—	—
86	Rn	1036.7	10.745	21.4 ± 1.8	29.4 ± 1.0	(44)	(55)	(67)	(97)	(111)	(166)	(190)	—	—	—	—	—	—	—	—	—
87	Fa	383.9	3.98 ± 0.10	22.5 ± 1.8	33.5 ± 1.5	(43)	(59)	(71)	(84)	(117)	(133)	(197)	—	—	—	—	—	—	—	—	—
88	Ra	509.1	5.277	10.144	(34)	(46)	(59)	(76)	(89)	(103)	(140)	(156)	—	—	—	—	—	—	—	—	—
89	Ac	664.5	6.89 ± 0.6	11.5 ± 0.4	—	(49)	(62)	(76)	(95)	(109)	(123)	(164)	—	—	—	—	—	—	—	—	—
90	Th	—	—	11.5 ± 1.0	20.0	28.7	(65)	(80)	(94)	(115)	(130)	(145)	—	—	—	—	—	—	—	—	—
91	Pa	—	—	—	—	—	—	(84)	(100)	(115)	(138)	(154)	—	—	—	—	—	—	—	—	—
92	U	386.0	4	—	—	—	—	—	(104)	(121)	(137)	(162)	—	—	—	—	—	—	—	—	—
94	Pu	492.2	5.1	—	—	—	—														

EXCITATION POTENTIALS FOR METASTABLE LEVELS

(FROM: Backer-Goudsmith, Atomic Energy States. New York 1932, Uyterhoeven, Electrical glow-discharge lamps. Springer, Berlin, 67, 1938, W.L. Granowski, Electric current in gas. State pub., techn. theoret. Lit., Moscow-Leningrad, 413, 1952).

LEGEND: eU_{Ms} = Excitation potential for metastable levels.

eU_{I_1} = Ionization potential of the neutral unexcited atoms.

Element		H_1	He	N	Ne	Na	Ar	Kr	Hg	
eU_{Ms}	from	10.2	19.72	2.37	16.57	2.12	11.49	9.86	4.66	eV
	to	12.7	20.51	3.56	16.66	4.27	11.66	10.51	5.43	
eU_{I_1}		13.59	24.56	14.55	21.56	5.14	15.76	13.94	10.44	eV

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REQUESTED BY: Bob H. Smith

CHECKED BY:

NO. 92

DATE 4-24-67

TITLE	PREPARED BY	DATE
LBL STANDARD STAINLESS HIGH-VACUUM FLANGES, DIMENSIONS AND APPLICATIONS	Richard Reimers	4/67
	REVISED BY Richard Reimers	DATE 3/80 Rev.A
	REVISED BY	DATE

Type 304 stainless steel 2.75" (69.85mm) outside diameter high-vacuum bakeable flanges are stocked here. This note gives information about these flanges which have been found to be very useful as a standard for use with 300 series stainless steel tubing from .750 to 1.750 inches o. d. Recent suppliers have been MDC Corp., Varian, Granville-Phillips.

1. Do not braze these flanges. Weld them. Use types 304, 304L, 316, 316L, or 321 stainless steel tubing. Internal welds wherever possible. These flanges may be welded to materials other than stainless steel. See Varian brochures.

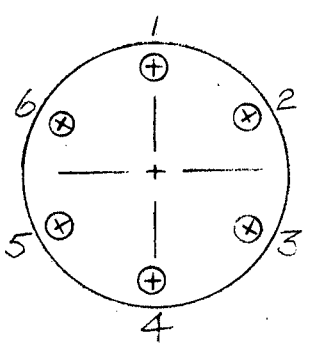
2. Outer part of rotatable flanges is Type 303 stainless (non weldable), not type 304 (weldable).

3. Advertised temperature range: -196° to +500°C. (Reliability above 300°C decreases.)

4. Handling: Keep flanges hydrocarbon free and keep seal edge nick-free.

5. Use high temperature lubricant Fel-Pro C100 (Varian #953-0031) on screws and between nuts and flange to prevent galling. First tighten bolts finger tight, then tighten them in order 1, 4, 2, 5, 3, 6. See figure 1. 16 foot lbs. torque recommended.

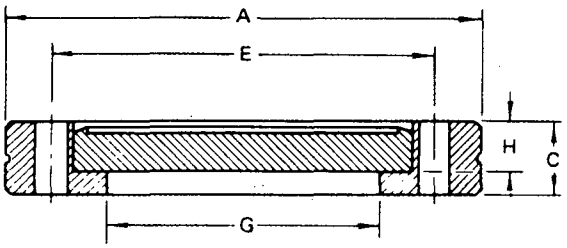
FIG. 1
NO SCALE



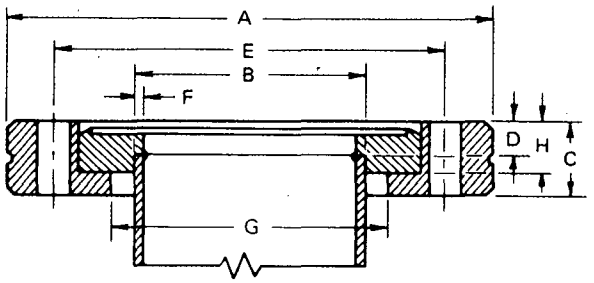
6. Gaskets: Varian recommends that a new copper gasket be used each time that a seal is made. Bring the flanges up just metal-to-meal. During the time that a system is being set up and debugged, many people use the Viton "A" gasket 4730-51142, which only requires 3 bolts to seal and is reusable if both flanges and gaskets are treated with care, i. e., no nicks in flange and no foreign material on gasket or knifedge. Note system bakeability is limited if Viton used.

7. Gaskets are LBL #4730-51141 (copper) or 4730-51142 (Viton).

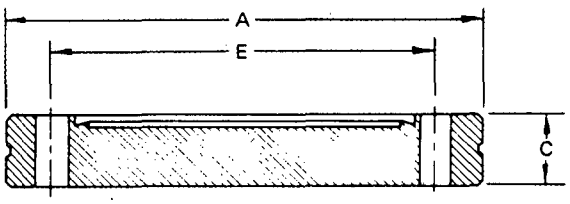
8. Washers are not required for hardware discussed in this DD93.



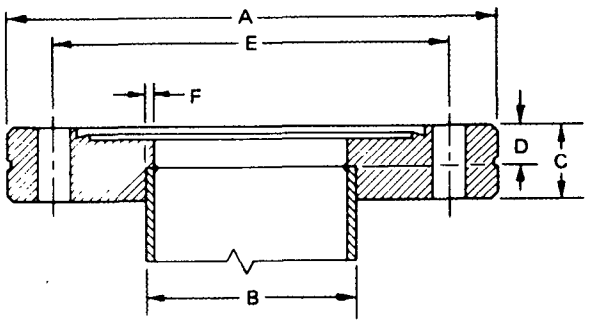
DRAWING III



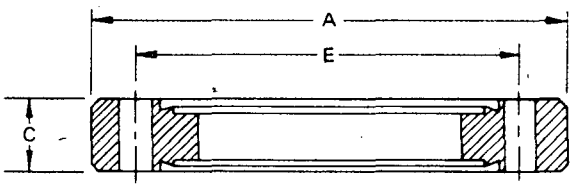
DRAWING IV
(Shown welded to tubing)



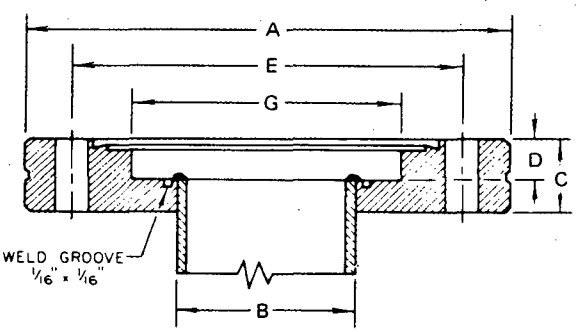
DRAWING V



DRAWING VI
(Shown welded to tubing)



DRAWING VII
Double-sided Flange



DRAWING VIII
(Shown welded to tubing)

ROTATABLE FLANGES

Note: All rotatable flanges are 2.750 inches outside diameter and use 1/4-28 UNF screws 1.250 inches long. Screws are Varian part no. 953-5020. All rotatable flanges have six .265" diameter bolt holes. Screws may also be purchased from Ferry Company or MDC. Must be type 304 or 316 S.S.

Varian Model Number	LBL Stock Number	Nom. I.D. (std. Tube O.D.)	Dwg. No.	B (I.D)	C (Thick)	D (Set-back)	E (B.C)	F (Step)	G (Clear.)	H (Rec. Depth)
954-5072	4730-51134	Blank	III	-	.500	-	2.312	-	1.560	.300
954-5075	4730-51135	.750	IV	.760	.500	.209	2.312	.035	1.560	.300
954-5073	Non-stock	1.000	IV	1.010	.500	.209	2.312	.035	1.560	.300
954-5074	Non-stock	1.250	IV	1.260	.500	.209	2.312	.035	1.560	.300
954-5071	4730-51133	1.500	IV	1.510	.500	.209	2.312	.070	1.560	.300

NON-ROTATABLE FLANGES

All non-rotatable flanges are 2-3/4 inches nominal and 2.73 inches actual O.D.

Varian Model Number	LBL Stock Number	Nom. I.D. (Standard Tube O.D.)	Dwg. No.	B (I.D.)	C (Thick)	D (Set-back)	E (B.C.)	F (Step)	G (Relief)	Bolt Holes No.	Bolt Holes Diam.	Screws Thd.	Screws Length
954-5077	4730-51139	Blank	V	-	.500	-	2.312	-	-	6	.265	1/4-28	1.250
954-5066	Non-stock	.750	VIII	.755	.500	.209	2.312	-	1.370	6	.265	1/4-28	1.250
954-5067	Non-stock	1.000	VIII	1.055	.500	.209	2.312	--	1.370	6	.265	1/4-28	1.250
954-5068	Non-stock	1.250	VI	1.260	.500	.209	2.312	.070	-	6	.265	1/4-28	1.250
954-5076	4730-51138	1.500	VI	1.510	.500	.209	2.312	.070	-	6	.265	1/4-28	1.250
954-5069	4730-51137	1.500	VI	1.510	.500	.209	2.312	.070	-	6	1/4-28*	1/4-28	.875
952-5001	4730-51140	1.500	VII	-	.750	-	2.312	-	-	6	.265	1/4-28	2.000
-	4730-56658	1.500	16D4553 (LBL)	-	1.000	-	2.312	-	-	6	1/4-28*	1/4-28	.875

*Tapped bolt holes

JOT/nh

SUBJECT

BENDING MAGNET POLE TIP MINIMUM WIDTH

PREPARED P. Hernandez
V. Kopytoff

CHECKED BY J. O. Turner

For simple low-field bending magnets ($B < 10$ kG) a minimum pole-tip can be found by the use of this Design Data when the useful field width and the allowable field variation are given. The pole tip may be contoured as shown on Fig. 2 or have a simple square edge.

Comparing the width of a simple square pole tip with the width of a contoured pole tip can help establish the early design and cost estimate. Accurate coordinates required for manufacturing a contoured pole tip can be obtained by using self-optimizing programs such as NIL or SMIRT.

How to Use:

To find how far the pole tip must extend beyond the edge of the usable field, x, when given the field uniformity ΔB in percent, use Fig. 1. The total pole-tip width in half gaps is: $p = w + 2x$, where w is the required usable field width in half gaps. $\Delta B = \pm (B - B_o)/B_o$.

The approximate shape of the pole tip would be similar to one of the shapes in Fig. 2. The effects of iron saturation and of coil currents are neglected. The 1% data has been checked with POISSON at 0.5, 10, and 15 kG. The POISSON solutions for $\mu = \infty$ and $B_o = 10$ kG are within 2% of the analytical solution(1) at all points. The $B_o = 15$ kG solution deviates from the $\mu = \infty$ solution by 3% because of saturation of the SAE 1010 steel. These curves are not recommended for general use above 10 kG.

The pole tips shown on Fig. 2 have a contour that extends to a height of two half gaps. The two curves in Fig. 1 intersect at a field uniformity of about 5% indicating that the square pole tip can be narrower when the midplane field variation is greater than 5%. The curves in Fig. 1 would have intersected at a different point had the contours of Fig. 2 extended to a point higher or lower than two half gaps.

Example:

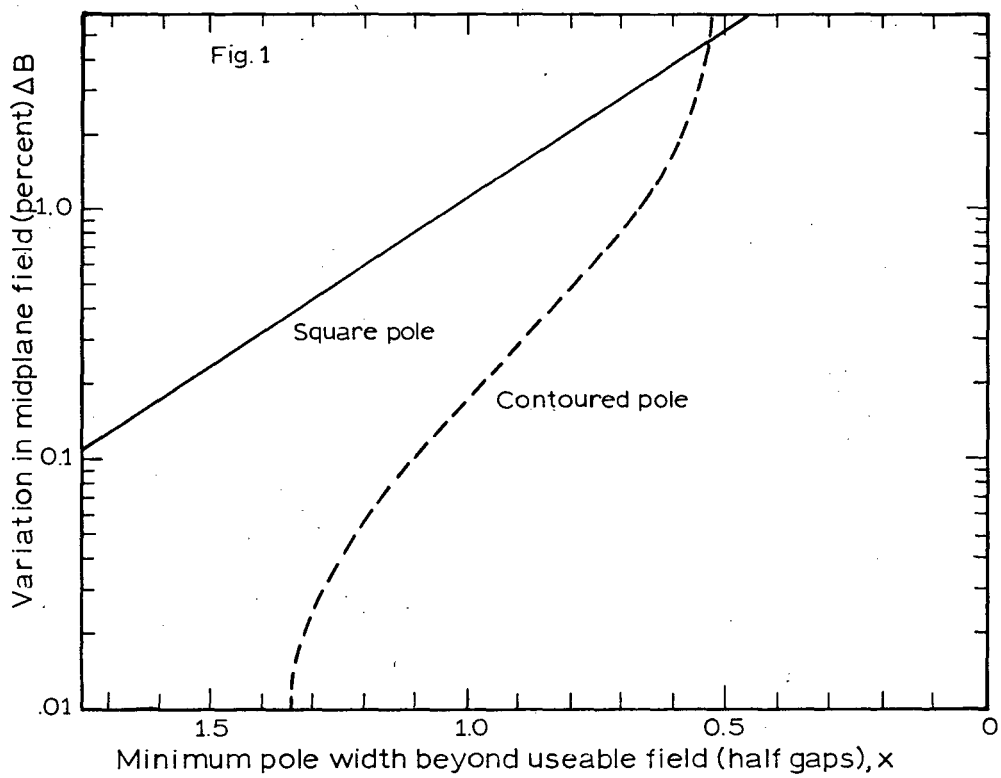
A low-field bending magnet is to have a magnetic field uniform within 0.2% at the midplane and over a width of 6 half gaps. What is the minimum width of a contoured pole tip? Of a square pole tip?

Solution:

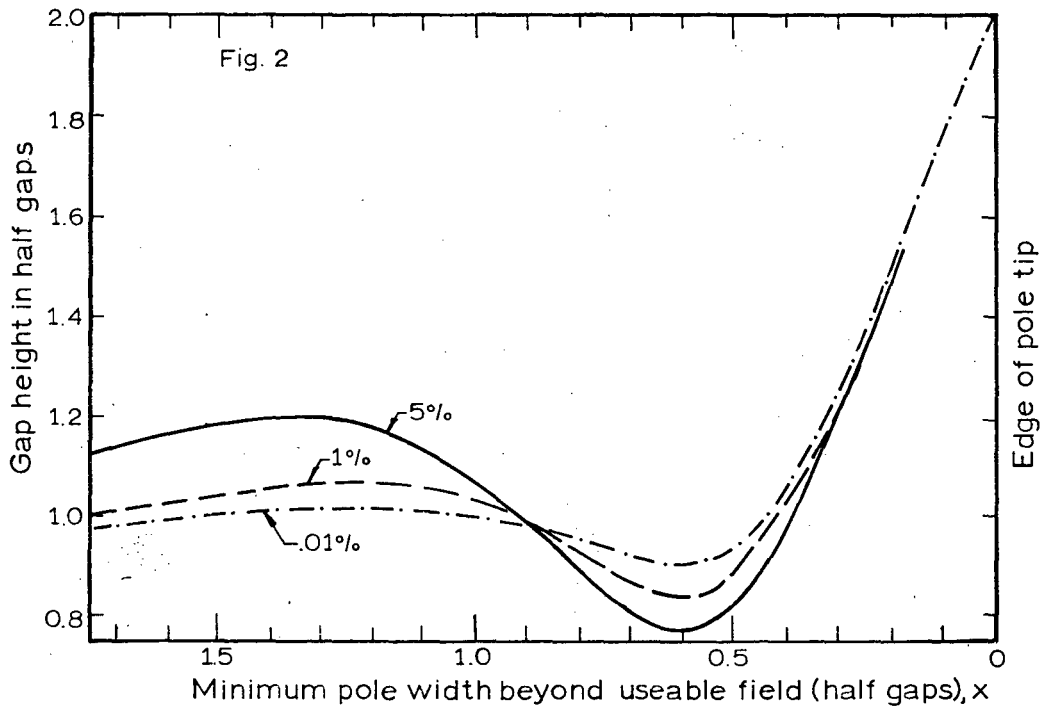
From Fig. 1 a contoured pole tip having a 0.2% allowable variation requires 0.97 half gaps to be added to each edge of the pole. The contoured pole width required then is $p = 6 + 2(0.97) = 7.99$ half gaps. From Fig. 2 a pole tip that satisfies these conditions has a shape somewhere between the 0.01 and the 1.0% curves. A square pole tip requires 1.55 half gaps added to each side to obtain the same 0.2% accuracy. The square pole width required is $p = 6 + 2(1.55) = 9.10$ half gaps.

---

(1) Further discussion is given on Engineering Note M3967 by Vadim Kopytoff, October 5, 1967, "Analytical Solution of Magnet Pole Shimming Problems."



Minimum pole width beyond useable field vs. acceptable variation in midplane field for infinitely permeable iron pole.



Approximate shape of contoured pole tips

SUBJECT

GRAPHIC SYMBOLS TO BE USED IN VACUUM TECHNOLOGY

PREPARED Dick Reimers

CHECKED BY J. O. Turner

The purpose of this standard is to establish a uniform system of graphic symbols in vacuum technology.

The graphic symbols are a shorthand used to show graphically the functioning and interconnections of vacuum components in a single-line schematic or flow diagram.

A single-line diagram is one in which the graphic symbols are shown without regard to the actual physical location, size, or shape of the components.

A symbol shall be considered as the aggregate of all its parts.

The orientation of a symbol on a drawing, including a mirror image presentation, does not alter the meaning of the symbol.

A symbol may be drawn to any scale that suits a particular drawing.

Arrows should be omitted unless necessary for clarification.

VACUUM GAUGES	
general symbol	
manometer, liquid level	L
manometer, diaphragm	D
McLeod	M
thermocouple	TC
Pirani	P
ionization, cold cathode	PIG
ionization, hot cathode	IG
Knudsen	K
residual gas analyzer	RGA
radioactive	R
nude see note 6	N

BAFFLES	
general symbol	
ambient	
refrigerated see note 7	LN_2
sorbent	
thimble trap	

VACUUM CHAMBERS AND ACCESSORIES	
general symbol	Vacuum chamber
bell jar	
view port	
blind flange port or door	

VALVES	
general symbol	
gate or slide -with seat orientation -without seat orientation	
gate, with bypass port	
poppet or globe, in-line or angle see note 4	
ball	
butterfly or quarter swing	
solenoid	
pneumatic	
bellows-sealed	
throttling or calibrated leak	
air admittance	
stopcock 2-way, 2-position	
stopcock 3-way, 2-position	
stopcock 3-way, 3-position	

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DESIGN DATA

DATE	D.D. NO.	PAGE 2 OF 2 PAGES
10-2-68	95	

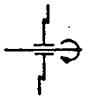
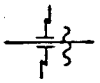
SUBJECT

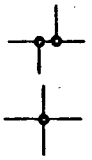
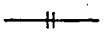
GRAPHIC SYMBOLS TO BE USED IN VACUUM TECHNOLOGY

PREPARED: Dick Reimers

CHECKED BY: J. O. Turner

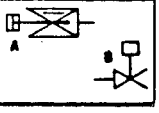
PUMPS	
MECHANICAL PUMPS: general symbol	
liquid-sealed, single-stage	
liquid-sealed, compound	
blower, lobe type, single-stage	
blower, lobe type, compound	
turbomolecular	
DIFFUSION PUMPS: general symbol	
diffusion, oil see note 1	
diffusion, mercury	
diffusion, booster see note 1	
diffusion-ejector see note 2	
ejector	
SORPTION PUMPS: general symbol	
getter-evaporation see note 3	
sputter-ion	
cryo see note 5	
cryo-sorbent	

FEED-THROUGHS	
general symbol	
rotating	
sliding	
bellows-sealed	
electrical	

LINES AND CONNECTIONS	
connected see note 4	
not connected	
flexible line	
demountable coupling	

NOTES

1. Optional: Add chemical name of oil below symbol.
2. Optional: Add chemical name of fluid below symbol
3. Use element symbol for designation of getter material.
4. Minimum diameter of dots five times line width.
5. Vacuum line (solid) omitted on cryo panels. Cryogenic lines (dotted) optional.
6. To specify type of nude gauge, add after N the proper letter or letters from vacuum gauges list above.
7. For others substitute LN with name of coolant or cooling
8. Typical combination of symbols: (a) pneumatic gate valve with seat orientation. (b) solenoid operated air-admittance valve



NOTE: This list of symbols is reprinted from AVS Tentative Standard 7.1 - 1966.

D-1(M)

Nomogram for Lame's Equation

F. Caplan, Kaiser Engineers, Oakland, Calif.

For thick-walled cylinders under internal pressure only, Lame's solution can be written:*

$$S = P_i \left(\frac{R^2 + r^2}{R^2 - r^2} \right) = P_i \left(\frac{D^2 + d^2}{D^2 - d^2} \right)$$

Where

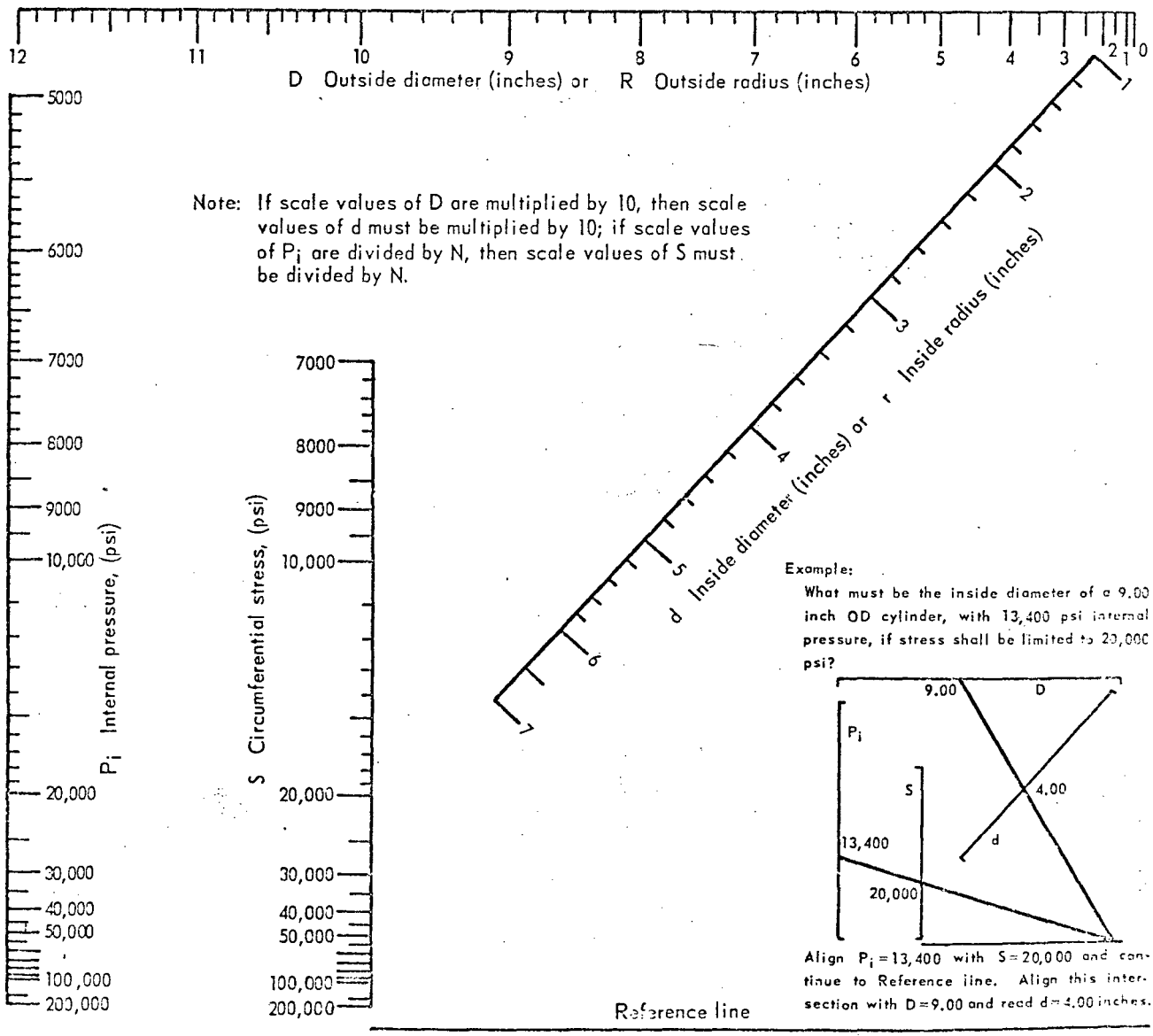
S = Maximum circumferential stress, occurring at the inner surface, psi.

P_i = Internal pressure, psi.

D and R = Outside diameter and radius, respectively.

d and r = Inside diameter and radius, respectively, in the same units as D or R.

Reference: F. B. Seely, "Resistance of Materials", John Wiley and Sons, Inc.



Note: If scale values of D are multiplied by 10, then scale values of d must be multiplied by 10; if scale values of P_i are divided by N, then scale values of S must be divided by N.

Example:

What must be the inside diameter of a 9.00 inch OD cylinder, with 13,400 psi internal pressure, if stress shall be limited to 20,000 psi?

Align P_i = 13,400 with S = 20,000 and continue to Reference line. Align this intersection with D = 9.00 and read d = 4.00 inches.

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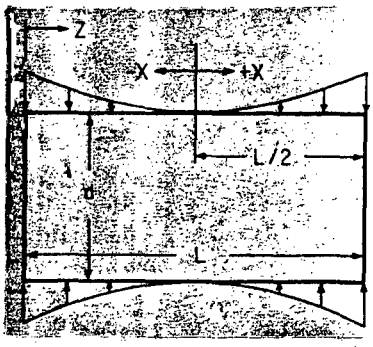
These formulas are applicable to stress problems that arise in the following situations: Reinforcing frames for rectangular ducting in test chambers, wind tunnels, containers, etc., under internal and external-pressure* conditions; reinforcing frames for rectangular openings in cylindrical and spherical pressure-shells where the radius of curvature is large relative to the frame dimensions; concentrated loadings on rectangular frames transmitted by hinges and latches, as exemplified in test cells, missile instrument compartments, wind tunnels; structures such as building frames, culverts, etc.

Loads, on top and bottom members, and side members, must be the same — self-equilibrating. All load cases may be superimposed and the moments added when different loadings are combined.

Moment is positive when the inner side of the frame is in tension.

w = applied load per unit length. W = total applied load. I = moment of inertia of frame cross section.

* A check should be made for stability-type failure.



1 . . PARABOLIC LOADING

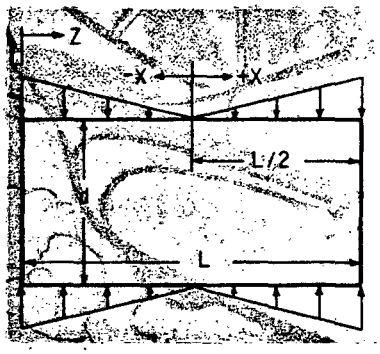
$$w = \frac{12W}{L^2}\left(Z - \frac{L}{2}\right)^2 \qquad w_{max} = \frac{3W}{L}$$

I is the same on all sides. On side d; $M = -\dfrac{WL^2}{20(L+d)}$

On side L

$$M = \frac{WL(4L+5d)}{20(L+d)} + \frac{WX}{2} - \frac{W}{2L^2}(2Z^4 - 4Z^3L + 3Z^2L^2)$$

$$+M_{max} = \frac{WL(L+5d)}{80(L+d)} \text{ at } Z = \frac{L}{2}; \quad -M_{max} = -\frac{WL^2}{20(L+d)}$$



2 . . DOUBLE TRIANGULAR LOADING

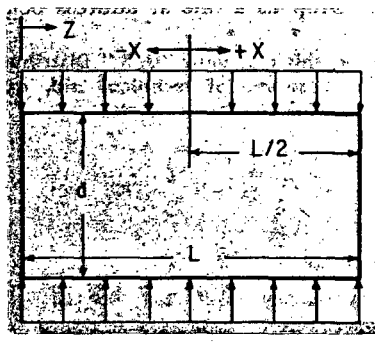
$$w_{max} = \frac{2W}{L}$$

I is the same on all sides. On side d; $M = -\dfrac{WL^2}{16(L+d)}$

On side L from $Z = 0$ to $Z = \dfrac{L}{2}$

$$M = \frac{WL(3L+4d)}{16(L+d)} + \frac{WX}{2} - \frac{2WZ^2}{L^2}\left(\frac{L}{2} - \frac{Z}{3}\right)$$

$$+M_{max} = \frac{WL(L+4d)}{48(L+d)} \text{ at } Z = \frac{L}{2}; \quad -M_{max} = -\frac{WL^2}{16(L+d)}$$



3 . . UNIFORM LOADING

$$w = \frac{W}{L}$$

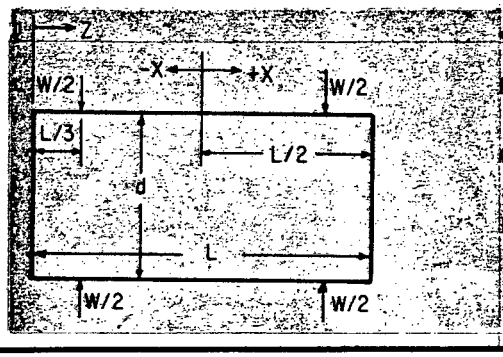
I is the same on all sides. On side d; $M = -\dfrac{WL^2}{12(L+d)}$

On side L

$$M = \frac{WL(2L+3d)}{12(L+d)} + \frac{WX}{2} - \frac{WZ^2}{2L}$$

$$+M_{max} = \frac{WL(L+3d)}{24(L+d)} \text{ at } Z = \frac{L}{2}; \quad -M_{max} = -\frac{WL^2}{12(L+d)}$$

Reprinted with permission from PRODUCT ENGINEERING Nov. 23, 1959.



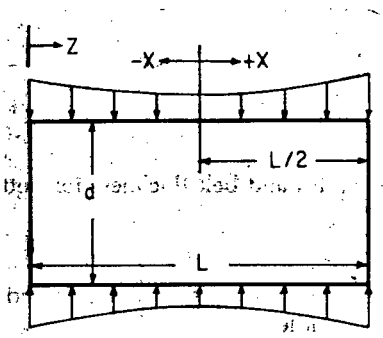
4 . . CONCENTRATED LOADING

I is the same on all sides. On side d; $M = \dfrac{WL^2}{9(L+d)}$

On side L from $Z = 0$ to $Z = \dfrac{L}{3}$; $M = \dfrac{WL(5L+9d)}{36(L+d)} + \dfrac{WX}{2}$

From $Z = \dfrac{L}{3}$ to $Z = \dfrac{2L}{3}$; $M = \dfrac{WL(L+3d)}{18(L+d)}$

$+M_{max} = \dfrac{WL(L+3d)}{18(L+d)}$; $-M_{max} = -\dfrac{WL^2}{9(L+d)}$



5 . . PARABOLIC LOADING

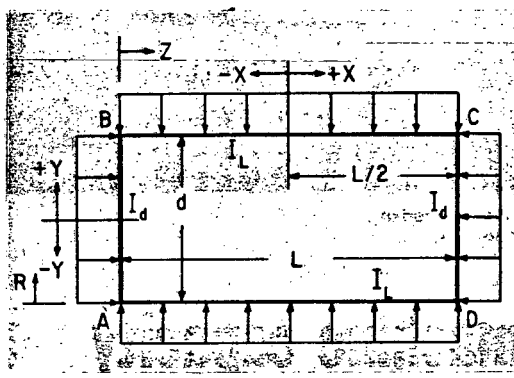
$w_{max} = \dfrac{9W}{5L}$; $w_{min} = \dfrac{w_{max}}{3}$ at $Z = \dfrac{L}{2}$

I is the same on all sides. On side d; $M = -\dfrac{7WL^2}{100(L+d)}$

On side L

$$M = \frac{WL(18L+25d)}{100(L+d)} + \frac{WX}{2} - \frac{3WZ^2}{10L} - \frac{W}{5L^2}(2Z^4 - 4Z^3L + 3Z^2L^2)$$

$+M_{max} = \dfrac{WL(2L+10d)}{100(L+d)}$; $-M_{max} = -\dfrac{7WL^2}{100(L+d)}$



6 . . UNIFORM LOADING

w is the same on all sides. $-M_{max} = -\dfrac{w(L^3I_d + d^3I_L)}{12(LI_d + dI_L)}$ at A,B,C,D

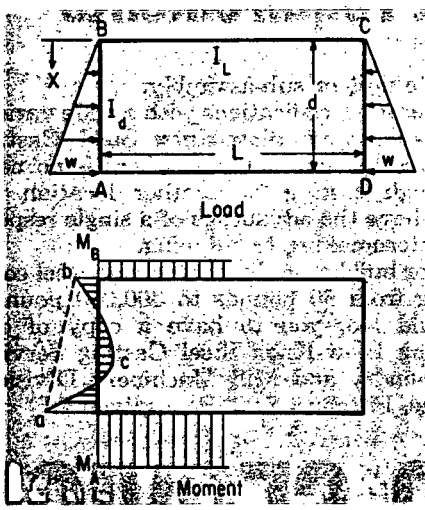
M at $\dfrac{d}{2} = (M \text{ at } A) + \dfrac{wd^2}{8}$; M at $\dfrac{L}{2} = (M \text{ at } A) + \dfrac{wL^2}{8}$

On side d

$$M = \frac{2w(L^3I_d + d^3I_L) + 3wdL(LI_L + dI_d)}{12(LI_d + dI_L)} + \frac{wdy}{2} + \frac{wL^2}{4} - \frac{wR^2}{2}$$

On side L

$$M = \frac{2w(L^3I_d + d^3I_L) + 3wdL(LI_L + dI_d)}{12(LI_d + dI_L)} + \frac{wd^2}{4} - \frac{wLx}{2} - \frac{wZ^2}{2} - \frac{wd^2}{2}$$



7 . . SINGLE TRIANGULAR LOADING

$$M_C = M_B = \frac{2I_LI_d + 4I_d^2}{4I_d^2 - (2I_L + 4I_d)^2}\left(\frac{wd^2}{30}\right)$$

$$M_A = M_D = \frac{6I_L^2 + 8I_LI_d}{4I_d^2 - (2I_L + 4I_d)^2}\left(\frac{wd^2}{30}\right)$$

Area $abca$ is the moment diagram for a simple beam of length d and loaded identically to AB. It is laid off from line ab. Moment distribution for AB with ab as base is

$$M = \frac{wX}{6d}(d^2 - X^2)$$

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DESIGN DATA

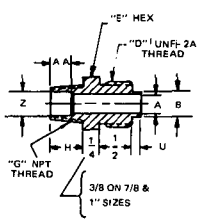
DATE	D.D. NO.	PAGE
12/6/71	98B	1 OF 4 PAGES

SUBJECT

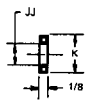
LRL STANDARD TUBING FITTINGS
OUTLINE DIMENSIONS AND TYPICAL APPLICATIONS

PREPARED: J. J. Dols

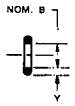
CHECKED BY: T. B. Lewis



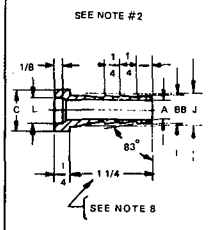
I UNION COUPLING WITH MALE PIPE THREAD



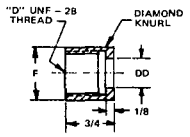
II UNION GASKET



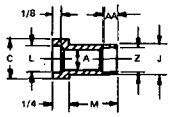
III UNION GASKET



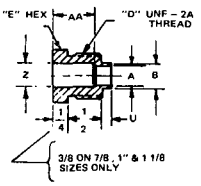
IV UNION NIPPLE FOR NON METALLIC TUBING



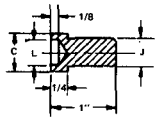
V UNION NUT



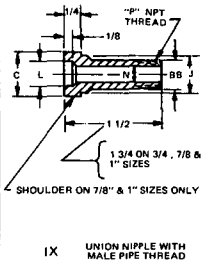
VI UNION NIPPLE FOR METALLIC TUBING



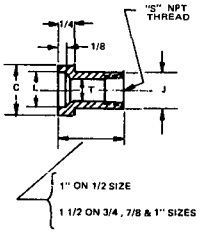
VII HALF UNION



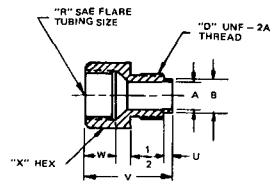
VIII UNION PLUG



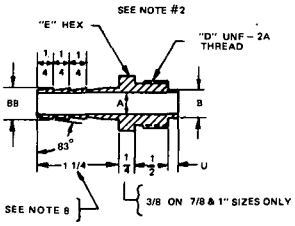
IX UNION NIPPLE WITH MALE PIPE THREAD



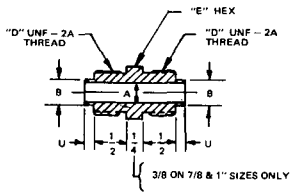
X UNION NIPPLE WITH FEMALE PIPE THREAD



XI UNION COUPLING WITH SAE FLARE FITTING THREAD



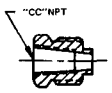
XII UNION COUPLING WITH NON-METALLIC TUBING NIPPLE



XIII COUPLING

SEE TYPE VII FOR DIMENSIONS

XIV HALF-UNION PLUG



SEE TYPE VII FOR OUTSIDE DIMENSIONS

XV HALF UNION WITH FEMALE PIPE THREAD

SIZE, CATALOGUE NUMBER & DIMENSIONS (SEE NOTE 10)

TYPE	1/4	3/8	1/2	3/4	7/8	1	1 1/8
I	4730–16170	4730–16171	4730–16172	4730–16173	4730–16174	4730–16175	
II	4730–16193	4730–16194	4730–16195	4730–16196	4730–16197	4730–16197	4730–16197
III	5330–22218	5330–22221	5330–22223	5330–22227	5330–22230	5330–22230	5330–22230
IV	4730–16161	4730–16162	4730–16163	4730–16164	4730–16165	4730–16165	4730–16165
V	4730–16133	4730–16134	4730–16135	4730–16136	4730–16137	4730–16137	4730–16137
VI	4730–16155	4730–16156	4730–16157	4730–16158	4730–16159	4730–16160	
VII	4730–16176	4730–16177	4730–16178	4730–16180	4730–16181	4730–16182	4730–16183
VIII	4730–16138	4730–16139	4730–16140	4730–16141	4730–16142	4730–16142	
IX		4730–16151	4730–16152	4730–16153	4730–16154	4730–16154	
X			4730–16148	4730–16149	4730–16150	4730–16150	
XI	See Type XI Dimensions Below						
XII	4730–16184	4730–16185	4730–16186	4730–16187	4730–16188	4730–16188	
XIII	4730–16128	4730–16129	4730–16130	4730–16131	4730–16132	4730–16132	
XIV	4730–16143	4730–16144	4730–16145	4730–16146	4730–16147	4730–16147	
XV		4730–16166	4730–16167	4730–16168	4730–16169	4730–16169	
A	3/16	5/16	7/16	11/16	27/32	27/32	27/32
B	1/4	3/8	1/2	3/4	1	1	1
C	.433/.423	.610/.600	.780/.770	1.000/0.990	1.380/1.370	1.380/1.370	
D	1/2–20	11/16–16	7/8–14	1 1/8–12	1 1/2–12	1 1/2–12	1 1/2–12
E	9/16	3/4	15/16	1 1/8	1 1/2	1 1/2	1 1/2
F	5/8	13/16	1	1 1/4	1 3/4	1 3/4	
G	1/8 NPT	1/4 NPT	3/8 NPT	3/4 NPT	1 NPT	1 NPT	
H	1/2	1/2	5/8	3/4	7/8	7/8	
J	.318/.313	.443/.438	.568/.563	.849/.844	1.110/1.105	1.110/1.105	
K	25/64	9/16	23/32	1	1 3/8	1 3/8	
L	9/32	13/32	17/32	25/32	1 1/32	1 1/32	
M	1/2	3/4	3/4	1	1 1/8	1 1/8	
N		1/4	3/8	5/8	13/16	13/16	
P		1/8 NPT	1/4 NPT	1/2 NPT	3/4 NPT	3/4 NPT	
S			1/8 NPT	3/8 NPT	1/2 NPT	1/2 NPT	
T			.339	37/64	23/32	23/32	
U	1/8	5/32	5/32	5/32	5/32	5/32	5/32
Y	1/16	3/32	3/32	3/32	1/8	1/8	
Z	.253/.255	.378/.380	.503/.505	.753/.755	.878/.880	1.004/1.006	1.129/1.131
AA	5/16	5/16	3/8	5/8	3/4	3/4	3/4
BB	.318/.313	.443/.438	.568/.563	.849/.844	1.068/1.063	1.068/1.063	
CC		1/8 NPT	1/4 NPT	3/8 NPT	3/4 NPT	3/4 NPT	
DD	.323/.328	.448/453	.573/578	.854/.859	1.115/1.120	1.115/1.120	
JJ	.22	.34	.47	.72	.97	.97	

TYPE XI DIMENSIONS

Part No.	16189	16190	16191	16192
Size	1/2 UCRL X 3/8 SAE[7]	1/2 UCRL X 1/2 SAE[7]	1/2 UCRL X 3/4 SAE[7]	3/4 UCRL X 3/4 SAE[7]
R	3/8 O.D.	1/2 O.D.	3/4 O.D.	3/4 O.D.
V	1 7/32	1 11/32	1 3/4	1 3/4
W	7/16	17/32	25/32	25/32
X	7/8	7/8	1 1/4	1 1/4

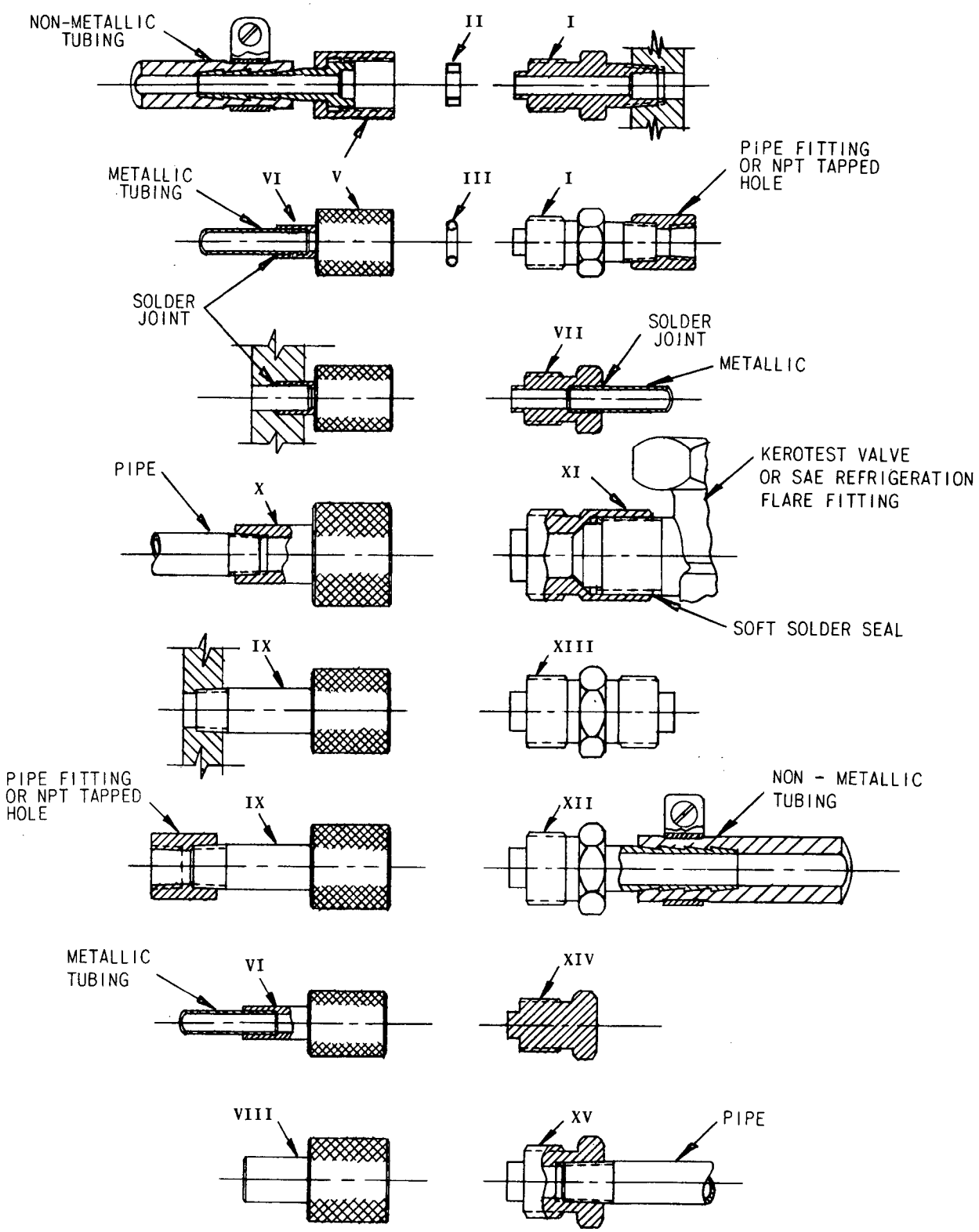
NOTES

1. THIS IS NOT A WORKING DRAWING. ORDER BY INDIVIDUAL PART NUMBER.
2. SIZES SHOWN ARE O.D. OF METALLIC TUBING, I.D. OF NON-METALLIC TUBING. EXTERNAL DIMENSIONS OF 7/8" FITTINGS ARE IDENTICAL TO 1" AND THEREFORE WILL NOT FIT 7/8 I.D. HOSE OR PLASTIC TUBING.
3. 1/8 AND 3/16 SIZES ARE NOT RECOMMENDED FOR GENERAL USE AND ARE NOT STOCKED.
4. SUB-NUMBERS OF O-RINGS CORRESPOND TO THOSE OF THE AN-6227 SERIES.
5. ALL PARTS EXCEPT GASKETS ARE MADE OF BRASS.
6. 1" UCRL FITTINGS SHOULD BE USED WITH CAUTION BECAUSE OF THE LACK OF SOLDER JOINT FITTINGS FOR 1" O.D. TUBING (TYPES K, L & M TUBING ARE NOT MADE IN 1" O.D. SIZE).
7. TYPE XI IS UCRL-TO-SAE FLARE FITTING FOR REFRIGERATION & MARINE TUBING'
8. FOR 7/8 AND 1" SIZES THIS DIMENSION IS 2" (6 BARBS).
9. FOR PROCUREMENT SPECIFICATION AND DRAWINGS, SEE MEL 500042.
10. 4730-16xxx IS TYPICAL LRL STOCK CATALOGUE NUMBER USE THIS WHEN CALLING OUT STOCK NUMBER.

D-1(M)

LRL TUBING FITTINGS, TYPICAL APPLICATIONS

ANY OF THE FITTINGS SHOWN IN THE LEFT HAND COLUMN MAY BE USED WITH ANY FITTING OF THE CORRESPONDING SIZE IN THE RIGHT HAND COLUMN



D-1(M)

SUBJECT
LBL STANDARD TUBING FITTINGS
OUTLINE DIMENSIONS AND TYPICAL APPLICATIONS

PREPARED J. J. Dols

CHECKED BY T. B. Lewis

Old LBL Drawing Conversion to LBL Stock Numbers and Figures on Engineering Standard Reference No. 623

Old LBL Drawing No.	O.D. Tube Size	LBL Stock No. 4730-	ESR 623 Fig. No.	Description
10A1011-3	1/4	16170		
10A1011-4	3/8	16171		Threadpiece, Union;
10A1011-5	1/2	16172	I	Male NPT and Tube
10A1011-6	3/4	16173		End.
10A1011-7	7/8	16174		
10A1011-8	1	16175		
10A1021-3	1/4	16193		
10A1021-4	3/8	16194		
10A1021-5	1/2	16195	II	Washer (Hycar)
10A1021-6	3/4	16196		
10A1021-8	7/8 & 1	16197		
10A1031-3	1/4	16161		
10A1031-4	3/8	16162		Tailpiece, Union;
10A1031-5	1/2	16163	IV	Hose or Flexible
10A1031-6	3/4	16164		Tubing End.
10A1031-8	7/8 & 1	16165		
10A1041-3	1/4	16133		
10A1041-4	3/8	16134		
10A1041-5	1/2	16135	V	Nut, Union
10A1041-6	3/4	16136		
10A1041-8	7/8 & 1	16137		
10A1051-3	1/4	16176		
10A1051-3	3/8	16177		
10A1051-5	1/2	16178		
10A1051-5.5	5/8	16179	VII	Threadpiece, Union;
10A1051-6	3/4	16180		Tube End.
10A1051-7	7/8	16181		
10A1051-8	1	16182		
10A1051-9	1-1/8	16183		
10A1061-4	3/8	16151		
10A1061-5	1/2	16152	IX	Tailpiece, Union;
10A1061-6	3/4	16153		Male NPT End.
10A1061-8	7/8 & 1	16154		
10A1071-5	1/2	16148	X	Tailpiece, Union;
10A1071-6	3/4	16149		Female NPT End.
10A1071-8	7/8 & 1	16150		

Old LBL Drawing Conversion to LBL Stock Numbers and Figures on Engineering Standard Reference No. 623

Old LBL Drawing No.	O.D. Tube Size	LBL Stock No. 4730-	ESR 623 Fig. No.	Description
10A1081-1	1/2 x 3/8 (1)	16189		
10A1081-2	1/2 x 1/2 (1)	16190	XI	Threadpiece, Union;
10A1081-3	1/2 x 3/4 (1)	16191		(1) SAE Thd. End
10A1081-4	3/4 x 3/4 (1)	16192		
10A1171-3	1/4	16155		
10A1171-4	3/8	16156		
10A1171-5	1/2	16157	VI	Tailpiece, Union;
10A1171-6	3/4	16158		Tube End
10A1171-7	7/8	16159		
10A1171-8	1	16160		
10A1181-3	1/4	16138		
10A1181-4	3/8	16139		
10A1181-5	1/2	16140	VIII	Tailpiece, Union;
10A1181-6	3/4	16141		Plug
10A1181-8	7/8 & 1	16142		
10A1191-3	1/4	16184		
10A1191-4	3/8	16185		Threadpiece, Union;
10A1191-5	1/2	16186	XII	Hose or Flexible
10A1191-6	3/4	16187		Tubing End
10A1191-8	7/8 & 1	16188		
10A1201-3	1/4	16128		
10A1201-4	3/8	16129		
10A1201-5	1/2	16130	XIII	Threadpiece, Union;
10A1201-6	3/4	16131		Nipple
10A1201-8	7/8	16132		
10A2061-3	1/4	16143		
10A2061-4	3/8	16144		
10A2061-5	1/2	16145	XIV	Threadpiece, Union;
10A2061-6	3/4	16146		Plug
10A2061-8	7/8 & 1	16147		
10A2071-4	3/8	16166		
10A2071-5	1/2	16167	XV	Threadpiece, Union;
10A2071-6	3/4	16168		Female NPT End
10A2071-8	7/8 & 1	16169		

D_o = Outside diameter

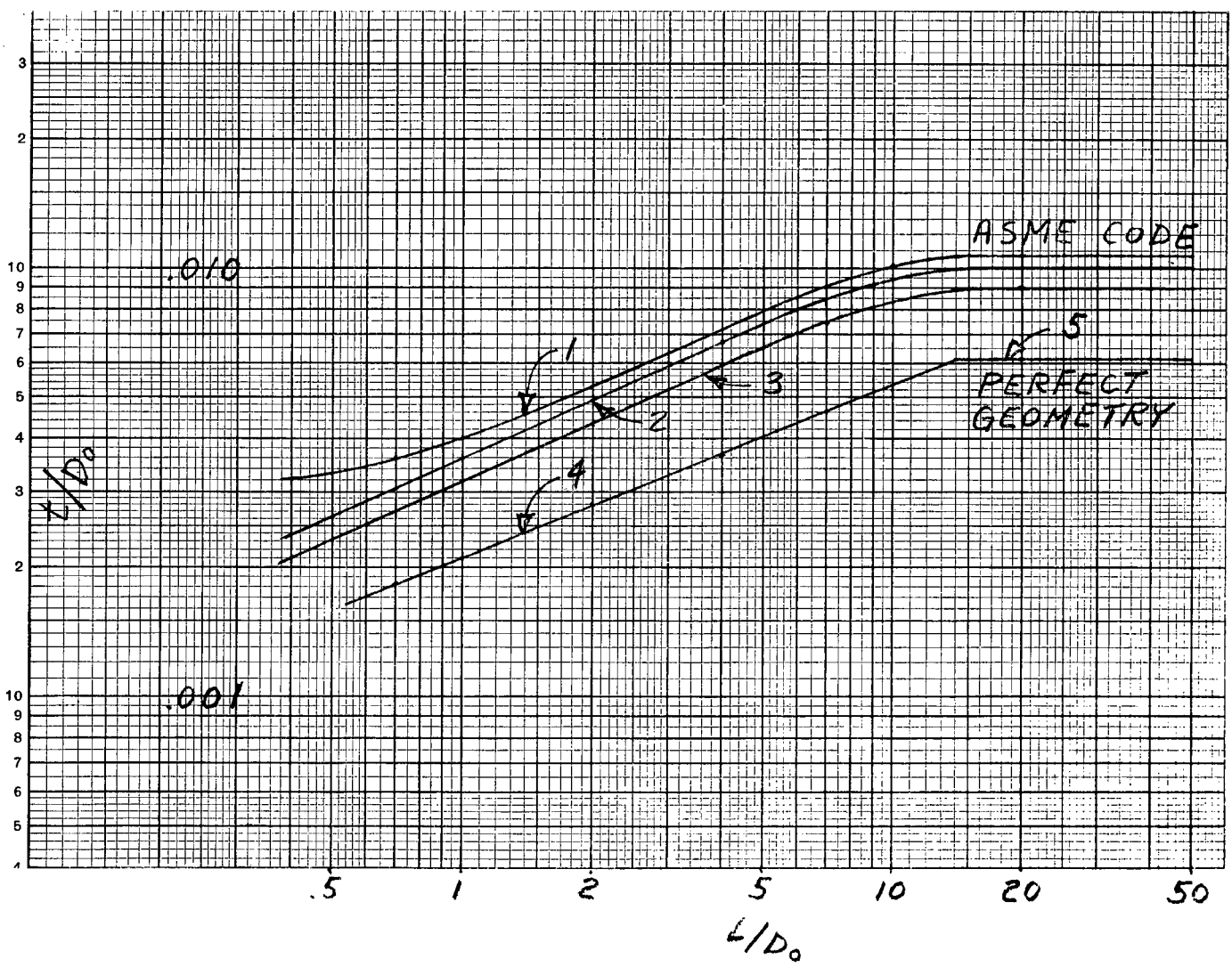
L = Length of unsupported cylindrical section plus 1/3 depth of domed heads, if used, as defined by ASME Code.

Chart gives t/D_o where t = minimum shell thickness.

Curve #1	ASME Boiler and Pressure Vessel Code 1968	Division 1 (General)	- for 900°F
" #2		Division 1 (General)	- " 100°F
" #3		Division 2 (Restricted)*	- " 100°F
" #4	Von Mises' Equation**	Assumes perfect geometry and collapsing pressure of 15 psi	
" #5	Bryan's Equation**		

*Division 2 may be used only if design, construction, inspection, and maintenance for the full life of the vessel all are under LRL control.

**Trans ASME 53, No. 15, pp 207-218 (1931). Because of uncertainties in materials and geometry it is strongly recommended to use the ASME Code except for special cases. In such special cases vessels should be tested to 30 psi external pressure.



SUBJECT: VACUUM VESSEL DESIGN - Minimum Wall Thickness of a Cylindrical Shell for 15 psi EXTERNAL Pressure

Graph #2 - Aluminum Alloy to 200°F and 400°F

PREPARED: F. S. Reinath

CHECKED BY: E. F. McLaughlin

D_o = Outside diameter

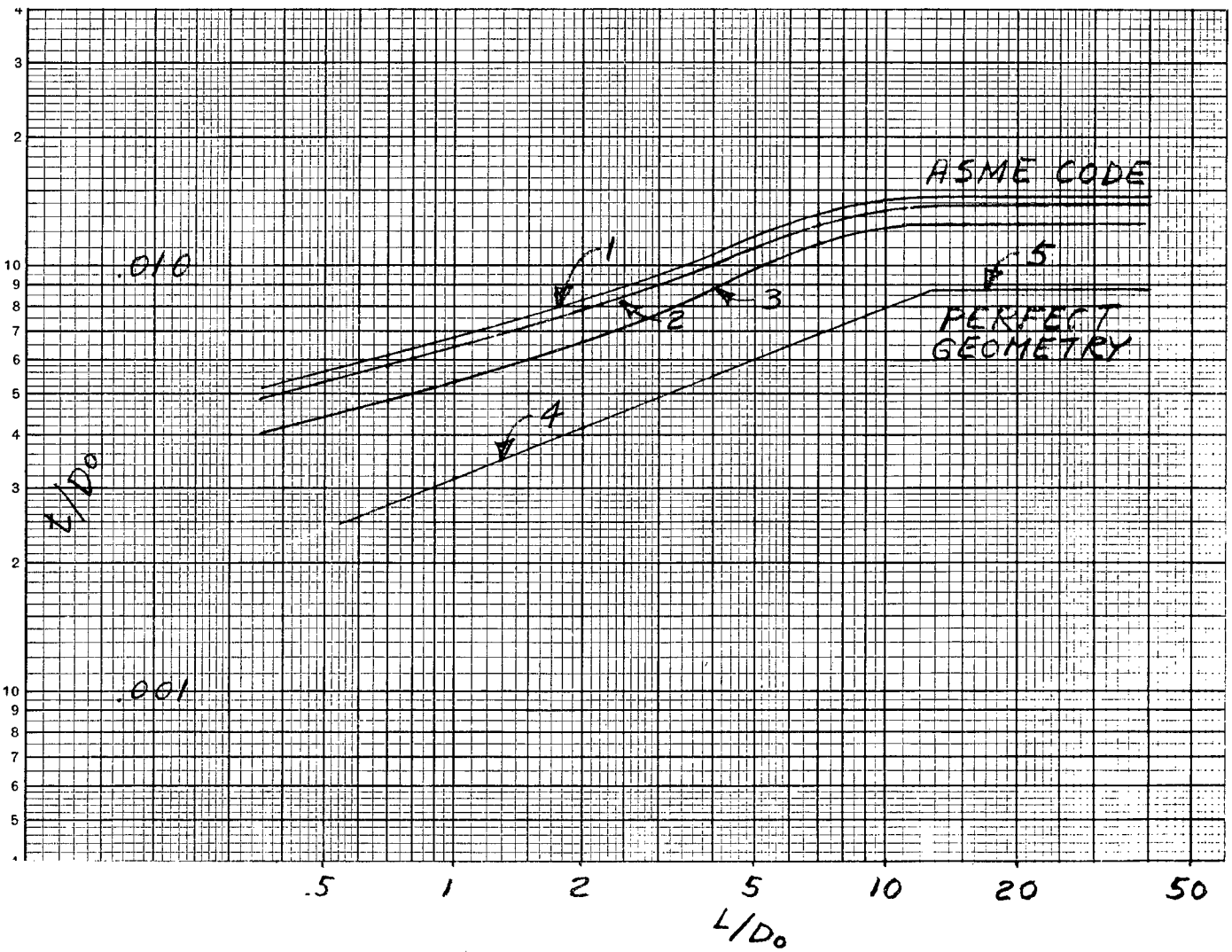
L = Length of unsupported cylindrical section plus 1/3 depth of domed heads, if used, as defined by ASME Code.

Chart gives t/D_o where t = minimum shell thickness.

Curve #1	ASME Boiler and Pressure Vessel Code 1968	Division 1 (General)	- for 400°F
" #2		Division 1 (General)	- for 200°F
" #3		Division 2 (Restricted)*	- for 200°F
" #4	Von Mises' Equation**	Assumes perfect geometry and collapsing pressure of 15 psi.	
" #5	Bryan's Equation**		

*Division 2 may be used only if design, construction, inspection, and maintenance for the full life of the vessel all are under LRL control.

**Trans ASME 53, No. 15, pp 207-218 (1931). Because of uncertainties in materials and geometry it is strongly recommended to use the ASME Code except for special cases. In such special cases vessels should be tested to 30 psi external pressure.



D-1(M)

D_o = Outside diameter

L = Length of unsupported cylindrical section plus 1/3 depth of domed heads, if used, as defined by ASME Code.

Chart gives t/D_o where t = minimum shell thickness.

Curve #1	ASME Boiler and Pressure Vessel Code 1968	Division 1 (General) - for 150°F
" #2		Division 2 (Restricted)* - for 150°F
" #3	Von Mises' Equation**	Assumes perfect geometry and collapsing pressure of 15 psi
" #4	Bryan's Equation**	

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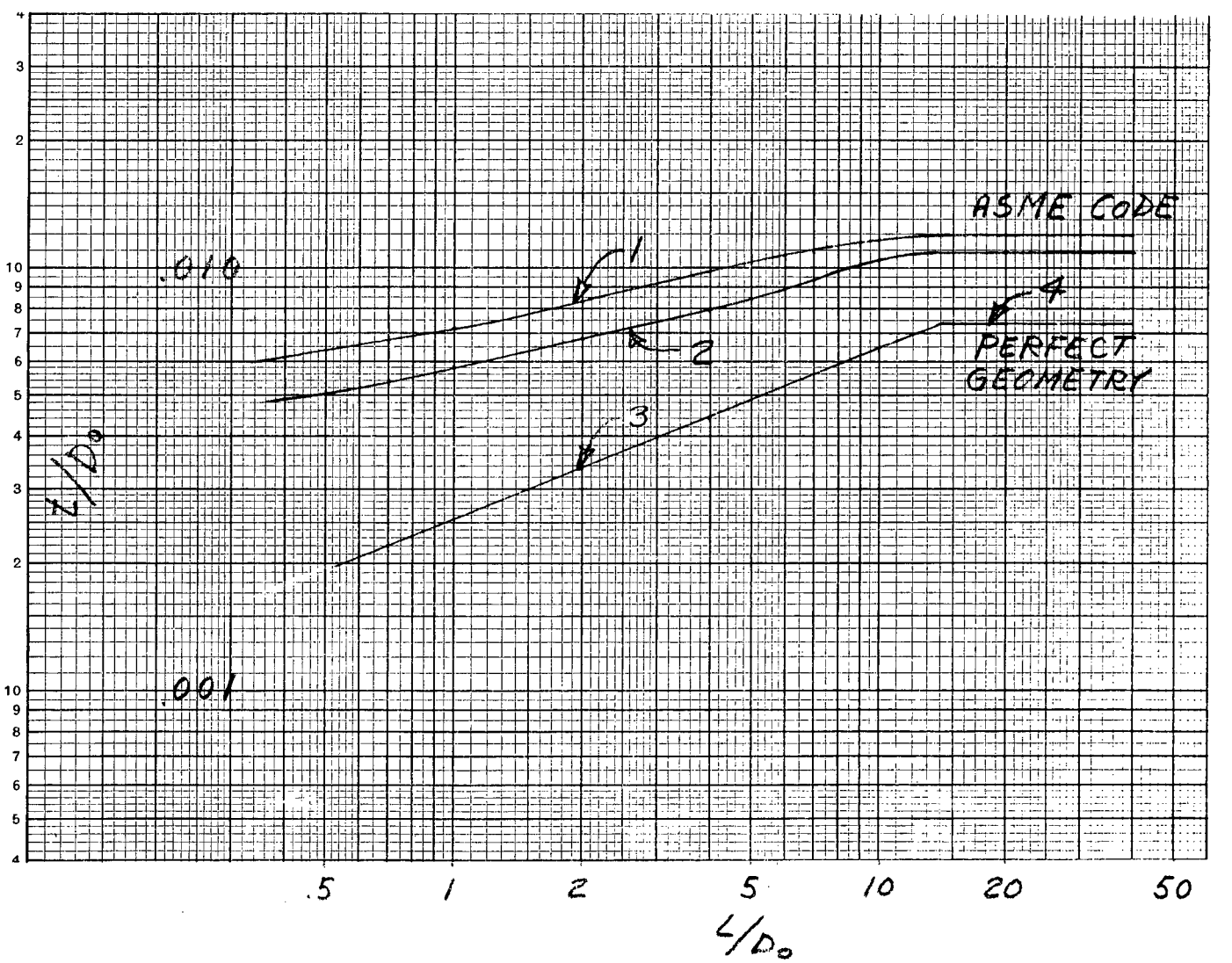
**Trans ASME 53, No. 15, pp 207-218 (1931). Because of uncertainties in materials and geometry it is strongly recommended to use the ASME Code except for special cases. In such special cases vessels should be tested to 30 psi external pressure.



D-1(M)

D_o = Outside diameter

L = Length of unsupported cylindrical section plus 1/3 depth of domed heads, if used, as defined by ASME Code.

Chart gives t/D_o where t = minimum shell thickness.

Curve #1	ASME Boiler and Pressure Vessel Code 1968	Division 1 (General)	- for 900°F
" #2		Division 1 (General)	- " 100°F
" #3		Division 2 (Restricted)*	- " 100°F
" #4	Von Mises' Equation**	Assumes perfect geometry and collapsing pressure of 15 psi	
" #5	Bryan's Equation**		

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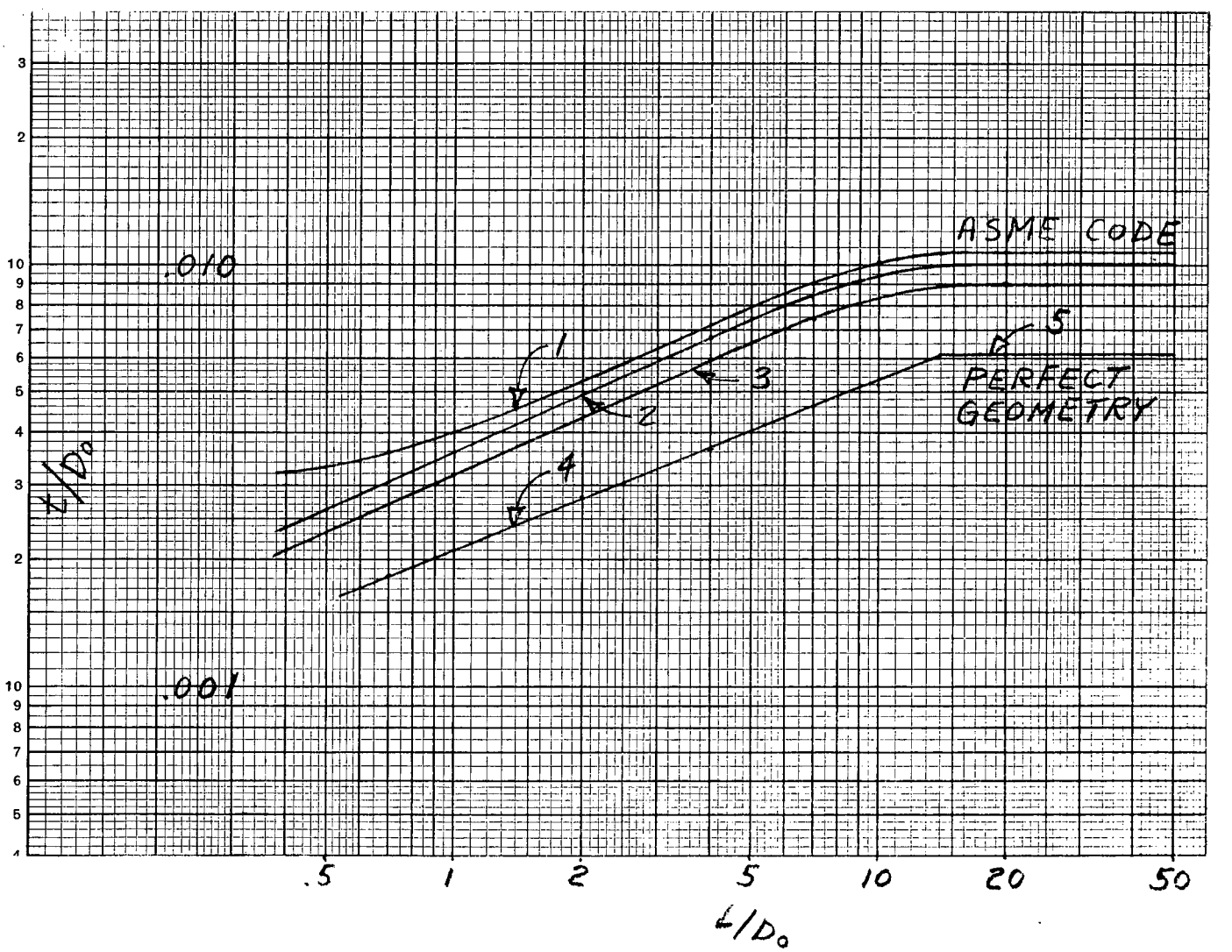
**Trans ASME 53, No. 15, pp 207-218 (1931). Because of uncertainties in materials and geometry it is strongly recommended to use the ASME Code except for special cases. In such special cases vessels should be tested to 30 psi external pressure.



SUBJECT VACUUM VESSEL DESIGN - Minimum Wall Thickness of a Cylindrical Shell for 15 psi EXTERNAL Pressure

Graph #2 - Aluminum Alloy to 200°F and 400°F

PREPARED F. S. Reinath

CHECKED BY E. F. McLaughlin

D_o = Outside diameter

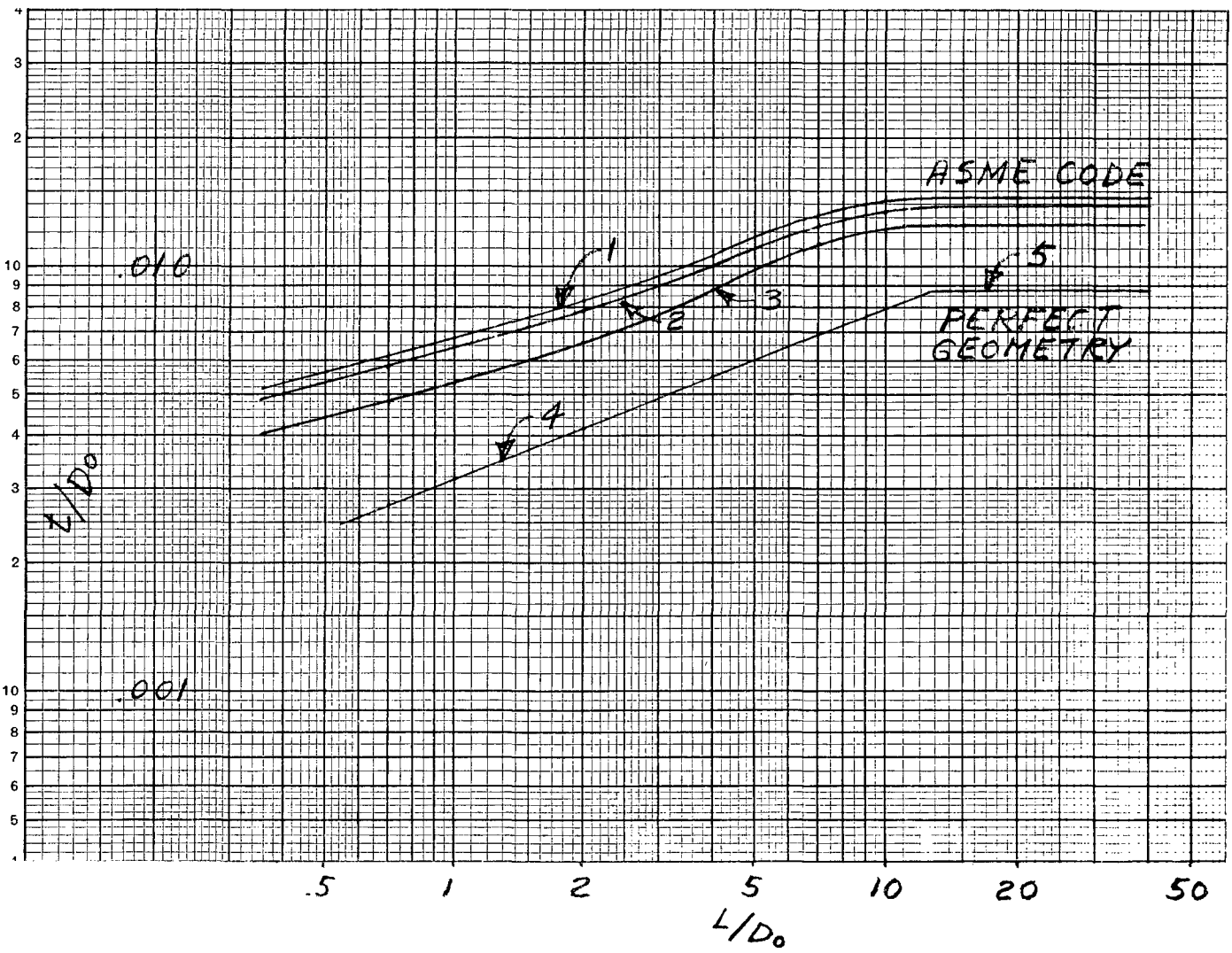
L = Length of unsupported cylindrical section plus 1/3 depth of domed heads, if used, as defined by ASME Code.

Chart gives t/D_o where t = minimum shell thickness.

Curve #1	ASME Boiler and Pressure Vessel Code 1968	Division 1 (General)	- for 400°F
" #2		Division 1 (General)	- for 200°F
" #3		Division 2 (Restricted)*	- for 200°F
" #4	Von Mises' Equation**	Assumes perfect geometry and collapsing pressure of 15 psi.	
" #5	Bryan's Equation**		

*Division 2 may be used only if design, construction, inspection, and maintenance for the full life of the vessel all are under LRL control.

**Trans ASME 53, No. 15, pp 207-218 (1931). Because of uncertainties in materials and geometry it is strongly recommended to use the ASME Code except for special cases. In such special cases vessels should be tested to 30 psi external pressure.



D-1(M)

D_o = Outside diameter

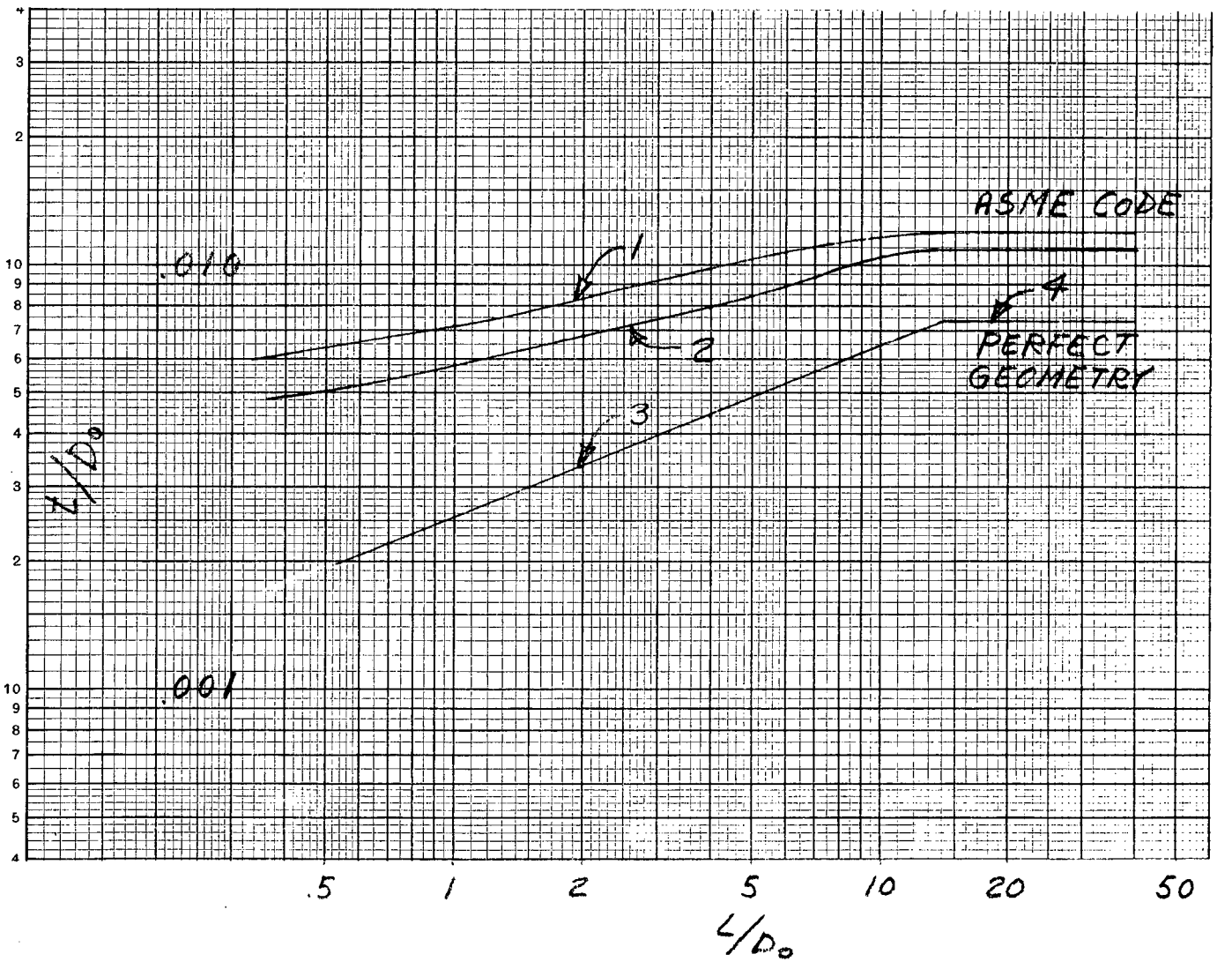
L = Length of unsupported cylindrical section plus 1/3 depth of domed heads, if used, as defined by ASME Code.

Chart gives t/D_o where t = minimum shell thickness.

Curve #1	ASME Boiler and Pressure Vessel Code 1968	Division 1 (General) - for 150°F
" #2		Division 2 (Restricted)* - for 150°F
" #3	Von Mises' Equation**	Assumes perfect geometry and collapsing pressure of 15 psi
" #4	Bryan's Equation**	

*Division 2 may be used only if design, construction, inspection, and maintenance for the full life of the vessel all are under LRL control.

**Trans ASME 53, No. 15, pp 207-218 (1931). Because of uncertainties in materials and geometry it is strongly recommended to use the ASME Code except for special cases. In such special cases vessels should be tested to 30 psi external pressure.



SUBJECT

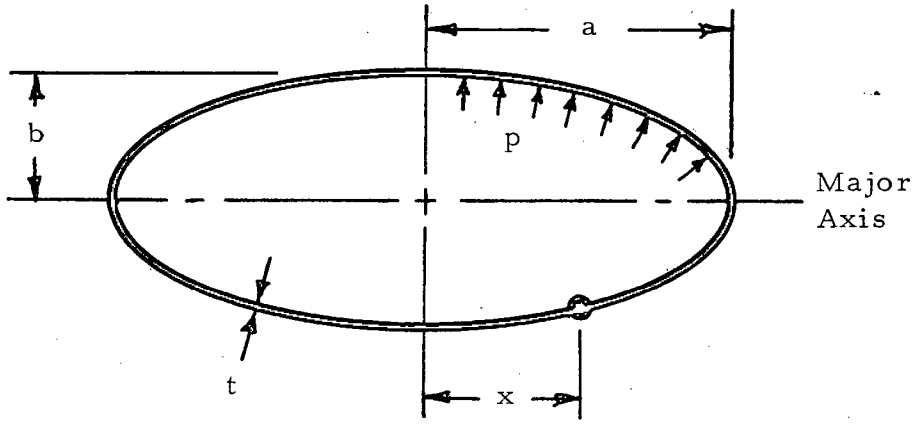
ELLIPTICAL CHAMBER STRESSES AND DEFLECTIONS UNDER UNIFORM PRESSURE LOADING

PREPARED R. T. Avery

CHECKED BY J. O. Turner

Stresses and deflections of long, uniform-wall, elliptical chambers can be calculated by these equations and graphs. p is uniform internal pressure (+) or vacuum (-). Positive sign (+) taken for deflections away from centerline and for moments producing tension on inside of wall. Suitable units are dimensions and deflections in inches, p and s in psi, and M in inch-lbs per inch of axial chamber length.

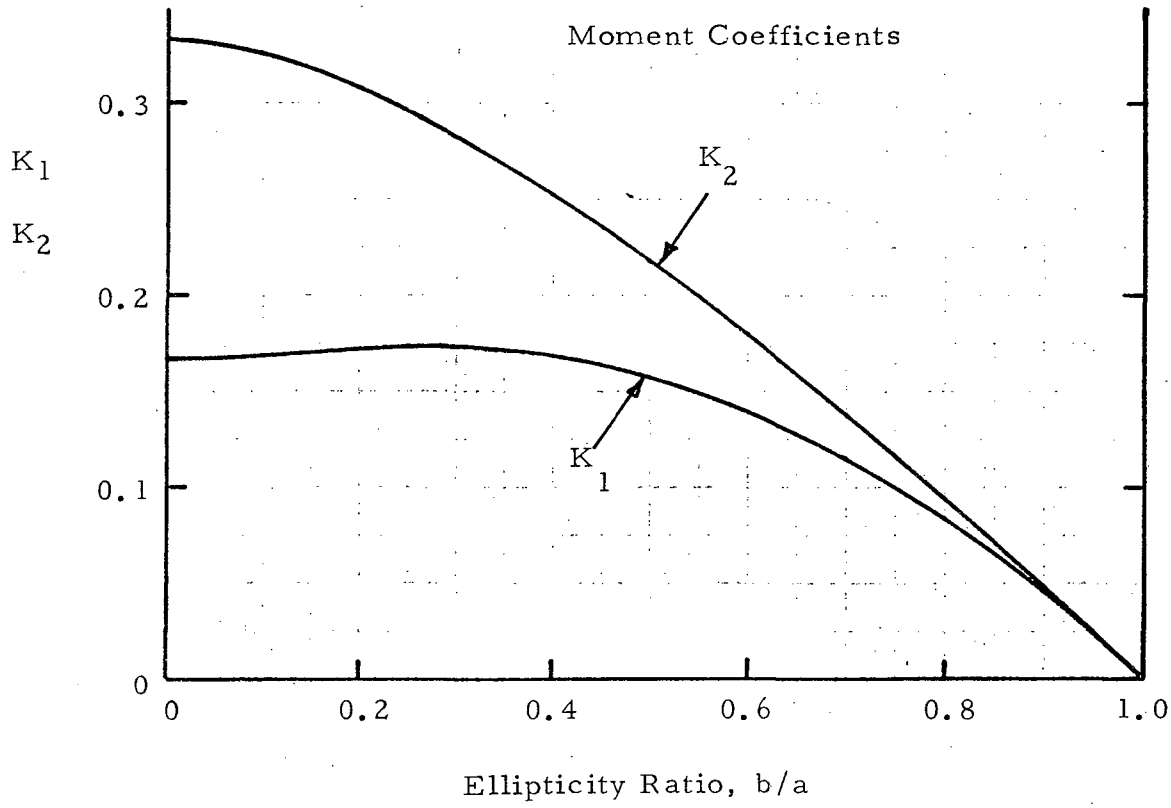
Stresses and deflections are lower near flanges and bulkheads. Resistance to buckling should be considered for nearly-round tubes. Analysis assumes wall t and deflections Δ are small compared to a and b . Moment equations agree with Roark. Actual deflections within elastic range of test chambers reported in Engineering Note M4106 (UCID-3288) are ~10% greater (good agreement) than values computed from equations herein. For derivations and additional data, see Engineering Note M4074A (UCID-3215).

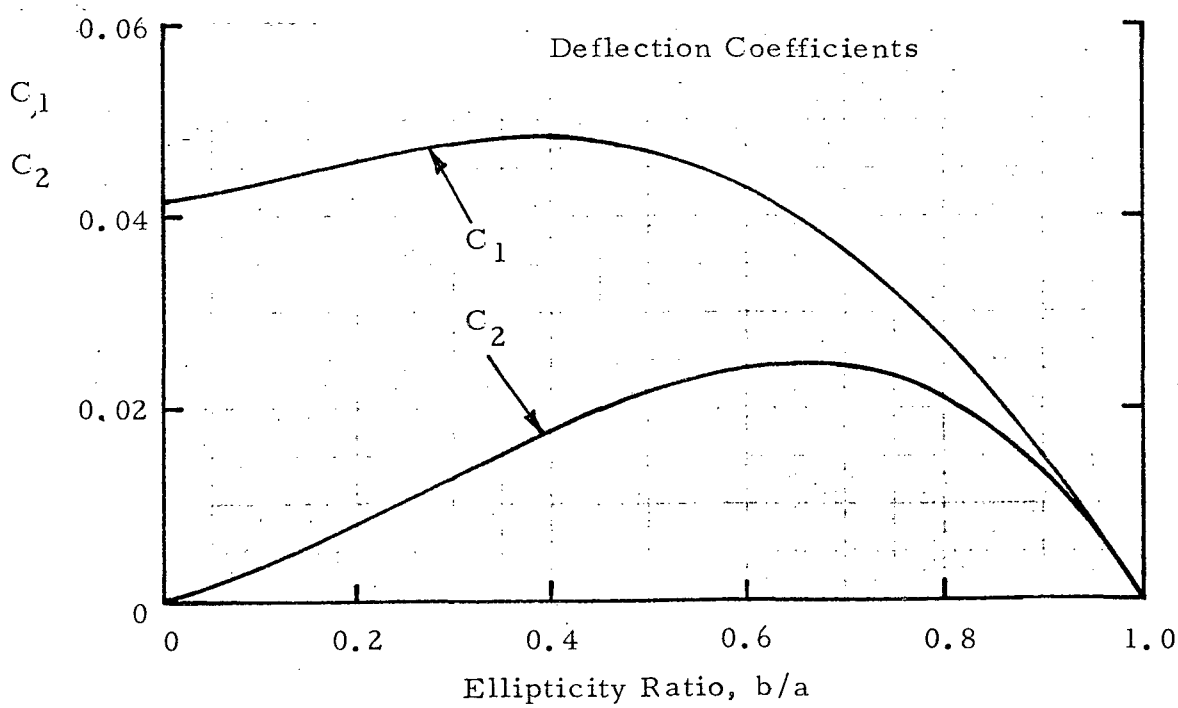


EQUATIONS

	p	= (internal pressure) - (external pressure)
Moment at minor axis:	M_1	$= -K_1 pa^2$
Moment at major axis:	M_2	$= K_2 pa^2$
Moment at any point x:	M	$= M_1 + (1/2)\, px^2 \, [1 - (b/a)^2]$
Bending stress:	s_m	$= Mc/I = 6M/t^2$
Hoop stress:	s_h	$= p\, b\, t^{-1} \{1 - [1 - (b/a)^2]\,(x/a)^2\}^{-1/2}$
Combined stress:	s	$= s_m + s_h$
Deflection at minor axis:	Δ_b	$= C_1\, pa^4/D$
Deflection at major axis:	Δ_a	$= -C_2\, pa^4/D$
where	D	$= Et^3/[12\,(1 - \mu^2)]$ = flexural rigidity.

(For values of K_1, K_2, C_1 and C_2, see graphs on page 2.)


Moment Coefficients
K_1
K_2
0.3
0.2
0.1
0
K_2
K_1
0
0.2
0.4
0.6
0.8
1.0
Ellipticity Ratio, b/a


Deflection Coefficients
C_1
C_2
0.06
0.04
0.02
0
C_1
C_2
0
0.2
0.4
0.6
0.8
1.0
Ellipticity Ratio, b/a

D-1(M)

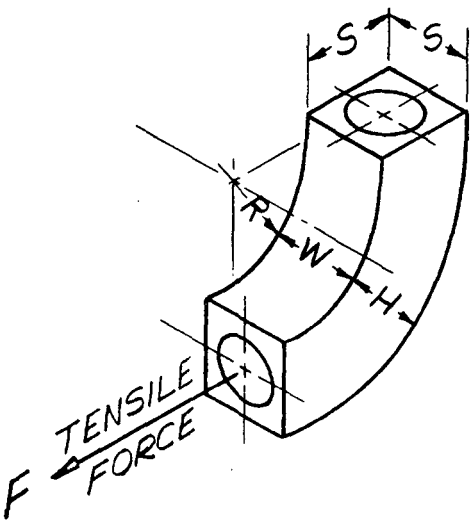
SUBJECT

DISTORTION OF SQUARE HOLLOW COPPER CONDUCTOR AT BENDS

PREPARED J. Gunn

CHECKED BY W. Pope/D. Norgren

Keystoning[1] and reduction of radial dimension may be quickly estimated within ± 5% for square copper conductor having a round hole (diam = 1/2 S) when bent under a tensile load. Curves (page 2) were derived from measurements of bent sections of five conductor sizes 0.251 in. to 0.555 in.: hole diameters were approximately one-half outside dimensions. Bending was performed under typical winding conditions using the Mechanical Shops' winding machine. Data scatter indicates ± 5% accuracy. Bent sections may be examined at Building 77 Assembly Shop.



An example illustrates the usage of the curves:

A 0.340 in. square hollow conductor (net area A of 0.087 sq. in.) is to be bent to a 0.730 in. radius using a winding tension force F of 520 lb.

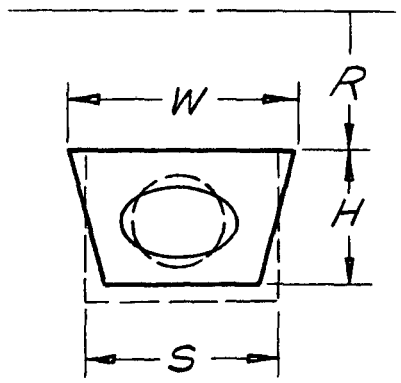
Average tensile stress (during bending) $= \frac{F}{A} = \frac{520}{.087} = 6000$ psi

Bend radius coefficient $= \frac{R}{S} = \frac{.730}{.340} = 2.15$

To find keystone coefficient and radial reduction coefficient, enter chart at R/S = 2.15 and read upward to intersect 6000 psi curves.

Read left to find:

Keystone coefficient: W/S = 1.039
Radial reduction coefficient: H/S = 0.965



Then:

Predicted keystone dimension (W):

W/S = 1.039

or W = 1.039 x S = 1.039 x 0.340 = 0.353 in.

And:

Predicted radial dimension (H):

H/S = 0.965

or H = 0.965 x S = 0.965 x 0.340 = 0.328 in.

[1]Keystoning: Bent cross section is wider at inner radius, narrower at outer radius, compared to nominal dimension.

MG:mp

RL-610-a

RADIATION LABORATORY - UNIVERSITY OF CALIFORNIA - BERKELEY

DESIGN DATA

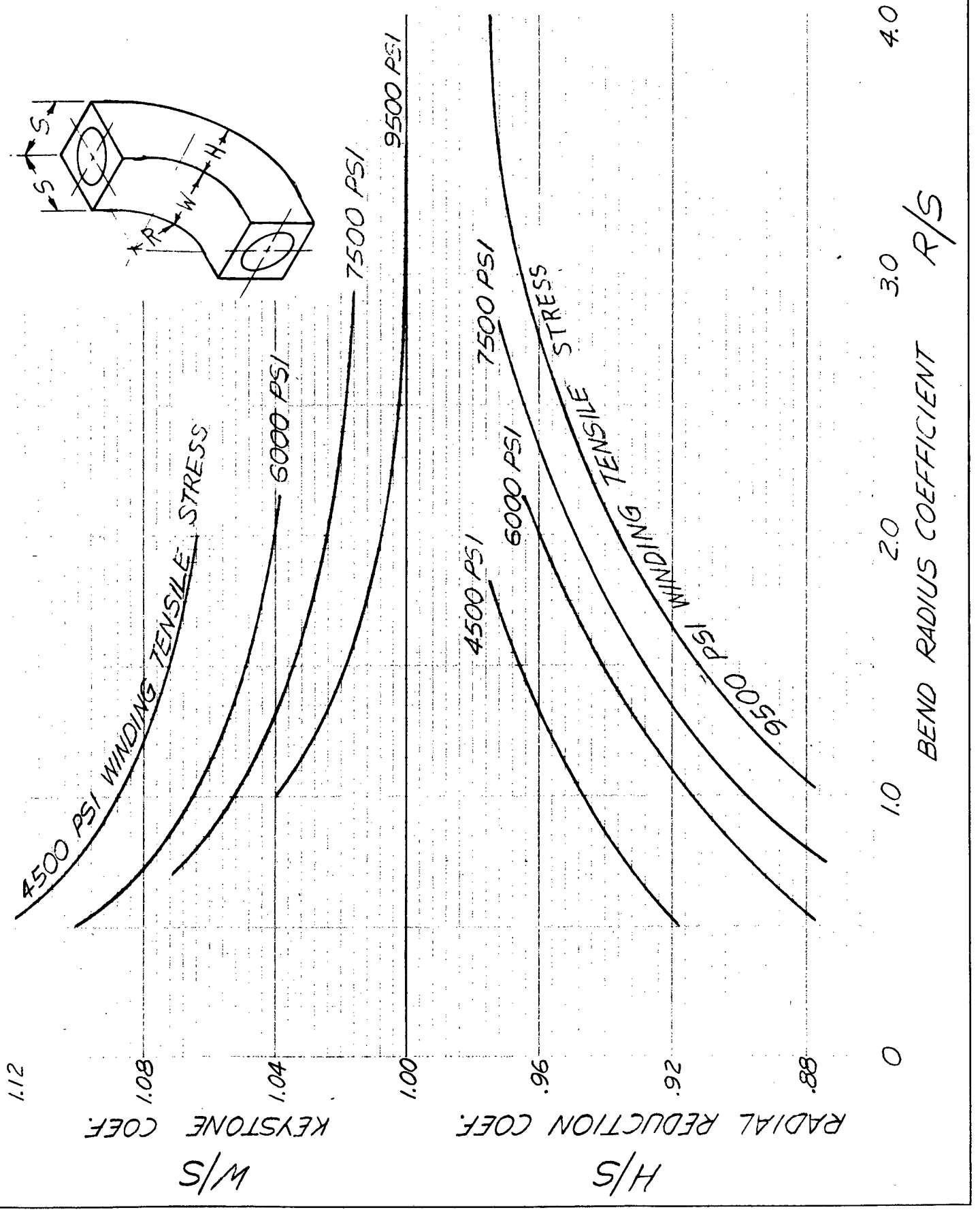
DATE	D.D.NO.	PAGE 2 OF 2 PAGES
5/4/73	101	

SUBJECT

DISTORTION OF SQUARE HOLLOW COPPER CONDUCTOR AT BENDS

PREPARED J. Gunn

CHECKED BY W. Pope/D. Norgren



DL-610-a

RADIATION LENGTH FOR ELECTRON ENERGIES GREATER THAN 50 MeV

Radiation length(X_0) is a property of matter, (just as are density, conductivity, etc.) and is customarily expressed in grams per square centimeter. To determine the distance (in centimeters), simply divide X_0 by the density (in grams per cubic centimeter).

For engineering purposes the values tabulated below are adequately accurate for energies above 50 MeV. For more details consult the reference* and it's bibliography

Element	Symbol	Z Atomic number	A Atomic weight g. per gram atom	Density at 68°F (20°C) g per cu cm	Density at 68°F (20°C) lb per cu in.	Atomic volume cu cm per g-atom	X_0 Radiation length g. per sq. cm.	Radiation Distance cm.
Actinium	Ac	89	227	....	....	....	6.06	...
Aluminum	Al	13	26.98	2.699	0.09751	9.996	24.01	8.90
Americium	Am	95	243	11.7	0.423	20.77	....	...
Antimony	Sb	51	121.76	6.62	0.239	18.4	8.72	1.32
Argon	A	18	39.994	1.784×10^{-3}	0.0645×10^{-3}	....	19.55	...
Arsenic	As	33	74.91	5.72	0.207	13.09	11.94	2.09
Astatine	At	85	211	....	....	....	6.07	...
Barium	Ba	56	137.36	3.5	0.13	39	8.31	2.37
Berkelium	Bk	97	247	....	....	....	....	...
Beryllium	Be	4	9.013	1.848	0.067	4.898	65.19	35.28
Bismuth	Bi	83	209.00	9.80	0.354	21.3	6.29	0.64
Boron	B	5	10.82	2.34	0.085	4.62	52.69	22.52
Bromine	Br	35	79.916	3.12	0.113	25.6	11.42	3.66
Cadmium	Cd	48	112.41	8.65	0.313	13.0	8.99	1.04
Calcium	Ca	20	40.08	1.55	0.056	25.86	16.14	10.41
Californium	Cf	98	251	....	....	....	....	...
Carbon (graphite)	C	6	12.011	2.25	0.081	5.33	42.70	18.98
Cerium	Ce	58	140.13	6.77(a)	0.245(a)	17.03	7.96	1.18
Cesium	Cs	55	132.91	1.903(b)	0.6876(b)	69.84	8.31	4.37
Chlorine	Cl	17	35.457	3.214×10^{-3}	0.116×10^{-3}	....	19.28	...
Chromium	Cr	24	52.01	7.19	0.260	7.23	14.94	2.08
Cobalt	Co	27	58.94	8.85(c)	0.322(c)	6.66	13.62	1.54
Columbium	Cb	41	92.91	8.57	0.310	10.8	9.92	1.16
Copper	Cu	29	63.54	8.96	0.324	7.09	12.86	1.44
Curium	Cm	96	247	....	....	....	....	...
Dysprosium	Dy	66	162.51	8.55	0.309	19.01	7.32	0.86
Einsteinium	E	99	254	....	....	....	....	...
Erbium	Er	68	167.27	9.15	0.331	18.28	7.14	0.78
Europium	Eu	63	152.0	5.245	0.1895	28.98	7.44	1.42
Fermium	Fm	100	253	....	....	....	....	...
Fluorine	F	9	19.00	1.696×10^{-3}	0.0613×10^{-3}	....	32.93	...
Francium	Fr	87	223	....	....	....	6.19	...
Gadolinium	Gd	64	157.26	7.86	0.284	20.01	7.48	0.95
Gallium	Ga	31	69.72	5.907	0.213	11.8	12.47	2.11
Germanium	Ge	32	72.60	5.323(d)	0.192(d)	13.64	12.25	2.30
Gold	Au	79	197.0	19.32	0.698	10.20	6.46	0.33
Hafnium	Hf	72	178.58	13.09	0.473	13.64	6.89	0.53
Helium	He	2	4.003	0.1785×10^{-3}	0.0064×10^{-3}	....	94.32	...
Holmium	Ho	67	164.94	6.79	0.245	24.3	7.23	1.06
Hydrogen	H	1	1.0080	0.0899×10^{-3}	0.0032×10^{-3}	....	63.05	...
Indium	In	49	114.82	7.31	0.264	15.71	8.85	1.21
Iodine	I	53	126.91	4.94	0.178	25.7	8.48	1.72
Iridium	Ir	77	192.2	22.5	0.813	8.54	6.59	0.29
Iron	Fe	26	55.85	7.87	0.284	7.1	13.84	1.76
Krypton	Kr	36	83.8	3.743×10^{-3}	0.135×10^{-3}	....	11.37	...
Lanthanum	La	57	138.92	6.19(e)	0.224(e)	22.44	8.14	1.32
Lead	Pb	82	207.21	11.36(f)	0.41(f)	18.27	6.37	0.56
Lithium	Li	3	6.940	0.534	0.019	12.99	82.76	154.98
Lutetium	Lu	71	174.99	9.85	0.356	17.76	6.92	0.70
Magnesium	Mg	12	24.32	1.74	0.0628	14.0	25.04	14.39
Manganese	Mn	25	54.94	7.43(g)	0.270(g)	7.39	14.64	1.97

(a) Face-centered cubic. (b) At 32 F (0 C). (c) Close-packed hexagonal. (d) At 77 F (25 C). (e) Hexagonal. (f) Rolled Lead. (g) Alpha; beta = 7.29 g per cu cm (0.263 lb per cu in.); gamma = 7.18 g per cu cm (0.259 lb per cu in.).

* Rev. Mod. Phys., Vol 46, No. 4, October 1974, Yung-Su Tsai author.

RADIATION LENGTH FOR ELECTRON ENERGIES GREATER THAN 50 MeV

Element	Symbol	Z Atomic number	A Atomic weight g. per gram atom	Density at 68°F (20°C) g per cu cm	Density at 68°F (20°C) lb per cu. in.	Atomic volume cu cm per g-atom	X_0 Radiation length g. per sq. cm.	Radiation Distance cm.
Mendelevium	Mv	101	256	....	....	....	....	...
Mercury	Hg	80	200.61	13.546	0.4894	14.81	6.44	0.48
Molybdenum	Mo	42	95.95	10.22	0.369	9.39	9.80	0.96
Neodymium	Nd	60	144.27	7.00(a)	0.253(a)	20.61	7.71	1.10
Neon	Ne	10	20.183	0.89999×10^{-3}	0.325×10^{-3}	....	28.94	...
Neptunium	Np	93	237	....	....	....	....	...
Nickel	Ni	28	58.71	8.902(b)	0.322(b)	6.59	12.68	1.42
Nitrogen (Nb see Cb)	N	7	14.008	1.250×10^{-3}	0.0451×10^{-3}	....	37.99	...
Nobelium	No	102	247	....	....	....	....	...
Osmium	Os	76	190.2	22.57(c)	0.8154(c)	8.43	6.68	0.30
Oxygen	O	8	16.00	* 1.429×10^{-3}	0.0509×10^{-3}	....	34.24	...
Palladium	Pd	46	106.7	12.02	0.4343	8.88	9.20	0.77
Phosphorus (white)	P	15	30.975	1.83	0.066	16.92	21.20	11.58
Platinum	Pt	78	195.09	21.45	0.775	9.09	6.54	0.30
Plutonium	Pu	94	242	19.00 to 19.72(d)	0.686 to 0.712(d)	12.27	....	...
Polonium	Po	84	210	....	....	....	6.19	...
Potassium	K	19	39.100	0.86	0.031	45.47	17.32	20.14
Praseodymium	Pr	59	140.92	6.77(a)	0.245(a)	20.82	7.76	1.15
Promethium	Pm	61	145	....	....	....	7.52	...
Protactinium	Pa	91	231.1	15.4	0.556	15.00	5.93	0.39
Radium	Ra	88	226.05	5.0	0.18	45	6.15	1.23
Radon	Rn	86	222	9.960×10^{-3}	0.3598×10^{-3}	....	6.28	...
Rhenium	Re	75	186.22	21.04	0.756	8.85	6.69	0.32
Rhodium	Rh	45	102.91	12.44	0.447	8.27	9.26	0.74
Rubidium	Rb	37	85.48	1.53	0.0553	55.87	11.03	7.21
Ruthenium	Ru	44	101.1	12.2	0.441	8.29	9.48	0.78
Samarium	Sm	62	150.35	7.49(e)	0.271(e)	20.07	7.57	1.01
Scandium	Sc	21	44.96	2.99(f)	0.108(f)	14.89	16.55	5.54
Selenium	Se	34	78.96	4.79	0.174	16.48	11.91	2.49
Silicon	Si	14	28.09	2.33(b)	0.084(b)	12.06	21.82	9.36
Silver	Ag	47	107.880	10.49	0.3790	10.28	8.97	0.86
Sodium	Na	11	22.991	0.9712	0.035	23.67	27.74	28.56
Strontium	Sr	38	87.63	2.60	0.094	34	10.76	4.14
Sulfur (yellow)	S	16	32.066	2.07	0.0748	15.5	19.50	9.42
Tantalum	Ta	73	180.95	16.6	0.600	10.9	6.82	0.41
Technetium	Tc	43	98	....	....	....	9.69	...
Tellurium	Te	52	127.61	6.24(a)	0.225(a)	20.45	8.83	1.42
Terbium	Tb	65	158.93	8.25	0.298	19.26	7.36	0.89
Thallium	Tl	81	204.39	11.85	0.428	17.25	6.42	0.54
Thorium	Th	90	232.05	11.62(g)	0.421(g)	19.90	6.07	0.52
Thulium	Tm	69	168.94	9.31	0.336	18.15	7.03	0.76
Tin	Sn	50	118.70	7.2984(h)	0.2637(h)	16.26	8.82	1.21
Titanium	Ti	22	47.90	4.507	0.163	10.63	16.17	3.59
Tungsten	W	74	183.86	19.3	0.697	9.53	6.76	0.35
Uranium	U	92	238.07	19.07	0.689	12.48	6.00	0.31
Vanadium	V	23	50.95	6.1	0.220	8.35	15.84	2.60
Xenon	Xe	54	131.30	5.896×10^{-3}	0.2130×10^{-3}	....	8.48	...
Ytterbium	Yb	70	173.04	6.96(i)	0.251(i)	24.86	7.02	1.01
Yttrium	Y	39	88.92	4.47(j)	0.161(j)	19.89	10.41	2.33
Zinc	Zn	30	65.38	7.133(b)	0.258(b)	9.17	12.43	1.74
Zirconium	Zr	40	91.22	6.489(j)	0.234(j)	14.06	10.19	1.57

(a) Hexagonal. (b) At 77 F (25 C). (c) Arc-melted button. (d) Observed values at 77 F (25 C). (e) Rhombohedral. (f) Calculated. (g) Arch-melted iodide. (h) Beta tin. (i) Face-centered cubic. (j) Close-packed hexagonal, low hafnium.

Assuming that molecular binding can be ignored, the following relationship holds for mixtures or molecules (M) of proportions (P).

$$\text{Radiation length of M} = \frac{\text{Weight of M}}{\Sigma\left(\dfrac{\text{Proportion of constituent}}{\text{Radiation length of constituent}}\right)}$$

Example: Water formula H_2O,

Hydrogen, Z = 1, A = 1.0080, X_0 = 63.05, P = 2,

Oxygen, Z = 8, A = 16.00, X_0 = 34.24, P = 1

$$X_0\,(H_2O) = \frac{2 \times 1.0080 + 1 \times 16.00}{\left(\dfrac{2 \times 1.0080}{63.05} + \dfrac{1 \times 16.00}{34.24}\right)} = \frac{18.016}{(0.03197 + 0.46729)} = \frac{18.016}{0.49926} = \underline{\underline{36.09}}$$

Example: Air,

Nitrogen (N_2), Z = 7, A = 14.01, X_0 = 37.99, P = 76.9%

Oxygen (O_2), Z = 8, A = 16.00, X_0 = 34.24, P = 21.8%

Argon (Ar), Z = 18, A = 39.994, X_0 = 19.55, P = 1.3%

$$X_0\,(\text{Air}) = \frac{0.769 + 0.218 + 0.013}{\left(\dfrac{0.769}{37.99} + \dfrac{0.218}{34.24} + \dfrac{0.013}{19.55}\right)} = \frac{1.0}{(0.02024 + 0.00637 + 0.00066)} = \frac{1.0}{0.02727} = \underline{\underline{36.66}}$$

* Rev. Mod. Phys., Vol 46, October 1974, Yung-Su Tsai author.

TITLE	PREPARED BY J. Hodges/ J. O. Turner	DATE June 1979
COMMERCIAL ISO METRIC MACHINE SCREWS, BOLTS & NUTS	REVISED BY	DATE
	REVISED BY	DATE

THE PRESENT SITUATION

Since the 1976 International Standards Organization Conference on Metric Fasteners, manufacturers in all industrial nations except the USA have been conforming to the ISO list of Recommended Sizes and Threads for Commercial Screws, Bolts and Nuts. (See TABLE I.) This ISO list introduces two new fastener sizes--M1.6 and M2.5 to replaced four previously used sizes in the same diameter range. All other sizes are interchangeable with select DIN and SI commercial screws previously used thoughout Europe. However, many of the old DIN and SI intermediate sizes have been relegated to "2nd Choice" status (see TABLE II).

By now, 1979, most ISO 2nd Choice thread sizes, as well as several pitch and size variants used by Japan and other countries have been phased out of commercial production. Foreign equipment items manufactured worldwide will have all fastening screws and bolts matching sizes in TABLE I.

COMPARISON WITH U. S. SYSTEM

As can be seen from the comparison data in TABLE I, more than half the metric sizes listed have thread O.D's close enough to share clearance holes with corresponding U.S. screws. Conspicuously missing, however, are metric screw diameters matching those of our popular 2-56, 6-32, 1/4" and 3/8" sizes. The American Society of Mechanical Engineers wishes to add an M6.3 screw size to match the diameter of our 1/4" screw when the USA converts to metric fasteners. The "Second Choice" M3.5 does closely match our 6-32 in diameter, but is rarely stocked by suppliers.

The U.S. tap-drill sizes listed in TABLE I are, with the exception of the three sizes in parentheses, fully adequate alternatives to the corresponding metric drill sizes recommended for commercial screw-thread fits. The actual diameter difference is ascertained as follows:

Nominal screw diameter minus pitch of screw = recommended tap drill size.
Metric tap drill size x .03937 = size in inches.
Locate nearest drill size on U.S. drill chart.

Example: M3 - .5 = 2.5 mm: x .03937 = .0984"; #40 U.S. drill is .0980" diameter.

CALL-OUTS

All coarse-Thread Series metric screws and bolts are denoted by nominal diameter in mm and length in mm as follows: M6 x 25; M12 x 25. No mention of thread spacing is required, even on engineering drawings. For the Fine-Thread Series, the pitch (spacing between two adjacent threads) is also given in mm: M12 x 1.25 x 25.

It should be noted that Fine-Thread Series fasteners smaller than M8 (approximately 5/16" diameter) are not used commercially, even on microscopes or cameras.

CHECKING FASTENER SIZES ON FOREIGN EQUIPMENT

On new equipment (post-1977) a measurement across the thread O.D. with an inch-reading micrometer on vernier caliper will suffice. Reference this to the "measured O.D. range in inches" column of TABLE I. (Coarse and fine pitch versions of M8 and larger screws can be distinguished by eye, or by counting the approximate number of threads in a half-inch span.)

On pre-1977 European items, use the same techniques, referencing to both TABLE I and II. On pre-1977 Japanese equipment (or pre-1965 French or Italian items) an inch or metric thread gage should be used to determine the pitch of any M3, M4, or M5 screws.

NOTE: Some of the U.S. NF (National Fine) screws found on vintage American transits, balances, microscopes, etc. are frequently confused with metric sizes of very similar diameter and thread spacing: 3-56 with M2.5, 4-48 with M3, 6-40 with M3.5 and 8-36 with M4.

HELP FROM BLDG. 25

The Bldg. 25 Micro-development Shop will gladly loan metric taps and dies, furnish replacements for lost or broken screws and answer questions about specific metric threads.

TO PURCHASE METRIC ITEMS

Probably the only U.S.-based supplier stocking a good selection of metric fasteners is METRIC & MULTISTANDARD COMPONENTS CORP., Hawthorne, N. Y. 10532; Tel. (914) 769-5020. (Bldg. 90 Engr. Library has catalog.) The following suggestions will expedite orders:

1. Order only screw sizes listed in TABLE I.
2. Specify one of these lengths in mm: 2,4,5,6,8,10,12,16,20,25,30,35 etc.
3. Specify material: Brass, Steel (plain or plated). Stainless Steel or one of 3 grades of heat-treated steel for socket head and hex head cap screws (see Catalog.)
4. Specify head style: Flat, Pan, Cheese (semi-fillister) Oval, Socket-head Cap, etc. (U.S.-style Round head no longer made in ISO fastener series.)
5. Order minimum quantity of 100, each size.

EXAMPLE: M10 x 40, Grade 12.9 Steel Socket Head Cap Screw.....100 ea.

DRILLS

LBL will shortly stock metric drill bits in the 1 to 10 mm range in increments of 0.1 mm.

TABLE I
COMMERCIAL ISO METRIC SCREWS BOLTS
AND NUTS AND COMPARABLE U.S. SIZES

Nominal Size Dia in mm	Pitch in mm	Tap Drill Size in mm	Approx. Threads per in.	Measured* O.D. range in inches	Suggested U.S. Drill Size		Nearest U.S. Size	
					Tap	Clearance	nominal	O.D. Range inches
M 1.6**	0.35	1.25	72 1/2	.058-61	(#55)	#50	0-80	.057-60
M 2	0.4	1.6	63 1/2	.075-78	#52	#44	1-72	.069-72
M 2.5	0.45	2.05	56 1/2	.093-96	#45	#36	3-56	.094-98
M 3	0.5	2.5	51	.112-16	#40	#31	4-48	.108-12
M 4	0.7	3.3	36 1/4	.150-55	(#30)	#18	8-36	.153-60
M 5	0.8	4.2	31 3/4	.192-98	#19	# 5	10-32	.185-93
M 6	1.0	5.0	25 1/2	.230-37	(# 8)	1/4	1/4-28	.242-49
M 8	1.25	6.75	20 1/4	.307-15	17/64	"Q"	5/16-18	.301-10
M 8 x 1	1.0	7.0	25 1/2	" "	"J"	"	5/16-24	" "
M 10	1.5	8.5	17	.384-92	"Q"	"Z"	3/8-16	.366-74
M 10 x 1.25	1.25	8.75	20 1/4	" "	11/32	"	3/8-24	" "
M 12	1.75	10.25	14 1/2	.461-70	"Y"	1/2	1/2-13	.489-99
M 12 x 1.25	1.25	10.75	20 1/4	" "	27/64	"	1/2-20	" "
M 16	2.0	14.0	12 1/2	.617-28	35/64	43/64	5/8-11	.612-23
M 16 x 1.5	1.5	14.5	17	" "	9/16	"	5/8-18	" "
M 20	2.5	17.5	10 1/4	.773-85	11/16	53/64	3/4-10	.734-47
M 20 x 2	2.0	18.0	12 1/2	" "	45/64	"	3/4-16	" "
M 24	3.0	21.0	8 1/2	.929-43	53/64	1"	1"-8	.980-97
M 24 x 2	2.0	22.0	12 1/2	" "	(7/8)	"	1"-12	" "
M 30	3.5	26.5	7 1/4	1.163-79	1 3/64	1 1/4	1 1/8-7	1.104-22
M 30 x 2	2	28.0	12 3/4	" "	1 7/64	"	1 1/8-12	" "
M 36	4	32.0	6 1/4	1.397-415	1 9/64	1 1/2	1 3/8-6	1.350-72
M 36 x 3	3	33.0	8 1/2	" "	1 19/64	"	1 3/8-12	" "

NOTES: * Permissible thread-O.D. tolerance allowances for ISO & U.S. commercial fasteners are slightly broader than the "measured O.D. range" given above.

** M 1.6 is the conventional dividing point between standard range and miniature fasteners. ISO commercial threads continue downward as follows:

M 1.4 (See Table II)	M 0.8 (x 0.2)	M 0.4 (x 0.1)
M 1.2 (x 0.25)	M 0.6 (x 0.15)	M 0.3 (x 0.08)
M 1 (x 0.25)	M 0.5 (x 0.125)	M 0.25 (x 0.075)

Sizes M 1.4 thru M 0.3 are fully interchangeable with same size and pitch screws of the U. S. Unified National Miniature Series (UNM)

TABLE II

SPECIAL OR DISCONTINUED METRIC THREADS FOUND ON LBL EQUIPMENT

Nominal Size (dia. in mm)	Pitch mm	Approx. threads per in.	Approx. O.D inches	Comments
M 1.4	.30	85	.053-55	Now ISO "2nd Choice"; much used on pre-1977 instruments. Still some use; screws stocked.
M 1.7 M 2.3 M 2.6	.35 .40 .45	72 1/2 63 1/2 56 1/2	.065-67 .087-89 .100-03	Discontinued DIN, SI, JIS size. " " " " " " " " " "
M 3.5	.60	42	.133-37	Now ISO "2nd Choice"; screws not stocked. Found on some pre-1977 microscopes, etc.
M 3 x .6 M 4 x .75 M 5 x .9		42 1/2 34 28	.111-15 .149-54 .191-97	Discontinued JIS and old CNM series thread pitches. Used thru 1977 on many Japan item; to 1965, some French & Italian items.
M 4.5 M 7	.75 1.0	34 25 1/2	.173-76 .270-275	ISO "2nd Choice"; rarely used; not stocked. " " " " "
M 7 x .5 M 7 x .75 M 8 x .75		51 34 34	.270-73 " " .309-14	Special Fine threads widely used on sleeve mounts of switches, pots, etc. Taps, dies, nuts available, but not commercial screws.
M 8 x .5 M 10 x .5 M 10 x 1 M 12,14,16x1		51 51 25 1/2 "	.309-14 .386-92 " "	Special Fine threads used for micrometers, lead screws, lens-mount sleeves, Custom fine-adjustment screws, etc. Taps and dies available, but not commercial screws.
M 12 x 1.5		17	.461-410	DIN automotive
M 14 M 14 x 1.5	2	12 3/4 17	.540-50 " "	ISO "2nd Choice"; rarely used. Electric conduit threads; bearing nuts.
M 14 x 1.25		20 1/4	.543-47	Universal Auto Spark Plug thread; also insulated lead-thrus, early LBL vacuum tanks.
M 15 x 1.5 M 17 x 1.5 M 20 x 1.5 M 25 x 1.5 M 30 x 1.5 M 35 x 1.5		17 " " " " "	.582-99 .660-67 .776-84 .974-82 1.170-79 1.366-75	Special Bearing Locknut threads found on foreign-made, power-driven equipment at LBL; machine tools, positioning devices, spectrometers, etc. Taps, dies available as well as various styles of locknuts.
M 18 M 18 x 1.5	2 1/2	10 1/4 17	.692-704 " "	ISO "2nd Choice"; rarely used " " " (fine pitch)
M 22 M 22 x 1.5	2 1/2	10 1/4 17	.852-64 " "	ISO "2nd Choice"; rarely used " " " (fine pitch)
M 27 M 27 x 2	3	8 1/2 12 3/4	1.048-61 " "	ISO "2nd Choice"; 1976, bolts available " " " (fine pitch)

Abbreviations: DIN---German Industrial Standard JIS---Japan Industrial Standard
SI----Systeme Internationale CNM---Old French Standard