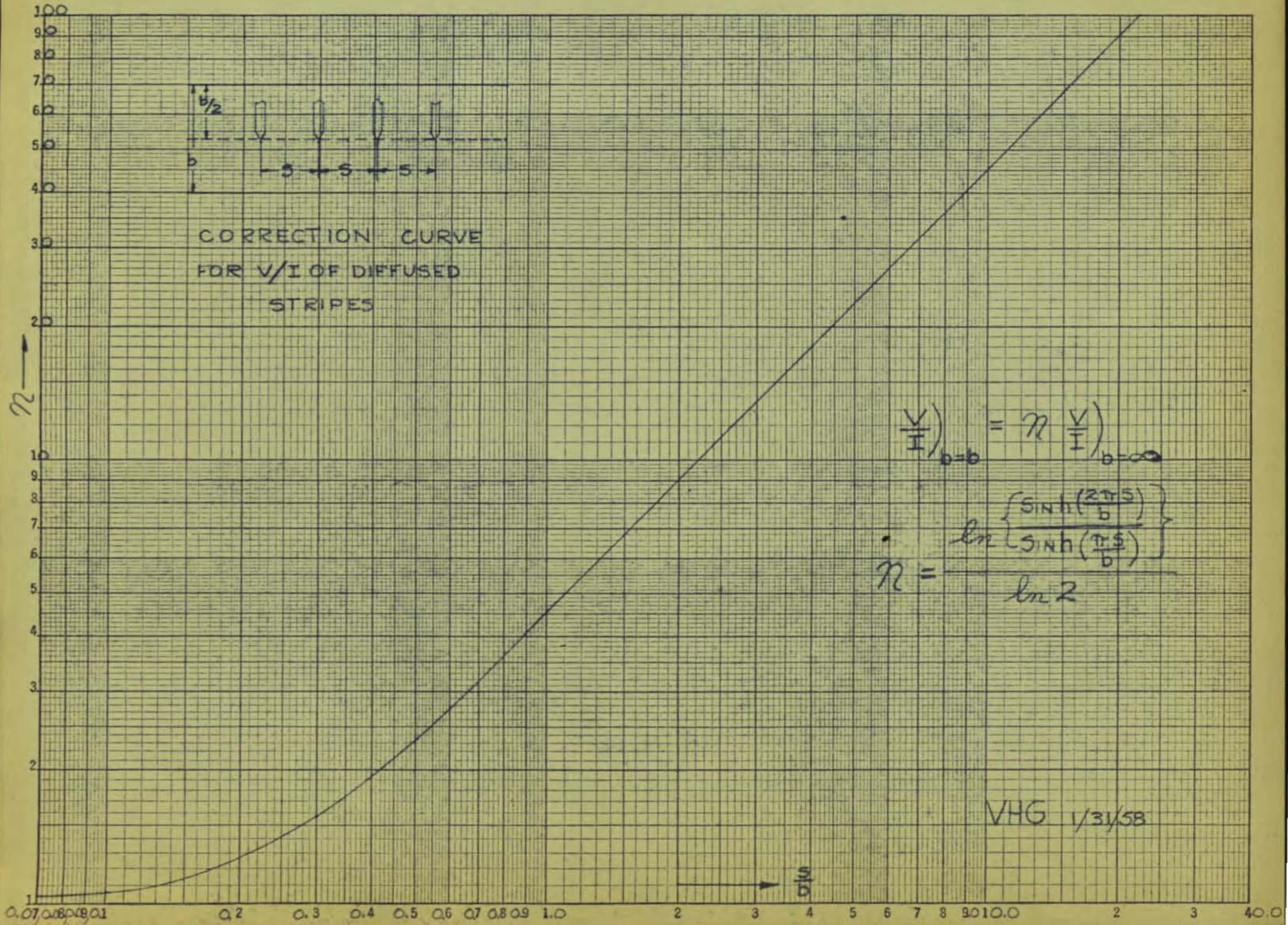
A-FACTOR

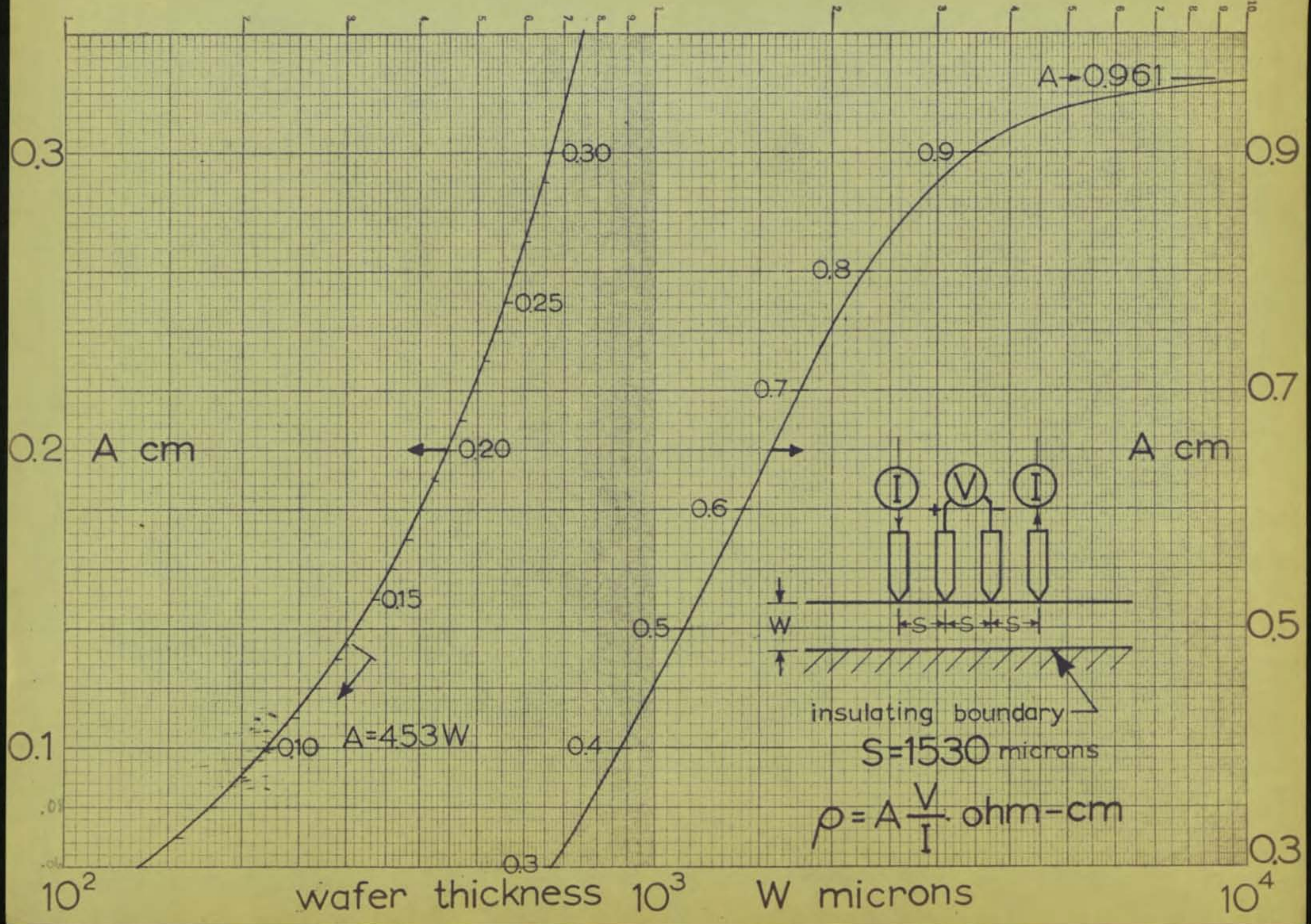


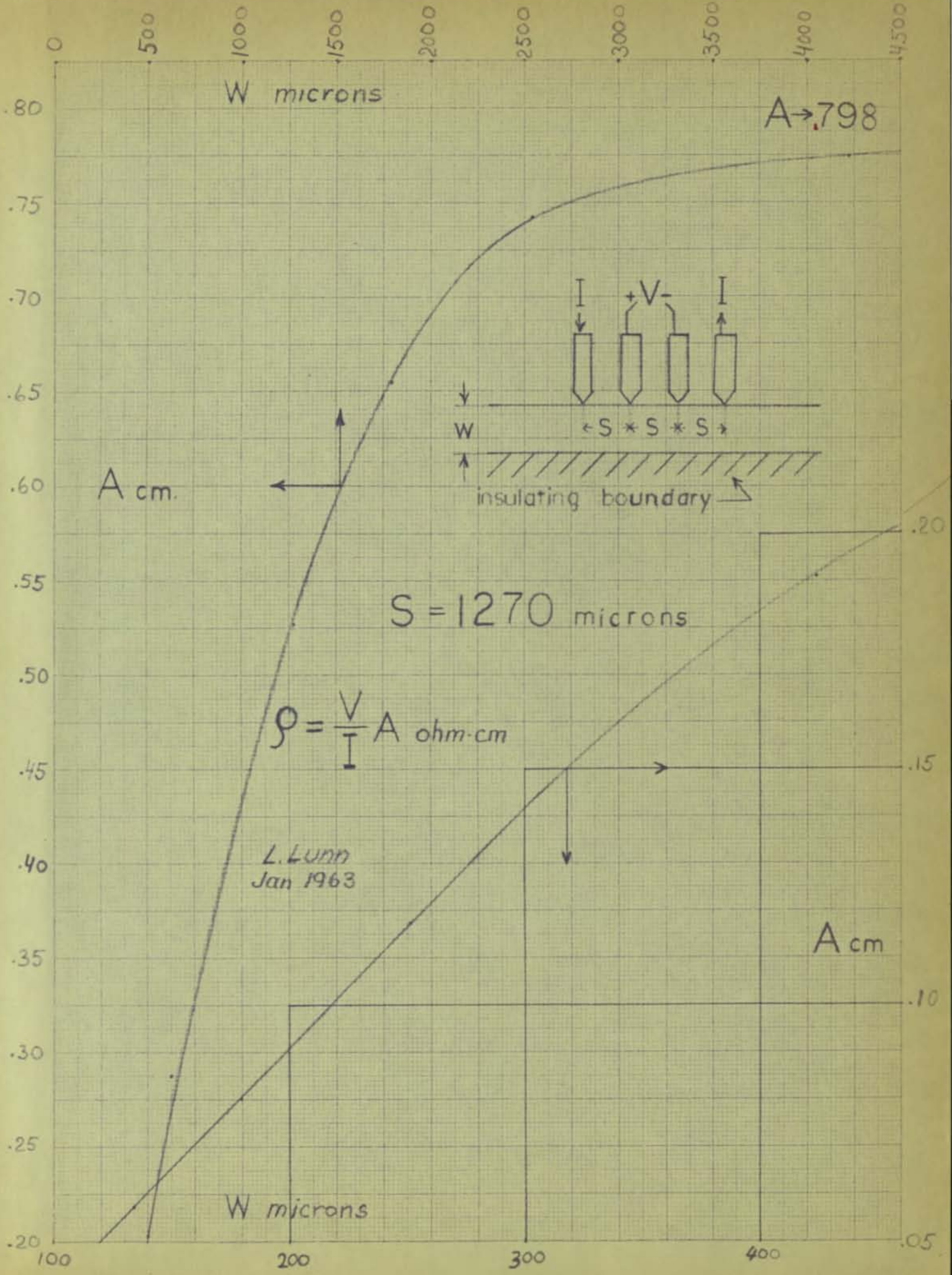
CORRECTION CURVE
FOR V/I OF DIFFUSED
STRIPES

$$\left.\frac{V}{I}\right)_{b=b} = \eta \left.\frac{V}{I}\right)_{b=\infty}$$

$$\eta = \frac{\ln\left\{\dfrac{\sinh\left(\frac{2\pi s}{b}\right)}{\sinh\left(\frac{\pi s}{b}\right)}\right\}}{\ln 2}$$

VHG 1/31/58

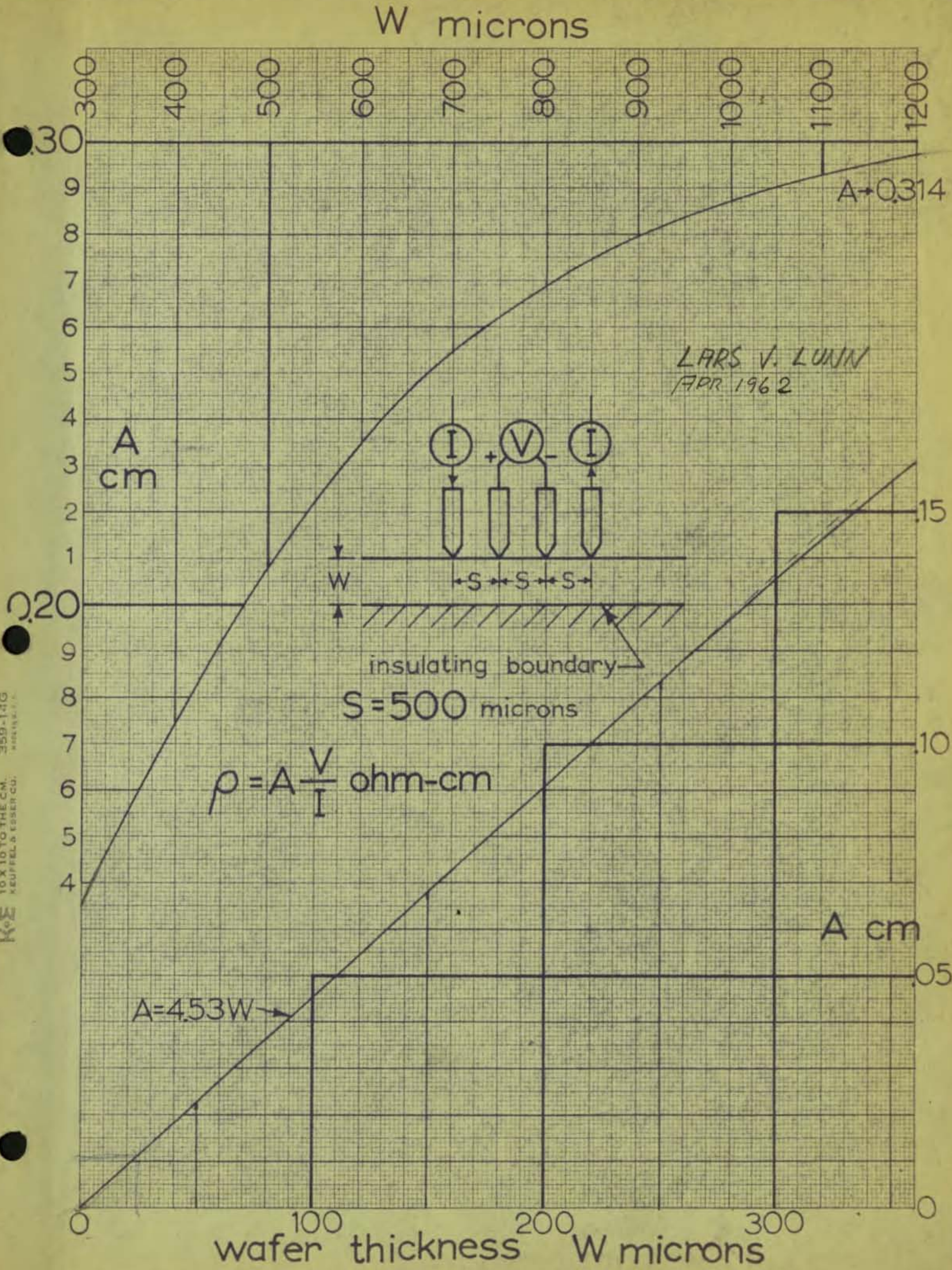

A→0.961
0.3
0.9
0.30
0.9
0.8
0.25
0.7
0.7
0.2 A cm
0.20
A cm
0.6
0.15
0.5
0.5
I
V
I
W
S S S
insulating boundary
A=453W
0.10
0.1
0.4
S=1530 microns
ρ = A V/I ohm-cm
0.3
0.3
10^2
wafer thickness
10^3
W microns
10^4



S = 1270 microns

$\rho = \frac{V}{I} A$ ohm-cm

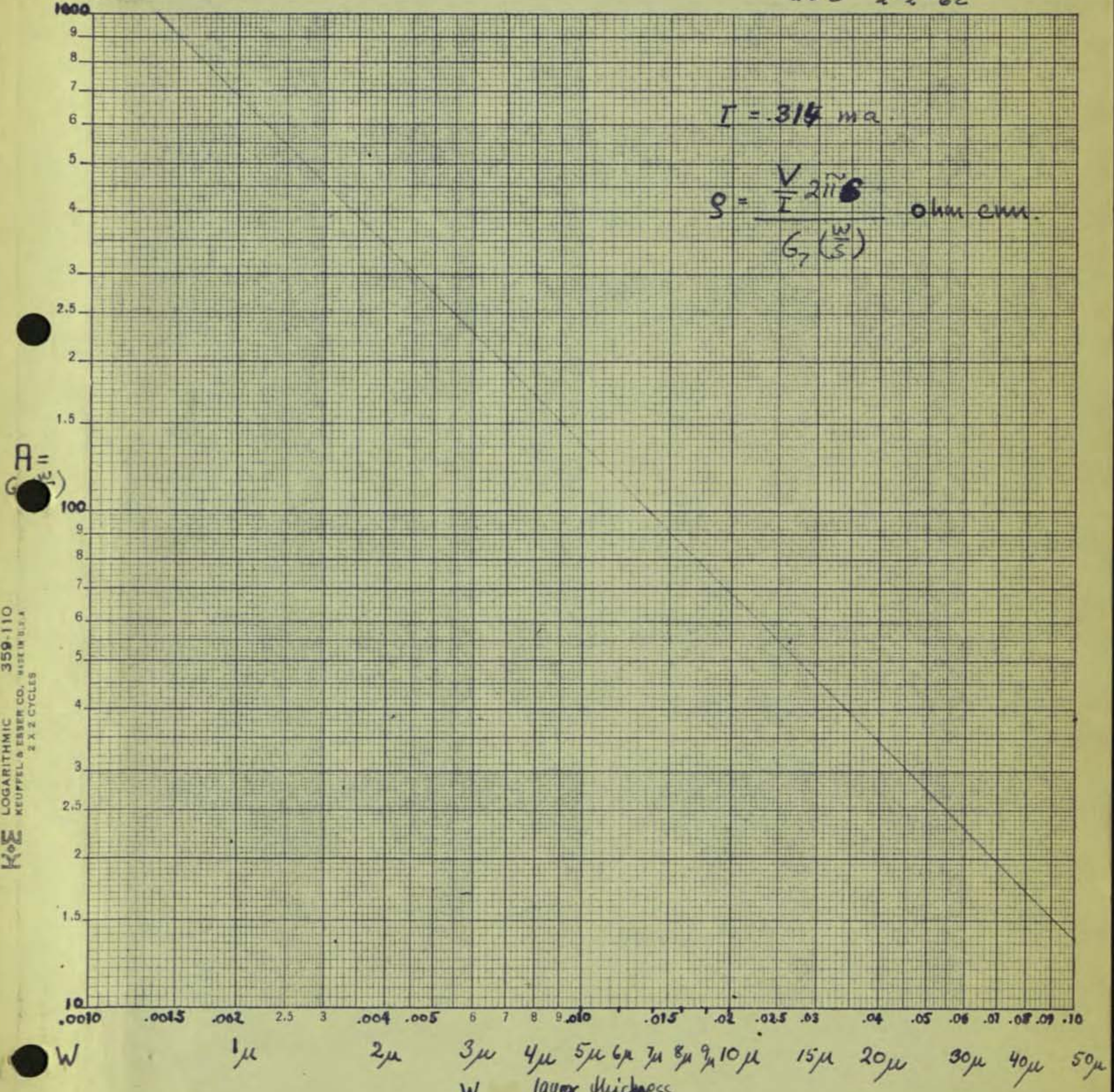
L. Lunn
Jan 1963



LARS V. LUNN
APR 1962

CORRECTION FACTOR

LVL 2-2-62



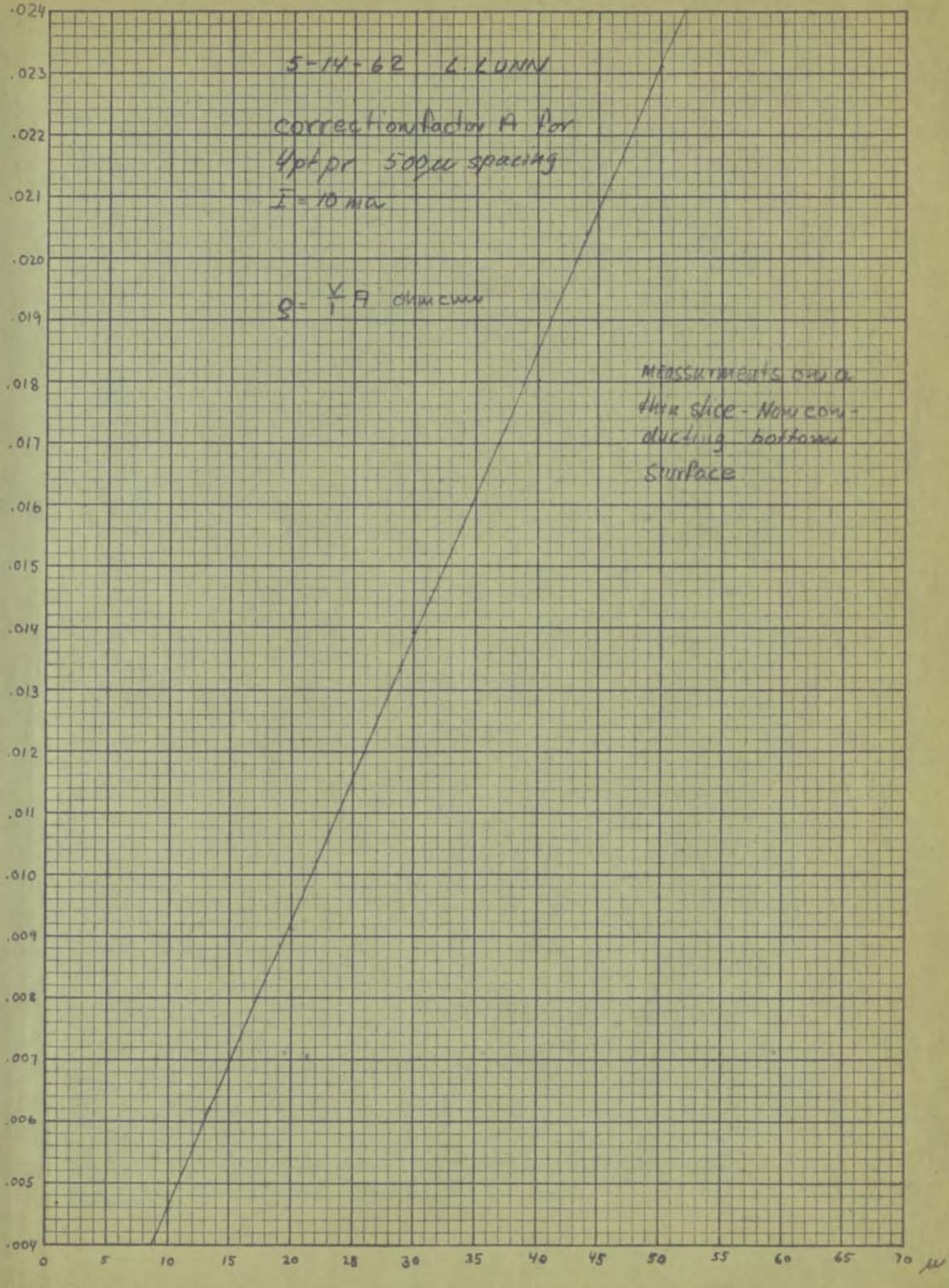
$I = .314$ ma

$$\rho = \frac{\frac{V}{I} 2\pi s}{G_7\left(\frac{W}{S}\right)} \text{ ohm cm.}$$

W layer thickness

S probe spacing

Probe spacing S = 508 μ or 20 mill

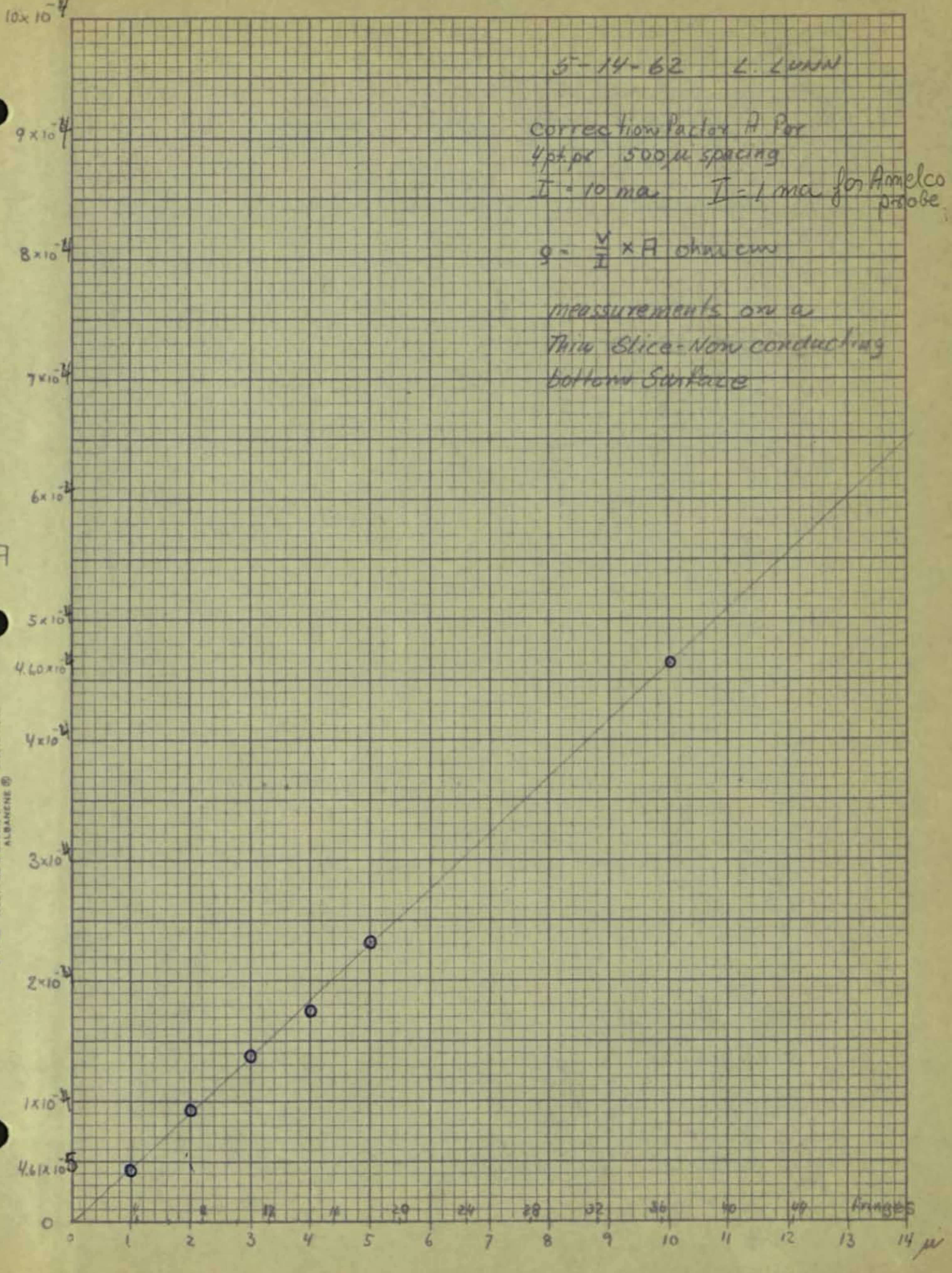


5-14-62 L. Lunn

correction factor A for
4pt pr 500μ spacing
$\bar{I}$ = 10 ma

$\varrho = \frac{V}{I} A$ ohm cm

Measurements on a
thin slice - Non con-
ducting bottom
surface



5-14-62 L. Lunn

correction factor A for
4pt pr 500μ spacing
$\underline{I}$ = 10 ma $\underline{I}$ = 1 ma for Amelco probe

$\rho = \frac{V}{I} \times A$ ohm cm

measurements on a
Thin Slice-Non conducting
bottom Surface

RESISTIVITY/ C b

MONOGRAPH 4092

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TECHNICAL PUBLICATIONS

Karl O. Lauer's

Resistivity of bulk silicon and of diffused layers in silicon

by

J. C. Irvin

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Resistivity of Bulk Silicon and of Diffused Layers in Silicon

By JOHN C. IRVIN

(Manuscript received July 25, 1961)

Measurements of resistivity and impurity concentration in heavily doped silicon are reported. These and previously published data are incorporated in a graph showing the resistivity (at $T = 300°\text{K}$) of n- and p-type silicon as a function of donor or acceptor concentration.

The relationship between surface concentration and average conductivity of diffused layers in silicon has been calculated for Gaussian and complementary error function distributions. The results are shown graphically. Similar calculations for subsurface layers, such as a transistor base region, are also given.

I. INTRODUCTION

A diffused layer in silicon is generally characterized by four parameters: the concentration, C_s, of diffused donors or acceptors at the surface, the concentration, C_B, of acceptors or donors originally in the material (background concentration), the depth, x_j, of the resultant junction, and the sheet resistivity, ρ_s, of the layer. A knowledge of the relationship between these parameters is essential to the establishment of device processing recipes, the evaluation of diffusion techniques, and investigations of the thermodynamic properties of silicon.

The desired relationship may be readily calculated, given a knowledge of the distribution of the diffused impurities, the variation of the resistivity of n- and p-type silicon with donor or acceptor density, and a fast electronic computer. The results of such a computation were first made generally available three years ago, in the form of curves relating C_s to $1/\rho_s x_j$ for a given C_B, for n- and for p-type layers in silicon, and for several common distributions.[1] Recent calculations, however, based on new and more extensive silicon resistivity data, have indicated considerable error in the earlier results. Thus a comprehensive recomputation has been undertaken, the outcome of which is presented herewith.

A necessary adjunct to the calculation is an accurate knowledge of the resistivity of n- and p-type silicon with varying dopant concentration. To this end, most of the extant data have been reviewed and supplemented here and there with some new determinations. The results of this search are also presented here.

II. THE RESISTIVITY OF SILICON AS A FUNCTION OF IMPURITY CONCENTRATION

The variation of the resistivity of silicon at 300°K as a function of the concentration of acceptors or donors is shown in Fig. 1. This graph represents the author's judgment of a most reasonable compromise to

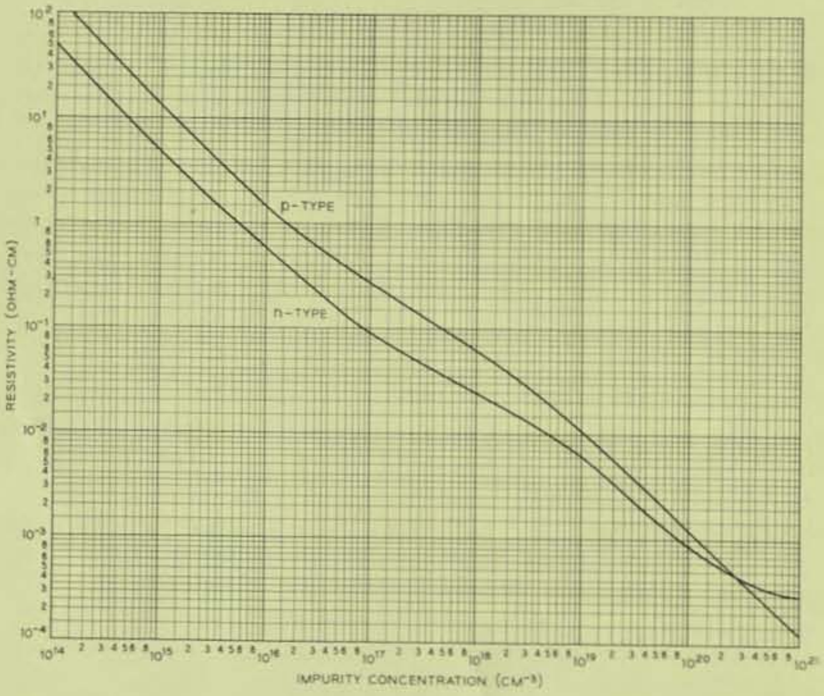

Fig. 1 — Resistivity of silicon at 300°K as a function of acceptor or donor concentration.

Table I — Resistivities and Impurity Concentrations in Silicon (T = 300°K)

Resistivity (ohm-cm)	Impurity	Impurity Concentration (cm^{-3})	Carrier Concentration (cm^{-3})
0.00076	B	1.66×10^{20}	
0.00089	B	1.41×10^{20}	
0.0010	B		1.49×10^{20}
0.0010	B	1.12×10^{20}	
0.0012	B	1.04×10^{20}	
0.0011	B	1.12×10^{20}	
0.0014	B	9.23×10^{19}	
0.0013	B	8.84×10^{19}	
0.0067	B	1.43×10^{19}	
0.0073	B	1.43×10^{19}	
0.013	B	7.41×10^{18}	
0.014	B	7.03×10^{18}	
0.00095	As	1.80×10^{20}	
0.00094	As	1.86×10^{20}	
0.00094	As		1.1×10^{20}
0.00093	As	1.87×10^{20}	
0.00094	As	1.97×10^{20}	
0.00088	As	2.10×10^{20}	
0.00088	As	2.19×10^{20}	
0.00089	As		1.1×10^{20}
0.00083	As	2.30×10^{20}	
0.00083	As	2.20×10^{20}	
0.00080	As	2.46×10^{20}	
0.00082	As	2.44×10^{20}	

the mass of available and not altogether compatible data on the subject. These data include most of the previously published work (Refs. 3–12), recent, unpublished results kindly provided by other investigators,[2,13] as well as some measurements obtained expressly for the present study.

The last data are shown in Table I. The crystals involved were pulled from quartz crucibles, and hence can not be expected to be particularly low in oxygen content. After dissolution of the boron-doped crystals and separation of the dopant,[14] boron concentrations were determined by a photometric carmine technique essentially similar to published methods.[15] Arsenic concentrations were measured by gamma-ray spectrometry after pile neutron activation. Resistivity measurements were done with a four-point probe. In the case of a few samples, resistivity and carrier concentration were measured in Hall-effect apparatus (where it was assumed $\mu_H/\mu = 1$).

Drawing curves through these many points was accomplished by a succession of smoothing procedures, which were primarily visual. 75 per cent of the data points deviate less than 10 per cent from the curves thus obtained, both for the p-type and the n-type cases. The uncertainty is greatest in the degenerate region. For p-type silicon, suitable data become scarce at dopings greater than 10^{19} cm^{-3}, and none are available beyond 3×10^{20} cm^{-3}. For n-type material, there is an abundance of rather conflicting data representing donor concentrations between 10^{19} cm^{-3} and 6×10^{20} cm^{-3}. In this region a 10 per cent variation in the chosen line still includes 67 per cent of the data, however.

A single pair of curves obviously can not characterize with the same degree of accuracy all silicon material, regardless of dopant employed or degree of compensation. However, over the range 10^{14} cm^{-3} $\leqq N_I \leqq$ 10^{20} cm^{-3}, and subject to the limitations discussed below, Fig. 1 is considered to be within 10 per cent of reality. This graph refers specifically to uncompensated silicon containing a donor or acceptor impurity concentration, N_I, consisting of arsenic, phosphorus, or antimony for n-type, and aluminum, boron, or gallium for p-type material. (Actually, even among samples doped with the aforementioned impurities, small but consistent differences in carrier concentration and mobility, depending on the specific choice of donor or of acceptor, have been reported recently for silicon in the 0.001 ohm-cm region.[10,12]) In case of moderate compensation, the net impurity density, $|N_A - N_D|$, should be used for N_I. However, heavy compensation requires allowance for the added impurity scattering.

For impurity densities near or greater than 10^{20} cm^{-3}, Fig. 1 can not be considered very reliable. At such concentrations, impurity band conduction is prominent and its effects are apt to differ appreciably depending on choice of impurity. Even more serious are the degrees of impurity precipitation and lattice imperfection which occur in highly doped material and which furthermore vary with growth conditions and history of the crystal. It will be noted with some consternation that the p-type and n-type curves are shown to cross near $N_I = 3 \times 10^{20}$ cm^{-3}. The paucity of data, of course, casts considerable doubt on this result. However, for what they are worth, such are the indications. Perhaps this can be understood in light of the acceptor action of imperfections, especially vacancies, which are abundant in very highly doped material.

The calculations discussed in the remainder of this paper require a mathematical representation of Fig. 1. Straight-line approximations of the form $(1/\rho) = BN_I^{\alpha}$ have been obtained, which depart 10 per cent from the desired curve at the turning points and rapidly approach coincidence elsewhere. The parameters B and α are listed in Table II for the respective straight-line regions.

III. DIFFUSION PROFILES AND CALCULATIONS

The diffusion profiles of current practical interest are the complementary error function, $C_x = C_s \operatorname{erfc} (x/2\sqrt{Dt})$, and the Gaussian,

TABLE II — VALUES OF B AND α IN THE EQUATION $(1/\rho) = BN_I^{\alpha}$, REPRESENTING STRAIGHT-LINE APPROXIMATIONS TO THE ρ VS N_I CURVES OF n-TYPE AND p-TYPE SILICON (T = 300°K)

Region (cm^{-3})	B	α
n-type		
$2.35 \times 10^{20} \leq N_D$	1.04×10^{-6}	0.456
$6.00 \times 10^{19} \leq N_D \leq 2.35 \times 10^{20}$	1.43×10^{-12}	0.744
$9.50 \times 10^{18} \leq N_D \leq 6.00 \times 10^{19}$	2.00×10^{-16}	0.940
$1.00 \times 10^{17} \leq N_D \leq 9.50 \times 10^{18}$	6.93×10^{-9}	0.543
$3.50 \times 10^{15} \leq N_D \leq 1.00 \times 10^{17}$	6.97×10^{-14}	0.837
$N_D \leq 3.50 \times 10^{15}$	2.00×10^{-16}	1.000
p-type		
$1.50 \times 10^{19} \leq N_A$	4.00×10^{-17}	0.966
$2.40 \times 10^{18} \leq N_A \leq 1.50 \times 10^{19}$	1.47×10^{-14}	0.832
$1.50 \times 10^{16} \leq N_A \leq 2.40 \times 10^{18}$	3.30×10^{-11}	0.650
$N_A \leq 1.50 \times 10^{16}$	7.20×10^{-17}	1.000

$C_x = C_s \exp(-x^2/4Dt)$. In these expressions, x, D, and t are the depth, diffusion coefficient (assumed independent of impurity density), and time, respectively. C_x is the concentration of the diffused impurity at depth x and C_s, that at the surface. The former distribution is expected when diffusion takes place with the surface concentration C_s held constant; the latter when the total impurity diffusing is constant. Unfortunately it must be admitted that the accuracy of these expectations is open to question in some situations.[2,16] Also, precipitation and compensation of impurities near the surface may further distort the distribution. However, it is still useful to solve the problem under these assumptions, leaving corrections for later determination.

The "average conductivity" of a diffused layer (which throughout this paper is assumed to be diffused into a silicon slice of opposite conductivity type and uniform doping C_B) is given by the expression

$$\bar{\sigma} = 1/\rho_s x_j = (1/x_j) \int_0^{x_j} q\mu C \, dx$$

where q is electronic charge, μ the carrier mobility typical of a total ionized impurity density of $C_x + C_B$, $C = r(C_x - C_B)$ is the density of carriers, r being the fraction of uncompensated diffused impurity atoms which are ionized, and C_x the total density of diffused impurity atoms at depth x. (Possible variation of the mobility as a function of the proximity of the surface is a hazard which should be recognized in passing but is otherwise ignored in the present calculation.) Multiplying and dividing within the integrand by r' $(C_x + C_B)$, where r' is the ionized fraction associated with an uncompensated dopant density of $(C_x + C_B)$, and writing

$$q\mu r'(C_x + C_B) = \sigma_{(Cx+CB)} = B(C_x + C_B)^{\alpha}$$

the average conductivity becomes

$$\bar{\sigma} = (1/x_j) \int_0^{x_j} (r/r')(C_x - C_B)B(C_x + C_B)^{\alpha-1}\, dx .$$

Now (r/r') represents the ratio of degrees of ionization corresponding to $C_x - C_B$ and $C_x + C_B$ respectively. This ratio is very nearly unity unless C_x and C_B are comparable in magnitude. Such is the case only for the lamina nearest the junction, which contributes negligibly to the conductance of the whole layer. Hence, (r/r') may be justifiably taken as equal to unity, and writing $C_x = C_S f(x)$, where $f(x)$ depends on the profile of interest,

$$\bar{\sigma} = (1/x_j) \int_0^{x_j} [C_S f(x) - C_B] B [C_S f(x) + C_B]^{\alpha-1}\, dx .$$

A program for the evaluation of this expression has been devised previously by others and employed in the analysis of diffused layers in germanium.[17] With slight additions to facilitate automatic plotting, the same program has been used in the present work. Computations were performed on an IBM 704, and plotting of points was carried out with an Electronic Associates Variplotter.

IV. PRESENTATION OF RESULTS

Of frequent interest in transistor design and in the analysis of diffused layers, are the characteristics of a "subsurface" layer such as illustrated in Fig. 2. This layer, bounded on one side by the junction and on the other by a plane paralleling the junction at depth x, may be characterized by an average conductivity

$$\bar{\sigma} = 1/[\rho_S'(x_j - x)] = \frac{1}{(x_j - x)} \int_x^{x_j} q\mu C\, dx$$

where ρ_s' is the sheet resistance of the subsurface layer. It will be recognized that the base region of a diffused-base, alloyed-emitter transistor is an example of a subsurface layer. Another example is that portion of a diffused layer remaining after removing the top strata of depth x. Here, however, it must be remembered that the value of C_s specifying this layer pertains to the original surface at $x = 0$.

Since a subsurface layer becomes the entire diffused layer when $x = 0$, it is convenient to display the properties of both in the same plot by introducing the parameter (x/x_j). On pages 394 to 410 such graphs are presented for n- and p-type diffused layers of Gaussian and complementary error function profile. Each graph contains the family of ten curves $(x/x_j) = 0, 0.1, \cdots, 0.9$, and relates the average conductivity of

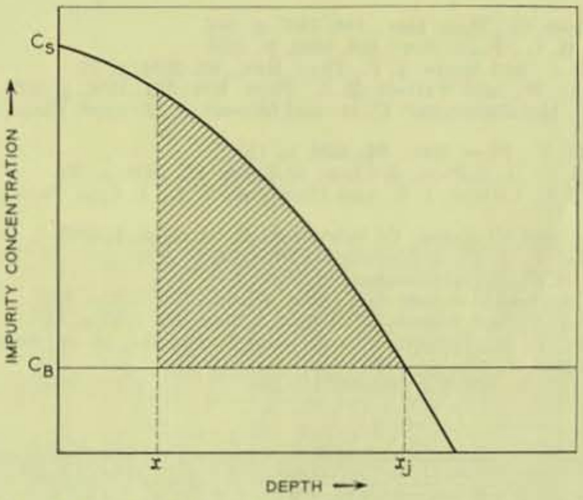

Fig. 2 — Profile of a diffused layer with subsurface layer shaded.

each layer to the surface concentration (at the *original* surface) for a given value of C_B. A separate graph is required for each value of C_B, which in the present work ranges from 10^{14} cm^{-3} to 10^{20} cm^{-3} at one-decade intervals. In each plot the range of surface concentrations spanned is from C_B to 10^{21} cm^{-3}. The so-called "Backenstoss" curve for a particular C_B is simply the right-most line ($x/x_j = 0$) in each graph.

The wiggle in the n-type average conductivity for diffusant concentrations near 10^{19} cm^{-3} is ascribable to the rather large change in slope occurring in the n-type resistivity plot at $N_I = 10^{19}$ cm^{-3}.

V. ACKNOWLEDGMENTS

It is a pleasure to acknowledge the contributions of many colleagues to this investigation. In particular, the boron determinations, devised and performed by C. L. Luke, were very valuable, as were the radioactive arsenic determinations of Miss K. Wolfstirn and Hall-effect measurements of R. A. Logan and R. L. Johnston. The author is indebted to D. Lassota for the growing of the boron-doped crystals, to D. B. Cuttriss, whose efforts brought about the preparation of the computer program, to Mrs. W. Mammel, for subsequent additions to it, to R. Lilienthal for various measurements, and especially to Mrs. M. S. Boyle for her indefatigable assistance in many measurements and the plotting of hundreds of curves.

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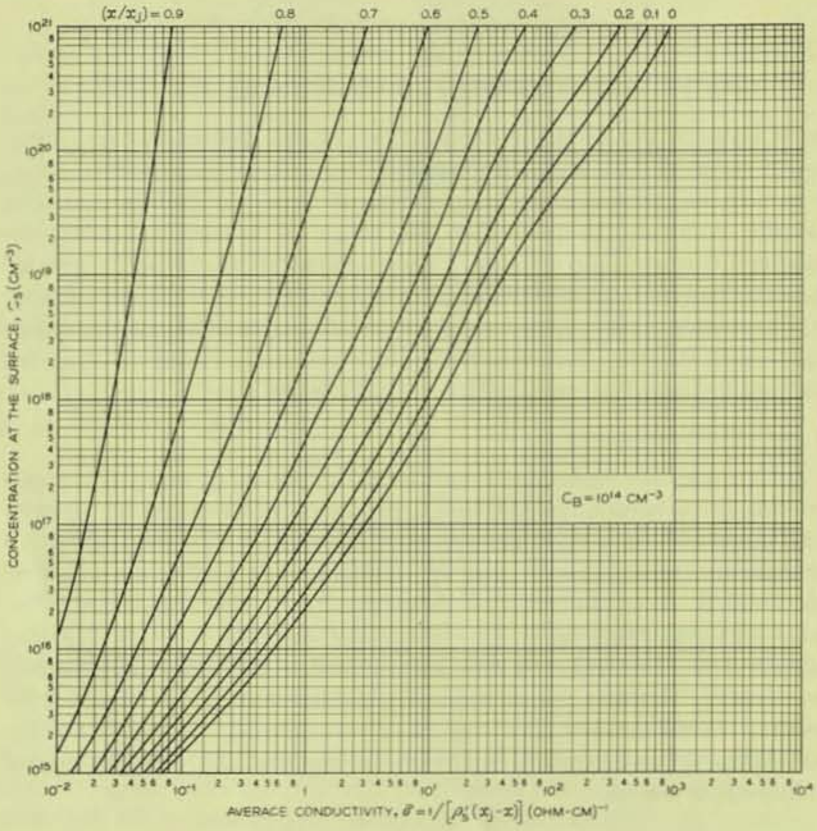


Fig. 3 — Average conductivity of n-type complementary error function layers in silicon.

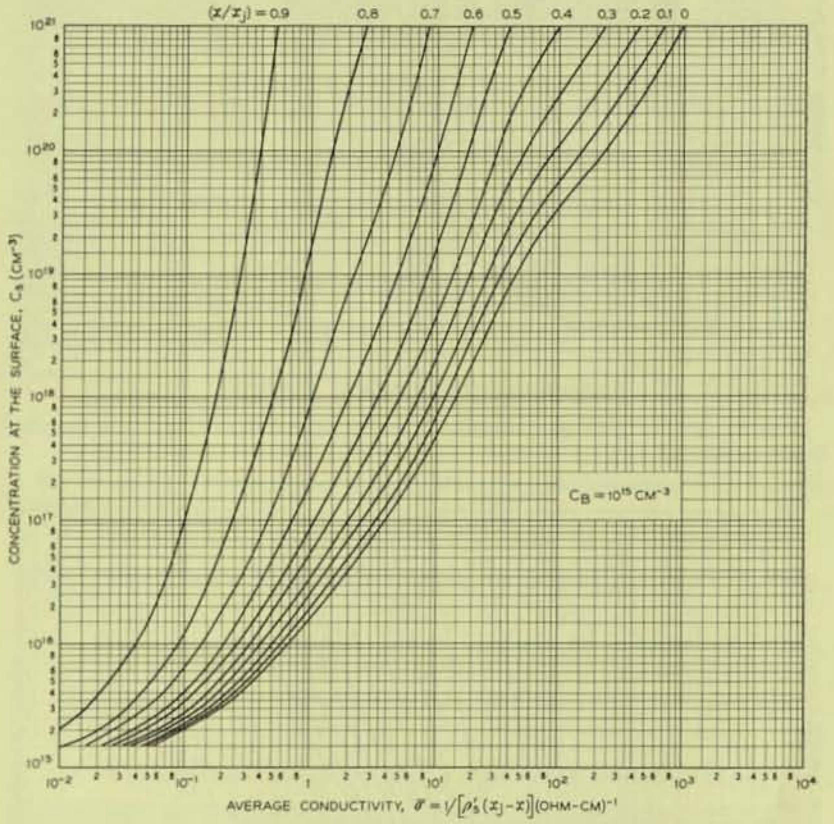


Fig. 3 (cont.) — Average conductivity of n-type complementary error function layers in silicon.

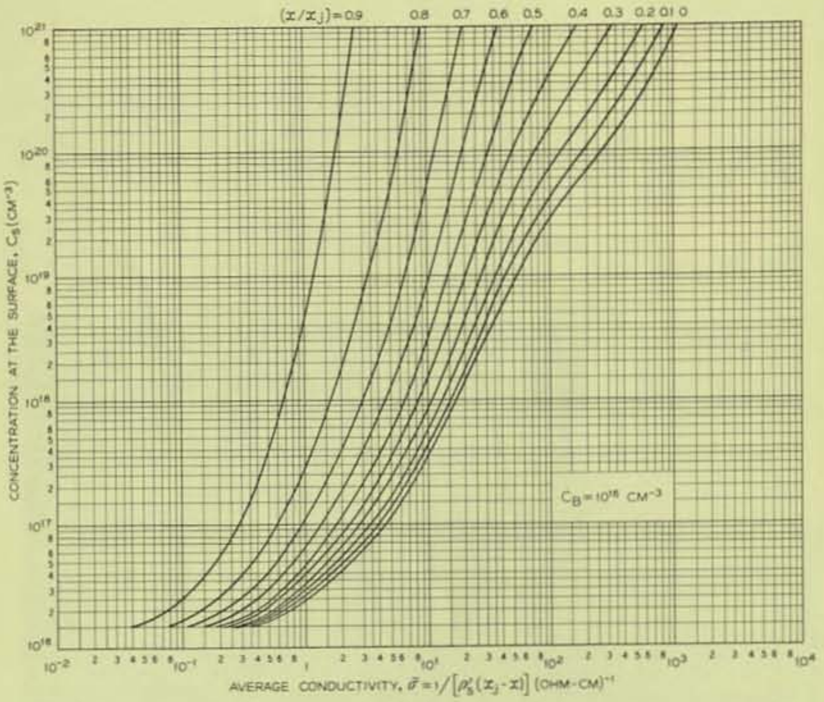


Fig. 3 (cont.) — Average conductivity of n-type complementary error function layers in silicon.

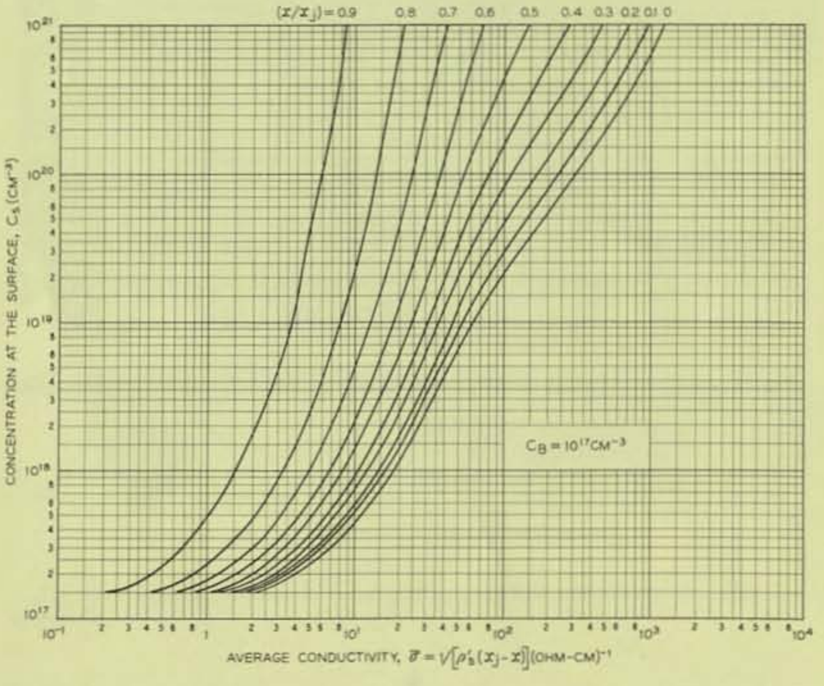


Fig. 3 (cont.) — Average conductivity of n-type complementary error function layers in silicon.

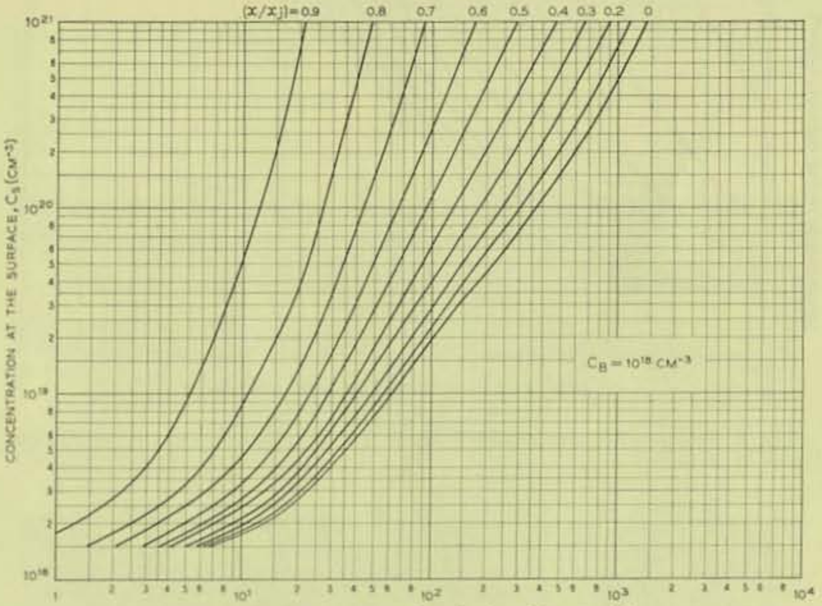


Fig. 3 (cont.) — Average conductivity of n-type complementary error function layers in silicon.

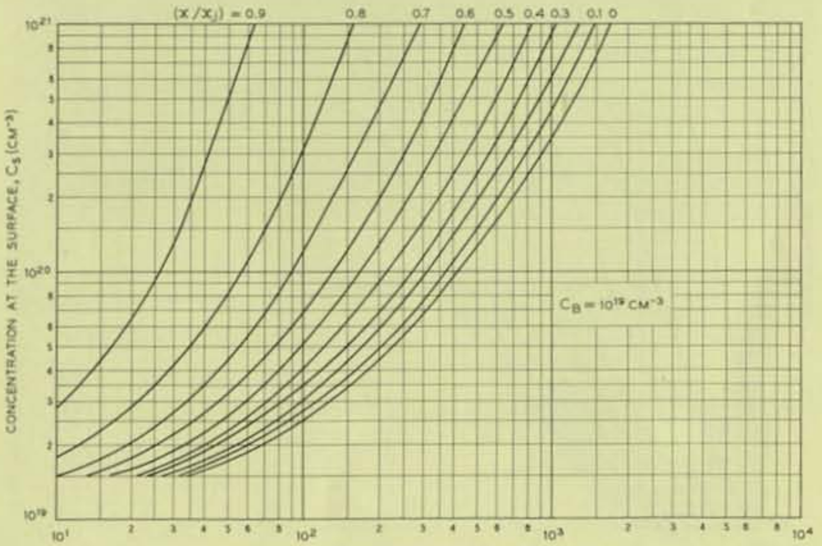


Fig. 3 (cont.) — Average conductivity of n-type complementary error function layers in silicon.

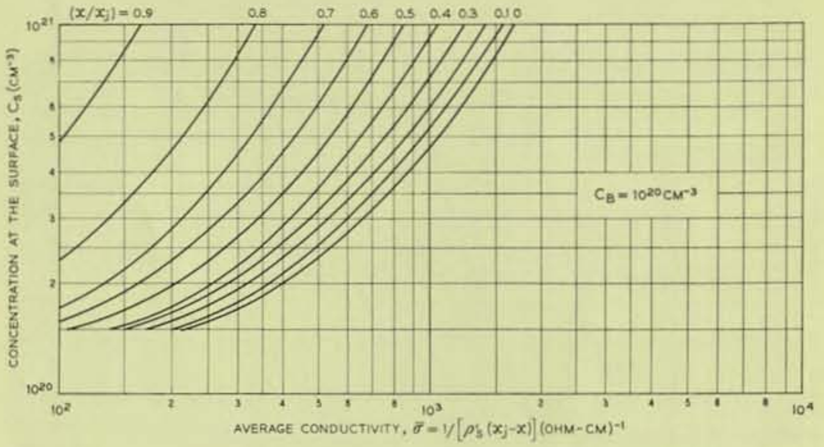


Fig. 3 (cont.) — Average conductivity of n-type complementary error function layers in silicon.

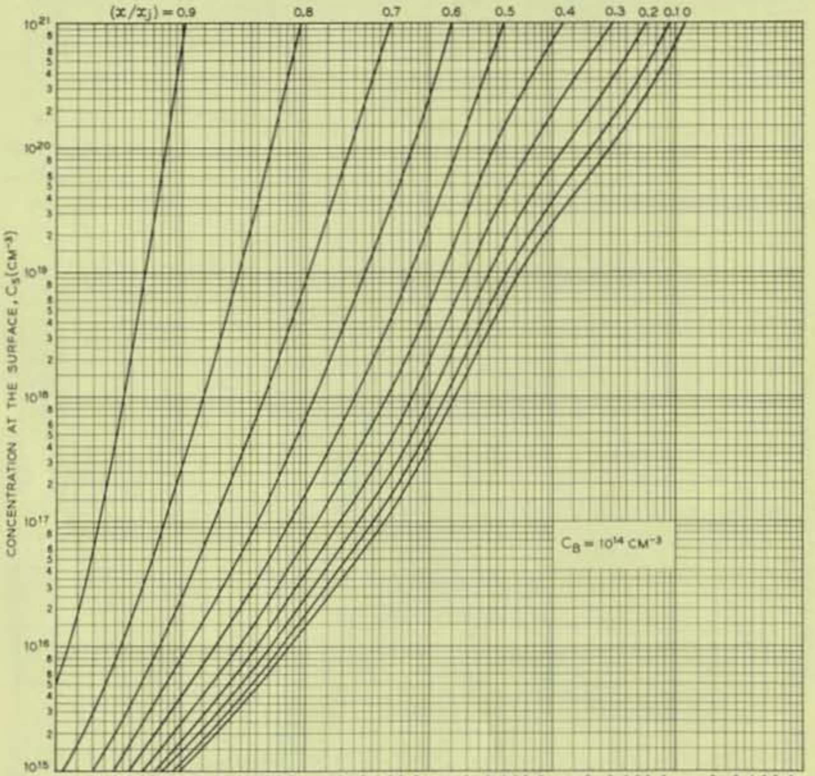


Fig. 4 — Average conductivity of n-type Gaussian layers in silicon.

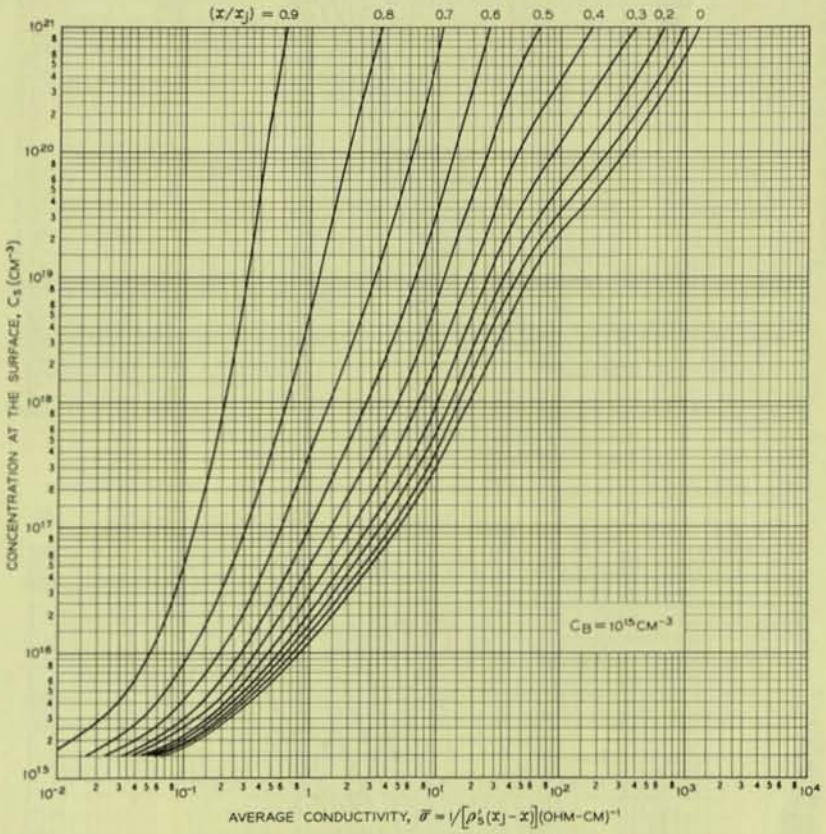


Fig. 4 (cont.) — Average conductivity of n-type Gaussian layers in silicon.

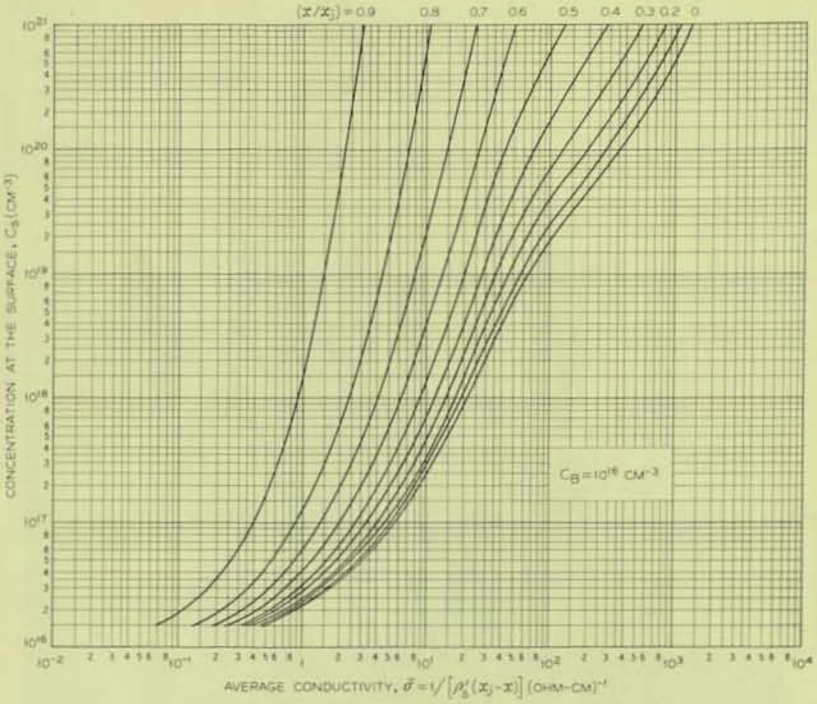


Fig. 4 (cont.) — Average conductivity of n-type Gaussian layers in silicon.

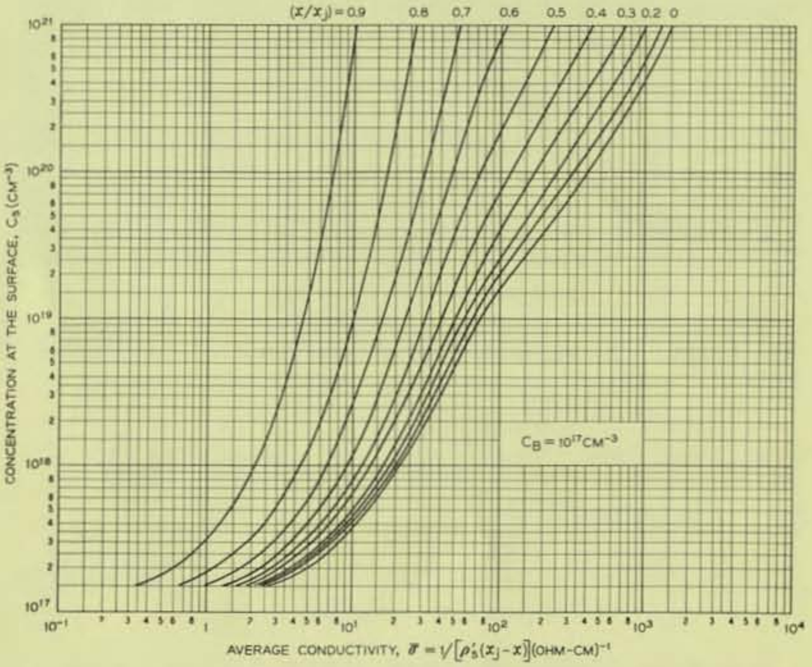


Fig. 4 (cont.) — Average conductivity of n-type Gaussian layers in silicon.

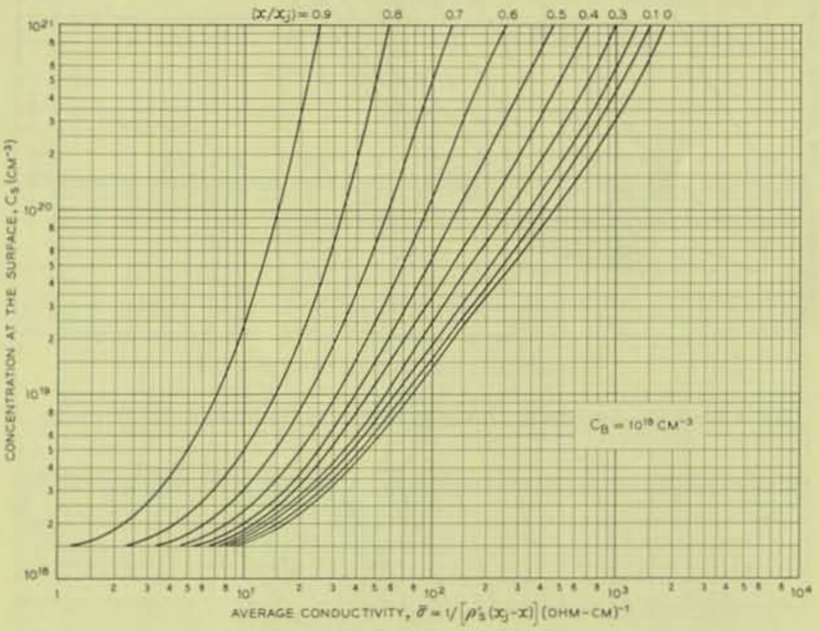


Fig. 4 (cont.) — Average conductivity of n-type Gaussian layers in silicon.

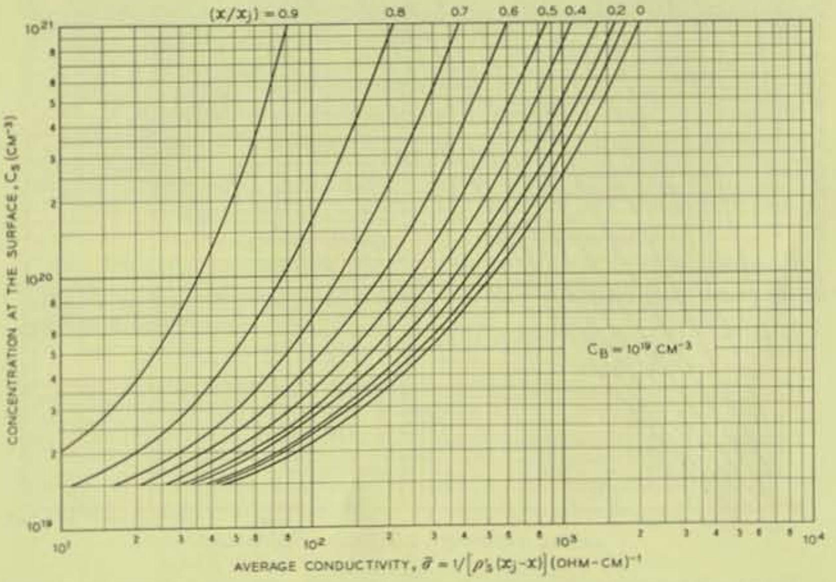


Fig. 4 (cont.) — Average conductivity of n-type Gaussian layers in silicon.

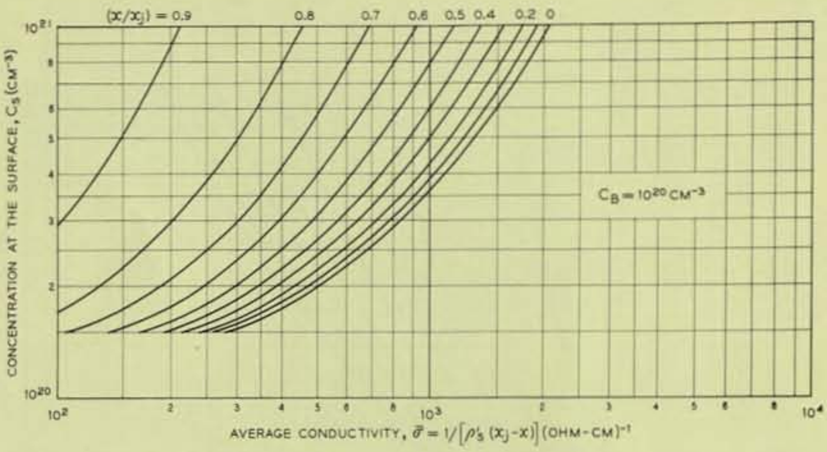


Fig. 4 (cont.) — Average conductivity of n-type Gaussian layers in silicon.

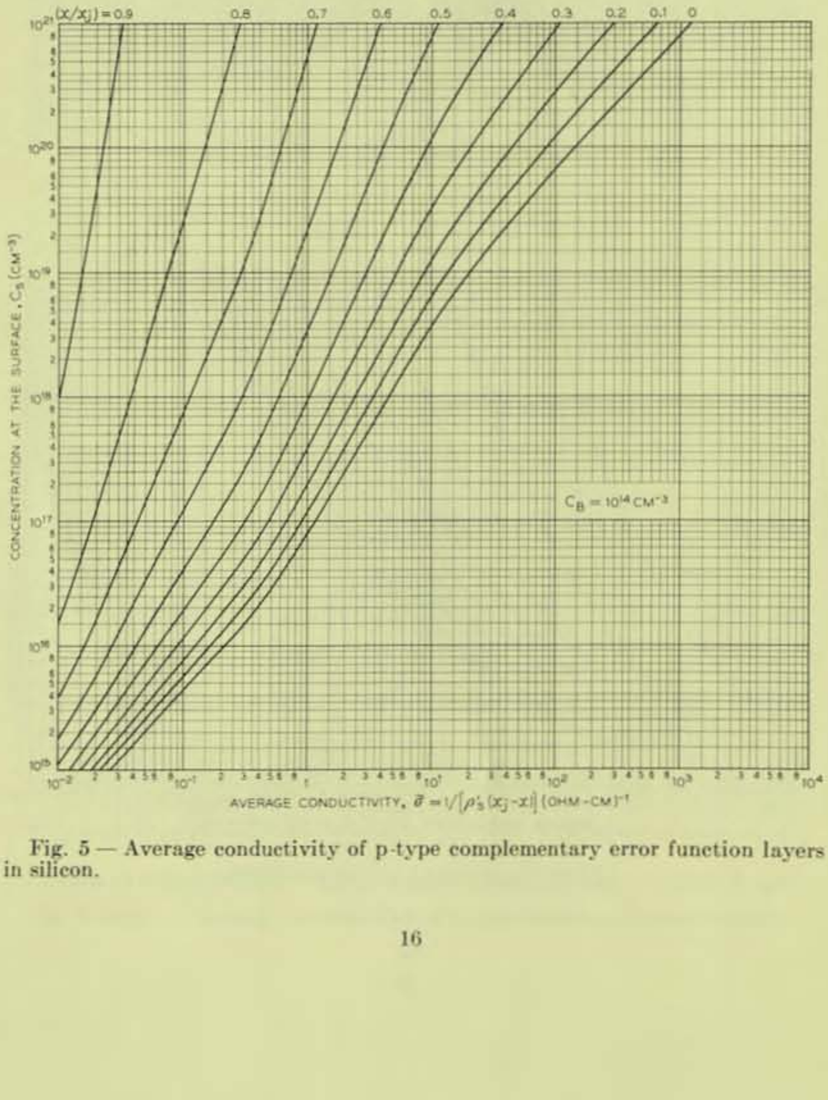


Fig. 5 — Average conductivity of p-type complementary error function layers in silicon.

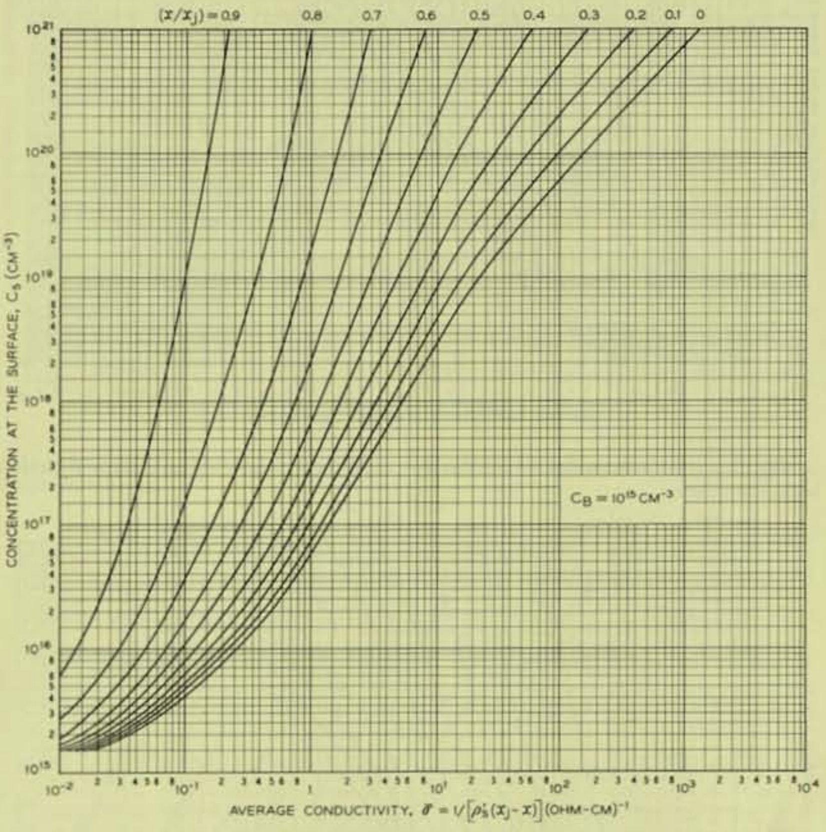


Fig. 5 (cont.) — Average conductivity of p-type complementary error function layers in silicon.

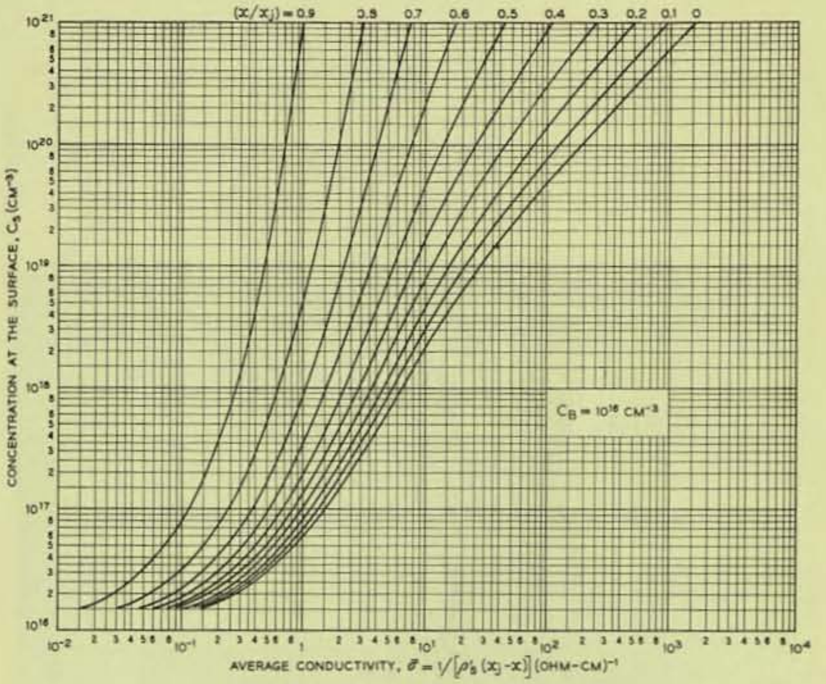


Fig. 5 (cont.) — Average conductivity of p-type complementary error function layers in silicon.

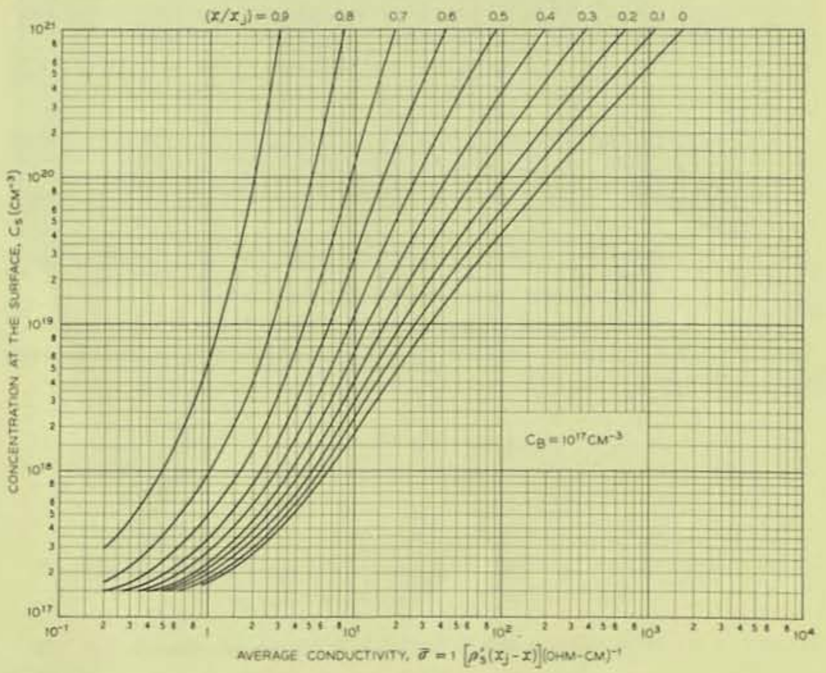


Fig. 5 (cont.) — Average conductivity of p-type complementary error function layers in silicon.

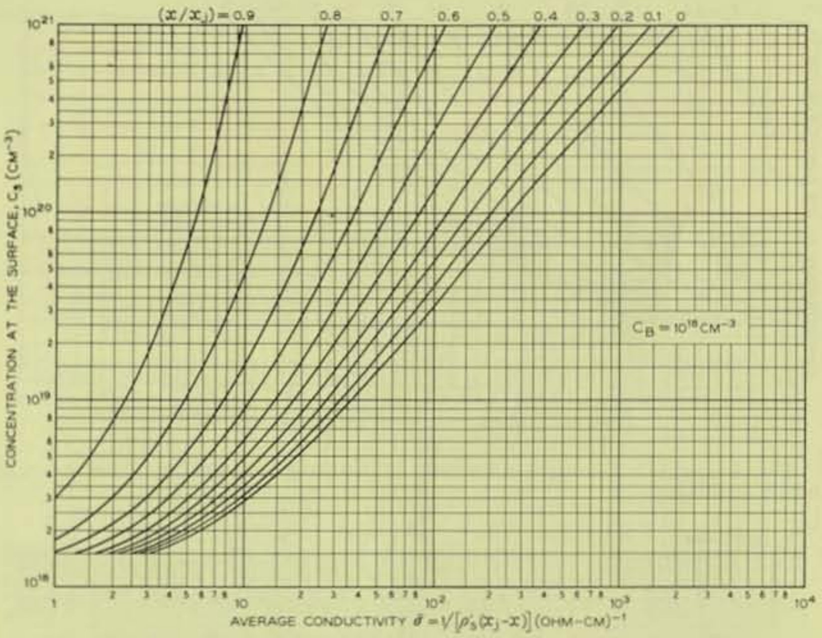


Fig. 5 (cont.) — Average conductivity of p-type complementary error function layers in silicon.

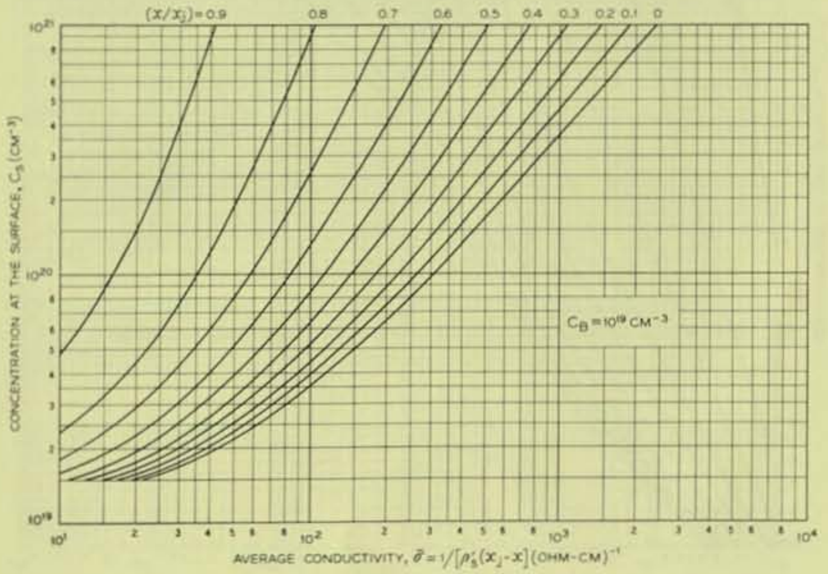


Fig. 5 (cont.) — Average conductivity of p-type complementary error function layers in silicon.

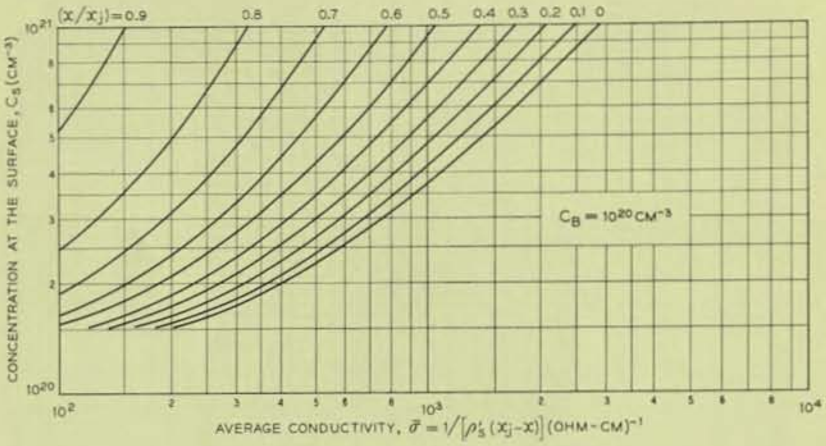


Fig. 5 (cont.) — Average conductivity of p-type complementary error function layers in silicon.

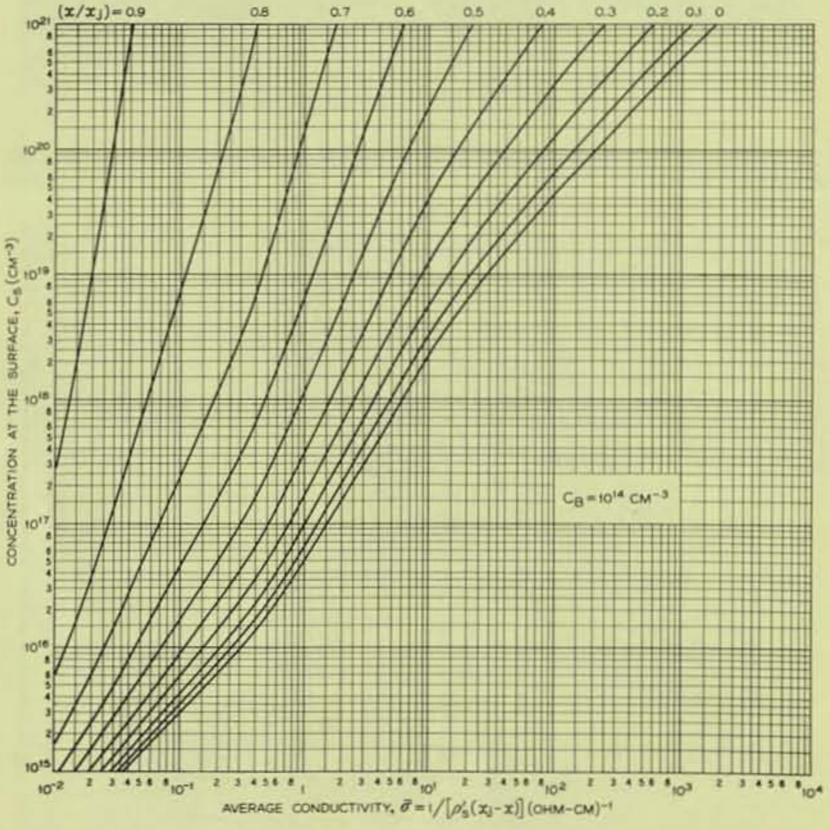


Fig. 6 — Average conductivity of p-type Gaussian layers in silicon.

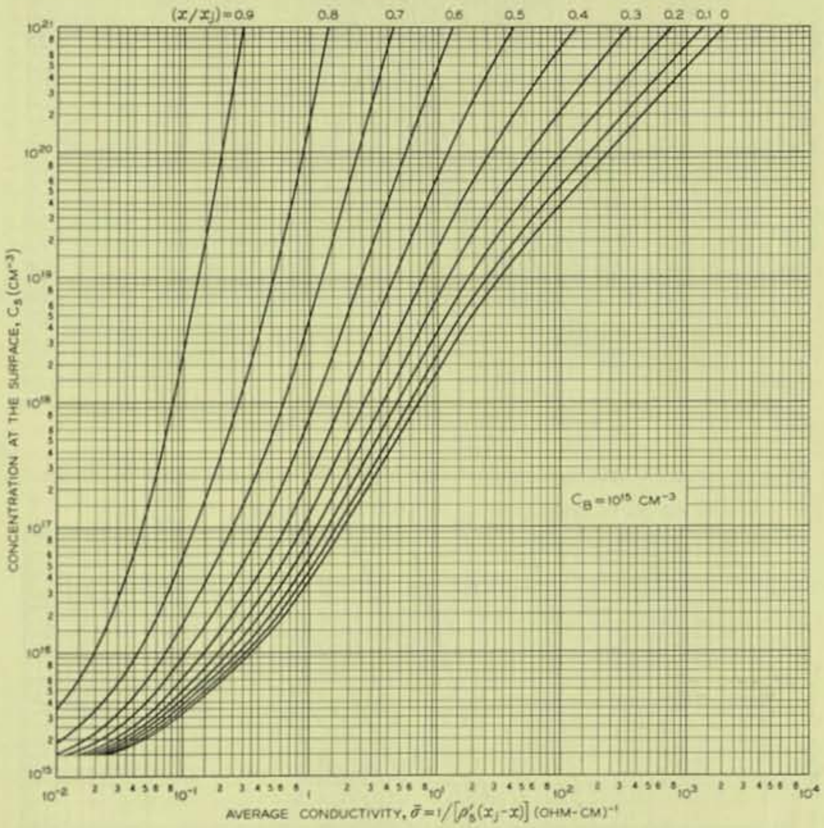


Fig. 6 (cont.) — Average conductivity of p-type Gaussian layers in silicon.

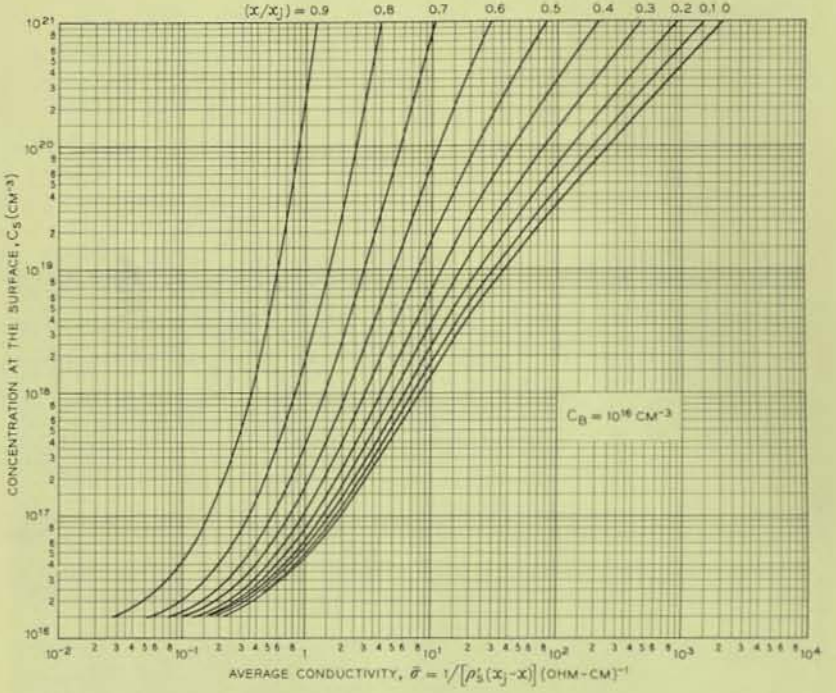


Fig. 6 (cont.) — Average conductivity of p-type Gaussian layers in silicon.

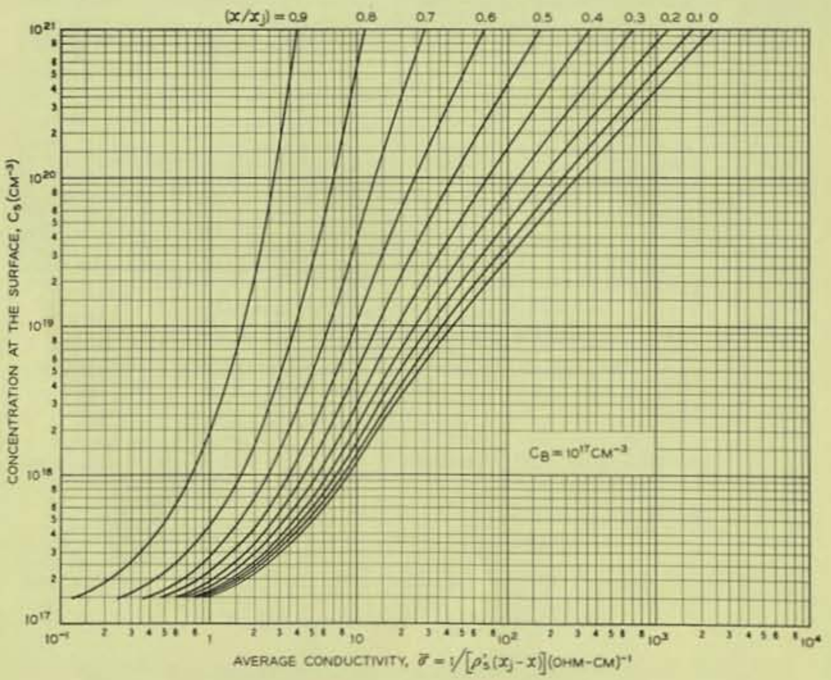


Fig. 6 (cont.) — Average conductivity of p-type Gaussian layers in silicon.

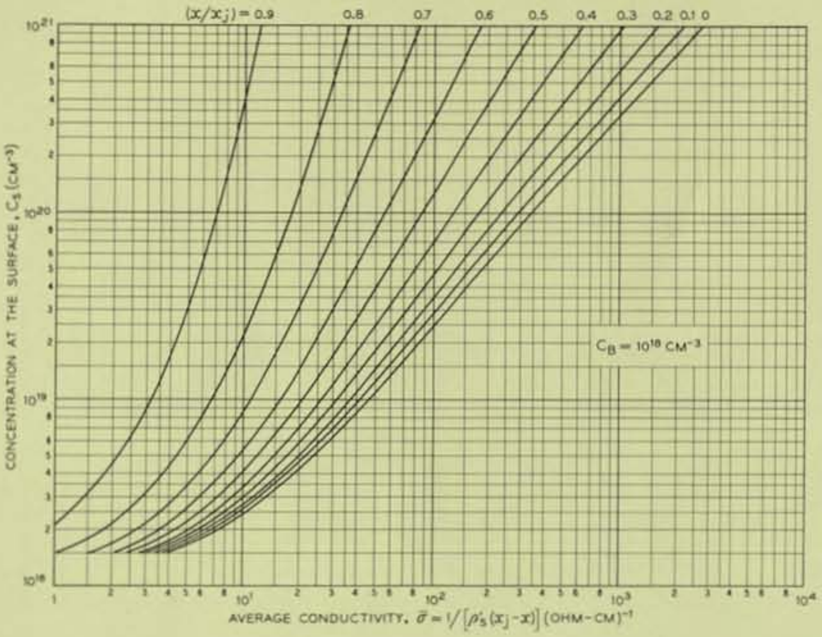


Fig. 6 (cont.) — Average conductivity of p-type Gaussian layers in silicon.

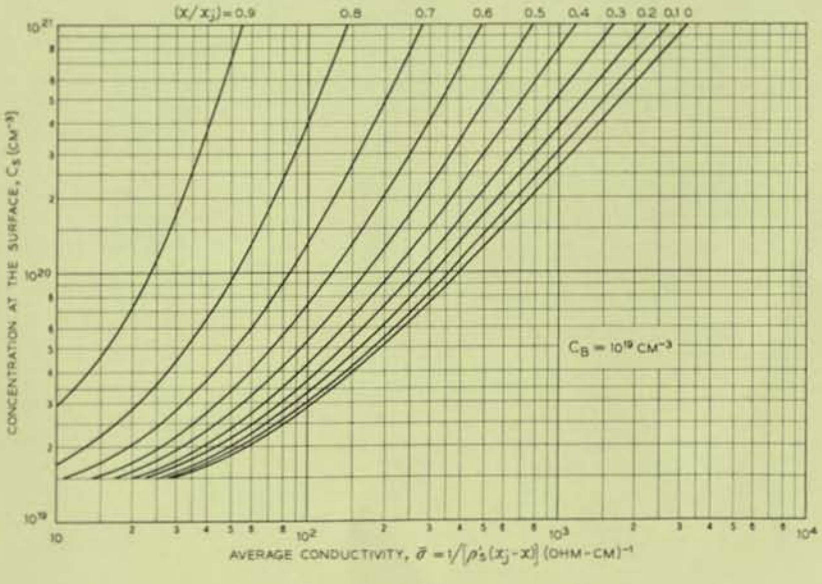


Fig. 6 (cont.) — Average conductivity of p-type Gaussian layers in silicon.

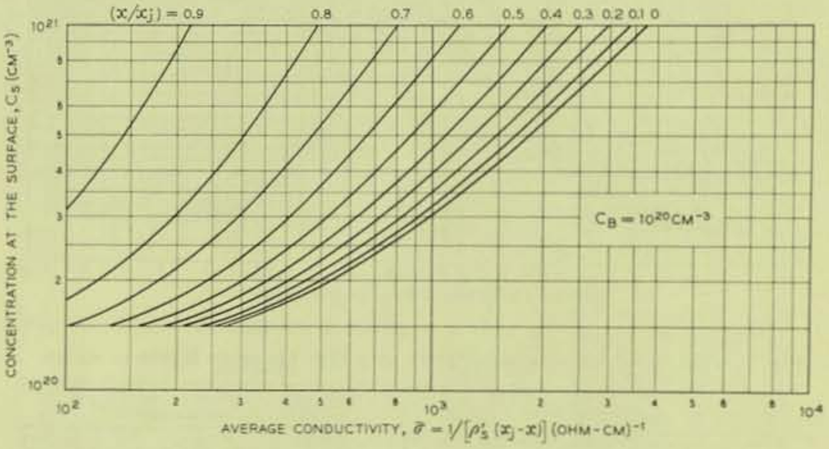


Fig. 6 (cont.) — Average conductivity of p-type Gaussian layers in silicon.

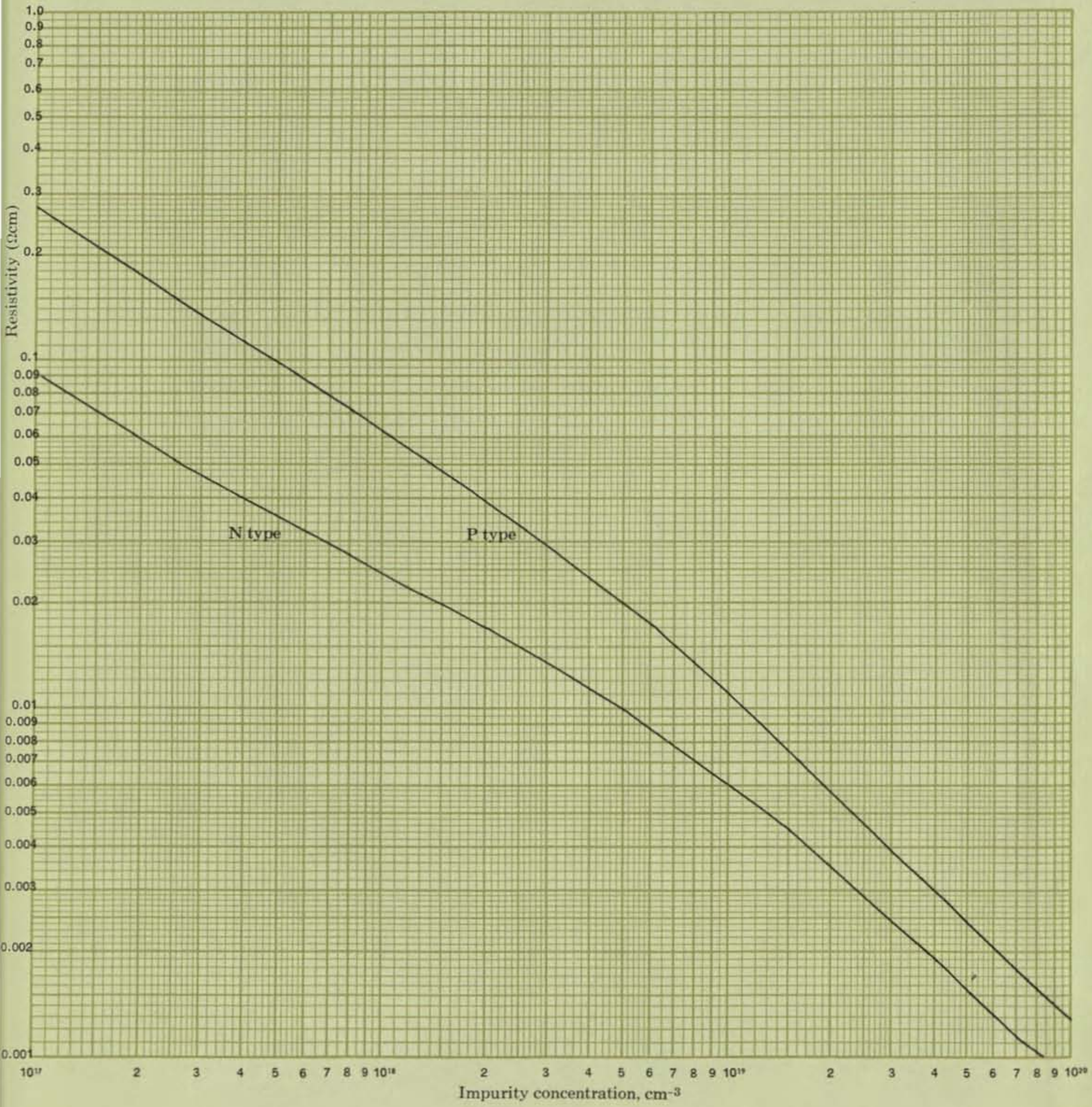
Issued May, 1962

4092: J. C. IRVIN

BELL TELEPHONE LABORATORIES, *incorporated*

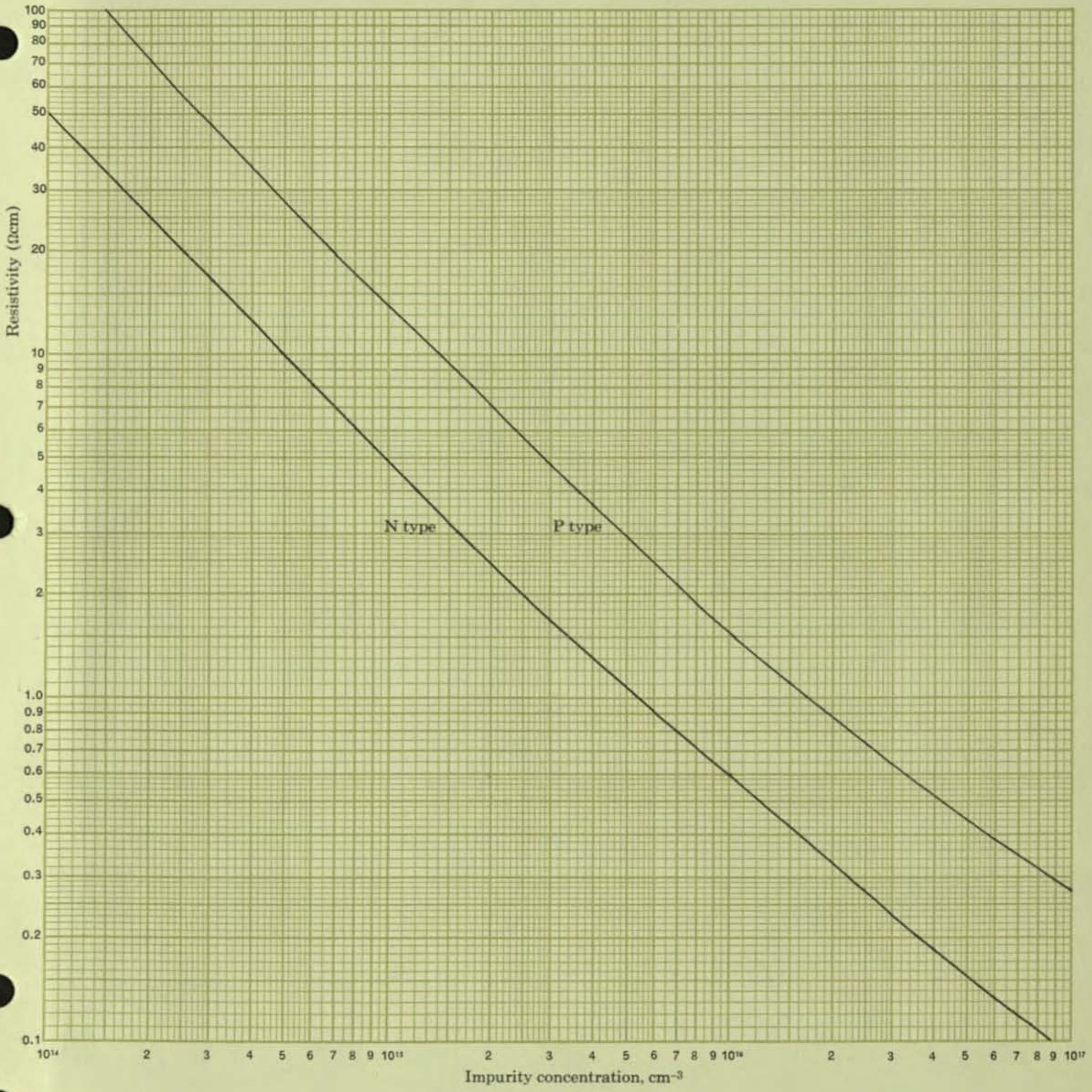
463 West Street, New York 14, N. Y.

monoSilicon, incorporated
139 East 157th Street Gardena, California

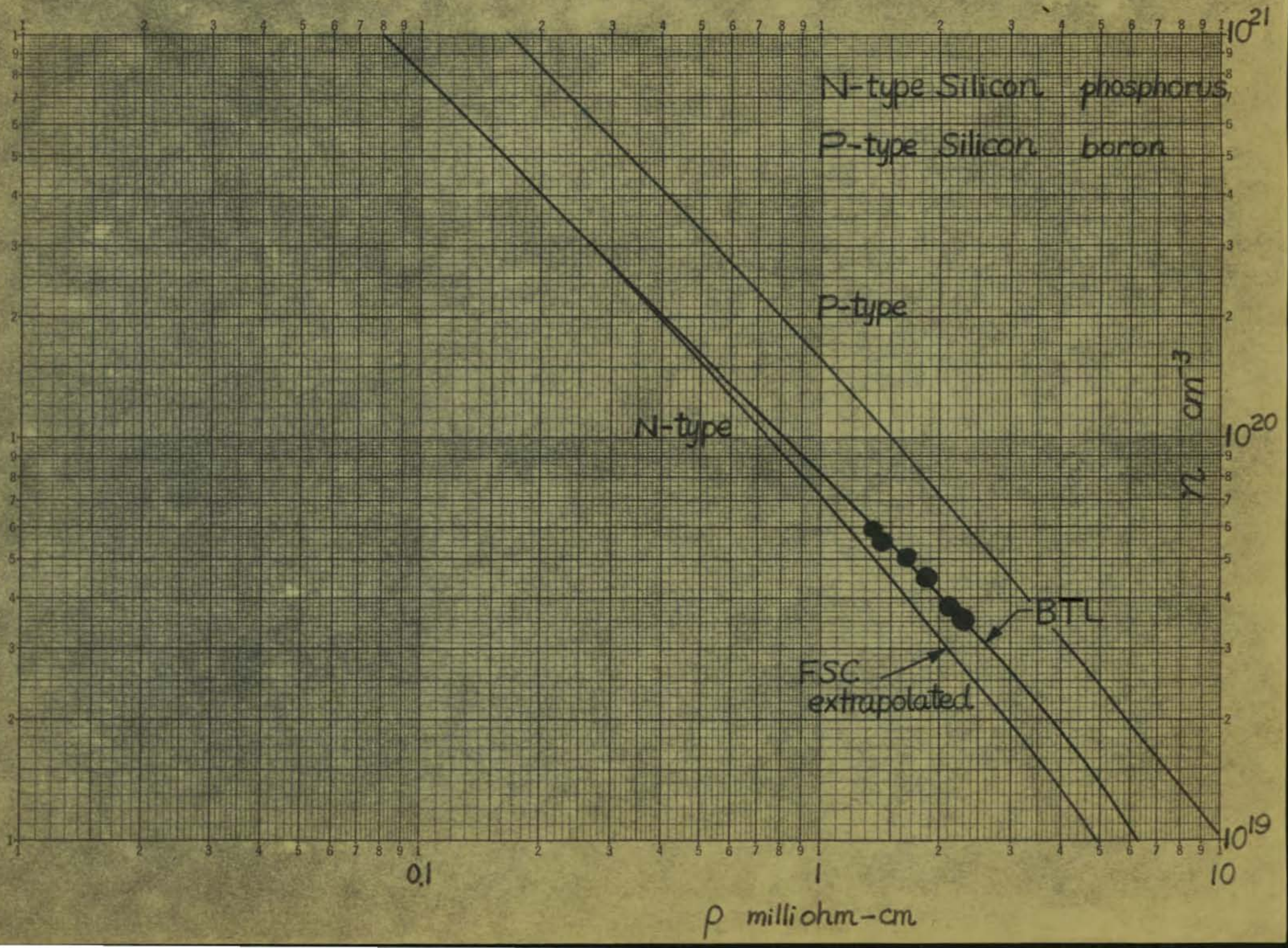


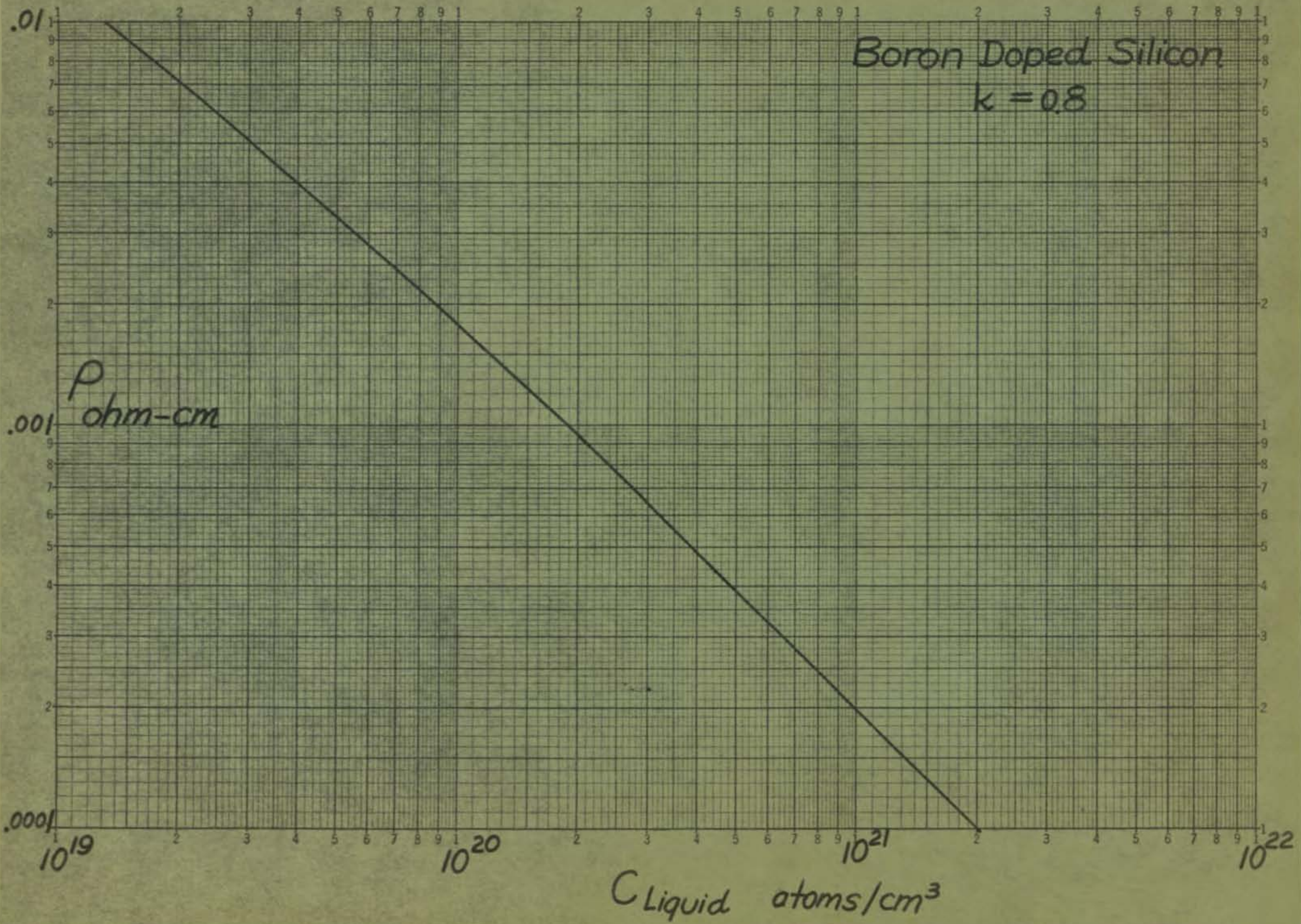
From an article by John C. Irwin in the March 1962 issue of the Bell System Tech. Journal.

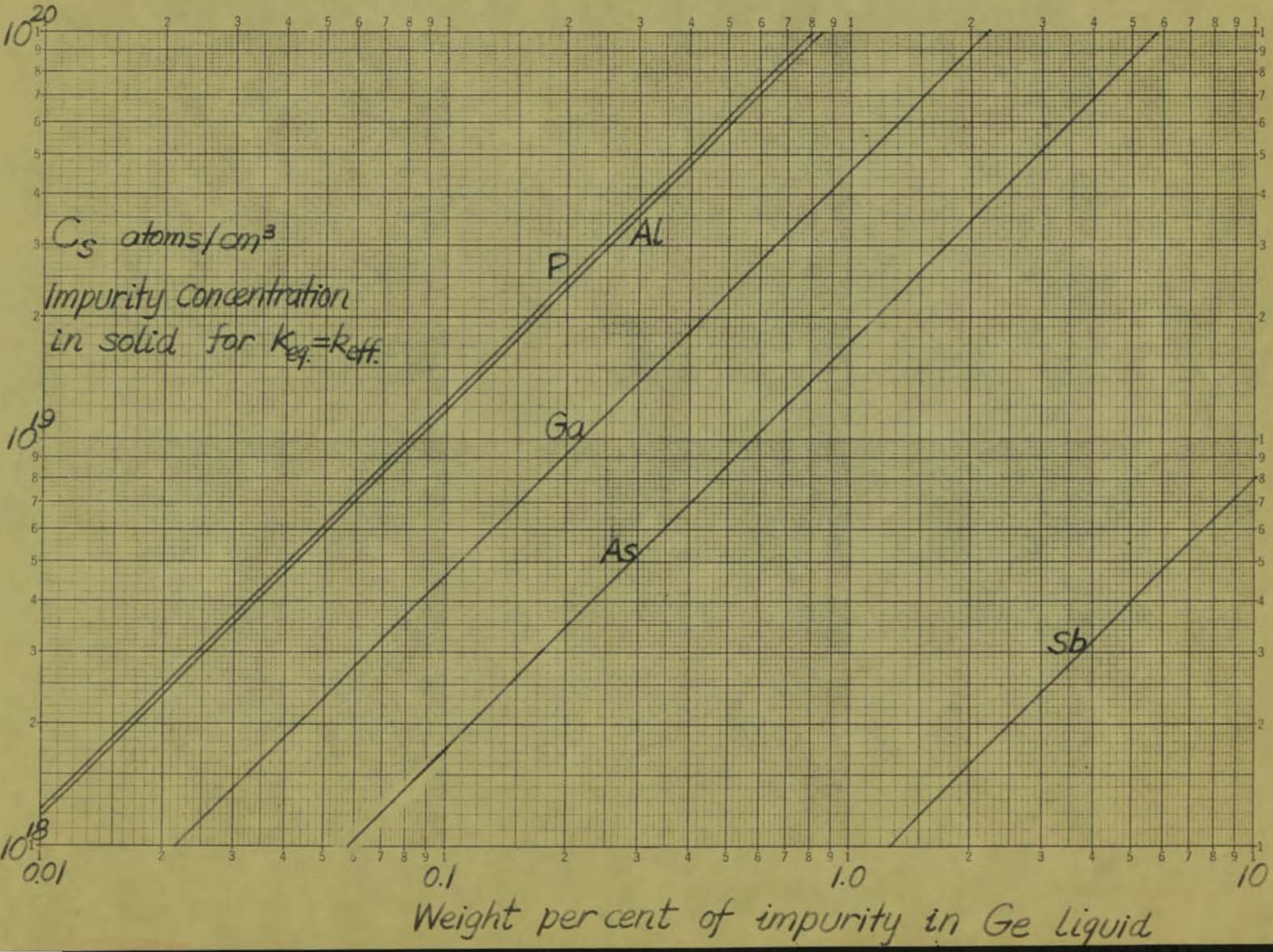
These curves, containing the latest data on the properties of silicon, have been prepared by **MonoSilicon, Inc.**, who pioneered the growth of dislocation free silicon crystals in production quantities. For a revue of the effects of dislocations on device characteristics see the article by W. Bardsley, "The Electrical Effects of Dislocations in Semiconductors," Volume 4 of Progress in Semiconductors, A. F. Gibson, Editor, John Wiley & Sons, Publishers, (1960).

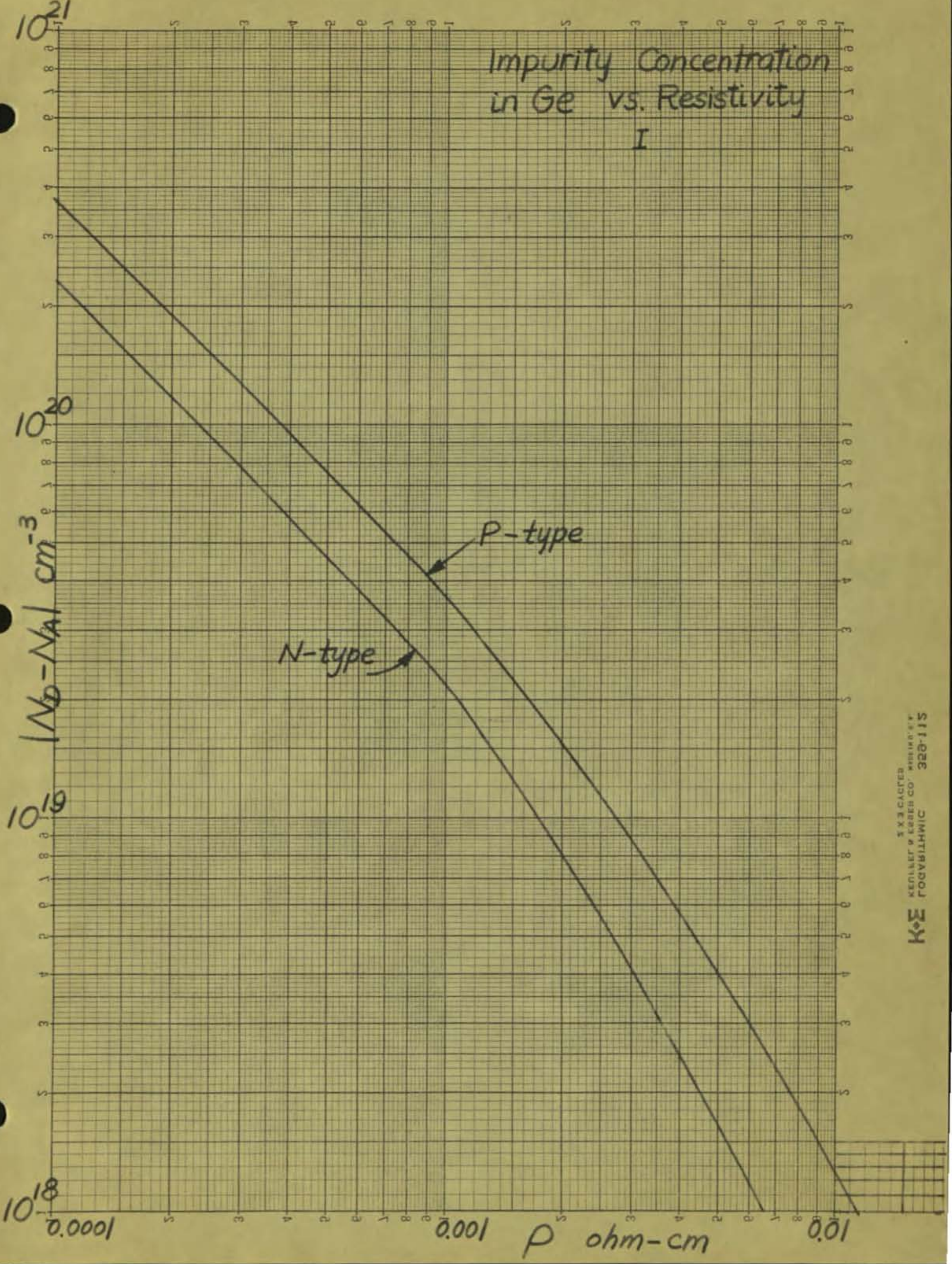


Resistivity of Silicon at 300° K. as a function of acceptor or donor concentration.


N-type Silicon phosphorus
P-type Silicon boron
P-type
N-type
BTL
FSC extrapolated
n cm^{-3}
10^{21}
10^{20}
10^{19}
0.1
1
10
ρ milliohm-cm

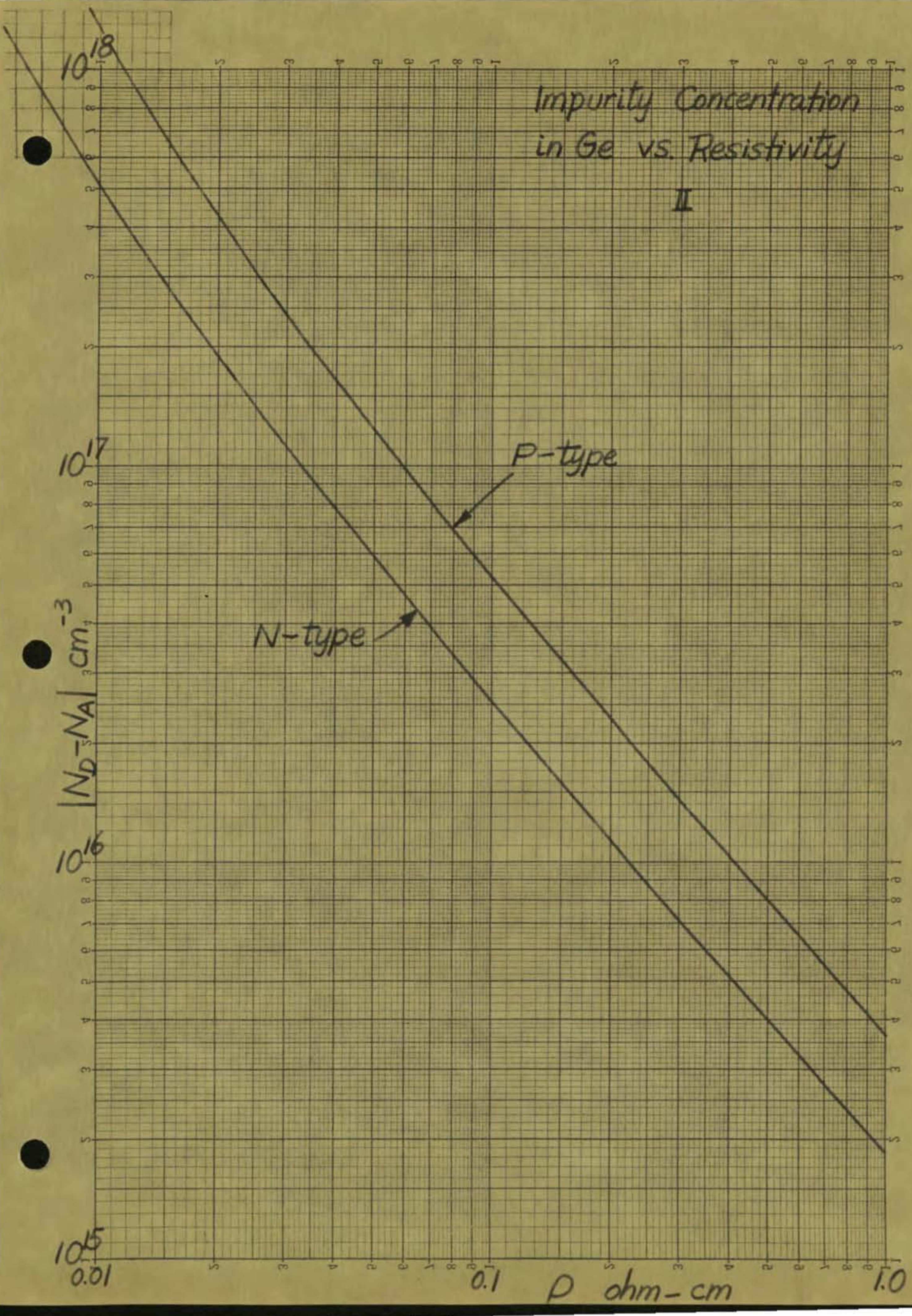

Boron Doped Silicon
k = 0.8
ρ ohm-cm
.01
.001
.0001
10^{19}
10^{20}
10^{21}
10^{22}
C Liquid atoms/cm³


10^{20}
10^{19}
10^{18}
C_s atoms/cm³
Impurity concentration
in solid for $k_{eq.}=k_{eff.}$
Al
P
Ga
As
Sb
0.01
0.1
1.0
10
Weight per cent of impurity in Ge liquid



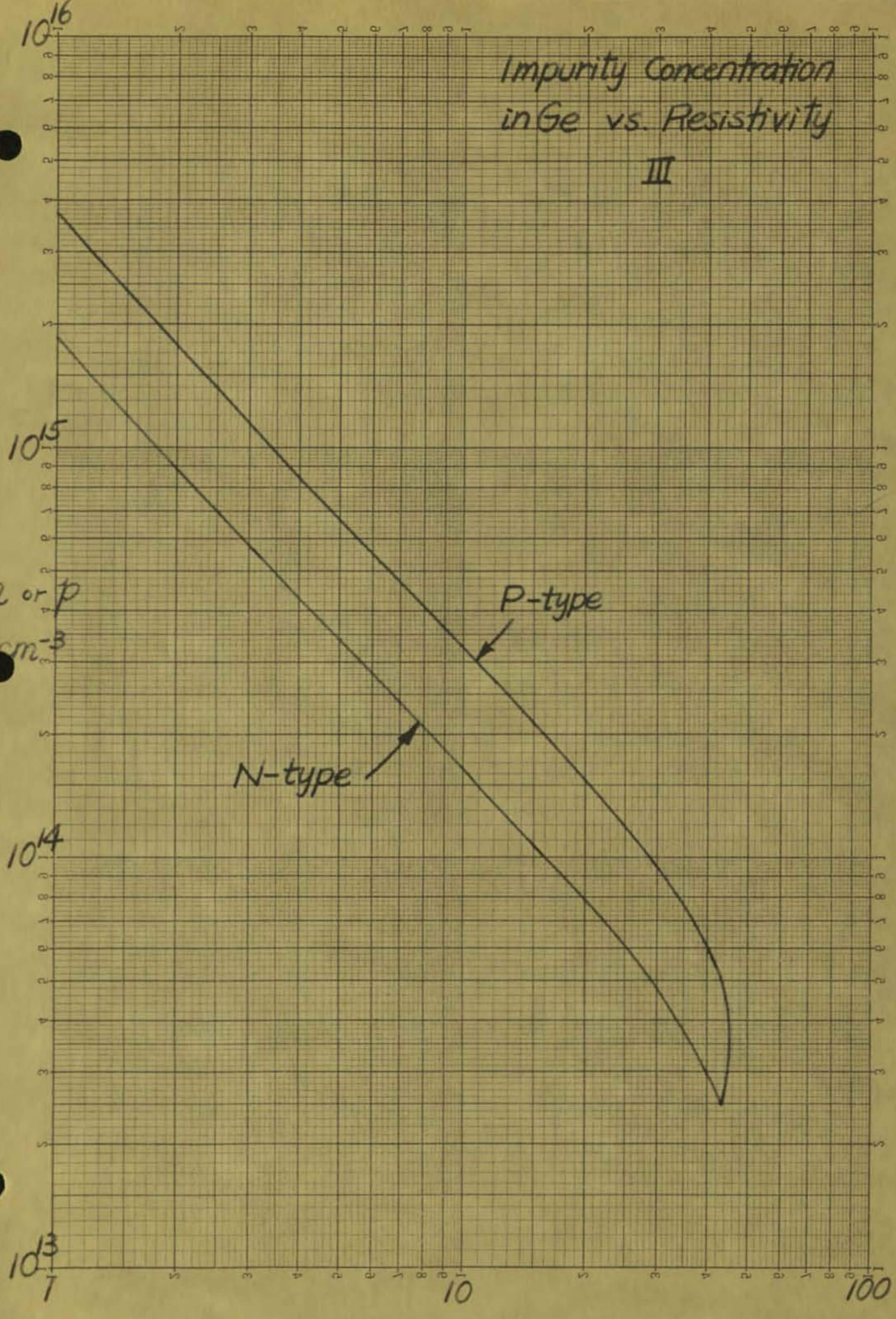
Impurity Concentration in Ge vs. Resistivity

I



Impurity Concentration in Ge vs. Resistivity

II



Impurity Concentration in Ge vs. Resistivity

III

Sample calculation for Ge doping

W_i = weight of impurity in grams

$$= C_L \frac{\text{atoms}}{\text{cm}^3} \; \frac{A_W \frac{\text{gm}}{\text{gmat. wt.}}}{N \frac{\text{atoms}}{\text{gmat. wt.}}} \; \frac{W_{Ge}\ \text{gm}}{d_{Ge} \frac{\text{gm}}{\text{cm}^3}}$$

C_L = concentration of impurity in the liquid $= k_{eff}^{-1} C_s = k_{eq.}^{-1} \left(\frac{k_{eff.}}{k_{eq.}}\right)^{-1} C_s$

A_W = atomic weight of impurity element

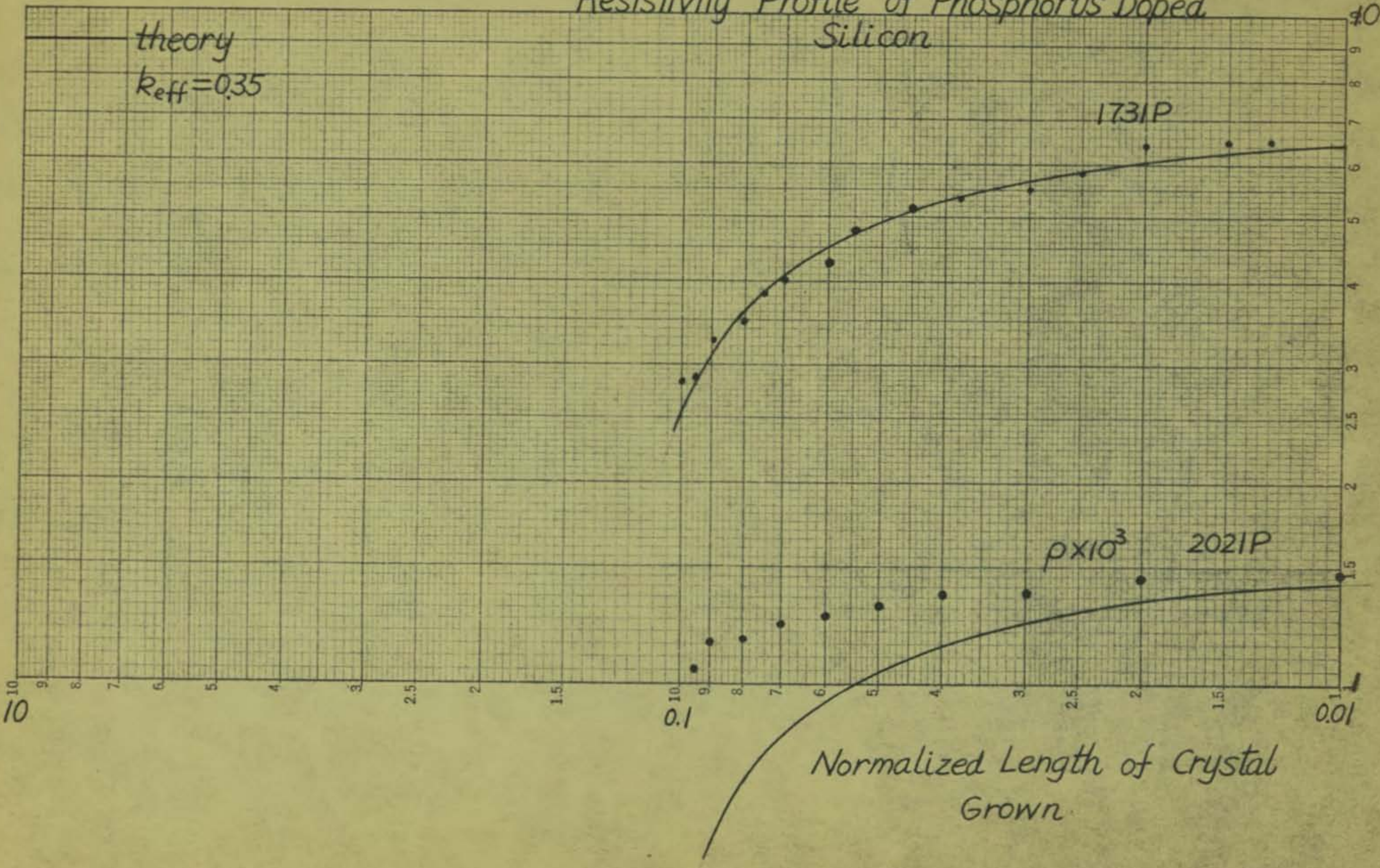
N = avagadro's number $= 6.06 \times 10^{23}$

W_{Ge} = weight of germanium in melt in gram = 100 gm

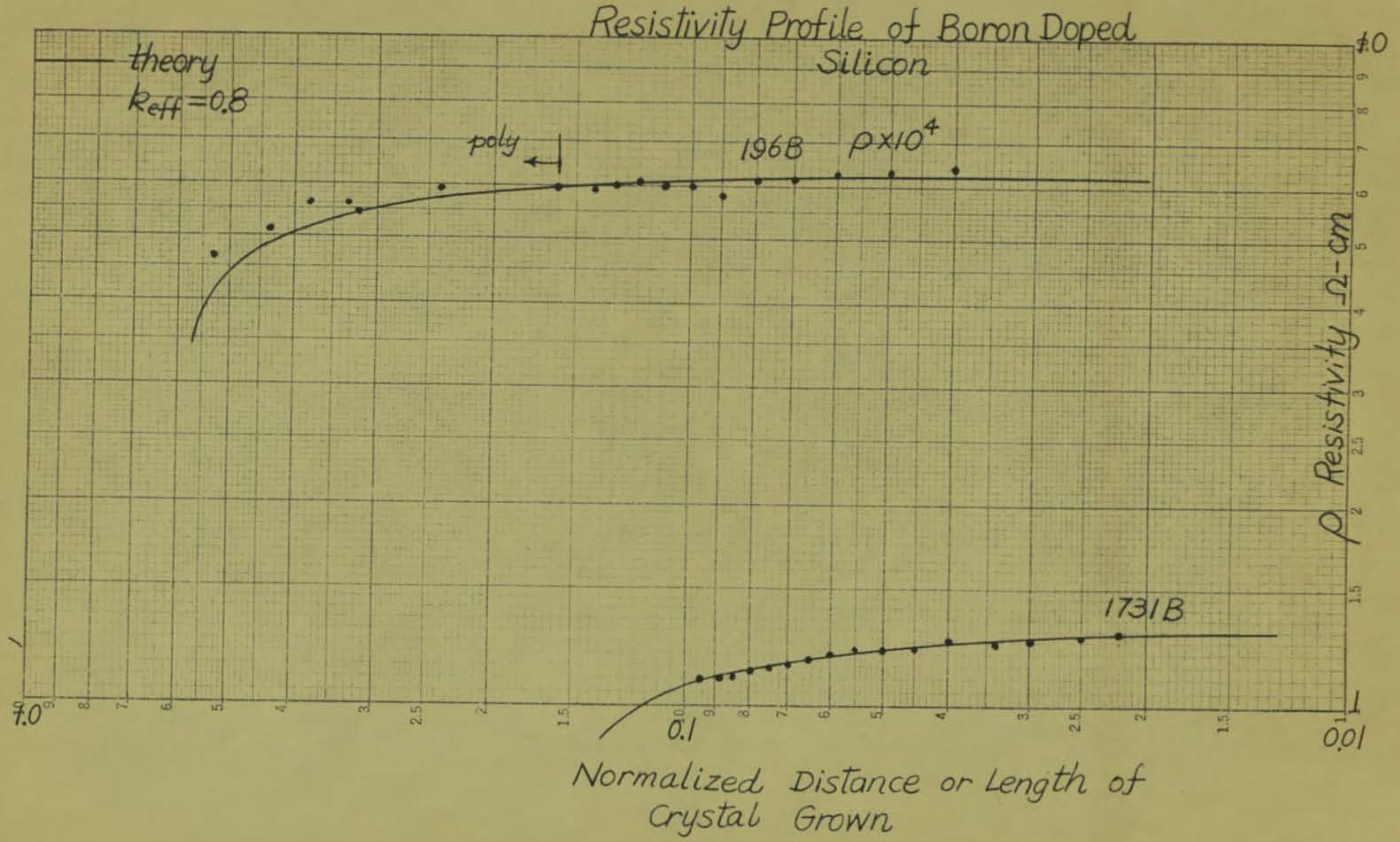
d_{Ge} = weight density of germanium in gm per cm^3. = 5.32 gm/cm^3

element	A_W	$\frac{A_W}{N} \frac{W_{Ge}}{d_{Ge}}$	$k_{eq.}$	$k_{eq.} \frac{A_W W_{Ge}}{N d_{Ge}}$
B	10.82	3.37×10^{-22}	17	1.98×10^{-23}
Al	26.98	8.38×10^{-22}	0.1	8.38×10^{-21}
Ga	69.72	2.17×10^{-21}	0.1	2.17×10^{-20}
P	30.98	9.63×10^{-22}	0.12	8.02×10^{-21}
As	74.91	2.33×10^{-21}	0.04	5.82×10^{-20}
Sb	121.76	3.78×10^{-21}	0.003	1.26×10^{-18}

Resistivity Profile of Phosphorus Doped Silicon



Resistivity Profile of Boron Doped Silicon



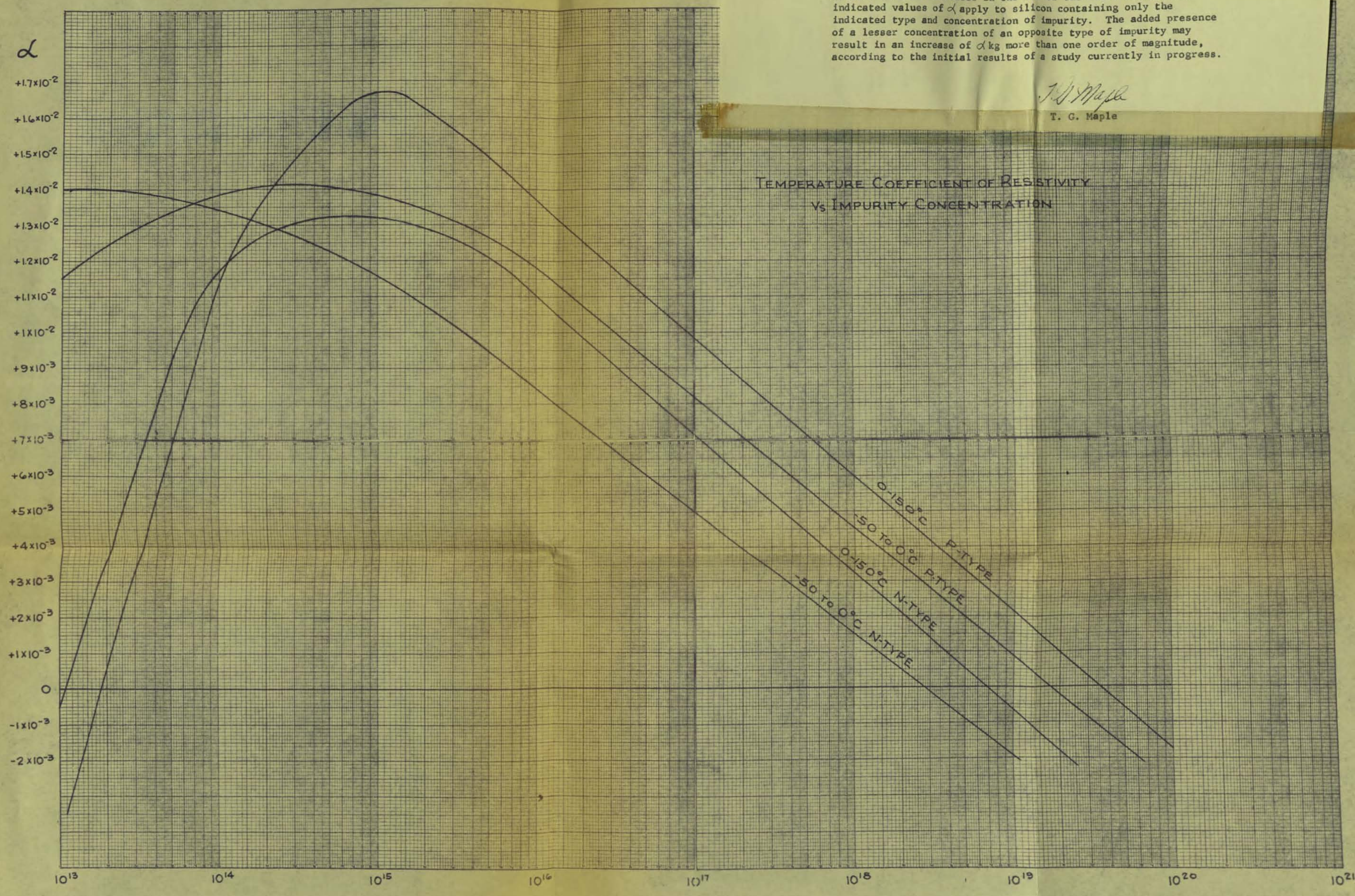
Design Reference Date, T.C. January 11, 1963

The attached chart of Temperature Coefficient of Resistivity vs. Impurity Concentration was prepared by drawing smooth curves through points calculated from the figures of conductance vs. temperature shown on page 51, W. W. Gartner, "Transistors-Principles, Design and Applications", Van Nostrand 1960.

Caution must be exercised in the use of the chart because the indicated values of α apply to silicon containing only the indicated type and concentration of impurity. The added presence of a lesser concentration of an opposite type of impurity may result in an increase of α_{kg} more than one order of magnitude, according to the initial results of a study currently in progress.

T. G. Maple

T. G. Maple



VAPOR PRESSURE
CURVES

H. Hald.

V. 39 (1947)

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(*Vapor Pressure of Pure Substances*)

INORGANIC COMPOUNDS

The preceding paper catalogued vapor pressure data of organic compounds. This article presents vapor pressure data for about 300 inorganic compounds and completes the coverage of this field at this time.

THE foregoing report (*441*) discussed the need for accurate vapor pressure data when certain physical laws are put into practical application. One of the constant cries of modern times is for more extensive and better data. To a fair extent, a new plant is no better than the data used in its design. These two reports are intended as a start toward the improvement of this circumstance.

The methodical exhaustion of the sources of vapor pressure data was begun some six years ago. *Chemical Abstracts* was searched through 1942, but the coverage since then has been incomplete. In the vast majority of cases the original documents were consulted. Existing collections of vapor pressure data (*9, 199, 249, 465*) were of great help. In this connection special attention should be focused on the excellent compilation of Kelley (*229*), which has bolstered our work admirably.

The treatment of data follows the style, format, and general plan of the preceding paper. The analytical method was retained and was based on semilogarithmic charts measuring 30 × 42 inches (where 1 mm. = 1° C.) and colored map tacks representing the plotted points over which a taut thread was stretched. This resulted in the introduction of a gentle curvature to the vapor pressure line, but sufficient tacks were inserted so that the curve was virtually continuous and without angles. For the permanent gases (those materials below −100° C.), the lines were penciled in with the help of a French curve, but, in view of the uncertainties in temperature measurement above 500° C. (becoming less certain with increase of temperature), it was felt that the penciling of the curves was unnecessary. Where the temperature fell within the range −150° C. to + 400° C. the Cox chart previously referred to was used.

So that ambiquity will be minimized, the name recognized by *Chemical Abstracts* has been used. The arrangement in the tables is alphabetical according to the name of the compound and the formula is also added so that there will be no doubt as to the substance meant.

Table I contains pressures (in millimeters of mercury) under 1 atmosphere, and Table II contains pressures (in atmospheres) over one atmosphere. All temperatures are in ° C. Since there is a discontinuity in a vapor pressure curve at the melting point, the melting point of the substance, where known, is listed in Table I. Since the vapor pressure curve ends at the critical point, Table II lists the critical temperature and pressure.

Assembling the results of many workers, as has been done here, leads to uncertainty as to the accuracy of the data. The temperature range is virtually from absolute zero to the highest temperatures man has devised. The lower part of the temperature scale is accurate, but as higher temperatures are reached, the uncertainty gap widens. In the opinion of the writer the figures given here represent the best experimental data possible with the graphic methods employed. The writer is certain that, as more reliable experimental measurements are made, a few of the figures given here should be revised.

NOMENCLATURE

d = decomposes
M.P. = melting point
P_c = critical pressure
p = polymerizes
s = solid
T_c = critical temperature

Tables I and II, pages 541-546

Literature citations, pages 547-550

Table I. Pressures L[illegible]han One Atmosphere

Formula	Name	Temperature, ° C.										M.P.	Citation No.
		1 mm.	5 mm.	10 mm.	20 mm.	40 mm.	60 mm.	100 mm.	200 mm.	400 mm.	760 mm.		
Al	Aluminum	1284	1421	1487	1555	1635	1684	1749	1844	1947	2056	660	(153, 229, 459)
AlB_3H_{12}	Aluminum borohydride	•	− 52.2	− 42.9	− 32.5	− 20.9	− 13.4	− 3.9	+ 11.2	28.1	45.9	− 64.5	(386)
$AlBr_3$	Aluminum bromide	81.3	103.8	118.0	134.0	150.6	161.7	176.1	199.8	227.0	256.3	97.5	(6, 127, 229)
$AlCl_3$	Aluminum chloride	100.0	116.4	123.8	131.8	139.9	145.4	152.0	161.8	171.6	180.2	192.4	(127, 130, 229, 264, 409, 410, 437)
AlF_3	Aluminum fluoride	1238	1298	1324	1350	1378	1398	1422	1457	1496	1537	1040	(362)
AlI_3	Aluminum iodide	178.0	207.7	225.8	244.2	265.0	277.8	294.5	322.0	354.0	385.5	....	(127, 229)
Al_2O_3	Aluminum oxide	2148	2306	2385	2465	2549	2599	2665	2766	2874	2977	2050	(229, 259, 269)
NH_3	Ammonia	−109.1	− 97.5	− 91.9	− 85.8	− 79.2	− 74.3	− 68.4	− 57.0	− 45.4	− 33.6	− 77.7	(25, 26, 33, 49, 62, 88, 142, 176, 192, 225, 231, 279, 306, 334, 429)
ND_3	Deutero ammonia	•	•	•	•	•	− 74.0	− 67.4	− 57.0	− 45.4	− 33.4	− 74.0	(445)
NH_4N_3	Ammonium azide	29.2	49.4	59.2	69.4	80.1	86.7	95.2	107.7	120.4	133.8	....	(151)
NH_4Br	Ammonium bromide	198.3	234.5	252.0	270.6	290.0	303.8	320.0	345.3	370.9	396.0	....	(405)
$NH_4CO_2NH_2$	Ammonium carbamate	− 26.1	− 10.4	− 2.9	+ 5.3	14.0	19.6	26.7	37.2	48.0	58.3	....	(48, 107)
NH_4Cl	Ammonium chloride	160.4	193.8	209.8	226.1	245.0	256.2	271.5	293.2	316.5	337.8	520	(333, 405)
NH_4HS	Ammonium hydrogen sulfide	− 51.1	− 36.0	− 28.7	− 20.8	− 12.3	− 7.0	0.0	+ 10.5	21.8	33.3	....	(200)
NH_4I	Ammonium iodide	210.9	247.0	263.5	282.8	302.8	316.0	331.8	355.8	381.0	404.9	....	(405)
NH_4CN	Ammonium cyanide	− 50.6	− 35.7	− 28.6	− 20.9	− 12.6	− 7.4	− 0.5	+ 9.6	20.5	31.7	36	(201)
Sb	Antimony	886	984	1033	1084	1141	1176	1223	1288	1364	1440	630.5	(168, 229, 255, 348, 456)
$SbBr_3$	Antimony tribromide	93.9	126.0	142.7	158.3	177.4	188.1	203.5	225.7	250.2	275.0	96.6	(9, 102)
$SbCl_3$	Antimony trichloride	49.2	71.4	85.2	100.6	117.8	128.3	143.3	165.9	192.2	219.0	73.4	(8, 9, 43, 102, 229, 264)
$SbCl_5$	Antimony pentachloride	22.7	48.6	61.8	75.8	91.0	101.0	114.1	d	....	....	2.8	(8, 9, 43, 229)
SbI_3	Antimony triiodide	163.6	203.8	223.5	244.8	267.8	282.5	303.5	333.8	368.5	401.0	167	(9, 102)
Sb_4O_6	Antimony trioxide	574	626	666	729	812	873	957	1085	1242	1425	656	(183, 229)
A	Argon	−218.2	−213.9	−210.9	−207.9	−204.9	−202.9	−200.5	−195.6	−190.6	−185.6	−189.2	(41, 63, 84, 86, 193, 229, 295, 329, 466)
As	Arsenic (metallic)	372	416	437	459	483	498	518	548	579	610	814	(143, 194, 229, 322, 348, 367)
$AsBr_3$	Arsenic tribromide	41.8	70.6	85.2	101.3	118.7	130.0	145.2	167.7	193.6	220.0	....	(9)
$AsCl_3$	Arsenic trichloride	− 11.4	+ 11.4	+ 23.5	36.0	50.0	58.7	70.9	89.2	109.7	130.4	− 18	(9, 20, 229, 264)
AsF_3	Arsenic trifluoride	•	•	•	•	− 2.5	+ 4.2	13.2	26.7	41.4	56.3	− 5.9	(376)
AsF_5	Arsenic pentafluoride	−117.9	−108.0	−103.1	− 98.0	− 92.4	− 88.5	− 84.3	− 75.5	− 64.0	− 52.8	− 79.8	(229, 382)
AsH_3	Arsenic hydride (arsine)	−142.6	−130.8	−124.7	−117.7	−110.2	−104.8	− 98.0	− 87.2	− 75.2	− 62.1	−116.3	(215)
As_4O_6	Arsenic trioxide	212.5	242.6	259.7	279.2	299.2	310.3	332.5	370.0	412.2	457.2	312.8	(229, 287, 373, 402, 405, 418, 479)
Ba	Barium	•	984	1049	1120	1195	1240	1301	1403	1518	1635	850	(167, 229, 355)
BeB_2H_8	Beryllium borohydride	+ 1.0	19.8	28.1	36.8	46.2	51.7	58.6	69.0	79.7	90.0	123	(60)
$BeBr_2$	Beryllium bromide	289	325	342	361	379	390	405	427	451	474	490	(229, 326)
$BeCl_2$	Beryllium chloride	291	328	346	365	384	395	411	435	461	487	405	(229, 326)
BeI_2	Beryllium iodide	283	322	341	361	382	394	411	435	461	487	488	(229, 326)
Bi	Bismuth	1021	1099	1136	1177	1217	1240	1271	1319	1370	1420	271	(17, 153, 164, 155, 229, 255, 343)
$BiBr_3$	Bismuth tribromide	•	261	282	305	327	340	360	392	425	461	218	(116, 229)
$BiCl_3$	Bismuth trichloride	•	242	264	287	311	324	343	372	405	441	230	(116, 229, 264)
BH_3CO	Borine carbonyl	−139.2	−127.3	−121.1	−114.1	−106.6	−101.9	− 95.3	− 85.5	− 74.8	− 64.0	−137.0	(29)
BBr_3	Boron tribromide	− 41.4	− 20.4	− 10.1	+ 1.5	14.0	22.1	33.5	50.3	70.0	91.7	− 45	(229, 421)
BCl_3	Boron trichloride	− 91.5	− 75.2	− 66.9	− 57.9	− 47.8	− 41.2	− 32.4	− 18.9	− 3.6	+ 12.7	−107	(229, 303, 334, 430)
BF_3	Boron trifluoride	−154.6	−145.4	−141.3	−136.4	−131.0	−127.6	−123.0	−115.9	−108.3	−110.7	−126.8	(59, 118, 229, 319, 382)
B_2H_6	Dihydrodiborane	−159.7	−149.5	−144.3	−138.5	−131.6	−127.2	−120.9	−111.2	− 99.6	− 86.5	−169	(229, 419, 423)
B_2BrH_5	Diborane hydrobromide	− 93.3	− 75.3	− 66.3	− 56.4	− 45.4	− 38.2	− 29.0	− 15.4	0.0	+ 16.3	−104.2	(229, 424)
$B_3H_6N_3$	Triborine triamine	− 63.0	− 45.0	− 35.3	− 25.0	− 13.2	− 5.8	+ 4.0	18.5	34.3	50.6	− 58.2	(229, 427)
B_4H_{10}	Tetrahydrotetraborane	− 90.9	− 73.1	− 64.3	− 54.8	− 44.3	− 37.4	− 28.1	− 14.0	+ 0.8	16.1	−119.9	(229, 423, 426, 428)
B_5H_9	Dihydropentaborane	•	− 40.4	− 30.7	− 20.0	− 8.0	− 0.4	+ 9.6	24.6	40.8	58.1	− 47.0	(229, 423)
B_5H_{11}	Tetrahydropentaborane	− 50.2	− 29.9	− 19.9	− 9.2	+ 2.7	10.2	20.1	34.8	51.2	67.0	....	(229, 426)
$B_{10}H_{14}$	Dihydrodecaborane	60.0	80.8	90.2	100.0	117.4	127.8	142.3	163.8	d	....	99.6	(229, 428)
Br_2	Bromine	− 48.7	− 32.8	− 25.0	− 16.8	− 8.0	− 0.6	+ 9.3	24.3	41.0	58.2	− 7.3	(88, 102, 171, 203, 217, 229, 231, 331, 345, 381, 453, 487)
BrF_5	Bromine pentafluoride	− 69.3	− 51.0	− 41.9	− 32.0	− 21.0	− 14.0	− 4.5	+ 9.9	25.7	40.0	− 61.4	(229, 365)
Cd	Cadmium	394	455	484	516	553	578	611	658	711	765	320.9	(17, 42, 61, 109, 111, 129, 163, 181, 210, 229, 243, 348)
$CdCl_2$	Cadmium chloride	•	618	656	695	736	762	797	847	908	967	568	(156, 229, 264)
CdF_2	Cadmium fluoride	1385	1504	1559	1617	1673	1709	1759	1834	1924	2024	520	(362)
CdI_2	Cadmium iodide	416	481	512	546	584	608	640	688	742	796	385	(229, 387)
CdO	Cadmium oxide	1000	1100	1149	1200	1257	1295	1341	1409	1484	1559	....	(119, 154, 229)
Ca	Calcium	•	926	983	1046	1111	1152	1207	1288	1388	1487	851	(167, 229, 318, 346, 355)
C	Carbon	3586	3828	3946	4069	4196	4273	4373	4516	4660	4827	....	(4, 176, 177, 229, 241, 242, 266, 377, 445, 480)
CBr_4	Carbon tetrabromide	•	•	•	•	96.3	106.3	119.7	139.7	163.5	189.5	90.1	(38)
CCl_4	Carbon tetrachloride	− 50.0	− 30.0	− 19.6	− 8.2	+ 4.3	12.3	23.0	38.3	57.8	76.7	− 22.6	(104, 179, 279, 334, 335, 413, 495)
CF_4	Carbon tetrafluoride	−184.6	−174.1	−169.3	−164.3	−158.8	−155.4	−150.7	−143.6	−135.5	−127.7	−183.7	(229, 270)
CO_2	Carbon dioxide	−134.3	−124.4	−119.5	−114.4	−108.6	−104.8	−100.2	− 93.0	− 85.7	− 78.2	− 57.5	(5, 46, 117, 172, 175, 211, 229, 272, 292, 302, 334, 420, 464, 467, 477, 497)
C_3O_2	Carbon suboxide	− 94.8	− 79.0	− 71.0	− 62.2	− 53.0	− 45.5	− 36.9	− 23.3	− 8.9	+ 6.3	−107	(237, 433)
CS_2	Carbon disulfide	− 73.8	− 54.3	− 44.7	− 34.3	− 22.5	− 15.3	− 5.1	+ 10.4	28.0	46.5	−110.8	(176, 229, 265, 328, 334, 335, 420, 467, 490)

CS_2

(Continued on next page)

Table I (*continued*)

Formula	Name	Temperature, °C.: 1 mm.	5 mm.	10 mm.	20 mm.	40 mm.	60 mm.	100 mm.	200 mm.	400 mm.	760 mm.	M. P.	Citation No.
C_3S_2	Carbon subsulfide	14.0	41.2	54.9	69.3	85.6	96.0	109.9	130.8_p	p	....	+ 0.4	(229, 429)
CSSe	Carbon selenosulfide	− 47.3	− 26.5	− 16.0	− 4.4	+ 8.6	17.0	28.3	45.7	65.2	85.6	− 75.2	(229, 456)
CO	Carbon monoxide	−222.0	−217.2	−215.0	−212.8	−210.0	−208.1	−205.7	−201.3	−196.3	−191.3	−205.0	(16, 67, 77, 78, 87, 229, 295, 465).
$COCl_2$	Carbonyl chloride	− 92.9	− 77.0	− 69.3	− 60.3	− 50.3	− 44.0	− 35.6	− 22.3	− 7.6	+ 8.3	−104	(14, 135, 229, 288, 309)
COSe	Carbonyl selenide	−117.1	−102.3	− 95.0	− 86.3	− 76.4	− 70.2	− 61.7	− 49.8	− 35.6	− 21.9	....	(325)
COS	Carbonyl sulfide	−132.4	−119.8	−113.3	−106.0	− 98.3	− 93.0	− 85.9	− 75.0	− 62.7	− 49.9	−138.8	(196, 229, 230, 422)
CCl_3NO_2	Chloropicrin	− 25.5	− 3.3	+ 7.8	20.0	33.8	42.3	53.8	71.8	91.8	111.9	− 64	(20, 51)
$CClF_3$	Chlorotrifluoromethane	−149.5	−139.2	−134.1	−128.5	−121.9	−117.3	−111.7	−102.5	− 92.7	− 81.2	....	(102, 447)
C_2N_2	Cyanogen	− 95.8	− 83.2	− 76.8	− 70.1	− 62.7	− 57.9	− 51.8	− 42.6	− 33.0	− 21.0	− 34.4	(74, 85, 102, 118, 315, 444)
CBrN	Cyanogen bromide	− 35.7	− 18.3	− 10.0	− 1.0	+ 8.6	14.7	22.6	33.8	46.0	61.5	58	(20, 229)
CClN	Cyanogen chloride	− 76.7	− 61.4	− 53.8	− 46.1	− 37.5	− 32.1	− 24.9	− 14.1	− 2.3	+ 13.1	− 6.5	(229, 334)
CFN	Cyanogen fluoride	−134.4	−123.8	−118.5	−112.8	−106.4	−102.3	− 97.0	− 89.2	− 80.5	− 72.6	....	(80, 229)
CIN	Cyanogen iodide	25.2	47.2	57.7	68.6	80.3	88.0	97.6	111.5	126.1	141.1	....	(229, 495)
CDN	Deuterocyanic acid	− 68.9	− 54.0	− 46.7	− 38.8	− 30.1	− 24.7	− 17.5	− 5.4	+ 10.0	26.2	− 12	(258)
CCl_2F_2	Dichlorodifluoromethane	−118.5	−104.6	− 97.8	− 90.1	− 81.6	− 76.1	− 68.6	− 57.0	− 43.9	− 29.8	....	(102, 144)
$CHCl_2F$	Dichlorofluoromethane	− 91.3	− 75.5	− 67.5	− 58.6	− 48.8	− 42.6	− 33.9	− 20.9	− 6.2	+ 8.9	−135	(255)
$CHClF_2$	Chlorodifluoromethane	−122.8	−110.2	−103.7	− 96.5	− 88.6	− 83.4	− 76.4	− 65.8	− 53.6	− 40.8	−160	(40, 255)
CCl_3F	Trichlorofluoromethane	− 84.3	− 67.6	− 59.0	− 49.7	− 39.0	− 32.3	− 23.0	− 9.1	+ 6.8	23.7	....	(255)
Cs	Cesium	279	341	375	409	449	474	509	561	624	690	28.5	(55, 132, 161, 229, 246, 251, 357, 394, 482)
CsBr	Cesium bromide	748	838	887	938	993	1026	1072	1140	1221	1300	636	(229, 367, 475)
CsCl	Cesium chloride	744	837	884	934	989	1023	1069	1139	1217	1300	646	(122, 229, 367, 475)
CsF	Cesium fluoride	712	798	844	893	947	980	1025	1092	1170	1251	683	(229, 270, 371, 475)
CsI	Cesium iodide	738	828	873	923	976	1009	1055	1124	1200	1280	621	(229, 367, 475)
Cl_2	Chlorine	−118.0	−106.7	−101.6	− 93.3	− 84.5	− 79.0	− 71.7	− 60.2	− 47.3	− 33.8	−100.7	(139, 166, 171, 214, 229, 239, 312, 452)
ClF	Chlorine fluoride	•	−143.4	−139.0	−134.3	−128.8	−125.3	−120.8	−114.4	−107.0	−100.5	−145	(229, 361)
ClF_3	Chlorine trifluoride	•	− 80.4	− 71.8	− 62.3	− 51.3	− 44.1	− 34.7	− 20.7	− 4.9	+ 11.5	− 83	(229, 360)
Cl_2O	Chlorine monoxide	− 98.5	− 81.6	− 73.1	− 64.3	− 54.3	− 48.0	− 39.4	− 26.5	− 12.5	+ 2.2	−116	(147, 229)
ClO_2	Chlorine dioxide	•	•	− 59.0	− 51.2	− 42.8	− 37.2	− 29.4	− 17.8	− 4.0	+ 11.1	− 59	(229, 234)
Cl_2O_6	Dichlorine hexoxide	+ 7.5	30.5	42.0	54.3	68.0	76.3	87.7	104.7	123.8	142.0	3.5	(149)
Cl_2O_7	Chlorine heptoxide	− 45.3	− 23.8	− 13.2	− 2.1	+ 10.3	18.2	29.1	44.6	62.2	78.8	− 91	(148, 229)
HSO_3Cl	Chlorosulfonic acid	32.0	53.5	64.0	75.3	87.6	95.2	105.3	120.0	136.1	151.0_d	− 80	(9)
Cr	Chromium	1616	1768	1845	1928	2013	2067	2139	2243	2361	2482	1615	(153, 229)
$Cr(CO)_6$	Chromium carbonyl	36.0	58.0	68.3	79.5	91.2	98.3	108.0	121.8	137.2	151.0	....	(484)
CrO_2Cl_2	Chromyl chloride	− 18.4	+ 3.2	13.8	25.7	38.5	46.7	58.0	75.2	95.2	117.1	....	(229, 27[illegible]
$COCl_2$	Cobaltous chloride	•	•	•	•	770	801	843	904	974	1050	735	(229, [illegible]
$Co(CO)_3NO$	Cobalt nitrosyl tricarbonyl	•	•	•	− 1.3	+ 11.0	18.5	29.0	44.4	62.0	80.0	− 11	(30)
CbF_5	Columbium pentafluoride	•	•	86.3	103.0	121.5	133.2	148.5	172.2	198.0	225.0	75.5	(229, 36[illegible]
Cu	Copper	1628	1795	1879	1970	2067	2127	2207	2325	2465	2595	1083	(153, 184, 155, 165, 218, 229, 262, 348, 359, 469)
Cu_2Br_2	Cuprous bromide	572	666	718	777	844	887	951	1052	1189	1355	504	(209, 229, 474)
Cu_2Cl_2	Cuprous chloride	546	645	702	766	838	886	960	1077	1249	1490	422	(229, 264, 474)
Cu_2I_2	Cuprous iodide	•	610	656	716	786	836	907	1018	1158	1336	605	(156, 209, 229, 474)
$FeCl_3$	Ferric chloride	194.0	221.8	235.5	246.0	256.8	263.7	272.5	[illegible]	298.0	319.0	304	(208, 229, 264)
$FeCl_2$	Ferrous chloride	....	....	700	737	779	805	842	[illegible]	961	1028	....	(229, 264)
F_2	Fluorine	−223.0	−216.9	−214.1	−211.0	−207.7	−205.6	−202.7	[illegible]	−193.2	−187.9	−223	(65, 229)
F_2O	Fluorine monoxide	−196.1	−186.6	−182.3	−177.8	−173.0	−170.0	−165.8	[illegible]	−151.9	−144.6	−223.9	(229, 363, 364)
Ga	Gallium	1349	1478	1541	1608	1680	1725	1784	1874	1974	2071	30	(165, 229)
$GaCl_3$	Gallium trichloride	48.0	67.8	76.5	91.3	107.5	118.0	132.[illegible]	152.8	176.3	200.0	77.0	(126, 253)
GeH_4	Germanium hydride	−163.0	−151.0	−145.3	−139.2	−131.6	−126.7	−120.3	−111.2	−100.2	− 88.9	−165	(79, 229, 307, 383)
$GeBr_4$	Germanium bromide	•	43.3	56.8	71.8	88.1	98.8	113.2	135.4	161.6	189.0	26.1	(45, 229)
$GeCl_4$	Germanium chloride	− 45.0	− 24.9	− 15.0	− 4.1	+ 8.0	16.2	27.[illegible]	44.4	63.8	84.0	− 49.5	(229, 284, 289)
$GeHCl_3$	Trichlorogermane	− 41.3	− 22.3	− 13.0	− 3.0	+ 8.8	16.2	26.[illegible]	41.6	58.3_d	75.0_d	− 71.1	(94, 229)
$Ge(CH_3)_4$	Tetramethylgermanium	− 73.2	− 54.6	− 45.2	− 35.0	− 23.4	− 16.2	− 6.[illegible]	+ 8.8	26.0	44.0	− 88	(93, 229)
Ge_2H_6	Digermane	− 88.7	− 69.8	− 60.1	− 49.9	− 38.2	− 30.7	− 20.[illegible]	− 4.7	+ 13.3	31.5	−109	(92, 229)
Ge_3H_8	Trigermane	− 36.9	− 12.8	− 0.9	+ 11.8	26.3	35.5	47.[illegible]	67.0	88.6	110.8	−105.6	(92, 229)
Au	Gold	1869	2059	2154	2256	2363	2431	2521	2657	2807	2966	1063	(164, 229, 348, 359, 469)
He	Helium	−271.7	−271.5	−271.3	−271.1	−270.7	−270.6	−270.3	−269.8	−269.3	−268.6	....	(227, 228, 229, 300, 301)
H_2	Hydrogen	−263.3	−261.9	−261.3	−260.4	−259.6	−258.9	−257.9	−256.3	−254.5	−252.5	−259.1	(68, 71, 173, 225, 229, 298, 299, 396, 454, 455)
HD	Hydrogen deuteride	....		−259.8	−259.1	−258.2	−257.6	−256.6	−255.0	−253.0	−251.0		(395)
HBr	Hydrogen bromide	−138.8	−127.4	−121.8	−115.4	−108.3	−103.8	− 97.7	− 88.1	− 78.0	− 66.5	− 87.0	(18, 103, 169, 229, 415, 416)
HCl	Hydrogen chloride	−150.8	−140.7	−135.6	−130.0	−123.8	−119.6	−114.0	−105.2	− 95.3	− 84.8	−114.3	(50, 69, 103, 118, 131, 169, 173, 223, 229, 416, 450)
HCN	Hydrogen cyanide	− 71.0	− 55.3	− 47.7	− 39.7	− 30.9	− 25.1	− 17.8	− 5.3	+ 10.2	25.9	− 13.2	(44, 164, 229, 233, 314, 397, 401)
HF	Hydrogen fluoride	•	− 74.7	− 65.8	− 56.0	− 45.0	− 37.9	− 28.2	− 13.2	+ 2.5	19.7	− 83.7	(76, 229, 394, 400)
HI	Hydrogen iodide	−123.3	−109.6	−102.3	− 94.5	− 85.6	− 79.8	− 72.1	− 60.3	− 48.3	− 35.1	− 50.9	(103, 169, 229, 415, 416)
H_2O_2	Hydrogen peroxide	15.3	35.8	50.4	63.3	77.0	85.8	97.9	116.5	137.4_d	158.0_d	− 0.9	(229, 230)
H_2Se	Hydrogen selenide	−115.3	−103.4	− 97.9	− 91.8	− 84.7	− 80.2	− 74.2	− 65.2	− 53.6	− 41.1	− 64	(87, 90, 91, 229, 235, 417)

Table I (c[illegible]nued)

Formula	Name	Temperature, °C 1 mm.	5 mm.	10 mm.	20 mm.	40 mm.	60 mm.	100 mm.	200 mm.	400 mm.	760 mm.	M.P.	Citation No.
H_2S	Hydrogen sulfide	−134.3	−122.4	−116.3	−109.7	−102.3	− 97.9	− 91.6	− 82.3	− 71.8	− 60.4	− 85.5	(118, 137, 229, 255, 256, 282, 334, 415, 416)
H_2S_2	Hydrogen disulfide	− 43.2	− 24.4	− 15.2	5.1	+ 6.0	12.8	22.0	35.3	49.6	64.0	− 89.7	(84, 229)
H_2Te	Hydrogen teluride	− 96.4	− 82.4	− 75.4	−67.8	59.1	− 53.7	− 45.7	32.4	− 17.2	− 2.0	− 49.0	(56, 229, 417)
NH_2OH	Hydroxylamine	•	39.0	47.2	[illegible]	64.6	70.0	77.5	87.9	99.2	110.0	34.0	(8, 25, 269)
I_2	Iodine	38.7	62.2	73.2	[illegible]	97.5	105.4	116.5	137.3	159.8	183.0	112.9	(10, 21, 22, 96, 136, 145, 155, 229, 282, 331, 336, 440, 483, 486)
IF_5	Iodine pentafluoride	− 15.2	+ 1.5	8.5	[illegible]	32.2	40.0	50.0	65.4	81.2	97.0	8.0	(361)
IF_7	Iodine heptafluoride	− 87.0	− 70.7	− 63.0	[illegible]	48.3	− 39.4	− 31.9	20.7	− 8.3	+ 4.0	5.5	(229, 368)
Fe	Iron	1787	1957	2039	[illegible]	2224	2283	2360	2475	2605	2735	1535	(155, 218, 229, 360)
$Fe(CO)_5$	Iron pentacarbonyl	..	− 6.5	+ 4.6	[illegible]	30.3	39.1	50.3	68.0	86.1	105.0	− 21	(229, 460)
Kr	Krypton	−199.3	−191.3	−187.2	[illegible]	−178.4	−175.7	−171.8	−165.9	−159.0	−152.0	−156.7	(5, 221, 229, 316, 317, 319)
Pb	Lead	973	1099	1162	1224	1309	1358	1421	1519	1630	1744	327.5	(110, 153, 154, 166, 165, 197, 229, 255, 341, 342, 343, 469, 471)
$PbBr_2$	Lead bromide	513	578	610	646	686	711	745	796	856	914	373	(156, 229, 465, 474)
$PbCl_2$	Lead chloride	547	615	648	684	725	750	784	833	893	954	501	(106, 156, 207, 229, 465, 474)
PbF_2	Lead fluoride	•	861	904	950	1003	1036	1080	1144	1219	1293	855	(229, 474)
PbI	Lead iodide	479	540	571	605	644	668	701	750	807	872	402	(156, 209, 229)
PbO	Lead oxide	943	1039	1085	1134	1189	1222	1265	1330	1402	1472	890	(119, 229)
PbS	Lead sulfide	852	928	975	1005	1048	1074	1108	1160	1221	1281	1114	(229, 382)
Li	Lithium	723	828	881	940	1003	1042	1097	1178	1273	1372	186	(56, 57, 167, 229, 257)
LiBr	Lithium bromide	748	840	888	939	994	1028	1076	1147	1226	1310	547	(229, 367, 475)
LiCl	Lithium chloride	783	880	932	987	1045	1081	1129	1203	1290	1382	614	(229, 264, 367, 475)
LiF	Lithium fluoride	1047	1156	1211	1270	1333	1372	1425	1503	1591	1681	870	(229, 371, 475)
LiI	Lithium iodide	723	802	841	883	927	955	993	1049	1110	1171	446	(229, 367, 475)
Mg	Magnesium	621	702	743	789	838	868	909	967	1034	1107	651	(153, 167, 229, 355, 469)
$MgCl_2$	Magnesium chloride	778	877	930	988	1050	1088	1142	1223	1316	1418	712	(229, 264)
Mn	Manganese	1292	1434	1505	1583	1666	1720	1792	1900	2029	2151	1260	(135, 153, 229, 349)
$MnCl_2$	Manganous chloride	•	736	778	825	879	913	960	1028	1108	1190	650	(229, 264)
Hg	Mercury	126.2	164.8	184.0	204.6	228.8	242.0	261.7	290.7	323.0	357.0	− 38.9	(26, 34, 109, 134, 169, 178, 181, 182, 185, 210, 222, 229, 240, 243, 271, 275, 277, 285, 316, 320, 330, 334, 342, 348, 459, 460, 494)
$HgBr_2$	Mercuric bromide	136.5	165.3	179.8	194.3	211.5	221.0	237.8	262.7	290.0	319.0	237	(212, 220, 229, 321, 465, 485)
$HgCl_2$	Mercuric chloride	136.2	166.0	180.2	195.8	212.5	222.2	237.0	256.5	275.5	304.0	277	(124, 212, 229, 324, 336, 367, 458, 485)
HgI_2	Mercuric iodide	157.5	189.2	204.5	220.0	238.2	249.0	261.8	291.0	324.2	354.0	259	(98, 212, 229, 324, 339, 458, 485)
Mo	Molybdenum	3102	3393	3535	3690	3859	3964	4109	4322	4553	4804	2622	(218, 229, 252)
MoF_6	Molybdenum hexafluoride	− 65.5	− 49.0	− 40.8	− 32.0	− 22.1	− 16.2	− 8.0	+ 4.1	17.2	36.0	17	(229, 347)
MoO_3	Molybdenum trioxide	734	785	814	851	892	917	955	1014	1082	1151	795	(120, 205, 229)
Ne	Neon	−257.3	−255.5	−254.6	−253.7	−252.6	−251.9	−251.0	−249.7	−248.1	−246.0	−248.7	(71, 229, 297, 455)
Ni	Nickel	1810	1979	2057	2143	2234	2289	2364	2473	2603	2732	1452	(218, 229, 349)
$NiCl_2$	Nickel chloride	671	731	759	789	821	840	866	904	945	987	1001	(125, 229, 264)
$Ni(CO)_4$	Nickel carbonyl	•	•	•	•	− 23.0	− 15.9	− 6.0	+ 8.8	25.8	42.5	− 25	(7, 96, 97, 229, 274)
N_2	Nitrogen	−226.1	−221.3	−219.1	−216.8	−214.0	−212.3	−209.7	−205.6	−200.9	−195.8	−210.0	(15, 70, 86, 100, 123, 138, 173, 174, 195, 229, 292, 321, 465, 467, 489)
NF_3	Nitrogen trifluoride	•	−175.5	−170.7	−165.7	−160.2	−156.5	−152.3	−145.2	−137.4	−129.0	−183.7	(229, 270)
NO	Nitric oxide	−184.5	−180.6	−178.2	−175.3	−171.7	−168.9	−166.0	−162.3	−156.8	−151.7	−161	(1, 146, 170, 216, 229, 279, 292, 294)
N_2O	Nitrous oxide	−143.4	−133.4	−128.7	−124.0	−118.3	−114.9	−110.3	−103.6	− 96.2	− 88.5	− 90.9	(29, 32, 53, 62, 115, 153, 229, 247, 327, 464)
N_2O_4	Nitrogen tetroxide	− 55.6	− 42.7	− 36.7	− 30.4	− 23.9	− 19.9	− 14.7	− 5.0	+ 8.0	21.0	− 9.3	(19, 108, 158, 229, 275, 317, 332, 374, 380, 385)
N_2O_5	Nitrogen pentoxide	− 36.8	− 23.0	− 16.7	− 10.0	− 2.9	+ 1.8	7.4	15.6	24.4	32.4	30	(89, 229, 375)
NOCl	Nitrosyl chloride	•	•	•	•	− 60.2	− 54.2	− 46.3	− 34.0	− 20.3	− 6.4	− 64.5	(52, 229, 451)
NOF	Nitrosyl fluoride	−132.0	−120.3	−114.3	−107.8	−100.3	− 95.7	− 88.8	− 79.2	− 68.2	− 56.0	−134	(366)
NO_2F	Nitroxyl fluoride	−143.7	−132.1	−126.2	−119.8	−112.8	−108.4	−102.3	− 93.5	− 83.2	− 72.0	−139	(366)
OsO_4	Osmium tetroxide (white)	− 5.6	+ 15.6	26.0	37.4	50.5	59.4	71.5	89.5	109.3	130.0	42	(229, 248, 290, 372, 468)
OsO_4	Osmium tetroxide (yellow)	3.2	22.0	31.3	41.0	51.7	59.4	71.5	89.5	109.3	130.0	56	(229, 245, 290, 372, 468)
O_2	Oxygen	−219.1	−213.4	−210.6	−207.5	−204.1	−201.9	−198.8	−194.0	−188.8	−183.1	−218.7	(15, 28, 58, 70, 86, 100, 114, 172, 174, 226, 229, 292, 296, 420, 456, 467, 488)
O_3	Ozone	−180.4	−168.6	−163.2	−157.2	−150.7	−146.7	−141.0	−132.6	−122.5	−111.1	−251	(229, 337, 338, 414)
P	Phosphorus (yellow)	76.6	111.2	128.0	146.2	166.7	179.8	197.3	222.7	251.0	280.0	44.1	(72, 186, 219, 229, 265, 322)
P	Phosphorous (violet)	237	271	287	306	323	334	349	370	391	417	590	(186, 229, 256, 406, 408)

(Continued on next page)

Table I (*continued*)

Formula	Name	Temperature, °C										M.P.	Citation No.
		1 mm.	5 mm.	10 mm.	20 mm.	40 mm.	60 mm.	100 mm.	200 mm.	400 mm.	760 mm.		
P	Phosphorous (black)	$290._s$	$323._s$	$338._s$	$354._s$	$371._s$	$381._s$	$393._s$	$413._s$	$432._s$	$453._s$	...	(*47, 186, 229, 286, 408*)
PBr_3	Phosphorous tribromide	7.8	34.4	47.8	62.4	79.0	89.8	103.6	125.2	149.7	175.3	−40	(*9*)
PCl_3	Phosphorous trichloride	−51.6	−31.5	−21.3	−10.2	+2.3	10.2	21.0	37.6	56.9	74.2	−111.8	(*229, 334*)
PCl_5	Phosphorous pentachloride	55.5_s	74.0_s	83.2_s	92.5_s	102.5_s	108.3_s	117.0_s	131.3_s	147.2_s	162.0_s		(*405*)
PH_3	Phosphorous hydride (phosphene)	•	•	•	•	−129.4	−125.0	−118.8	−109.4	−98.3	−87.5	−132.5	(*50, 178, 229, 416, 420*)
PH_4Br	Phosphonium bromide	-43.7_s	-28.5_s	-21.2_s	-13.3_s	-5.0_s	$+0.3_s$	7.4_s	17.6_s	28.0_s	38.3_d	...	(*202, 213*)
PH_4Cl	Phosphonium chloride	-91.0_s	-79.6_s	-74.0_s	-68.0_s	-61.5_s	-57.3_s	-52.0_s	-44.0_s	-35.4_s	-27.0_s	−28.5	(*59, 444*)
PH_4I	Phosphonium iodide	-25.2_s	-9.0_s	-1.1_s	$+7.3_s$	16.1_s	21.9_s	29.3_s	39.9_s	51.6_s	62.3_s	...	(*213, 405*)
P_4O_6	Phosphorous trioxide	•	39.7	53.0	67.8	84.0	94.2	108.3	129.0	150.3	173.1	22.5	(*229, 384, 461*)
$POCl_3$	Phosphorous oxychloride	•	•	2.0	13.6	27.3	35.8	47.4	65.0	84.3	105.1	2	(*12, 15, 229*)
P_2O_5	Phosphorous pentoxide (stable form)	$384._s$	$424._s$	$442._s$	$462._s$	$481._s$	$493._s$	$510._s$	$532._s$	$556._s$	591	569	(*187, 229, 407*)
P_2O_5	Phosphorous pentoxide (metastable form)	189	220	236	253	270	280	294	314	336	358	...	(*187, 229, 407*)
$PSBr_3$	Phosphorous thiobromide	50.0	72.4	83.6	95.5	108.0	116.0	126.3	141.8	157.8	175.0_d	38	(*9*)
$PSCl_3$	Phosphorous thiochloride	−18.3	+4.6	16.1	29.0	42.7	51.8	63.8	82.0	102.3	124.0	−36.2	(*9*)
Pt	Platinum	2730	3007	3146	3302	3469	3574	3714	3923	4169	4407	1755	(*218, 229, 252*)
K	Potassium	341	408	443	483	524	550	586	643	708	774	62.3	(*106, 122, 161, 163, 181, 229, 246, 257, 285, 357, 478*)
KBr	Potassium bromide	795	982	940	994	1050	1087	1137	1212	1297	1383	730	(*122, 229, 367, 475*)
KCl	Potassium chloride	821	919	968	1020	1078	1115	1164	1239	1322	1407	790	(*122, 156, 162, 195, 204, 229, 243, 367, 475*)
KF	Potassium fluoride	885	988	1039	1096	1156	1193	1245	1323	1411	1502	880	(*229, 371, 476*)
KOH	Potassium hydroxide	719	814	863	918	976	1013	1064	1142	1233	1327	380	(*204, 229, 476*)
KI	Potassium iodide	745	840	887	938	995	1030	1080	1152	1238	1324	723	(*122, 155, 229, 365, 475*)
Rn	Radon	-144.2_s	-132.4_s	-126.3_s	-119.2_s	-111.3_s	-106.2_s	-99.0_s	-87.7_s	-75.0_s	−61.8	−71	(*152, 229, 244*)
Re_2O_7	Rhenium heptoxide	212.5_s	237.5_s	248.0_s	261.0_s	272.0_s	280.0_s	289.0_s	307.0	336.0	362.4	296	(*229, 291*)
Rb	Rubidium	297	358	389	422	459	482	514	563	620	679	38.5	(*161, 229, 357, 394*)
RbBr	Rubidium bromide	781	876	923	975	1031	1066	1114	1186	1267	1352	682	(*229, 367, 476*)
RbCl	Rubidium chloride	792	887	937	990	1047	1084	1133	1207	1294	1381	715	(*229, 367, 476*)
RbF	Rubidium fluoride	921	982	1016	1052	1096	1123	1168	1239	1322	1408	760	(*229, 371, 475*)
RbI	Rubidium iodide	748	839	884	935	991	1026	1072	1141	1223	1304	642	(*229, 367, 475*)
Se	Selenium	356	413	442	473	506	527	554	594	637	680	217	(*99, 206, 229, 322*)
SeO_2	Selenium dioxide	157.0_s	187.7_s	202.5_s	217.5_s	234.1_s	244.6_s	258.0_s	277.0_s	297.7_s	317.0_s	340	(*6, 206, 229*)
SeF_6	Selenium hexafluoride	-118.6_s	-105.2_s	-98.9_s	-92.3_s	-84.7_s	-80.0_s	-73.9_s	-64.8_s	-55.2_s	-45.8_s	−34.7	(*229, 238, 421*)
$SeOCl_2$	Selenium oxychloride	34.8	59.8	71.9	84.2	98.0	106.5	118.0	134.6	151.7	168.0	8.5	(*229, 264*)
$SeCl_4$	Selenium tetrachloride	74.0_s	96.3_s	107.4_s	118.1_s	130.1_s	137.8_s	147.5_s	161.0_s	176.4_s	191.5_d		(*420*)
SiH_4	Silane	−179.3	−168.6	−163.0	−156.9	−150.3	−146.3	−140.5	−131.6	−122.0	−111.5	−185	(*2, 229, 431*)
Si	Silicon	1724	1835	1888	1942	2000	2036	2083	2151	2220	2287	1420	(*229, 429, 470*)
SiO_2	Silicon dioxide	•	•	1732	1798	1867	1911	1969	2053	2141	2227	1710	(*229, 369*)
$SiCl_4$	Silicon tetrachloride	−63.4	−44.1	−34.4	−24.0	−12.1	−4.8	+5.4	21.0	38.4	56.8	−68.8	(*24, 224, 229, 334, 434*)
SiF_4	Silicon tetrafluoride	-144.0_s	-134.8_s	-130.4_s	-125.9_s	-120.8_s	-117.5_s	-113.3_s	-107.2_s	-100.7_s	-94.8_s	−90	(*40, 229, 310, 347*)
SiH_3Br	Bromosilane	•	−85.7	−77.3	−68.3	−57.8	−51.1	−42.3	−28.6	−13.3	+2.4	−93.9	(*229, 431*)
SiH_3Cl	Chlorosilane	−117.8	−104.3	−97.7	−90.1	−81.8	−76.0	−68.5	−57.0	−44.5	−30.4	...	(*431*)
SiH_3F	Fluorosilane	−153.0	−145.5	−141.2	−136.3	−130.8	−127.2	−122.4	−115.2	−106.8	−98.0	...	(*112*)
SiH_3I	Iodosilane	•	−53.0	−43.7	−33.4	−21.8	−14.3	−4.4	+10.7	27.9	45.4	−57.0	(*112*)
$SiBrCl_2F$	Bromodichlorofluorosilane	−86.5	−68.4	−59.0	−48.8	−37.0	−29.0	−19.5	−3.2	+15.4	35.4	−112.3	(*389*)
$SiBrF_3$	Bromotrifluorosilane	•	•	•	•	•	•	•	−60.8	−55.9	−41.7	−70.5	(*388*)
$SiClF_3$	Chlorotrifluorosilane	-144.0_s	−133.0	−127.0	−120.5	−112.8	−108.[illegible]	−101.7	−91.7	−81.0	−70.0	−142	(*40, 229, 392*)
$SiBr_2ClF$	Dibromochlorofluorosilane	−65.2	−45.5	−35.6	−24.5	−12.0	−4.[illegible]	+6.[illegible]	23.0	43.0	59.5	−99.3	(*389*)
$SiBr_2F_2$	Dibromodifluorosilane	•	•	−66.8	−57.7	−47.4	−41.0	−31.9	−18.2	−2.6	+13.7	−66.9	(*389*)
SiH_2Br_2	Dibromosilane	−60.9	−40.0	−29.4	−18.0	−5.2	+3.2	14.[illegible]	31.6	50.7	70.5	−70.2	(*229, 432*)
$SiCl_2F_2$	Dichlorodifluorosilane	−124.7	−110.5	−102.9	−94.5	−85.0	−78.6	−70.[illegible]	−58.0	−45.0	−31.8	−139.7	(*40, 229, 392*)
SiH_2F_2	Difluorosilane	−146.7	−136.0	−130.4	−124.3	−117.6	−113.3	−107.[illegible]	−98.3	−87.6	−77.8	...	(*112*)
SiH_2I_2	Diiodosilane	•	+3.8	18.0	34.1	52.6	64.0	79.4	101.8	125.5	149.5	−1.0	(*113*)
Si_2H_6	Disilane	−114.8	−99.3	−91.4	−82.7	−72.8	−66.4	−57.[illegible]	−44.6	−29.0	−14.3	−132.6	(*229, 431, 434*)
$(SiH_3)_2O$	Disiloxane	−112.5	−95.8	−88.2	−79.8	−70.4	−64.2	−55.[illegible]	−43.5	−29.3	−15.4	−144.2	(*229, 434*)
$SiCl_3F$	Fluorotrichlorosilane	−92.6	−76.4	−68.3	−59.0	−48.8	−42.2	−33.[illegible]	−19.3	−4.0	+12.2	−120.8	(*40*)
Si_2Cl_6	Hexachlorodisilane	+4.0	27.4	38.8	51.5	65.3	73.9	85.4	102.2	120.6	139.0	−1.2	(*229, 267*)
$(SiCl_3)_2O$	Hexachlorodisiloxane	−5.0	17.8	29.4	41.5	55.2	63.8	75.4	92.5	113.6	135.6	−33.2	(*229, 434*)
Si_2F_6	Hexafluorodisilane	-81.0_s	-68.8_s	-63.1_s	-57.0_s	-50.6_s	-46.7_s	-41.7_s	-34.2_s	-26.4_s	-18.9_s	−18.6	(*229, 391, 392*)
Si_3Cl_8	Octachlorotrisilane	46.3	74.7	89.3	104.2	121.5	132.0	146.0	166.2	189.5	211.4		(*229, 267*)
Si_4H_{10}	Tetrasilane	−27.7	−6.2	+4.3	15.8	28.4	36.6	47.4	63.6	81.7	100.0	−93.6	(*229, 431*)
$SiBr_3F$	Tribromofluorosilane	−46.1	−25.4	−15.1	−3.7	+9.2	17.4	28.6	45.7	64.6	83.8	−82.5	(*388*)
$SiHBr_3$	Tribromosilane	−30.5	−8.0	+3.4	16.0	30.0	39.2	51.6	70.2	90.2	111.8	−73.5	(*390*)
$SiHCl_3$	Trichlorosilane	−80.7	−62.6	−53.4	−43.8	−32.9	−25.8	−16.4	−1.8	+14.5	31.8	−126.6	(*229, 437*)
$SiHF_3$	Trifluorosilane	-152.0_s	−142.[illegible]	-138.2_s	-132.9_s	−127.3	−123.7	−118.7	−111.3	−102.8	−95.0	−131.4	(*113*)
Si_3H_8	Trisilane	−68.9	−49.7	−40.0	−29.0	−16.9	−9.0	+1.6	17.8	35.5	53.1	−117.2	(*229, 431*)
$(SiH_3)_3N$	Disilazane	−68.7	−49.9	−40.4	−30.0	−18.5	−11.0	−1.1	+14.0	31.0	48.7	−105.7	(*229, 435*)
Ag	Silver	1357	1500	1575	1658	1743	1795	1865	1971	2090	2212	960.5	(*155, 164, 156, 1[illegible], 184, 218, [illegible] 343, 469, 471*)
AgCl	Silver chloride	912	1019	1074	1134	1200	1242	1297	1379	1467	1564	455	(*229, 264, 474*)
AgI	Silver iodide	820	927	983	1045	1111	1152	1210	1297	1400	1506	552	(*209, 229*)

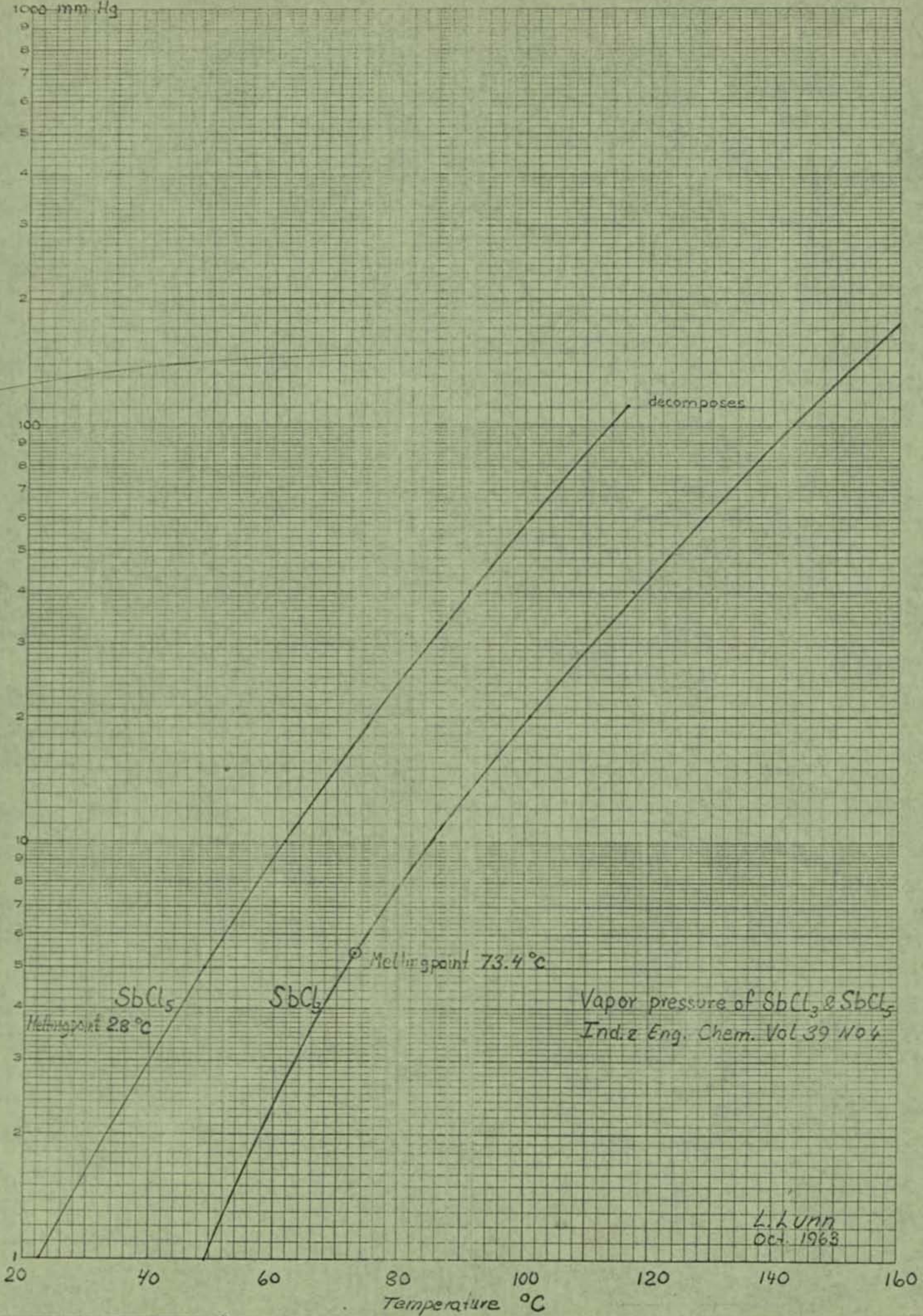
Table I (continued)

Formula	Name	Temperature, ° C 1 mm.	5 mm.	10 mm.	20 mm.	40 mm.	60 mm.	100 mm.	200 mm.	400 mm.	760 mm.	M.P.	Citation No.
Na	Sodium	439	511	549	589	633	662	701	758	823	892	97.5	(106, 134, 150, 160, 161, 165, 181, 229, 248, 257, 340, 343, 344, 357, 446, 472, 478)
NaBr	Sodium bromide	806	903	952	1003	1063	1099	1148	1220	1304	1392	755	(229, 367, 473)
NaCl	Sodium chloride	865	967	1017	1072	1131	1169	1220	1296	1379	1465	800	(122, 156, 162, 195, 229, 243, 264, 362, 367, 473)
NaCN	Sodium cyanide	817	928	983	1046	1115	1156	1214	1302	1401	1497	564	(198, 229)
NaF	Sodium fluoride	1077	1186	1240	1300	1363	1403	1455	1531	1617	1704	992	(229, 371, 475)
NaOH	Sodium hydroxide	739	843	897	953	1017	1057	1111	1192	1288	1378	318	(229, 473)
NaI	Sodium iodide	767	857	903	952	1005	1039	1083	1150	1225	1304	651	(156, 229, 367, 476)
$SnBr_4$	Stannic bromide	•	58.3	72.7	88.1	105.5	116.2	131.0	152.8	177.7	204.7	31.0	(9)
$SnCl_4$	Stannic chloride	−22.7	−1.0	+10.0	22.0	35.2	43.5	54.7	72.0	92.1	113.0	−30.2	(229, 279, 481, 494, 496)
SnH_4	Stannic hydride	−140.0	−125.8	−118.5	−111.2	−102.3	−96.6	−89.2	−78.0	−65.2	−52.3	−149.9	(229, 306)
SnI_4	Stannic iodide	•	156.0	175.8	196.2	218.8	234.2	254.2	283.5	315.5	348.0	144.5	(283)
$SnCl_2$	Stannous chloride	316	366	391	420	450	467	493	533	577	623	246.8	(229, 264)
Sr	Strontium	•	847	898	953	1018	1057	1111	1192	1285	1384	800	(167, 229, 366)
SrO	Strontium oxide	2068.	2198.	2262.	2333.	2410.						2430	(75, 229)
S	Sulfur	183.8	223.0	243.8	264.7	288.3	305.5	327.2	359.7	399.6	444.6	112.8	(17, 34, 64, 66, 73, 157, 191, 229, 268, 278, 284, 323, 334, 353, 364, 482)
SF_6	Sulfur hexafluoride	−132.7	−120.6	−114.7	−108.4	−101.5	−96.8	−90.9	−82.3	−72.6	−63.5	−50.2	(229, 238)
SO_2	Sulfur dioxide	−95.5	−83.0	−76.8	−69.7	−60.5	−54.6	−46.9	−35.4	−23.0	−10.0	−73.2	(25, 33, 51, 63, 68, 140, 142, 175, 229, 261, 280, 334, 385, 415, 420)
S_2Cl_2	Sulfur monochloride	−7.4	+15.7	27.5	40.0	54.1	63.2	75.3	93.5	115.4	138.0	−80	(168, 229, 453)
SO_2Cl_2	Sulfuryl chloride	•	−35.1	−24.8	−13.4	−1.0	+7.2	17.8	33.7	51.3	69.2	−54.1	(229, 448, 449)
SO_3	Sulfur trioxide (α)	−39.0	−23.7	−16.5	−9.1	−1.0	+4.0	10.5	20.5	32.6	44.8	16.8	(27, 161, 229, 411, 412)
SO_3	Sulfur trioxide (β)	−34.0	−19.2	−12.3	−4.9	+3.2	8.0	14.3	23.7	32.6	44.8	32.3	(27, 161, 229, 411, 412)
SO_3	Sulfur trioxide (γ)	−15.3	−2.0	+4.3	11.1	17.9	21.4	28.0	35.8	44.0	51.6	62.1	(27, 161, 229, 411, 412)
H_2SO_4	Sulfuric acid	145.8	178.0	194.2	211.5	229.7	241.5	257.0	279.8	305.0	330.0	10.5	(9)
$SOBr_2$	Thionyl bromide	−6.7	+18.4	31.0	44.1	58.8	68.3	80.6	99.0	119.2	139.5	−52.2	(229, 269)
$SOCl_2$	Thionyl chloride	−52.9	−32.4	−21.9	−10.5	+2.2	10.4	21.4	37.9	56.5	75.4	−104.5	(11, 13, 229)
TaF_5	Tantalum pentafluoride	•	•	•	•	•	110.3	130.0	159.9	194.0	230.0	96.8	(229, 365)
Te	Tellurium	520	605	650	697	753	789	838	910	997	1087	452	(101, 229)
$TeCl_4$	Tellurium tetrachloride	•	•	233	253	273	287	304	330	360	392	224	(229, 399)
TeF_6	Tellurium hexafluoride	−111.3	−98.8	−92.4	−86.0	−78.4	−73.8	−67.9	−57.3	−48.2	−38.6	−37.8	(229, 232, 491)
Tl	Thallium	825	931	983	1040	1103	1143	1196	1274	1364	1457	303.5	(143, 229, 255, 469)
TlBr	Thallium bromide	•	490	522	559	598	621	653	703	759	819	460	(229, 465, 474)
TlCl	Thallium chloride	•	487	517	550	589	612	645	694	748	807	430	(229, 465, 474)
TlI	Thallium iodide	440	502	531	567	607	631	663	712	763	823	440	(229, 465, 474)
Sn	Tin	1492	1634	1703	1777	1855	1903	1968	2063	2169	2270	231.9	(153, 154, 158, 165, 229, 348, 469, 471)
$TiCl_4$	Titanium tetrachloride	−13.9	+9.4	21.3	34.2	48.4	58.0	71.0	90.5	112.7	136.0	−30	(11, 229)
W	Tungsten	3990	4337	4507	4690	4886	5007	5168	5403	5636	5927	3370	(218, 229, 250, 498, 499)
WF_6	Tungsten hexafluoride	−71.4	−56.5	−49.2	−41.5	−33.0	−27.5	−20.3	−10.0	+1.2	17.3	−0.5	(229, 347)
UF_6	Uranium hexafluoride	−38.8	−22.0	−13.8	−5.2	+4.4	10.4	18.2	30.0	42.7	55.7	69.2	(229, 356)
$VOCl_3$	Vanadyl trichloride	−23.2	+0.2	12.2	26.6	40.0	49.8	62.5	82.0	103.5	127.2	....	(128)
H_2O	Water	−17.3	+1.2	11.3	22.2	34.1	41.6	51.6	65.5	83.0	100.0	0.0	(81, 95, 104, 121, 189, 190, 217, 222, 229, 232, 303, 304, 378, 379, 404, 476, 481)
Xe	Xenon	−168.5	−158.2	−152.8	−147.1	−141.2	−137.7	−132.8	−125.4	−117.1	−108.0	−111.6	(3, 180, 229, 311, 315, 329)
Zn	Zinc	487	558	593	632	673	700	736	788	844	907	419.4	(17, 42, 61, 109, 134, 158, 165, 181, 210, 229, 235, 342, 343)
$ZnCl_2$	Zinc chloride	428	481	508	536	566	584	610	648	689	732	365	(208, 229, 264)
ZnF_2	Zinc fluoride	1243	1328	1359	1402	1448	1480	1527	1602	1690	1770	872	(362)
$ZrBr_4$	Zirconium tetrabromide	207.	237.	250.	266.	281.	289.	301.	318.	337.	357.	450	(229, 326)
$ZrCl_4$	Zirconium tetrachloride	190.	217.	230.	243.	259.	268.	~~279.~~	295.	312.	331.	437	(229, 326)
ZrI_4	Zirconium tetraiodide	264.	297.	311.	329.	344.	355.	369.	389.	409.	431.	499	(229, 326)

ZrI_4

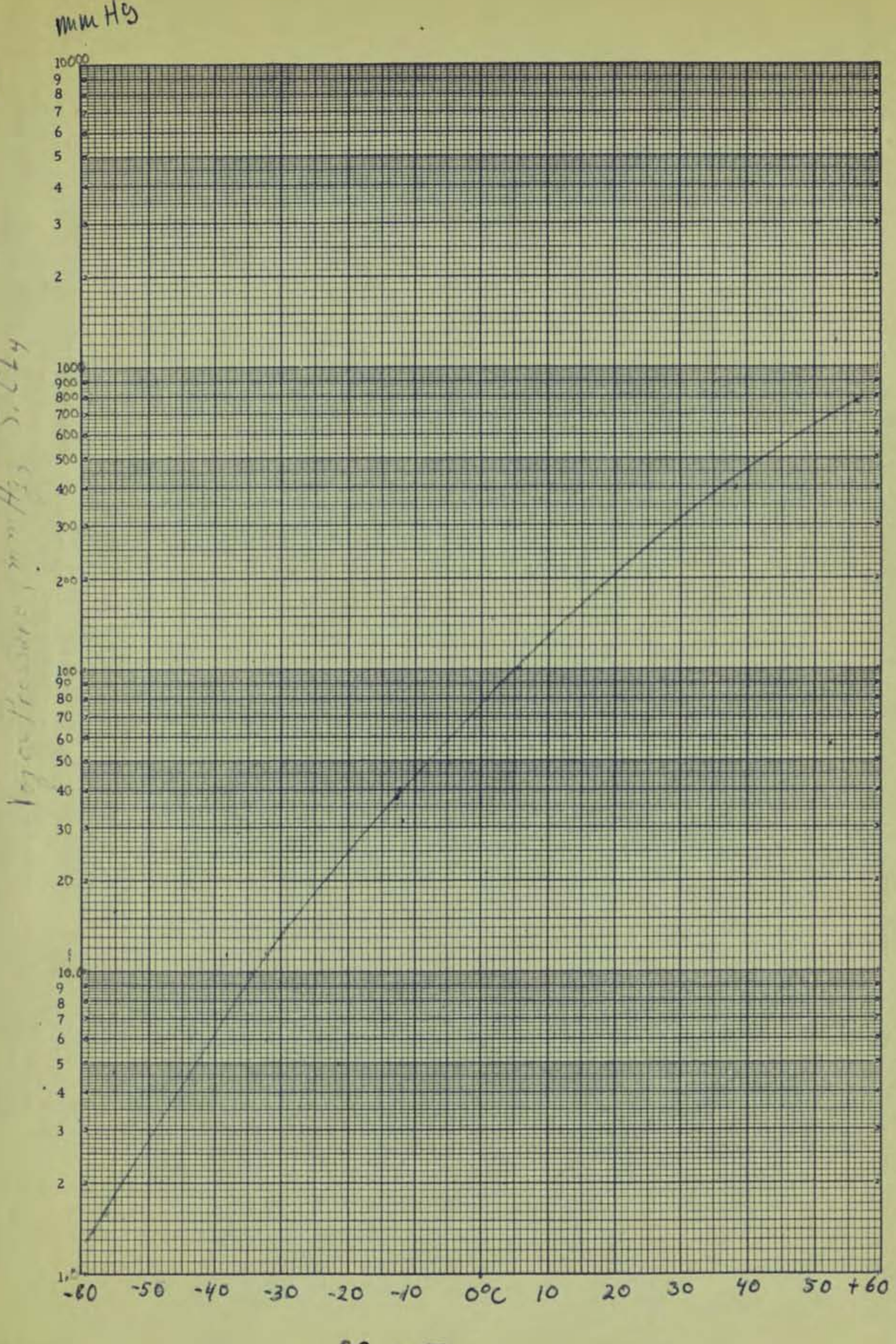
Table II. Pressures Greater than One Atmosphere

Formula	Name	Temperature, ° C.											
		1 atm.	2 atm.	5 atm.	10 atm.	20 atm.	30 atm.	40 atm.	50 atm.	60 atm.	T_c	P_c	Citation No.
NH_3	Ammonia	− 33.6	− 18.7	+ 4.7	25.7	50.1	66.1	78.9	89.3	98.3	132.4	111.5	(25, 26, 33, 49, 62, 82, 142, 175, 192, 223, 231, 279, 306, 334, 420)
A	Argon	−185.6	−179.0	−166.7	−154.9	−141.3	−132.0	−124.9	....	....	−122.0	48.0	(41, 83, 193, 229, 295, 329, 466)
BCl_3	Boron trichloride	12.7	33.2	66.0	96.7	135.4	161.5	....	....	....	178.8	38.2	(229, 308, 334, 430)
BF_3	Boron trifluoride	−100.7	− 89.4	− 72.6	− 57.7	− 40.0	− 28.4	− 19.0		....	− 12.2	49.2	(39, 118, 229, 319, 352)
Br_2	Bromine	58.2	78.8	110.3	139.8	174.0	197.0	216.0	230.0	243.5	302.2	121	(88, 102, 171, 203, 217, 229, 281, 331, 345, 381, 468, 487)
CCl_4	Carbontetrachloride	76.7	102.0	141.7	178.0	222.0	251.2	276.0	....	....	283.1	45.0	(104, 179, 279, 334, 335, 413, 495)
CO_2	Carbon dioxide	-78.2_s	-69.1_s	− 56.7	− 39.5	− 18.9	− 5.3	+ 5.9	14.9	22.4	31.1	73.0	(5, 46, 117, 172, 175, 211, 229, 272, 292, 302, 334, 420, 464, 467, 477, 497)
CS_2	Carbon disulfide	46.5	69.1	104.8	136.3	175.5	201.5	222.8	240.0	256.0	273.0	72.9	(175, 229, 265, 328, 331, 335, 420, 467, 490)
CO	Carbon monoxide	−191.3	−183.5	−170.7	−161.0	−149.7	−141.9	....		....	−138.7	34.6	(16, 67, 77, 78, 87, 229, 293, 465)
$COCl_2$	Carbonyl chloride	+ 8.3	27.3	57.2	85.0	119.0	141.8	159.8	174.0	....	181.7	56.0	(14, 135, 229, 288, 309)
$CClF_3$	Chlorotrifluoromethane	− 81.2	− 66.7	− 42.7	− 18.5	+ 12.0	34.8	52.8	....	....	53	40.3	(102, 447)
C_2N_2	Cyanogen	− 21.0	− 4.4	+ 21.4	44.6	72.6	91.6	106.5	118.2	....	126.6	58.2	(74, 88, 102, 118, 313, 444)
CCl_2F_2	Dichlorodifluoromethane	− 29.8	− 12.2	+ 16.1	42.4	74.0	95.6	....	....	....	111.5	39.6	(102, 144)
$CHCl_2F$	Dichlorofluoromethane	8.9	28.4	59.0	87.0	121.2	144.0	162.6	177.5	....	178.5	51.0	(233)
$CHClF_2$	Chlorodifluoromethane	− 40.8	− 24.7	+ 0.3	24.0	52.0	70.3	85.3	....	....	96.0	48.7	(40, 233)
CCl_3F	Trichlorofluoromethane	23.7	44.1	77.3	108.2	146.7	172.0	194.0		....	198.0	43.2	(233)
Cl_2	Chlorine	− 33.8	− 16.9	+ 10.3	35.6	65.0	84.8	101.6	115.2	127.1	144.0	76.1	(139, 166, 171, 214, 229, 239, 312, 452)
He	Helium	−268.6	−268.0	....	....	....	....	....	....	....	−267.9	2.26	(227, 228, 229, 300, 301)
H_2	Hydrogen	−252.5	−250.2	−246.0	−241.8	....	....	....	....	....	−240.0	12.80	(58, 71, 173, 225, 229, 298, 299, 396, 454, 455)
HBr	Hydrogen bromide	− 66.5	− 51.5	− 29.1	− 8.4	+ 16.8	33.9	48.1	60.0	70.6	90.0	84.4	(18, 103, 169, 229, 415, 416)
HCl	Hydrogen chloride	− 84.8	− 71.4	− 50.5	− 31.7	− 8.8	+ 5.9	17.8	27.9	36.2	51.4	81.6	(50, 69, 103, 118, 141, 169, 176, 223, 229, 416, 420)
HCN	Hydrogen cyanide	25.9	45.8	75.8	102.7	135.0	153.8	169.9	183.5	....	183.5	50.0	(44, 164, 229, 258, 314, 397, 401)
HI	Hydrogen iodide	− 35.1	− 18.9	+ 7.3	32.0	62.2	83.2	100.7	116.2	127.5	151.0	82.0	(103, 169, 229, 415, 416)
H_2S	Hydrogen sulfide	− 60.4	− 45.9	− 22.3	− 0.4	+ 25.5	41.9	55.8	66.7	76.3	100.3	88.9	(118, 137, 229, 235, 236, 292, 334, 415, 416)
H_2Se	Hydrogen selenide	− 41.1	− 25.2	0.0	+ 23.4	50.8	69.7	84.6	97.2	108.7	137	91.0	(57, 90, 91, 229, 292, 417)
Kr	Krypton	−152.0	−143.5	−130.0	−118.0	−101.7	− 88.8	−78.4	− 66.5	...	− 63	54	(3, 221, 229, 315, 317, 329)
Ne	Neon	−246.0	−243.8	−239.9	−236.0	−230.8	....	....	....	....	−228.3	26.9	(71, 229, 297, 455)
N_2	Nitrogen	−195.8	−189.2	−179.1	−169.8	−157.6	−148.3	....		....	−147.2	33.5	(15, 70, 86, 100, 123, 158, 173, 174, 193, 229, 292, 321, 463, 467, 489)
NO	Nitric oxide	−151.7	−145.1	−135.7	−127.3	−116.8	−109.0	−103.2	99.0	94.8	− 92.9	64.6	(1, 148, 170, 216, 229, 279, 292, 294)
N_2O	Nitrous oxide	− 88.5	− 76.8	− 58.0	− 40.7	− 18.8	4.3	+ 8.0	18.0	27.4	36.5	71.7	(29, 32, 53, 62, 116, 188, 229, 247, 327, 484)
N_2O_4	Nitrogen tetroxide	21.0	37.3	59.8	79.4	100.3	112.3	121.[illegible]	127.0	132.2	158	99	(19, 108, 138, 223, 275, 317, 332, 374, 380, 485)
O_2	Oxygen	−183.1	−176.0	−164.5	−153.2	−140.0	−130.7	−124		....	−118.9	49.7	(15, 28, 58, 76, 86, 100, 114, 172, 174, 226, 229, 291, 296, 420, 456, 467, 488)
SiF_4	Silicon tetrafluoride	-94.8_s	− 84.4	− 67.9	− 52.6	− 33.4	− 21.2			...	− 14.2	36.7	(40, 229, 310, 347)
$SiClF_3$	Chlorotrifluorosilane	− 70.0	− 57.3	− 37.2	− 18.6	+ 4.1	19.4		...	....	34.8	34.2	(40, 229, 398)
$SiCl_2F_2$	Dichlorodifluorosilane	− 31.8	− 15.1	+ 11.8	36.6	66.2	86.0		...	....	95.8	34.5	(40, 229, 398)
$SiCl_3F$	Fluorotrichlorosilane	12.2	32.4	64.6	94.2	131.8	156.0		...	....	165.3	35.3	(40)
$SnCl_4$	Stannic chloride	113.0	141.3	184.3	223.0	270.0	299.8			....	318.7	37.9	(229, 279, 481, 494, 496)
SO_2	Sulfur dioxide	− 10.0	+ 6.3	32.1	55.5	83.8	102.6	118.[illegible]	130.2	141.7	157.2	77.7	(25, 33, 51, 65, 68, 140, 142, 175, 228, 261, 280, 334, 335, 415, 420)
SO_3	Sulfur trioxide	44.8	60.0	82.5	104.0	138.0	157.8	175.0	187.8	198.0	218.3	83.6	(27, 131, 229, 411, 412)
H_2O	Water	100.0	120.1	152.4	180.5	213.1	234.6	251.1	264.7	276.5	374.2	218.0	(81, 95, 104, 121, 189, 190, 217, 222, 225, 232, 303, 304, 378, [illegible], 404, 478, 481)

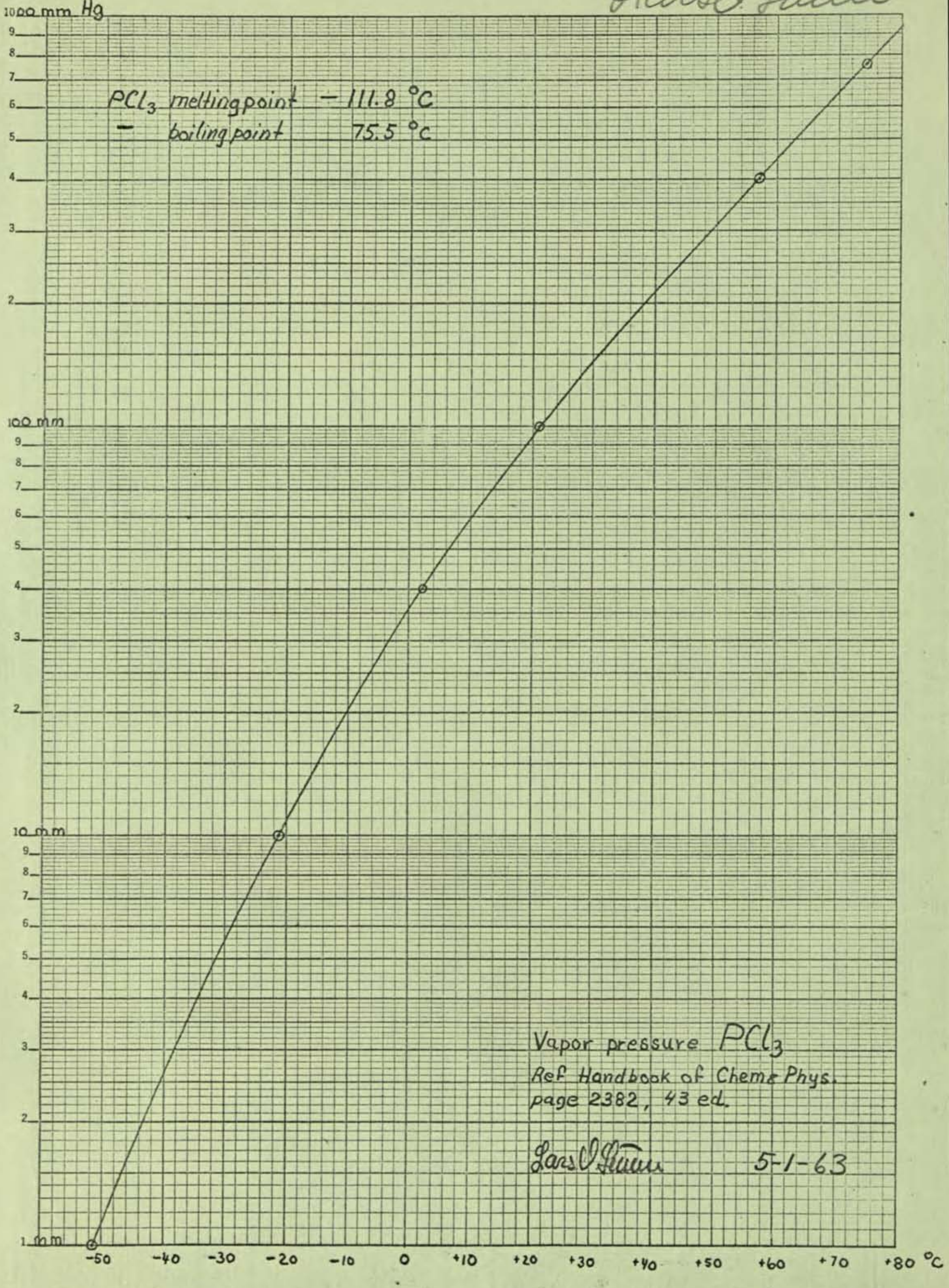


Vapor pressure of SbCl$_3$ & SbCl$_5$
Ind. & Eng. Chem. Vol 39 No 4

L. Lunn
Oct. 1963


mm Hg
Vapor Pressure, mm Hg, SiCl4
10000
9
8
7
6
5
4
3
2
1000
900
800
700
600
500
400
300
200
100
90
80
70
60
50
40
30
20
10.0
9
8
7
6
5
4
3
2
1.0
-60
-50
-40
-30
-20
-10
0°C
10
20
30
40
50
+60
°C →

Lars O [illegible]



PCl_3 meltingpoint -111.8 °C
– boiling point 75.5 °C

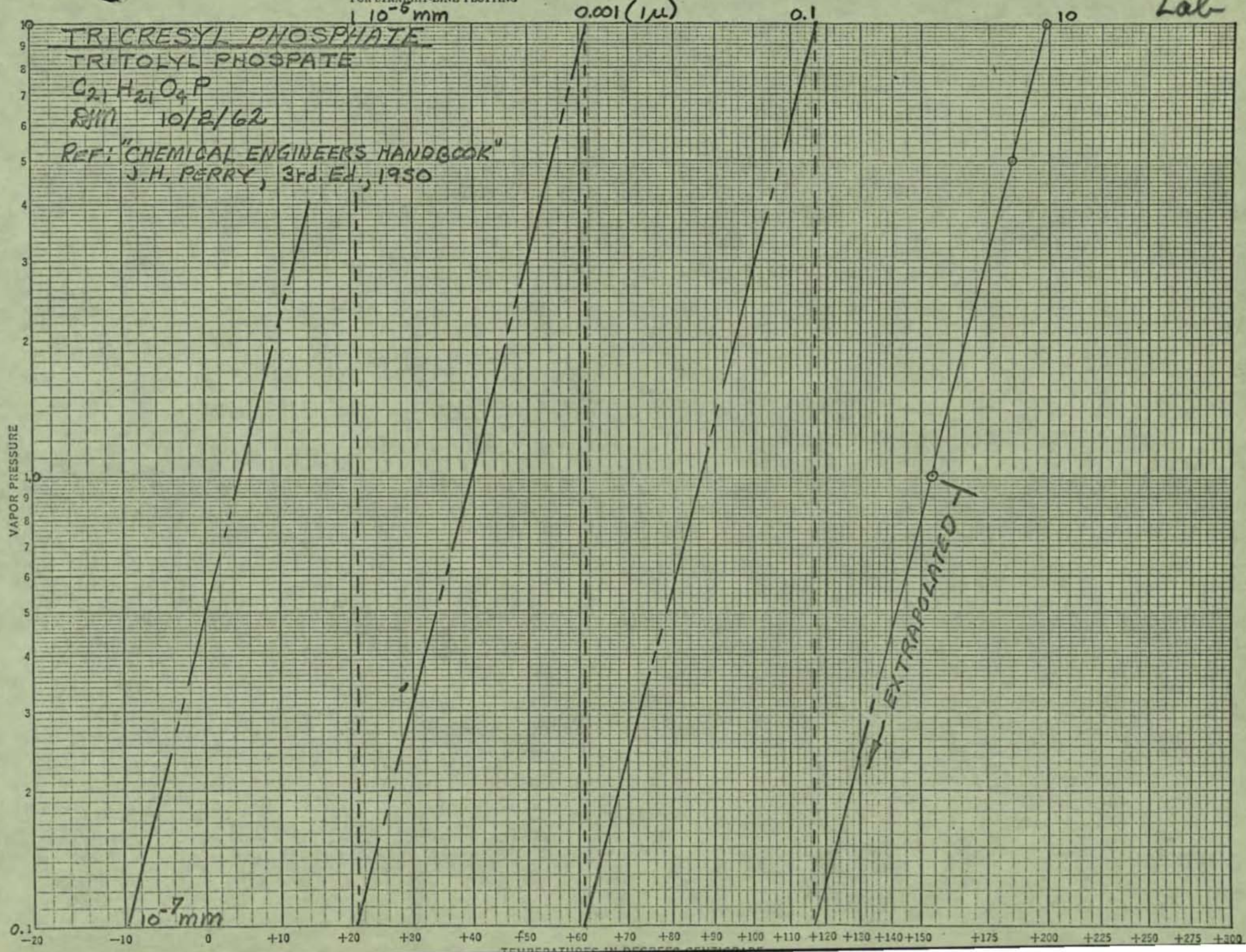
Vapor pressure PCl_3
Ref Handbook of Chem & Phys.
page 2382, 43 ed.

Lars O [illegible] 5-1-63

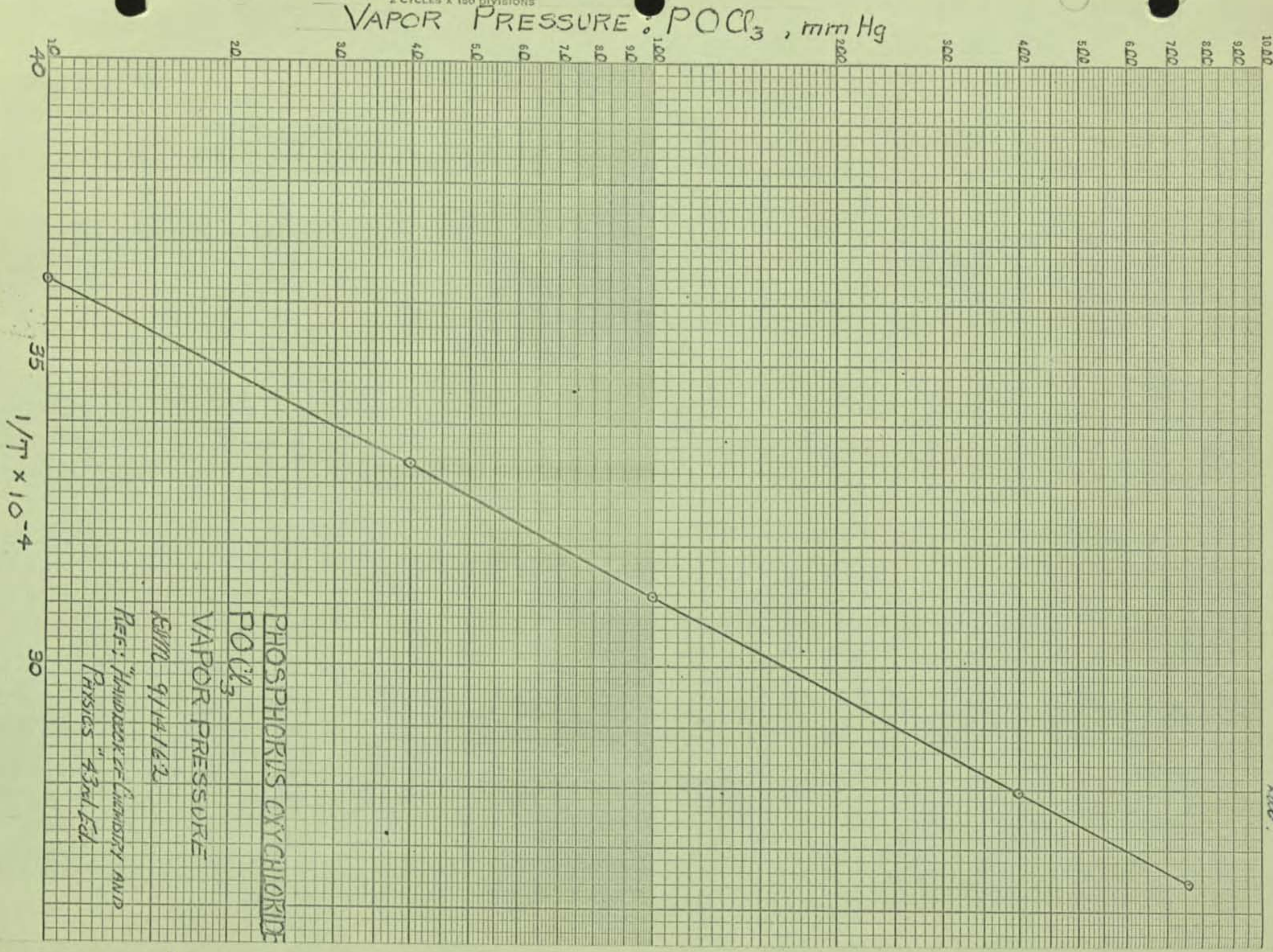
K&E CO., N.Y. 14035
Original Job 41963

VAPOR PRESSURE × TEMPERATURE
Log P. (2 Cycle) × 1/(t°C.+230°)
FOR STRAIGHT-LINE PLOTTING

Lab

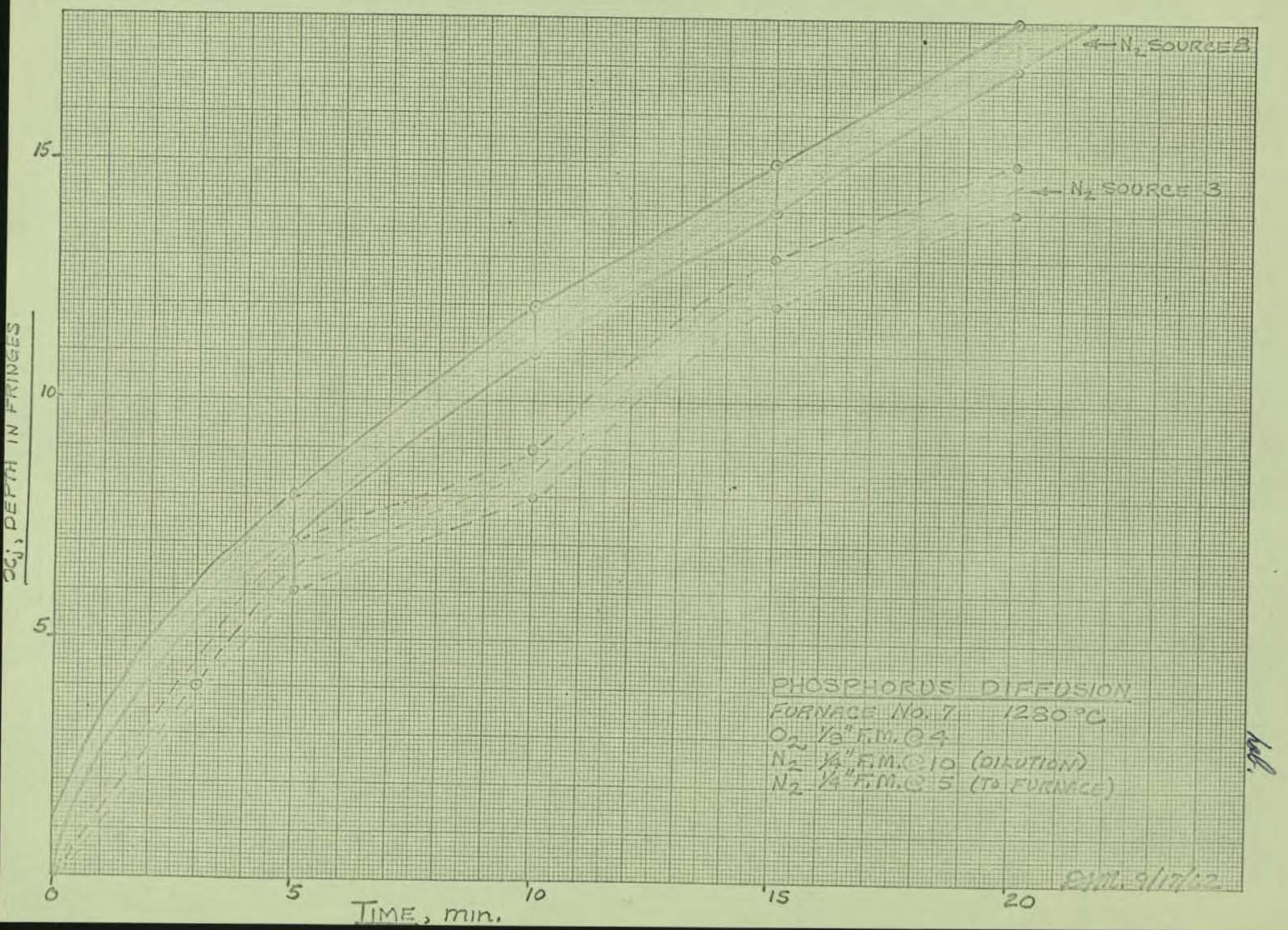


TRICRESYL PHOSPHATE
TRITOLYL PHOSPATE
$C_{21}H_{21}O_4P$
RHM 10/2/62
REF: "CHEMICAL ENGINEERS HANDBOOK"
J.H. PERRY, 3rd. Ed., 1950



PHOSPHORUS OXYCHLORIDE
$POCl_3$
VAPOR PRESSURE
EWM 9/14/62
REF: "HANDBOOK OF CHEMISTRY AND PHYSICS" 43rd Ed.

ia8.

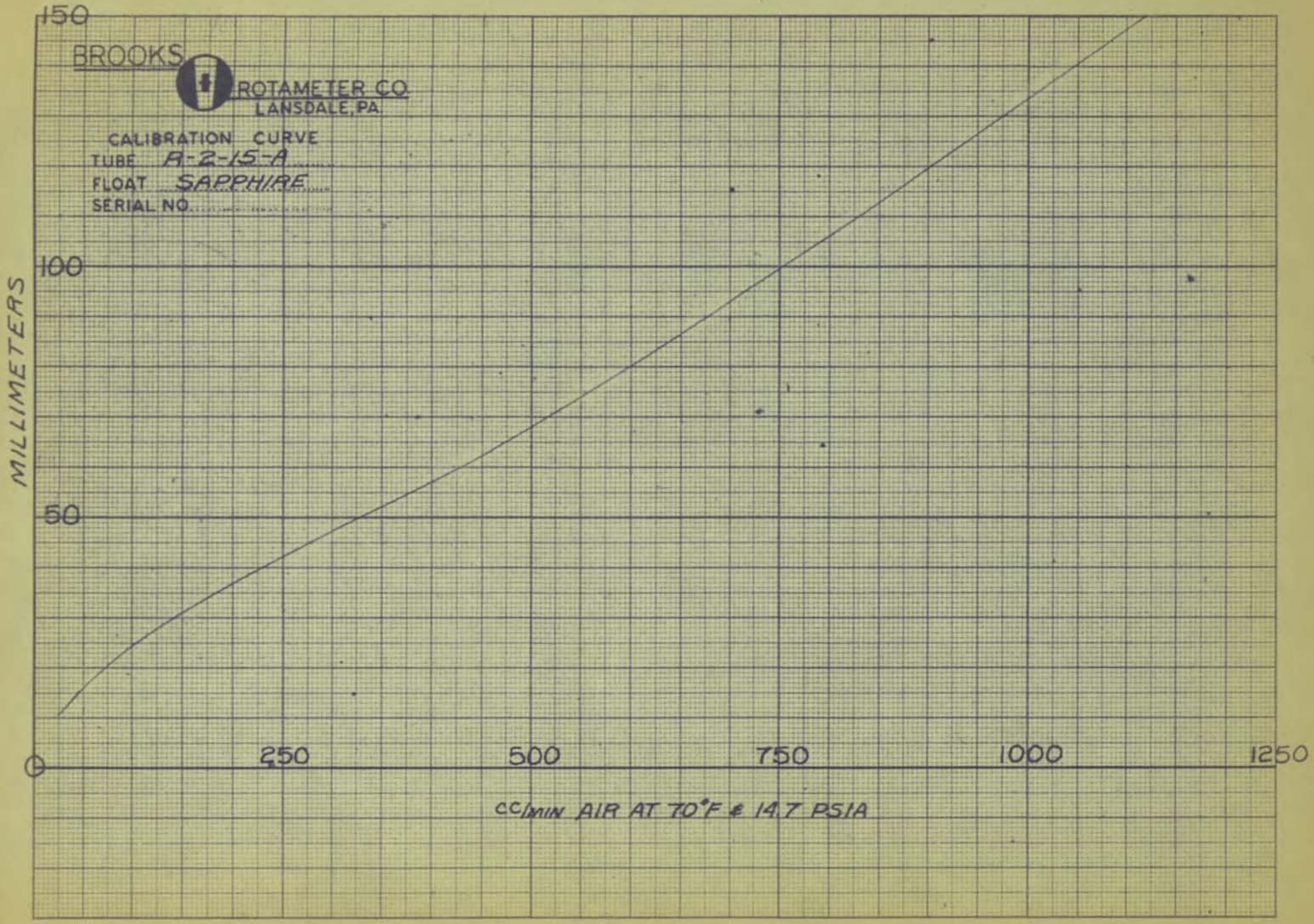

← N_2 SOURCE 8
← N_2 SOURCE 3
PHOSPHORUS DIFFUSION
FURNACE No. 7 1280°C
O_2 1/8" F.M. @ 4
N_2 1/4" F.M. @ 10 (DILUTION)
N_2 1/4" F.M. @ 5 (TO FURNACE)
x_j, DEPTH IN FRINGES
15
10
5
0
5
10
15
20
TIME, min.
R.M.M. 9/17/62

FLOW METERS

CALIBRATION CHART

cc/min AIR METERED AT 14.7 psia & 70 F

	1/2"		1/4"			1/8"			1/16"					
	ALL TUBES		ALL TUBES			ALL TUBES			-20-, -16-, -12-			-10-, -08-		
SC[illegible] READING	STN STL (17360)	GLASS (9340)	TANTALUM (8940)	STN STL (6160)	GLASS (3292)	TANTALUM (3165)	STN STL (2180)	SAPPHIRE (1550)	TANTALUM (1117)	STN STL (772)	SAPPHIRE (549)	TANTALUM (1117)	STN STL (772)	SAPPHI (549)
25	143500	73600	35200	23400	11750	5580	3660	2480						
20	112700	57900	27600	18400	9100	4325	2860	1910	681	426	271			
18	99600	51200	24450	16250	8050	3820	2510	1670	596	370	234			
16	87000	44500	21160	14100	6950	3270	2120	1420	510	315	196			
14	75000	38200	18200	12000	5900	2785	1790	1190	420	260	159			
12	62500	31700	15100	10000	4850	2292	1470	960	332	206	122			
10	50900	25700	12250	8050	3850	1835	1156	741	258	154	88	240	136	75
8	39100	19750	9360	6050	2860	1341	840	525	189.5	104	57	159	83.3	43.5
7	33600	16780	7990	5100	2370	1133	687	425	149	80	43	118.5	60	31
6	28300	14000	6660	4175	1900	900	538	325	116.1	57	31	82.5	41	20.7
5	23380	11050	5270	3320	1440	682	397	233	81.2	39	21	52	25.3	13
4	17670	8200	3880	2460	1010	472.5	263	147.5	50.75	25	13.5	29.8	13.5	7
3	12950	5700	2697	1650	600	279.7	145	75	30.1	14	7.5	7.64	5.3	2.75
2	8190	3405	1598	880	270	125.5	60	30	15.6	7	3.5		0.4	0.3

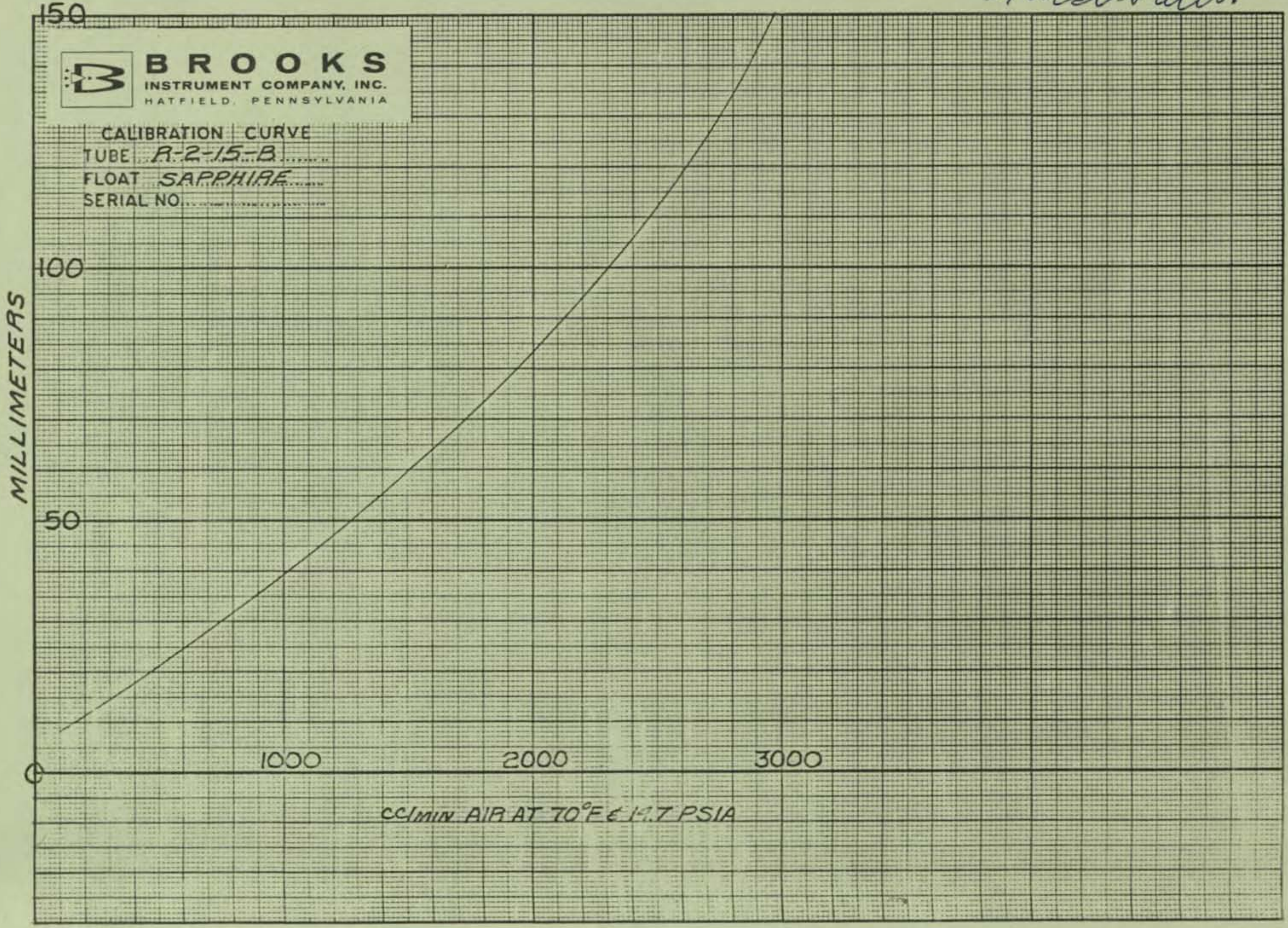


BROOKS ROTAMETER CO.
LANSDALE, PA

CALIBRATION CURVE
TUBE R-2-15-A
FLOAT SAPPHIRE
SERIAL NO.

5-18-60

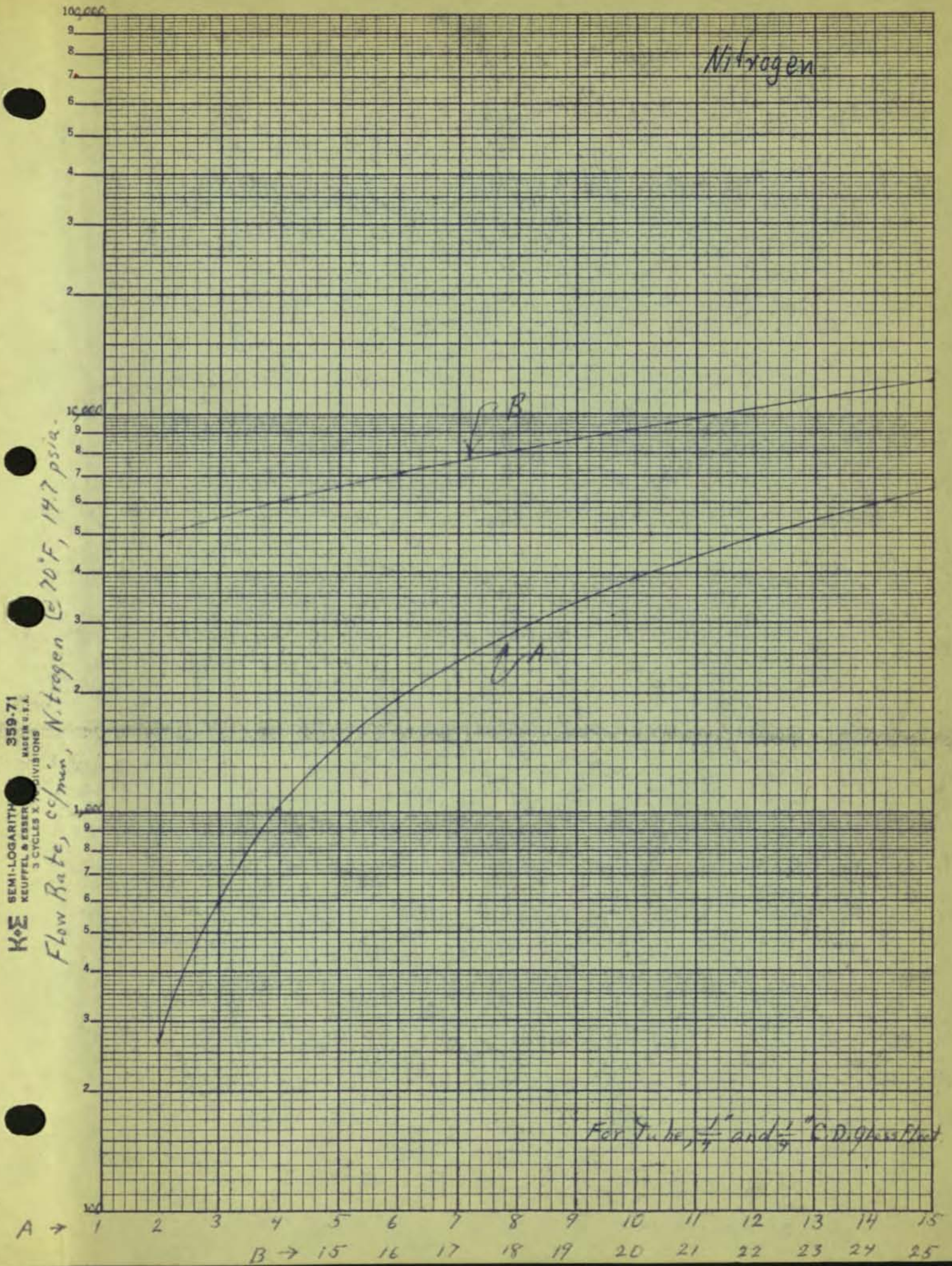
Alloy Furnace proces 216.

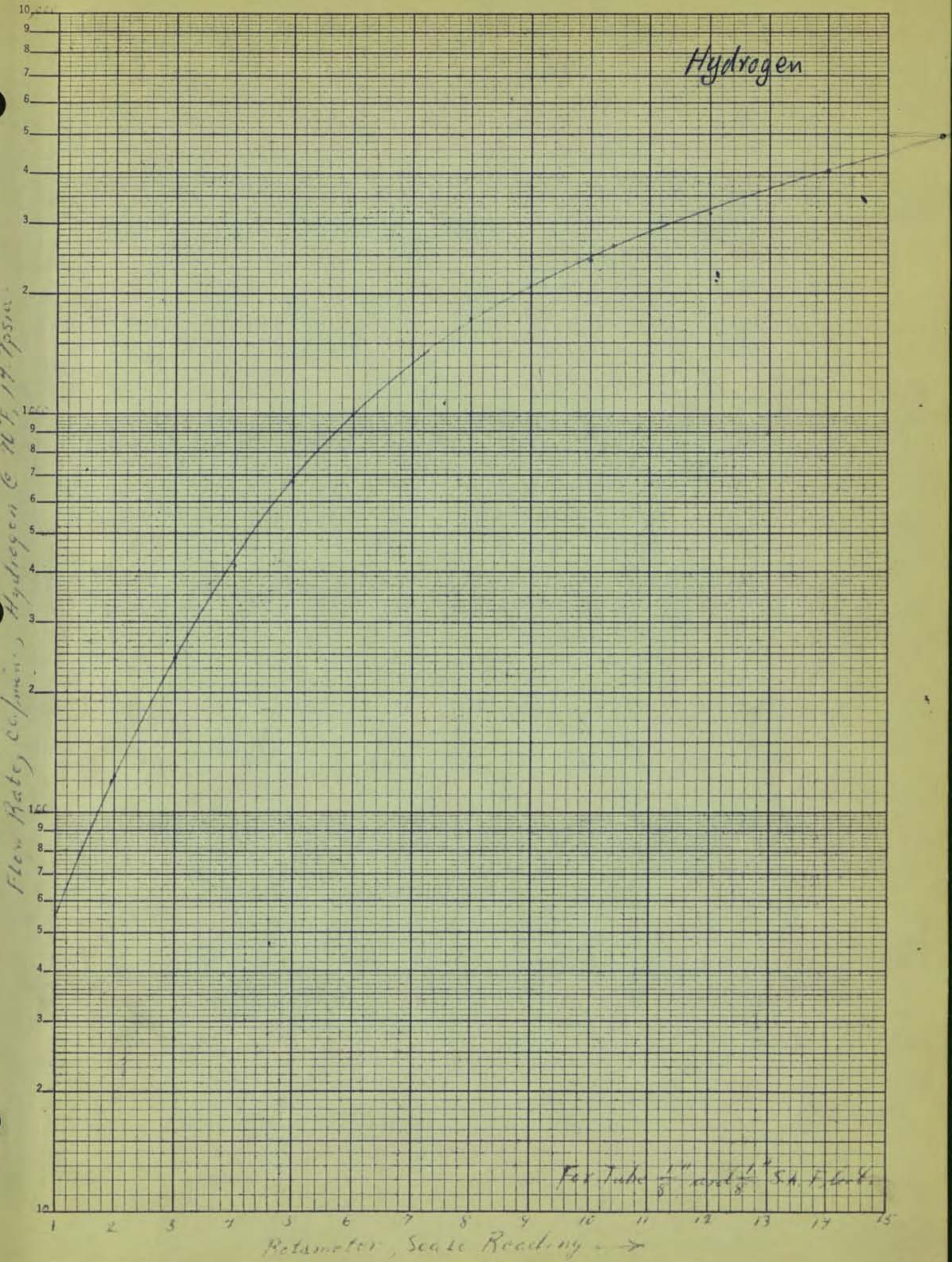


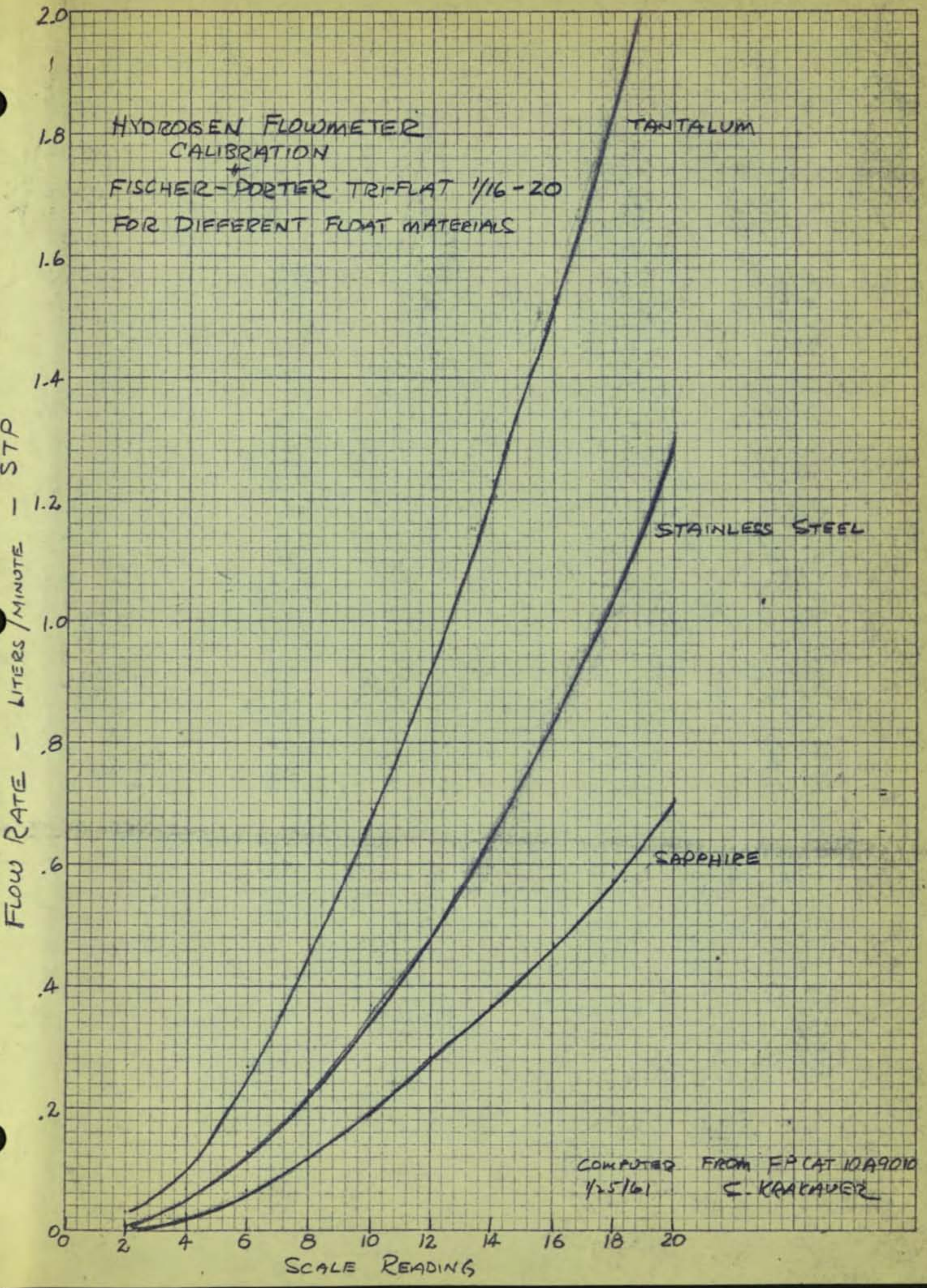
BROOKS
INSTRUMENT COMPANY, INC.
HATFIELD, PENNSYLVANIA

CALIBRATION CURVE
TUBE R-2-15-B
FLOAT SAPPHIRE
SERIAL NO.

5-1960


Nitrogen
Flow Rate, cc/min, Nitrogen @ 70°F, 14.7 psia.
100,000
9
8
7
6
5
4
3
2
10,000
1,000
100
B
A
For Tube, 1/4" and 1/4" C.D. Glass Float
A → 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
B → 15 16 17 18 19 20 21 22 23 24 25
K+E SEMI-LOGARITHMIC 359-71
KEUFFEL & ESSER CO. MADE IN U.S.A.
3 CYCLES X 70 DIVISIONS


Hydrogen
Flow Rate, cc/min., Hydrogen @ 70°F, 14.7 psia
10,000
9
8
7
6
5
4
3
2
1000
9
8
7
6
5
4
3
2
100
9
8
7
6
5
4
3
2
10
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
Rotameter, Scale Reading →
For Tube 1/5" and 1/8" S.S. F. [illegible]

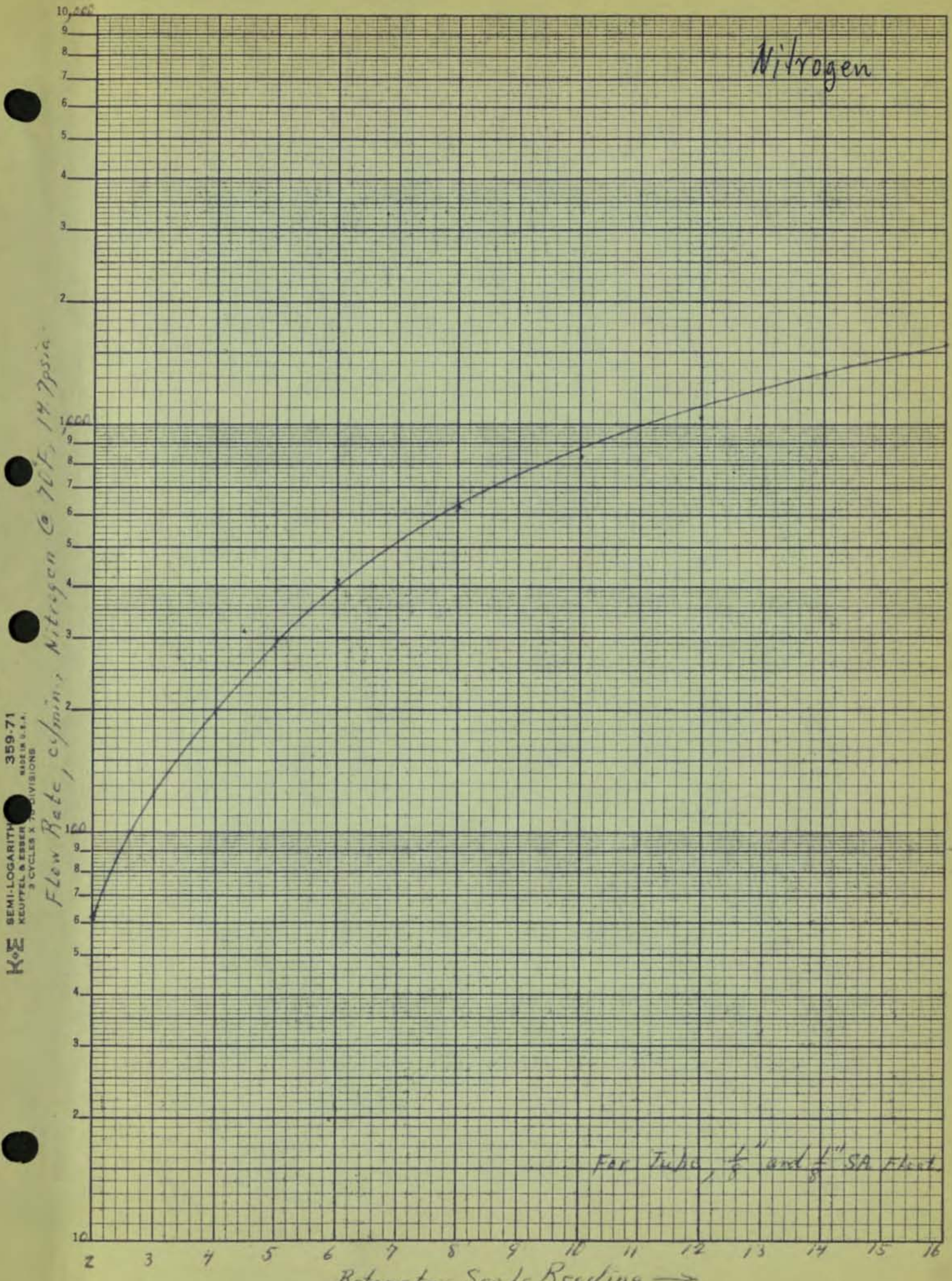

HYDROGEN FLOWMETER CALIBRATION

FISCHER-PORTER TRI-FLAT 1/16-20

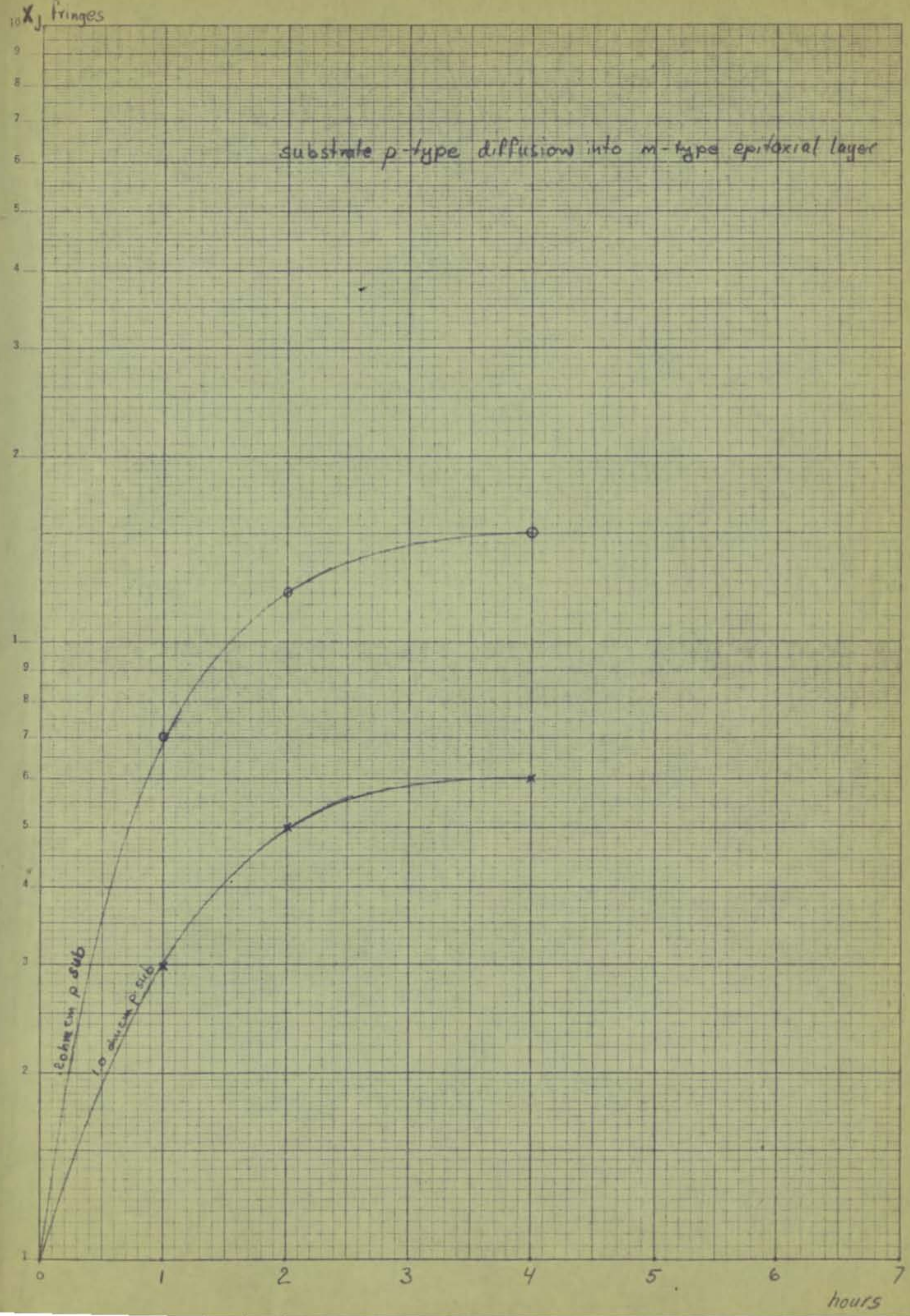
FOR DIFFERENT FLOAT MATERIALS

COMPUTED FROM FP CAT 10A9010

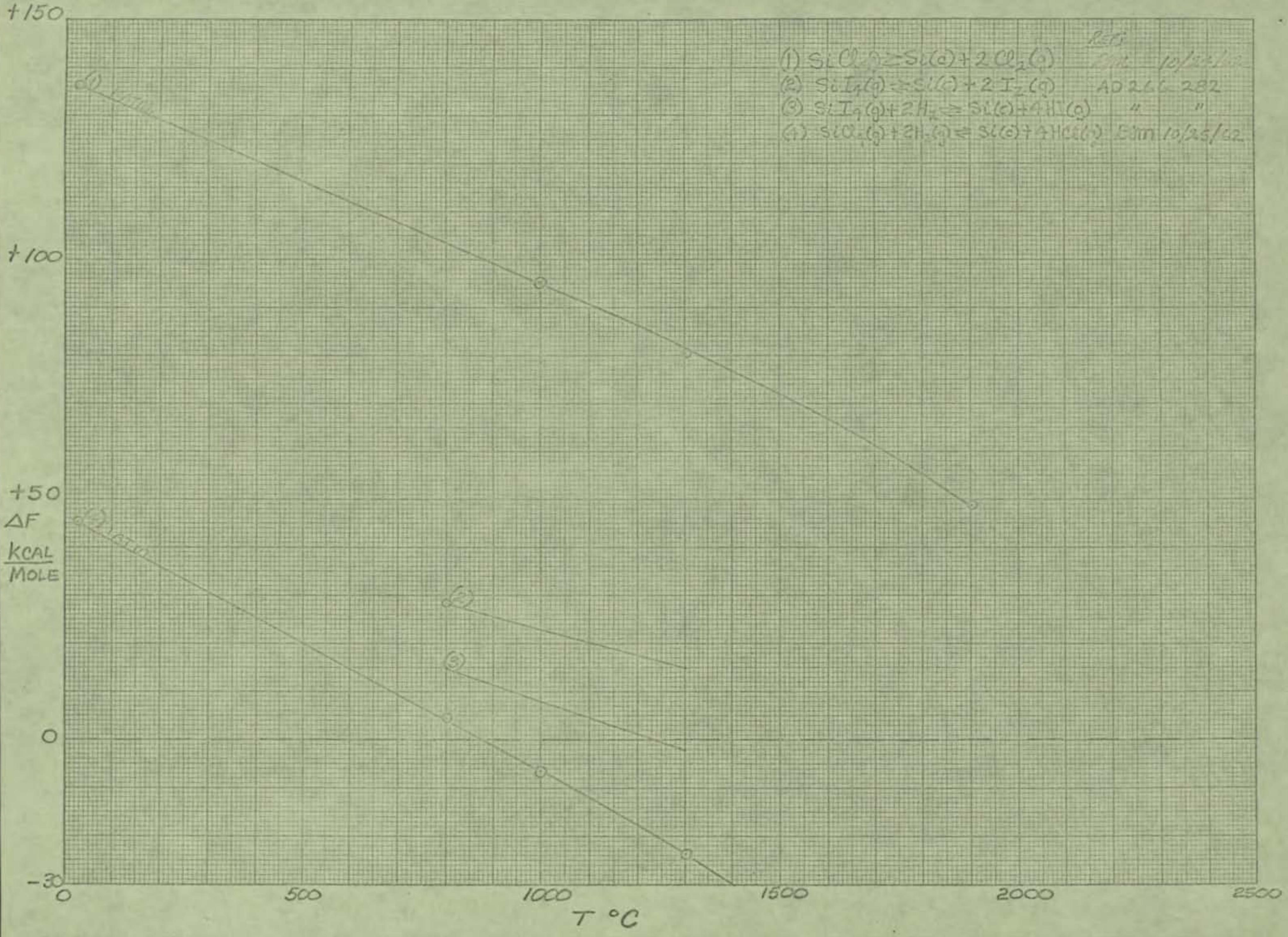
1/25/61 C. KRAKAUER

Nitrogen
Flow Rate, cc/min, Nitrogen @ 70°F, 14.7 psia
10,000
9
8
7
6
5
4
3
2
1000
9
8
7
6
5
4
3
2
100
9
8
7
6
5
4
3
2
10
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
Rotameter Scale Reading →
For Tube, 1/8" and 1/8" SA Float
K&E SEMI-LOGARITHMIC 359-71
KEUFFEL & ESSER MADE IN U.S.A.
3 CYCLES X 70 DIVISIONS

EPITAXY



substrate p-type diffusion into n-type epitaxial layer


(1) $SiCl_4(g) \rightleftarrows Si(c) + 2\,Cl_2(g)$
(2) $SiI_4(g) \rightleftarrows Si(c) + 2\,I_2(g)$
(3) $SiI_4(g) + 2H_2 \rightleftarrows Si(c) + 4HI(g)$
(4) $SiCl_4(g) + 2H_2(g) \rightleftarrows Si(c) + 4HCl(g)$
Ref.
Eim 10/25/62
AD 266 282
"
"
Eim 10/25/62
+150
+100
+50
ΔF
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−30
0
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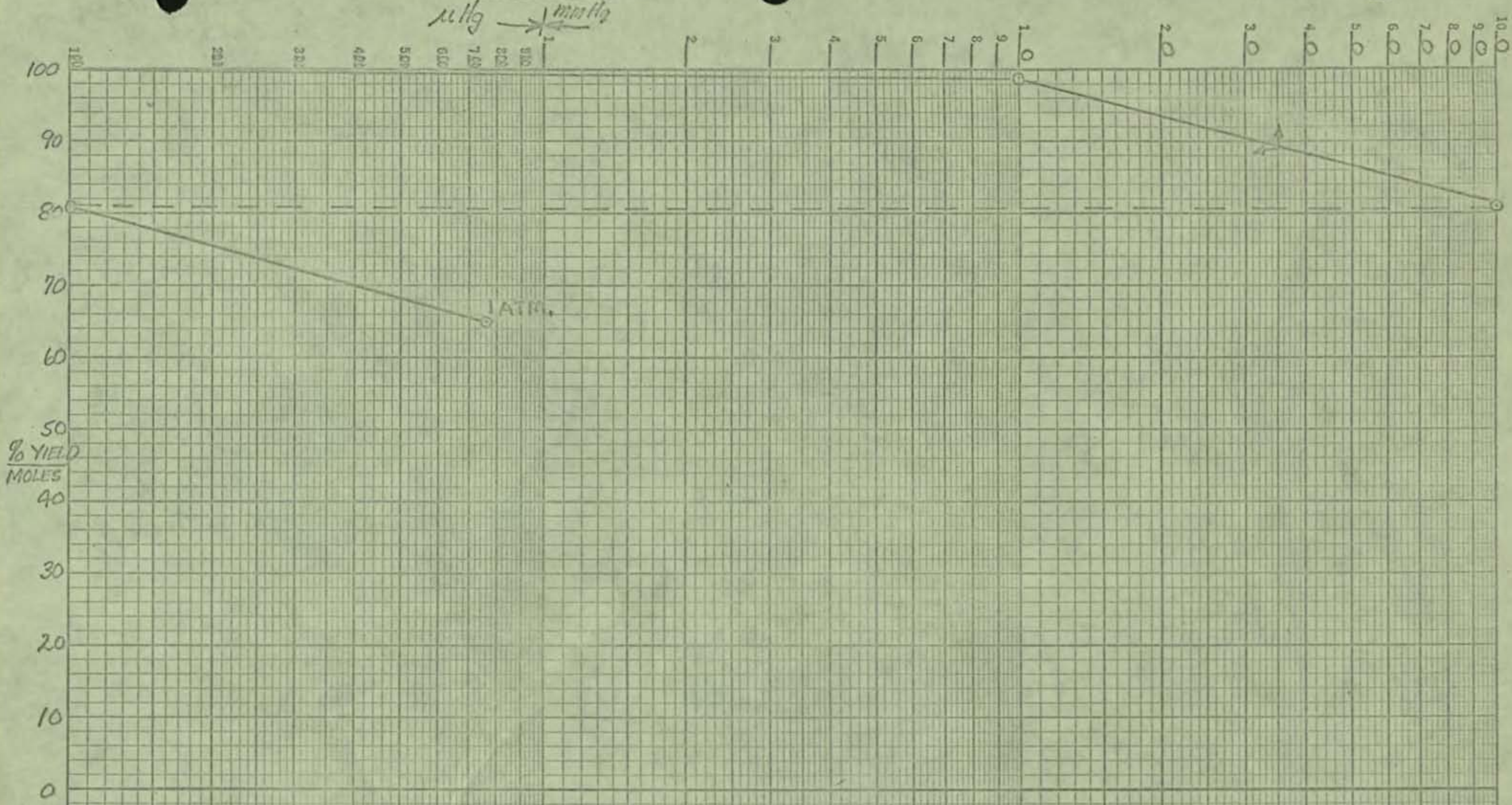
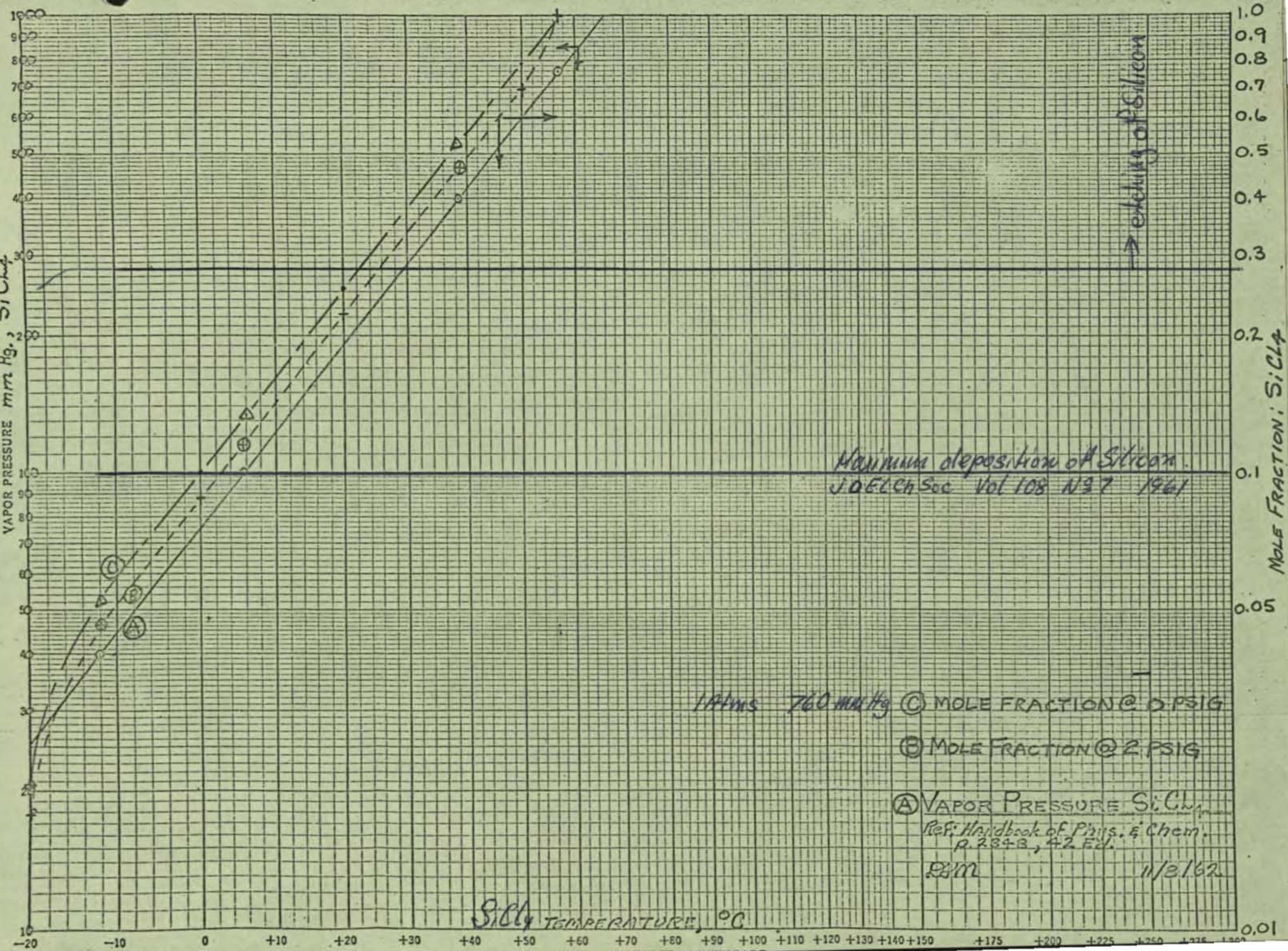
1000
1500
2000
2500
T °C
(1)
(4)
(2)
(3)



MOLE % YIELD OF Si AT 1000°C
VS. TOTAL PRESSURE.
STOCHIOMETRIC STARTING RATIO
FOR $SiCl_4(g) + 2H_2(g) \rightarrow Si(s) + 4HCl(g)$
RAM 10/25/62

..N.Y. 10035
inal Job 41963

VAPOR PRESSURE × TEMPERATURE
Log P. (2 Cycle) × y(t°C.+230°)
FOR STRAIGHT-LINE PLOTTING



1Atms 760 mm Hg Ⓒ MOLE FRACTION @ 0 PSIG

Ⓑ MOLE FRACTION @ 2 PSIG

Ⓐ VAPOR PRESSURE SiCl4

Ref: Handbook of Phys. & Chem. p. 2343, 42 Ed.

LBM 11/8/62

ALLOYING

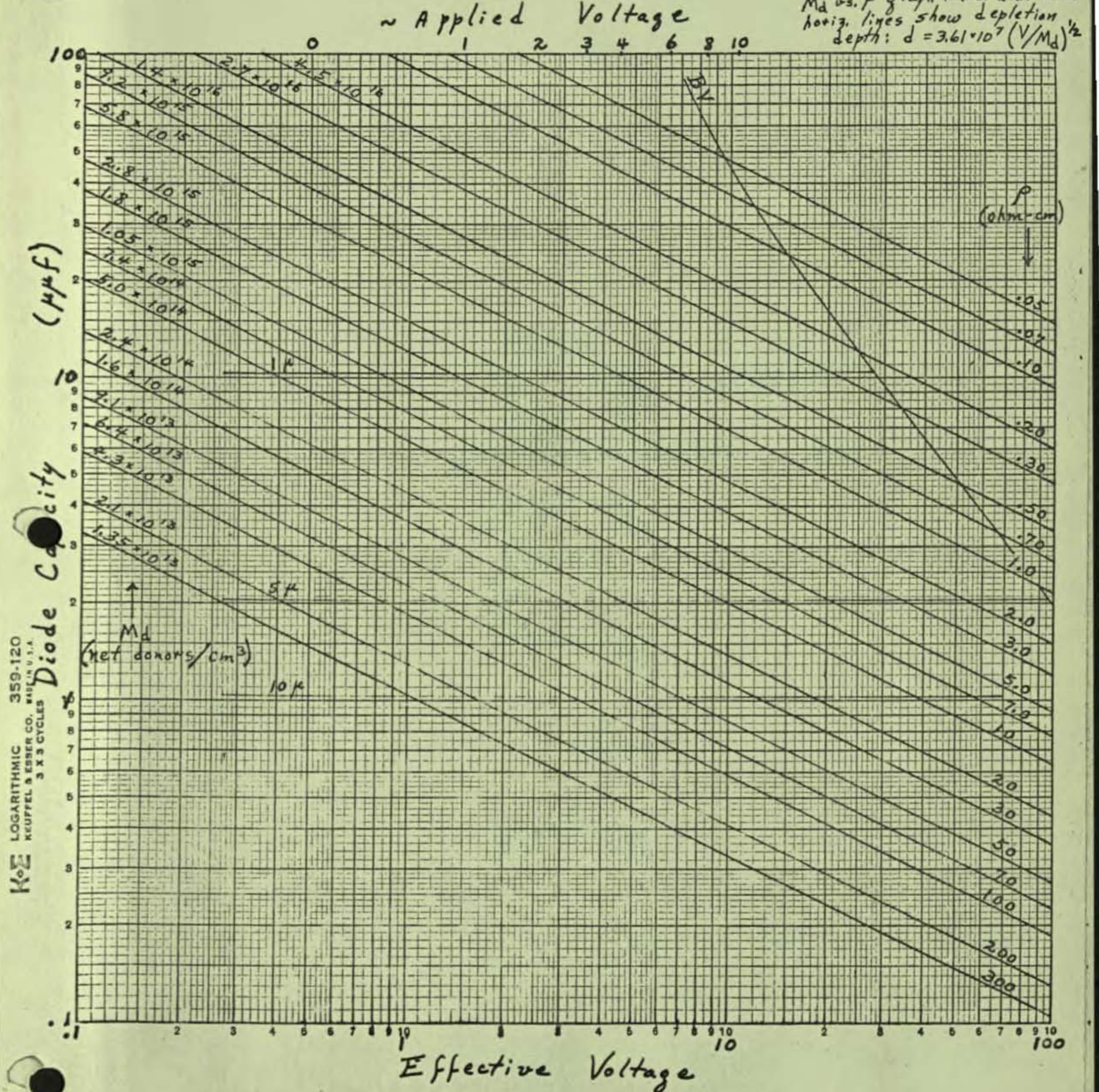
Junction Capacity vs. Voltage for Various Resistivities of n-type Si alloyed devices

$C^2 = 7.995 \times 10^{-14} M_d/V$

for diode area $= .0995\,mm^2$

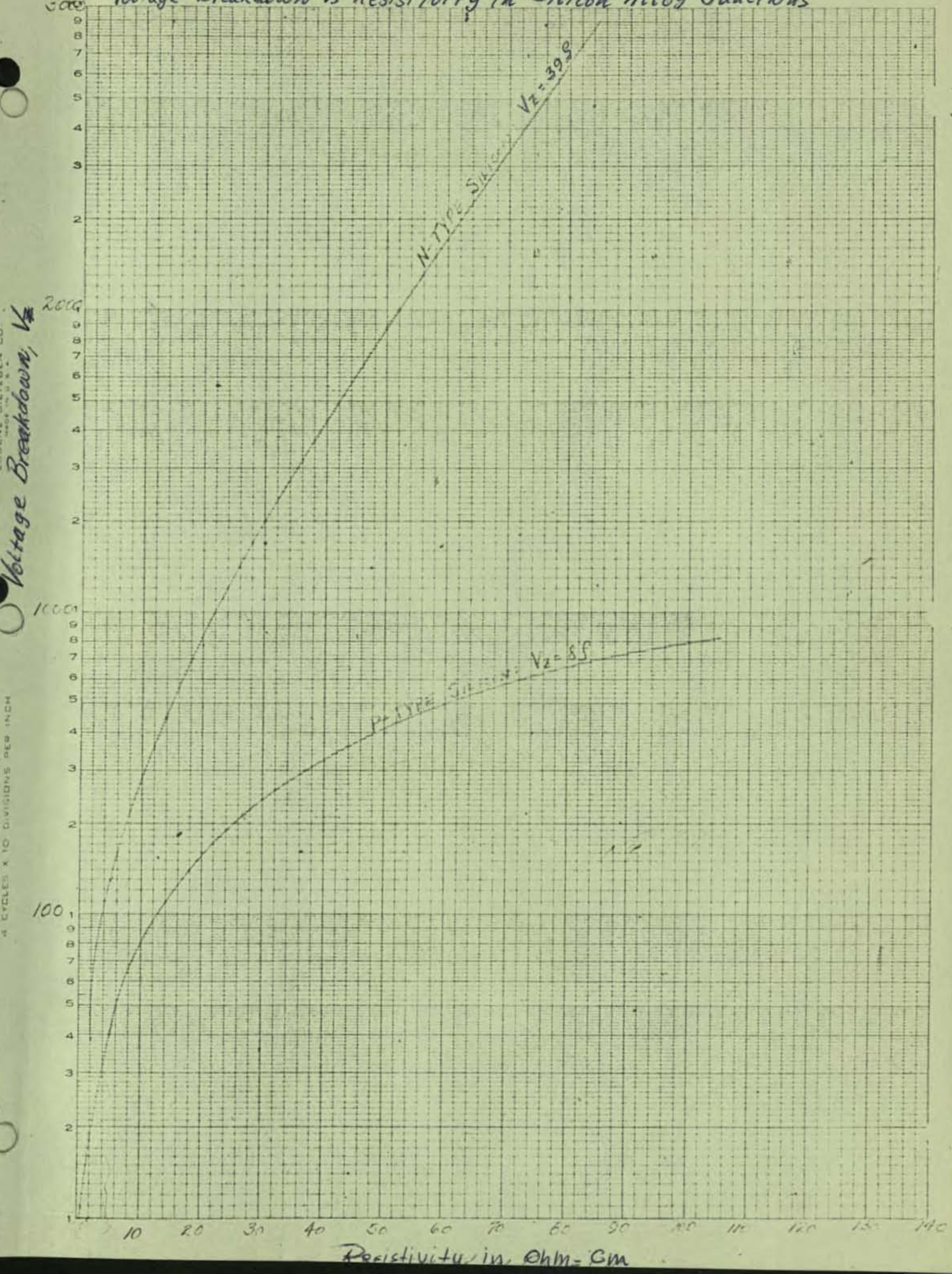
M_d vs. ρ graph 1-9-61 WRL used

horiz. lines show depletion depth: $d = 3.61 \times 10^7 (V/M_d)^{1/2}$

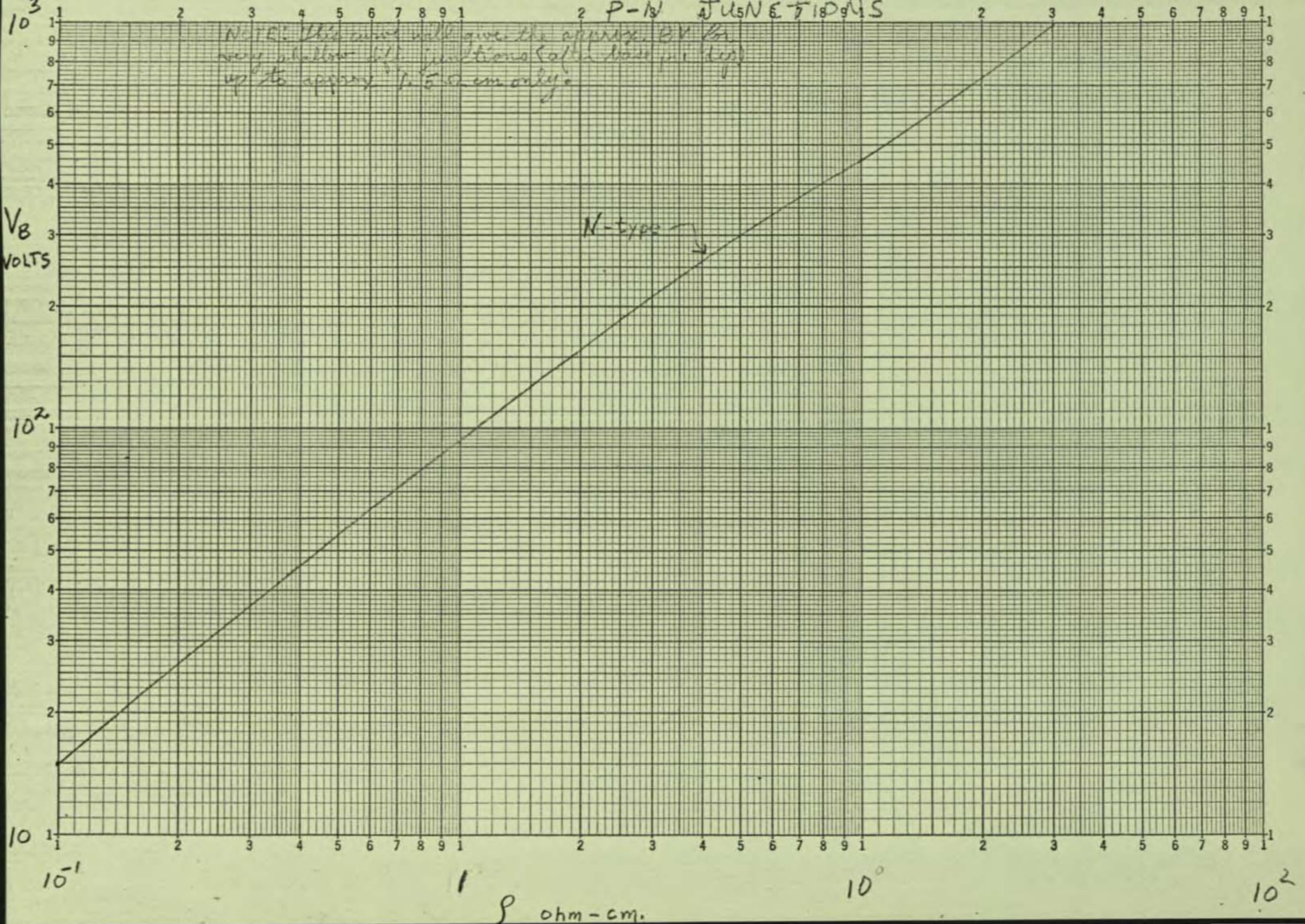


1-10-61

Voltage Breakdown Vs Resistivity in Silicon Alloy Junctions



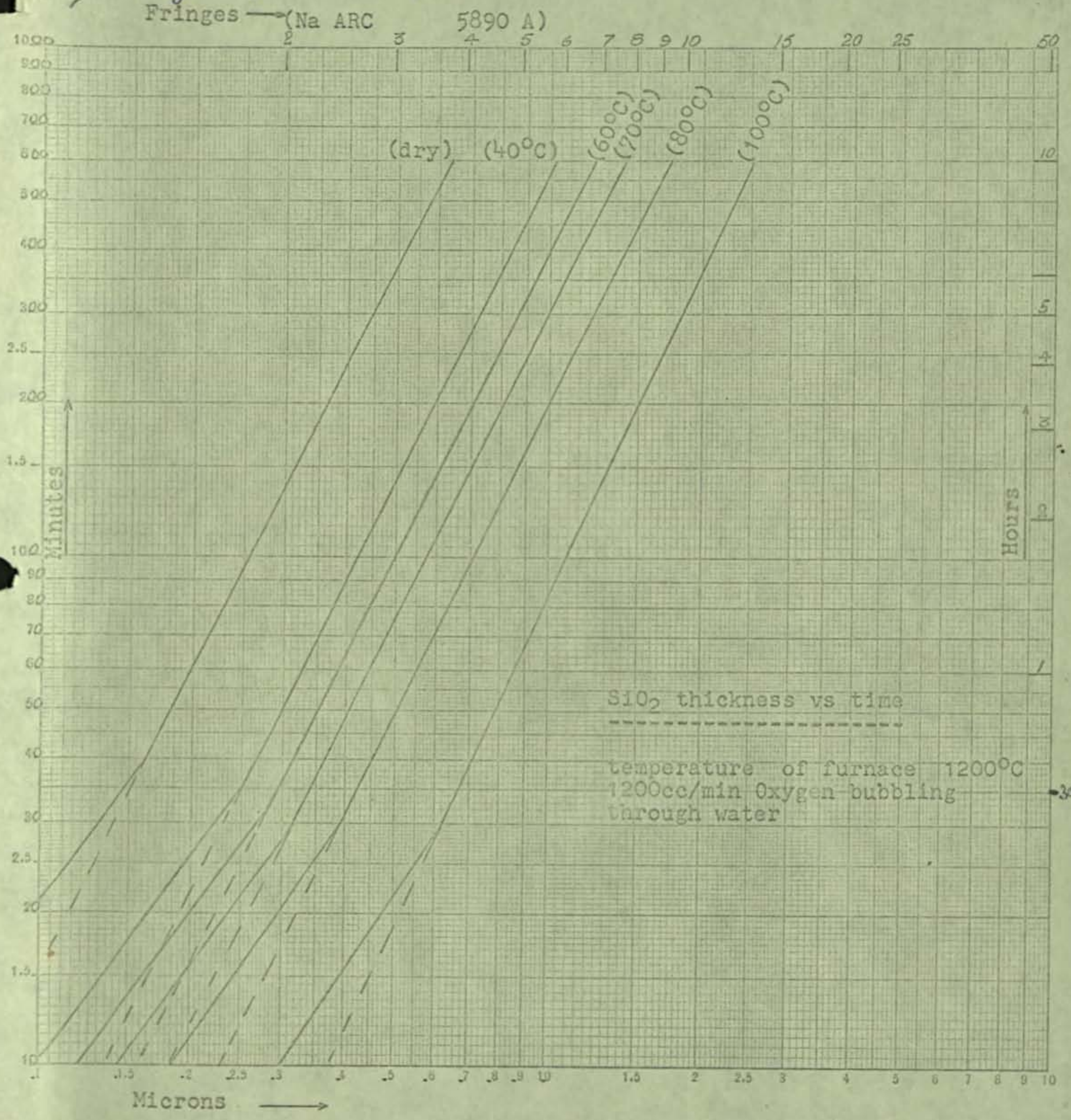
BREAKDOWN FOR ALLOY SILICON P-N JUNCTIONS



OXIDATION

Lars O.

2. only through Oxide layer.

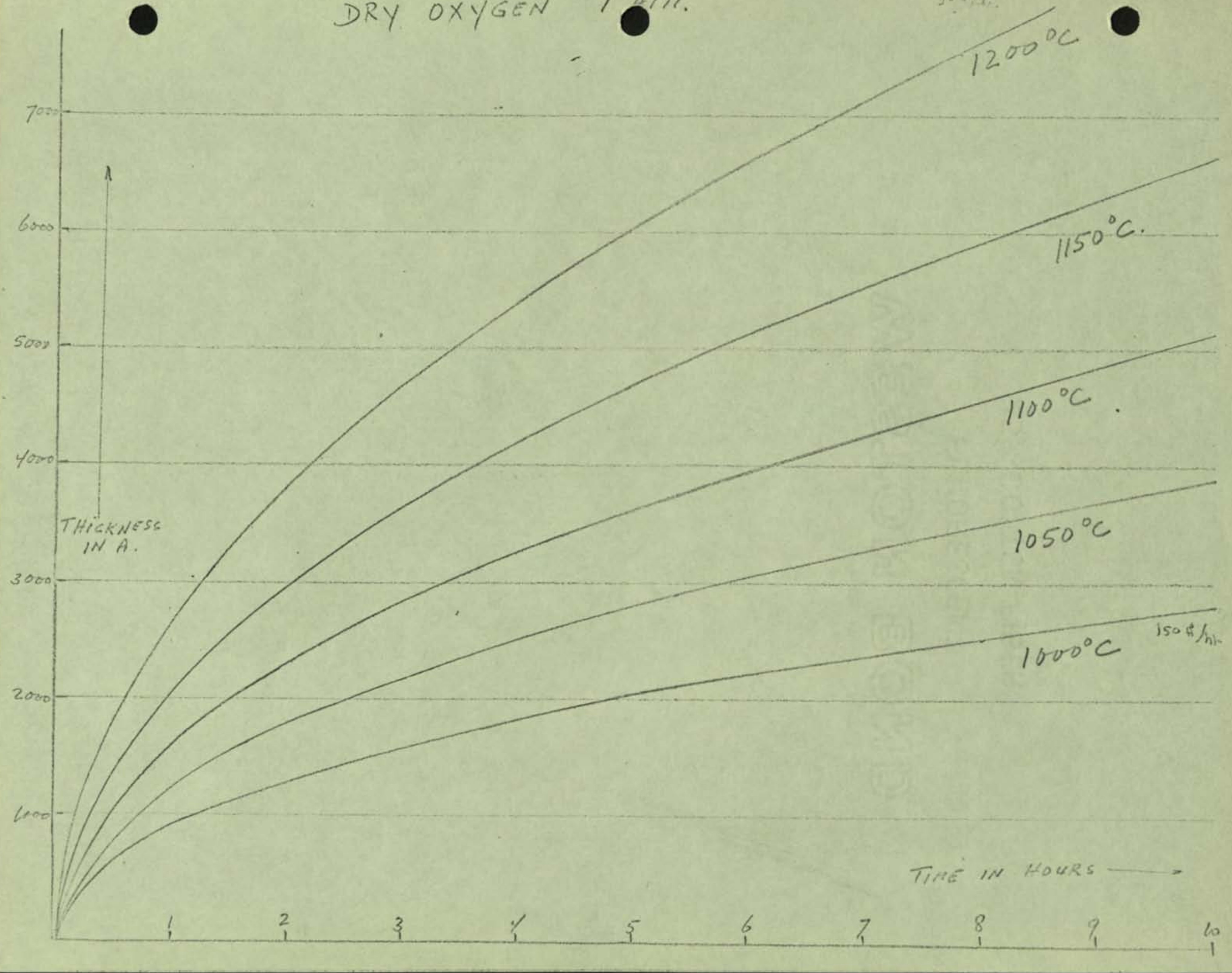


SiO$_2$ thickness vs time

temperature of furnace 1200°C
1200cc/min Oxygen bubbling
through water

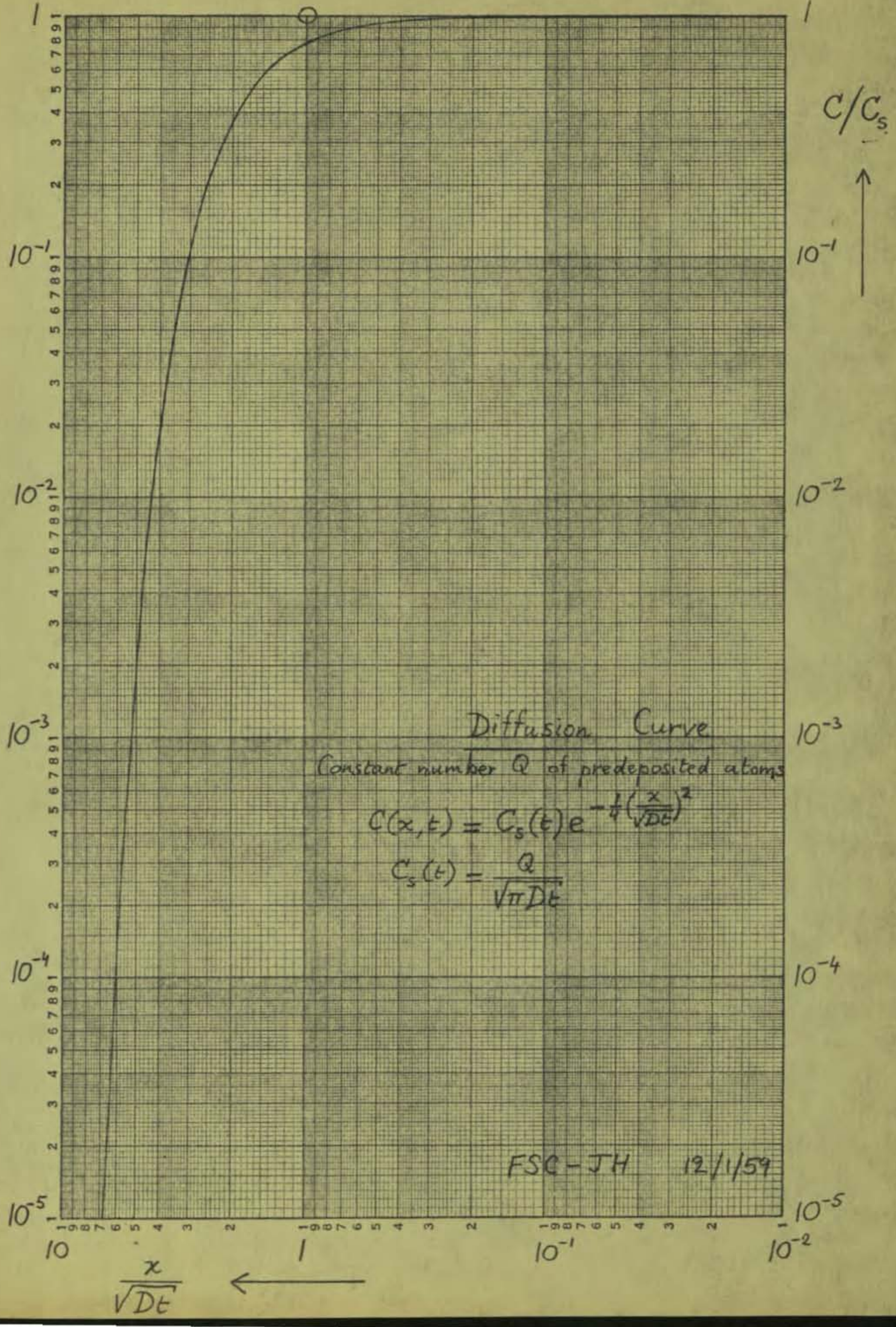
kr 2/15/62

DRY OXYGEN 1 ATM.



Order	Color	Thickness in Angstrom Units
	Brownish white	685
	Clear brown	733
	Dark brown	795
	Red brown	850
I	Dark purple	884
	Dark violet	925
	Dark blue	959
	Clearish blue to greenish	1120
	Still clear blue	1610
	Pale blue green	1680
	Pale green	1760
	Clear yellow green	1860
	Clear yellow	1930
	Golden yellow	2060
II	Orange	2410
	Red	2550
	Deep purple	2650
	Violet	2800
	Blue	2980
	Clearish blue	3180
	Bluish green	3360

DIFFUSION



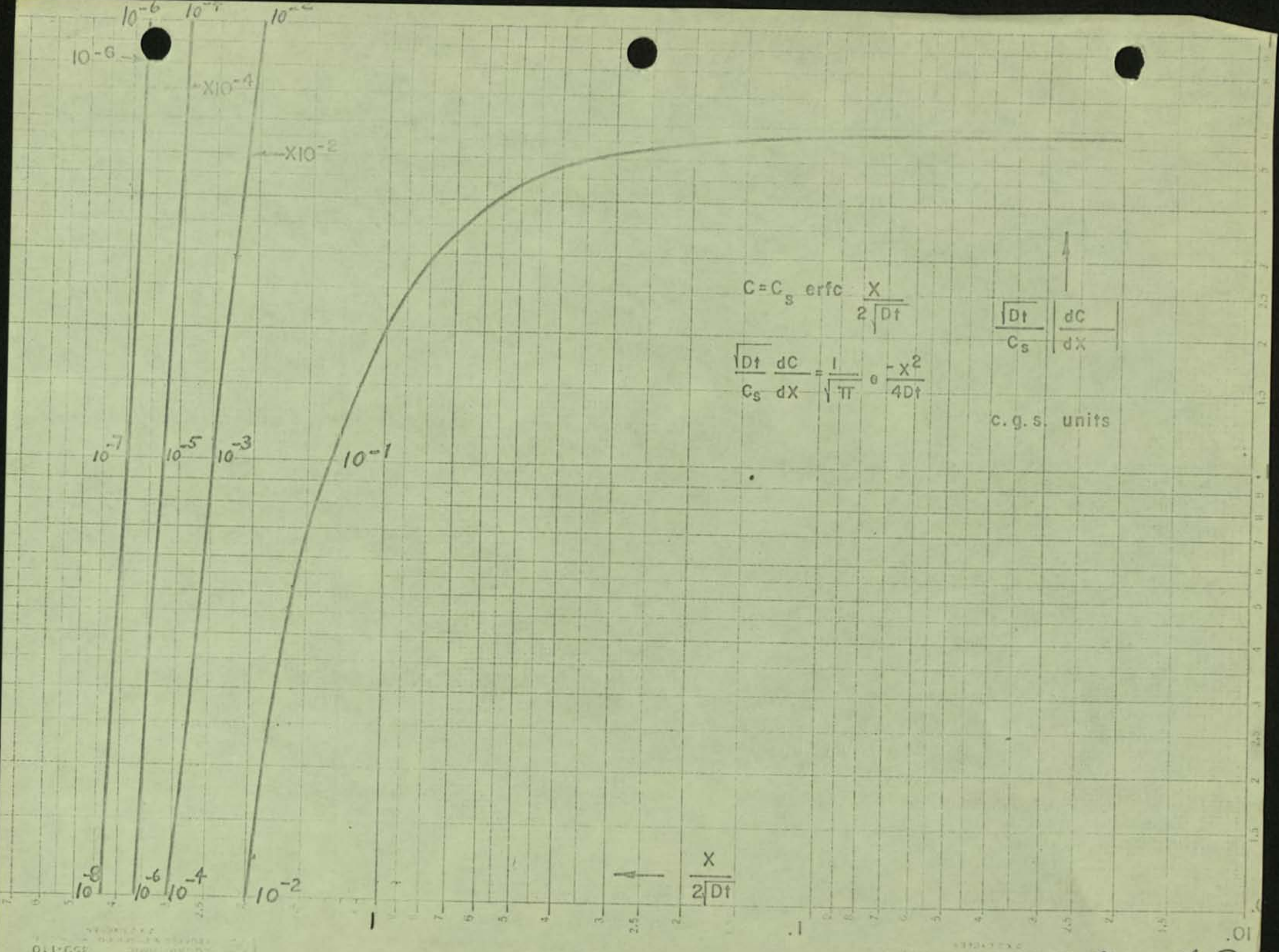
Diffusion Curve

Constant number Q of predeposited atoms

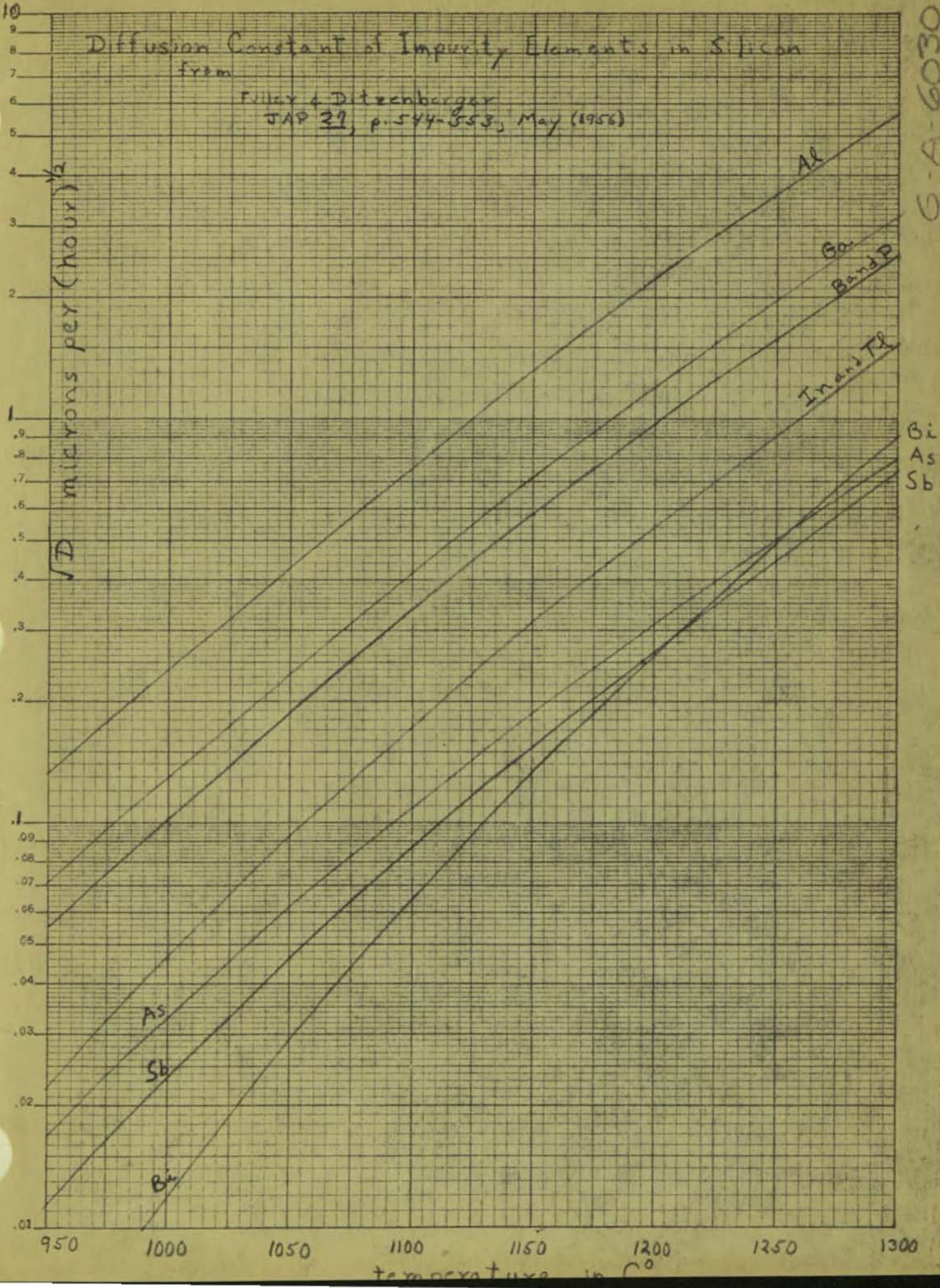
$$C(x,t) = C_s(t)\, e^{-\frac{1}{4}\left(\frac{x}{\sqrt{Dt}}\right)^2}$$

$$C_s(t) = \frac{Q}{\sqrt{\pi D t}}$$

FSC - JH 12/1/59



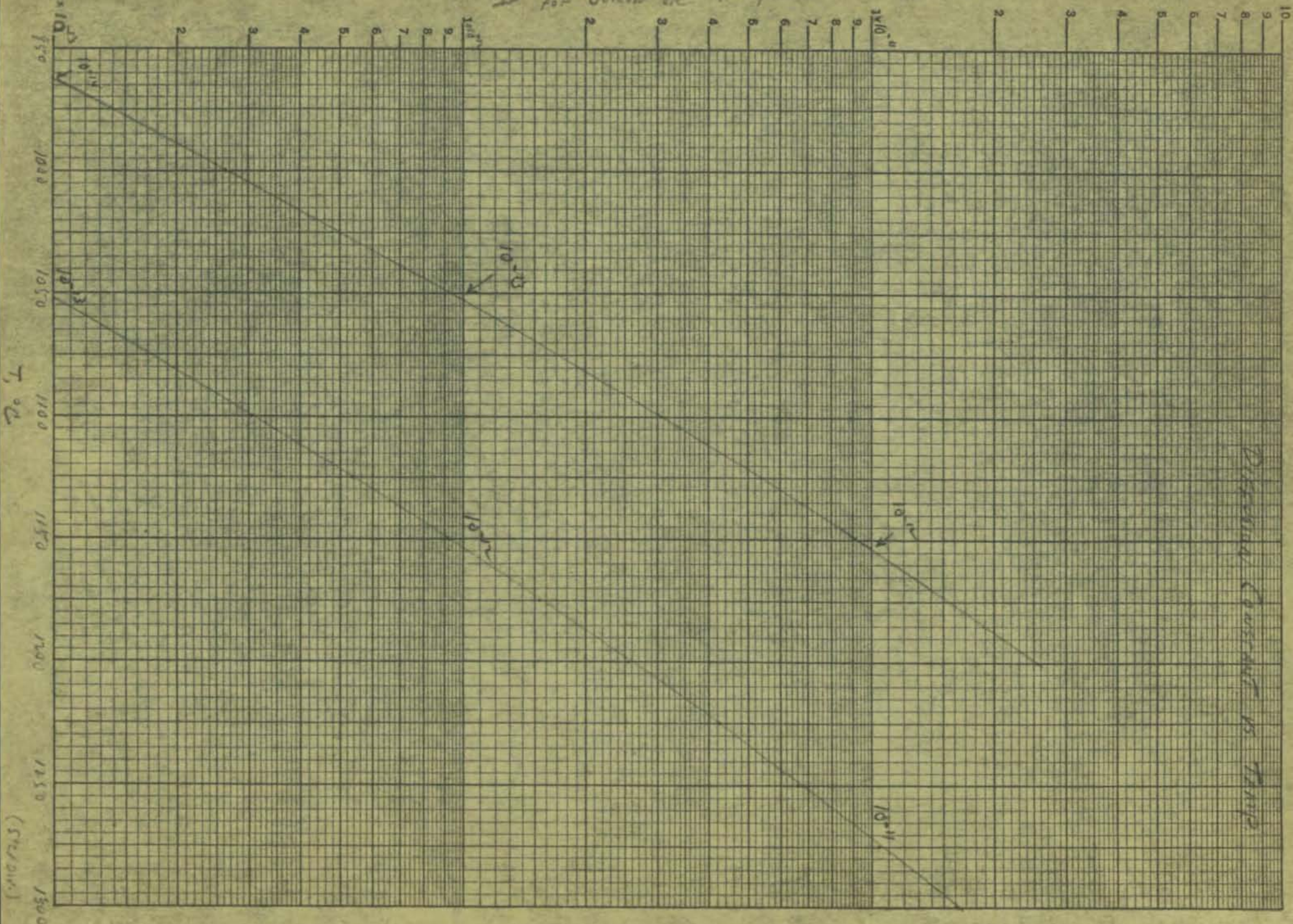
DERIVATIVE OF ERROR FUNCTION

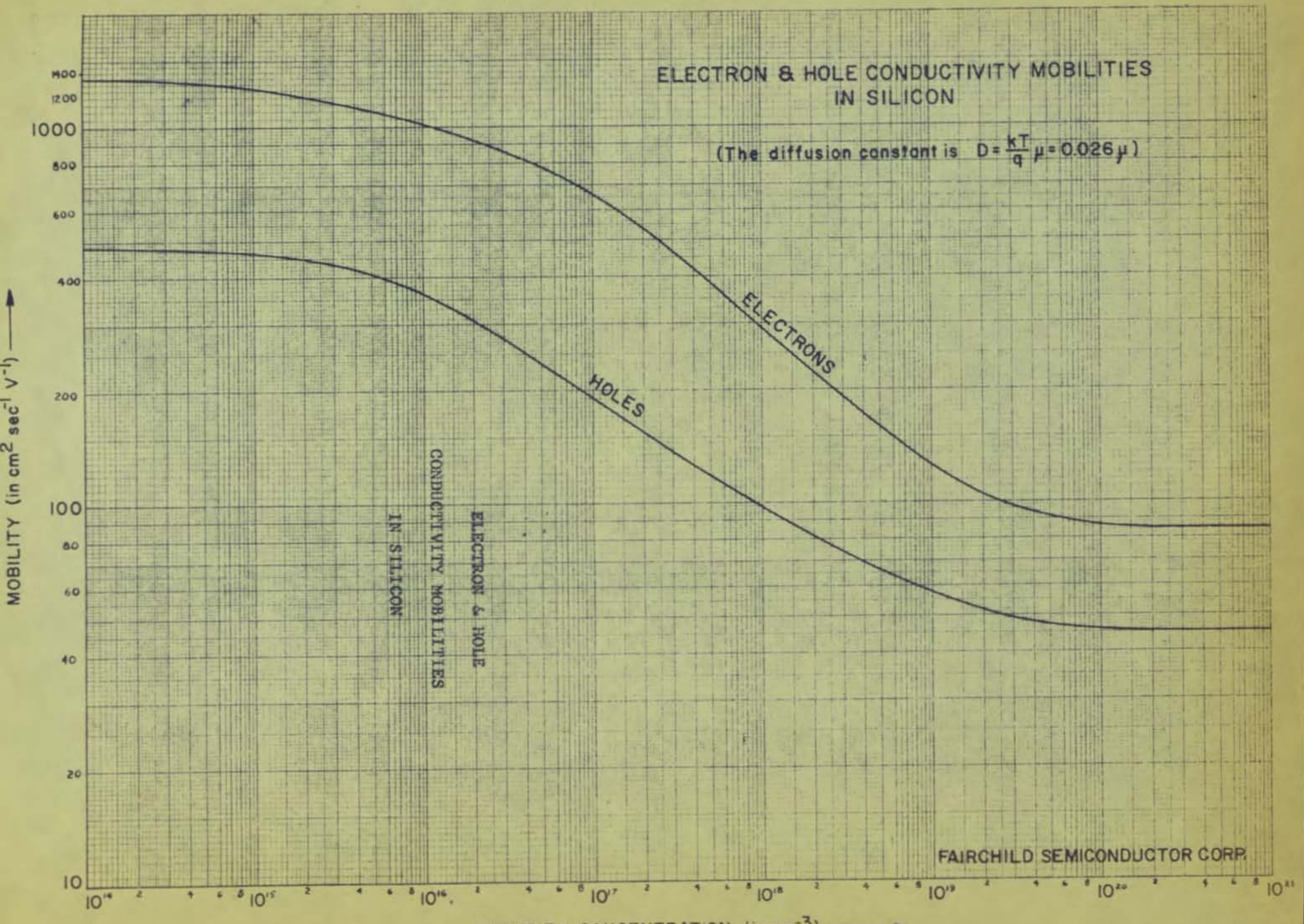


Diffusion Constant of Impurity Elements in Silicon
from
Fuller & Ditzenberger
JAP 27, p. 544-553, May (1956)

6-A-6030

D for Boron and Phosphorus cm²/sec.

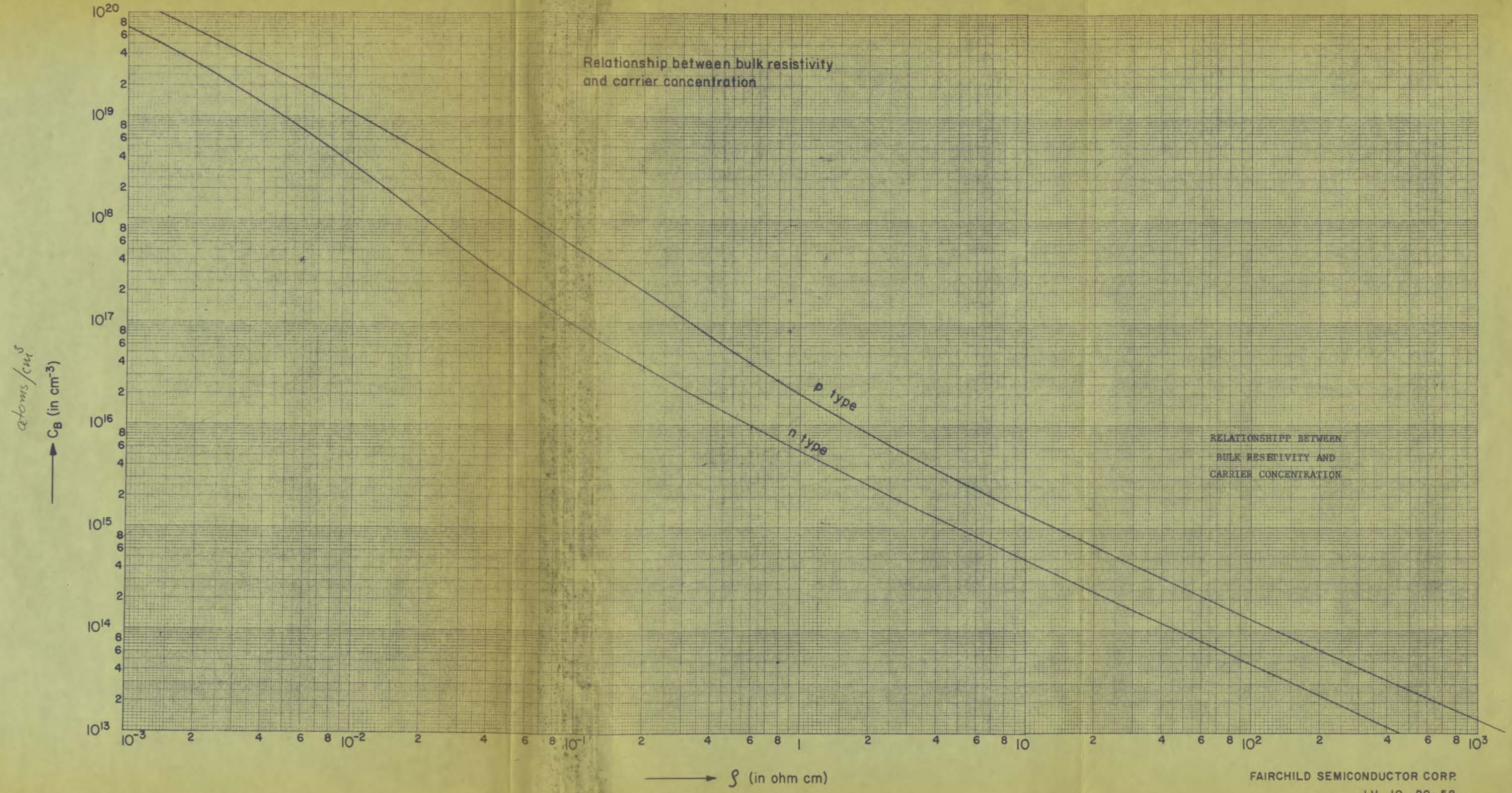




ELECTRON & HOLE CONDUCTIVITY MOBILITIES IN SILICON

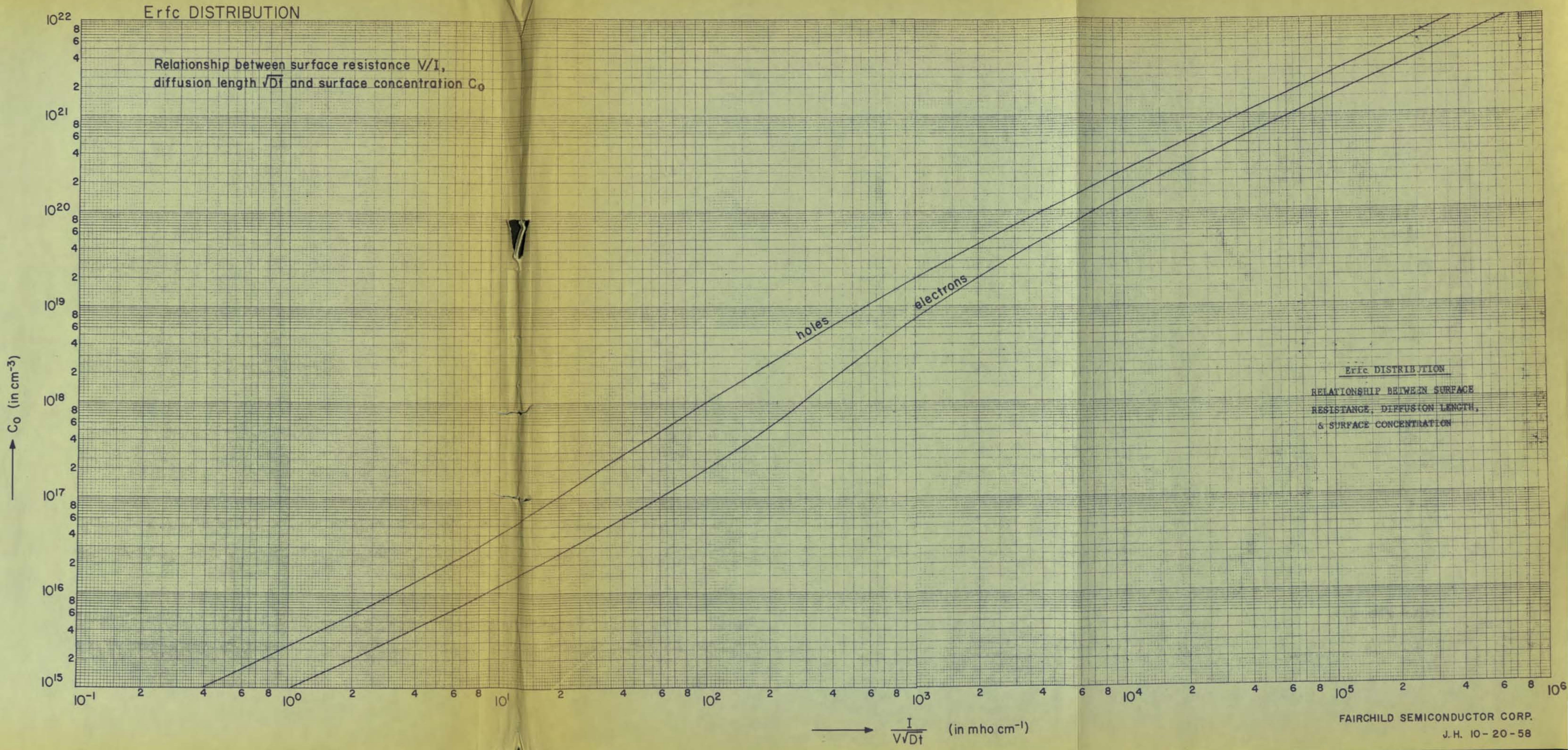
(The diffusion constant is $D = \frac{kT}{q}\mu = 0.026\mu$)

J.H. 10-20-58


Relationship between bulk resistivity and carrier concentration

FAIRCHILD SEMICONDUCTOR CORP.

J.H. 10-20-58



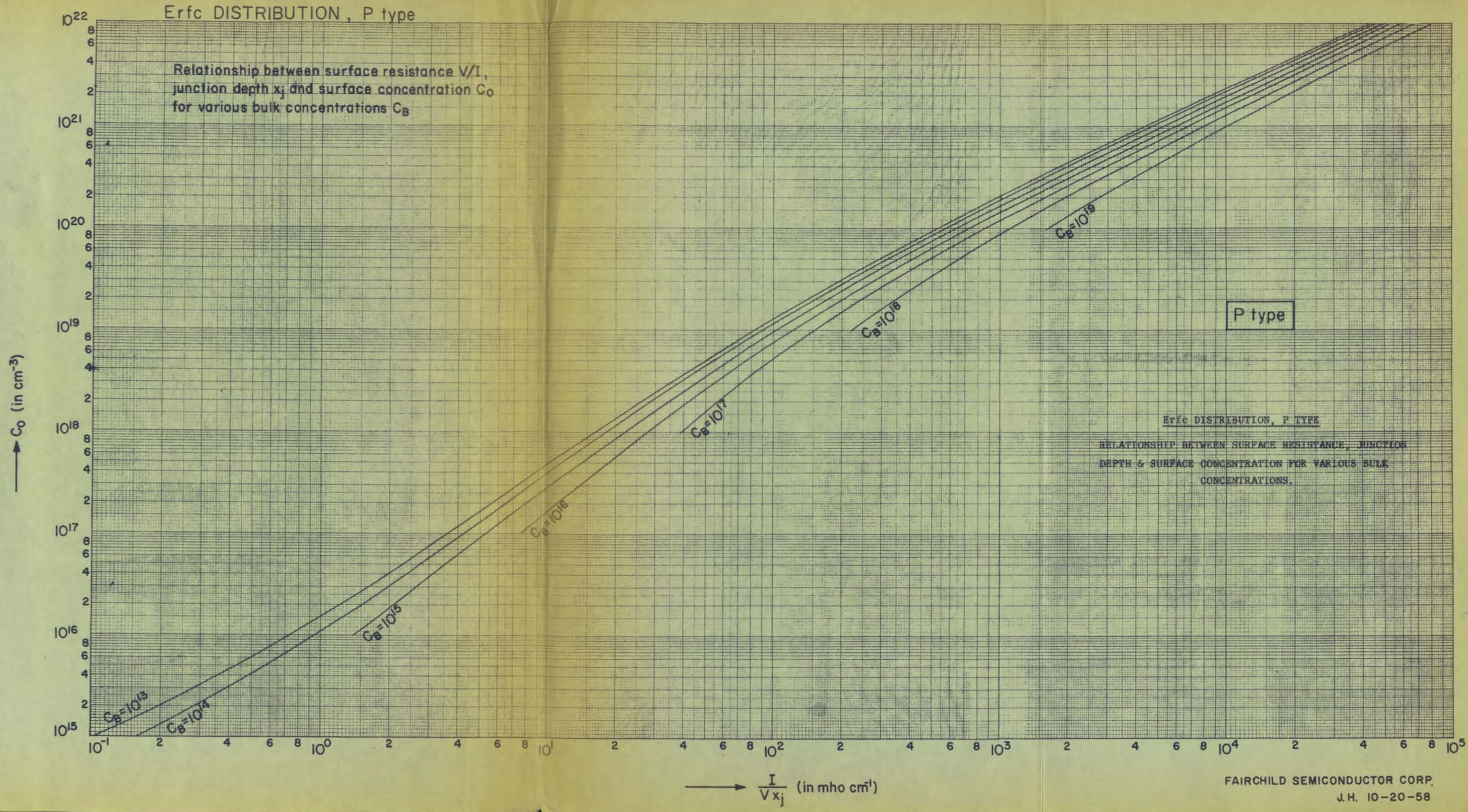
Erfc DISTRIBUTION

Relationship between surface resistance V/I, diffusion length $\sqrt{Dt}$ and surface concentration C_0

Erfc DISTRIBUTION

RELATIONSHIP BETWEEN SURFACE
RESISTANCE, DIFFUSION LENGTH,
& SURFACE CONCENTRATION

FAIRCHILD SEMICONDUCTOR CORP.
J. H. 10-20-58



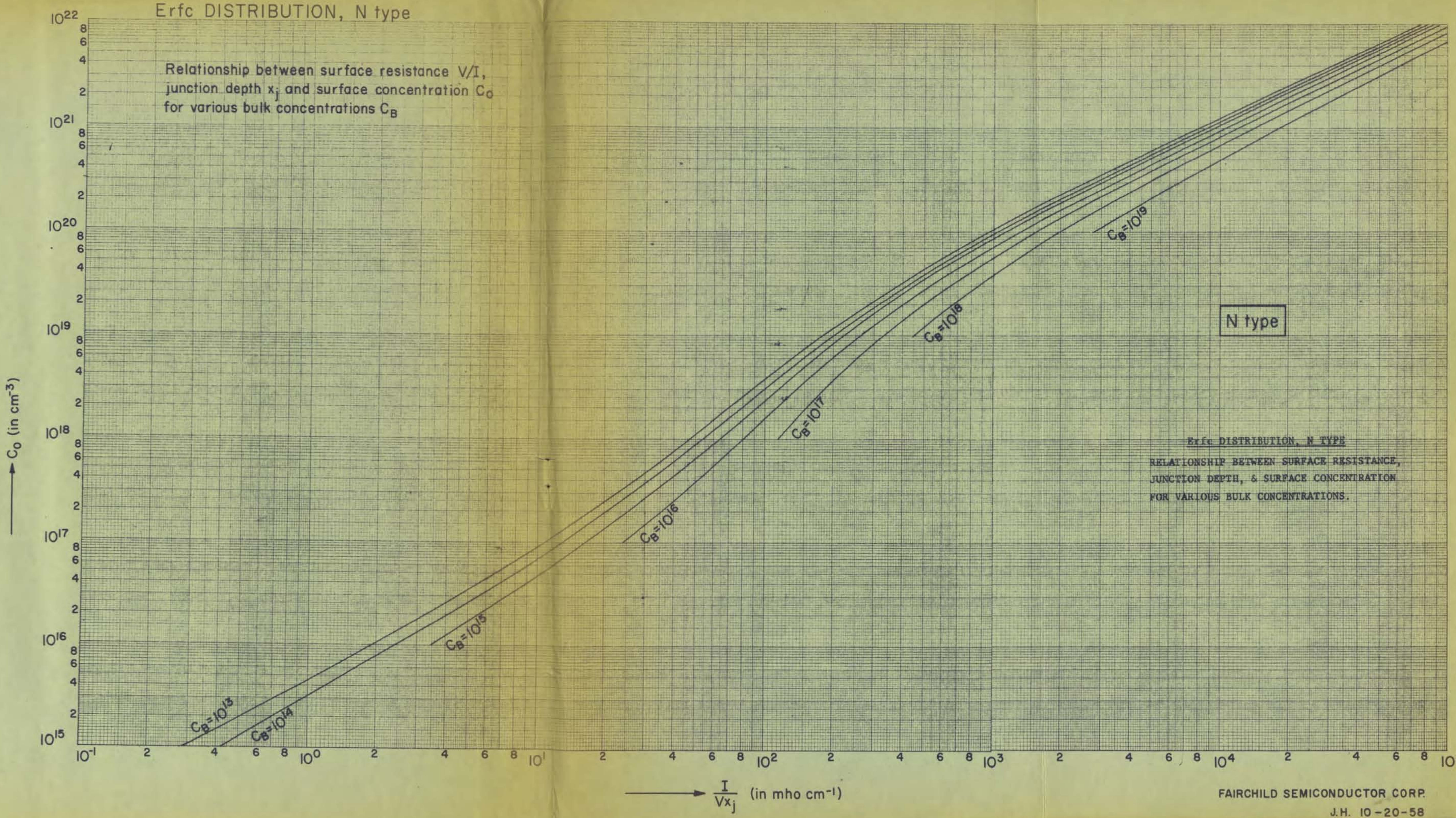
Erfc DISTRIBUTION, P type

Relationship between surface resistance V/I, junction depth x_j and surface concentration C_o for various bulk concentrations C_B

Erfc DISTRIBUTION, P TYPE

RELATIONSHIP BETWEEN SURFACE RESISTANCE, JUNCTION DEPTH & SURFACE CONCENTRATION FOR VARIOUS BULK CONCENTRATIONS.

FAIRCHILD SEMICONDUCTOR CORP.
J.H. 10-20-58



Erfc DISTRIBUTION, N type

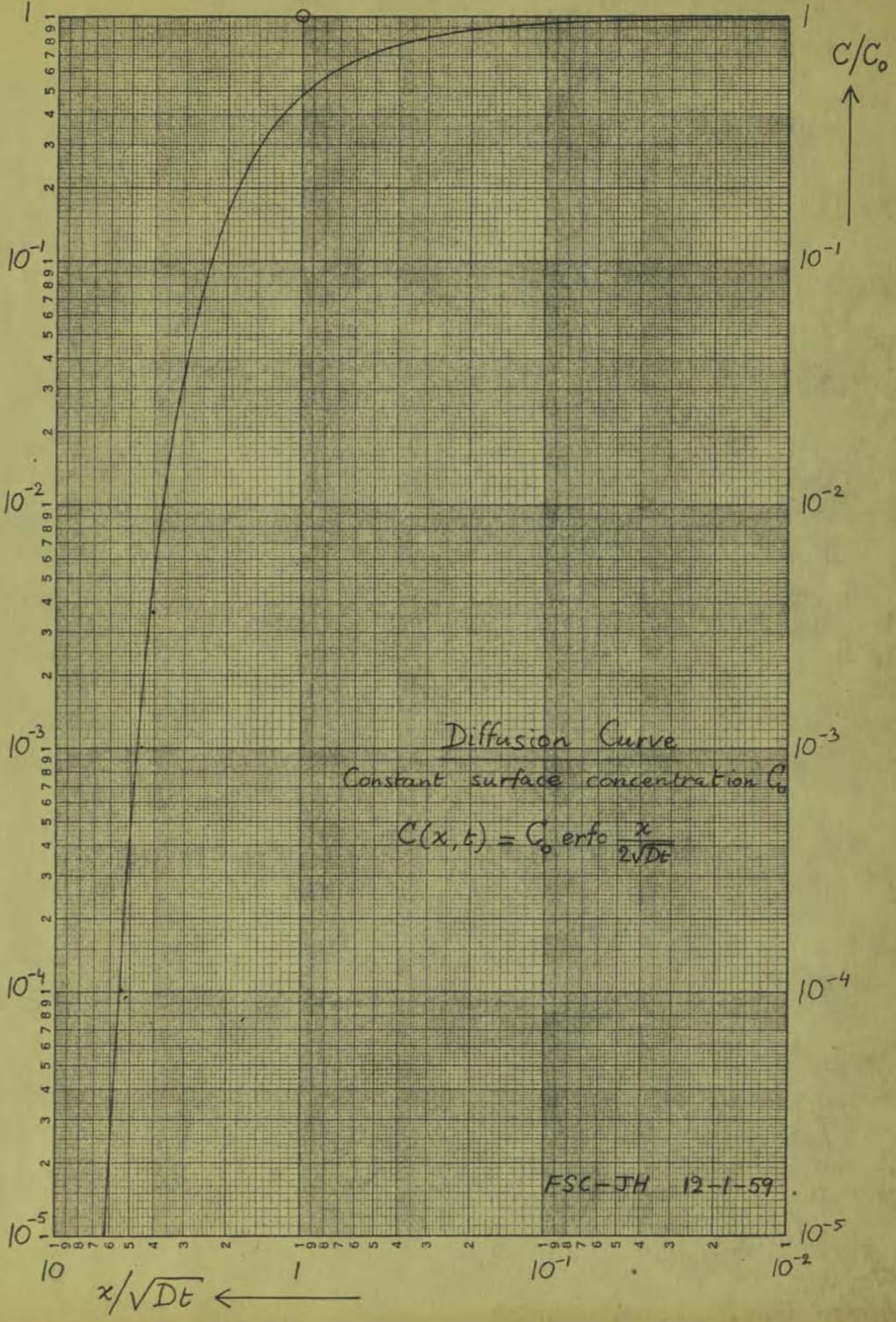
Relationship between surface resistance V/I, junction depth x_j and surface concentration C_0 for various bulk concentrations C_B

Erfc DISTRIBUTION, N TYPE

RELATIONSHIP BETWEEN SURFACE RESISTANCE, JUNCTION DEPTH, & SURFACE CONCENTRATION FOR VARIOUS BULK CONCENTRATIONS.

FAIRCHILD SEMICONDUCTOR CORP.

J.H. 10-20-58

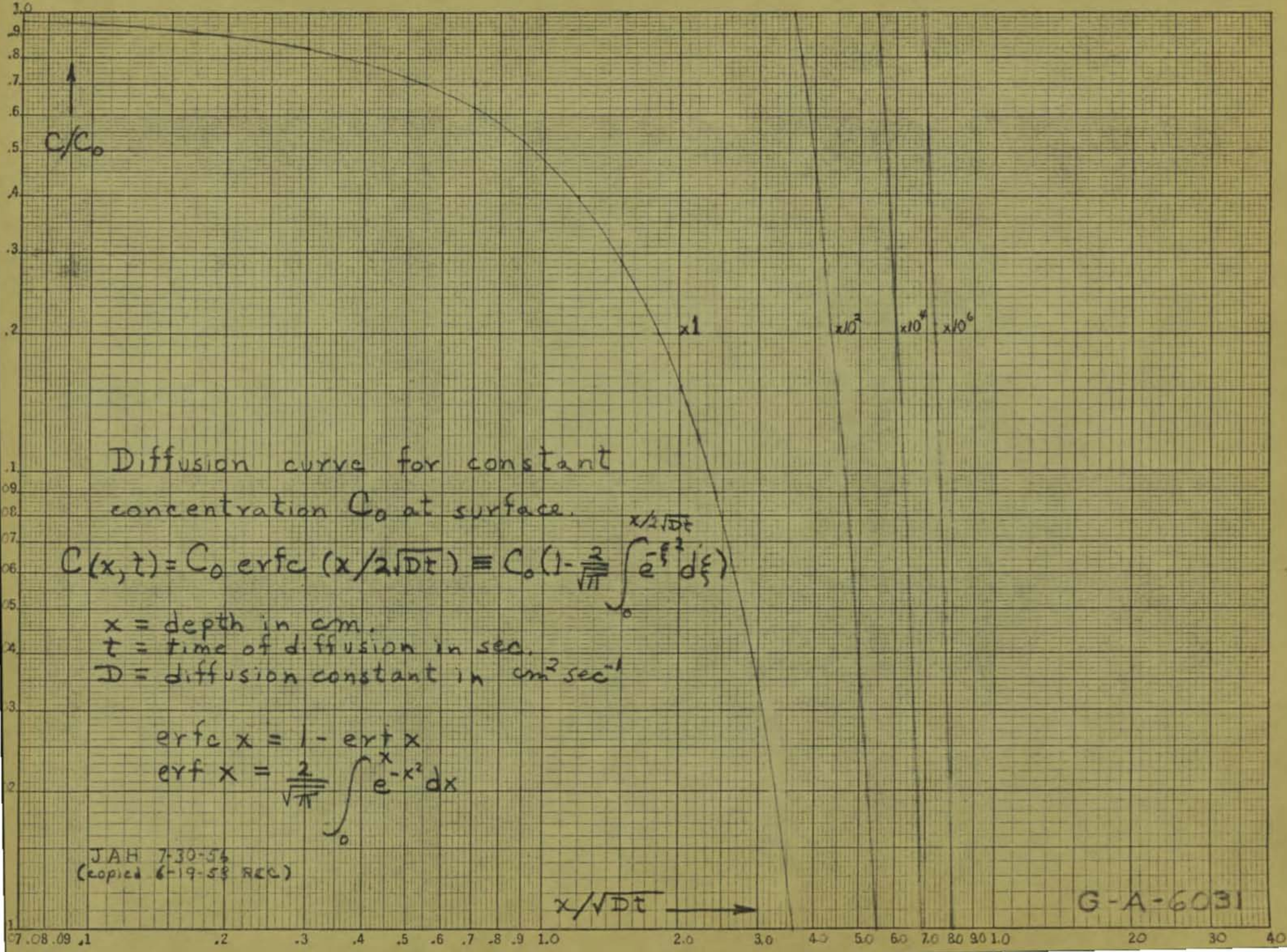


Diffusion Curve

Constant surface concentration C_0

$$C(x,t) = C_0 \operatorname{erfc} \frac{x}{2\sqrt{Dt}}$$

FSC-JH 12-1-59.



Diffusion curve for constant concentration C_0 at surface.

$$C(x,t) = C_0 \operatorname{erfc}\left(x/2\sqrt{Dt}\right) \equiv C_0\left(1 - \frac{2}{\sqrt{\pi}}\int_0^{x/2\sqrt{Dt}} e^{-\xi^2}\,d\xi\right)$$

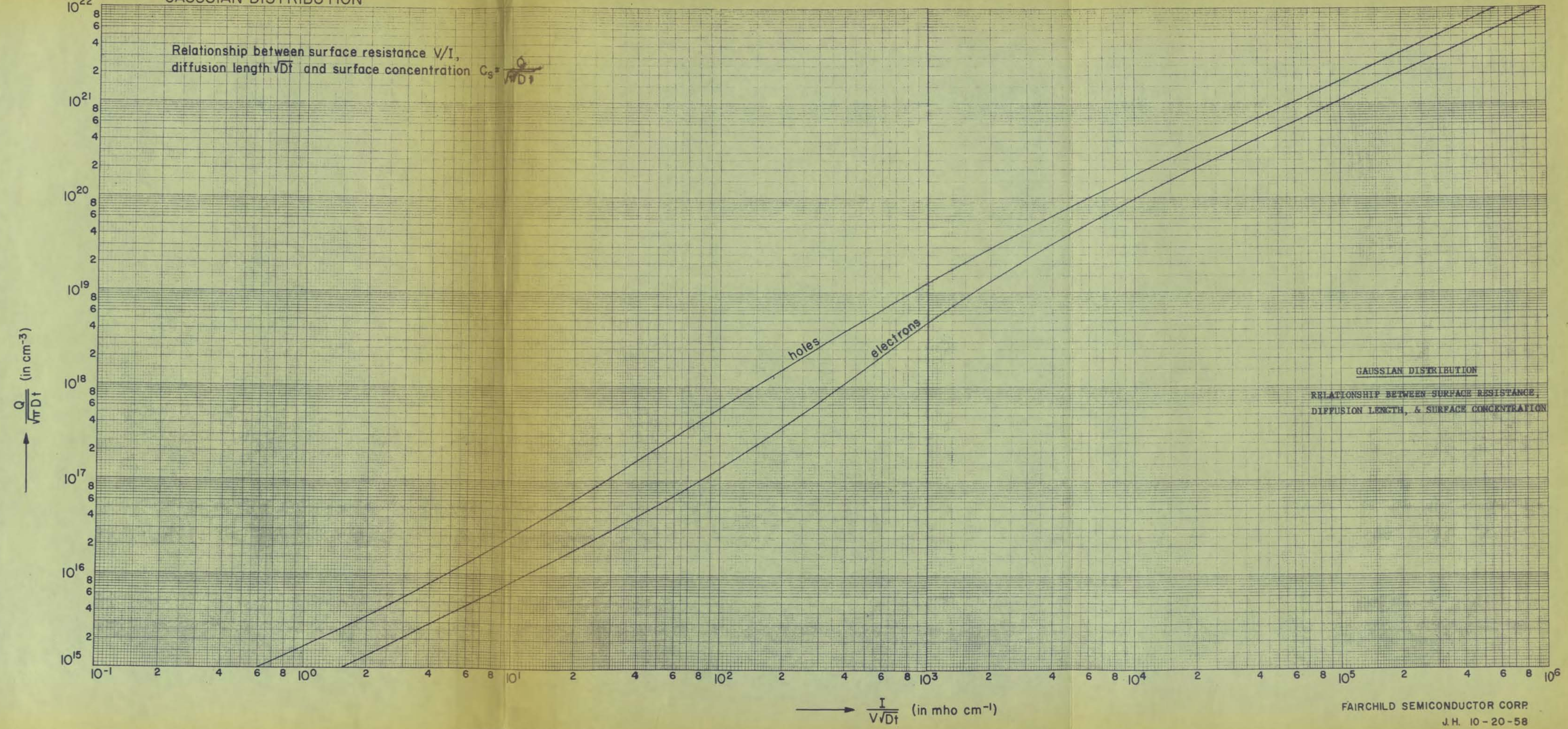
x = depth in cm.
t = time of diffusion in sec.
D = diffusion constant in $cm^2\,sec^{-1}$

$$\operatorname{erfc} x = 1 - \operatorname{erf} x$$
$$\operatorname{erf} x = \frac{2}{\sqrt{\pi}}\int_0^x e^{-x^2}\,dx$$

JAH 7-30-56
(copied 6-19-58 REC)

G-A-6031

GAUSSIAN DISTRIBUTION

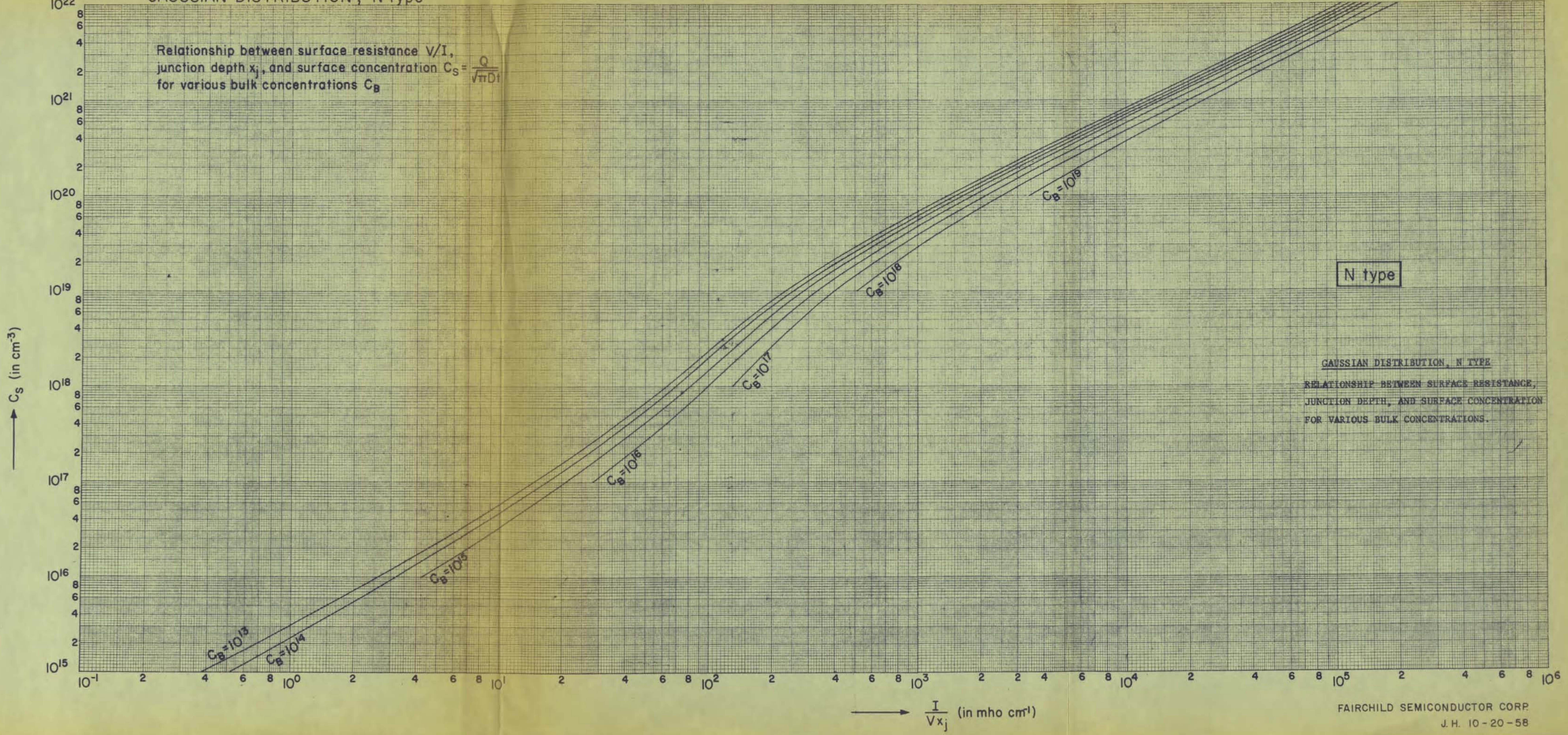


GAUSSIAN DISTRIBUTION

RELATIONSHIP BETWEEN SURFACE RESISTANCE,
DIFFUSION LENGTH, & SURFACE CONCENTRATION

FAIRCHILD SEMICONDUCTOR CORP.
J.H. 10-20-58

GAUSSIAN DISTRIBUTION , N type



Relationship between surface resistance V/I, junction depth x_j, and surface concentration $C_S = \frac{Q}{\sqrt{\pi D t}}$ for various bulk concentrations C_B

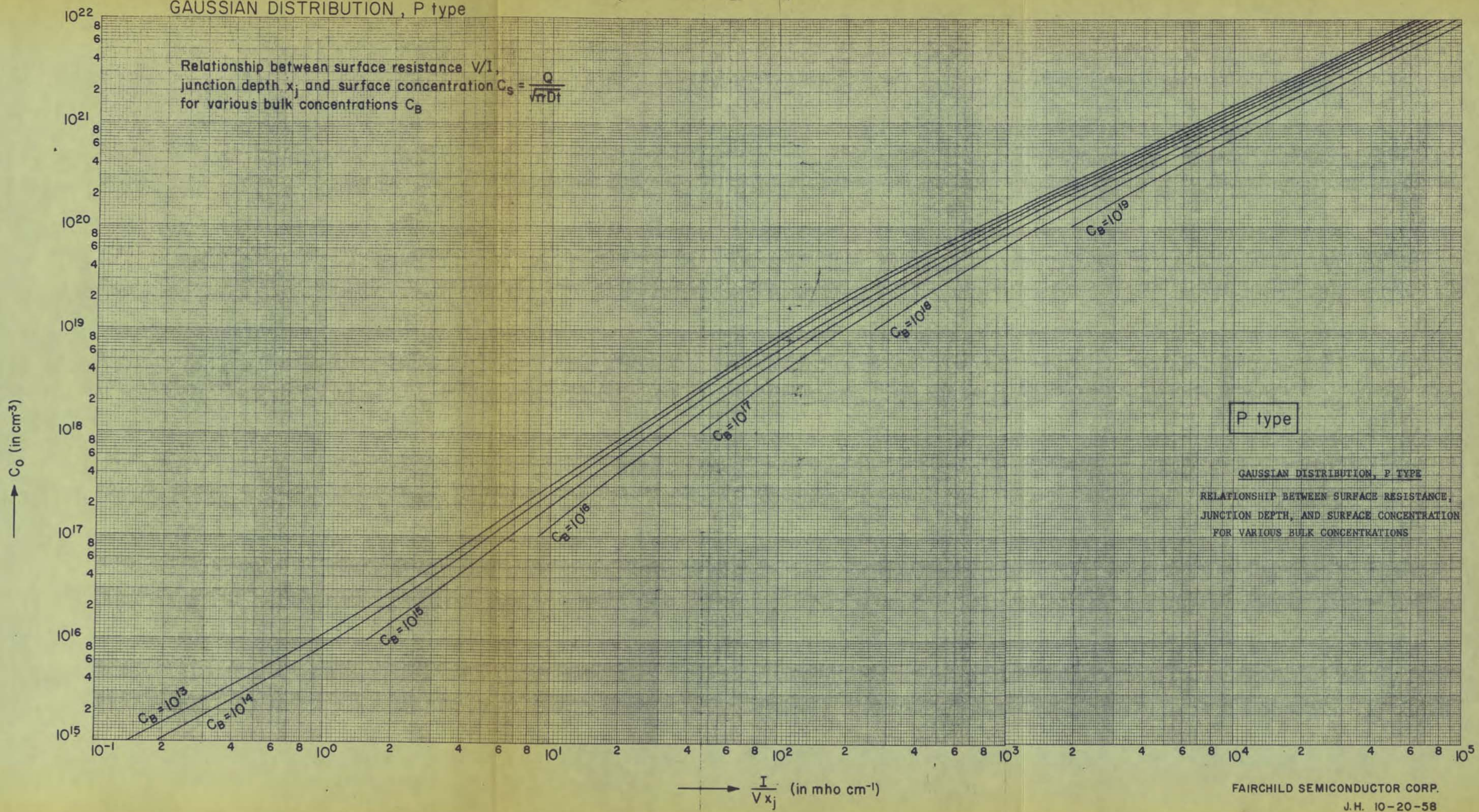
GAUSSIAN DISTRIBUTION, N TYPE

RELATIONSHIP BETWEEN SURFACE RESISTANCE, JUNCTION DEPTH, AND SURFACE CONCENTRATION FOR VARIOUS BULK CONCENTRATIONS.

FAIRCHILD SEMICONDUCTOR CORP.
J.H. 10-20-58

GAUSSIAN DISTRIBUTION , P type

Relationship between surface resistance V/I, junction depth x_j and surface concentration $C_s = \frac{Q}{\sqrt{\pi D t}}$ for various bulk concentrations C_B

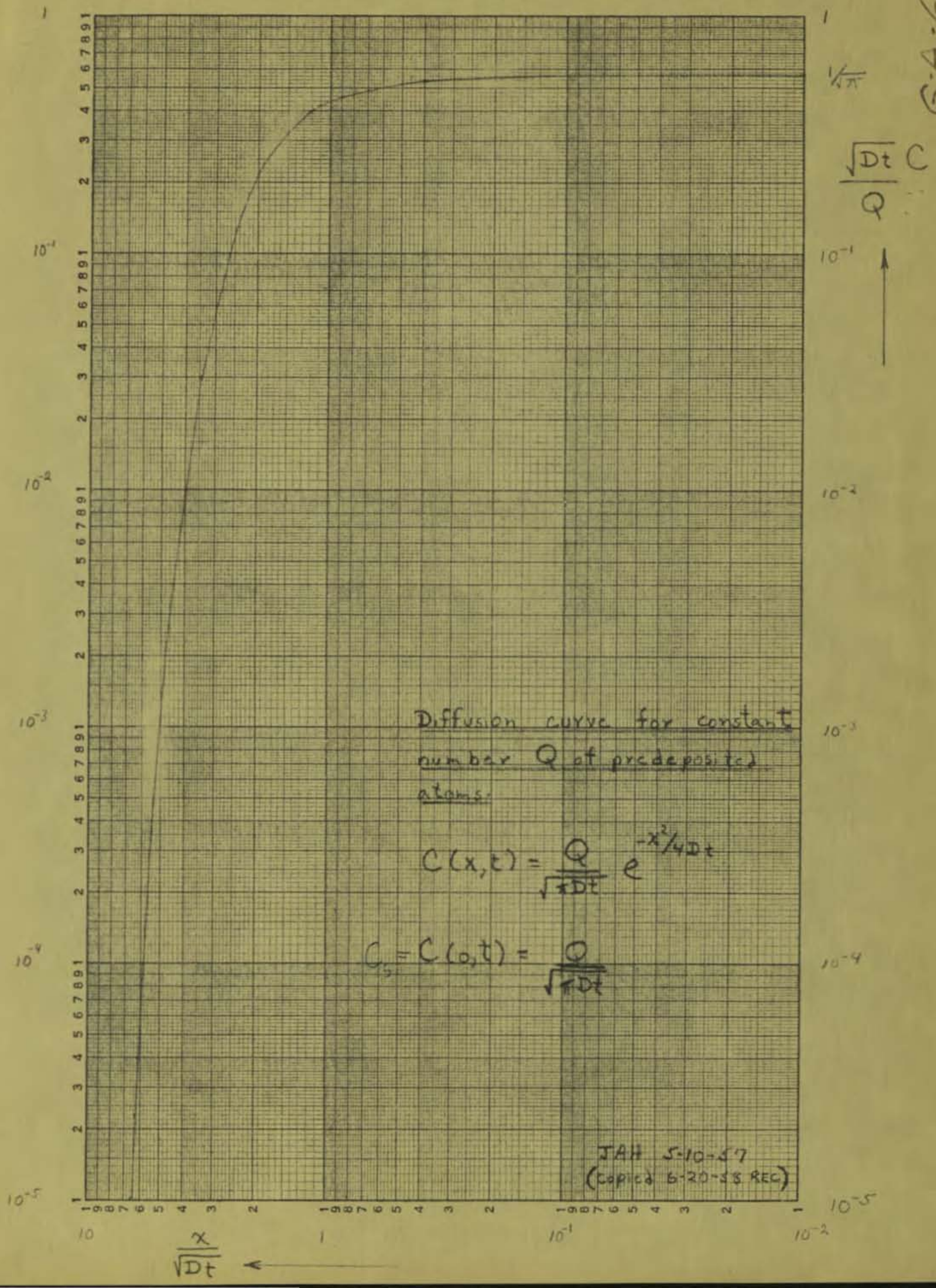


GAUSSIAN DISTRIBUTION, P TYPE

RELATIONSHIP BETWEEN SURFACE RESISTANCE,
JUNCTION DEPTH, AND SURFACE CONCENTRATION
FOR VARIOUS BULK CONCENTRATIONS

FAIRCHILD SEMICONDUCTOR CORP.
J.H. 10-20-58

G-A-6033

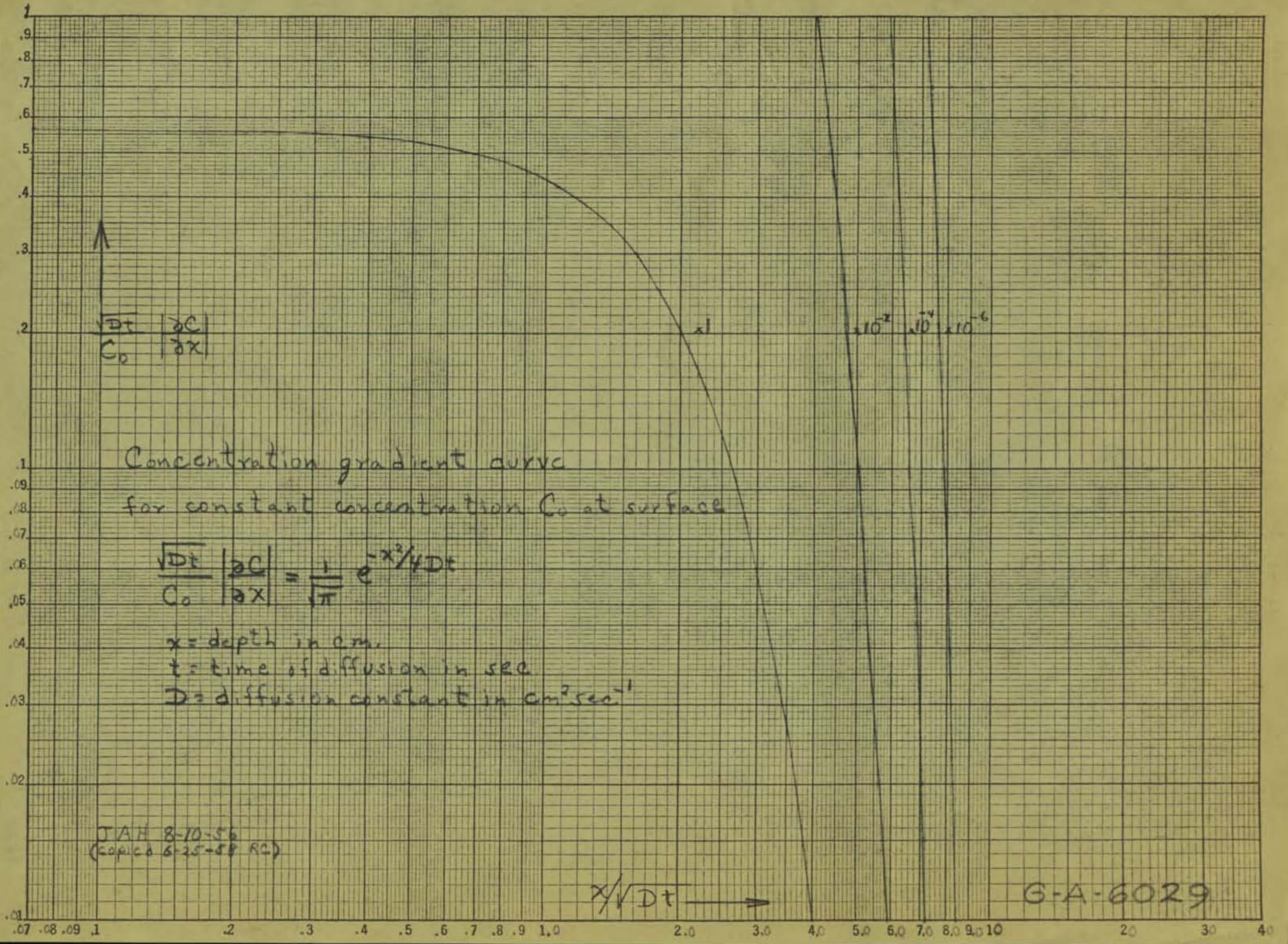


Diffusion curve for constant number Q of predeposited atoms.

$$C(x,t) = \frac{Q}{\sqrt{\pi Dt}}\, e^{-x^2/4Dt}$$

$$C_s = C(0,t) = \frac{Q}{\sqrt{\pi Dt}}$$

JAH 5-10-57
(copied 6-20-58 REC)



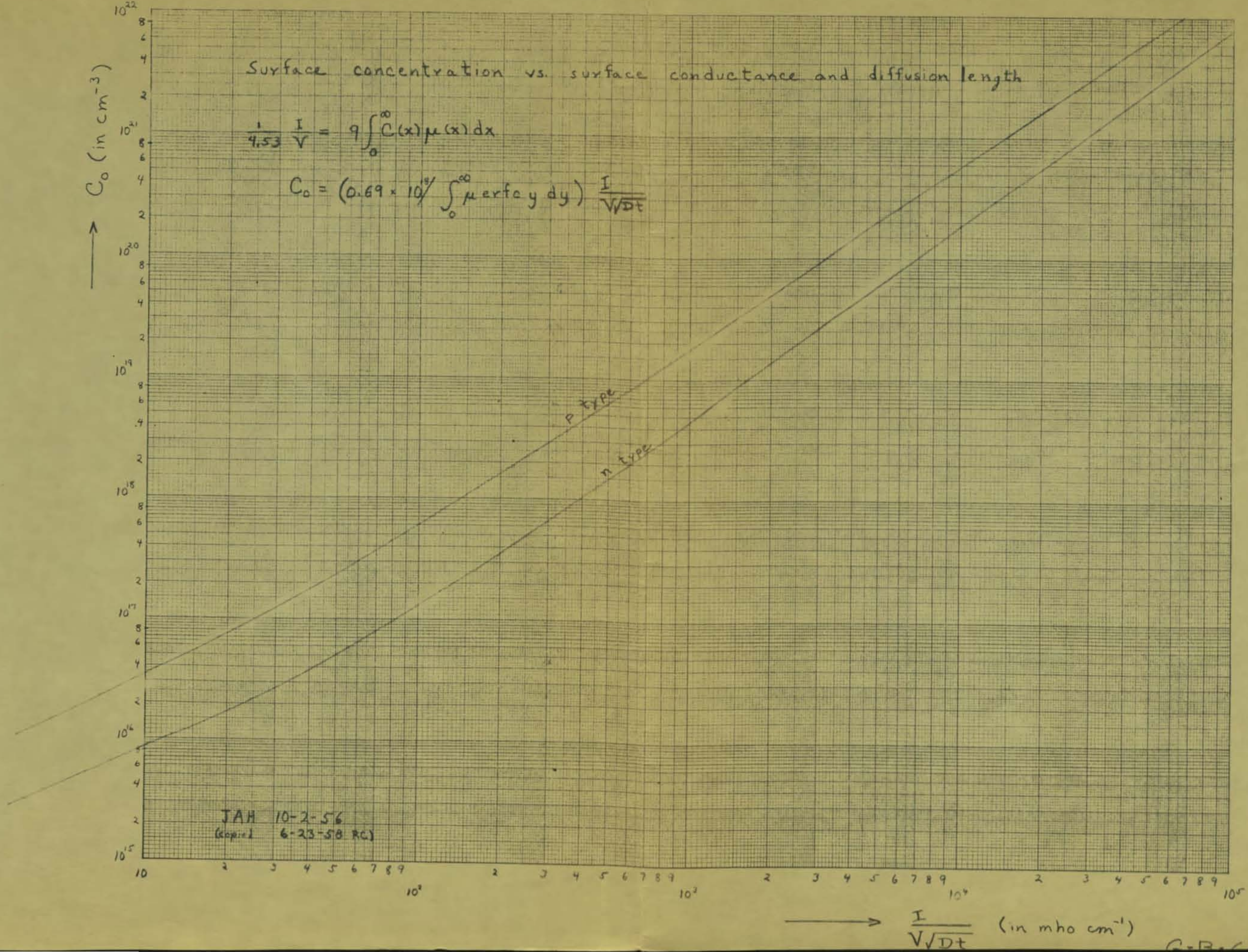
Concentration gradient curve
for constant concentration C_0 at surface

$$\frac{\sqrt{Dt}}{C_0}\left|\frac{\partial C}{\partial x}\right| = \frac{1}{\sqrt{\pi}}\, e^{-x^2/4Dt}$$

x = depth in cm.
t = time of diffusion in sec
D = diffusion constant in $cm^2 sec^{-1}$

JAH 8-10-56
(copied 6-25-58 RC)

G-A-6029



Surface concentration vs. surface conductance and diffusion length

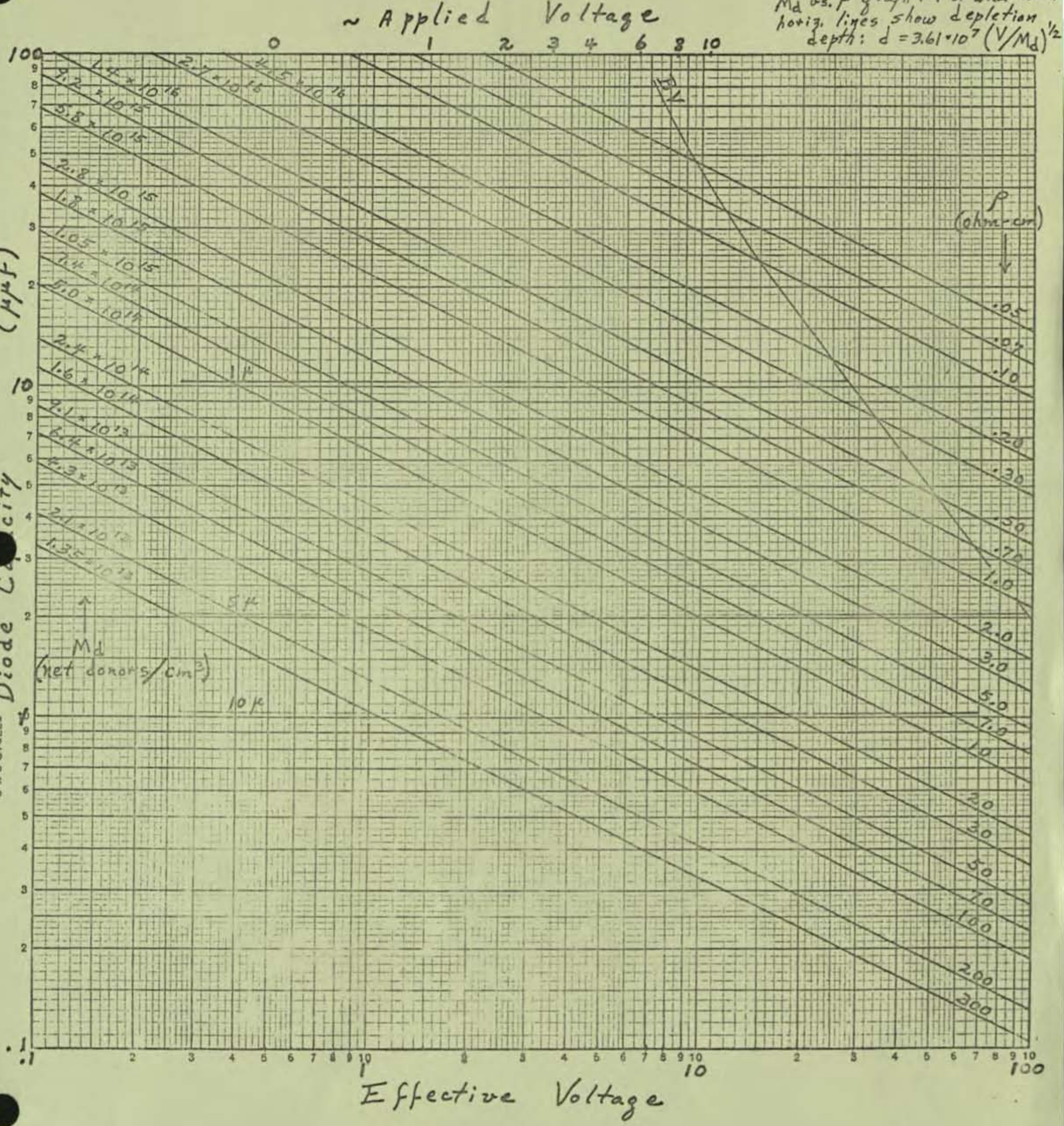
$$\frac{1}{4.53}\frac{I}{V} = q\int_0^\infty C(x)\mu(x)\,dx$$

$$C_0 = \left(0.69\times 10^{19} / \int_0^\infty \mu\,\mathrm{erfc}\,y\,dy\right)\frac{I}{V\sqrt{Dt}}$$

JAH 10-2-56
(copied 6-23-58 RC)

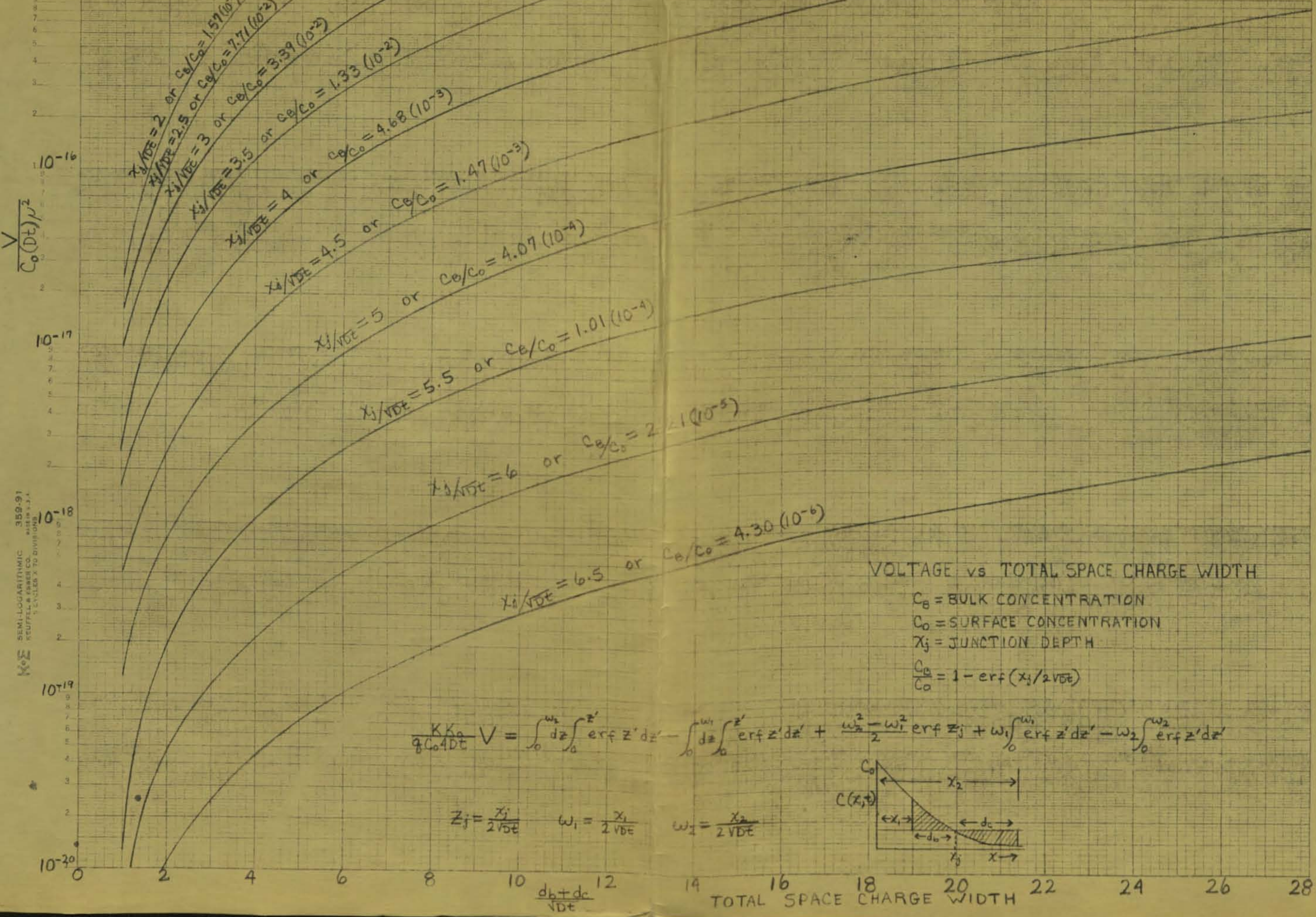
Junction Capacity vs. Voltage for Various Resistivities of n-type Si

$C^2 = 7.995 \times 10^{-14}\ M_d / V$
for diode area $= .0995\ mm^2$
M_d vs. ρ graph 1-9-61 WRL used
horiz. lines show depletion
depth: $d = 3.61 \times 10^7\ (V/M_d)^{1/2}$



1-10-61

8-7-58



VOLTAGE vs TOTAL SPACE CHARGE WIDTH

C_B = BULK CONCENTRATION

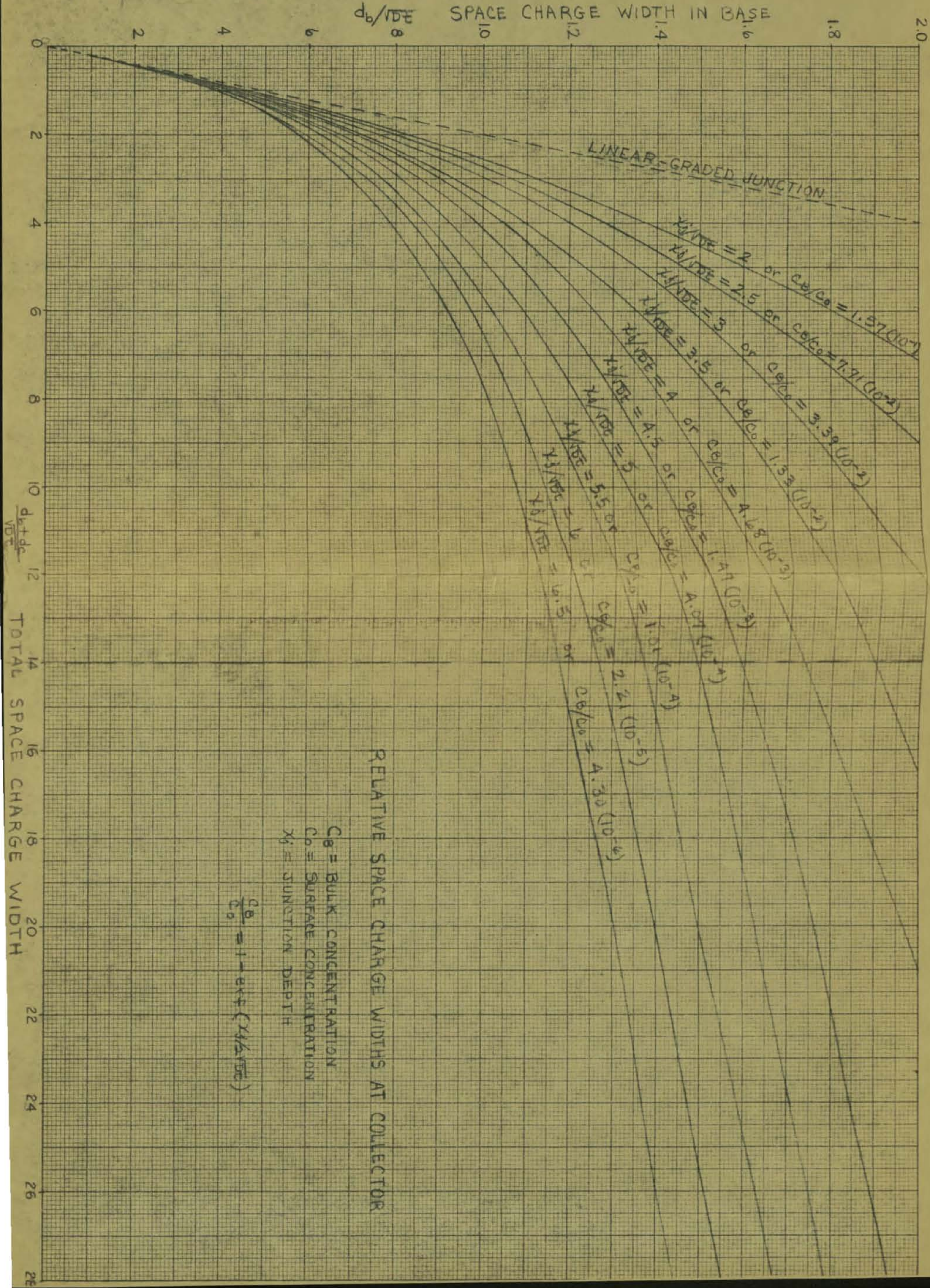
C_0 = SURFACE CONCENTRATION

x_j = JUNCTION DEPTH

$\frac{C_B}{C_0} = 1 - \operatorname{erf}(x_j/2\sqrt{Dt})$

$$\frac{KK_0}{qC_0 4Dt} V = \int_0^{\omega_2} dz \int_0^{z'} \operatorname{erf} z' dz' - \int_0^{\omega_1} dz \int_0^{z'} \operatorname{erf} z' dz' + \frac{\omega_2^2 - \omega_1^2}{2} \operatorname{erf} z_j + \omega_1 \int_0^{\omega_1} \operatorname{erf} z' dz' - \omega_2 \int_0^{\omega_2} \operatorname{erf} z' dz'$$

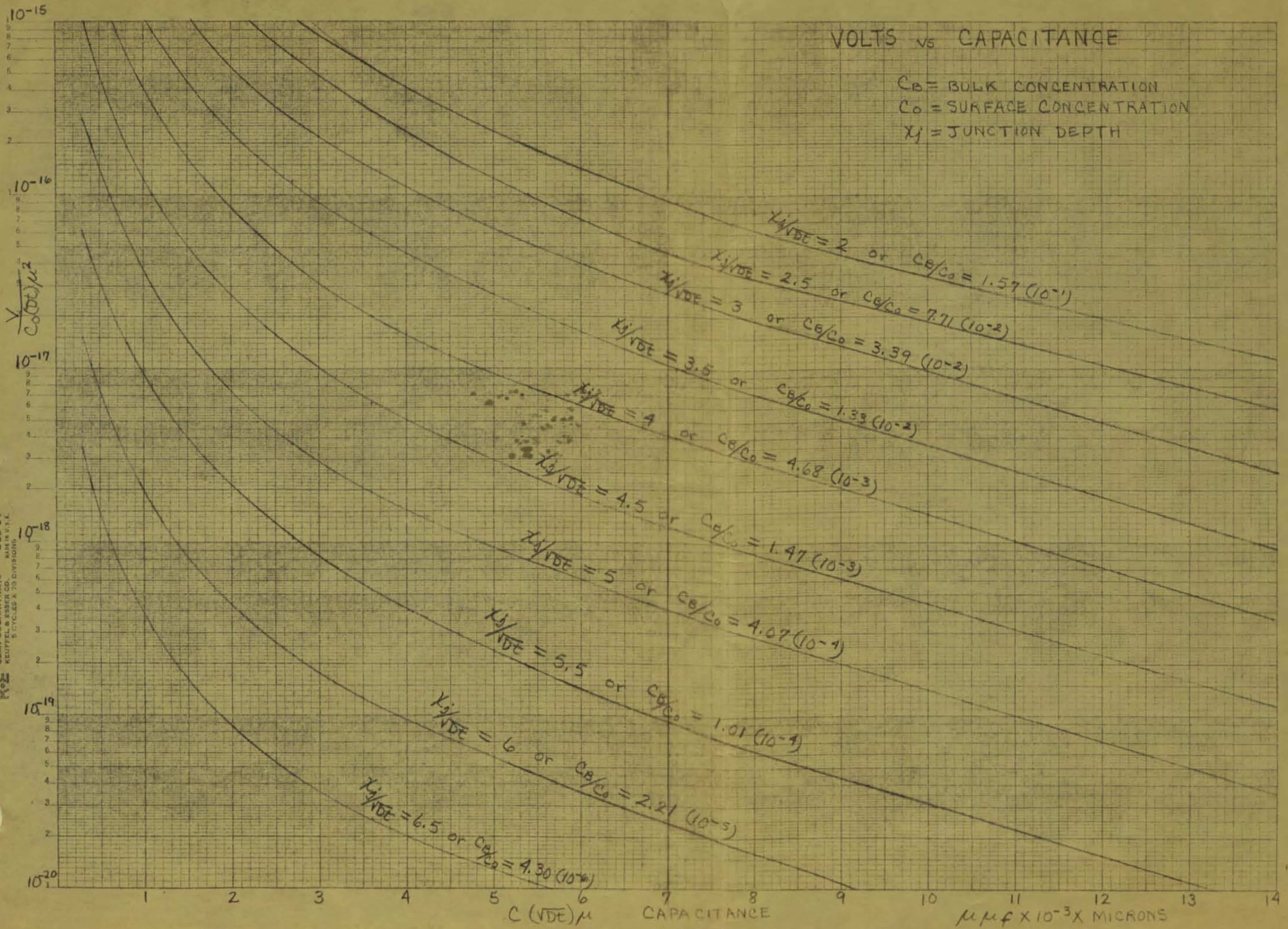
$z_j = \frac{x_j}{2\sqrt{Dt}}$ $\omega_1 = \frac{x_1}{2\sqrt{Dt}}$ $\omega_2 = \frac{x_2}{2\sqrt{Dt}}$



RELATIVE SPACE CHARGE WIDTHS AT COLLECTOR

C_B = BULK CONCENTRATION
C_0 = SURFACE CONCENTRATION
x_j = JUNCTION DEPTH

$$\frac{C_B}{C_0} = 1 - \mathrm{erf}\,(x_j/2\sqrt{Dt})$$



VOLTS vs CAPACITANCE

C_B = BULK CONCENTRATION
C_o = SURFACE CONCENTRATION
X_j = JUNCTION DEPTH

VOLTAGE RATINGS FOR DOUBLE DIFFUSED SILICON SWITCHING TRANSISTORS

BY V. H. GRINICH

DEFINITIONS

The various voltages and resistances appropriate to this discussion are defined by the circuit diagram in Figure 1. The example illustrates the polarities appropriate for an n-p-n transistor. The important consideration is what values can be used for V_{CC} and R_L for given values of V_{BB} and R_B without endangering the transistor. As examples we illustrate the points by showing typical curves for a Fairchild 2N697 Double Diffused Silicon Mesa Transistor.

For grounded base operation the collector current-voltage plot with open emitter is shown in Figure 2. No appreciable current flows at voltages below the collector-base diode breakdown voltage, BV_{CBO}. Used in this manner there is negligible negative resistance region (neglecting thermal effects, which are small in the operating temperature range for the device), so the device can be operated at peak voltages up to the order of BV_{CBO}. This is the important limit in many amplifier* and oscillator applications. It is, therefore, a reasonable parameter from which to establish a voltage rating for devices used in this sort of application.

Figure 3 is a v-i plot for grounded emitter operation with base open. In this case, a negative resistance region will exist at normal temperatures. The peak voltage, BV_{CEO}, is a function of BV_{CBO} and current gain at this point. As the current is increased, the voltage drops and continues through a minimum. The exact current at which the minimum is located depends upon variation of current gain with collector current. For the 2N697 the broad, flat minimum occurs in the vicinity of 50 ma.** This minimum voltage, called the lower limiting voltage, LV_{CEO}, for n-p-n silicon transistors is related approximately to BV_{CBO} and h_{FE}, the large signal current gain by

$$LV_{CEO} = \frac{BV_{CBO}}{(h_{FE})^{1/n}}$$

where n is a function of BV_{CBO}.

In using a transistor as a switch with a resistive load and allowing the base to open, it is important that the load line remains at all times below and to the left of the curve in Figure 3; otherwise, the transistor will not return to the "off" state when the base is opened. This mode of operation puts the most severe restriction on the maximum voltage that can be used. Essentially, in this extreme case, when switching moderate or high currents where R_L is small, the voltage V_{CC} cannot exceed LV_{CEO}. Fortunately, LV_{CEO} is a bulk property of the device not subject to degradation with life.

Figure 4 shows the case for a short between base and emitter. In this case, no appreciable current flows below $BV_{CES}(=BV_{CBO})$. The current then increases at about the same voltage until at current I_{C1} the voltage drop across the internal base spreading resistance ($r_{BB'}$) causes the emitter-base diode to become forward biased at the point farthest removed from the base contact. The voltage then drops to LV_{CES} with increased current because of the avalanche multiplication associated with current flow through this new path. On reducing the current the voltage remains low until it reaches I_{C2} where the voltage again returns to the upper curve. In general I_{C2} is below I_{C1}. The hysteresis is related to the different current flow paths which made $r_{BB'}$ effectively higher approaching from the high current side than from the lower.

Because some of the current flows out the base lead in this case, LV_{CES} is in general significantly higher than LV_{CEO}. The difference is a function of $r_{BB'}$, h_{FE}, and $r_{EE'}$, the emitter spreading resistance.

This case (of $V_{BB} = R_B = 0$) is of considerable importance since it closely represents many practical situations. As an example, in core switching circuitry where the base drive is supplied by cores, the d-c impedance from base to ground is that of the core winding which is essentially a d-c short. In this case for $R_L = 0$, the use of a V_{CC} less than LV_{CES} is a necessary condition for a conservative design. Other conditions such as additional voltages induced in the collector circuit and the exact value of R_L will determine the final value of V_{CC} in the particular application.

Other examples where LV_{CES} is the proper rating would be in a transformer input Class B grounded emitter power amplifier where the d-c resistance of the winding from base to emitter is negligible.

In place of a short (or near short) between base and emitter, a resistor R may be included. In this case the appropriate ratings are called BV_{CER} and LV_{CER}. The values of BV_{CER} and LV_{CER} are between BV_{CEO} and BV_{CES} or LV_{CEO} and LV_{CES}, respectively. For $R = 10\,\Omega$ the value of LV_{CER} is typically equal to LV_{CES}. This value of resistance also guarantees that all units will be "locked" on the low voltage leg of the v-i curve with 100 ma of collector current.

In Figure 5, a curve of LV_{CER} at $I_c = 100$ ma is plotted for a typical 2N697 transistor. For values of $R > 5$ K, LV_{CER} is very nearly equal to LV_{CEO}. For values of $R < 100\,\Omega$, it is nearly the same as LV_{CES}.

By holding off the base, it is possible to use the transistor at higher voltages. Figure 6 illustrates typical results with the 2N697 for the base held off through several values of base resistance. No simple method to relate the voltage to transistor parameters under these conditions is known. Appropriate data should be taken before using this manner. In this case, the breakdown voltage is BV_{CEX} and the minimum voltage LV_{CEX}.

A general statement one can make regarding BV_{CEX} for a negative value of V_{BB} is that it is limited to less than ($BV_{CBO} - V_{BB}$), since at this voltage the collector-base diode breakdown occurs. The lower boundary of BV_{CEX} is BV_{CEO} for V_{BB} negative. The lower boundary of LV_{CEX} is LV_{CEO} and the upper bound is $BV_{CBO} - V_{BB}$. Another practical limit occurs when the current pulled through the base is so large that the voltage drop across $r_{bb'}$, causes the emitter base diode to break down at the point where the base contact comes closest to the emitter junction. Ratings for BV_{CEX} and LV_{CEX} are non-conservative, since when used near these maximum voltages in this manner, a power failure in the hold-off voltage with collector voltage still applied can allow the transistor to get into the negative resistance region and burn out if the collector current is not limited.

---

* Linearity considerations may dictate a lower value for amplifier use.

** Measurements made on breakdown voltages at high currents should be made at a very low duty cycle with short pulses in order to keep the dissipation and temperature rise low.

MEASUREMENT

BV_{CBO} can be measured by forcing a collector current and measuring the collector-to-base voltage. For use as an absolute maximum rating, one need only be sure that the power dissipation of the device not be exceeded, although it is convenient to measure at a much lower current - of the order of microamps.

Using the same techniques as for BV_{CBO}, BV_{CEO} must be measured at a sufficiently low current so that the device is not in a negative resistance region which will cause oscillations. This requires currents of about 10μamp for the 2N697.

BV_{CES} can be measured at currents considerably higher than used in the measurement of a BV_{CEO}. The same method of measurement is used.

LV_{CEO} and LV_{CES} are high power dissipation measurements and ordinarily must be done on a low duty cycle with short pulses. A circuit for measuring these parameters is shown in Figure 7. In order to be sure of getting on the right region of the characteristics, a current pulse into the base turns the device "on" in each case. For LV_{CES} a switching core is used as the base pulse generator. Inserting a diode with the proper polarity in the base leads makes this a LV_{CEO} test. Paralleling the diode by a resistor R makes it a LV_{CER} test. BV_{CER}, BV_{CEX} and LV_{CEX} can be measured in similar ways.

To illustrate typical magnitudes and differences between these various breakdown voltages, Table I summarizes the data on a group of 2N697 transistors.

CONCLUSIONS

Voltage ratings of transistors as switches require close examination of circuit conditions. This refers to both d-c and dynamic conditions.

The highest collector voltage rating is that of the collector-to-base breakdown voltage BV_{CBO}. This is a useful rating in many oscillator and amplifier circuits.

The lowest collector voltage rating in any practical switching circuit is the lower limiting voltage LV_{CEO}. This corresponds to the case where a very high impedance path lies between the base and emitter and no turn-off current is used ($R_B = \infty$; $V_{BB} = 0$).

For many practical applications of Fairchild 2N696 and 2N697 Diffused Silicon Transistors, the conditions of $R_B \simeq 10\Omega$ is very nearly met. Then the appropriate collector voltage rating for switching currents in the order of tens and hundreds of milliamperes is LV_{CER}. Hence, Fairchild Semiconductor has inaugurated this as one of the voltage ratings for the 2N696 and 2N697.

For the case where the current switched is small so that the load line passes completely under the second part of the v-i curve (for the 2N696 and 2N697 this is in the order of milliamperes) the rating BV_{CES} could be used for the case $V_B = 0$ and R_B is negligible.

For the variety of other conditions that can exist where $R_B > 10\ \Omega$ or $R_B \neq \infty$, the appropriate tests should be made if the most conservative rating is not used.

TABLE I

Typical Breakdown and Asymptotic Voltages for Fairchild 2N697 Diffused Silicon Transistors

	Conditions	Typical Value (volts)
BV_{CEO}	$I_C = 10\ \mu a$	75
BV_{CBO}	$I_C = 100\ \mu a$	120
LV_{CEO}	$I_C = 100$ ma, 167 µs pulse, 1% Duty Cycle	35
LV_{CER}	$I_C = 100$ ma, $R = 10\Omega$, 167 µs pulse 1% Duty Cycle	70

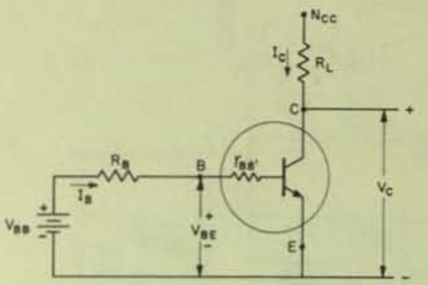


Fig. 1 Definitions of Circuit and Device Variables.

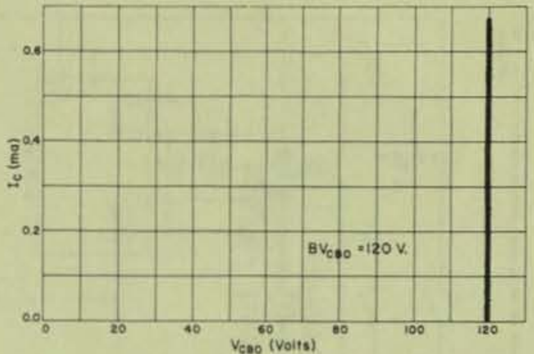


Fig. 2 I_C versus V_{CB} for $I_E = 0$
for a typical Fairchild 2N697

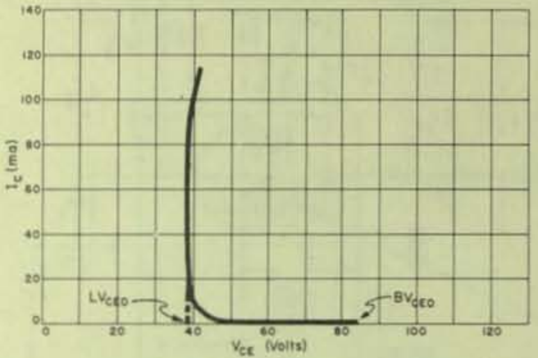


Fig. 3 BV_{CEO} and LV_{CEO}
for a typical Fairchild 2N697

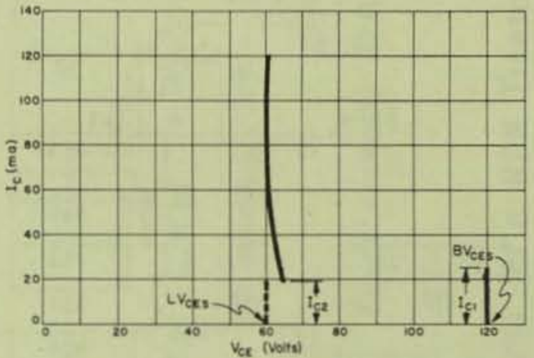


Fig. 4 BV_{CES} and LV_{CES}
for a typical Fairchild 2N697

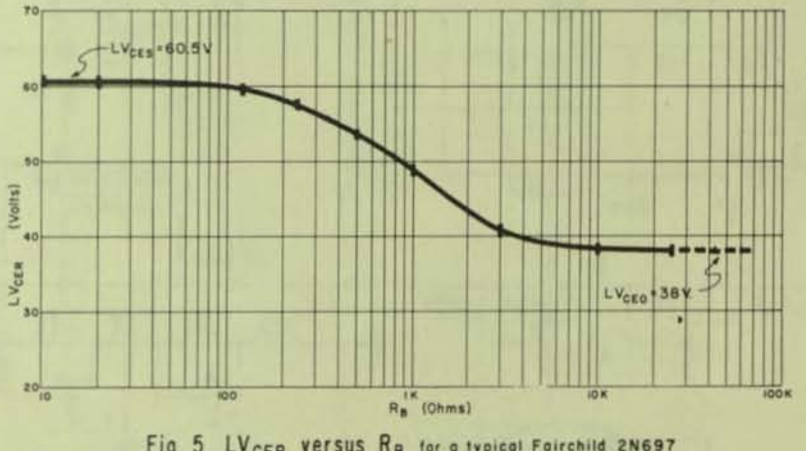
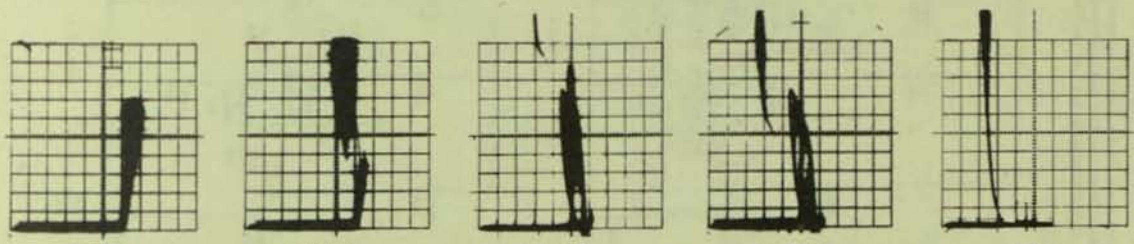


Fig. 5 LV_{CER} versus R_B for a typical Fairchild 2N697
at 100 ma, 167 μs pulse, 1% duty cycle

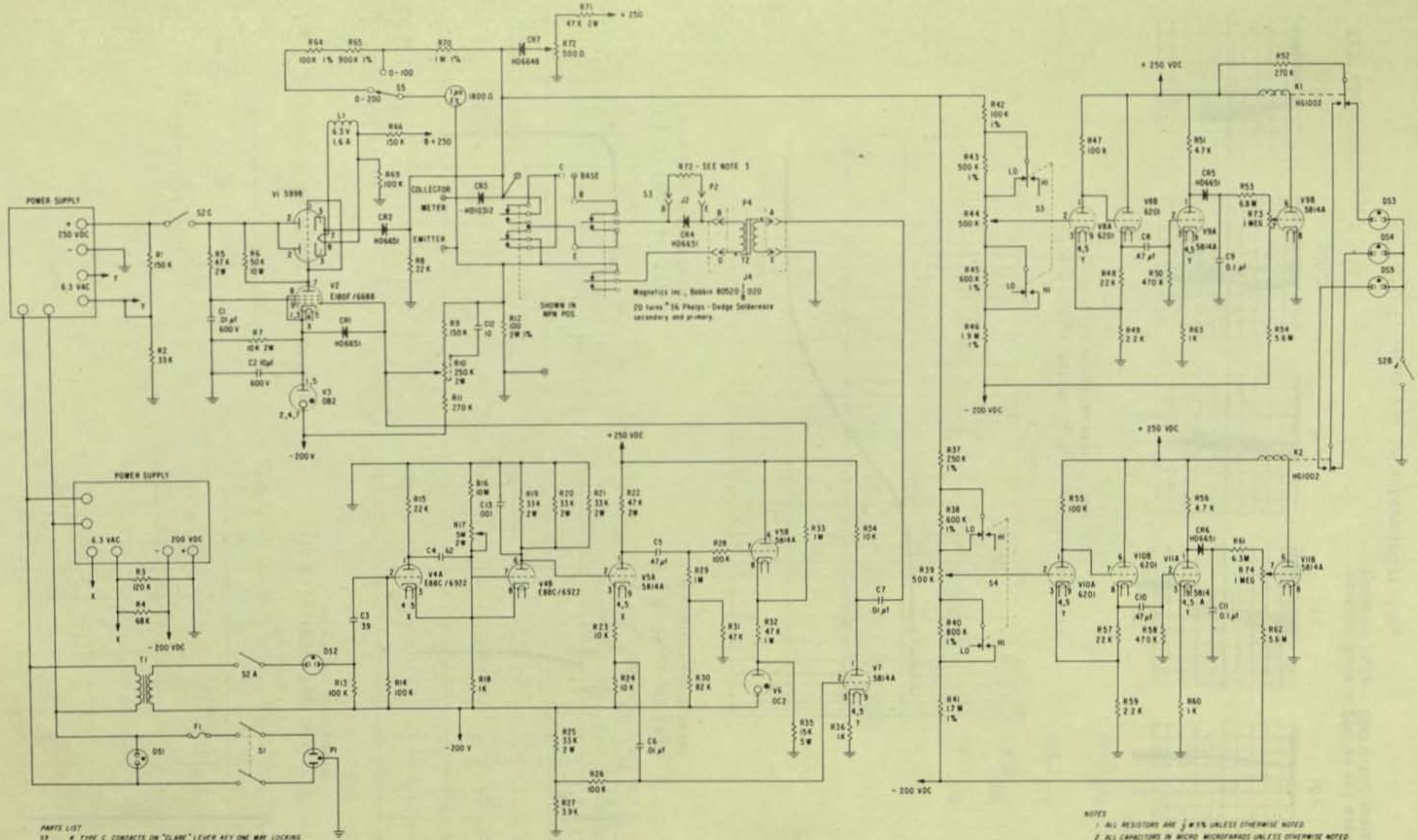


100 Ω 500 Ω 3 K 5 K 10 K

TEST CONDITIONS : $V_{BB} = -1.5$ V

Vertical Scale = 200 ma full scale
Horizontal Scale = 200 V full scale

Fig 6 I_C versus V_{CE} for various values of R_B

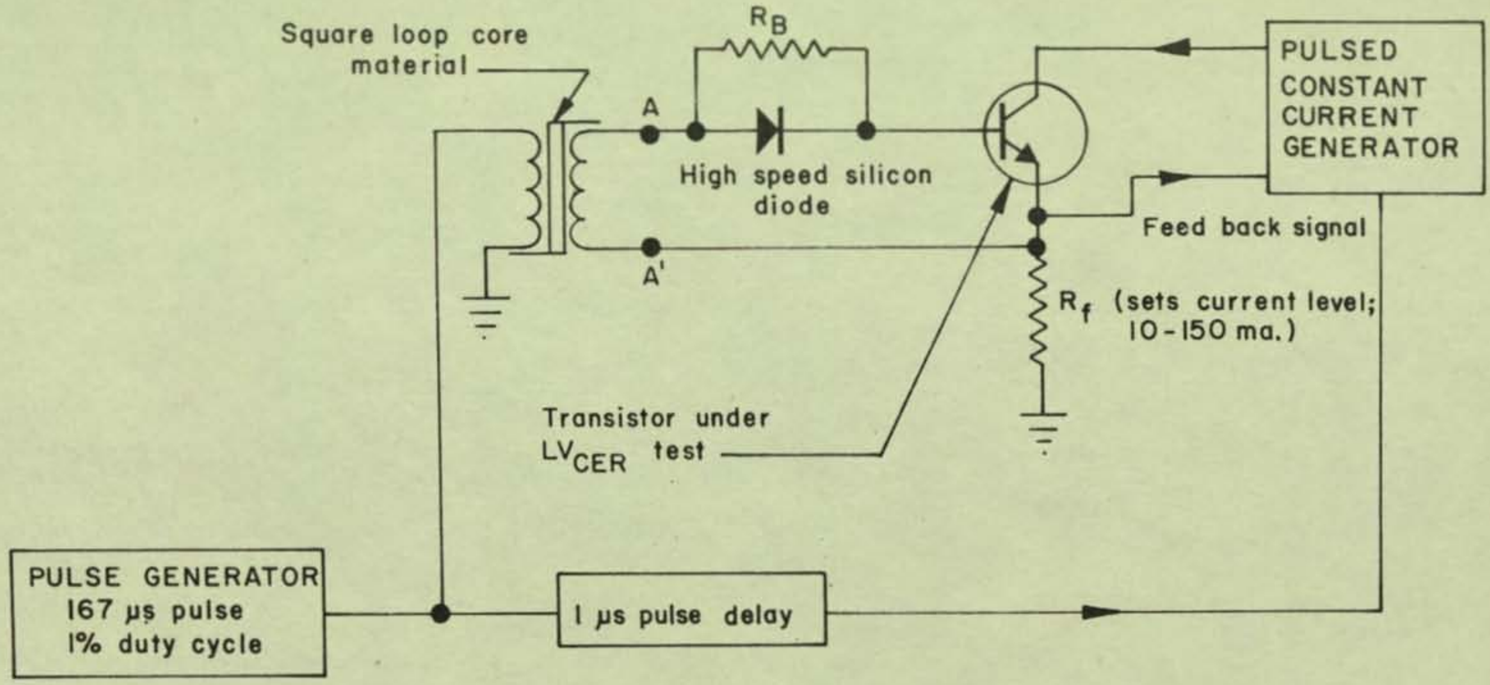


PARTS LIST
S3 4 TYPE C CONTACTS ON "CLARE" LEVER KEY ONE WAY LOCKING

NOTES
1. ALL RESISTORS ARE ½ W 5% UNLESS OTHERWISE NOTED
2. ALL CAPACITORS IN MICRO MICROFARADS UNLESS OTHERWISE NOTED
3. VALUE OF RESISTOR R72 MAY BE 10 Ω 1%, 24 Ω 1% OR 50 Ω 1%

Fig. 7 SCHEMATIC LV_{CER}

$R = 10\,\Omega$; $I_c = 100$ ma

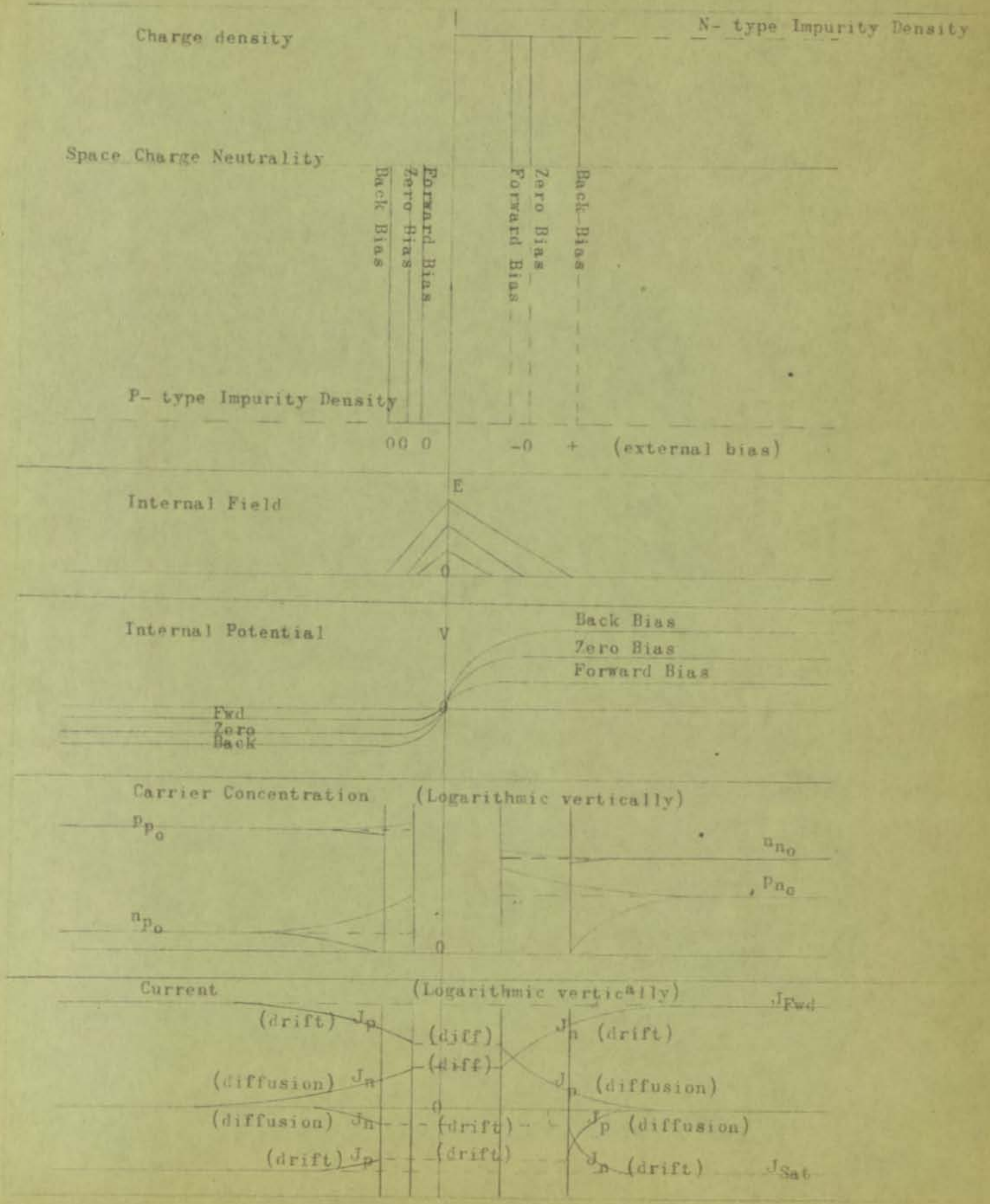


At terminals A-A': open circuit voltage is 2.5v p-p, with 2 μs pulse duration.

R_B is normally 10 Ω.

Fig. 7A Block Diagram of LV_{CER} Tester for a NPN Transistor.

FORWARD, ZERO, & BACK BIASED ABRUPT P-N JUNCTION



DEVICE PHYSICS REFERENCE NOTES

NOMENCLATURE & SYMBOLS

P = thermal equilibrium concentration of holes
N = " " " " electrons
n_i = " " " " " or holes in intrinsic material
ϵ_o = permittivity of vacuum = 8.85×10^{-12} farad/meter
ϵ = permittivity
ϵ_r = relative dielectric constant ($\epsilon_{r,Si} = 12$, $\epsilon_{r,Ge} = 16$)
M_A = acceptor dopant concentration
M_D = donor " "
X_p = depletion region width from metallurgical junction in P-type semiconductor
X_n = " " " " " " " N " "
V_B = contact potential
V = externally applied voltage in forward direction
V_D = barrier voltage = contact potential minus applied voltage
q = charge of electron = -1.6×10^{-19} coulomb
k = Boltzmann's constant = 1.38×10^{-23} joule / °K
T = absolute temperature (°K)
C = capacitance per unit area
Q = charge per unit area
D_p = diffusion constant of holes
D_n = " " " electrons
τ = lifetime
L_A = constant of linear junction relationship
J = current per unit area
J_s = minority carrier diffusion current per unit area (saturation)
L_p = diffusion length of holes
L_n = " " " electrons
p_p = hole concentration in P-type material
p_n = " " " N " "
n_p = electron " " P " "
n_n = " " " N " "
BV_D = avalanche breakdown voltage
m = empirical constant in avalanche equation
n_1 = electron density in excess of thermal equilibrium density at edge of depletion layer on P side
p_2 = hole " " " " " " " " " " N "
μ_n = mobility of electrons
μ_p = " " holes
n_o = electron concentration at thermal equilibrium
p_o = hole " " " "
σ = conductivity = $1/\rho$
ρ = resistivity

REFERENCE EQUATIONS

1. Mass action law in homogeneous region

$NP = n_i{}^2 = M_c M_v \exp(\mathcal{E}_g/KT)$ where M_c = energy state density in conduction band
and M_v = " " " " valence "

2. Einstein equations of mobility

$\mu_n = qD_n/kT$
$\mu_p = qD_p/kT$

3. Conductivity equations

$J_{drift} = \sigma E = E/\rho = qE(P\mu_p + N\mu_n)$

$J_{diff} = q(D_n \nabla N - D_p \nabla P)$

$J = J_{drift} + J_{diff}$

4. Rectifier equation or small current equation

$J = J_s[\exp(qV/kT) - 1]$ where

$J_s = q(D_p p_n/L_p + D_n n_p/L_n)$ and

$L_p = (D_p \tau_p)^{1/2}$ and

$L_n = (D_n \tau_n)^{1/2}$

5. Back Bias current near avalanche breakdown

$J = \dfrac{-J_s}{1 - (-V/BV_D)^m}$ where $1.5 < m < 4$ for silicon

6. Capacitance per unit area

Abrupt Junction:

$C_{AJ} = dQ/dV = \mathcal{E}/(X_p + X_n) = [q\mathcal{E}M_A M_D/2(M_A + M_D)]^{1/2}\, V_D{}^{-1/2}$

Graded Junction:

$C_{GJ} = dQ/dV = \mathcal{E}/2X_p = \mathcal{E}/2X_n = (q\mathcal{E}^2 n_i/12L_A)^{1/3}\, V_D{}^{-1/3}$ where
$M_D - M_A = n_i x/L_A$

7. Depletion Region widths

Abrupt junction:

$$X_p = \left[\frac{2\mathcal{E}V_D}{qM_A(1 + M_A/M_D)}\right]^{1/2}$$

$X_n = \left[\dfrac{2\mathcal{E}V_D}{qM_D(1 + M_D/M_A)}\right]^{1/2}$ where $V_D = V_B - V$ and

V_B = contact potential $= kT/q\, \ln(M_D M_A/n_i{}^2)$

Graded junction:

$X_p = X_n = (V_D 3\mathcal{E}L_A/\,2qn_i)^{1/3}$ where the graded junction definitionis
$M_D - M_A = n_i x/L_A$

REFERENCE EQUATIONS

8. Excess minority carrier density at edge of depletion layer

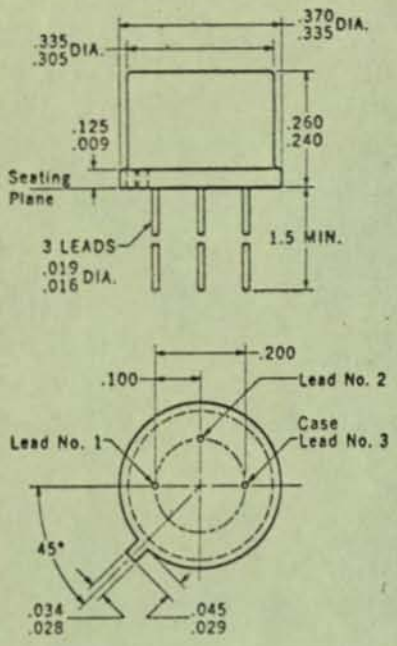
$n_1 = n_p[\exp(qV/kT) - 1]$ on uniform P-type side of junction

$p_2 = p_n[\exp(qV/kT) - 1]$ " " N " " " " where

n_1 = electron density in excess of thermal equilibrium density at edge of depletion region on P-type side, and

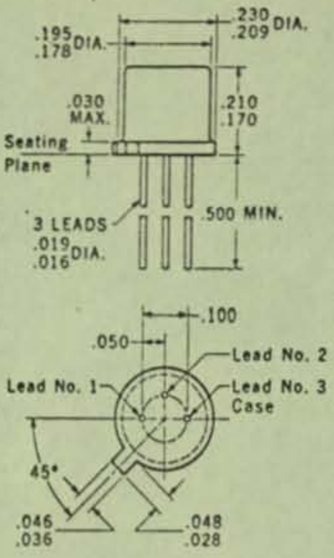
p_2 = hole density in excess of thermal equilibrium density at edge of depletion region on N-type side

PHYSICAL DIMENSIONS A
in accordance with
JEDEC (TO-5) outline
(15 mil kovar)



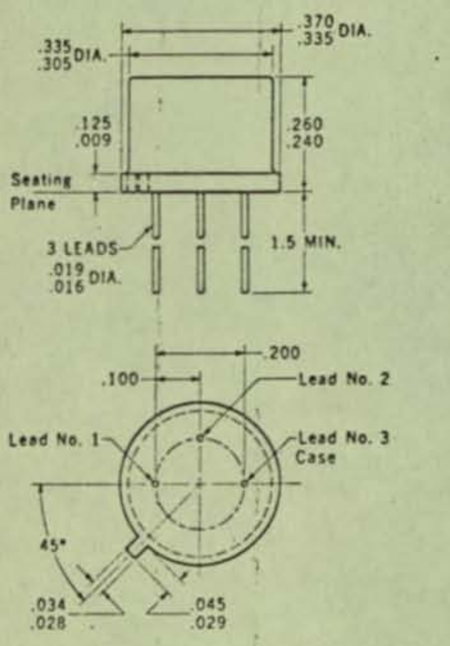
NOTES: All dimensions in inches
Leads are gold-plated kovar
Lead No. 3 internally connected to case
Package weight is 1.11 grams

PHYSICAL DIMENSIONS B
in accordance with
JEDEC (TO-18) outline
(8 mil kovar)



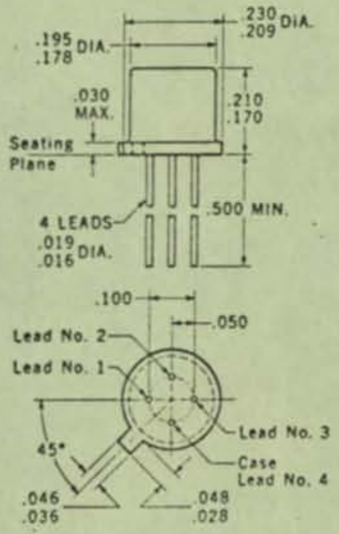
NOTES: All dimensions in inches
Same as "CB" except for lead length
Leads are gold-plated kovar
Lead No. 3 internally connected to case
Package weight is 0.44 gram

PHYSICAL DIMENSIONS C
in accordance with
JEDEC (TO-5) outline
(60 mil kovar)



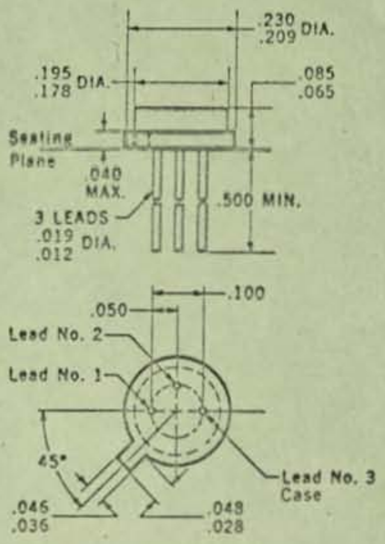
NOTES: All dimensions in inches
Leads are gold-plated kovar
Lead No. 3 internally connected to case
Package weight is 1.23 grams

PHYSICAL DIMENSIONS D
in accordance with
JEDEC (TO-72) outline
(Similar to packages
"F", "M" and "AV")
(8 mil kovar)



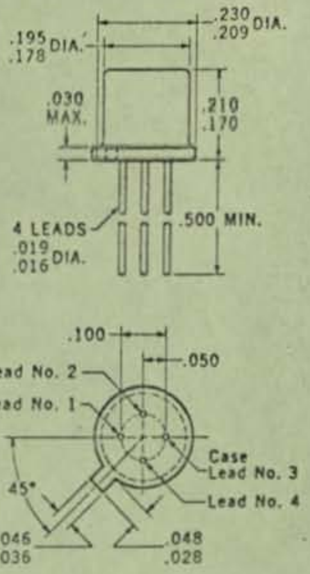
NOTES: All dimensions in inches
Dimensions similar to JEDEC TO-18 except
4 lead 90° spacing, bridge type
Leads are gold-plated kovar
Internal collector lead length is 110 mils
Collector club head length is 75 mils
Package weight is 0.50 gram

PHYSICAL DIMENSIONS E
in accordance with
JEDEC (TO-46) outline
(45 mil kovar)



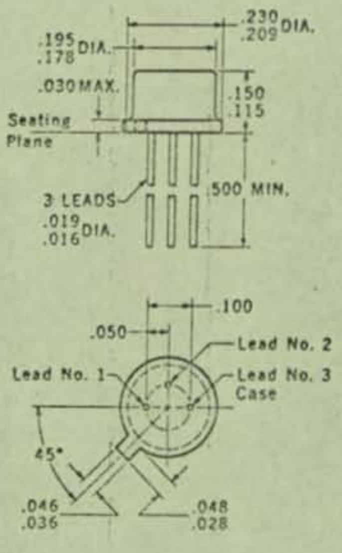
NOTES: All dimensions in inches
Lead No. 3 internally connected to case
Leads are gold-plated kovar
Package weight is 0.35 gram

PHYSICAL DIMENSIONS F
in accordance with
JEDEC (TO-72) outline
(Similar to packages
"D", "M" and "AV")
(8 mil kovar)



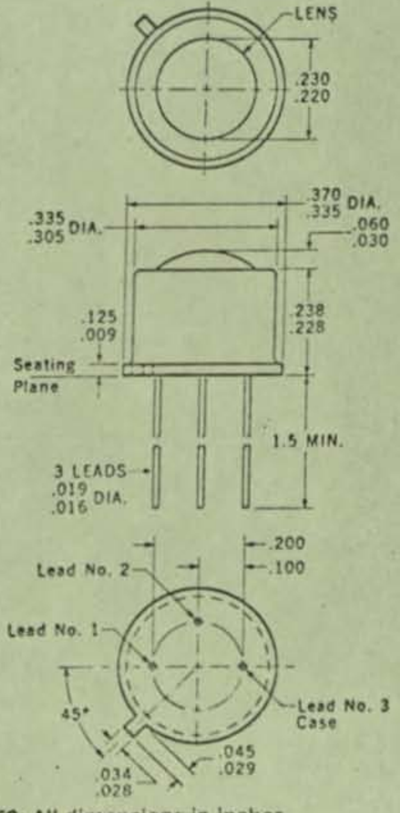
NOTES: All dimensions in inches
Dimensions similar to JEDEC TO-18 except 4 leads 90° spacing
Leads are gold-plated kovar
Package weight is 0.47 gram

PHYSICAL DIMENSIONS H
in accordance with
JEDEC (TO-52) outline
(8 mil kovar)



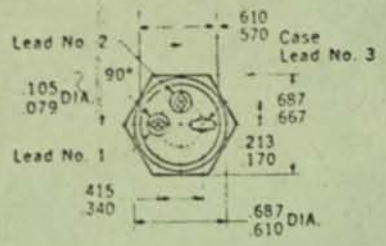
NOTES: All dimensions in inches
Leads are gold-plated kovar
Lead No. 3 internally connected to case
Package weight is 0.31 gram

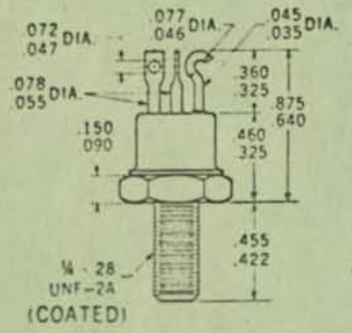
PHYSICAL DIMENSIONS I
(15 mil kovar)



NOTES: All dimensions in inches
Leads are gold-plated kovar
Lead No. 3 internally connected to case
Dimensions similar to JEDEC (TO-5) except for short height and lens top
Package weight is 1.34 grams

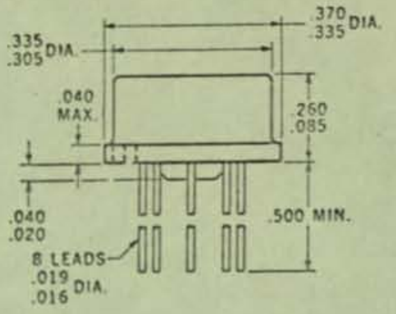
PHYSICAL DIMENSIONS J
Similar*to JEDEC (TO-61) outline

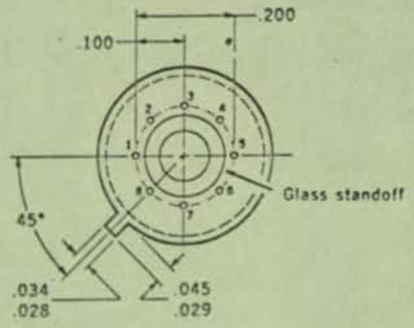




NOTES: All dimensions in inches
Header and stud are gold-plated copper
Cap is kovar
Disc is beryllia
*Identical to TO-61 with exception of lead solder lug
Package weight is 14.10 grams

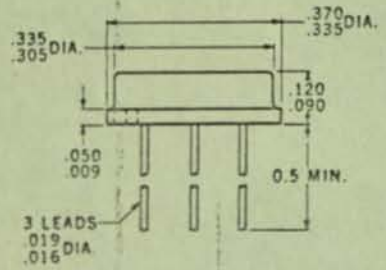
PHYSICAL DIMENSIONS K
(15 mil kovar)

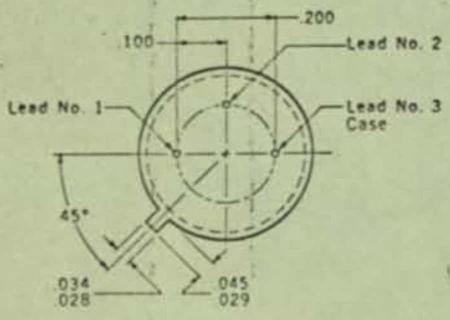




NOTES: All dimensions in inches
8 leads, 45° spacing, omitted pins are specified on individual specifications
Dimensions are similar to JEDEC (TO-5) except for 8 leads and short height
Leads are gold-plated kovar
Package weight is 0.95 grams

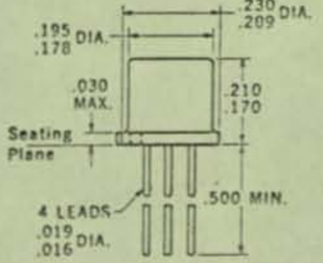
PHYSICAL DIMENSIONS L
(60 mil kovar)

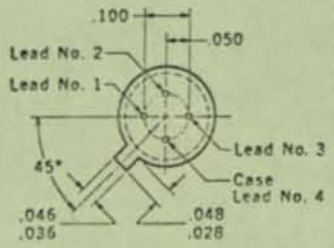




NOTES: All dimensions in inches
Dimensions similar to JEDEC TO-5 except for overall height
Lead No. 3 internally connected to case
Leads are gold-plated kovar
Package weight is 0.98 gram

PHYSICAL DIMENSIONS M
Single island package in accordance with JEDEC (TO-72) outline
(Similar to packages "D", "F" and "AV")

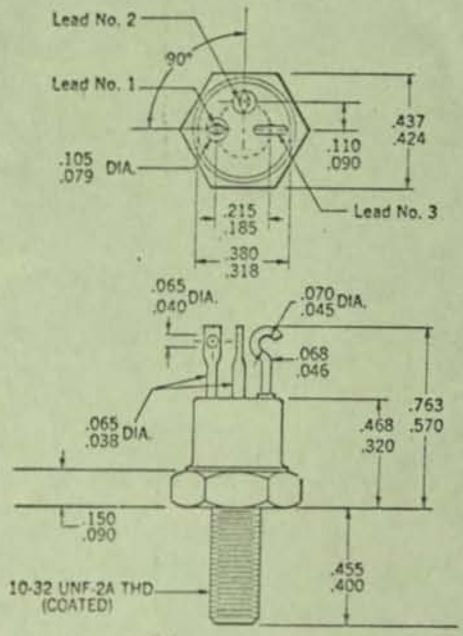




NOTES: All dimensions in inches
Dimensions similar to JEDEC TO-18 except 4 leads 90° spacing, single island type
Leads are gold-plated kovar
Kovar island thickness = 15 mils
Package weight is 0.47 gram

PHYSICAL DIMENSIONS P

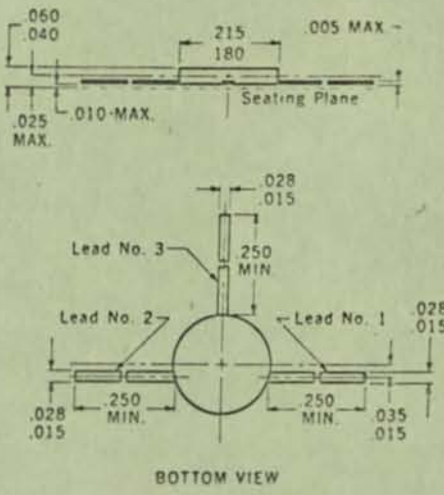
in accord with JEDEC (TO-59) outline



NOTES: All dimensions in inches
Stud and header are gold-plated copper
Cap is gold-plated kovar
Disc is silver tungsten
Package weight is 5.65 grams
Lead No. 3 electrically connected to case

PHYSICAL DIMENSIONS Q

in accordance with JEDEC (TO-50) outline

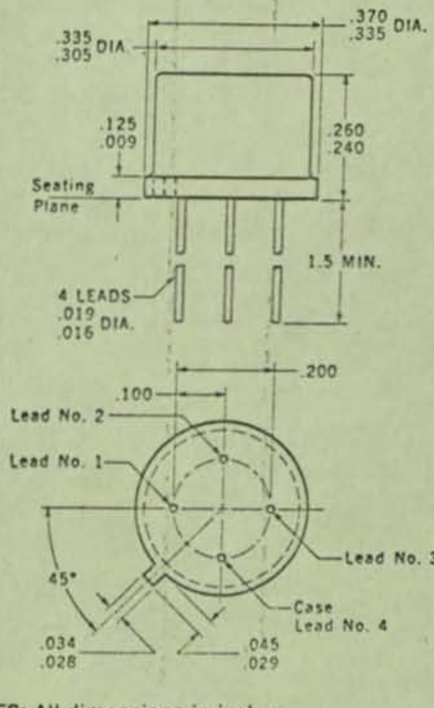


NOTES: All dimensions in inches
Leads are gold-plated kovar
Base material is ceramic and is 10 mils thick
Package weight is 0.126 gram

PHYSICAL DIMENSIONS R

in accordance with JEDEC(TO-33) outline

(15 mil kovar)

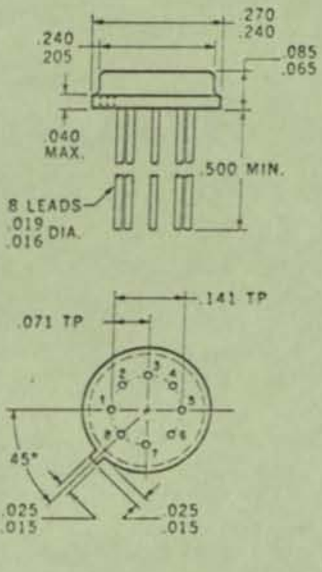


NOTES: All dimensions in inches
Leads are gold-plated kovar
Internal collector lead length is 75 mils
Island is 60 mils wide, 80 mils long and 15 mils thick
Package weight is 1.22 grams

PHYSICAL DIMENSIONS T

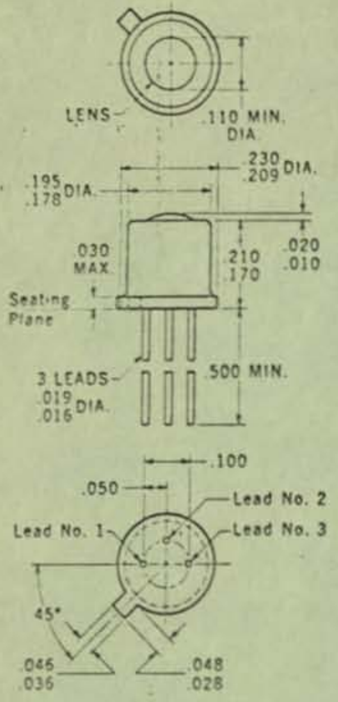
in accordance with JEDEC (TO-70) outline

(45 mil kovar)



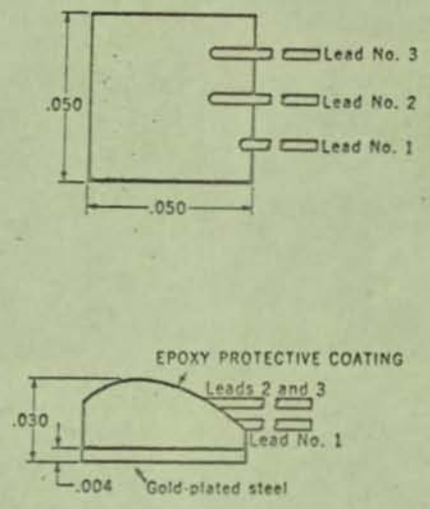
NOTES: All dimensions in inches
Leads are gold-plated kovar
Dimensions are similar to JEDEC TO-47 except 8 lead 45° spacing
Omitted leads are specified on individual specifications
Package weight is 0.67 gram

PHYSICAL DIMENSIONS U
(8 mil kovar)



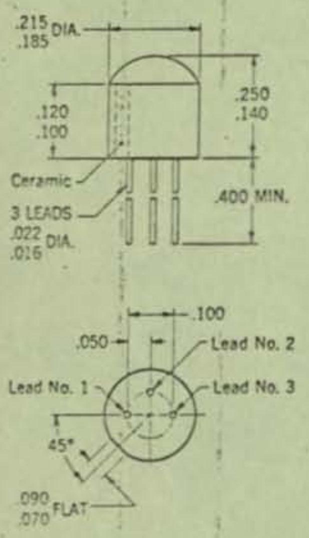
NOTES: All dimensions in inches
Lead No. 3 internally connected to case
Dimensions similar to JEDEC (TO-18) except for lens top
Lead No. 2 omitted for 2 lead package
Leads are gold-plated kovar
3 lead package weight is 0.43 gram
2 lead package weight is 0.38 gram

PHYSICAL DIMENSIONS W
(Typical)



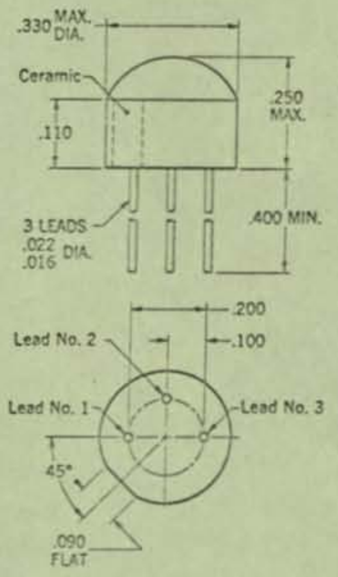
NOTES: All dimensions in inches
Leads are 1 mil diameter gold
Package weight is 0.004 gram

PHYSICAL DIMENSIONS Y
Epoxy package



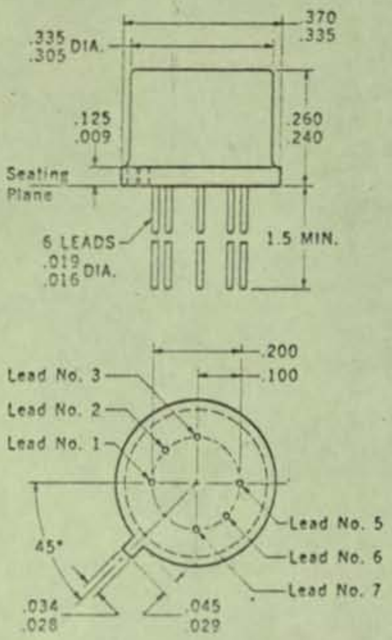
NOTES: All dimensions in inches
Ceramic Base
Internal collector lead length is 110 mils
Collector club head length is 85 mils
Emitter and Base leads are gold-plated nickel
Collector lead is gold-plated kovar
Package weight is 0.31 gram

PHYSICAL DIMENSIONS Z
Epoxy package



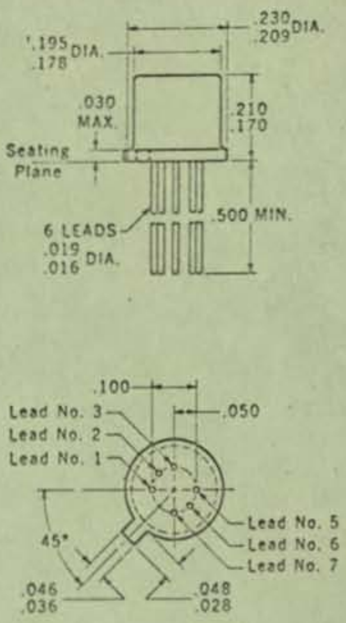
NOTES: All dimensions in inches
Leads are gold-plated kovar
Ceramic base
Internal collector lead length is 110 mils
Collector club head length is 180 mils
Package weight is 0.68 gram

PHYSICAL DIMENSIONS AA
Adjacent two island package



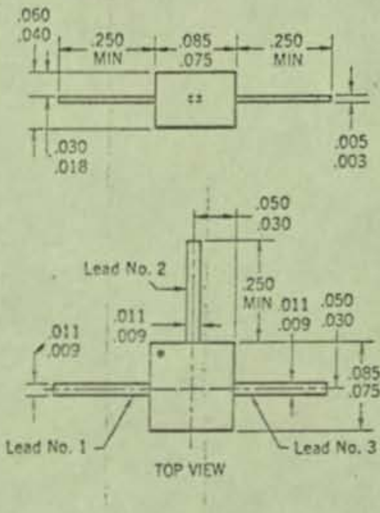
NOTES: All dimensions in inches
Dimensions similar to JEDEC TO-5 except 8 lead 45° spacing, leads 4 and 8 omitted
Lead No. 1 internally connected to one island,
Lead No. 7 internally connected to other island
Leads are gold-plated kovar
Kovar island thickness = 15 mils
Package weight is 1.23 grams

PHYSICAL DIMENSIONS AB
Opposed two island package



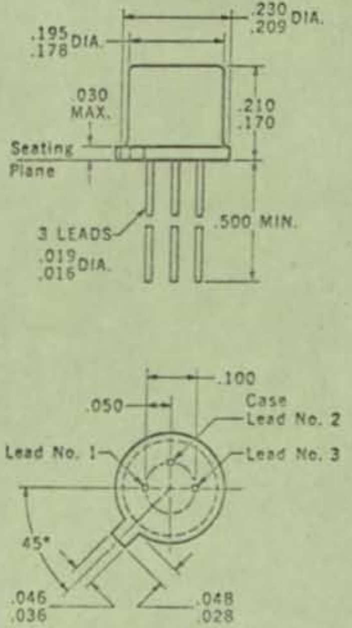
NOTES: All dimensions in inches
Dimensions similar to JEDEC TO-18 except 8 lead 45° spacing, leads 4 and 8 omitted
Lead No. 3 internally connected to one island,
Lead No. 7 internally connected to other island
Leads are gold-plated kovar
Kovar island thickness = 15 mils
Package weight is 0.60 gram

PHYSICAL DIMENSIONS AC
HERMET TM package



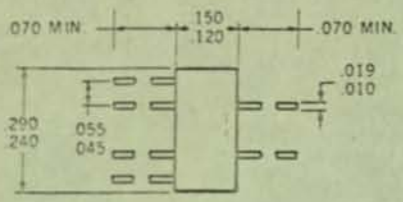
NOTES: All dimensions in inches
Leads are gold-plated nickel alloy
Package weight is 0.015 gram

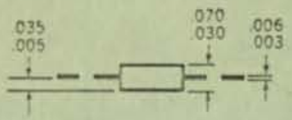
PHYSICAL DIMENSIONS AD
in accordance with JEDEC (TO-18) outline
(8 mil kovar)



NOTES: All dimensions in inches
Leads are gold-plated kovar
Identical to package "B" except that lead No. 2 is internally connected to case
Package weight is 0.44 gram

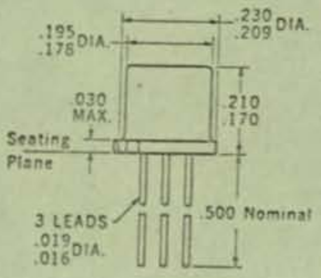
PHYSICAL DIMENSIONS AE
in accordance with
JEDEC (TO-89) outline
Network Package

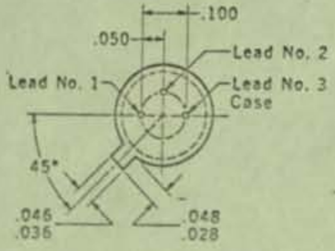




NOTES: All dimensions in inches
Leads are gold-plated kovar
Base material is gold-plated kovar
4 mils in thickness. Chips are mounted on a 4 mil thick gold-plated kovar slab which is separated from the base material by a 6 to 7.5 mil ceramic insulator
Package weight is .09 gram

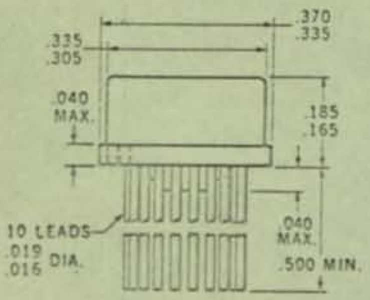
PHYSICAL DIMENSIONS AF
Similar* to JEDEC
(TO-18) outline
(8 mil kovar)

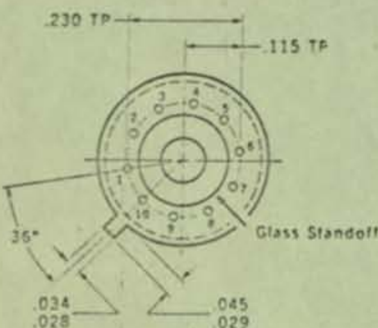




NOTES: All dimensions in inches
OBSOLETE — For information only
Leads are gold-plated kovar
Lead No. 3 internally connected to case
Package weight is 0.34 gram
*Identical to package "B" except that lead length is specified 0.5 inch nominal instead of 0.5 inch minimum

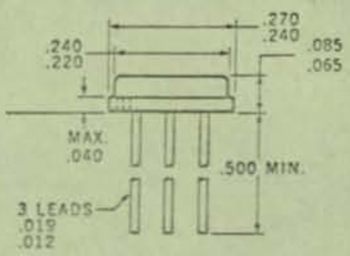
PHYSICAL DIMENSIONS AG
(15 mil kovar)
in accordance with
JEDEC (TO—100) outline

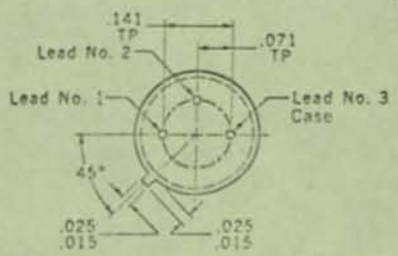




NOTES: All dimensions in inches
Leads are gold-plated kovar
Dimensions similar to TO-5 except 10 leads 36° spacing and short height
Package weight is 1.02 grams

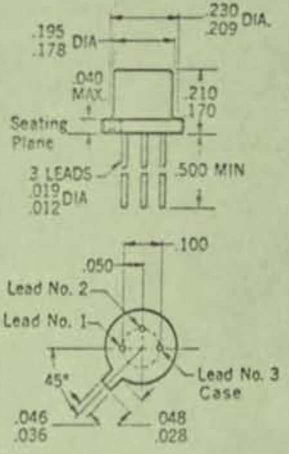
PHYSICAL DIMENSIONS AH
in accordance with
JEDEC (TO-47) outline
(45 mil kovar)





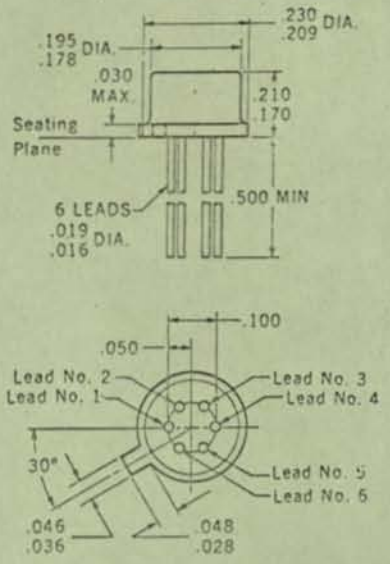
NOTES: All dimensions in inches
Leads are gold-plated kovar
Lead No. 3 internally connected to case
Package weight is 0.55 gram

PHYSICAL DIMENSIONS AI
(45 mil kovar)



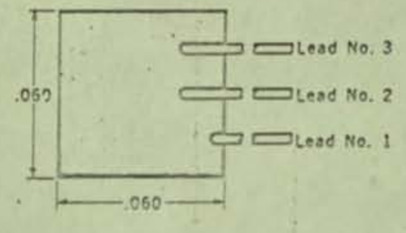
NOTES: All dimensions in inches
TO-46 header with TO-18 cap
Lead No. 3 internally connected to case
Leads are gold-plated kovar
Package weight is 0.43 gram

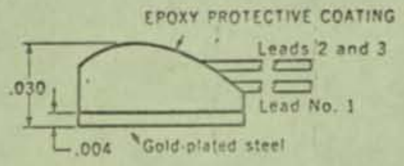
PHYSICAL DIMENSIONS AJ
Adjacent two island package
(8 mil kovar)



NOTES: All dimensions in inches
Dimensions similar to JEDEC TO-18 except 6 lead, 60° spacing
Lead No. 1 internally connected to one island,
Lead No. 6 internally connected to other island
Package weight is 0.60 gram

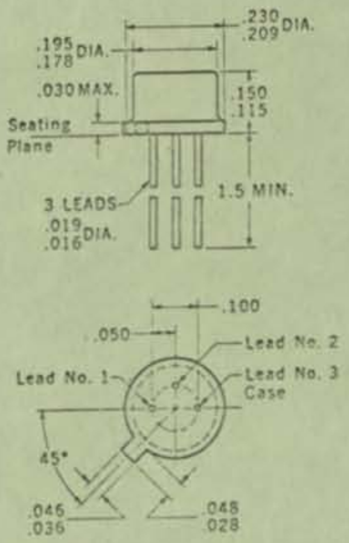
PHYSICAL DIMENSIONS AK
(Typical)





NOTES: All dimensions in inches
Leads are 2 mil diameter gold
Package weight is 0.006 gram

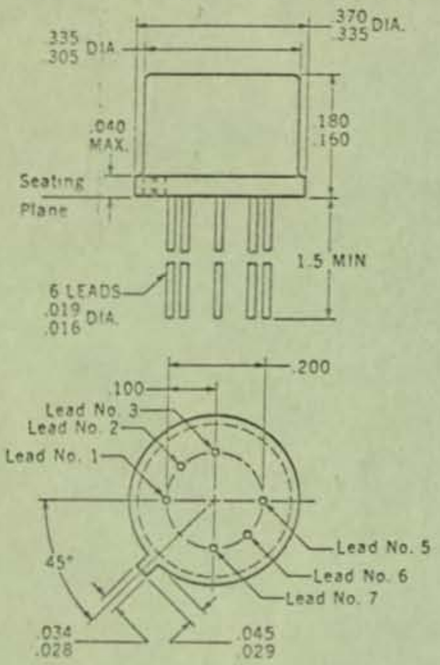
PHYSICAL DIMENSIONS* AL
(8 mil kovar)



NOTES: All dimensions in inches
*Identical to the "H" package JEDEC TO-52 except minimum lead length
Leads are gold-plated kovar
Lead No. 3 internally connected to case
Package weight is 0.40 gram

PHYSICAL DIMENSIONS AM

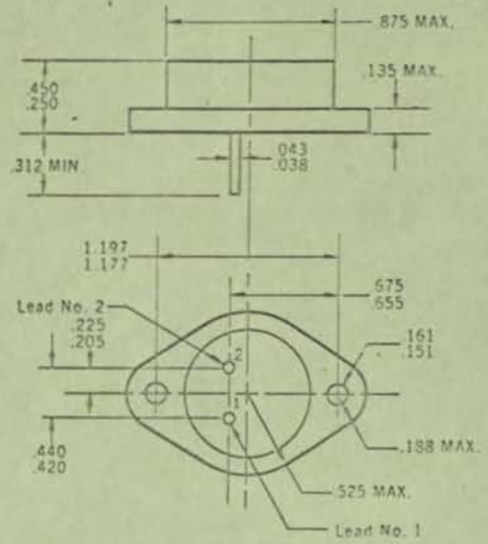
Adjacent two island package in accord with JEDEC TO-78



NOTES: All dimensions in inches
- Dimensions similar to JEDEC TO-5 except short height.
- 8 lead 45° spacing, leads 4 and 8 omitted
- Identical to "AA" package except for height
- Lead No. 1 internally connected to one island,
- Lead No. 7 internally connected to other island
- Leads are gold-plated kovar
- Kovar island thickness = 15 mils
- Package weight is 1.08 grams

PHYSICAL DIMENSIONS AN

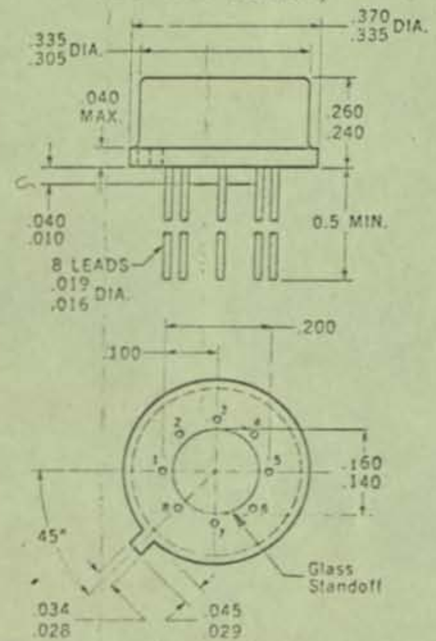
in accordance with JEDEC (TO-3) outline



NOTES: All dimensions in inches
- Leads 1 & 2 electrically isolated from case
- Case is third electrical connection
- Leads are nickel – alloy
- Package weight 8.71 grams

PHYSICAL DIMENSIONS AP

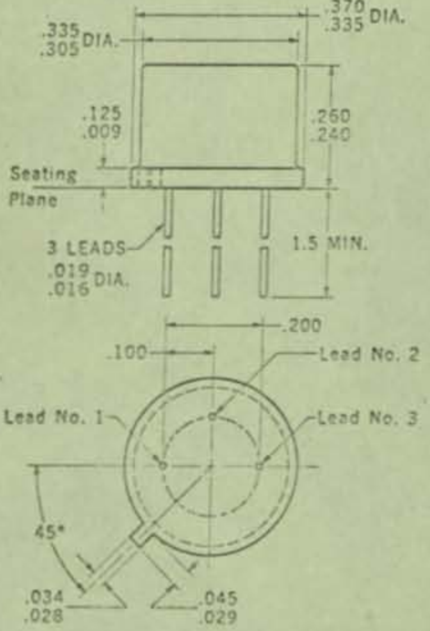
in accordance with JEDEC (TO-76) outline (15 mil kovar)



NOTES: All dimensions in inches
- Same as K package except for standard TO-5 height
- 8 leads, 45° spacing, omitted pins are specified on individual specifications
- Dimensions are similar to JEDEC (TO-5) except for 8 leads
- Leads are gold-plated kovar
- Package weight is 1.22 grams

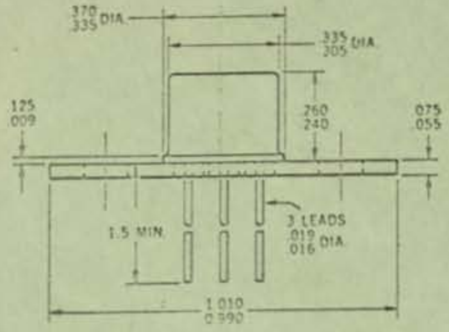
PHYSICAL DIMENSIONS AQ

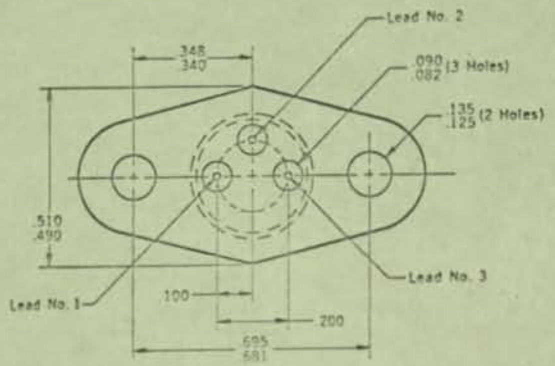
in accordance with JEDEC (TO-5) outline (15 mil kovar)



NOTES: All dimensions in inches
- Same as "AS" except for lead diameter
- Leads are gold-plated kovar
- Solid kovar header
- This package also used as part of "AR" assembly
- Collector internally connected to case
- Package weight is 0.75 gram

PHYSICAL DIMENSIONS AR

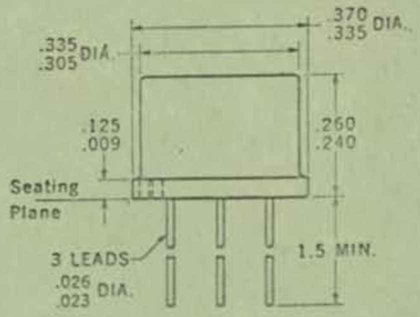


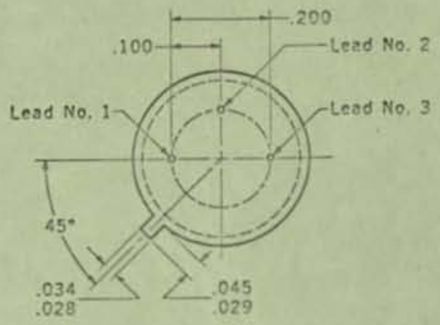


NOTES: All dimensions in inches
Same as "AQ" except for addition of flange
Leads are gold-plated copper
Emitter and Base flange holes countersunk to 0.141 ±0.005 on seating plane
Collector internally connected to case
Solid kovar header
Package weight 3.84 grams

PHYSICAL DIMENSIONS AS

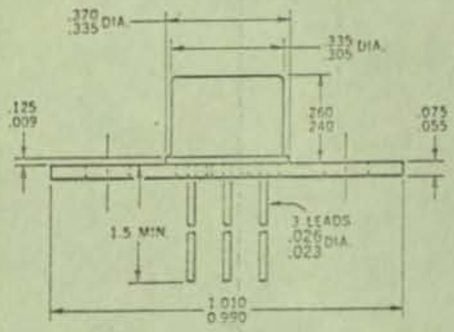
(15 mil kovar)

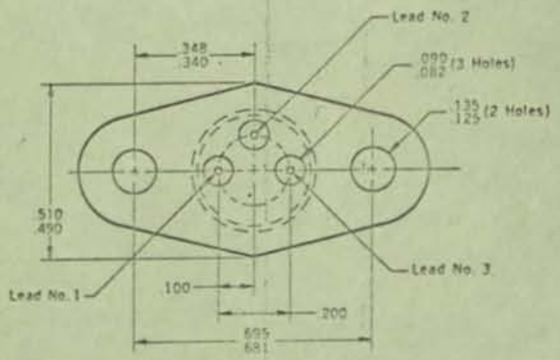




NOTES: All dimensions in inches
Same as "AQ" except for lead diameter
Leads are gold-plated kovar
Solid kovar header
This package also used as part of "AT" assembly
Package weight is 0.98 gram

PHYSICAL DIMENSIONS AT

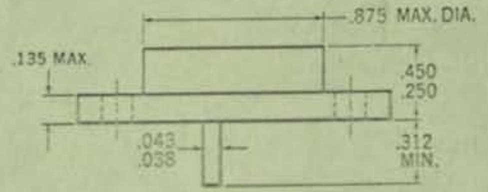


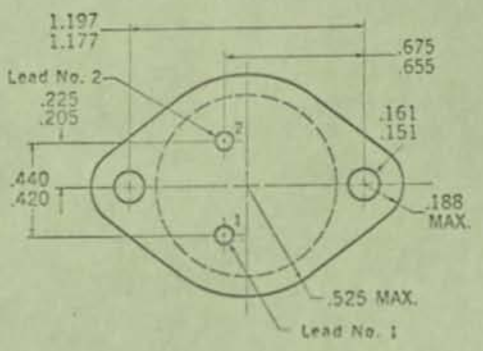


NOTES: All dimensions in inches
Same as "AS" except for addition of flange
Leads are gold-plated kovar
Flange is nickel-plated copper
Emitter and Base flange holes countersunk to 0.141 ±0.005 on seating plane
Collector internally connected to case
Solid kovar header
Package weight is 4.1 grams

PHYSICAL DIMENSIONS AU

in accordance with JEDEC (TO-3) outline

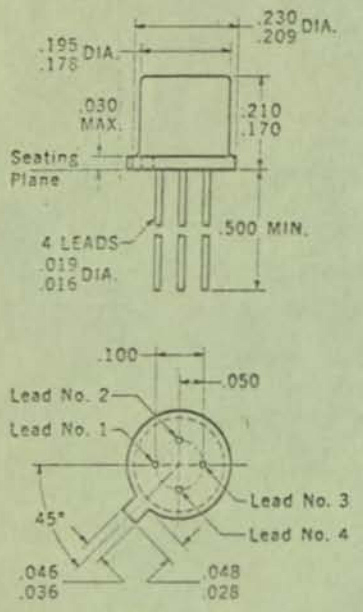




NOTES: All dimensions in inches
Identical to "AN" except for base thickness
Leads 1 and 2 electrically isolated from case
Case is third electrical connection
Leads are gold-plated nickel alloy
Package weight 8.8 grams
Steel flange

PHYSICAL DIMENSIONS AV

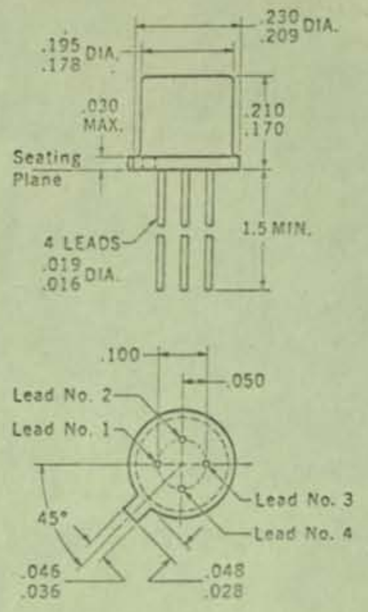
in accordance with
JEDEC (TO-72) outline



NOTES: All dimensions in inches
- Identical to "AW" except for lead length
- Similar to packages "D," "F" and "M"
- Nail head collector
- Leads are gold-plated kovar
- Lead No. 3 electrically isolated from case
- Package weight is 0.36 gram

PHYSICAL DIMENSIONS AW

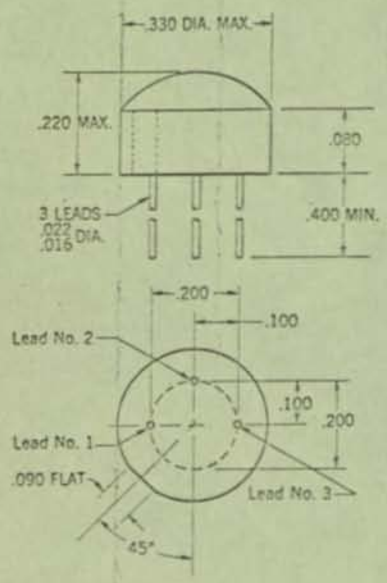
in accord with
JEDEC (TO-72) outline



NOTES: All dimensions in inches
- Identical to "AV" except for lead length
- Similar to packages "D," "F" and "M"
- Nail head collector
- Leads are gold-plated kovar
- Lead No. 3 electrically isolated from case
- Package weight is 0.5 gram

PHYSICAL DIMENSIONS AZ

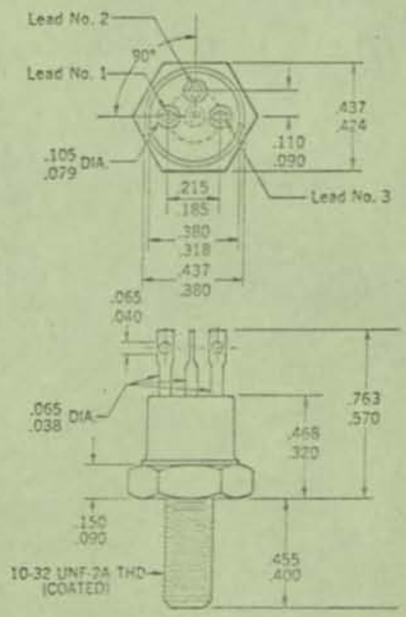
Epoxy package



NOTES: All dimensions in inches
- Internal collector lead length is .080
- Same as "Z" package except for height
- Leads 1 and 2 are gold-plated nickel
- Lead No. 3 is gold-plated kovar
- Ceramic base
- Package weight is 0.5 gram

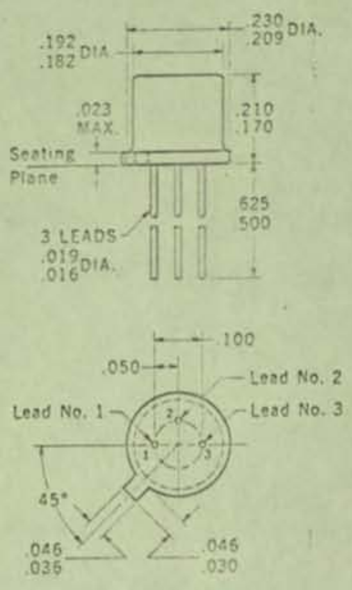
PHYSICAL DIMENSIONS BA

ISOLATED COLLECTOR
in accord with JEDEC (TO-59) outline



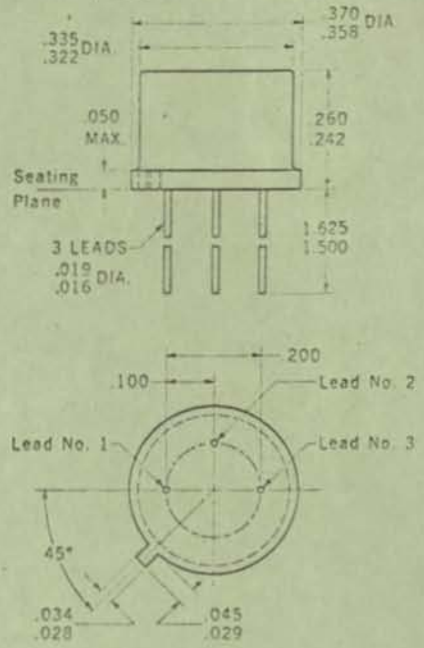
NOTES: All dimensions in inches
- Stud and header are gold-plated copper
- Cap is gold-plated kovar
- All leads electrically isolated from case by beryllia disc
- Package weight is 5.65 grams

PHYSICAL DIMENSIONS BB
in accordance with
JEDEC (TO-56) outline



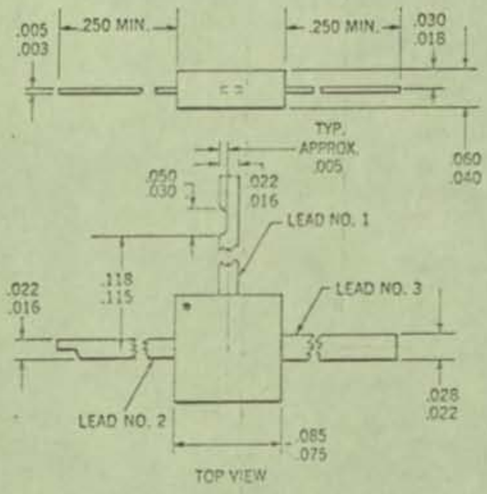
NOTES: All dimensions in inches
Leads are gold-plated kovar
Collector internally connected to case
Package weight is 0.43 gram

PHYSICAL DIMENSIONS BC
in accordance with
JEDEC (TO-55) outline
(15 mil kovar)



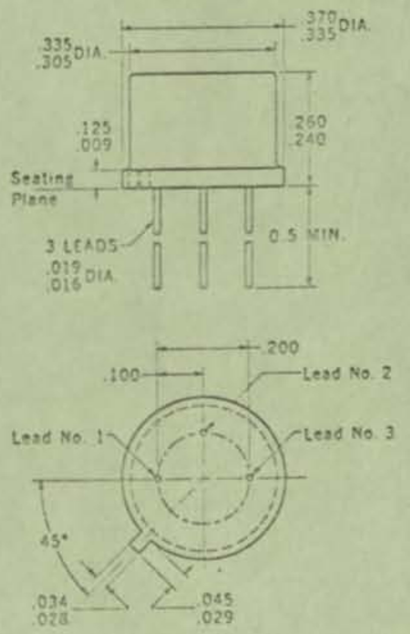
NOTES: All dimensions in inches
Leads are gold-plated kovar
Lead No. 3 internally connected to case
Package weight is 1.23 grams

PHYSICAL DIMENSIONS BD
HERMET™ package



NOTES: All dimensions in inches
Leads are gold-plated nickel alloy
Package weight is 0.034 gram

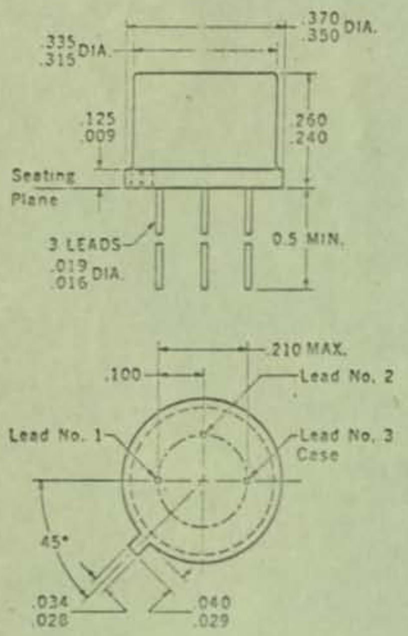
PHYSICAL DIMENSIONS BE
in accord with JEDEC
(TO-39) outline
(15 mil kovar)



NOTES: All dimensions in inches
Identical to package "A" except for lead length
Leads are gold-plated kovar
Lead No. 3 internally connected to case
Package weight is 1.11 grams

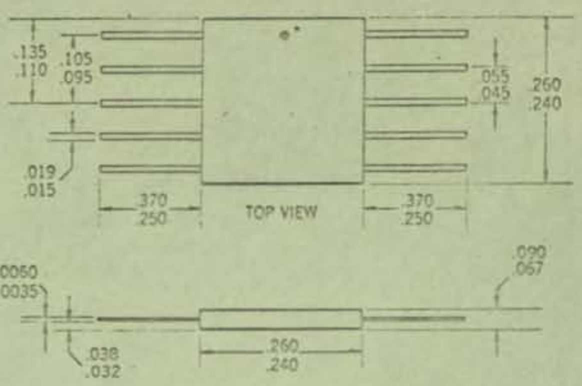
PHYSICAL DIMENSIONS BF

in accord with JEDEC
(TO-39) outline
(50 mil kovar)



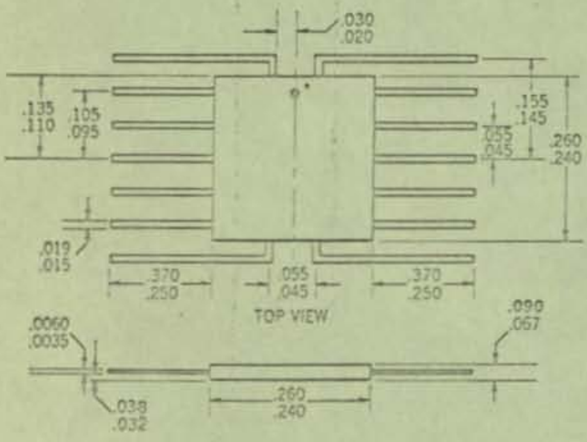
NOTES: All dimensions in inches
Identical to package "C" except for lead length
Leads are gold-plated kovar
Lead No. 3 internally connected to case
Package weight is 1.23 grams

PHYSICAL DIMENSIONS BG



NOTES: All dimensions in inches
*Alternate marking of dot in upper left hand corner is also acceptable
Package weight is approximately 0.7 gram

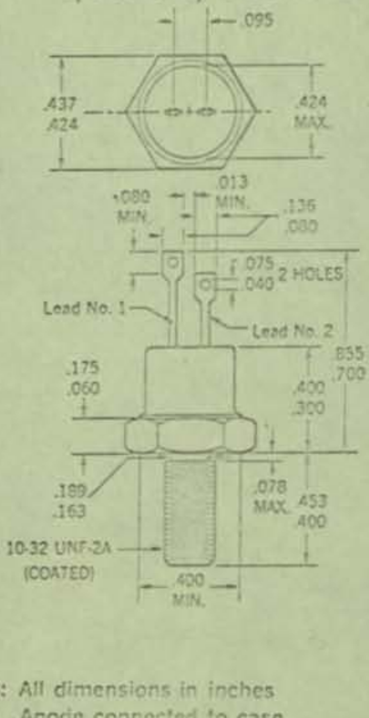
PHYSICAL DIMENSIONS BH



NOTES: All dimensions in inches
*Alternate marking of dot in upper left hand corner is also acceptable
Package weight is approximately 0.718 gram

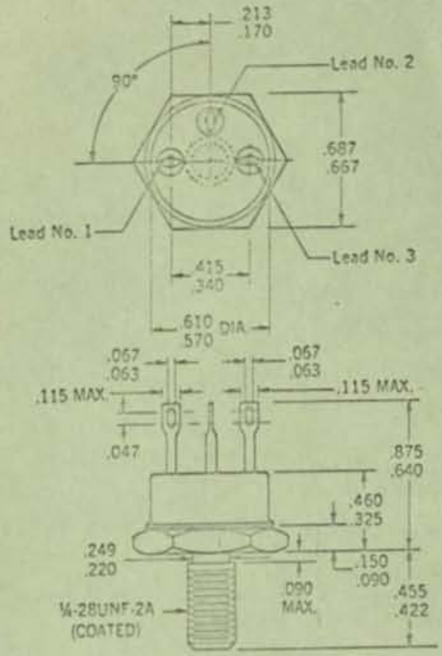
PHYSICAL DIMENSIONS BI

in accordance with JEDEC
(TO-64) outline



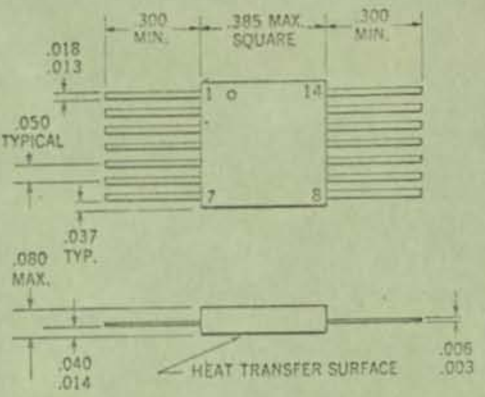
NOTES: All dimensions in inches
Anode connected to case
Stud and header are nickel-plated copper
Cap is nickel-plated steel
Package weight is 5.3 grams

PHYSICAL DIMENSIONS BJ
ISOLATED COLLECTOR
Similar to JEDEC (TO-61) outline*



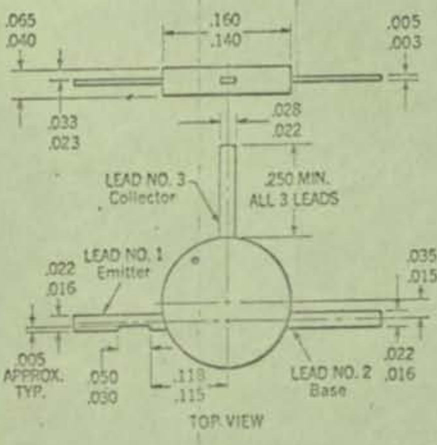
NOTES: All dimensions in inches
Stud and header are copper
Cap is kovar
All leads electrically isolated from case
Disc is beryllia
Package weight is 14.1 grams
*Identical to TO-61 except for lead solder lugs

PHYSICAL DIMENSIONS BK



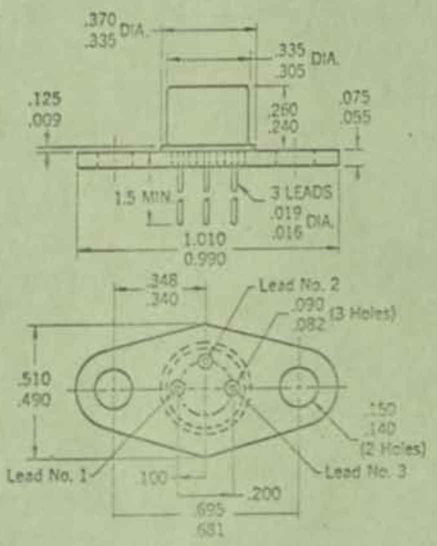
NOTES: All dimensions in inches
Leads are gold-plated KOVAR
Package weight is 0.55 gram

PHYSICAL DIMENSIONS BN



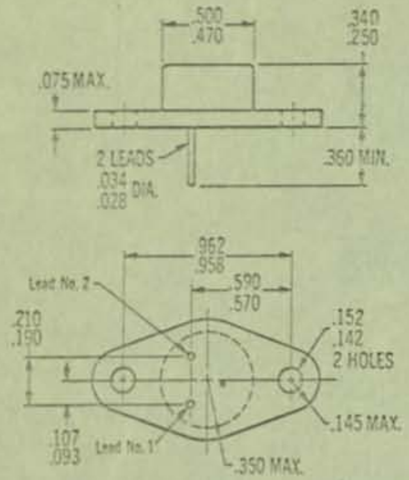
NOTES: All dimensions in inches
Leads are gold-plated nickel-iron
*Similar to JEDEC TO-51
Package weight is 0.04· gram

PHYSICAL DIMENSIONS BR



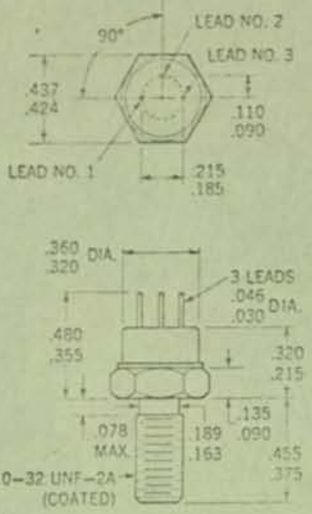
NOTES: All dimensions in inches
Same as "AQ" except for addition of flange
Identical to "AR" except for size of flange holes
Leads are gold-plated copper
Emitter and base flange holes countersunk
to 0.141 ±0.005 on seating plane
Collector internally connected to case
Solid kovar header
Package weight 3.84 grams

PHYSICAL DIMENSIONS BU
Identical to (TO-66)
except for flange thickness



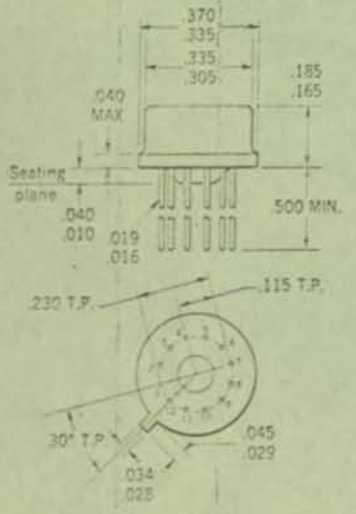
NOTES: All dimensions in inches
Leads are gold or nickel-plated nickel alloy
Identical to "CU" except die mounting pedestal is steel
Leads 1 and 2 electrically isolated from case
Case is third electrical connection
Package weight is 6.192 grams

PHYSICAL DIMENSIONS BV
in accordance with
JEDEC (TO—60)



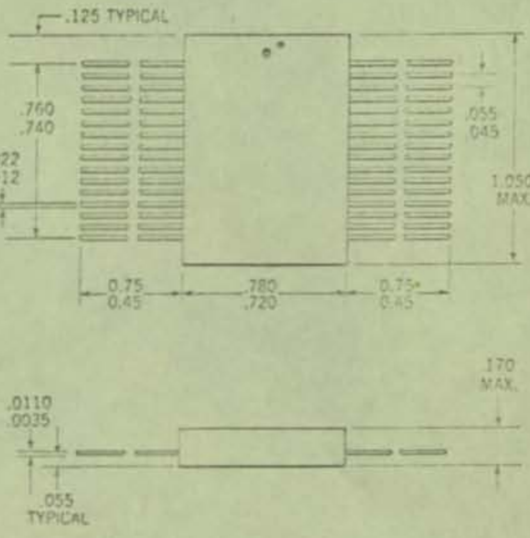
NOTES: All dimensions in inches
Leads are gold-plated KOVAR
All leads electrically ~~connected to~~ isolated from case
Package weight is 4.8 grams

PHYSICAL DIMENSIONS BW
in accordance with
JEDEC (TO—101)



NOTES: All dimensions in inches
Leads are gold-plated KOVAR
Lead No. 6 internally connected to case
Package weight is 1.08 grams

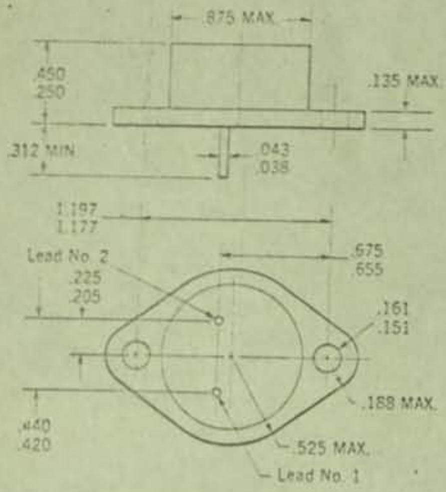
PHYSICAL DIMENSIONS BY



NOTES: All dimensions in inches
*Alternate marking of dot in upper left hand corner is also acceptable
Package weight is approximately 5.0 grams

PHYSICAL DIMENSIONS BZ

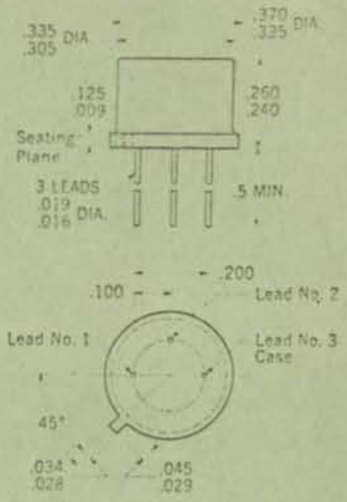
in accordance with
JEDEC (TO—3)



NOTES: All dimensions in inches
Leads 1 & 2 electrically isolated from case
Case is third electrical connection
Leads are nickel alloy
Package weight 16.5 grams
Copper flange

PHYSICAL DIMENSIONS CA

Similar to
JEDEC (TO—5) outline
low RTH package

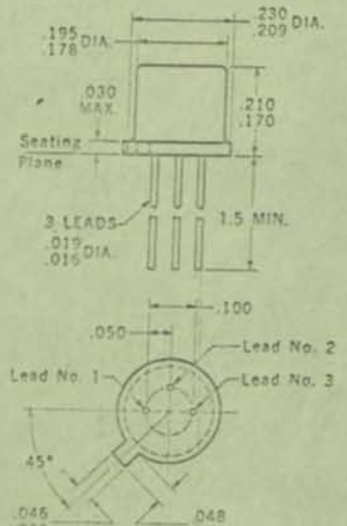


NOTES: All dimensions in inches
Leads are gold-plated kovar
Lead No. 3 internally connected to case
Package weight is 1.3 grams

PHYSICAL DIMENSIONS CB

Similar to JEDEC
(TO-18) outline*

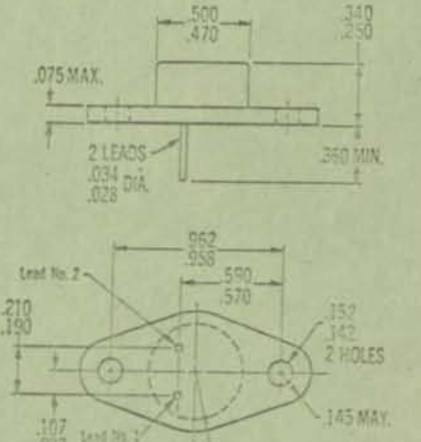
8 mil kovar



NOTES: All dimensions in inches
Leads are gold-plated kovar
Lead No. 3 internally connected to case
Package weight is 0.44 gram
*Identical to package "B" except for 1½ inch minimum lead length

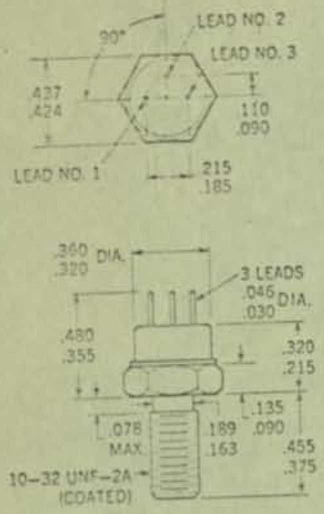
PHYSICAL DIMENSIONS CU

Identical to (TO-66)
except for flange thickness



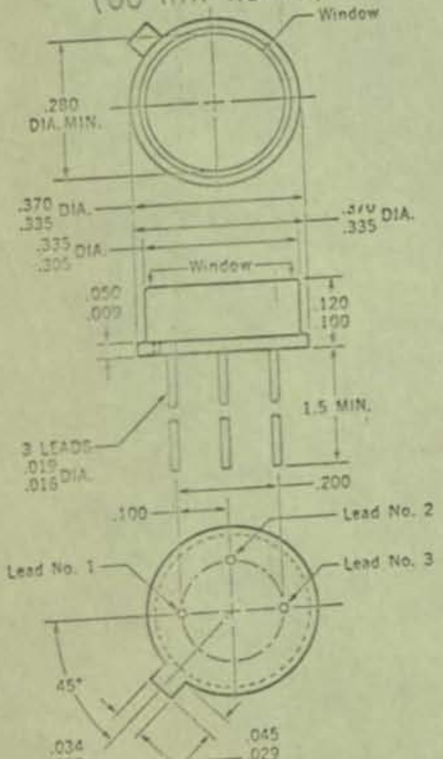
NOTES: All dimensions in inches
Leads are gold or nickel-plated nickel alloy
Identical to "BU" except die mounting pedestal is copper
Leads 1 and 2 electrically isolated from case
Case is third electrical connection
Package weight is 6.192 grains

PHYSICAL DIMENSIONS CV
in accordance with
JEDEC (TO—60)



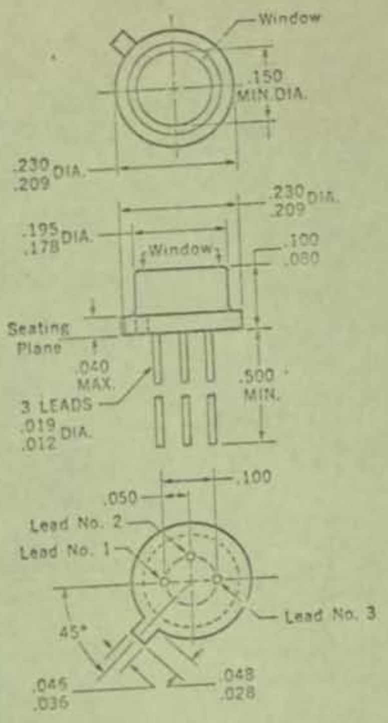
NOTES: All dimensions in inches
Leads are gold-plated kovar
Emitter is electrically connected to case
Package weight is 4.8 grams

PHYSICAL DIMENSIONS LC
(60 mil kovar)



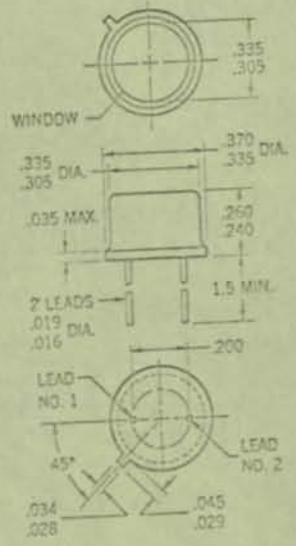
NOTES: All dimensions in inches
Dimensions similar to JEDEC TO-5 except for
overall height and semi-rigid silicone
resin window
Lead No. 3 internally connected to case
Leads are gold-plated kovar
Package weight is 1.0 gram

PHYSICAL DIMENSIONS LB
(45 mil kovar)



NOTES: All dimensions in inches
Dimensions similar to JEDEC TO-46 except for
overall height and semi-rigid silicone
resin window
Lead No. 3 internally connected to case
Leads are gold-plated kovar
Package weight is 0.317 gram

PHYSICAL DIMENSIONS PP
(15 mil kovar)



NOTES: All dimensions in inches
Leads are gold-plated kovar
Both leads are electrically isolated from case
Dimensions similar to JEDEC (TO-5) except
for 2 leads and window top
Package weight is 1.056 grams

Specification Parameters

Parameter	Test Conditions (must be specified)	Meaning of Specification
BV_{GSS}	I_G $V_{DS} = 0$	Breakdown voltage from gate to channel. Drain and source are shorted, and a reverse bias placed across the gate-channel junction.
BV_{GDS}	I_G $V_{DS} = 0$	Identical to BV_{GSS}.
BV_{GDO}	I_D $I_S = 0$	Breakdown voltage from gate to drain with source open.
BV_{SGO}	I_S $I_D = 0$	Breakdown voltage from gate to source with drain open.
BV_{DSS} BV_{DGS}	I_D $V_{GS} = 0$	Breakdown from drain to source with $V_{GS} = 0$. This is normally specified for enhancement MOS devices. It represents breakdown from drain to substrate.
BV_{DSX}	I_D V_{GS}	Breakdown from drain to source with $V_{GS} \neq 0$. It represents breakdown from drain to substrate.
BV_{SDS}	I_S $V_{DG} = 0$	Breakdown voltage from source to drain with $V_{DG} = 0$.
I_{GSS}	V_{GS} $V_{DS} = 0$	Gate-channel leakage with $V_{DS} = 0$.
I_{DGO}	V_{GD} $I_S = 0$	Drain-to-gate leakage current with source open.

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Specification Parameters

Parameter	Test Conditions (must be specified)	Meaning of Specification
I_{SGO}	V_{SG} $I_D = 0$	Source-to-gate leakage current with drain open.
I_G	V_{DS} or V_{DG} V_{GS}	Gate leakage current under certain operating conditions. It is usually somewhat lower than I_{DGO} since I_{DGO} is the limiting case of I_G.
I_{SDS}	V_{SD} $V_{GD} = 0$	Source-to-drain leakage current with zero gate-drain voltage.
I_{DSS}	V_{DS} $V_{GS} = 0$	Drain saturation current, the value of I_D measured above the knee of the V_{DS}-I_D characteristic curve where $V_{DS} \geqslant V_P$. I_{DSS} is actually defined as I_D at the V_{DS} required for channel pinch-off. In enhancement MOS devices, I_{DSS} is essentially the drain-substrate leakage plus any residual drain-source channel current.
$I_{D\,(ON)}$	V_{DS} V_{GS}	Drain current under specified bias conditions. Specified for enhancement MOS devices as a max intended operating drain current when V_{GS} is biased for max channel conduction.

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Specification Parameters

Parameter	Test Conditions (must be specified)	Meaning of Specification
I_D	V_{DS} or V_{DG} V_{GS} or V_{SG}	Drain-source current under certain specified operating conditions.
I_D (OFF)	V_{DS} V_{GS}	Drain-gate leakage current with $V_{GS} \gg V_{GS(OFF)}$. $I_{D(OFF)}$ is slightly lower than I_{DGO}.
$V_{GS(OFF)}$	V_{DS} $I_{D(OFF)}$	Gate cut-off voltage. Gate-source voltage required to cut-off channel current.
V_P		Pinch-off voltage, interchangeable with $V_{GS(OFF)}$.
$V_{GS(th)}$, V_T	V_{DS} I_D	Gate-threshold voltage. Gate-source voltage required to initiate channel conduction in enhancement MOS devices.
V_{GS}	V_{DS} I_D	Gate-source voltage at any given operating point.
$\lvert V_{GS1}-V_{GS2}\rvert$	V_{DS} I_D	Magnitude of gate-to-gate differential offset voltage in differential (matched) pairs.
$\Delta\frac{\lvert V_{GS1}-V_{GS2}\rvert}{\Delta T}$	T_{A1} & T_{A2}	Incremental change in $V_{GS1} - V_{GS2}$ expressed in μV/°C.
$\frac{I_{DSS1}}{I_{DSS2}}$	V_{DS}	Match in I_{DSS} of differential pairs, expressed as a fraction.

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Specification Parameters

Parameter	Test Conditions (must be specified)	Meaning of Specification
$\lvert I_{G1}-I_{G2}\rvert$	V_{DS} and V_{GS} V_{DG} and/or I_D T_A	Magnitude of match in I_G for differential pairs. Usually specified at an elevated temperature near 100°C.
$r_{DS(ON)}$	I_D V_{DS} and/or V_{GS}	Static drain-source resistance when biased to full ON conditions (maximum operating I_D). This resistance is defined in the ohmic region.
r_o	$V_{GS} = 0$	Minimum value of the $r_{DS(ON)}$ for $V_{GS} = 0$ (only for FET devices).

Small Signal Characteristics of FET's

Parameter	Test Conditions (must be specified)	Meaning of Specification
$r_{ds(on)}$	V_{GS} $V_{DS}=0$ or I_S frequency	Drain-to-source resistance when the gate is biased to full ON conduction. This resistance is defined in the saturation region.
Y_{fs}	V_{DS} V_{GS} frequency	Common-source forward transfer admittance. Measured at $V_{GS}=0$ unless otherwise specified.
g_m, g_{fs}	V_{GS} V_{DS} frequency	Common-source forward transfer conductance. This is perhaps a more informative term than Y_{fs}. At 1 KH_Z, $Y_{fs} \approx g_{fs}$. However, at high frequencies, Y_{fs} includes the effect of gate-drain capacity, and it may therefore be misleadingly high. The term g_{fs} should be used for all high frequency measurments..
g_{mo}		Same as g_m, but specifically at a $V_{GS}=0$.
Y_{iss}	V_{DS} V_{GS} $v_{ds}=0$ frequency	Common-source input admittance with output shorted. Important for high frequency operation.

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Small Signal Characteristics of FET's

Parameter	Test Conditions (must be specified)	Meaning of Specification
G_{iss}	V_{DS} V_{GS} v_{ds} frequency	Common-source input conductance with output shorted. This must be specified for high frequency applications, as $g_{iss} \equiv 1/\omega^2$.
g_{is}		Same as g_{iss}.
Y_{OSS}	V_{DS} V_{GS} $V_{gs} = 0$ frequency	Output admittance, input shorted.
g_{OSS}	V_{DS} V_{GS} $V_{gs} = 0$ frequency	Common-source output conductance, input shorted.
C_{iss}	V_{DS} V_{GS} $V_{ds} = 0$	Common-source input capacitance, output shorted $C_{iss} = C_{dg} + C_{gs}$
C_{gss}	$V_{DS} = V_{GS}$ $v_{do} = 0$ frequency	Gate-source capacitance.
C_{rss}, C_{rs}	V_{DS} V_{GS} frequency	Reverse transfer capacitance.
C_{dg}	V_{DS} V_{GS} frequency	Actual value of drain-gate capacitance.

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Small Signal Characteristics of FET's

Parameter	Test Conditions (must be specified)	Meaning of Specification
C_{gs}	Value in equivalent circuit	Actual value of gate-capacitance.
C_{ds}	-do-	Actual value of drain-source capacitance, essentially header capacitance.
C_{oss}	V_{DS} V_{GS} $V_{gs} = 0$ frequency	Common-source output capacitance, input shorted. $C_{oss} = C_{rss} + C_{ds}$
C_{os}	V_{DS} V_{GS} $V_{gs} = 0$ frequency	Same as C_{oss} if $V_{GS} = 0$.
C_{dgs}	-do-	Same as C_{oss}.

FET Performance Parameters

Parameter	Test Conditions (must be specified)	Meaning of Specification
$t_{delay(on)}$	V_{DD} $I_{D(ON)}$ $V_{GS(ON)}$ pulse characteristics	Delay time before turn on when pulsed from OFF to ON condition.
t_{rise}		Rise time when pulsed from OFF to ON condition.
t_{on}		$t_{rise} + t_{delay(on)}$
$t_{delay(off)}$	$V_{GS(ON)}$ $V_{GS(OFF)}$ V_{DD} $I_{D(on)}$ input pulse characteristics	Delay time before turn off when pulsed from ON to OFF condition.
t_{fall}		Fall time pulsed from ON to OFF condition.
t_{off}		$t_{fall} + t_{delay(on)}$
e_n	V_{DS} V_{GS} or I_D frequency bandwidth frequency	Common-source equivalent short-circuit input noise voltage. Measured at the output with the input shorted, and referred to the input. Expressed as rms volts per root cycle, $\mu V/\sqrt{H_Z}$. A function of frequency, so frequency value must be stated.
i_n	V_{DS} V_{GS} or I_D frequency bandwidth	Common-source equivalent open circuit input noise current. Expressed as $pA/\sqrt{H_Z}$, a function of frequency.

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FET Performance Parameters

Parameter	Test Conditions (must be specified)	Meaning of Specification
PG	frequency V_{DS}; P_{in} I_D	Neutralised Power Gain. It expresses the power gain of the device when its reverse transmission is neutralised by an equal and apposite external circuit (neutralisation circuit).
NF	V_{DS} V_{GS} or I_D $R_{generator}$ frequency bandwidth	Noise figure. This represents a ratio between input signal to noise and output signal to noise. NF is a function both of frequency and generator resistance R_s. Both must be stated or the specification is meaningless. When properly qualified, NF includes the effects of both e_n and i_n.

Our FET and MOS-FET Characteristics

Line	Type	I_{GSS} (max)	I_{DSS} (max)	$Y_{FS}(g_m)$ at 1 KHz (min)	$R_{ds(on)}$ (max)	V_p or V_{TH} (max)	Structure	Notes
0028	BSX 83 BSX 84		0.5 nA 0.5 nA	400 μmhos 700 μmhos	1.5 KOhm 1 KOhm	-6 V -6 V	P-Channel MOS P-Channel MOS	Enhancement Mode Enhancement Mode
0049	BSX 85 BSX 86			1500 μmhos 2500 μmhos	500 Ohm 250 Ohm	-6V -6V	Dual P-MOS Dual P-MOS	Enhancement Mode Enhancement Mode
0057	BFX 78	10 pA	25 mA	6000 μmhos			N-MOS	Depletion Mode-High P_G (20 dB) and low noise (2.7 dB) at 100 MHz
0030	Not yet announced	1 nA	30 mA	4000 μmhos	350 Ohm	[illegible]	P-Channel FET	Very low noise (1.5 dB at 0.1-100 KHz).