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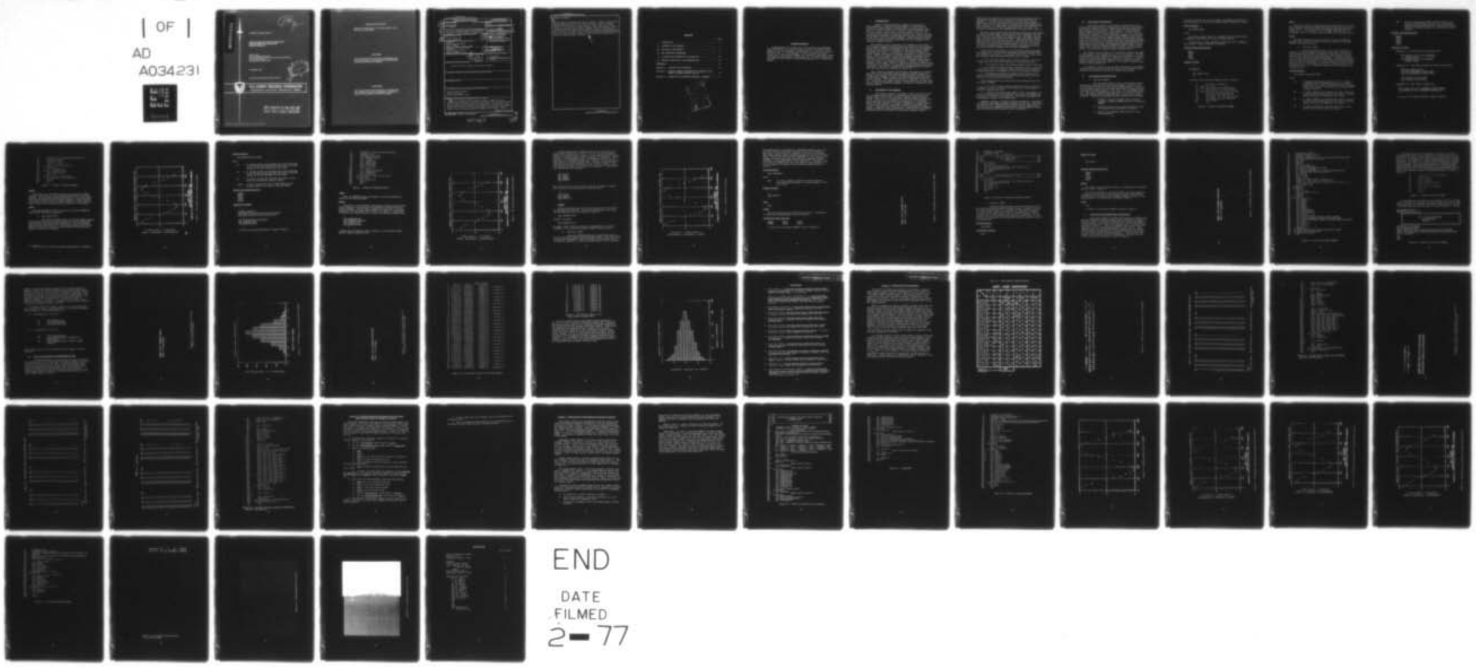

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ANNOTATION AND CONTROL SUBROUTINE SUBPROGRAMS FOR INTERACTIVE GRAPHIC DISPLAYS

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5 November 1976

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Recently, numerous digital computer simulation programs have been developed and/or modified to incorporate the usage of the interactive computer graphics terminal system into their resulting output. The interactive computer graphics terminal system is used primarily to obtain interactive graphic displays as a portion of the simulation program output results. These displays are ideal for data analysis, data reduction and retention, and for

ABSTRACT (Continued)

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inclusion within presentations and technical reports. However, these displays require annotations such that they can be identified at some future date. Certain difficult problems are associated with these annotations and their placement on the interactive graphic displays. Hence, this technical report is an attempt to describe those difficult problems, to provide a technique for their solution, and to acquaint the interactive computer graphics terminal system user of their existence. The use of these techniques and subroutines should make the interactive computer graphic displays more easily annotated and controlled than they have been in the past.

CONTENTS

		Page
I.	INTRODUCTION	3
II.	STATEMENT OF THE PROBLEM	3
III.	SOLUTION OF THE PROBLEM	5
IV.	THE SUBROUTINE SUBPROGRAMS	5
V.	AN APPLICATION PROGRAM AND ITS EXECUTION	19
VI.	RESULTS, CONCLUSIONS, AND RECOMMENDATIONS	23
REFERENCES		31
Appendix A.	CHARACTER CODE CONVERSION	33
Appendix B.	STANDARD OPERATING PROCEDURE FOR TEKTRONIX 4002A GRAPHIC COMPUTER TERMINAL TURN-ON	42
Appendix C.	COMPARISON OF PROGRAMMING METHODS BY EXAMPLES	44

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I. INTRODUCTION

Digital computer simulation programs are continuously being developed, or simplified in some manner, to incorporate the interactive computer graphics terminal system to obtain graphic displays as a portion of their output results. These displays are ideal for data analysis, reduction and retention purposes, as well as for inclusion within technical reports and presentations. However, the displays require annotations and labelings such that they can be identified at some future date for reference purposes. Certain difficult problem areas are encountered with the annotations and their placement on the interactive graphic displays.

This technical report, therefore, fully documents for the interactive computer graphics terminal system user some of the more difficult problem areas, techniques and methods for their solution, and available subroutines which have been developed for interactive graphic display annotations and control. A discussion of the difficult problems of graphic display annotations is contained in Section II of this technical report. Section III presents a possible technique and method for the solutions to the problems. Subroutine subprograms, which have been developed and placed in the system library, for graphic display annotations and control are completely documented in Section IV along with examples of their usage. Section V contains an application program which illustrates the utilization of the graphic display annotation and control subroutines. The results, conclusions, and recommendations for future study and application are contained in Section VI.

These simulation programs and subroutine subprograms are presently being used on the interactive computer graphics terminal system [1,2] located in the Guidance and Control Analysis Simulation Facility of the US Army Missile Command's Guidance and Control Directorate at Redstone Arsenal, Alabama. This simulation facility is described by Jolly et al. [2]. Familiarity with digital computer system operations and some knowledge of computer programming languages, in particular, Fortran IV [3-10], has been assumed.

II. STATEMENT OF THE PROBLEM

This section contains a discussion of some of the more difficult problems associated with the annotating and controlling of the graphic display plots by the interactive computer graphics terminal system. First of all, the input/output (I/O) done by the terminal control system (TCS) Plot-10 software is performed by two subroutines, RD7611 for input and WT7611 for output, respectively. A description of the TCS Plot-10 software is presented in reports by Tektronix, Inc. [11,12]. Alternate entry points for the two subroutines are TINPUT and TOUTPT for input and output, respectively. These routines are system-dependent and must be provided for each digital computer system.

Their function is simply to input and output American Standard Code for Information Interchange (ASCII) characters (see the ASCII Table in Appendix A). The data are transferred to and from the Xerox Sigma 5 analog coupler driver system and the Tektronix model 4002A graphics computer terminal by the Xerox model 7611 character-oriented communications (COC) controller on a character-by-character basis; for output, the character is contained in the rightmost byte of the word (i.e., byte 3).

Secondly, the Extended Binary-Coded-Decimal Interchange Code (EBCDIC) is used by the Xerox Sigma 5 analog coupler driver simulation facility, where there are four characters or bytes per word. Therefore, this presents a problem of conversion from EBCDIC to ASCII for graphic display output and from ASCII to EBCDIC for input. Additionally, only certain characters may be converted from EBCDIC to ASCII and vice-versa by the subroutines and function subprograms provided in the COC I/O, control, and utility software package. The particulars pertaining to the character code conversion processes can be found in Appendix A.

Finally, the characteristics of, and strappable options available and provided with, the Tektronix 4002A graphic computer terminal effect the annotations and control of the graphic display output. Some of the more important characteristics and options are as follows:

a) 39 lines of 85 normal size or italic characters in the main display area. One line of 84 characters in the scratch pad area.

b) A 94 upper and lower case printing character (ASCII code) set.

c) The optional character rotator card module, which is installed in the drawer unit of the Tektronix 4002A, provides for the rotation of displayed characters in increments of 90 deg in a clockwise direction.

d) The optional horizontal tab feature permits insertion and removal of horizontal tab positions and shifting the start of the displayed line to any selected tab position.

These characteristics and options have the following affects upon the graphic displays:

a) If a line of output characters greater than the 85 allowed is attempted, the output is jumbled on the right side of the cathode ray tube (CRT) display screen area.

b) If more than the 39 allowed number of lines is attempted, the output is returned to the "home" position (top left of the screen) and the output is continued until completion. This causes overlapping and overprinting of output on the display area.

Appendix B presents a standard operating procedure for "turning-on" the Tektronix 4002A graphic computer terminal each morning. This procedure should help in eliminating the difficulty usually encountered in obtaining the first graphical displays from a digital computer program when the Tektronix 4002A terminal is first "powered-up."

III. SOLUTION OF THE PROBLEM

The obvious solution to the difficult problem areas is to develop generalized subroutine subprograms for handling the annotations and control of graphic displays. These generalized subroutines have been developed and placed in the system library of the Xerox Sigma 5 analog coupler driver simulation system facility. If any of the subroutines are required by a user's application program, the subroutines are loaded at load time by the overlay loader "OLOAD" processor of the hybrid real-time batch monitor (HRBM) operating system. These subroutines have been written in the extended Fortran IV programming language; however, the subroutines are compatible for usage with application programs written in the Fortran IV-H programming language and/or with the macro-symbol assemblier language, provided the proper linkage is established. Thus, the subroutines are easily accessed by all application users of the interactive computer graphics terminal system.

The objective of this report is to describe the function and usage of these graphic display annotation and control subroutines. The functional description and examples for usage of the annotation and control subroutines for graphic displays are contained in Section IV. Section V presents a typical application program for the interactive computer graphics terminal system which makes use of the graphic display annotation and control subroutines.

For comparison purposes only, Appendix C includes four programming examples which illustrates the various methods and techniques of annotating and controlling the interactive graphic display plots.

IV. THE SUBROUTINE SUBPROGRAMS

A. Subroutine CHARRD

This subroutine enables a user to interactively control the generation and hard copy output of CRT displays. Control is provided by characters input via the Tektronix 4002A keyboard. These control characters enable a user to obtain a hard copy of a graphic display, to redraw the current display(s), or to step to the next program function. The control characters are upper case; i.e., the shift lock key of the CRT keyboard should be depressed prior to selecting a control character. The control characters and their functions are as follows:

C — Continue to the next program function (Fortran statement, assumed) following the call to subroutine CHARRD.

D — Produce a hard copy of the current display and wait for further control characters to be input.

R — Return to the statement label specified in the calling sequence.

All other characters are ignored; however, the program loops (waits) in this subroutine until one of the preceding control characters is input.

Calling Sequence:

CALL CHARRD (&LAB)

where:

The calling argument (&LAB) is a statement label by which control is transferred upon detection of the R control character.

A normal return (to the statement following the call to CHARRD) is made when the C control character is detected.

External Subprograms Required:

BELL
HDCOPY
NDIG
NSTCK
RD7611

Example of Usage:

```
    ⋮
105 CONTINUE
    ⋮
    CALL CHARRD (&105)
    ⋮
```

A listing of the subroutine CHARRD is shown in Figure 1.

```
      SUBROUTINE CHARRD(*)
 1203 CALL BELL
 1201 CALL RD7611(1,ICHAR,IFLAG)
      IF(IFLAG .LT. 0) GO TO 1201
 1202 IF(NSTCK(I) .GE. 4) GO TO 1202
      ICHAR1 = NDIG(ICHAR,1,-10)
      IF(ICHAR1 .EQ. 67) RETURN
      IF(ICHAR1 .EQ. 68) CALL HDCOPY
      IF(ICHAR1 .EQ. 82) RETURN 1
      GO TO 1203
      END
```

Figure 1. Listing of subroutine CHARRD.

Input:

The execution of control character selected for input from the Tektronix 4002A keyboard as subroutine CHARRD depends upon the expected output results. output results. The possible inputs have already been described previously as: 'C' — to continue, 'D' — to make a hard copy, and 'R' — to transfer control to a Fortran statement label of the calling routine.

Output:

The output resulting from the execution of subroutine CHARRD is dependent upon the control character selected as input from the 4002A keyboard (see preceding input).

B. Subroutine HITLES

Subroutine HITLES enables a user to output specified character strings for graphic plot display annotations. The user must specify position and character orientation for the character strings, where position specifies the starting position for the first character of the string (specified in screen coordinates). Orientation specifies that the character strings shall be output either as a horizontal string read in a left to right manner, or a vertical string with each character rotated 90 deg counterclockwise such that the character string is read from bottom to top, i.e., assuming the bottom of the CRT display is the horizontal axis.

Calling Sequence:

CALL HITLES (LS,MH,MV,NC,HLAB)

where:

LS — An integer variable with a value of 1 or 2. A value of 1 specifies that the character string is to be output horizontally and a value of 2 specifies that the character string shall be output vertically with the 90-deg counterclockwise rotation.

MH — An integer variable that specifies the screen coordinates in the X-direction from the lower left corner of the CRT display for the first character of the string.

MV — An integer variable that specifies the screen coordinates in the Y-direction from the lower left corner of the CRT display for the first character of the string.

NC — An integer variable that specifies the number of characters in the character string to output.

HLAB – An array containing the EBCDIC character string to be output to the CRT graphic display. The calling program (main/subroutine) may generate this string by filling the array with Hollerith constants or by specifying a Literal constant.

External Subprograms Required:

HLABEL
MOVABS
NASCII
NSTCK
RVTITL

Example(s) of Usage:

Example No. 1. Depleting Hollerith constant data.

```
     :
     CALL HITLES(1,150,75,26,26H INDEPENDENT
          VARIABLE LABEL)
     CALL HITLES(2,60,640,24,24H DEPENDENT
          VARIABLE LABEL)
     :
```

Example No. 2. Containing Hollerith and Literal constant data.

```
     :
     DIMENSION LABH(7),LABV(6)
     DATA LABH/'INDEPENDENT VARIABLE LABEL  '/
     DATA LABV/24HDEPENDENT VARIABLE LABEL   /
     :
     CALL HITLES(1,150,75,26,LABH)
     CALL HITLES(2,60,640,24,LABV)
     :
```

Example No. 3. With Literal constant data.

```
     :
   CALL HITLES(1,150,75,26,'INDEPENDENT VARIABLE LABEL')
   CALL HITLES(2,60,640,24,'DEPENDENT VARIABLE LABEL')
     :
```

A listing of the subroutine HITLES is shown in Figure 2.

```
      SUBROUTINE HITLES(LS,MH,MV,NC,HLAB)
      INTEGER HLAB(NC)
      INTEGER HL(80)
      DO 20, I = 1,NC
      HL(I) = NASCII(HLAB,I)
   20 CONTINUE
      GO TO (30,40), LS
   30 CALL MOVABS(MH,MV)
      CALL HLABEL(NC,HL)
      GO TO 10
   40 CALL RVTITL(MH,MV,NC,HL)
   10 IF(NSTCK(I) .GE. 3) GO TO 10
      RETURN
      END
```

Figure 2. Listing of subroutine HITLES.

<u>Output:</u>

The output to the CRT display resulting from subroutine HITLES execution is dependent upon the parameters passed within its calling sequence. For the simple examples previously given, the output appearing on the CRT display screen is shown in Figure 3.* Other illustrations, which contain calls to subroutine HITLES and its resulting output, are shown in other subsections and in Section V of this report.

<u>Input:</u>

None, the parameters that are required of subroutine HITLES are passed within the calling statements.

C. Subroutine RVTITL

The subroutine RVTITL outputs to the CRT display character strings specified by ASCII integer values in the vertical manner with each character rotated 90 deg counterclockwise. Then, the character string is read from bottom to top. The user must specify the starting position for the first character of the string also, as well as the number of characters to be output.

---

*This figure was output from program example number 4 in Appendix C.

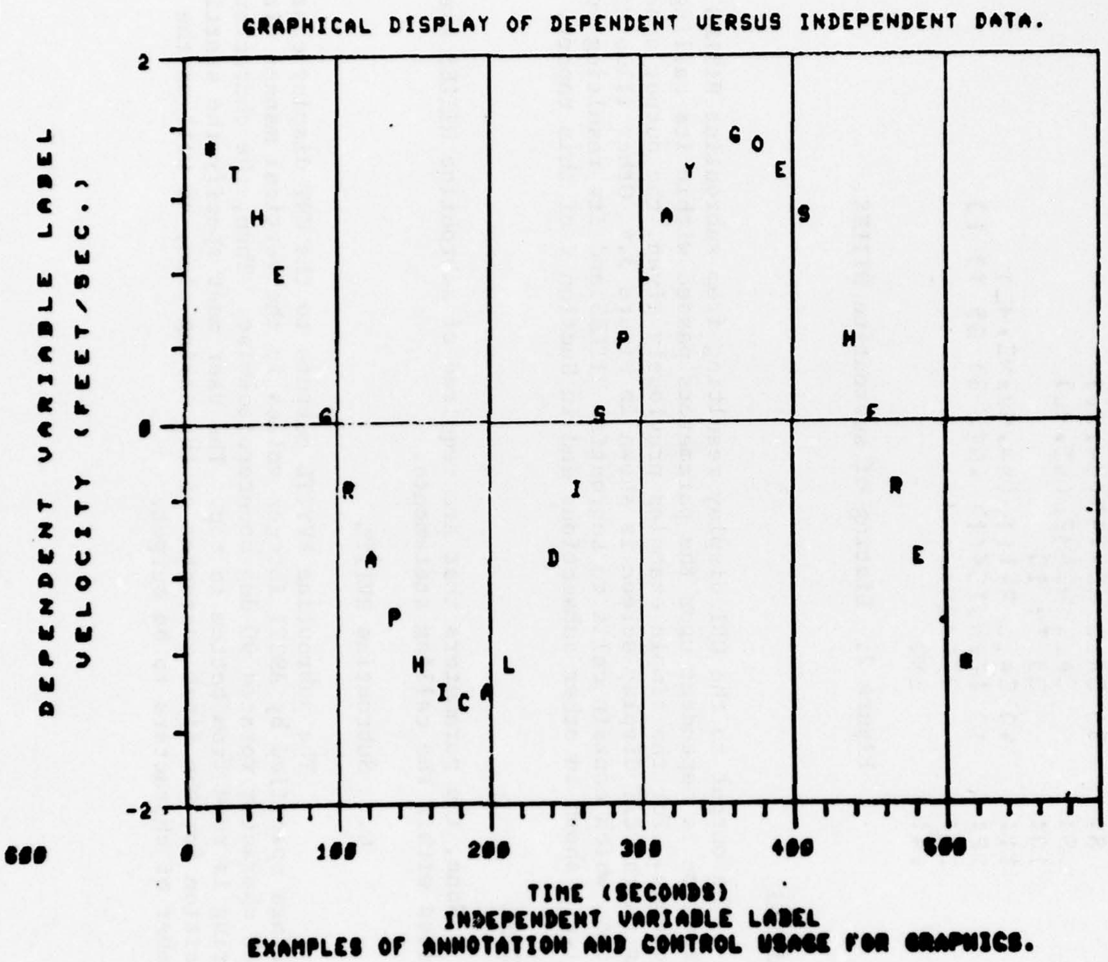

Figure 3. CRT display output by subroutine HITLES.

Calling Sequence:

```
CALL RVTITL(MH,MV,NC,LABRV)
```

where:

MH — An integer variable that specifies the screen coordinate in the X-direction from the lower left corner of the CRT display for the last character of the string.

MV — An integer variable that specifies the screen coordinate in the Y-direction from the lower left corner of the CRT display for the last character of the string.

NC — An integer variable that specifies the number of characters in the character string to output.

LABRV — An array containing the ASCII integer values of the character string to be output to the CRT display.

External Subprograms Required:

ANMODE
MOVABS
NSTCK
TOUTPT
WT7611

Example(s) of Usage:

```
    :
DIMENSION LABRV(26)
DATA LABRV/73,78,68,69,80,69,78,68,69,78,84,32,
186,65,82,73,65,66,76,69,32,76,65,66,69,76/
    :
CALL RVTITL(MH1,MV1,NC1,LABRV(3))
CALL MOVABS(MH2,MV2)
CALL HLABEL(26,LABRV)
    :
```

A listing of the subroutine RVTITL is shown in Figure 4.

```
      SUBROUTINE RVTITL(MH,MV,NC,RV_AB)
      INTEGER RVLAB
      DIMENSION RV_AB(NC)
      CALL MOVABS(MH,MV)
      CALL ANMODE
      CALL WT7611(21)
      CALL WT7611(21)
      CALL WT7611(21)
      DO 10 J = 1,NC
      K = (NC+1) - J
      CALL WT7611(RV_AB(K))
      CALL TOUTPT(8)
      CALL TOUTPT(10)
   20 IF(NSTCK(I) .GE. 3) GO TO 20
   10 CONTINUE
      CALL WT7611(21)
      RETURN
      END
```

Figure 4. Listing of subroutine RVTITL.

Input:

None, the parameters that are required of subroutine RVTITL are passed by the calling statement.

Output:

The output to the CRT graphic display area resulting from subroutine RVTITL execution is dependent upon the parameters contained within its calling statement. For the simple examples previously given, the output appearing on the CRT display area is shown as in Figure 5. Heretofore, it has been the customary practice to make the following statement calls:

```
   :
CALL MOVABS(MH1,MV1)
CALL VLABEL(NC1,LABRV(3))
CALL MOVABS(60,600)
CALL VLABEL(20,IDVL)
   :
```

to obtain the CRT display as shown in Figure 6 on the Tektronix 4002A graphic computer terminal screen.

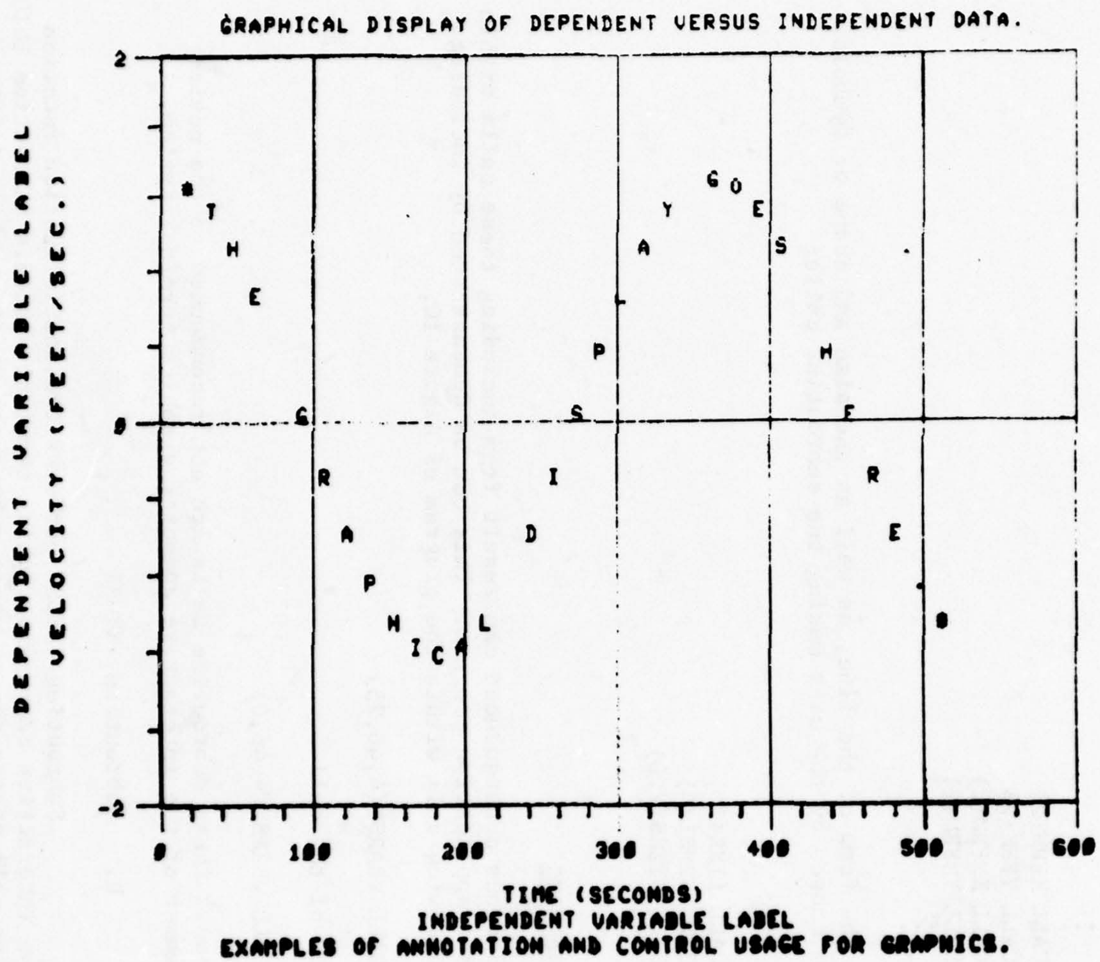

Figure 5. CRT display output by subroutine RVTITL.

Program example number 3 (Appendix C) was used in obtaining the output results contained in Figure 5. This is, in reality, Figure 3 redrawn to a different scale. Figure 6 is the output resulting from the execution of program example number 2 statements in Appendix C. Notice that this is the customary practice for obtaining the grid lines and tick marks on the graphical display plot. However, the user may control these options by including various calls to routines to handle these functions as described in References 11 and 12 and as shown in the program listings of Figure 10 and Figure C-2 in Appendix C. These subroutine calls include the following:

```
      :
CALL XFRM(2)
CALL YFRM(2)
CALL XMFRM(2)
CALL YMFRM(2)
      :
```

Also, the form of the line, as well as the size and shape of symbols, can be chosen by the user making the subroutine calls:

```
      :
CALL LINE(14)
CALL SYMBL(4)
CALL SIZES(2.0)
      :
```

WARNING

Serious consequences can result from including these calls within the user application program. This can be demonstrated by including the following call within the program of Figure 10,

```
CALL VBARST(4,46,25)
```

instead of the call

```
CALL VBARST(4,46,0)
```

as shown. These subroutine calls are not recommended to the novice programmer of the interactive computer graphics terminal system.

D. Subroutine INTCRT

Subroutine INTCRT performs the initialization function for the interactive computer graphics terminal system. Subroutine INTCRT contains call statements to other subprogram routines which initiates the hardware components by resetting the Xerox Model 7611 COC controller

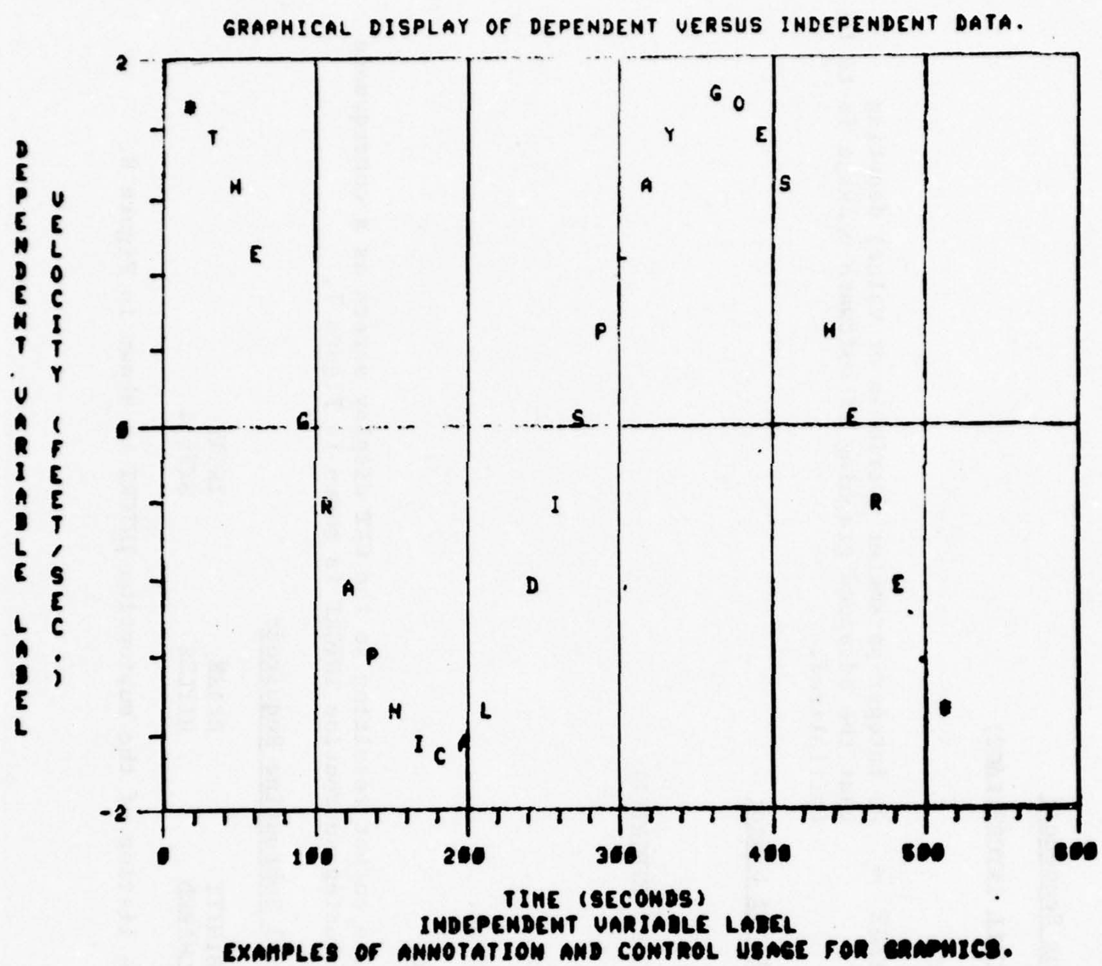

Figure 6. Customary form of CRT display.

and checking that it is switched on. External interrupts 6 and 7 are centrally connected and various software counters are initialized. Also, calls to subroutines are performed to initialize the Tektronix Model 4002A graphics computer terminal hardware and the Plot-10 software system. The one call to subroutine INTCRT within a main program or a subprogram routine replaces the three necessary (required) calling statements to subprograms ST7611, INITT, and BINITT. A message is output to the CRT display screen that the program is ready and that a 'C' control character is required as input from the display keyboard to continue.

Calling Sequence:

```
CALL INTCRT(KAG2)
```

where:

KAG2 – An integer parameter (variable or value) denoting that the advanced graphing II software package is to be initialized.

Example of Usage:

```
     :
     CALL INTCRT(1)
     :
```

Input:

None.

Output:

The output resulting to the CRT display screen as a consequence of executing subroutine INTCRT is shown in Figure 7.

External Subroutine Required:

BINITT	ERASE	INITT
CHARRD	HITLES	ST7611

A listing of the subroutine INTCRT is shown in Figure 8.

```
4002A ICGTS PROGRAM READY.
TYPE C TO CONTINUE.
```

Figure 7. CRT display output from subroutine INTCRT.

```
      SUBROUTINE INTCRT(KAG2)
      DIMENSION LABH(5)
      DATA LABH / 'TYPE C TO CONTINUE. ' /
C *** * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * **
C ***                USER INITIALIZATION OF I C G T S                  ***
C ***                      BY: LARMON S. ISOM                          ***
C ***                         1 MARCH 1976                             ***
C *** * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * ****
   10 CALL ST7611
      CALL INITT(120)
      IF(KAG2 .NE. 0) CALL BINITT
      CALL HITLES(1,200,400,26,'4002A ICGTS PROGRAM READY,' )
      CALL HITLES(1,200,370,19,LABH)
      CALL CHARRD(510)
      CALL ERASE
      RETURN
C *** * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * ****
C ***                USER FINALIZATION OF I C G.T C                    ***
C *** * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * ****
      ENTRY CRTFIN
   20 CALL ERASE
      CALL HITLES(1,200,400,30,'4002A ICGTS PROGRAM COMPLETED,' )
      CALL HITLES(1,200,370,19,LABH)
      CALL CHARRD(520)
      CALL ERASE
      CALL FINITT(0,740)
      CALL HT7611
      RETURN
      END
```

Figure 8. Listing of subroutines INTCRT and CRTFIN.

E. Subroutine CRTFIN

Subroutine CRTFIN performs the terminating function for the interactive computer graphics terminal system. A message is output to the CRT display screen that the program is completed and requires a 'C' input from the keyboard to continue. The CRT display is erased (cleared) and the cursor moved to the home (0,740) position. The I/O activity from/to the keyboard/display through the Xerox Model 7611 COC controller is terminated and the centrally connected interrupts (6 and 7) are disconnected.

<u>Calling Sequence:</u>

CALL CRTFIN

<u>Parameter(s) Entered:</u>

None.

Example of Usage:

```
      .
      .
      .
      CALL CRTFIN
      .
      .
      .
```

External Subprograms Required:

CHARRD
ERASE
FINITT
HITLES
HT7611

Output:

The output to the CRT display screen as a consequence of subroutine CRTFIN is shown in Figure 9.

The calling statement to subroutine CRTFIN in the main program or a subprogram routine replaces the necessary (required) three calling statements to the subroutines HOME or MOVABS, FINITT, and HT7611. Subroutine CRTFIN is an entry point in subroutine INTCRT.

Input:

None.

A listing of the subroutine CRTFIN is shown in Figure 9.

V. AN APPLICATION PROGRAM AND ITS EXECUTION

This section presents a typical user application program which uses the interactive computer graphics terminal system for a portion of the output result. This program illustrates the usage of the graphic display annotation and control subroutines that have been developed and discussed in Section IV. Most of the examples given in Section IV have been used within the main program contained in this section. Other examples have been included, for comparison purposes only, to compare these techniques and methods with the customary practice used to annotate and control graphic displays heretofore. A listing of the main program, which contains the calling statements to the annotation and control subroutine subprograms, is shown in Figure 10.

```
4002A ICGTS PROGRAM COMPLETED.
TYPE C TO CONTINUE.
```

Figure 9. CRT display output from subroutine CRTFIN.

```
      REAL*8 RNDM1, RNDM2, E1
      DIMENSION YNUM(15), XDAT(15)
      DATA YNUM / 15*0.0 /
      DATA XDAT / -3.50,-3.00,-2.50,-2.00,-1.50,-1.00,-0.50,0.0,0.50,
     1 1.00,1.50,2.00,2.50, 3.00, 3.50 /
      IX = 1000
      PRINT 15
      PRINT 20
      DO 10 I = 1,1000
      CALL RANDU(IX,IY,RNDM1)
      IF(I .LE. 25) PRINT 25,I,IX,IY,RNDM1
      CALL RANDU(IX,IY,RNDM2)
      E1 = DSQRT(-2.0D0*DLOG(RNDM1))*DCOS(6.283185307D0*RNDM2)
      IF(I .LE. 25) PRINT 25,I,IX,IY,RNDM2,E1
      ERN = SNGL(E1)
      XLLIM = -3.25
      XULIM = -2.75
      DO 100 J = 2,14
      IF(ERN .LT. -3.25) YNUM(1) = YNUM(1) + 1.0
       IF(ERN .GE. 3.25) YNUM(15) = YNUM(15) + 1.0
      IF(ERN .GE. XLLIM .AND. ERN .LT. XULIM) YNUM(J) = YNUM(J) + 1.0
      XLLIM = XLLIM + 0.5
      XULIM = XULIM + 0.5
  100 CONTINUE
   10 CONTINUE
      PRINT 15
      DO 11 N = 1,15
      PRINT 30,N,XDAT(N),YNUM(N)
   11 CONTINUE
      PRINT 15
   12 CONTINUE
C *** PLOT THE DATA ***
      CALL INTCRT(1)
      CALL NPTS(15)
      CALL LINE(2)
      CALL XFRM(2)
      CALL YFRM(2)
      CALL XMFRM(2)
      CALL XMFRM(2)
      CALL VBARST(4,46,0)
      CALL CHECK(XDAT,YNUM)
      CALL DSPLAY(XDAT,YNUM)
      CALL LINE(14)
      CALL CPLOT(XDAT,YNUM)
      CALL HITLES(1,300,30,24,'RANGE OF RANDOM NUMBERS.')
      CALL HITLES(2,25,600,25,'FREQUENCY OF DISTRIBUTION')
      CALL HITLES(1,200,730,38,' HISTOGRAM OF RANDOM NUMBER GENERATION')
      CALL FRAME
      CALL CHARRD(512)
      CALL CRTFIN
      CALL FG$RLS('OV      ')
      CALL EXIT
   15 FORMAT (1H1,/,/)
   20 FORMAT(14X,1HI,5X,2HIX,10X,2HIY,6X,13HRANDOM NUMBER)
   25 FORMAT(10X,I5,I12,I12,2D15.5)
   30 FORMAT(10X,I3,2E15.5)
      END
```

Figure 10. Listing of the main program.

The primary purpose of this program is to generate a series of random variables (in this case, 1000) and to plot the output result in the form of a histogram (see Reference 13 for a discussion of a histogram plot). The program uses a random number generated with a uniform distribution by a subroutine to obtain a random number with a Gaussian distribution (zero-mean, unity-variance) using the Box-Muller transformation technique. The random number generator is subroutine RANDU. Subroutine RANDU generates random numbers with a uniform distribution in the closed set [0,1]. The listing of the subroutine RANDU, which is based on the recurrence formula or multiplicative method, is shown in Figure 11.

```
      SUBROUTINE RANDU(IX,IY,YFL)
      REAL*8 YFL
      IY = IX*65539
      IF(IY) 5,6,6
    5 IY = IY+2147483647+1
    6 YFL = IY
      YFL = YFL*.4656613E-9
      IX = IY
      RETURN
      END
```

Figure 11. Listing of subroutine RANDU.

All programs that are written for and executed on the Xerox Sigma 5 analog coupler driver simulation facility are under control of the HRBM operating system. The necessary job control commands that are required by the HRBM operating system are shown in order in Figure 12. The main

```
!JOB RANDOM,NUMBER TEST
!FORTRAN SI,LS,GO,BC(25),NS
    ****************************************************************
    **                                                            **
    **               USER'S APPLICATION PROGRAM                   **
    **                  AND SUBROUTINES                           **
    **                     GO HERE.                               **
    **                                                            **
    ****************************************************************
!ASSIGN (M:LO,LPA02),NOVFC
!ASSIGN (M:LL,LPA02),NOVFC
!OLOAD (TEMP,450),(UDCB,1),(FORE,2300),(LIB,USER,SYSTEM),(MAP)
:ROOT (FILE,BT,GO,EOD),(FILE,D6,MOCAG2BO,EOD),(FILE,D6,AG2FILBO,EOD)
:ASSIGN (F:6,LPA05)
!FG
!ROV
!FIN
```

Figure 12. Listing of job control commands.

program and subroutine RANDU are compiled by the extended Fortran IV compiler, loaded by the system processor overlay loader "OLOAD" from the "GO" file onto the "OV" file along with the required TCS Plot-10 files, MOCAG2BO and AG2FILBO, and the library of subroutine subprograms. Then, the program is executed in the foreground area of computer memory. The resulting outputs from the execution of the program are shown in Figures 13 through 17. Figures 13, 14, and 15 are the outputs to the Tektronix 4002A CRT display area. The output listings to the foreground line printer are shown in Figures 16 and 17.

An alternate form of the graphic display for the same basic data may be obtained by making a few modifications to the Fortran statements shown in Figure 10. These modifications are:

a) To statements 40, 41, and 42.

```
              .
              .
              .
40:        CALL HBARST(4,37,0)
41:        CALL CHECK(YNUM,XDAT)
42:        CALL DSPLAY(YNUM,XDAT)
              .
              .
              .
```

b) To statements 44, 45, and 46.

```
              .
              .
              .
44:        CALL CPLOT(YNUM,XDAT)
45:        CALL HITLES(1,300,30,25,'FREQUENCY OF
           DISTRIBUTION')
46:        CALL HITLES(2,25,600,24,'RANGE OF RANDOM
           NUMBERS.')
              .
              .
              .
```

The resulting output to the CRT display area will appear as shown in Figure 18.

VI. RESULTS, CONCLUSIONS, AND RECOMMENDATIONS

This section presents the conclusions and comments concerning the annotation and control subroutines for graphic displays previously discussed in Section IV of this report. The graphic display output resulting from the execution of a typical user's application program using these techniques and methods has already been described in Section V; however, their use and application extends directly to the larger graphic display utilization of application programs such as the CLGP, PATRIOT (SAM-D), and SIG-D.

```
4002A ICGTS PROGRAM READY.
TYPE C TO CONTINUE.
```

Figure 13. CRT display output by calling INTCRT in the main program.

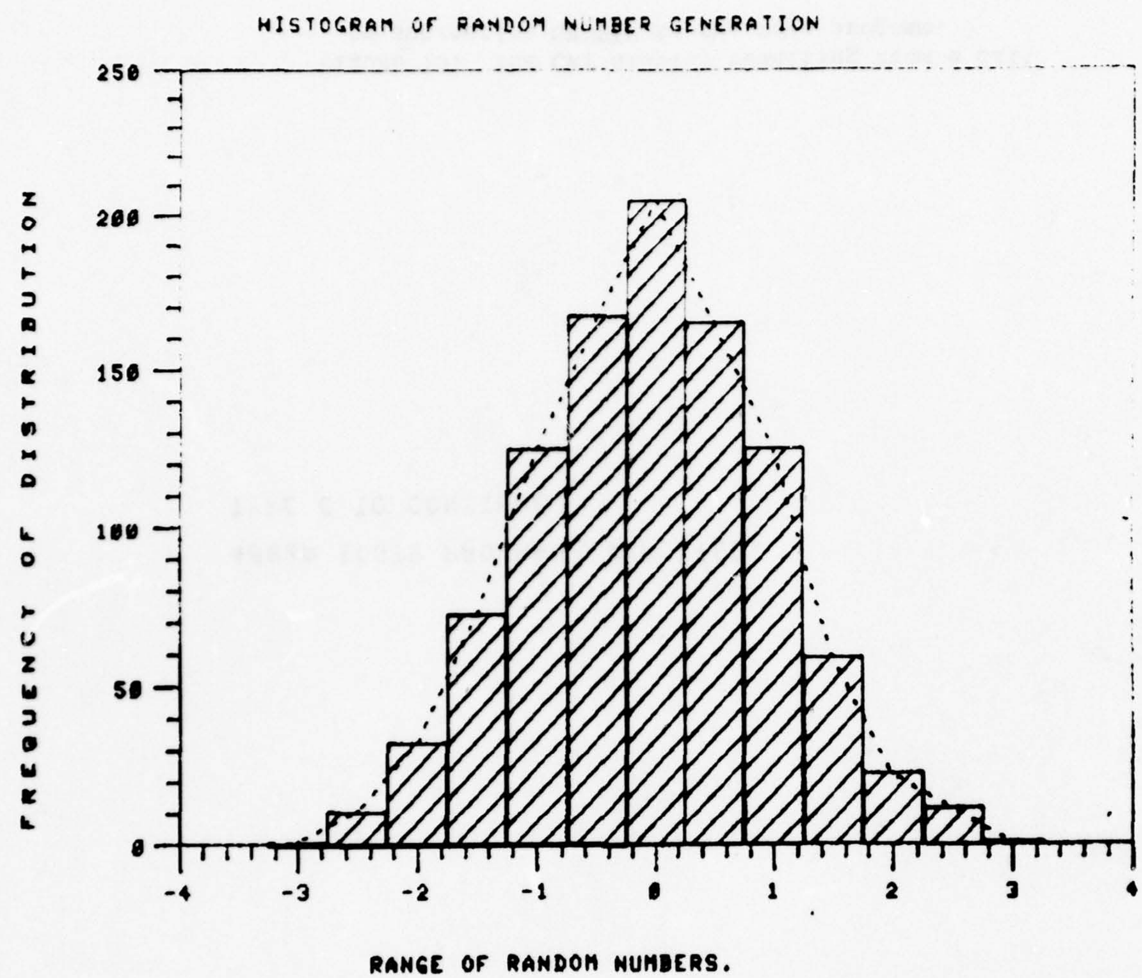

Figure 14. A CRT display of the random number histogram.

4ØØ2A ICGTS PROGRAM COMPLETED.

TYPE C TO CONTINUE.

Figure 15. The CRT display resulting from a call to subroutine CRTFIN in the main program.

I	IX	IY	RANDOM NUMBER	
1	65539000	65539000	.30519D-01	
1	393225000	393225000	.18311D 00	.10779D 01
2	1769499000	1769499000	.82399D 00	
2	635518056	635518056	.29594D 00	-.17712D 00
3	772519224	772519224	.35973D 00	
3	1062336488	1062336488	.49497D 00	-.14292D 01
4	1572423560	1572423560	.73222D 00	
4	2015632616	2015632616	.93860D 00	.73150D 00
5	89413304	89413304	.41636D-01	
5	1723139112	1723139112	.80240D 00	.81522D 00
6	944180344	944180344	.43967D 00	
6	894248296	894248296	.41642D 00	-.11092D 01
7	1162833976	1162833976	.54149D 00	
7	1076252840	1076252840	.50117D 00	-.11076D 01
8	286978552	286978552	.13363D 00	
8	625530344	625530344	.29129D 00	-.51463D 00
9	1170375096	1170375096	.54500D 00	
9	1302477480	1302477480	.64842D 00	-.55642D 00
10	2116456312	2116456312	.98555D 00	
10	166440552	166440552	.77505D-01	.15078D 00
11	1277889336	1277889336	.59506D 00	
11	1874403752	1874403752	.87284D 00	.71062D 00
12	1892202136	1892202136	.88145D 00	
12	930229912	930229912	.43317D 00	-.46873D 00
13	1430162616	1430162616	.66597D 00	
13	208905768	208905768	.97277D-01	.73842D 00
14	1266872952	1266872952	.58993D 00	
14	1426118504	1426118504	.66409D 00	-.52803D 00
15	1449821752	1449821752	.67513D 00	
15	158831272	158831272	.73962D-01	.79240D 00
16	789493752	789493752	.36764D 00	
16	1159097416	1159097416	.54017D 00	-.13699D 01
17	2002024376	2002024376	.93227D 00	
17	1572169512	1572169512	.73210D 00	-.42038D-01
18	4732280	4732280	.22036D-02	
18	911253608	911253608	.42434D 00	-.31100D 01
19	1129963832	1129963832	.52618D 00	
19	725084168	725084168	.33806D 00	-.59553D 00
20	628681464	628681464	.29275D 00	
20	1533198568	1533198568	.71395D 00	-.35200D 00
21	1393574584	1393574584	.64893D 00	
21	1005111336	1005111336	.46804D 00	-.91129D 00
22	2078431352	2078431352	.96785D 00	
22	1277102440	1277102440	.59470D 00	-.21173D 00
23	1841634360	1841634360	.85758D 00	
23	1703367848	1703367848	.79317D 00	.14860D 00
24	87948792	87948792	.40954D-01	
24	229767656	229767656	.10699D 00	.19777D 01
25	587066808	587066808	.27337D 00	
25	1454491944	1454491944	.67730D 00	-.71035D 00

Figure 16. Line printer listing of the random numbers.

1	-.35000E 01	.00000E 00
2	-.30000E 01	.10000E 01
3	-.25000E 01	.11000E 02
4	-.20000E 01	.33000E 02
5	-.15000E 01	.73000E 02
6	-.10000E 01	.12500E 03
7	-.50000E 00	.16700E 03
8	.00000E 00	.20500E 03
9	.50000E 00	.16500E 03
10	.10000E 01	.12500E 03
11	.15000E 01	.59000E 02
12	.20000E 01	.23000E 02
13	.25000E 01	.12000E 02
14	.30000E 01	.10000E 01
15	.35000E 01	.00000E 00

Figure 17. Line printer listing of the random number histogram data.

As can be observed from the application program presented in Section V, it can be concluded that graphic displays may be annotated and controlled more easily by the techniques and methods presented in this report than has been possible within past programs. Additionally, these methods and techniques produce no affects upon the output resulting from the execution of user's application programs written in the past that utilizes the interactive computer graphics terminal system. However, the use of these subroutines would lessen the cost and shorten the time frame for obtaining properly annotated graphic displays. It is recommended that these programming practices and procedures be adopted in future user application programs which involve the interactive compute graphics terminal system.

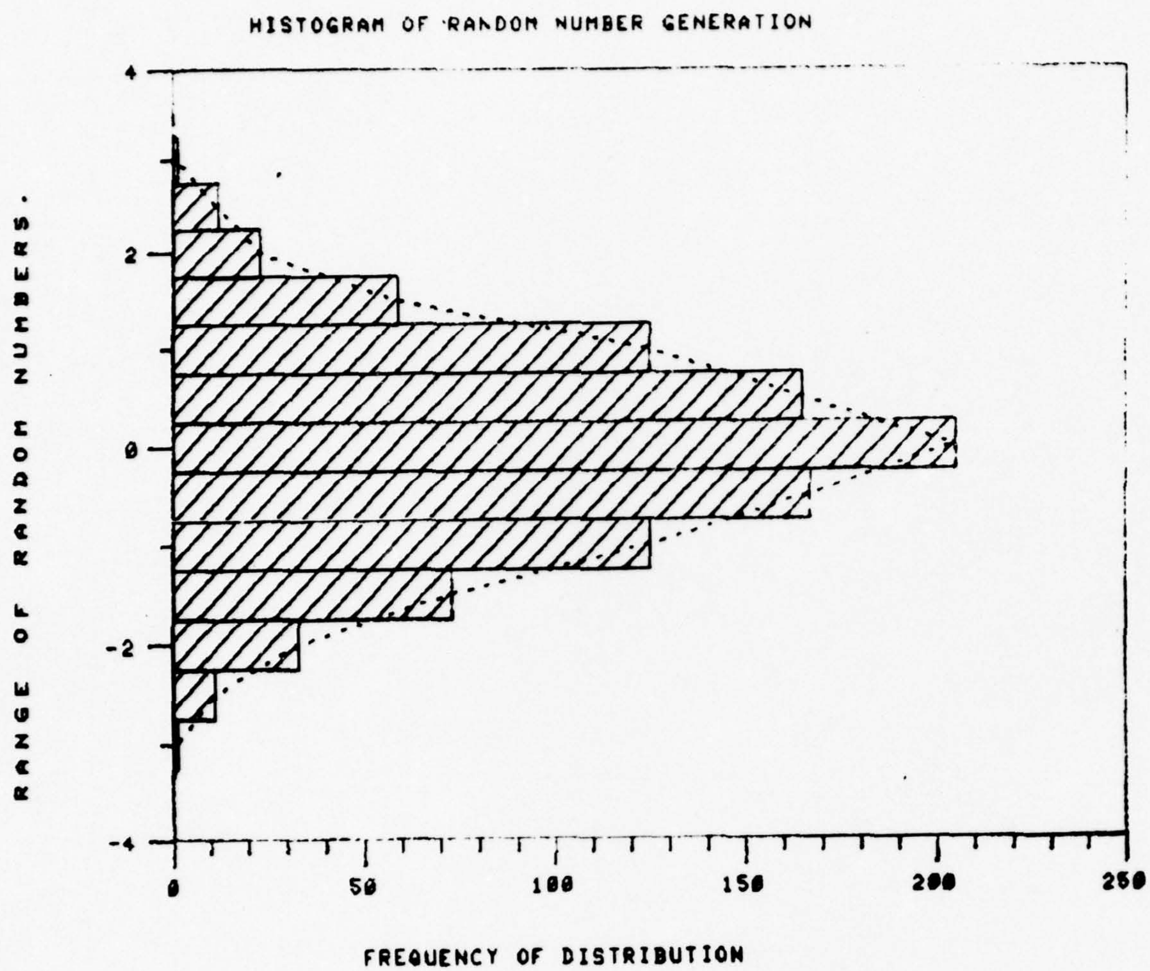

Figure 18. An alternate CRT display output.

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Appendix A: CHARACTER CODE CONVERSION

This appendix addresses the problem and the process of character code conversion between the ASCII character codes for the Tektronix 4002A graphic computer terminal and the EBCDIC for the character codes of the Xerox Sigma 5 digital computer. The primary purpose of this appendix is to show that conversion from ASCII to EBCDIC can be performed, and vice-versa, as well as to determine what character codes in ASCII/EBCDIC are converted to what EBCDIC/ASCII character codes by the COC software package.

Table A-1 presents the possible 128 ASCII character codes and their functions for the Tektronix 4002A graphic computer terminal in the various formats; such as binary, decimal integers, and graphical alphanumerics. Figure A-1 depicts the output to the CRT display area resulting from these 128 character codes being transmitted to the display area by the Sigma 5 digital computer. The line printer listing of these same 128 character codes upon being converted from ASCII to EBCDIC are contained in Table A-2. These outputs and code conversions were accomplished by executing the main program as shown in the listing of Figure A-2 with the aid of the Tektronix Plot-10 and the COC software packages. It should be readily observed that a majority of the ASCII character codes are converted to the EBCDIC code for a blank space (40_{16} or 64_{10}) by the COC software package; also, that the results returned from the Fortran function call to "NEBCD" is contained in the last byte (rightmost) of the word.

In a similiar fashion, the 256 possible EBCDIC character codes were converted to ASCII character codes by the COC software package, transmitted through the Xerox Model 7611 COC device by the Sigma 5 digital computer, to the Tektronix 4002A CRT display screen. The resulting output to the CRT display area is shown in Figure A-3, while Table A-3 presents the line printer output listing for the program execution. Again, it is observable that a majority of the EBCDIC character codes are converted by the COC software package to the ASCII character code of 00_{16}, which is a "NUL" character. The main program to accomplish this EBCDIC to ASCII conversion is depicted as the listing shown in Figure A-4. Observe that not all alphanumeric symbols displayed on the CRT display area are printable on the line printer.

TABLE A-1. 4002A GRAPHIC COMPUTER TERMINAL

ASCII CODE FUNCTIONS

BITS B_4	B_3	B_2	B_1	$B_7B_6B_5$ = Ø Ø Ø	Ø Ø 1	Ø 1 Ø	Ø 1 1	1 Ø Ø	1 Ø 1	1 1 Ø	1 1 1
				CONTROL		HIGH ORDER X & Y		LOW ORDER X		LOW ORDER Y	
Ø	Ø	Ø	Ø	NUL Ø	DLE 16	SP 32	Ø 48 CLEAR TAB *	@ 64	P 8Ø	96	p 112
Ø	Ø	Ø	1	SOH 1 HOME	DC1 17	! 33	1 49 SET TAB *	A 65	Q 81	a 97	q 113
Ø	Ø	1	Ø	STX 2	DC2 18	" 34	2 5Ø	B 66	R 82	b 98	r 114
Ø	Ø	1	1	ETX 3	DC3 19	# 35	3 51	C 67 CLEAR SCRATCH *	S 83	c 99	s 115
Ø	1	Ø	Ø	EOT 4 REFRESH 1	DC4 2Ø	$ 36	4 52	D 68	T 84	d 1ØØ	t 116
Ø	1	Ø	1	ENQ 5	NAK 21 ROTATE	% 37	5 53	E 69	U 85	e 1Ø1	u 117
Ø	1	1	Ø	ACK 6	SYN 22	& 38	6 54	F 7Ø	V 86	f 1Ø2	v 118
Ø	1	1	1	BEL 7 BELL	ETB 23 HARDCOPY	' 39	7 55	G 71	W 87	g 1Ø3	w 119
1	Ø	Ø	Ø	BS 8 BACKSPACE	CAN 24 ERASE	(4Ø	8 56	H 72	X 88	h 1Ø4	x 12Ø
1	Ø	Ø	1	HT 9 TAB	EM 25 DOUBLE SIZE	) 41	9 57	I 73	Y 89	i 1Ø5	y 121
1	Ø	1	Ø	LF 1Ø LINEFEED	SUB 26	* 42	: 58	J 74	Z 9Ø	j 1Ø6	z 122
1	Ø	1	1	VT 11	ESC 27	+ 43	; 59	K 75	[91	k 1Ø7	{ 123
1	1	Ø	Ø	FF 12 PAGE	FS 28 POINT PLOT	, 44	< 6Ø	L 76	\ 92	l 1Ø8	| 124
1	1	Ø	1	CR 13 RETURN	GS 29 VECTOR	– 45	= 61	M 77 CLEAR TABS	] 93	m 1Ø9	} 125 ALT MODE 2
1	1	1	Ø	SO 14 ITALIC	RS 3Ø INC PLOT	. 46	> 62	N 78	^ 94	n 11Ø	~ 126
1	1	1	1	SI 15	US 31 RESET COMPOSE *	/ 47	? 63 EDIT 1 *	O 79	_ 95	o 111	RUB OUT 127
						GRAPHIC INPUT					

* PRECEDED BY ESC
1 PRECEDED BY SELECTION OF COMPOSE MODE
2 TTY TRANSMIT ONLY

```
!"#$%&'()*+,-./Ø123456789:;<=>?
@ABCDEFGHIJKLMNOPQRSTUVWXYZ[\]^_
`abcdefghijklmnopqrstuvwxyz{|}~
```

Figure A-1. ASCII character codes output to CRT display.

TABLE A-2. LINE PRINTER LISTING OF ASCII CHARACTER CODES CONVERTED TO EBCDIC

①	②	③	④	①	②	③	④	①	②	③	④	①	②	③	④
0	00	40		64	40	7C	@	96	60	40		32	20	40	
1	01	40		65	41	C1	A	97	61	40		33	21	5A	
2	02	40		66	42	C2	B	98	62	40		34	22	7F	
3	03	40		67	43	C3	C	99	63	40		35	23	7B	#
4	04	40		68	44	C4	D	100	64	40		36	24	5B	$
5	05	40		69	45	C5	E	101	65	40		37	25	6C	%
6	06	40		70	46	C6	F	102	66	40		38	26	50	&
7	07	40		71	47	C7	G	103	67	40		39	27	7D	'
8	08	40		72	48	C8	H	104	68	40		40	28	4D	(
9	09	40		73	49	C9	I	105	69	40		41	29	5D	)
10	0A	40		74	4A	D1	J	106	6A	40		42	2A	5C	*
11	0B	40		75	4B	D2	K	107	6B	40		43	2B	4E	+
12	0C	40		76	4C	D3	L	108	6C	40		44	2C	6B	,
13	0D	40		77	4D	D4	M	109	6D	40		45	2D	60	-
14	0E	40		78	4E	D5	N	110	6E	40		46	2E	4B	.
15	0F	40		79	4F	D6	O	111	6F	40		47	2F	61	/
16	10	40		80	50	D7	P	112	70	40		48	30	F0	0
17	11	40		81	51	D8	Q	113	71	40		49	31	F1	1
18	12	40		82	52	D9	R	114	72	40		50	32	F2	2
19	13	40		83	53	E2	S	115	73	40		51	33	F3	3
20	14	40		84	54	E3	T	116	74	40		52	34	F4	4
21	15	40		85	55	E4	U	117	75	40		53	35	F5	5
22	16	40		86	56	E5	V	118	76	40		54	36	F6	6
23	17	40		87	57	E6	W	119	77	40		55	37	F7	7
24	18	40		88	58	E7	X	120	78	40		56	38	F8	8
25	19	40		89	59	E8	Y	121	79	40		57	39	F9	9
26	1A	40		90	5A	E9	Z	122	7A	40		58	3A	7A	:
27	1B	40		91	5B	4F	|	123	7B	40		59	3B	5E	;
28	1C	40		92	5C	4A		124	7C	40		60	3C	4C	<
29	1D	40		93	5D	6D		125	7D	40		61	3D	7E	=
30	1E	40		94	5E	40		126	7E	40		62	3E	6E	>
31	1F	40		95	5F	40		127	7F	40		63	3F	6F	

Legend:

① Decimal integer ② ASCII hexidecimal code ③ EBCDIC hexidecimal code ④ Line printer/CRT display alphanumeric symbol

```
      DATA LDIGIC / 8700000000 /
      DATA INC / 8700000001 /
C
    5 CONTINUE
      CALL INTCRT(1)
C
      CALL ERASE
      CALL MOVABS(0,700)
      CALL NEWLIN
      PRINT 20
      CALL ANMODE
      CALL DBLSIZ
      LDIG = LDIGIC
C
      DO 10 I = 1,128
      LCHR = NEBCD(LDIG,4)
      KDIG = LCHR
      PRINT 15,LDIG,LDIG,LCHR,KDIG
      IF(I .GT. 32) CALL WT7611(LDIG)
      IF(I .EQ. 32) CALL NEWLIN
      IF(I .EQ. 32) PRINT 20
      IF(I .EQ. 64) CALL NEWLIN
      IF(I .EQ. 64) PRINT 20
      IF(I .EQ. 96) CALL NEWLIN
      IF(I .EQ. 96) PRINT 20
      IF(I .EQ. 128) CALL NEWLIN
      IF(I .EQ. 128) PRINT 20
      LDIG = LDIG + INC
   10 CONTINUE
      CALL NRMSIZ
      CALL CHARRD(55)
C
      CALL CRTFIN
C
      CALL FG$RLS('OV      ')
      CALL EXIT
   15 FORMAT(10X,I5,3X,Z8,3X,Z2,A4)
   20 FORMAT(1H1,/,/,/)
      END
```

Figure A-2. Listing of main program for ASCII/EBCDIC character code conversion.

```
\.<(+[&!$*);
-/,%]>?:#@'="

ABCDEFGHIJKLMNOPQR
STUVWXYZØ123456789
```

Figure A-3. Results of EBCDIC character codes converted to ASCII and output to the CRT display area.

TABLE A-3. LINE PRINTER LISTING OF EBCDIC CHARACTER CODES

(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
0	00	00		32	20	00		64	40	20		96	60	2D	-
1	01	00		33	21	00		65	41	00		97	61	2F	/
2	02	00		34	22	00		66	42	00		98	62	00	
3	03	00		35	23	00		67	43	00		99	63	00	
4	04	00		36	24	00		68	44	00		100	64	00	
5	05	00		37	25	00		69	45	00		101	65	00	
6	06	00		38	26	00		70	46	00		102	66	00	
7	07	00		39	27	00		71	47	00		103	67	00	
8	08	00		40	28	00		72	48	00		104	68	00	
9	09	00		41	29	00		73	49	00		105	69	00	
10	0A	00		42	2A	00		74	4A	5C		106	6A	00	
11	0B	00		43	2B	00		75	4B	2E	.	107	6B	2C	,
12	0C	00		44	2C	00		76	4C	3C	<	108	6C	25	%
13	0D	00		45	2D	00		77	4D	28	(	109	6D	5D	
14	0E	00		46	2E	00		78	4E	2B	+	110	6E	3E	>
15	0F	00		47	2F	00		79	4F	5B	|	111	6F	3F	
16	10	00		48	30	00		80	50	26	&	112	70	00	
17	11	00		49	31	00		81	51	00		113	71	00	
18	12	00		50	32	00		82	52	00		114	72	00	
19	13	00		51	33	00		83	53	00		115	73	00	
20	14	00		52	34	00		84	54	00		116	74	00	
21	15	00		53	35	00		85	55	00		117	75	00	
22	16	00		54	36	00		86	56	00		118	76	00	
23	17	00		55	37	00		87	57	00		119	77	00	
24	18	00		56	38	00		88	58	00		120	78	00	
25	19	00		57	39	00		89	59	00		121	79	00	
26	1A	00		58	3A	00		90	5A	21		122	7A	3A	:
27	1B	00		59	3B	00		91	5B	24	$	123	7B	23	#
28	1C	00		60	3C	00		92	5C	2A	*	124	7C	40	@
29	1D	00		61	3D	00		93	5D	29	)	125	7D	27	'
30	1E	00		62	3E	00		94	5E	3B	;	126	7E	3D	=
31	1F	00		63	3F	00		95	5F	00		127	7F	22	

Legend:

(1) Decimal integer (2) EBCDIC hexidecimal code (3) ASCII hexidecimal code (4) Line printer/CRT display alphanumeric symbol

TABLE A-3. (Concluded).

①	②	③	④	①	②	③	④	①	②	③	④	①	②	③	④
128	80	00		160	A0	00		192	C0	00		224	E0	00	
129	81	00		161	A1	00		193	C1	41	A	225	E1	00	
130	82	00		162	A2	00		194	C2	42	B	226	E2	53	S
131	83	00		163	A3	00		195	C3	43	C	227	E3	54	T
132	84	00		164	A4	00		196	C4	44	D	228	E4	55	U
133	85	00		165	A5	00		197	C5	45	E	229	E5	56	V
134	86	00		166	A6	00		198	C6	46	F	230	E6	57	W
135	87	00		167	A7	00		199	C7	47	G	231	E7	58	X
136	88	00		168	A8	00		200	C8	48	H	232	E8	59	Y
137	89	00		169	A9	00		201	C9	49	I	233	E9	5A	Z
138	8A	00		170	AA	00		202	CA	00		234	EA	00	
139	8B	00		171	AB	00		203	CB	00		235	EB	00	
140	8C	00		172	AC	00		204	CC	00		236	EC	00	
141	8D	00		173	AD	00		205	CD	00		237	ED	00	
142	8E	00		174	AE	00		206	CE	00		238	EE	00	
143	8F	00		175	AF	00		207	CF	00		239	EF	00	
144	90	00		176	B0	00		208	D0	00		240	F0	30	0
145	91	00		177	B1	00		209	D1	4A	J	241	F1	31	1
146	92	00		178	B2	00		210	D2	4B	K	242	F2	32	2
147	93	00		179	B3	00		211	D3	4C	L	243	F3	33	3
148	94	00		180	B4	00		212	D4	4D	M	244	F4	34	4
149	95	00		181	B5	00		213	D5	4E	N	245	F5	35	5
150	96	00		182	B6	00		214	D6	4F	O	246	F6	36	6
151	97	00		183	B7	00		215	D7	50	P	247	F7	37	7
152	98	00		184	B8	00		216	D8	51	Q	248	F8	38	8
153	99	00		185	B9	00		217	D9	52	R	249	F9	39	9
154	9A	00		186	BA	00		218	DA	00		250	FA	00	
155	9B	00		187	BB	00		219	DB	00		251	FB	00	
156	9C	00		188	BC	00		220	DC	00		252	FC	00	
157	9D	00		189	BD	00		221	DD	00		253	FD	00	
158	9E	00		190	BE	00		222	DE	00		254	FE	00	
159	9F	00		191	BF	00		223	DF	00		255	FF	00	

Legend:

① Decimal integer ② EBCDIC hexidecimal code ③ ASCII hexidecimal code ④ Line printer/CRT display alphanumeric symbol

```
      DATA LDIGIC / 8Z00000000 /
      DATA INC / 8Z00000001 /
    5 CONTINUE
C
      CALL INTCRT(1)
C
      CALL ERASE
      CALL MOVABS(0,700)
      CALL NEWLIN
      CALL ANMODE
      CALL DBLSIZ
      LDIG = LDIGIC
      PRINT 20
C
      DO 10 I = 1,256
      LCHR = NASCII(LDIG,4)
      KDIG = LDIG
      IF(LCHR .EQ. LDIGIC) KDIG = 64
      PRINT 15,LDIG,LDIG,LCHR,KDIG
      CALL WT7611(LCHR)
      IF(I .EQ. 32) CALL NEWLIN
      IF(I .EQ. 32) PRINT 20
      IF(I .EQ. 64) CALL NEWLIN
      IF(I .EQ. 64) PRINT 20
      IF(I .EQ. 96) CALL NEWLIN
      IF(I .EQ. 96) PRINT 20
      IF(I .EQ. 128) CALL NEWLIN
      IF(I .EQ. 128) PRINT 20
      IF(I .EQ. 160) CALL NEWLIN
      IF(I .EQ. 160) PRINT 20
      IF(I .EQ. 192) CALL NEWLIN
      IF(I .EQ. 192) PRINT 20
      IF(I .EQ. 224) CALL NEWLIN
      IF(I .EQ. 224) PRINT 20
      IF(I .EQ. 256) CALL NEWLIN
      IF(I .EQ. 256) PRINT 20
      LDIG = LDIG + INC
   10 CONTINUE
      CALL NRMSIZ
      CALL CHARRD(N5)
C
      CALL CRTFIN
C
      CALL FG$RLS('OV     ')
      CALL EXIT
   15 FORMAT(10X,I5,3X,Z2,3X,Z2,A4)
   20 FORMAT(1H1,/,/,/)
      END
```

Figure A-4. Listing of the main program for EBCDIC/ASCII character code conversion.

Appendix B. STANDARD OPERATING PROCEDURE FOR TEKTRONIX 4002A GRAPHIC COMPUTER TERMINAL TURN-ON

When first "powered-up" each day, the Tektronix 4002A graphic computer terminal user usually has difficulty in obtaining the first graphical display from a Xerox Sigma 5 digital computer program. To obtain this graphical display, the program has to be reexecuted, which is time consuming. To eliminate this difficulty in the future, it is suggested that the following standard operating procedure be adopted for "Turning-On" the Tektronix 4002A graphic computer terminal for the first time each day.

1) Turn the power switch ON, vertical to horizontal – clockwise. Allow to "Warm-Up" a few minutes.

2) Set the "On Line-Local" rocker switch to Local.

3) Set the "Direct-Scratch Pad" rocker switch to Scratch Pad.

4) Press the following keys:

a) Home.

b) Erase.

c) Space bar, to enter the scratch pad mode of operation.

d) Full, to clear the scratch pad area.

e) Enter information into the scratch pad area by pressing the desired keyboard keys.

f) Send, to send the information to the CRT (Cathrode Ray Tube) screen.

g) To enter a full CRT screen of information, enter Line Feed and Return while in the scratch pad mode of operation; press and hold down the Space bar and Send keys while repeatedly pressing the Repeat key.

5) When Item 4 has been completed, press the following keys:

a) Space bar, to enter scratch pad mode.

b) Full, to clear the scratch pad area.

c) Home, to exit the scratch pad mode.

d) Erase, to clear the CRT screen.

e) Set the "On Line-Local" rocker switch to On Line.

f) Set the "Direct-Scratch Pad" rocker switch to Direct.

6) The Tektronix 4002A graphic computer terminal system is now ready for operation by an application program from the Xerox Sigma 5 digital computer.

7) If hard copies are to be obtained, turn-on the Tektronix 4601 Hard Copier Unit.

8) When the program has been completed, the CRT screen should be erased and the cursor beam returned to the home position.

Appendix C. COMPARISON OF PROGRAMMING METHODS BY EXAMPLES

This appendix compares the programming methods for annotating and controlling interactive graphic display plots. The main application program is contained in Figure C-1. This program contains essentially four identical graphic displays. Each display is annotated by a different technique and is produced by subroutine PLOTSD, which is shown in Figure C-2. The first programming example of the main program produces Figure C-3, which is the graphic display output produced by subroutine PLOTSD. It contains no annotations except for those output by the subroutine DATER.

Programming example number 2 of the main program is the Fortran statement numbers 40 through 56 of Figure C-1. This example is the customary manner in which interactive graphic displays have been annotated in the past. Observe that a large number of Fortran dimension and data statements are required as well as calls to subroutine MOVABS in order to annotate the graphic display by this example. Also, observe that the vertical annotations have not been rotated as they are in other examples. Figure C-4 shows the CRT display output from program example number 2.

Program example number 3, Fortran statements 58 through 72 of the main program, is almost identical to programming example number 2. However, it calls the subroutine RVTITL to rotate and place the vertical annotations. The resulting output to the CRT display area is contained in Figure C-5.

The program example number 4 of the main program is Fortran statements 74 through 83 of Figure C-1. This example uses the calls to subroutine HITLES to place the annotations on the interactive graphic display plots. This method is recommended in the future for all programs which contain outputs to the CRT display area, because no dimension and data statements are required in the main program. Figure C-6 is the output to the CRT display screen area resulting from the execution of program example number 4.

Although these four programming examples have been lumped together within one large application main program, they do represent the various techniques of graphic display annotations and the amount of programming effort involved.

1) No annotations, no effort involved by example 1.

2) Annotations by example 4, some effort involved, but not as much as required by examples 2 and 3.

3) Annotations by examples 2 and 3, the maximum amount of effort involved.

Notice that by removing the Fortran statements for each programming example along with the required dimension and data statements, four separate and distinct programs could be developed from these four examples.

Finally, Figure C-7 shows a listing of the subroutine DATER. The CRT display output as a result of a call to subroutine DATER is contained in Figure C-8.

Additionally, the calls to subroutine CHARRD in the main program permit the user/operator to perform adjustments on the Tektronix 4002A graphic computer terminal and/or the 4601 hard copier unit. The contrast control on the 4601 hard copier unit may be set too low (light), producing a copy as shown in Figure C-9, or set too high (dark), producing a copy as shown in Figure C-10. Likewise, the intensity control on the Tektronix 4002A gràphic computer terminal may be set too low or too high, producing similiar resulting copies as shown in Figures C-9 or C-10 also. Further, the supply of 4601 hard copy paper can be depleted while an application program is executing. Subroutine CHARRD allows the program to continue without hard copies being made, and/or the paper supply replenished in the 4601 hard copier unit.

```
C *** * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * ** * ***
C ***                                                                      ***
C ***  A DEMONSTRATION PROGRAM FOR LABELING GRAPHIC DISPLAYS.              ***
C ***                    BY: LARMON S. ISOM                                ***
C ***                     1 OCTOBER 1976                                   ***
C ***                                                                      ***
C *** * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * ** * ***
C
C                           DIMENSION STATEMENTS
      DIMENSION IGDT(14), ICGTST(14), LABV(6), LABH(7)
      DIMENSION IVL(14), IDVL(20), IHL(56), LABRV(26)
C                            DATA  STATEMENTS
      DATA LABRV / 73,78,68,69,80,69,78,68,69,78,84,32,86,65,82,73,65,
     166,76,69,32,76,65,66,69,76 /
      DATA IDVL / 86,69,76,79,67,73,84,89,32,40,70,69,69,84,47,83,69,67,
     1 46,41 /
      DATA IVL / 84,73,77,69,32,40,83,69,67,79,78,68,83,41 /
      DATA MH1/ 30 /, MV1/ 640 /, NC1/ 24 /, MV2,MH2/ 50, 300 /
      DATA LABH / 'INDEPENDENT VARIABLE LABEL  ' /
      DATA LABV / 24HDEPENDENT VARIABLE LABEL  /
      DATA IGDT / 'GRAPHICAL DISPLAY OF DEPENDENT VERSUS INDEPENDENT DAT
     1A. ' /
      DATA ICGTST(1) / 4HEXAM /, ICGTST(2) / 'PLES' /,ICGTST(3) / 4H OF
     1 /,  ICGTST(4) / 'ANNO' /, ICGTST(5) / 4HTATI /, ICGTST(6)/ 'ON A'
     2 /,  ICGTST(7) / 4HND C /, ICGTST(8) / 'ONTR' /, ICGTST(9) /4HOL U
     3 /,  ICGTST(10)/ 'SAGE' /, ICGTST(11)/ 4H FOR /, ICGTST(12) / ' GR
     4A' /,ICGTST(13)/ 4HPHIC /, ICGTST(14) / 'S.  ' /
C                          ICGTS INITIALIZATION STATEMENTS
      CALL ST7611
      CALL INITT(120)
      CALL BINITT
C
      DO 10 I = 1,55
      IHL(I) = NASCII(ICGTST,I)
   10 CONTINUE
C                            PROGRAM EXAMPLE NUMBER 1.
      CALL PLOTSD(36,1.0)
      CALL CHARRD(510)
C                            PROGRAM EXAMPLE NUMBER 2.
   99 CONTINUE
      CALL PLOTSD(36,1.75)
      CALL MOVABS(MH1,MV1)
      CALL VLABEL(NC1,LABRV(3))
      CALL MOVABS(60,600)
      CALL VLABEL(20,IDVL)
      CALL MOVABS(200,10)
      CALL HLABEL(55,IHL)
      CALL MOVABS(360,30)
      CALL HLABEL(26,LABRV)
      CALL MOVABS(430,50)
      CALL HLABEL(14,IVL)
      CALL MOVABS(200,720)
      DO 20 J = 1,55
      CALL HLABEL(1,NASCII(IGDT,J))
   20 CONTINUE
      CALL CHARRD(599)
C                            PROGRAM EXAMPLE NUMBER 3.
   98 CONTINUE
      CALL PLOTSD(36,1.25)
      CALL RVTITL(MH1,MV1,NC1,LABRV(3))
      CALL RVTITL(60,600,20,IDVL)
      CALL MOVABS(200,10)
```

Figure C-1. Listing of application main program.

```
      CALL HLABEL(55,IHL)
      CALL MOVABS(360,30)
      CALL HLABEL(26,LABRV)
      CALL MOVABS(430,50)
      CALL HLABEL(14,IVL)
      CALL MOVABS(200,720)
      DO 30 J = 1,55
      CALL HLABEL(1,NASCII(IGOT,J))
   30 CONTINUE
      CALL CHARRD(598)
C                           PROGRAM EXAMPLE NUMBER 4.
   97 CONTINUE
      CALL PLOTSD(36,1.5)
      CALL HITLES(1,360,30,26,LABH)
      CALL HITLES(2,30,640,24,LABV)
      CALL HITLES(1,430,50,14,'TIME (SECONDS)')
      CALL HITLES(2, 60,600,20,'VELOCITY (FEET/SEC.)')
      CALL HITLES(1,200,720,55,'GRAPHICAL DISPLAY OF DEPENDENT VERSUS IN
     1DEPENDENT DATA.' )
      CALL HITLES(1,200,10,55,ICGTST)
      CALL CHARRD(597)
C
      CALL CHARRD(510)
C                           ICGTS FINALIZATION STATEMENTS
      CALL ERASE
      CALL FINITT(0,760)
      CALL HT7611
C
      CALL FG$RLS('OV      ')
      CALL EXIT
      END
```

Figure C-1. (Concluded).

```
         SUBROUTINE PLOTSD(NOP,SF)
         DIMENSION X(101), SOX(100),COX(100)
         DIMENSION COXB(100), SOXB(100)
         DIMENSION IHL(36)
         DATA IHL / 32,42,84,72,69,32,71,82,65,80,72,73,67,65,76,32,68,73,
        1 83,80, 76,65,89,32,71,79,69,83,32,72,69,82,69,46,42,32 /
         DATA IGO / 0 /
         AMIN = +10000.0
         BMIN = AMIN
         AMAX = -10000.0
         BMAX = AMAX
         IF(IGO .NE. 0) GO TO 11
         IGO = 1
         X(1) = 0.0
         DO 10 I = 1,NOP
         COXB(I) = COS(X(I))
         SOXB(I) = SIN(X(I))
         X(I+1) = X(I) + 0.2617994
         X(I) = X(I)*57.29577951
      10 CONTINUE
      11 CONTINUE
         DO 12 I = 1,NOP
         COX(I) = SF*COXB(I)
         SOX(I) = SF*SOXB(I)
      12 CONTINUE
         CALL ERASE
 X       CALL FRAME
         CALL NPTS(NOP)
 X       CALL XFRM(3)
 X       CALL YFRM(6)
 X       CALL XMFRM(3)
 X       CALL YMFRM(3)
         CALL LINE(0)
         CALL SYMBL(0)
         CALL MNMX(X,AMIN,AMAX)
         CALL MNMX(COX,BMIN,BMAX)
         CALL MNMX(SOX,BMIN,BMAX)
         CALL DLIMX(AMIN,AMAX)
         CALL DLIMY(BMIN,BMAX)
         CALL CHECK(X,COX)
         CALL CHECK(X,SOX)
         CALL DSPLAY(X,SOX)
         DO 15 I = 1,NOP
         CALL MOVEA(X(I),COX(I))
         CALL ANMODE
         CALL HLABEL(1,IHL(I))
      16 IF(NSTCK(I) .GE. 3) GO TO 16
      15 CONTINUE
         CALL DATER
         RETURN
         END
```

Figure C-2. Listing of subroutine PLOTSD.

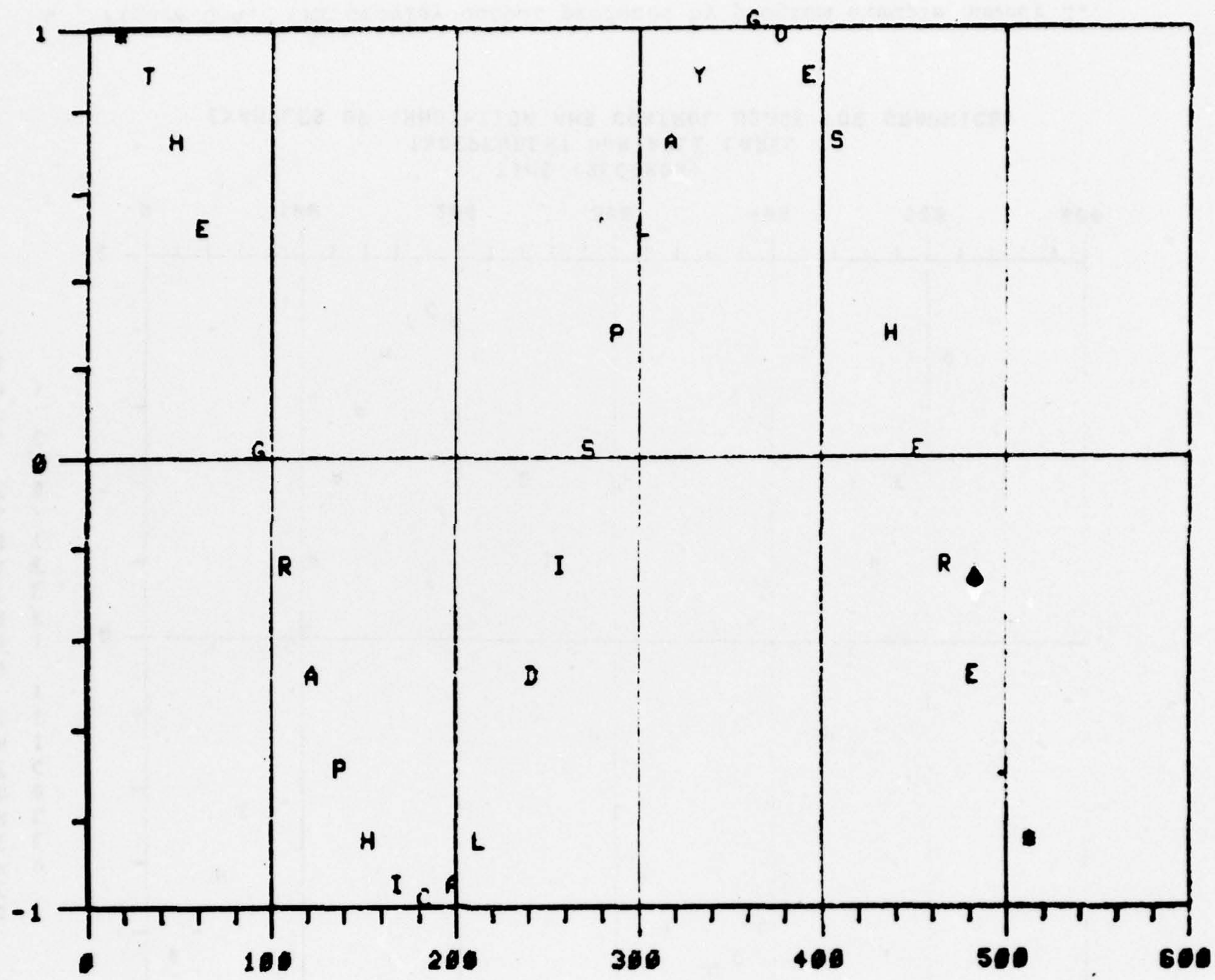

Figure C-3. Graphic display output by PLOTSD.

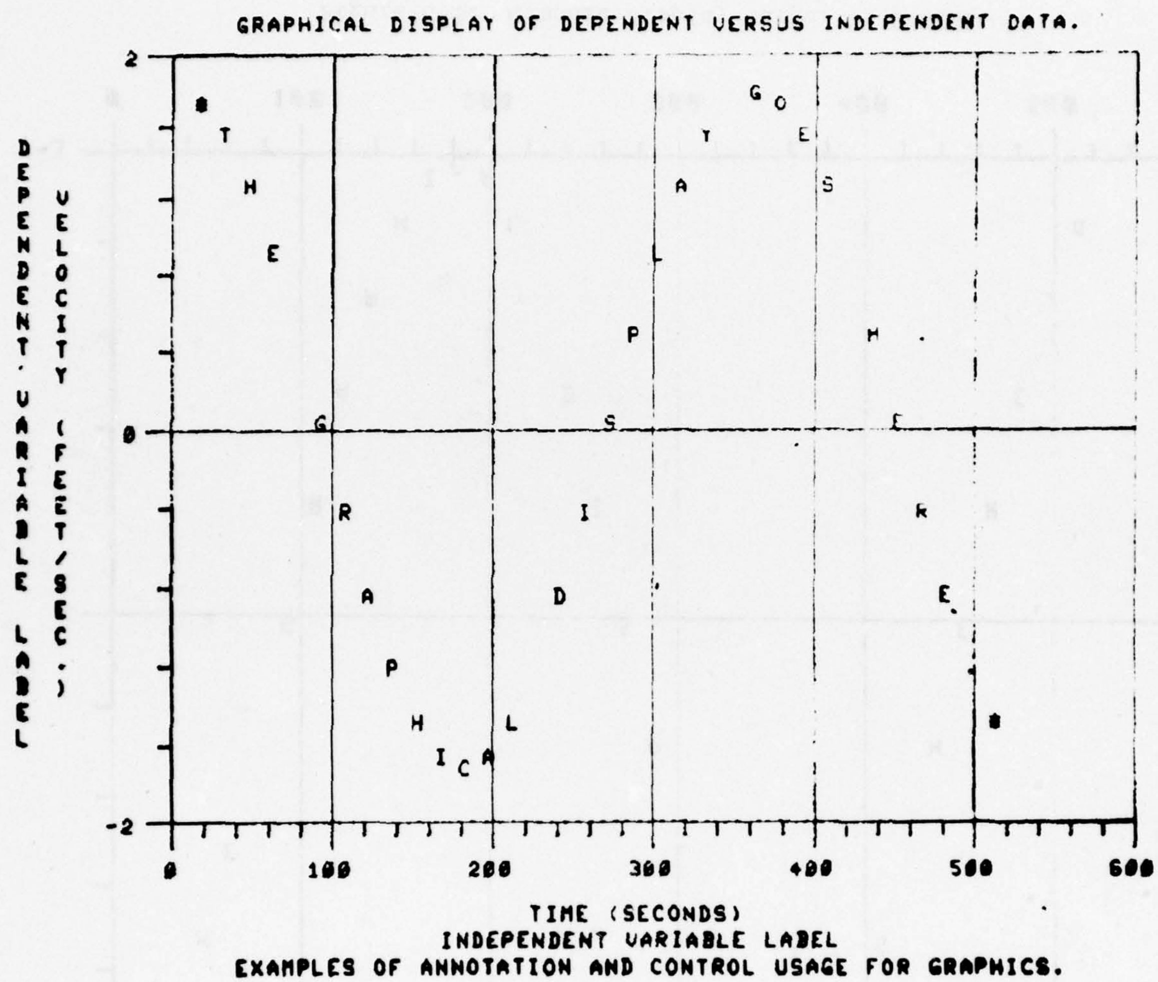

Figure C-4. CRT display output produced by program example number 2.

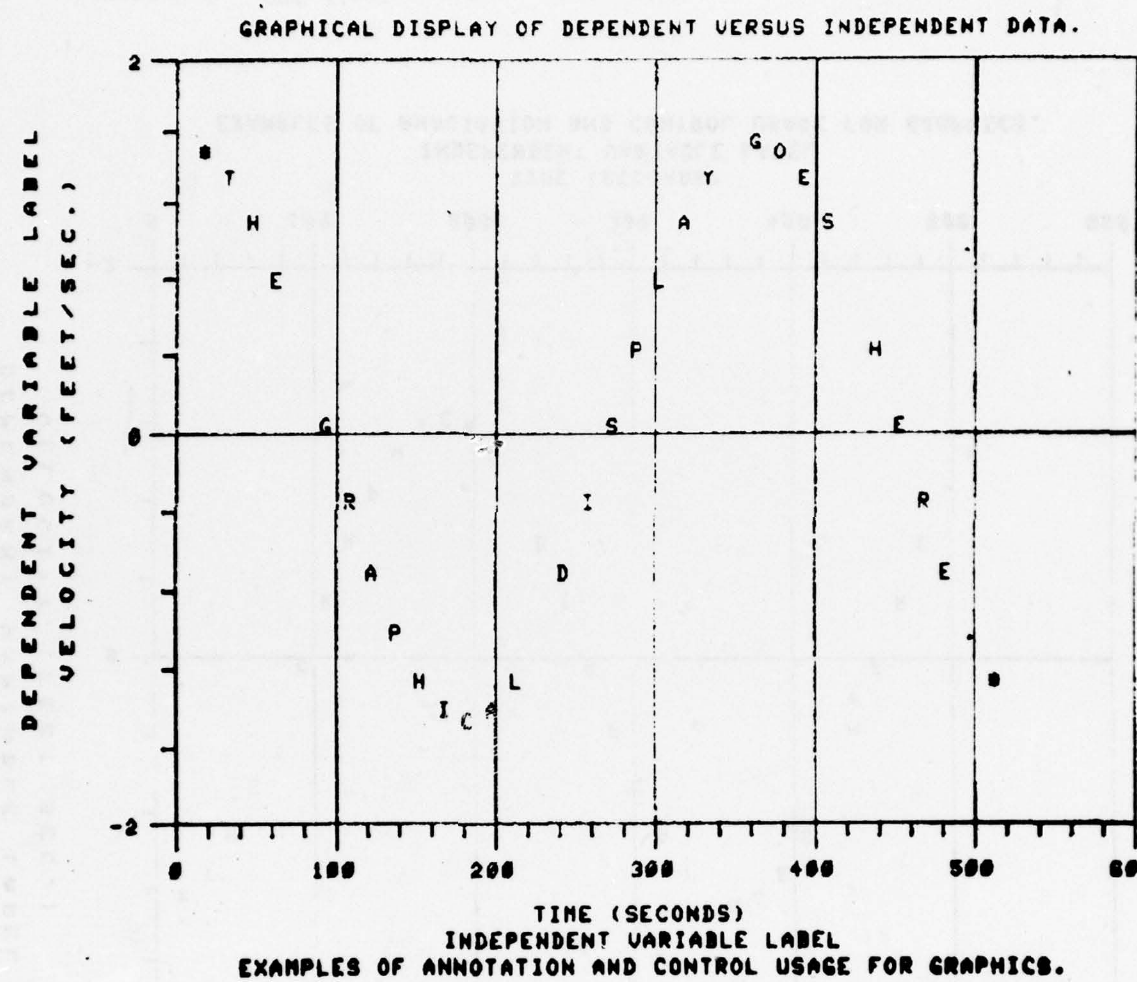

Figure C-5. CRT display output produced by program example number 3.

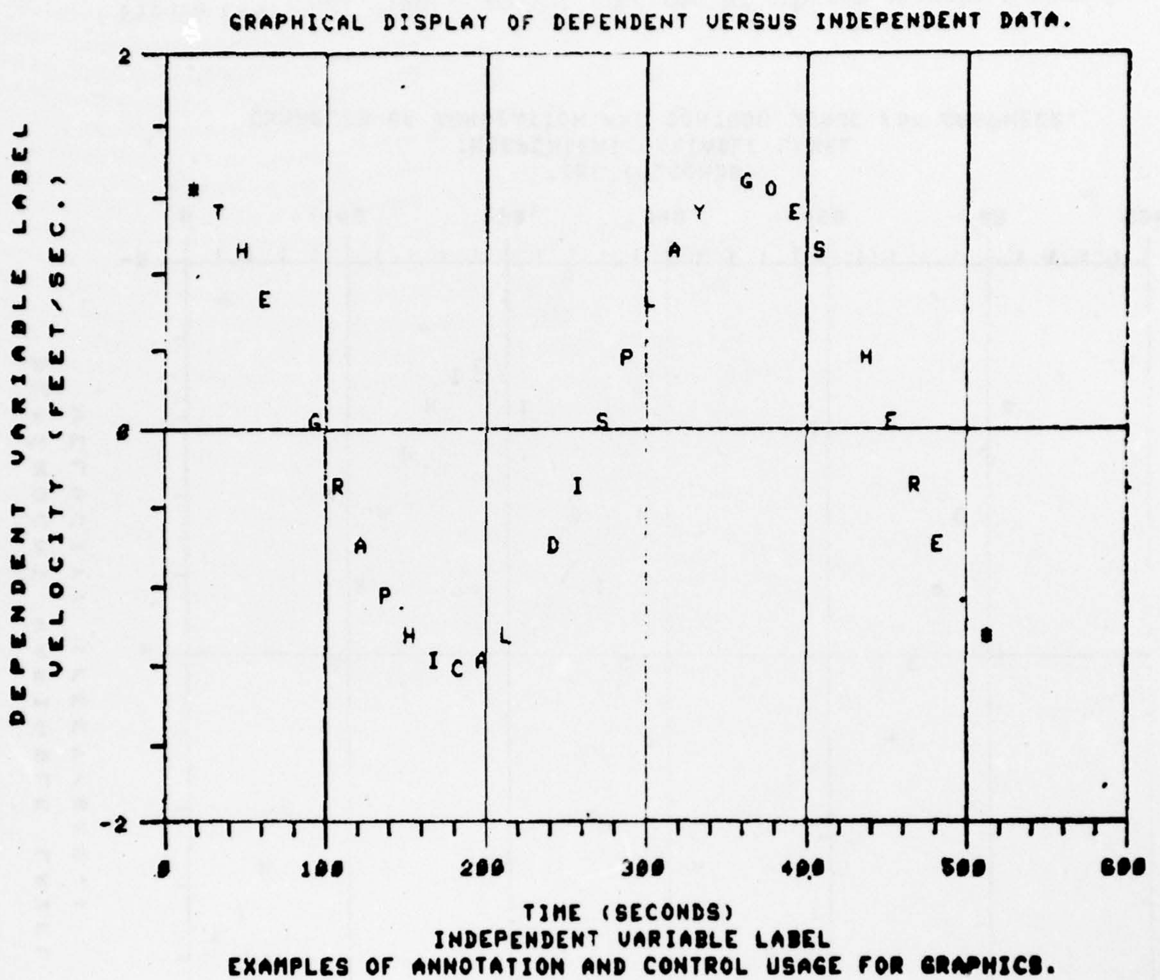

Figure C-6. CRT display output produced by program example number 4.

```
      SUBROUTINE DATER
      DIMENSION NAME(20), IDAT(22)
      DATA NAME / 68,82,65,87,78,32,66,89,58,32,76,46,32,83,46,32, 73,
     183,79,77 /
      DATA IDAT / 68,65,84,69,58,32,56,32,79,67,84,79,66,69,82,32,49,
     157,55,54,32,32 /
      DATA NCN, NCD / 20, 22 /
C                                      OUTPUT NAME
      CALL MOVABS(1000,500)
      CALL ANMODE
      CALL WT7611(21)
      DO 11 II = 1,NCN
      CALL WT7611(NAME(II))
      CALL WT7611(8)
      CALL WT7611(10)
   10 IF(NSTCK(II) .GE. 3) GO TO 10
   11 CONTINUE
C                                      OUTPUT DATE
      CALL MOVABS(975,500)
      CALL ANMODE
      CALL WT7611(21)
      DO 21 JJ = 1,NCD
      CALL WT7611(IDAT(JJ))
      CALL WT7611(8)
      CALL WT7611(10)
   20 IF(NSTCK(JJ) .GE. 3) GO TO 20
   21 CONTINUE
      CALL WT7611(21)
      CALL WT7611(21)
      CALL WT7611(21)
C
      RETURN
      END
```

Figure C-7. Listing of subroutine DATER.

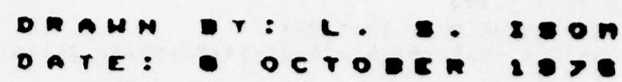

Figure C-8. CRT display output produced by subroutine DATER.

Figure C-9. Contrast/intensity set too low.

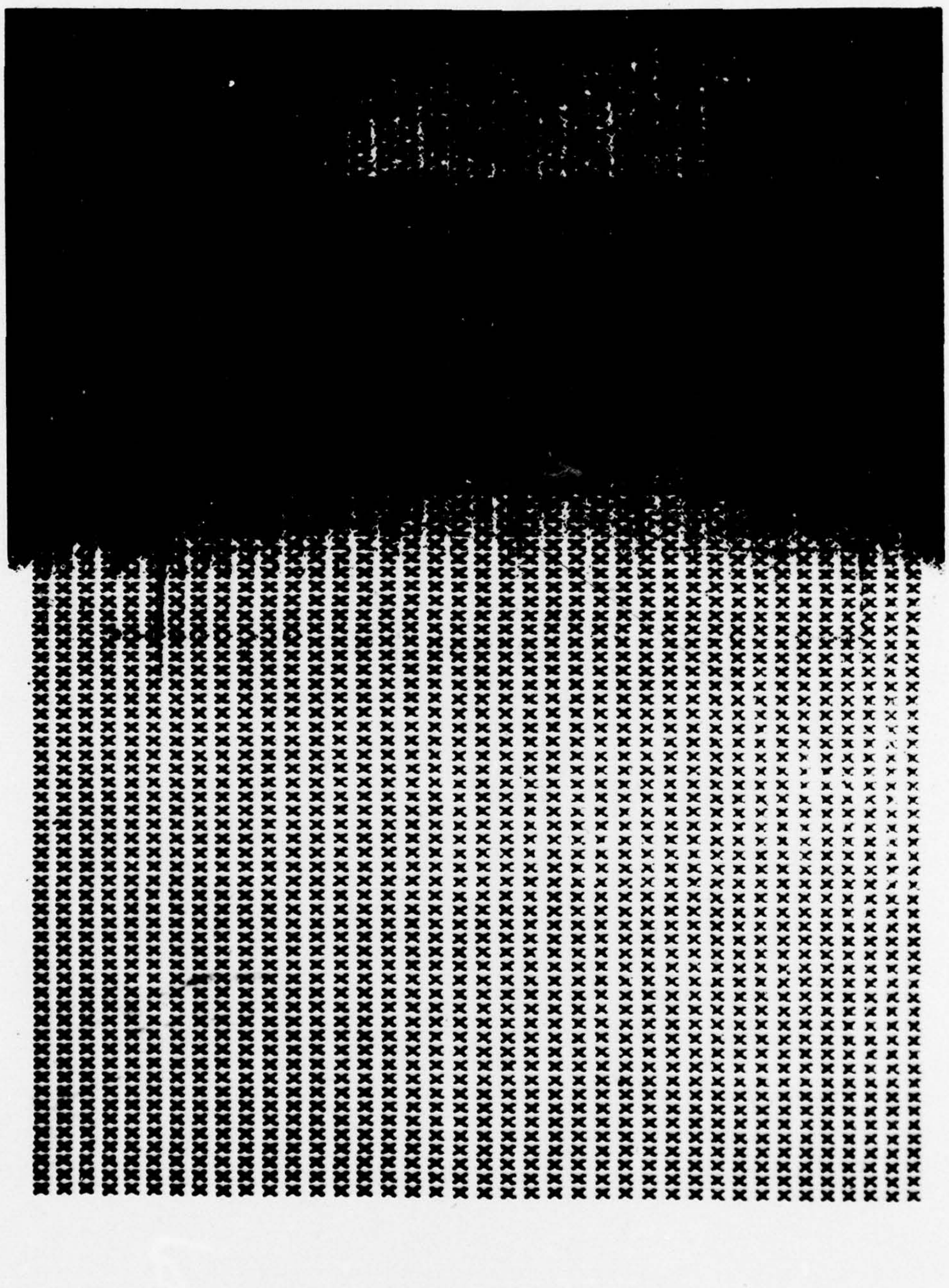

Figure C-10. Contrast/intensity set too high.

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