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APPLICATION OF AUTOMATIC DRAFTING MACHINE

Victor H. Montouri

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This report is a summary of applications on an automatic drafting machine utilizing the machine's drafting, the FORTRAN language, and interfacing with an interactive graphics system. Interfacing is accomplished by punched tape rather than a direct electronic communication. Some programs are included.

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Also, thanks to Mr. Richard Haggerty for developing WARP on the Computer Graphics System and Mr. William Lorenson for interfacing the two systems, i.e., the ADM and CGS.

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STATEMENT OF THE PROBLEM

To achieve the maximum usage of the automatic drafting machine (ADM), it was essential that software be developed to meet the requirements of this installation. This project effort was to focus on the development of software needed to enhance the ADM capabilities. This was simultaneously accompanied with a program to develop procedures for digitizing existing drawings of components, tools, and inspection devices. Numerical control (N/C) tapes that are produced by N/C parts programmer had required verification by actually machining a component. Under this project a process was to be developed for the verification and the production of N/C tapes directly from the drawings on the ADM.

BACKGROUND AND INTRODUCTION

An ADM was procured from the Gerber Scientific Instruments Co. The ADM is comprised of three units: the Series 2000 control, the operator's desk, and the Model 75 table.

The Series 2000 control consists of four (4) major components, namely: a digital computer for control; a hardware interface for electrically matching the computer output to the ADM input; computer peripheral devices for data transfer; and a computer program for directing the operation of the system as an automatic drafting machine.

The digital computer incorporated into the Series 2000 control is the Honeywell Model 316 with a 16 bit word length and 8192 words of memory. The Model 75 Table/Series 2000 control interface functions, such as interpolation and acceleration/deceleration, are handled by the control's computer under program control.

The peripheral devices for data transfer consist of a high speed, photoelectric, punched tape reader for data input (approximately 400 cps), a high speed tape punch for data output (approximately 100 cps) and an ASR-33 teletypewriter for operator/drafting system communication.

The basic drafting program contains many desirable features. The main feature is the "look ahead" capability. The control reads information up to 50 data blocks ahead of that which is being drawn. This enables the system to calculate optimum velocity and acceleration/deceleration values. Thus, drafting speeds up to 500 inches per minute are attainable.

The Model 75 table has a 5' x 8' rubber platen, flat bed for a drawing surface, a vacuum unit for a sectionalized hold down system and an elevation mechanism for ease in viewing larger drawings.

An additional feature of the ADM is the optical line follower with its support equipment and software. Briefly, this feature enables the system to automatically follow and record data (digitize) for a line of any contour. When the drafting and digitizing capabilities are combined, the possible applications of the system from the engineering design stage through the manufacturing process are greatly increased.

One immediate use of the ADM is verifying N/C tapes. The accuracy of every tape produced, prior to the advent of the ADM, was verified on the N/C machine by "cutting" air or the actual component. In many cases of large operations, this required 3-5 hours or longer. On the ADM, it takes only a few minutes for each verification. In addition, corrections to the tape can be made immediately. With additional software, it will be possible to verify tapes for most of Watervliet Arsenal's N/C machines and to eventually produce N/C tapes directly on the ADM. The importance of these functions increases as the number of N/C machines increases.

Techniques and software were required for simplified production of comparator charts, overlays, template drawings, etc.

APPROACH TO THE PROBLEM

With the installation of the ADM in 1972, attempts at making drawings of a more complex nature on the ADM were made. It was realized that programming of complex geometries was tedious, cumbersome and time consuming. Although additional software could be purchased from the Gerber Scientific Instruments Co., a more specialized software was needed to meet the needs at Watervliet Arsenal. Thus, special purpose software was developed when needed.

Since the Honeywell Computer, which is the control system for the ADM, has its own FORTRAN compiler, it was decided to develop programs in FORTRAN which could be processed directly on the ADM. These programs, although specific in nature, would be general enough in that they could be used repeatedly like any other FORTRAN program. This differs from the drafting language that was supplied with the ADM in that if a configuration is written (programmed) in the drafting language, only <u>that</u> configuration can be drawn. Although variations of the figure can be made, i.e., change in scale, mirror image or combinations thereof, it is still the same configuration. Programming in this fashion is cumbersome.

With this idea in mind, the thought was to produce as much software as possible to meet Watervliet Arsenal's requirements. As with any new system, many things had to be learned and peculiarities discovered and overcome. The following are some examples of software developed to meet the requirements at Watervliet Arsenal.

Our first attempt at familiarization and testing the idea proved successful in the area of cam path drawing. Cam path drawings formed from analytical data were cumbersome and time consuming for the draftsman to plot manually. A FORTRAN program to process the analytical data into ADM "understandable" data has simplified the task immensely. Not only has the time required to produce a cam path drawing been reduced, but the quality and accuracy has been considerably improved. Figure 1 is a cam path drawing produced from the program in Appendix A.

In the field of statistical analysis, one of the prerequisites for data analysis is the plotting of data points. Several programs have been written to plot data, to plot data and draw a line of best fit of the form $Y = B_0 + B_1 X$, or to plot data and draw the best fit line of the form $Y = BX$. The line in either case is determined by the method of least squares which is used to calculate the values of the slope (B_1) and Y - intercept (B_0). Table 1 lists a portion of these values for a sample data set. The listing also contains the predicted value at each data point and the upper and lower confidence limit for each predicted value. The plotted data and line of best fit can be seen in Figure 2. Appendix B contains the listing of the linear regression program for

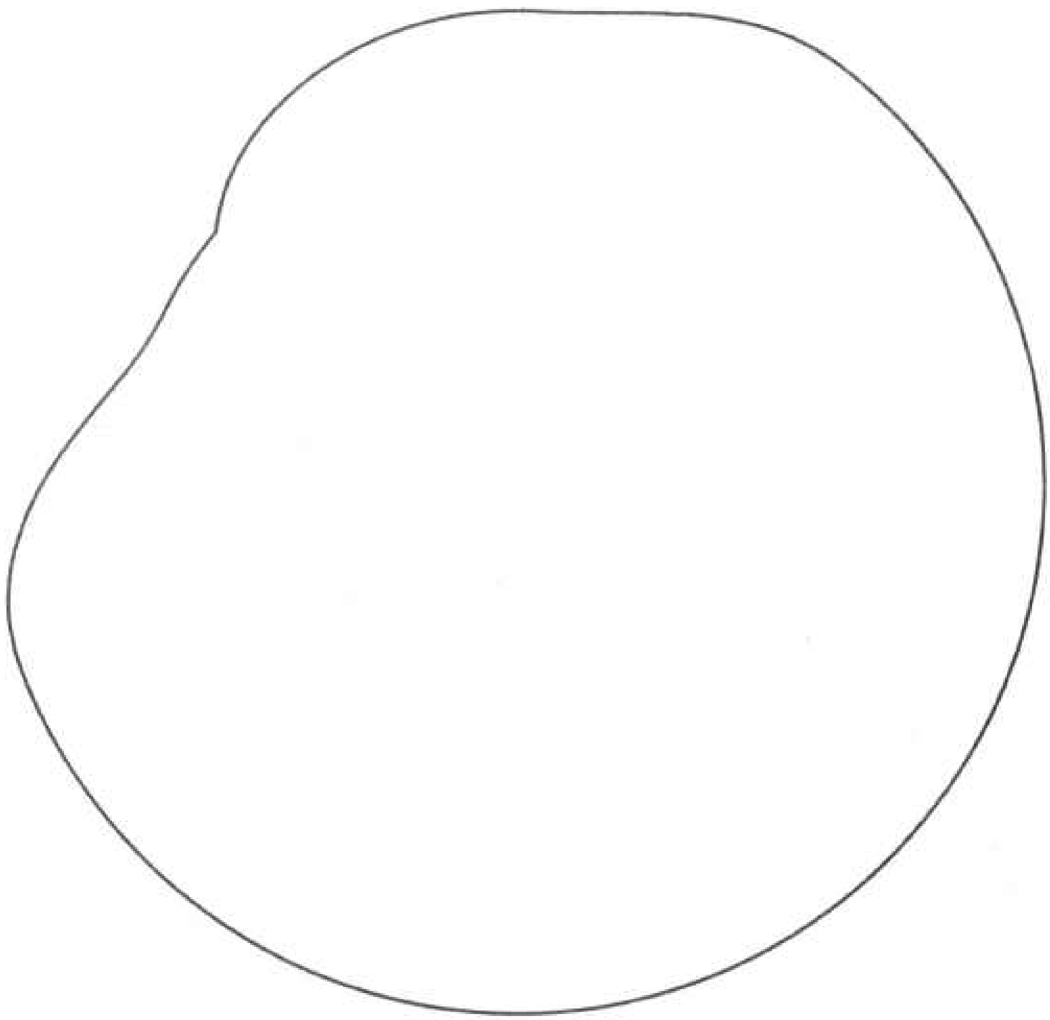

Figure 1. General cam path drawing.

TABLE 1. REGRESSION ANALYSIS TERMINAL OUTPUT

```
DATA ENTRY? (ASR-1, HSR-0)0
       AVERAGE              STD DEVIATION

X...      0.438E 02          0.128E 02
Y...      0.316E 01          0.127E 01

SLOPE =        0.994E-01
Y-INTERCEPT =       -0.119E 01
CORRELATION COEFFICIENT =        0.998E 00
```

X	Y	PRED	LCLY	UCLY
0.783E 02	0.673E 01	0.659E 01	0.640E 01	0.678E 01
0.779E 02	0.662E 01	0.655E 01	0.636E 01	0.674E 01
0.530E 02	0.395E 01	0.407E 01	0.390E 01	0.425E 01
0.457E 02	0.329E 01	0.335E 01	0.317E 01	0.353E 01
0.449E 02	0.317E 01	0.327E 01	0.309E 01	0.345E 01
0.416E 02	0.288E 01	0.294E 01	0.276E 01	0.312E 01
0.375E 02	0.253E 01	0.253E 01	0.236E 01	0.271E 01
0.632E 02	0.520E 01	0.509E 01	0.491E 01	0.527E 01
0.482E 02	0.360E 01	0.360E 01	0.342E 01	0.378E 01
0.427E 02	0.300E 01	0.305E 01	0.287E 01	0.323E 01
0.399E 02	0.270E 01	0.277E 01	0.260E 01	0.295E 01
0.624E 02	0.510E 01	0.501E 01	0.483E 01	0.519E 01
0.495E 02	0.370E 01	0.373E 01	0.355E 01	0.390E 01
0.434E 02	0.310E 01	0.312E 01	0.294E 01	0.330E 01
0.374E 02	0.260E 01	0.252E 01	0.235E 01	0.270E 01
0.615E 02	0.500E 01	0.492E 01	0.474E 01	0.510E 01
0.499E 02	0.380E 01	0.377E 01	0.359E 01	0.394E 01
0.420E 02	0.300E 01	0.298E 01	0.280E 01	0.316E 01
0.410E 02	0.290E 01	0.288E 01	0.270E 01	0.306E 01
0.515E 02	0.400E 01	0.393E 01	0.375E 01	0.410E 01
0.507E 02	0.390E 01	0.385E 01	0.367E 01	0.402E 01
0.829E 02	0.670E 01	0.705E 01	0.685E 01	0.724E 01
0.400E 02	0.270E 01	0.278E 01	0.260E 01	0.296E 01
0.316E 02	0.190E 01	0.195E 01	0.177E 01	0.213E 01
0.279E 02	0.150E 01	0.158E 01	0.140E 01	0.176E 01

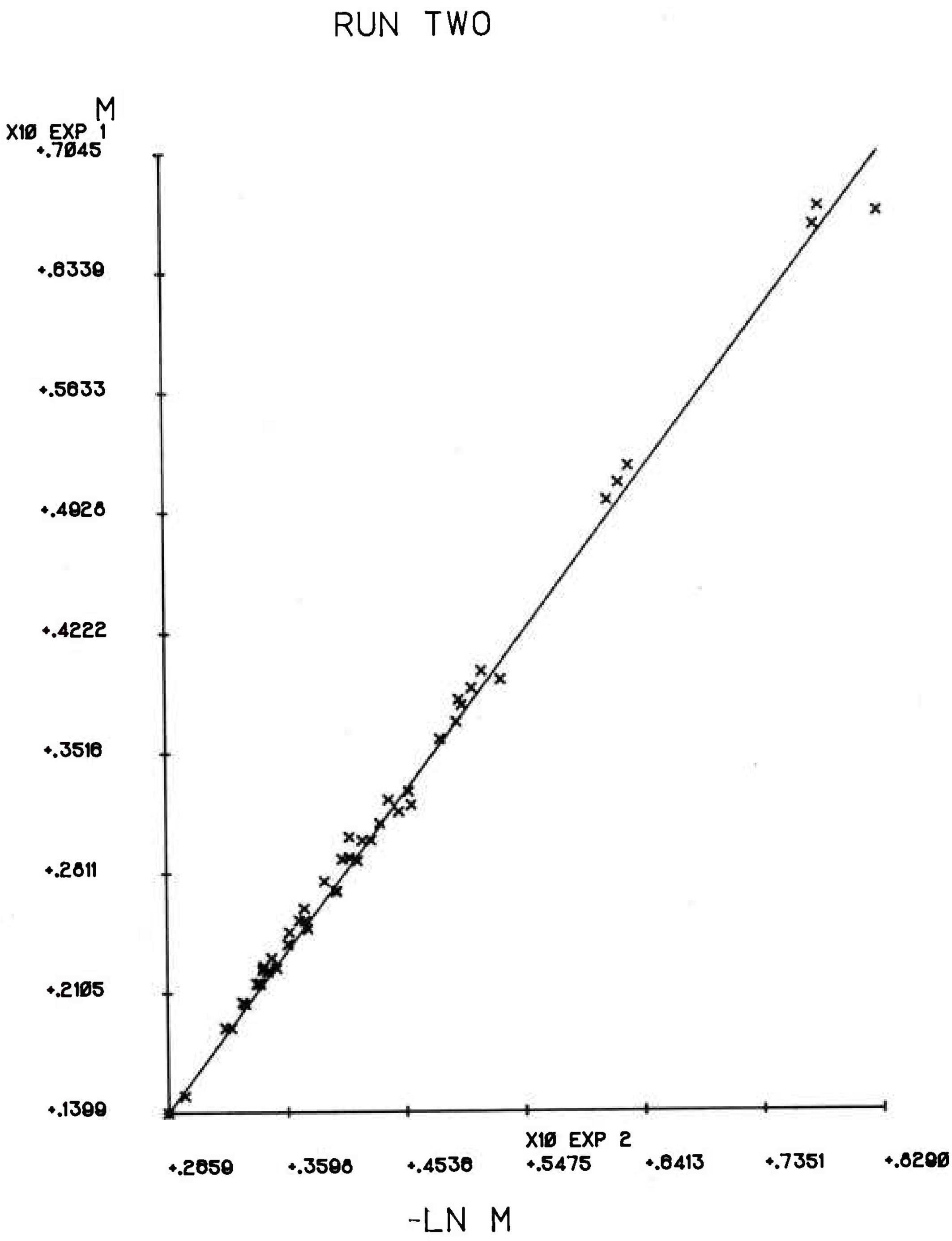

Figure 2. Sample data plot with regression line.

the model $Y = B_0 + B_1X + e$ along with the input data and output (drafting language) commands.

In the manufacture of component parts, dimensions must be checked to insure they have been manufactured within drawing specifications. One method for checking is by using comparator machines. Briefly, this machine projects a silhouette of the component upon a screen which has an accurate outline of the component with its maximum and minimum tolerances. This accurate drawing was previously drawn manually at a much larger scale and then photographically reduced and reproduced on a transparent material - mylar or glass. With the introduction of the ADM, these comparator charts are currently being drawn on the ADM. One particular type of comparator chart, which is used regularly, is in the production of broach teeth used in the manufacture of cannon rifling. The procedure, whether done manually or on the ADM, was tedious and time consuming, requiring approximately 16 hours to complete. The program, listed in Appendix C, reduces this task to one which requires <u>less</u> than one hour from broach drawing to finished comparator chart. Figure 3 is an example of a comparator chart for the broach teeth used in the manufacture of a 105mm M68 gun tube.

Similarly, in shaping various contours, as in the manufacture of breech ring sectors on a gun tube, a cutter form tool is used. In general, these tools have similar geometries which make them conducive to writing a general program to aid in the production of comparator charts. Figure 4 is an example of a comparator chart for a tool used on the 152mm M81 gun tube. Appendix D is the listing of the FORTRAN

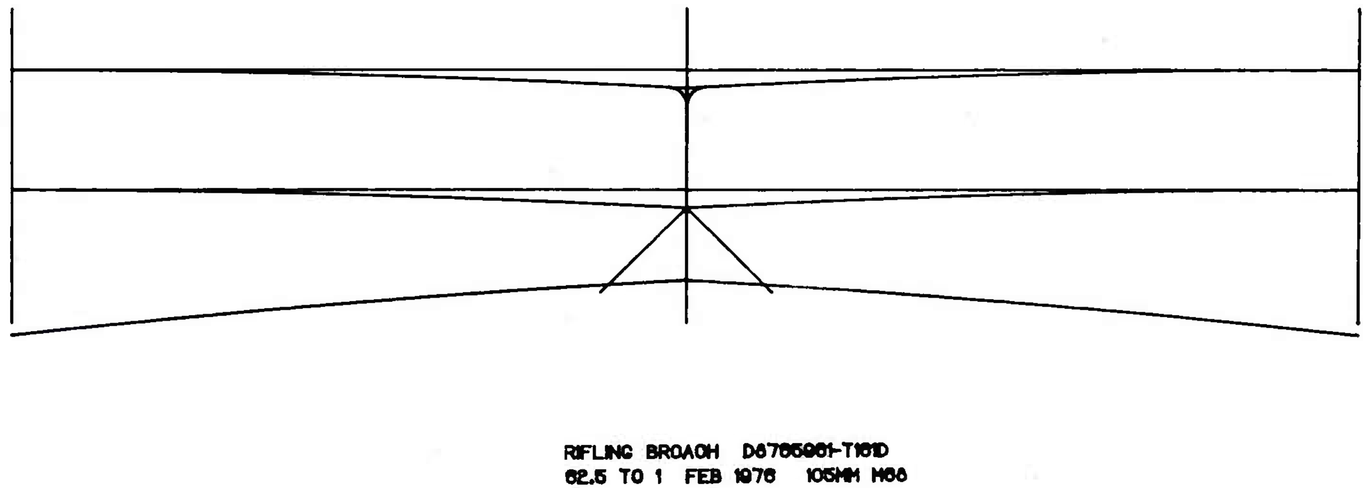

Figure 3. Broach teeth comparator chart for the 105mm M68 gun tube.

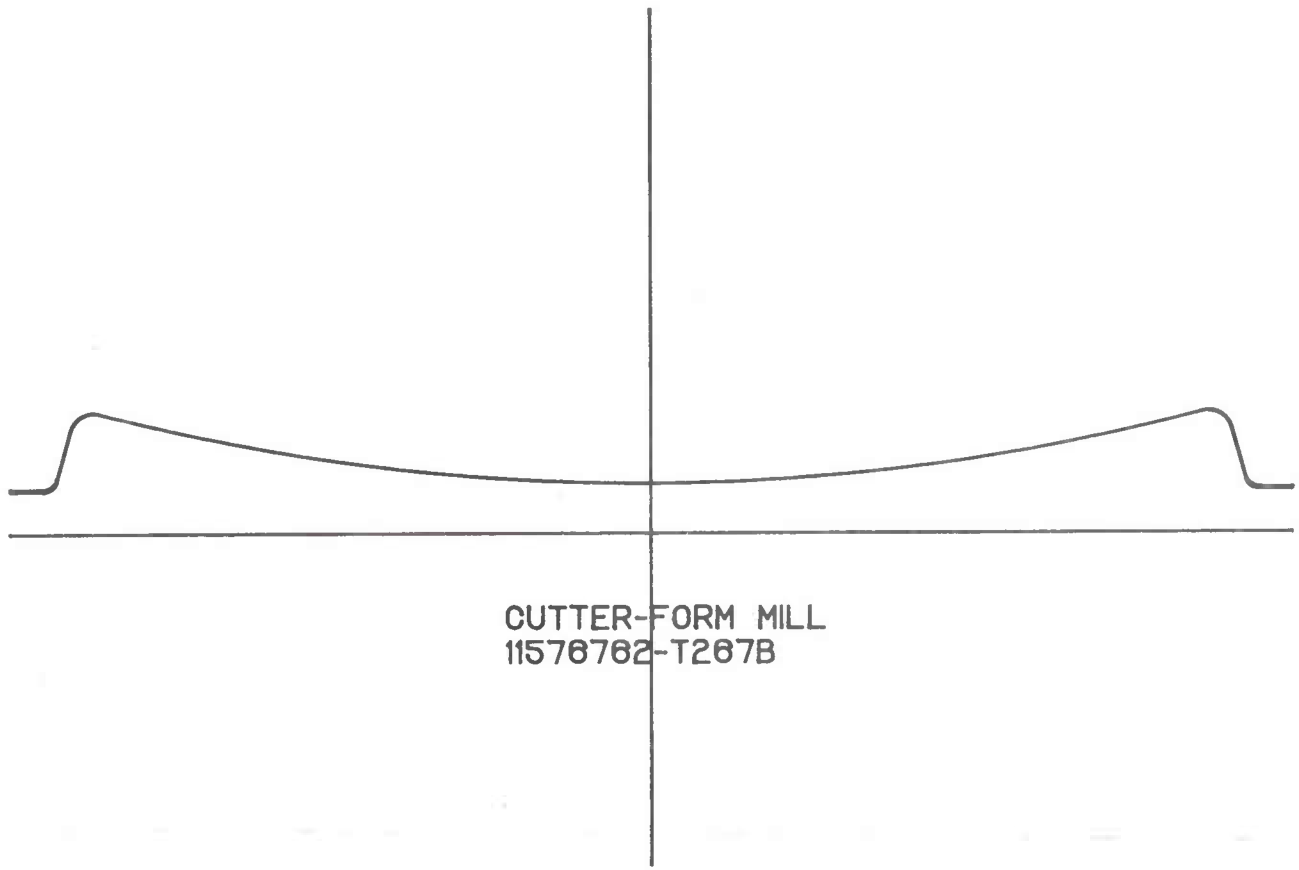

Figure 4. Cutter form tool comparator chart for the 152mm M81 gun tube.

program used to produce the chart.

In drawing gear tooth profiles, the form most commonly used today is the involute profile. The involute is the curve that is formed by the end of a line that is unwound from the circumference of a circle. It is not the intent here to present the theory or mathematics necessary for developing gear profiles. However, by viewing Figure 5, one can appreciate the task involved in obtaining the end result. The heavy lined portion is the "useable" or "physical" gear. The general program is listed in Appendix E and was used to form the gear profile template needed in the production of the 20mm torsion bar.

Numerous special purpose programs were written to assist in the efficiency and versatility of programming for increased utilization of the ADM. Some programs are aids in developing and producing Vu-graphs. These programs reduced the latter task from a few hours down to a few minutes. Two such examples are shown in Figures 6 and 7. Although they are relatively simple in appearance, prior to the programs developed (Appendix F), consideration had to be given to letter size, spacing, etc. If the letter size was not appropriate, reprogramming was necessary (or redrawing if done manually), resulting in wasted effort. With the computer program, a minor change can be made, resulting in acceptable Vu-graphs.

Other FORTRAN programs were extremely beneficial in reducing the time involved in tedious mathematical calculations necessary for programming in the ADM language. Some of these include determining points of tangency, a point of intersection for two circles, a line and a

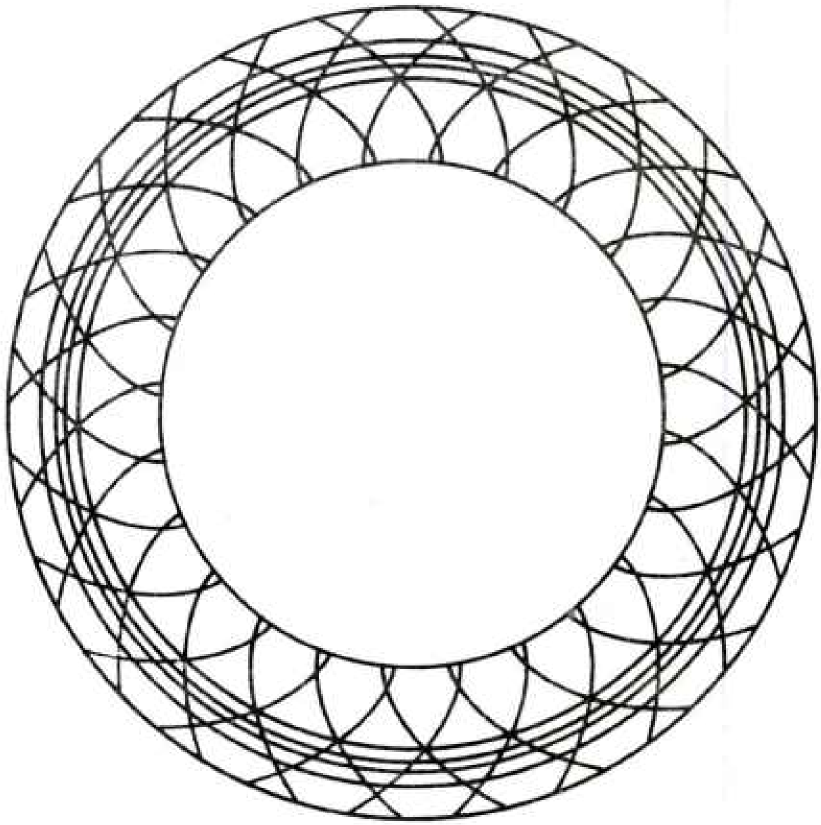

Figure 5. Gear teeth profiles for the 20mm torsion bar.

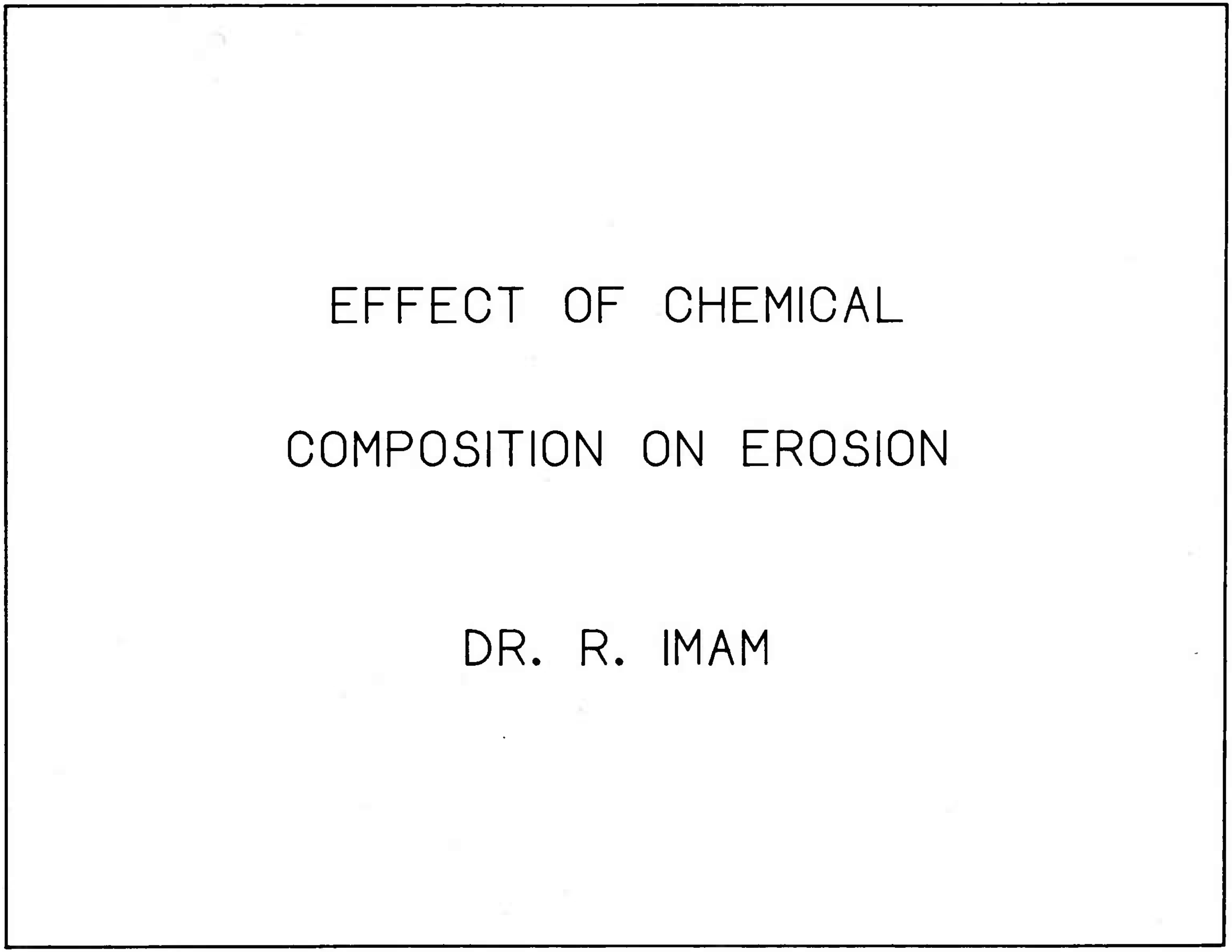

Figure 6. Example of vu-graph application.

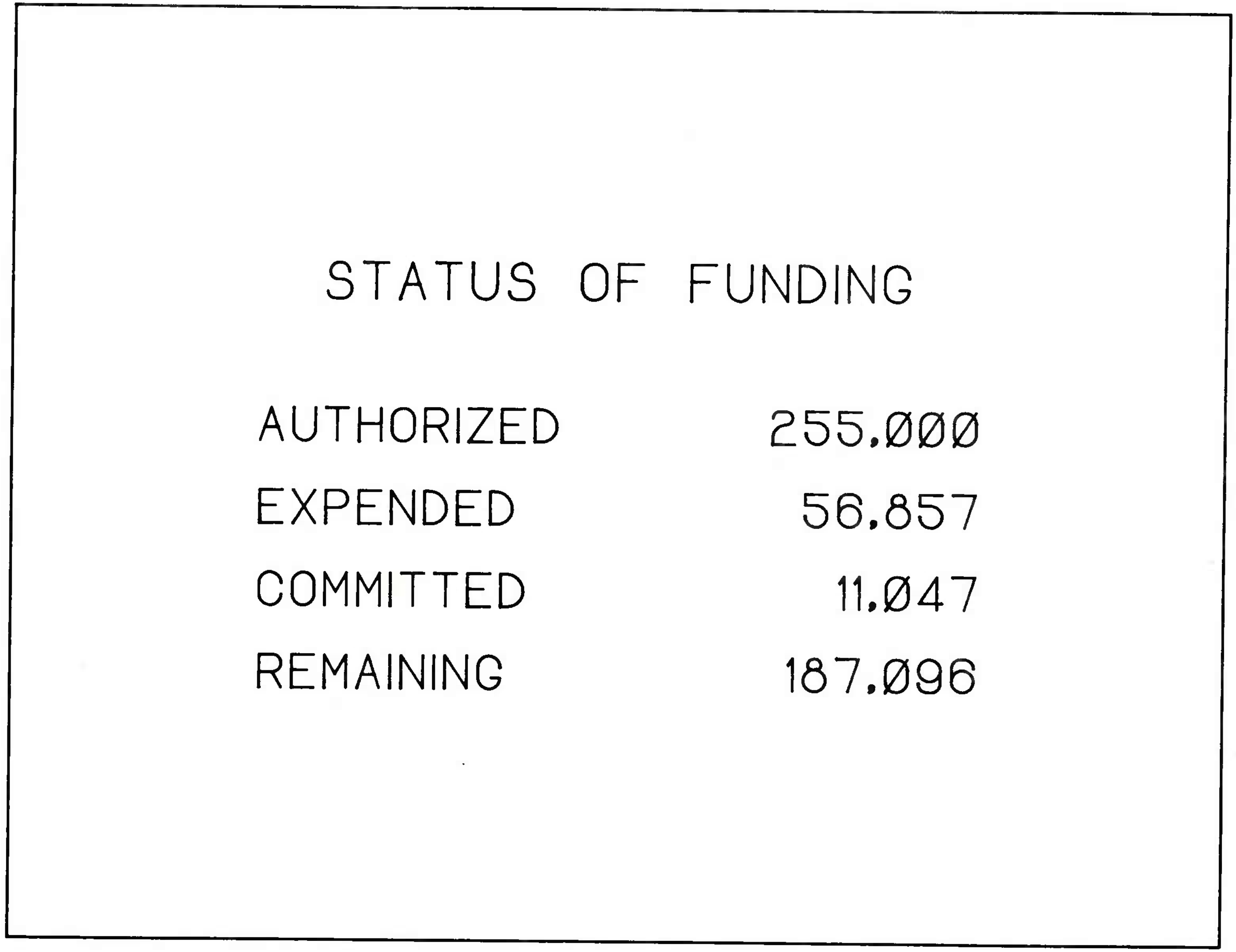

Figure 7. Example of vu-graph application.

circle, two lines, etc. Each of these was in the form of a main program and also as a subroutine so they could be run alone or as part of another main program.

All of the preceding programs were written in a form acceptable to the ADM control. Another approach was to investigate methods of interfacing the ADM with Watervliet Arsenal's main frame computer, IBM 360, Model 44. Initially, there were no feasible means of interfacing the two systems without the procurement of additional hardware which was beyond the scope of this project. It was not until the Computer Science Office purchased a Lundy Computer Graphics System (CGS) that a breakthrough was made. Since one of the I/O devices on the Lundy was punched tape, and the ADM also operates with punched tape, this was the obvious way to proceed with a minimum cost. Therefore, software was developed which now permits any configuration that can be drawn on the CGS to be drawn on the ADM. Figure 8 is an example which was "drawn" on the CGS and then reproduced on the ADM. Figure 9 is another example of interfacing the two systems. In this case, a WARP (Work and Resources Plan) chart program was written specifically for the CGS as a preliminary step to being drawn on the ADM. WARP charts are created on the CGS from a sketch or a "marked up" WARP which is to be modified. The process, depending upon complexity, requires from 10 minutes to one hour to complete. "Mistakes" may be "erased" easily on the CGS prior to a finished drawing. Thus, this type of computerization releases the draftsmen from the mundane tasks to more technical projects. The "drawing" of WARP charts can now be done with clerical level personnel, thus, con-

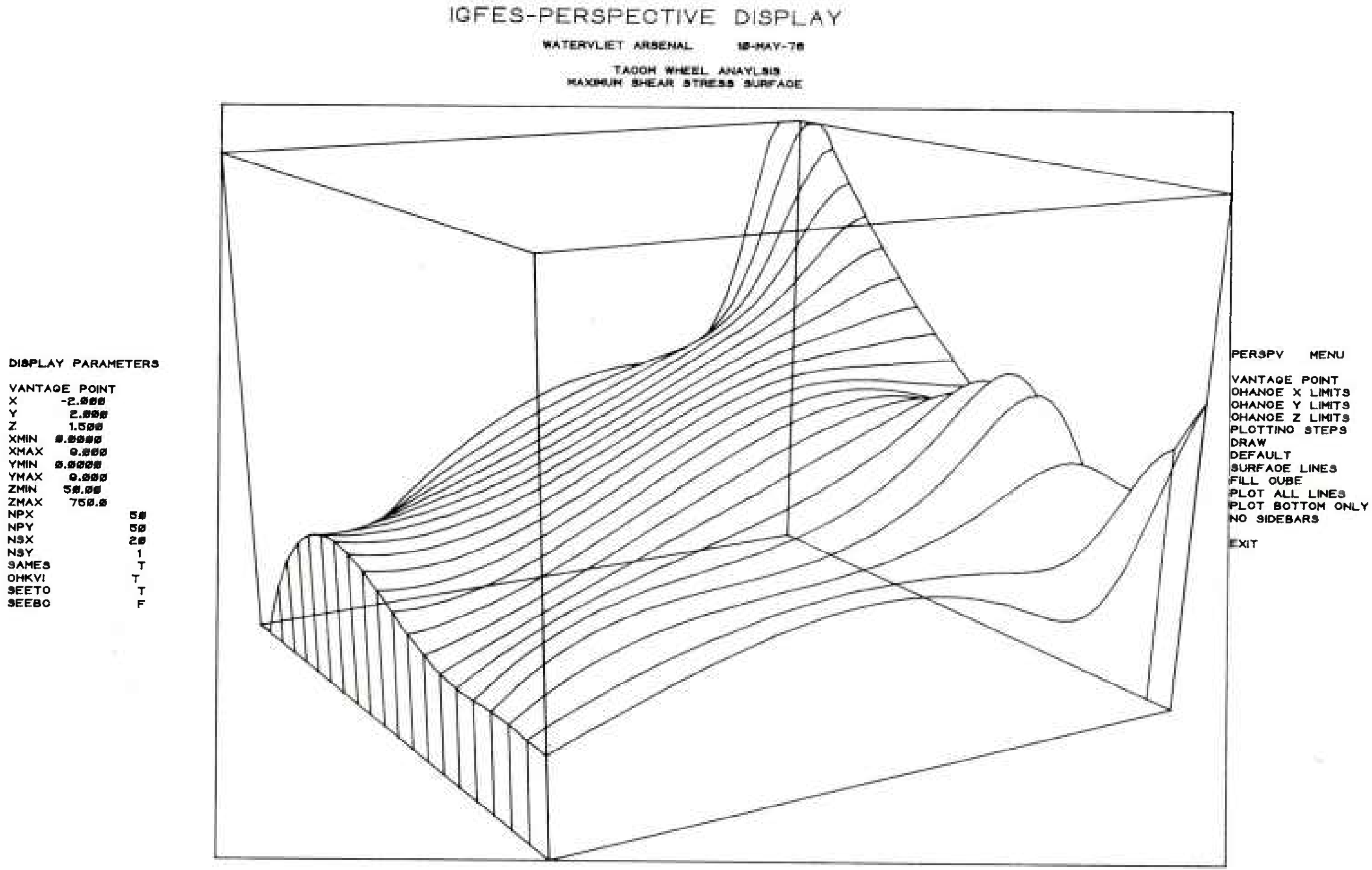

Figure 8. Computer graphics system reproduction.

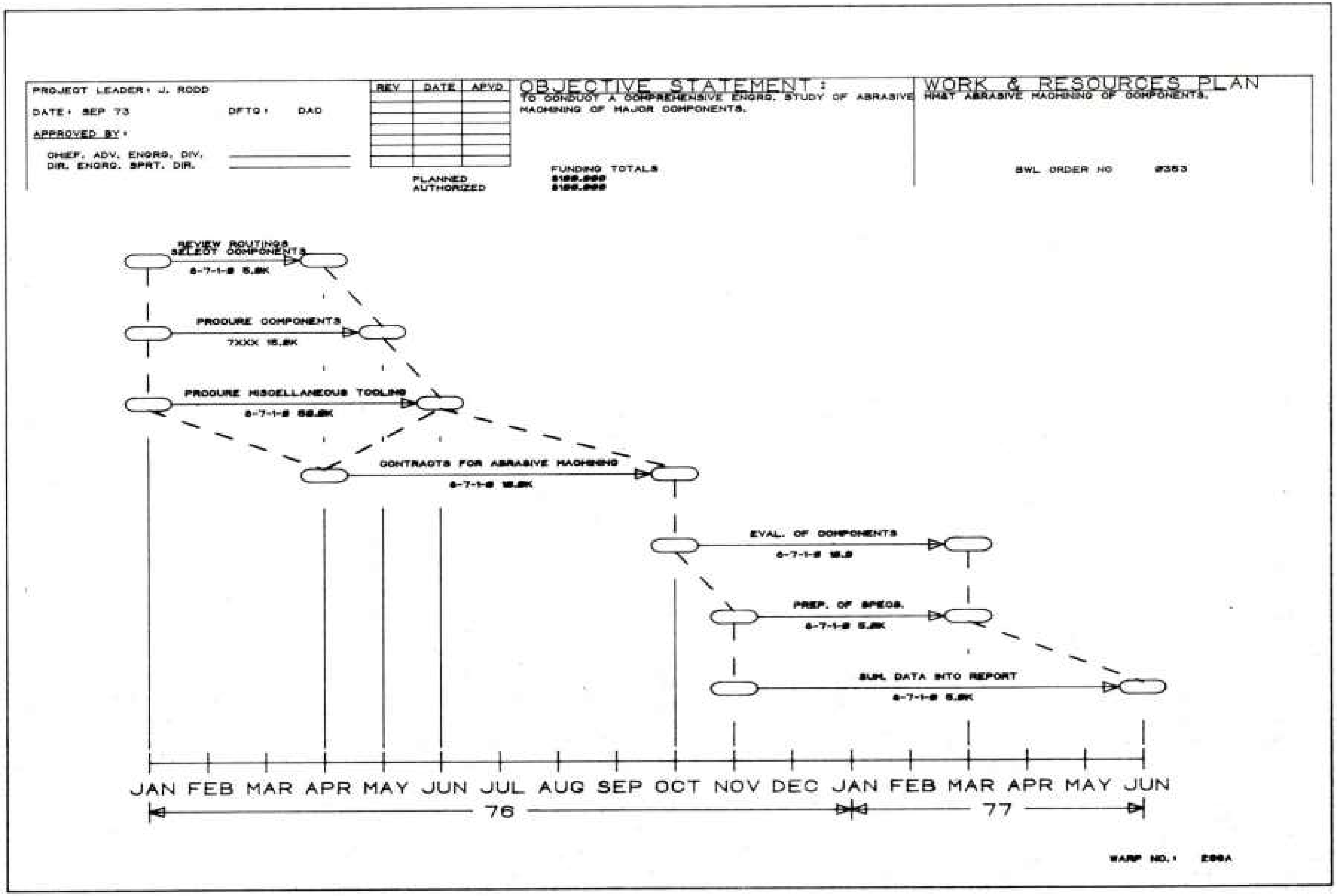

Figure 9. WARP chart.

siderable cost savings will be realized.

Relative to the field of numerically controlled (N/C) machines, the ADM has been an extremely useful tool. Watervliet Arsenal has over 50 N/C machines whose tool movements are directed by commands on punched tape. Prior to the advent of the ADM, N/C tapes were verified directly on the machine for which they were intended. This process was often time consuming and frustrating. Delays were encountered in waiting for a break in production. When a machine was eventually available, the tape was verified by cutting air, then by possibly cutting wood or plastic and then finally, an actual steel component. At each stage when errors were detected, corrections had to be made and the process repeated. Some tapes required up to five or six hours to run through their cycle. Now, with the use of the ADM, instead of cutting air or wood, etc., the center line of the path of the cutting tool is drawn on paper in minutes. Tool movements can be magnified by a change in scale to detect minute errors which could not have been detected until the final component was produced and inspected. Figure 10 represents the path of an N/C tape verified on the ADM.

Since the ADM was installed, over 200 tapes have been verified. Although the ADM is a versatile machine, tapes for all types of machines and manufacturing applications cannot be verified. The listing in Table 2 is a summary of the various types of N/C machines which can be verified on the ADM. Prior to January 1976, many of those machines listed could be verified but on several of the machines (marked *) problems were encountered, many of which were minor in nature. Using Digital Assembly

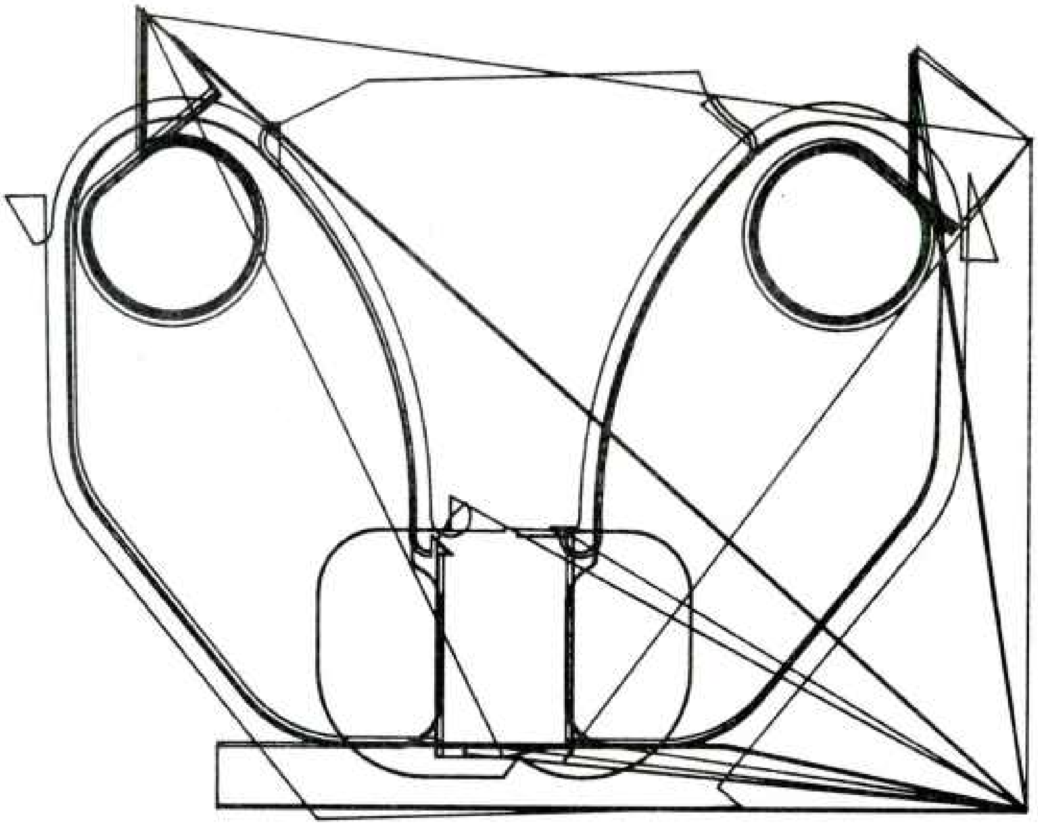

Figure 10. N/C verification - centerline of cutting tool path.

TABLE 2. N/C MACHINES VERIFIED ON THE ADM

Wolverine, P&W Vertical Spindle Mill
Kearney & Trecker Machining Center
Lodge and Shipley Lathe
Cincinnati Turning Center
Sunstrand Machining Center
Omnimil
Bostomatic Vertical Spindle Mill
LeBlond Horizontal Lathe (Tubes)
LeBlond CXR - Horizontal Lathe (Small Components)
Pratt & Whitney Wolverine - Vertical Spindle Mill
Cincinnati Hydrotel - Vertical Spindle Mill
Bullard UTL - Vertical Lathe
CIM-X 720 - Horizontal Spindle Mill & Drill
XLO Chucker-Vertical Lathe
*American Lathe
*Giddings and Lewis Machining Center

*Verified but with minor problems.

Programming (DAP), modifications were made to the Drafting Language Program which permitted the ADM to now process tapes for those N/C machines. Verification of the few other machines not listed are currently being pursued.

A recently completed contract with RRC International, Inc., forms the initial step to producing N/C tapes directly on the ADM. The software developed by this company permits Watervliet Arsenal to produce an N/C tape for any N/C machine for which an N/C APT post-processor exists. The process is summarized as follows:

a. An accurate drawing of the part profile is digitized on the ADM.

b. The resulting tape is then processed on the IBM 360-44 for the requested N/C machine.

c. This resulting tape is then used to control an N/C machine.

While this software was being developed, consideration was given to producing N/C tapes on the ADM without using a main frame computer. That is, a component profile was digitized and, with the aid of a parts programmer, machine parameters were entered manually via the teletypewriter unit. The successful machining of the profile shown in Figure 11 was accomplished on a Bostomatic Milling Machine.

Although both contract and in-house efforts have been successful in producing N/C tapes, more work is needed before the ADM can act as an independent supplement to the parts programmer. This will be pursued. However, the use of the ADM for verifying tapes has been accepted as economical by the Arsenal Operations Directorate.

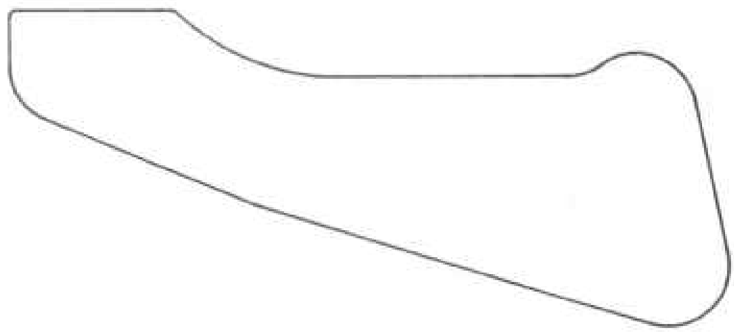

Figure 11. Extractor.

CONCLUSIONS

The preceding accomplishments are representative of the type of automatic drafting applications at Watervliet Arsenal. The problems pertaining to N/C verification have been overcome and those associated with N/C production are in the process of being solved with no real problems in sight.

Since no new drafting languages exist which can help in programming the ADM, the FORTRAN language will continue to be an extremely useful aid in a generalized programming of the ADM. As the need arises, new computer programs will continue to be developed to minimize drafting program efforts and to maximize ADM utilization.

With the advent of the new Computer Graphics System, a whole new realm of computer aided drafting applications has opened for the ADM. As more developments are introduced in the computer graphics field, greater ADM applications are foreseen.

APPENDIX A

COMPUTER PROGRAM TO PRODUCE CAM PATH DRAWINGS

```
\\DIMENSIONJX(5),JY(5)
\\DATAIP,M/1H+,1H-/
\\WRITE(2,17)
17\\FORMAT(1H*)
20\\READ(1,1)N
1\\FORMAT(I3)
\\IF(N)2,2,3
3\\I=1
10\\READ(1,4)A,R
4\\FORMAT(2F8.0)
\\ISX=IP
\\ISY=IP
\\A=A/180.*3.14159
\\X=R*COS(A)
\\IF(X)13,13,14
13\\ISX=M
14\\Y=R*SIN(A)
\\IF(Y)15,15,16
15\\ISY=M
16\\IX=X*1000.
\\IY=Y*1000.
\\CALL CONVER(IX,5,JX)
\\CALL CONVER(IY,5,JY)
\\IF(I-1)5,5,6
5\\WRITE(2,7)ISX,JX,ISY,JY
7\\FORMAT(4HG01X,A1,5A1,1HY,A1,5A1,4HD02*)
\\I=I+1
\\GO TO 10
6\\WRITE(2,8)ISX,JX,ISY,JY
8\\FORMAT(4HG01X,A1,5A1,1HY,A1,5A1,4HD01*)
\\I=I+1
\\IF(I-N)10,10,9
9\\WRITE(2,11)
11\\FORMAT(8HD02*M00*)
\\GO TO 20
2\\WRITE(2,12)
12\\FORMAT(4HM30*)
\\STOP
\\END
\\$0
\\
```

COMPUTER PROGRAM TO PRODUCE CAM PATH DRAWINGS (cont)

```
\\SUBROUTINE CONVER(JN,N,IOUT)
\\DIMENSION IOUT(1),ITOA(10)
\\DATA ITOA(1),ITOA(2),ITOA(3),ITOA(4),ITOA(5),ITOA(6),ITOA(7),
     1ITOA(8),ITOA(9),ITOA(10)/1H0,1H1,1H2,1H3,1H4,1H5,1H6,1H7,1H8,1H9/

\\IN=IABS(JN)
\\DO1 I=1,N
\\NMI=N-I
\\NO=IN/10**NMI
\\IN=IN-NO*10**NMI
\\NP1=NO+1
1\\IOUT(I)=ITOA(NP1)
\\RETURN
\\END
\\$0
\\
```

APPENDIX B

LINEAR REGRESSION ANALYSIS PROGRAM

```
C\\ CHAIN JOB-SEG. 1
C\\LINEAR REGRESSION (LINREG) PROGRAM-PLOTS DATA POINTS AND LINE
C\\OF "BEST FIT." PROGRAM WILL ACCEPT UP TO 50 DATA POINTS.
C\\TITLE ALLOWANCE-32 CHARACTERS
C\\X AND Y AXIS LABELS-16CHARACTERS
C\\THE FOLLOWING PARAMETERS ARE NEEDED TO PLOT POINTS:
C\\(1) SYMBOLS D73,D85 (2) SSM50 5. M51 12.5 (3) FSNA X13Y13
C\\(4)ICA
\\COMMON XMIN,XMAX,YMIN,YMAX,X,Y,A,B,N
\\DIMENSION IHEAD(16),LABX(8),LABY(8),X(50),Y(50)
\\DIMENSION JX(4),JY(4)
\\EQUIVALENCE(IHEAD(1),LABX(1)),(IHEAD(9),LABY(1))
\\DATA MARK/1H*/
C\\
C\\READ SAMPLE SIZE,'T'VALUE
C\\
\\WRITE(1,40)
40\\FORMAT(26HDATA ENTRY? (ASR-1, HSR-0))
\\READ(1,41)MASR
41\\FORMAT(I1)
\\IF(MASR.EQ.1)GOTO48
99\\READ(2,1)N,T
\\GOTO49
48\\READ(1,1)N,T
1\\FORMAT(I3,F7.0)
C\\
C\\READ GRAPH HEADINGS ND X,Y LABELS
C\\
49\\IF(MASR.EQ.1)GOTO42
2\\READ(2,3)IHEAD
3\\FORMAT(16A2)
\\GOTO43
42\\READ(1,3)IHEAD
C\\
C\\PRINT HEADING, X&Y LABELS
C\\
43\\WRITE(2,21)
21\\FORMAT(18H*G01X0000Y9000D02*)
\\WRITE(2,22)IHEAD,MARK
22\\FORMAT(9HM51G56D10,16A2,A1)
\\IF(MASR.EQ.1)GOTO44
\\READ(2,3)LABX,LABY
\\GOTO45
44\\READ(1,3)LABX,LABY
45\\WRITE(2,23)
23\\FORMAT(18HG01X-0500Y8300D02*)
\\WRITE(2,24)LABY,MARK
24\\FORMAT(6HG56D10,8A2,A1)
\\WRITE(2,25)
25\\FORMAT(18HG01X2000Y-1000D02*)
```

LINEAR REGRESSION ANALYSIS PROGRAM (cont)

```
\\WRITE(2,26)LABX,MARK
26\\FORMAT(6HG56D10,8A2,A1,4HM00*)
\\XMIN=1.E10
\\XMAX=-1.E10
\\YMIN=1.E10
\\YMAX=-1E10
C\\
C\\READ DATA
C\\
\\DO 5 I=1,N
\\IF(MASH.EQ.1)GOTO46
\\READ(2,4)X(I),Y(I)
\\GOTO47
46\\READ(1,4)X(I),Y(I)
4\\FORMAT(2F10.0)
47\\XMIN=AMIN1(XMIN,X(I))
\\XMAX=AMAX1(XMAX,X(I))
\\YMIN=AMIN1(YMIN,Y(I))
\\YMAX=AMAX1(YMAX,Y(I))
5\\CONTINUE
C\\
C\\CALCULATE STATISTICS ON RAW DATA
C\\
\\CALL STAT(X,Y,N,T,A,B)
\\CALL CHAIN
\\END
\\$0
```

LINEAR REGRESSION ANALYSIS PROGRAM (cont)

```
C       CHAIN JOB SEG.-2
$1   CONTINUE CHAIN
       COMMON XMIN,XMAX,YMIN,YMAX,X,Y,A,B,N
       DIMENSION X(50),Y(50),JX(4),JY(4),TICX(7),TICY(9)
       EQUIVALENCE (X(1),TICX(1)),(Y(1),TICY(1))
       DATA MARK,IP,M/1H*,1H+,1H-/
       PLO=A+B*XMIN
       PHI=A+B*XMAX
       DUM=0.
       IF(PLO.LT.PHI)GOTO300
       DUM=PHI
       PHI=PLO
       PLO=DUM
300    YMIN=AMIN1(YMIN,PLO)
       YMAX=AMAX1(YMAX,PHI)
C      SCALE DATA TO INCHES((X.XXX)*1000.)&PLOT
C

C
C      PUNCH DATA POINTS
C
       DELX=(XMAX-XMIN)/6.
       DELY=(YMAX-YMIN)/8.
       DO 9 I=1,N
       IX=1000.*(X(I)-XMIN)/DELX
       IY=1000.*(Y(I)-YMIN)/DELY
       CALL CONVER(IX,4,JX)
       CALL CONVER(IY,4,JY)
       WRITE(2,8)JX,JY
8      FORMAT(4HG01X,4A1,1HY,4A1,4HD02*,10HM50G52D73*)
9      CONTINUE
C
C      DRAW AXIS
C
       WRITE(2,11)
11     FORMAT(17HG01X0000Y8000D02*)
       WRITE(2,12)
12     FORMAT(12HG01Y0000D01*)
       WRITE(2,13)
13     FORMAT(9HG01X6000*)
C
C      TIC-MARK LABELS
C
       DO 6 I=1,7
       XI=I-1
       TICX(I)=XMIN+XI*DELX
6      CONTINUE
       DO 7 I=1,9
       XI=I-1
       TICY(I)=YMIN+XI*DELY
```

```
7       CONTINUE
        KEX=0
        IF(ABS(TICX(1)).LT.ABS(TICX(7)))GOTO200
        XX=ABS(TICX(1))
        GOTO65
200     XX=TICX(7)
65      IF(XX-10.**KEX)67,66,66
66      KEX=KEX+1
        GO TO 65
C
C       X-AXIS LABELS&TIC MARKS
C
67      DO 69 I=1,7
        ITIC=(TICX(I)/10.**KEX)*10000.
        IST=IP
        IF(ITIC)80,81,81
80      IST=M
81      CALL CONVER(ITIC,4,JX)
        IM1=1000*(I-1)
        CALL CONVER(IM1,4,JY)
        WRITE(2,68)JY,IST,JX
68      FORMAT(4HG01X,4A1,16HY-0500D02*G56D10,A1,1H.,4A1,1H*)
        WRITE(2,70)JY
70      FORMAT(4HG01X,4A1,16HY0000D02*G52D85*)
69      CONTINUE
        KEY=0
        IF(ABS(TICY(1)).LT.ABS(TICY(9)))GOTO201
        XX=ABS(TICY(1))
        GOTO71
201     XX=TICY(9)
71      IF(XX-10.**KEY)73,72,72
72      KEY=KEY+1
        GO TO 71
C
C       Y-AXIS LABELS & TIC MARKS
C
73      DO 75 I=1,9
        ITIC=(TICY(I)/10.**KEY)*10000.
        IST=IP
        IF(ITIC)82,83,83
82      IST=M
83      CALL CONVER(ITIC,4,JY)
        IM1=1000*(I-1)
        CALL CONVER(IM1,4,JX)
        WRITE(2,74)JX,IST,JY
74      FORMAT(10HG01X-1000Y,4A1,10HD02*G56D10,A1,1H.,4A1,1H*)
        WRITE(2,76)JX
76      FORMAT(9HG01X0000Y,4A1,11HD02*G53D85*)
75      CONTINUE
```

APPENDIX B

LINEAR REGRESSION ANALYSIS PROGRAM (cont)

```
C
C       PRINT MAGNITUDE OF TIC MARK LABELS
C
C       X-AXIS
C
        WRITE(2,77)KEX
77      FORMAT(32HG01X3000Y-0300D02*G56D10X10 EXP ,I1,1H*)
C
C       Y-AXIS
C
        WRITE(2,78)KEY
78      FORMAT(32HG01X-1250Y8150D02*G56D10X10 EXP ,I1,1H*)
C
C       DRAW PREDICTED LINE
C
        IF(DUM.EQ.0.)GOTO301
        PLO=PHI
        PHI=DUM
301     IYLO=1000.*(PLO-YMIN)/DELY
        CALL CONVER(IYLO,4,JX)
        IYHI=1000.*(PHI-YMIN)/DELY
        CALL CONVER(IYHI,4,JY)
        WRITE(2,14)JX
14      FORMAT(8HG01X0000,1HY,4A1,4HD02*)
        WRITE(2,15)JY
15      FORMAT(8HG01X6000,1HY,4A1,4HD01*)
C
C       DRAW 8.5 X 11 BORDER
C
96      WRITE(2,16)
16      FORMAT(18HG01X-1750Y9500D02*)
        WRITE(2,17)
17      FORMAT(13HG01Y-1500D01*)
        WRITE(2,18)
18      FORMAT(9HG01X6750*)
        WRITE(2,19)
19      FORMAT(9HG01Y9500*)
        WRITE(2,20)
20      FORMAT(10HG01X-1750*)
        WRITE(2,100)
100     FORMAT(12HG01X9999D02*)
50      WRITE(2,28)
28      FORMAT(4HM30*)
        END
        $0
```

APPENDIX B

LINEAR REGRESSION ANALYSIS PROGRAM (cont)

INPUT

```
 462.0168
           RUN TWO
-LN M                  M
78.3        6.73
77.9        6.62
53.         3.95
45.7        3.29
44.9        3.17
41.6        2.88
37.5        2.53
63.2        5.2
48.2        3.6
42.7        3.
39.9        2.7
62.4        5.1
49.5        3.7
43.4        3.1
37.4        2.6
61.5        5.
49.9        3.8
42.         3.
41.         2.9
51.5        4.
50.7        3.9
82.9        6.7
40.         2.7
31.6        1.9
27.9        1.5
26.6        1.4
32.5        2.05
34.8        2.31
45.9        3.21
36.1        2.39
31.1        1.9
32.7        2.04
34.5        2.23
33.6        2.16
33.9        2.16
35.2        2.25
37.7        2.48
40.4        2.89
37.         2.53
34.1        2.24
34.2        2.26
49.7        3.83
39.         2.76
36.2        2.46
41.         3.02
44.1        3.24
```

APPENDIX B

LINEAR REGRESSION ANALYSIS PROGRAM (cont)

OUTPUT (DRAFTING LANGUAGE COMMANDS)

```
*G01X0000Y9000D02*
M51G56D10          RUN TWO                  *
G01X-0500Y8300D02*
G56D10M                 *
G01X2000Y-1000D02*
G56D10-LN M             *M00*
G01X5509Y7553D02*M50G52D73*
G01X5467Y7397D02*M50G52D73*
G01X2813Y3613D02*M50G52D73*
G01X2035Y2678D02*M50G52D73*
G01X1950Y2508D02*M50G52D73*
G01X1598Y2097D02*M50G52D73*
G01X1161Y1601D02*M50G52D73*
G01X3900Y5384D02*M50G52D73*
G01X2301Y3117D02*M50G52D73*
G01X1715Y2267D02*M50G52D73*
G01X1417Y1842D02*M50G52D73*
G01X3815Y5243D02*M50G52D73*
G01X2440Y3259D02*M50G52D73*
G01X1790Y2409D02*M50G52D73*
G01X1150Y1700D02*M50G52D73*
G01X3719Y5101D02*M50G52D73*
G01X2483Y3401D02*M50G52D73*
G01X1641Y2267D02*M50G52D73*
G01X1534Y2125D02*M50G52D73*
G01X2653Y3684D02*M50G52D73*
G01X2568Y3542D02*M50G52D73*
G01X5999Y7510D02*M50G52D73*
G01X1428Y1842D02*M50G52D73*
G01X0532Y0708D02*M50G52D73*
G01X0138Y0141D02*M50G52D73*
G01X0000Y0000D02*M50G52D73*
G01X0628Y0921D02*M50G52D73*
G01X0873Y1289D02*M50G52D73*
G01X2056Y2564D02*M50G52D73*
G01X1012Y1402D02*M50G52D73*
G01X0479Y0708D02*M50G52D73*
G01X0650Y0906D02*M50G52D73*
G01X0841Y1176D02*M50G52D73*
G01X0746Y1076D02*M50G52D73*
G01X0777Y1076D02*M50G52D73*
G01X0916Y1204D02*M50G52D73*
G01X1182Y1530D02*M50G52D73*
G01X1470Y2111D02*M50G52D73*
G01X1108Y1601D02*M50G52D73*
G01X0799Y1190D02*M50G52D73*
G01X0809Y1218D02*M50G52D73*
G01X2461Y3443D02*M50G52D73*
G01X1321Y1927D02*M50G52D73*
G01X1023Y1502D02*M50G52D73*
G01X1534Y2295D02*M50G52D73*
```

APPENDIX B

LINEAR REGRESSION ANALYSIS PROGRAM (cont)

OUTPUT (DRAFTING LANGUAGE COMMANDS)

```
G01X1865Y2607D02*M50G52D73*
G01X0000Y8000D02*
G01Y0000D01*
G01X6000*
G01X0000Y-0500D02*G56D10+.2659*
G01X0000Y0000D02*G52D85*
G01X1000Y-0500D02*G56D10+.3598*
G01X1000Y0000D02*G52D85*
G01X2000Y-0500D02*G56D10+.4536*
G01X2000Y0000D02*G52D85*
G01X3000Y-0500D02*G56D10+.5475*
G01X3000Y0000D02*G52D85*
G01X4000Y-0500D02*G56D10+.6413*
G01X4000Y0000D02*G52D85*
G01X5000Y-0500D02*G56D10+.7351*
G01X5000Y000QD02*G52D85*
G01X6000Y-0500D02*G56D10+.8290*
G01X6000Y0000D02*G52D85*
G01X-1000Y0000D02*G56D10+.1399*
G01X0000Y0000D02*G53D85*
G01X-1000Y1000D02*G56D10+.2105*
G01X0000Y1000D02*G53D85*
G01X-1000Y2000D02*G56D10+.2811*
G01X0000Y2000D02*G53D85*
G01X-1000Y3000D02*G56D10+.3516*
G01X0000Y3000D02*G53D85*
G01X-1000Y4000D02*G56D10+.4222*
G01X0000Y4000D02*G53D85*
G01X-1000Y5000D02*G56D10+.4928*
G01X0000Y5000D02*G53D85*
G01X-1000Y6000D02*G56D10+.5633*
G01X0000Y6000D02*G53D85*
G01X-1000Y7000D02*G56D10+.6339*
G01X0000Y7000D02*G53D85*
G01X-1000Y8000D02*G56D10+.7045*
G01X0000Y8000D02*G53D85*
G01X3000Y-0300D02*G56D10X10 EXP 2*
G01X-1250Y8150D02*G56D10X10 EXP 1*
```

APPENDIX C

COMPUTER PROGRAM TO DRAW RIFLING BROACH COMPARATOR CHARTS

```
C\\PROGRAM TO DRAW RIFLING BROACH COMPARATOR CHART.
C\\R1-LARGE RADIUS
C\\R2-SMALL RADIUS
C\\A-BROACH ANGLE
C\\W-ONE-HALF BROACH WIDTH
C\\RC,RCM-MAX AND MIN CORNER RADIUS.
\\COMMON JX(8),JY(8),KX(8),KY(8)
\\DATA IP,M/1H+,1H-/
\\WRITE(2,5)
5\\FORMAT(38H*%FSNAX35Y35*SSM50.267*SFA62.5B62.5*%*)
\\I=0
\\III=0
\\JJ=3
70\\II=0
\\READ(1,2)R1,A,W,RC,RCM,R2
\\IF(III.EQ.0)SC=R1
2\\FORMAT(6F10.0)
\\A=A*.01745329
\\IF(III.EQ.0)W1=W
50\\J=2
\\BB=R1*100000.
\\CALL CONVER(BB,8,JY)
\\CALL CONVER(0.,8,JX)
\\WRITE(2,3)IP,JX,JY,J
3\\FORMAT(4HG01X,A1,8A1,1HY,8A1,2HD0,I1,1H*)
\\J=1
\\AA=W1*100000.
\\CALL CONVER(AA,8,JX)
\\WRITE(2,3)IP,JX,JY,J
\\C3=SQRT((R1*R1)-W*W)
\\BB=C3*100000.
\\CC=R1*100000.
\\AA=(W1-W)*100000.
\\CALL CONVER(0.,8,JX)
\\CALL CONVER(AA,8,KX)
\\CALL CONVER(BB,8,JY)
\\CALL CONVER(CC,8,KY)
\\WRITE(2,4)JJ,IP,KX,JY,JX,KY
4\\FORMAT(2HG0,I1,1HX,A1,8A1,1HY,8A1,1HI,8A1,1HJ,8A1,4HD01*)
\\IF(RC.EQ.0.)GOTO80
30\\IF(A.EQ.0.)GOTO10
\\AA=W/(SIN(A)/COS(A))+C3-RC/SIN(A)
\\BB=(AA*SIN(A))/(R1-RC)
\\BB=AA*COS(A)-(R1-RC)*SQRT(1.-BB*BB)
\\AA=(SIN(A)*BB)
\\GOTO11
10\\AA=W-RC
11\\BB=AA/SQRT((R1-RC)*(R1-RC)-AA*AA)
\\BB=ATAN(BB)
\\DD=(W-RC*SIN(BB)-AA)*100000.
```

COMPUTER PROGRAM TO DRAW RIFLING BROACH COMPARATOR CHARTS (cont)

```
\\CC=(SQRT((R1-RC)*(R1-RC)-AA*AA)+RC*COS(BB))*100000.
\\CALL CONVER(DD,8,JX)
\\CALL CONVER(CC,8,JY)
\\J=2
\\WRITE(2,3)IP,JX,JY,J
12\\CC=(CC/100000.-RC*COS(BB)+RC*SIN(A))*100000.
\\DD=(AA+RC*COS(A)-W)*100000.
\\IF(A.EQ.0.)DD=0.
\\AA=(RC*SIN(BB))*100000.
\\EE=(RC*COS(BB))*100000.
\\CALL CONVER(DD,8,JX)
\\CALL CONVER(CC,8,JY)
\\CALL CONVER(AA,8,KX)
\\CALL CONVER(EE,8,KY)
\\WRITE(2,4)JJ,M,JX,JY,KX,KY
\\IF(I.EQ.1)GOTO20
\\IF(RC.EQ.RCM)GOTO20
\\I=I+1
\\RP=RC
\\RC=RCM
\\GOTO30
20\\AA=1.57079632-A
\\BB=(CC/100000.)+(SIN(AA)/COS(AA))*DD/100000.
\\AA=SIN(AA)/COS(AA)
\\IF(II.EQ.1)AA=-AA
\\CC=W
\\IF(II.EQ.1)CC=-W
\\CALL CIRLIN(CC,0.,R2,AA,BB,X,Y,XX,YY)
\\IF(YY.GT.Y)X=XX
\\IF(YY.GT.Y)Y=YY
\\J=1
\\X=X*100000.
\\Y=Y*100000.
\\CALL CONVER(X,8,JX)
\\CALL CONVER(Y,8,JY)
\\WRITE(2,3)M,JX,JY,J
\\AA=(SQRT(R2*R2-4.*CC*CC))*100000.
\\BB=W*100000.
\\CALL CONVER(AA,8,JY)
\\CALL CONVER(BB,8,JX)
\\CC=ABS(X)+ABS(W*100000.)
\\CALL CONVER(CC,8,KX)
\\CALL CONVER(Y,8,KY)
\\WRITE(2,4)JJ,M,JX,JY,KX,KY
90\\IF(II.EQ.1)GOTO40
\\II=II+1
\\AA=M
\\JJ=2
\\M=IP
\\IP=AA
```

APPENDIX C

COMPUTER PROGRAM TO DRAW RIFLING BROACH COMPARATOR CHARTS (cont)

```
\\IF(I.EQ.1)RC=RP
\\IF(III.EQ.1)RC=0.
\\I=0
\\GOTO50
40\\IF(III.EQ.1)GOTO60
\\III=III+1
\\AA=IP
\\JJ=3
\\IP=M
\\M=AA
\\GOTO70
80\\CC=1.57079632-A
\\AA=(BB/100000.-(SIN(CC)/COS(CC))*AA/100000.)
\\AA=((R2-.008-AA)/(SIN(CC)/COS(CC)))*100000.
\\BB=(R2-.008)*100000.
\\CALL CONVER(AA,8,JX)
\\CALL CONVER(BB,8,JY)
\\WRITE(2,3)M,JX,JY,J
\\GOTO90
60\\I=0
\\AA=W1*100000.
102\\BB=SC*100000.+1600.
\\I=I+1
\\J=2
\\CALL CONVER(AA,8,JX)
\\CALL CONVER(BB,8,JY)
\\WRITE(2,3)IP,JX,JY,J
\\BB=R2*100000.-1600.
\\CALL CONVER(BB,8,JY)
\\J=1
\\WRITE(2,3)IP,JX,JY,J
\\AA=AA-W1*100000.
\\IF(I.NE.2)GOTO101
\\II=IP
\\IP=M
\\M=II
101\\IF(I.NE.3)GOTO102
\\STOP
\\END
\\$0
\\
```

APPENDIX D

COMPUTER PROGRAM TO DRAW CUTTER FORM COMPARATOR CHARTS

```
C       PROGRAM TO DRAW CUTTER COMPARATOR CHART.
C       DRAWS WITH SF 10 TO 1.
C       ANG,ANGM-ANGLE IN DEGREES(MAX,MIN).
C       R1,R1M-LARGE RADIUS(MAX,MIN).
C       R2U,R2UM-SMALL RADIUS-UPPER(MAX,MIN)
C       R2L,R2LM-SMALL RADIUS-LOWER(MAX,MIN)
C       AL1,AL1M-TOP RADIUS TO BOTTOM(MAX,MIN)
C       AL,ALM-CENTER TO SHARP CORNER(MAX,MIN)
C       AL2,AL2M-SHARP CORNER TO OUTSIDE(MAX,MIN).
C       ITITLE-TITLE
C       INUM-DRAWING NUMBER.
        COMMON ITITLE(15),INUM(15),JX(8),JY(8),KX(8),KY(8)
        READ(1,1)R1,R2U,R2L,AL,AL1,AL2,ANG
        READ(1,1)R1M,R2UM,R2LM,ALM,AL1M,AL2M,ANGM
        READ(1,2)ITITLE,INUM
1       FORMAT(7F10.0)
2       FORMAT(30A2)
        I=0
        CEN=0.
        WRITE(2,3)
3       FORMAT(25H*%FSNAX35Y35*SSM5016.6*%*)
200     AA=(R1M-CEN)*1000000.
        CALL CONVER(AA,8,JY)
        WRITE(2,4)JY
4       FORMAT(6HG01XY-,8A1,8HD02*D01*)
        ANG=ANG*.01745329
        AA=1.57079632-ANG
        S=-SIN(AA)/COS(AA)
        ALY=SQRT(R1M*R1M-AL*AL)-CEN
        BB=ALY
        ALY=R2UM*SIN(ANG)+ALY
        ALX=AL-R2UM*COS(ANG)
        B=-ALY-S*ALX
        AA=R1M+R2UM
        CALL CIRLIN(0.,CEN,AA,S,B,X,Y,XX,YY)
        IF(X.LT.0.)X=XX
        IF(Y.GT.0.)Y=YY
        AA=ABS((Y+CEN)/X)
        TH=ATAN(AA)
        AX=R2UM*COS(TH)
        AY=R2UM*SIN(TH)
        AXX=(X-AX)*1000000.
        AYY=(-Y-AY)*1000000.
        AA=R1M*1000000.
        CALL CONVER(AXX,8,JX)
        CALL CONVER(AYY,8,JY)
        CALL CONVER(AA,8,KY)
        WRITE(2,5)JX,JY,KY
5       FORMAT(4HG03X,8A1,2HY-,8A1,2HIJ,8A1,1H*)
        AYY=(-Y-R2UM)*1000000.
```

APPENDIX D

COMPUTER PROGRAM TO DRAW CUTTER FORM COMPARATOR CHARTS (cont)

```
      AX=AX*1000000.
      AY=AY*1000000.
      AA=X*1000000.
      CALL CONVER(AA,8,JX)
      CALL CONVER(AYY,8,JY)
      CALL CONVER(AX,8,KX)
      CALL CONVER(AY,8,KY)
      WRITE(2,6)JX,JY,KX,KY
6     FORMAT(4HG02X,8A1,2HY-,8A1,1HI,8A1,1HJ,8A1,1H*)
      FX=(X+R2UM*COS(ANG))*1000000.
      FY=(-Y-R2UM*SIN(ANG))*1000000.
      AA=R2UM*1000000.
      CALL CONVER(FX,8,JX)
      CALL CONVER(FY,8,JY)
      CALL CONVER(AA,8,KY)
      WRITE(2,7)JX,JY,KY
7     FORMAT(4HG02X,8A1,2HY-,8A1,2HIJ,8A1,1H*)
      IF(R2L.NE.0.)GOTO10
      AA=(AL2/(SIN(ANG)/COS(ANG))+EE)*1000000.
      FX=(AL+AL2)*1000000.
      CALL CONVER(FX,8,JX)
      CALL CONVER(AA,8,JY)
      WRITE(2,8)JX,JY
8     FORMAT(4HG01X,8A1,2HY-,8A1,1H*)
      GOTO100
10    IF(I.NE.0)GOTO15
      A=-Y
      B2=R2UM
15    AMY=(A-B2+AL1M)
      AIY=AMY-R2L
      FX=FX/1000000.
      AKY=AIY+R2L*SIN(ANG)
      FY=FY/1000000.
      AKX=FX+(AKY-FY)*(SIN(ANG)/COS(ANG))
      AMX=(AKX+R2L*COS(ANG))*1000000.
      AA=AKX*1000000.
      BB=AKY*1000000.
      CALL CONVER(AA,8,JX)
      CALL CONVER(BB,8,JY)
      WRITE(2,8)JX,JY
      AA=(R2L*COS(ANG))*1000000.
      BB=(R2L*SIN(ANG))*1000000.
      AMY=AMY*1000000.
      CALL CONVER(AMX,8,JX)
      CALL CONVER(AMY,8,JY)
      CALL CONVER(AA,8,KX)
      CALL CONVER(BB,8,KY)
      WRITE(2,11)JX,JY,KX,KY
11    FORMAT(4HG03X,8A1,2HY-,8A1,1HI,8A1,1HJ,8A1,1H*)
```

APPENDIX D

COMPUTER PROGRAM TO DRAW CUTTER FORM COMPARATOR CHARTS (cont)

```
      AA=(AL+AL2)*1000000.
      CALL CONVER(AA,8,JX)
      WRITE(2,12)JX
12    FORMAT(4HG01X,8A1,1H*)
100   CEN=R1-R1M
      ANG=ANGM
      R1M=R1
      R2UM=R2U
      R2L=R2LM
      AL1M=AL1
      AL=ALM
      AL2=AL2M
      I=I+1
      IF(I.EQ.1)GOTO200
      AA=(R1M-1.)*1000000.
      CALL CONVER(AA,8,JY)
      WRITE(2,4)JY
      AA=(R1M+.8)*1000000.
      CALL CONVER(AA,8,JY)
      WRITE(2,20)JY
20    FORMAT(2HY-,8A1,1H*)
      AA=(R1M+.1)*1000000.
      CALL CONVER(AA,8,JY)
      WRITE(2,4)JY
      AA=(AL+AL2)*1000000.
      CALL CONVER(AA,8,JX)
      WRITE(2,12)JX
      WRITE(2,26)
26    FORMAT(4HM00*)
      AA=(R1M+.3)*1000000.
      CALL CONVER(AA,8,JY)
      WRITE(2,21)JY
21    FORMAT(15HG01X-00300000Y-,8A1,4HD02*)
      WRITE(2,22)ITITLE
22    FORMAT(9HM50G56D10,15A2,1H*)
      AA=(R1M+.33)*1000000.
      CALL CONVER(AA,8,JY)
      WRITE(2,21)JY
      WRITE(2,22)INUM
      AA=(R1M+.36)*1000000.
      CALL CONVER(AA,8,JY)
      WRITE(2,21)JY
      WRITE(2,25)
25    FORMAT(18HG56D10MAG-10 TO 1*)
      STOP
      END
      $0
```

APPENDIX E

COMPUTER PROGRAM TO DRAW GEAR TOOTH PROFILES

```
\\COMMONJX(8),JY(8)
\\READ(1,5)PD,PA,GAM,BETA,RS,SF,XINC,RI,SPR,FR
5\\FORMAT(10F7.0)
\\DEG=.01745329
\\PI=3.1415927
\\PA=PA*DEG
\\BETA=BETA*DEG
\\R=PD*COS(PA)/2.
\\T1=0.
\\GD=0.
\\K=0
\\WRITE(2,45)
45\\FORMAT(1H*)
\\N=360./GAM
200\\K=K+1
\\I=0
100\\D=DEG*T1
\\IF(D.EQ.0.)GOTO80
\\T=ATAN(D)
\\GOTO90
C\\RP-RPRIME
80\\T=0.
90\\IF(T)10,20,10
20\\RP=R
\\GOTO30
10\\RP=R/COS(T)
\\IF(RP.GT.RS)GOTO70
30\\PHI=T1*DEG-T
C\\90 DEG = PI/2 - 1.5707963 RADIANS.
\\TDUM=(PI+BETA)/2.-PHI-GD
\\X=RP*COS(TDUM)
\\Y=RP*SIN(TDUM)
\\X=X*SF*100000.
\\Y=Y*SF*100000.
\\CALL CONVER(X,8,JX)
\\CALL CONVER(Y,8,JY)
\\IF(I-1)40,50,60
40\\WRITE(2,15)
15\\FORMAT(4HD02*)
\\GOTO60
50\\WRITE(2,25)
25\\FORMAT(4HD01*)
60\\WRITE(2,35)JX,JY
35\\FORMAT(4HG01X,8A1,1HY,8A1,1H*)
\\I=I+1
\\T1=T1+XINC
\\GOTO100
```

```
70\\GD=GD+GAM*DEG
\\T1=0.
\\IF(K.LT.N)GOTO200
\\WRITE(2,55)
55\\FORMAT(4HMOO*)
\\PD=PD/2.
\\CALL CIRABS(R,SF)
\\CALL CIRABS(RI,SF)
\\CALL CIRABS(RS,SF)
\\CALL CIRABS(PD,SF)
\\CALL CIRABS(SPR,SF)
\\CALL CIRABS(FR,SF)
\\STOP
\\END
\\$0
\\
```

COMPUTER PROGRAM TO DRAW GEAR TOOTH PROFILES (cont)

```
C\\THIS SUBROUTINE WILL DRAW A COMPLETE CIRCLE(CLOCKWISE)
C\\IN FSNAX25Y25 FORMAT STARTING ON THE POSITIVE Y-AXIS.
C\\USES SUBROUTINE CONVER WITH SIGN.
\\SUBROUTINE CIRABS(R,SF)
\\DIMENSION IR(8)
\\DATA M/1H-/,IP/1H+/
\\R=R*100000.*SF
\\CALL CONVER(R,8,IR)
\\WRITE(2,1)IR
1\\FORMAT(5HG01XY,8A1,4HD02*)
\\DO100K=1,4
\\IF(K.EQ.2.OR.K.EQ.3)IR(1)=M
\\IF(K.GT.3)IR(1)=IP
\\IF(K.EQ.1.OR.K.EQ.3)GOTO30
\\WRITE(2,20)IR,IP,(IR(I),I=2,8)
20\\FORMAT(2HXY,8A1,1HI,8A1,1H*)
\\GOTO100
30\\WRITE(2,10)IR,IP,(IR(I),I=2,8)
10\\FORMAT(4HG02X,8A1,2HYJ,8A1,4HD01*)
100\\CONTINUE
\\RETURN
\\END
\\$0
\\
```

APPENDIX F

COMPUTER PROGRAM TO DRAW VU-GRAPH TITLES OR HEADINGS

```
C   TITLE-THIS PROGRAM WILL CENTER VU-GRAPH TITLES OR HEADINGS
C          FOR UP TO 40 CHARACTERS AND UP TO 10 LINES.
C          DRAWING CONCLUDES WITH AN 8.5X11 IN. BORDER.
C          SAMPLE INPUT:
C          .375HANDBOOK OF<(CR)
C          1.
C          .500MATHEMATICAL<(CR)
C          1.
C          .375FUNCTIONS<(CR)
C   FIRST FOUR SPACES-LETTER SIZE FOLLOWED BY NARRATIVE(< END
C   OF LINE INDICATOR). NEXT LINE IS SPACING BETWEEN LINES.
C   DRAFTING PARAMETERS:
C   FSNAX23Y23*ORIGIN IS UPPER LEFT CORNER OF BORDER.SFA1B1*>
        COMMON MS(10),SS(10),LTR(10,40),SPACE(10),JX(5),JY(5)
        COMMON IMS(5),XSS(5)
        DATA IARO/1H</,ICA/1H,/,IONE/1H1/,IEYE/1HI/,IPER/1H./
        DATA IPL/1H+/,MIN/1H-/,IAST/1H*/
        K=0
200     K=K+1
        READ(1,1)SS(K),(LTR(K,I),I=1,40)
        WRITE(1,35)
35      FORMAT(1H )
        READ(1,1)SPACE(K)
        WRITE(1,35)
1       FORMAT(F4.0,40A1)
        IF(SPACE(K).GT.0.)GOTO200
        SUM=0.
        MS(1)=0
        IC=0
        M=1
        DO10I=1,K
        SUM=SUM+SS(I)+SPACE(I)
        SS(I)=SS(I)/.015
        IF(I.GT.1)GOTO15
45      IMS(M)=MS(I)
        XSS(M)=SS(I)
        M=M+1
        GOTO10
15      IDUM=I-1
12      IF(SS(I).EQ.SS(IDUM))GOTO9
        IDUM=IDUM-1
        IF(IDUM)11,11,12
11      MS(I)=IC+1
        IC=IC+1
        GOTO45
9       MS(I)=MS(IDUM)
10      CONTINUE
53      IF(M-5)51,51,52
51      IMS(M)=IC+1
        IC=IC+1
```

APPENDIX F

COMPUTER PROGRAM TO DRAW VU-GRAPH TITLES OR HEADINGS (cont)

```
      XSS(M)=0.
      M=M+1
      GOTO53
52    WRITE(2,4)(IMS(M),XSS(M),M=1,5)
4     FORMAT(6H*%SSM5,I1,F5.1,4(2HM5,I1,F5.1),3H*%*)
      IF(SUM.GT.6.75)GOTO14
      SUM=(8.5-SUM)/2.+SS(1)*.015
      SUM=SUM*1000.
      CALL CONVER(SUM,5,JY)
      DO20I=1,K
      SUMX=0.
      M=0
60    M=M+1
      IF(LTR(I,M).EQ.ICA)GOTO30
      IF(LTR(I,M).EQ.IONE)GOTO30
      IF(LTR(I,M).EQ.IEYE)GOTO40
      IF(LTR(I,M).EQ.IPER)GOTO30
      IF(LTR(I,M).EQ.IPL)GOTO50
      IF(LTR(I,M).EQ.MIN)GOTO50
      IF(LTR(I,M).EQ.IARO)GOTO70
      SUMX=SUMX+.015
      GOTO60
30    SUMX=SUMX+.007
      GOTO60
40    SUMX=SUMX+.005
      GOTO60
50    SUMX=SUMX+.011
      GOTO60
70    LTR(I,M)=IAST
      SUMX=(SUMX-.005)*SS(I)
      IF(SUMX.GT.8.5)GOTO16
      SUMX=(11.-SUMX)*500.
      IF(I.EQ.1)GOTO80
      SUM=SUM+(SPACE(I-1)+SS(I)*.015)*1000.
      CALL CONVER(SUM,5,JY)
80    CALL CONVER(SUMX,5,JX)
      WRITE(2,2)IPL,JX,MIN,JY
2     FORMAT(5H*G01X,6A1,1HY,6A1,4HD02*)
      WRITE(2,3)MS(I),(LTR(I,II),II=1,M)
3     FORMAT(2HM5,I1,6HG56D10,40A1)
20    CONTINUE
      WRITE(2,5)
5     FORMAT(31HG01XY-08500D02*X11000D01*Y00000)
      WRITE(2,6)
6     FORMAT(30H*X00000*Y-08500*X15000D02*M30*)
      GOTO25
14    WRITE(1,7)
7     FORMAT(8HVERT ERR)
      GOTO25
16    WRITE(1,8)
8     FORMAT(8HHORZ ERR)
25    STOP
      END
      $0
```

APPENDIX F

COMPUTER PROGRAM TO DRAW VU-GRAPH TITLES OR HEADINGS (cont)

```
.3   EFFECT OF CHEMICAL<
1.
.3   COMPOSITION ON EROSION<
1.5
.3   DR. R. IMAM<


ST
```

```
*%SSM50 20.0M51  0.0M52  0.0M53  0.0M54  0.0*%*
*G01X+02950Y-02850D02*
M50G56D10EFFECT OF CHEMICAL*
*G01X+02550Y-04150D02*
M50G56D10COMPOSITION ON EROSION*
*G01X+04160Y-05950D02*
M50G56D10DR. R. IMAM*
G01XY-08500D02*X11000D01*Y00000
*X00000*Y-08500*X15000D02*M30*
```

APPENDIX F

COMPUTER PROGRAM TO DRAW VU-GRAPH TITLES OR HEADINGS (cont)

```
C   THIS PROGRAM OUTPUTS STATUS OF FUNDING VU-GRAPH.
C   UPPER LEFT CORNER OF BORDER(.25,.25)
C   TAPE IS SELF-SUFF. FOR DRAFTING PARAMETERS.
C   VALUES FOR AUTHORIZED, EXPENDED, COMMITTED, REMAINING
C   READ(FROM ASR) IN 13A1,DECIMAL OPTIONAL,COMMAS ARE USED,$ NOT USED.
\\COMMON IX(13),JX(5),JY(5)
\\DATA ID,IB/1H1,1H /
100\\WRITE(2,1)
1\\FORMAT(28H*%FSTAX23Y23*SSM5020M5122*%*)
\\WRITE(2,2)
2\\FORMAT(9HG01XYD02*)
\\WRITE(2,3)
3\\FORMAT(37HX026Y-024*M51G56D10STATUS OF FUNDING*)
\\WRITE(2,4)
4\\FORMAT(35HG01X02Y-037D02*M50G56D10AUTHORIZED*)
\\WRITE(2,5)
5\\FORMAT(28HG01Y-0445D02*G56D10EXPENDED*)
\\WRITE(2,6)
6\\FORMAT(28HG01Y-052D02*G56D10COMMITTED*)
\\WRITE(2,7)
7\\FORMAT(29HG01Y-0595D02*G56D10REMAINING*)
\\YY=2950.
\\DO10I=1,4
\\AJ=13.
\\YY=YY+750.
\\DUM=4700.
\\WRITE(1,51)
51\\FORMAT(1H )
\\READ(1,11)IX
\\DO30J=1,13
11\\FORMAT(13A1)
\\IF(IX(J).EQ.ID)DUM=DUM+160.
\\IF(IX(J).EQ.IB)GOTO32
\\GOTO30
32\\AJ=J-1
\\J=13
30\\CONTINUE
\\DUM=DUM+(13.-AJ)*300.
\\IF(AJ.GT.4.)DUM=DUM+160.
\\IF(AJ.GT.8.)DUM=DUM+160.
\\IF(AJ.GT.12.)DUM=DUM+160.
\\CALL CONVER(DUM,5,JX)
\\CALL CONVER(YY,5,JY)
\\WRITE(2,40)JX,JY,IX
40\\FORMAT(4HG01X,5A1,2HY-,5A1,10HD02*G56D10,13A1,1H*)
10\\CONTINUE
\\WRITE(2,41)
41\\FORMAT(47HG01X-0025Y0025D02*X1075D01*Y-0825*X-0025*Y0025*)
\\WRITE(2,42)
42\\FORMAT(11HX15D02*M30*)
\\WRITE(1,50)
50\\FORMAT(49HANOTHER VU-GRAPH? PRESS FOR LEADER THEN HIT START)
\\PAUSE
\\GOTO100
\\END
\\$0
\\
```

APPENDIX F

COMPUTER PROGRAM TO DRAW VU-GRAPH TITLES OR HEADINGS (cont)

```
255,000
56,857
11,047
187,096
ANOTHER VU-GRAPH? PRESS FOR LEADER THEN HIT START
PA
```

```
*%FSTAX23Y23*SSM5020M5122*%*
G01XYD02*
X026Y-024*M51G56D10STATUS OF FUNDING*
G01X02Y-037D02*M50G56D10AUTHORIZED*
G01Y-0445D02*G56D10EXPENDED*
G01Y-052D02*G56D10COMMITTED*
G01Y-0595D02*G56D10REMAINING*
G01X06660Y-03700D02*G56D10255,000        *
G01X06960Y-04450D02*G56D1056,857         *
G01X07280Y-05200D02*G56D1011,047         *
G01X06820Y-05950D02*G56D10187,096        *
G01X-0025Y0025D02*X1075D01*Y-0825*X-0025*Y0025*
X15D02*M30*
```

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