engineering design graphics journal

Published by the Engineering Design Graphics Division, American Society for Engineering Education

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ENGINEERING DESIGN GRAPHICS JOURNAL is published - one volume per year, three numbers per volume, in Winter, Spring and Fall - by the Engineering Design Graphics Division of the American Society for Engineering Education - for teachers of Engineering Graphics, Computer Graphics and Design Graphics.

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ENGINEERING DESIGN GRAPHICS JOURNAL OBJECTIVES:

The objectives of the JOURNAL are:

1. To publish articles of interest to teachers of Engineering Graphics, Computer Graphics and allied subjects.

2. To stimulate the preparation of articles and papers on the following topics (but not limited to them):

   A. Engineering Graphics
   B. Creative Design
   C. Research in Graphics
   D. Graphic Methods
   E. Computer Graphics
   F. Teaching Methods and Techniques

3. To encourage teachers of Graphics to innovate on, experiment with, and test appropriate techniques and topics to further improve quality of and modernize instruction and courses.

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1974 -- Rensselaer Polytechnic Institute

1975 -- Colorado State University

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The Editor welcomes articles submitted for publication in the JOURNAL. The following is an author style guide for the benefit of anyone wishing to contribute material to Engineering Design Graphics Journal. In order to save time, expedite the mechanics of publication, and avoid confusion, please adhere to these guidelines.

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2. Each page of the manuscript is to be consecutively numbered.

3. Two copies of each manuscript are required.

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proudly announces that Mr. Arnold Cammarata, formerly Vice-President of Marketing at Teledyne-Post, is now joining our firm.

He and I, together with the other members of our organization, are looking forward to serving the educational field with increased devotion.

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A COMPUTER GRAPHICS PACKAGE

Clyde H. Kearns
Professor of Engineering Graphics and
Professor of Computer and Information Science
The Ohio State University

The electronic digital computer is more than twenty-five years old. Computers have changed a great deal in this quarter-century of development. During the early years, a few large vacuum-tube systems, specially designed and constructed at a number of universities and research centers, solved complex mathematical problems. Input and output procedures, for reading character data from punched cards and tape, and printing out results, were slow and difficult.

Today's widespread and ever-increasing use of the computer is a matter of common knowledge. Computer technology is affecting almost every facet of modern society. Data processing systems are available over a wide range of sizes, costs, and differing characteristics. Systems are modular and flexible, and the system designer makes use of a variety of input and output devices. These include terminals that provide graphic displays, some interactive, and several types of incremental plotters for generating hard copy of annotated line drawings on paper, film, or other medium.

The graphic language plays a vital role in the communication of ideas and information. Sketches and layouts and finished drawings, charts, and illustrations are essential to the various stages in the design, fabrication, installation, and operation of manufactured products, machines, and structures. The preparation of these drawings represents a large investment of time and effort. Drafting is a major engineering cost item. Engineering cost is often a major item in a project budget.

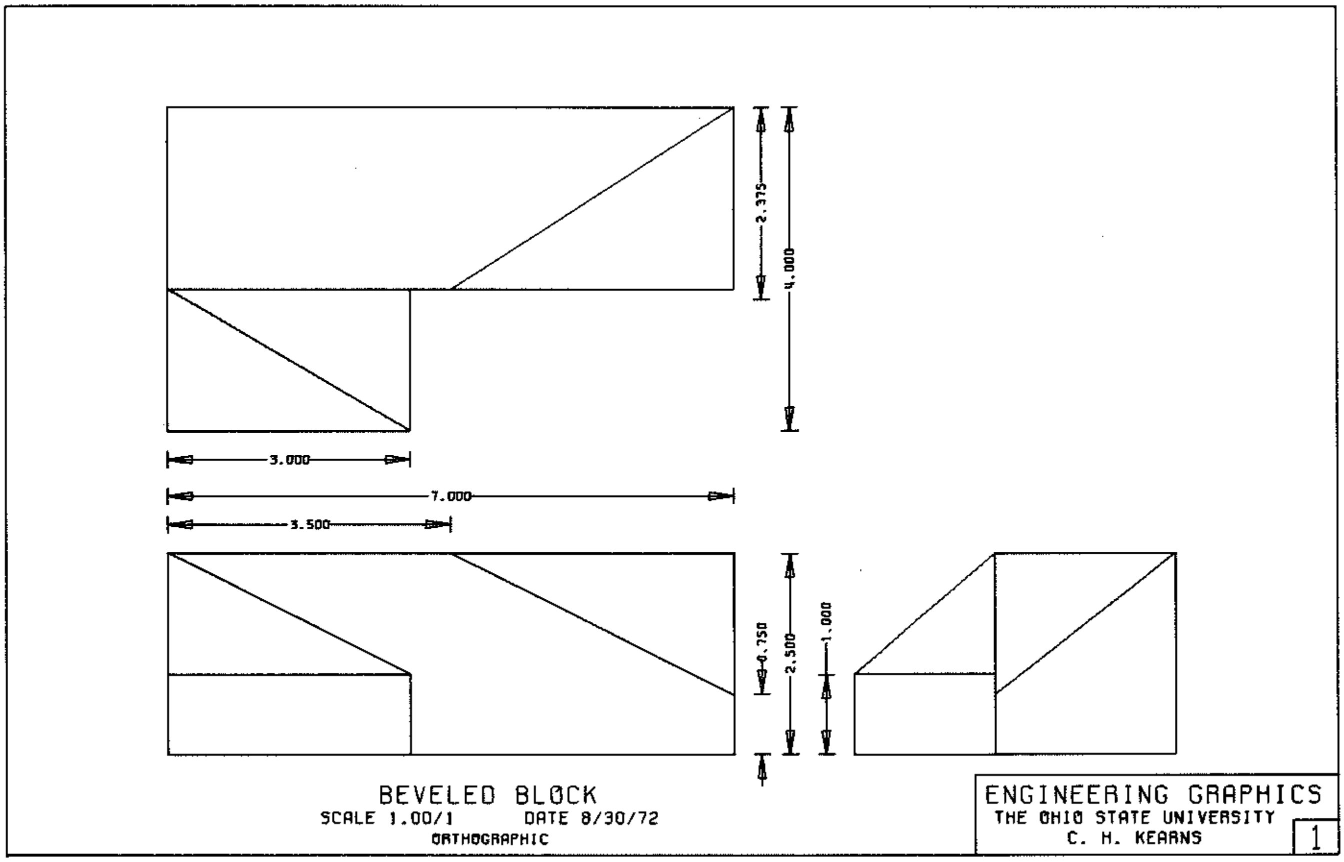
The computer is a powerful computational tool. Its use has led to radical changes in engineering methods and procedures. Indeed, it is now possible to obtain solutions to problems that would not have been attempted a few years ago. Many projects of major import, our space program being the most obvious, would be impossible without computers to carry out complex arithmetic processing of large volumes of numeric data. When the computer can be used, with like success, for the processing of graphic information, and particularly for the production of dimensioned engineering drawings, a major goal will have been achieved.

Computer-directed graphics are now employed in a number of specialized areas, notably printed circuit artwork and the preparation of certain types of schematic drawings, maps, and precise undimensioned layouts for inspection and quality control. The general development of automated drafting, however, is proceeding slowly. This is so for a number of reasons. Higher level programming languages are only a little more than ten years old. Graphic output devices are even newer. Many engineers are unfamiliar with computer techniques. Moreover, mechanical drafting is a laborious and complicated process. An engineering drawing does not have to be accurate per se. It must, on the other hand, convey an enormous amount of information and conform to certain standards and conventions. The programming of a dimensioned detail drawing, followed by computer processing, followed by automated plotting, is more costly than manual drafting unless the program is sufficiently flexible to be used many times.

Engineering schools have long presented courses in graphics. Most engineering students are now exposed to at least one course in computer programming. In a recent issue of this journal, Professor Hall (1) of Louisiana State University presented a lucid and convincing argument for the inclusion of computer graphics in beginning courses. Four introductory FORTRAN programs, for the plotting of orthographic, isometric, and axonometric views, appear in the article. Professor Hall recommends that students be encouraged to modify or add to the programs. This will certainly strengthen the student's understanding of graphics, for one must thoroughly understand all the principles involved in an application in order to program it.

Engineering students soon recognize the value of the computer. Early in their work they are shown how the computer can assist them in analyzing electrical circuits, in solving material and energy balances, in designing structures, and in a variety of other significant

(Illustrations follow - Text Continued on p. 12)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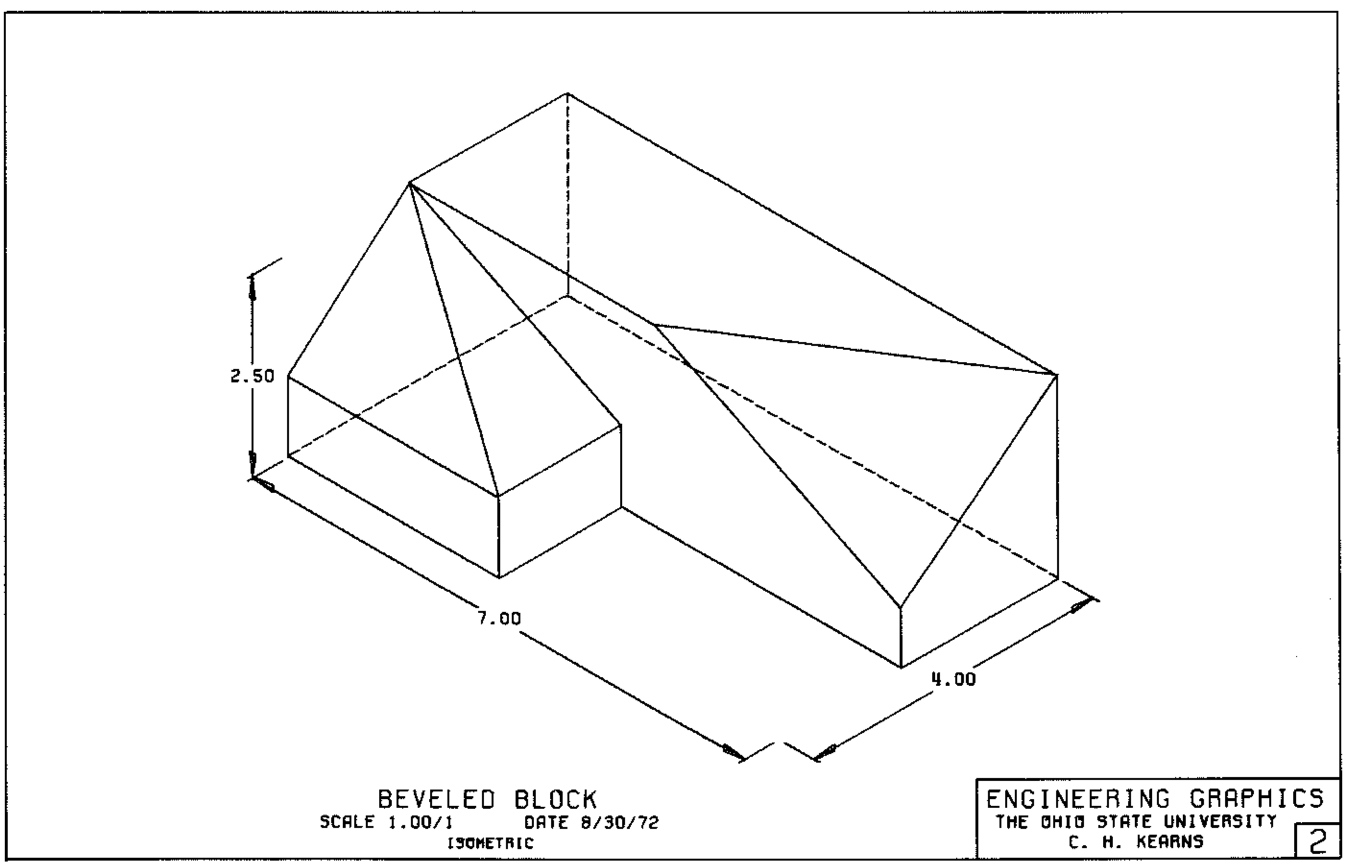
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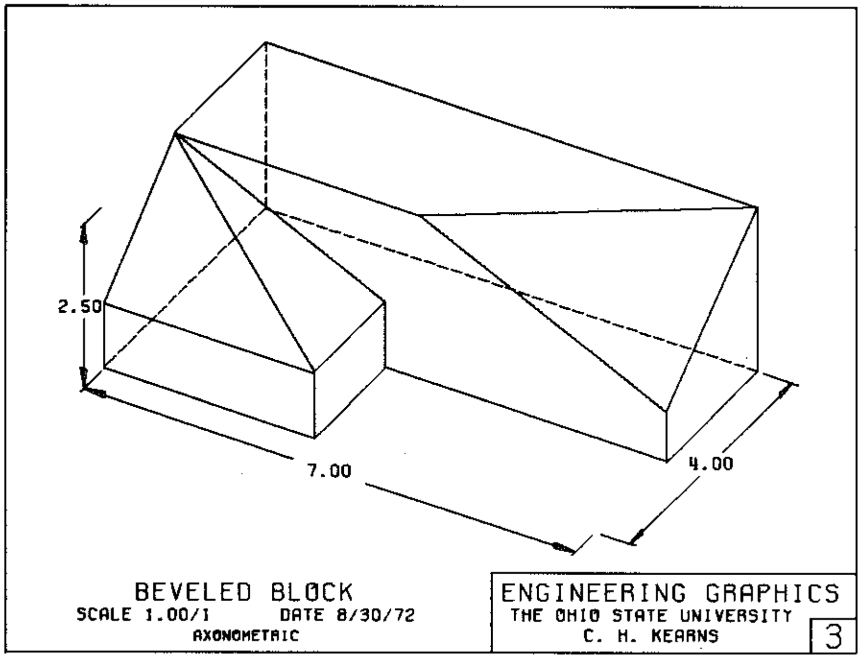
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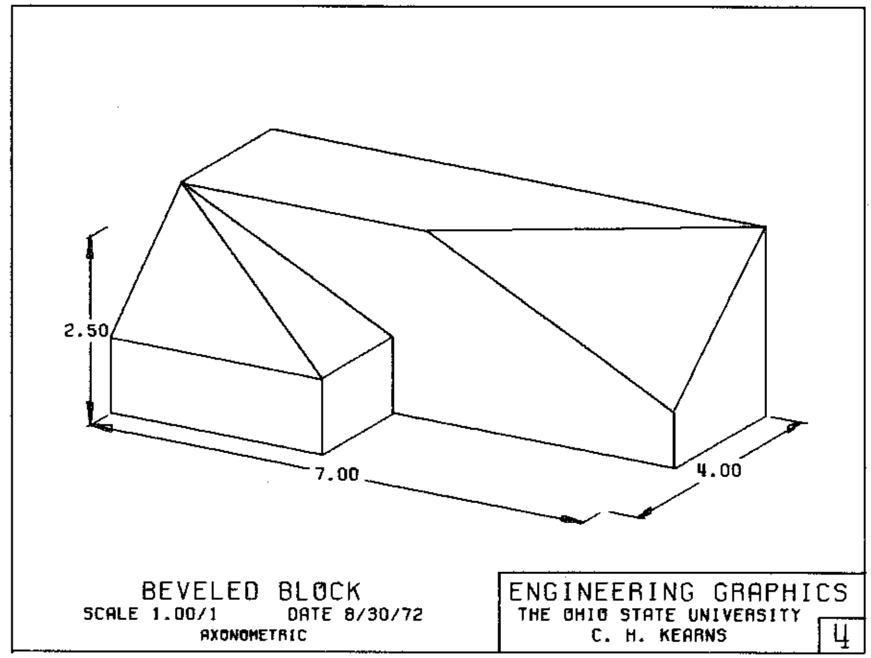
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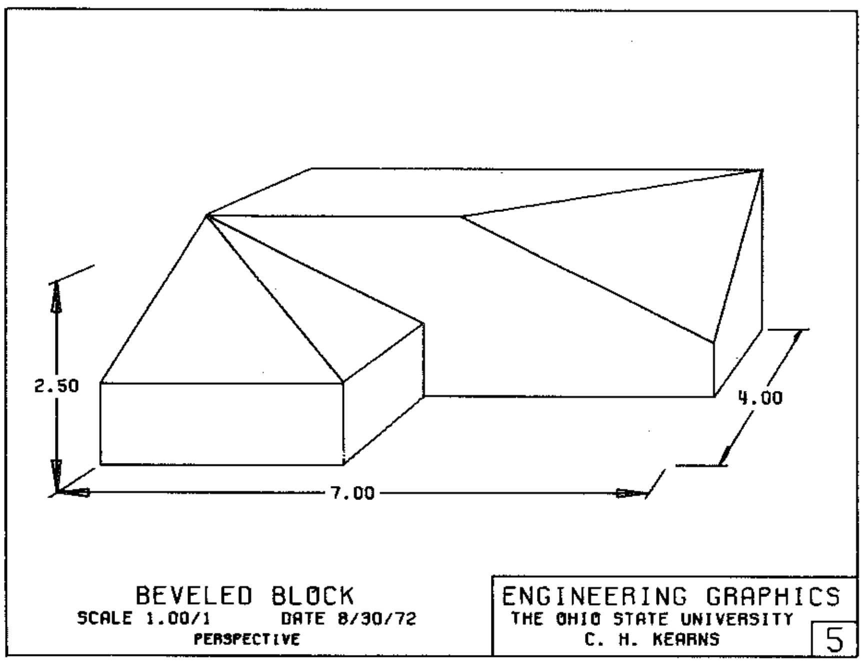
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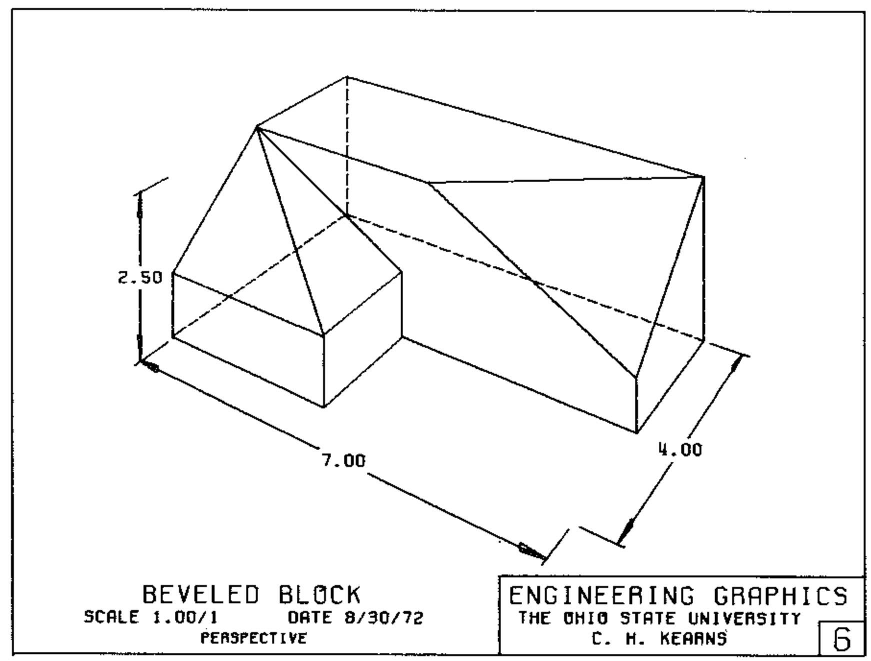
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```fortran
C  COMPUTER GRAPHICS PACKAGE.  FORTRAN PROGRAMMING LANGUAGE.
C  COMPUTER-GENERATED ENGINEERING DRAWINGS OF OBJECT WITH PLANE SURFACES
C  ONLY.  ALL SURFACES FULLY VISIBLE OR INVISIBLE.  PROGRAM PROCESSED BY
C  IBM SYSTEM/370 MODEL 165 DATA PROCESSING SYSTEM EMPLOYING FORTRAN G1
C  COMPILER, STANDARD CALCOMP PLOTTING SUBROUTINES, AND CALCOMP MODEL 563
C  DRUM-TYPE DIGITAL PLOTTER WITH 10-MIL INCREMENTAL STEP.
C        W,D,H = OBJECT OVERALL WIDTH, DEPTH, AND HEIGHT IN INCHES.
C        NSFS  = NUMBER OF PLANE SURFACES.
C        NPTS  = NUMBER OF POINTS.
C        XC,YC,ZC = POINT WIDTH, DEPTH, AND HEIGHT COORDINATES IN INCHES,
C                ORIGIN AT LOWER LEFT FRONT CORNER OF OBJECT.
C        NCRS  = SURFACE NUMBER OF CORNERS.
C        NPT   = SURFACE POINT NUMBERS IN PLOT SEQUENCE.
C        X,Y,Z = SURFACE WIDTH, DEPTH, AND HEIGHT COORDINATES IN INCHES,
C                ORIGIN AT LOWER LEFT FRONT OR LOWER RIGHT FRONT CORNER
C                OF OBJECT.
C        VIS   = SURFACE VISIBILITY CODED TRUE OR FALSE.
C        MODE  = PICTORIAL DRAWING MODE CODED AS FOLLOWS:
C                  1 FOR VISIBLE SURFACES ONLY, NO DIMENSIONS.
C                  2 FOR VISIBLE SURFACES ONLY, OVERALL DIMENSIONS.
C                  3 FOR ALL SURFACES, NO DIMENSIONS.
C                  4 FOR ALL SURFACES, OVERALL DIMENSIONS.
C        XO,YO,ZO = WIDTH, DEPTH, AND HEIGHT DIMENSIONS OF LINE-OF-SIGHT
C                PRISM.  ALL DIMENSIONS POSITIVE FOR STATION POINT ABOVE
C                AND TO THE RIGHT OF FRONT CORNER OF OBJECT.
C        THETA = CLOCKWISE LATERAL ANGLE OF 1ST ROTATION OF OBJECT ABOUT
C                VERTICAL AXIS, 0 TO 90 DEGREES.
C        DELTA = COUNTER-CLOCKWISE ELEVATION ANGLE OF 2ND ROTATION OF
C                OBJECT ABOUT HORIZONTAL-FRONTAL AXIS, 0 TO 90 DEGREES.
C        DWGNO = DRAWING NUMBER.
C        TITLE = DRAWING TITLE (28 CHARACTERS MAX).
C        NCT   = NUMBER OF CHARACTERS IN TITLE.
C        SCALE = DRAWING SCALE = RATIO DRAWING SIZE/OBJECT SIZE.
C        DATE  = DRAWING DATE IN FORM XX-XX-XX (8 CHARACTERS MAX).
C
      LOGICAL VIS
      DIMENSION XC(40),YC(40),ZC(40),NCRS(20),VIS(20),NPT(20,17),
     *          X(20,17),Y(20,17),Z(20,17),TITLE(7),DATE(2),FMT(2)
      DATA FMT/'(I4,','9A4)'/
C
C  READ DRAWING TITLE AND DATE.
      READ (5,FMT) NCT,TITLE,DATE
C
C  READ OVERALL WIDTH, DEPTH, HEIGHT, NUMBER OF PLANE SURFACES AND
C  NUMBER OF POINTS.
      READ (5,*) W,D,H,NSFS,NPTS
C
C  READ COORDINATES OF POINTS.
      READ (5,*) (XC(N),YC(N),ZC(N),N=1,NPTS)
C
C  READ SURFACE SPECIFICATIONS AND ASSIGN COORDINATES.
      DO 10 I=1,NSFS
      READ (5,*) VIS(I),JMAX,(NPT(I,J),J=1,JMAX)
      NCRS(I)=JMAX
      DO 10 J=1,JMAX
      X(I,J)=XC(NPT(I,J))
      Y(I,J)=YC(NPT(I,J))
   10 Z(I,J)=ZC(NPT(I,J))
C
C  INITIATE PLOT WITH PEN POSITIONED AT DRUM PLOT RIGHT HAND MARGIN.
      CALL PLTLMT(-33.5,33.5,-21.5,21.5)
C
C  PLOT ORTHOGRAPHIC DRAWING.
      DWGNO=1.
      SCALE=1.
      CALL OPDWG(W,D,H,NSFS,NCRS,X,Y,Z,VIS,DWGNO,TITLE,NCT,SCALE,DATE)
C
C  MOVE ORIGIN TO LOWER RIGHT FRONT CORNER OF OBJECT.
      DO 15 I=1,NSFS
      JMAX=NCRS(I)
      DO 15 J=1,JMAX
   15 X(I,J)=W-X(I,J)
C
C  PLOT ISOMETRIC DRAWING.
      DWGNO=2.
      MODE=4
      CALL ISODWG(W,D,H,NSFS,NCRS,X,Y,Z,VIS,MODE,DWGNO,TITLE,NCT,SCALE,
     *            DATE)
C
C  PLOT AXONOMETRIC DRAWING, LINE-OF-SIGHT PRISM SPECIFIED.
      DWGNO=3.
      XO=5.
      YO=8.66
      ZO=7.07
      CALL AXODW1(W,D,H,XO,YO,ZO,NSFS,NCRS,X,Y,Z,VIS,MODE,DWGNO,TITLE,
     *            NCT,SCALE,DATE)
C
C  PLOT AXONOMETRIC DRAWING, TWO ROTATIONS OF OBJECT SPECIFIED.
      DWGNO=4.
      MODE=2
      THETA=30.
      DELTA=20.
      CALL AXODW2(W,D,H,THETA,DELTA,NSFS,NCRS,X,Y,Z,VIS,MODE,DWGNO,
     *            TITLE,NCT,SCALE,DATE)
C
C  PLOT PERSPECTIVE DRAWINGS.
      DWGNO=5.
      THETA=0.
      XO=5.5
      YO=15.
      ZO=8.
      CALL PSPDWG(W,D,H,THETA,XO,YO,ZO,NSFS,NCRS,X,Y,Z,VIS,MODE,DWGNO,
     *            TITLE,NCT,SCALE,DATE)
C
      DWGNO=6.
      MODE=4
      THETA=30.
      XO=0.
      ZO=12.
      CALL PSPDWG(W,D,H,THETA,XO,YO,ZO,NSFS,NCRS,X,Y,Z,VIS,MODE,DWGNO,
     *            TITLE,NCT,SCALE,DATE)
C
      STOP
      END
```

```
      SUBROUTINE PICDWG
C   PLOT ISOMETRIC OR AXONOMETRIC DRAWING OF OBJECT.
C   FRONT TOP RIGHT-SIDE ORIENTATION.
C         X,Y,Z = SURFACE WIDTH, DEPTH, AND HEIGHT COORDINATES IN INCHES.
C                 ORIGIN AT LOWER RIGHT FRONT CORNER OF OBJECT.
C         WP,HP = PLOT OVERALL WIDTH AND HEIGHT IN INCHES.
C         XP,ZP = PLOT WIDTH AND HEIGHT COORDINATES IN INCHES.
C         WD,HI = DRAWING BORDER WIDTH AND HEIGHT IN INCHES.
C
      LOGICAL VIS
      DIMENSION NCRS(20),VIS(20),X(20,17),Y(20,17),Z(20,17),XP(20,17),
     *          ZP(20,17),TITLE(7),DATE(2),FORM1(3),FORM2(3)
      DATA FORM1/'ISOM','ETRI','C'/,
     *     FORM2/'AXON','OMET','RIC'/
      XPIC(X,Y)=(Y*S1-X*C1)*SCALE
      ZPIC(X,Y,Z)=(Z*C3+(X*S2+Y*C2)*S3)*SCALE
C
      ENTRY ISODWG(W,D,H,NSFS,NCRS,X,Y,Z,VIS,MODE,DWGNO,TITLE,NCT,SCALE,
     *             DATE)
C   PLOT ISOMETRIC DRAWING OF OBJECT.
C
C   COMPUTE PLOT PARAMETERS.
      S1=.866025
      C1=S1
      S2=.5
      C2=S2
      S3=1.
      C3=S3
      MARK=1
      GO TO 15
C
      ENTRY AXODW1(W,D,H,XO,YO,ZO,NSFS,NCRS,X,Y,Z,VIS,MODE,DWGNO,TITLE,
     *             NCT,SCALE,DATE)
C   PLOT AXONOMETRIC VIEW OF OBJECT.  LINE-OF-SIGHT PRISM SPECIFIED.
C
C   COMPUTE LINE-OF-SIGHT ANGLES.
      THRAD=ATAN(XO/YO)
      DELRAD=ATAN(ZO/SQRT(XO**2+YO**2))
      GO TO 10
C
      ENTRY AXODW2(W,D,H,THETA,DELTA,NSFS,NCRS,X,Y,Z,VIS,MODE,DWGNO,
     *             TITLE,NCT,SCALE,DATE)
C   PLOT AXONOMETRIC VIEW OF OBJECT.  SUCCESSIVE ROTATIONS, THROUGH
C   ANGLE THETA AND THEN THROUGH ANGLE DELTA, SPECIFIED.
C
C   COMPUTE PLOT PARAMETERS.
      THRAD=THETA*3.141593/180.
      DELRAD=DELTA*3.141593/180.
   10 S1=SIN(THRAD)
      C1=COS(THRAD)
      S2=S1
      C2=C1
      S3=SIN(DELRAD)
      C3=COS(DELRAD)
      MARK=2
C
C   VERIFY SCALE OF DRAWING.
   15 WP=XPIC(O.,D)-XPIC(W,O.)
      HP=ZPIC(W,D,H)
   20 IF (WP.LE.32..AND.HP.LE.20.) GO TO 25
      SCALE=.5*SCALE
      WP=.5*WP
      HP=.5*HP
      GO TO 20
   25 IF (WP.GT.4.5.OR.HP.GT.3.25) GO TO 30
      SCALE=2.*SCALE
      WP=2.*WP
      HP=2.*HP
      GO TO 25
   30 IF(MODE.EQ.1.OR.MODE.EQ.3) GO TO 35
      WP=WP+.8
      HP=HP+.25
C
C   PLOT DRAWING BORDER AND TITLE.
   35 CALL BORDER(WP,HP,DWGNO,TITLE,NCT,SCALE,DATE,WD,HI)
      IF (MARK.EQ.1) CALL SYMBOL(.5*WD-2.79,.15,.12,FORM1,0.,9)
      IF (MARK.EQ.2) CALL SYMBOL(.5*WD-2.91,.15,.12,FORM2,0.,11)
C
C   DEFINE ORIGIN AT FRONT CORNER OF OBJECT.
      XPO=.5*(WD-WP)-XPIC(W,0.)+.4
      ZPO=.5*(HI-HP)
      IF (ZPO.LT.1.25) ZPO=1.25
      IF (MODE.EQ.2.OR.MODE.EQ.4) ZPO=ZPO+.25
      CALL PLOT(XPO,ZPO,-3)
C
C   PLOT PICTORIAL VIEW OF OBJECT.
      DO 40 I=1,NSFS
      IF (.NOT.VIS(I).AND.(MODE.EQ.1.OR.MODE.EQ.2)) GO TO 40
      XP(I,1)=XPIC(X(I,1),Y(I,1))
      ZP(I,1)=ZPIC(X(I,1),Y(I,1),Z(I,1))
      CALL PLOT(XP(I,1),ZP(I,1),3)
      JMAX=NCRS(I)
      DO 40 J=2,JMAX
      XP(I,J)=XPIC(X(I,J),Y(I,J))
      ZP(I,J)=ZPIC(X(I,J),Y(I,J),Z(I,J))
      CALL LINE(XP,ZP,I,J,NCRS,VIS)
   40 CONTINUE
      IF (MODE.EQ.1.OR.MODE.EQ.3) GO TO 45
C
C   PLOT OVERALL DIMENSIONS.
      CALL PICDIM(0.,0.,0.,W,SCALE,S1,C1,S2,C2,S3,C3,1)
      CALL PICDIM(0.,0.,0.,D,SCALE,S1,C1,S2,C2,S3,C3,2)
      CALL PICDIM(W,0.,0.,H,SCALE,S1,C1,S2,C2,S3,C3,3)
C
C   MOVE PEN OFF PLOT.
   45 CALL PLOT(WD-XPO+2.,-ZPO-3.,-3)
C
      RETURN
      END
```

```
      SUBROUTINE OPDWG(W,D,H,NSFS,NCRS,X,Y,Z,VIS,DWGNO,TITLE,NCT,SCALE,
     *                DATE)
C  PLOT ORTHOGRAPHIC DRAWING OF OBJECT.  FRONT, TOP, AND RIGHT SIDE VIEWS.
C        X,Y,Z = SURFACE WIDTH, DEPTH, AND HEIGHT COORDINATES IN INCHES.
C                ORIGIN AT LOWER LEFT FRONT CORNER OF OBJECT.
C        WP,HP = PLOT OVERALL WIDTH AND HEIGHT IN INCHES.
C        XP,ZP = PLOT WIDTH AND HEIGHT COORDINATES IN INCHES.
C        WD,HI = DRAWING BORDER WIDTH AND HEIGHT IN INCHES.
C        NW,ND,NH = NUMBERS OF WIDTH, DEPTH, AND HEIGHT DIMENSIONS.
C        XD,ZD = DIMENSION PLOT COORDINATES IN INCHES.
C        VALUE = DIMENSION VALUE IN INCHES.
C
      LOGICAL VIS
      DIMENSION NCRS(20),VIS(20),X(20,17),Y(20,17),Z(20,17),TITLE(7),
     *          DATE(2),FORM(3),XD(10),ZD(10),VALUE(10)
      DATA FORM/'ORTH','OGRA','PHIC'/
C
C  VERIFY SCALE OF DRAWING.
   10 WP=(W+D)*SCALE+1.5
      HP=(H+D)*SCALE+1.5
   15 IF (WP.LE.32..AND.HP.LE.20.) GO TO 20
      SCALE=.5*SCALE
      GO TO 10
   20 IF (WP.GT.4.5.OR.HP.GT.3.25) GO TO 25
      SCALE=2.*SCALE
      GO TO 10
C
C  PLOT DRAWING BORDER AND TITLE.
   25 CALL BORDER(WP,HP,DWGNO,TITLE,NCT,SCALE,DATE,WD,HI)
      CALL SYMBOL(.5*WD-2.97,.15,.12,FORM,0.,12)
C
C  PLOT ORTHOGRAPHIC VIEWS.  NEW ORIGIN AT LOWER LEFT CORNER OF EACH VIEW.
      XPO=.5*(WD-WP)
      ZPO=.5*(HI-HP)
      IF (ZPO.LT.1.25) ZPO=1.25
      CALL PLOT(XPO,ZPO,-3)
      CALL OPVIEW(NSFS,NCRS,X,Z,VIS,SCALE)
      ZP=H*SCALE+1.5
      CALL PLOT(0.,ZP,-3)
      CALL OPVIEW(NSFS,NCRS,X,Y,VIS,SCALE)
      XP=W*SCALE+1.5
      CALL PLOT(XP,-ZP,-3)
      CALL OPVIEW(NSFS,NCRS,Y,Z,VIS,SCALE)
C
C  READ DIMENSION DATA AND PLOT.
      DSCALE=1./SCALE
C  ORIGIN FOR WIDTH DIMENSIONS IS UPPER LEFT CORNER OF FRONT VIEW.
      CALL PLOT(-XP,H*SCALE,-3)
      READ (5,*) NW,(XD(N),ZD(N),VALUE(N),N=1,NW)
      DO 30 N=1,NW
      DS=VALUE(N)*SCALE
   30 CALL DIMENS(XD(N),ZD(N),DS,0.,DSCALE)
C  ORIGIN FOR DEPTH DIMENSIONS IS LOWER RIGHT CORNER OF TOP VIEW.
      CALL PLOT(W*SCALE,1.5,-3)
      READ (5,*) ND,(XD(N),ZD(N),VALUE(N),N=1,ND)
      DO 35 N=1,ND
      DS=VALUE(N)*SCALE
   35 CALL DIMENS(XD(N),ZD(N),DS,90.,DSCALE)
C  ORIGIN FOR HEIGHT DIMENSIONS IS LOWER RIGHT CORNER OF FRONT VIEW.
      CALL PLOT(0.,-ZP,-3)
      READ (5,*) NH,(XD(N),ZD(N),VALUE(N),N=1,NH)
      DO 40 N=1,NH
      DS=VALUE(N)*SCALE
   40 CALL DIMENS(XD(N),ZD(N),DS,90.,DSCALE)
C
C  MOVE PEN OFF PLOT.
      CALL PLOT(WD-W*SCALE-XPO+2.,-ZPO-3.,-3)
C
      RETURN
      END
```

```
      SUBROUTINE OPVIEW(NSFS,NCRS,X,Y,VIS,SCALE)
C  PLOT ORTHOGRAPHIC VIEW.
C        X,Y   = SURFACE CORNER COORDINATES IN INCHES.  ORIGIN AT LOWER
C                LEFT CORNER OF VIEW.
C
      LOGICAL VIS
      DIMENSION NCRS(20),VIS(20),X(20,17),Y(20,17),XP(20,17),ZP(20,17)
C
C  PLOT LINES TO DRAW VIEW.
      DO 10 I=1,NSFS
      XP(I,1)=X(I,1)*SCALE
      ZP(I,1)=Y(I,1)*SCALE
      CALL PLOT(XP(I,1),ZP(I,1),3)
      JMAX=NCRS(I)
      DO 10 J=2,JMAX
      XP(I,J)=X(I,J)*SCALE
      ZP(I,J)=Y(I,J)*SCALE
   10 CALL LINE(XP,ZP,I,J,NCRS,VIS)
C
      RETURN
      END
```

```
      SUBROUTINE PDIMEN
C  PLOT PICTORIAL WIDTH, DEPTH, OR HEIGHT DIMENSION.  FRONT TOP RIGHT-SIDE
C  VIEW ORIENTATION.
C        N      = DIMENSION NUMBER CODED AS FOLLOWS:
C                    1 FOR WIDTH DIMENSION.
C                    2 FOR DEPTH DIMENSION.
C                    3 FOR HEIGHT DIMENSION.
C        XR,YR,ZR = WIDTH, DEPTH, AND HEIGHT COORDINATES OF DIMENSION
C                RIGHTWARD, FORWARD, OR LOWER REFERENCE POINT IN INCHES.
C        XINC,YINC,ZINC = WIDTH, DEPTH, AND HEIGHT INCREMENTS IN INCHES.
C        XP,ZP = PLOT WIDTH AND HEIGHT COORDINATES IN INCHES.
C        MODE  = DIMENSION PLOT MODE CODED AS FOLLOWS:
C                    1 FOR ARROWHEADS AND VALUE INSIDE EXTENSION LINES.
C                    2 FOR ARROWHEADS INSIDE AND VALUE OUTSIDE EXTENSION
C                      LINES.
C                    3 FOR ARROWHEADS AND VALUE OUTSIDE EXTENSION LINES.
C        LGTH  = DIMENSION PLOT LENGTH IN INCHES.
C        XLGTH,ZLGTH = DIMENSION PLOT HORIZONTAL AND VERTICAL OFFSETS.
C        SLOPE = DIMENSION SLOPE.
C
      REAL LGTH
      LOGICAL TEST
      DIMENSION XINC(5,3),YINC(5,3),ZINC(5,3)
      DATA XINC/0.,0.,.3,.3,.35,-.08,.5,5*0.,-.04,.04,0./,
     *     YINC/-.08,.5,5*0.,.3,.3,.35,-.08,.5,3*0./,
     *     ZINC/0.,0.,-.04,.04,3*0.,-.04,.04,3*0.,.3,.3,.35/
      XPIC(X,Y)=(Y*S1-X*C1)*SCALE
      ZPIC(X,Y,Z)=(Z*C3+(X*S2+Y*C2)*S3)*SCALE
      XPSP(X,Y)=(XO*(X*S+Y*C)-YO*(X*C-Y*S))*SCALE/(YO+(X*S+Y*C)*SCALE)
      ZPSP(X,Y,Z)=ZO-YO*(ZO-Z*SCALE)/(YO+(X*S+Y*C)*SCALE)
C
      ENTRY PICDIM(XR,YR,ZR,VALUE,SCALE,S1,C1,S2,C2,S3,C3,N)
C  PLOT ISOMETRIC OR AXONOMETRIC DIMENSION.
      MARK=1
      SIZE=1.
      GO TO 10
C
      ENTRY PSPDIM(XR,YR,ZR,VALUE,SCALE,S,C,XO,YO,ZO,N)
C  PLOT PERSPECTIVE DIMENSION.
      MARK=2
      SIZE=1.25
C
C  DETERMINE END POINT COORDINATES.
   10 XR1=XR
      YR1=YR
      ZR1=ZR
      IF (N.EQ.1.OR.N.EQ.3) YR1=YR1-.5*SIZE/SCALE
      IF (N.EQ.2) XR1=XR1-.5*SIZE/SCALE
      GO TO (12,14),MARK
   12 XP1=XPIC(XR1,YR1)
      ZP1=ZPIC(XR1,YR1,ZR1)
      GO TO 16
   14 XP1=XPSP(XR1,YR1)
      ZP1=ZPSP(XR1,YR1,ZR1)
   16 XR2=XR1
      YR2=YR1
      ZR2=ZR1
      IF (N.EQ.1) XR2=XR2+VALUE
      IF (N.EQ.2) YR2=YR2+VALUE
      IF (N.EQ.3) ZR2=ZR2+VALUE
      GO TO (18,20),MARK
   18 XP2=XPIC(XR2,YR2)
      ZP2=ZPIC(XR2,YR2,ZR2)
      GO TO 22
   20 XP2=XPSP(XR2,YR2)
      ZP2=ZPSP(XR2,YR2,ZR2)
   22 XLGTH=XP2-XP1
      ZLGTH=ZP2-ZP1
      LGTH=SQRT(XLGTH**2+ZLGTH**2)
      IF (ABS(XLGTH).LT..01) GO TO 24
      SLOPE=ZLGTH/XLGTH
      GO TO 26
   24 SLOPE=1000.
C
C  DETERMINE MODE.
   26 MODE=1
      IF (ABS(SLOPE).LT..2) GO TO 28
      ZMIN=.8*SIZE*ZLGTH/LGTH+.3
      IF (ZLGTH.LT.ZMIN) MODE=2
      ZMIN=ZMIN-.3
      IF (ZLGTH.LT.ZMIN) MODE=3
      GO TO 30
   28 XMIN=.8*SIZE+.7
      IF (ABS(XLGTH).LT.XMIN) MODE=2
      XMIN=XMIN-.7
      IF (ABS(XLGTH).LT.XMIN) MODE=3
C
C  PLOT EXTENSION LINE.
   30 TEST=.FALSE.
      SIGN=1.
      IF (MODE.EQ.3) SIGN=-SIGN
   32 X=XR1+XINC(1,N)*SIZE/SCALE
      Y=YR1+YINC(1,N)*SIZE/SCALE
      Z=ZR1+ZINC(1,N)*SIZE/SCALE
      GO TO (34,36),MARK
   34 XP=XPIC(X,Y)
      ZP=ZPIC(X,Y,Z)
      GO TO 38
   36 XP=XPSP(X,Y)
      ZP=ZPSP(X,Y,Z)
   38 CALL PLOT(XP,ZP,3)
      XSAVE=XP
      X=X+XINC(2,N)*SIZE/SCALE
      Y=Y+YINC(2,N)*SIZE/SCALE
      Z=Z+ZINC(2,N)*SIZE/SCALE
      GO TO (40,42),MARK
   40 XP=XPIC(X,Y)
      ZP=ZPIC(X,Y,Z)
      GO TO 44
   42 XP=XPSP(X,Y)
      ZP=ZPSP(X,Y,Z)
   44 IF (.NOT.TEST.AND.N.EQ.3) GO TO 45
      CALL PLOT(XP,ZP,2)
   45 XSAVE=ABS(XP-XSAVE)
      CALL PLOT(XP1,ZP1,3)
C
C  PLOT 2-DIMENSIONAL ARROWHEAD.
      DO 52 J=3,5
      IF (J.EQ.5.AND.MODE.NE.3) GO TO 52
      X=XR1+XINC(J,N)*SIZE*SIGN/SCALE
      Y=YR1+YINC(J,N)*SIZE*SIGN/SCALE
      Z=ZR1+ZINC(J,N)*SIZE*SIGN/SCALE
      GO TO (46,48),MARK
   46 XP=XPIC(X,Y)
      ZP=ZPIC(X,Y,Z)
      GO TO 50
   48 XP=XPSP(X,Y)
      ZP=ZPSP(X,Y,Z)
```

```
 50 CALL PLOT(XP,ZP,2)
    IF (J.NE.4) GO TO 52
    CALL PLOT(XP1,ZP1,2)
 52 CONTINUE
    IF (TEST) RETURN
    XSIGN=1.
    IF (N.EQ.1) XSIGN=-1.
C
C   PLOT DIMENSION LINE.
    GO TO (54,64,66),MODE
 54 IF (N.EQ.3) GO TO 60
    IF (ABS(SLOPE).LT..2) GO TO 58
    XP=XP1+.5*XLGTH-.15/SLOPE
    ZP=ZP1+.5*ZLGTH-.15
    CALL PLOT(XP,ZP,2)
    XP=XP+.3/SLOPE
    ZP=ZP+.3
    GO TO 62
 58 XP=XP1+.5*XLGTH-.35*XSIGN
    ZP=ZP1+.5*ZLGTH-.35*XSIGN*SLOPE
    CALL PLOT(XP,ZP,2)
    XP=XP+.7*XSIGN
    ZP=ZP+.7*XSIGN*SLOPE
    GO TO 62
 60 XP=XP1
    ZP=ZP1+.5*ZLGTH-.15
    CALL PLOT(XP,ZP,2)
    ZP=ZP+.3
 62 CALL PLOT(XP,ZP,3)
 64 CALL PLOT(XP2,ZP2,2)
C
C   PLOT DIMENSION VALUE.
 66 XP=XP1+.5*XLGTH-.32
    IF (VALUE.LT.10.) XP=XP+.07
    ZP=ZP1+.5*ZLGTH-.07
    IF (MODE.EQ.1.AND.N.EQ.3) GO TO 76
    IF (MODE.EQ.1) GO TO 78
    IF (N.EQ.3) GO TO 74
    IF (ZLGTH.LT..3) GO TO 68
    XP=XP+.32*XSIGN
    IF (VALUE.LT.10.) XP=XP-.07*XSIGN
    IF (MODE.EQ.2) XP=XP+.15/SLOPE
    IF (MODE.EQ.3) XP=XP-.15/SLOPE
    GO TO 78
 68 IF (N.EQ.2) GO TO 70
    XP=XP2-.74
    IF (VALUE.LT.10.) XP=XP+.14
    GO TO 72
 70 XP=XP2+.1
 72 IF (MODE.EQ.3.AND.ABS(SLOPE).LT..2) XP=XP+.35*SIZE*XLGTH/LGTH
    GO TO 78
 74 ZP=ZP2+.2
    IF (MODE.EQ.3) ZP=ZP+.3*SIZE
    GO TO 78
 76 IF (VALUE.LT.10..AND.XSAVE.LT..3) XP=XP-(.3-XSAVE)
    IF (VALUE.GE.10..AND.XSAVE.LT..37) XP=XP-(.37-XSAVE)
 78 CALL NUMBER(XP,ZP,.14,VALUE,0.,2)
C
C   PLOT SECOND EXTENSION LINE AND ARROWHEAD.
    TEST=.TRUE.
    SIGN=-SIGN
    XR1=XR2
    YR1=YR2
    ZR1=ZR2
    XP1=XP2
    ZP1=ZP2
    GO TO 32
C
    END
```

```
      SUBROUTINE BORDER(WP,HP,DWGNO,TITLE,NCT,SCALE,DATE,WIDE,HIGH)
C   PLOT STANDARD BORDER AND TITLE FOR ENGINEERING DRAWING.
C        N      = DRAWING SIZE, CODED 1 FOR A-SIZE, 2 FOR B-SIZE,
C                   3 FOR C-SIZE, AND 4 FOR D-SIZE.
C        WD,WIDE = DRAWING BORDER WIDTH IN INCHES.
C        HI,HIGH = DRAWING BORDER HEIGHT IN INCHES.
C
      DIMENSION TITLE(7),DATE(2),WD(4),HI(4),HDNG1(5),HDNG2(7),HDNG3(3),
     *      HDNG4(3),HDNG5(1)
      DATA WD,HI/10.5,16.5,21.5,33.5,8.,10.5,16.5,21.5/
      DATA HDNG1/'ENGI','NEER','ING ','GRAP','HICS'/,
     *      HDNG2/'THE ','OHIO',' STA','TE U','NIVE','RSIT','Y'/,
     *      HDNG3/'C. H','. KE','ARNS'/,
     *      HDNG4,HDNG5/'SCAL','E   ','  /1','DATE'/
C
C   SELECT DRAWING SIZE.
      DO 10 N=1,4
      IF (WP+1.5.LE.WD(N).AND.HP+1.5.LE.HI(N)) GO TO 15
   10 CONTINUE
   15 WIDE=WD(N)
      HIGH=HI(N)
C
C   DEFINE ORIGIN AT LOWER LEFT CORNER OF BORDER.
      CALL PLOT(0.,.25,2)
      CALL PLOT(2.,3.,-3)
C
C   PLOT DRAWING BORDER.
      CALL RECT(0.,0.,HIGH,WIDE,0.,2)
C
C   PLOT DRAWING TITLE BLOCK.
      CALL PLOT(WIDE,1.,3)
      CALL PLOT(WIDE-4.5,1.,2)
      CALL PLOT(WIDE-4.5,0.,2)
      CALL SYMBOL(WIDE-4.35,.65,.21,HDNG1,0.,20)
      CALL SYMBOL(WIDE-4.25,.40,.14,HDNG2,0.,25)
      CALL SYMBOL(WIDE-3.34,.15,.14,HDNG3,0.,12)
      CALL PLOT(WIDE,.44,3)
      CALL PLOT(WIDE-.56,.44,2)
      CALL PLOT(WIDE-.56,0.,2)
      XP=WIDE-.5
      IF (DWGNO.LT.10.) XP=XP+.14
      CALL NUMBER(XP,.08,.28,DWGNO,0.,-1)
C
C   PLOT DRAWING TITLE.
      XP=.5*WIDE-2.25
      CALL SYMBOL(XP-FLOAT(NCT)*.105,.65,.21,TITLE,0.,NCT)
C
C   PLOT DRAWING SCALE AND DATE.
      CALL SYMBOL(XP-2.1,.4,.14,HDNG4,0.,12)
      CALL NUMBER(XP-1.26,.4,.14,SCALE,0.,2)
      CALL SYMBOL(XP+.42,.4,.14,HDNG5,0.,4)
      CALL SYMBOL(XP+1.12,.4,.14,DATE,0.,8)
C
      RETURN
      END
```

```
      SUBROUTINE PSPDWG(W,D,H,THETA,XO,YO,ZO,NSFS,NCRS,X,Y,Z,VIS,MODE,
     *                 DWGNO,TITLE,NCT,SCALE,DATE)
C  PLOT PERSPECTIVE DRAWING OF OBJECT BY ORTHOGRAPHIC METHOD.  FRONT TOP
C  RIGHT-SIDE ORIENTATION.
C        X,Y,Z = SURFACE WIDTH, DEPTH, AND HEIGHT COORDINATES IN INCHES.
C                ORIGIN AT LOWER RIGHT FRONT CORNER OF OBJECT.
C        LAV   = LATERAL ANGLE OF VIEW IN DEGREES.
C        EAV   = ELEVATION ANGLE OF VIEW IN DEGREES.
C        OMEGA = LATERAL/ELEVATION ANGLE IN RADIANS BETWEEN LINE-OF-SIGHT
C                AND NORMAL TO PICTURE PLANE.
C        ALPHA,BETA = LAV COMPONENT ANGLES IN RADIANS.
C        GAMMA = EAV COMPONENT ANGLE IN RADIANS.
C        WP,HP = PLOT OVERALL WIDTH AND HEIGHT IN INCHES.
C        XP,ZP = PLOT WIDTH AND HEIGHT COORDINATES IN INCHES.
C        WD,HI = DRAWING BORDER WIDTH AND HEIGHT IN INCHES.
C
      REAL LAV
      LOGICAL VIS
      DIMENSION NCRS(20),VIS(20),X(20,17),Y(20,17),Z(20,17),XP(20,17),
     *          ZP(20,17),TITLE(7),DATE(2),FORM(3)
      DATA FORM/'PERS','PECT','IVE'/
      XPSP(X,Y)=(XO*(X*S+Y*C)-YO*(X*C-Y*S))*SCALE/(YO+(X*S+Y*C)*SCALE)
      ZPSP(X,Y,Z)=ZO-YO*(ZO-Z*SCALE)/(YO+(X*S+Y*C)*SCALE)
C
C  VERIFY LATERAL ANGLE OF VIEW.
      THRAD=THETA*3.141593/180.
      S=SIN(THRAD)
      C=COS(THRAD)
   10 OMEGA=ATAN(XO/YO)
      ALPHA=ATAN((XPSP(0.,D)-XO)/YO)
      BETA=ATAN((XO-XPSP(W,0.))/YO)
      IF (XO) 15,25,20
   15 IF (ALPHA.LT.OMEGA) ALPHA=OMEGA
      GO TO 25
   20 IF (BETA.LT.OMEGA) BETA=OMEGA
   25 LAV=(ALPHA+BETA)*180./3.141593
      IF (LAV.LE.30.) GO TO 30
      YO=1.1*YO
      GO TO 10
C
C  VERIFY ELEVATION ANGLE OF VIEW.
   30 OMEGA=ATAN(ZO/YO)
      GAMMA=ATAN((ZO-ZPSP(W,D,H))/YO)
      EAV=(OMEGA-GAMMA)*180./3.141593
      IF (EAV.LE.30.) GO TO 35
      YO=1.1*YO
      GO TO 10
C
C  VERIFY SCALE OF DRAWING.
   35 WP=XPSP(0.,D)-XPSP(W,0.)
      HP=ZPSP(W,D,H)
   40 IF (WP.LE.32..AND.HP.LE.20.) GO TO 45
      SCALE=.5*SCALE
      WP=.5*WP
      HP=.5*HP
      XO=.5*XO
      ZO=.5*ZO
      YO=.5*YO
      GO TO 40
   45 IF (WP.GT.4.5.OR.HP.GT.3.25) GO TO 50
      SCALE=2.*SCALE
      WP=2.*WP
      HP=2.*HP
      XO=2.*XO
      YO=2.*YO
      ZO=2.*ZO
      GO TO 45
   50 IF (MODE.EQ.1.OR.MODE.EQ.3) GO TO 55
      WP=WP+.8
      HP=HP+.4
C
C  PLOT DRAWING BORDER AND TITLE.
   55 CALL BORDER(WP,HP,DWGNO,TITLE,NCT,SCALE,DATE,WD,HI)
      CALL SYMBOL(.5*WD-2.91,.15,.12,FORM,0.,11)
C
C  DEFINE ORIGIN AT FRONT CORNER OF OBJECT.
      XPO=.5*(WD-WP)-XPSP(W,0.)+.4
      ZPO=.5*(HI-HP)
      IF (ZPO.LT.1.25) ZPO=1.25
      IF (MODE.EQ.2.OR.MODE.EQ.4) ZPO=ZPO+.4
      CALL PLOT(XPO,ZPO,-3)
C
C  PLOT PERSPECTIVE VIEW OF OBJECT.
      DO 60 I=1,NSFS
      IF (.NOT.VIS(I).AND.(MODE.EQ.1.OR.MODE.EQ.2)) GO TO 60
      XP(I,1)=XPSP(X(I,1),Y(I,1))
      ZP(I,1)=ZPSP(X(I,1),Y(I,1),Z(I,1))
      CALL PLOT(XP(I,1),ZP(I,1),3)
      JMAX=NCRS(I)
      DO 60 J=2,JMAX
      XP(I,J)=XPSP(X(I,J),Y(I,J))
      ZP(I,J)=ZPSP(X(I,J),Y(I,J),Z(I,J))
      CALL LINE(XP,ZP,I,J,NCRS,VIS)
   60 CONTINUE
      IF (MODE.EQ.1.OR.MODE.EQ.3) GO TO 65
C
C  PLOT OVERALL DIMENSIONS.
      CALL PSPDIM(0.,0.,0.,W,SCALE,S,C,XO,YO,ZO,1)
      CALL PSPDIM(0.,0.,0.,D,SCALE,S,C,XO,YO,ZO,2)
      CALL PSPDIM(W,0.,0.,H,SCALE,S,C,XO,YO,ZO,3)
C
C  MOVE PEN OFF PLOT.
   65 CALL PLOT(WD-XPO+2.,-ZPO-3.,-3)
C
      RETURN
      END
```

```
      SUBROUTINE LINE(XP,ZP,I,J,NCRS,VIS)
C  PLOT STRAIGHT LINE.
C        SLOPE = LINE SLOPE.
C        YINT,XINT = LINE Y OR X-SCALE INTERCEPT.
C
      LOGICAL VIS
      EQUIVALENCE (XINT,YINT)
      DIMENSION XP(20,17),ZP(20,17),SLOPE(20,17),XINT(20,17),
     *          YINT(20,17),NCRS(20),VIS(20),KCP(20),KCS(20),LCS(20)
C
C  COMPUTE LINE SLOPE AND INTERCEPT.
      IF (ABS(XP(I,J)-XP(I,J-1)).LT..01) GO TO 10
      SLOPE(I,J)=(ZP(I,J)-ZP(I,J-1))/(XP(I,J)-XP(I,J-1))
      YINT(I,J)=ZP(I,J)-XP(I,J)*SLOPE(I,J)
      GO TO 15
   10 SLOPE(I,J)=1000.
      XINT(I,J)=XP(I,J)
C
C  TEST FOR FIRST SURFACE PLOTTED.
   15 IF (I.EQ.1.AND.VIS(I)) GO TO 45
      IF (I.EQ.1.) GO TO 40
C
C  CHECK PREVIOUSLY PLOTTED LINES.
      NCP=0
      NCS=0
      DO 30 K=1,I
      LMAX=NCRS(K)
      DO 30 L=2,LMAX
      IF (K.EQ.I.AND.L.EQ.J) GO TO 35
C
C  TEST FOR COINCIDING POINTS.
      IF (ABS(XP(I,J-1)-XP(K,L-1)).LT..02.AND.ABS(ZP(I,J-1)-ZP(K,L-1)).L
     *T..02.AND.ABS(XP(I,J)-XP(K,L)).LT..02.AND.ABS(ZP(I,J)-ZP(K,L)).LT.
     *.02) GO TO 20
      IF (ABS(XP(I,J-1)-XP(K,L)).LT..02.AND.ABS(ZP(I,J-1)-ZP(K,L)).LT..0
     *2.AND.ABS(XP(I,J)-XP(K,L-1)).LT..02.AND.ABS(ZP(I,J)-ZP(K,L-1)).LT.
     *.02) GO TO 20
C
C  TEST FOR COINCIDING SLOPE AND INTERCEPT.
      IF (ABS(SLOPE(I,J)).GT..001) GO TO 18
      IF (ABS(SLOPE(K,L)).LT..001.AND.ABS(YINT(I,J)-YINT(K,L)).LT..02)
     *GO TO 25
      GO TO 30
   18 IF (ABS((SLOPE(I,J)-SLOPE(K,L))/SLOPE(I,J)).LT..001.AND.ABS(YINT(I
     *,J)-YINT(K,L)).LT..02) GO TO 25
      GO TO 30
   20 NCP=NCP+1
      KCP(NCP)=K
      GO TO 30
   25 NCS=NCS+1
      KCS(NCS)=K
      LCS(NCS)=L
   30 CONTINUE
   35 IF (NCP.GT.0) GO TO 50
      IF (NCS.GT.0.AND..NOT.VIS(I)) GO TO 60
      IF (VIS(I)) GO TO 45
C
C  PLOT INVISIBLE LINE.
   40 CALL DASHLN(XP(I,J-1),ZP(I,J-1),XP(I,J),ZP(I,J),.125,2.5)
      RETURN
C
C  PLOT VISIBLE LINE.
   45 CALL PLOT(XP(I,J),ZP(I,J),2)
      RETURN
C
C  COMPARE VISIBILITIES OF LINES WITH COINCIDING POINTS.
   50 IF (.NOT.VIS(I)) GO TO 75
      DO 55 N=1,NCP
      IF(VIS(KCP(N))) GO TO 75
   55 CONTINUE
      GO TO 45
C
C  TEST OVERLAP OF LINES WITH COINCIDING SLOPE AND INTERCEPT.
   60 DO 70 N=1,NCS
      K=KCS(N)
      L=LCS(N)
      IF (SLOPE(I,J).EQ.1000.) GO TO 65
C
C  TEST NON-VERTICAL LINE FOR ABSENCE OF OVERLAP.
      IF (XP(I,J-1).LE.XP(K,L-1).AND.XP(I,J).LE.XP(K,L-1).AND.XP(I,J-1).
     *LE.XP(K,L).AND.XP(I,J).LE.XP(K,L)) GO TO 70
      IF (XP(I,J-1).GE.XP(K,L-1).AND.XP(I,J).GE.XP(K,L-1).AND.XP(I,J-1).
     *GE.XP(K,L).AND.XP(I,J).GE.XP(K,L)) GO TO 70
      GO TO 75
C
C  TEST VERTICAL LINE FOR ABSENCE OF OVERLAP.
   65 IF (ZP(I,J-1).LE.ZP(K,L-1).AND.ZP(I,J).LE.ZP(K,L-1).AND.ZP(I,J-1).
     *LE.ZP(K,L).AND.ZP(I,J).LE.ZP(K,L)) GO TO 70
      IF (ZP(I,J-1).GE.ZP(K,L-1).AND.ZP(I,J).GE.ZP(K,L-1).AND.ZP(I,J-1).
     *GE.ZP(K,L).AND.ZP(I,J).GE.ZP(K,L)) GO TO 70
      GO TO 75
   70 CONTINUE
      GO TO 40
C
C  PLOT LINE WITH PEN UP.
   75 CALL PLOT(XP(I,J),ZP(I,J),3)
      RETURN
C
      END
```

DATA FOR BEVELED BLOCK

```
 13BEVELED BLOCK            8/30/72
7. 4. 2.5 11 14
0. 0. 0. 3. 0. 0. 3. 0. 1. 0. 0. 1. 0. 1.75 2.5 3. 1.75 1. 3. 1.75 0. 7. 1.75
0. 7. 1.75 .75 3.5 1.75 2.5 7. 4. 2.5 0. 4. 2.5 0. 4. 0. 7. 4. 0.
T 5 1 2 3 4 1
T 4 3 4 5 3
T 4 3 5 6 3
T 5 3 2 7 6 3
T 7 5 6 7 8 9 10 5
T 5 5 10 11 12 5
T 4 10 11 9 10
T 5 9 8 14 11 9
F 7 8 14 13 1 2 7 8
F 5 14 11 12 13 14
F 6 1 4 5 12 13 1
3 0. .35 3.5 0. .7 7. 0. 1.15 3.
2 .35 1.625 2.375 .7 0. 4.
3 .35 0. .75 .7 0. 2.5 1.15 0. 1.
```

ways. They encounter relatively large and flexible programs, capable of accepting different input values and producing different results, depending on the input. Students are often motivated to examine such programs in detail, either individually or in groups, and propose changes in the programs or the manner in which they are used.

On the premise that students are increasingly aware of the value of computer graphics, this article presents a somewhat larger and more advanced graphics package that can likewise be modified or expanded. The language is FORTRAN IV. The program makes use of the IBM System/370 FORTRAN-G1 compiler and standard CalComp plotting routines (2) residing in the system library. Drawings were generated on a CalComp Model 563 drum plotter with 10-mil incremental step. The program subroutines produce orthographic, isometric, axonometric and perspective drawings, in standard sizes, complete with border and title block. Insofar as possible, program logic follows the thought and action that a draftsman might employ. Meaningful names and symbols are used and sufficient comments are included to permit the reader to follow the steps in the program.

The program structure can be briefly described. A main program reads in data and calls on subroutines to plot each type of drawing. These programs, in turn, make use of subordinate routines to draw borders, title blocks, lines, lettering, and dimensions. Unformatted stream input permits data values, separated by one or more blanks, or commas, to be punched continuously across data cards without regard to card columns. The object to be drawn is defined by specifying X, Y, and Z coordinates for each of its corners and then visibility and corner numbers, in plotting sequence, for each of its surfaces. Only plane surfaces and straight edges are plotted by the program. Surfaces must be fully visible or invisible. The origin of coordinates for orthographic projection is the lower left front corner of the object. The object is oriented, for pictorial representation, to show front, top, and right-side, and the origin is moved to the lower right front corner.

The orthographic drawing of the Beveled Block (Drawing 1) is produced by program subroutine OPDWG which, in turn, issues calls to subroutines BORDER and OPVIEW. BORDER plots drawing border and title. OPVIEW plots a single orthographic view, employing subroutine LINE which tests visibility, coinciding endpoints, and possible overlapping, before plotting each line. Dimensions are added to the drawing.

Isometric and axonometric drawings (Drawings 2, 3, and 4) are produced by subroutine PICDWG. Three entries are provided: ISODWG for isometric, AXODW1 for axonometric specified by line-of-sight prism, and AXODW2 for axonometric specified by successive rotations of the object, first about a vertical axis and second about a horizontal-frontal axis. Subroutines BORDER and LINE are employed as before. Overall dimensions are optionally added to the pictorial views by calls to PICDIM entry of subroutine PDIMEN. Drawings of the Beveled Block in "parallel" and "angular" perspective (Drawings 5 and 6) are produced by subroutine PSPDWG. Subroutines BORDER and LINE are again employed and overall dimensions are added by calls to PSPDIM entry of subroutine PDIMEN. All the program procedures are free to access the standard plotting routines. PLOT and DASHLN are used to draw visible and invisible lines. DIMENS is used to plot orthographic dimensions. SYMBOL and NUMBER are used to add letters and numbers.

It must be emphasized that a program of the type presented here is only a first step in the development of a truly comprehensive computer graphics package. Many features essential to fully automated drafting are not implemented. A list of such features would be long and would certainly include the following items:

1. Plotting of curved outlines, particularly circles and circle arcs.
2. Implementation and use of a full set of line symbols.
3. Symbol routines for other types of drafting symbols.
4. Solution of the hidden line problem, documented by Loutrel (3) for convex and non-convex polyhedrons.
5. Adequate treatment of overlapping lines. Subroutine LINE does not plot overlapped invisible lines.
6. Optional full dimensioning of pictorial drawings.

The proper programming of subroutines requires that parameter values be checked for validity. Error routines are necessary to print out appropriate diagnostics and initiate corrective action if values are in error. These would have to be incorporated into a graphics package before it could be made available for general use.

It is the author's hope that Engineering Design Graphics Journal readers, engineers,

(See COMPUTER - p. 56)

PICTORIAL SHADE AND SHADOW

Eugene G. Paré
Washington State University

The extension of the principles of pictorial intersections to pictorial shade and shadows provides a fascinating new application of these descriptive geometry concepts. It is expected that the visual perception demanded in the solution of such projects will serve to expand our students' ability to observe and learn by more effective utilization of that most dominant learning sense, sight.

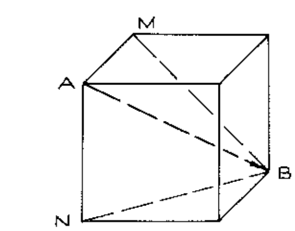
Some introductory concepts of pictorial shade and shadows are presented in the oblique pictorial of Figure 19-10 which utilizes the selected light ray direction AB. Direction NB represents the projection of AB on a horizontal plane and MB provides the projection on a frontal plane.

The shadow of point 1 on the horizontal base plane is secured by the introduction of pictorial ray 1-11 parallel to AB above and its horizontal projection 0-11 parallel to NB. Since 0-11 and 1-11 both exist in a single plane they intersect at point 11, the shadow of point 1 on the horizontal base. As point 0 already lies in the same base plane, line 0-11 is the shadow of vertical line 0-1 on the plane. Note that the shadow of a vertical line on a horizontal plane takes a direction parallel to NB.

The shadow of point 2 on the base plane is established at the intersection of pictorial ray 2-12 and its horizontal projection. Observe that the shadow of horizontal line 1-2 on the horizontal base plane is a parallel line 11-12. Note the similar construction needed to obtain points 13 and 14 which represent the shadows of 3 and 4.

A portion of the shadow of line 5-6 falls on horizontal plane H of the pictorial itself. The shadow of point 5 on plane H is located at the intersection of pictorial ray 5-15 and its horizontal projection. Although this shadow point 15 lies beyond the limits of plane H, line 15-6 does establish the appropriate initial direction of the shadow for line 6-5. Since the actual shadow of point 5 does not fall on plane H, it should be apparent that it must fall on the frontal plane 7-3-2. This shadow point 25 is established at the intersection of pictorial ray 5-25 and its frontal projection that is added parallel to MB through point 7. Other shadow lines are added as shown and shaded areas are designated to complete the solution.

The solution of the shade and shadow isometric of Figure 19-11 involves some extension of the preceding procedures. Shadow point 11 is located at the intersection of the pictorial ray from point 1 with its projection on the horizontal base plane. Other shadow points, such as 12, on the base plane are similarly established.



LIGHT RAY DIRECTION

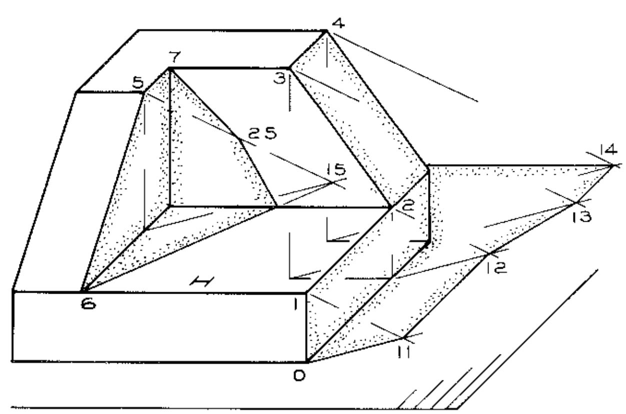
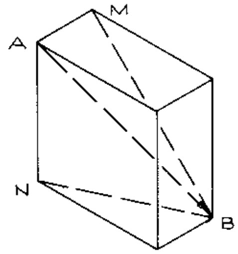


FIGURE 19-10
OBLIQUE SHADE AND SHADOW



LIGHT RAY DIRECTION

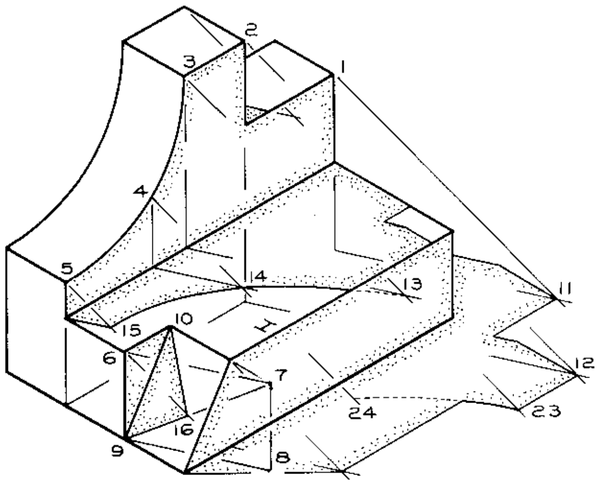


FIGURE 19-11

The ellitical shadow segment of the arc 3-5 falls primarily on horizontal plane H of the pictorial itself. The procedure for obtaining the shadows of the three points 3, 4 and 5 is demonstrated. Note that shadow point 13 is desirable even though this point exists beyond the limits of plane H. Similarly, shadow point 24 is needed to help orient that elliptical shadow segment of arc 3-5 which falls on the base plane.

The shadow of point 6, which falls on the inclined plane of the pictorial, requires the use of the cutting plane technique for locating the intersection of pictorial ray 6-16 with this inclined plane. The cutting plane consists of the horizontal lines 6-7 and 9-8 drawn parallel to NB above. This cutting plane intersects the

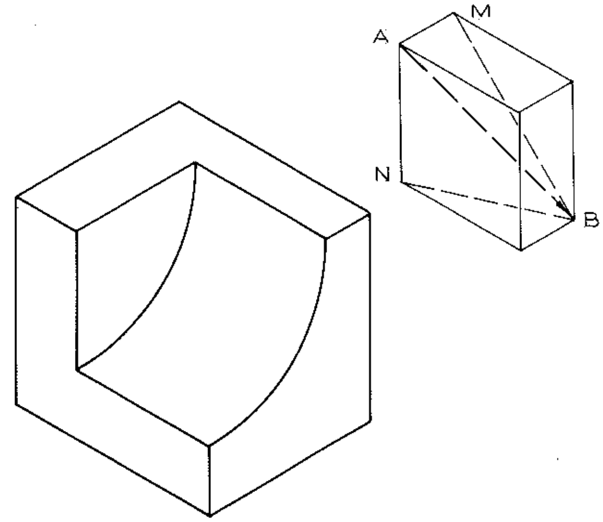


FIGURE 19-12

inclined plane in the line 9-7. Point 7 is a point on this line of intersection since line 10-7 of the inclined plane and 6-7 of the cutting plane both lie in the same horizontal plane. By a comparable analysis, it can be observed that point 9 is another point on this line of intersection. Now since 9-7 and 6-16 both exist in the same cutting plane, point 16 represents the piercing point, or shadow, of the pictorial ray with the desired pictorial plane. Additional shadow points are located as shown in the illustration to complete the solution.

Some 60 oblique, isometric, and perspective pictorial shade and shadow projects have been recently class tested at Washington State University with enthusiastic student response.

One of the more perplexing solutions for this writer involves the shadow on a curved surface, see Figure 19-12; and since we all agree that learning is best achieved through actual experience, perhaps it would be well to leave this solution for the reader.

MACHINING OF COMPOUND ANGLES

M. F. Spotts
Northwestern University
Evanston, Illinois

A plane surface, located at some arbitrary angle in space, must first be rotated into the horizontal before any machining or grinding can be done. Trial and error is sometimes employed but such a process is costly in both time and spoiled material. This article will derive some simple formulas by which the engineer can specify the rotations necessary to bring the surface into the horizontal so that fabrication can proceed without delay.

USE OF MILLING MACHINE OR PLANER

In Fig. 1, the surface to be machined is $P_1 P_2 P_3$. Although a rectangular body is illustrated, the body may have any shape so long as the projections of $P_1 P_2 P_3$ on the base will form a right angle at O. It is assumed that an adjustable sine plate is available for holding the workpiece. The body is placed on the sine plate at angle Ψ between the hinge is rotated through angle θ. Angles Ψ and θ

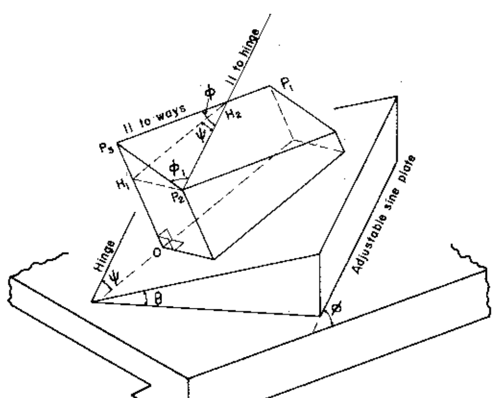
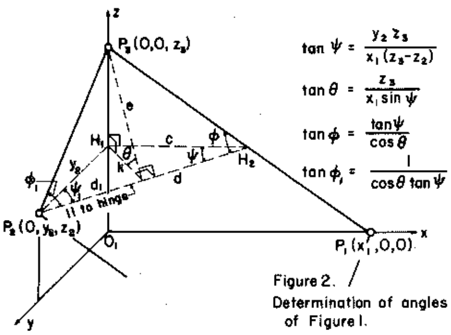


Figure I. Arbitrarily inclined surface $P_1 P_2 P_3$ rotated into the horizontal with edge $P_1 P_3$ parallel to ways of milling machine.

will bring P_1 P_2 P_3 into the horizontal. If in addition, due to obstructions or other reasons, it would be necessary to do the machining parallel to side P_1 P_3, then the sine plate would be located with respect to the ways of the milling machine or planer at angle φ.



$$\tan \psi = \frac{y_2 z_3}{x_1 (z_3 - z_2)}$$

$$\tan \theta = \frac{z_3}{x_1 \sin \psi}$$

$$\tan \phi = \frac{\tan \psi}{\cos \theta}$$

$$\tan \phi_1 = \frac{1}{\cos \theta \tan \psi}$$

Figure 2. Determination of angles of Figure I.

The rectangular coordinates for the three points P_1, P_2, and P_3 are assumed to be known. Then by simple addition and subtraction, the coordinates of the points can be adjusted so that P_1 is on the x-axis, P_2 lines in the y z-plane, and P_3 is on the z-axis as indicated by Fig. 2. The coordinates of the three points then are:

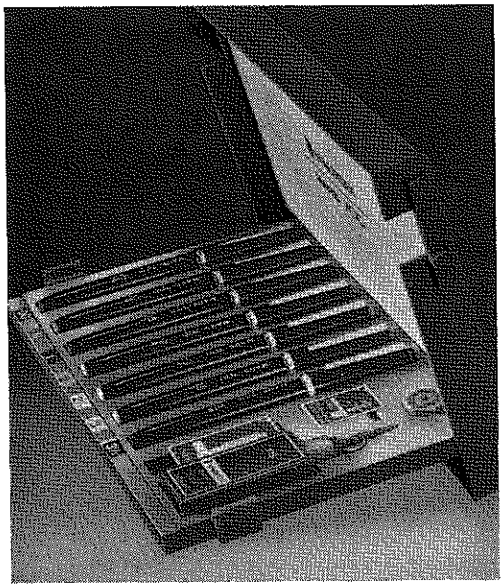
P_1 $(x_1, 0, 0)$

P_2 $(0, y_2, z_2)$

P_3 $(0, 0, z_3)$

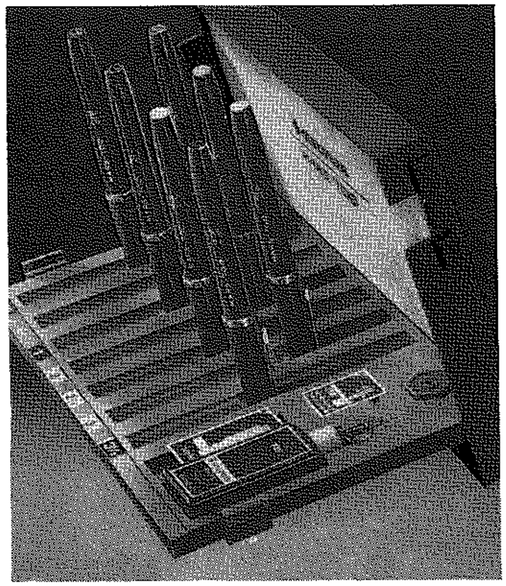
When the body is resting on the horizontal and before it is placed on the angle plate, let a horizontal plane be passed through point P_2. As shown in Fig. 2 it will intersect the inclined plane P_1, P_2, P_3 in line P_2 H_2. Rotation about this line through angle θ will bring P_1, P_2, P_3 into the horizontal. Line P_2H_2 must then be located parallel to the hinge of the sine plate or at angle Ψ thereto. In other words, Ψ must be the angle between the hinge and the projection of P_1 P_2 on the base. This is plainly indicated in the figure.

No other technical pen set could have done this advertisement



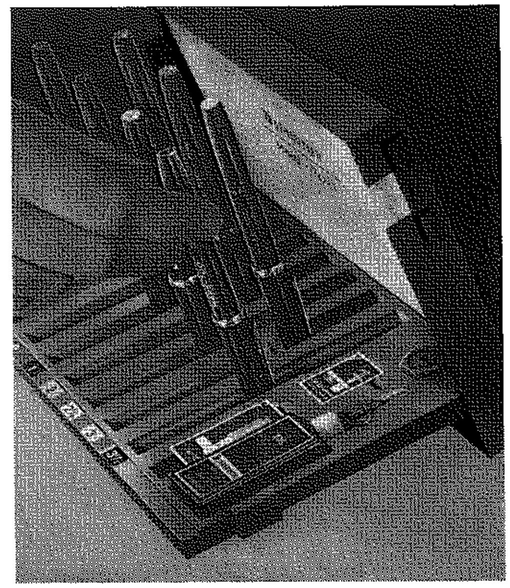
9:00 A.M.

You arrive at work, take your MARS 700 technical pen set from the drawer (it really fits in drawers), and open it. The pen points are resting at a 15 degree angle. This is to keep the ink *away* from the points. (It keeps the points from clogging.)



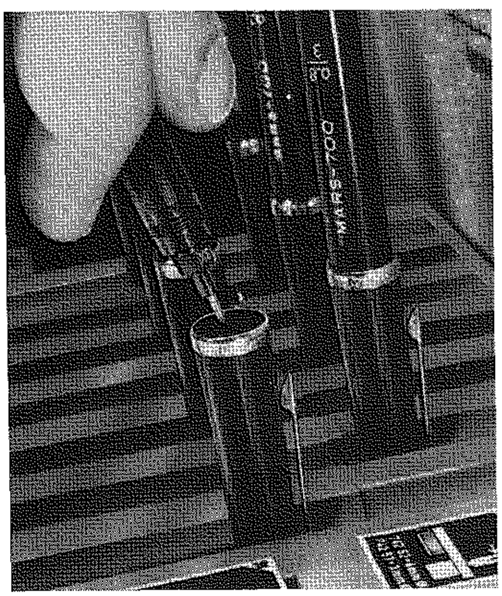
9:02 A.M.

You have now converted your pen set into a working stand. The pens have been removed from their slots and inserted in their keyholes. The caps are locked in their holes.



9:03 A.M.

You unscrew your first pen of the day from its cap, and it's ready to go.

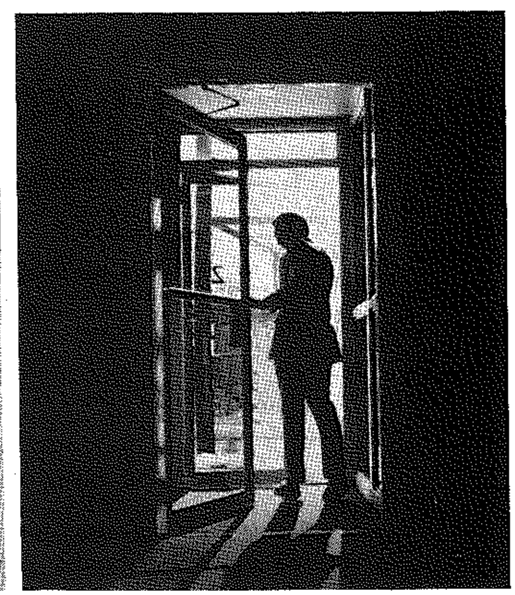


10:32 A.M.

You need a finer line width. You screw the first pen back into its locked (and waiting) cap, and unscrew the second pen. One handed point changing. Marvelous.

4:58 P.M.

Screw the pen you're using into its cap, unplug all pens from their keyholes, lay them into their slots, and close the case.



5:00 P.M.

Go home. And tomorrow, try this ad with the pen set you have now.

Mars 700 technical pen sets.

Write for details: J.S. Staedtler, Inc., Montville, N.J. 07045.
In Canada: Staedtler-Mars Ltd., Rexdale, Ont.

STAEDTLER MARS

By similar triangles in Fig. 2,

$$\frac{c}{z_3 - z_2} = \frac{x_1}{z_3} \quad \text{or} \quad c = \frac{x_1 (z_3 - z_2)}{z_3} \qquad (1)$$

Then $$\tan \Psi = \frac{y_2}{c} = \frac{y_2 \; z_3}{x_1 (z_3 - z_2)}$$

Also $$\tan \theta = \frac{z_3 - z_2}{k} = \frac{z_3 - z_2}{c \sin \Psi} = \frac{z_3}{x_1 \sin \Psi} \qquad (2)$$

In Fig. 2, $e = \dfrac{k}{\cos \theta}$, $d = \dfrac{k}{\tan \Psi}$,

$$\tan \varphi = \frac{e}{d} = \frac{\tan \Psi}{\cos \theta} \qquad (3)$$

should it be desired to do the machining parallel to P_2 P_3, then angle φ_1 would lie between the hinge and the ways of the machine. It is noted in Fig. 2 that angles Ψ and Ψ_1 are complementary so that $\tan \Psi_1 = \cot \Psi$. Then

$$d_1 = \frac{k}{\tan \Psi_1} = \frac{k}{\cot \Psi} = k \tan \Psi$$

and $$\tan \varphi_1 = \frac{e}{d_1} = \frac{1}{\cos \theta \tan \Psi} \qquad (4)$$

The above equations will apply to a body opposite hand to Fig. 2 if the coordinates are arranged as shown in Fig. 3.

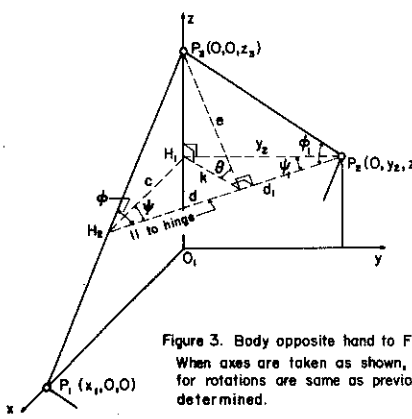


Figure 3. Body opposite hand to Figure 2. When axes are taken as shown, equations for rotations are same as previously determined.

The foregoing equations were derived on the assumption that P_3, the point with the greatest vertical coordinate was located between the other two points. The known dimensions may have to be adjusted to give three points suitable for the application of the equations. This is illustrated by the following example.

Example 1. The body shown in Fig. 4 has a rectangular base and the dimensions shown. Find the values for angles Ψ, θ, φ and φ_1.

Solution. Points A, B, and C will be used with the equations. It is thus necessary

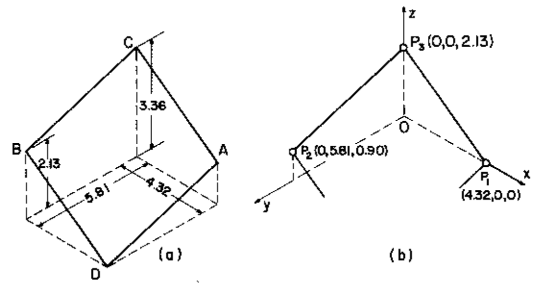


Figure 4. Determination of coordinates from dimensions to make equations of Figure I applicable.

to have the height of A above the base. This is merely 3.36 - 2.13 = 1.23 in. This height is then subtracted from all three heights to give the corresponding z-coordinate. The coordinates of the three points are:

$P_1\ (x_1, 0, 0) = P_1\ (4.32, 0, 0)$

$P_2\ (0, y_2, z_2) = P_2\ (0, 5.81, 0.90)$

$P_3\ (0, 0, z_3) = P_3\ (0, 0, 2.13)$

By. Eq. (1)

$$\tan \Psi = \frac{y_2 \; z_3}{x_1 (z_3 - z_2)} = \frac{5.81 \times 2.13}{4.32 \times 1.23} = 2.32898$$

$\Psi = 66.763^\circ$

By Eq. (2),

$$\tan \theta = \frac{z_3}{x_1 \sin \Psi} = \frac{2.13}{4.32 \times 0.918881} = 0.536583$$

$\theta = 28.217^\circ$

By Eq. (3),

$$\tan \varphi = \frac{\tan \Psi}{\cos \theta} = \frac{2.32898}{0.881163} = 2.643075$$

$\varphi = 69.276^\circ$

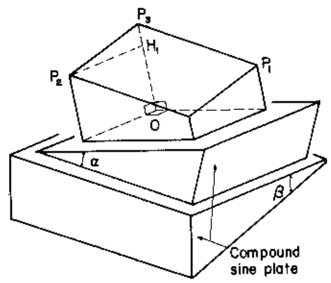
By Eq. (4),

$$\tan \varphi_1 = \frac{1}{\cos \theta \tan \Psi} = \frac{1}{0.881163 \times 2.32898} = 0.487279$$

$\varphi_1 = 25.979^\circ$

USE OF COMPOUND SINE PLATE OR SHAPER

Surface $P_1 P_2 P_3$ can also be machined on a compound sine plate or shaper providing the box table is rotatable about an axis parallel to the ways. The body, ready for machining, is shown in Fig. 5. Side $P_1 P_3$ 0 is perpendicular to the hinge of the sine plate and this hinge is perpendicular to the ways. The sine plate is adjusted to angle α which brings edge $P_1 P_3$ into the horizontal. The other hinge or the box table is then rotated through angle β which brings the surface into the horizontal.



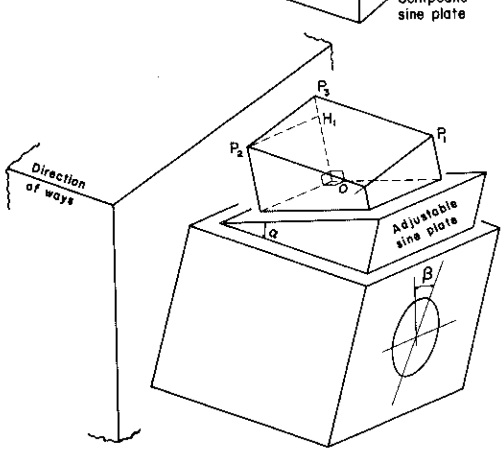


Figure 5. Angles α and β on compound sine plate or shaper required to bring surface $P_1 P_2 P_3$ into the horizontal for machining.

Equations for angles α and β can be derived by reference to Fig. 6. Angle α is easily found.

$$\tan \alpha = \frac{z_3}{x_1} \tag{5}$$

By similar triangles

$$\frac{g}{z_3 - z_2} = \frac{x_1}{\sqrt{x_1^2 + z_3^2}} \qquad \text{or}$$

$$g = \frac{x_1 (z_3 - z_2)}{\sqrt{x_1^2 + z_3^2}}$$

$$\tan \beta = \frac{g}{y_2} = \frac{x_1 (z_3 - z_2)}{y_2 \sqrt{x_1^2 + z_3^2}}$$

A body opposite hand to Fig. 6 is shown in Fig. 7. If the axes are marked as shown, Eqs. (5) and (6) will also apply to Fig. 7.

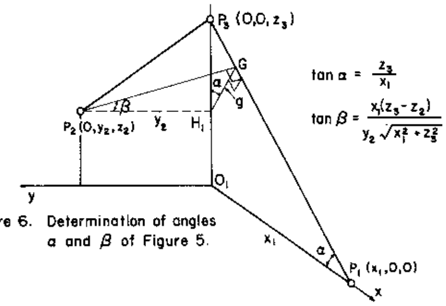


Figure 6. Determination of angles α and β of Figure 5.

Example 2. Let the points be the same as for Example 1, namely:

$P_1 (x_1, 0, 0) = P_1 (4.32, 0, 0)$

$P_2 (0, y_2, z_2) = P_2 (0, 5.81, 0.90)$

$P_3 (0, 0, z_3) = P_3 (0, 0, 2.13)$

Find the value of angles α and β.

Solution

By Eq. (5),

$$\tan \alpha = \frac{z_3}{x_1} = \frac{2.13}{4.32} = 0.493,056$$

$$\alpha = 26.246^{\circ}$$

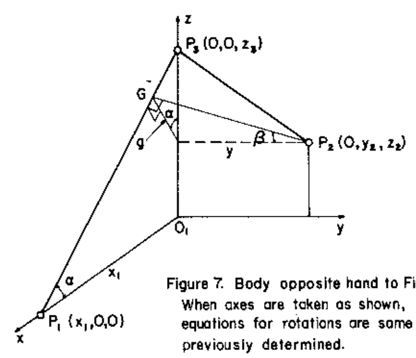


Figure 7. Body opposite hand to Figure 6. When axes are taken as shown, equations for rotations are same as previously determined.

By Eq. (6),

$$\tan \beta = \frac{x_1 (z_3 - z_2)}{y_2 \sqrt{x_1^2 + z_3^2}} = \frac{4.32 \times 1.23}{5.81 \sqrt{4.32^2 + 2.13^2}}$$

$$= 0.189878$$

$$\beta = 10.751^{\circ}$$

If the body is opposite hand to that shown in Fig. 6, angle β will be turned in the opposite direction.

The foregoing calculations are easily made and permit the machine work to proceed without delay.

STUDENT DESIGNERS LOOK AT RECYCLING

Robert B. Aronson
Associate Editor
Machine Design

(Reprinted from Machine Design, February 10, 1972. Copyright 1972, by The Penton Publishing Co., Cleveland, Ohio)

The voice of experience said, "I can't see anyone starting a project that ambitious for at least the next 60 years." And the student answered, "We can't see why we couldn't begin tomorrow."

In a heartening display of faith that the world's problems can be solved and technology has some of the answers, teams of students from three schools recently set out to tell a panel of experienced engineers and businessmen how they would tackle the problem of "Recycling Manufactured and Consumer Products." The forum was the seventh annual student design program sponsored by Armco Steel Co. It is an event that is not a contest. There is no winner and no prize. The main purpose is to give students a chance to personally present their ideas to industrial pros in a useful confrontation between the campus and industry.

At the beginning of the school term, Armco poses the problem to be considered to the selected schools and provides money for materials the students will use. There is also a grant to the schools. The students and their faculty advisors take it from there and prepare presentations as part of their course work. The critique by the 25-man panel of industrialists is a kind of final exam.

Each of the three schools offered a different approach.

Michigan State University's display first stressed the importance of getting public cooperation in any recycling program by proposing a series of communication vans. Each van would contain a number of audio-visual presentations explaining the need for public support and cooperation. These vehicles would travel to various areas and stage their shows.

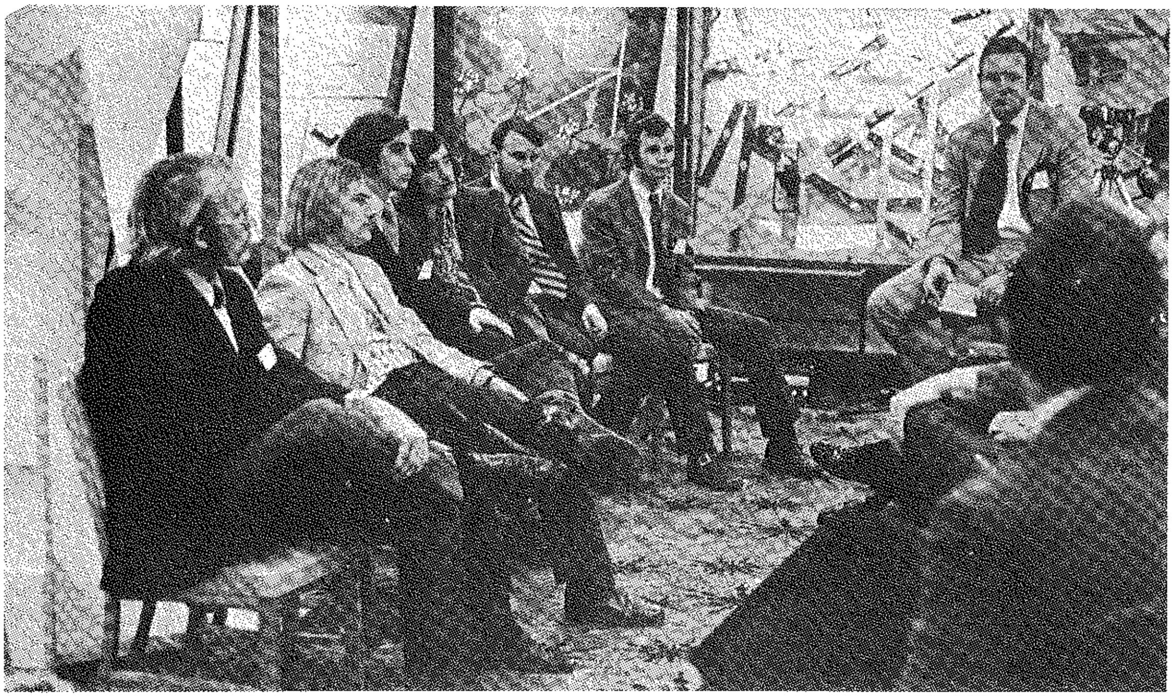
Another designer proposed a "trash train" to service those areas of the country where it would not be economical for an individual community to have its own solid-waste collection and recycling plant. Each community would have collection centers where the trash would be packed in containers designed to be carried on special railroad cars. Regularly, the trash train would pick up these containers. Once aboard the train, the trash would be fed by conveyor to an onboard processing plant in another series of cars. Reusable refuse would be conveyed back to empty containers and left off at plants for further processing of salvageable material.

To encourage people to help with trash sorting, several color coded trash cans instead of the usual one were proposed for both home and public use. Just as most have learned red means stop, the public could be taught which color can to use for glass, metal, plastic, or paper.

A proposal for attacking the problem of waste paper at its source suggested the use of microfilm cards and readers to replace conventional newspapers and magazines. Cards would be delivered or mailed to homes or available for reading on public transportation through coin-operated viewers.

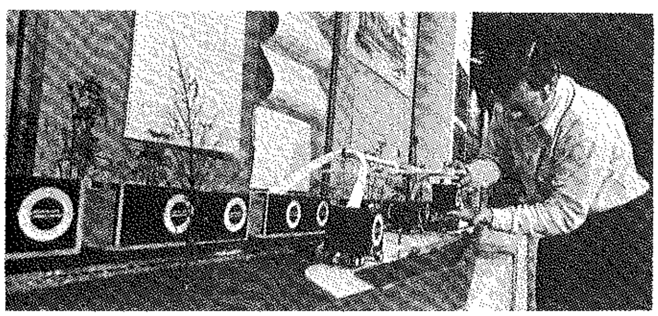
Other ideas proposed by Michigan students included:

Limiting the number of packaging materials to make sorting easier. Another project to make trash sorting feasible called for color coding or otherwise impregnating all packaging with a material that would activate a sensor.



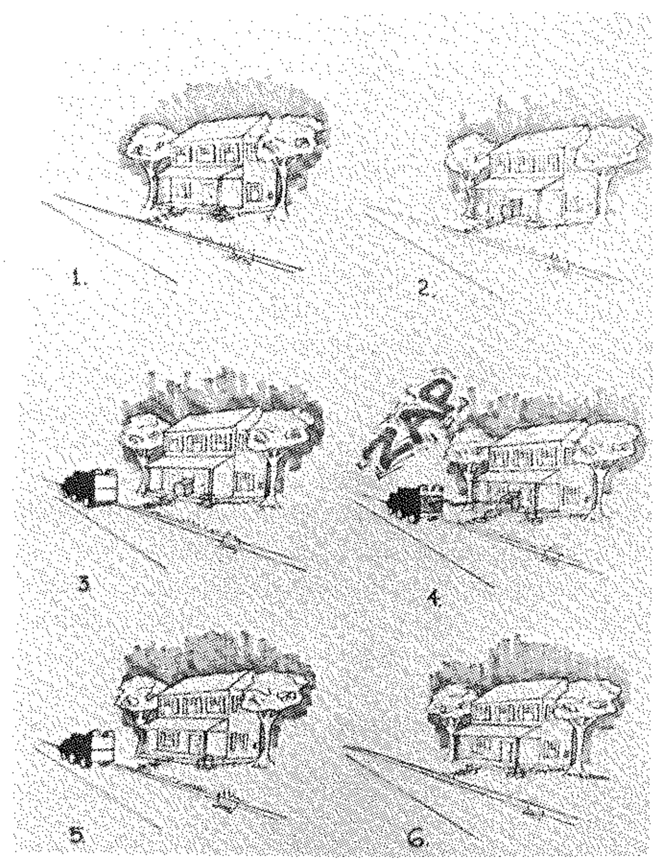
Friendly confrontation between students and industrial pros at the seventh annual student design program sponsored by Armco Steel Corp.

University of Bridgeport students stressed design of long-lived reliable products as a way to reduce the amount of solid waste generated by the consumer. For example, they proposed more standardization of parts to make repairs easier and cheaper. Also, they suggest appliances with highly reliable, working components, that could be easily removed from the decorative shell. This would allow the consumer to change styles periodically by buying only a new shell. Of, if there were a major component failure, the old shell could be retained and the working hardware repaired or replaced. The total result, they reasoned, would be fewer junked appliances and components.



Trash train, proposed by Dave Stedman of Michigan State University, would pick up waste from smaller cities and towns, process it in an onboard plant, and deliver usable materials to factories for reuse.

The wrecked car disposal problem might be eliminated, say two Bridgeport design students, by sending old cars back to the manufacturer for disassembly. Each incoming train or truck loaded with new cars would take back a load of wrecks to the disassembly plants. There, they would be fed onto conveyors and broken down into their components. Salvageable parts would be re-worked others re-melted.



Too bad it isn't that simple. Bridgeport University students suggested this futuristic no-fuss, no-muss way to get rid of old appliances.

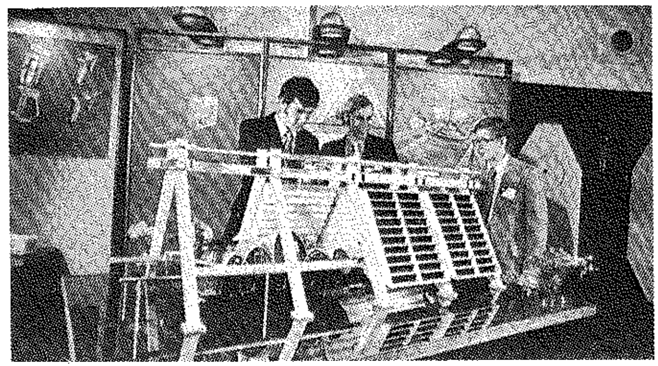
As part of this plan cars would have to be designed for easy disassembly. One proposal includes a car made in four detachable modules: front section, with engine and drive train; center; rear; and seating.

Georgia Tech, attacking its project with a dual team of engineers and industrial design-

And they will form their wrecked cars into bar stools. Bridgeport University design student Mark Lange demonstrates a unique way to recycle old auto parts.

ers, took a radically different approach. Their premise was that products should not have to be recycled. Instead, the items we use and the environment we live in could be designed so they do not generate a lot of broken, unusable, and obsolete products in the first place. To achieve this goal, they proposed a "total living environment." Central element in the plan is a massive A-frame, high-rise apartment complex that would straddle a major transportation artery. Apartment dwellers would have the option of driving their cars, which would be parked in garages under the complex, or taking a linear-motor powered rapid system running along the top of the buildings. For short distances, a "people mover," conveyor-belt system would be available.

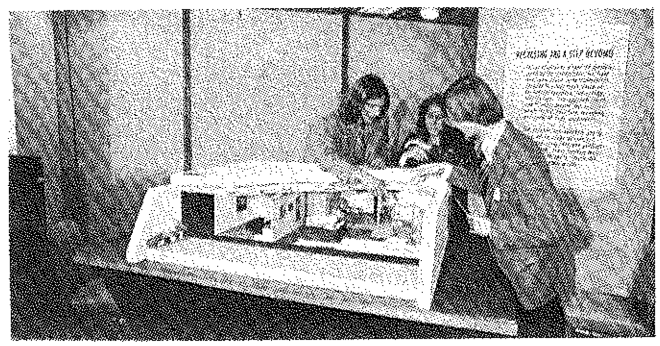
A family need not leave the building to shop. Shopping-center modules, riding on rails through the center of the A-frame, would roll by periodically. The shopper could either go to the mobile store in person or place an order in advance that would be delivered to the apartment. Several of these mobile centers, following preset schedules and offering a wide



All products we use should be designed to generate minimum waste was the idea behind the Georgia Tech display. Students Henry Vrruttia, John Folden and Jesse Elrod explain their "total living environment" model, a huge A-frame apartment complex. Food and merchandise would be delivered directly to each apartment from mobile shopping centers.

variety of merchandise, would be available. Each apartment would be served by an elevator running down the interior walls of the building.

Packaging wastes would be minimized by supplying all food in returnable containers, or no container at all. It is proposed that some foods be available encased only in ice.



Features of a single apartment module from the Georgia Tech A-frame are explained by John Moore, Corda Grant, and John Bryant. Industrial-design students were assisted by a team of mechanical engineering undergraduates headed by Jeff Farmer.

Each apartment would have movable walls for easy expansion and redecorating. Kitchens would be modular so that appliances and work areas could be modified as the family grew. Most furniture could be recessed into the floor when not in use.

One idea that sent tremors through electric-motor manufacturers present was that most appliances would be pneumatic supplied from a central air source Blenders and can openers, for example, would be powered by small air turbines. This, reasoned the Georgia-Tech team, would conserve valuable metals and make disposal of broken appliances easier since they could be made almost totally of plastic. The same pneumatic system would replace all aerosol cans. Sprayable materials would be sold in unpressurized containers that could be easily plugged into the apartment's pneumatic system.

PROGRAMMED INVENTION

Scott W. Miller
Van Dyck Corporation

Today, the most creative people in business are the financial professionals.

For the last century we in the United States seemed to have had a monopoly on industrial creativity; that is, up until the mid 1960's. From that point on it is readily apparent that either the monopoly never existed, or we are actually failing to keep pace with the rest of the world. In spite of this, the research and development expenditures for United States industry this next year, although actually increasing in dollars based on the percentage of sales, is dropping.

Businessmen seem to have forgotten what made them successful in the first place.

It is being stated over and over again that the United States Industrial Complex is now in trouble. One of the main reasons is a very basic lack of creative problem solving that should have been going on over the past many years. What we seem to have over the past decade is mass problem solving in the "belief" that given enough time and enough money we can solve any given problem.

Why the lack of creativity in the technological world exists today is not my purpose in being here... what American business is doing about having creative input brought into their companies is.

There are, of course, many different ways of building creativity inside an industrial organization, and there are many ways that American companies get their technological ideas.

Of course, the first and possibly the best way of creating new product ideas is from internal impetus. However, businessmen tend to grow too old much too early. They are committed to stability and to the accompanying security. The process of staying in and doing business from day to day is often times the maximum that an organization is capable of handling. Also, new ideas tend to shake the status quo. Thus, it is inherently difficult to get an organization of almost any size to become creative at almost any level. This problem extends to non-business, educational and industrial organizations, as well as our homes.

One of the more successful ways of establishing a creative base in an organization is going outside the organization and hiring a consultant group. Problems do develop when bringing in an outside group... some of them being that an outside group is not aware of day-to-day problems that are meaningful, and so the recommendations of the outside organization are not clearly defined because of these problems. Also, there are very few organizations completely devoted to the creative process of originating new product ideas. I want to tell you about one of the companies that has been in this business for probably the longest time of them all.

The company--the Van Dyck Corporation in Southport, Connecticut--is a wholly unique group of creative people. It is a small group of management-oriented, experienced, highly creative professionals. In addition to the small nucleus, we have established and continually add to a list of many hundreds of creative consultants. The personnel are considered "generalists"--extremely flexible and not at all specialists in any field. One of the big secrets, of course, in this type of creative effort is not to have the people working on a particular problem for a client get too involved in day-to-day problems or "hang-ups" of their client industry.

The company atmosphere is loose... it is free... and most important it is creative. The physical facility tries to encourage a creative atmosphere. The company's clients include many of the top 500 corporations in the United States.

The basic approach to our problem solving techniques is synergism. If one creative person privately analyzes and reviews a particular problem, he'll get a few good ideas, and it will take him a good many hours to do it. Have a group of creative individuals, all that have been briefed with the particular problem, sit down and begin the creative effort, the ideas will multiply by the cube of the number of people involved.

The subject can be anything from a package to a missile system, but a collective discussion will result in many ideas to make a new product that is cheaper, safer, easier to manufacture, more versatile, in an extremely short period of time. It would probably take a single person well in excess of two to three years of design development, with a continuous creative effort, to come anywhere near the results of group synergistic creativity.

Generally speaking, the program is divided into three phases. Phase I, the problem identification area, might include technological fact-finding; market information gathering; discussion and investigation of manufacturing technique or techniques. From this early part of the first phase, information is generated in order to assist in the creative efforts that will be following. Naturally the information gathered is boiled down into very readible information. It is at this point that our client decides the general product innovation area. The chances of success in a given area is called "innovation potential". Innovation potential has a series of check lists that must be applied to each one of the product ideas during the evaluation area of the program.

A briefing document is prepared and approved by the client and describes the nature of the problem, but in particular, gets each of the participants who will be involved in the creative sessions to think about particular aspects of particular problems.

Phase II is the creative activity. We know that quality is a function of quantity. The more ideas that are discussed, the better chance of getting outstanding new thoughts. A typical program consists of two to three Creative Sessions with an Evaluation Session after each. Each of the sessions consists of no more than eight participants. The figure of eight is an ideal quantity for a creative session. If the number is more than this, the group tends to break up into smaller groups, and as a consequence, less ideas are generated from that particular session.

The ground rules for a Programmed Invention session are actually quite simple: be loose; laugh a lot; be positive; never negative. The people that are invited for a particular session are not usually there for their particular expertise but for their creative ability.

The participants have been briefed prior to coming to the session to the extent that is required of them for that particular program. Often the participants are requested to prepare a number of ideas prior to coming to the session so that they are "tuned in" on the exact problem area. A number of devices are used to motivate the participants. Always the motivation techniques are aimed at getting the people to attack the problem from an unusual viewpoint. We do not allow judgment at the sessions. It is explained very carefully to each participant that specific problem solving is to be done at a later date and not to be done during the creative session. If there are negative things to say, they are to be put on the card, thrown on the table, and not discussed at all.

After each creative session, a creative evaluation session is held with the client's participation. Implicating a client in the crime tends to make the job of having the client recognize good, useful ideas and accepting these ideas a lot easier near the end of the program.

A typical result of a Programmed Invention series of creative sessions is to have upwards of 400 different ideas. Naturally not all of these are good ideas.

Prior to the final evaluation session, the ideas are generally screened into large groups: "A" for now; "B" for maybe later; "C" for never by the Van Dyck personnel. In evaluating these we generally apply the innovation potential guidelines to each idea. Often times that "gut" feeling on a particular problem is as good as facts and figures.

At the final evaluation session the number of ideas agreed upon at the commencement of the program is chosen. Each of the "A" ideas are voted upon, discussed for both good and bad points, and various formulas are used with weighted portions. For example, in a marketing-oriented problem, marketing has much more import than would engineering. At this point it has been found that the intuition, not reason, is at the heart of the scientific process. The key to scientific discovery, technical innovations and product realizations are intuition, and so it is most important to stress to our clients that intuition is as important as the marketing facts and the seemingly correct guesstimates of production costs, etc. If the product feels right--it probably is.

At this point the chosen ideas are drawn up; some industrial design input; some engineering input; some marketing input; and the final aspects of the problem are put down on paper. This is put together in a presentation form for the client's use. This gives the client a decision-making package for a most reasonable amount of money. He also gets somewhere between 300 and 500 idea cards which can be used to stimulate further creativity within his own organization or be developed at some later date.

At this point the NIH factor comes into play. It is almost impossible to pinpoint the results of many of the programs at this completion and in subsequent years because of the basic insecurity of people in any organization.

Modifications and changes in a product, as it goes through the final manufacturing, engineering stages, make it difficult to pinpoint the initial idea. It is extremely difficult to get a company to admit they received help from an outside group, as they feel this would jeopardize their reputation.

I want to cite a few examples of some worthwhile programs. These programs are interesting for a number of reasons... number one, they are varied, and often times the scope of the problem is very unusual.

The program we did for United States Steel a couple of years ago was to assist U. S. Steel in developing new techniques in shipbuilding. During the 1950's and early 60's, United States shipyards lost a great deal of their business to foreign competition because of antiquated shipbuilding facilities. In order to assist the shipyards, U. S. Steel decided to help these yards become more competitive. One of the ways they were helping these shipyards was to give them new production concepts. Because of the lack of creativity on the part of shipbuilders, we did not include any shipbuilders in the panels on this program... an aircraft designer, an architect... all people familiar with building products or systems similar to ships were used.

One interesting fact that seemed to escape most builders of ships at the time this program was done was that most shipyards are located near water--hence, a suggestion for building ships on floating barges; floating them together; welding them up; sinking the barges from underneath the ships. Cherry pickers, unheard of in shipbuilding, were suggested for movable welding platforms. Other suggestions; such as, building ships in parts, floating them and welding them together, have been used in more recent years (such as the case of the U. S. S. Manhatten).

The program was interesting because of the way the ideas, as they were presented to U. S. Steel, were taken and presented to shipyards. The program took in excess of a year, and U. S. Steel deemed it very worthwhile, and they felt that many of the ideas were accepted by shipyards throughout the United States.

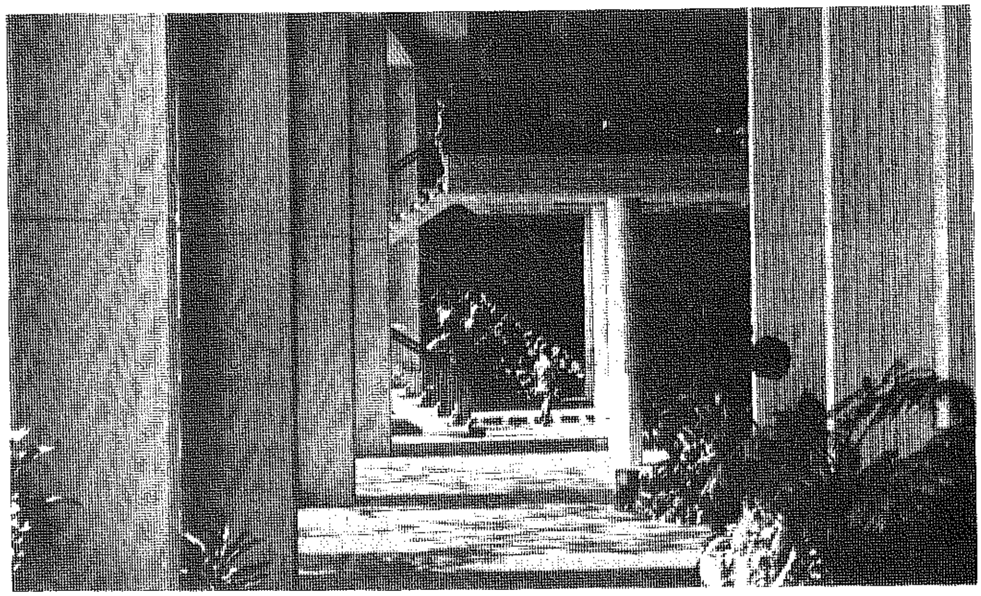
A company that had a unique process for foaming glass and was capable of making a product which was no longer in demand was Pittsburgh Corning. Foamglas has some unusual characteristics--lot of them bad. One of its main uses over the past few years was as insulation. However, in more recent years other materials (polyurethane foam, fiberglass) replaced this material. One of the main drawbacks with foamglas is that it breaks quite easily. In discussing these, it turned out to be one of the main attributes of the product. We learned that foamglas will stop a 22 bullet within a very short distance. One of the suggestions was as crash barriers to be used along freeways and turnpikes. A very large research project into developing the actual product and testing out the main characteristics of this product for this purpose is being carried out now.

Programs have covered many different areas from toys to cooking utensils, new uses for a microwave technology, new ways of processing paper, etc. Creative solutions by creative people, not specialists but generalists, has proven to be economically feasible for many companies in the United States.

Solutions are not arrived at by just more and more money. Creative solutions in education, in business and in our personal lives are our real hope for survival.

(Ed. Note: This paper was presented at the ASEE Annual Conference, 1972.)

the invigoration of a classic



McGraw-Hill Book Company
proudly announces the eleventh edition of
ENGINEERING DRAWING AND GRAPHIC TECHNOLOGY
Thomas E. French, and Charles J. Vierck, University of Florida

1972, 984 pages, $12.95

Yes, this renowned text has been rejuvenated with the implementation of the latest refinements in book design.

Realizing recent research has proven that page makeup, effective use of color, illustration placement, and caption content greatly effect the learning process and student retention, Professor Vierck has incorporated these findings while revising his textual material.

In accomplishing his objectives, author Vierck has revitalized the basic layout of the text for easier reference use by the students. Additionally, he has inaugurated the employment of a second color for greater separation within figures and improved readability throughout the volume.

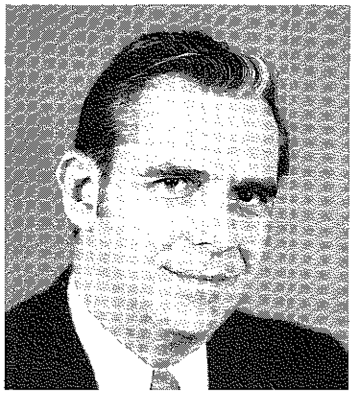
While recognizing the increased emphasis on graphic communication and design in this text, as well as in its briefer version *Fundamentals of Engineering Drawing and Graphic Technology, Third Edition,* Professor Vierck still stresses the development of drafting skills and their precision in his explication.

FUNDAMENTALS OF ENGINEERING DRAWING AND GRAPHIC TECHNOLOGY, third edition

1972, 648 pages, $11.50

This briefer edition of the standard text in engineering drawing for over six decades incorporates all the major changes and refinements in design, format, and use of color of the larger version. A compilation of the first eleven chapters, the third edition has been expanded to include an additional chapter on drawing for engineering design and construction, as well as containing many of the appendices from *Engineering Drawing.*

Beginning with an examination of the instruments used in drawing, this handbook of techniques continues through to discussions of lettering, sketching, and design.



MATH MOTIVATES STUDENTS TO LEARN GRAPHICS

W. A. Wockenfuss
Associate Dean
University of Maryland

"Yip-peeee!" was an exclamation that rang out to announce the solution of a spatial problem. A student had just completed a dihedral angle problem and he was reasonably sure it was right. He had already solved the problem by vector mathematics and the graphical solution was serving as a proof for him. Others in the class had solved a problem graphically and were working on mathematical proofs.

Several years ago, I accidentally discovered a powerful teaching aid by suggesting that a student solve a descriptive geometry problem mathematically as well as graphically. Since that time I have repeatedly used this simple concept to engender enthusiasm in the study of spatial relationships. Below are four examples of descriptive geometry problems with corresponding mathematical solutions:

Shortest Distance from a Point to a Line

In this problem we are to find the shortest distance from point P, which has coordinates of (2, 2, 0), to a line which passes through the points A (5, -7, 2) and B (-1, 1, 2). Figure 1 shows a typical graphical solution in which the line AB is shown as a point and the shortest distance from P to the line appears in true length in that view. According to the scale used the length of CP is 3.6 units.

Let us now look at a mathematical solution. Referring to Figure 2, we see that the shortest distance from point P to line AB is represented by a vector PC which is perpendicular to line AB. By vector addition: $\overline{PC} = \overline{PB} - \overline{CB}$. From the two known points on the given line, we can determine a unit vector in the direction of vector $\overline{CB}$.

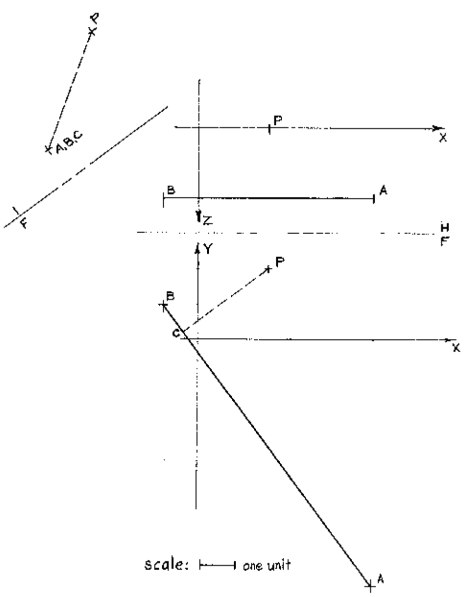


Fig. 1 - Distance From Point to Line

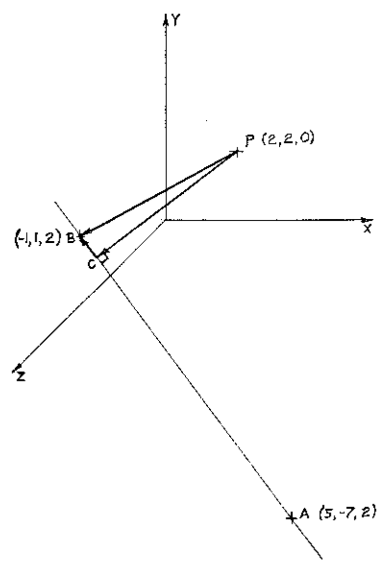


Fig. 2 - Vector Sketch

Q. name a better engineering graphics text than Earle.

A. EARLE'S SECOND EDITION.

ENGINEERING DESIGN GRAPHICS, SECOND EDITION, by James H. Earle, has just been published! It's an updated version of the standard freshman engineering graphics text that was published in 1969 and has been adopted at over 150 colleges and universities.

Like the first edition, this new one introduces students to engineering design through the application of descriptive geometry and graphical principles. This highly-readable book guides the student through the design process from problem identification to the design and analysis of his solution, including team dynamics, gathering data, human engineering, patents, technical reports, oral presentation, and final implementation.

The second edition places greater emphasis on traditional areas like working drawings, data analysis, and dimensioning. Among the other areas that have been strengthened are problems, drawings, and discussions of written reports and supervising student design teams.

ELEVEN COMPANION PROBLEMS BOOKS

James H. Earle and seven other members of the engineering graphics department at Texas A&M University have written eleven companion problems books. Five are in the series called DESIGN AND DESCRIPTIVE GEOMETRY PROBLEMS—they introduce the student to the engineering design process through a series of problems that are solved with descriptive geometry.

ENGINEERING GRAPHICS AND DESIGN PROBLEMS is a four-volume workbook series that introduces engineering, communication, and design, including instruments, geometric construction, design problems, and engineering analysis.

ENGINEERING DESIGN GRAPHICS PROBLEMS C & D synthesize, respectively, the third and fourth volumes of both problems series. They are intended for a one-semester program in engineering graphics.

If you would like examination copies of any of these books, contact Mary Clare McEwing at Addison-Wesley.

Addison-Wesley
PUBLISHING COMPANY, INC.
Reading, Massachusetts 01867

THE SIGN OF
EXCELLENCE

Vector $\overline{AB}$ is in same direction as vector $\overline{CB}$.

$$\overline{AB} = -6i + 8j$$

$$\overline{U}_{AB} = -.6i + .8j \text{ (unit vector in direction of } \overline{CB})$$

The magnitude of $\overline{CB}$ can now be found through the scalar (dot) product, $\overline{PB} \cdot \overline{U}_{AB}$, and the vector $\overline{CB}$ can be expressed as $(\overline{PB} \cdot \overline{U}_{AB})\ \overline{U}_{AB}$. Substituting this expression for $\overline{CB}$ in the original equation, we have:

$$\overline{PC} = \overline{PB} - (\overline{PB} \cdot \overline{U}_{AB})\ \overline{U}_{AB}$$

$$= (-3i-j+2k)-[(-3i-j+2k)(-.6i+.8j)]\ (-.6i+.8j)$$

$$= (-3i-j+2k)-(1.0)\ (-.6i+.8j)$$

$$= 2.4i - 1.8j + 2k$$

The shortest distance from point P to the line AB is the magnitude of the vector $\overline{PC}$.

$$|\overline{PC}| = \sqrt{(2.4)^2+(1.8)^2+(2)^2}$$

$$= \sqrt{13.00}$$

$$= 3.61$$

It is not unusual for a student who has completed the graphical solution first as in this example, to show his anxiety as he makes the final mathematical step in the solution. If he finds his answer is close but somewhat different, he usually checks carefully all calculations and reviews his drafting procedures. Drafting accuracy becomes a critical issue because of the student's own desire to obtain answers which check.

Shortest Distance from a Point to a Plane

The shortest distance from a point to a plane may be represented by a line drawn from the point perpendicular to the plane. Vectorially this distance is the scalar component normal to the plane of a vector from the point P to any point lying in the plane. The mathematical solution can therefore be obtained by finding the scalar product of a vector from P to the plane and a unit vector perpendicular to the plane. We will now look at a specific example.

We are to determine the minimum distance from point P (4, -3, -1) to the plane $2x - 6y + 3z = 10$.

Three points on the plane can be located by finding the axial intercepts. Let point A be the x-axis intercept, point B be the y-axis intercept and point C be the z-axis intercept. The coordinate locations of the three points are:

point A $(5,\ 0,\ 0)$

point B $(0,\ -\frac{10}{6},\ 0)$

point C $(0,\ 0,\ \frac{10}{3})$

In the mathematical solution we need to use only one of the three points. We arbitrarily choose point B to form a vector $\overline{PB}$ from point P to a point on the plane, point B.

$$\overline{PB} = -4i + \frac{4}{3}j + k$$

We now need a unit vector perpendicular to the given plane. When the equation of a plane is given, the coefficients of the x, y, and z terms are the x, y, and z components of a vector (not necessarily unit) normal to the plane.

$$\overline{N} = 2i - 6j + 3k \text{ (vector perpendicular to plane)}$$

$$\overline{U}_N = \frac{2}{7}i - \frac{6}{7}j + \frac{3}{7}k \text{ (unit vector perpendicular to plane)}$$

The shortest distance, d, is the scalar component of vector $\overline{PB}$ in the direction parallel to the unit vector $\overline{U}_N$.

$$d = |\overline{PB} \cdot \overline{U}_N|$$

$$= \left|(-4i + \frac{4}{3}j + k) \cdot (\frac{2}{7}i - \frac{6}{7}j + \frac{3}{7}k)\right|$$

$$= \left|-\frac{8}{7} - \frac{8}{7} + \frac{3}{7}\right|$$

$$= \left|-\frac{13}{7}\right|$$

$$= 1.857$$

Note that the absolute value sign is used because we are interested in the distance parallel to the unit vector and not in sign convention relative to the unit vector.

The graphical solution is shown in Figure 3. The given plane was located on the axes by plotting the three intercepts A, B, and C. Any line perpendicular to the plane would project in true length in a view that shows the plane as an edge. The plane ABC was therefore shown as an edge in an auxiliary view adjacent to the horizontal view and a line was drawn from point P perpendicular to the plane in that auxiliary view. The measured distance is 1.8 units.

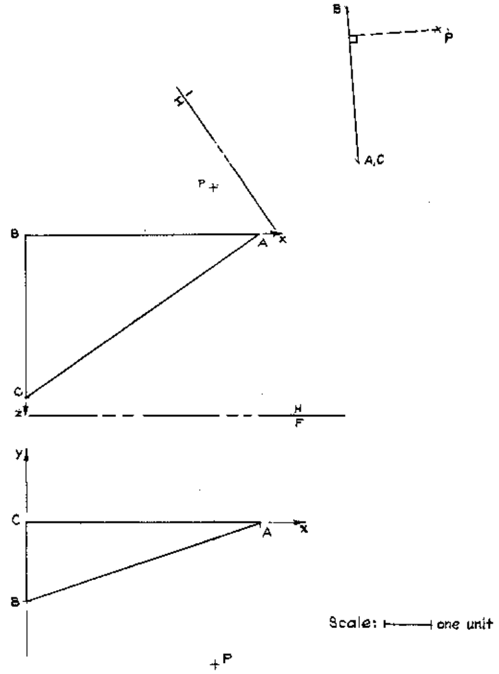


Fig. 3 - Distance From Point to Plane

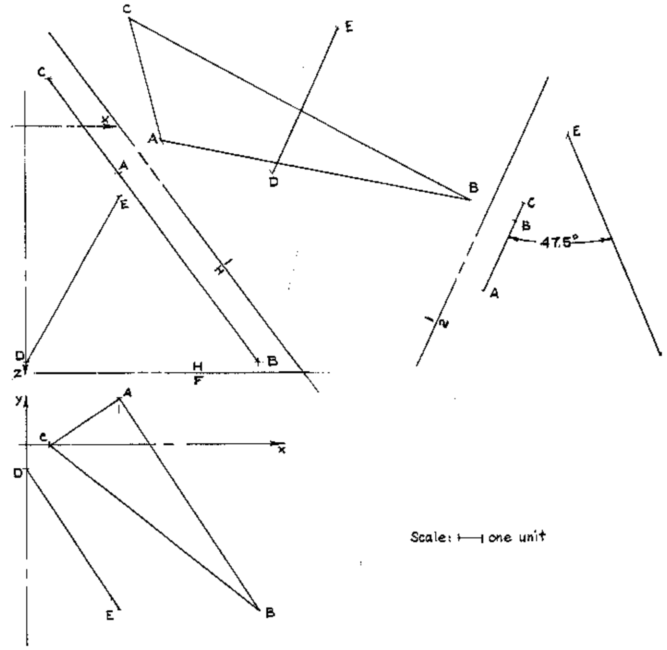


Fig. 4 - Line-Plane Angle

Line-Plane Angle

Our third illustration requires an angular measurement. Students find that drafting accuracy is extremely important in problems which require angular measurements. Because of the small scales we must use for classroom problems, a slight linear discrepancy in plotting points from one view to another can result in a relatively large angular error.

In order to show the angle between a line and a plane in true size, we must produce a view in which the plane projects as an edge and the line projects true length. Although other techniques such as rotation may be employed, in Figure 4, we have solved the given problem through auxiliary view projections. The given plane is determined by the three points A (4, 2, 2), B (10, -7, 10), and C (1, 0, -1) and the given line is determined by the points D (0, -1, 10) and E (4, -7, 3). In solving the problem, the first step was to draw a view in which the plane projected in true size and shape. In any view adjacent to this view, the plane will project as an edge parallel to the projection hinge-plane line. The second step in the graphical procedure was to draw a view which is adjacent to the true size and shape view of the plane and which shows the line CD in true length. The measured angle is 47. 5 degrees.

The sketch in Figure 5 will help in visualizing the geometry of the mathematical procedure used in this example. Vector $\overline{N}$ is perpendicular to the plane ABC and is found by finding the vector (cross) product of two vectors which lie in plane ABC. The angle θ between vector $\overline{N}$ and vector $\overline{DE}$ (a vector along the given line) is gound thr ough the use of the scalar product. Because $\overline{N}$ is perpendicular to the given plane, the line-plane angle is the complement of angle θ.

Let us form vectors from point A to the other two points in the plane:

$\overline{AB} = 6i-9j+8k$ and $\overline{AC} = -3i-2j-4k$

Vector $\overline{N}$ is the vector product of vectors $\overline{AB}$ and $\overline{AC}$.

$$\overline{N} = \overline{AB} \times \overline{AC} = \begin{vmatrix} i & j & k \\ 6 & -9 & 8 \\ -3 & -2 & -4 \end{vmatrix}$$

$$= (36+16)i+(-24+24)j+(-12-27)k$$

$$= 52i - 39k$$

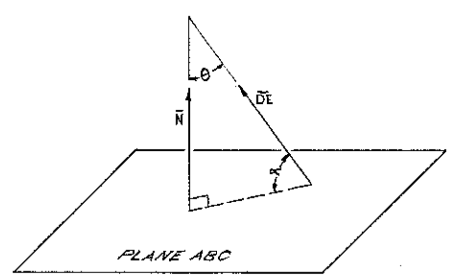


Fig. 5 - Line-Plane Angle

The magnitude of vector $\overline{N}$ is

$$|\overline{N}| = \sqrt{(52)^2 + (39)^2} = 65$$

A vector in the direction of the given line is

$$\overline{DE} = 4i - 6j - 7k$$

And its magnitude is

$$|\overline{DE}| = \sqrt{(4)^2 + (6)^2 + (7)^2} = 10.05$$

By definition the scalar product of two vectors is equal to the product of the magnitudes of the two vectors by the cosine of the angle formed by the two vectors.

Therefore:

$$\cos\theta = \frac{\overline{DE} \cdot \overline{N}}{|\overline{DE}||\overline{N}|}$$

$$= \frac{208 + 273}{(10.05)\ (65)} = \frac{481}{653.25}$$

$$= .736$$

Then $\theta = 42.6^{\circ}$

And $\alpha = 90^{\circ} - \theta = 90^{\circ} - 42.6^{\circ} = 47.4^{\circ}$

Again our mathematical answer agrees with our graphical solution. Although these examples use vector algebra and geometry, it is not uncommon for a student to solve such problems through mathematics which does not involve the use of vectors. When a student uses a less conventional method, I frequently have him lead a class discussion on solving his problem. In such discussions, several procedures for attacking the problem may be evolved.

Dihedral Angle

For the sake of brevity, our dihedral angle problem will use plane ABC as defined in the preceding illustration. We are to find the angle between plane ABC and a plane defined by the points D (0, 1, 8), E (2, -4, 1) and F (10, -6, 5).

Graphically our goal is to produce a view in which both planes project as an edge. We might find the line of intersection between the two planes in the frontal and horizontal views and project the intersection line as a point. Such a view would show both planes as edges. In the previous problem we projected plane ABC in true size and shape and stated that any adjacent view would show plane ABC as an edge. If we can draw a view which is adjacent to the view showing plane ABC in

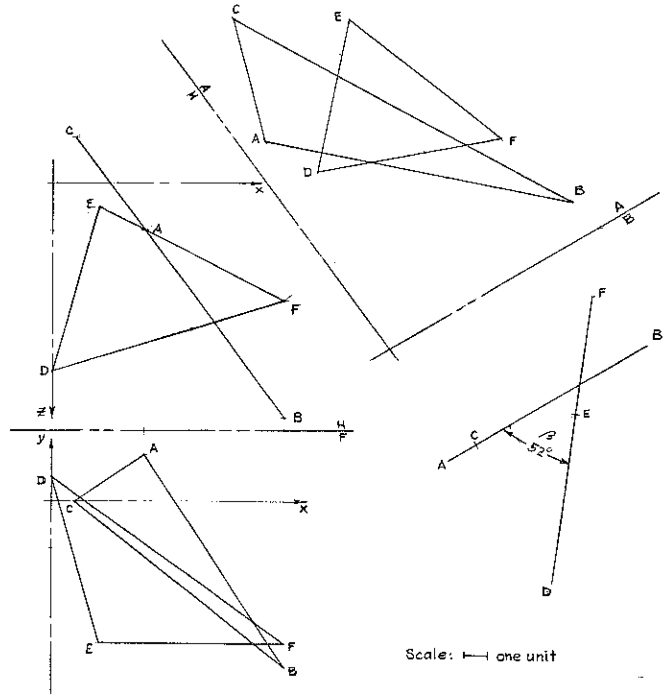


Fig. 6 - Dihedral Angle

true size and shape and which shows plane DEF as an edge, we will have both planes projecting as edges. The latter procedure is used in the graphical solution shown in Figure 6. The measured angle is 52°.

The dihedral angle between two planes is the same as the angle between two lines, each of which is perpendicular to one of the planes. In the previous problem we found a vector $\overline{N}$ which was perpendicular to plane ABC. In similar manner we can find vector $\overline{P}$ which is perpendicular to plane DEF.

We use two vectors in plane DEF

$\overline{DE} = 2i - 5j - 7k$ and $\overline{DF} = 10i - 7j - 3k$

Finding the cross (vector) product

$$\overline{P} = \overline{DE} \times \overline{DF} = \begin{vmatrix} i & j & k \\ 2 & -5 & -7 \\ 10 & -7 & -3 \end{vmatrix}$$

$$= (15-49)i + (-70+6)j + (-14+50)k$$

$$= -34i - 64j + 36k$$

The magnitude of vector $\overline{P}$ is

$$\overline{P} = \sqrt{(34)^2 + (64)^2 + (36)^2} = 81$$

The angle between the two perpendicular vectors may be found through the scalar product.

(See MOTIVATES - p. 56)

GRAPHICAL PROBABILITY ANALYSIS

Professor Charles J. Baer
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Increasing demands for a better understanding of probability and statistics are showing up in many places in the engineering curriculum. The use of logarithmic paper for plotting data which form a straight line and the resulting equation are well known to persons who have been teaching in the engineering graphics area for sometime. The method of least squares has also added to the interest of modern graphics courses because it provides an excellent example of the use of graphics, the desk calculator and digital computer.

Another graphical approach which can be taught to students at any level is the use of probability paper. At the suggestion of one engineering department head, this has been taught for three semesters to students in course ME 57, Introduction to Design. At the beginning of each semester the height and weight of each student is taken. One or the other -- height or weight -- is recorded in tabular form so that each student can prepare a histogram and a plot on probability paper. If the class has less than 30 students, it has been the practice to add the equivalent data from a previous class to the tabulations in order to get satisfactory material from a plotting standpoint. This is to say that 50 data points will be likely to provide a "pattern", while 25 or 20 will not be likely to provide much of a pattern.

Table 1 lists in ascending order the heights of 55 students in the class. It also assigns an order number to each student going from one to 55 in column two. The third column provides a G value, which we may call a cumulative distribution function (or factor) for each student. This function will be explained shortly.

HISTOGRAM

Students can immediately plot a histogram, given the raw data. They can be assigned an interval (one inch in this case) to be used in establishing the horizontal scale, or they may be asked to establish their own interval. In the case of the heights this interval of one inch is more or less automatically established because we measured, with a few exceptions,

TABLE 1. TABULATION OF HEIGHTS OF ME 7 STUDENTS

Ht in inches	Order No.	$G = \frac{J}{N+1}$	Ht in inches	Order No.	G
65.5	1	.018	71	30	.536
66	2	.036	72	31	.556
66	3	.054	72	32	.573
66	4	.072	72	33	.588
68	5	.089	72	34	.606
68	6	.108	72	35	.625
68	7	.126	72	36	.643
68	8	.143	72	37	.661
68	9	.161	72	38	.680
69	10	.188	72	39	.700
69	11	.197	72	40	.718
69	12	.215	72.5	41	.735
69	13	.233	73	42	.752
69	14	.252	73	43	.770
69	15	.268	73	44	.786
69	16	.287	73	45	.804
70	17	.302	73	46	.821
70	18	.323	73	47	.839
70	19	.340	73.5	48	.852
70	20	.360	74	49	.875
70	21	.376	74	50	.893
71	22	.394	74	51	.911
71	23	.411	74	52	.929
71	24	.430	74	53	.946
71	25	.448	75	54	.964
71	26	.465	75	55	.982
71	27	.484			
71	28	.500			
71	29	.518			

J = Order No.

$G = \frac{J}{N+1}$

N = 55

N + 1 = 56

every student to the nearest inch. But in the case of certain other data, such as the weights of students, it is more of a job to select an interval and obtain a meaningful histogram.

Figure 1 shows a histogram drawn from the data of Table 1. The heights of the bars are plotted by determining the frequencies (number of students of the same height) starting with 65. 5 (changed to 65 inches for a more uniform bar spacing) and concluding with 75 inches. (The 72. 5 and 73. 5 measurements were moved to the left one-half inch and added to the bars as shown.) At this point the histogram may be considered to be complete, or it can be augmented by fitting a curve through the bars as has been done in Fig. 1. This may be, and is, called a distribution or frequency curve. Some readers might draw the curve somewhat differently than has been done here. The writer agrees that they have this right, and that there may be curves that are more truly representative than the one drawn here.

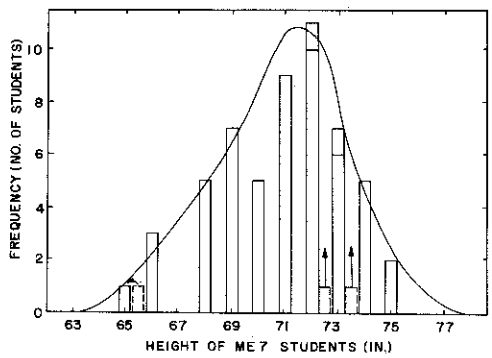

Fig. 1 Heights of ME 7 students plotted in the form of a histogram. A frequency curve has been added.

THE NORMAL DISTRIBUTION CURVE

The student and the reader have noticed by now that the curve drawn in Fig. 1 is skewed to the right--a condition which some statisticians and engineers call kurtosis. Usually one wants to know how far such a curve departs from a normal distribution curve. A "normal" curve is shown in Fig. 2a. In Fig. 2b an attempt has been made to draw a normal curve and the distribution curve of Fig. 1 on the same graph. (The areas under these curves should be equal.) The result is about, as anyone who is familiar with the normal curve, might expect. There is a fair amount of difference. But how significant is this difference, or is it significant at all? Figure 2b does not provide this information.

Before going to the next figure, let us examine Fig. 2a. The horizontal scale is

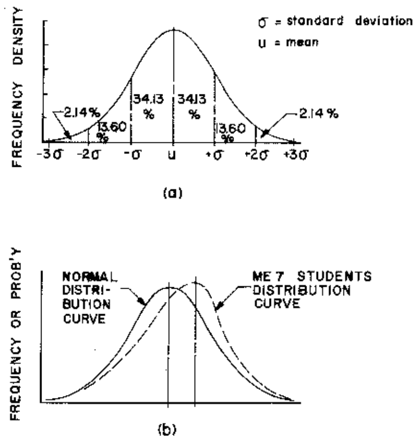

Fig. 2 Frequency, or distribution curves: (a) Normal frequency curve with areas under the curve. (b) Normal distribution curve and distribution of Kansas ME 7 students by height.

divided into equal-size segments one sigma apart. Sigma is the symbol for one standard deviation. The standard deviation of a collection of data may be obtained several ways. It shall be done graphically in this paper. For the uninformed, sigma is the root-mean-square deviation and can be obtained by this equation:

$$\sigma = \sqrt{\frac{\Sigma i = 1 \, (X_1 - U)^2}{n - 1}} \qquad (1)$$

where U is the average or mean.

THE USE OF PROBABILITY PAPER

It is also possible--and sometimes desirable--to plot a distribution of data, cumulatively. One way to do this is to arrange the data in order, as we have done in Table 1. These data can be plotted on normal probability paper. Before this can be done it is usually the practice to assume a distribution. This will be explained in a few paragraphs when the d-Test for fitness is described. Certain data follow certain distribution. Some of the different types of distribution are: normal, binomial, Poisson, Weibull and beta.

In order to plot the data on probability paper and to make a test of its fit, we have assumed beta distribution. The beta distribution is in accordance with the following equation:

$$\beta = \frac{N!\,(Z)^{J-1}}{(N-J)!\,(J-1)!} \qquad (2)$$

This can be integrated and divided by the abscissa to get a mean value which is:

$$\frac{J}{N+1} \qquad (3)$$

This can be used to get the cumulative distribution function, which has been plotted as G, the cumulative percentage, on the normal probability paper of Fig. 3. Each of the 55 heights has been given an order no. (N), and a G value has been computed from equation (2) and placed beside the corresponding height in Table 2. A straight line has been passed through the "average" of these heights as shown in Fig. 3. Some persons would draw a line, curved at the ends, to pass through the average of the plots at 66, 74, and 75 inches. We have elected to draw the straight line and to apply a test to see if it is, or is not, a good fit.

The same data have also been plotted on another type of probability paper called Weibull paper. A straight line drawn through these plots fits about as well as the line in Fig. 3. Many items of mechanical equipment yield a straight line pattern when their failures are plotted. The reliability departments in automotive and heavy equipment manufacturing companies use Weibull paper. Note that the Weibull paper is considerably different than the normal probability paper. This is because the equations are considerably different, viz:

Normal distribution

$$y = \frac{1}{\sqrt{2\pi}} \cdot e^{-z^2/2} \qquad (4)$$

Weibull distribution

$$y = \frac{b}{\theta} x^{b-1} e^{-(x/\theta)^b} \qquad (5)$$

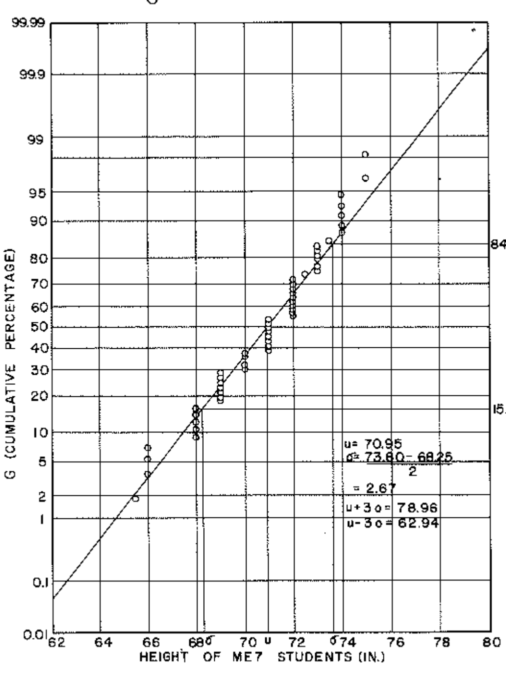

Fig. 3 The heights of ME 7 students plotted cumulatively on normal probability paper.

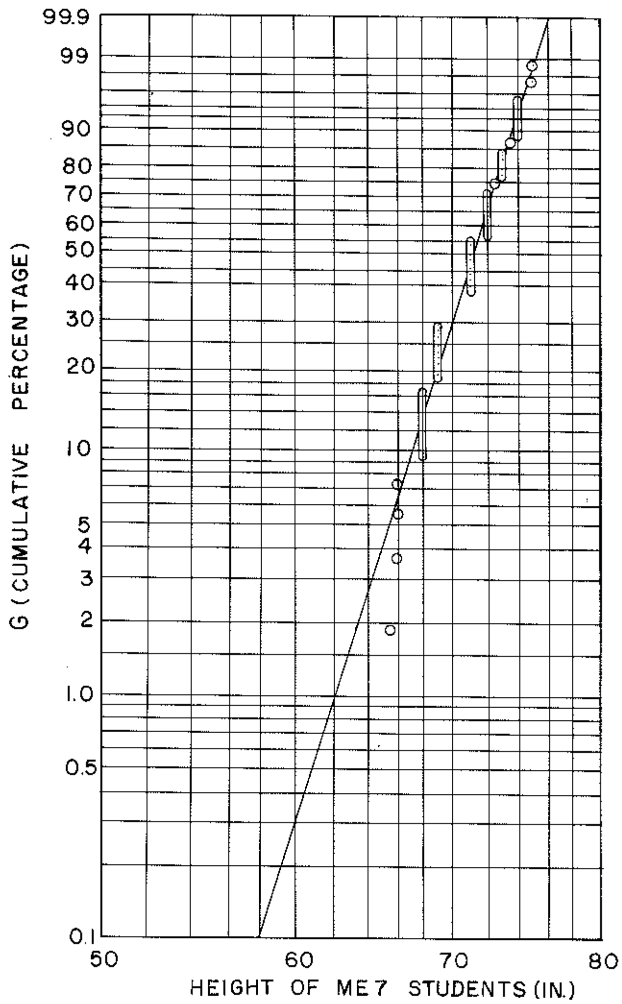

Fig. 4 The heights of ME 7 students plotted on Weibull paper.

No more will be said about the Weibull paper at this time. Another article might well be written on the subject.

THE KOLMOGOROV -- SMIRNOV TEST FOR GOODNESS OF FIT

A simple test can be applied to Fig. 3 to see if the data fit the normal distribution or not. It is often called the d-Test, but is officially listed as the Kolmogorov-Smirnov test. Table 2 shows some deviation factors which have been computed from the K-S assumption that the maximum deviation between actual and expected cumulative frequencies will not be exceeded by a curve that fits normal probability well.

A value of 0.183 has been computed for the (vertical) deviation from the normal at a .05 significance level. We could have selected a d-value for any of the levels shown in Table 2. If an observation falls within the .05 significance envelope it is not significantly different than normal probability. In other words, if we draw such a conclusion a large number of times

TABLE 2

DEVIATION FACTORS

from

KOLMOGOROV - SMIRNOV TEST
FOR GOODNESS OF FIT

TABLE OF CRITICAL d VALUES

Sample Size (N)	Level of Significance 0.20	0.15	0.10	0.05	0.01 *
10	0.322	0.342	0.368	0.410	0.490
15	0.266	0.283	0.304	0.338	0.404
20	0.231	0.246	0.264	0.294	0.356
25	0.210	0.22	0.24	0.27	0.32
30	0.190	0.20	0.22	0.24	0.29
40	0.17	0.18	0.19	0.21	0.25
50	0.15	0.16	0.17	0.19	0.23
over 50	$\frac{1.07}{\sqrt{N}}$	$\frac{1.14}{\sqrt{N}}$	$\frac{1.22}{\sqrt{N}}$	$\frac{1.36}{\sqrt{N}}$	$\frac{1.63}{\sqrt{N}}$
55	0.145	0.154	0.164	0.183	0.22

*This is equivalent to the 99% confidence limit.

From STATISTICS IN RESEARCH, B. Ostle.

we shall be wrong in not more than 5 percent of all the cases. Fig. 5 is the data of Fig. 3 with the upper and lower limits of the d-Test added. Let us be even more restrictive than 5 percent and construct the .01 significance levels using the d-value of .22 which has been computed. Graphically, we lay off points .22 units on each side of the straight line at enough locations to get the two curved limit lines shown. At pt. 1 (Fig. 5) we are at .58 which is .22 above .36, the straight line ordinate. Pt. 2 is at .14, exactly .22 below the .36 ordinate value of the straight line. This .22 deviation is plotted vertically above and below the line and varies as we move right or left to plot more points. Near the ends, the limit curves get farther away from the straight line. But so do the data points which were used to get the line. If our data points fall within the two curves -- which they do -- we have satisfied the .01 significance level, and we have a good fit. (Only about one out of every 100 points should lie outside the envelope.)

Probably a better known test for significance is the chi-squared test, but it is not necessarily any better than the d-test. The following example shows how the X^2 test works:

The number of failures in equal-sized sections of a class were 3, 8 and 10. Were the instructors different in their methods of grading? If the sections were taken at random the null hypothesis permits us to say that the expected number of failures is $\frac{3+8+10}{3} = 7$.

The data can be tabulated as follows:

Section	O	E	O-E
A	3	7	4
B	8	7	1
C	10	7	3

$$X^2 = \frac{4^2}{7} + \frac{1^2}{7} + \frac{3^2}{7} = 3.715$$

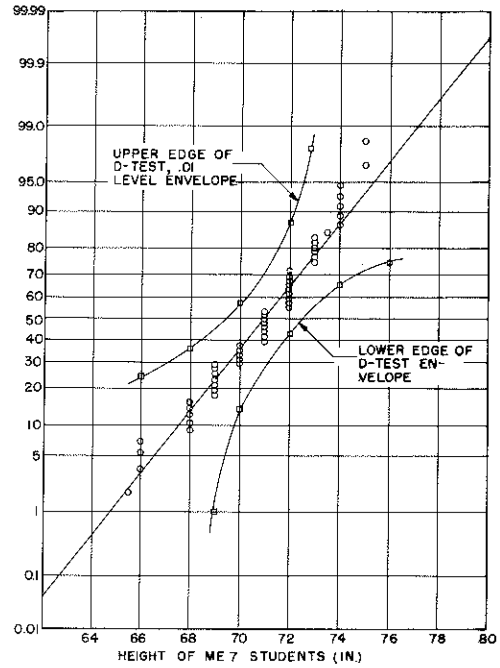

Fig. 5 Height data of ME 7 students and d-Test curves for the .01 significance level.

There are two degrees of freedom in this situation, therefore we go to line 2 of a table such as Table 3. At the .05 level of significance the value of X^2 is 5.991, much larger than the 3.715 computed above. Inasmuch as the computed X^2 is within the allowable area of the X^2 curve, we must conclude that there is no significant difference among the instructors insofar as their grading is concerned. The chi-squared test is more difficult to compute than the d-Test and is easier to do incorrectly because of the necessity of obtaining the correct number of degrees of freedom, a subject we will not go into in detail at this time.

TABLE 3 CHI-SQUARED VALUES

Degrees of freedom	Probability of a Deviation Greater Than X^2 .50	.10	.05	.01
1	.455	2.706	3.841	6.635
2	1.386	4.605	5.991	9.210
3	2.366	6.251	7.815	11.345
⋮	⋮	⋮	⋮	⋮

(See PROBABILITY - p. 55)

EDUCATION FOR ENGINEERING DESIGN INVOLVEMENT

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(Ed. Note: This paper was presented at the ASEE Annual Conference - 1972)

In recent years, it has become the vogue to introduce "design" courses into engineering curricula. Up until about five years ago, the trend in many institutions was to eliminate such courses, and those schools that failed to do so were considered out of step and "old hat", according to the conventional wisdom. Of those institutions that did not go along with the conventional wisdom, there may, indeed, be schools that have continued to conduct design courses in the same way that they did twenty and thirty years ago. Others, however, have seen the necessity of instructing the student in the design process and of making such instruction pertinent and relevant, and have updated their course work accordingly.

In many institutions that have dropped design courses, the situation may have come about by the retirement of the old-timer who taught those courses and the failure to replace him with someone specifically selected to teach design. Other faculty members may have felt uncomfortable with an assignment to a design course, and eventually the easiest way was simply to drop the requirement for the design courses, in accord with the trend. Many of the newer faculty members felt uncomfortable with a design course assignment because they had no great experience in the design process, their preparatory work consisting primarily of earning a doctorate that did not require a major design effort. Now, after all of this, many forward thinking faculty members realize that they must acquaint their engineering students with design, but are at a loss as to how to proceed.

Having decided that education in design is a necessary part of an engineering curriculum, two requirements exist: (1) get someone to teach design, and (2) modify the curriculum to incorporate that instruction. With respect to the first requirement, a search must be conducted among designers if a reasonable likelihood of acquiring a design teacher is expected. This may well mean that the institution will have to digress from the pattern of having all new faculty members hold a doctorate, since there are not too many designers who hold doctorates right now.

With respect to the second requirement, one approach would be to wait to find out the new design teacher's suggestions. Obviously, he must be satisfied with the content of the program, but it is important to observe the curricular qualifications he might look for. To identify these, we must examine the design process.

Reference 1 identifies a five-phase general procedure for solving an engineering problem as:

1. Problem Formulation - the problem at hand (society's "need") is defined broadly.
2. Problem Analysis - now the need is defined in detail.
3. The Search - alternative solutions are acquired through inquiry, invention, research, etc.
4. Decision - the alternatives are evaluated, compared, and screened until the best solution evolves.
5. Specification - the chosen solution is documented in detail.

Considering each of these phases separately, it is apparent that the first phase is often done by someone other than the engineer.

Certainly the engineer should be more involved in this phase, and, even when the problem identification is stated by others, it may need to be restated before the engineer can progress. The general education of engineers helps in this phase. An incisiveness and a precision with the language is needed. Design courses can illustrate the phase, but cannot teach it.

Phase 2 expresses all of the "musts" and "must nots" of the first phase, and should also identify the "don't cares". This requires technical analysis knowledge, to know what will be affected in the design, to permit the classification of desires.

Phase 3 is the synthesis phase, which requires some creativity and some experience on the part of the designer. Technical analysis courses help, in that problems solved in such courses contribute to the designer's experience background to some extent. Innovativeness is necessary, but it has not yet been determined whether or not this can be taught.

Phase 4 begins as an analysis process which is best taught by the conventional analysis courses. Since there will frequently be a large volume of analysis, it is necessary that the engineer have a means to perform this analysis without drudgery. The digital computer serves this function well, so it is essential that the engineer be well versed in its use for problem solving. Various alternative solutions must be compared, so as to select the "best" one. This means that a way to compare alternatives must be devised. If this can be put into quantitative terms, the computer can be used for this purpose, to great advantage. If there is some part of the evaluation of alternatives that cannot be quantified, the computer can be programmed to identify all of the otherwise acceptable alternatives to permit the designer to make the best selection. This type of use of the computer is usually taught in a "design" course.

Phase 5 involves communication to those who will implement the selected design. This requires skill in graphical, oral, and written communications media. The need for course work to develop such skills, if they are not already held by the student, is obvious.

Based on the above, it can be seen that many of the traditional engineering analysis courses are not only useful but also essential for a student going into design. In addition, oral and written communication is necessary. If graphic communication has been dropped from the curriculum, it must be reinstated. However, this does not need to be the old style mechanical drafting course. The topic is graphic communication, and, for the engineer, this involves communication to other engineers and to draftsmen who prepare the engineering drawings. It is not necessary to be, and probably should not be, a course to make a draftsman of the engineering student. If, in his chosen field of work, the need exists for him to be more capable in drafting work, the foundation will have been established in a graphic communication course. If no more detailed need should arise, the means for graphic communication is established with one course. At the University of Hartford, we will be offering this fall for the first time a new course in Graphic Communication, required of all engineering students, taught by a member of our Art School faculty. This replaces our old Engineering Graphics course.

The reference above to computer use indicates the necessity of instruction in a mathematically oriented computer language. At the University of Hartford we have been offering a two credit required course in Fortran programming to first semester freshmen. It has been placed in this semester primarily as a come-on for the new engineering student, who is taking most of his course work in Mathematics, Science and liberal arts. It can be taken as much as a year later without prerequisite difficulties. All engineering students at the University of Hartford must acquire a knowledge of Fortran.

Somewhere along the way, the student needs to be introduced to the five-phase procedure for design, and given an opportunity to practice it. At the University of Hartford we offer a two credit course, "Introduction to Engineering," for all first semester engineering freshmen, which acquaints the student with the design process before his approach is inhibited by artificial limitations inferred in the technical analysis courses. This course is intended as purely orientational, so that the student can find out what engineering is about early in his course of study and commit himself to it. Since we believe that engineering is designing, the course is based on team design projects. Advanced standing students who are already committed to engineering are not required to take the course, and, in fact, we do not want them mixed in with the freshmen, telling them what cannot be done, based on their "advanced" knowledge.

A design course is also necessary at the upper end of the curriculum, wherein the various technical skills acquired along the way can now be applied in some meaningful way. At this point, we do not believe it is possible to have a single course that will be applicable to all disciplines of engineering. The Mechanical Engineering department requires the course, "Mechanical Design," of all M. E. majors. This is offered in the first semester of the senior year, and has certain specific prerequisite requirements. It is not the same as the old style "Machine Design" course that was taught at many institutions as recently as ten to twenty years ago. In that old style course, approximately one-third to one-half of the semester was spent in going over structural analysis methods that the student had been introduced to in a "Strength of Materials" course, and the balance of the semester was spent in solving analysis problems on various types of machine elements. Thus, such a course was not truly a design course at all. It was frequently followed by "Machine Design II", in which the student spent the entire semester doing an individual design of a compressor or an engine. Now, it is just not possible for one person to truly design an entire compressor or engine in the time available in a one semester course. As a result, there was very little design, and mostly just drawing of an engine or compressor. When this author came to the University of Hartford to teach design some years ago, the first thing that happened was that the old Machine Design II was changed to consist of a series of smaller design projects, each of which was aimed at illustrating certain mechanical concepts in design, and which could be completed by the student in a relatively short period of time. Some projects involve a simple layout as the fastest and easiest way to solve the problem. Occasionally a project involves some detail drawing, to acquaint the student with that function. Most frequently, the projects involve no drawing at all, the design process stopping short of that phase.

The second thing that happened was the initiation of a new required prerequisite course in structural analysis and design, so that M. E. majors could have a whole semester after "Strength of Materials" to learn the structural analysis and design techniques that they must have in mechanical design, in place of the former one-third to one-half semester, and at the same time, the business of solving analysis problems was dispensed with, so the first semester senior design course, also, became a series of smaller design projects. Thus the old two semesters of "Machine Design" was replaced by a semester of "Basic Structures" and two semesters of small design projects.

Since that time we have reduced the requirements so that the "Basic Structures" and only the first semester of design projects is required. The second semester course is still available as an elective. Any school that still has the old style Machine Design I and II could convert them to a structural analysis course and a small projects course very simply. Any school that does not have both of these courses for their M. E. majors should create them. The mechanical engineering designer must have a sound knowledge of basic structural analysis, and must try his hand by doing some design projects. Our "Basic Structures" course is now, also, the first structures course after "Strength of Materials" taken by Civil Engineering majors, who then go on into their own special advanced topics courses. If such a course cannot be developed with the Civil Engineering people, it must be developed without them, because M. E. majors need it.

The use of the computer to evaluate alternative solutions to the design problem is also taught in the "Mechanical Design" course at the University of Hartford. This involves the establishment of functions of merit and the techniques of maximizing them, as well as iterative solution procedures, on the computer. A necessary part of any merit function is the cost factor, so some time is devoted in the course to engineering economy studies, too. Thus the "Mechanical Design" course is not solely a sequence of small design projects. In fact, half of the class time is assigned to lectures on engineering economy, the merit function, use of the computer, and special design topics. As a result, these matters can be incorporated into the projects which take the other half of the class time.

Jones (reference 2) classifies designing as occurring at four levels of complexity. These are, in increasing order of complexity, the components level, the products level, the systems level, and the community level. Traditional methods of designing, by craft evolution and design-by-drawing, have been satisfactory in the past for the first two of these levels of complexity. Design-by-drawing has been the method taught in engineering curricula in the past, but in many "design" courses it frequently turned out to be mostly drawing and very little designing, so it frequently caused engineering students to equate designing and drawing and turned many away from design. While some acquaintance with design-by-drawing is necessary in a design course, some projects need to be assigned at the systems or community level, where design-by-drawing is inadequate.

To clarify the identification of these levels, consider a metropolitan area with a great deal of traffic congestion as people move to and from work. The problem is how to move people expeditiously. It might be solved by building more highways, or by building some sort of mass transit system, or by some combination of these. For a mass transit system, a sub-problem involves deciding the means to use: subway or underground tube, busses, including exclusive highway bus lanes, monorail, etc. Routes to be followed form another part of the problem. This is design at the community level. Having decided to build an underground tube system, for instance, many things still must be decided, such as the tractive equipment and passenger cars to use, and whether underground trackage should be on the level or be built with a series of up and down grades. (There are advantages to both.) This is design at the systems level. Having decided, perhaps, that a new type of passenger car will be required, its design occurs at the products level, within limitations established at higher levels. It is at this level that design-by-drawing becomes feasible. From here we can move down to the design of a new set of trucks for the car, at the components level. This is all designing, at different levels, and the student must be introduced to it in a design course.

The old-timer who taught the Machine Design courses before he retired was frequently the person who taught "Kinematics" or "Mechanisms" too. His approach to kinematic analysis was often limited to graphical techniques, so this course frequently wound up being a lot of drawing, also. When he retired, this course, too, was abandoned at some schools. At some others, new people were able to convert and update it, introducing new and powerful analytical techniques and the use of the digital computer in the analysis work. Every mechanical engineering designer must be acquainted with the various mechanisms that produce motion, and with the motion analysis of these mechanisms. Thus, a course in "Kinematics" is a necessary prerequisite for "Mechanical Design," and will give the student an opportunity to apply his knowledge of computer programming in the repetitive analysis of the motion of mechanisms.

Cyclic motion of the parts of a machine may well produce vibration problems, and so an applied introductory course in "Mechanical Vibrations" also is a necessary prerequisite to the "Mechanical Design" course.

Thus, at the University of Hartford, our mechanical engineering design core consists of "Introduction to Engineering" and "Computer Programming" in the freshman year, "Graphic Communication" and "Kinematics" in the sophomore year, "Basic Structures" and "Mechanical Vibrations" in the junior year, and "Mechanical Design" in the senior year. All of these are required of all M. E. majors, and are taught from an applied standpoint. Additional elective courses are available in all of these fields except graphics, for those who wish to specialize further, but with these required courses the student graduates with a sound exposure in the concept and practice of design.

The basic design core comprises 18 credit hours, and corresponds with our Thermodynamics and Fluid Mechanics core of 17 credit hours. In our program, 15 credit hours of professional elective work permit the student a large latitude in developing his own special area of interest.

It is essential that the Kinematics, Structures, and Vibrations courses, which are prerequisite to "Mechanical Design", involve the student in practical analysis and design problems, and not simply develop theory. The use of design as a means to apply the theoretical concepts must be emphasized, and if this is done, the theory will usually get through a lot better. Slaymaker (reference 3) has said, "In the actual business of designing, theories are developed to solve problems; problems are not created to illustrate theory." He continues, "learning progresses from specific experiences to generalized conclusions. Most individuals show an immediate interest in the details of a specific task but are slower to grasp an abstract principle embracing all tasks."

At the University of Hartford, we are fortunate to have on our M. E. faculty an engineer with a national reputation in the field of acoustics. Noise problems are basically special cases of vibration, and so our mechanical engineering curriculum requires "Engineering Acoustics" in the senior year, concurrent with "Mechanical Design". Also concurrent with "Mechanical Design" is our course in "Automatic Controls." The prerequisite for both of these is the vibrations course. By taking these two courses concurrent with the design course, the concepts learned in them can be applied in the design project work when appropriate, and the projects assigned can have considerations involving noise and automatic control.

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MOBIL COMPUTER GRAPHICS LABORATORY

Gerald R. McClain
Mechanical Design Technology
Oklahoma State University

Students majoring in drafting and design technology in Oklahoma's junior colleges and technical institutes will now have a course in computer graphics. This innovative program sponsored by the State Department of Vocational and Technical Education and certified by the American Institute for Design and Drafting has the objective of narrowing the technology gap between industry and the schools.

Vocational and Technical educators have, as one of their greatest tasks, the responsibility of keeping up to date with the many technological advancements in business and industry. One of the most difficult things for our educator to do is to keep the activities he directs in the classroom relative to the activities taking place in modern industry. Educators cannot allow the technological gap between what is going on in our schools and what is going in industry to become very wide or, before we know it, our most recent graduates are obsolete before they can get on the job. This is the reason we no longer stress vacuum tube fundamentals in our electronics programs. This is the reason so much work has recently been done in the area of electro-mechanical technology, which has been described as an emerging technology; and this is the basic reason for the establishment of a computer graphics facility.

Computer graphics, too, is an emerging technology. Unfortunately, one of the inherent characteristics of an emerging technology is a lack of an accurate descriptive definition of the technology. When the technology becomes firmly established, it can be very explicitly defined, and it ceases to be an emerging technology. An established technology has proven its worth and benefits to the industrial society, and is characterized by various divisions of labor required for its maintenance; the operatives who handle the production, the professionals who creatively and theoretically apply the technology and, the technicians who support both.

We invision full blown educational programs specifically and exclusively for the purpose of training computer graphics technicians. But this is in the future. What we need now is an instructional program to introduce this emerging technology to our students currently studying to be technicians.

The idea of a mobil computer graphics laboratory came as a result of several events. First, in the summer of 1970, Oklahoma State University's Mechanical Design Technology program with the cooperation of the State Department of Vocational and Technical Education, conducted a three-day computer graphics seminar for drafting and design teachers throughout the state of Oklahoma. For the first time teachers became convinced that this technology was not going to replace and make obsolete the draftsman or designer, but it would be a tool for him to increase his output and decrease the amount of boring routine and repetitious work he had to do. Our teachers at this point became intensely interested in the technology and its possibilities and began to think about ways to get their students exposed to it.

Second, through our visitations with industrial advisory committees at about this same time, we learned that industry had begun asking what our drafting and design students knew about computer programming, incremented plotters, digitizers and the like and also through our follow-up studies, we found that a few of our graduates had found themselves in jobs working with plotters, digitizers and computer equipment.

Third, during the 1970-71 school year the state department for Vocational Technical Education began getting equipment requisitions for plotters and other graphic equipment from the junior colleges. Almost all of our junior colleges and technical institutes have computers and our teachers were wanting plotters for them. The cost of the plotters being requested ranged from \$4, 200 to \$16, 000 each. It quickly became obvious that this activity could become very expensive and since there are over 12 drafting and design, and civil technology programs in the state, the price tag for equipping these programs could easily be \$100, 000.

It occurred to Vo-Tec that if a mobil unit could be acquired which would house a plotter, a small computer, and classroom furniture which could be shared by all the institutions almost all the disadvantages of each institution having their own plotter equipment could be overcome and almost all the advantages too, could be acquired. So in the summer of 1972, Vo-Tec received the mobil laboratory in which they housed seminar type classroom furniture, a U. C. C. plotter, and IBM 1130 (8k) computer with a printer and card reader, and 2 keypunch machines. Vo-Tec also employed two people, a teacher who would travel throughout the state with the facility during that year to train teachers to use the system and a consultant for the summer only who had industrial experience in this area. The teacher and the consultant used the summer of 1972 to develop a flexible and efficient drafting programming language and to develop two sets of instructional materials : a systems users manual and a combination text and workbook. The instructional materials developed through the Curriculum and Instructional Materials Center, Vo-Tec, are written using measurable behavioral objectives.

Now it is possible for each institution to provide computer graphics instruction to their students. No institution will now have an expensive piece of equipment receiving only limited use and being idle most of the time. Now each institution will have a trained teacher in this area and their students will use instructional materials which were heretofore nonexistent.

The computer graphics laboratory is being shared with 12 institutions with the time being spent on any given campus of approximately three weeks. This three-week period is ample time for a one to three credit hour or equivalent mini-course. Currently this instruction is being conducted as part of existing courses or as special problems courses.

The general objectives of the computer graphics program are (1) to introduce the student to the computer as an analytical problem solving and graphics tool through the utilization of a problem oriented programming system that enables the student without prior computer experience to solve engineering related graphics problems and (2) to expose the student to a "hands-on" environment solving selected problems in drafting (civil, mechanical, electrical, architectural, etc.) which will involve interaction with the computer and the on-line incremental plotter for graphic output. The course outline is as follows:

I. Introduction to computer graphics
   A. Systems Philosophy
   B. Introduction to the IBM 1130 hardware & basic operations

II. Introduction to the "General Drafting Graphics System" (GDGS)
   A. Basic coordinate generating system applications
   B. Basic plot generating system applications

III. System Applications
   A. Utilization of GDGS in solving structural problems
   B. Utilization of GDGS in solving student selected problems

The "General Drafting Graphics System" (GDGS) is based on repetitive use of basic coordinate and plot generating commands. These commands are modular in construction and perform all basic operations within the system. All command modules interact with a common data storage area which contains all generated coordinate data stored under associated point members. This storage area is known as the "coordinate table" and provides the basic levels between coordinate generation and plot generation.

The operator uses the coordinate generation sub-system to generate coordinates with associated point members. Any reference to a specific coordinate need only be referenced by point member. These generated points may then be used to generate a plot using the plot generation sub-system's commands or dumped to cards for future use.

In actual practice GDGS constitutes a problem-oriented programming system which allows the technician to use the computer to generate computer graphic output using a "point number oriented" system. The prime feature of the system is its very general applications in the field of graphics and engineering technology.

The American Institute for Design and Drafting's certification program normally evaluates only complete curriculums, but due to the mobility of the Oklahoma Computer Graphics Laboratory and its innovative and futuristic approach, AIDD's evaluation team extended certification to the Mobil Computer Graphics Laboratory.

The Oklahoma State Department of Vocational Technical Education is providing the computer graphics laboratory to at least one dozen institutions in Oklahoma during the academic year. The institutions currently scheduled to use the facility during the current year are: Northeastern Oklahoma A & M College, Miami; Tulsa Ava To-Tec School; Tulsa, Tulsa Junior

McClain (See MOBIL - p. 48)

Division Mid-Winter Meeting - 1973

THEME: ENGINEERING AND SOCIETY

WEDNESDAY, JANUARY 17, 1973

12:00 Noon	Registration Starts
5:00 - 7:00 P. M.	Table Exhibits

THURSDAY, JANUARY 18, 1973

7:30 - 9:00 A. M.	Executive Committee Meeting; also individual Committee Meetings
8:00 - 9:00 A. M.	Table Exhibits
9:00 A. M.	Welcome - Radisson Hotel - Dr. Max S. Peters, Dean of Engineering, University of Colorado, Boulder, Colorado
9:15 A. M.	Morning Session - Presiding, Byard Houck, North Carolina State University
	"Computer Graphics in Biomechanics of the Spine" - Dr. C. H. Suh, Chairman, Department of Engineering Design and Economic Evaluation, University of Colorado, Boulder, Colorado
9:45 A. M.	"Two Biomechanical Techniques for Spinal Investigations" - Professor L. Duane Ball, Department of Engineering Design and Economic Evaluation, University of Colorado, Boulder, Colorado
10:15 - 11:00 A. M.	Coffee Break and Table Exhibits
11:00 A. M.	"Effects from the Nuclear Power Plant" - Mr. Sam Ross, Research and Development Engineer, Public Service Company of Colorado, Denver, Colorado
11:30 A. M.	"Animation and Analyses of Linkages by Use of Computers and Plotters" - Professor George J. Raczkowski, Texas A & M University, College Station, Texas
12:00 Noon	Buses to Coors, Golden, Colorado
12:30 P. M.	Lunch stop enroute at Pinehurst Country Club
1:30 P. M.	Afternoon Session - Pinehurst Country Club - Presiding, Professor Klaus Kroner, University of Massachusetts, Amherst, Massachusetts
	"Measure for Measure - A Universal Language for International Standards" - Frances J. Laner, Technical Editor, Technical Information Office, Rocky Flats Division, Dow Chemical Company, Golden, Colorado
2:00 P. M.	Proceed to Coors Plant
2:30 P. M.	At Coors: "One Company's Contributions to Environmental Quality" - Adolph Coors Company, Golden, Colorado
	Tour Coors Facilities
4:45 P. M.	Buses leave for Radisson Hotel
5:30 - 7:00 P. M.	Table Exhibits
7:30 P. M.	Banquet at the Radisson Hotel - Guest Speaker, Dr. Ved P. Nanda, Professor of Law and Director of International Legal Study Program, University of Denver College of Law

8:00 - 9:00 A. M.	Table Exhibits. This is absolutely a must for all participants.
9:00 A. M.	Morning Session - Radisson Hotel - Presiding (to be announced) "Earthquakes and Their Effects on Structures" - Dr. S. T. Algermissen, National Oceanic and Atmospheric Administration, Boulder, Colorado
9:30 A. M.	"Earthquakes Caused from Discharging Toxic Wastes Into Deep Wells" - Professor Maurice W. Major, Department of Geophysics, Colorado School of Mines, Golden, Colorado
10:00 - 10:30 A. M.	Coffee Break and Visitation of Exhibits
10:30 A. M.	"Control of Solids in Industrial Discharges" - Jack R. Weigel, Assistant Manager of Engineering, Western Electric Company, Denver, Colorado
11:00 A. M.	"Photographic Film for Engineering Designers" - Eastman Kodak Company, Windsor, Colorado
11:45 A. M.	Buses to Martin-Marietta Company, Waterton, Colorado
12:30 - 1:30 P. M.	Lunch, Cafeteria No. 2, Martin-Marietta Company
1:40 P. M.	Briefing - Earth Resources - Viking Presentation Room
2:40 P. M.	Skylab Tour
3:10 P. M.	Launch Vehicles - Tour of Manufacturing Building
3:50 P. M.	Depart via buses to Radisson Hotel - No planned dinner
8:00 P. M.	National Western Stock Show and Rodeo

LADIES PROGRAM

In Charge: Mrs. Virginia Bechtold, Mrs. Gladys Oppenheimer

For Thursday afternoon, we plan a visit to the Air Force Academy for the ladies after the luncheon at the Pinehurst Country Club.

For Friday, we are going to plan an equally exciting experience for the ladies after having lunch in an absolutely first-rate place.

JOURNAL Self-Study Report

DIVISION OF ENGINEERING DESIGN GRAPHICS,
ASEE

June, 1972

To: Members of the Executive Committee
Division of Engineering Design Graphics,
ASEE

From: Steve M. Slaby, Chairman,
Journal Study Committee

Subject: Report and Recommendations of the
Journal Study Committee

Attached herewith, is the Report, including Recommendations and a Proposed Administrative Format for the Engineering Design Graphics Journal developed by the Journal Study Committee. These materials represent the general concensus (as I have interpreted it) of the Journal Study Committee.

It is hoped that members of the Division Executive Committee will be able to read the attached Report and related materials prior to their meeting which is to be held at the 1972 Annual Meeting of the A. S. E. E. at Texas Tech in Lubbock, Texas (June, 1972).

It is my hope, furthermore, that the Recommendations of the Journal Study Committee will, in principle, receive the approval of the Division Executive Committee at the Lubbock meeting and that a resolution to this effect will be passed by the Executive Committee.

I want to express my appreciation to the members of the Journal Study Committee for their complete participation and dedication to our collective effort.

Respectfully submitted,
/s/ Steve M. Slaby

Steve M. Slaby, Chairman
Journal Study Committee
Princeton University
Princeton, New Jersey 08540
June 1, 1972

P. S. The Report is presented in a form which reflects the nature and quality of the discussion that occurred at our Committee meeting. Some overlap and repetition therefore will be apparent. If, in writing this Report I have misinterpreted the concensus of the Journal Study Committee in any particular points, I urge the members of this Committee to make known to me and the Executive Committee any corrections that should be made in the Report.

GENERAL SUMMARY OF RECOMMENDATIONS

1. The Division By-Laws should define design and graphics so that these terms are clearly understood by people in and outside our Division.

2. The Journal should project the true image of the Division emphasizing its diversity and the wide ranging interests and accomplishments of its members.

3. The Journal should be directed to a wider audience provided the interests of the Division members are always being served. In line with this, the Journal should expand its technical areas of coverage as they relate to Engineering Design Graphics in order to attract a wider range of readers (and contributors) inside and outside the Division.

4. The size of the Journal should be increased to 80 pages (this is contingent on the availability of high quality articles and papers).

5. The Journal should serve the members of our Division as a "stimulator" of new ideas in addition to its traditional service to the Division.

6. The format of the Journal (including the cover) should be completely revised having sections in it regularly devoted to specific topics and areas.

7. A Special issue of the Journal should be published once a year. This would be a "show case" issue focusing on one specific topic or on a limited number of topics which in the judgment of the Director of Publications would most suit the interests of the Division at a particular time. The Special Issue should be the responsibility of a specifically assigned editor under the direction of the Director of Publications.

8. The Journal should be published quarterly (this includes the Special Issue).

9. The Masthead of the Journal (or in some other appropriate place in the Journal) should contain a statement as to what are the goals of the Journal. These goals and

related areas of interest should be specifically listed and this list should be as inclusive of the interests represented in our Division as possible.

10. A periodic Newsletter dealing with the "day to day" business of the Division should be published under the direction of the Director of Publications. This Newsletter should be sent to all members of the Division.

11. An economic study should be immediately instituted by the Division to determine the actual costs involved in producing a high quality quarterly Journal plus one or more Newsletters per year.

12. Subscription rates for the Journal (which includes the Newsletter) should be increased in price, beginning the next publishing year. ($5 per year was an order of magnitude suggested by the Committee and $7 per year for foreign subscriptions, excluding Canada and Mexico).

13. Per page advertising charges should be increased beginning the next publishing year. (An order of magnitude suggested by the Committee would be in the range of $300 per page in the Special Issue and $100 to $125 per page in the regular issues.)

14. Special advertising rates should be established for individuals who are Division members.

15. The Division Executive Committee should budget adequate funds on a yearly basis for Division publications (Journal and Newsletter). The Director of Publications should prepare a yearly budget for submission to and for approval of the Executive Committee.

16. The positions of Circulation Manager, Treasurer, and Advertising Manager should be divided among three persons. This division of labor is critical if the Division publications effort is to succeed.

17. Chairmen of Standing and Ad Hoc Division Committees should be responsible for generating articles, papers, reviews, and pertinent information for possible publication in the Journal and Newsletter.

18. Induce the A. S. E. E. parent organization to publish a page in its journal, at least twice a year, calling for papers for our Journal.

19. Papers presented at our Division Annual and Mid-Year conferences should become the "property" of the Division and should receive priority consideration for publication in the Journal.

20. The Administrative Format of the Journal publishing operation should be revised.

21. The Director of Publications should develop a set of published "Author Guidelines" for authors who submit papers to the Journal. These "guidelines" should be sent to every member in the Division.

22. Work on a "showcase" Special Issue of the Journal should begin immediately so that its publication can be possible for June 1, 1973.

23. If our Division cannot support - intellectually and financially - a Journal of the highest professional quality, then the Division should cease publishing the Journal and revert to publishing only a periodic Newsletter.

(Ed. Note - The complete report is on file with the Division Secretary and has not been reprinted in the JOURNAL.)

MOBIL (p. 44)

College; Oklahoma State Tech, Okmulgee; Connors State College, Warner; Eastern Oklahoma State College, Wilburton; Northeastern State College, Talequah; Murray State College, Tishomingo; Cameron State College, Lawton; Oklahoma State University Technical Institute, Oklahoma City; Oscar Rose Junior College, Midwest City; Northern Oklahoma College, Tonkawa; Oklahoma State University, School of Technology, Stillwater. In addition to the pre-service education of engineering technicians the State Vo-Tech Department and AIDD would also like to use the facility to train teachers and to train interested persons in business and industry. For further information contact Gerald R. McClain, Oklahoma State University, Mechanical Design Technology, 112 Crutchfield Hall, Stillwater, Oklahoma 74074.

Wanted: Your Participation

Iowa State University will be the site of the 1973 ASEE Annual Conference and the Sixth Creative Engineering Design Display sponsored by the Design Graphics Division. Your support of this student activity is needed so that the Display will continue to be an important part of the Annual Conference. Consider this announcement an invitation for you and your students to participate in the 1973 Design Display.

If you have not seen previous Design Displays, you should know that entries have ranged from sets of design and working drawings to a complete design report with models or prototypes. Each school may enter seven projects, two freshman and one each from sophomore, junior, senior and graduate levels and one from a cooperative program. Team projects are limited to eight students. Display space limitations are such that each project can occupy no more than 2 1/2 x 4 feet of horizontal area and/or 4 x 6 feet of vertical area.

Industrial cooperation has allowed for both school and individual recognition of winners in each category. Schools will receive plaques for first place winners and all individual winners will receive certificates. This type of recognition, it is hoped, will encourage more students toward creative design, both in the classroom and in their professional careers. Industrial support grows as the display grows and is very encouraging. In future years this support may allow for cash awards.

Judging of the display will again be done by individuals from industry, ASEE Division chairmen and distinguished educators from various disciplines. The wide range of backgrounds of the judges brings a balance to the evaluation of the displays which themselves vary over a wide range of fields.

To assist with preliminary planning, it would be appreciated if you will write or call R. C. Pare'. This does not commit you to display but will provide information needed to estimate space requirements at Iowa State.

Additional information or applications are available at the address or phones listed below.

Ronald C. Pare'
Coordinator
Creative Engineering Design Display
Mechanical Engineering Department
California State Polytechnic University
Pomona, California 91768
Phone (714) 598-4356 or 598-4353

Engineering Education. . . . . Impact on Life

is the theme for the 1973 ASEE Annual Conference--it is important for engineering education and for you!

Engineering, its practice, and its career education have perhaps more impact on life and living throughout the world than any other single profession or field of endeavor. Everyone, without exception, everywhere in the world, is affected by engineering in the pursuit of his daily life. Engineering education, therefore, must have a dual role in today's society. That role must be both concerned with the education of engineers and prospective engineers, and concerned with the education of the general public to make the nation's citizens more aware of the role, potential and limitations of engineering on personal and national life in this country. This is what the theme for the 1973 ASEE Annual Conference is all about: the relationship of engineering and society and the implications of that relationship for engineering education and for you.

The theme, the Annual Conference, the Plenary Session, and the numerous activities that will be connected with the theme are the beginning for a new level of involvement of engineers in society helping to solve meaningful social-technical problems.

Start thinking about it now. Discover the issues for yourself. Become personally involved. Come to the 1973 ASEE Annual Conference!

Editorial

At the most recent meeting of the Publication Board of the Engineering Design Graphics Journal, a number of items were discussed. One of these was the seeming lack of interest in the Journal on the part of the majority of Division members. Of the 500 plus subscribers, about 150 are members of the Division. It is obvious that this should be a matter of concern when we note that the Division has approximately 900 members total (as of September 1972). The Journal has long been considered the official publication of the Division. Articles should be of interest to all members. The Journal should serve as a significant means of communication between Division members and their officers and committees.

In considering steps that might be taken to remedy the situation, the Publication Board is being guided by valuable comments and suggestions being offered by the Journal Self-Study Committee and the Journal Implementation Committee. The Self-Study Committee was chaired by Steve Slaby. The Implementation Committee consists of Jim Earle, Bob Christenson, and is chaired by Claude Westfall. Since your Editor has been privileged to serve as advisor to both committees, he is well aware of the efforts they have expended on your behalf in improving the operation of the Journal. A summary of the Journal Self-Study Committee Report is contained in this issue. A report by the Journal Implementation Committee will be published in the Spring issue.

It is often said that a product which fills a need and offers satisfactory quality at a reasonable price will sell itself. The price of the Journal is reasonable, $3.00 per year to ASEE members. The matter of quality is difficult to assess. If all the Division members were polled, we might have 900 different opinions as to quality. In any event, this would not seem to be sufficient cause for a level of acceptance of but one sixth of our membership.

One proposal to the Board gave consideration to the possibility that there may be many Division members who are not familiar with the Journal in its present form. Many have never subscribed. Many former subscribers may not have examined a recent issue. The proposal that a copy of the Winter 1973 issue be mailed to all members of the Division (whose ASEE membership is current) was favorably received and approved by the Board. Thus it is that those of you who are not regular subscribers are now reading your own personal copy of this issue. We hope that all of our readers will examine this issue critically and constructively.

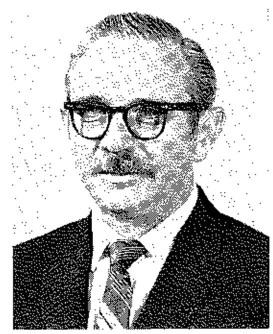
All comments and suggestions, pro or con, on the operation of the Journal, will be welcomed and very much appreciated by the Journal staff. We are anxious to prepare a publication that best serves your needs and interests. Letters to the Editor will be published, unless the writers request specifically that they not be printed. Actions and reports by the Publication Board, Self-Study Committee, and Implementation Committee will be reported to you so that you may be aware of the Journal's progress. We hope that the Engineering Design Graphics Journal will merit every Division member's support.

Division Nominations: 1973-1974

The Nominating Committee for the ASEE Engineering Design Graphics Division submits the following nominations for Division officers for 1973-1974. Ballots will be mailed to Division members about February 1, 1973.

VICE-CHAIRMAN

BORAH L. KREIMER
Northeastern University



Earned the B. S. degree at North Carolina State University and the Ed. M. degree at Northeastern University.

After serving in the armed forces during World War II he taught in the junior and senior high schools in Massachusetts. He was appointed an instructor in the Engineering Drawing Department of Northeastern University in 1952.

Borah Kreimer was a draftsman with the Hunt-Spiller Corporation, a tool designer with the Boston Gear Works and, during several summers, worked as a designer for the Instrumentation Laboratory at MIT.

Borah Kreimer has been a member of ASEE since 1953 and in March of 1967 was the coordinator of the Engineering Graphics Division mid-year conference which was held at Northeastern University. He served as a workshop leader at the Creative Design Summer School at Michigan State University in 1967. He was elected editor of the Journal of Engineering Graphics for two terms--1967 and 1970. He was chairman of the Creative Engineering Design Display between 1969 and 1971. He was a member of the Division's Self-Study Committee and in 1971 was appointed chairman of the Self-Study Implementation Committee, a position to which he was reappointed in 1972.

He has been active in civic and religious organizations and has become quite interested in photography and can be found with a camera wherever he goes.

CLAUDE Z. WESTFALL
University of Maine at Orono

Received his BS degree from West Virginia University in 1952 and MS degree from the University of Maine at Orono in 1954. At present he is an Associate Professor in the General Engineering Department.

Professor Westfall has been a member of ASEE and the Engineering Design Graphics Division since 1956. Activities include: Chairman of the Educational Exhibits for the 1964 Annual ASEE meeting at the University of Maine, Division Secretary 1971-1972, member of the Division's Self-Study Implementation Committee, and Chairman of the Implementation Committee for the Journal Study.

Other activities include the publication of two problem books in graphics and a text on Map Drawing. He is currently serving as national Vice-President of the Honor Society, Phi Kappa Phi.

SECRETARY

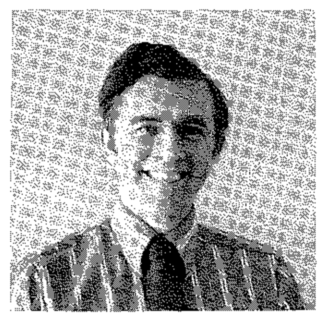
PAUL S. DeJONG
Iowa State University

B. S. (M. E.) 1960 I. S. U.
M. S. (M. E.) 1965 I. S. U.
Registered Engineer: Iowa, S. Dakota

Experience
- Radio announcing
- Cartographic Drafting, U. S. Army
- Draftsman & Designer, cement industry
- Design Engineer, Ames Lab, Atomic Energy Commission
- Private consulting work in Mech. Engr. & Design
- Joined I. S. U. Engineering Graphics Faculty in 1966
- Co-author of text Engineering Graphics with J. S. Rising & M. W. Almfeldt

Organizations
- Active in Design Graphics Division, & ASEE, ASME, NSPE
- Member of Pi Tau Sigma M. E. Honorary
- Member of Kiwanis Club

RONALD C. PARE'
California State Polytechnic Univ.



Received BSME at Washington State University in 1965 and MSME at California State University, Los Angeles in 1971. Assistant Professor of Mechanical Engineering at Cal Poly, Pomona since 1968. Member of ASEE and Engineering Design Graphics Division since 1968.

Division activities include Creative Design Display Committee since 1970; Public Relations Committee since 1971 and Awards Committee Chairman this year. ASEE Section activities include attendance at an Effective Teaching Seminar and presenting a paper at the 1971 meeting. Currently a nominee for Pacific Southwest Section Director.

Campus activities include Faculty Senate Committee and University Scholarship and Loan Committee. An ASME member since 1963; currently local section Education Committee Chairman and Executive Committee. Montclair Jaycee's Treasurer and City Community Action Committee.

DIRECTOR

KLAUS E. KRONER
University of Massachusetts

Began his teaching career in January of 1950 at New York University as an instructor of Engineering Drawing and Descriptive Geometry. Held a similar position at the University of Maine between 1955 and 1957. At present he is an Associate Professor in the Industrial Engineering Department.

Professor Kroner has been a member of ASEE since 1953 and has held several positions in the Engineering Design Graphics Division including Educational Relations Committee (1962-1969 ; chairman 1966-1969), Journal Advertising Manager (1969-1972); Host and Program Coordinator for the Mid-Year meeting of 1970.

Other activities include membership on an NSF sponsored Engineering Graphics Course Content Study in 1962; participation in three summer graphics conferences; made educational innovations such as computer-aided supplementary teaching aids; publication of articles in the Division's Journal and other periodicals; chairman of the New England Engineering Graphics Association (1965-1966).

Other professional interests include: metrication, plant layout, and industrial development.

RALPH M. COLEMAN
University of Texas at El Paso

Position: Professor of Mechanical Engineering. Has been teaching at Texas for 27 years.

EDG Division Participation: For 22 years; presently serving as chairman of the Educational Relations Committee and Zone III Sectional Group of the Division.

Publications: include eight graphics books and manuals and four articles in the Journal.

Professional activities: include research and consulting for several agencies.

Honors: Nominated outstanding teacher in 1969 by the El Paso chapter of the Texas Association of College Teachers; and nominated for the "Piper Professor" award in 1971.

JOURNAL EDITOR

JAMES H. EARLE
Texas A & M University

Position: Head of the Engineering Design Graphics Department at Texas A & M University; 1965 to Present; fifteen years teaching experience.

EDG Division Duties: Division Chairman: 1970-1971; Secretary: 1968-1969; Circulation Manager & Treasurer of Journal : 1965-1968.

Publications: Four textbooks and twenty problem books in the area of engineering graphics and design; numerous articles.

AL ROMEO
Ohio State University

Position: Professor of Engineering Graphics; qualified to teach all courses in the Department including Computer Solutions for Engineering Problems and Special Problems in Computer Graphics. Has been teaching 17 years.

ASEE Activities: Member since 1956. Active in EDG Division since 1960

Joint Meeting: CED, RWI, and EDGD

On Wednesday, June 23, 1972, at the Annual ASEE Meeting in Lubbock, Texas, the individuals named below representing ASEE Divisions indicated met to discuss the possibility of the three divisions working together on the Creative Engineering Design Displays.

Cooperative Education Division

A. K. Borman, Northeastern Univ.
W. E. Weisel, Cincinnati, Milacron

Relations with Industry

A. F. Hartford, E. I. duPont
Henry G. Hutton, General Electric

Engineering Design Graphics

R. Britton, Univ. Missouri Rolla
R. Pare', Cal. Poly. Pomona
R. Sexton, Northeastern Univ.
R. LaRue, Ohio State

Final agreement may be summarized as follows:

1. EDGD will maintain responsibility for the Displays as it has in the past. Co-ordinator, space, and publicity chairmen will all be from this division.

2. Each of the three divisions mentioned will have a representative on the Judging Committee. This committee will furnish the Coordinator with a list of judges as well as criteria for judging. Final approval of these items will be by the Coordinator.

3. CED will supply names of individuals who should be contacted regarding projects submitted from co-op schools and cooperating industry.

4. RWI will supply names of individuals associated with industrial organizations who may be contacted for possible financial support of the Displays.

5. It was felt that some additional categories other than academic level might be advisable in view of probable differences in time spent on project, etc., by the co-op student as opposed to one enrolled in a strictly academic program. Such categorization would probably not be needed at freshman and sophomore levels.

R. D. LaRue
Acting Chairman

Participate in Your Profession - Enhance Your Career

The Editor of the ENGINEERING DESIGN GRAPHICS JOURNAL invites you to submit your papers and articles for publication. It is through the continual presentation of timely, vital articles of interest and concern to you that the only Journal exclusively serving your field, can continue to fulfill the voracious "need to know" technical appetites of its readers.

Articles in the following broad subject areas are particularly encouraged: Computer Graphics, Engineering Graphics, Graphic Methods, Research in Graphics, Teaching Techniques and Methods, and Creative Design. Journal authors know that when their papers are published in Engineering Design Graphics Journal, they benefit in terms of increased prestige and professional stature. Through the Journal's pages, information is disseminated, knowledge shared, problems aired and solutions offered. Most of all, you share in the satisfaction gained from contributing significantly to advancement in your field.

Our Editorial Department is available for any assistance you may require. We will be pleased to discuss your plans for an article with you and help in any way we can.

Call or write:

Al Romeo, Editor
Engineering Graphics,
The Ohio State University
2070 Neil Avenue, Cols., O. 43210
Phone: (Area Code 614) 422-2358

Preview of JOURNAL Articles

The attached is a list of articles that have been submitted for publication in the JOURNAL. JOURNAL readers may be interested in the diversity of topics they may expect to see in this and future issues. This list is not intended to reflect an absolute publication schedule, but rather is representative of the diversity of interests of our authors. You, too, are invited to submit a paper for publication.

Freshman Graphics Course With the Computer
    Mosillo
Homology vs. Monge Method
    Rotenberg
Pictorial Shade and Shadow
    E. Pare'
Math Motivated Students to Learn Graphics
    Wockenfuss
Education for Engineering Design Involvement
    Stevenson
Programmed Invention
    Miller
Computer Mediated Instruction in Graphics
    Kroner
Machining of Compound Angles
    Spotts
Graphical Probability Analysis
    Baer
Human Engineering Using Off-the-Shelf Parts
    Woodson
Computer-Aided Pipe Sketching
    Roberts
The Role of Visualization in Creative Behavior
    Faste
Automatic Drafting System Aids Bridge Design
    Schuchardt
Computer Drafting - A Big Step Forward
    DeNapou
A Computer Graphics Package
    Kearns
Student Designers Look at Recycling
    Aronson
Modified Self-Paced Course in Descriptive Geometry
    R. Pare'
Clip System of Instruction
    H. D. Christensen
Laboratory in Consumer Product Evaluation
    Clemow
Course Structuring For Student Self-Pacing
    Evett
Mobil Computer Graphics Laboratory
    McClain
Slide Rule Course on TV
    Sarchett
Getting the Point Across - II
    Marvin & Baird

PROBABILITY (p. 38)

PREDICTION

Having class data plotted on probability paper and knowing it follows a normal curve of probability, we are now in a position to make certain predictions about the future. We can predict that a very large portion of future ME 7 students will be between 5' 6" and 6' 3". But this does not preclude that the first student who enrolls in the course next semester will be 6' 10" tall. However, the probabilities are that 99.74 percent of the students ($U \pm 3\sigma$ -- see Figs. 2 and 3) will be between 62.94 inches and 78.96 inches, and that 68.26 percent ($U \pm \sigma$) will be between 68.25 inches and 73.60 inches.

If instead of using student heights or weights we were to plot data concerning the length of useful life of telephone poles, we can derive a probabilistic answer about how long a telephone pole, or a mile-long stretch of poles, will last. These data have been obtained for telephone poles and other objects that have to be replaced. Such data are constantly being gathered so that engineers can plan for future replacement or locate weaknesses in design or

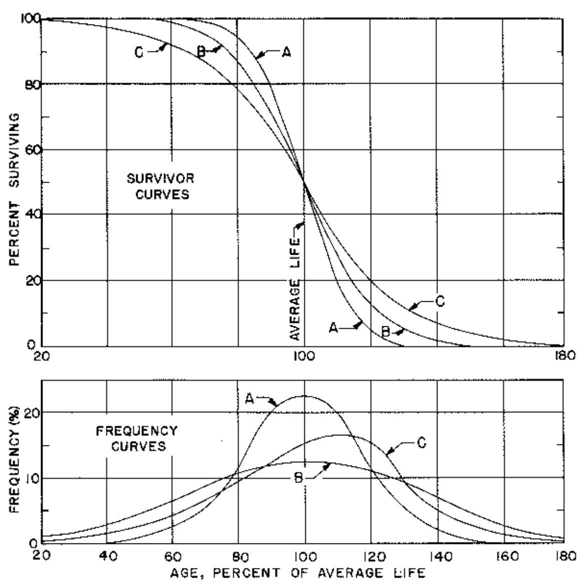


Fig. 6 Curves for probable frequency and survivor lives of three different kinds of physical assets.

materials. Fig. 6 shows some survivor and probable life curves that have been developed for certain types of machines, structures or objects.

MOTIVATES (p. 34)

$$\cos \beta = \frac{\overline{N} \cdot \overline{P}}{|\overline{N}|\ |\overline{P}|} = \frac{1768 + 1404}{(65)\ (81)} = \frac{3172}{5265} = .6025$$

Then $\beta = 52^{\circ}$

The Challenge

By simply requesting a mathematical companion solution to graphical spatial problems, the students are challenged to do more accurate work, more original ideas and to a deeper understanding of geometric space. Moreover, the challenge is internal; the student places upon himself the responsibility to produce identical answers. Seldom is he satisfied with a "near miss." Some students take pride in finding several mathematical solutions.

Using this teaching technique is very rewarding but it is also more demanding. In order to produce the challenging atmosphere in the classroom, the instructor cannot give a "drawing plate" to all students. He has to have many variations of data given and information sought. He has to be willing to spend a great deal of time in individual assistance and encouragement. Most students enjoy the learning process if we as teachers can provide the stimulation.

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COMPUTER (p. 12)

draftsmen, graphics teachers and students, and other interested persons, will be motivated to improve and expand the program presented here. Comments, criticisms and suggestions will be most welcome. Computer-directed drafting of special types of engineering drawings, structural and piping schematics, for example, is now practicable. Perhaps, the day of fully-automated general drafting is not too far distant if a concerted effort can be made in that direction.

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