COMPUTERIZED DRAWING OF STEREOGRAPHIC PROJECTIONS

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JANUARY 1980

TECHNICAL REPORT AFML-TR-79-4137
Interim Report for period June 1974 — September 1977

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AIR FORCE/56780/13 APRIL 1980 — 100
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Stereographic Projections
Computer Program in Materials Science

A computer program was developed to plot stereographic projections for any crystal system.
FOREWORD

The preparation of stereographic projections can be time consuming and tedious, especially for non-cubic crystal systems. This study was an attempt to adapt an existing computer program to a CDC 6600/Cyber 76 mainframe computer with Calcomp plotting subroutines. Some modifications to the program plotting capabilities also were made.

The author would like to acknowledge the help of F.J. Moroz, Jr. of the Armco Steel Research Center, Middletown, Ohio in interpreting the functions of the different plotting commands in the original computer program (Reference 1).
<table>
<thead>
<tr>
<th>SECTION</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>2. PROGRAM ARCHITECTURE</td>
<td>1</td>
</tr>
<tr>
<td>3. INPUT DATA DESCRIPTION</td>
<td>5</td>
</tr>
<tr>
<td>3.1 On-Line Plotting</td>
<td>5</td>
</tr>
<tr>
<td>3.2 Off-Line Plotting</td>
<td>8</td>
</tr>
<tr>
<td>4. CONTROL CARDS</td>
<td>9</td>
</tr>
<tr>
<td>5. RESULTS</td>
<td>9</td>
</tr>
<tr>
<td>6. CONCLUSIONS</td>
<td>9</td>
</tr>
<tr>
<td>REFERENCES</td>
<td>14</td>
</tr>
<tr>
<td>APPENDIX</td>
<td>15</td>
</tr>
<tr>
<td>SOURCE LISTING OF COMPUTER PROGRAM</td>
<td></td>
</tr>
</tbody>
</table>
1. INTRODUCTION

Automating the generation of stereographic projections is of great convenience to the materials scientist. A source listing of computer programs which provides the capability to draw stereographic projections for any crystal system is contained in the appendix. This computer program has the following capabilities:

1. Draw stereographic projections of any size up to 5.4 inch radius (13 cm) on the 11 inch on-line plotter or draw stereographic projections up to 14.75 inch radius on the 30 inch off-line plotter.

2. Plot stereographic projections for plane normals, directions, or directions superimposed on plane normal projections. Hexagonal projections use the 4-index notation.

3. Up to nine different plots can be drawn per computer run for a given crystallographic system.

4. The user can adjust the spacing of the plots and the size of the drawn symbols. Also, an enclosing square can be drawn around each projection.

This program is written in FORTRAN EXTENDED code for processing on a CDC 6600/Cyber 76 computer using Calcomp Plotting Subroutines. The basic reference which was used is given in Reference 1.

2. PROGRAM ARCHITECTURE

A flow chart is contained in Figure 1. Note that subroutines are used extensively throughout the program to perform specialized tasks.

The main program acts as an organizer, reading in the key parameters, and directing the calling of appropriate subroutines. Subroutine PRO1 calculates some geometric quantities from the crystal lattice data and stores them in unlabeled common. Subroutine PRO2 computes some geometric quantities from the plane index value selected to be the center of the projection. Subroutine PRO3 reads in the index value of the center of
Fig. 1. Flowchart
Fig. 1 - Continued
Fig. 1 - Concluded
the projection and calculates various parameters which are placed in Common. Subroutine PRO4 calculates the plotting coordinates of the indices (in inches) and determines which indices are within the field of projection. The accuracy is 0.010 radian. The index coordinates are placed in common for use in subroutine PRO5. Subroutine PRO5 does the actual plotting and labeling of the indices. Subroutine PRO6 calculates quantities from the index values of directions and places them in common for use in subroutine PRO4. Subroutine PRO7 draws the projection circle, the enclosing square, and prints the title. Subroutine PRO8 can be used to permute indices for plotting. For example, by reading in a number, N, all possible combinations of indices from NNN to NNN could be generated, thereby simplifying the inputing of data. However, in this version it is inoperative.

3. DATA INPUT DESCRIPTION

The set up for the data deck structure is identical for on-line plotting and off-line plotting.

3.1 On-Line Plotting.

A typical data deck structure is shown in Table 1. The first data card takes care of some "housekeeping" chores. It is this data card which specifies the desired plot radius (in cm), the height of the symbols to be plotted (in inches), the permutation code (must be 0), and the separation distance (in inches) between plots. An unformatted read statement is used, so that the parameters must be separated by commas. If the last parameter is a 1, an enclosing square will be drawn.

The second data card which reads in a number to drive the pen to the -Y limit position in order to establish an origin should be at least -11.5.

The third data card provides information about the crystallographic system and the projection option desired. The first three parameters - A,B,C - provide the length of the crystallographic axes. The next three parameters -
TABLE 1. TYPICAL DATA DECK STRUCTURE

9.00, .070, 0, 4.0, 1
-12.0
1.00, 1.00, 1.587, 90., 90., 120., 1
-01003-02000
-01003-02001
-01003-02002
-01003-02003
00102-02003
00101-01003
00102-03000
00102-03001
01012-03002
00102-03003
00103-02003
002001-03000
002001-03001
002001-03002
002001-03003
-02000-02003
-01000001003
01030-01003
'02000-02003
003-01-02000
003-02-01000
002-0301000
001-03-02000
-01-0263000
-02-01003000

1
0 0 0 1 STD PROJ HEXAGONAL PLANES C/A=1.587
0 0 0 1
a, b, γ provide the crystallographic angles. The angles are determined by the usual crystallographic convention. The last parameter, NN, specifies the projection type requested: (a) NN=1 specifies a projection of plane normals; (b) NN=2 specifies a projection of directions; and (c) NN=3 specifies a projection of directions superimposed on plane normals. An unformatted read statement is used for this data card too.

The next group of data cards provides the indices that are to be plotted. If the hexagonal system is hexagonal (α+β+γ=300 Degrees), the 4 index system must be used. Data is entered under the format specification 313 (non hexagonal) or 413 (hexagonal). A negative index has the form: -XX. Note that although the capability exists for entering an index value greater than 9, only integers up to 9 will be plotted above the location on the projection. The data set is terminated as follows:

(a) Non-hexagonal system: Place a -1 in card columns 10-11.
(b) Hexagonal system: Place a -1 in card columns 13-14.

The next data card specifies the number of plots to be run.

The final data card set consists of the title for the stereographic projection and the index of the center of the projection. There must be as many of these sets as there are plots to be run. The plotter draws four lines of 20 characters each, so that each line begins with card columns 1, 21, 41, and 61. The index of the center spot must be of the same form as the other indices. Thus, for a hexagonal system, the 4 index notation must be used.

For the cases where plane normals (NN=1) or direction (NN=2) projections are requested, the final data set would have the arrangement:

Title Card
Index of Center of Projection
Title Card
Index of Center of Projection
Etc.

For the case where the plane normals are superimposed on directions (NN=3), the final data set would have the arrangement:
3.2 Off-Line Plotting

The advantages of off-line plotting are: (a) large plots can be run, and (b) the accuracy of plotting is greater than for on-line plotting. The disadvantage is that the turn-around time is much greater (typically, at least one day).

The setup of the data deck is the same as for on-line plotting. The second data card which reads in a number to drive the pen to the -Y limit position in order to establish an origin should be at least -19.50.
4. CONTROL CARDS

A detailed description of the control cards used in running a job will not be given since these cards change with changes in the operating systems. However, the following general comments should be helpful:

(a) The library subroutine which draws the projection circle and enclosing square must be accessed, or a similar subroutine added to the computer program.

(b) For off-line plotting, the library subroutine which places the plotting commands on magnetic tape must be accessed.

(c) For off-line plotting, the job card must contain the appropriate parameter to indicate that a magnetic tape is required to man the job. Also, a tape LABEL control card is necessary. The tape library must be notified to load the magnetic tape reel prior to the execution of the job; and after the completion of the job, the tape library must be notified to run the off-line plot.

5. RESULTS

The utility of the stereographic plotting computer program is depicted in Figures 2-4. Figure 2 shows a stereographic projection of plane normals for hexagonal titanium. Figures 3a and 3b show a stereographic projection of plane normals for face centered tetragonal Ni₄W using different unit cells. Figure 4 shows a superimposed projection of directions on plane normals for a tri-clinic crystal. These projections, which can be readily obtained, are extremely useful in x-ray and electron diffraction investigations. For example, they can be used to determine the crystallographic orientation of a portion of a foil in transmission electron microscopy work.

6. CONCLUSIONS

Computer plotting of stereographic projections provides the capability to easily and quickly plot desired projections with good accuracy.
Fig. 2. Stereographic Projection of Plane Normals in a Hexagonal Crystal System for C/A = 1.587.
Fig. 3. Stereographic Projection of Plane Normals in a Face Centered Tetragonal Crystal System (a) Projection using a unit cell where $A = B = 5.750\AA$, $C = 3.553\AA$. 

[Diagram of a tetragonal crystal system with labeled planes and indices.]
Fig. 3 (b) Projection using a unit cell where $A = B = 3.618$, $c = 3.567$. 
Fig. 4. Stereographic Projection of Plane Normals Superimposed on Directions in a Triclinic Crystal System.
REFERENCES


APPENDIX

SOURCE LISTING COMPUTER PROGRAM
PROGRAM STER (INPUT,OUTPUT,PLOT)

REALelon AND THOMAS, THE STEREORAPHIC PROJECTION AND ITS
APPLICATIONS, TECHNIQUES OF METALS RESEARCH, IIA, INTERSCIENCE,
1965, PP 107-132

-----------------------------------------------------------------------
MODIFIED BY CAPT 908 J. SHAFFRAT, AFML

DIMENSION NT(4,20)

INTEGER RET
COMMON /A/ PI
COMMON N3,N4,N5,,R,N,S,VOL,S11,S22,S33,S12,S23,S31,MD,M1,V1,U1
COMMON R1,R2,R(250),S(250),T(250),D(250),X(250),Y(250),Z(250)
COMMON /G/ ALPHA,BETA,GAMMA
COMMON /V/ HT
COMMON /I/ IH(250),IK(250),IT(250),L(250)
COMMON /I/ IR,I
COMMON /I/ IMP
COMMON /I/ I

DATA NMAX/250/
PI=2.*ASIN(1.0)

PRINT 7

7 FORMAT (1H1,T2,*OFF-LINE PLOT/)
C SET-UP FOR OFF-LINE PLOT. NOTE THAT TOTAL PLOT MUST BE LESS THAN
C 10.5 INCHES
C 10.5 INCHES
C READ PLOT RADIUS(24),HT OF PLOTTED SYMBOL (IN),NPERM=0, AND
C SEPERATION DISTANCE BETWEEN PLOTS (IN)
C THE FOLLOWING VALUES ARE RECOMMENDED
C FOR ON-LINE PLOT RADIUS=1.5, HT=0.70, NPERM=0, SEP=0.80
C FOR OFF-LINE PLOT RADIUS=1.5, HT=1.00, NPERM=0, SEP=0.80
C TO DRAW THE ENCLOSING RECTANGLE, RET=1
C IF A RECTANGLE IS NOT DESIRED, RET=2
C READ *, RADIUS, HT, NPERM,SEP,RET
C IF (RADIUS=1) RET=0
C PRINT 59, RADIUS, HT, NPERM,SEP
59 FORMAT (T2,*OFF-LINE PLOT RADIUS IS *, RADIUS, * CM, HT OF NUMBERS IS*, HT, 
* INCHES, NPERM IS *, NPERM, * INCHES*)
C SEPARATION BETWEEN PLOTS IS *, SEP, * INCHES*
C IF RET=1 OR 2 PRINT 143
C 143 FORMAT (F22,9.3, * ENCLOSING RECTANGLE*)
C RADIUS IS THE SPACING BETWEEN CENTERS OF THE PLOTS
C HT=1 IS THE HEIGHT OF THE ENCLOSING SQUARE
C HT=2 IS THE HEIGHT OF THE ENCLOSING RECTANGLE
C HT=3 IS THE HEIGHT OF THE ENCLOSING TRAPEZOID
C INITIALIZE ORIGIN AT BOTTOM OF PAGE
C READ X0,Y0, ORIG
C MOVE ORIGIN TO CENTER OF PAGE
C READ IN PARAMETERS OF CRYSTAL LATTICE
C A,B,C ARE THE LENGTHS OF THE 3 CRYSTALLOGRAPHIC AXES
C ALPHA, BETA, GAMMA ARE THE THREE CRYSTALLOGRAPHIC ANGLES
C NN=1 PROVIDES A PLANE PROJECTION
C NN=2 PROVIDES A DIRECTION PROJECTION
C NN=3 PROVIDES A DIRECTION PROJECTION SUPERIMPOSED
C ON A PLANE PROJECTION
C READ *, A,B,C,ALPHA,BETA,GAMMA,NN
C TEST FOR AN HEXAGONAL CRYSTAL STRUCTURE
C IF HEXAGONAL STRUCTURE, USE 4-INDEX NOTATION

16
IF (ABS(ALPHA+BETA+GAMMA-300.0) .LE. 0.001) NSS=2
IF(NN.EQ.1.AND.NSS.EQ.1) PRINT 40
IF(NN.EQ.1.AND.NSS.EQ.2) PRINT 41
IF(NN.EQ.2.AND.NSS.EQ.1) PRINT 42
IF(NN.EQ.2.AND.NSS.EQ.2) PRINT 43
IF(NN.EQ.3.AND.NSS.EQ.1) PRINT 44
IF(NN.EQ.3.AND.NSS.EQ.2) PRINT 46

43 FORMAT (/T2,*PLOT PLANE PROJECTIONS- NON-HexAGONAL CRYSTAL STRUCT*)
44 FORMAT (/T2,*PLOT DIRECT PROJECTIONS- NON-HexAGONAL CRYSTAL STRUCT*)
45 FORMAT (/T2,* PLOT PLANE & DIRECTION PROJECTIONS- NON-HexAGONAL*)

C PRO1 CALCULATES SOME BASIC QUANTITIES USED LATER
CALL PRO1
C NPERM CAN BE USED TO PROVIDE PERMUTED INDICES.
C THIS WOULD ELIMINATE THE NEED FOR DATA CARDS WITH THE INDICES.
C HOWEVER, THIS ASPECT OF THE PROGRAM IS NOT DEVELOPED.
C SET NPERM=4
IF (NPERM.NE.0) GO TO 150
C THIS PART OF THE PROGRAM READS THE INDICES, COUNTS THEM,
C AND STORES THEM IN ARRAYS.
C NOTE: HEXAGONAL INDICES MUST BE GIVEN IN 4-INDEX NOTATION
I=0
GO TO (21,22), NSS
201 I=I+1
READ 2,IN(I),K(I),L(I), M
2 FORMAT (313,12)
IF (M.LT.0) GO TO 4
GO TO 201
202 I=I+1
READ 22,IN(I),K(I),L(I), M
22 FORMAT (413,12)
IF (M.LT.0) GO TO 4
GO TO 202
4 I=I-1
IF (I.GT.NMAX) PRINT 3,NMAX
9 FORMAT (3(I),3I4,3X,*YOU HAVE EXCEEDED ARRAY DIMENSIONS FOR *,
*A THE INDICES*, /, I3, *THE ARRAY DIMENSIONS ARE SET FOR *,14,
B 3(I) )
29 PRINT 44, I
44 FORMAT (/T2,*NO. OF INDICES USED WAS *,I5)
C THIS PART OF THE PROGRAM CALCULATES THE APPROPRIATE COORDINATES
C AND PLOTS THEM.
NNO=1
NN1=0
10 READ IN NUMBER OF PLOTS DESIRED (1 TO 9)
120 READ 5, I
5 FORMAT (I)
C THIS BRANCH TRANSFERS THE PROGRAM TO THE APPROPRIATE PLACE
C DEPENDING ON THE TYPE OF PROJECTION REQUESTED.
GO TO (23,21,32), NN
C PP02 CALCULATES PARAMETERS FOR PLANE PROJECTIONS
20 CALL PRO2(I,NSS)
C A TRANSFER TO STATEMENT 30 BELOW IS DONE IF A PLANE PROJECTION IS
REQUESTED.
GO TO (59,51), NN
C PP06 CALCULATES PARAMETERS FOR DIRECTIONS
21 CALL PRO6 (1,J,V,4,NSS)
C REQUESTED.
GO TO (59,51), NN
C THIS SECTION PROVIDES FOR PLOTTING PLANES AND DIRECTIONS ON THE
C SAME PLOT.
92 NN=3
GO TO 10
C READ TITLE, NEW LINES BEGIN WITH CC1,CC21,CC41, AND CC61 OF THE
C DATA CARD.
C NOTE: THERE MUST BE AS MANY TITLE CARDS AS PLOTS DESIRED
READ 450, (*) (NT(KA,JA),JA=1,20),KA=1,6)
450 FORMAT (9(A1))
650 GO TO 111
C PRO1 DRAWS THE CIRCLE OF THE PROJECTION AND THE ENCLOSING SQUARE.
C ALSO IT PRINTS THE TITLE.
0 CALL PRO1(M1,11,NT,RAJI,RET)
NNO=NNO+1
C THIS SECTION ACTUALLY CALC POSITION COORDS, AND PLOTS PLANES
C AND DIRECTIONS ON THE SAME PLOT.
DO 99 I1=1,2
NN=181
GO TO(20,21),HN
C PRO2 READS THE CENTER INDEX AND CALC SEVERAL PARAMETERS
51 CALL PRO2(NNN,U,V,W,NN5)
C PLOTTING OF THE INDICES IS DONE IN THIS DO-LOOP
DO 10 N=1,1
C PRO4 CALC PLOTTING COORD AND DETERMINES IF INDEX IS WITHIN
10 CALL PRO4(NNSW)
C THE PROJECTION FIELD.
C ACCURACY IS 0.10 RADIAN
CALL PRO4(N,NNSW)
GO TO (11,100),NNSW
C PRO5 DOES THE PLOTTING OF ALL INDICES
11 CALL PRO5(N,NNSW,NN)
100 CONTINUE
99 CONTINUE
NNO=NNO+1
GO TO 30
C BEGIN SECTION FOR PLOTTING PLANE OR DIRECTION PROJECTIONS
50 DO 310 I1=1,1
C READ TITLE. NEW LINES ARE GIVEN WITH CC1,CC2,CC3,AND CC61 OF THE
C DATA CARDS.
C NOTE: THERE MUST BE AS MANY TITLE CARDS AS PLOTS DESIRED.
READ 450, (*) (NT(KA,JA),JA=1,20),KA=1,6)
IF (II.GT.1) GO TO 111
C PRO7 DRAWS THE CIRCLE OF THE PROJECTION AND THE ENCLOSING SQUARE.
C ALSO IT PRINTS THE TITLE.
30 CALL PRO7(M1,11,NT,RAJI,RET)
C PRO3 READS THE CENTER INDEX AND CALC SEVERAL PARAMETERS
51 CALL PRO3(NNN,U,V,W,NN5)
C PLOTTING OF THE INDICES IS DONE IN THIS DO-LOOP
DO 10 N=1,1
C PRO4 CALC PLOTTING COORD AND DETERMINES IF INDEX IS WITHIN
10 CALL PRO4(NNSW)
C THE PROJECTION FIELD.
C ACCURACY IS 0.10 RADIAN
CALL PRO4(N,NNSW)
GO TO (31,310),NNSW
C PRO5 DOES THE PLOTTING OF ALL INDICES
11 CALL PRO5(N,NNSW,NN)
310 CONTINUE
C END OF SECTION FOR PLOTTING PLANE OR DIRECTION PROJECTIONS
GO TO 97
30 STOP
111 CALL PLOT (0,0,0,0,3)
CALL PLOT (RADPL,0,0,-3)
IF (NN12.EQ.3) GO TO 36
GO TO 30
C PROB NOT OPERATIONAL. BE SURE NPERM=0
C
SUBROUTINE PRO1
C THIS PROGRAM CALCULATES BASIC QUANTITIES FROM THE CRYSTAL LATTICE
C DATA AND PLACES THEM IN COMMON.
COMMON N3,N0, P,Q,R,S,VOL,S11,S22,S33,S12,S23,S31,MO,W,V,U
1RAD1,R2H(250),G(250),F(250),X(250),Y(250),Z1(250),Z2(250),SH,
2SK,SL,Y,V2Z2,Y2Z2,X,Y
3,A,3C,ALPHA,3ETA,GAMMA
COMMON /A/ PI
P=cos(ALPHA*PI/180.0)
Q=cos(ETA*PI/180.0)
R=cos(GAMMA*PI/180.0)
RS=SQR(T(1.0-R*R)
VOL=A*B*C*SQR(T(1.-P*P-Q*Q-R*R)+2.0*P*Q*R)
S11=3.0*C*C*(1.-P*P)
S22=3.0*C*C*(1.-Q*Q)
S33=3.0*C*C*(1.-R*R)
S12=3.0*C*C*(P*Q-R)
S23=3.0*C*C*(Q-R*P)
S31=3.0*C*C*(R-P*Q)
W=(C+SQR(T(1.0-Q-Q*(1.-P*R)/RS)**2))
W/A/W0
V=((W*C*(P-Q*R))/(B*R*S))
U=((-C+&323)+&323)/A
R=(RAD1*RAD1+&323)
RETURN
END
C
SUBROUTINE PRO2
C THIS PROGRAM CALCULATES VARIOUS QUANTITIES FROM THE CRYSTAL LATTICE
C DATA AND PLACES THEM IN COMMON.
COMMON N3,N0, P,Q,R,S,VOL,S11,S22,S33,S12,S23,S31,MO,W,V,U
1RAD1,R2H(250),G(250),F(250),X(250),Y(250),Z1(250),Z2(250),SH,
2SK,SL,Y,V2Z2,Y2Z2,X,Y
3,A,3C,ALPHA,3ETA,GAMMA
COMMON /C/ IH(250),K(250),IT(250),L(250)
DO 5 I=1,IC
H(I)=IH(I)
G(I)=IK(I)
F(I)=IL11
D(I)=VOL*SQR(T(S11*H(I)*H(I))+S22*G(I)*G(I))+S33*F(I)*F(I))+(2.*C)*P
S12*H(I)*G(I)+(2.*S31*H(I)*F(I)+(2.*S23*G(I)*F(I)))
X1(I)=RAD1*H(I)*G(I)/A
Y1(I)=RAD1*G(I)+(16*I/I)+H(I)*Q/A)/RS
Z1(I)=RAD1*G(I)+(H(I)*U+G(I)*V+F(I)*W)/A
5 CONTINUE
RETURN
END
C
SUBROUTINE PRO3(INH1,INH2,IMP1,IMP2,INH3,IMP3)
C THIS PROGRAM READS IN THE INDEX OF CENTER OF THE PROJECTION AND
C CALCULATES VARIOUS PARAMETERS WHICH ARE PLACED IN COMMON.
C NOTE: A HEXAGONAL SYSTEM REQUIRES 4-INDEX NOTATION
C ALSO IF A NEGATIVE NUMBER ON THE DATA CARD AFTER THE INDEX DATA
C WILL TERMINATE THE INPUTTING OF DATA.
COMMON N3,N0, P,Q,R,S,VOL,S11,S22,S33,S12,S23,S31,MO,W,V,U
1RAD1,R2H(250),G(250),F(250),X(250),Y(250),Z1(250),Z2(250),SH,
2SK,SL,Y,V2Z2,Y2Z2,X,Y
3,A,3C,ALPHA,3ETA,GAMMA
COMMON /A/ PI
P=cos(ALPHA*PI/180.0)
Q=cos(ETA*PI/180.0)
R=cos(GAMMA*PI/180.0)
RS=SQR(T(1.0-R*R)
VOL=A*B*C*SQR(T(1.-P*P-Q*Q-R*R)+2.0*P*Q*R)
S11=3.0*C*C*(1.-P*P)
S22=3.0*C*C*(1.-Q*Q)
S33=3.0*C*C*(1.-R*R)
S12=3.0*C*C*(P*Q-R)
S23=3.0*C*C*(Q-R*P)
S31=3.0*C*C*(R-P*Q)
W=(C+SQR(T(1.0-Q-Q*(1.-P*R)/RS)**2))
W/A/W0
V=((W*C*(P-Q*R))/(B*R*S))
U=((-C+&323)+&323)/A
R=(RAD1*RAD1+&323)
RETURN
END
C
IRAOIR2,4(25C),G(25C),F(250),O(250),Xl(250),Yl(250),zl(250),SN, C00262
2SK,SL,EK2,Y2,Z2,XY, C00263
3,4,5,C,ALPHA,ETA,GAMMA, C00264
GO TO (4,31),M.SS, C00265
4,5R,2,1,HN,NX,NL,N, C00266
2 FORMAT(313,12) C00267
CALL PLOT(10,3,0,-3), C00268
1 CALL PLOT(3,3,1,0,0), C00269
5 FORMAT(T24*PROGRAM TERMINATED FROM PRO3*), C00270
PRINT 5, C00271
GO TO (49,31), C00272
NSW11, C00273
GO TO (1,3),NN, C00274
1 SM=-NM, C00275
SK=-NK, C00276
SL=-NL, C00277
E=VOL/SQRT((S11*SHHZ)+(S22*SKSK)+(S33*SL*SL)+(Z2*S12*SH*SK)+(Z2*S31*SL*SH)), C00278
X2=RADI*N+L/A, C00279
Y2=RADI*(S/K)+(SH*RAI/A)/RS, C00280
Z2=RADI*(SH+SK+SL*W)/A, C00281
GO TO 3, C00282
9 SU=-NM, C00283
SV=-NL, C00284
SHz-NH, C00285
SV=-(NK-41), C00286
SHz-NL, C00287
GO TO 4.3, C00288
END, C00289
C COUTU11E, C00290
THIS PROGRAM CALCULATES THE PLOTTING COORDINATES OF THE INDICES C00291
AND DETERMINES IF THE INDEX IS WITHIN THE FIELD OF PROJECTION C00292
ACCURACY IS 0.10 RAWIAN, C00293
COMMON N1,NO, PQ,R,RS,VOLSII,S22,S33,S12,S23,S31,WO,WVU, C00294
ZSK,SL,EtE?9y?,Z29xgy, C00295
39&,3,C,AL*HA,93ETA,GA'4A, C00296
C00297
OENO49X2*(X1(N)-X2)4Y2*(Y1(N5-Y2),Z2*(L(N)-ZZ), C00298
IFC(OENOHS, C00299
10 NSW2, C00300
GO TO 14, C00301
21 X3.(X2'Y1(N)*Y2.Z1(N)'Z2)-Xl(f4)(Y2 4
Y24Z2'Z2))/OENOII, C00302
Y3:(Y2*(X2*Xl(N)4Z2Z1(4)-Y1CNIIX2*X2Z2*Z2))/OENON, C00303
23=(Z2*( XII ,(Y2*Y2)Y2+1(NIS-Zl(N)*1X2'X2.Y2'Y2))/OENON, C00304
TzX3*X3*Y 3Y3.Z3*Z3, C00305
IFIT-R2) 9,6,10, C00306
6IFISHI9,11,9, C00307
20

THIS PAGE IS BEST QUALITY PRACTICABLE
11 IF(SK)=9,12,9
12 X=X3
Y=Y3
GO TO 14
9 S=SQR((X2+X2+Y2+Y2))
A11=-(X2+Z2)/(RAOI*S)
A12=-(Y2+Z2)/(RAOI*S)
A13=S/RADI
A21=Y2/S
A22=X2/S
X=-(A11*X3+A12+Y3+A13*Z3)
Y=A21*X3+A22*Y3
14 RETURN
END
C
C $$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
C
SUBROUTINE PRO5TN, NSS, NNA
C THIS PROGRAM DOES THE PLOTTING OF THE INDICES
COMMON NND, N, P, Q, R, KS, VOL, S11, S22, S33, S12, S23, S31, W0, W1, W2, U0, U1, U2
COMMON RADI, S
COMMON /3/ HT
COMMON /9/ IA18,
DIMENSION NM(4), NJ(4), NAST(4), RDF(4)
C NO IS USED TO PLOT A LINE OVER AN INDEX INDICATING A NEG VALUE
C NR IS USED TO PLOT A BLANK SPACE OVER AN INDEX INDICATING A POSITIVE VALUE
C NSYM SPECIFIES THE SYMBOL USED TO PLOT THE POINT
C PLANES HAVE AN X
C DIRECTIONS HAVE A DIAMOND
IF (NNA=1.1) NSYM=4
IF (NNA=2.2) NSYM=5
KH=H(N)
KK=G(N)
KL=F(N)
IND=3
GO TO (291, 292), NSS
C THIS SECTION DETERMINES HEXAGONAL 4-INDICES. THE INPUTTED 4-INDICES WERE CONVERTED TO 3-INDICES FOR COMPUTATIONAL REASONS.
291 IND=6
GO TO (2301, 2002), NNA
C HEXAGONAL PLANES
2001 NJ(1)=KH
NJ(2)=KK
NJ(3)=(KH+KK)
NJ(4)=KL
GO TO 203
C HEXAGONAL DIRECTIONS
2002 RDF(1)=2*(KK=KH)/3
C HEXAGONAL DIRECTION TEST FOR TRUNCATION OF INDEX DUE TO RECOMPUTATION
C PROGRAM WILL PLOT AN ASTERISK ABOVE TRUNCATED INDEX
RDF(2)=2*(KK=KH)/3
RDF(3)=2*(KH+KK)/3
RDF(4)=KL
DO 45 IL=1,4
NJ(IL)=RDF(IL)
NAST(IL)=1
IF (AABS(J(NJ(IL))=RDF(IL)) GT 1.E-3) NAST(IL)=2
45 CONTINUE
GO TO 203
C THIS PAGE IS BEET QUALITY PRACTICABLE
C THIS SECTION DETERMINES NON-HEXAGONAL 3 INDICES

C TEST FOR SIGN OF INDEX

C DRAW SPECIAL SYMBOL IN CENTER FOR PLANE PROJECTION (SQUARE)

C DRAW SPECIAL SYMBOL IN CENTER FOR DIRECTION PROJECTION (TRIANGLE) AND

C TEST FOR INDEX INTEGER EXCEEDING 9

C DRAW THE INDEX INTEGERS

C DRAW THE INDEX SYMBOL

C POSITION PEN ABOVE INDEX THAT WILL BE LABELED

C MOVE PEN TO SPACE NUMBERS

C CALC ARRAY VALUE FOR TABLE FOR THE INDEX INTEGERS

C TEST FOR INDEX INTEGER EXCEEDING 9

C DRAW THE INDEX INTEGERS

C POSITION PEN ABOVE NUMBER TO DRAW LINE INDICATING NEG

C DRAW ASTERISK FOR SIX DIRECTIONS TO INDICATE TRUNCATION

C PRINT 0

C PRINT 1

C PRINT 10

C PRINT 11

C PRINT 16

END
SUBROUTINE PRO6 (IC,UZ,VZ,W2,NSS)

C THIS PROGRAM CALCULATES QUANTITIES FROM INDEX VALUES OF DIRECTIONS

C AND PLACES THEM IN COMMON FOR USE IN PRO4.

COMMON N1,N0, P0,Q0,R0,S0,VOL,S11,S22,S33,S12,S23,S31,N0,W,U0,VO

RA0,RA2,H(250),G(250),F(250),D(250),X(250),Y(250),Z(250),S,I

2K0,SL0,E2X2,Y2,Z2,K

3,A,B,CA,OM,ET,4,GA

COMMON /G/ IH(250),IK(250),IT(250),IL(250)

IF (NSS.EQ.2) GO TO 20

DO 6 I=1,IC

H(I)=IM(I)

G(I)=K(I)

F(I)=L(I)

CONTINUE

6 CONTINUE

RETURN

20 DO 9 I=1,IC

X(I)=RADI*(H(I)+AGI**2)*I

Y(I)=PLOI**2.*PH(I)*C*(P-Q*RS)/D(I)

Z(I)=RAI*ZC**(F(I)*UZ+CW**2)*G(I)*VZ+C*(F(I)*UZ+CW**2)*F(I)*UZ+FW

1G(I)=A*(G(I)*H(I)+H(I)*Z(I))/D(I)

CONTINUE

RETURN

END

C

SUBROUTINE PRO7 (W1,H1,N,T,RADI,RE)

C THIS PROGRAM DRAWS THE PROJECTION CIRCLE, THE ENCLOSING SQUARE, AND

C PRINTS THE TITLE.

DIMENSION NT(4,20)

COMMON /A/ PI

INTEGER RET

RADI=RADI*2.54

W1=H1*2.

H1=W1*2.

CALL RECT (M1,M1,NT,RADI,RE)

C CALL A SPECIAL CALC0P ROUTINE- MUST USE SPECIAL

C CONTROL CARDS TO ACCESS IT.

IF (RET.EQ.1) CALL RECT (M1,-M1,H1,H1,3,0,3)

C THIS SECTION OF THE PROGRAM DRAWS THE PROJECTION CIRCLE

C DRAW CIRCLE USES A SPECIAL CALC0P ROUTINE- MUST USE SPECIAL

C CONTROL CARDS TO ACCESS IT.

CALL CIRCLE (400,0.0,0.3,350.0,RAD,RAD,6,0)

C PRINT TITLE FROM NT ARRAY. TITLE WILL BE PLACES IN LOWER

C LEFT-HAND CORNER BETWEEN SQUARE AND CIRCLE.

C LETTER HT FIXED AT 0.126 INCH

CALL PLOT (0.0,0.0,0.3)

DO 90 LS=1,4

90 CONTINUE

RETURN

END
C SUBROUTINE PROB (INPERM,NSS)
C THIS SUBROUTINE COULD BE DEVELOPED TO PERMUTE INDICES IN ORDER TO
C AVOID READING IN THE CARD DATA.
RETURN
END