NASA TECHNICAL MEMORANDUM

NASA TM X-73364

MSFC SOLAR SIMULATOR TEST PLANE UNIFORMITY MEASUREMENT

(NASA-TM-X-73364) MSFC SOLAR SIMULATOR TEST PLANE UNIFORMITY MEASUREMENT (NASA) 64 p HC A04/MF A01 CSCL 10A

N77-18558

Unclas

G3/44 17244

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December 1976

NASA

George C. Marshall Space Flight Center
Marshall Space Flight Center, Alabama

TECHNICAL REPORT STANDARD TITLE PAGE

1. REPORT NO.	2. GOVERNMENT ACCESSION NO.	3. RECIPIENT'S CATALOG NO.
NASA TM X-73364		

4. TITLE AND SUBTITLE

MSFC Solar Simulator Test Plane Uniformity Measurement

5. REPORT DATE

December 1976

6. PERFORMING ORGANIZATION CODE

7. AUTHOR(S)

Donald B. Griner

8. PERFORMING ORGANIZATION REPORT #

9. PERFORMING ORGANIZATION NAME AND ADDRESS

George C. Marshall Space Flight Center
Marshall Space Flight Center, Alabama 35812

10. WORK UNIT NO.

11. CONTRACT OR GRANT NO.

13. TYPE OF REPORT & PERIOD COVERED

Technical Memorandum

12. SPONSORING AGENCY NAME AND ADDRESS

National Aeronautics and Space Administration
Washington, D.C. 20546

14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES

Prepared by Electronics and Control Laboratory, Science and Engineering

16. ABSTRACT

The equipment and procedure used to measure the test plane uniformity produced by the MSFC 405 lamp solar simulator array is presented along with details on the computer program used to analyze the measurement data. The results of the first measurement are given which showed the uniformity not to be as good as expected. The best uniformity obtained had a standard deviation of 4 percent with peak-to-peak values of ±11 percent.

17. KEY WORDS

Solar simulator
Solar energy
Irradiance measurement
Lamps

18. DISTRIBUTION STATEMENT

Unclassified — Unlimited

19. SECURITY CLASSIF. (of this report)	20. SECURITY CLASSIF. (of this page)	21. NO. OF PAGES	22. PRICE
Unclassified	Unclassified	63	NTIS

MSFC - Form 3292 (Rev December 1972)

For sale by National Technical Information Service, Springfield, Virginia 22151

ACKNOWLEDGMENT

The data presented in this report were made possible through the combined efforts of Mr. B. Wiesenmaier, who recognized the need and set the effort in motion; Mr. C. A. Hawkins, who designed and fabricated the mechanical hardware for the scanner; Dr. T. L. McCrickard, Mr. J. C. Reily, and the other personnel of ET44 who built and operated the simulator during the checkout period; and Mr. S. Patrich and the other personnel of Wyle Laboratory, who now operate the simulator. Special thanks goes to Julie Taylo, EC32. who spent many tedious hours reading data from chart paper and typing it into the computer for analysis.

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MSFC SOLAR SIMULATOR TEST PLANE UNIFORMITY MEASUREMENT

SUMMARY

The Marshall Space Flight Center (MSFC) solar simulator lamp array is designed to produce a uniform illumination on a 1.2 by 2.4 m (4 by 8 ft) test plane. Prior to completion, an analysis of the simulator was made to predict the test plane uniformity. A procedure was also developed to measure the actual uniformity produced by the simulator after it was in operation. That procedure is described here and the results of the first measurement presented. The measurement revealed the test plane illumination was not as uniform as the analysis predicted. The best actual uniformity obtained had a standard deviation of 4 percent and a peak-to-peak variation of ±11 percent. The computer program used to analyze the measurement data is discussed, and a listing of the program along with example runs is given. The reason for the variation in uniformity from that predicted is not fully resolved, but seems to be due to variations in individual lamp flux levels in the actual array from the levels when measured in a special test box.

I. INTRODUCTION

A large low cost solar simulator has been constructed at MSFC for the evaluation of flat plate solar collectors. The simulator consists of 405 tungsten-halogen projector lamps with Fresnel lenses arranged in a 15 by 27 array. The Fresnel lenses are used to provide a near collimated beam of illumination. It will be used to test solar collectors with surface areas up to 1.2 by 2.4 m (4 by 8 ft). The simulator is located in Building 4619 and will be part of the Solar Test Facility under development at MSFC.

An analysis of the uniformity of illumination expected in the test plane was described in Reference 1. Now that the simulator is in operation, the actual uniformity has been measured. This report gives the procedure used to measure the test plane uniformity as well as the first measurement results.

II. DISCUSSION OF TEST APPARATUS

A. Test Philosophy

The test plane measurement apparatus was developed to produce data on the uniformity in scan lines. This was done to ease comparison with the computed scan lines given by the computer program reported in NASA TM X-64991. The computer program was set up to calculate the irradiance at 5 cm (2 in.) intervals across the narrow axis of the test plane. Scan lines at any desired spacing along the long axis can be calculated. The mechanical scanner was designed to produce the same type scans, except the output is a continuous signal recorded on chart paper. Figure 1 is a layout of the measurement system.

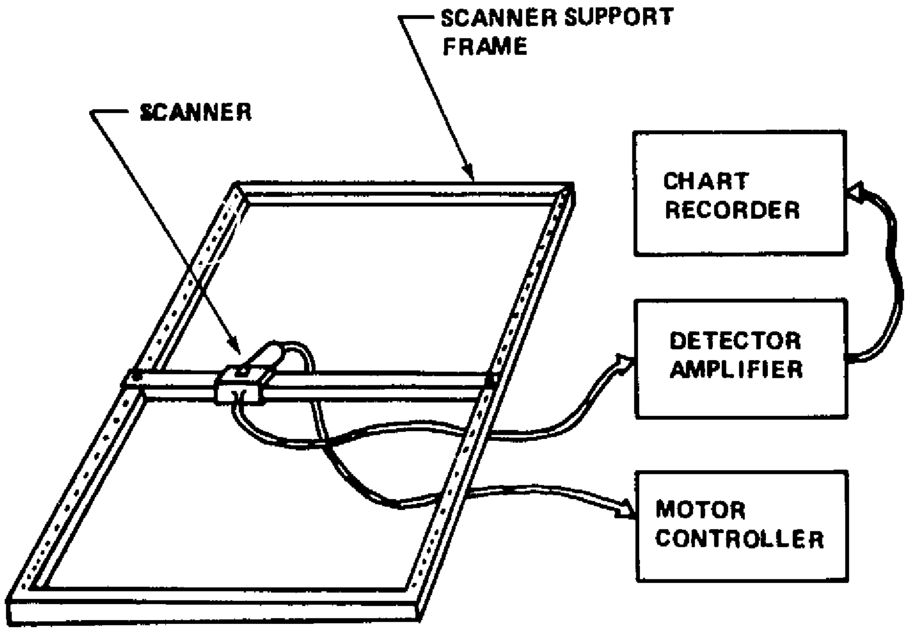


Figure 1. Layout of test plane uniformity measurement apparatus.

B. Scanner

The scanner is a motorized platform which has a 10 cm (4 in.) square plate on which a detector can be mounted. It is driven by a small 115 Vac 400 Hz synchronized motor which is geared to move the platform across the width of the test plane in approximately 30 s.

The scanner moves on a rail which can be positioned at 15 cm (6 in.) intervals along the frame. The frame is approximately 1.5 by 3.0 m (5 by 10 ft) so that an area larger than the actual test plane can be scanned. The scanner bar is positioned in the frame by means of pins placed in holes. The holes are drilled in the frame along the long axis, and near the end the holes are placed at 5 cm (2 in.) intervals to allow higher density of scans near the edge of the test plane.

C. Detector Circuit

The detector used on the scanner platform for the first series of tests was a Motorola MRD 300 phototransistor. The circuit used with the phototransistor is shown in Figure 2. The output is recorded on a Mosley model 680 strip chart recorder. The collector base junction of the phototransistor is used as a current source into the operational amplifier to provide a linear output voltage for varying levels of incident radiation. The linearity of the detector was checked by comparing its output with readings from an Eppley black and white pyranometer model 8-48. The output is very linear with a constant voltage on the tungsten-halogen lamps and using neutral density filters to reduce the light level. However, when varying the voltage of the bulb to reduce the light level, a difference between the two detectors was noted. Figure 3 shows a plot of the phototransistor output compared with the pyranometer, as the lamp voltage is changed. For comparison, a curve is also shown which gives the expected change if the light output varied as a function of the square of the voltage. These data are normalized to 100 Vac. The phototransistor agrees with the pyranometer for higher voltages but drops off at lower voltages. The reason for the drop off is that the pyranometer has a better infrared response than the phototransistor. At lower voltages the peak output of the lamp is shifted slightly toward the infrared.

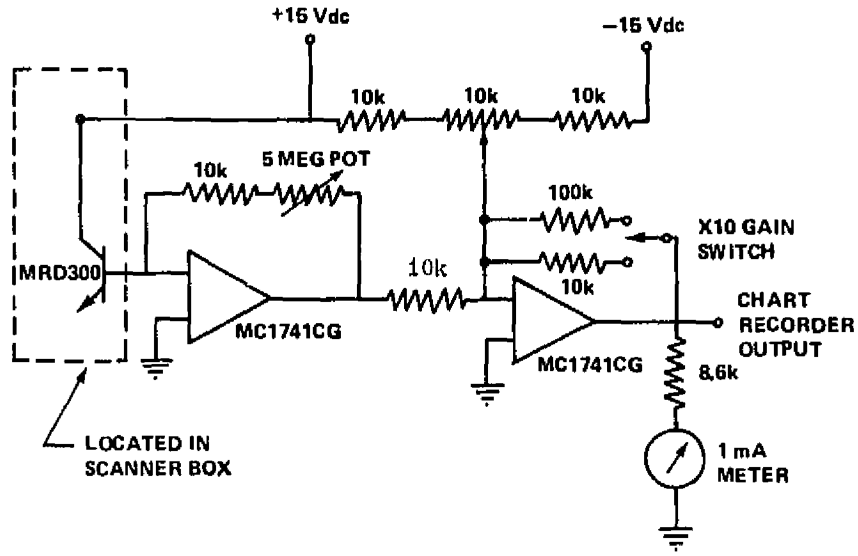


Figure 2. Detector circuit.

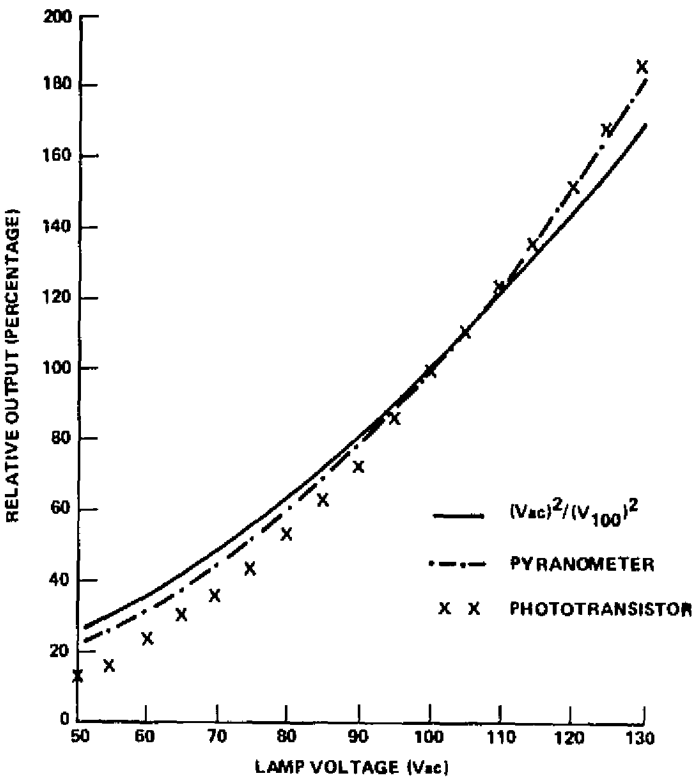


Figure 3. Comparison of detector output with pyranometer.

D. Motor Drive Control

The scanner motor control circuit is shown in Figure 4. The circuit automatically stops the scanner at the end of the scan. Microswitches on the scanner are used to indicate the end of the travel. When the microswitch hits the contact at the end of the bar, power to relay 1 as well as relay 2 is cut off, but the capacitor C_1 on relay 2 holds that relay in momentarily. The result is that a brief reversing pulse is supplied to the motor to serve as a brake. Power to the motor is cut off by means of relay 2 before the motor can actually reverse. To restart the scan in the other direction, the reversing switch is changed and the reset button is pushed. The reset button has to be held down until the microswitches are clear of the contacts. The red indicator bulb is used to show that the end of travel has been reached.

III. COMPUTER ANALYSIS PROGRAM

A. Background

The data recorded by the test plane measurement equipment are a voltage level on chart paper representing the light intensity level for scans across the narrow axis of the test plane. Sample points have to be manually read from the chart paper to calculate the statistics and present the data in a useful form. A computer program, Statistical Analysis for the Solar Simulator (SASS), was developed to analyze the data. The sample points at regular intervals along each scan are read from the chart paper and recorded in a computer file for storage. The computer program reads the data from the file and performs the data analysis.

The number of points recorded from the scans and the total number of scans used can be varied. The normal procedure used was to read 29 points on each scan and use a total of 19 scans. Twenty-nine points on a scan at 5 cm (2 in.) intervals cover a range of -71 to 71 cm (-28 to 28 in.). Nineteen scans cover the test plane plus 15 cm (6 in.) on each end. Within the computer program the extra points and scans are dropped to provide data only on the test plane. The test plane area can then be defined as the best 1.2 by 2.4 m (4 by 8 ft) area in the recorded data. The program also allows any number of points or scans to be dropped in case the collector to be tested is smaller than the standard test plane.

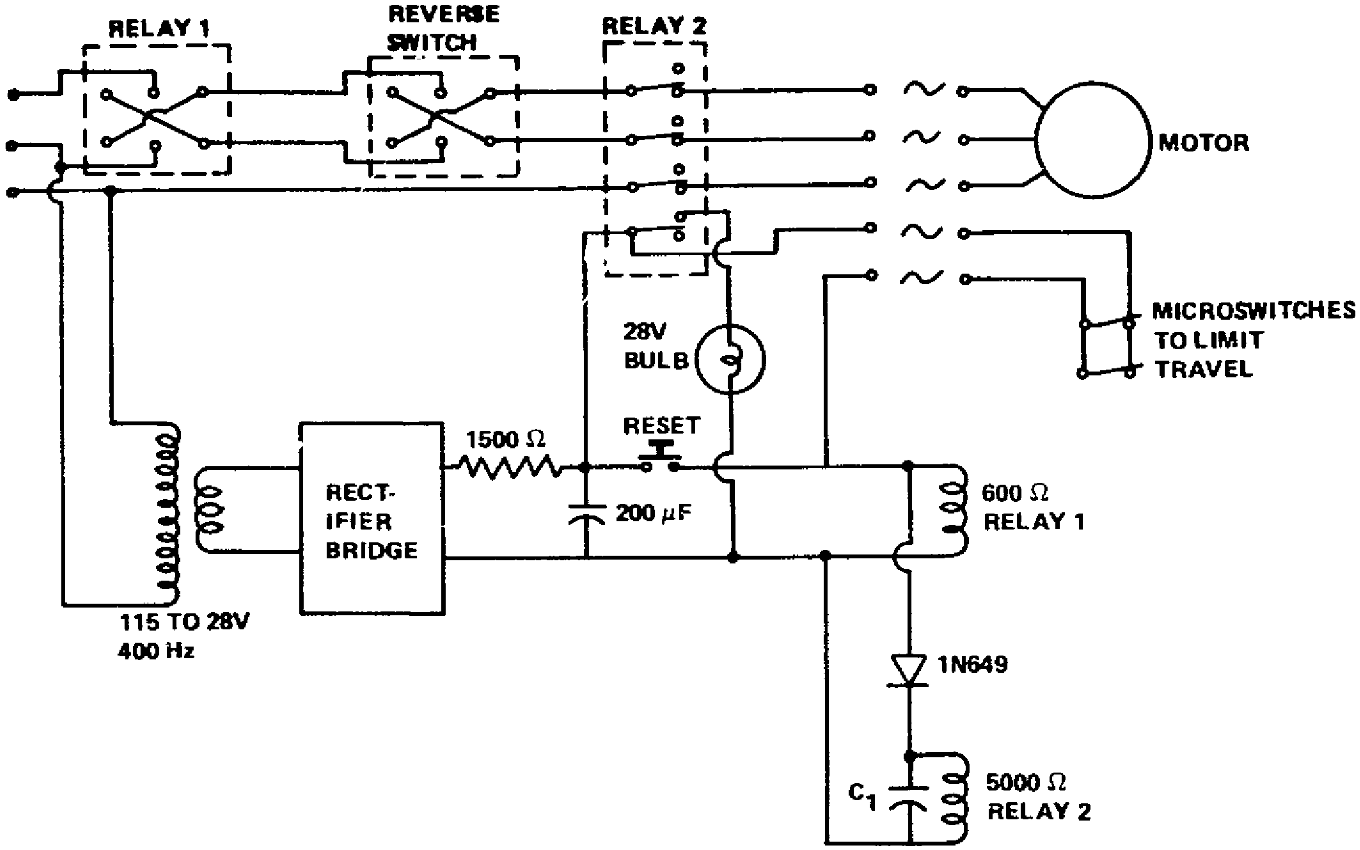


Figure 4. Scan motor control circuit.

Figure 5 is a simplified flow diagram of the compute. program. The full Fortran listing is given in Appendix A. The program is written is XDS extended Fortran IV for use on an XDS Sigma V time share computer. Except for the plot subroutine, the program can be run on any Fortran computer with very little modification.

B. Data Input

Table 1 presents a listing of the input section of the computer program, lines 1 to 37. A listing of the variables used in the input and the main section of the program and their definitions is given in Table 2.

The dimension statement on line 3 sets the size of the arrays. The arrays are now set for a limit of 27 scans with 31 points on each scan. By changing the dimension statement, the limit can be changed to any value.

These data are read in from a file on unit 100. When running the program, the input file name has to be assigned to unit 100. Appendix B gives a sample of an input file named T2. Appendix C gives an example run of the program together with the set commands to inform the computer which file will be read by unit 100. Line 9 is a rewind file statement which assures that the read statement will start with the first line in the input file. Line 11 is a read statement to input the title comment. The format statement, line 16, allows up to 80 characters in the title. Lines 1? to 22 are the commands to input the control variables. Comment statements are included to define each variable. The format statements 110 and 111 allow a general input; the numbers can be fixed or floating point and only have to be separated by commas. The actual sample data points are input by statements 23 to 34. The points are input into the B(J, K) array, where J indicates the points on the scan and K indicates the scan number.

These data are stored in the input file with consecutive lines containing the same point on each scan; for example, the first point on lines 7 to 37 of the input file T2 in Appendix B made up one scan. The second point on each line comprises the second scan, etc. Because of the limit on the size of a line in a file, all the scan points could not be put on one line; therefore, the scans were split up and NLP1 number of them is read in first with statement 27. The rest is read in with statement 34. One line in a file will hold 72 characters;

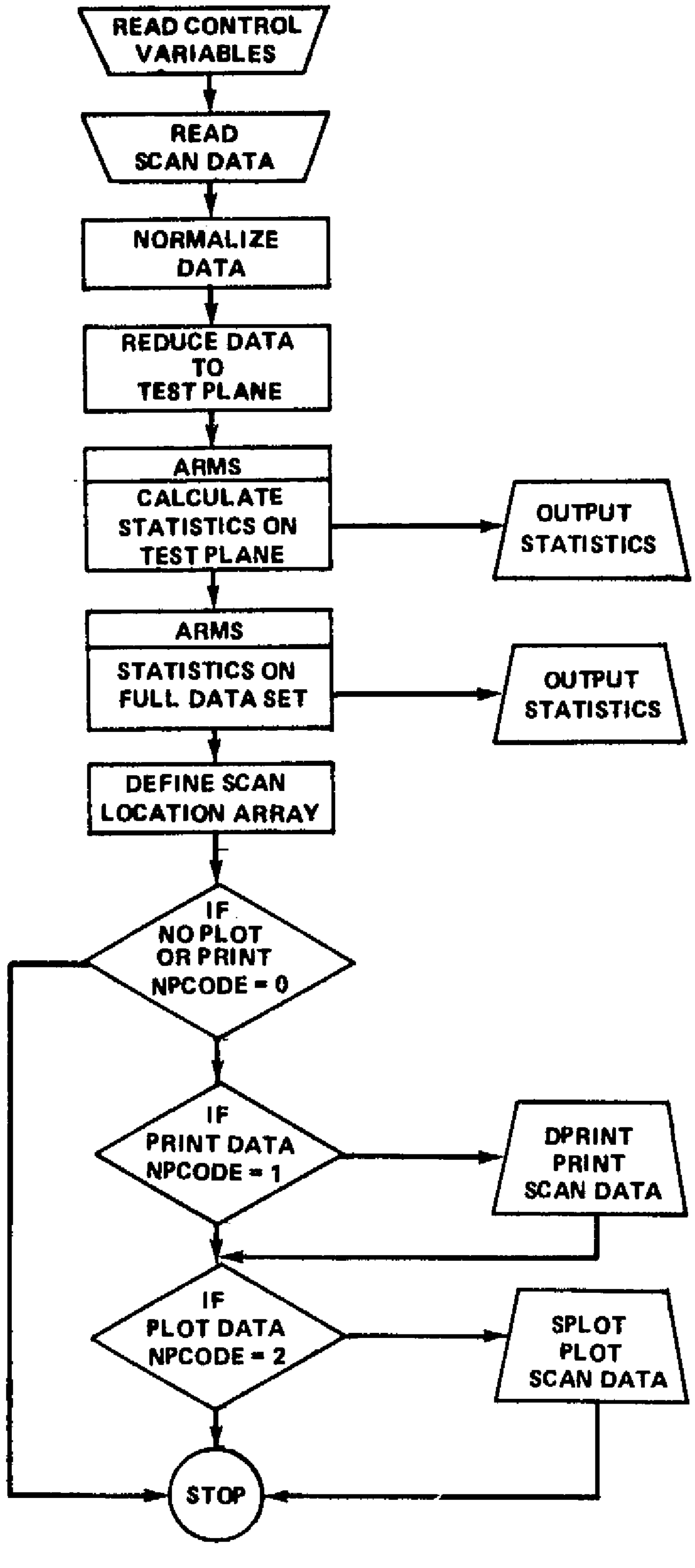


Figure 5. Flow diagram for computer program SASS.

TABLE 1. INPUT SECTION OF PROGRAM SASS

```
INPUT SECTION OF PROGRAM SASS_
TY 1-37
C       PROGRAM SASS
C       PROGRAM TO CALCULATE STATISTICS ON DATA
        DIMENSION B(31,27),D(31,27),IDATA(20)
C       IDATA IS COMMENT ARRAY
        DIMENSION X(31),ASPOS(31)
C       *
C       INPUT SECTION
C       *
        REWIND 100
C       READ IN DATA
        READ (100,100) IDATA
        READ(100,110) NSCAN,NPOS,NPCODE
        READ(100,111) SSLOC,TSINC
C       SSLOC-POSITION OF FIRST SCAN
C       TSINC-THE SCAN INCREMENT DISTANCE
   100  FORMAT (20A4)
C       NSD-NUMBER SCAN TO START TEST PLANE DATA
C       NED-NUMBER SCAN TO END TEST PLANE DATA ON
        READ(100,111) NSD,NED
C       NPDS-NUMBER POINT TO START DATA SCANS ON
C       NPDE-NUMBER POINT TO END DATA SCANS ON
        READ(100,111) NPDS,NPDE
        READ (100,110) NL,NLP1,ANV
   110  FORMAT(3G)
   111  FORMAT(2G)
        DO 200 J=1,NL
        READ (100,250) X(J),NLP1,(B(J,K),K=1,NLP1)
   200  CONTINUE
   250  FORMAT (1G,NG)
        IF(NLP1.GE.NSCAN) GO TO 300
        READ (100,111) NL,NLP2
        NP=NLP1+NLP2
        DO 300 J = 1,NL
        READ (100,250) X(J),NLP2,(B(J,K),K=NLP1+1,NP)
   300  CONTINUE
C       *
C       END OF INPUT SECTION
*
```

TABLE 2. LISTING OF VARIABLES USED IN THE INPUT AND THE MAIN SECTION OF PROGRAM SASS (IN THE ORDER OF THEIR APPEARANCE)

Variable	Definition
B(J,K)	Input data array
D(J,K)	Array containing points of test plane
IDATA(I)	Comment array to store title
X(I)	Array containing the position of each point on the scan
ASPOS(I)	Array containing the scan locations
NSCAN	Number of total scans
NPOS	Number of points on each scan
NPCODE	Code to print or plot input data
SSLOC	Location of first scan
TSINC	Distance between scans
NSD	Number of scan on which to start test plane
NED	Number of scan on which to end the test plane
NPDS	Number of point on scan to start test plane
NPDE	Number of point on scan to end test plane
NL	Number of lines for this input statement
NLP1	Number of points on line for this input statement
AMV	A multiplication value to normalize the data
NLP2	Number of points on line for this input statement
NDUM	Number of points on each scan used in test plane
ND	Number of scans used in test plane
ADUMA	Dummy variable to hold scan position

consequently, the number of digits used for a scan point will determine the maximum number of scans on a line. As in file T2, typically 11 scans are put in the first section.

C. Main Section of Program

Table 3 presents a listing of the main section of the computer program SASS. In statements 41 to 43 the data are normalized. The value of the variable AMV is selected to make the maximum value 100 percent, or it can be selected to convert the detector output to power units such as W/cm^2 or $Btu/h\text{-}ft^2$. The proper value for AMV to convert the output to power units is obtained by measuring the same point on the test plane with the phototransistor and the pyranometer.

Lines 45 to 47 reduce the data array to the desired test plane and store the new points in the D(J, K) array. The size test plane would depend on the size collector under test. For evaluation of the simulator, the maximum test plane size of 1.2 by 2.4 m (4 by 8 ft) is used. Lines 53 to 54 define the variables NDUM and ND, where NDUM is the number of scans in the test plane and ND is the number of points on each scan which lie in the test plane. Statements 51 to 59 print out the statistical data on the test plane. All the actual computations take place in the subroutine ARMS which is described in Section III. D.

The scan locations are set up in statements 60 to 63 and stored in the ASPOS(I) array. Statements 64 to 73 use NPCODE to select the print or plot options. If NPCODE is set equal to zero, no print or plot of the input sample data will take place. If the variable NPCODE is set equal to one, the input scan data will be printed out along with a printout of the points used in the test plane evaluation. If NPCODE is set equal to two, the input scan data will be plotted but no printout of the data will be obtained. No option is set to obtain both a printout and a plot as it is impractical on the CRT display terminal. The printout is usually set to be produced on the line printer. Sections III. E and III. F describe the SPLOT and DPRINT subroutines and explain how to set the output device code to obtain the desired output.

TABLE 3. MAIN SECTION OF PROGRAM SASS

```
MAIN SECTION OF PROGRAM SASS
TY 39-77
C      START INITALIZATION
C      *
       DO 500 J=1,NPOS
       DO 500 K=1,NSCAN
 500   B(J,K) = B(J,K)*AMV
C       REDUCE ARRAY TO TEST PLANE SIZE
        DO 1000 J = NPDS,NPDE
        DO 1000 K = NSD,NED
 1000   D(J-(NPDS-1),K-(NSD-1)) = B(J,K)
C       *
C       PRINT STATISTICS ON TEST PLANE
C       *
        WRITE (108,2200) IDATA
 2200   FORMAT(1H1,20A4,//,'TEST PLANE DATA')
        NDUM  = NPDE-NPDS+1
        ND = NED-NSD+1
        CALL ARMS(D,ND,NDUM)
C       PRINT STATISTICS ON FULL MEASUREMENT DATA
        WRITE(108,2400)
 2400   FORMAT(1H0,'FULL MEASUREMENT DATA SET')
        CALL ARMS(B,NSCAN,NPOS)
        ADUMA = SSLOC + TSINC
        DO 3000 I = 1,NSCAN
        ADUMA = ADUMA - TSINC
 3000   ASPOS(I) = ADUMA
        IF(NPCODE.EQ.0) GO TO 4000
        IF(NPCODE.NE.1) GO TO 3100
        CALL DPRINT(X,B,ASPOS,1,NSCAN,1,NPOS,IDATA)
        CALL DPRINT(X,B,ASPOS,NSD,NED,NPDS,NPDE,IDATA)
 3100   IF(NPCODE.NE.2) GO TO 4000
        CALL TPAUSE
        CALL SPLOT(X,B,NPOS,NSCAN,IDATA)
        CALL TPLOT(0.0,170.0,0,0)
        CALL ARMS(D,ND,NDUM)
 4000   CONTINUE
        STOP
        END
C       *
C       END OF MAIN SECTION OF PROGRAM
```

D. Subroutine ARMS

Subroutine ARMS computes the statistical data. The subroutine calculates five values to characterize the uniformity.

RMS — Root mean square value computed from a zero intensity reference.

PTP — The difference between the highest and the lowest sample point value.

EBAR — The mean value of all the data points.

SIGMA — The standard deviation of the measured values from the mean value.

VMAX — The largest data point measured.

A listing of subroutine ARMS is presented in Table 4. Table 5 presents a list of the variables used in the subroutine. The statistical values calculated by the program are slightly different in form from the standard approximation formulas. The standard approximation formulas as stated in Reference 2 are given by equations (1), (2), and (3):

$$\mathrm{EBAR} = \frac{\sum_{i=1}^{n} y_i}{n-1} \tag{1}$$

$$\mathrm{RMS} = \left[\frac{\sum_{i=1}^{n} y_i^2}{n-1}\right]^{1/2} \tag{2}$$

$$\mathrm{SIGMA} = \left[\frac{\sum_{i=1}^{n} (y_i - \bar{y})^2}{n-1}\right]^{1/2} , \tag{3}$$

TABLE 4. SUBROUTINE ARMS OF PROGRAM SASS

```
TY 80-130
      SUBROUTINE ARMS(G1,M,N)
C     SUBROUTINE ARMS IS TO COMPUTE STATISTICS
C     G1 IS SAMPLE DATA ARRAY
C     G2 IS ARRAY OF SQUARED VALUES
C     G3 IS ARRAY OF DEVIATION SQUARED VALUES
C     N IS NUMBER OF POINTS IN EACH LINE
C     M IS NUMBER OF LINES IN ARRAY
      DIMENSION G1(31,1),G2(31,27),G3(31,27)
C     COMPUTE TAP, TOTAL NUMBER OF POINTS IN ARRAY
      TAP = FLOAT(N*M)
C     CALCULATE MEAN VALUE-EBAR
      CALL AFUNC(G1,EBAR,M,N)
C     FIND G2 AND G3 ARRAYS
      DO 100 J = 1,N
      DO 100 K = 1,M
      G2(J,K) = G1(J,K)**2
  100 G3(J,K) = (G1(J,K)-EBAR)**2
      DUM = 0.0
      CALL AFUNC(G2,DUM,M,N)
      RMS = SQRT(DUM)
      CALL AFUNC(G3,DUM,M,N)
      SIGMA = SQRT(DUM)
C     FIND MOST NEGATIVE NUMBER
      C = G1(1,1)
      DO 300 J = 1,N
      DO  300 K = 1,M
      IF(C-G1(J,K)) 300,300,290
  290 C = G1(J,K)
  300 CONTINUE
C     C IS NOW MOST NEGATIVE NUMBER
C     FIND MOST POSTIVE NUMBER
      D = G1(1,1)
      DO 400 J = 1,N
      DO 400 K = 1,M
      IF(G1(J,K)-D) 400,400,390
  390 D = G1(J,K)
  400 CONTINUE
C     D IS NOW MOST POSTIVE NUMBER
      PTP = D-C
      VMAX = D
C     PRINT OUT DATA
 1000 FORMAT(1H0,'STATISTICS ON ARRAY DATA')
      WRITE(108,1100)
 1100 FORMAT(1H0,3X,'RMS',11X,'PTP',11X,'EBAR',9X,
     X'SIGMA',8X,'VMAX')
      WRITE(108,1200) RMS,PTP,EBAR,SIGMA,VMAX
 1200 FORMAT(1H ,2(F8.4,5X),F10.5,2(5X,F8.4),/)
      WRITE(108,1400) TAP
 1400 FORMAT(1H0,'NUMBER OF POINTS IN ARRAY = ',2X,I4)
      RETURN
      END
```

TABLE 5. LIST OF VARIABLES IN SUBROUTINE ARMS

Variable	Definition
G1(I)	Sample data array
G2(I)	Array of squared values
G3(I)	Array of deviation of squared values
N	Number of sample points on each scan
M	Number of scans
TAP	Total number of sample points
DUM	Dummy variable
RMS	Root mean squared value
SIGMA	Standard deviation
C	Smallest sample point value
D	Largest sample point value
PTP	Difference between D and C
VMAX	Redefinition of D

where n is the number of sample points, y_i is the value of ith sample point, and $\bar{y}$ is the mean value of all sample points (EBAR).

It should be noted that slightly different equations are used when working with sample points which do not represent a function. The sample points are then considered a population, and n is used instead of n-1 (see Reference 3).

The formulas given in equations (1), (2), and (3) are approximation formulas used for sample points representing a one-dimensional function. The irradiance of the test plane is a two-dimensional function where the irradiance is a function of both the x and y directions in the test plane (Fig. 6). To understand the equations that will be used to calculate the mean value (EBAR), root mean squared value (RMS) and the standard deviation (SIGMA, it is instructive to review the derivations of equations (1), (2), and (3).

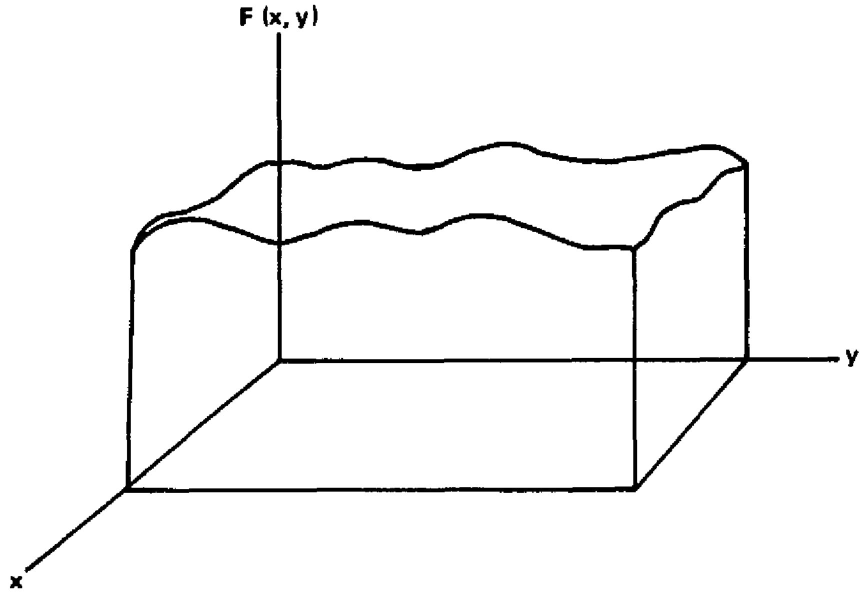


Figure 6. Representation of irradiance function F(x,y).

The proper definitions of EBAR, RMS, and SIGMA as given in Reference 3 are given by equations (4), (5), and (6):

$$\text{EBAR} = \frac{1}{b-a} \int_a^b F(x)\,dx \tag{4}$$

$$\text{RMS} = \left[\frac{1}{b-a} \int_a^b F^2(x)\,dx \right]^{1/2} \tag{5}$$

$$\text{SIGMA} = \left[\frac{1}{b-a} \int_a^b (F(x) - \text{EBAR})^2 \right]^{1/2} . \tag{6}$$

All three of the previously mentioned formulas can be written as one equation in the form of equation (7):

$$A = \frac{1}{b - a} \int_a^b G(x)\, dx \quad . \tag{7}$$

In equations (4), (5), and (6) the function F(x) is integrated over the range from a to b, and in equation (7) the function G(x) is integrated over the range from a to b. The function G(x) is assigned the following values in order to give equations (4), (5), and (6):

If $G(x) = F(x)$ then $A = \text{EBAR}$

If $G(x) = F^2(x)$ then $A = (\text{RMS})^2$

If $G(x) = (F(x) - \text{EBAR})^2$ then $A = (\text{SIGMA})^2$.

Since all three equations are similar, the derivation of equation (1), using $G(x) = F(x)$, will at the same time give equations (2) and (3).

If F(x) is a function (as represented in Fig. 7), then a set of sample points also can represent the function (as shown in Fig. 8), in terms of G(x). Performing the integral from a to b is the same as finding the area under the curve from a to b. When working with a set of sample points, the area is approximated by adding the area segments of width Δx under each sample point as shown in Figure 9. The formula for the integral is given by equation (8):

$$\int_a^b G(x)\, dx \simeq \sum_{i=1}^{n} y_i \Delta x \quad . \tag{8}$$

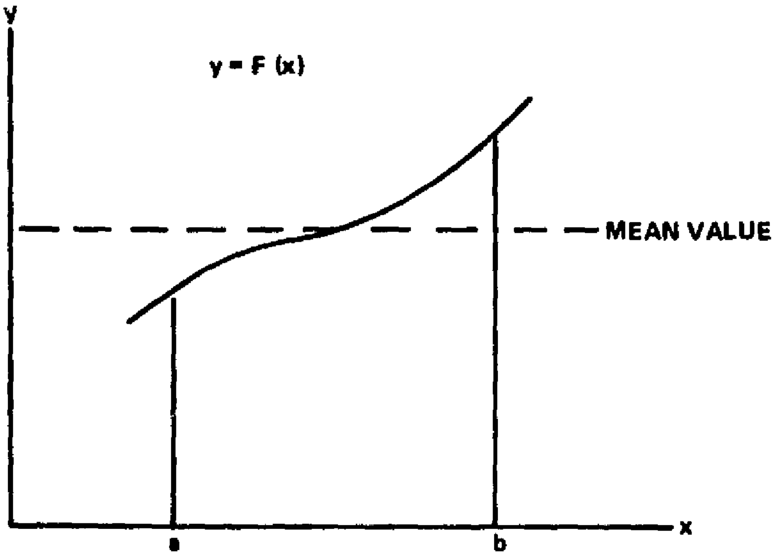


Figure 7. Example of function F(x).

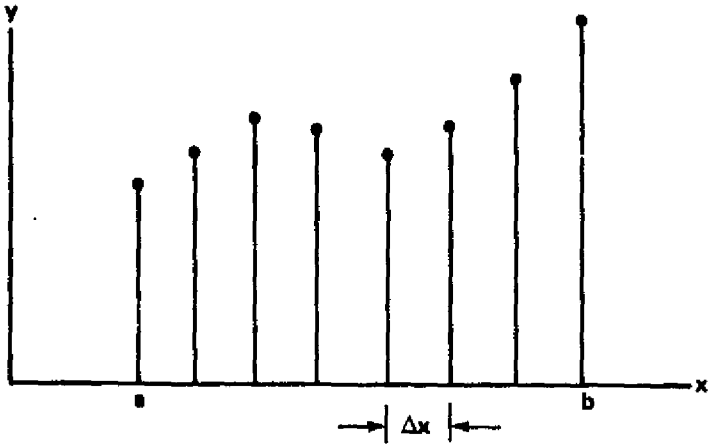


Figure 8. Sample representation of function G(x).

Since Δx is a constant, the summation can be rearranged as in equation (9):

$$\sum_{i=1}^{n} y_i \Delta x = \Delta x \sum_{i=1}^{n} y_i \quad . \tag{9}$$

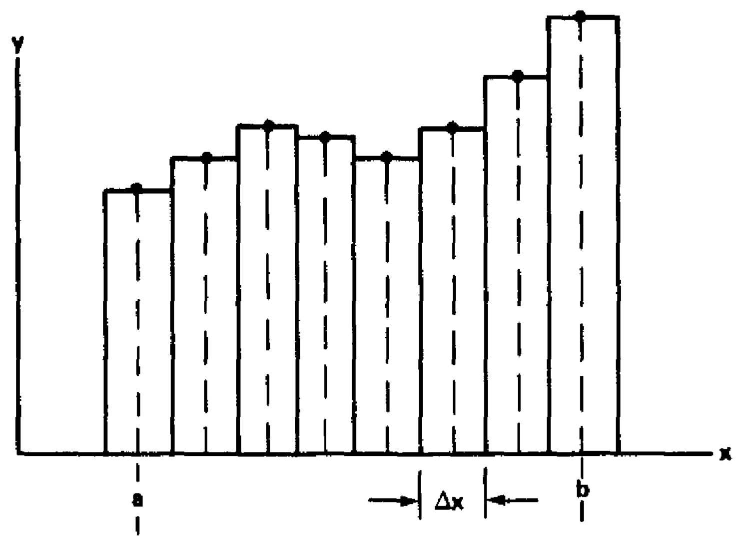


Figure 9. Approximation of area under function G(x) in region a to b.

From Figure 9, it can be seen that Δx is given by equation (10):

$$\Delta x = \frac{b - a}{n - 1} \quad . \qquad (10)$$

Substituting the value of Δx into equation (9) gives equation (11):

$$\Delta x \sum_{i=1}^{n} y_i = \frac{b - a}{n - 1} \sum_{i=1}^{n} y_i \quad . \qquad (11)$$

If this value for the integral is put into equation (7), then the value of A is given by equation (12),

$$A \simeq \frac{1}{b-a} \frac{b-a}{n-1} \sum_{i=1}^{n} y_i \quad , \tag{12}$$

which reduces to equation (13),

$$A \simeq \frac{1}{n-1} \sum_{i=1}^{n} y_i \quad . \tag{13}$$

Equation (13) is the same as equation (1); therefore, we have derived equations (2) and (3) as well. For the limit, as n approaches infinity, the summation is truly equal to the integral. However, for small values of n, the approximation can be improved. By referring to Figure 9, it can be seen that half of the Δx wide area for the first and last point is outside the range of a to b. If one half of the area for each point is dropped, equation (8) is rewritten to equation (14). That is,

$$\int_a^b G(x)\, dx \simeq \sum_{i=2}^{n-1} y_i \Delta x + \frac{y_1 \Delta x}{2} + \frac{y_n \Delta x}{2} \quad , \tag{14}$$

or rearranging to equation (15),

$$\int_a^b G(x)\, dx \simeq \Delta x \left[\sum_{i=2}^{n-1} y_i + \frac{(y_1 + y_n)}{2} \right] \quad . \tag{15}$$

The value of Δx is the same as in equation (10); therefore, A is now equal to equation (16):

$$A \simeq \frac{1}{n-1} \left[\sum_{i=2}^{n-1} y_1 + \frac{(y_1 + y_n)}{2} \right] \quad . \tag{16}$$

The improvement in the approximation of equation (16) over equation (13) is not very substantial for a one-dimensional function with a practical number of n sample points. However, the improvement can be important when working with a two-dimensional function.

The two-dimensional case is derived using the same technique as for the one-dimensional case. The two-dimensional formulas equivalent to equations (4), (5), and (6) are given by equations (17), (18), and (19):

$$\text{EBAR} = \frac{1}{(b-a)(d-c)} \int_a^b \int_c^d F(x,y)\, dx\, dy \tag{17}$$

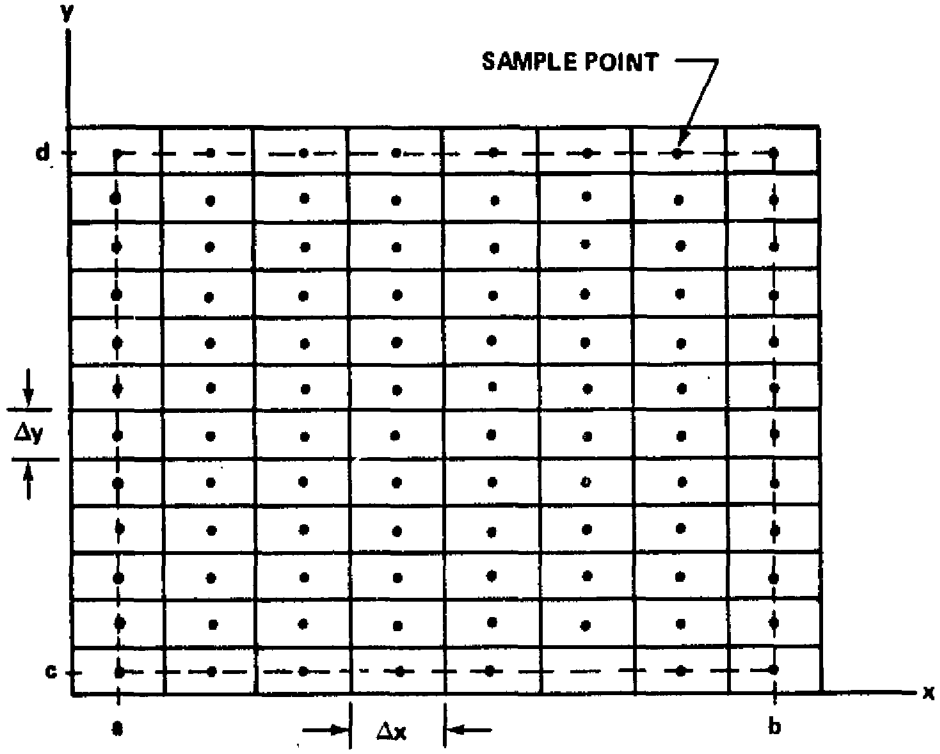
$$\text{RMS} = \frac{1}{(b-a)(d-c)} \int_a^b \int_c^d F^2(x,y)\, dx\, dy \tag{18}$$

$$\text{SIGMA} = \frac{1}{(b-a)(d-c)} \int_a^b \int_c^d (F(x,y) - \text{EBAR})^2\, dx\, dy \quad , \tag{19}$$

where a and b are the limits of the function $F(x,y)$ along the x axis and c and d are the limits along the y axis. Again, using a general function $G(x,y)$ to derive all three values at one time, the double integral is approximated by a summation of $\Delta x \Delta y$ volume sections centered on each sample point z_{jk} (Fig. 10). The formula for A would be given by equation (20):

$$A \simeq \frac{1}{(n-1)(m-1)} \sum_{j=1}^{n} \sum_{k=1}^{m} z_{jk} \quad , \tag{20}$$

where n is the number of sample points along the x axis and m is the number of sample points along the y axis.



NOTE: DASHED LINES ENCLOSE THE ACTUAL AREA UNDER THE FUNCTION BY DEFINITION.

Figure 10. Approximation of area under function G(x, y).

As in the one-dimensional case, the approximation can be improved for small numbers of n and m if the sample points fall on the edge of the function. If the volume outside the area bounded by a, b, c, and d is discarded, the resulting approximation is given by equation (21):

$$\int_a^b \int_c^d G(x,y)\,dx\,dy \simeq \Delta x \Delta y \left\{ \sum_{j=2}^{n-1} \left[\sum_{k=2}^{m-1} z_{jk} + \frac{(z_{j1} + z_{jm})}{2} \right] + \frac{1}{2} \left[\sum_{k=2}^{m-1} z_{1k} + \frac{(z_{11} + z_{1m})}{2} \right] + \frac{1}{2} \left[\sum_{k=2}^{m-1} z_{nk} + \frac{(z_{n1} + z_{nm})}{2} \right] \right\} . \quad (21)$$

The values of Δx and Δy are given by equations (22) and (23):

$$\Delta x = \frac{b - a}{n - 1} \tag{22}$$

$$\Delta y = \frac{d - c}{m - 1} \quad . \tag{23}$$

Because the right-hand side of equation (21) is cumbersome, the following variables are defined:

$$V1 = \sum_{j=2}^{n-1} \left[\sum_{k=2}^{m-1} z_{jk} + \frac{(z_{j1} + z_{jm})}{2} \right] \tag{24}$$

$$V2 = \sum_{k=2}^{m-1} z_{1k} + \frac{(z_{11} + z_{1m})}{2} \tag{25}$$

$$V3 = \sum_{k=2}^{m-1} z_{nk} + \frac{(z_{n1} + z_{nm})}{2} \quad . \tag{26}$$

Using equations (21-26), the value of A is given by equation (27):

$$A \simeq \frac{\left(V1 + \frac{1}{2} V2 + \frac{1}{2} V3\right)}{(n - 1)(m - 1)} \quad . \tag{27}$$

In the computer program the values of EBAR, RMS, and SIGMA are calculated by finding the three different values of the function $G(x,y)$. Three sample point arrays are used. The first, labeled G1, contains all the sample points as measured and is used to calculate EBAR. The second, labeled G2, contains all the sample points squared and is used to calculate the RMS value. The third, labeled G3, contains the squared values of the deviation of all the sample points from the mean value EBAR. A subroutine is called from the ARMS subroutine to calculate the value of A for each case. The subroutine is called AFUNC and is described in Section III. E.

After calculating EBAR, RMS, and SIGMA, subroutine ARMS continues, calculating the lowest sample point, C, then the highest, D, and finally the difference which is labeled PTP. Lines 121 to 128 print out all the values along with the total number of points, TAP.

E. Subroutine AFUNC

A Fortran listing of the subroutine AFUNC is presented in Table 6. The variables used in the subroutine are given in Table 7. The subroutine is used to approximate the integral of a two-dimensional function represented by sample points where the outside sample points fall at the limits of the area. It actually computes the height of a box which if multiplied by the area under the sample points would be the integral of the function.

Four variables are transferred through subroutine AFUNC. The first, AV1, is a two-dimensional array containing the sample points. The second, AV2, is the value of A in equation (27) of Section III. D. The third, M, is the number of points in the y direction. The fourth, N, is the number of points in the x direction.

F. Subroutine DPRINT

Subroutine DPRINT is used to print the sample point values. A listing of the subroutine is presented in Table 8. A list of the variables used is given in Table 9. The subroutine is called twice in the main program, once to print all the input sample points after normalization and again to print only the points used in the test plane.

TABLE 6. SUBROUTINE AFUNC OF PROGRAM SASS

```
SUBROUTINE AFUNC OF PROGRAM SASS
TY 134-161
                SUBROUTINE AFUNC(AV1,AV2,M,N)
       C        SUBROUTINE TO CALCULATE INTERGAL
       C        INTERGAL IS VOLUME UNDER AREA GIVEN BY AV1 ARRAY
       C        RESULT AV2 IS HEIGHT OF VOLUME BOX
       C        AV1 IS ARRAY OF SAMPLE POINTS REPERSENTING  G(X,Y)
                DIMENSION AV1(31,1)
       C        CALCULATE V1
                V1 = 0
                DO 200 J = 2,N-1
                DO 100 K = 2,M-1
         100    V1 = V1+AV1(J,K)
         200    V1 = V1+(AV1(J,1)+AV1(J,M))/2.0
       C        COMPUTE V2
                V2 = 0
                DO 300 K = 2,M-1
         300    V2 = V2+AV1(1,K)
                V2 = V2+ (AV1(1,1)+AV1(1,M))/2.0
                V2 = .5*V2
       C        COMPUTE V3
                V3 = 0.0
                DO 400 K = 2,M-1
         400    V3 = V3+AV1(N,K)
                V3 = V3+(AV1(N,1)+AV1(N,M))/2.0
                V3 = 0.5*V3
       C        CALCULATE HEIGHT WHICH TIMES AREA GIVES VOLUME
                AV2 = (V1+V2+V3)/FLOAT((M-1)*(N-1))
                RETURN
                END
```

TABLE 7. LIST OF VARIABLES IN SUBROUTINE AFUNC

Variable	Definition
AV1(J, K)	Sample point data array
AV2	Result of integral calculation
M	Number of scans
N	Number of points on the scans
V1	First term of integral
V2	Second term of integral
V3	Third term of integral

TABLE 8. SUBROUTINE DPRINT OF PROGRAM SASS

```
SUBROUTINE DPRINT OF PROGRAM SASS
TY 163-179
           SUBROUTINE DPRINT(P,A,SP,NSS,NES,NSP,NEP,ID)
           DIMENSION A(31,1),SP(1),ID(1),P(1)
           WRITE(108,100) (ID(I),I = 1,20)
     100   FORMAT(1H1,20A4)
           WRITE(108,110)
     110   FORMAT(1H0,'DATA',31X,'SCAN POSITION')
           NS = NES-NSS+1
           WRITE(108,120) NS,(SP(I),I = NSS,NES)
     120   FORMAT(1H ,' POS ',1X,N(F5.1,1X))
           WRITE(108,150)
     150   FORMAT(1H ,119(1H-))
           DO 500 I = NSP,NEP
           WRITE(108,510) P(I),NS,(A(I,J),J = NSS,NES)
     500   CONTINUE
     510   FORMAT(1H ,F4.0,'I',1X,N(F5.1,1X))
           RETURN
           END
```

TABLE 9. LIST OF VARIABLES IN SUBROUTINE DPRINT

Variable	Definition
P(I)	Location of sample points on scan
A(J, K)	Array of sample data points
SP(I)	Location of scans
NSS	Number of scan to start printing
NES	Number of scan to end printing
NSP	Number of point on scan to start printing
NEP	Number of point on scan to end printing
IA(I)	Comment or title array
NS	Number of scans in array to print

The subroutine is almost standard Fortran, but it should be noted that a variable format statement is used to control the number of sample points printed. Some computers cannot handle a variable format statement.

Using the set commands, the printout can be assigned to different devices. Usually, the unit 108 is set to the line printer if PCODE is assigned the value of 1 for a printout.

G. Subroutine SPLOT

Subroutine SPLOT is used to plot the scan sample data in a three-dimensional format as an aid to visualizing the test plane uniformity. Table 10 presents a listing of the subroutine and Table 11 gives a listing of the variables used. The plot package used is a special package developed by Computer Science Corporation for MSFC. It was developed for a Datacraft computer and made available on the Sigma V. Since this subroutine is computer-dependent, it will not be explained in detail. If the program is used on a computer other than the Sigma V, a new plot routine will have to be developed.

The set command is used to control the location of the printed data in the plot routine. All write statements in subroutine SPLOT use unit 150 and the command set F:150 = ME is used when the NPCODE is assigned the value of 2 for a plot of the input data.

IV. RESULTS OF FIRST MEASUREMENTS

The computer program described in Reference 1 was used to calculate the uniformity of the 405 lamp solar simulator. Given the assumption that all lamps have the same intensity level at the same voltage, the program gave the results shown in Figure 11. The test plane showed only a tendency to decrease in intensity near the edge. Using the procedure developed by Lewis Research Center, 405 lamps were tested and sorted for placement in the array in a manner to provide the most uniform test plane intensity. Using the measured values for the lamps in the computer program, the uniformity was again calculated and the results are shown in Figure 12. The standard deviation increased from 1.09 to 1.45 percent. The PTP value was still less than 7 percent which was substantially less than the tolerance placed on the uniformity, ±7 percent deviation from the mean value.

TABLE 10. SUBROUTINE SPLOT OF PROGRAM SASS

```
TY 180-236
      SUBROUTINE SPLOT(TX,TPI,NX,NY,IDATA)
      DIMENSION TX(31),TPI(31,27),IDATA(20),IA(10)
      DATA (IA(I),I = 1,10)/1HP,1HE,1HR,1HC,1HE,1HN,1HT,
     X1HA,1HG,1HE/
      CALL BEGIN(300)
      CALL ERASE
      CALL SCALE(6.0,3.0,200.0,150.0)
      CALL VECTOR
      CALL AXIS(0.0,0.0,60.0,100.0,6.0,20.0,1,1)
      CALL ALPHA
      NA = -36;X = -10.0;Y = -10.0
      DO 100 I = 1,11
      NA = NA+6;X = X+6.0
      CALL TPLOT(X,Y,0,0)
      WRITE(150,110) NA
  100 CONTINUE
  110 FORMAT(I3)
      X = -18.0;Y = 100.0
      DO 150 I = 1,10
      Y = Y-8.0
      CALL TPLOT(X,Y,0,0)
      WRITE(150,160) IA(I)
  160 FORMAT(1A1)
  150 CONTINUE
      X = -12.0;Y = -21.0;NA = -20
      DO 200 I = 1,6
      NA = NA+20;Y = Y+20.0
      CALL TPLOT(X,Y,0,0)
      WRITE(150,210) NA
  200 CONTINUE
  210 FORMAT(I4)
      CALL TPLOT(0.0,-20.0,0,0)
      WRITE(150,220)
  220 FORMAT('DISTANCE FROM CENTERLINE - INCHES')
      CALL VECTOR
      ZERO = 30.0;XSHIFT = 3.0;YSHIFT = 5.0
      DEL = TX(1)+ZERO
      XS = -XSHIFT;YS = -YSHIFT
      DO 300 I = 1,NY
      YS = YS+YSHIFT
      XS1 = (XS+DEL+XSHIFT)*(1.0-FLOAT(I-1)*.01)
      CALL TPLOT(XS1,YS,0,0)
      XS = XS+XSHIFT
      DO 250 J = 1,NX
      X = (TX(J)+ZERO+XS)*(1.0-FLOAT(I-1)*.01)
      Y = TPI(J,I)+YS
      CALL TPLOT(X,Y,1,0)
  250 CONTINUE
      CALL TPLOT(X,YS,1,0)
  300 CONTINUE
      CALL TPLOT(0.0,180.0,0,0)
      CALL ALPHA
      WRITE(150,400) (IDATA(I),I = 1,20)
  400 FORMAT(20A4)
      CALL TPAUSE
      RETURN
      END
```

TABLE 11. LIST OF VARIABLES IN SUBROUTINE SPLOT

Variable	Definition
TX(I)	Array containing location of sample points on scan
TPI(J, K)	Data array of sample points
NX	Number of sample points on scan
NY	Number of scans
IDATA	Comment or title array
IA(I)	Axis label array
NA	Variable used to number the axis
X	Variable used to position number of the x axis
Y	Variable used to position number of the y axis
ZERO	Shift necessary to position data in center of plot
XSHIFT	Shift in x direction for each scan for three-dimensional effect
YSHIFT	Shift in y direction for each scan for three-dimensional effect
DEL	Shift of sample point to position correctly on x axis
XS	Temporary variable for shift value in x direction
YS	Temporary variable for shift value in y direction

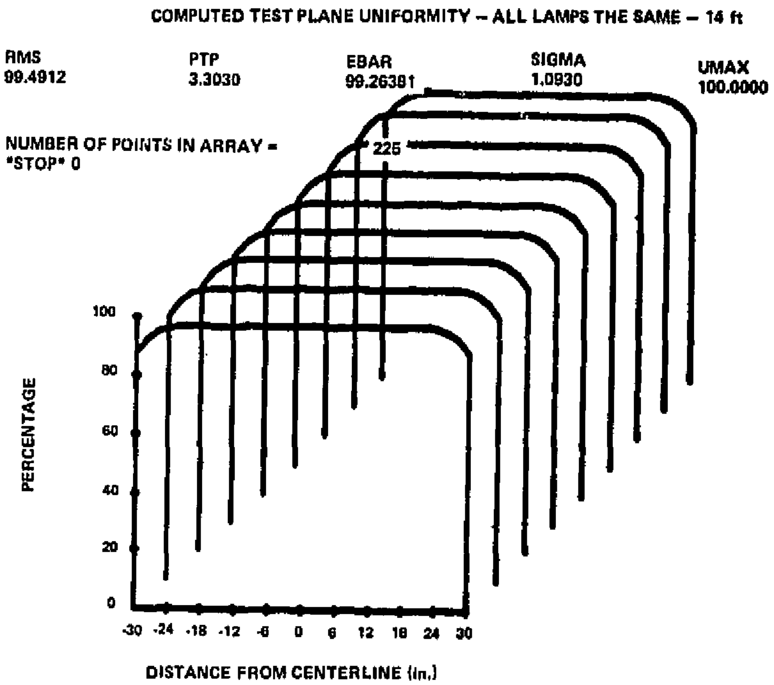


Figure 11. Plot of test plane uniformity with all lamps set at the same value.

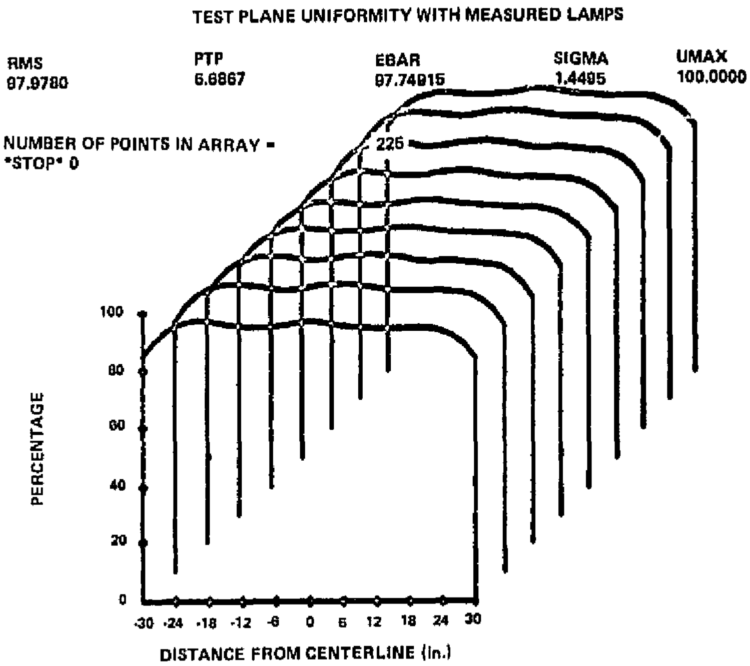


Figure 12. Plot of computed test plane uniformity with measured lamps.

On May 20, 1976 the simulator was turned on and the actual test plane uniformity measured. A plot of the results is shown in Figure 13. After reviewing the data, it appeared the test plane measurement apparatus had not been centered under the simulator; therefore, a second test was conducted. The second measurement in (Fig. 14) gave results that are now considered typical. The PTP value was 22.6 percent (±11.3 percent), and the standard deviation was 3.6 percent.

Measurements with the test plane at greater distances than the standard 2.74 m (9 ft) distance from the simulator show that the edge drop-off increases as the computer program predicted. Figure 15 is a computer plot of the test plane at 3.66 m (12 ft), and Figure 16 is a plot of the test plane as measured at the same distance. Figures 17 and 18 give similar comparison for 4.57 m (15 ft).

At this time it is not clear why the measured results show a much larger variation in uniformity than that predicted by computer analysis. At first, it appeared that light spillover from one lamp to the adjacent Fresnel lens might be causing the nonuniformity, but a test was conducted in which an aluminum honeycomb 2.3 cm (0.9 in.) thick with holes approximately 0.5 cm (0.2 in.) in diameter was placed between the lamps and the Fresnel lens. The intensity was greatly reduced with the honeycomb (approximately 80 percent), but the uniformity was not significantly changed when normalized. (The honeycomb was painted black to reduce reflection in the channels.) A check of the individual lamp intensities were made while in the full array, and they were not as measured prior to placement in the array. They were placed correctly by serial number, but the intensities were different. Why they were different is unexplained. It could be due to such factors as contact resistance in the lamp sockets or voltage drops in the power lines feeding the individual lamps.

A subsequent test of lamps in the special test box has revealed that different intensity levels, on the order of 15 to 20 percent, will be measured if a lamp is rotated 180 degrees in the lamp socket. The reason for this is unexplained also, but could account for some of the variations of the lamp intensities when measured in the actual array.

After operating the simulator, it was noted that the Fresnel lens sagged due to the heat, resulting in a warped surface with a curve up to 6 mm (0.25 in.) deep across the 12.7 cm (5 in.) diameter, perpendicular to the two mounting screws at the edge. The warping seems to have little effect on the optical property, but could account for some of the test plane variation. The warping is a

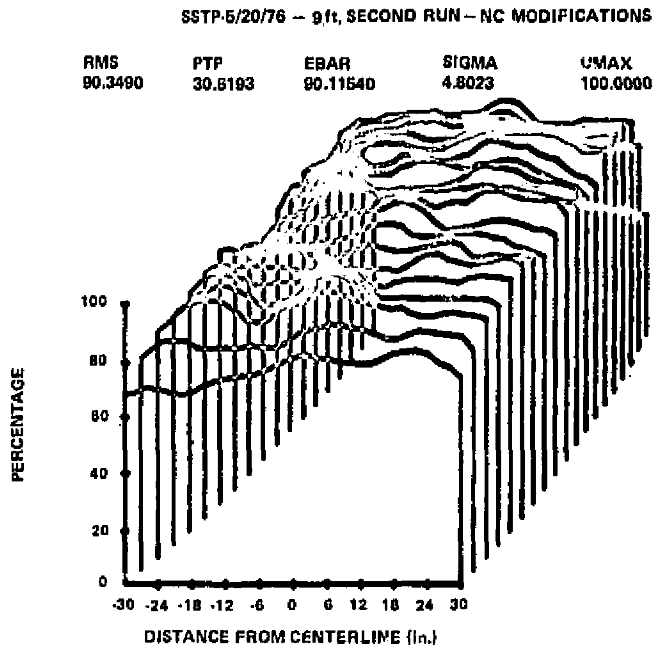


Figure 13. Plot of first measured test plane uniformity.

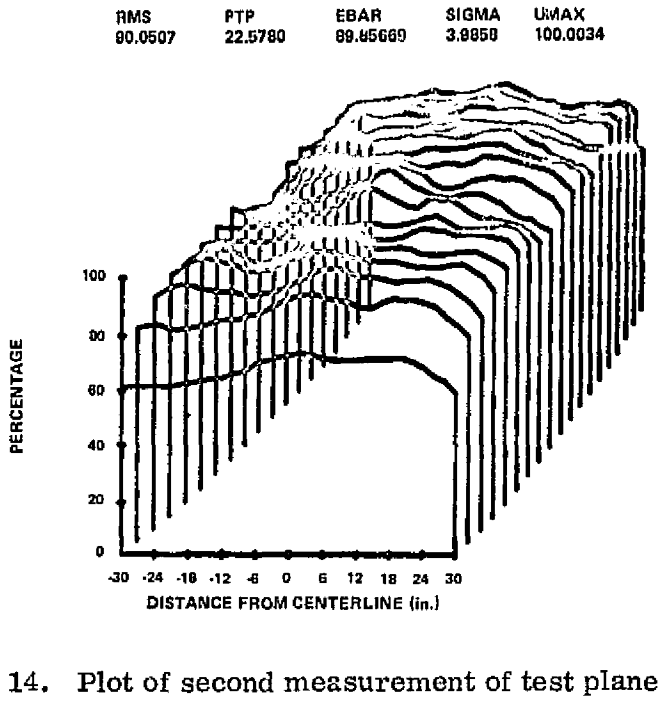


Figure 14. Plot of second measurement of test plane uniformity.

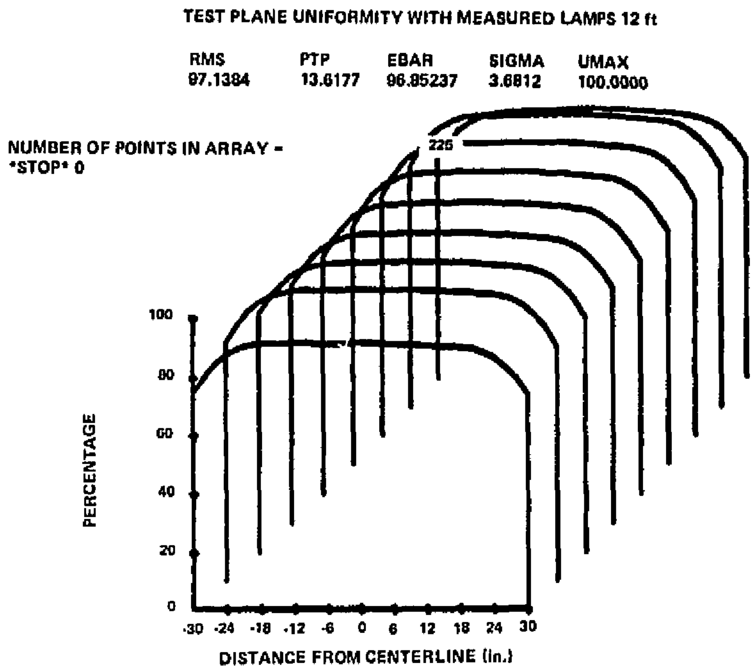


Figure 15. Plot of computed test plane uniformity at 3.66 m (12 ft).

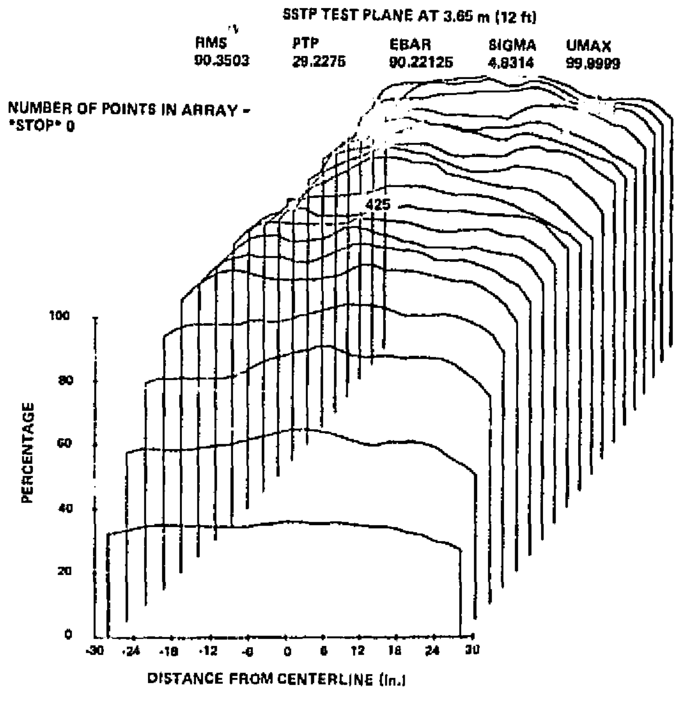


Figure 16. Plot of measured test plane uniformity at 3.66 m (12 ft).

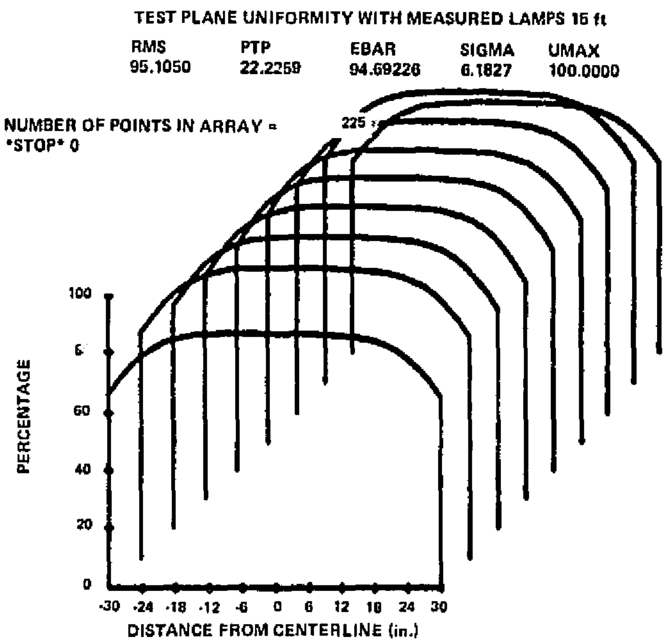


Figure 17. Plot of computed test plane uniformity at 4.57 m (15 ft).

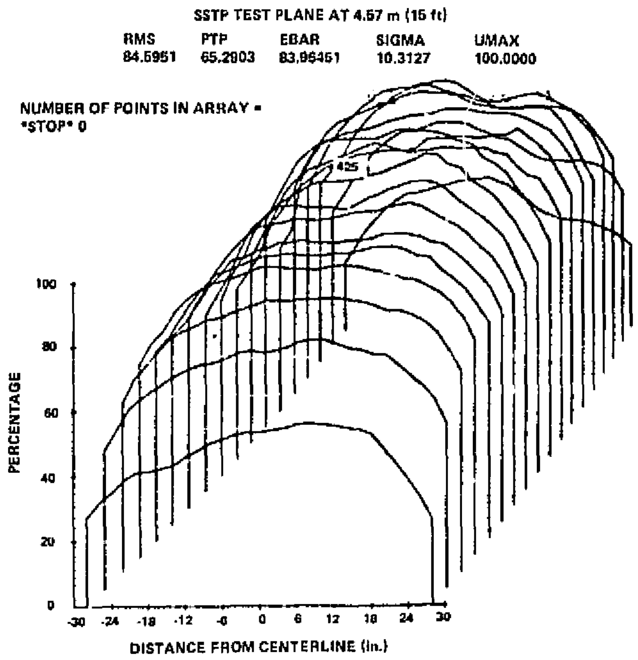


Figure 18. Plot of measured test plane uniformity at 4.57 m (15 ft).

problem in that thermal cycling may result in physical failure of the lens. Dr. McCrickard of ET44 has an effort underway to investigate the warping effect and to develop means to minimize the problem.

Another anomaly observed was that the flux level from the lamp array was about 30 percent higher than expected. This had to be corrected because the maximum life of the lamps is achieved only if the lamps are operated between 90 and 110 Vac. To reduce the test plane intensity to Air Mass 2 and still operate above 90 Vac, screen wire was placed between the lamps and the Fresnel lens. The screen wire reduced the intensity by approximately 30 percent and left the uniformity unchanged.

V. CONCLUSIONS

The 405 lamp solar simulator has been placed into operation. The test plane uniformity is not as good as predicted but is within acceptable limits. The reason for the difference between the measured results and the predicted performance continues to be evaluated. It is felt at this time that the difference is the sum of several effects, but that the primary reason is the variation in flux levels for the individual lamps when measured in the test box from the levels measured when placed in the actual simulator. Other possibilities include the warping of the Fresnel lens or individual manufacturing variations in the lens.

The total flux level at the test plane was higher than the predicted value. Compensation is obtained by placing screen wire between the lamps and the Fresnel lens which reduced the test plane intensity level to the design value.

Although the process to manually read the sample points from the chart paper is tedious, the procedure used to measure the test plane uniformity worked very well.

The computer program to reduce the measurement data uses slightly modified formulas to calculate the statistics on the test plane uniformity. The formulas were modified to allow the edge of the test plane to be defined by sample points. The modifications are not required if the sample points are taken at the center of each sample area.

The test plane measurements at different distances from the simulator indicate that the computer program given in Reference 1 to calculate the test plane uniformity gives accurate results; however, it will not be fully proven until a comparison can be made in which the individual lamp intensities are accurately known. The large variation observed in lamp performance in the simulator indicates that it is extremely difficult to control all the parameters to insure that the individual lamp intensities measured in a test fixture will be repeatable in the simulator operating conditions.

To more fully understand the variations from the predicted performance and to provide operational flexibility and efficiency, further evaluation and possible design improvements are recommended as follows:

a. Test a variety of lamps to determine expected variation due to quality control, voltage, orientation, operating temperature, etc.

b. Build and test lamps in a large simulator in the lab to determine problems when going from the test of one lamp to an assembly of lamps.

c. Conduct test on a large sample of Fresnel lenses to determine manufacturing variations and changed in optical performance due to warping.

d. Design and build an automated scanner to measure the test plane uniformity. An inexpensive microprocessor with a motor driven scanner would quickly provide the test plane uniformity or the illumination on a collector of varying sizes, at a large saving in manpower and time involved to obtain the measurement results.

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2. Samuel, M. S.: Standard Mathematical Tables. The Chemical Rubber Co., 19th edition, 1971, p. 557.

3. Merritt, F. S.: Applied Mathematics in Engineering Practice. McGraw Hill, New York, N. Y., 1970, p. 259.

4. Yass, K. and Curtis, H. B.: Operational Performance of a Low Cost, Air Mass 2 Solar Simulator. NASA TM X-71662, April 1975.

APPENDIX A

LISTING OF PROGRAM SASS

```
C       PROGRAM SASS
C       PROGRAM TO CALCULATE STATISTICS ON DATA
        DIMENSION B(31,27),D(31,27),IDATA(20)
C       IDATA IS COMMENT ARRAY
        DIMENSION X(31),ASPOS(31)
C       *
C       INPUT SECTION
C       *
        REWIND 100
C       READ IN DATA
        READ (100,100) IDATA
        READ(100,110) NSCAN,NPOS,NPCODE
        READ(100,111) SSLOC,TSINC
C       SSLOC=POSITION OF FIRST SCAN
C       TSINC=THE SCAN INCREMENT DISTANCE
 100    FORMAT (20A4)
C       NSD=NUMBER SCAN TO START TEST PLANE DATA
C       NED=NUMBER SCAN TO END TEST PLANE DATA ON
        READ(100,111) NSD,NED
C       NPDS=NUMBER POINT TO START DATA SCANS ON
C       NPDE=NUMBER POINT TO END DATA SCANS ON
        READ(100,111) NPDS,NPDE
        READ (100,110) NL,NLP1,AMV
 110    FORMAT(3G)
 111    FORMAT(2G)
        DO 200 J=1,NL
        READ (100,250) X(J),NLP1,(B(J,K),K=1,NLP1)
 200    CONTINUE
 250    FORMAT (1G,NG)
        IF(NLP1.GE.NSCAN) GO TO 300
        READ (100,111) NL,NLP2
        NP=NLP1+NLP2
        DO 300 J = 1,NL
        READ (100,250) X(J),NLP2,(B(J,K),K=NLP1+1,NP)
 300    CONTINUE
C       *
C       END OF INPUT SECTION
C       *
C       START INITALIZATION
C       *
        DO 500 J=1,NPOS
        DO 500 K=1,NSCAN
 500    B(J,K) = B(J,K)*AMV
C       REDUCE ARRAY TO TEST PLANE SIZE
        DO 1000 J = NPDS,NPDE
        DO 1000 K = NSD,NED
 1000   D(J-(NPDS-1),K-(NSD-1)) = B(J,K)
C       *
C       PRINT STATISTICS ON TEST PLANE
C       *
        WRITE (108,2200) IDATA
 2200   FORMAT(1H1,20A4,///,'TEST PLANE DATA')
        NDUM  = NPDE-NPDS+1
```

```
      ND = NED-NSD+1
      CALL ARMS(D,ND,NDUM)
C      HPRINT STATISTICS ON FULL MEASUREMENT DATA
      WRITE(108,2400)
 2400 FORMAT(1H0,'FULL MEASUREMENT DATA SET')
      CALL ARMS(B,NSCAN,NPOS)
      ADUMA = SSLOC + TSINC
      DO 3000 I = 1,NSCAN
      ADUMA = ADUMA - TSINC
 3000 ASPOS(I) = ADUMA
      IF(NPCODE.EQ.0) GO TO 4000
      IF(NPCODE.NE.1) GO TO 3100
      CALL DPRINT(X,B,ASPOS,1,NSCAN,1,NPOS,IDATA)
      CALL DPRINT(X,B,ASPOS,NSD,NED,NPDS,NPDE,IDATA)
 3100 IF(NPCODE.NE.2) GO TO 4000
      CALL TPAUSE
      CALL SPLOT(X,B,NPOS,NSCAN,IDATA)
      CALL TPLOT(0,0,170,0,0,0)
      CALL ARMS(D,ND,NDUM)
 4000 CONTINUE
      STOP
      END
C     *
C     END OF MAIN SECTION OF PROGRAM
C     SUBROUTINE ARMS
C     *
      SUBROUTINE ARMS(G1,M,N)
C     SUBROUTINE ARMS IS TO COMPUTE STATISTICS
C     G1 IS SAMPLE DATA ARRAY
C     G2 IS ARRAY OF SQUARED VALUES
C     G3 IS ARRAY OF DEVIATION SQUARED VALUES
C     N IS NUMBER OF POINTS IN EACH LINE
C     M IS NUMBER OF LINES IN ARRAY
      DIMENSION G1(31,1),G2(31,27),G3(31,27)
C     COMPUTE TAP, TOTAL NUMBER OF POINTS IN ARRAY
      TAP = FLOAT(N*M)
C     CALCULATE MEAN VALUE=EBAR
      CALL AFUNC(G1,EBAR,M,N)
C     FIND G2 AND G3 ARRAYS
      DO 100 J = 1,N
      DO 100 K = 1,M
      G2(J,K) = G1(J,K)**2
  100 G3(J,K) = (G1(J,K)-EBAR)**2
      DUM = 0.0
      CALL AFUNC(G2,DUM,M,N)
      RMS = SQRT(DUM)
      CALL AFUNC(G3,DUM,M,N)
      SIGMA = SQRT(DUM)
C     FIND MOST NEGATIVE NUMBER
      C = G1(1,1)
      DO 300 J = 1,N
      DO 300 K = 1,M
      IF(C-G1(J,K)) 300,300,290
  290 C = G1(J,K)
  300 CONTINUE
```

```
C       C IS NOW MOST NEGATIVE NUMBER
C       FIND MOST POSTIVE NUMBER
        D = G1(1,1)
        DO 400 J = 1,N
        DO 400 K = 1,M
        IF(G1(J,K)-D) 400,400,390
  390   D = G1(J,K)
  400   CONTINUE
C       D IS NOW MOST POSTIVE NUMBER
        PTP = D-C
        VMAX = D
C       PRINT OUT DATA
 1000   FORMAT(1HO,'STATISTICS ON ARRAY DATA')
        WRITE(108,1100)
 1100   FORMAT(1HO,3X,'RMS',11X,'PTP',11X,'EBAR',9X,
      X'SIGMA',8X,'VMAX')
        WRITE(108,1200) RMS,PTP,EBAR,SIGMA,VMAX
 1200   FORMAT(1H ,2(F8.4,5X),F10.5,2(5X,F8.4),/)
        WRITE(108,1400) TAP
 1400   FORMAT(1HO,'NUMBER OF POINTS IN ARRAY = ',2X,I4)
        RETURN
        END
C       *
C       SUBROUTINE AFUNC
C       *
        SUBROUTINE AFUNC(AV1,AV2,M,N)
C       SUBROUTINE TO CALCULATE INTERGAL
C       INTERGAL IS VOLUME UNDER AREA GIVEN BY AV1 ARRAY
C       RESULT AV2 IS HEIGHT OF VOLUME BOX
C       AV1 IS ARRAY OF SAMPLE POINTS REPERSENTING  G(X,Y)
        DIMENSION AV1(31,1)
C       CALCULATE V1
        V1 = 0
        DO 200 J = 2,N-1
        DO 100 K = 2,M-1
  100   V1 = V1+AV1(J,K)
  200   V1 = V1+(AV1(J,1)+AV1(J,M))/2.0
C       COMPUTE V2
        V2 = 0
        DO 300 K = 2,M-1
  300   V2 = V2+AV1(1,K)
        V2 = V2+ (AV1(1,1)+AV1(1,M))/2.0
        V2 = .5*V2
C       COMPUTE V3
        V3 = 0.0
        DO 400 K = 2,M-1
  400   V3 = V3+AV1(N,K)
        V3 = V3+(AV1(N,1)+AV1(N,M))/2.0
        V3 = 0.5*V3
C       CALCULATE HEIGHT WHICH TIMES AREA GIVES VOLUME
        AV2 = (V1+V2+V3)/FLOAT((N-1)*(M-1))
        RETURN
        END
```

```
C      SUBROUTINE DPRINT TO PRINT INPUT DATA
       SUBROUTINE DPRINT(P,A,SP,NSS,NES,NSP,NEP,ID)
       DIMENSION A(31,1),SP(1),ID(1),P(1)
       WRITE(108,100) (ID(I),I = 1,20)
  100  FORMAT(1H1,20A4)
       WRITE(108,110)
  110  FORMAT(1H0,'DATA',31X,'SCAN POSITION')
       NS = NES-NSS+1
       WRITE(108,120) NS,(SP(I),I = NSS,NES)
  120  FORMAT(1H ,' POS ',1X,N(F5.1,1X))
       WRITE(108,150)
  150  FORMAT(1H ,119(1H-))
       DO 500 I = NSP,NEP
       WRITE(108,510) P(I),NS,(A(I,J),J = NSS,NES)
  500  CONTINUE
  510  FORMAT(1H ,F4.0,'I',1X,N(F5.1,1X))
       RETURN
       END
       SUBROUTINE SPLOT(TX,TPI,NX,NY,IDATA)
       DIMENSION TX(31),TPI(31,27),IDATA(20),IA(10)
       DATA (IA(I),I = 1,10)/1HP,1HE,1HR,1HC,1HE,1HN,1HT,
      X1HA,1HG,1HE/
       CALL BEGIN(300)
       CALL ERASE
       CALL SCALE(6.0,3.0,200.0,150.0)
       CALL VECTOR
       CALL AXIS(0.0,0.0,60.0,100.0,6.0,20.0,1,1)
       CALL ALPHA
       NA = -36;X = -10.0;Y = -10.0
       DO 100 I = 1,11
       NA = NA+6;X = X+6.0
       CALL TPLOT(X,Y,0,0)
       WRITE(150,110) NA
   100 CONTINUE
   110 FORMAT(I3)
       X = -18.0;Y = 100.0
       DO 150 I = 1,10
       Y = Y-8.0
       CALL TPLOT(X,Y,0,0)
       WRITE(150,160) IA(I)
   160 FORMAT(1A1)
   150 CONTINUE
       X = -12.0;Y = -21.0;NA = -20
       DO 200 I = 1,6
       NA = NA+20;Y = Y+20.0
       CALL TPLOT(X,Y,0,0)
       WRITE(150,210) NA
   200 CONTINUE
   210 FORMAT(I4)
       CALL TPLOT(0.0,-20.0,0,0)
       WRITE(150,220)
   220 FORMAT('DISTANCE FROM CENTERLINE - INCHES')
       CALL VECTOR
       ZERO = 30.0;XSHIFT = 3.0;YSHIFT = 5.0
       DEL = TX(1)+ZERO
```

```
      XS = -XSHIFT,YS = -YSHIFT
      DØ 300 I = 1,NY
      YS = YS+YSHIFT
      XS1 = (XS+DEL+XSHIFT)*(1.0-FLØAT(I-1)*.01)
      CALL TPLØT(XS1,YS,0,0)
      XS = XS+XSHIFT
      DØ 250 J = 1,NX
      X = (TX(J)+ZERØ+XS)*(1.0-FLØAT(I-1)*.01)
      Y = TPI(J,I)+YS
      CALL TPLØT(X,Y,1,0)
  250 CØNTINUE
      CALL TPLØT(X,YS,1,0)
  300 CØNTINUE
      CALL TPLØT(0.0,180.0,0,0)
      CALL ALPHA
      WRITE(150,400) (IDATA(I),I = 1,20)
  400 FØRMAT(20A4)
      CALL TPAUSE
      RETURN
      END
```

APPENDIX B

SAMPLE OF INPUT FILE

```
SAMPLE OF INPUT FILE FOR PROGRAM SASS      PAGE 1_
TY 1-40
   1.000  SSTP-6/22/76-NINE FT,2ND RUN- NO MODIFICATIONS
   2.000 19,31,1
   3.000 60,6
   4.000 2,19
   5.000 4,28
   6.000   31,11,1.065
   7.000 -30,57.3,73,78.5,80.9,81,82.7,84.5,85.8,80.5,76,76.4
   8.000 -29,58,73.9,81,84,83.3,83.3,84,85,81.7,78,79.9
   9.000 -26,58,74,82.6,86.1,85.8,84,84,83.3,82,80.5,82
  10.000 -24,58,72.8,82.6,87.3,85.9,84.1,84.8,84.1,83.1,81.9,84.8
  11.000 -22,58,72.7,81.4,87,85.4,84.4,84.6,84,83.7,84,87
  12.000 -20,58.6,73.4,80.8,85.5,84,84,85.3,84.1,83.6,86,87.5
  13.000 -18,59.3,74,80.2,84.8,82,83.7,85.3,84.1,83.5,87.1,87.1
  14.000 -16,60,75.3,80.3,82.5,80.6,84.6,84.8,84.1,84.2,86,89
  15.000 -14,61,75.8,79.4,82.5,82,86,84.1,84.5,86,86.4,86
  16.000 -12,61.1,76,79,82.6,85.5,85.5,84.4,84.6,87,89.9,87
  17.000 -10,62.6,77.6,79.7,85,85,87.7,84.7,86.8,86.4,91.7,86.7
  18.000 -8,63.7,77.8,80.4,86.8,86.4,88.1,84.5,88.7,89.3,91.6,89.2
  19.000 -6,66.5,80.1,81.9,87.6,91.3,89,84.8,91,90.3,91.8,88.6
  20.000 -4,67.6,82,83.7,89.7,91.9,89,85.4,92.8,93,91.7,87
  21.000 -2,68.6,83,85.7,90.1,91.9,88.7,85.5,91.9,93.9,90.7,86
  22.000 0,69.2,84,87.5,90,91.6,86.9,85.8,90.1,91.6,89.5,85
  23.000 2,69.8,84.1,88,88,89,85,84.9,88.3,89,88,86
  24.000 4,69.2,82.8,88.1,87.5,86.8,84.8,85,87,87.5,84.8,86.6
  25.000 6,66,82.2,86.2,86.8,86,85,85.6,86.5,86,85.5,86.4
  26.000 8,67.7,81.5,85.3,86.1,86.6,86,86.6,89,84.1,83.4,86.1
  27.000 10,67.3,80,85,86.3,86.5,87.8,87.7,89.9,84.2,84,87.3
  28.000 12,67.7,79.8,84.5,85.8,86,88.6,88.4,89.5,86,86,86.9
  29.000 14,68,81.4,83.4,84.6,84,88.1,86.6,87.4,86.1,86.5,86.7
  30.000 16,68,82.8,84,84,84,87.7,84.3,85,86.1,87.3,86.3
  31.000 18,68.2,82.1,84.1,83.8,84,86.1,83.6,83,84.6,86.3,87.5
  32.000 20,68.4,82.6,84.2,84.1,84.7,87,83.9,83,83,86.4,87
  33.000 22,67,81.3,83,85,85,87,84.2,82,80.4,86,86
  34.000 24,65,80,82,85.2,85.4,86.3,85.6,81.3,78.5,84,85.4
  35.000 26,61.8,76.5,79.3,82.8,83.7,85.5,85.3,80.3,78,82,84
  36.000 28,60,74,76.4,80.6,82,84.2,84,78.1,75.7,80.3,81
  37.000 30,55.8,70.5,72,76,79,80.3,79,75,74,76,76.2
  38.000 31,6
  39.000 -30,81.5,82,78,78,76.3,78,71.5,59.1
  40.000 -28,82.2,82.3,80,80,81,79.6,72.1,60.5
```

REPRODUCIBILITY OF THE
ORIGINAL PAGE IS POOR

```
SAMPLE OF INPUT FILE FOR PROGRAM GASS      PAGE 2_
TY 41-69
 41.000 -26,83,83.4,81.6,81.1,82,79.9,72.6,60.8
 42.000 -24,83.8,85,83,83,83,80.4,73,61
 43.000 -22,84.6,85.8,82.8,85.9,83.5,81,75,60.9
 44.000 -20,84.7,85.7,82.2,84.7,83.4,81.6,77.4,60.6
 45.000 -18,82.4,84.6,81.4,84,82.1,80,77,62
 46.000 -16,83.6,84.2,81.6,84.9,84.1,80.5,78.5,62.6
 47.000 -14,83,85.7,82.5,85.3,84.5,80.2,79.7,63.2
 48.000 -12,82.8,86,82.5,85.2,83.7,80,78.8,64
 49.000 -10,84,86,82.4,84.5,82.5,80.1,78.7,64
 50.000 -8,85,87.6,82,84.6,82.7,80.2,78.2,63.5
 51.000 -6,85.1,88.4,82.4,85,83.6,81.3,78.7,63.7
 52.000 -4,85.4,88,82.6,84.7,85,82.5,79,63.4
 53.000 -2,86.5,87.1,83.2,85.9,86.4,84.4,80,63
 54.000 0,86.8,86.6,84.4,87.8,87.3,85.5,81.6,62
 55.000 2,86.5,86,84.6,87.7,87.4,84,82.3,62.3
 56.000 4,87,86,85.5,87.7,85.6,81.8,80.8,63
 57.000 6,87.2,87.4,86.8,87.2,83.6,81.2,79.3,62
 58.000 8,88.2,88.6,86.6,87.4,83,79.9,77,62
 59.000 10,88.4,88.9,86,88.6,83,78,78,61
 60.000 12,88.5,89.1,85.6,89.4,82.6,77.2,76.1,59
 61.000 14,88,88.9,84.4,88.3,81.3,78.2,73.9,56
 62.000 16,86.1,86.3,84,87.6,79.9,79,74,56.6
 63.000 18,85,84,82.3,85.5,78,78.5,74.3,54.1
 64.000 20,84.1,83,81.8,84.4,78,79.3,73.6,54.1
 65.000 22,83.2,80,80,83.7,79.5,79.3,73.9,54
 66.000 24,82.8,78.7,79.6,83.4,80.7,79.8,74.2,54.5
 67.000 26,83,76.8,78,82.6,80,79,75.4,55.3
 68.000 28,82.5,76.4,78.3,83.2,80.4,80.7,75,55
 69.000 30,79.4,74,78,80,78.4,78.5,72,54
*
```

DESCRIPTION OF INPUT FILE

LINE 1 Comment or Title input, (IDATA) can contain up to 80 characters

LINE 2 NSCAN, NPOS and NPCODE are input on this line.

- NSCAN — Number of scans
- NPOS — Number of points on each scan
- NPCODE — Code to print or plot input data.
  - 0 for no print or plot
  - 1 for printout on line printer
  - 2 for plot on CRT

LINE 3 SSLOC and TSINC are input on this line.

- SSLOC — The position of the first scan in inches.
- TSINC — The interval between scans in inches.

LINE 4 NSD and NED are input on this line.

- NSD — Number of scan to start the test plane.
- NED — Number of scan to end the test plane.

LINE 5 NPDS and NPDE are input on this line.

- NPDS — Number of sample point on the scan to start the test plane.
- NPDE — Number of sample point on the scan to end the test plane.

LINE 6 NL, NLP1, and AMV are input on this line.

- NL — Number of lines in the first set of data.
- NLP1 — Number of sample points on each line.
- AMV — Scale factor to multiply against each sample point.

The line numbers may vary from here on depending on the number of sample points on each scan.

LINES 7–37 These lines contain the first group of sample points. The first lines start at the negative end and progress to the positive end. Each line contains the sample point on each scan at the same distance from the center point.

LINE 38 NL and NLP2 are input on this line.

NL — Number of lines in the second group of data.

NLP2 — Number of points on each line in the second group.

LINES 39-69 These lines contain the rest of the sample data points.

APPENDIX C

SAMPLE RUN OF PROGRAM

SAMPLE RUN OF PROGRAM SASS_ **(NPCODE set to 0 for no plot or print of the input data.)**

CONTROL COMMANDS_

```
!SET F:100/T2

!SET F:150 = ME

!START TD2


 SSTP-6/22/76-NINE FT,2ND RUN- NO MODIFICATIONS
TEST PLANE DATA

   RMS           PTP          EBAR          SIGMA        VMAX
 90.4249       22.5780      90.35193       3.6324      100.0034

 NUMBER OF POINTS IN ARRAY =    425
 FULL MEASUREMENT DATA SET

   RMS           PTP          EBAR          SIGMA        VMAX
 88.0832       42.4935      87.81999       6.8102      100.0034

 NUMBER OF POINTS IN ARRAY =    589
 *STOP* 0

!
```

EXAMPLE OF RUN TO GET OUTPUT ON THE LINE PRINTER_

CONTROL COMMANDS_

```
!SET F:100/T2

!SET F:108 = LP

!EDIT T2
EDIT HERE
*TY2
   2.000 19,31,0
*IN2
   2.000 19,31,1
*END

!START TD2
 *STOP* 0

!
```

SSTP-6/22/76-NINE FT,2ND RUN. NO MODIFICATIONS

TEST PLANE DATA

RMS	PTP	EBAR	SIGMA	VMAX
90.4249	22.6780	90.35193	3.6324	100.0034

NUMBER OF POINTS IN ARRAY = 425

FULL MEASUREMENT DATA SET

RMS	PTP	EBAR	SIGMA	VMAX
88.0832	42.4935	87.81969	6.8102	100.0034

NUMBER OF POINTS IN ARRAY = 589

SSTP-6/22/76-NINE FT,2ND RUN- NO MODIFICATIONS

DATA POS	54.0	48.0	42.0	36.0	30.0	24.0	18.0	12.0	6.0	.0	-6.0	-12.0	-18.0	-24.0	-30.0	-36.0	-42.0
-24.I	77.5	88.0	93.0	91.5	89.6	90.3	89.6	88.5	87.2	90.3	89.2	90.5	88.4	88.4	88.4	86.6	77.7
-22.I	77.4	86.7	92.7	91.0	89.9	90.1	89.5	89.1	89.5	92.7	90.1	91.4	88.2	91.5	88.9	86.3	79.9
-20.I	78.2	85.8	91.1	89.5	89.5	90.8	89.6	89.0	91.6	93.2	90.2	91.3	87.5	90.2	88.8	86.9	82.4
-18.I	78.8	85.4	90.3	87.3	89.1	90.8	89.6	89.2	92.8	92.8	87.8	90.1	86.7	89.5	87.4	85.2	82.0
-16.I	80.2	85.5	87.9	85.8	90.1	90.3	89.6	89.7	93.7	94.8	89.0	89.7	87.1	90.4	89.6	85.7	83.6
-14.I	80.7	84.6	87.9	87.3	91.6	89.6	90.0	91.6	95.2	93.7	88.4	91.3	87.9	90.8	90.0	85.4	84.9
-12.I	80.9	84.1	88.2	88.9	91.1	89.9	90.3	92.7	95.7	92.7	88.2	91.6	87.9	90.7	89.1	85.2	83.9
-10.I	82.6	84.9	90.5	90.5	93.4	90.2	92.2	94.1	97.7	94.5	89.5	91.6	87.8	90.0	87.9	85.3	83.8
-8.I	82.9	85.6	92.4	94.1	93.8	90.0	94.5	95.1	97.6	95.0	90.5	93.3	87.3	90.1	88.1	85.4	83.3
-6.I	85.3	87.2	93.5	97.2	94.8	90.3	96.9	96.2	97.8	94.4	90.6	94.1	87.8	90.5	89.0	86.6	83.8
-4.I	87.3	89.1	95.5	97.9	94.8	91.0	98.5	99.0	97.7	92.7	91.0	93.7	88.0	90.2	90.5	87.9	84.1
-2.I	88.4	91.3	96.0	97.9	94.5	91.1	97.9	100.0	96.6	91.6	92.1	92.8	88.6	91.5	92.0	89.9	85.2
0.I	89.5	93.2	95.8	97.6	92.5	91.4	96.0	97.6	95.3	90.5	92.4	92.2	89.9	93.5	93.0	91.1	86.9
2.I	89.6	93.7	93.7	94.8	90.5	90.4	94.0	94.8	93.7	91.6	92.1	91.6	90.1	93.4	93.1	89.5	87.6
4.I	88.2	93.8	93.2	92.4	90.3	90.5	92.7	93.2	90.3	92.2	92.7	91.6	91.1	93.4	91.2	87.1	85.8
6.I	87.5	91.8	92.4	91.6	90.5	91.2	92.1	91.6	88.9	92.0	92.9	93.1	92.4	92.9	89.0	86.5	84.5
8.I	86.8	90.8	91.7	92.2	91.6	92.2	94.8	89.6	88.8	91.7	93.9	94.4	92.2	93.1	88.4	85.1	82.0
10.I	85.2	90.5	91.9	92.1	93.5	93.4	95.7	90.3	89.5	93.0	94.1	94.7	91.6	94.4	88.4	83.1	80.9
12.I	85.0	90.0	91.4	91.6	94.4	94.1	95.3	91.6	91.6	94.7	94.3	94.9	91.2	95.2	88.0	82.2	81.0
14.I	86.7	88.8	90.1	89.5	93.8	92.2	93.1	91.7	92.1	94.5	93.7	94.7	89.9	94.0	86.6	83.3	78.7
16.I	88.2	89.5	89.5	89.5	93.4	89.8	90.5	91.7	93.0	94.0	91.7	91.9	89.5	93.3	85.1	84.1	78.8
18.I	87.4	89.6	89.2	89.5	91.7	89.0	88.4	90.1	91.9	93.2	90.5	89.5	87.6	91.1	83.1	83.6	79.1
20.I	88.0	89.7	89.6	90.2	92.7	89.4	88.4	88.4	92.0	92.7	89.6	88.4	87.1	89.9	83.1	84.5	78.6
22.I	86.6	88.4	90.5	90.5	92.7	89.7	87.3	85.6	91.6	91.6	88.6	85.2	85.2	89.1	84.7	84.5	78.7
24.I	85.2	87.3	90.7	91.0	91.9	91.2	86.6	83.6	89.5	91.0	88.2	83.8	84.8	88.8	85.9	85.0	79.0

SSTP-6/22/76-NINE FT,2ND RUN- NO MODIFICATIONS

DATA POS	SCAN POSITION 60.0	54.0	48.0	42.0	36.0	30.0	24.0	18.0	12.0	6.0	.0	-6.0	-12.0	-18.0	-24.0	-30.0	-36.0	-42.0	-48.0
-30.I	61.0	77.7	83.6	86.2	86.3	88.1	90.0	91.4	85.7	80.9	81.4	86.8	87.3	83.1	83.1	83.4	83.1	76.1	62.9
-28.I	61.8	78.7	86.3	89.5	88.7	88.7	89.5	90.5	87.0	83.1	85.1	87.5	87.6	85.2	85.2	86.3	84.8	76.8	64.4
-26.I	61.8	78.8	88.0	91.7	91.4	89.5	89.5	88.7	87.3	85.7	87.3	88.4	88.8	86.9	86.4	87.3	85.1	77.3	64.8
-24.I	61.8	77.5	88.0	93.0	91.5	89.6	90.3	89.6	88.5	87.2	9_.3	89.2	90.5	88.4	88.4	88.4	85.6	77.7	65.0
-22.I	61.8	77.4	86.7	92.7	91.0	89.9	90.1	89.5	89.1	89.5	92.7	90.1	91.4	88.2	91.5	88.9	86.3	79.9	64.9
-20.I	62.4	78.2	85.8	91.1	89.5	89.5	90.8	89.6	89.0	91.6	93.2	90.2	91.3	87.5	90.2	88.8	86.9	82.4	64.5
-18.I	63.2	78.8	85.4	90.3	87.3	89.1	90.8	89.6	89.2	92.8	92.6	87.8	90.1	86.7	89.5	87.4	85.2	82.0	66.0
-16.I	63.9	80.2	85.5	87.9	85.8	90.1	90.3	89.6	89.7	93.7	94.8	89.0	89.7	87.1	90.4	89.6	85.7	83.6	66.7
-14.I	65.0	80.7	84.6	87.9	87.3	91.6	89.6	90.0	91.6	95.2	93.7	88.4	91.3	87.9	90.8	90.0	85.4	84.9	67.3
-12.I	65.1	80.9	84.1	88.2	88.9	91.1	89.9	90.3	92.7	95.7	92.7	88.2	91.6	87.9	90.7	89.1	85.2	83.9	68.2
-10.I	66.7	82.6	84.9	90.5	90.5	93.4	90.2	92.2	94.1	97.7	94.5	89.5	91.6	87.8	90.0	87.9	85.3	83.8	68.2
-8.I	67.8	82.9	85.6	92.4	94.1	93.8	90.0	94.5	95.1	97.6	95.0	90.5	93.3	87.3	90.1	88.1	85.4	83.3	67.6
-6.I	70.8	85.3	87.2	93.5	97.2	94.8	90.3	96.9	96.2	97.8	94.4	90.6	94.1	87.8	90.5	89.0	86.6	83.8	67.8
-4.I	72.0	87.3	89.1	95.5	97.9	94.8	91.0	98.8	99.0	97.7	92.7	91.0	93.7	88.0	90.2	90.5	87.9	84.1	67.5
-2.I	73.1	88.4	91.3	96.0	97.9	94.5	91.1	97.9	100.0	96.6	91.6	92.1	92.8	88.6	91.5	92.0	89.9	85.2	67.1
0.I	73.7	89.5	93.2	95.8	97.6	92.5	91.4	96.0	97.6	95.3	90.5	92.4	92.2	89.9	93.5	93.0	91.1	86.9	66.0
2.I	74.3	89.6	93.7	93.7	94.8	90.5	90.4	94.0	94.8	93.7	91.6	92.1	91.6	90.1	93.4	93.1	89.5	87.6	66.3
4.I	73.7	88.2	93.8	93.2	92.4	90.3	90.5	92.7	93.2	90.3	92.2	92.7	91.6	91.1	93.4	91.2	87.1	85.8	67.1
6.I	72.4	87.5	91.8	92.4	91.6	90.5	91.2	92.1	91.6	88.9	92.0	92.9	93.1	92.4	92.9	89.0	86.5	84.5	66.0
8.I	72.1	86.8	90.8	91.7	92.2	91.6	92.2	94.8	89.6	88.8	91.7	93.9	94.4	92.2	93.1	88.4	85.1	82.0	66.0
10.I	71.7	85.2	90.5	91.9	92.1	93.6	93.4	95.7	90.3	89.5	93.0	94.1	94.7	91.6	94.4	88.4	83.1	80.9	65.0
12.I	72.1	85.0	90.0	91.4	91.6	94.4	94.1	95.3	91.6	91.6	94.7	94.3	94.9	91.2	95.2	88.0	82.2	81.0	62.8
14.I	72.4	86.7	88.8	90.1	89.5	93.8	92.2	93.1	91.7	92.1	94.5	93.7	94.7	89.9	94.0	86.6	83.3	78.7	61.8
16.I	72.4	88.2	89.5	89.5	89.5	93.4	89.8	90.5	91.7	93.0	94.0	91.7	91.9	89.5	93.3	85.1	84.1	78.8	60.3
18.I	72.6	87.4	89.6	89.2	89.5	91.7	89.0	88.4	90.1	91.9	93.2	90.5	89.5	87.6	91.1	83.1	83.6	79.1	57.6
20.I	72.8	88.0	89.7	89.6	90.2	92.7	89.4	88.4	88.4	92.0	92.7	89.6	88.4	87.1	89.9	83.1	84.5	78.6	57.6
22.I	71.4	86.6	88.4	90.5	90.5	92.7	89.7	87.3	85.6	91.6	91.6	88.6	85.2	85.2	89.1	84.7	84.5	78.7	57.5
24.I	69.2	85.2	87.3	90.7	91.0	91.9	91.2	86.6	83.6	89.5	91.0	88.2	83.8	84.8	88.8	85.9	85.0	79.0	58.0
26.I	65.8	81.5	84.5	88.2	89.1	91.1	90.8	85.5	83.1	87.3	89.5	88.4	81.6	83.1	88.0	85.2	84.1	80.3	58.9
28.I	63.9	78.8	81.4	85.8	87.3	89.7	89.5	83.2	80.6	85.5	86.3	87.9	81.4	83.4	88.6	85.6	85.9	79.9	58.6
30.I	59.4	75.1	76.7	80.9	84.1	85.5	84.1	79.9	78.8	80.9	83.3	84.6	78.8	83.1	85.2	83.5	83.6	76.7	57.5

EXAMPLE OF RUN TO OBTAIN PLOT

CONTROL COMMANDS:

!SET F:100/T2 (T2 is name of input file.)

!SET F:150 = ME

!EDIT T2 (Need to edit T2 to change plot code.)

```
*TY2
  2.000 19,31,1
*IN2
  2.000 19,31,2
*END
```

!START TD2 (Command to run program SASS in file TD2.)

The following data is output on the CRT

SSTP-6/22/76-NINE FT,2ND RUN- NO MODIFICATIONS

TEST PLANE DATA

RMS	PTP	EBAR	SIGMA	VMAX
90.4249	22.5780	90.35193	3.6324	100.000

NUMBER OF POINTS IN ARRAY = 425

FULL MEASUREMENT DATA SET

RMS	PTP	EBAR	SIGMA	VMAX
88.0832	42.4935	87.81969	6.8102	100.000

NUMBER OF POINTS IN ARRAY = 589

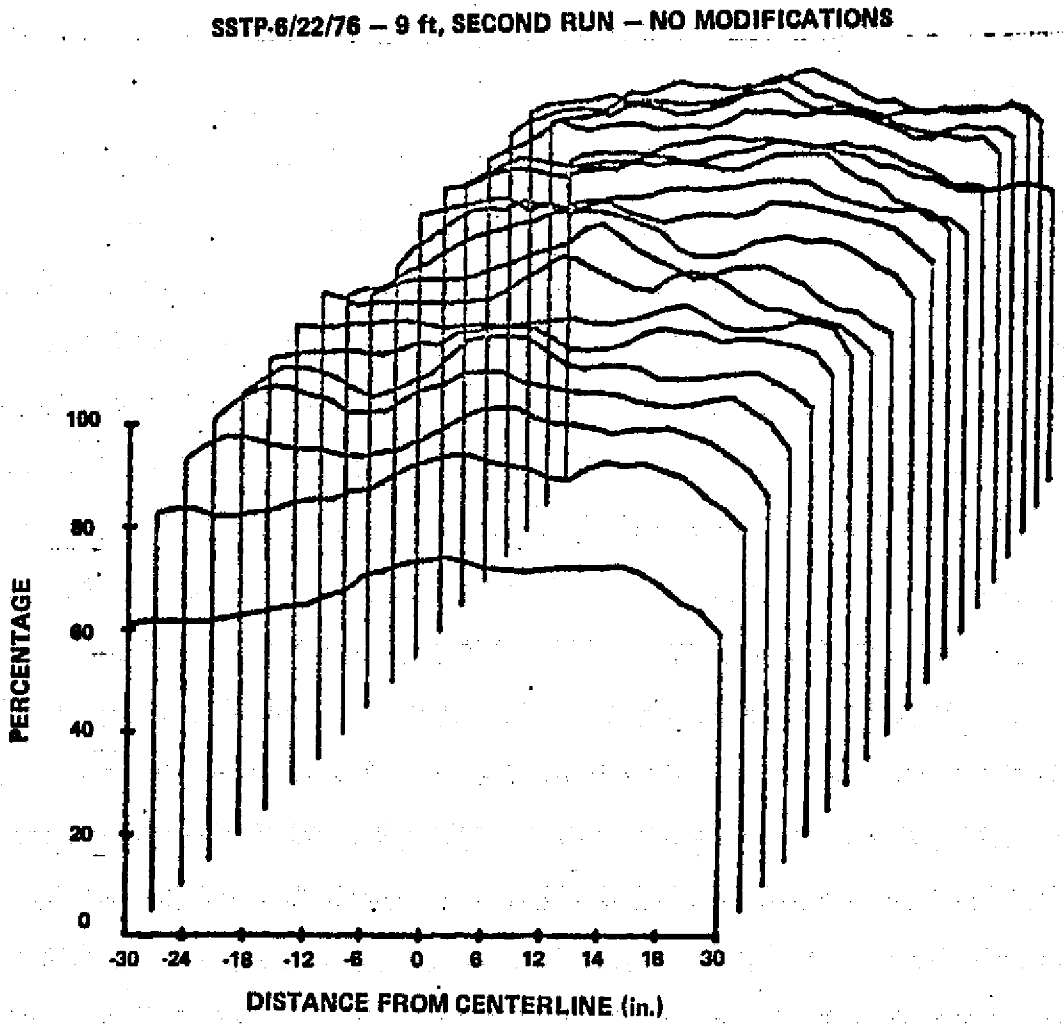

Figure C-1. Example of plot of input data.

APPROVAL

MSFC SOLAR SIMULATOR TEST PLANE UNIFORMITY MEASUREMENT

By Donald B. Griner

The information in this report has been reviewed for security classification. The report, in its entirety, has been determined to be unclassified and contains no information concerning Department of Defense or Atomic Energy Commission programs.

This document has also been reviewed and approved for technical accuracy.

F. Brooks Moore

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Director, Electronics and Control Laboratory

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