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Computer Use in the High Temperature Mechanical Metallurgy Testing Laboratory

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ABSTRACT

High speed digital computers have come into use in the high temperature metals testing laboratory. This paper presents some of the advantages and disadvantages of the use of computers for test control, data acquisition, and the graphing of test results. While tests have been run for years without the use of computers, the significant enhancements offered by the computer in accuracy, repeatability, user interaction, and management of large amounts of data make the use of computers almost mandatory when data from many tests by different laboratories are compared and evaluated. The particular case of the use of MTS hydraulic test frames with the DEC PDP-11/34 computer is treated here, under the assumption that other computer-based systems would display similar advantages and similar problems.

INTRODUCTION

The function of this laboratory involves the testing of the compressive and tensile properties of various metals at high temperature. This testing requires the monitoring of the applied stress and the resulting strain. These data must be saved and stored for analysis of the test and comparison to test results from similar or related tests, and reduction to graphical form for presentation to others involved in similar testing. Frequently large numbers of variables must be held constant throughout a series of tests. Test parameters must be accurately set for each test, and data acquired in the test must be in known units. The use of the digital computer in the high temperature testing laboratory minimizes the variations in test setups, data acquisition, and data analysis.

Many methods of data analysis such as curve fitting are difficult, if not impossible, without a computer. A function describing the change of a parameter and subsequent derivation of change rates can be obtained by computer for use in further data analysis. Plotting of data by hand is difficult to do accurately, and subsequent small changes in the plot are just as difficult as the first plot. Plotting data files on a digital plotter is easy and quick, and small changes can be made just as quickly and easily. The modern digital computer makes work easier and more accurate in many cases, but it brings its own set of problems which must be taken into consideration in the testing process.

TEST EQUIPMENT

The equipment used in this laboratory for high temperature cyclic strain testing of metals are the MTS servo-hydraulic test frames, MTS electronics systems, Digital Equipment Corporation computers with Tektronics terminal, and Lepel RF generators. [See Appendix III for addresses of manufacturers of equipment]. The MTS equipment consists of a load frame which houses the load cell and hydraulic actuator, the hydraulic power supply for hydraulic pressure, and the control electronics. An MTS 442 controller provides closed-loop control of the test in response to a command signal through various plug-in modules. The main control system modules are the servo controller to control and drive the servo valves, the feedback selector to provide selection of the desired control mode, and transducer conditioners to provide excitation and signal conditioning for the system transducers. An MTS digital function generator is used to provide the command signals in either a cyclic or ramp format when computer control is not needed. The MTS processor interface unit is used with the DEC PDP 11/34 computer for analog-to-digital and digital-to-analog conversion, data acquisition, function generation, and real time control of the test. MTS BASIC is used as the programming language for the PDP 11/34. It combines several MTS testing routines and commands with DEC Multi-user BASIC language.

High temperatures are obtained using Lepel RF generators, which are controlled by Leeds and Northrup temperature controllers via type K thermocouples welded onto the specimens under test. Strain measurement is made through the use of MTS high temperature quartz rod extensometers. The DEC PDP 11/34 computer system consists of the PDP 11 processor with 64K words of memory, an RK05F fixed magnetic disk, an RK05J removable disk, DEC LA36 printer, Tektronix 4010-1 terminal, and Tektronix 4631 hard copy unit. Another computer, a DEC LSI 11/23, is used for data acquisition on test frames which are not connected to the DEC PDP 11/34 and for plotting of graphs. This system consists of a DEC LSI 11 processor with 64K words of memory, DEC RX02 dual floppy disk drive, DEC VT103 terminal, and a Tektronics 4662 digital interactive plotter. FORTRAN IV is the language used for data acquisition and graph plotting with this computer. The DEC LSI 11/23 computer is also connected with the DEC LA36 printer, and has an interface with the DEC PDP 11/34 computer for transfer of programs and data files.

TESTING METHODS

On the MTS material testing systems, tests can be run under load or strain control; however, most testing in this laboratory is done in strain control. The specimens, which are cylindrical or rectangular in gage cross section, are heated to the required temperature by induction. The MTS test frame is powered by a servo-controlled hydraulic ram, which moves in response to a control signal, +/- 10 volts, coming from the electronics section of the system. This voltage is supplied either by a function generator or by the computer.

When the signal is supplied by a function generator, the only waveforms available are a ramp and a sine wave, from which haversine, sawtooth, square, and combination waveforms can be achieved. The frequency is variable, as is a hold period, which can be instituted at several places in the waveform. The amplitude of the waveform is +/- 10 volts out of the function generator, but can be attenuated at the MTS controller to any level between those extremes. After the frequency, amplitude, hold time, and waveform shape are chosen, the test is started, and these parameters are not easily changed without stopping the test. The test can be stopped by the operator or by a timer or counter in the MTS electronics, but not by the test itself. Interlocks can also stop the test if set limits are exceeded, usually because of the failure of the specimen.

When the signal is supplied by the computer, many of the above limitations are reduced or removed. The waveforms available from the computer are limited mainly by the imagination of the programmer. The same +/- 10 volt signal is made possible by the digital-to-analog converters, which transform numbers between -2048 and +2047 to voltage levels between -10 volts and +10 volts in approximately 5 millivolt steps. These steps can be troublesome if care is not taken in setting up the controller in the MTS electronics system. The amount of movement of the hydraulic ram is variable in four steps. In the systems in this laboratory, those steps are 0.05, 0.1, 0.2, and 0.5 mm per 10 volts for strain control. If the test requires the specimen to experience a change of 0.01 mm and the controller is set to the 0.5 mm per 10 volts setting, then the voltage change needed to effect a change of 0.01 mm would be 0.2 volts. This change would give a waveform defined by only 40 steps, which might result in a rather rough function. If the controller is set to 0.05 mm per 10 volt, the same 0.01 mm change would require a voltage change of 2 volts with a waveform of 400 steps, smoother by a factor of 10.

The voltage from the function generator is attenuated by a span setting, which incorporates a 10 turn potentiometer. The markings are such that a setting is readable and repeatable to about 0.2%. The voltage from the computer is repeatable to one part in 2048, or about 0.05%. This variation can be quite important when several tests are to be run to the same strain range, or if a test must be stopped and later restarted at the same parameters. This voltage level can be changed at any time by the computer program without stopping the test. This possibilty for change is accomplished by putting the parameters for the output waveform in an array. [See HOLDTM.BAS in Appendix I]. The control signal is read from the array for each cycle. This array can be changed during the cycle by the program without affecting the cycle currently being completed. The next cycle will be controlled by the new contents of the array.

This method can be used for any test but it is especially useful when running a test in plastic strain control which is accomplished by running the test in total strain control, while monitoring the plastic strain. [See PLASDQ.BAS in Appendix I]. During each cycle the plastic strain is read directly by the computer or is calculated from the peak stress readings taken by the computer. The error between the actual plastic strain and the desired plastic strain is calculated and converted to an error in total strain. This error is then applied to the signal going to the controller, which changes the amount of movement of the ram. This feedback is repeated continuously, resulting in a plastic strain range within a small error of the desired range. In actual practice the computer has time to correct the total strain every third or fourth cycle if the test is run at a rate of one cycle every 5 seconds or faster without a hold period. If a hold period is used in the test, the updating can easily by done every cycle.

The calculating of a new signal and the changing of the parameters of the controlling program take very little time, but when data are being acquired at a high rate and stored on disk file, and computations are done during every cycle, the computer can have trouble keeping up with all the operations. Test control has the highest priority, so inevitably some data are lost in the process. Unless the test parameters are changing rapidly, updating control signals every 3 or 4 cycles will not cause a substantial change when updating does take place. Unfortunately, if the parameters are changing rapidly, both control and data acquisition are very important, and the test operator does not want to sacrifice either one to the other, so careful balancing of control rate and data acquisition rate must be done to result in a useful test.

Data acquisition without a computer is done in this laboratory by means of X-Y chart recorders and Y-Time strip chart recorders. These methods give a continuous analog record on paper of the variables being monitored. To make use of the data on these charts usually requires someone to read selected points along the curves on the charts and record them as lists of numbers which later are transferred to another graph by hand. If the test is changing rapidly, X-Y recorders have difficulty in keeping up with the signal, so that the waveform drawn on the chart may not be an accurate representation of what actually took place during the test. When a computer is used for data acquisition, the problem of slow response or overshoot is removed, but a new problem arises. Analog-to-digital converters change the +/- 10 volt signals from the MTS test frames to numbers between -2048 and +2047, giving a minimum voltage change between points of about 5 millivolts. The shortest practical time between points is 1 millisecond. In actual practice data points are seldom read at such a high rate, but rather the rate is set to be consistent with the speed of the waveform being monitored. This rate has a lower bound defined by the Nyquist Sampling Theorem *, which states that to recover a waveform exactly, it is necessary to sample the waveform at a rate greater than twice its highest frequency component. In a stress-strain loop, there are many different frequency components, and a loop which takes 2 seconds to complete may have sections which are changing at a rate of 10 Hz or more. A sampling rate of greater than 20 Hz is then required.

An upper limit usually exists which is lower than the 1 KHz limit of the computer. If there exists a 60 Hz noise component of sufficient amplitude, it may be desirable to sample at less than a 120 Hz rate to avoid accurately defining the noise. If the noise is not completely defined, the process of data smoothing and curve fitting is made

* Samuel D. Stearns: DIGITAL SIGNAL ANALYSIS. Rochelle Park, New Jersey: Hayden Book Company, 1975, p. 37

easier. With the sampling rate somewhere between these two limits, the waveform is sufficiently defined to give the same information as the analog waveform, while maintaining more accuracy. If data are taken at too high a rate, other aspects of the test may suffer. The amount of data which can be [illegible] and stored is limited by time, storage space, and the need to maintain adequate control over the test. Again, data acquisition and test control must be carefully balanced to get the necessary data while still controlling the test at a rate which will result in a test within allowable error limits. When the variables in the test are changing quite slowly, fewer data points are needed to define the curves of the output data. Whenever possible, calculations and storage of data should be done during times of little change in the parameters. In the case of a test with a hold period, calculations and storage of data can be done during the hold period.

If data acquisition and control rates are a little too fast, control of the test will not suffer and only a few data points will be lost. This loss can sometimes be tolerated if the general shape of the curve is clear and the missing data points are scattered. However, if the program uses much time with calculations, control of the test can suffer. In an extreme case, generation of the control signal can stop, resulting in the momentary stopping of the test. Proper programming can avoid this by not requiring the controller to have to wait for the next level, but allowing it to use the levels of the last cycle when a new command is not received. The test will continue without stopping, but if the time problem is not temporary, the test will constantly be behind in control updates, and when updating does occur, it will be in larger steps at irregular intervals. Inconsistent updating observed in testing a program requires that either the data acquisition rate be reduced, or that calculations be streamlined and performed at more opportune times until the test runs smoothly.

DATA REDUCTION

Data acquired and stored on X-Y charts or Y-Time strip charts must be read by hand, point by point. This method results in data read at points which must be selected and read as carefully as possible. When the data are on a strip chart, the time coordinate is frequently compressed, making the determination of the time very difficult. The curve defined by the data points acquired in a test is often rough and requires some smoothing to be readable and comparable to the data from other tests. Data smoothing must be done by eye from charts, with the accuracy of the process somewhat dependent on the person smoothing the data. Reducing the data to a function must be done by trial and error and is tedious and error prone at best. When the data are in some final form, a graph is usually drawn by hand. Small changes are hard to make without redrawing the entire graph. Accuracy is not good, especially for logarithmic plots of data.

When data acquisition has been done by computer, the data are not subject to the inaccuracies due to slow response of a mechanical drawing device. But the data still are in digital form and have spaces between the points. These spaces can be tolerated so long as the points are sufficiently close together. The positions of the points in relation to the data curve are very important, especially in the case of stress-strain loops. It is sometimes quite difficult to capture the peaks of the loop when data is taken at set time intervals. A data point on each side of the peak may not give much of an indication of the value of the peak itself. Data points can be taken at a higher rate to put the points closer together and therefore closer to the peak, but that brings back the problem of balance between control and data acquisition.

MTS provides a means of looking only for the peaks and valleys of a curve, and this method will guarantee the aquisition of those peaks, but then the rest of the curve is lost. Data can be gathered both at set time intervals and at the time of peaks and valleys, but both methods require the computer to look for data points constantly, creating the time problem again. As usual, compromises among the methods will have to be made to assure the collection of data which best describes the variables in the test. The results are very likely to be rough, with straight lines between the data points. The test probably did not progress in such a rough fashion, so the data need to be smoothed before they become useful. Data smoothing can be done by a computer program in a point-by-point manner, resulting in a smooth curve which follows the general direction of the original data faithfully. This smoothed set of data can then be reduced to an analytic function in another program. [See CRVFIT.BAS in Appendix I]. Derivatives can be found directly from the smoothed data on a point-by-point basis, giving another file of data which can be easily plotted. [See DERIVA.BAS in Appendix I]. These derivatives will then define the rates of change for the test. Derivatives can also be found from the analytic function, which is useful when the information is to be used in another program which requires a functional form.

Data files acquired from MTS tests are in binary format and must be converted to ASCII format before BASIC programs can read or use them. This conversion is accomplished using an MTS addition to BASIC which reads the binary data file and makes it available to the program in ASCII one block of data at a time. [See BN2ASC.BAS in Appendix I]. A program to convert the blocks of data to sequential files of ASCII data must be run before any data manipulation can be done. The result is a file of numbers between -2048 and 2047 which are quite meaningless until they are converted to engineering units by another program. [See ENGCNV.BAS in Appendix I]. This data file is then smoothed if necessary and curve fitting can be done, resulting in a function which can be used in programs to compare with theoretical models or with data from other similar or related tests. Any amount of data manipulation can be performed on the original or smoothed data while still preserving the original file. Even trial and error methods are much faster using the computer, and can result in better curve fits or more iterations.

On test frames which are not connected to the PDP-11/34, data acquisition is handled by the LSI-11/23 computer, utilizing software from Data Translation, Inc.

This software consists of FORTRAN IV callable subroutines, and programs for data acquisition are therefore written in FORTRAN IV. The same advantages for data acquisition apply to this system, and so this system will not be treated at length here. The major difference lies in the format of data files, which are also binary files, but which consist of numbers between -10 and +10, directly indicating the voltage levels received from the MTS test frame. A true plastic strain control test can not be done on these frames, since they lack computer control. But a program to add plastic strain values to a file of load and strain voltages while also converting the voltage levels to engineering units allows some comparison with other tests. [See PLSADD.FOR in Appendix I].

The final output of the data is the form to be used for presentation or publication. In this laboratory we use the DEC LSI 11/23 computer and the Tektronics 4662 digital plotter to prepare graphs. Software for plotting comes from the Tektronics Plot10 software package. With the computer, the plots can be simple or quite complex. [See Appendix II for sample graphs]. Small changes are easily shown on a new plot. The digital plotter is also used to read data from X-Y charts or strip charts. Crosshairs on the plotter arm are positioned over each data point to be read, and the plotter reads the coordinates and sends them to the computer, which stores them on disk for later analysis and plotting. This method has been found to be more accurate and less time consuming than the previous method of reading by hand.

CONCLUSIONS: USE OF COMPUTERS IN THE LABORATORY

The use of computers in the high temperature mechanical metallurgy test laboratory has allowed the test operators much closer control over the tests than was possible with the method of control previously used. The variety of tests available has increased because of the ability of the computer to transmit many waveforms with a high degree of accuracy. The ability to change the control signals continuously during the test has made convenient some methods of testing which were only done with difficulty and uncertainty with the function generator method of control. Data acquisition is more precise, and the data is stored in a form which is easier to manipulate than the X-Y and Y-T charts. Data manipulation and analysis can be done more easily and in many more ways than was formerly possible. Plotting of the final output can be done very neatly and accurately, and if changes need to be made, new plots can be made as easily as the first plots.

The computer should not be considered a panacea for all testing and data acquisition problems. It brings some problems of its own to be solved. Maximum control and maximum data collection are usually mutually exclusive goals, and the resulting necessary compromises must be made carefully to obtain the best possible test. Test control with the computer can be more precise and complicated, but the computer must be in control all of the time, and programs must be written which guarantee that nothing interrupts the computer from test control. While a computer will run a test in the same manner every time the test is run, the operator must not forget that the computer will just as easily run the test in the wrong way every time if the program has a bug in it. The computer will collect data whenever it is told to do so, with no concern about the suitability of that data. New ways of looking at the data acquisition process are needed to cope with the manner in which the computer collects and stores data.

It has been our experience that even in light of the new problems brought about by the computer, the results are sufficiently better to warrant the time and effort needed to solve the problems and devise new methods of testing, allowing tests to be run which were previously difficult or impossible. The computer affects nearly all phases of the testing process, usually resulting in more precisely monitored and controlled tests.

APPENDIX I

These programs are referenced in the text by name.

HOLDTM.BAS

Program for tests containing a hold time. Frequency, amplitude, and number and lengths of hold times are all variables.

```
10 REM *-*-*-*-* PROGRAM HOLDTM WRITTEN BY BOB HUFNAGEL OF E G & G
20 REM *-*-*-*-* FOR DIV. 5835 OF SANDIA NATIONAL LABS
30 PRINT "THIS PROGRAM ALLOWS TESTS TO BE RUN WITH VARIABLE TENSILE"
40 PRINT "AND COMPRESSIVE HOLD TIMES.  THE TEST IS UNDER TOTAL STRAIN"
50 PRINT "CONTROL.  EITHER TERMINAL MAY BE USED FOR CONTROL."
60 PRINT "LOAD AND STRAIN DATA ARE STORED ON DISK FOR FUTURE REFERENCE."
70 PRINT  \ PRINT
80 PRINT "THE FOLLOWING GRAPH OF STRAIN VS. TIME INDICATES THE OUTPUT"
90 PRINT "OF THIS PROGRAM.  T1 AND/OR T2 CAN BE ZERO.  "
100 PRINT  \ PRINT  \ PRINT
110 PRINT "    ******---------------------"
120 PRINT "   *'    '                   /\"
130 PRINT "  * '    ' *                 ' "
140 PRINT " *  '    '  *                ' "
150 PRINT "*------------*------------*  S   (S DETERMINED BY STRAIN)"
160 PRINT "    '    '    *          *   ' "
170 PRINT "    '    '     *        *    ' "
180 PRINT "    '<T1>'      *      *     \/"
190 PRINT "    '    '       ******--------"
200 PRINT "         '       '    '        "
210 PRINT "         '<--T-->'    '         (T DETERM. BY STRAIN RATE)"
220 PRINT "         '       '    '        "
230 PRINT "                 '<T2>'        "
240 PRINT "                 '    '        "
250 PRINT  \ PRINT  \ PRINT
260 REM
270 REM*************** INPUT ROUTINE ***************
280 REM
290 PRINT "ENTER NUMBER OF CYCLES TO BE RUN "; \ INPUT N
300 PRINT
310 PRINT "***** HOLD TIMES MUST BE EXPRESSED IN SECONDS. *****"
320 PRINT
330 PRINT "ENTER TENSILE HOLD TIME (T1 ON GRAPH) "; \ INPUT T1
340 PRINT
350 PRINT "ENTER COMPRESSIVE HOLD TIME (T2 ON GRAPH) "; \ INPUT T2
360 PRINT
370 PRINT "***** DIAMETER MUST BE EXPRESSED IN MILLIMETERS. *****"
380 PRINT
390 PRINT "ENTER TEMPERATURE CORRECTED DIAMETER OF SPECIMEN "; \INPUT D
400 PRINT
410 PRINT "ENTER STRAIN RANGE BUTTON NUMBER."; \ INPUT E2
420 PRINT
430 PRINT "ENTER STRAIN RATE PER SECOND."; \ INPUT R
```

```
440 PRINT
450 PRINT "ENTER TOTAL AXIAL STRAIN IN %."; \ INPUT E3
460 E3=E3/100
470 PRINT
480 PRINT "MAKE SURE EVERYTHING IS READY AT THE TEST MACHINE."
490 PRINT
500 PRINT " ENTER 'BREAK' AND 'S' TO STOP TEST."
510 PRINT
520 PRINT "ENTER A <CR> TO START TEST."; \ INPUT C$
530 REM
540 REM*************** CALCULATIONS ***************
550 REM
560 BUTN("S", LINE 1080) \ REM    TO STOP TEST IF NEEDED
570 D9=(E3/2)*D \ L=D9/E2
580 EDUMP \ MSWFG(1,1)
590 ENABL \ FG(1,0)
600 DIM E(10),E1(10)
610 E=2 \ E(0)=1 \ E(2)=2047*L
620 E1=2 \ E1(0)=1 \ E1(2)=L*(-2047)
630 R1=R/2 \ T9=E3/R1 \ J=1
640 E(1)=40.95/T9
650 GOSUB 770
660 T=E3/R \ E(1)=40.95/T \ E1(1)=E(1)
670 GOSUB 870
680 IF J=N GO TO 970
690 PRINT "CYCLE #";J
700 J=J+1
710 GOSUB 770 \ REM    FIRST SEGMENT
720 GOSUB 870 \ REM    SECOND SEGMENT
730 IF J=N GO TO 970 \ REM     LAST SEGMENT
740 PRINT "CYCLE #";J
750 J=J+1 \ GO TO 710
760 REM
770 REM*************** FIRST SEGMENT *****************
780 REM
790 FG(1,E,1,7,0)
800 BUFF(1,B)
810 IF B=-2 GO TO 1060
820 IF B=-1 GO TO 840
830 GO TO 800
840 ETIME \ SLEEP(T1)
850 RETURN
860 REM
870 REM*************** SECOND SEGMENT ***************
880 REM
890 FG(1,E1,1,7,0)
900 BUFF(1,B1)
910 IF B1=-2 GO TO 1060
920 IF B1=-1 GO TO 940
930 GO TO 900
940 ETIME \ SLEEP(T2)
950 RETURN
960 REM
```

```
970 REM**************** LAST SEGMENT ****************
980 REM
990 E(1)=40.95/T9 \ E(2)=0
1000 FG(1,E,1,7,0)
1010 BUFF(1,B)
1020 IF B=-2 GO TO 1060
1030 IF B=-1 GO TO 1060
1040 GO TO 1010
1050 REM
1060 REM**************** ENDING ****************
1070 REM
1080 MSWFG(1,0) \ GTIME(S,M,H)
1090 PRINT "TEST STOPPED ON CYCLE #";J;
1100 PRINT " @ ";STR$(H)":"STR$(M)":"STR$(S)
1110 REM
1120 REM**************** LIST OF VARIABLES ****************
1130 REM
1140 REM     N=NUMBER OF CYCLES             T1=TENSILE HOLD TIME
1150 REM     T2=COMPRESSIVE HOLD TIME       D=DIAMETER OF SPECIMEN
1160 REM     E3=TOTAL AXIAL STRAIN          R=STRAIN RATE PER SECOND
1170 REM     L=END LEVEL OF RAMP            E2=STRAIN RANGE BUTTON
1180 REM     I=COUNTER                      J=CYCLE NUMBER
1190 REM     E=UP SEGMENT ARRAY             E1=DOWN SEGMENT ARRAY
1200 REM     R1=HALF SEGMENT RATE           T=RAMP TIME
1210 REM     D9=CHANGE IN DIAMETER
1220 PRINT  \ PRINT
1230 END
```

PLASDQ.BAS

Program for a plastic strain controlled test with data acquisition.

```
10 REM  *****        PROGRAM PLASDQ WRITTEN BY BOB HUFNAGEL       ******
20 REM  *                                                              *
30 REM  ****************************************************************
40 REM  *                  PLASTIC STRAIN CONTROL TEST                 *
50 REM  *     THIS TEST COMPUTES PLASTIC STRAIN AFTER EACH CYCLE       *
60 REM  *     AND UPDATES THE MACHINE CONTROL COMMANDS FOR THE         *
70 REM  *     NEXT CYCLE.  THE TEST IS RUN IN TOTAL STRAIN CONTROL     *
80 REM  *     AND THE PROGRAM READS TOTAL STRESS TO COMPUTE THE        *
90 REM  *     ACTUAL PLASTIC STRAIN AFTER EACH CYCLE.  THIS IS         *
100 REM *     COMPARED TO THE PLASTIC STRAIN DESIRED AND THEN THE      *
110 REM *     APPROPRIATE CORRECTION IS MADE TO THE COMMAND SIGNAL     *
120 REM *     TO BRING THE ACTUAL PLASTIC STRAIN TO THE DESIRED        *
130 REM *     LEVEL.  CORRECTION IS DONE THROUGHOUT THE TEST.          *
140 REM ****************************************************************
150 REM
1000 REM <><><><><><><><><><><><><><><><> ENTER TEST PARAMETERS <><><><><>
1010 REM
1020 PRINT "IS THIS BEING RUN FROM THE PRINTER TERMINAL (Y OR N) ";
1030 INPUT P$
1040 IF P$="N" THEN ERASE
```

```
1050 PRINT  \ PRINT "THIS PROGRAM IS A PLASTIC STRAIN CONTROL TEST."
1060 PRINT  \ PRINT "IT ASSUMES A CYLINDRICAL SPECIMEN WITH DIAMETRAL"
1070 PRINT "EXTENSOMETER FOR STRAIN MEASUREMENT." \ PRINT
1080 REM
1090 Q1=.33 \ REM                                    ***** POISSON'S RATIO
1100 PRINT "ENTER YOUNG'S MODULUS FOR THIS MATERIAL IN MPA";
1110 INPUT E1
1120 Q2=Q1/E1 \ REM             ***** POISSON'S RATIO OVER YOUNG'S MODULUS
1130 PRINT  \ PRINT "ENTER THE LOAD XDUCER RANGE IN KN/10V";
1140 INPUT L1
1150 PRINT  \ PRINT "ENTER STRAIN XDUCER RANGE IN MM/10V";
1160 INPUT S1
1170 PRINT  \ PRINT "ENTER TOTAL DIAM. PLASTIC STRAIN (NOT %)";
1180 INPUT P1
1190 PRINT  \ PRINT "ENTER NUMBER OF CYCLES TO BE RUN (<32767)";
1200 INPUT N9
1210 IF N9>=32767 GO TO 1190 \ REM                ***** CHECK CYCLES LIMIT
1220 PRINT  \ PRINT "SHOULD TEST BE RUN TO FAILURE (Y OR N)";
1230 INPUT S$
1240 PRINT  \ PRINT "ENTER TIME FOR ONE CYCLE IN SECONDS";
1250 INPUT F1
1260 IF F1>=.5 GO TO 1280 \ REM         ***** CHECK FREQUENCY LIMIT <2 HZ
1270 PRINT  \ PRINT "TIME MUST BE > .5 SECONDS." \ GO TO 1240
1280 PRINT  \ PRINT "ENTER SPECIMEN DIAMETER IN MM";
1290 INPUT A1
1300 PRINT  \ PRINT "ENTER INITIAL TOTAL DIAM. STRAIN (NOT %)";
1310 INPUT T1
1320 PRINT  \ PRINT "ENTER FILE NAME FOR STRAIN DATA";
1330 INPUT F1$
1340 PRINT  \ PRINT "ENTER FILE NAME FOR LOAD DATA";
1350 INPUT F2$
1360 OPEN F1$ FOR OUTPUT AS FILE #1, FILESIZE 100 \ REM      ***** STRAIN
1370 OPEN F2$ FOR OUTPUT AS FILE #2, FILESIZE 100 \ REM        ***** LOAD
1380 IF P$="N" THEN ERASE
1390 PRINT  \ PRINT "ENTER THE CYCLE NUMBERS WHICH ARE TO BE STORED."
1400 PRINT  \ PRINT "ENTER A ZERO TO STOP INPUT."
1410 DIM C(100) \ N=1 \ C(0)=-1 \ REM    ***** SET UP CYCLE NUMBER ARRAY
1420 PRINT "CYCLE #";N; \ INPUT C(N)
1430 IF C(N)=0 GO TO 1480
1440 IF C(N)<=N9 GO TO 1470
1450 PRINT  \ PRINT "CYCLE # TOO HIGH.  ONLY"N9" CYCLES ARE TO BE RUN."
1460 GO TO 1420
1470 N=N+1 \ GO TO 1420
1480 IF P$="N" THEN ERASE
1490 N=N-1 \ PRINT  \ PRINT "CYCLES TO BE STORED ARE:"
1500 FOR C=1 TO N \ PRINT C(C) \ NEXT C
1510 PRINT  \ PRINT "ARE THESE CORRECT"; \ INPUT Q$
1520 IF Q$="N" GO TO 1390
1530 IF P$="N" THEN ERASE
1540 PRINT  \ PRINT "MAKE SURE THAT EVERYTHING IS READY!!"
1550 PRINT  \ PRINT "PUSH 'BREAK' AND 'S' TO STOP TEST."
1560 PRINT  \ PRINT  \ PRINT "ENTER A <CR> TO START TEST."; \ INPUT Q$
1570 PRINT  \ PRINT "TEST IN PROGRESS - - DO NOT DISTURB!!!!!"
```

```
970 REM*************** LAST SEGMENT ***************
980 REM
990 E(1)=40.95/T9 \ E(2)=0
1000 FG(1,E,1,7,0)
1010 BUFF(1,B)
1020 IF B=-2 GO TO 1060
1030 IF B=-1 GO TO 1060
1040 GO TO 1010
1050 REM
1060 REM*************** ENDING ***************
1070 REM
1080 MSWFG(1,0) \ GTIME(S,M,H)
1090 PRINT "TEST STOPPED ON CYCLE #";J;
1100 PRINT " @ ";STR$(H)":"STR$(M)":"STR$(S)
1110 REM
1120 REM*************** LIST OF VARIABLES ***************
1130 REM
1140 REM      N=NUMBER OF CYCLES              T1=TENSILE HOLD TIME
1150 REM      T2=COMPRESSIVE HOLD TIME        D=DIAMETER OF SPECIMEN
1160 REM      E3=TOTAL AXIAL STRAIN           R=STRAIN RATE PER SECOND
1170 REM      L=END LEVEL OF RAMP             E2=STRAIN RANGE BUTTON
1180 REM      I=COUNTER                       J=CYCLE NUMBER
1190 REM      E=UP SEGMENT ARRAY              E1=DOWN SEGMENT ARRAY
1200 REM      R1=HALF SEGMENT RATE            T=RAMP TIME
1210 REM      D9=CHANGE IN DIAMETER
1220 PRINT  \ PRINT
1230 END
```

PLASDQ.BAS

Program for a plastic strain controlled test with data acquisition.

```
10 REM  *****        PROGRAM PLASDQ WRITTEN BY BOB HUFNAGEL        ******
20 REM  *                                                               *
30 REM  *****************************************************************
40 REM  *                 PLASTIC STRAIN CONTROL TEST                   *
50 REM  *      THIS TEST COMPUTES PLASTIC STRAIN AFTER EACH CYCLE       *
60 REM  *      AND UPDATES THE MACHINE CONTROL COMMANDS FOR THE         *
70 REM  *      NEXT CYCLE.  THE TEST IS RUN IN TOTAL STRAIN CONTROL     *
80 REM  *      AND THE PROGRAM READS TOTAL STRESS TO COMPUTE THE        *
90 REM  *      ACTUAL PLASTIC STRAIN AFTER EACH CYCLE.  THIS IS         *
100 REM *      COMPARED TO THE PLASTIC STRAIN DESIRED AND THEN THE      *
110 REM *      APPROPRIATE CORRECTION IS MADE TO THE COMMAND SIGNAL     *
120 REM *      TO BRING THE ACTUAL PLASTIC STRAIN TO THE DESIRED        *
130 REM *      LEVEL.  CORRECTION IS DONE THROUGHOUT THE TEST.          *
140 REM *****************************************************************
150 REM
1000 REM <><><><><><><><><><><><><><><><> ENTER TEST PARAMETERS <><><><><>
1010 REM
1020 PRINT "IS THIS BEING RUN FROM THE PRINTER TERMINAL (Y OR N) ";
1030 INPUT P$
1040 IF P$="N" THEN ERASE
```

```
1050 PRINT  \ PRINT "THIS PROGRAM IS A PLASTIC STRAIN CONTROL TEST."
1060 PRINT  \ PRINT "IT ASSUMES A CYLINDRICAL SPECIMEN WITH DIAMETRAL"
1070 PRINT "EXTENSOMETER FOR STRAIN MEASUREMENT." \ PRINT
1080 REM
1090 Q1=.33 \ REM                                       ***** POISSON'S RATIO
1100 PRINT "ENTER YOUNG'S MODULUS FOR THIS MATERIAL IN MPA";
1110 INPUT E1
1120 Q2=Q1/E1 \ REM            ***** POISSON'S RATIO OVER YOUNG'S MODULUS
1130 PRINT  \ PRINT "ENTER THE LOAD XDUCER RANGE IN KN/10V";
1140 INPUT L1
1150 PRINT  \ PRINT "ENTER STRAIN XDUCER RANGE IN MM/10V";
1160 INPUT S1
1170 PRINT  \ PRINT "ENTER TOTAL DIAM. PLASTIC STRAIN (NOT %)";
1180 INPUT P1
1190 PRINT  \ PRINT "ENTER NUMBER OF CYCLES TO BE RUN (<32767)";
1200 INPUT N9
1210 IF N9>=32767 GO TO 1190 \ REM                ***** CHECK CYCLES LIMIT
1220 PRINT  \ PRINT "SHOULD TEST BE RUN TO FAILURE (Y OR N)";
1230 INPUT S$
1240 PRINT  \ PRINT "ENTER TIME FOR ONE CYCLE IN SECONDS";
1250 INPUT F1
1260 IF F1>=.5 GO TO 1280 \ REM        ***** CHECK FREQUENCY LIMIT <2 HZ
1270 PRINT  \ PRINT "TIME MUST BE > .5 SECONDS." \ GO TO 1240
1280 PRINT  \ PRINT "ENTER SPECIMEN DIAMETER IN MM";
1290 INPUT A1
1300 PRINT  \ PRINT "ENTER INITIAL TOTAL DIAM. STRAIN (NOT %)";
1310 INPUT T1
1320 PRINT  \ PRINT "ENTER FILE NAME FOR STRAIN DATA";
1330 INPUT F1$
1340 PRINT  \ PRINT "ENTER FILE NAME FOR LOAD DATA";
1350 INPUT F2$
1360 OPEN F1$ FOR OUTPUT AS FILE #1, FILESIZE 100 \ REM      ***** STRAIN
1370 OPEN F2$ FOR OUTPUT AS FILE #2, FILESIZE 100 \ REM        ***** LOAD
1380 IF P$="N" THEN ERASE
1390 PRINT  \ PRINT "ENTER THE CYCLE NUMBERS WHICH ARE TO BE STORED."
1400 PRINT  \ PRINT "ENTER A ZERO TO STOP INPUT."
1410 DIM C(100) \ N=1 \ C(0)=-1 \ REM    ***** SET UP CYCLE NUMBER ARRAY
1420 PRINT "CYCLE #";N; \ INPUT C(N)
1430 IF C(N)=0 GO TO 1480
1440 IF C(N)<=N9 GO TO 1470
1450 PRINT  \ PRINT "CYCLE # TOO HIGH.  ONLY"N9" CYCLES ARE TO BE RUN."
1460 GO TO 1420
1470 N=N+1 \ GO TO 1420
1480 IF P$="N" THEN ERASE
1490 N=N-1 \ PRINT  \ PRINT "CYCLES TO BE STORED ARE:"
1500 FOR C=1 TO N \ PRINT C(C) \ NEXT C
1510 PRINT  \ PRINT "ARE THESE CORRECT"; \ INPUT Q$
1520 IF Q$="N" GO TO 1390
1530 IF P$="N" THEN ERASE
1540 PRINT  \ PRINT "MAKE SURE THAT EVERYTHING IS READY!!"
1550 PRINT  \ PRINT "PUSH 'BREAK' AND 'S' TO STOP TEST."
1560 PRINT  \ PRINT  \ PRINT "ENTER A <CR> TO START TEST."; \ INPUT Q$
1570 PRINT  \ PRINT "TEST IN PROGRESS - - DO NOT DISTURB!!!!!"
```

```
1580 FOR K=1 TO 68 \ PRINT "*"; \ NEXT K \ PRINT
1590 REM
2000 REM <><><><><><><><> INITIALIZE HSG AND DACQ PARAMETERS <><><><><>
2010 REM
2020 DIM L9(2),S9(2),X1(3),Y1(3) \ REM                ***** CONTROL ARRAYS
2030 DIM D5(100),D6(100) \ REM                     ***** DATA FILE ARRAYS
2040 QUIT \ FG(1,0) \ REM                          ***** RESET EVERYTHING
2050 TIME(50) \ REM                      ***** 5 MSEC BETWEEN INTERUPTS
2060 BUTN("S", LINE 5000) \ REM                       ***** TO STOP TEST
2070 A2=(A1/2)^2*PI \ REM                          ***** AREA OF SPECIMEN
2080 X1=3 \ REM                ***** READ TO THIRD ELEMENT FOR EACH CYCLE
2090 X1(1)=2047/F1 \ REM                 ***** ASSUME MAX FG FREQ IS 2 HZ
2100 X1(2)=(T1*A1*2047)/(S1*4) \ REM              ***** POSITIVE END LEVEL
2110 IF X1(2)<2047 GO TO 2140 \ REM         ***** CHECK FOR CORRECT RANGE
2120 PRINT  \ PRINT S1;"MM/10 VOLTS IS TOO SMALL A RANGE."
2130 CLOSE  \ GO TO 1150
2140 X1(3)=-X1(2) \ REM                           ***** NEGATIVE END LEVEL
2150 Y1=3 \ REM                 ***** READ TO THIRD ELEMENT FOR SHUTDOWN
2160 Y1(1)=X1(1) \ REM            ***** SAME FREQ. AS CYCLE FOR SHUTDOWN
2170 Y1(3)=0 \ REM             ***** END LEVEL TO ZERO STRAIN AT SHUTDOWN
2180 REM
3000 REM <><><><><><><><><><><><><><><><><><><><> START TEST <><><><><>
3010 REM
3020 EDUMP \ ENABL \ REM      ***** OPEN CONTROL CHANNEL AND ENABLE BUTN
3030 MSWFG(1,1) \ C=1 \ G5=0 \ B1=0 \ REM    ***** GO TO STRAIN CONTROL
3040 T3=INT(F1*10) \ G1=0 \ REM                       ***** DATA ACQ. TIME
3050 FG(1,X1,N9,7,6) \ REM                     ***** START CONTROL COMMAND
3060 START \ REM                             *****  START DATA ACQUISITION
3070 DACQ(1,L9,0,100,L9) \ DACQ(1,S9,1,100,S9) \ REM  ***** PEAK VALUES
3080 LEFT(1,G1) \ REM                 ***** COUNT SEGMENTS - 2 PER CYCLE
3090 IF G1<>C(C)*2-1 GO TO 3150 \ REM ***** CHECK FOR DATA TAKING CYCLE
3100 D5=0 \ D6=0 \ REM                              ***** RESET DATA ARRAYS
3110 DACQ(3,D5,0,T3) \ DACQ(6,D6,1,1) \ REM           ***** DATA FOR FILES
3120 IF D5<100 GO TO 3120 \ REM              ***** WAIT FOR COMPLETE CYCLE
3130 AOUT(1,D6(1),D6,B1,F8) \ AOUT(2,D5(1),D5,B1,F9) \ REM  ***** FILES
3140 C=C+1 \ B1=B1+1 \ REM                ***** UPDATE STORAGE PARAMETERS
3150 BUFF(1,F) \ IF F=-1 GO TO 5030 \ REM   ***** CHECK FOR END OF TEST
3160 LEFT(1,G1)
3170 IF G1<G5+2 GO TO 3160
3180 G5=G1
3190 REM
4000 REM <><><> CALCULATE NEXT LIMIT, AND UPDATE FG COMMANDS <><><><><>
4010 REM
4020 E6=((S9(1)-S9(2))*S1)/(2047*A1) \ REM               ***** STRAIN RANGE
4030 S6=((L9(1)-L9(2))*L1*1000)/(2047*A2) \ REM       ***** STRESS RANGE
4040 P2=-2*(-E6+Q2*S6) \ REM                    ***** ACTUAL PLASTIC STRAIN
4050 E2=P1-P2 \ REM                 ***** CALCULATE ERROR, DESIRED - ACTUAL
4060 T1=T1+E2/4 \ X1(2)=INT((T1*A1*2047)/(S1*4)) \ REM  ***** ADD ERROR
4070 X1(3)=-INT(X1(2)) \ REM                          ***** NEW END LEVELS
4080 IF X1(2)<2047 GO TO 3080 \ REM       ***** REPEAT UNTIL END OF TEST
4090 PRINT  \ PRINT "END LEVEL IS OUT OF LIMITS FOR MACHINE CONTROL."
4100 REM
5000 REM <><><><><><><><><><><><><><><><><><> STOP EVERYTHING !<><><><><>
```

```
5010 REM
5020 X1=0 \ GO TO 5040 \ REM       ***** STOP FG BY SETTING ARRAY TO ZERO
5030 IF S$="Y" GO TO 3050 \ REM        ***** FG AGAIN IF TEST TO FAILURE
5040 QUIT \ REM                                ***** STOP DATA AQUISITION
5050 Y1(2)=INT(.75*(X1(2)-((P2*A1*2047)/(S1*4)))) \ REM  *****  ELASTIC
5060 FG(1,Y1,1,7,5) \ REM            ***** GO TO ZERO LOAD, ZERO STRAIN
5070 BUFF(1,F) \ IF F>-1 GO TO 5070
5080 MSWFG(1,0) \ REM                            ***** GO TO LOAD CONTROL
5090 CLOSE  \ GO TO 6340
5100 REM
6000 REM  <><><><><><><><><><><><><><><> DEFINITION OF VARIABLES <><><><><>
6010 REM
6020 REM        *********** ARRAYS AND ARRAY POINTERS ***********
6030 REM
6040 REM      C[100]  - CYCLE NUMBERS TO STORE IN FILE - POINTER - C
6050 REM      D5[100] - LOAD ARRAY FOR FILE            - POINTER - D5
6060 REM      D6[100] - STRAIN ARRAY FOR FILE          - POINTER - D6
6070 REM      L9[2]   - LOAD CONTROL ARRAY             - POINTER - L9
6080 REM      S9[2]   - STRAIN CONTROL ARRAY           - POINTER - S9
6090 REM      X1[3]   - FG CONTROL ARRAY FOR TEST      - POINTER - X1
6100 REM      Y1[3]   - FG CONTROL ARRAY FOR SHUTDOWN  - POINTER - Y1
6110 REM
6120 REM            *********** STRING VARIABLES ***********
6130 REM
6140 REM      F1$ - FILE NAME FOR STRAIN DATA
6150 REM      F2$ - FILE NAME FOR LOAD DATA
6160 REM      P$  - TERMINAL TYPE QUERY
6170 REM      Q$  - CYCLE NUMBERS CORRECT QUERY
6180 REM      S$  - TEST TO FAILURE QUERY
6190 REM
6200 REM          *********** NUMERICAL VARIABLES ***********
6210 REM
6220 REM      A1 - SPECIMEN DIAMETER          A2 - SPECIMEN AREA
6230 REM      B1 - FILE BLOCK POINTER         E1 - YOUNG'S MODULUS
6240 REM      E2 - PLASTIC STRAIN ERROR       E6 - ACTUAL STRAIN RANGE
6250 REM      F  - BUFF VARIABLE              F1 - CYCLE TIME
6260 REM      G1 - LEFT VARIABLE              G5 - + SEGMENT COUNTER
6270 REM      L1 - LOAD TRANSDUCER RANGE      N  - COUNTER
6280 REM      N9 - TOTAL NO. OF CYCLES        P1 - DESIRED PLASTIC STRAIN
6290 REM      P2 - ACTUAL PLASTIC STRAIN      Q1 - POISSON'S RATIO
6300 REM      Q2 - Q1/E1                      S  - BUTN FOR TEST HALT

6310 REM      S1 - STRAIN TRANSDUCER RANGE    S6 - ACTUAL STRESS RANGE
6320 REM      T1 - INITIAL DIAM. STRAIN       T3 - DATA ACQ. INTERRUPTS
6330 REM
6340 END
```

CRVFIT.BAS

Program for curve fitting of data in a file. An initial guess of the function is entered and changed as necessary to fit the data.

```
10 REM *-*-*-*-* PROGRAM CRVFIT WRITTEN BY BOB HUFNAGEL OF E G & G
20 REM *-*-*-*-* FOR DIV. 5835 OF SANDIA NATIONAL LABS
30 Z=SYS(6,0) \ REM                                      ENABLE GRAPHICS
40 ERASE \ PRINT "THIS PROGRAM ALLOWS A FUNCTION TO BE CHANGED UNTIL"
50 PRINT  \ PRINT "IT DESCRIBES A FILE OF DATA.  THE FUNCTION AND THE"
60 PRINT  \ PRINT "DATA FILE ARE PLOTTED TOGETHER TO CHECK THE FIT."
70 PRINT  \ GOSUB 440 \ REM                             ENTER DATA FILE
80 CLOSE  \ V7=V+1
90 PRINT  \ PRINT "THE FIRST DATA POINT IS:" \ PRINT
100 FOR K=1 TO V \ PRINT "COL.";K, \ NEXT K \ PRINT  \ PRINT
110 FOR K=1 TO V \ PRINT X(1,K), \ NEXT K \ PRINT  \ PRINT
120 PRINT "WHICH COLUMN CONTAINS THE INDEPENDENT VARIABLE"; \ INPUT X7
130 PRINT "WHICH COLUMN CONTAINS THE DEPENDENT VARIABLE  "; \ INPUT Y7
140 GOSUB 530 \ ERASE \ REM                            FIND FILE LIMITS
150 PRINT "ENTER THE FUNCTION AT LINE 300 IN THE FORM:"
160 PRINT "          Y=F(X)" \ PRINT
170 PRINT "WHEN FUNCTION IS ENTERED, TYPE 'GO TO 400' TO RESTART."
180 PRINT  \ STOP
190 ERASE \ PRINT "ENTER FUNCTION FIRST!!!!!" \ GO TO 150
200 RETURN
210 REM *-*-*-*-* LOAD ARRAY WITH NEW Y VALUES
220 FOR I=1 TO N \ X=X(I,X7)
230 GOSUB 190 \ REM                      X INTO FUNCTION  RETURN NEW Y
240 X(I,V7)=Y \ NEXT I
250 S=0 \ A=0 \ REM                                   FIND AVERAGE ERROR
260 FOR I=1 TO N \ S=S+X(I,V7)-X(I,Y7) \ NEXT I
270 A=S/N
280 REM *-*-*-*-* PLOT THE DATA FROM FILE AND FROM FUNCTION
290 ERASE \ PHYL(100,975,55,750)
300 SCALE(0,X1,X2,Y1,Y2)
310 X3=ABS((X2-X1)/10) \ Y3=ABS((Y2-Y1)/10) \ REM     GRAPH INCREMENTS
320 X$="INDEP. VARIABLE" \ Y$="DEP. VARIABLE" \ REM       GRAPH LABELS
330 LABEL(X$,Y$,X3,Y3,1)
340 AXES(X1,Y1) \ AXES(X2,Y2) \ AXES(0,0)
350 FOR I=1 TO N
360 MARK("+",X(I,X7),X(I,Y7)) \ NEXT I \ REM             ORIGINAL DATA
370 INVEC \ FOR I=1 TO N
380 PLOT(X(I,X7),X(I,V7)) \ NEXT I \ REM           DATA FROM FUNCTION
390 INVEC \ HOME \ PRINT  \ PRINT  \ PRINT
400 PRINT "                 AVERAGE ERROR IS";A \ PRINT
410 PRINT "                 ANOTHER TRIAL"; \ INPUT Q$
420 IF Q$<>"N" GO TO 150
430 GO TO 650
440 REM - - - - - - - - - - FILE INPUT SUBROUTINE - - - - - - - - - -
450 DIM X(300,7)
460 PRINT "ENTER DISK NO. AND FILE NAME FOR INPUT - "; \ INPUT F$
470 OPEN F$ FOR INPUT AS FILE #1 \ N=1
480 PRINT  \ PRINT "ENTER NUMBER OF VARIABLES IN FILE - "; \ INPUT V
490 FOR J=1 TO V \ INPUT #1:X(N,J) \ NEXT J
```

```
500 IF END #1 GO TO 520
510 N=N+1 \ GO TO 490
520 CLOSE #1 \ RETURN
530 REM *-*-*-*-* FILE LIMITS SUBROUTINE
540 X1=X(1,X7) \ X2=X1
550 Y1=X(1,Y7) \ Y2=Y1
560 FOR I=2 TO N
570 IF X(I,X7)<X1 THEN X1=X(I,X7)
580 IF X(I,X7)>X2 THEN X2=X(I,X7)
590 IF X(I,Y7)<Y1 THEN Y1=X(I,Y7)
600 IF X(I,Y7)>Y2 THEN Y2=X(I,Y7)
610 NEXT I
620 REM X VALUES RANGE FROM X1 TO X2
630 REM Y VALUES RANGE FROM Y1 TO Y2
640 RETURN
650 END
```

DERIVA.BAS

Program to find the first derivative of a file of data.

```
10 REM *-*-*-*-* PROGRAM DERIVA WRITTEN BY BOB HUFNAGEL OF E G & G
20 REM *-*-*-*-* FOR DIV. 5835 OF SANDIA NATIONAL LABS
30 PRINT "THIS PROGRAM COMPUTES THE FIRST DERIVATIVE OF THE DATA"
40 PRINT "STORED IN A DISK FILE."
50 GOSUB 430 \ REM                           ENTER DATA INTO COMPUTER
60 PRINT  \ PRINT "THE FIRST DATA POINT IN THE FILE IS:" \ PRINT
70 FOR K=1 TO V \ PRINT "COL.";K, \ NEXT K \ PRINT  \ PRINT
80 FOR K=1 TO V \ PRINT X(1,K), \ NEXT K \ PRINT  \ PRINT
90 PRINT "WHICH COLUMN CONTAINS THE INDEPENDENT VARIABLE"; \ INPUT X7
100 PRINT "WHICH COLUMN CONTAINS THE DEPENDENT VARIABLE  "; \ INPUT Y7
110 PRINT  \ PRINT "THE FIRST DERIVATIVE OF "F$" IS BEING CALCULATED."
120 M=N-1 \ V7=V+1 \ V8=V+2
130 FOR I=1 TO M
140 X(I,V7)=(X(I+1,X7)+X(I,X7))/2
150 X(I,V8)=(X(I+1,Y7)-X(I,Y7))/(X(I+1,X7)-X(I,X7))
160 NEXT I \ PRINT
170 PRINT "DO YOU WANT TO STORE THE DERIVATIVE POINTS IN THE ORIGINAL";
180 PRINT " FILE"; \ INPUT Q$
190 IF Q$<>"Y" GO TO 280
200 OPEN F$ FOR OUTPUT AS FILE #2
210 FOR I=1 TO M \ FOR J=1 TO V8
220 PRINT #2:X(I,J) \ REM   ONE LESS DERIV. POINT THAN ORIGINAL POINTS
230 NEXT J \ NEXT I
240 FOR I=1 TO V
250 PRINT #2:X(N,I) \ REM                    EXTRA ORIGINAL DATA POINT
260 NEXT I
270 CLOSE #2 \ GO TO 370
280 PRINT  \ PRINT "DO YOU WANT THE DERIVATIVE POINTS IN A NEW FILE";
290 INPUT Q$
300 IF Q$<>"Y" GO TO 370
310 PRINT  \ PRINT "ENTER NAME OF DERIVATIVE DATA FILE"; \ INPUT F1$
```

```
320 OPEN F1$ FOR OUTPUT AS FILE #3
330 FOR I=1 TO M \ FOR J=V7 TO V8
340 PRINT #3:X(I,J)
350 NEXT J \ NEXT I
360 CLOSE #3
370 FOR I=1 TO M \ FOR J=1 TO V8
380 PRINT X(I,J), \ REM                              PRINT DATA ON SCREEN
390 NEXT J \ PRINT  \ NEXT I
400 FOR I=1 TO V
410 PRINT X(N,I), \ NEXT I \ PRINT
420 GO TO 520
430 REM - - - - - - - - - - FILE INPUT SUBROUTINE - - - - - - - - - -
440 DIM X(300,7)
450 PRINT "ENTER DISK NO. AND FILE NAME FOR INPUT - "; \ INPUT F$
460 OPEN F$ FOR INPUT AS FILE #1 \ N=1
470 PRINT  \ PRINT "ENTER NUMBER OF VARIABLES IN FILE - "; \ INPUT V
480 FOR J=1 TO V \ INPUT #1:X(N,J) \ NEXT J
490 IF END #1 GO TO 510
500 N=N+1 \ GO TO 480
510 CLOSE #1 \ RETURN
520 END
```

BN2ASC.BAS

Program to convert a binary file to ASCII.

```
10 REM *-*-*-*-* PROGRAM BN2ASC WRITTEN BY BOB HUFNAGEL OF E G & G
20 REM *-*-*-*-* FOR DIV. 5835 OF SANDIA NATIONAL LABS
30 PRINT "THIS PROGRAM READS FILES WRITTEN WITH AOUT AND PRINTS"
40 PRINT "THE DATA ON THE SCREEN OR ON THE PRINTER, AND CAN"
50 PRINT "WRITE THEM IN ASCII TO A DISK FILE." \ PRINT  \ PRINT
60 PRINT "ENTER THE FILE NAME OF THE INPUT DATA"; \ INPUT F1$
65 PRINT "ENTER THE NUMBER OF BLOCKS OF DATA IN FILE"; \ INPUT B9
70 OPEN F1$ FOR INPUT AS FILE #1 \ PRINT
74 PRINT "DO YPU WANT DATA PRINTED ON SCREEN"; \ INPUT P$
76 B9=B9-1 \ REM FILE STARTS AT BLOCK 0
80 PRINT "DO YOU WANT TO WRITE THE DATA TO A FILE (Y OR N)";
90 INPUT Q$
100 PRINT  \ IF Q$="N" GO TO 130
110 PRINT "ENTER THE FILE NAME OF THE OUTPUT DATA"; \ INPUT F2$
120 OPEN F2$ FOR OUTPUT AS FILE #2
130 B1=0 \ DIM A(256)
140 AINP(1,A(1),-1,B1,F)
150 IF F<0 GO TO 240 \ REM                     SOME ERROR HAS BEEN FOUND
155 IF P$<>"Y" GO TO 170 \ REM                    DO NOT PRINT ON SCREEN
160 FOR I=1 TO F \ PRINT A(I) \ NEXT I
170 IF Q$<>"Y" GO TO 190 \ REM                      DO NOT WRITE TO FILE
180 FOR I=1 TO F \ PRINT #2:A(I) \ NEXT I
190 B1=B1+1 \ IF B1>B9 GO TO 230 \ REM                       END OF FILE
```

```
200 GO TO 140 \ REM                                    READ ANOTHER BLOCK
230 CLOSE #1 \ GO TO 250 \ REM                             END OF PROGRAM
240 PRINT  \ PRINT "ERROR IN FILE READING"
250 END
```

ENGCNV.BAS

Program to convert a file to engineering units.

```
10 REM *-*-*-*-* PROGRAM ENGCNV WRITTEN BY BOB HUFNAGEL OF E G & G
20 REM *-*-*-*-* FOR DIV. 5835 OF SANDIA NATIONAL LABS
30 ERASE \ PRINT "THIS PROGRAM TAKES ASCII DATA FILES OF LOAD AND"
40 PRINT "STRAIN WHICH ARE STORED IN COMPUTER NUMBERS"
50 PRINT "AND CONVERTS THE DATA TO ENGINEERING UNITS."
60 PRINT "THE DATA FILES CAN BE IN SEPARATE FILES OF"
70 PRINT "LOAD AND STRAIN OR COMBINED IN ONE FILE."
80 PRINT "THE OUTPUT FILE IS ONE FILE OF PAIRS OF X,Y"
90 PRINT "SUCH THAT X=STRAIN AND Y=STRESS IN MPA." \ PRINT
100 DIM D(1000,2) \ N=1
110 PRINT  \ PRINT "ENTER FILE NAME FOR OUTPUT DATA"; \ INPUT F2$
120 OPEN F2$ FOR OUTPUT AS FILE #3
130 PRINT  \ PRINT "ARE STRAIN AND LOAD IN ONE FILE"; \ INPUT C$
140 IF C$="Y" GO TO 250 \ REM                          COMBINED FILE INPUT
150 PRINT  \ PRINT "ENTER FILE NAME OF STRAIN DATA"; \ INPUT S$
160 OPEN S$ FOR INPUT AS FILE #1
170 PRINT  \ PRINT "ENTER FILE NAME OF LOAD DATA"; \ INPUT L$
180 OPEN L$ FOR INPUT AS FILE #2
190 INPUT #1:D(N,1)
200 INPUT #2:D(N,2)
210 IF END #1 GO TO 240 \ REM                                  CLOSE FILES
220 IF END #2 GO TO 240
230 N=N+1 \ GO TO 190 \ REM                             ANOTHER DATA POINT
240 CLOSE  \ GO TO 310 \ REM                              INPUT PARAMETERS
250 PRINT  \ PRINT "ENTER FILE NAME OF DATA"; \ INPUT F$
260 OPEN F$ FOR INPUT AS FILE #1
270 INPUT #1:D(N,1),D(N,2)
280 IF END #1 GO TO 300 \ REM                                   CLOSE FILE
290 N=N+1 \ GO TO 270 \ REM                             ANOTHER DATA POINT
300 CLOSE  \ ERASE
310 PRINT "ENTER THE FOLLOWING INFORMATION AS PROMPTED:" \ PRINT
320 PRINT "ENTER LOAD RANGE SETTING ON MTS FRAME";TAB(60); \ INPUT L1
330 PRINT "ENTER STRAIN RANGE SETTING ON MTS FRAME";TAB(60); \ INPUT S1
340 PRINT "WAS THIS A RECTANGULAR GAGE SPECIMEN";TAB(60); \ INPUT R$
350 IF R$<>"Y" GO TO 390
360 PRINT "ENTER GAGE WIDTH IN MM AT TEST TEMP.";TAB(60); \ INPUT W
370 PRINT "ENTER GAGE THICKNESS IN MM AT TEST TEMP.";TAB(60); \ INPUT D
380 A=D*W \ GO TO 410 \ REM                 AREA OF RECTANGULAR SPECIMEN
390 PRINT "ENTER GAGE DIAMETER IN MM AT TEST TEMP.";TAB(60); \ INPUT D
400 A=3.14159*(D/2)^2 \ REM                 AREA OF CYLINDRICAL SPECIMEN
410 FOR I=1 TO N
420 D(I,1)=(D(I,1)*S1)/(2047*D) \ REM                               STRAIN
430 D(I,2)=(D(I,2)*L1)/(2047*A) \ REM                        STRESS IN MPA
```

```
440 PRINT #3:D(I,1) \ PRINT #3:D(I,2)
450 NEXT I
460 CLOSE  \ PRINT
470 IF C$="Y" GO TO 500
480 PRINT "STRAIN DATA FROM "S$" AND LOAD DATA FROM "L$
490 GO TO 510
500 PRINT "STRAIN AND LOAD DATA FROM "F$
510 PRINT "ARE CONVERTED TO ENGINEERING UNITS AND STORED ON "F2$
520 END
```

PLSADD.FOR

Program to add plastic strain to a file of load and strain voltages while also converting the voltages to engineering units.

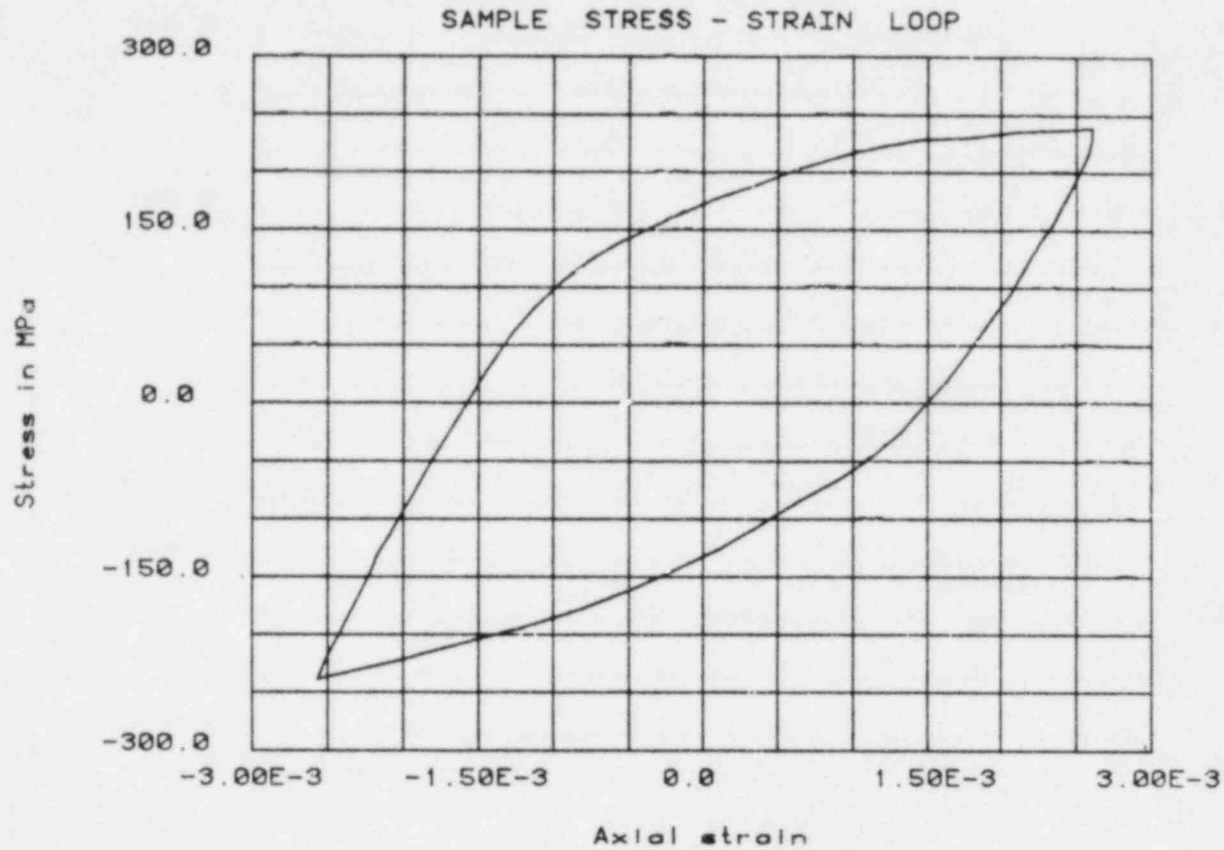
```
C  <><><><><> THIS PROGRAM WRITTEN BY BOB HUFNAGEL <><><><><>
C  <><><><><>     FOR LSI-11/23 IN DIVISION 5835.   <><><><><>
C
C  DATA PAIRS COME FROM FILES ORIGINATING WITH 'CYCDAT' AND
C  CONVERTED TO ASCII WITH 'BACON'.  THE OLD FILE CONSISTS OF
C  LOAD IN VOLTS, TOTAL DIAMETRAL STRAIN IN VOLTS, AND TIME.
C  THE NEW FILE WILL CONTAIN ENGINEERING STRESS IN MPA,
C  ENGINEERING TOTAL DIAMETRAL STRAIN, TIME IN SECONDS, AND
C  ENGINEERING PLASTIC AXIAL STRAIN.  THIS PROGRAM IS VALID
C  FOR 316 SS ONLY.  IF ANOTHER METAL IS USED, LINES 1, 2,
C  AND 3 MUST BE CHANGED ACCORDINGLY.
C
       PROGRAM PLSADD
       IMPLICIT BYTE(B)
       REAL SETLOD,SETSTN,DIAM,AREA,CONVER
       REAL POISNP,POISNE,YMOD
       LOGICAL ERROR
       DIMENSION BFIN(20),BFON(20),FILE(250,4),LINE(80)
C
C  FORMAT STATEMENTS FOR ENTIRE PROGRAM.
C
15        FORMAT('0 THIS PROGRAM ADDS PLASTIC STRAIN TO FILES OF',/,
     +  ' STRAIN, STRESS, AND TIME FROM CYCDAT PROGRAM.')
25        FORMAT('$ENTER THE FILE NAME OF THE INPUT DATA - ')
35        FORMAT(Q,80A1)
44        FORMAT('$ENTER THE FILE NAME FOR OUTPUT DATA - ')
47        FORMAT(80A1)
55        FORMAT(3(1PE13.6))
56        FORMAT(' THE FOLLOWING COMMENTS ARE IN THE FILE.',/)
57        FORMAT('0THESE COMMENTS WILL NOT BE IN THE NEW FILE.')
65        FORMAT('0 SOME ERROR HAS BEEN DISCOVERED IN THE INPUT FILE.')
105        FORMAT(4(1PE13.6))
125        FORMAT('0 SOME ERROR HAS BEEN MADE IN WRITING TO THE FILE.')
310        FORMAT('0TO CONVERT TO ENG. STRAIN AND ENG. STRESS, THE ',/,
     +  ' FOLLOWING INFORMATION IS NEEDED:',/)
320        FORMAT('$KIPS PER VOLT LOAD SETTING - - - - - ')
330        FORMAT(F5.2)
```

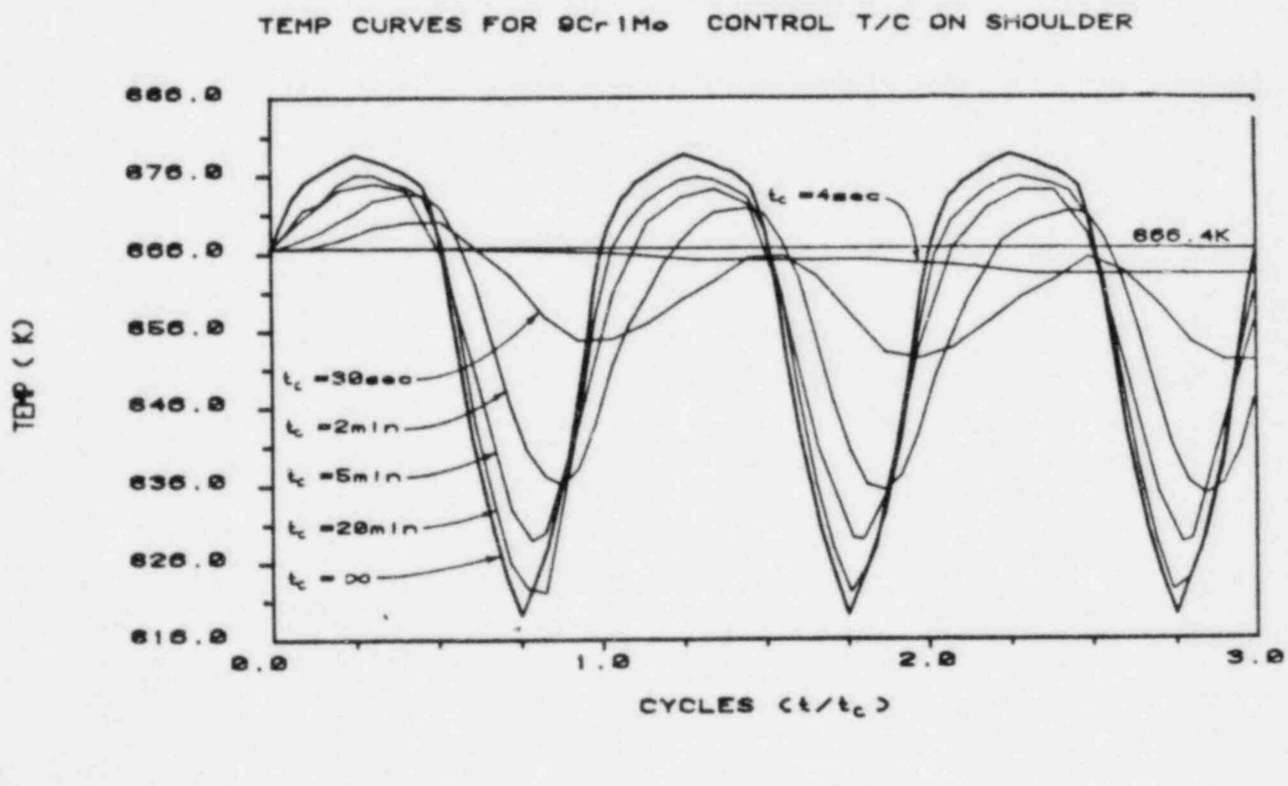
```
340        FORMAT(/,'$MM PER VOLT STRAIN SETTING - - - - ')
350        FORMAT(/,'$SPECIMEN DIAMETER IN MM AT TEMP. - ')
360        FORMAT(F6.4)
C
C  INITIALIZE SOME VARIABLES
C
1        POISNP=0.5 !>>>>>                        PLASTIC POISSAN'S RATIO
2        POISNE=0.31 !>>>>>                       ELASTIC POISSAN'S RATIO
3        YMOD=1.48E+05 !>>>>>                             YOUNG'S MODULUS
       DATA N,M/1,0/
       WRITE (5,15)
C
C  ENTER INPUT AND OUTPUT FILE NAMES.
C
20         WRITE (5,25)
       READ (5,35) IN, (BFIN(I), I=1,IN) !>>>>>        INPUT FILE NAME.
       BFIN(IN+1)=0
       OPEN (UNIT=1, NAME=BFIN, TYPE='OLD', ERR=20)
40         WRITE (5,44)
       READ (5,35) IT, (BFON(J), J=1,IT) !>>>>>       OUTPUT FILE NAME.
       BFON(IT+1)=0
       OPEN (UNIT=2, NAME=BFON, TYPE='NEW', RECORDSIZE=80, ERR=40)
       GO TO 300 !>>>>>                           INPUT TEST PARAMETERS.
45         CONTINUE
C
C  START TO READ FILE WHICH MAY HAVE COMMENT LINES STARTING WITH *.
C
       WRITE (5,56)
46         READ (1,35, ERR=40) NO, (LINE(K), K=1,NO) !>>>>>   READ A LINE.
       IF (LINE(1).NE.'*') GO TO 48 !>>>>>    CHECK FOR COMMENT LINES.
       M=M+1 !>>>>>                                 COUNT COMMENT LINES.
       WRITE (5,47) (LINE(K), K=1,NO) !>>>>>      COMMENTS ON SCREEN.
       GO TO 46
48         BACKSPACE 1 !>>>>>              GO BACK TO BEGINNING OF RECORD.
       WRITE (5,57)
C
C  START AT FIRST DATA LINE AND INPUT TO ARRAY.
C
50         READ (1,55, END=70, ERR=60) FILE(N,1),FILE(N,2),FILE(N,3)
C
C  CONVERT TO ENG. STRAIN AND ENG.STRESS, COMPUTE ENG. PLASTIC STRAIN.
C
       FILE(N,1)=FILE(N,1)*SETSTN/DIAM
       FILE(N,2)=FILE(N,2)*SETLOD*CONVER
       FILE(N,4)=-(1/POISNP)*FILE(N,1)-(POISNE/POISNP)*(FILE(N,2)/YMOD)
       N=N+1
       GO TO 50
C
C  ERROR ROUTINE - CLOSE FILES - GO TO END
C
60         WRITE (5,65)
       ERROR=.TRUE.
70         CLOSE (UNIT=1) !>>>>>                        CLOSE INPUT FILE.
```

```
      IF (ERROR) GO TO 130 !>>>>>       DROP OUT OF PROGRAM IF ERROR.
C
C  WRITE DATA TO NEW FILE.
C
      N=N-1
100      CONTINUE
       DO 110, I=1,N
       WRITE (2,105, ERR=120) FILE(I,1),FILE(I,2),FILE(I,3),FILE(I,4)
110      CONTINUE
      GO TO 200
C
C  CLOSE FILES AND QUIT.
C
120     WRITE (5,125)
130     CLOSE (UNIT=2, DISP='DELETE') !>>>>>  DELETE FILE IF ERROR
      GO TO 999
200     CLOSE (UNIT=2, DISP='SAVE') !>>>>>         SAVE GOOD FILE
      GO TO 999
C
C  ENTER PARAMETERS FOR FILE CONVERSION TO ENG. STRESS AND STRAIN.
C
300     WRITE (5,310)
      WRITE (5,320)
      READ (5,330) SETLOD !>>>>>                  INPUT LOAD SETTING.
      WRITE (5,340)
      READ (5,330) SETSTN !>>>>>                INPUT STRAIN SETTING.
      WRITE (5,350)
      READ (5,360) DIAM !>>>>>               INPUT SPECIMEN DIAMETER.
      AREA=3.14159*(DIAM/2)**2 !>>>>>               AREA IN SQUARE MM.
      CONVER=4450.0/AREA !>>>>>           TO CONVERT FROM KIPS TO MPA.
      GO TO 45 !>>>>>                GO BACK TO MAIN LINE OF PROGRAM.
999     STOP
      END
```

Appendix II

The following are sample graphs drawn by the LSI-11/23 computer and the Tektronics 4662 Digital Plotter.





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