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Authors
Brobeck, W.M.
Scalise, D.T.

Publication Date
1957-09-01

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UCRL DESIGN DATA OF GENERAL INTEREST

BERKELEY, CALIFORNIA

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UCRL-3687
Physics and
Mathematics

UNIVERSITY OF CALIFORNIA

Radiation Laboratory
Berkeley, California

Contract No. W-7405-eng-48

UCRL DESIGN DATA OF GENERAL INTEREST

W. M. Brobeck and D. T. Scalise

September 1957

Printed for the U. S. Atomic Energy Commission

UCRL DESIGN DATA OF GENERAL INTEREST

W. M. Brobeck and D. T. Scalise

Radiation Laboratory
University of California
Berkeley, California

September 1957

INTRODUCTION

The design data herein, with a few exceptions, were prepared by members of the Mechanical Engineering Department at UCRL. The individual data sheets have been issued from time to time since 1946; they represent summarized information which we have found useful in our design work.

This collection was selected to meet the requests of outside organizations for copies of our design data. Those design data which would not be of general interest, such as size and capacities of our machine shop tools, are omitted.

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DESIGN DATA

DATE	D.Q. NO.	PAGE
5-30-46	2	1

SUBJECT

HEAT TRANSFER AT MODERATE TEMPERATURES

PREPARED W. M. Brobeck

CHECKED BY Retyped: 7-28-50 AH

Corrected: 9-13-50

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)

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

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

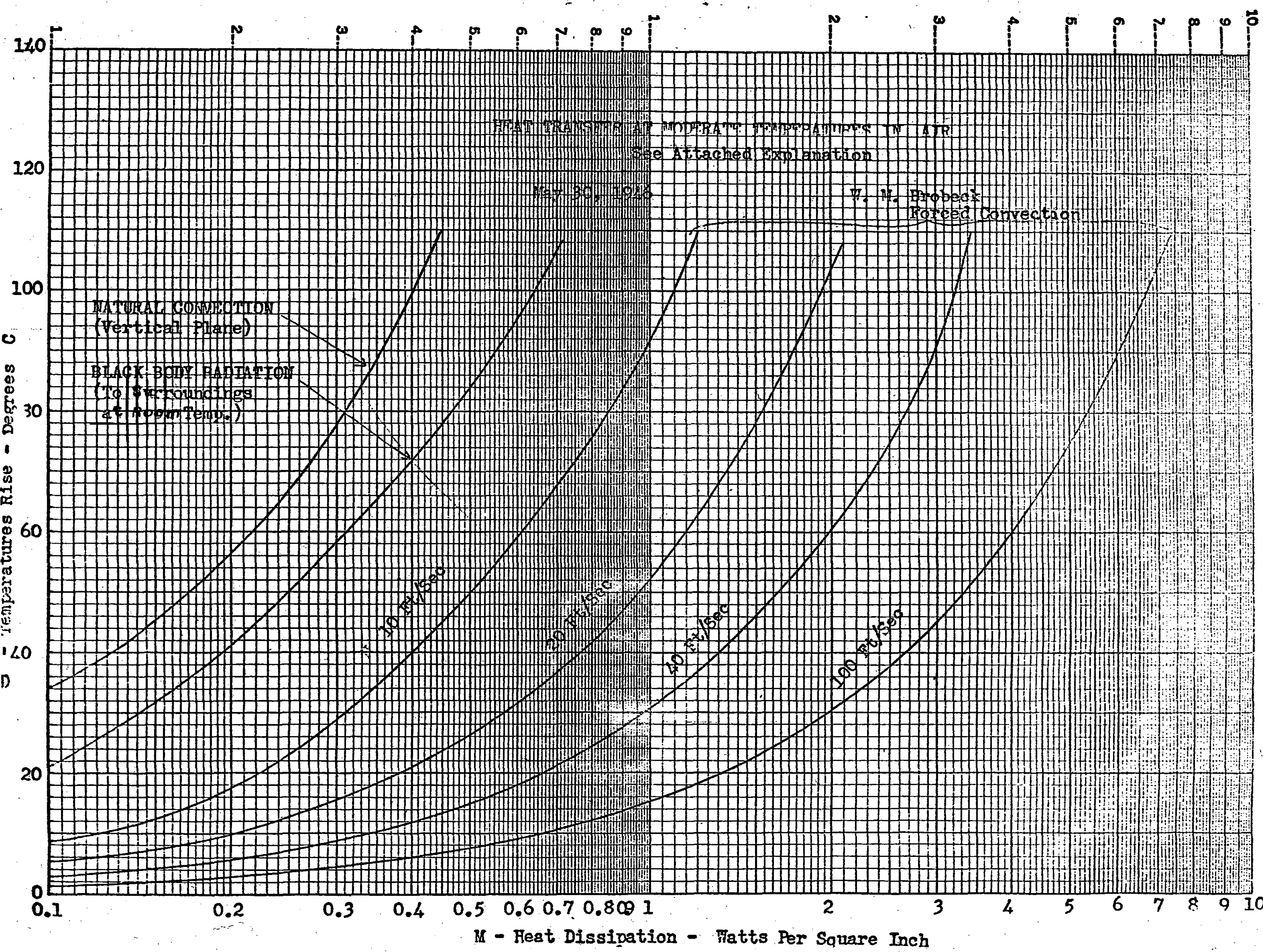
Below V = 16 ft./sec. $\frac{M}{\theta} = 0.0037\,(1+0.2V)\ \frac{\text{watts}}{\text{in.}^2\ {}^\circ\text{C}}$

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 = 2¼ inches of water) will usually be found uneconomical.

WMB:E:ah W. M. Brobeck



Radiation Laboratory
Design Data No. 2

RADIATION LABORATORY - UNIVERSITY OF CALIFORNIA - BERKELEY

DESIGN DATA

DATE ORIGINAL 9-10-46 REDRAWN 3-3-52	D. D. NO. 5	PAGE 1

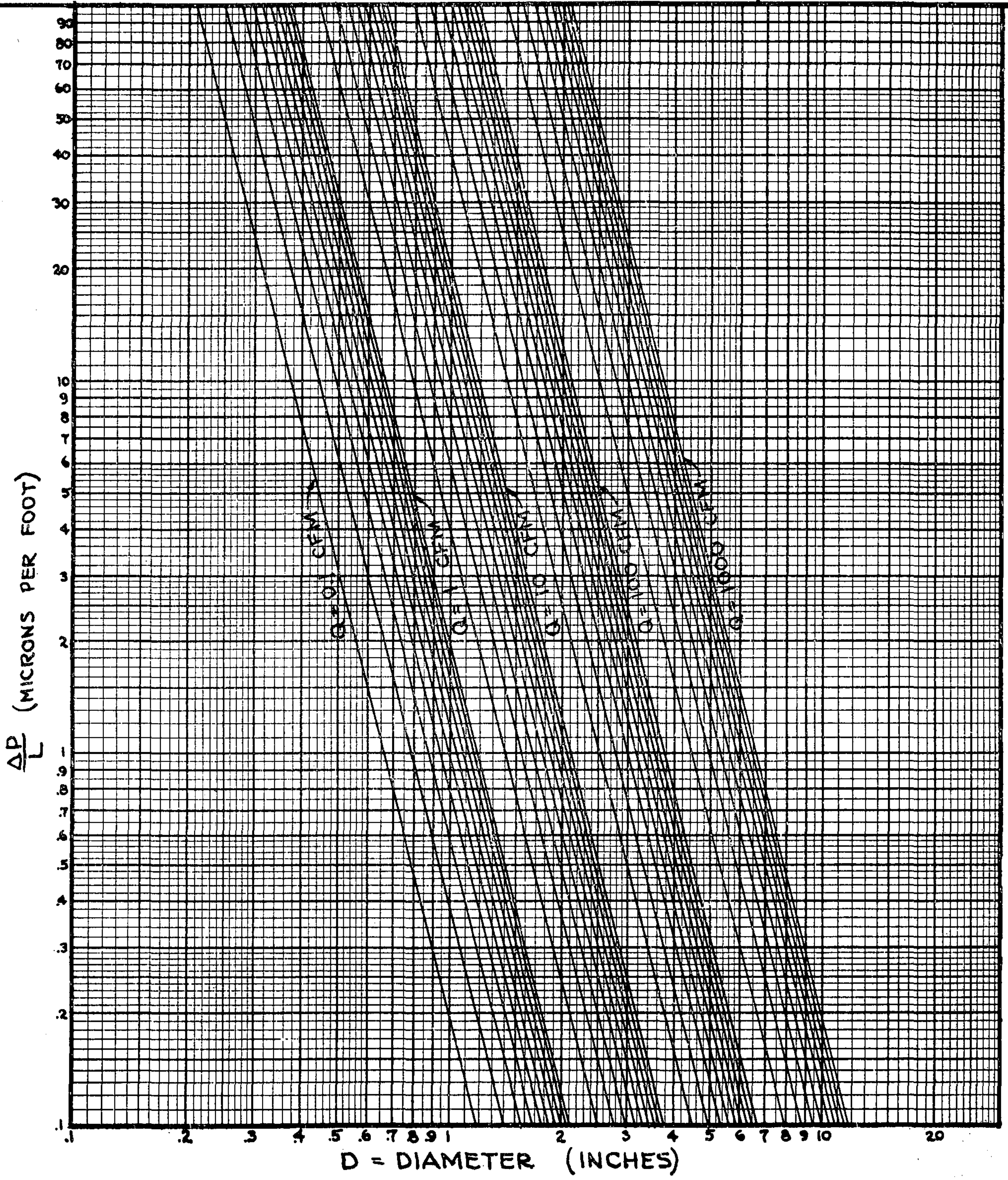
SUBJECT

PRESSURE DROP IN FOREVACUUM PIPES FOR STREAMLINE FLOW

PREPARED W. M. BROBECK

CHECKED BY

DRAWN BY SEEGMILLER



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 TO THAT OF AIR AT 20°C.

CONDITIONS FOR STREAMLINE FLOW:
(ALSO CALLED VISCOUS FLOW)

1. REYNOLDS NO. < 2000
2. $P > \frac{200}{D}$ (P IN MICRONS) (D IN INCHES)

RADIATION LABORATORY - UNIVERSITY OF CALIFORNIA - BERKELEY

DESIGN DATA

SUBJECT

PROPERTIES OF HIGH VOLTAGE CERAMICS

PROPERTY	WESTINGHOUSE ZIRCON	OTHER ZIRCONS	FUSED QUARTZ	HIGH VOLTAGE PORCELAIN	COORS TYPE AB-2 HIGH STRENGTH ALUMINA CERAMIC	FRENCHTOWN No. 4462 HIGH ALUMINA CERAMIC
SPECIFIC GRAVITY (GRAMS/CC)	3.68	3.0 TO 3.8	2.2	2.3 TO 2.5	3.42	3.88
MOHS' HARDNESS	8.0	7.5 TO 8.5	5.0 TO 7.0	7.0	9	9
COEFF. LINEAR THERMAL EXPANSION (AVE. FOR 20 TO 700C RANGE)	4.9×10^{-6}/°C.	3.5 TO 5.5×10^{-6}/°C.	$.55 \times 10^{-6}$/°C.	5.0 TO 6.8×10^{-6}/°C.	7.4×10^{-6}/°C.	7.0×10^{-6}/°C.
THERMAL CONDUCTIVITY WATTS/IN. °C.	.124	.106 TO .159	.035 TO .038	.027 TO .041	.044 AT 25C. .073 AT 400 C.	.191 AVE. FOR 82 TO 204C RANGE
TENSILE STRENGTH (PSI)	12,700	10,000 TO 15,000	2,500 TO 7,000	3,400 TO 8,000	17,000 TO 18,000	15,500
COMPRESSIVE STRENGTH (PSI)	90,000	80,000 TO 150,000	20,000 TO 30,000	40,000 TO 80,000	OVER 200,000	187,100
TRANSVERSE STRENGTH (PSI)	25,000	20,000 TO 35,000	10,000 TO 11,000	9,000 TO 15,000		
MODULUS OF ELASTICITY (PSI)	24×10^{6}	20×10^{6} TO 30×10^{6}	10×10^{6}	7×10^{6} TO 14×10^{6}		
POWER FACTOR (AT 1 MEGACYCLE)	.0010 - .0014	.0002 TO .002	.0002 TO .0023	.006 TO .010		.000352
DIELECTRIC CONSTANT (AT 1 MEGACYCLE)	9.2	8.0 TO 10.0	3.2 TO 4.2	6.0 TO 7.5	8.16	9.2
DIELECTRIC STRENGTH (VOLTS/MIL)	290	250 TO 350	100 TO 400	250 TO 400	230	220
RESISTIVITY: (OHM CM.) (OHM INCHES)	10^{13} 4×10^{12}	10^{13} TO 10^{15} 4×10^{12} TO 4×10^{14}	10^{15} 4×10^{14}	10^{12} TO 10^{14} 4×10^{11} TO 4×10^{13}		
Te VALUE = TEMP. AT WHICH RESISTIVITY IS EQUAL TO 1 MEGOHM CM. = .394 MEGOHM IN.	>700 C.	>700 C.	700 TO 900 C.	300 TO 500 C.	850 C.	800 C.

REFERENCES:

1. COORS PORCELAIN CO., GOLDEN, COLORADO FOR TYPE AB-2 ALUMINA CERAMIC
2. FRENCHTOWN PORCELAIN CO., FRENCHTOWN, NEW JERSEY FOR No. 4462 (ENG NOTE 12-1M44 GIVES ADDITIONAL PROPERTIES)
3. "WESTINGHOUSE ENGINEER" MAY 1946 p. 93 FOR OTHER CERAMICS.

DATE	D.D. NO.	PAGE
12-3-46 REVISED 4-23-52	6	1

PREPARED BROBECK/SCALISE

CHECKED BY

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DESIGN DATA

DATE	D.D.NO.	PAGE 1 OF 1 PAGES
1/17/47	10	

SUBJECT

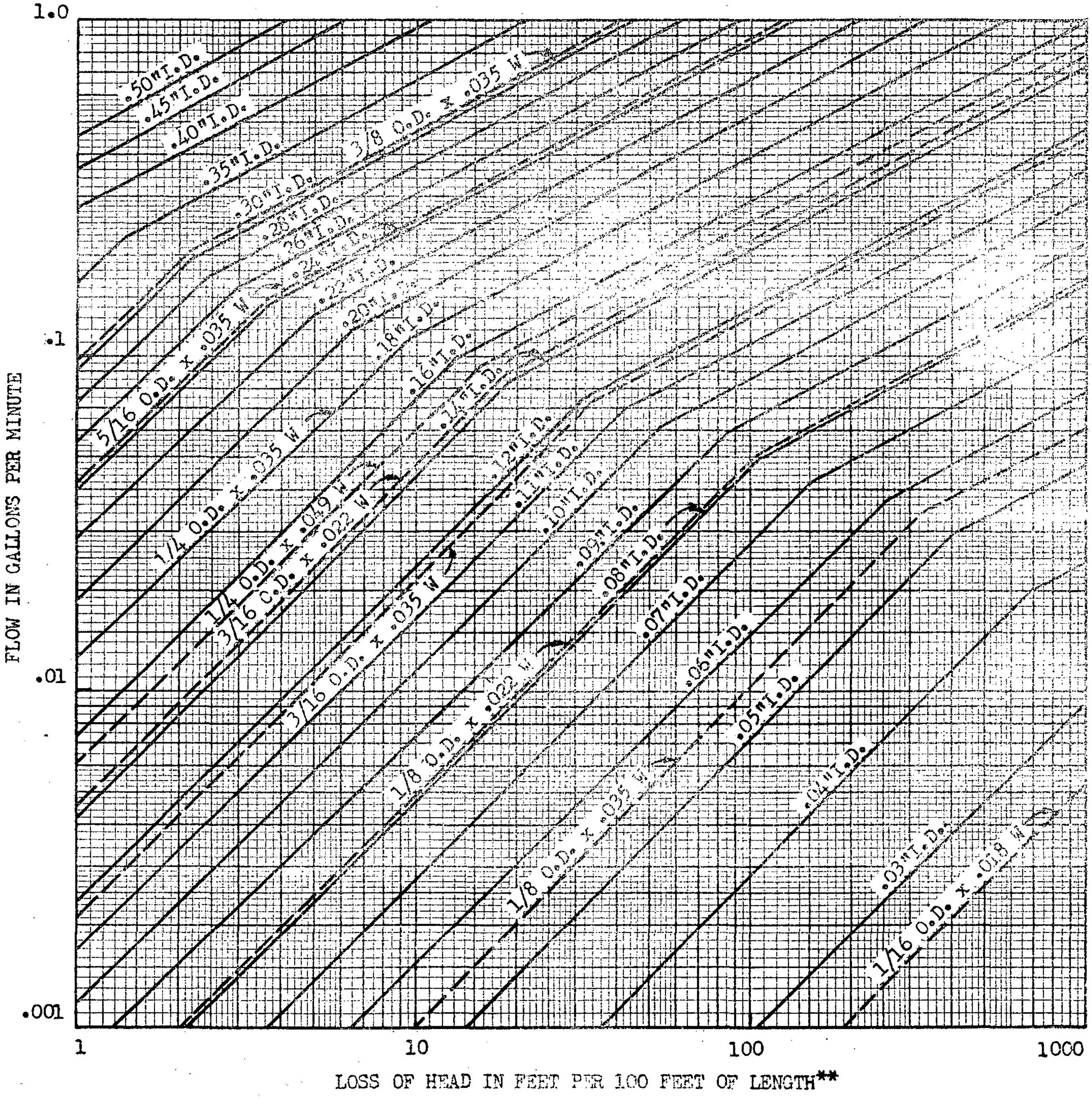
WATER FLOW IN SMALL SMOOTH TUBES, SUCH AS BRASS AND COPPER*

PREPARED

R. Peters

CHECKED BY

Redrawn: 11/7/57



*Data taken from Williams and Hazen, "Hydraulic Tables"

**Loss in psi = Loss in Feet x .433

RL-610-a

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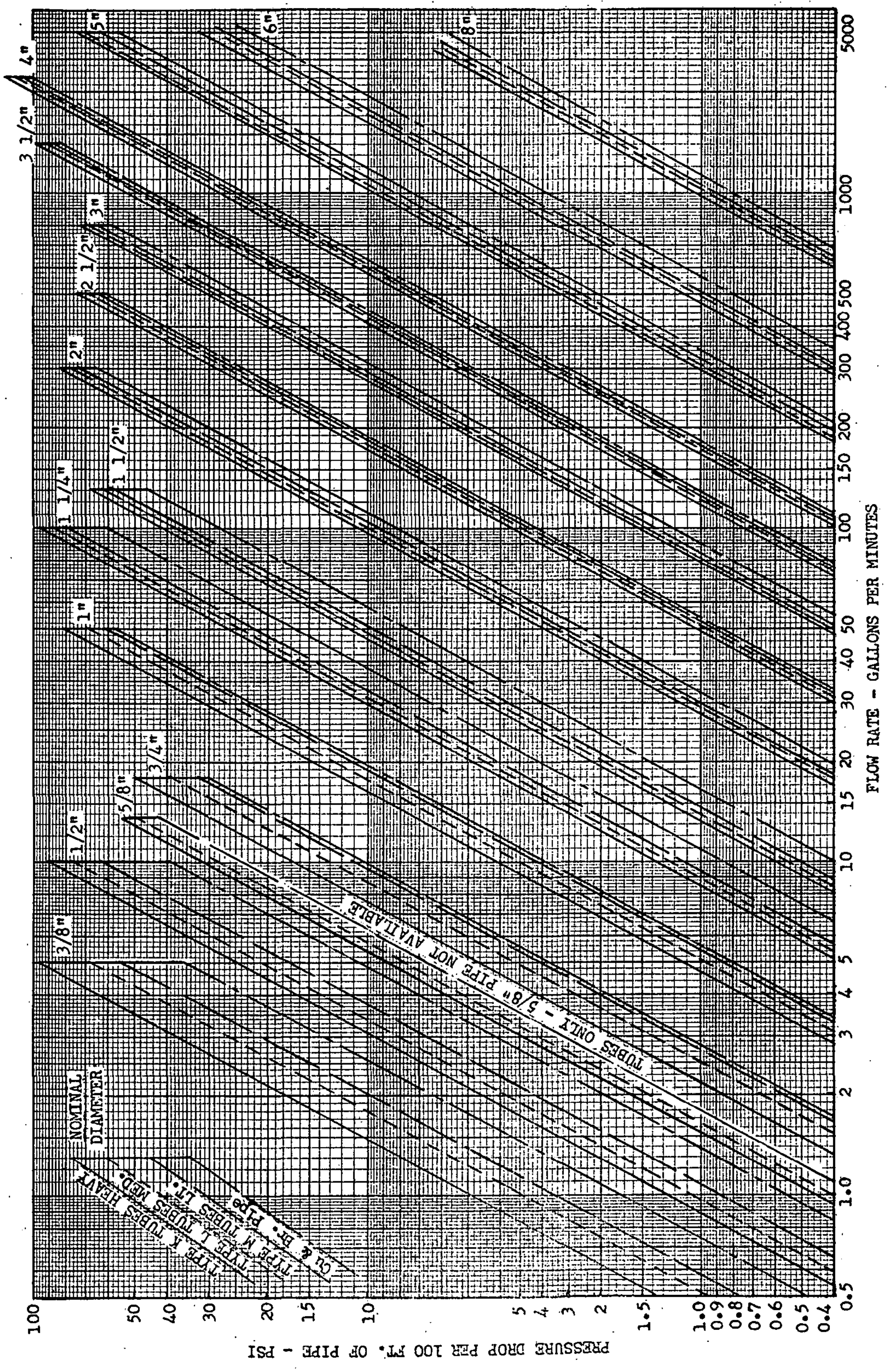
DESIGN DATA

DATE 11/2/49	D.D.NO. 10.1	PAGE 1 OF 2 PAGES	
SUBJECT WATER FLOW IN COPPER AND BRASS TUBES AND PIPE*	PREPARED R. Peters	CHECKED BY	

*From "Cameron Hydraulic Data"

Redrawn: 11/7/57



RL-610-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

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DESIGN DATA

SUBJECT

CU TUBE AND PIPE DIMENSIONS

DATE 7-25-51

D.Q. NO. 10.1

PAGE 2 of

PREPARED Ralph Peters

CHECKED BY

Retyped: 9-10-51

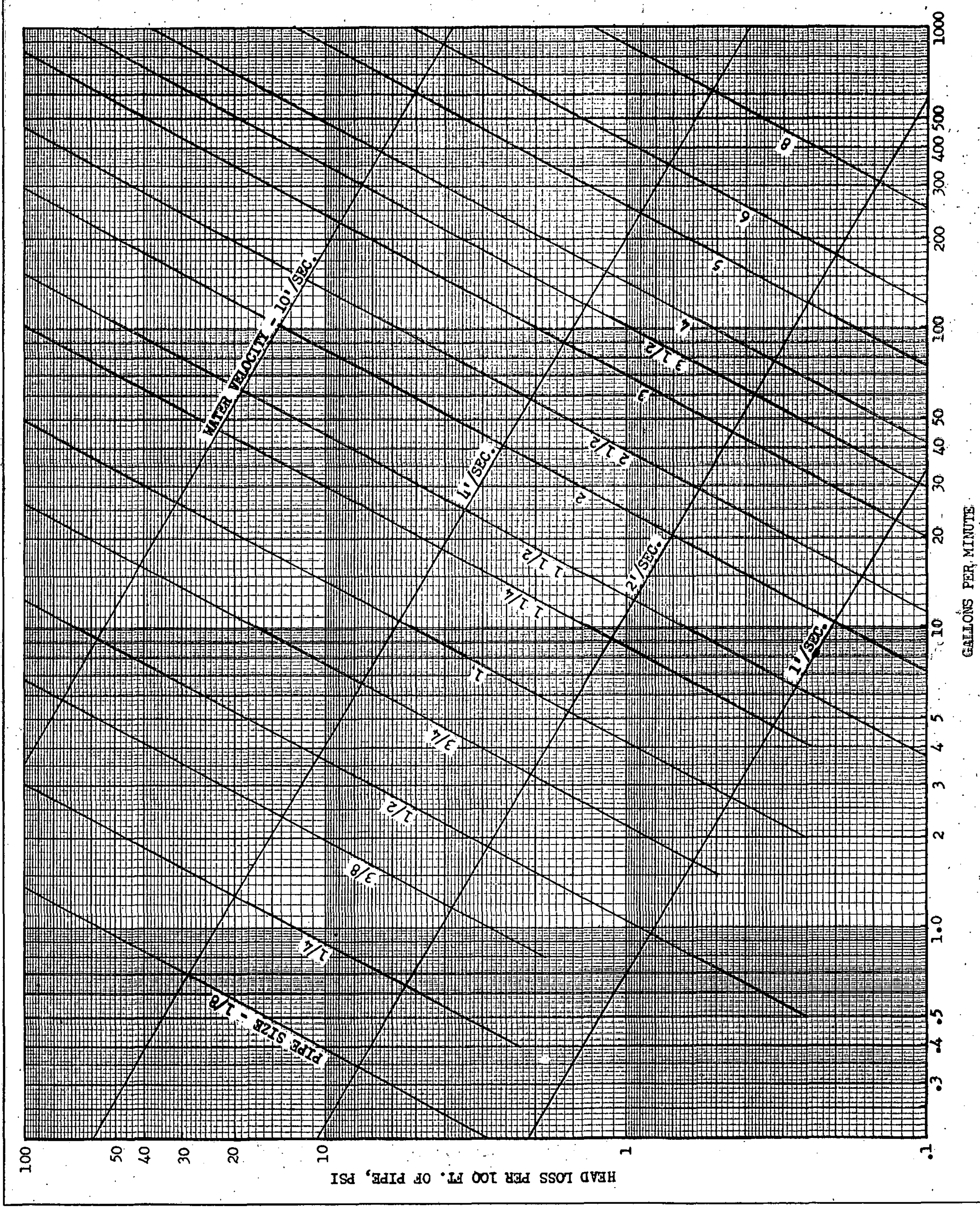
RADIATION LABORATORY - UNIVERSITY OF CALIFORNIA - BERKELEY

DESIGN DATA

DATE 11/3/49	D. D. NO. 10.2	PAGE 1 1 OF PAGES	
SUBJECT WATER FLOW IN STANDARD WEIGHT STEEL PIPE (SCHED. 40)*	PREPARED R. Peters	CHECKED BY	

Redrawn: 11/8/57

*Taken from Cameron Hydraulic Data



RL-610-a

RADIATION LABORATORY - UNIVERSITY OF CALIFORNIA - BERKELEY DESIGN DATA	DATE	D.D. NO.	PAGE
	2-24-47	11	1 of 2
SUBJECT PROPERTIES AND IDENTIFICATION OF MICA	PREPARED W. W. Salsig, Jr. CHECKED BY Retyped: 9-11-50		

Although Webster lists eight distinct varieties of mica, only two are suitable as electrical insulators. These two varieties are "<u>Moscovite</u>," (sometimes known as "White" or "Potash" mica), and "<u>Philogopite</u>," (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 ($AI_2\,O_3$)	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, <u>Standard Handbook for Electrical Engineers</u>, 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.

RADIATION LABORATORY · UNIVERSITY OF CALIFORNIA · BERKELEY DESIGN DATA	DATE 2-24-47	D.Q. NO. 11	PAGE 2 of 2
SUBJECT PROPERTIES AND IDENTIFICATION OF MICA	PREPARED W. W. Salsig, Jr. CHECKED BY Retyped: 9-11-50		

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 <u>Moscovite</u> or <u>Philogopite</u>. 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

RADIATION LABORATORY - UNIVERSITY OF CALIFORNIA - BERKELEY

DESIGN DATA

SUBJECT POWER REQUIRED TO ROTATE A HOLLOW SHAFT IN A MAGNETIC FIELD	DATE 3-14-47	D.D. NO. 13	PAGE 1 of 1
	PREPARED E.M. McMillan per W.M.B.		
	CHECKED BY Retyped: 9-12-50		

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

RADIATION LABORATORY - UNIVERSITY OF CALIFORNIA - BERKELEY

DESIGN DATA

DATE 3-14-47	D.D. NO. 14	PAGE 1 of 2

SUBJECT

PREFERRED UNITS

PREPARED W. M. Brobeck

CHECKED BY Revised 9-22-47

Retyped: 9-12-50

The following practical units have been found most useful in engineering work at the Laboratory, and are recommended for all tables, graphs, calculations, test reports, etc. Quantities on which there is no question have not been included. Numbers in parentheses refer to notes following the table.

Quantity	Preferred Unit (9)	Undesirable Units
Length	Inch(1) Foot	Meters, centimeters
Weight, Mass	Pound Gram (8) Proton(3)	Ounce
Temperature	Degrees Centigrade Degrees Kelvin	Fahrenheit
Power	Watt	Horsepower
Volume	Cubic Feet	Liters
Gas Flow	Cubic Feet/second(2), minute or Hour	Liters/second, etc.
Liquid Flow	Gallons/minute	Liters/second, etc.
Pressure	Pounds/square inch Microns(5)	Kg/cm^2, feet of water mm of mercury
Energy	Watt Seconds (Joules)	BTU
Torque	Pound Inches	Pound Feet
Magneto Motive Force	Ampere Turns	
Magnetic Flux	Maxwells (lines) (6)	Webers
Magnetic Intensity	Ampere Turns/inch	Oersteds
Magnetic Flux Density	Maxwells/square inch (Lines/square inch) Gauss(7) (Lines/square cm.)	
Heat Conductivity	Watts/degree C inch	Units based on BTU or °F
Heat Transfer Factor	Watts/degree C square inch	" " " " " "
Specific Heat	Watt sec/degree C lb.	" " " " " "
Specific Weight	Pounds/cubic inch	Avoid specific gravity
Resistivity	Ohm Inches	Ohm Centimeters

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DESIGN DATA

	DATE 3-14-50	D.Q. NO. 14	PAGE 2 of 2
SUBJECT PREFERRED UNITS	PREPARED W. M. Brobeck CHECKED BY Re: 9-22-47 Retyped: 9-12-50		

Often specifications must be written in undesirable units, but in these cases it is preferable to make the calculation in preferred units and convert only the result to the other units.

(1) Inches are preferable below 6 feet and for all dimensions of equipment, even though quite large (e.g., cyclotrons). Feet are preferable for dimensions of buildings, maps, pipe and wire lengths. However, structural calculations should be kept in inches regardless of the size of the structure.

(2) Liters per second is the conventional unit for pumping speed of high vacuum pumps, but cubic feet per second is coming into common use and is preferred as consistent with length and volume units. Seconds, minutes, hours, days, and years should be used wherever desired for rates.

(3) The mass of the proton is preferred where atomic quantities are involved.

(4) Omit the degree sign (°) after figures, as it is difficult to type and unnecessary.

(5) Used for vacuum calculations.

(6) "Maxwells" and "Lines" are two names for the same unit.

(7) The gauss, although based on the centimeter, is the unit in general use by the Laboratory, and to a considerable extent, in industry.

(8) Grams are used for small quantities of chemicals (e.g., deuterium oxide).

(9) Multiples of ten, as kilo, deci, etc., are to be used wherever desired. Distinguish abbreviations of milli, micro, and mega when necessary.

W. M. Brobeck

WMB:E/ah

RADIATION LABORATORY - UNIVERSITY OF CALIFORNIA - BERKELEY

DESIGN DATA

	DATE	D.D. NO.	PAGE 1 OF 2 PAGES
SUBJECT RADIO FREQUENCY POWER LOSS IN SHEET CONDUCTORS	3/17/47	15	
	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

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

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

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

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

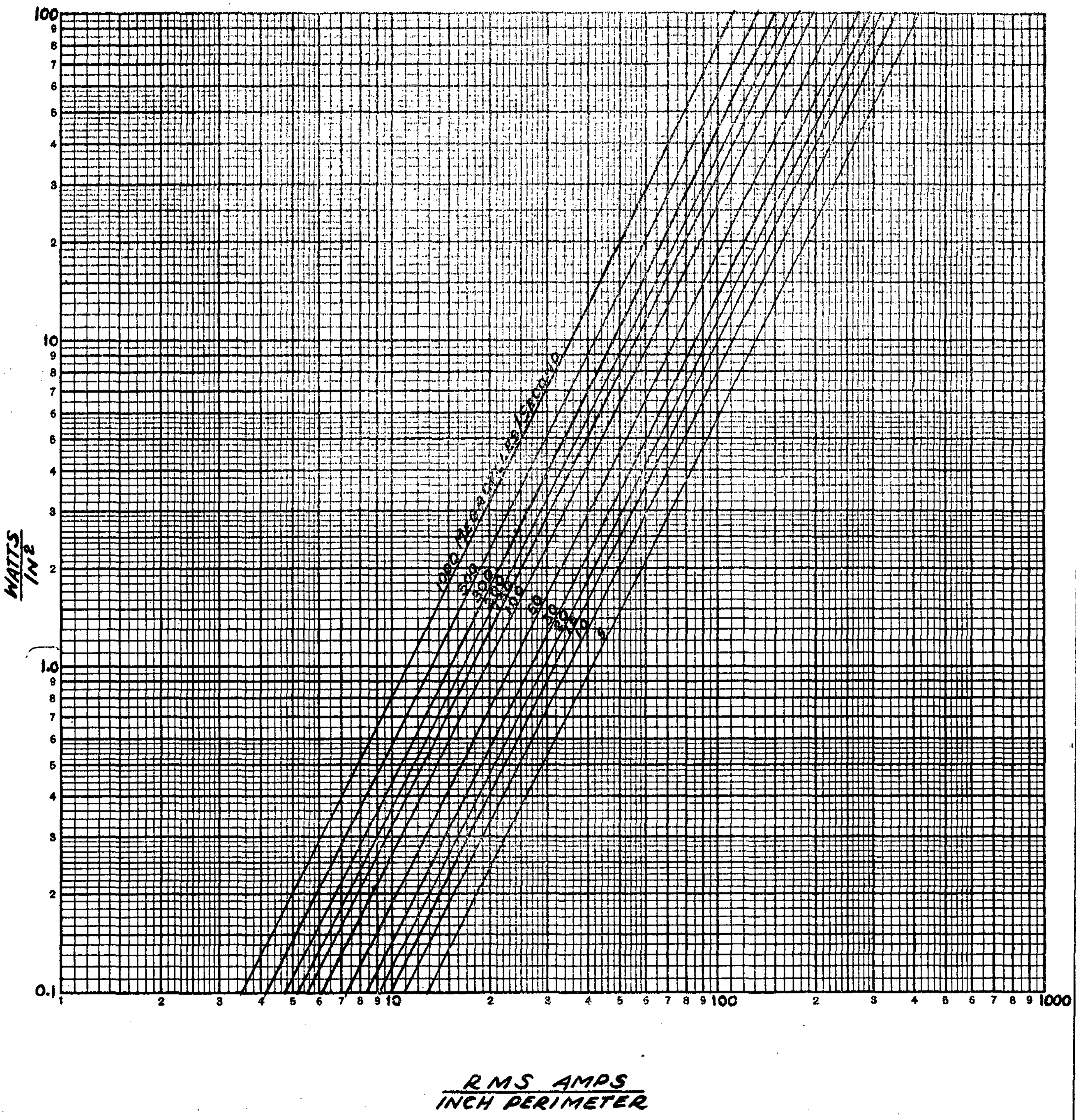
SUBJECT

RADIO FREQUENCY POWER LOSS IN SHEET CONDUCTORS

PREPARED W. M. Brobeck

CHECKED BY

Copied 12/5/57 by K. Connelly

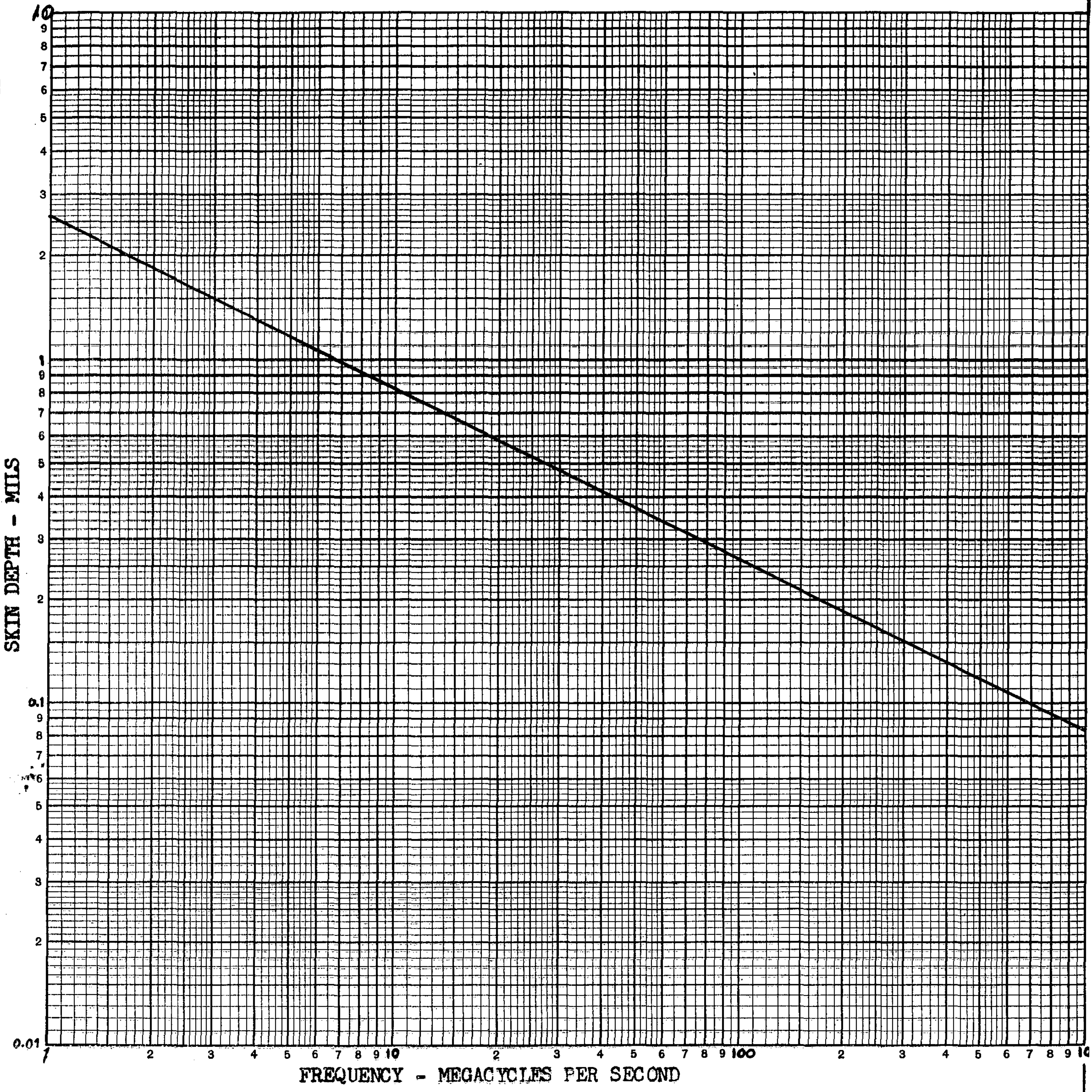


RADIATION LABORATORY - UNIV. OF CALIFORNIA - BERKELEY
DESIGN DATA

Date 3-17-47	D.D. 15	page 3
Prepared W. M. Brobeck		
Copied K. Connelly 10-15-57		

Subject

SKIN DEPTH* OF RADIO FREQUENCY CURRENT



*Thickness of DC conductor that would have same resistance.

RADIATION LABORATORY · UNIVERSITY OF CALIFORNIA · BERKELEY
DESIGN DATA

DATE 4-2-47
D D NO. 17
PAGE 1 of 4

SUBJECT
PUMPING SPEED OF PIPES & ORIFICES AT HIGH VACUUM

PREPARED Marvin Martin
CHECKED BY Rev: 9-22-47
Retyped: 9-15-50

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) $Q = \frac{GP}{\rho}$

where ρ is the mass density of the gas at pressure P.

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

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

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

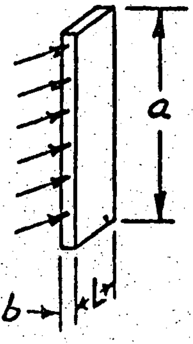
Q is in micron liters/sec.
A is cross sectional area in square inches.
P_1 and P_2 are in microns.
K is a factor whose value depends on the geometry of the pipe.
($K = 1$ for an orifice in a thin diaphragm)

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 $a \gg L \gg b$ — $K = \frac{b}{L}\log_e\frac{b}{L}$

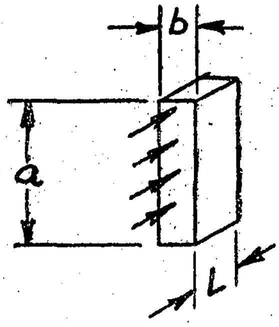


RADIATION LABORATORY • UNIVERSITY OF CALIFORNIA • BERKELEY DESIGN DATA	DATE 4-2-47	D.D. NO. 17	PAGE 2 of 4
SUBJECT PUMPING SPEED OF PIPES & ORIFICES AT HIGH VACUUM	PREPARED Marvin Martin		
	CHECKED BY Retyped: 9-15-50		

4. A long rectangular tube where $L >> a$ and $L >> b$
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 $a >> b$ and $a >> L$
Find K as a function of $\frac{L}{b}$ from Curve II.



Marvin Martin

MM:bw/ah

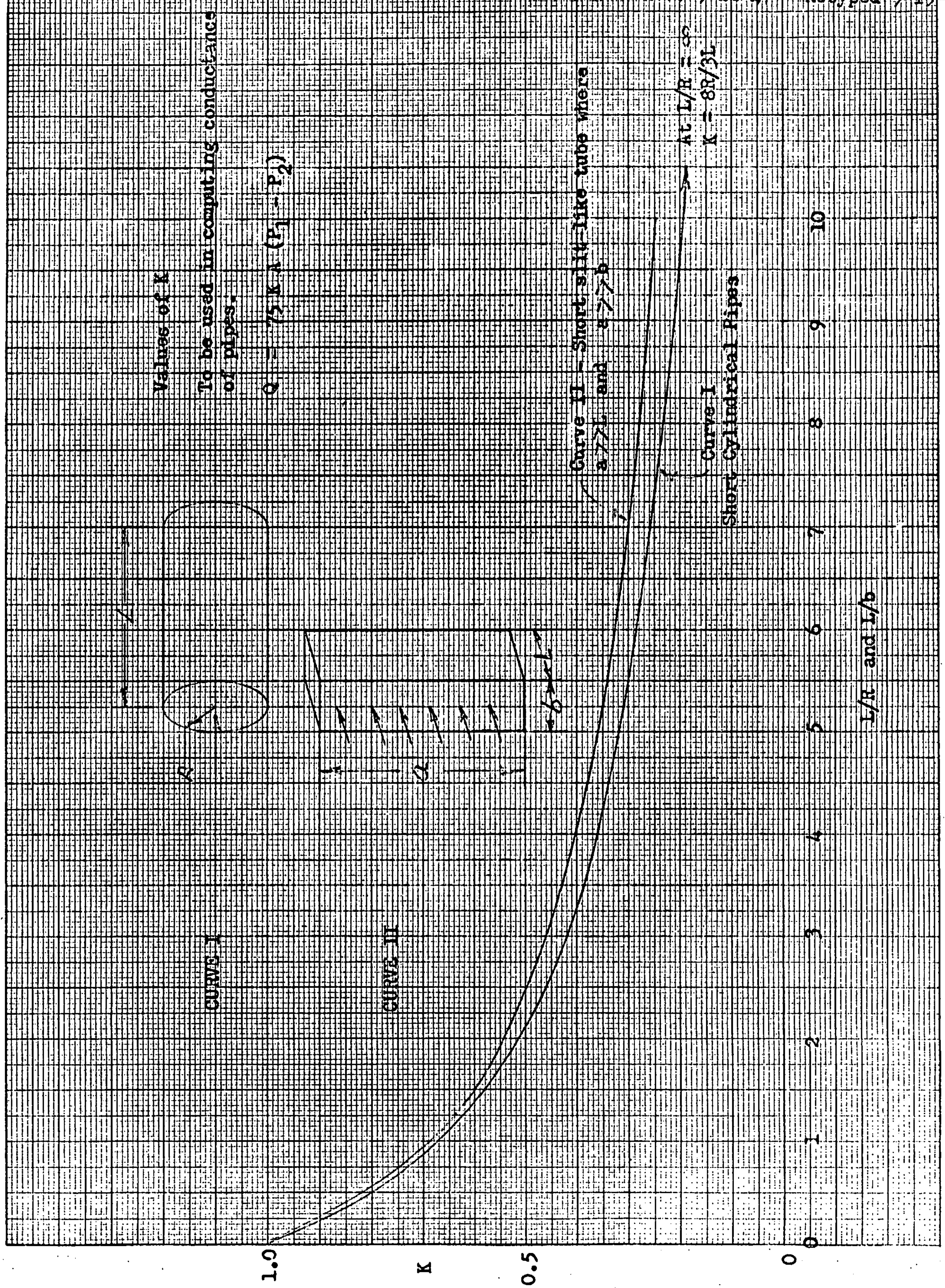
Note: Notation used differs from that of Loeb, ref. 1.

* 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



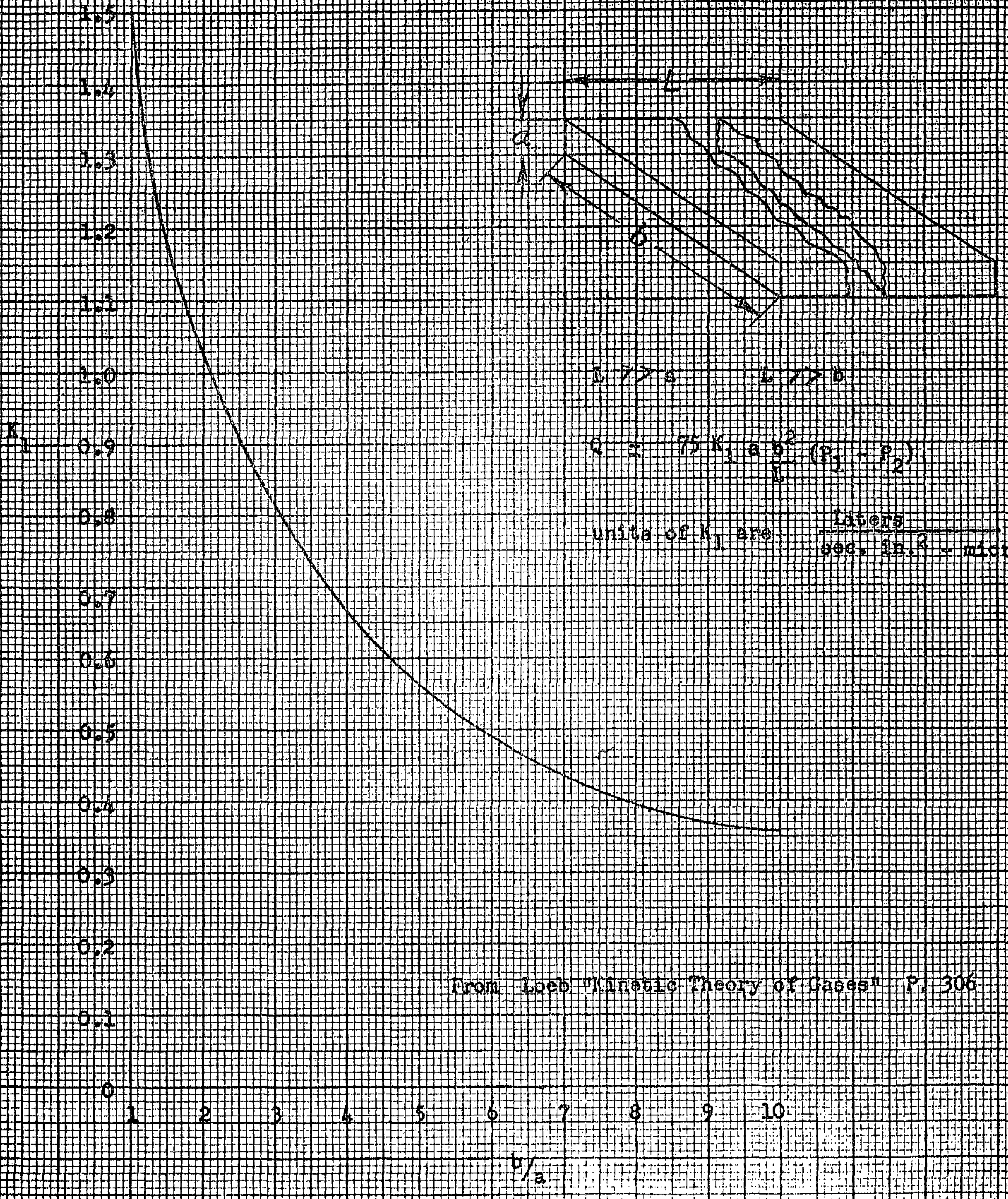
Values of K

To be used in computing conductance of pipes.

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

W. M. Broback

CONDUCTANCE OF RECTANGULAR TUBES



$L \gg a \qquad L \gg b$

$Q = 75\, K_1\, a\, \frac{b^2}{L}\, (P_1 - P_2)$

units of K_1 are $\frac{\text{liters}}{\text{sec. in.}^2 - \text{micron}}$

From Loeb "Kinetic Theory of Gases" P. 306

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DESIGN DATA

DATE	D.D. NO.	PAGE
6-20-50	23	1

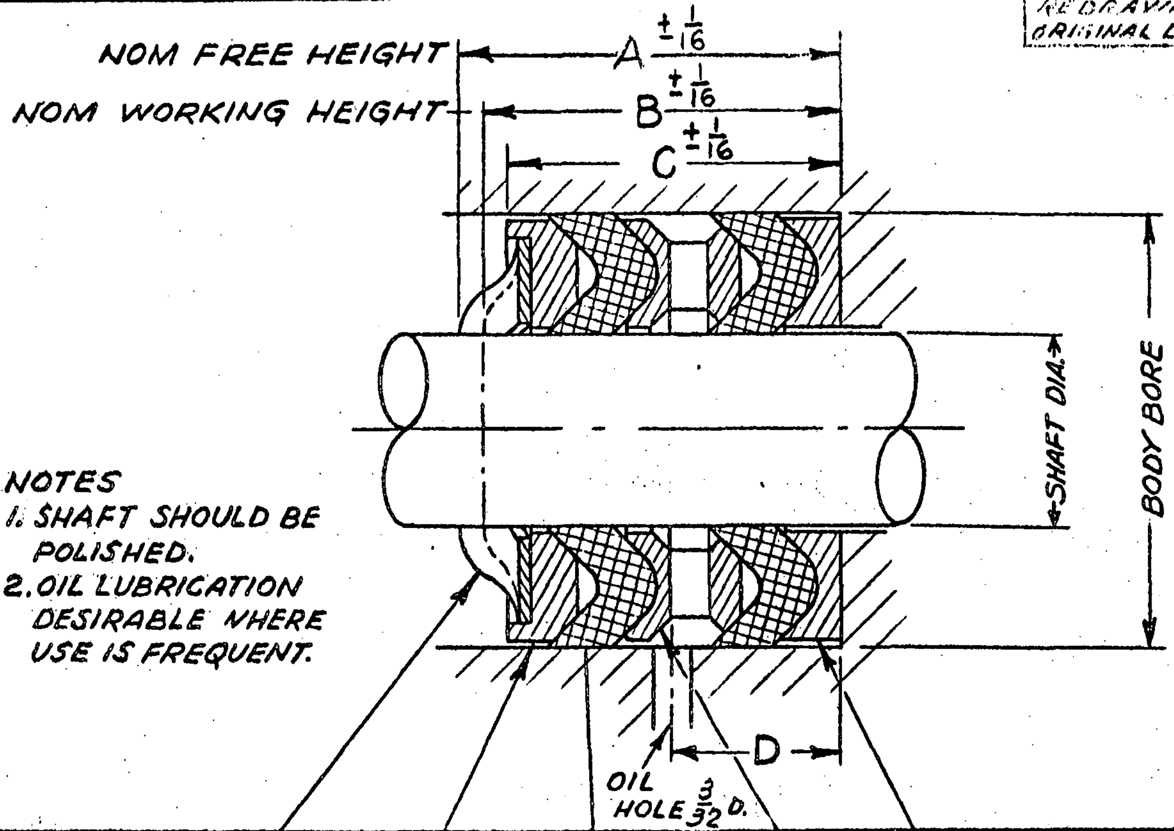
SUBJECT

CHEVRON SEAL
INTERNAL PARTS

PREPARED W.D.DECKER 9-15-49

CHECKED BY

REDRAWN BY J MCKAY
ORIGINAL DESTROY. 4·23·50



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	4E4352-1	1K7101	3G6001	1K7111	1K7121	13/16	23/32	11/16	3/8
1/2	1.125 1.127	" -2	3G1141	3G6011	3G1131	3G1121	1	15/16	7/8	7/16
3/4	1.362 1.366	" -3	1G1351B	3G6021	1G1291A	1G1381A	1	15/16	7/8	7/16
1	1.625 1.627	" -4	9901	2N4711A	9881A	9891	1 5/64	1 1/64	15/16	1/2
1 1/4	1.875 1.877	" -5	4E4011	4E4001	4E3981	4E4021	1	15/16	7/8	7/16
1 1/2	2.111 2.115	" -6	1G1361B	3G6031	1G1311A	1G1391A	1	15/16	7/8	7/16
1 3/4	2.250 2.253	" -7	1G1371B	3G6041	1G1331A	1G1401A	13/16	3/4	11/16	3/8
2	2.625 2.627	" -8	2Q2982	2N5301	2Q2972	2Q2992	1	15/16	7/8	7/16
2 1/2	3.125 3.127	" -9	4E4342	4E4311	4E4322	4E4332	1	15/16	7/8	7/16
3	3.750 3.753	" -10	2Q3402A	2N4241	2Q3392	2Q3382	1 1/32	31/32	29/32	1/2

RADIATION LABORATORY - UNIVERSITY OF CALIFORNIA - BERKELEY

DESIGN DATA

DATE 6-20-50
D.D. NO. 23
PAGE 2

SUBJECT

CHEVRON SEAL ASSOCIATED PARTS

PREPARED W. DECKER 9-15-49

CHECKED BY

REDRAWN BY J. MCKAY
ORIGINAL DESTROYED 4-23-50

THE FOLLOWING ARE DRAWING NUMBERS OF PARTS PREVIOUSLY DESIGNED. WHEN NEW PARTS ARE DESIGNED, THEY SHOULD BE ADDED TO THIS LIST FOR GENERAL REFERENCE.

SHAFT DIA.	NUT DRAWING NUMBER	HOUSING DRAWING NUMBER	
$\frac{3}{8}$	6E2531	6E2521	
$\frac{1}{2}$	3G1161, 5L3291	1G1172	
$\frac{3}{4}$	1G1421		
1	9932, 9942, 4B5011	9922	
$1\frac{1}{4}$			
$1\frac{1}{2}$	1G1431, 4A9661	4K2561, 4A9622	
$1\frac{3}{4}$	1G1441		
2	2Q3002		
$2\frac{1}{2}$	5L3322	5L3364	
3	4B5332, 2Q3412A	2Q6344	

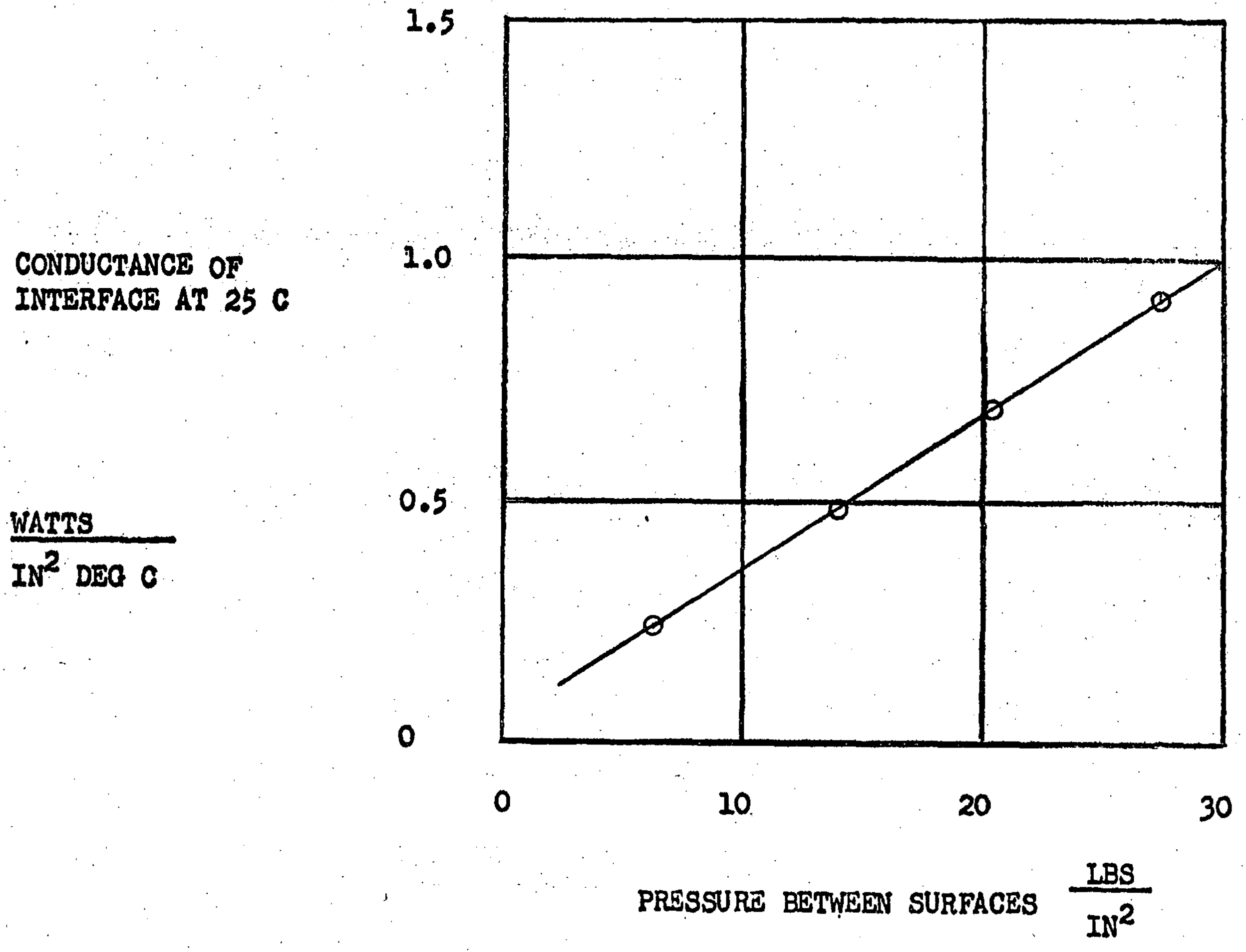
RADIATION LABORATORY · UNIVERSITY OF CALIFORNIA · BERKELEY

DESIGN DATA

SUBJECT	DATE	D.D. NO.	PAGE
HEAT TRANSFER BETWEEN CONTACT SURFACES IN VACUUM	11-3-47	24	1 [illegible]
	PREPARED W. M. Brobeck		
	CHECKED Addition: 9/20/48 RB Retyped 9-26-50		

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/RB/FP

RADIATION LABORATORY · UNIVERSITY OF CALIFORNIA · BERKELEY

DESIGN DATA

SUBJECT HARD SOLDER	DATE 3-19-48	D. Q. NO. 25	PAGE 1 of 3
	PREPARED Ralph Peters		
	CHECKED BY Retyped: 9-19-50		

SOLDER	MADE BY	MELTING POINT		FLOW POINT		COMPOSITION	CONDUCTIVITY % of COPPER	COST PER LB. Approx.	TENSILE STRENGTH
		F°	C°	F°	C°				
Easy-Flo	Handy & Harman	1160	627	1175	635	50% Ag. 15.5 Cu. 16.5 Zn. 18 Cd.	18%	$ 6.27	45,000-130,000 psi.
Sil-Fos	Handy & Harman	1185	641	1300	704	15% Ag. 80 Cu. 5 P.	14%	$ 3.25	40,000-60,000 psi.
Phos-Copper	Westinghouse	1304	707	1382	750	92% Cu. 8% P.	4%	$ 2.85	20,000-40,000 psi.
Easy Silver Solder	Handy & Harman	1280	693	1325	718	65% Ag. 20% Cu. 15% Zn.	23%	$ 7.32	64,800 psi.
Easy-Flo #3	Handy & Harman	1195	646	1270	688	50% Ag. 20% Cu. 15% Zn. Cd. Ni.		$ 6.45	

GENERAL

Solder 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 solder with a melting point between 1175° F (635°C) to 1600°F (871°C).

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

Use soft solder on brass bellows whenever possible.

Specify if machining is to be done before or after soldering. Nearly always, of course, it should be done after soldering.

Data on electrical conductivity is not conclusive. Values given above were measured at R.L. and are the conductivity of the wire solder before using in a joint, which may or may not be related to the resistance of an actual joint. 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.

Hard soldering always anneals metals.

EASY-FLO

The first solder listed above is what is commonly called Easy-Flo.

It melts at a lower temperature than any other hard solder.

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 solder joints copper to copper soldered with Phos-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 solder for funace brazing. 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 solder on a two solder assembly where the first solder is not to remelt when the second soldering is done. It is good for the second solder on such an assembly. Use everywhere, except on the exceptions just indicated.

SIL-FOS

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 Lab 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.

PHOS-COPPER

Phos-Copper makes practically a fool-proof 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. Lab 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 solders and flows very well by capillary action. Do not use in furnace brazing jobs. Never use on ferrous parts.

EASY SILVER SOLDER

This solder has approximately the same characteristics as Easy-Flo but a higher melting point. Use it as the <u>first</u> solder in two-solder assemblies, possibly excepting copper two-solder assemblies where Phos-Copper or Sil-Fos could be used.

Use it even on copper two-solder assemblies if it is a furnace brazing job. Easy Silver Solder works well in the furnace. Phos-Copper and Sil-Fos do not.

EASY-FLO #3

This solder has a wider plastic range than Easy-Flo. Use it on all applications, except copper-to-copper, where heavy fillets are required. Use Sil-Fos for fillets on copper-to-copper.

SUMMARY

Use Sil-Fos on copper joints to be remade or requiring fillets.
Use Phos-Copper on permanent unflexed copper joints.
Use Easy Silver solder on two-solder assemblies.
Use Easy-Flo #3 for fillets except on copper.
Use Easy-Flo everywhere else.

Ralph Peters

RP:FP/ah

RADIATION LABORATORY · UNIVERSITY OF CALIFORNIA · BERKELEY DESIGN DATA	DATE 5-24-51	D.D. NO. 25.1	PAGE 1
SUBJECT ELECTRICAL CONDUCTIVITY OF SOLDERED AND WELDED JOINTS	PREPARED R. Nickerson CHECKED BY		

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

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DESIGN DATA

DATE	D.Q. NO.	PAGE
2-8-49	29	1

PREPARED W. M. Brobeck

CHECKED BY Retyped: 7-28-50

SUBJECT

CONVENIENT FACTORS FOR USE IN COOLING CALCULATIONS

Heat generated in copper conductor* at current density of 1000 amps/in^2.

°C	KW/TON
20	4.20
40	4.55
60	4.90
80	5.20

Water flow for 1°C temperature rise = 3.80 GPM/KW

Transformer oil flow for 1°C temperature rise = 7.6 GPM/KW

Air Flow for 1°C temperature rise = 1750 CFM/KW

Theoretical Power to pump 1000 GPM against 1 psi. = 0.582 HP

Theoretical Power to pump 1000 CFM against 1" water pressure = 0.158 HP

W. M. Brobeck

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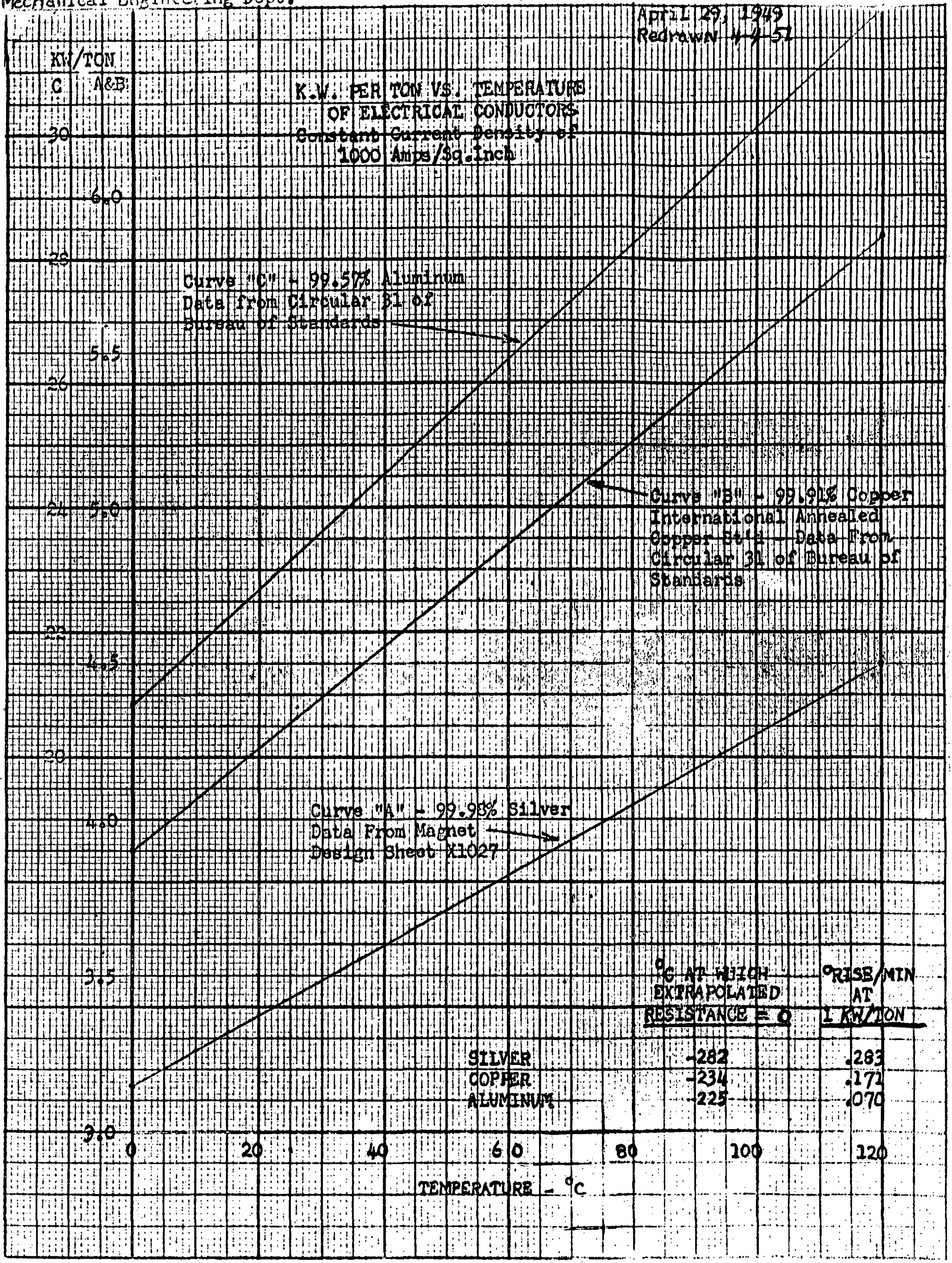
*International Annealed Copper Standard Resistivity

WMB:FP:ah

Radiation Laboratory
Mechanical Engineering Dept.

DESIGN DATA NO. 30
April 29, 1949
Redrawn 4-4-51



K.W. PER TON VS. TEMPERATURE
OF ELECTRICAL CONDUCTORS
Constant Current Density of
1000 Amps/Sq.inch

	°C AT WHICH EXTRAPOLATED RESISTANCE = 0	°RISE/MIN AT 1 KW/TON
SILVER	-282	.283
COPPER	-234	.171
ALUMINUM	-225	.070

Calculation and Graph 6-8-48 AW

RADIATION LABORATORY · UNIVERSITY OF CALIFORNIA · BERKELEY
DESIGN DATA

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

SUBJECT
FORMULAS FOR PARTICLE ACCELERATOR CALCULATIONS USING "ELECTRON VOLT" UNITS

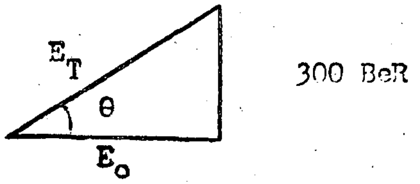
PREPARED W. M. Brobeck
CHECKED BY Retyped: 9-19-50

E_T = total energy } electron volts
E_k = kinetic energy } electron volts
E_o = rest energy } electron volts
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	$\beta=\sqrt{\frac{E_T^2-E_o^2}{E_T^2}}$	$\beta=\sqrt{\frac{2E_k}{E_o}}$	$1.978\times10^{-3}\sqrt{E_k}$	$46.17\times10^{-6}\sqrt{E_k}$	$32.67\times10^{-6}\sqrt{E_k}$	$2316\times10^{-6}\sqrt{E_k}$
MAGNETIC	$R_{mag}=\frac{\sqrt{E_T^2-E_o^2}}{300\ Be}$	$R_{mag}=\frac{\sqrt{2E_oE_k}}{300\ Be}$	$\frac{3.370\sqrt{E_k}}{B}$	$\frac{144.4\sqrt{E_k}}{B}$	$\frac{204.0\sqrt{E_k}}{B}$	$\frac{143.9\sqrt{E_k}}{B}$
	$f=\frac{300\ Bec}{2\pi E_T}$	$f=\frac{300\ Bec}{2\pi E_o}$	2.80×10^6B	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



$\sin\theta=\beta$

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

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

W.M. Brobeck

RADIATION LABORATORY - UNIVERSITY OF CALIFORNIA - BERKELEY

DESIGN DATA

SUBJECT PROPERTIES OF NON-MAGNETIC MANGANESE STEELS From Jessup Steel Co.	DATE 11-2-49	D. D. NO. 33	PAGE 1
	PREPARED W. C. Twitchell		
	CHECKED BY Retyped 7-10-50		

Properties		Jessop Type	
		#9 Super High Tensile	E-200
Chemical:	C	.30/.40	.25/.45
	Mn	12/12.75	10.50/12.50
	Si	.40/.60	---
	S	.040 max.	(.040 max.)
	P	.090 max.	(.090 max.)
	Ni	3.10/3.40	7.00/8.00
	Cr	4.00/4.25	(.20/.30)
	Mo	.40/.60	---
Physical: (Average)	TS	115-130,000 PSI	80-100,000 PSI
	YP (.2% offset)	85-100,000 PSI	30-60,000 PSI
	El-2"	35-56%	50-75%
	Red. Area	40-50%	30-70%
	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)	22.2×10^{-6}/degree C.	20×10^{-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 chrome-nickel flux coated electrode. The electrode most commonly used is Type 316 stainless (19% chromium, 13% nickel, 2-1/2% molybdenum)......

RADIATION LABORATORY UNIVERSITY OF CALIFORNIA · BERKELEY

DESIGN DATA

DATE	D. D. NO.	PAGE
11-2-49	33	2

SUBJECT
PROPERTIES OF NON-MAGNETIC MANGANESE STEELS

From Jessup Steel Co.

PREPARED
W. C. Twitchell

CHECKED BY
Retyped 7-10-50

"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.

"Manganese-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

Type E-200 is stocked in bars and plates. See RL Metals Catalog for sizes on hand.

Jessop steels are available from the mill as plates, sheets, and bars. The maximum plate size at 1" thickness is 48" x 120". The current price for 1/2" plate is 31 cents per lb., F.O.B. mill.

W. C. Twitchell

WCT:FF/ah

RADIATION LABORATORY - UNIVERSITY OF CALIFORNIA - BERKELEY DESIGN DATA	DATE 11-4-49	D.D. NO. 34	PAGE 1A OF 3 PAGES
SUBJECT RULES FOR HIGH PRESSURE GAS EQUIPMENT	PREPARED W. M. Brobeck CHECKED BY Retyped: 4-8-54		

I. DESIGN

Equipment designed under these rules is expected to have a reasonable factor of safety and require only the ordinary precautions expected of commercial high pressure installation. Equipment not meeting these requirements may be designed only on specific approval of the undersigned.

Pressure vessels within the scope of the ASME codes (over 6 inches dia. and 15 psi for unfired pressure vessels) are to be designed and constructed according to the requirements of those codes.

Pressure vessels made of commercial pipe and/or pipe fittings must not be used above the working pressure for which the pipe and/or fittings are rated. Such vessels must comply with all the rules herein.

For pressure vessels not withing the scope of the ASME codes the calculated stresses at the working pressure and temperature are to be not more than two-fifths the yield point nor one-fifth of the tensile strength at the working temperature of the material used.

Welding is to be avoided for longitudinal joints of shells of such pressure vessels under 6 inches in diameter. Where any welding is used the complete part if to be stress relieved according to the procedure required for the material used. Where welding is used design stresses must be suitable reduced.

Pressure vessels for use at temperatures below -50C must be made of material having impact strength as required by paragraph UG84 of the 1950 code for unfired pressure vessels.

Welding should be avoided in pressure vessels for use at temperatures below -50 C. All causes of stress concentration must be avoided in vessels for use at these temperatures.

A record of the stress calculations and strengths of materials with sources of data is to be kept in the engineering note file for all pressure vessel designs.

II. TESTING

All pressure vessels are to be tested at least twice their working pressure.

Any special conditions of temperature or temperature cycles to which the vessel is to be subjected in use are to be reproduced as closely as possible while the test pressure is applied.

A report of the test is to be written by the engineer in charge and kept in the engineering note file.

The test pressure, working pressure, date and initials of the tester, as well as the drawing number, are to be stamped on the vessel if this can be done without affecting its strength.

Completed pressure vessels are to be free from manufacturing defects that might affect their performance in their intended use.

RADIATION LABORATORY - UNIVERSITY OF CALIFORNIA - BERKELEY DESIGN DATA	DATE 11-4-49	D.D. NO. 34	PAGE 2A OF 3 PAGES
SUBJECT RULES FOR HIGH PRESSURE GAS EQUIPMENT	PREPARED W. M. Brobeck CHECKED BY Retyped: 4-8-54		

III. INSTALLATION

All pressure equipment is to be installed in a substantial manner with supports strong enough to stand the reaction of a jet resulting from breaking of any pipe or fitting.

A safety valve or blowout disk must be installed on each pressure vessel operative at any time the vessel is charged.

Safety valves or blowout disks must limit the pressure to 20% above the working pressure.

All safety valves or sample blowout disks must be tested.

No valves may be used between the safety valve or blowout disk and any pressure vessel.

Pressure gages are to be included with will indicate pressure in any part of the system in which it may exist. This dose not apply to portable pressure vessels.

Changes made in equipment or its assembly for use only at pressures below that for which the equipment was originally designed (reduction in the number of bolts in flanged joints for example) must be approved* and all safety requirements met for the lower pressure. Where less than the originally intended bolts or other supports are used the number of bolts or supports required for the reduced working pressure must be clearly shown on a sign or by such obvious means as plugging holes.

IV. PORTABLE PRESSURE VESSELS

Pressure vessels to be moved while under pressure must be protected well enough to stand accidents in handling such as dropping from a height of 10 ft. to a concrete floor.

Portable pressure vessels must be clearly marked to show when they are charged and with what type of gas and pressure.

Portable pressure vessels must be stored in a safe place.

Portable pressure vessels must be provided with a blowout disk as described under "installation".

V. GENERAL

Omission from these rules of mention of any factors affecting the safety of pressure gas installations does not mean such factors are to be disregarded but rather that they are to be left to the judgment of the engineer in charge.

---

*by the engineer in charge.

RADIATION LABORATORY · UNIVERSITY OF CALIFORNIA · BERKELEY

DESIGN DATA

SUBJECT RULES FOR HIGH PRESSURE GAS EQUIPMENT	DATE 11-4-49	D.D. NO. 34	PAGE 3 of 3
	PREPARED W. M. Brobeck		
	CHECKED BY Retyped: 9-19-50		

VI. INSTRUCTIONS

Instructions stating the precautions to be taken in operating the equipment are to be prepared and copies sent to all persons concerned. One copy is to be filed in the engineering note file.

The installation is to include a sign reading "DANGER, HIGH PRESSURE EQUIPMENT".

A list of persons authorized to operate the equipment and the name of the engineer in charge is to be attached to the equipment.

All instructions and lists of authorized persons are to be signed by the engineer in charge.

All pressure vessels containing high pressure gas are to be painted yellow.

The working pressure of the equipment is to be clearly shown on a sign or nameplate.

When systems contain a poisonous gas a sigh must state the name of the gas and that it is poisonous as "DANGER - HIGH PRESSURE BORON TRIFLUORIDE GAS - POISONOUS".

W. M. Brobeck

WMB:FP/ah

RADIATION LABORATORY · UNIVERSITY OF CALIFORNIA · BERKELEY

DESIGN DATA

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

PREPARED H. Gordon, M. Mart
D. Theodore Scalise.

CHECKED BY
Retyped 7-10-50

		Multiple Quantity Expressed in →	by →	To Obtain Quantity Expressed in
Symbol	Quantity	Conventional Units		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	$\frac{\text{B.T.U.}}{\text{lb. }^{\circ}\text{F}}$	1899	$\frac{\text{watt sec.}}{\text{lb. }^{\circ}\text{C}}$
		$\frac{\text{cal}}{\text{gm }^{\circ}\text{C}}$	1899	$\frac{\text{watt sec.}}{\text{lb. }^{\circ}\text{C}}$
μ	Absolute Viscosity	centipoise*	6.72×10^{-4}	$\frac{\text{lb. (mass)}}{\text{sec. ft.}}$
		centipoise	2.42	$\frac{\text{lb. (mass)}}{\text{hr. ft.}}$
		centipoise	2.09×10^{-5}	$\frac{\text{lb. (force) sec.}}{\text{ft.}^2}$
k	Heat Conductivity	$\frac{\text{cal}}{\text{sec.cm}^2\ (^{\circ}\text{C/cm})}$	10.632	$\frac{\text{watts}}{^{\circ}\text{C in.}}$
		$\frac{\text{B.T.U.}}{\text{hr.ft.}^2\ (^{\circ}\text{F/ft.}}$	0.04394	$\frac{\text{watts}}{^{\circ}\text{C in.}}$
		$\frac{\text{watts}}{\text{cm }^{\circ}\text{C}}$	2.54	$\frac{\text{watts}}{^{\circ}\text{C in.}}$

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

RADIATION LABORATORY · UNIVERSITY OF CALIFORNIA · BERKELEY

DESIGN DATA

DATE	11-14-49
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PAGE	2 of
SUBJECT	CONVERSION CHART FOR U.C.R.L. PREFERRED HEAT TRANSFER UNITS
PREPARED	H. Gordon, M. Martin, D.T. Scalise
CHECKED BY	Retyped 7-10-50

		Multiply Quantity Expressed in →	by →	To Obtain Quantity Expressed in
Symbol	Quantity	Conventional Units		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.

RADIATION LABORATORY - UNIVERSITY OF CALIFORNIA - BERKELEY

DESIGN DATA

DATE	D.D. NO.	PAGE
7-7-50	35	3

SUBJECT

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

PREPARED H.Gordon, Martin Scalise 11-14-49

CHECKED BY

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

HG;MM;DTS/FP/ah

RADIATION LABORATORY - UNIVERSITY OF CALIFORNIA - BERKELEY

DATE	D. D. NO.	PAGE
4/27/51	36	1

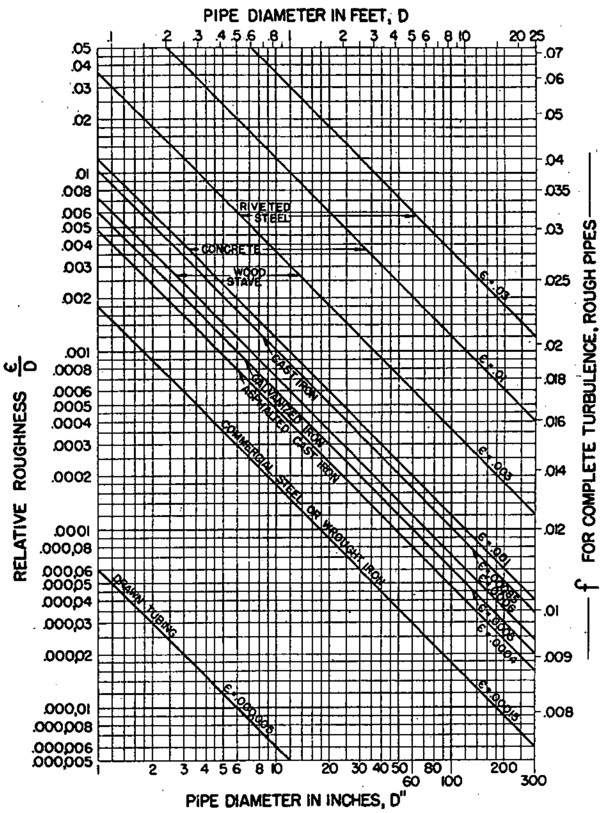
DESIGN DATA

PREPARED: L. E. Brown

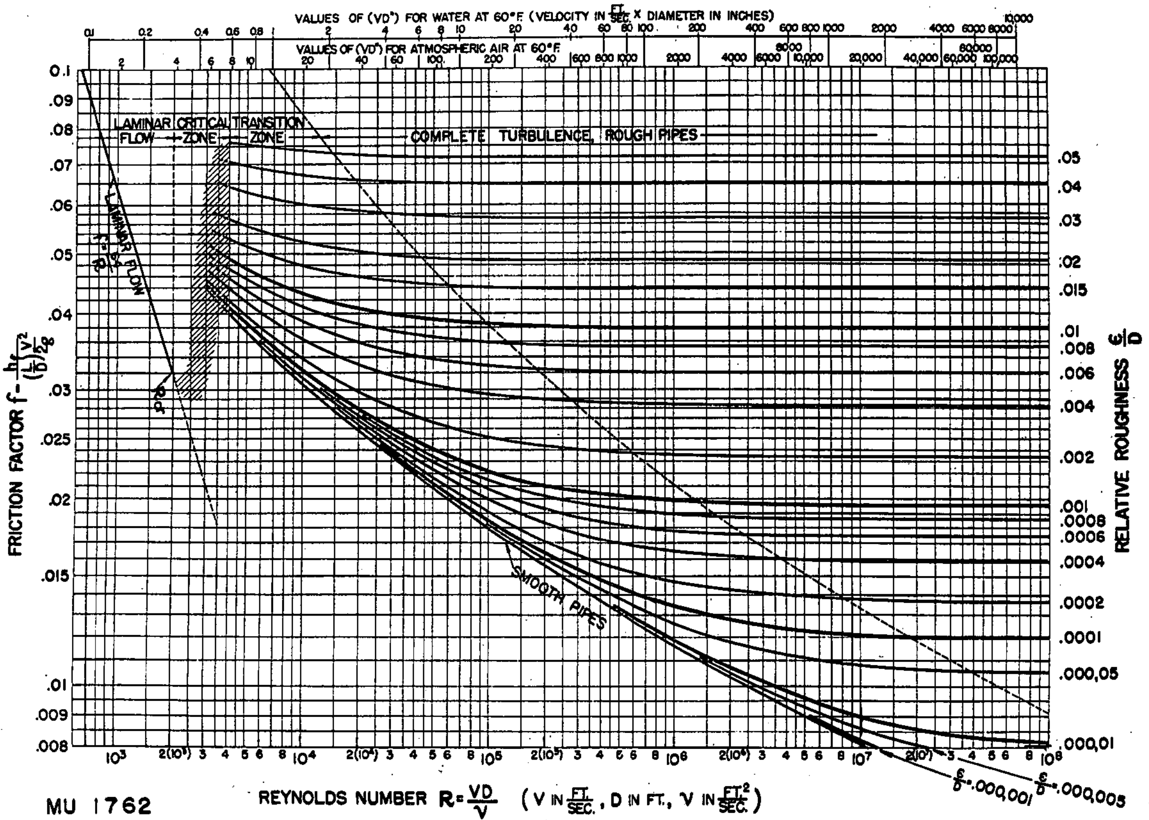
CHECKED BY: W. Brobeck

FRICTION FACTORS FOR PIPE FLOW

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



MU 1763



MU 1762

D-22(M)

DESIGN DATA	DATE	D.D. NO.	PAGE
	7-11-50	37	1

SUBJECT

PROPERTIES OF METALS AT LOW TEMPERATURES

PREPARED R. A. Nickerson ✓

CHECKED BY

ALLOY & COMPOSITION	T°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	20	8.6	31.4	48	76	43 Iz	62 C-V
- 99.98% Soft	-80	10.1	38.5	47	74	44 Iz	
	-180	18.3	50.8	58	77	50 Iz	69 C-V
Pure Copper	20	43.3	45.8	16	55.9		>20% Reduction
-99.9% Rolled	-180	50.4	53.0	19	55.4		
Cartridge Brass	20	28	51	49	78	66 Iz	Typical of behavior of brasse at low temperatures
70-30 Cu-Zn	-80	27	58	60	79	69 Iz	
Annealed	-180	30	74	75	73	79 Iz	
Naval Brass	20	28.8	57.1	49.4	50.5		Annealed
60 Cu, 39.25 Zn, .75Sn	-180	37.2	81.1	48.3	48.4		
Beryllium Copper	20	24.9	76.2	36	50	41 Iz	Typical example of property changes in precipitation hardenable alloy
2.56 Be	-80	29.1	86.7	38	54	40 Iz	
(Solution Treated)	-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	20	24	72.4	28	44	20 Iz	Annealed
38.85 Zn, 1.43 Mn,	-80	27	75.5	31	43	22 Iz	
1.25 Pb, .9 Sn	-180	28.8	94.8	37	41	20 Iz	

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

RADIATION LABORATORY - UNIVERSITY OF CALIFORNIA - BERKELEY

DESIGN DATA

DATE	D.Q. NO.	PAGE
7-11-50	3V	2

SUBJECT

PROPERTIES OF METALS AT LOW TEMPERATURES

PREPARED R. A. Nickerson

CHECKED BY

ALLOY & COMPOSITION	T°C	Y.S. 1000 psi	T. S. 1000 psi	Elong %	R.A.	Impact	Remarks
NICKEL & ALLOYS							
"A" Nickel	24		62	23.5	75	216 C V	Annealed
99.4 Ni, .1 Cu,	-80					235 C V	
.15 Fe, .2 Mn,	-190		86	22	58	234 C V	
.05 Si, .1 C,							
.005 S	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	21	31.3	78.7	57.5	75	189 C V	100 Iz 119 Iz Annealed
671 Vi, 30 Cu,	-183	49.5	115.3	49.5	72	184 C V	
1.4 Fe, 1 Mn,							
.1 Si, .15 C,	24	93.7	103.8	19	72	216 C V	Cold Drawn
.01 S	-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	24		94			130 C K	Quench 1750°F
66 Ni, 29 Cu,	-80					133 C K	
2.75 Al, .9 Fe,							
.25 Mn, .15 C,							
.5 Si							
Magnetic Transformation	24	125.9	157.3	15.5	37.4	27 C K	Quench & Age (See note on Be-Cu)
<-135°C Soft Quench	-80	134.6	171.6	17.3	41.1	28 C K	
<-101°C Aged							
Inconel	24	36	94	31	65	130 C K	Quench 1750°F
78.5 Ni, 14 Cr,	-80	42.5	106	40	64	133 C K	
6.5 Fe, .25 Mn,							
.2 Cu, .25 Si,	24	147	132	70	49	58 C V	Quench & Age 525°F. No appreciable dedrease in properties of unaged
.08 C, .008 S	-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

RADIATION LABORATORY · UNIVERSITY OF CALIFORNIA · BERKELEY **DESIGN DATA**	DATE 7-11-50	D.D. NO. 37	PAGE 3
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
STAINLESS STEELS							
302 .11 C, 16.2 Cr, 11.5 Ni	20	44.8	93	48	52	118 Iz	Water Quench 2010°F
	-180	118	220	55	75	118 Iz	
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	
	20	91.5	152	22	64	66 Iz	Annealed & Cold Drawn (-180°C, 65 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:

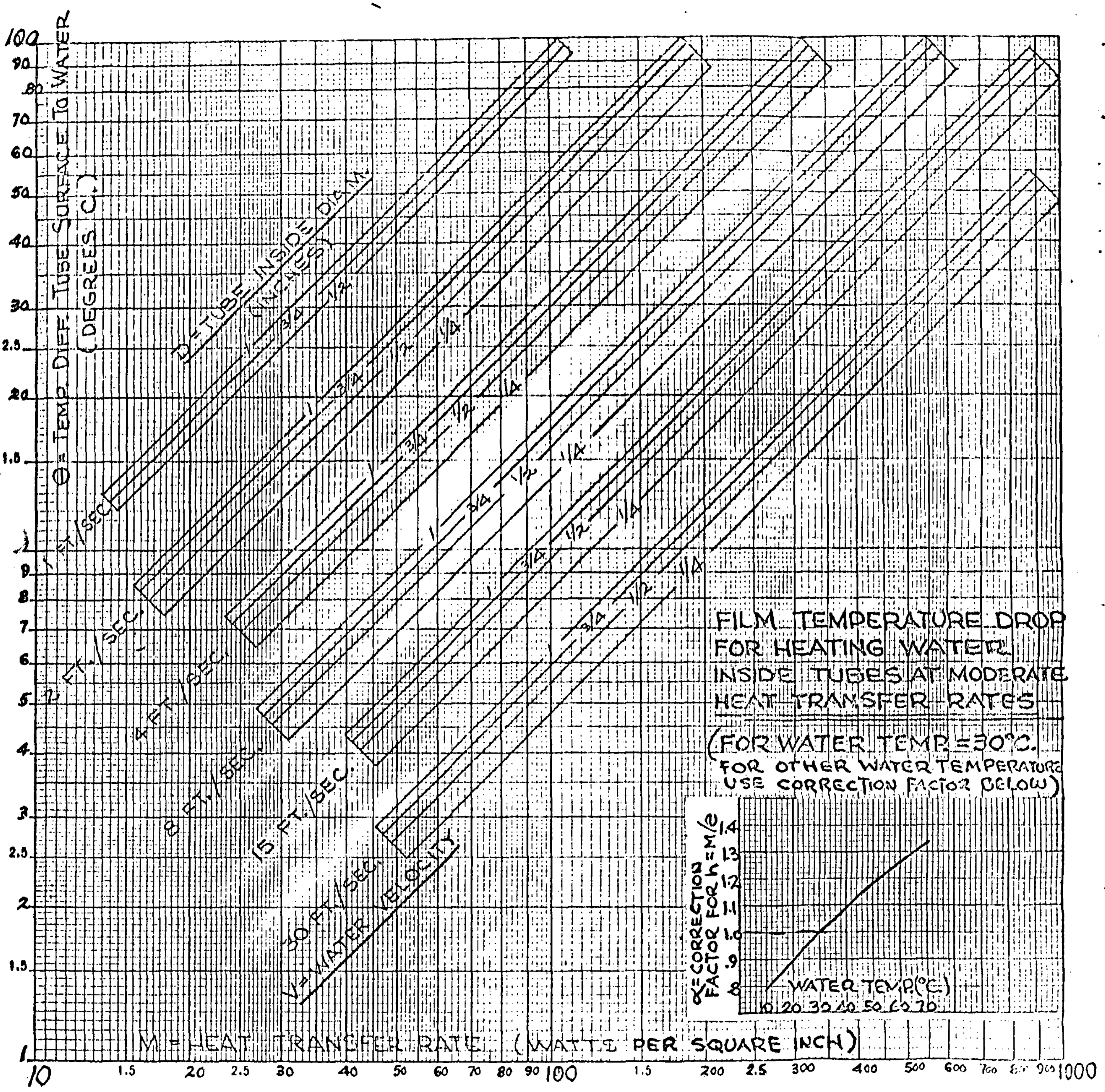
American Society For Metals Handbook & references therein on Low Temperature properties. ASME, ASTM Symposium on "Effect of Temperature on Metals", June 23, 1931.
U.S. Dept. of Commerce - Bureau of Standards Research Paper 1882, 40, 1948 "Influence of Low Temperature on Mechanical Properties of 18.8"
International Nickel Co. Technical Bulletins

RN:ah

U.C.R.L.
DESIGN DATA No. 38

Page 1 of 1

T. Scalise
9-25-50



FILM TEMPERATURE DROP FOR HEATING WATER INSIDE TUBES AT MODERATE HEAT TRANSFER RATES

(FOR WATER TEMP. = 30°C. FOR OTHER WATER TEMPERATURES USE CORRECTION FACTOR BELOW)

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)

RADIATION LABORATORY · UNIVERSITY OF CALIFORNIA · BERKELEY **DESIGN DATA**	DATE 11-1-50	D.D. NO. 39	PAGE 1
SUBJECT CALCULATION OF ULTIMATE PRESSURES OF KINETIC VACUUM SYSTEMS USING RUBBER GASKETS AND OTHER VOLATILE MATERIALS*	PREPARED Marvin Martin CHECKED BY		

(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.

RADIATION LABORATORY - UNIVERSITY OF CALIFORNIA - BERKELEY

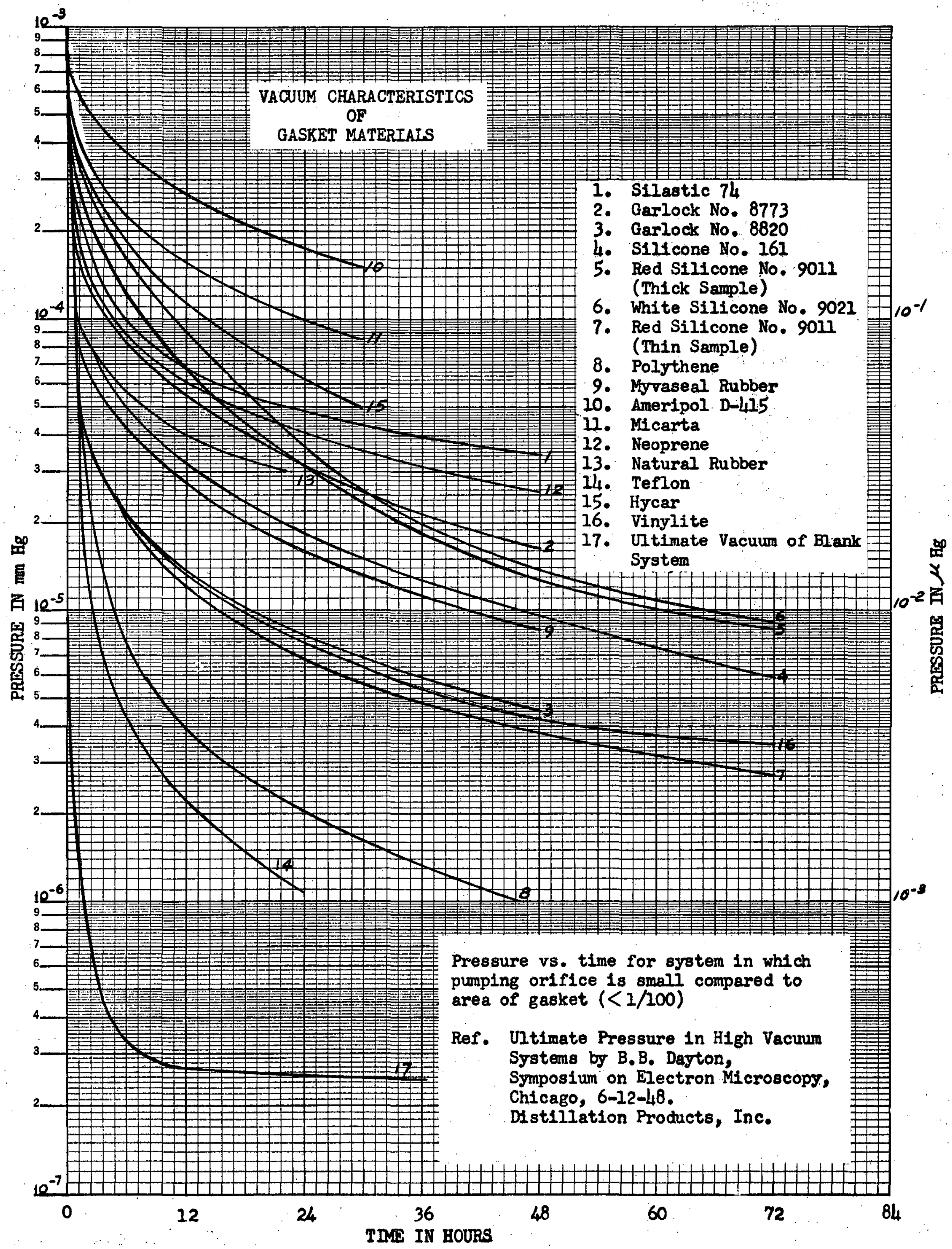
DESIGN DATA

DATE	D.D.NO.	PAGE 2 OF 4 PAGES	
11-1-50*	39		

SUBJECT CALCULATION OF ULTIMATE PRESSURE OF KINETIC VACUUM SYSTEMS USING RUBBER GASKETS AND OTHER VOLATILE MATERIAL

PREPARED M. Martin

CHECKED BY * COPY 10-15-57 K.CONNELLY

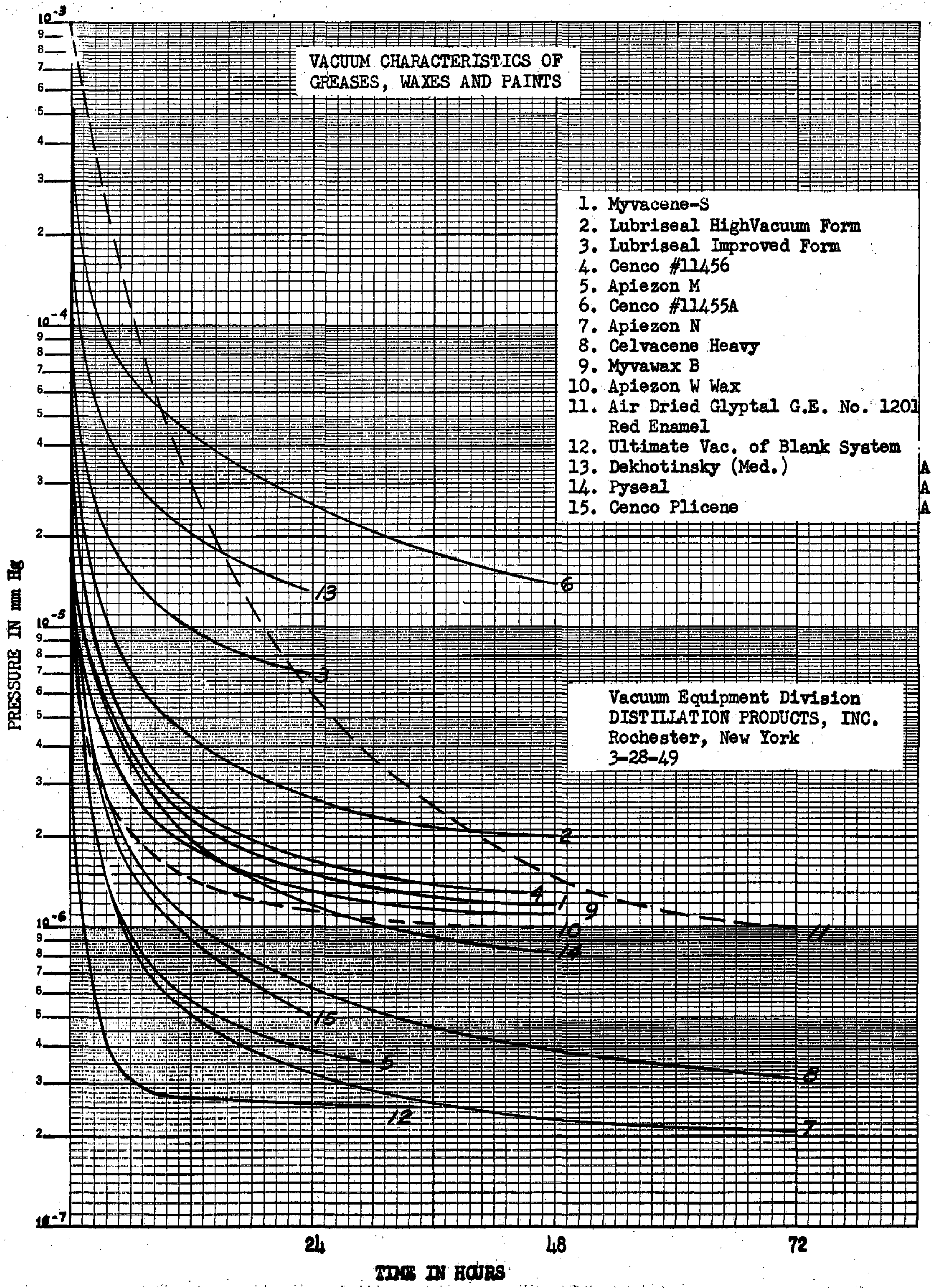


VACUUM CHARACTERISTICS OF GASKET MATERIALS

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.

RADIATION LABORATORY - UNIVERSITY OF CALIFORNIA - BERKELEY **DESIGN DATA**	DATE 11-1-50*	D.D.NO. 39	PAGE 3A OF 4 PAGES
SUBJECT **CALCULATION OF ULTIMATE PRESSURES OF KINETIC VACUUM SYSTEMS USING RUBBER GASKETS AND OTHER VOLATILE MATERIALS**	PREPARED M. Martin CHECKED BY A REVISION 9-22-52 * COPY 10-15-57 K. CONNELLY		



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

RADIATION LABORATORY - UNIVERSITY OF CALIFORNIA - BERKELEY

DESIGN DATA

DATE 9-22-52*

D.D.NO. 39

PAGE 4 OF 4 PAGES

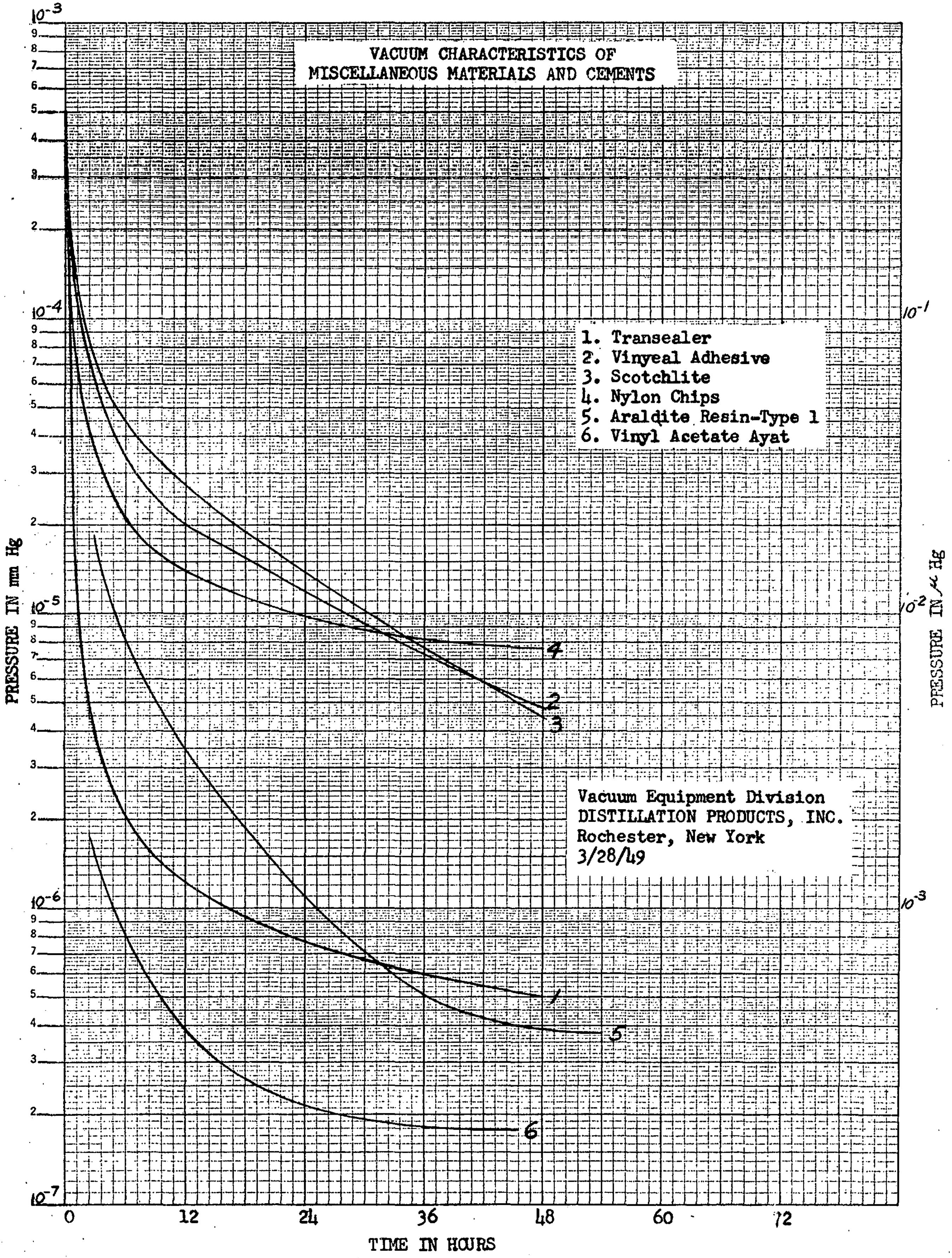
SUBJECT

CALCULATION OF ULTIMATE PRESSURES OF KINETIC VACUUM SYSTEMS USING RUBBER GASKETS AND OTHER VOLATILE MATERIALS

PREPARED M. Martin

CHECKED BY

* COPY 10-15-57 K.CONNELLY



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

RADIATION LABORATORY - UNIVERSITY OF CALIFORNIA - BERKELEY

DESIGN DATA

SUBJECT	DATE	D. D. No.	PAGE
BEND RADII FOR TUBES	12-21-50	40	1
	PREPARED D. Vorkoeper		
	CHECKED BY		

Tube benders are available in the shop for the following size tubes and bends. These radii should be adopted as standard wherever practical:

TUBES O.D.	RADIUS OF BEND TO TUBE CENTER LINE	ALTERNATE: AVAILABLE IN SHEET METAL SHOP
3/16	7/16	
1/4	9/16	
5/16	11/16	
3/8	15/16	
7/16	1 1/2	
1/2	1 1/2	1 1/4
5/8	2	1 9/16
3/4	2 1/2	1 7/8
7/8	3	
1	3 1/2	

DW:EM

FLAT PLATES FOR VACUUM TANKS

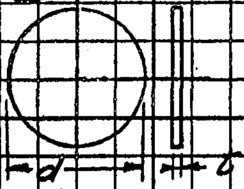
DESIGN DATA NO. 41
March 29, 1951
Robert Meuser
Page 1 of 1.

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

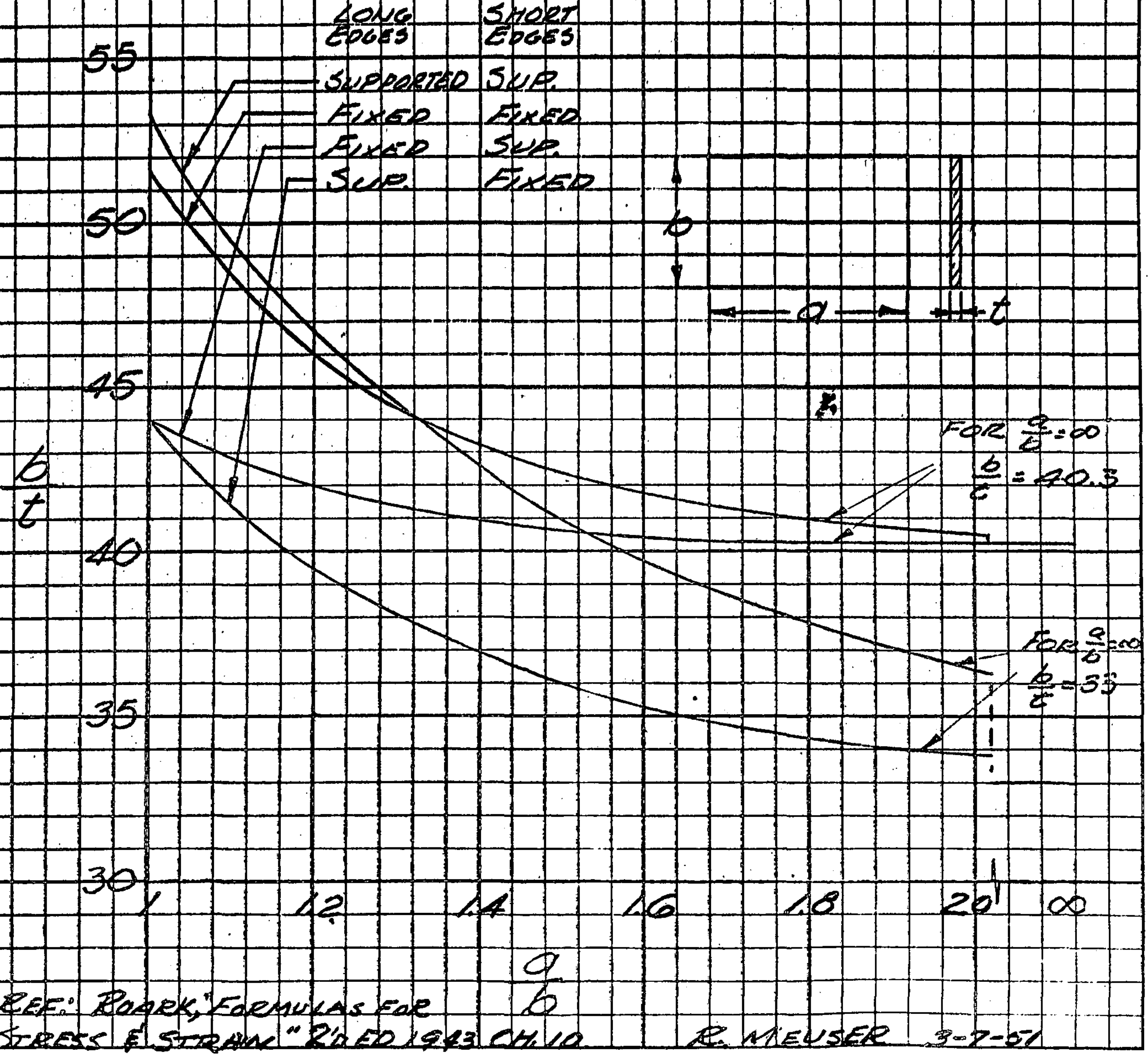
$$\frac{t_2}{t_1} = \sqrt{\frac{12000}{S_2} \times \frac{p_2}{14.7}}$$

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

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DESIGN DATA

DATE 4-11-51*	D.D. NO. 42	PAGE 1 of

SUBJECT

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

PREPARED Marvin Martin

CHECKED BY

*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:

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

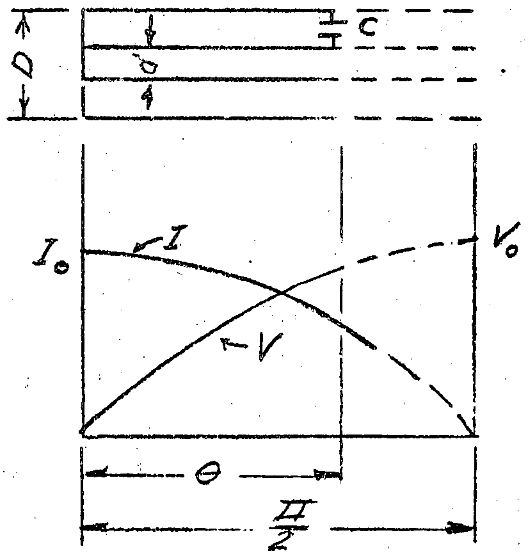
Where Z_o = Characteristic impedance of line = $138 \log_{10}\frac{D}{d}$

* 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

DATE 4/11/51

NO. 42

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

PREPARED Marvin Martin

CHECKED BY

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.

CASE I Capacity fixed, length variable, Z_o variable (This is the usual case in cyclotron design where C is the Dee 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.

CASE II

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.

R.F. Power Loss in Capacity Loaded Quarter Wave Transmission Lines DESIGN DATA NO. 42

Marvin Martin
4/11/51
Page 3

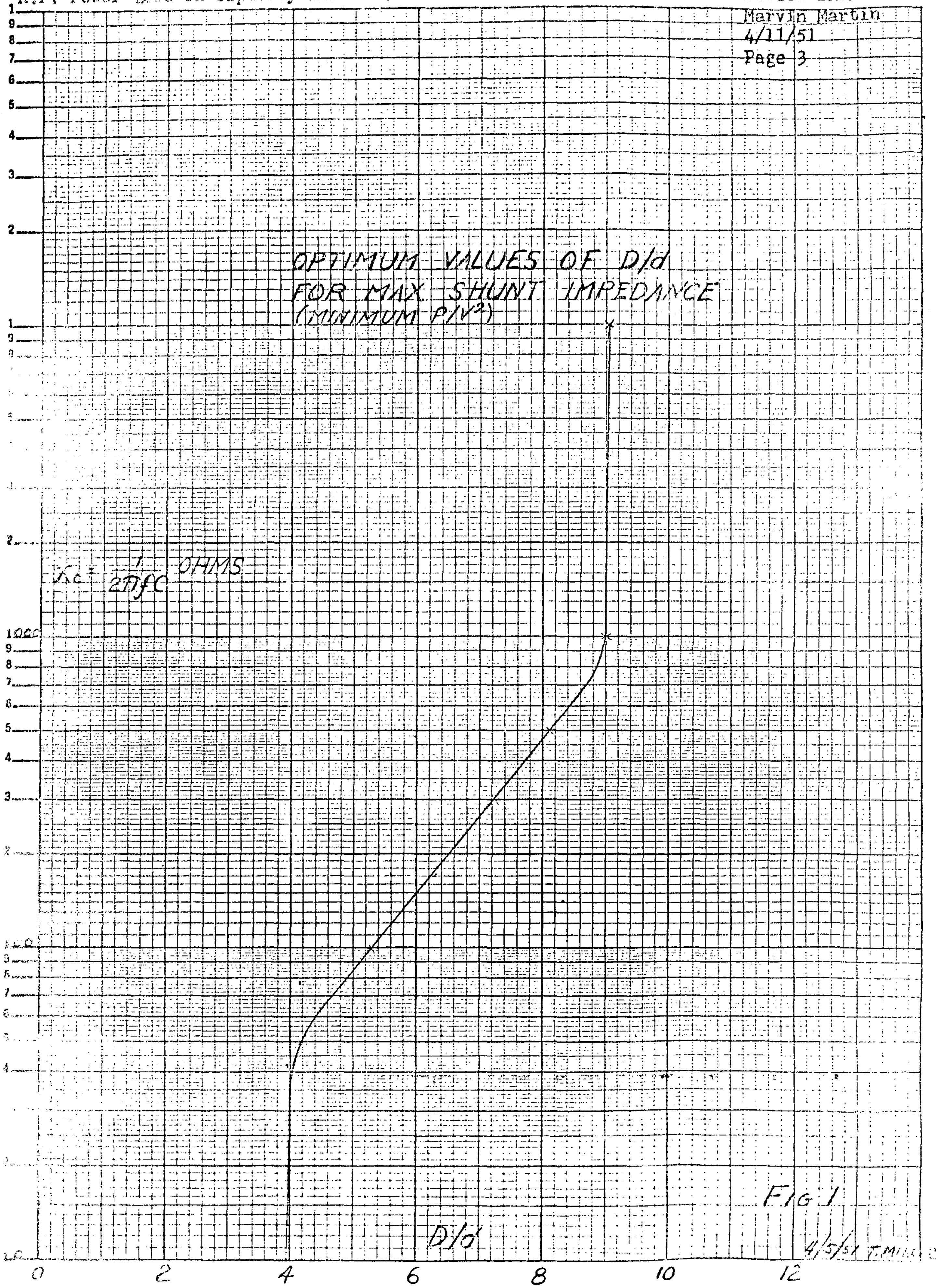


FIG 1

4/5/51 T.MIL

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

DESIGN DATA NO. 42

Marvin Martin
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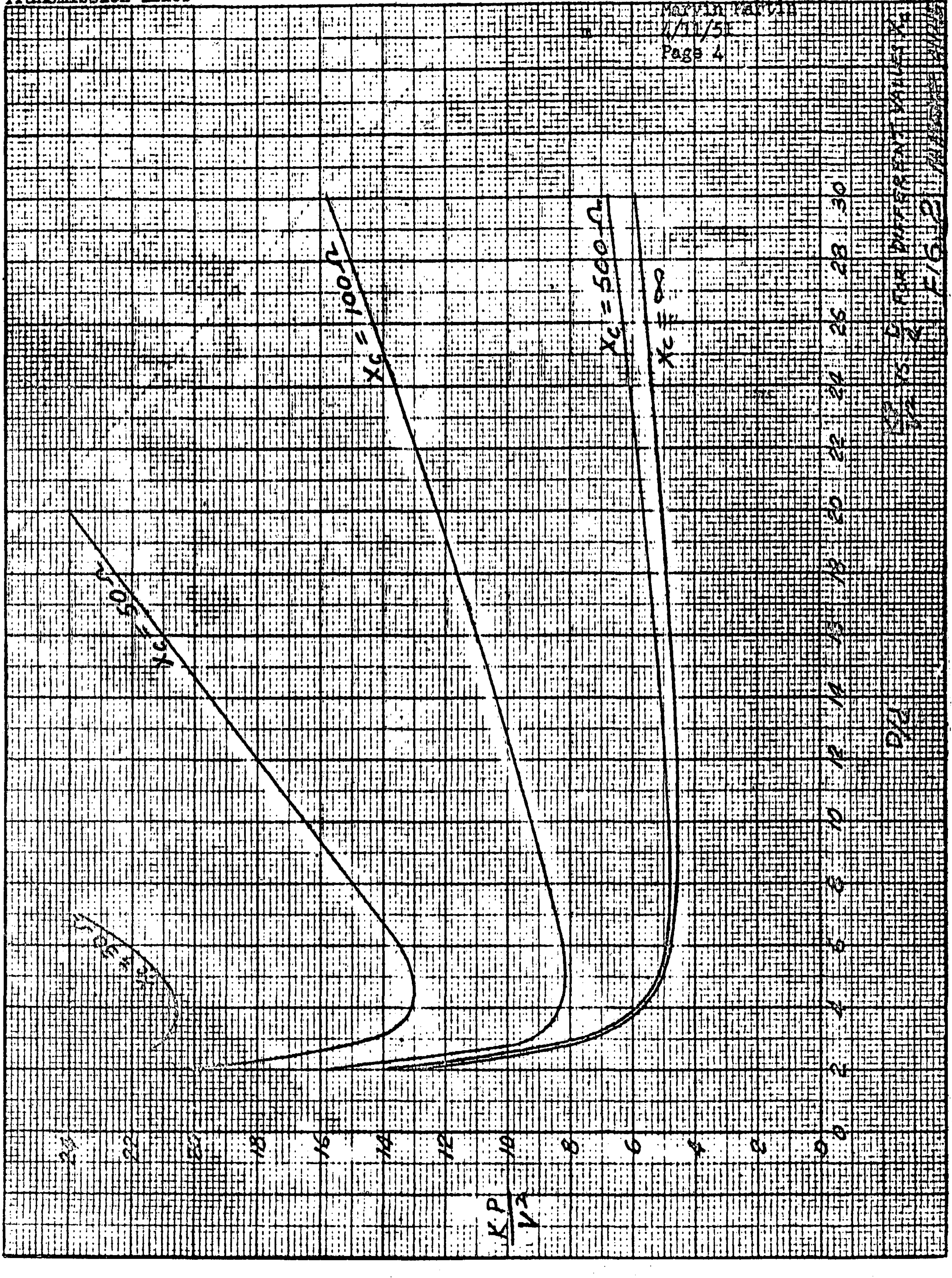
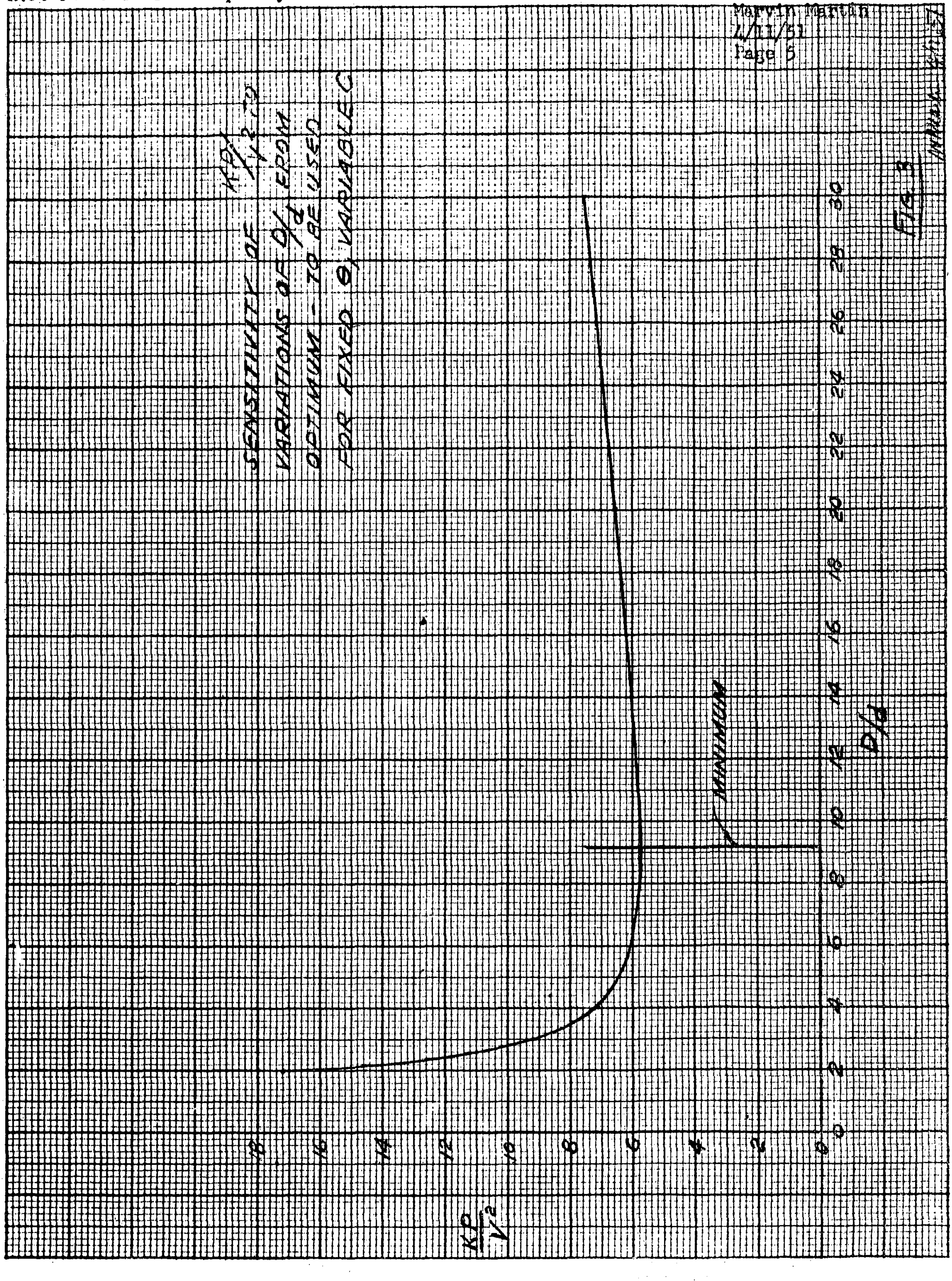
Page 4



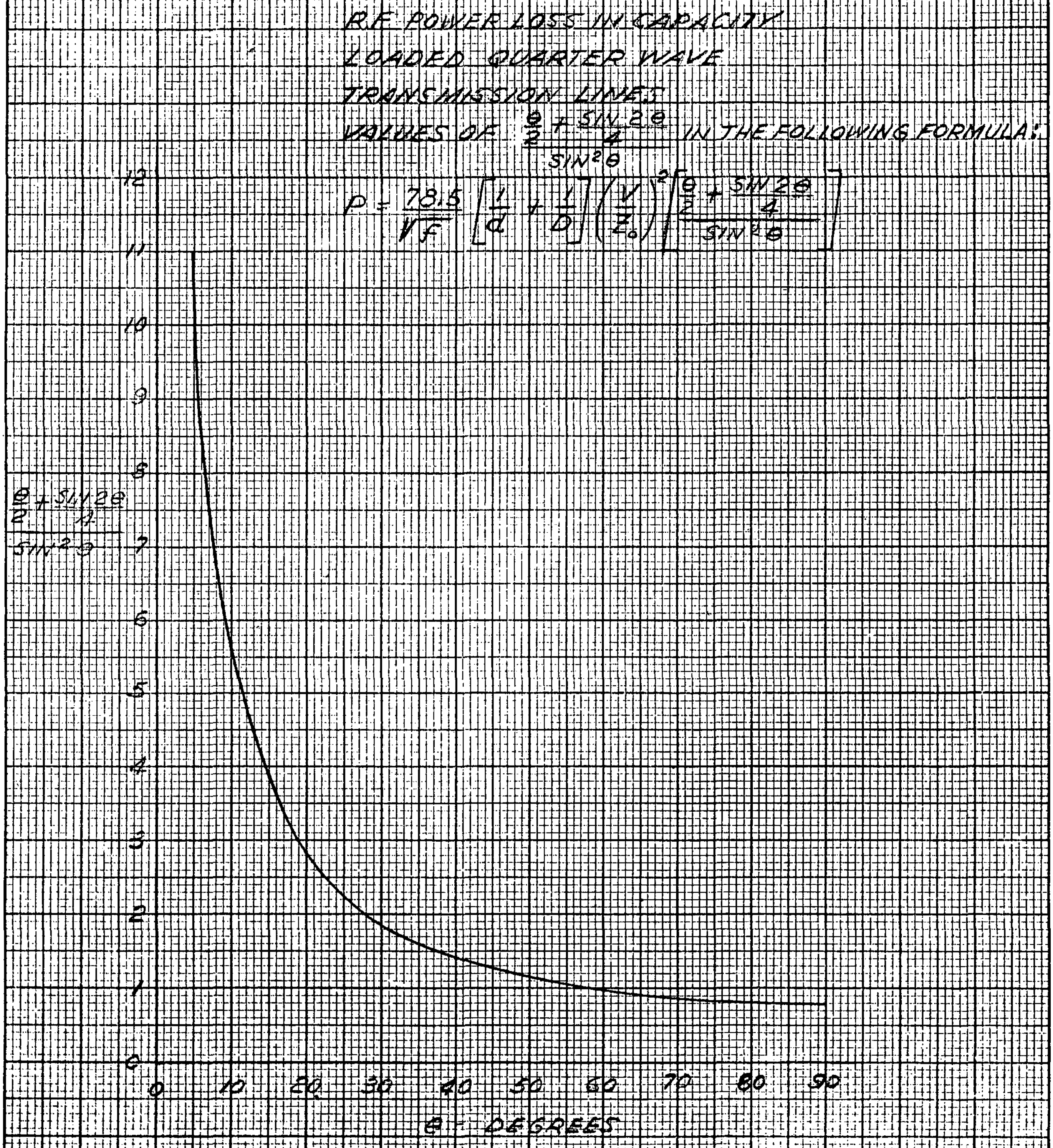
$\frac{KP}{V^2}$ VS D/d FOR DIFFERENT VALUES X_c

FIG 2



SENSITIVITY OF $\frac{KP}{V^2 D}$ TO VARIATIONS OF D/d FROM OPTIMUM - TO BE USED FOR FIXED θ, VARIABLE C

FIG. 3



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

VALUES OF $\frac{\frac{\theta}{2}+\frac{\sin 2\theta}{4}}{\sin^2\theta}$ 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

MMartin 4/12/51

RADIATION LABORATORY · UNIVERSITY OF CALIFORNIA · BERKELEY DESIGN DATA	DATE 10-5-51	D.D. NO. 42.1	PAGE 1
SUBJECT Relation Between "Q" and Shunt Impedance In Capacity Loaded Quarter Wave Transmission Line, at Resonance	PREPARED M. Martin Mitchell Dazey CHECKED BY		

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

RADIATION LABORATORY - UNIVERSITY OF CALIFORNIA - BERKELEY

DESIGN DATA

DATE	D.D. NO.	PAGE
8/5/52	42.2	1

SUBJECT

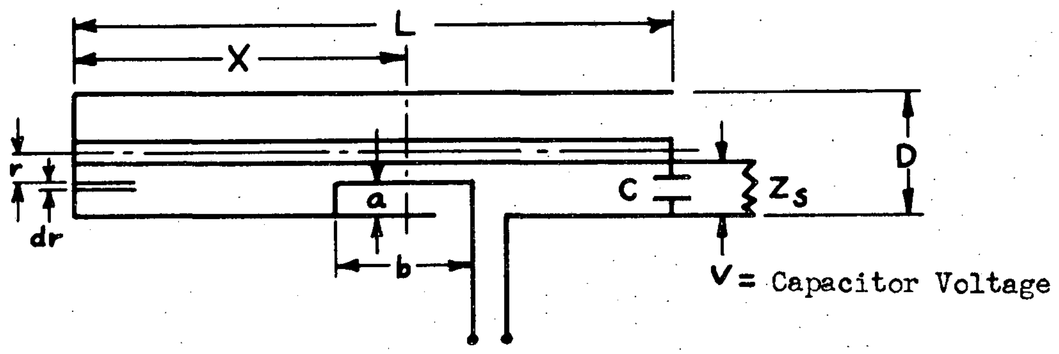
IMPEDANCE OF A LOOP COUPLED TO A CAPACITY LOADED, QUARTER WAVE TRANSMISSION LINE

PREPARED

B. H. Smith

CHECKED BY

D. Mack



V_ℓ, Z_ℓ = Loop Voltage and Impedance

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

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

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

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

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

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

Converting to Inches, Megacycles/sec., and Volts

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

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

RADIATION LABORATORY - UNIVERSITY OF CALIFORNIA - BERKELEY

DESIGN DATA

DATE 5-28-51

D.D. NO. 44

PAGE 1

SUBJECT

MAGNETIC PERMEABILITY OF COLD WORKED 18-8 STAINLESS STEELS

PREPARED Nickerson, R.

CHECKED BY

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 <u>in</u> <u>solution</u> and <u>not</u> 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 B-H 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	Δ
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

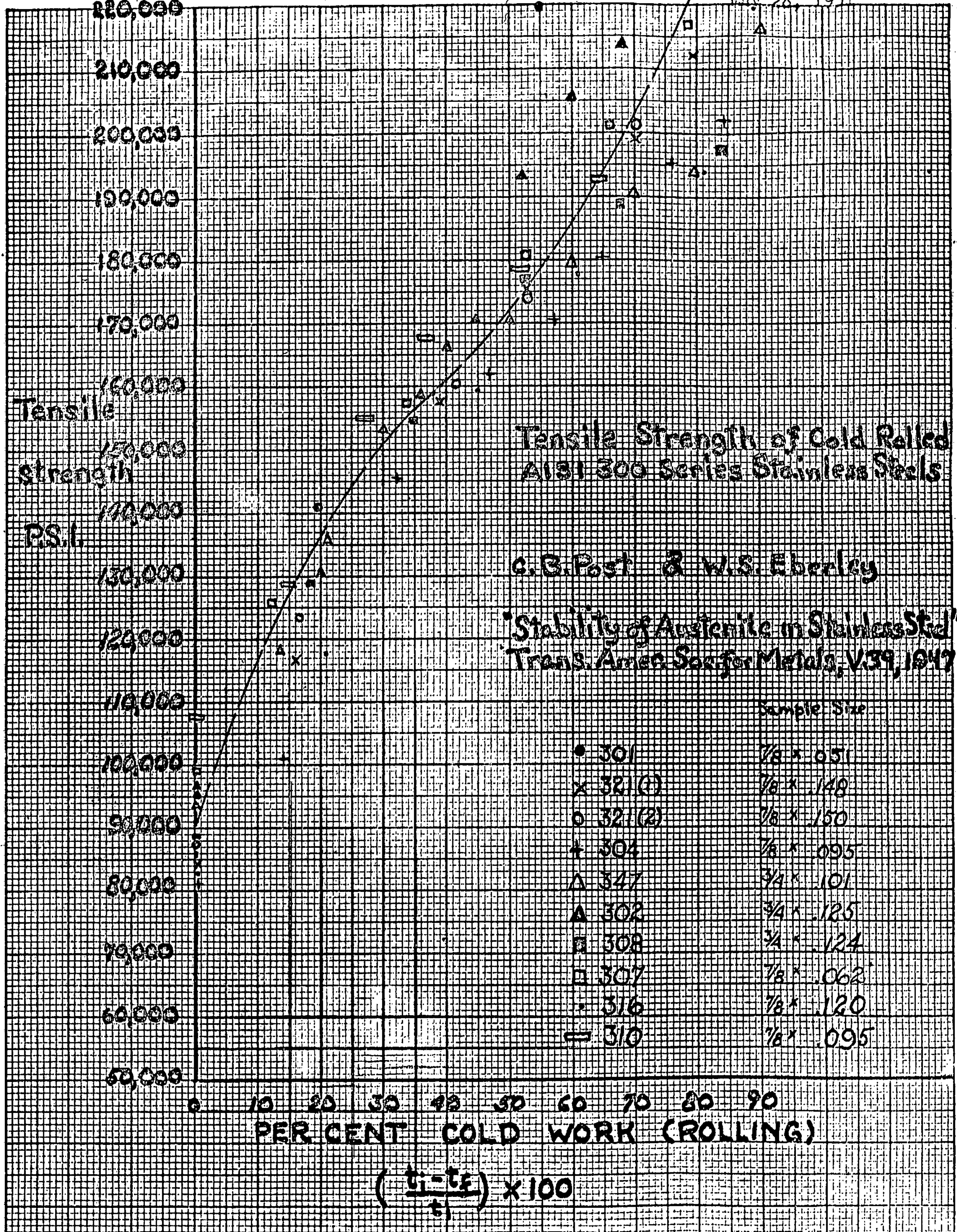
DATE 5-28-51

D.D. NO. 44

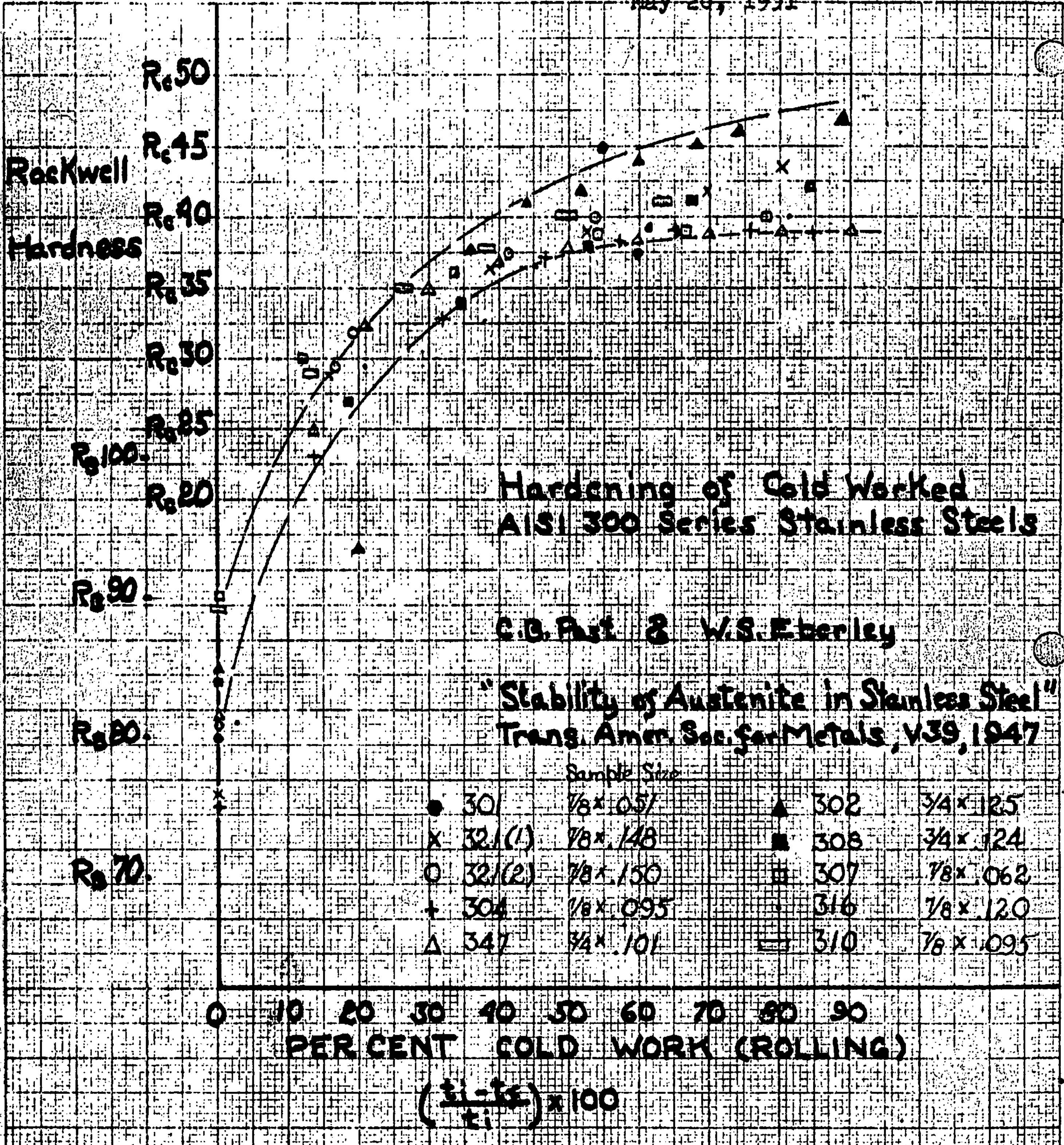
PAGE 2

PREPARED Nickerson, R.

CHECKED BY



R.A. Nickerson



Hardening of Cold Worked AISI 300 Series Stainless Steels

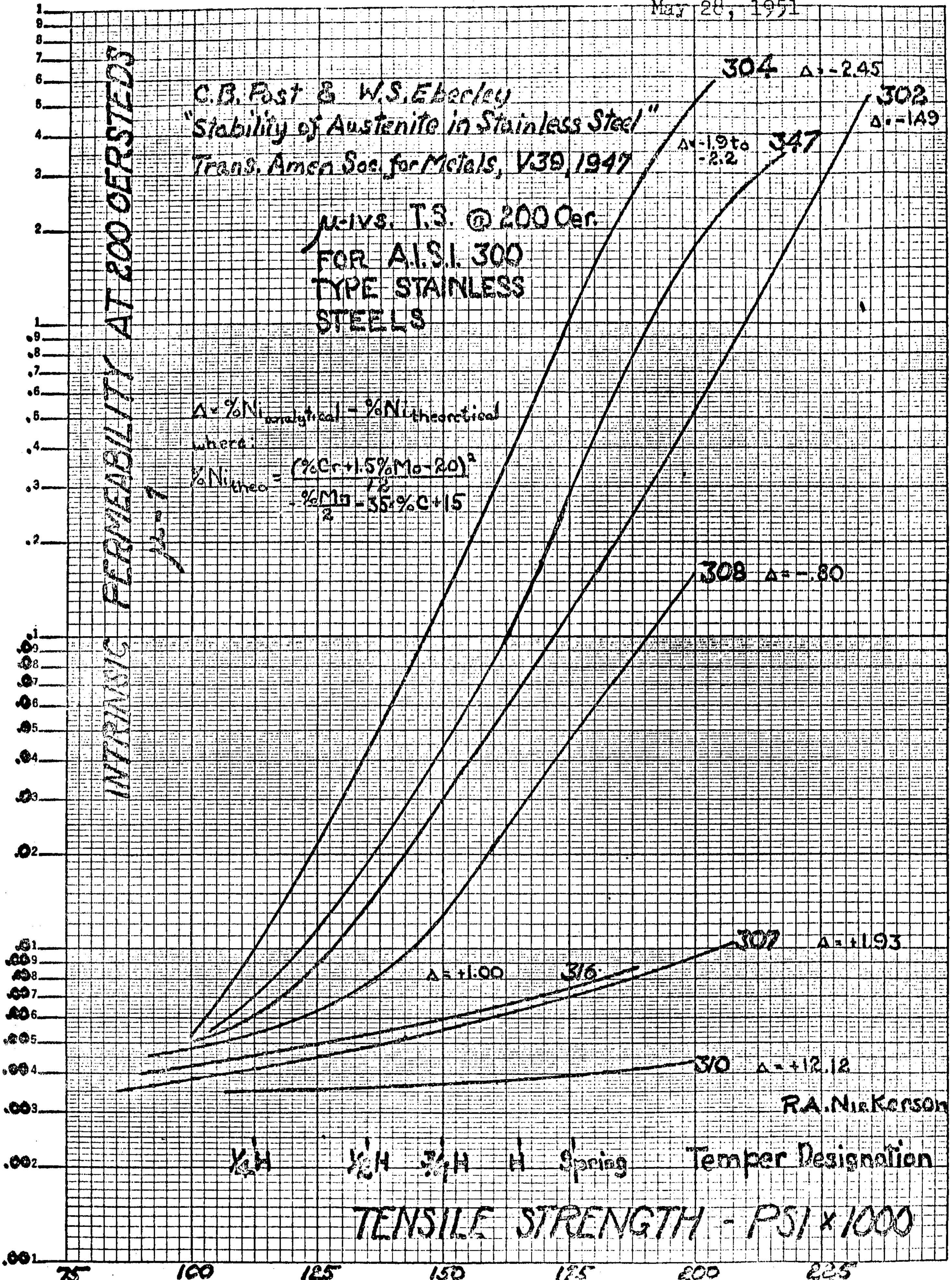
C.B. Post & W.S. Eberley

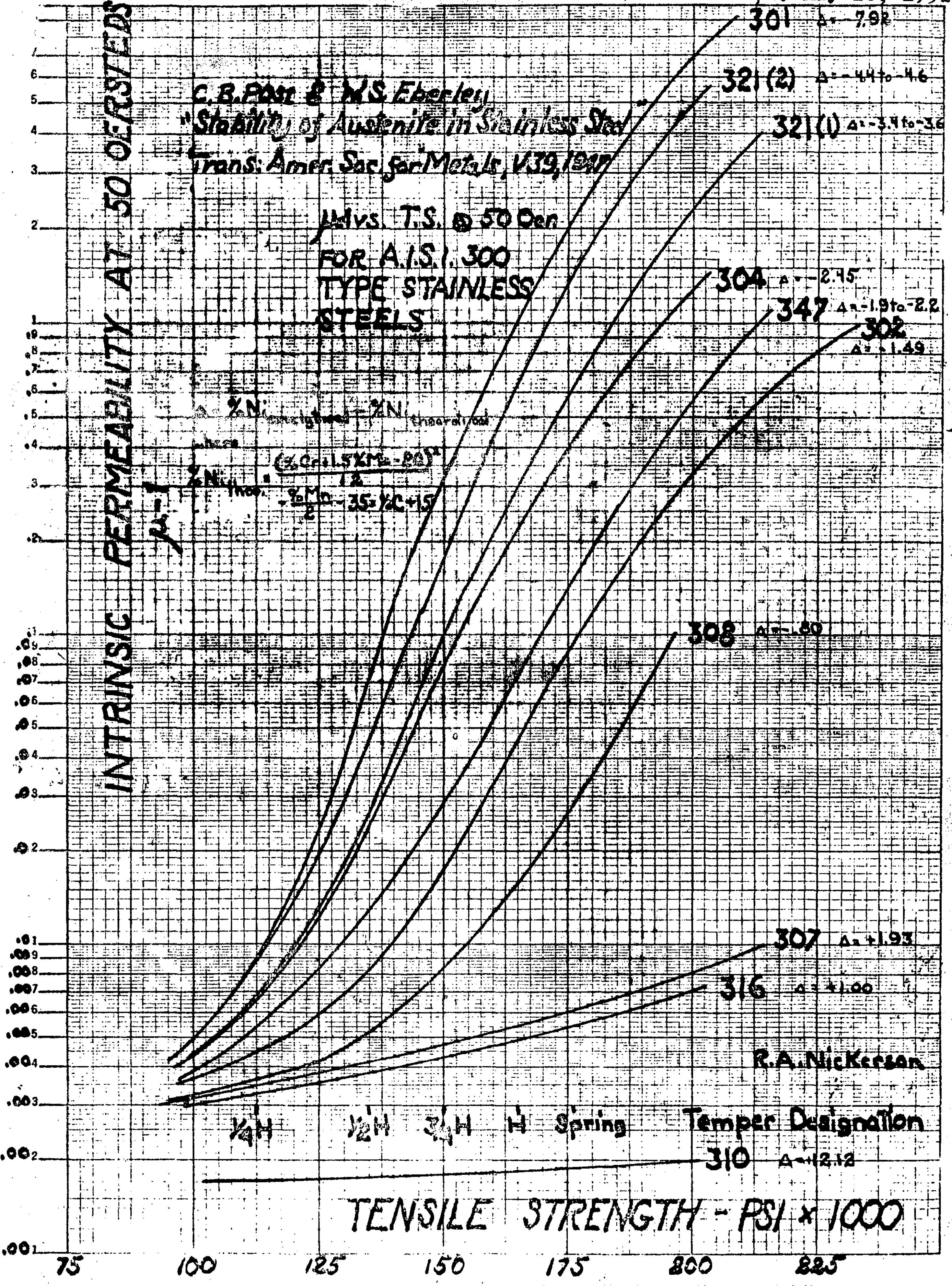
"Stability of Austenite in Stainless Steel"
Trans. Amer. Soc. for Metals, V39, 1947

R.A. Nickerson

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, V.39, 1947

μ vs. T.S. @ 50 Oer.
FOR A.I.S.I. 300
TYPE STAINLESS
STEELS

$$\Delta = \%Ni_{analytical} - \%Ni_{theoretical}$$

where

$$\%Ni_{theo.} = \frac{(\%Cr + 1.5 \times Mo - 20)^2}{12} - \frac{\%Mn}{2} - 35 \times \%C + 15$$

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DESIGN DATA

SUBJECT ELECTRON WORK FUNCTIONS OF THE ELEMENTS	DATE 8/17/51	D.D. NO. 45	PAGE 1 of 2
	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	Sc	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

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DESIGN DATA

SUBJECT	DATE 8/17/51	D.D. NO. 45	PAGE 2 of 2
ELECTRON WORK FUNCTIONS OF THE ELEMENTS	PREPARED H. P. Hernandez		
	CHECKED BY		

ELEMENT	WORK FUNCTION Øm, 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 Øm 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, Øm; 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

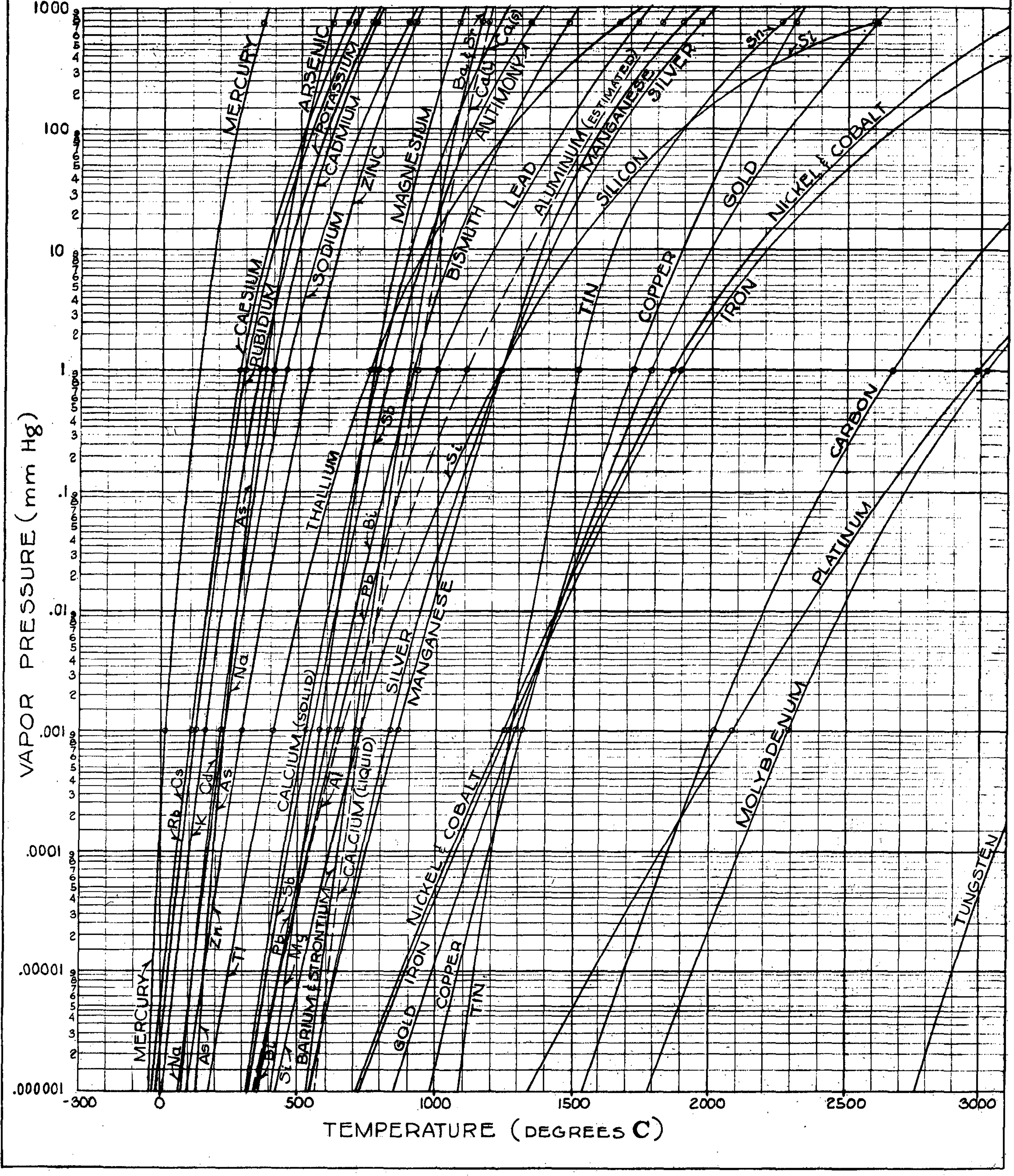
DATE	D.D. No.	PAGE
9-12-51	46	1 OF 1

VAPOR PRESSURE vs. TEMPERATURE

PREPARED

CHECKED BY
V. Mc Clain

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



RADIATION LABORATORY • UNIVERSITY OF CALIFORNIA • BERKELEY DESIGN DATA	DATE 10/11/51	D. D. No. 47	PAGE 1 of 1
SUBJECT SURFACE FINISHES TYPICAL APPLICATIONS AND COST COMPARISONS	PREPARED W. M. Brobeck CHECKED BY		

The following table is copied from Oak Ridge National Laboratory report ORNL-1051. It should be stated that the relative cost varies considerably with the design of the piece to be finished and the shop facilities available.

The laboratory has a profilometer available for the measurement of surface finishes.

COST COMPARISONS AND SURFACE FINISH APPLICATION TABLE

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

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DESIGN DATA

DATE	D. D. NO.	PAGE
11/26/51	48	1

SUBJECT

THREADS - LOADS AND STRESSES PER UNIT TORQUE

PREPARED W. M. Brobeck

CHECKED BY

The following tabulation is copied from "Bolts, Nuts, and Screws" by Lamson and Sessions Company.

SIZE, IN.	NO. OF THREADS PER IN.			BASIC AREA OF SECTION AT ROOT OF THREADS, SQ. IN.	MAX. COMBINED TENSILE STRESS, LB. PER SQ. IN., IN SCREW WITH TORQUE OF 1 IN. LB. ON NUT.	MAX. AXIAL LOAD, LB., ON SCREW WITH TORQUE OF 1 IN. LB. ON NUT.
	COARSE	FINE	EXTRA FINE			
1/4	20			0.0269	1,115	20.6
		28		0.0326	879	21.5
			32	0.0352	807	21.7
5/16	18			0.0454	512	16.6
		24		0.0524	432	17.1
			32	0.0590	377	17.6
3/8	16			0.0678	292	14.3
		24		0.0809	261	14.9
			32	0.0890	213	15.3
7/16	14			0.0933	179	12.2
		20		0.1090	150	12.6
			28	0.1217	132	13.0
1/2	13			0.1257	118	10.9
		20		0.1486	97.1	11.4
			28	0.1634	86.3	11.7
9/16	12			0.1620	82.3	9.9
		18		0.1888	68.8	10.3
			24	0.2054	63.3	10.5
5/8	11			0.2018	59.3	8.72
		18		0.2400	48.2	9.24
			24	0.2586	44.3	9.33
3/4	10			0.3020	32.1	7.34
		16		0.3513	27.0	7.64
			20	0.3725	25.3	7.68
7/8	9			0.4193	20.4	6.52
		14		0.4805	17.6	6.78
			20	0.5200	16.1	6.92
1	8			0.5510	13.6	5.73
		14		0.6464	11.6	5.99
			20	0.6921	10.6	6.09
1 1/8	7			0.6931	9.61	5.08
		12		0.8118	8.06	5.32
			18	0.8772	7.43	5.43
1 1/4	7			0.8898	6.71	4.62
		12		1.0238	5.73	4.80
			18	1.0969	5.35	4.90
1 3/8	6			1.0541	5.17	4.18
		12		1.2602	4.24	4.40
1 1/2	6			1.2938	3.84	3.86
		12		1.5212	3.31	4.16
			18	1.6101	3.17	4.32

The loads and stresses per unit torque have been calculated, based on a coefficient of friction equal to 0.12 between the threads and a coefficient of friction equal to 0.14 between nut and washer or bearing surfaces.

D-20(M)

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DESIGN DATA

SUBJECT GRADES OF GRAPHITE	DATE 2-15-52	D.D. NO. 50	PAGE 1
	PREPARED D. Vorkoeper		
	CHECKED BY SCALISE		

Relative Size of Crystalline Structure	Commercial Designations	Remarks
Very fine	C-15 555	Hard. Molded under high pressure. Used for intricate and delicate parts.
Fine	C-18	Formed by jar-molding. Not as hard as C-15 but more dense than 85, 185, or AGVX. Used for intricate and delicate parts.
Fine	85 185 AGVX	Extruded. About same particle size as C-18 but not as dense.
Medium	CS	Extruded. Particles about 1/16 inch diameter. Used for large parts where finish and strength are not very important.
Coarse	AGR	Extruded. Particles up to 1/8 inch diameter. Used for large parts where finish and strength are not very important.

DV:ple

RADIATION LABORATORY · UNIVERSITY OF CALIFORNIA · BERKELEY

DESIGN DATA

SUBJECT: STUD SPACING FOR GASKETED FLANGES	DATE 3/27/52	D.D. NO. 51	PAGE 1
	PREPARED R. Meuser		
	CHECKED BY SCALISE		

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

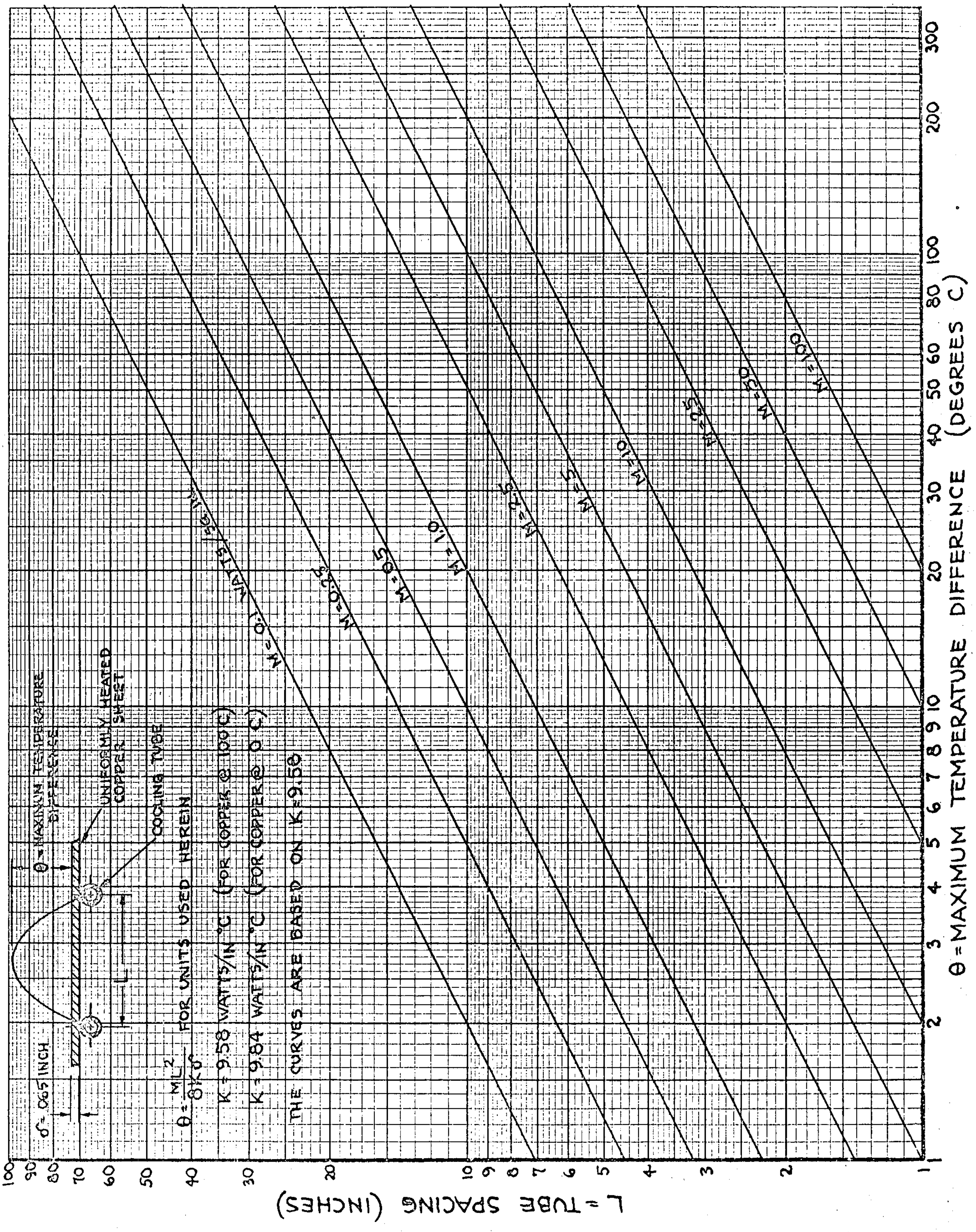
SUBJECT

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

PREPARED D. VANCE

CHECKED BY SCALISE

DRAWN BY SEEGMILLER



$\theta = \frac{ML^2}{8K\delta}$ FOR UNITS USED HEREIN

K = 9.58 WATTS/IN °C (FOR COPPER @ 100°C)

K = 9.84 WATTS/IN °C (FOR COPPER @ 0°C)

THE CURVES ARE BASED ON K = 9.58

U-27 (M)

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	166.8	.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. For Ta or W filaments it is 0.23 watts per ampere.

DATE	D.D. NO.	PAGE
10/14/44	54	2

SUBJECT
CHARACTERISTICS OF PURE TUNGSTEN FILAMENTS

PREPARED
T. W. Macomber

CHECKED BY

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	.546	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.

D-35(M)

RADIATION LABORATORY · UNIVERSITY OF CALIFORNIA · BERKELEY

DESIGN DATA

SUBJECT

PRICES AND CHARACTERISTICS OF MECHANICAL VACUUM PUMPS

DATE 5/2/52
D.D. NO. 55
PAGE 1
PREPARED Chupp/H.Smith/Scalise
CHECKED BY

PUMP MODEL	PUMP DISPLACEMENT (CFM)	ULTIMATE VACUUM (MICRONS)	UNIT PRICE IN MARCH, 1952		PUMP RPM	MOTOR HORSEPOWER	INTAKE SIZE (INCHES)	OUTLET SIZE (INCHES)
			Pump-Motor Assembly F.O.B.-Berkeley	$/CFM DISPLACEMENT				
KINNEY								
CVM 3153	2.0	0.1	$ 214	107	755	1/4	3/4 NPT	-
CVM 3534	4.9	0.1	331	68	600	1/3	1 NPT	-
VSM 556	13.1	10.0	476	36	450	1/2	1 1/4 NPT	1 NPT
CVM 556	15.2	0.2	797	52	525	1	2 NPT	1 NPT
VSD 778	27.0	10.0	699	26	360	1 1/2	1 1/4 NPT	1 1/4 NPT
CVM 8610	46.0	0.2	1,189	26	500	3	3 NPT	1 1/2 NPT
VSD 8811	46.8	10.0	962	21	360	2	1 1/2 NPT	1 1/4 NPT
DVD 8810	110.3	10.0	1,416	13	450	5	2 NPT	1 1/4 NPT
DVD 12814	217.9	10.0	2,444	11	415	10	5 ASA 125# Flg.	3 NPT
DVD 14918	311.4	10.0	3,257	10	360	15	6	3 NPT
DVD 141418	486	10.0	4,274	9	360	25	6	3 NPT
DVD 181420	702	10.0	6,352	9	360	40	8	3 NPT
DVH 272034	1,612	10.0	13,500	8	230	75	12	8 ASA 125# Flg.
CENCO								
Hyvac	0.36	0.3	97	270	350	1/4	1/4 ID	-
Megavac	1.1	0.1	219	199	325	1/3	49/64 ID	-
Megavac	2.0	0.1	235	118	600	1/2	49/64 ID	-
Hypervac 23	8.5	5.0	398	47	510	1/2	13/16 ID	-
Hypervac 25	9.3	0.1	529	57	570	3/4	13/16 ID	-
Hypervac 100	33.9	0.1	1,870	55	450	2	3 ASA 125# Flg.	-
WELCH								
1400B	0.74	0.1	103	139	450	1/4		-
1405H	1.18	0.05	195	165	300	1/3	5/8 ID	-
1406H	1.18	5.0	100	85		1/4		-
1404H	1.18	20.0	103	87		1/4		-
1405B	2.05	0.1	210	102	525	1/2	5/8 ID	-
1403B	3.54	5.0	190	54		1/2		-
1397B	10.6	0.1	490	46		3/4		-

NOTES: (1) Kinney Models CVM Models (formerly called CVD Models) are <u>COMPOUND PUMPS</u>. Model VSM 556 was formerly numbered VSD 556.

(2) Prices are for a single pump-motor assembly and <u>DO NOT</u> include installation costs or quantity discounts. Kinney prices include costs of a belt guard and oil solenoid valves. (Cenco and Welch do not provide these accessories).

(3) One CFM = .472 liters/second.

(4) Pump displacement is the swept volume per unit time and is different from the pump capacity.

DTS:
plc

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DESIGN DATA

	DATE 6/5/52	D.D. NO. 56 B	PAGE 1 OF 1 PAGES
SUBJECT MAGNET DESIGN INFORMATION	PREPARED A. Schmidt, D. T. Scalise CHECKED BY E. Kane, L. E. Brown		

CONDUCTOR PROPERTIES

** Revised 10-21-56
* Revised 10-5-55

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

⟨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)

⟨Pounds force between long parallel conductors⟩ = 4.496×10^{-8} x (amps. in one cond.) x (amps in other cond.) x $\left(\frac{\text{inches length cond.}}{\text{inches between cond.}}\right)$

⟨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
(kilowatts) x (tons)	= (.039) (.118) (.131)	Al. Cu Ag	kilo (~~Mega~~-amp. turns)^2 x $\left(\frac{\text{inches mean}}{\text{turn length}}\right)^2$	ρ w
$\frac{\text{(Amperes)}}{\text{(sq. inch)}}$	= (202) (469) (525)	Al Cu Ag	$\sqrt{\frac{\text{(kilowatts)}}{\text{(tons)}}}$	$\sqrt{\frac{w}{\rho}}$
(Sq. inches Cross Section)	= (4.95) (2.13) (1.90)	Al Cu Ag	$\frac{\sqrt{\text{(kilowatts) x (tons)}}}{\text{(volts) x (parallel paths)}}$	$\sqrt{\frac{\rho}{w}}$
(Sq. inches Cross Section)	= (1.20) (.732) (.69)	Al Cu Ag	$\frac{\text{(Meg-amp. turns) x }\left(\frac{\text{inches mean}}{\text{turn length}}\right)}{\text{(volts) x (parallel paths)}}$	ρ

FOR RECTANGULAR CONDUCTOR LOSING HEAT FROM TWO EDGES

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

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

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

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DESIGN DATA

DATE 8/26/52

D.D. NO. 60

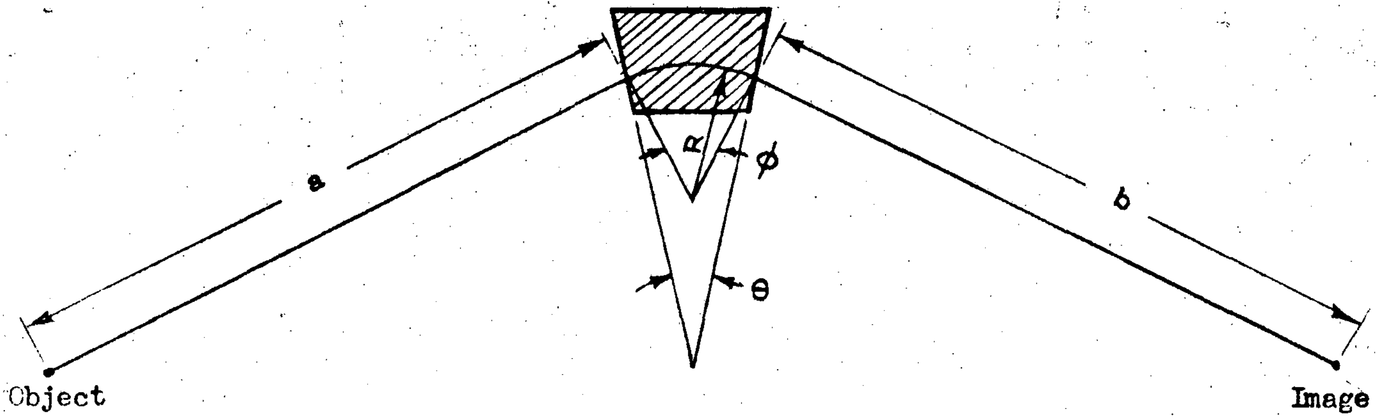
PAGE 1

SUBJECT

APPROXIMATE FOCAL LENGTH OF WEDGE MAGNETS WITH UNIFORM MAGNETIC FIELD

PREPARED W. M. Brobeck

CHECKED BY



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 $= \dfrac{1}{\frac{1}{a} + \frac{1}{b}}$

Horizontal focal length (in place 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

D-10(M)

RADIATION LABORATORY - UNIVERSITY OF CALIFORNIA - BERKELEY

DESIGN DATA

SUBJECT

INDUSTRIAL LAMINATED PLASTICS
(Bakelite, Formica, Textolite, Micarta, etc.)
APPROXIMATE ESTIMATING PRICES AS OF 10/13/52

DATE 10/13/52
D.D. NO. 62
PAGE 1
PREPARED J. Turner
CHECKED BY

NEMA GRADE	BASE	RESIN	CUBIC INCHES PER POUND	SHEETS 300# and over .050" thickness & over	TUBES 2" ID x 1/2" wall 500' & over		RODS 2 1/4" Diameter 500' & over	
				$/pound	$/pound	$/lin.ft.	$/pound	$/lin. ft.
XX	Paper	Phenolic	20	.9	1.3	3.0	2.7	6.5
C or CE	Coarse Cotton (Canvas)	Phenolic	20	1.4	2.3	5.5	4.4	10.4
L or LE	Fine Cotton	Phenolic	20	1.7	2.7	6.4	4.7	10.9
C5*	Coarse Cotton	Melamine	18.1	1.6	2.3	6.0	4.3	11.2
L5*	Fine Cotton	Melamine	18.1	1.8	2.7	6.9	4.6	11.8
A	Asbestos Paper	Phenolic	16	1.0	1.3	3.8	2.4	6.9
AA	Asbestos Cloth	Phenolic	16	2.2	3.5	10.2	5.3	15.5
G1	Staple Fibre Glass Cloth	Phenolic	16	2.6	3.7	10.8	6.5	19.0
G3	Continuous Filament Glass Cloth	Phenolic	16	2.6	3.7	10.8	6.5	19.0
G5	Continuous Filament Glass Cloth	Melamine	14.25	2.9	4.9	15.9	7.4	24.3
G6	Staple Fibre Glass Cloth	Silicone	15.1	6.5				
G7	Continuous Filament Glass Cloth	Silicone	15.1	6.5				
NS	Nylon Cloth	Phenolic	24	3.3				

* Taylor Fibre Co. designations (not NEMA); NEMA = National Electrical Manufacturers' Association

RADIATION LABORATORY - UNIVERSITY OF CALIFORNIA - BERKELEY

DESIGN DATA

DATE	11/24/52
D. D. NO.	63
PAGE	1 of 2
SUBJECT	HEAT CONDUCTIVITY OF METALS AND ALLOYS
PREPARED	R. A. Nickerson
CHECKED BY	

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

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 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	
SC	Steel AISI 1080	
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	
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

D-44(M)

RL-610-a

RADIATION LABORATORY - UNIVERSITY OF CALIFORNIA - BERKELEY

DESIGN DATA

SUBJECT

HEAT CONDUCTIVITY OF METALS AND ALLOYS*

DATE 11/24/52

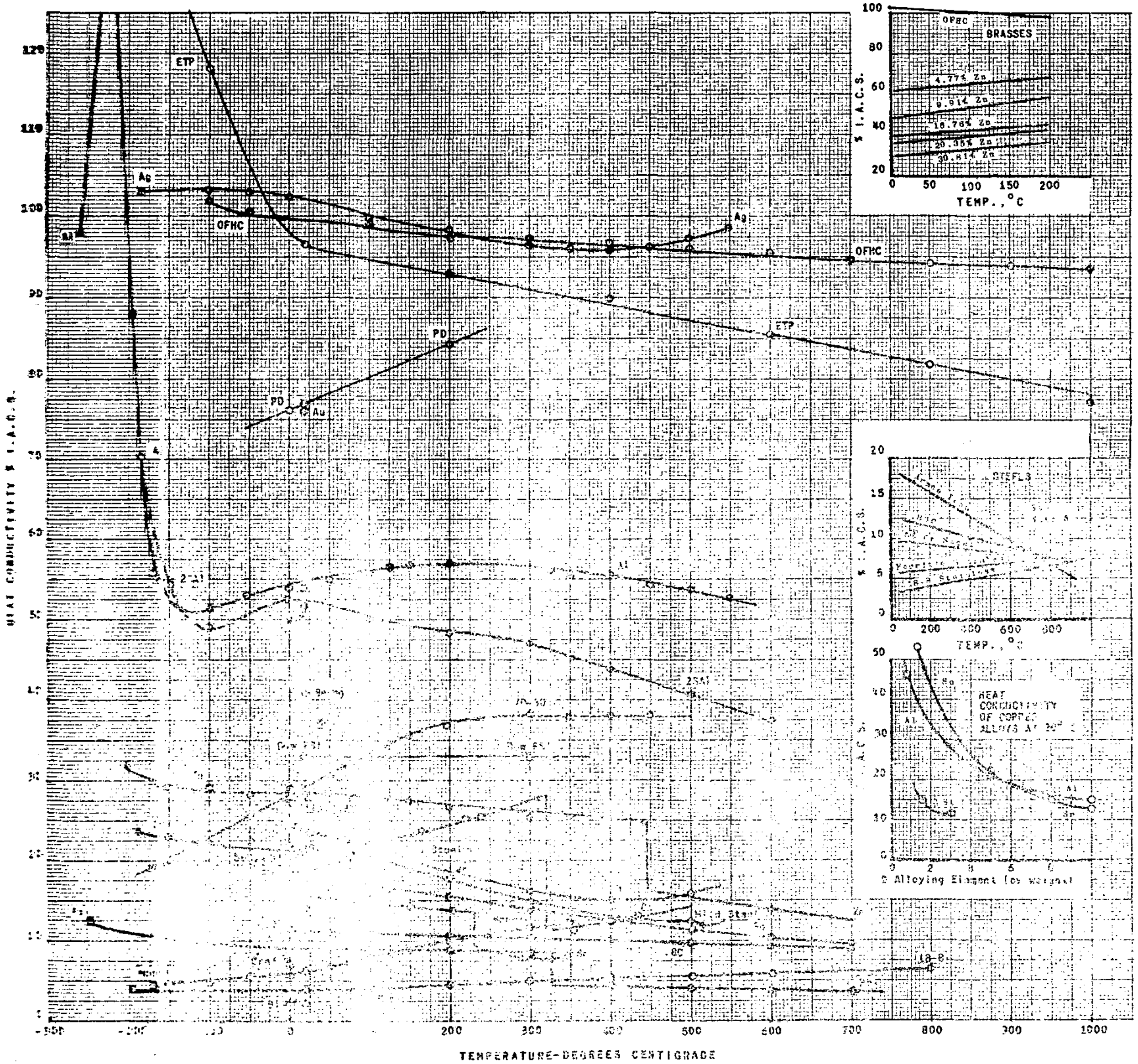
D.D. NO. 63

PAGE 1 OF 1 PAGES

PREPARED R. A. Nickerson

CHECKED BY

Copy 11/15/57 K. Connelly



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 FSl	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 40% 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.

$$\text{I.A.C.S.} = .93 \times \frac{\text{cal}}{\text{sec. cm}^2(^\circ\text{C/cm})} = 9.9 \times \frac{\text{Watts}}{^\circ\text{C in}} = 3.91\ \frac{\text{Watts}}{^\circ\text{C cm}}$$

RADIATION LABORATORY - UNIVERSITY OF CALIFORNIA - BERKELEY

DESIGN DATA

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10-10-57	65 A	1 OF 1.

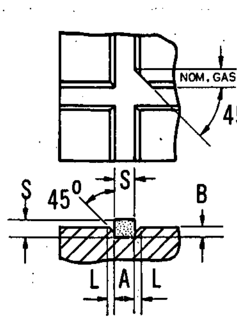
SUBJECT

GROOVES FOR RUBBER GASKETS & O-RINGS FOR VACUUM SERVICE

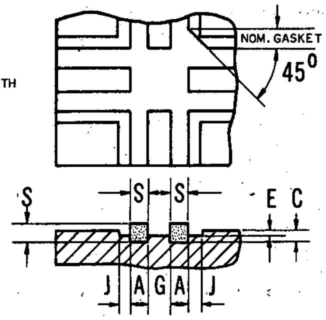
PREPARED V. MCCLAIN

CHECKED L. J. YOST/R. BURLEIGH

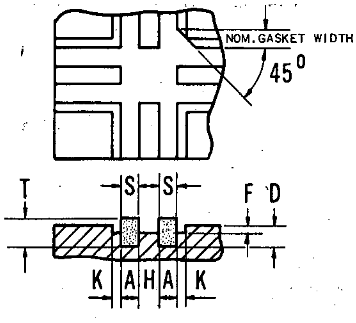
D. D. NO. 65 A SUPERSEDES D. D. NO. 65, PAGES 1, 2 AND 3; AND D. D. NO. 31.



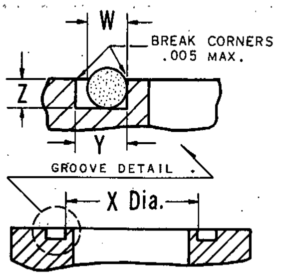
SQUARE REGULAR



SQUARE METAL-TO-METAL



RECTANGULAR METAL-TO-METAL



O-RINGS

NOTE: UNLESS OTHERWISE SHOWN, EDGES AND FILLETS TO BE 1/64 RADIUS MAX.

TABLE I: SQUARE AND RECTANGULAR GASKETS

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, -0.
**TOLERANCE ± 1/64.

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 UCRL 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. 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 ARE UCRL STOCK SIZES, BUT STOCK SHOULD BE CONSULTED 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 ON 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 UCRL 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 SQUARE 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. THIS DESIGN DATA SHEET APPLIES TO UCRL STOCK HYCAR GASKETING (SQUARE AND RECTANGULAR) AS PER SPEC. M9B. THE HARDNESS RANGE OF THIS 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 35 ±5 PERCENT COMPRESSION WITH A RESULTING PRESSURE BASED ON THE PROJECTED AREA, OF ABOUT 400 PSI.

TABLE II: O-RINGS

O-RING DIMENSIONS (UCRL STOCK)						GROOVE DIMENSIONS		
NO. AN 6227	NOMINAL SIZE			ACTUAL SIZE				
	W	I.D.	O.D.	W.	I.D.	X DIA.	Y	Z
-1	1/16	1/8	1/4	.070	.114±.005	.128±.004	.113	.044
-3		3/16	5/16		.176	.191		
-5		1/4	3/8	±.003	.239	.254	+.015	+.004
-6		5/16	7/16		.301	.317	-.000	-.000
-7		3/8	1/2		.364	.380		
-9	3/32	7/16	5/8	.103	.424±.005	.447±.010	.151	.064
-10		1/2	11/16		.487	.510		
-11		9/16	3/4	±.003	.549	.573	+.015	+.006
-12		5/8	13/16		.612	.637	-.000	-.000
-13		11/16	7/8		.674	.699		
-14		3/4	15/16		.737	.763		
-15	1/8	3/4	1	.139	.734±.006	.761±.010	.205	.086
-17		7/8	1 1/8		.859	.887		
-19		1	1 1/4	±.004	.984	1.013	+.015	+.009
-21		1 1/8	1 3/8		1.109	1.140	-.000	-.000
-23		1 1/4	1 1/2		1.234	1.266		
-25		1 3/8	1 5/8		1.359	1.392		
-27		1 1/2	1 3/4		1.484	1.518		
-29	3/16	1 5/8	2	.210	1.600±.010	1.639±.010	.297	.134
-31		1 7/8	2 1/4		1.850	1.892		
-33		2 1/8	2 1/2	±.005	2.100	2.144	+.015	+.010
-34		2 1/4	2 5/8		2.225	2.270	-.000	-.000
-35		2 3/8	2 3/4		2.350	2.397		
-37		2 5/8	3		2.600	2.649		
-39		2 7/8	3 1/4		2.850±.015	2.906		
-41		3 1/8	3 1/2		3.100	3.159		
-43		3 3/8	3 3/4		3.350	3.411		
-45		3 5/8	4		3.600	3.664		
-47		3 7/8	4 1/4		3.850	3.916		
-49		4 1/8	4 1/2		4.100	4.168		
-52		4 1/2	4 7/8		4.475	4.547		
-56	1/4	5	5 1/2	.275	4.975±.015	5.052±.010	.385	.177
-57		5 1/8	5 5/8		5.100±.023	5.186		
-60		5 1/2	6	±.006	5.475	5.565	+.015	+.012
-64		6	6 1/2		5.975	6.070	-.000	-.000
-66		6 1/2	7		6.475	6.575		
-68		7	7 1/2		6.975	7.080		
-70		7 1/2	8		7.475±.030	7.591		
-72		8	8 1/2		7.975	8.096		
-74		9	9 1/2		8.975	9.106		
-76		10	10 1/2		9.975	10.116		
-78		11	11 1/2		10.975	11.125		
-80		12	12 1/2		11.975	12.135		
-82		13	13 1/2		12.975	13.145		
-84		14	14 1/2		13.975	14.155		
-86		15	15 1/2		14.975	15.165		
6230	LIGHT SERIES							
-2	1/8	1 3/4	2	.139	1.734±.010	1.772±.010	.205	.086
-4		2	2 1/4		1.984	2.027		
-6		2 1/4	2 1/2	±.004	2.234	2.280	+.015	+.009
-8		2 1/2	2 3/4		2.484	2.532	-.000	-.000
-10		2 3/4	3		2.734±.015	2.790		
-12		3	3 1/4		2.984	3.042		
-14		3 1/4	3 1/2		3.234	3.294		
-16		3 1/2	3 3/4		3.484	3.547		
-18		3 3/4	4		3.734	3.799		
-20		4	4 1/4		3.984	4.051		
-22		4 1/4	4 1/2		4.234	4.304		
-24		4 1/2	4 3/4		4.484	4.556		
-26		4 3/4	5		4.734	4.809		
-28		5	5 1/4		4.984	5.061		
-30		5 1/4	5 1/2		5.234±.023	5.321		
-32		5 1/2	5 3/4		5.484	5.574		
-34		5 3/4	6		5.734	5.826		
-36		6	6 1/4		5.984	6.079		
-38		6 1/2	6 3/4		6.484	6.583		
-40		7	7 1/4		6.984	7.088		
-42		7 1/2	7 3/4		7.484±.030	7.601		
-44		8	8 1/4		7.984	8.105		
-46		8 1/2	8 3/4		8.484	8.610		
-48		9	9 1/4		8.984	9.115		
-50		9 1/2	9 3/4		9.484	9.620		
-52		10	10 1/4		9.984	10.125		

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SUBJECT PROPERTIES OF MATERIALS Approximate Electrical Resistivities of Metals and Alloys	PREPARED L. Polentz CHECKED BY		

INDEX

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 $\text{microhm}^{-1}\ \text{cm}^{-1}$ (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)

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DESIGN DATA

SUBJECT
PROPERTIES OF MATERIALS
Approximate Electrical Resistivities of Metals and Alloys

DATE 2-17-53
D.D. NO. 66
PAGE 4 OF 14 PAGES
PREPARED L. Polentz
CHECKED BY

Material	Resistivity at 20° C.		Conductance Percent IACS (3)	Temp. Coeff. of Elect. Resist. per °C. (4)		Reference
	Microhm-cm (1)	Microhm-in (2)		a	Temp. C	
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}(6)	--			1

Material	Resistivity at 20° C.		Conductance Percent IACS (3)	Temp. Coeff. of Elect. Resist. per °C. (4)		Reference
	Microhm-cm (1)	Microhm-in (2)		α	Temp. C.	
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

RADIATION LABORATORY - UNIVERSITY OF CALIFORNIA - BERKELEY

DESIGN DATA

SUBJECT

PROPERTIES OF MATERIALS

Approximate Electrical Resistivities of Metals and Alloys

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PREPARED L. Polentz

CHECKED BY

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) a	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

RADIATION LABORATORY • UNIVERSITY OF CALIFORNIA • BERKELEY

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Approximate Electrical Resistivities of Metals and Alloys

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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

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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. 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

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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
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

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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
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

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
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

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Material	Resistivity at 20° C.		Conductance Percent IACS (3)	Temp. Coeff. of Elect. Resist. per °C. (4)		Reference
	Microhm-cm (1)	Microhm-in (2)		α	Temp. C	
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

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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

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RADIATION LABORATORY - UNIVERSITY OF CALIFORNIA - BERKELEY

DESIGN DATA

SUBJECT PROPERTIES OF MATERIALS
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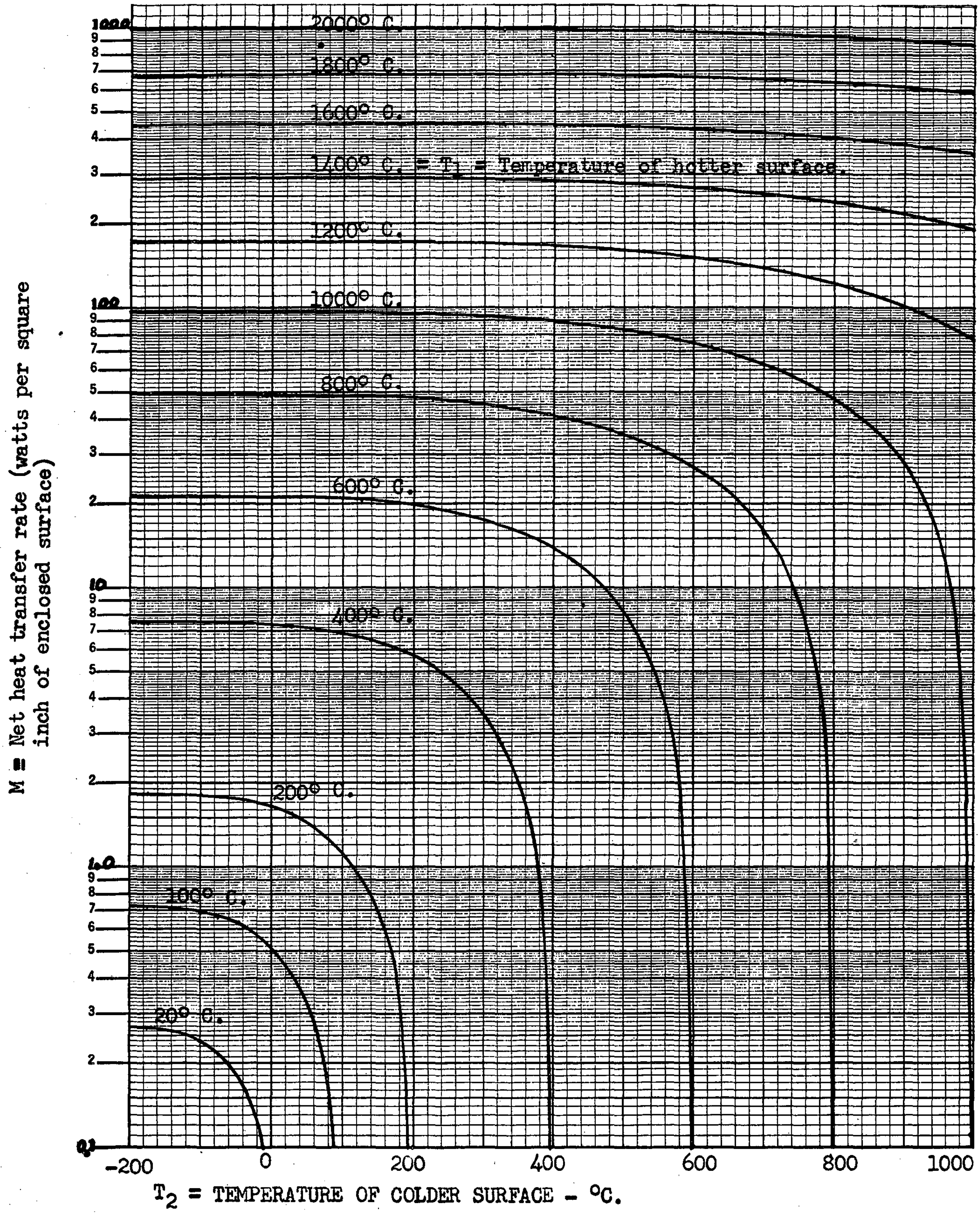
IRON ALLOYS (Cont.)						
Malleable Iron						
ASTM Spec A47-33 Grade 35018	30	12	5.7			8
ASTM Spec A47-33 Grade 32510	32	13	5.4			8
Annealed Carbon Steel Castings						
0.07 - 0.20 Percent C	13-14	5.1-5.5	13			7
0.20 - 0.45 Percent C	14-16	5.5-6.3	11			7
0.45 - 1.50 Percent C	16-20	6.3-7.9	9.6			7
Low 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

RADIATION LABORATORY - UNIVERSITY OF CALIFORNIA - BERKELEY **DESIGN DATA**	DATE 2-28-53	D.D. NO. 67	PAGE 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.



RADIATION LABORATORY — UNIVERSITY OF CALIFORNIA — LIVERMORE DESIGN DATA	DATE 1/16/56	D.D.NO. 71
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SUBJECT PRECIOUS METAL BRAZING ALLOYS	PREPARED Frey & Turner	
	CHECKED BY Lewis	

NO.	LIQUIDUS °C	SOLIDUS °C	COMPOSITION IN WEIGHT PERCENT 1)	SOLIDUS °F	LIQUIDUS °F	NOTES PG. 2	COST APPROXIMATE AS OF 12/1/55
1	2080	2000	Molybdenum - Boron 100	3632	3776	3) 4)	$23.00/lb
2	1966	1966	Rhodium 100	3574	3574	3)	$150.00/oz. in powder form
3	1773	1773	Platinum 100	3223	3223	3)	$90.00/oz.
4	1555	1555	Palladium 100	2831	2831	3)	$29.00/oz.
5	1450	1450	Nickel 100	2642	2642	3)	$1.15 to 2.60/lb.
6	1449	1427	Palladium - Gold 35 65	2600	2640	3)	$38.00/oz.
7	1371	1149	Platinum - Gold 25 75	2100	2500	3)	$60.00/oz
8	1330	1330	Molybdenum - Cobalt (Eutectic) 37 63	2426	2426	3)	Not available
9	1320	1320	Molybdenum - Nickel (Eutectic) 46.5 53.5	2408	2408	3)	Not available
10	1235	1170	Nickel - Copper 30 70	2138	2255	3)	Not available
11	1213	1150	Nickel - Copper 25 75	2201	2215	Coin Nickel 3)	Not available
12	1160	1160	Platinum - Silver (Peritectic) 27 73	2120	2120	3)	$36.00/oz.
13	1083	1083	Copper 100	1981	1981	[B Cu] 3) 5)	$00.65/lb
14	1066	960	Cr:16.5; Si:4.5; Fe:4.0; B:3.85; C:0.60; Bal.Ni	1760	1950	[BNiCr] 5) 6)	$7.95/lb.
15	1063	1063	Gold 100	1945	1945	24 K	$38.00/oz.
16	1025	980	Gold - Nickel - Copper 35 3 Bal.	1814	1877	8.4K	$17.00/oz.
17	1010	970	Gold - Copper 35 65	1778	1850	8.4K	$17.00/oz.
18	1005	950	Gold - Indium - Copper 20 3 Bal.	1742	1841	4.8K	$12.00/oz.
19	991	957	Gold - Copper 37.5 62.5	1755	1815	[BCuAu-I] 5) 9K red gold	$18.00/oz.
20	985	663	Tin - Silver - Copper 8 7 Bal.	1225	1805		Not available
21	980	950	Copper - Gold 6 94	1742	1796	22.6 K	$39.00/oz.
22	970	960	Manganese - Silver 15 85	1760	1778	[BAgMn] 5)	
23	963	963	Manganese - Silver 4 96	1765	1765		
24	963	932	Gold - Silver - Copper 41.7 2.8 Bal	1710	1765	10K red gold	$20.00/oz.
25	960	960	Silver 100	1760	1760		$1.50/oz.
26	950	950	Nickel - Gold 17.5 82.5	1742	1742	19.8 K white gold	$35.00/oz.
27	950	779	Silver - Copper 30 70	1434	1742		$1.65/oz.
28	945	925	Gold - Copper 50 50	1697	1733	12 K	$22.50/oz.
29	918	902	Copper - Silver - Gold 39.6 2.1 Bal.	1656	1684	14 K red gold	$26.00/oz.
30	910	779	Silver - Copper 40 60	1434	1670		$1.70/oz.
31	904	810	Copper - Silver 7.5 92.5	1490	1659	Sterling Silver	$1.75/oz.
32	899	893	Copper - Silver - Gold 20 5 Bal.	1638	1650	18 K red gold	$32.00/oz.
33	899	707	Phosphor - Copper 5 95	1305	1650	[BCuP-I] 5)	$28.00/oz.
34	893	769	Copper - Indium - Gold 37 3 Bal.	1415	1640	14.4K	$26.50/oz.
35	891	779	Copper - Silver 10 90	1435	1635	Coin Silver	$1.75/oz.
36	855	779	Copper - Silver 50 50	1434	1571		$1.60/oz.
37	843	819	Silver - Copper - Gold 24 17.7 Bal.	1505	1550	14 K	$26.00/oz.
38	827	804	Copper - Silver - Gold 23.5 27.5 Bal.	1480	1520		$23.00/oz.
39	821	796	Copper - Silver - Gold 20.5 29.5 Bal.	1465	1510	12 K	$23.00/oz.
40	788	707	Copper - Tin - Nickel - Silver 28.5 6.0 2.5 Bal.	1305	1450		Not available
41	785	752	Copper - Manganese - Nickel - Silver 28 5 2 Bal.	1385	1445		Not available
42	779	779	Copper - Silver (Eutectic) 28 72	1435	1435	[BAg-8] 5)	$1.80/oz.
43	760	743	Copper - Tin - Silver 27 5 Bal.	1370	1400		Not available
44	743	607	Copper - Indium - Silver 27 13 Bal.	1125	1370		Not available
45	743	604	Copper - Tin - Silver 30 10 Bal.	1120	1370		Not available
46	740	688	Copper - Indium - Silver 27 10 Bal.	1270	1360		$2.10/oz.
47	730	604	Copper - Tin - Manganese - Silver 32.7 7.0 3.0 Bal.	1120	1345		Not available
48	687	640	Copper - Indium - Silver 24 15 Bal.	1184	1269		$2.40/oz.
49	232	232	Tin 100	450	450	8)	$1.00/lb.
50	157	157	Indium 100	315	315	8)	$3.50/oz.

RADIATION LABORATORY — UNIVERSITY OF CALIFORNIA — LIVERMORE **DESIGN DATA**	DATE 1/16/55	D.D.NO. 71	PAGE 2 OF 2 PAGES
SUBJECT PRECIOUS METAL BRAZING ALLOYS (Metals Salts & Oxides)	PREPARED Frey & Turner CHECKED BY Lewis		

NO	LIQUIDUS °C	SOLIDUS °C	COMPOSITION IN WEIGHT PERCENT 1)	SOLIDUS °F	LIQUIDUS °F	NOTES PG 2	COST APPROXIMATE AS OF 12/1/55
1	d	500	Thorium Nitrate	932	d	$Th(NO_3)_4$	Not available
2	455	455	Silver Chloride	851	851	AgCl	$13.85 to 14.85/lb.
3	d	370	Platinum Chloride	698	d	$PtCl_4$	$43.40/oz.
4	d	300	Silver Oxide	572	d	Ag_2O	Not available
5	d	254	Gold Chloride	489	d	$AuCl_3$	$20.00/oz.
6	d:444	212	Silver Nitrate	414	d:831	$AgNO_3$	$1.00/oz.

NOTES:

1) Alloy constituents are given in the following order: the largest additive first, with lesser ones following and the bulk constituent last, as balance, if more than two elements are involved.

   The materials listed are available, in most cases, from many different suppliers under various tradenames or can be made to order.

   "Electron Tube Grade" should always be specified when ordering materials, as impurity content may be excessive for "Regular Grade" although it is sold under the same tradename.

2) Tradenames and suppliers are listed in Engineering Note: 3430-01 P-16.

3) These filler metals wet molybdenum and tungsten.

4) Dry Hydrogen of Dew Point - 60°C or better is necessary for successful furnace brazing with this material.

5) The letter codes in square brackets refer to the symbols adopted by the American Welding Society (AWS) and the American Society for Testing Materials (ASTM) in their Tentative Specifications ASTM - B260-52T and AWS - A5.8-52T. The letter B stands for Brazing Filler Metal and appears in all of the seven main groups which have been established. The chemical symbols following the letter B indicate the main constituents while the numbers indicate subgroups of various relative percentage compositions. Many"Electronic"brazing alloys are not covered by this code.

6) For Stainless Steel,Inconel, etc.high strength and corrosion resistance at elevated temperatures up to 1000°C. Pure, dry hydrogen of Dew Point less than -40°C required for furnace brazing.. Dissociated ammonia not recommended.

7) Phosphor - containing alloys are not generally accepted for vacuum tubes although their use has been demonstrated to be practical. Restricted to copper and nonferrous alloys to be brazed at 1300°F or higher.

8) While "Brazing" is performed, by definition,at a temperature of 800°F or higher, tin and indium, as well as some of the metal salts, have been listed for convenience of reference.

9) Metal salts may be used in liquid or paste form for very intricate brazes, to close small leaks, to join light parts where no mechanical strength is expected. The letter "d" indicates decomposition at the temperature stated.

Compiled by : Walter H. Kohl, Electronics Consultant on Materials and Techniques. - P.O. Box 426,Los Altos, California.