CAFA: A COMPUTER-AIDED CURVE-FIT AND ANALYSIS PROGRAM

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by

B. W. Noel

Bureau of Engineering Research
The University of New Mexico
Albuquerque, New Mexico

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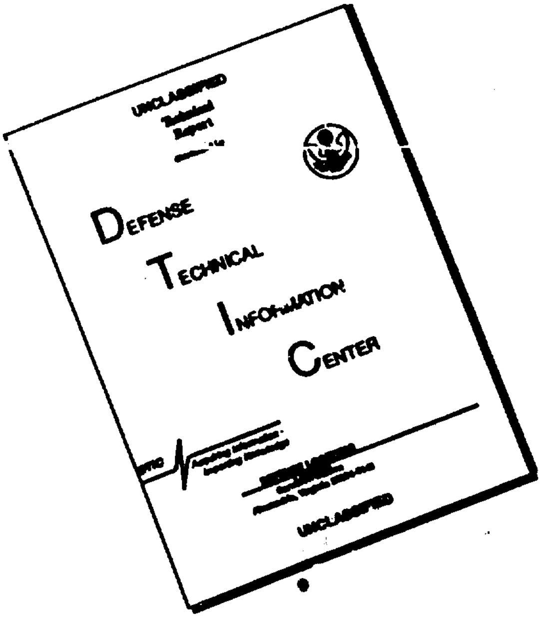

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ABSTRACT

The theoretical basis for the CAFA program is discussed. An approximate technique evolving from the theory is applied to the analysis of the current-voltage characteristic of a hypothetical diode, with good results. A printout of the resultant program and data is included.

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INTRODUCTION

The CAFA (Computer-Aided Fit and Analysis; pronounced "café") program was developed for fitting smooth curves to experimental current-voltage and similar data and for using the curves obtained to analyze the data. The original goal was to allow the slope of such curves to be obtained at any point in order to assist in determining the current mechanisms existing in solid-state devices. The program was found to be useful for several other purposes. One, in particular, allowed interpolation between data points. The preliminary results obtained have been encouraging. The program was used extensively to analyze the data discussed in Reference 1.

The subroutine which makes the program possible is the SMOOTH subroutine originally developed by Reinsch (1967), adapted for Fortran by R. E. Jones of Sandia Laboratories, and modified by the author to include interpolation. This subroutine fits a series of spline (cubic) functions to the data points and smooths the transitions between functions by requiring continuity of the first and second derivatives within a certain error chosen by the user. The first and second derivatives are available as printout in addition to the fitted data points and the coefficients of each cubic equation. The latter permitted interpolation between data points. Examination of the program, Fig. 2, reveals the use of these features.

Several general approaches to determining current mechanisms from the CAFA program are discussed below, along with the specialized version used in this study.

THEORETICAL BACKGROUND

Suppose the current in a diode, I, is given by

$$I = I_o \exp(\beta V/m) \quad , \qquad (1)$$

where I_o is constant, $\beta = q/kT$, V is the applied voltage, and m has a constant value.* In this case, the current in the diode is described by one mechanism and the slope of the ln(I) vs. V curve is

$$\frac{\partial \ln(I)}{\partial V} = \frac{\beta I}{m} \quad . \qquad (2)$$

Since everything in Eq. (2) is known except m, m can be determined and the current mechanism can often (but not always) be identified. Unfortunately, total diode currents given by Eq. (1) usually do not exist in practice. The current in real diodes is more often given by an expression of the form

$$I = \sum_i I_{oi} \exp(\beta V/m_i) + \sum_j I_{oj} \exp(V/\phi_j) \quad , \qquad (3)$$

where m_i describes the i^{th} temperature-dependent mechanism (e.g., diffusion, space-charge region recombination, surface) and ϕ_j describes the j^{th} nontemperature-dependent mechanism (e.g., tunneling). Even Eq. (3) does not describe the most general current form because it neglects nonlinear effects, such as interactions between current components, plus it

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*To be perfectly general, "current" should be replaced by "flux" and "voltage" should be replaced by "force."

assumes all the I_o's are constant and that $V = V_j$, the junction voltage. Nevertheless, Eq. (2) is often an excellent approximation. For real diodes, one often does not know what the current mechanisms are but could deduce the mechanisms if the m_i's in Eq. (3) were known. If, however, the diode current consists of only two components and is of the form

$$I = I_{01} \exp(\frac{\beta V}{m_1}) + I_{02} \exp(\frac{\beta V}{m_2}) , \quad (4)$$

then

$$\frac{\partial \ln(I)}{\partial V} = \frac{\beta}{I}(\frac{1}{m_1} + \frac{1}{m_2}) , \quad (5)$$

and the two values of m cannot be determined easily unless each current type has a clearly defined region of dominance and the experimenter has data covering those regions. Even the simple case of Eq. (5) is not usually seen in practical diodes. To further complicate matters, the value of m describing one mechanism may vary; as an example $2 \leq m < \infty$, depending on injection level, for donor-acceptor pair (DAP) recombination in the space-charge region.[2] A method for finding the value of m at any point, given a current-voltage curve, is therefore desirable. A graphical approach suffers on several counts: It is not accurate enough unless the ln(I) vs. V curve is quite linear, as will be seen below; and it is extremely tedious and time consuming to obtain m at many points. The numerical approach discussed here is quick and gives good results for the special cases discussed.

Given an experimental current-voltage curve in which the current is presumed to arise from the mechanisms described in Eq. (3), we assume that the current at any point on the curve can be written as

$$I = I_o \exp\left(\frac{\beta V}{m(I)}\right) . \tag{6}$$

Thus, our basic assumption is that the experimentally-determined current given by Eq. (6) is equivalent to the theoretical current given by Eq. (3). The parameter that allows Eq. (6) to describe the current at any point is, of course, m(I). If m(I) is constant, Eq. (6) reduces to Eq. (1). The slope obtained from Eq. (6) is

$$\frac{\partial I}{\partial V} = \beta I \frac{\partial}{\partial V}\left(\frac{V}{m(I)}\right) . \tag{7}$$

But m(I) = m(V) implicitly, since I ∝ V. That is,

$$\frac{\partial}{\partial V} \frac{V}{m(I)} = V \frac{\partial}{\partial V} \frac{1}{m(I)} + \frac{1}{m(I)} \frac{\partial V}{\partial V} ,$$

or

$$\frac{\partial}{\partial V} \frac{V}{m(I)} = V \left[- \frac{1}{m(I)^2} \frac{\partial m(I)}{\partial I} \frac{\partial I}{\partial V} \right] + \frac{1}{m(I)} . \tag{8}$$

The dependence of m on I will be understood unless otherwise stated.

A differential equation can be obtained that would solve for m in closed form if a closed form solution exists for the differential equation. By combining Eqs. (8) and (7) we obtain

$$\frac{\partial I}{\partial V} = \frac{\beta I}{m + \frac{\beta IV}{m} \frac{\partial m}{\partial I}} \quad . \qquad (9)$$

By rearranging Eq. (9) we obtain, since $\partial m/\partial I = dm/dI$ (m is a function only of the current at constant temperature),

$$\frac{dm}{dI} + \frac{1}{\beta IV} m^2 - \frac{1}{V \partial I/\partial V} = 0 \quad . \qquad (10)$$

This is a very nonlinear d.e. of the form

$$\frac{dy}{dx} + \frac{y^2}{axz} - \frac{y}{bz} = 0 \quad , \qquad (11)$$

where $x = x(z)$ is known and b $(= \partial I/\partial V)$ is known. The d.e. might be solvable using numerical techniques.

We shall briefly discuss the errors which result when the nonlinearity in Eq. (7) is assumed negligible. Considering the derivative on the right-hand side,

$$\frac{\partial}{\partial V} \left(\frac{V}{m}\right) = - \frac{V}{m^2} \frac{\partial m}{\partial V} + \frac{1}{m} \quad , \qquad (12)$$

which is

$$\frac{\partial}{\partial V} \left(\frac{V}{m}\right) \approx \frac{1}{m} \qquad (13)$$

if $\partial m/\partial V$ is negligible. This requires

$$\frac{1}{m} >> -\frac{V}{m^2}\frac{\partial m}{\partial V} \quad ,$$

so that

$$m >> -V\frac{\partial m}{\partial V} \quad . \tag{14}$$

For $m \approx 2$, $V \approx 1$ volt,

$$\left|\frac{\partial m}{\partial V}\right| << 2 \text{ units/volt.} \tag{15}$$

The rate of change of m with V must be very small for this condition not to be violated. Hence, the approximation that $\partial m/\partial V$ is negligible is often not valid. This approximation is numerically identical to that obtained using an incremental approach which approximates the curve between a series of closely adjacent data points by a set of straight lines, and is approximately equivalent to the results which would be obtained using a graphical technique. Therefore, unless a ln(I) vs. V curve is very linear, a graphical or incremental approach, or an approach which neglects $\partial m/\partial V$ will not suffice for determining the value of m from an experimental curve.

As a special case of the relationship between Eqs. (3) and (6) we write the relation as

$$I = I_0 \exp(\frac{\beta V}{m}) = I_{01} \exp(\frac{\beta V}{m_1}) + I_{02} \exp(\frac{\beta V}{m_2}) . \tag{16}$$

The two terms on the right-hand side of Eq. (16) may be considered as two distinct components or as one distinct component plus a sum of other components, so that the relation is not necessarily restricted to only two distinct components. This will be called the "two-process" model. We shall assume Eq. (16) holds and determine the effective m vs. V for various ratios R,

$$R \equiv I_{01}/I_{02} \ . \tag{17}$$

R will be constant or nearly so for many situations. Using Eq. (17) we can rewrite Eq. (16) as

$$I = I_{02}\left[R \exp\left(\frac{\beta V}{m_1}\right) + \exp\left(\frac{\beta V}{m_2}\right)\right] \ . \tag{18}$$

The derivative is

$$\frac{\partial I}{\partial V} = I_{02}\left[\frac{R\beta}{m_1} \exp\left(\frac{\beta V}{m_1}\right) + \frac{\beta}{m_2} \exp\left(\frac{\beta V}{m_2}\right)\right] \ . \tag{19}$$

Define

$$f \equiv \frac{I}{\partial I/\partial V} \ ; \tag{20}$$

combining Eqs. (18) and (19) gives

$$f = \frac{R \exp\left(\frac{\beta V}{m_1}\right) + \exp\left(\frac{\beta V}{m_2}\right)}{\beta\left[\frac{R}{m_1} \exp\left(\frac{\beta V}{m_1}\right) + \frac{1}{m_2} \exp\left(\frac{\beta V}{m_2}\right)\right]} \ . \tag{21}$$

Equation (21) can be solved for R:

$$R = -\frac{\frac{\beta f}{m_2} - 1}{\frac{\beta f}{m_1} - 1} \exp\left[\beta V\left(\frac{1}{m_2} - \frac{1}{m_1}\right)\right] . \qquad (22)$$

Since R is constant with V, we must have

$$\frac{\partial R}{\partial V} = 0 . \qquad (23)$$

Performing the indicated operations on Eq. (22), realizing that $\exp\left[\beta V\left(\frac{1}{m_2} - \frac{1}{m_1}\right)\right] \not\equiv 0$, and rearranging gives

$$\frac{\partial f}{\partial V} = \left(\frac{\beta f}{m_2} - 1\right)\left(\frac{\beta f}{m_1} - 1\right) . \qquad (24)$$

This is the criterion for R to be constant. One way to use Eq. (24) would be to find f(V) (from the results of curve-fitting to the I-V characteristic using the SMOOTH subroutine, since this gives $\partial I/\partial V$ also), curve fit to the points f, find $\partial f/\partial V$ from the curve fit and plot the right-hand side and $\partial f/\partial V$ vs. βf on the same curve, using m_1 and m_2 as parameters; one could inspect the results to find integer values of m_1 and m_2 such that the curves intersect. Another way would be to find a second expression describing $\partial f/\partial V$. By differentiating Eq. (20) directly, we obtain

$$\frac{\partial f}{\partial V} = 1 - \frac{I}{(\partial I/\partial V)^2} \frac{\partial^2 I}{\partial V^2} . \qquad (25)$$

Since the second derivatives can also be obtained from the curve fit of I vs. V, we have enough information to find $\partial f/\partial V$;

that is, if the second derivatives are reasonably well behaved. A third method is to rearrange Eq. (24), if $\partial f/\partial V$ can be found, to obtain

$$\beta f = \frac{m_1 + m_2}{2} \quad \frac{1}{2}\sqrt{(m_1 + m_2)^2 - 4m_1m_2(1 - \frac{\partial f}{\partial V})} . \qquad (26)$$

Both sides of Eq. (26) can be plotted vs. V with m_1 and m_2 as parameters. The solutions would be obtained at the curve intersections. For the special case when $\partial f/\partial V = 0$, Eq. (26) reduces to

$$\beta f = m_1 \text{ or } m_2 . \qquad (27)$$

Thus, one of the m's can be found if $\partial f/\partial V = 0$ somewhere. If $\partial f/\partial V = 1$,

$$\beta f = m_1 + m_2 \text{ or } 0 . \qquad (28)$$

If $\partial f/\partial V = 1$ and $\beta f \neq 0$, then

$$m_2 = \beta f - m_1$$

if m_1 was found at a point where $\partial f/\partial V = 0$. Still another approach uses f in the differential equation (10). Using the definition of f, Eq. (10) becomes

$$V \frac{dm}{dV} = m - \frac{m^2}{\beta f} . \qquad (29)$$

If βf is a determinable function, this can be solved to get a family of curves for various V's. Even if f is <u>not</u> a determinable function, the expression (26) could be substituted into the d.e. and then one would have a d.e. in terms of m, m_1, and m_2, so that m could be predicted given m_1 and m_2 (a trial-and-error approach). For the special case when $\partial f/\partial V = 1$, the d.e. becomes

$$\frac{dm}{dV} = \frac{1}{V}\left(m - \frac{m^2}{m_1 + m_2}\right) , \tag{30}$$

where we have used Eq. (28) with $\beta f \not\approx 0$. This can be solved, yielding

$$\frac{m^2 - m_o^2}{2} - \frac{m^3 - m_o^3}{3(m_1 + m_2)} = \ln\left(\frac{V}{V_o}\right) , \tag{31}$$

where m_o is a known value of m at $V = V_o$. This transcendental equation may also be solved graphically.

A somewhat simpler and less tedious approximate approach to determining m_1 and m_2 has been developed and will be discussed next. The approach is useful in a transition region or any region where superposition of two or more current components results in some curvature of the experimental ln(I) vs. V curve.

AN APPROXIMATE APPROACH

If the two-process model, Eq. (16), is valid, and if the ln(I) vs. V curve is nonlinear, one may obtain a pair of equations (24) for each two adjacent data points. If the curve is nearly linear, the pair of equations thus obtained may not be linearly independent or may not have a solution, so that the procedure described here will not work in such a region. If a linearly independent pair of equations is obtained, each pair has a unique solution from which the m's can be determined approximately. Since each such pair has a unique solution whether or not the two- or one-process model is valid, values of m can be determined, but these may not be the integer values expected. We define

$$G \equiv 1 - \frac{\partial f}{\partial V} , \tag{32}$$

$$RPM \equiv \frac{1}{m_1 m_2} , \tag{33}$$

(the reciprocal product of m's), and

$$SRM = \frac{m_1 + m_2}{m_1 m_2} \tag{34}$$

(the sum of reciprocals of m's). These symbols are useful computer words. Let I and I + 1 be adjacent data points and look for the J^{th} solution of the pair of equations obtained from Eq. (24). To be compatible with computer language, let $\beta f \rightarrow BF$

and $(\beta f)^2 \rightarrow$ BF2. Also rewrite Eq. (24) as

$$G = 1 - \frac{\partial f}{\partial V} = \left(\frac{m_1 + m_2}{m_1 m_2} \right) \beta f - \frac{1}{m_1 m_2} (\beta f)^2 \tag{35}$$

Then

$$\mathrm{BF(I)SRM(J)} - \mathrm{BF2(I)RPM(J)} = \mathrm{G(I)} \tag{36}$$

and

$$\mathrm{BF(I+1)SRM(J)} - \mathrm{BF2(I+1)RPM(J)} = \mathrm{G(I+1)} \tag{37}$$

to a good approximation. The solution of this pair of equations is

$$\mathrm{SRM(J)} = \frac{\mathrm{BF2(I+1)G(I)} - \mathrm{BF2\ (I)G(I+1)}}{\mathrm{BF(I)BF2(I+1)} - \mathrm{BF(I+1)BF2(I)}} \tag{38}$$

and

$$\mathrm{RPM(J)} = \frac{\mathrm{BF(I+1)G(I)} - \mathrm{BF(I)G(I+1)}}{\mathrm{BF(I)BF2(I+1)} - \mathrm{BF(I+1)BF2(I)}} \ . \tag{39}$$

Letting XM2 $\equiv m_2$ and XM1 $\equiv m_1$,

$$\mathrm{XM2(J)} = \frac{\mathrm{SRM(J)}}{\mathrm{2RPM(J)}} - \frac{1}{\mathrm{2RPM(J)}} \sqrt{[\mathrm{SRM(J)}]^2 - \mathrm{4RPM(J)}} \tag{40}$$

and

$$\mathrm{XM1(J)} = \frac{\mathrm{SRM(J)}}{\mathrm{RPM(J)}} - \mathrm{XM2(J)} \ . \tag{41}$$

Once the m's have been obtained, there are nine possible combinations (which will not be enumerated) of results, wherein m_1

and m_2 are constants of correct value (i.e., integers), constants of incorrect value, or variables. If one of the m's = 1, the current component may be injection current. If so, its correct I_o can be found as described below. If the other m is, say, 2, where the 2 is found to describe space-charge region recombination current, the I_o found for it may vary, because I_o for such current is, in general, injection-level dependent. This will complicate the results somewhat, but judicious inspection may help in deciphering the results. For any case where one of the m's is not constant, the value of I_o obtained may be treated as a "subtotal" current of the form

$$I_{oi} = I_{oi}' \exp(\frac{\beta V}{m}) , \tag{42}$$

where m = m(I). It is possible to treat this subtotal current in the same fashion as the total current: Curve fit to it, assume two current mechanisms and break it up into m_1' and m_2', as before, continuing until the currents have been resolved satisfactorily. The foregoing also applies to any case where one of the m's is constant but incorrect.

In any case, when values of m_1 and m_2 have been obtained, we write

$$I = I_{01} \exp(\frac{\beta V}{m_1}) + I_{02} \exp(\frac{\beta V}{m_2}) . \tag{43}$$

For two adjacent interpolated data points J and J+1, we have

$$I(J) = I_{01}(J)\ \exp\left(\frac{\beta V(J)}{m_1}\right) + I_{02}(J)\ \exp\left(\frac{\beta V(J)}{m_2}\right) \tag{44}$$

and

$$I(J+1) = I_{01}(J)\ \exp\left(\frac{\beta V(J+1)}{m_1}\right) + I_{02}(J)\ \exp\left(\frac{\beta V(J+1)}{m_2}\right) \tag{45}$$

to a good approximation, because the I_{oi}'s should be nearly constant between two closely adjacent data points. This pair of simultaneous equations can be solved for $I_{01}(J)$ and $I_{02}(J)$. If $I_{01}(J) = I_{01}(J+1)$, the answers are exact (this will be the case for $m_i = 1$, for example) if the m's are exact. If $I_{01}(J) \neq I_{01}(J+1)$, it does not matter, since a better value will be found on the second iteration. The solutions of Eqs. (44) and (45) are

$$I_{01}(J) = \frac{I(J)\ \exp\left(\frac{\beta \Delta V}{m_2}\right) - I(J+1)}{\exp\left(\frac{\beta V(J)}{m_1}\right)\left[\exp\left(\beta \Delta V\left(\frac{1}{m_2} - \frac{1}{m_1}\right)\right)\right]} \tag{46}$$

and

$$I_{02}(J) = \frac{I(J+1) - I(J)\ \exp\left(\frac{\beta \Delta V}{m_1}\right)}{\exp\left(\frac{\beta V(J)}{m_2}\right)\left[\exp\left(\beta \Delta V\left(\frac{1}{m_2} - \frac{1}{m_1}\right)\right)\right]} \tag{47}$$

where

$$\Delta V \equiv V(J+1) - V(J) \tag{48}$$

and we have assumed m_1 and m_2 do not change much between J and J + 1.

To demonstrate two of the approaches which have been used successfully[1] and to test their validity, data from a hypothetical diode were analyzed by the program. This diode had $m_1 = 1$, $m_2 = 2$, $I_{01} = 10^{-8}$ units and $I_{02} = 1$ unit. Its I-V characteristic is plotted in Fig. 1. The resultant computer printout is given in Fig. 2.

In the lowermost and uppermost portions of the curve, where m_2 and m_1, respectively, dominate, Eq. (2) is an excellent approximation. Hence, XM or XMPRIM describes the current mechanisms very well and one could deduce the components easily for this diode. PPRIM is equivalent to I_o and it is seen to give the correct values at either end of the range.

For the transition region near the center of the curve, the value of m as calculated from Eq. (2) does not give the correct value, as expected. In this region (roughly from subscripts I = 50 to I = 70), the approach using Eqs. (36) through (41) finds its application and the values of m_1 and m_2 are determined with good accuracy in this region. Note also that Eq. (27) can be used to find m_1 and m_2 at the two extremes, since βf (called BFP) $\simeq 1$ at either end of the curve. The experimental results from real diodes usually do not show large regions of linearity in which Eq. (2) is useful, so that the utility of the latter approach in regions of curvature becomes very apparent. This approach does not work well in the linear

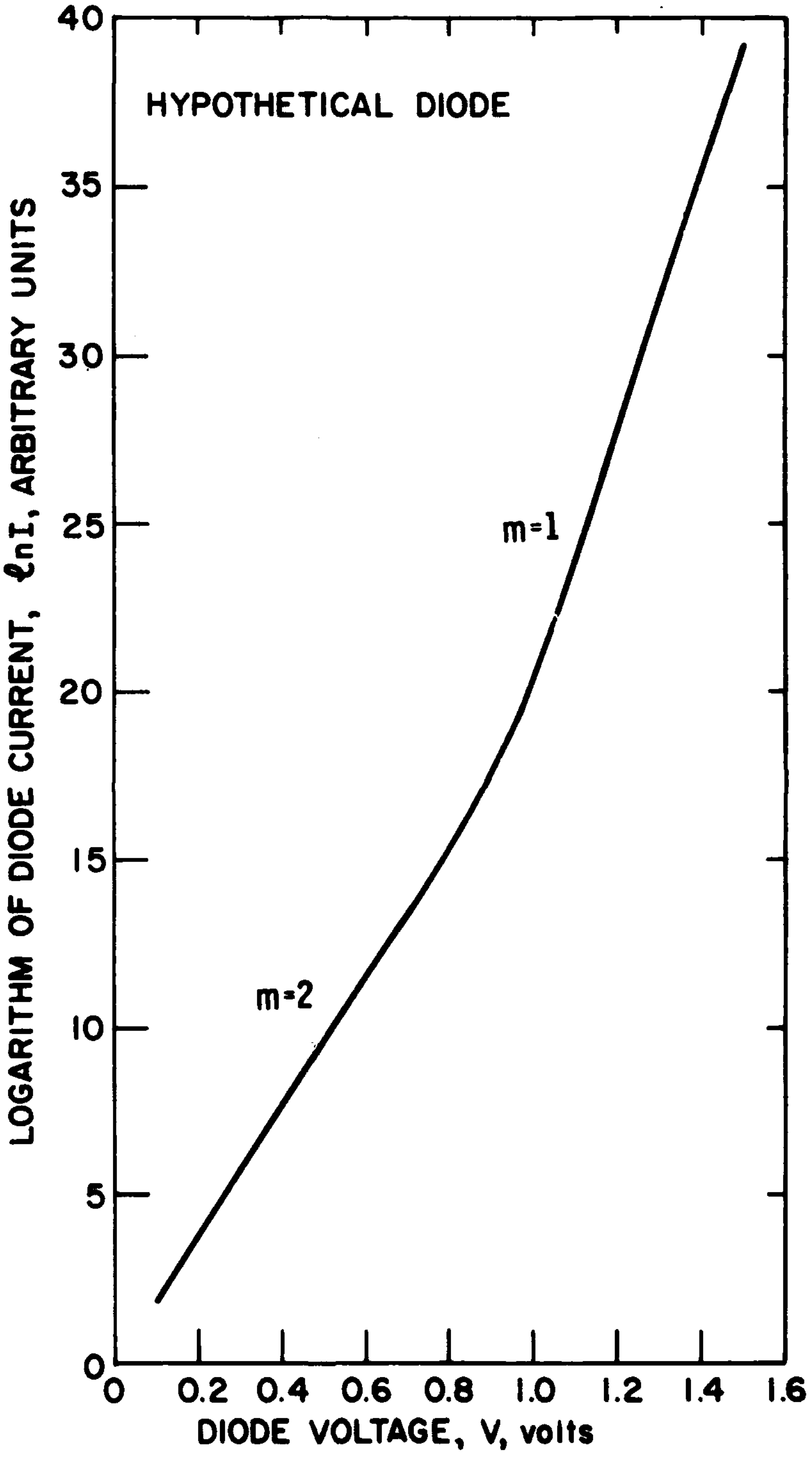
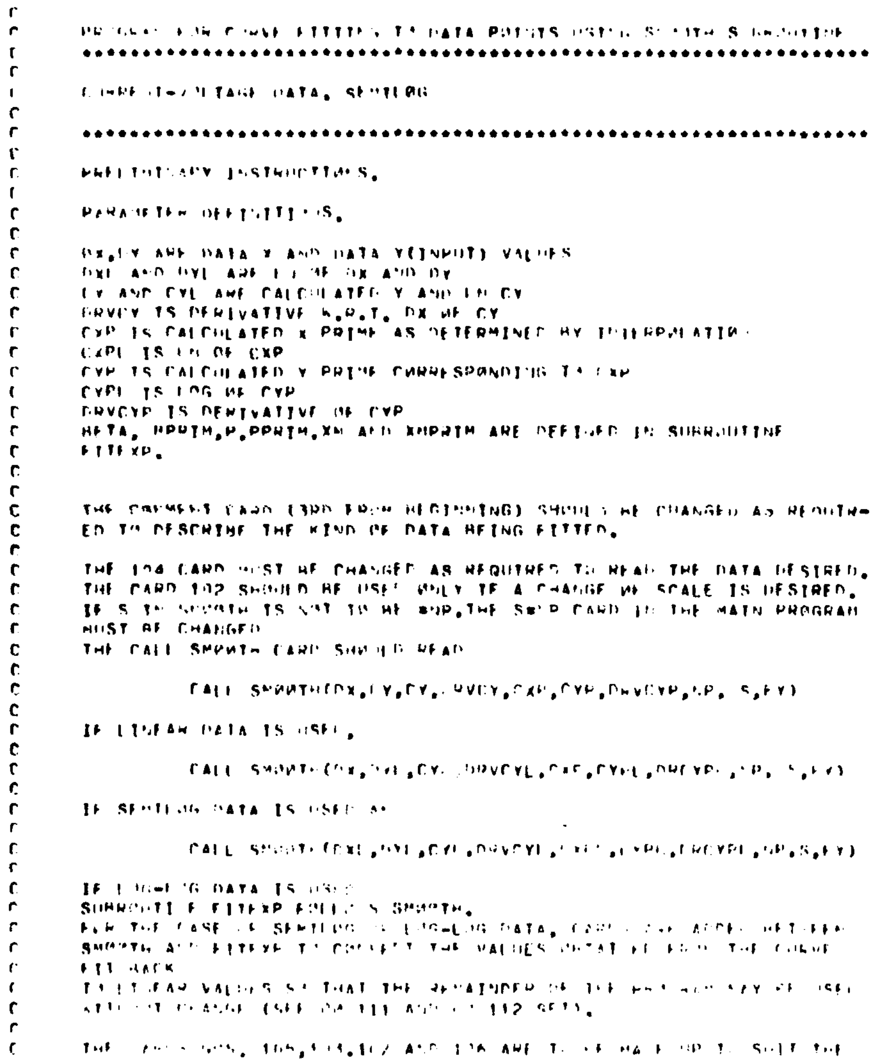


Figure 1. Current-voltage Characteristic of a Hypothetical Diode

regions, as discussed earlier. The values obtained in the nonlinear region for I_{01} and I_{02} (called CY01 and CY02 or CY01P and CY02P in the program) are not as satisfactory as those obtained for m_1 and m_2. The least error occurs where m_1 (or m_2) passes through its correct value. In this case the error may be negligible (less than 1%), but it may be off by a factor of two or three; however, it is well within an order of magnitude in the worst case, and this would often be adequate. If there is a linear region where m_1 or m_2 is determined correctly, I_{01} and I_{02} will always be calculated within ±20%.

At present, the CAFA program is in a primitive stage of development. Further work should provide a more useful, accurate and flexible program which will be of considerable value in experimental research.



```
C
C      PRØGRAM FOR CURVE FITTING TO DATA POINTS USING SMITH S ROUTINE
C      ************************************************************
C
C      CURRENT-VOLTAGE DATA, SEMILOG
C
C      ************************************************************
C
C      PRELIMINARY INSTRUCTIONS.
C
C      PARAMETER DEFINITIONS.
C
C      DX,DY ARE DATA X AND DATA Y(INPUT) VALUES
C      DXL AND DYL ARE LN OF DX AND DY
C      CY AND CYL ARE CALCULATED Y AND LN CY
C      DRVCY IS DERIVATIVE W.R.T. DX OF CY
C      CXP IS CALCULATED X PRIME AS DETERMINED BY INTERPOLATION
C      CXPL IS LN OF CXP
C      CYP IS CALCULATED Y PRIME CORRESPØNDING TO CXP
C      CYPL IS LOG OF CYP
C      DRVCYP IS DERIVATIVE OF CYP
C      BETA, BPRIM,P,PPRIM,XM AND XMPRIM ARE DEFINED IN SUBROUTINE
C      FITEXP.
C
C
C      THE COMMENT CARD (3RD FROM BEGINNING) SHOULD BE CHANGED AS REQUIR-
C      ED TO DESCRIBE THE KIND OF DATA BEING FITTED.
C
C      THE 104 CARD MUST BE CHANGED AS REQUIRED TO READ THE DATA DESIRED.
C      THE CARD 102 SHOULD BE USED ONLY IF A CHANGE OF SCALE IS DESIRED.
C      IF S IN SMOOTH IS NOT TO BE NP,THE S=NP CARD IN THE MAIN PRØGRAM
C      MUST BE CHANGED
C      THE CALL SMOOTH CARD SHOULD READ
C
C              CALL SMOOTH(DX,DY,CY,DRVCY,CXP,CYP,DRVCYP,NP, S,FY)
C
C      IF LINEAR DATA IS USED,
C
C              CALL SMOOTH(DX,DYL,CY,DRVCYL,CXP,CYPL,DRCYP,NP, S,FY)
C
C      IF SEMILOG DATA IS USED AS
C
C              CALL SMOOTH(DXL,DYL,CYL,DRVCYL,CXPL,CYPL,DRCYPL,NP,S,FY)
C
C      IF LOG-LOG DATA IS USED
C      SUBROUTINE FITEXP FOLLOWS SMOOTH.
C      FOR THE CASE OF SEMILOG OR LOG-LOG DATA, CARDS ARE ADDED BETWEEN
C      SMOOTH AND FITEXP TO CONVERT THE VALUES OBTAINED FROM THE CURVE
C      FIT BACK
C      TO LINEAR VALUES SO THAT THE REMAINDER OF THE PROGRAM MAY BE USED
C      WITHOUT CHANGE (SEE [illegible] 111 AND [illegible] 112 SETS).
C
C      THE CARDS [illegible], 105,113,117 AND 136 ARE TO BE MADE UP TO SUIT THE
```

Figure 2. The CAFA Program. Printout for the Hypothetical Diode has been Included. The PLOTIT Plots have not been Included in order to Save Space.

```
C       INDIVIDUAL REQUIREMENTS OF THE PROGRAM AND DATA BEING FITTED, A
C       SIMILAR TREATMENT IS REQUIRED FOR CARDS 257,259,261 AND 260.
C
C       THE PLOTIT CARDS ARE CHANGED TO SUIT WHAT IS TO BE PLOTTED AND
C       THE STATION RANDOM DISC CARDS MUST BE CHANGED ACCORDINGLY.
C       FOR EXAMPLE, THE FIRST VARIABLE IN A PLOTIT CALL IS EITHER PDX
C       OR CXP FOR LINEAR OR SEMILOG DATA, AND IS EITHER PDXL OR CXPL FOR
C       LOG-LOG DATA. IF CALCOMP CALLS ARE USED, THESE MUST BE MODIFIED
C       TO SUIT EACH DATA SET.
C
C       DETERMINATION OF APPROPRIATE ERROR, EY(I).
C
C       SUBROUTINE SMOOTH REQUIRES AN OPTIMUM CHOICE OF EY(I) FOR THE
C       CURVE-FIT FUNCTION AND ITS DERIVATIVES TO BE SMOOTH SIMULTANE-
C       OUSLY. IF THE ERROR IS ZERO, THE CURVE FIT WILL BE NEARLY PERFECT
C       BUT THE DERIVATIVES WILL EXHIBIT NOISE. IF THE ERROR IS LARGE, THE
C       DERIVATIVES WILL BE SMOOTH BUT THE CURVE FIT WILL DETERIORATE.
C       AN OPTIMUM ERROR CAN BE FOUND BY TRIAL AND ERROR TO BE IN BETWEEN
C       THE TWO EXTREMES.
C       FOR CURRENT-VOLTAGE DATA OR SIMILAR DATA IN WHICH THE ORDINATE EX-
C       TENDS OVER SEVERAL ORDERS OF MAGNITUDE, THE ERROR SHOULD BE PRO-
C       PORTIONAL TO THE LOG OF THE ORDINATE.  AN ERROR
C
C                    EY(I)=0.0005*CYL(I)
C
C       HAS BEEN FOUND TO BE A GOOD COMPROMISE FOR CERTAIN I-V DATA.
C
        DIMENSION DZ(25)
        DIMENSION DX(25),DY(25),DXL(25),DYL(25)
        DIMENSION CY(25),CYL(25),P(25),BETA(25),XM(25),DRVCY(25),DRVCYL(25
       1)
        DIMENSION CXP(100),CYP(100),CXPL(100),CYPL(100),FPRTN(100),
       1[illegible](100),XMPRE(100),DRVCYP(100),DRCYPL(100)
        DIMENSION XML(25),XMPRE[illegible](100)
        DIMENSION EY(25)
        DIMENSION D2YDX2(25), D2YDXP(100),DEV(25),DEVXP(100),G(25),GP(1
       10),BE(25),BE2(25),BEP(100),BE2P(100)
        DIMENSION D2LY(25),D2LYP(100)
        DIMENSION [illegible](25),Y2(25),[illegible](100),[illegible]
        DIMENSION [illegible](100),[illegible]
        DIMENSION VP(2),VP(2),XMR(2)
        COMMON DELTX
        READ (5,150)IZERO
150     FORMAT(I2)
        READ(5,100) N,IS,ITER,[illegible]
        IF([illegible]
        IF ([illegible]
100     FORMAT(I2,I3,I4,I3)
C
        READ(5,104)([illegible](I),[illegible](I),I=1,[illegible])
104     FORMAT([illegible]
        [illegible]
        [illegible]
```

NOT REPRODUCIBLE

```
151   IF(I.GT.NP)GO TO 152
      IF(DY(I).EQ.0.)GO TO 150
      DX(J)=DX(I)
      DY(J)=DY(I)
      DZ(J)=DZ(I)
      J=J+1
150   I=I+1
      GO TO 151
152   NP=J-1
      I=1
      J=1
153   IF(I.GT.NP)GO TO 154
      IF(DY(I).EQ.0.)GO TO 156
      DX(J)=DX(I)
      DY(J)=DY(I)
      DZ(J)=DZ(I)
      J=J+1
156   I=I+1
      GO TO 153
154   NP=J-1
      IF(NP.EQ.0)STOP
      IF (NP.GT.50)STOP'NP.GT.50'
      WRITE(6,110)ND,IN,ITEMP,NP
110   FORMAT(//,5X,'DIODE NO. ',I2,5X,'IRRAD. NO.',I3,5X,'TEMPERATURE',I
     14,' DEG.K',5X,'NO.OF DATA POINTS IS',I4,//)
      TEMP=ITEMP
      XMP(1) =1.
      XMP(2)=10.
      YP(1)=DY(1)
      YP(2)=DY(1)
      VP(1)=0.2
      VP(2)=1.5
      DO 101 I=1,NP
C     DYL IS LOG OF DATA ORDINATE
      DYL(I)=ALOG(DY(I))
C     DXL IS LOG OF DATA ABSCISSA
      DXL(I)=ALOG (DX(I))
C
C     EY IS ERROR IN SUBROUTINE SMOOTH
C
C
      EY(I)=.005*DYL(I)
101   CONTINUE
      S=NP
C     HAVE USED XM,BETA,XMEDIN,WPRIM,XMI AND [illegible] AS DUMMY VARIABLES
C     IN THE SMOOTH SUBROUTINE CALLS IN ORDER TO SAVE ARRAY SPACE.
      CALL SMOOTH(DX,DYL,EY,DRVCYL,CXP,CYPL,DRCYPL,[illegible],S,EY,D2LY,[illegible])
      DO 900 I=1,NP
900   EY(I)=.0005*DRVCYL(I)
      CALL SMOOTH(DX,DRVCYL,XM,BETA,CXP,XMEDIN,WPRIM,[illegible],S,EY,XMI,[illegible])
      DO 901 I=1,NP
      DRVCYL(I)=XM(I)
      D2LY(I)=BETA(I)
```

```
901     FY(I)=.0005*D2LY(I)
        DO 902 I=1,100
        DRCYPL(I)=XPRIM(I)
        D2LYP(I)=BPRIM(I)
902     CONTINUE
        CALL SMOOTH(DX,D2LY,XM,BETA,EXP,XMPRIM,BPRIM,NP,S,FY,XML,XMPLM[illegible])
        DO 111 I=1,NP
        D2LY(I)=XM(I)
        CY(I)=EXP(CYL(I))
        DRVCY(I)=CY(I)*DRVCYL(I)
        D2YDX2(I)=CY(I)*(DRVCYL(I)*DRVCYL(I)+D2LY(I))
        G(I)=CY(I)*D2YDX2(I)/(DRVCY(I)*DRVCY(I))
        DEDX(I)=1.-G(I)
        HE(I)=100.*CY(I)/(.026*TEMP*DRVCY(I))
        HE2(I)=HE(I)*HE(I)
111     CONTINUE
        DO 112 I=1,100
        D2LYP(I)=XMPRIM(I)
        CYP(I)=EXP(CYPL(I))
        DRVCYP(I)=DRCYPL(I)*CYP(I)
        D2YDXP(I)=CYP(I)*(DRCYPL(I)*DRCYPL(I)+D2LYP(I))
        GP(I)=CYP(I)*D2YDXP(I)/(DRVCYP(I)*DRVCYP(I))
        DEDXP(I)=1.-GP(I)
        HEP(I)=100.*CYP(I)/(.026*TEMP*DRVCYP(I))
        HE2P(I)=HEP(I)*HEP(I)
        CXPL(I)=ALOG(CXP(I))
112     CONTINUE
        DO 113 I=2,100
        IF(DRCYPL(I))115,116,115
116     DRCYPL(I)=DRCYPL(I-1)
115     CONTINUE
        IF(DRVCYP(I))113,114,113
114     DRVCYP(I)=DRVCYP(I-1)
113     CONTINUE
        NPM=NP-1
        DO 120 I=1,NPM
        TMLY=HE(I)*HE2(I+1)-HE(I+1)*HE2(I)
        IF(TMLY)121,122,121
122     XM1(I)=0.
        XM2(I)=0.
        GO TO 120
121     SRM=(HE2(I+1)*G(I)-HE2(I)*G(I+1))/TMLY
        ROM=(HE(I+1)*G(I)-HE(I)*G(I+1))/TMLY
        TMLY=SRM*SRM-4.*ROM
        IF (TMLY)122,123,123
123     TMLY=SQRT(TMLY)
        IF(ROM)124,[illegible],124
124     TMLY=1./(2.*ROM)
        XM2(I)=TMLY*[illegible]
        XM1(I)=-[illegible]
        IF(1.-[illegible])125,126,[illegible]
125     WRITE [illegible]
126     FORMAT [illegible]
```

```
      XM1(I)=10.
126   IF(10.-ABS(XM2(I)))127,120,120
127   WRITE(6,129)I,XM2(I)
129   FORMAT('FOR I= ',I2,',XM2(I) WAS CHANGED FROM ',F11.4,' TO 10.0')
      XM2(I)=10.
120   CONTINUE
      XM1(NP)=10.
      XM2(NP)=10.
      DO 130 I=1,99
      TMLY=RFP(I)*RF2P(I+1)-RFP(I+1)*RF2P(I)
      IF (TMLY)131,132,131
132   IF (I-1) 135,135,136
135   XM1P(1)=1.
      XM2P(1)=1.
      WRITE(6,800)
800   FORMAT (/,'XM1P(1)AND XM2P(1) WERE SET=TO 1')
      GO TO 130
136   XM1P(I)=XM1P(I-1)
      XM2P(I)=XM2P(I-1)
      WRITE (6,801)I
801   FORMAT(/,'XM1P(I) AND XM2P(I)WERE SET EQUAL TO THEIR NEXT LOWER
     1VALUES FOR I= ',I2)
      GO TO 130
131   SRMP=(RF2P(I+1)*GP(I)-RF2P(I)*GP(I+1))/TMLY
      RPMP=(RFP(I+1)*GP(I)-RFP(I)*GP(I+1))/TMLY
      TMLY=SRMP*SRMP-4.*RPMP
      IF(TMLY)132,133,133
133   TMLY=SQRT(TMLY)
      IF (RPMP)134,132,134
134   TMLY1=1./(2.*RPMP)
      XM2P(I)=TMLY1*(SRMP-TMLY)
      XM1P(I)=-XM2P(I)+SRMP/RPMP
      IF(10.-ABS(XM1P(I)))140,141,141
140   WRITE (6,142)I,XM1P(I)
142   FORMAT('FOR I= ',I2,',XM1P(I) WAS CHANGED FROM ',F11.4,' TO 10.0')
      XM1P(I)=10.
141   IF (10.-ABS(XM2P(I)))143,144,144
143   WRITE(6,145)I,XM2P(I)
145   FORMAT('FOR I= ',I2,',XM2P(I) WAS CHANGED FROM ',F11.4,' TO 10.0')
      XM2P(I)=10.
144   CONTINUE
      IF(XM1P(I))804,130,130
804   TEMP1=-XM1P(I)
      XM1P(I)=XM2P(I)
      XM2P(I)=TEMP1
      WRITE(6,833)I
833   FORMAT('XM1P(I) AND XM2P(I) WERE INTERCHANGED FOR I= ',I2,' AND TH
     1E SIGN OF THE NEW XM2P(I) WAS CHANGED')
130   CONTINUE
      XM1P(100)=10.
      XM2P(100)=10.
      TMLY=[illegible]*DELTX/(.026*TEMP)
      DO 200 I=1,99
```

```
      IF(XM1P(I)-XM2P(I))701,702,701
702   IF(I-1)703,703,704
703   CYO1P(I)=0.
      CYO2P(I)=0.
      WRITE(6,705)
705   FORMAT(/,'CYO1P(I)AND CYO2P(I) WERE SET=TO 0')
      GO TO 700
704   CYO1P(I)=CYO1P(I-1)
      CYO2P(I)=CYO2P(I-1)
      WRITE (6,706)I
706   FORMAT(/,'CYO1P(I) AND CYO2P(I) WERE SET EQUAL TO THEIR NEXT LOWER
     1VALUES FOR I= ',I2)
      GO TO 700
701   IF(XM1P(I).EQ.0..OR.XM2P(I).EQ.0.)GO TO 702
      TMLY1=EXP(TMLY/XM2P(I))-EXP(TMLY/XM1P (I))
      IF((CXP(I)/(XM1P(I)*TEMP))-.0074)707,707,708
708   CYO1P(I)=0.
      WRITE(6,709)I
709   FORMAT(/,'CYO1P(I) WAS SET EQUAL TO ZERO FOR I= ',I2)
      GO TO 711
707   DEN1=TMLY1*EXP(300.*CXP(I)/(.026*TEMP*XM1P(I)))
      CYO1P(I)=(CYP(I)*EXP(TMLY/XM2P(I))-CYP(I+1))/DEN1
711   IF((CXP(I)/(XM2P(I)*TEMP))-.0074)712,712,713
713   CYO2P(I)=0.
      WRITE(6,714)I
714   FORMAT(  'CYO2P(I) WAS SET EQUAL TO ZERO FOR I= ',I2)
      GO TO 700
712   DEN2=TMLY1*EXP(300.*CXP(I)/(.026*TEMP*XM2P(I)))
      CYO2P(I)=(CYP(I+1)-CYP(I)*EXP(TMLY/XM1P(I)))/DEN2
700   CONTINUE
      CYO1P(100)=CYO1P(99)
      CYO2P(100)=CYO2P(99)
      DO 604 I=1,100
C     HPRIM(I) IS EQUIVALENT TO Q/MPRIM(I)KT
      HPRIM(I)=DRVCYP(I)/CYP(I)
C     CYPL IS LOG OF CYP
      CYPL(I)=ALOG(CYP(I))
C     PPRIM IS PRE-EXPONENTIAL FACTOR
      PPRIM(I)=EXP(CYPL(I)-HPRIM(I)*CXP(I))
C     XMPRIM IS MPRIM(I)
      XMPRIM (I)=300./(.026*TEMP*HPRIM(I))
      XMPRML(I)=ALOG(XMPRIM(I))
604   CONTINUE
      DO 607 I=1,NP
C     HETA(I) IS EQUIVALENT TO Q/M(I)KT
      HETA(I)=DRVCY(I)/CY(I)
C     CYL IS LOG OF CY
      CYL(I)=ALOG(CY(I))
C     P IS PRE-EXPONENTIAL FACTOR
      P(I)=EXP(CYL(I)-HETA(I)*CX(I))
      XM(I)=300./(.026*TEMP*HETA(I))
      XML(I)=ALOG(XM(I))
607   CONTINUE
```

NOT REPRODUCIBLE

```
      WRITE (6,270)
270   FORMAT(3X,'I',6X,'DZ')
      WRITE(6,271)(I,DZ(I),I=1,NP)
271   FORMAT(I4,F12.5)
105   WRITE(6,103)
103   FORMAT(3X,'I',5X,'DX',9X,'DY',9X,'DXL',8X,'DYL',8X,'CY',9X,'CYL',
     18X,'DRVCY',6X,'BETA',8X,'P',9X,'XM',9X,'XML')
107   WRITE(6,106)(I,DX(I),DY(I),DXL(I),DYL(I),CY(I),CYL(I),DRVCY(I),
     1BETA(I),P(I),XM(I),XML(I),I=1,NP)
106   FORMAT(I4,F11.4,8E11.4,2F11.4)
      WRITE (6,300)
300   FORMAT(/,3X,'I',4X,'DFDX',7X,'1-DFDX',5X,'BF',6X,'BFSQR',7X,'XM1',
     18X,'XM2')
      WRITE (6,301)(I,DFDX(I),G(I),BF(I),BF2(I),XM1(I),XM2(I),I=1,NP)
301   FORMAT (I4,4E11.4,2F11.4)
257   WRITE(6,259)
259   FORMAT(/,3X,'I',5X,'CXP',19X,'CXPL',18X,'CYP',6X,'CYPL',6X,
     1'DRVCYP',6X,'BPRIM',6X,'PPRIM',5X,'XMPRIM',5X,'XMPRML')
261   WRITE(6,260)(I,CXP(I),CXPL(I),CYP(I),CYPL(I),DRVCYP(I),BPRIM(I),
     1PPRIM(I),XMPRIM(I),XMPRML(I),I=1,100)
260   FORMAT(I4,F11.4,11X,E11.4,11X,5E11.4,2F11.4)
      WRITE(6,400)
400   FORMAT(/,3X,'I',4X,'DFDXP',6X,'1-DFDXP',4X,'BFP',7X,'BFSQRP',6X,'X
     1M1P',7X,'XM2P',6X,'CY01P',6X,'CY02P',6X,'D2YDXP',6X,'D2LYP')
      WRITE (6,401)(I,DFDXP(I),GP(I),BFP(I),BF2P(I),XM1P(I),XM2P(I),
     1CY01P(I),CY02P(I),D2YDXP(I),D2LYP(I),I=1,100)
401   FORMAT (I4,4E11.4,2F11.4,4E11.4)
      CALL PLOTIT (CXP,CYP,100,1)
      CALL PLOTIT (CXP,CYPL,100,1)
      CALL PLOTIT (CXP,DRVCYP,100,1)
      CALL PLOTIT (CXP,XMPRIM,100,1)
      CALL PLOTIT (CYP,XMPRIM,100,1)
      CALL PLOTIT (CYPL,XMPRIM,100,1)
      CALL PLOTIT(CYPL,XMPRML,100,1)
      CALL PLOTIT(CXP,XM1P,100,1)
      CALL PLOTIT(CXP,XM2P,100,1)
      CALL  PLOTIT(CXP,CY01P,100,1)
      CALL  PLOTIT(CXP,CY02P,100,1)

MEMORY MAP

PROCEDURES
 00004 = )NS4      12072 = )0EE       17230 = )ARG      17324 = )ELF       12451 = )SIP
 16072 = )SI6      17221 = )[illegible]  12576 = )COI   16653 = ALOG       16175 = )MI6
 12674 = SMOOTH    16204 = EXP        13146 = )AI6      16043 = )[illegible]16  14501 = SQRT
 14944 = ABS       16003 = )[illegible]  17334 = PLOTIT  17434 = [illegible]

LOCAL RELATIVE
 17541 = LTO.01    00101 = DZ         00163 = DX        00245 = [illegible]  00327 = DXL
 00411 = DYL       00473 = CY         00555 = CYL       00637 = P          00721 = BETA
 01003 = XM        01065 = DRVCY      01147 = DRVCYL    01231 = CXP        01541 = CYP
 02051 = CXPL      02361 = CYPL       02671 = PPRIM     03231 = XMPRIM     03511 = [illegible]
 04021 = DRVCYP    04331 = [illegible]  04641 = XML     04723 = XMPRML     05233 = FX
```

NOT REPRODUCIBLE

```
 05315 = 02YOX2      05377 = 02YOXP      05707 = DEDX        05771 = DEDXP       06301 = G
 06363 = GP          06673 = RF          16755 = RF2         07037 = RFP         07347 = RF2P
 07667 = 02LY        07711 = 02LYP       10251 = XM1         10333 = XM2         10415 = XM1P
 10725 = XM2P        11235 = CYL1P       11545 = CYL2P       12055 = YP          12361 = YP
 12065 = XMP         17457 = TEMP        17473 = S           17500 = RTO,01      17506 = RTO,02
 17515 = TMLY        17517 = SEC         17521 = EOM         17525 = RTO,03      17531 = TMLY1
 17533 = SRMP        17535 = RDRP        17537 = TERP1       17542 = RTO,04      17546 = DEN1
 17550 = DEN2        174370= I2E         174400= [illegible] 17441 = TK          174420= ITEMP
 17443 = RP          17444 = I           17445 = ITO,01      17446 = ITO,02      17447 = I
 17452 = ITO,03      17453 = ITO,04      17454 = ITO,05      17455 = ITO,06      17475 = ITO,07
 17476 = ITO,08      17477 = ITO,09      17502 = ITO,10      17503 = ITO,11      17512 = ITO,12
 17513 = ITO,13      17514 = RPM

LOCAL DYNAMIC

ABSOLUTE

STMNT LABELS
 12105 = 000160      12155 = 000100      12216 = 000104      12230 = 000151      12327 = 000152
 12323 = 000150      12336 = 000153      12434 = 000154      12430 = 000156      12510 = 000110
 12664 = 000101      12713 = 000900      12776 = 000901      13044 = 000902      13233 = 000111
 13411 = 000112      13467 = 000113      13443 = 000115      13430 = 000116      13454 = 000114
 14127 = 000120      13560 = 000121      13542 = 000122      13661 = 000123      13667 = 000124
 13736 = 000125      14025 = 000126      13761 = 000128      14043 = 000127      14063 = 000129
 15076 = 000130      14375 = 000131      14215 = 000132      14221 = 000135      14264 = 000136
 14237 = 000800      14324 = 000801      14500 = 000133      14507 = 000134      14556 = 000140
 14645 = 000141      14601 = 000142      14663 = 000143      14747 = 000144      14703 = 000145
 14760 = 000804      15014 = 000803      16005 = 000700      15437 = 000701      15156 = 000702
 15154 = 000703      15224 = 000704      15176 = 000705      15266 = 000706      15524 = 000707
 15450 = 000708      15472 = 000709      15615 = 000711      15712 = 000712      15642 = 000713
 15561 = 000714      16126 = 000604      16234 = 000607      16250 = 000270      16507 = 000271
 16314 = 000105      16322 = 000103      16406 = 000107      16520 = 000106      16543 = 000300
 16665 = 000301      16675 = 000257      16704 = 000259      16772 = 000261      17073 = 000260
 17124 = 000400      17326 = 000401

COMMON
 000000= DELTY

 17554 = RANGE
                       END
```

NOT REPRODUCIBLE

```
      SUBRØUTINE SMØØTH(X,Y,R,R1,CXP,RPRIM,R1PRIM,N,S,DY,R2,R2PRIM)
C
C     ABSTRACT
C        SMØØTH FITS A SMØØTH SPLINE THRØUGH THE GIVEN SET ØF DATA
C        BY MINIMIZING THE INTEGRAL ØF THE SECØND DERIVATIVE SUBJECT
C        TØ THE CØNSTRAINT THAT
C                N
C               SUM ( (R(I)-Y(I))/DY(I))**2 ) .LE. S.
C               I=1
C
C     DESCRIPTIØN ØF ARGUMENTS
C        N  - NUMBER ØF DATA VALUES
C        X  - ABSCISSA ARRAY
C        Y  - ØRDINATE ARRAY
C        DY - WEIGHT ARRAY.  IF S=N, DY(I) SHØULD BE AN ESTIMATE
C             ØF THE ERRØR IN Y(I).
C        S  - SCALE FACTØR FØR WEIGHTS, NØRMALLY = N.
C        A,B,C,D - CUBIC BETWEEN X(I) AND X(I+1) IS
C             A(I) + B(I)*H + C(I)*H**2 + D(I)*H**3
C             WHERE H IS DESIRED ABSCISSA MINUS X(I).
C        R  - ARRAY ØF SMØØTH SPLINE VALUES
C        R1 - ARRAY ØF SMØØTH SPLINE DERIVATIVES
C        R2 - ARRAY ØF SMØØTH SPLINE SECØND DERIVATIVES
C        T,T1,U,V - WØRK ARRAYS
C
C        X,Y,DY,A,B,C,D MUST BE DIMENSIØNED AT LEAST N
C        R,R1,R2,T,T1,U,V MUST BE DIMENSIØN AT LEAST N+2
C
C     REFERENCE -- NUMERISHE MATHEMATIK 10,177-183 (1967) C H REINSCH
C     CØNVERSIØN FRØM THE ALGØL BY R E JØNES, DIV 9422, SANDIA LABS
C     THE ØRIGINAL N1 WAS FIXED AT 1 TØ AVØID WASTED WØRK ARRAY SPACE
C     THE ØRIGINAL N2 IS CALLED N HERE
C     ALL WØRK ARRAY INDICES ARE 1 LARGER THAN IN THE ALGØL,
C     TØ AVØID A ZERØ SUBSCRIPT.
C
C     PRØGRAM HAS BEEN MØDIFIED TØ CALCULATE CXP,RPRIM AND R1PRIM WITH-
C     IN THE PRØGRAM, INSTEAD ØF ØUTSIDE...B. [illegible],12/1/70
C
      DIMENSIØN X(25),Y(25),DY(25)
      DIMENSIØN R(25),R1(25),R2(25),T(25),T1(25),U(25),V(25),A(25),
     1B(25),C(25),D(25)
      DIMENSIØN CXP(100),RPRIM(100),R1PRIM(100)
      DIMENSIØN Z(100)
      DIMENSIØN R2PRIM(100)
      CØMMØN DELTX
C
C     INITIALIZE
C
      R(1) = 0.0
      R(2) = 0.0
      R1(N+1) = 0.0
      R2(N+1) = 0.0
      R2(N+2) = 0.0
```

NOT REPRODUCIBLE

```
      U(1) = 0.0
      U(2) = 0.0
      U(N+1) = 0.0
      U(N+2) = 0.0
      P = 0.0
      N2 = N-1
C
      H = X(2)-X(1)
      F = (Y(2)-Y(1))/H
      DO 100 I=2,N2
      G = H
      H = X(I+1)-X(I)
      E = F
      F = (Y(I+1)-Y(I))/H
      A(I) = F-E
      T(I+1) = 2.0*(G+H)/3.0
      T1(I+1) = H/3.0
      R2(I+1) = DY(I-1)/G
      R(I+1) = DY(I+1)/H
  100 R1(I+1) = -DY(I)/G - DY(I)/H
C
      DO 200 I=2,N2
      B(I)= R(I+1)*R(I+1) + R1(I+1)*R1(I+1) + R2(I+1)*R2(I+1)
      C(I)= R(I+1)*R1(I+2) + R1(I+1)*R2(I+2)
  200 D(I)= R(I+1)*R2(I+3)
      F2  = -S
C
C     NEXT ITERATION
C
  250 DO 300 I=2,N2
      R1(I) = F*R(I)
      R2(I-1) = G*R(I-1)
      R(I+1)=1.0/(P*B(I)+T(I+1)-F*R1(I)-G*R2(I-1))
      U(I+1)=A(I)-R1(I-1)*U(I)-R2(I-1)*U(I-1)
      F = P*C(I)+T1(I+1)-H*R1(I)
      G = H
  300 H = D(I)*P
C
      DO 400 I=2,N2
      J=N2-(I-2)
  400 U(J+1)=R(J+1)*U(J+1)-R1(J+1)*U(J+2)-R2(J+1)*U(J+3)
      E=0.0
      H=0.0
C
      DO 500 I=1,N2
      G = H
      H = (U(I+2)-U(I+1))/(X(I+1)-X(I))
      V(I+1) = (H-G)*DY(I)*DY(I)
  500 E = E+V(I+1)*(H-G)
      V(N+1) = -H*DY(N)*DY(N)
      G = V(N+1)
      E = E-G*H
      G = [illegible]
```

NOT REPRODUCIBLE

```
      F2= F+P*P
      IF ((F2.GE.S). P.(F2.LE.G)) GO TO 650
      F = 1.0
      H = (V(3)-V(2))/(X(2)-X(1))
C
      DO 600 I=2,M2
      G = H
      H = (V(I+2)-V(I+1))/(X(I+1)-X(I))
      G=H-G-R1(I)*R(I)-R2(I-1)*R(I-1)
      F = F+G*R(I+1)*G
  600 R(I+1) = G
      H = E-F*F
      IF (H.LE.0.0) GO TO 650
      P = P+(S-F2)/((SQRT(S/F)+P)*H)
      GO TO 250
C
C     FINISH
C
  650 DO 700 I=1,N
      A(I)=Y(I)-P*V(I+1)
  700 C(I)=R(I+1)
C
      DO 800 I=1,M2
      H=X(I+1)-X(I)
      D(I)=(C(I+1)-C(I))/(3.0*H)
  800 B(I)=(A(I+1)-A(I))/H-(H*D(I)+C(I))*H
      B(N)=0.0
      D(N)=0.0
C
C     OUTPUT DERIVATIVES, ETC.
C
      DO 900 I=1,M2
      R(I) = A(I)
      R1(I) = B(I)
  900 R2(I) = 2.0*C(I)
      R(N) = A(N)
      H = X(N)-X(M2)
      R1(N)=(3.0*D(M2)*H+2.0*C(M2))*H+B(M2)
      R2(N)=6.0*D(M2)*H+2.0*C(M2)
C
C     DELTX IS INCREMENT 'DELTA X' ON X AXIS
C
      DELTX =(X(N)-X(1))/99.
      K=0
      DO 201 I=1,100
C
      EXP(I)    = X(1)+K*DELTX
      K=K+1
201   CONTINUE
      I=1
      DO 302 I=1,100
333   IF (EXP(I)    .GE. X(I+1)) GO TO 301
302   CONTINUE
```

NOT REPRODUCIBLE

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              Z(J)=CXP(I)-X(J)
              RPRIME(I)=A(I)+Z(J)*(B(I)+Z(J)*(C(I)+D(I)*Z(J)))
              R1PRIM(I)=B(I)+Z(J)*(2.*C(I)+3.*D(I)*Z(J))
              R2PRIM(I)=2.*C(I)+6.*D(I)*Z(J)
              GO TO 305
        301   I=I+1
              GO TO 302
        305   IF (I.LE.N) GO TO 308
              GO TO 304
        308   CONTINUE
        301   RETURN

MEMORY MAP

PROCEDURES
 00004 = JSS4        03046 = JI16        03117 = JD16        03333 = JA16        03324 = JM16
 02476 = INGT        02527 = SQRT        03160 = JC01        03412 = N[illegible]

LOCAL RELATIVE
 03506 = LTO.01      03414U= X           03415U= Y           03416 = R           03417 = R1
 03420 = CXP         03421 = RPRIME      03422 = R1PRIM      03424U= S           03425U= DY
 03426 = R2          03427 = R2PRIM      00035 = T           00117 = T1          00201 = U
 00263 = V           00345 = A           00427 = B           00511 = C           00573 = D
 00655 = Z           00000U= [illegible] 03441 = P           03446 = H           03452 = F
 03455 = G           03457 = E           03465 = RTO.01      03467 = RTO.02      03471 = RTO.03
 03473 = F2          03477 = RTO.04      03503 = RTO.05      03423U= N           03443 = M2
 03430 = ITO.01      03433 = ITO.02      03434 = ITO.03      03435 = ITO.04      03436 = ITO.05
 03437 = ITO.06      03442 = ITO.07      03444 = ITO.08      03445 = ITO.09      03450 = ITO.10
 03451 = ITO.11      03453 = J           03501 = ITO.12      03502 = ITO.13      03505 = I
 03513 = K

LOCAL DYNAMIC

ABSOLUTE

STMNT LABELS
 01431 = [illegible] 01554 = [illegible] 01605 = 000250      0200[illegible] = [illegible] 02026 = [illegible]
 02176 = [illegible] 02541 = [illegible] 02456 = 000600      02571 = [illegible] 02652 = [illegible]
 02776 = [illegible] 03171 = [illegible] 03401 = 000308      03201 = [illegible] 03361 = [illegible]
 03225 = 000302      03365 = 000305      03407 = 000304

COMMON
 00000 = DELTX

 03514 = RANGE
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NOT REPRODUCIBLE

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NEXT JOB
X

     DIODE NO. 32      IRRAD. [illegible]      TEMPERATURE 300 DEG.K      NO. OF DATA POINTS IS   9

FOR I=  1,XM1P(I) WAS CHANGED FROM      33.8333 TO 10.0
FOR I=  2,XM1P(I) WAS CHANGED FROM      22.6774 TO 10.0
FOR I=  3,XM1P(I) WAS CHANGED FROM      1[illegible].0976 TO 10.0
FOR I= 22,XM1P(I) WAS CHANGED FROM      12.2167 TO 10.0
XM1P(I) AND XM2P(I) WERE INTERCHANGED FOR I= 23 AND THE SIGN OF THE NEW XM2P(I) WAS CHANGED
XM1P(I) AND XM2P(I) WERE INTERCHANGED FOR I= 24 AND THE SIGN OF THE NEW XM2P(I) WAS CHANGED
XM1P(I) AND XM2P(I) WERE INTERCHANGED FOR I= 25 AND THE SIGN OF THE NEW XM2P(I) WAS CHANGED
XM1P(I) AND XM2P(I) WERE INTERCHANGED FOR I= 26 AND THE SIGN OF THE NEW XM2P(I) WAS CHANGED
XM1P(I) AND XM2P(I) WERE INTERCHANGED FOR I= 27 AND THE SIGN OF THE NEW XM2P(I) WAS CHANGED
XM1P(I) AND XM2P(I) WERE INTERCHANGED FOR I= 28 AND THE SIGN OF THE NEW XM2P(I) WAS CHANGED
XM1P(I) AND XM2P(I) WERE INTERCHANGED FOR I= 29 AND THE SIGN OF THE NEW XM2P(I) WAS CHANGED
XM1P(I) AND XM2P(I) WERE INTERCHANGED FOR I= 30 AND THE SIGN OF THE NEW XM2P(I) WAS CHANGED
XM1P(I) AND XM2P(I) WERE INTERCHANGED FOR I= 31 AND THE SIGN OF THE NEW XM2P(I) WAS CHANGED
FOR I= 97,XM1P(I) WAS CHANGED FROM      -73.4045 TO 10.0
XM1P(I) AND XM2P(I) WERE INTERCHANGED FOR I= 98 AND THE SIGN OF THE NEW XM2P(I) WAS CHANGED
XM1P(I) AND XM2P(I) WERE INTERCHANGED FOR I= 99 AND THE SIGN OF THE NEW XM2P(I) WAS CHANGED
  I     DZ
  1  .00000E 00
  2  .00000E 00
  3  .00000E 00
  4  .00000E 00
  5  .00000E 00
  6  .00000E 00
  7  .00000E 00
  8  .00000E 00
  9  .00000E 00
  I      DX          DY            [illegible]         CYI          CY          CYI         DRVLY        BETA          P              XM          XMI
  1     .400[illegible]   .2250E 04  -.[illegible]63E [illegible]   .7710E 01   .2250E 04   .7712E 01   .4441E 05   .1[illegible]E 02   .[illegible]6E 01     1.9[illegible]33      .6898
  2     .500[illegible]   .1550E 05  -.6034E [illegible]   .9649E 01   .1550E 05   .9649E [illegible]1   .2304E 06   .1[illegible]E 02   .0[illegible]49E 00     1.9921      .6892
  3     .600[illegible]   .1070E 06  -.51[illegible]E 00   .1158E [illegible]2   .1070E 06   .1158E [illegible]2   .2[illegible]E 07   .1433E 02   .0834E 00     1.9[illegible]      .6861
  4     .7[illegible]   .7420E 06  -.4567E 00   .1352E [illegible]2   .7405E 06   .1352E [illegible]2   .1437E 08   .1[illegible]21E [illegible]2   .[illegible]2[illegible]E 00     1.9614      .6836
  5     .[illegible]   .5342E 07  -.2231E [illegible]   .1549E [illegible]2   .5208E 07   .1545E [illegible]2   .1[illegible]81E 09   .2[illegible]E 02   .1132E 00     1.[illegible]      .6342
  6     .[illegible]   .47[illegible]E 08  -.[illegible]54E 00   .1767E [illegible]2   .4793E 08   .1769E [illegible]2   .1174E 10   .24[illegible]E [illegible]2   .1267E-01     1.5717      .4515
  7     1.[illegible]   .421[illegible]E 09   .7154E-[illegible]   .2053E [illegible]2   .5363E [illegible]9   .2[illegible]4E [illegible]2   .2[illegible]E 11   .31[illegible]1E 02   .1281E-[illegible]     1.2[illegible]1      .1[illegible]49
  8     1.[illegible]   .2[illegible]2[illegible]E 11   .05[illegible]E-[illegible]1   .2411E [illegible]2   .[illegible]77E 11   .24[illegible]E [illegible]2   .10[illegible]1E 13   .37[illegible]3E 02   .2173E-07     1.[illegible]1[illegible]      .[illegible]138
  9     1.2[illegible]   .1320E 13   .[illegible]2[illegible]E [illegible]0   .2791E [illegible]2   .13[illegible]E 13   .27[illegible]E [illegible]   .[illegible]85E 14   .[illegible]2E 02   .6[illegible]23E-[illegible]      .[illegible]57     -.[illegible]144

  I     [illegible]        1-[illegible]X        [illegible]         [illegible]          XM1          [illegible]2
  1  -.3142E-0[illegible]   .1[illegible]E 01   .1[illegible]E [illegible]1   .3[illegible]3E [illegible]1      1.9050      1.74[illegible]
  2  -.4[illegible]58E-0[illegible]   .1[illegible]E 01   .1[illegible]2E [illegible]1   .3962E 01      1.9054      1.6[illegible]
  3  -.[illegible]75E-[illegible]3   .10[illegible]1E 01   .1[illegible]0E [illegible]1   .39[illegible]E [illegible]1      1.9016      1.14[illegible]
  4  -.2[illegible]8E-[illegible]2   .1[illegible]2E 01   .19[illegible]E [illegible]1   .3942E [illegible]1      1.9886       .8[illegible]
  5  -.5780E-[illegible]   .105[illegible]E 01   .1[illegible]E [illegible]1   .3611E [illegible]1      2.0534      1.[illegible]7[illegible]
  6  -.[illegible]09E [illegible]   .111[illegible]E [illegible]1   .15[illegible]E 01   .24[illegible]2E [illegible]1      1.9522      1.[illegible]
  7  -.670[illegible]E-[illegible]   .1[illegible]67E 01   .1[illegible]7E [illegible]1   .11[illegible]E [illegible]1      1.74[illegible]       .[illegible]
  8  -.1962E-[illegible]   .1[illegible]2[illegible]E [illegible]1   .[illegible]E [illegible]1   .1[illegible]E [illegible]1       .3551       .[illegible]
  9  -.234[illegible]E-[illegible]2   .1[illegible]E 01   .[illegible]E [illegible]   .[illegible]E [illegible]      [illegible].[illegible]      1.
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NOT REPRODUCIBLE

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 I    CXP         CXPI          CYP        CYPI       DRVCYP      HPSIH       PPRIH      YMPRIH    XMPRMI
  1  .4000     -.9163E 00    .2250E 04  .7719E 01  .4441E 05  .1930E 02  .1001E 01   1.9933    .6898
  2  .4081     -.8963E 00    .2630E 04  .7875E 01  .5074E 05  .1930E 02  .1000E 01   1.9932    .6898
  3  .4162     -.8767E 00    .3073E 04  .8031E 01  .5931E 05  .1930E 02  .9998E 00   1.9931    .6897
  4  .4242     -.8574E 00    .3592E 04  .8186E 01  .6932E 05  .1930E 02  .9994E 00   1.9930    .6897
  5  .4323     -.8386E 00    .4198E 04  .8342E 01  .8102E 05  .1930E 02  .9989E 00   1.9929    .6896
  6  .4404     -.8201E 00    .4906E 04  .8498E 01  .9469E 05  .1930E 02  .9985E 00   1.9928    .6896
  7  .4485     -.8019E 00    .5734E 04  .8654E 01  .1107E 06  .1930E 02  .9980E 00   1.9927    .6895
  8  .4566     -.7840E 00    .6702E 04  .8810E 01  .1294E 06  .1930E 02  .9975E 00   1.9926    .6894
  9  .4646     -.7665E 00    .7833E 04  .8966E 01  .1512E 06  .1930E 02  .9970E 00   1.9925    .6894
 10  .4727     -.7492E 00    .9156E 04  .9122E 01  .1767E 06  .1930E 02  .9965E 00   1.9924    .6893
 11  .4808     -.7323E 00    .1070E 05  .9278E 01  .2066E 06  .1931E 02  .9960E 00   1.9923    .6893
 12  .4889     -.7156E 00    .1251E 05  .9434E 01  .2415E 06  .1931E 02  .9954E 00   1.9922    .6892
 13  .4970     -.6992E 00    .1462E 05  .9590E 01  .2823E 06  .1931E 02  .9948E 00   1.9920    .6892
 14  .5051     -.6831E 00    .1709E 05  .9746E 01  .3300E 06  .1931E 02  .9942E 00   1.9919    .6891
 15  .5131     -.6672E 00    .1997E 05  .9902E 01  .3857E 06  .1931E 02  .9936E 00   1.9918    .6890
 16  .5212     -.6516E 00    .2335E 05  .1006E 02  .4509E 06  .1931E 02  .9929E 00   1.9916    .6890
 17  .5293     -.6362E 00    .2729E 05  .1021E 02  .5271E 06  .1931E 02  .9922E 00   1.9915    .6889
 18  .5374     -.6211E 00    .3190E 05  .1037E 02  .6161E 06  .1931E 02  .9915E 00   1.9914    .6888
 19  .5455     -.6061E 00    .3729E 05  .1053E 02  .7203E 06  .1932E 02  .9907E 00   1.9912    .6887
 20  .5535     -.5914E 00    .4359E 05  .1068E 02  .8421E 06  .1932E 02  .9899E 00   1.9911    .6887
 21  .5616     -.5769E 00    .5096E 05  .1084E 02  .9844E 06  .1932E 02  .9891E 00   1.9909    .6886
 22  .5697     -.5626E 00    .5957E 05  .1099E 02  .1151E 07  .1932E 02  .9882E 00   1.9907    .6885
 23  .5778     -.5486E 00    .6964E 05  .1115E 02  .1346E 07  .1932E 02  .9873E 00   1.9906    .6884
 24  .5859     -.5347E 00    .8140E 05  .1131E 02  .1573E 07  .1932E 02  .9863E 00   1.9904    .6883
 25  .5939     -.5210E 00    .9516E 05  .1146E 02  .1839E 07  .1933E 02  .9853E 00   1.9902    .6882
 26  .6020     -.5075E 00    .1112E 06  .1162E 02  .2150E 07  .1933E 02  .9842E 00   1.9900    .6881
 27  .6101     -.4941E 00    .1301E 06  .1178E 02  .2514E 07  .1933E 02  .9831E 00   1.9898    .6880
 28  .6182     -.4810E 00    .1520E 06  .1193E 02  .2939E 07  .1933E 02  .9818E 00   1.9896    .6879
 29  .6263     -.4680E 00    .1778E 06  .1209E 02  .3437E 07  .1933E 02  .9805E 00   1.9894    .6878
 30  .6343     -.4552E 00    .2078E 06  .1224E 02  .4018E 07  .1934E 02  .9790E 00   1.9891    .6877
 31  .6424     -.4425E 00    .2430E 06  .1240E 02  .4698E 07  .1934E 02  .9773E 00   1.9888    .6876
 32  .6505     -.4300E 00    .2841E 06  .1256E 02  .5494E 07  .1934E 02  .9753E 00   1.9885    .6874
 33  .6586     -.4177E 00    .3321E 06  .1271E 02  .6425E 07  .1935E 02  .9730E 00   1.9882    .6872
 34  .6667     -.4055E 00    .3883E 06  .1287E 02  .7514E 07  .1935E 02  .9705E 00   1.9877    .6870
 35  .6747     -.3934E 00    .4541E 06  .1303E 02  .8788E 07  .1935E 02  .9675E 00   1.9873    .6868
 36  .6828     -.3815E 00    .5310E 06  .1318E 02  .1028E 08  .1936E 02  .9642E 00   1.9867    .6865
 37  .6909     -.3697E 00    .6209E 06  .1334E 02  .1202E 08  .1936E 02  .9604E 00   1.9861    .6862
 38  .6990     -.3581E 00    .7262E 06  .1350E 02  .1407E 08  .1937E 02  .9561E 00   1.9855    .6859
 39  .7071     -.3466E 00    .8493E 06  .1365E 02  .1646E 08  .1938E 02  .9511E 00   1.9847    .6855
 40  .7152     -.3353E 00    .9934E 06  .1381E 02  .1926E 08  .1939E 02  .9442E 00   1.9836    .6849
 41  .7232     -.3240E 00    .1162E 07  .1397E 02  .2255E 08  .1940E 02  .9340E 00   1.9821    .6841
 42  .7313     -.3129E 00    .1360E 07  .1412E 02  .2642E 08  .1943E 02  .9190E 00   1.9798    .6830
 43  .7394     -.3019E 00    .1592E 07  .1428E 02  .3099E 08  .1946E 02  .8970E 00   1.9766    .6813
 44  .7475     -.2911E 00    .1865E 07  .1444E 02  .3637E 08  .1950E 02  .8694E 00   1.9720    .6790
 45  .7556     -.2803E 00    .2186E 07  .1459E 02  .4275E 08  .1956E 02  .8327E 00   1.9661    .6761
 46  .7636     -.2697E 00    .2563E 07  .1476E 02  .5033E 08  .1964E 02  .7873E 00   1.9588    .6722
 47  .7717     -.2591E 00    .3007E 07  .1492E 02  .5933E 08  .1973E 02  .7334E 00   1.9493    .6675
 48  .7798     -.2487E 00    .3531E 07  .1508E 02  .7008E 08  .1985E 02  .6715E 00   1.9381    .6617
 49  .7879     -.2384E 00    .4151E 07  .1524E 02  .8294E 08  .1998E 02  .6031E 00   1.9247    .6548
 50  .7960     -.2282E 00    .4883E 07  .1540E 02  .9837E 08  .2015E 02  .5300E 00   1.9091    .6466
 51  .8040     -.2181E 00    .5750E 07  .1556E 02  .1169E 09  .2034E 02  .4538E 00   1.8911    .6372
 52  .8121     -.2081E 00    .6780E 07  .1573E 02  .1394E 09  .2056E 02  .3804E 00   1.8708    .6264
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NOT REPRODUCIBLE

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 53    .8202       -.1982E 00       .8100E 07  .1593E 02  .1666E 09  .2081E 02  .3101E 00     1.8464     .6143
 54    .8283       -.1884E 00       .9471E 07  .1606E 02  .1997E 09  .2109E 02  .2463E 00     1.8241     .6011
 55    .8364       -.1787E 00       .1124E 08  .1623E 02  .2402E 09  .2139E 02  .1906E 00     1.7970     .5865
 56    .8444       -.1691E 00       .1335E 08  .1641E 02  .2900E 09  .2173E 02  .1435E 00     1.7701     .5710
 57    .8525       -.1596E 00       .1591E 08  .1658E 02  .3514E 09  .2209E 02  .1051E 00     1.7409     .5544
 58    .8606       -.1501E 00       .1901E 08  .1676E 02  .4276E 09  .2249E 02  .7493E-01     1.7104     .5368
 59    .8687       -.1408E 00       .2281E 08  .1694E 02  .5225E 09  .2291E 02  .5195E-01     1.6780     .5182
 60    .8768       -.1315E 00       .2746E 08  .1713E 02  .6414E 09  .2336E 02  .3501E-01     1.6465     .4987
 61    .8848       -.1223E 00       .3319E 08  .1732E 02  .7913E 09  .2384E 02  .2293E-01     1.6134     .4784
 62    .8929       -.1132E 00       .4030E 08  .1751E 02  .9811E 09  .2435E 02  .1459E-01     1.5798     .4573
 63    .9010       -.1042E 00       .4915E 08  .1771E 02  .1223E 10  .2488E 02  .9012E-02     1.5457     .4355
 64    .9091       -.9531E-01       .6024E 08  .1791E 02  .1533E 10  .2545E 02  .5410E-02     1.5115     .4131
 65    .9172       -.8646E-01       .7419E 08  .1812E 02  .1932E 10  .2603E 02  .3165E-02     1.4773     .3902
 66    .9253       -.7769E-01       .9183E 08  .1834E 02  .2446E 10  .2664E 02  .1810E-02     1.4437     .3672
 67    .9333       -.6899E-01       .1142E 09  .1855E 02  .3114E 10  .2726E 02  .1016E-02     1.4108     .3441
 68    .9414       -.6037E-01       .1428E 09  .1878E 02  .3983E 10  .2790E 02  .5617E-03     1.3788     .3212
 69    .9495       -.5183E-01       .1794E 09  .1901E 02  .5119E 10  .2853E 02  .3070E-03     1.3479     .2985
 70    .9576       -.4335E-01       .2265E 09  .1924E 02  .6608E 10  .2918E 02  .1666E-03     1.3183     .2763
 71    .9657       -.3495E-01       .2874E 09  .1948E 02  .8568E 10  .2981E 02  .9012E-04     1.2900     .2547
 72    .9737       -.2661E-01       .3665E 09  .1972E 02  .1116E 11  .3045E 02  .4880E-04     1.2632     .2337
 73    .9818       -.1835E-01       .4697E 09  .1997E 02  .1459E 11  .3107E 02  .2657E-04     1.2380     .2135
 74    .9899       -.1015E-01       .6051E 09  .2022E 02  .1917E 11  .3167E 02  .1462E-04     1.2143     .1942
 75    .9980       -.2023E-02       .7834E 09  .2048E 02  .2527E 11  .3226E 02  .8160E-05     1.1922     .1758
 76   1.0061        .6041E-02       .1019E 10  .2074E 02  .3346E 11  .3282E 02  .4644E-05     1.1718     .1585
 77   1.0141        .1404E-01       .1333E 10  .2101E 02  .4447E 11  .3336E 02  .2700E-05     1.1529     .1423
 78   1.0222        .2198E-01       .1751E 10  .2128E 02  .5930E 11  .3387E 02  .1606E-05     1.1355     .1271
 79   1.0303        .2985E-01       .2309E 10  .2156E 02  .7935E 11  .3436E 02  .9770E-06     1.1194     .1128
 80   1.0384        .3766E-01       .3059E 10  .2184E 02  .1065E 12  .3482E 02  .6090E-06     1.1047     .0996
 81   1.0465        .4542E-01       .4065E 10  .2213E 02  .1433E 12  .3525E 02  .3891E-06     1.0912     .0873
 82   1.0545        .5311E-01       .5422E 10  .2241E 02  .1933E 12  .3565E 02  .2552E-06     1.0788     .0759
 83   1.0626        .6074E-01       .7254E 10  .2270E 02  .2613E 12  .3603E 02  .1718E-06     1.0676     .0654
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 91   1.1273        .1198E 00       .8038E 11  .2511E 02  .3051E 13  .3796E 02  .2093E-07     1.0132     .0131
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 94   1.1515        .1411E 00       .2024E 12  .2603E 02  .7743E 13  .3826E 02  .1486E-07     1.0052     .0052
 95   1.1596        .1481E 00       .2757E 12  .2634E 02  .1057E 14  .3833E 02  .1376E-07     1.0035     .0035
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 97   1.1758        .1619E 00       .5127E 12  .2696E 02  .1970E 14  .3842E 02  .1228E-07     1.0010     .0010
 98   1.1838        .1688E 00       .6996E 12  .2727E 02  .2691E 14  .3846E 02  .1177E-07     1.0000     .0000
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  1 -.3142E-03  .1000E 01  .1004E 01  .3073E 01    10.0000    2.0000 -.2147E 01  .1031E 01  .8379E 06  .1171E 00
  2 -.2660E-03  .1000E 01  .1004E 01  .3073E 01    10.0000    1.9893  .1475E 01  .9420E 00  .9794E 06  .9986E-01
  3 -.2236E-03  .1000E 01  .1004E 01  .3073E 01    10.0000    2.0000 -.2794E 01  .1032E 01  .1145E 07  .8341E-01
  4 -.1836E-03  .1000E 01  .1004E 01  .3072E 01     5.0298    1.9867  .1372E 01  .9637E 00  .1339E 07  .6855E-01
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NOT REPRODUCIBLE

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 7 -.1136E-03   .1000E 01   .1993E 01   .3971E 01     2.9563      2.0000 -.1680E 00   .1163E 01   .2136E 07   .4134E-01
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17 -.9160E-03   .1001E 01   .1992E 01   .3966E 01     1.9930       .6941  .9996E 00   .2160E-11   .1019E 08   .3419E 00
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23 -.1210E-02   .1001E 01   .1991E 01   .3962E 01     1.9900      3.1849  .9837E 00   .2672E-01   .2603E 08   .4518E 00
24 -.1066E-02   .1001E 01   .1990E 01   .3962E 01     1.9894      1.3547  .9818E 00 -.3805E-05   .3043E 08   .3979E 00
25 -.8388E-03   .1001E 01   .1990E 01   .3961E 01     1.9895       .8351  .9814E 00 -.2278E-10   .3557E 08   .3133E 00
26 -.5193E-03   .1001E 01   .1990E 01   .3960E 01     1.9893       .6341  .9804E 00 -.1863E-14   .4158E 08   .1940E 00
27 -.1144E-03   .1000E 01   .1990E 01   .3959E 01     1.9904       .6036  .9866E 00   .1957E-15   .4860E 08   .4275E-01
28  .3371E-03   .9997E 00   .1990E 01   .3959E 01     1.9894       .6660  .9808E 00 -.8257E-15   .5680E 08 -.1259E 00
29  .7911E-03   .9992E 00   .1989E 01   .3958E 01     1.9884       .8816  .9751E 00 -.7851E-10   .6639E 08 -.2956E 00
30  .1205E-02   .9988E 00   .1989E 01   .3957E 01     1.9913      1.4976  .9886E 00   .5981E-04   .7760E 08 -.4504E 00
31  .1535E-02   .9985E 00   .1989E 01   .3955E 01     1.9906      7.5725  .9892E 00 -.1329E 02   .9072E 08 -.5741E 00
32  .1740E-02   .9983E 00   .1989E 01   .3954E 01     2.4401      2.0000 -.3344E 00   .1083E 01   .1061E 09 -.6506E 00
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36  .4301E-03   .9996E 00   .1987E 01   .3947E 01     1.9866       .4346  .9631E 00   .2005E-24   .1989E 09 -.1610E 00
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39 -.3973E-02   .1004E 01   .1985E 01   .3939E 01     1.9864       .3605  .9618E 00   .2625E-29   .3202E 09   .1492E 01
40 -.6295E-02   .1006E 01   .1984E 01   .3935E 01     1.9873       .4381  .9676E 00   .4104E-24   .3758E 09   .2367E 01
41 -.9076E-02   .1009E 01   .1982E 01   .3929E 01     1.9884       .5217  .9750E 00   .1230E-19   .4416E 09   .3418E 01
42 -.1233E-01   .1012E 01   .1980E 01   .3919E 01     1.9907       .6037  .9902E 00   .2753E-16   .5197E 09   .4653E 01
43 -.1606E-01   .1016E 01   .1976E 01   .3906E 01     1.9934       .6813  .1008E 01   .7291E-14   .6127E 09   .6080E 01
44 -.2026E-01   .1020E 01   .1972E 01   .3889E 01     1.9968       .7511  .1042E 01   .4470E-12   .7238E 09   .7707E 01
45 -.2493E-01   .1025E 01   .1966E 01   .3866E 01     2.0012       .8123  .1062E 01   .9758E-11   .8572E 09   .9541E 01
46 -.3006E-01   .1030E 01   .1959E 01   .3836E 01     2.0063       .8640  .1100E 01   .1014E-09   .1018E 10   .1159E 02
47 -.3561E-01   .1036E 01   .1949E 01   .3800E 01     2.0120       .9094  .1143E 01   .6091E-09   .1212E 10   .1386E 02
48 -.4155E-01   .1042E 01   .1938E 01   .3756E 01     2.0179       .9465  .1190E 01   .2429E-08   .1449E 10   .1636E 02
49 -.4784E-01   .1048E 01   .1925E 01   .3704E 01     2.0243       .9764  .1243E 01   .6919E-08   .1737E 10   .1910E 02
50 -.5442E-01   .1054E 01   .1909E 01   .3644E 01     2.0305       .9990  .1298E 01   .1512E-07   .2090E 10   .2209E 02
51 -.6123E-01   .1061E 01   .1891E 01   .3576E 01     2.0366      1.0186  .1354E 01   .2776E-07   .2524E 10   .2533E 02
52 -.6813E-01   .1068E 01   .1871E 01   .3500E 01     2.0430      1.0341  .1415E 01   .4505E-07   .3061E 10   .2880E 02
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54 -.8149E-01   .1081E 01   .1824E 01   .3327E 01     2.0553      1.0579  .1537E 01   .9908E-07   .4554E 10   .3623E 02
55 -.8761E-01   .1088E 01   .1798E 01   .3232E 01     2.0611      1.0664  .1597E 01   .1305E-06   .5589E 10   .4010E 02
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57 -.9808E-01   .1098E 01   .1741E 01   .3031E 01     2.0707      1.0775  .1700E 01   .1878E-06   .8525E 10   .4787E 02
58 -.1022E 00   .1102E 01   .1710E 01   .2926E 01     2.0738      1.0803  .1745E 01   .2070E-06   .1060E 11   .5168E 02
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NOT REPRODUCIBLE

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 62 -.1101E 00   .1110E 01   .1560E 01   .2496E 01    2.0677    1.0772   .1643E 01   .1915E-06   .2652E 11   .6526E 02
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 67 -.1012E 00   .1101E 01   .1411E 01   .1990E 01    1.9692    1.0367   .7667E 00   .5151E-07   .9349E 11   .7522E 02
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 73 -.7713E-01   .1077E 01   .1234E 01   .1533E 01    1.7971     .9929   .1565E 00   .7561E-08   .4864E 12   .7445E 02
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 78 -.5456E-01   .1055E 01   .1135E 01   .1280E 01    1.7425     .9817   .8374E-01   .4956E-08   .2118E 13   .6260E 02
 79 -.5016E-01   .1050E 01   .1119E 01   .1254E 01    1.7383     .9812   .7035E-01   .4848E-08   .2463E 13   .5921E 02
 80 -.4588E-01   .1046E 01   .1105E 01   .1220E 01    1.7361     .9810   .7606E-01   .4801E-08   .3878E 13   .5561E 02
 81 -.4174E-01   .1042E 01   .1091E 01   .1191E 01    1.7361     .9803   .7676E-01   .4740E-08   .5262E 13   .5186E 02
 82 -.3775E-01   .1038E 01   .1079E 01   .1164E 01    1.7385     .9811   .7677E-01   .4837E-08   .7152E 13   .4802E 02
 83 -.3401E-01   .1034E 01   .1068E 01   .1140E 01    1.7431     .9816   .8299E-01   .4956E-08   .9735E 13   .4414E 02
 84 -.3045E-01   .1030E 01   .1057E 01   .1118E 01    1.7514     .9820   .9204E-01   .5043E-08   .1327E 14   .4026E 02
 85 -.2712E-01   .1027E 01   .1048E 01   .1099E 01    1.7614     .9825   .1043E 00   .5172E-08   .1810E 14   .3651E 02
 86 -.2404E-01   .1024E 01   .1040E 01   .1082E 01    1.7747     .9831   .1232E 00   .5311E-08   .2470E 14   .3287E 02
 87 -.2124E-01   .1021E 01   .1033E 01   .1067E 01    1.7907     .9840   .1500E 00   .5409E-08   .3372E 14   .2944E 02
 88 -.1871E-01   .1019E 01   .1027E 01   .1054E 01    1.8153     .9845   .2067E 00   .5634E-08   .4606E 14   .2626E 02
 89 -.1648E-01   .1016E 01   .1022E 01   .1044E 01    1.8594     .9855   .3513E 00   .5922E-08   .6300E 14   .2336E 02
 90 -.1440E-01   .1014E 01   .1017E 01   .1034E 01    1.9403     .9862   .7766E 00   .6302E-08   .8590E 14   .2072E 02
 91 -.1271E-01   .1013E 01   .1013E 01   .1027E 01    2.0451     .9872   .2554E 01   .6514E-08   .1174E 15   .1832E 02
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 94 -.8468E-02   .1008E 01   .1006E 01   .1011E 01    3.0321     .9926   .2449E 04   .8114E-08   .2986E 15   .1231E 02
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 96 -.6144E-02   .1006E 01   .1002E 01   .1004E 01    8.7001     .9948   .1423E 08   .9242E-08   .5572E 15   .9056E 01
 97 -.5135E-02   .1005E 01   .1001E 01   .1002E 01   10.0000     .9967   .3041E 08   .9750E-08   .7600E 15   .7576E 01
 98 -.4173E-02   .1004E 01   [illegible] 01   [illegible] 01     .0066    7.3232   .1005E-07   .5307E-07   .1038E 16   .6173E 01
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NOT REPRODUCIBLE

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1. B. W. Noel, C. E. Barnes, and H. D. Southward, "Neutron Irradiation Effects on Diffused GaAs Laser Diodes," Bureau of Engineering Research, The University of New Mexico, Technical Report No. EE-186(71)ONR-005, September 1971.

2. L. W. Aukerman and M. F. Millea, Phys. Rev. 148, 759 (1966).