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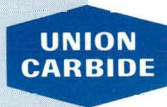
**MASTER**

A REMOTE DATA STATION INTERFACE TO THE  
PRODUCTION CONTROL COMPUTER

G. L. Bowers  
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A. E. Stephens

**UNION CARBIDE CORPORATION  
NUCLEAR DIVISION  
OAK RIDGE Y-12 PLANT**

*operated for the* **ATOMIC ENERGY COMMISSION** *under* **U. S. GOVERNMENT** **Contract W-7405 eng 26**



OAK RIDGE Y-12 PLANT  
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UNION CARBIDE CORPORATION  
Nuclear Division

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## ABSTRACT

Throughout the Y-12 Plant's Product Certification Division, acquisition and data reporting comprises a major problem for all departments. In the past, this work has been handled either by manual methods or by automation via a small computer. However, studies were needed that would establish the feasibility of using a larger computer for solving data problems on a real-time basis. From this study, a nondestructive test station has been successfully interfaced to a CDC-3300 computer. Sufficient hard-wired circuitry was provided to automate the testing sequence while the computer acquired and analyzed the data and reported the results to the remote station.

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## SUMMARY

A remote data station at the Oak Ridge Y-12 Plant,<sup>(a)</sup> where nondestructive tests are performed, has been interfaced to a Control Data Corporation's (CDC) 3300 computer located in another area of the Plant. Hard-wired circuitry has been used to provide the control functions that are necessary to automate the testing sequence. The CDC-3300 provides the data-handling features only; serial telecommunication interfacing circuitry links the station to the computer. Two software packages were developed, both application and executive, to take the data, analyze it, and present the results at the gage. All of the objectives of the project have been realized, and the feasibility of a real-time analysis of the gage data with the CDC-3300 computer was established. Based on these findings, the production control computer is recommended as a strong candidate for solving all future data problems where feedback control and fast response (less than a few milliseconds) are not required.

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(a) Operated by the Union Carbide Corporation's Nuclear Division for the US Atomic Energy Commission.

## INTRODUCTION

Throughout the Y-12's Product Certification Division a major problem for all of the departments is data—both the acquisition of good data and the analysis stage of mathematical manipulation and preparation of reports to the various customers. The data problem is becoming more and more complex as each manufacturing system continues to become more sophisticated. In some cases, digital computation is not only an economically attractive alternate solution, but appears to be the only solution. New ideas and techniques are needed for handling data in order to keep this problem from becoming a master instead of a servant.

In the past, the Y-12 Plant has handled its data problems either with manual methods or by automation via a small computer. Due to its low cost and extreme flexibility, the small computer has been chosen for this type of work and has proven its value. One disadvantage that has been encountered, however, is the machine language programming requirement. Software costs generally overshadow the capital cost of the small computer.

One means of simplifying the software problem is to use a higher-level language, such as Fortran. This improvement can be effectively realized only in a larger computer with more memory and a more powerful central processing unit. Y-12 has such a computer available, the production control CDC-3300 computer. Permission was requested and received from the Data Systems Department to perform an initial investigation using this facility to determine if it is feasible to apply the larger computer to data problems on a real-time basis. Therefore, in the hope of developing a new capability for handling gage data, a pilot project was begun which consisted of computerizing a DXT gage for the Physical Testing Department.

## REMOTE TEST STATION DATA HANDLING

### TELECOMMUNICATION INTERFACE

A prototype remote data station was developed to communicate with the production control computer. The test station chosen involved the nondestructive testing of a part using the DXT method. Examination of the test requirements revealed that Teletype speeds (110 baud) would be adequate for data transmission and reception. The first decision to be made concerned the interfacing technique to be used. Control Data Corporation offers a complete line of telecommunication hardware which handles serial data for remote applications. Data can also be acquired in parallel, which is faster, but this method has the disadvantage of requiring more conductors in the transmission cable. Also, the vendor does not offer standard hardware, thereby requiring in-house development and possible conflicts with maintenance contracts. For these reasons, serial interfacing was chosen.

ASCII, the American Standard Code for Information Interchange, was used for the common communication code. Numeral 5, Code 265, is shown framed in Figure 1 with one start and two stop bits, requiring eleven bits to be transmitted for each character. In order to eliminate the complex and expensive AC signaling techniques which utilize modems or data sets, DC signaling with relays was used, as suggested by Martin<sup>(b)</sup> for distances of about three miles. The gage located in one of the production buildings was tied to the CDC-3300 computer in the communication building by means of two pairs of cable borrowed from the transacter system and relay circuitry, as sketched in Figure 2. A detailed engineering drawing of the DXT gage is presented in Appendix A.

### PART INSPECTION PROCEDURE

Determination of the density uniformity of a part requires measurements along a latitude and a longitude which call for movement in the  $\theta$  and Z directions, respectively. Latitude inspections are made by holding the longitude fixed and varying  $\theta$  from 0 to 360 degrees in increments of 60 degrees (7 locations); longitude examinations require a fixed latitude and stepping in the Z direction from 0 to 1,200 inches in 0,200-inch steps (7 locations). At each location, five 10-second readings (6 digits per reading) are made. The first reading is a zero check on the picoammeter, then four measurements of the part are made. Preset indexers and stepping motors position the axes of motion.

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(b) Martin, James; Telecommunications and the Computer, Chapter 7; Prentice-Hall, Inc, Englewood Cliffs, New Jersey (1969).

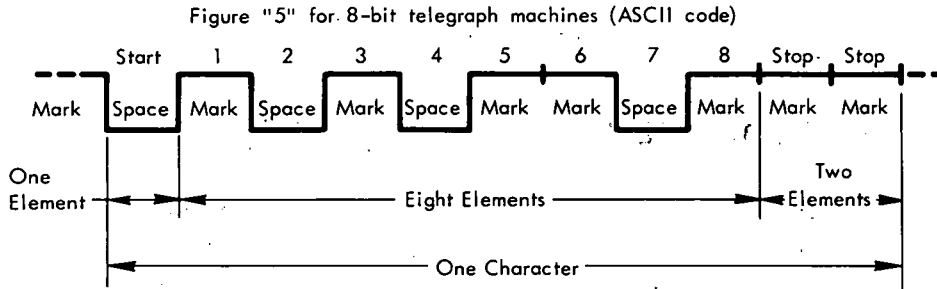


Figure 1. BIT FORMAT FOR DATA TRANSMISSION.

The calibration consists in reading three standards corresponding to the thickness of the part, with five readings per standard. The first step in inspecting a part is to read the initial standard again. At the end of the test, another check on this same standard enables electronic drift to be corrected. Since the test procedure includes a lot of part positioning, calibration, and drift checking, automation of these functions by computer cut the inspection time in half (from 2 hours to 1 hour per part).

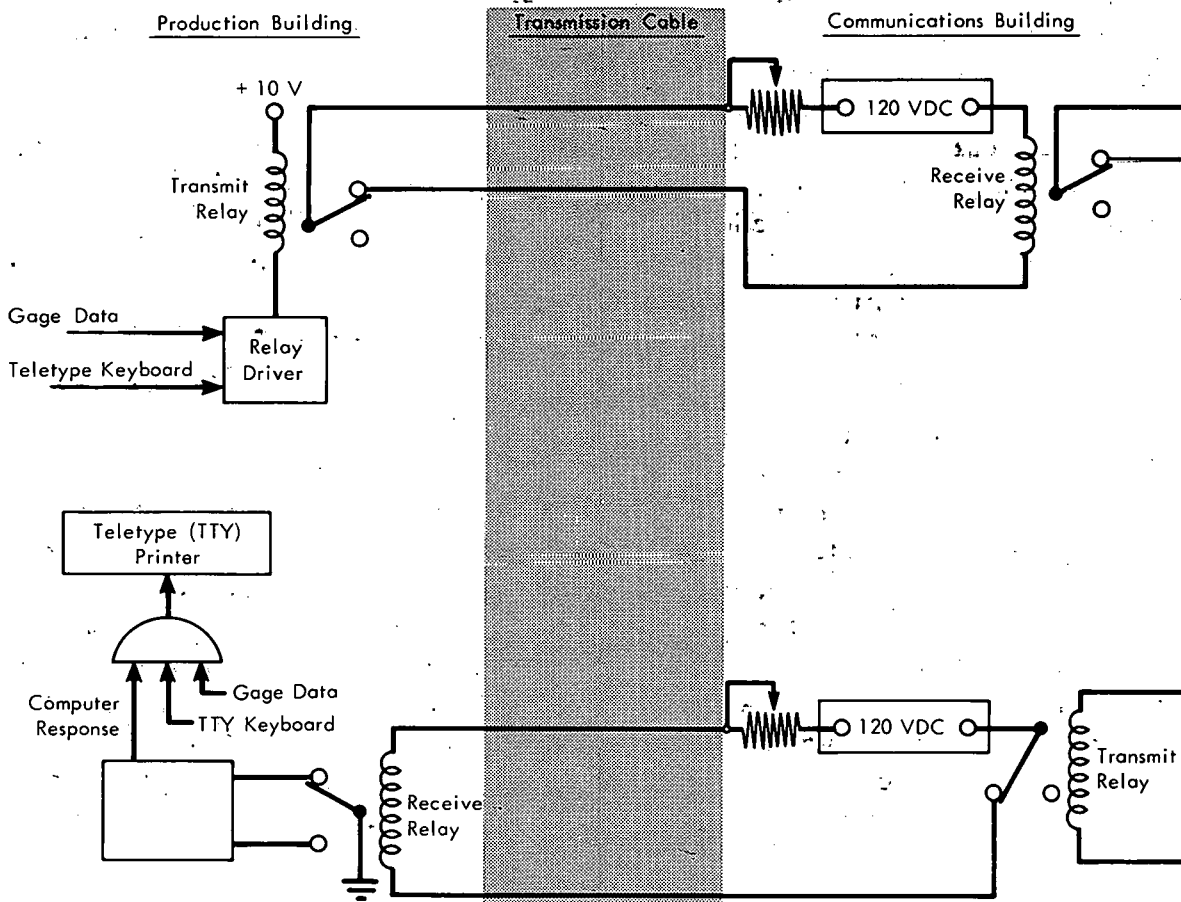


Figure 2. DC SIGNALING TELECOMMUNICATIONS INTERFACE.

## SYSTEM DESCRIPTION

The block diagram in Figure 3 shows the various instruments, elements, and circuits that make up the system. The source emits a collimated beam of radiation through the part to the detector. The EPUT meter totalizes a count which is a function of the beam intensity that is detected and the density of the part. Gage data are correlated with standard data to obtain the absolute thickness values for the part. Most of the electronic circuitry was used to automate the inspection cycle by positioning the axes, zeroing the picoammeter, resetting the frequency meter, transmitting gage data, and receiving the results. Some manual intervention was required for calibration. The Teletype keyboard was interfaced to permit transmission of the control characters to the CDC-3300. All of the gage and keyboard data were printed simultaneously with the transmission, and a hard copy of the test results was also obtained. A typical printout is seen in Figure 4.

## APPLICATION PROGRAM

A listing of the application software is given in Appendix B, and a detailed program flow chart is provided in Appendix C. For purposes of discussing the software, the abbreviated flow chart of Figure 5 can be used.

An experienced programmer will notice that the computer program has a great deal of redundancy and has not been optimized with respect to execution time and storage requirements. This situation came about because of the short development time which was allotted, and also because none of these things were critical for this demonstration. The objective was to keep the program simple and loosely knit so that changes or additions could be made easily. This provision turned out to be an important point in the success of the program development in the given time.

In Block ① of the flow chart (Figure 5), the hi-lo test consists of determining whether or not at least three of the four readings being inspected lie within a certain small range of each other. If so, the three (or four) good readings are averaged and the average is used as the DXT reading for that location. This step helps reduce the statistical variation in the data. If one reading is out of the range, it is considered erroneous and is discarded; if three points lying in the desired small range cannot be found, then a data error is considered to have occurred. The remote station is signaled via the Teletype to repeat the particular inspection step before proceeding further.

In Block ②, the zero-set correction consists of subtracting the background count rate from the averaged DXT readings.

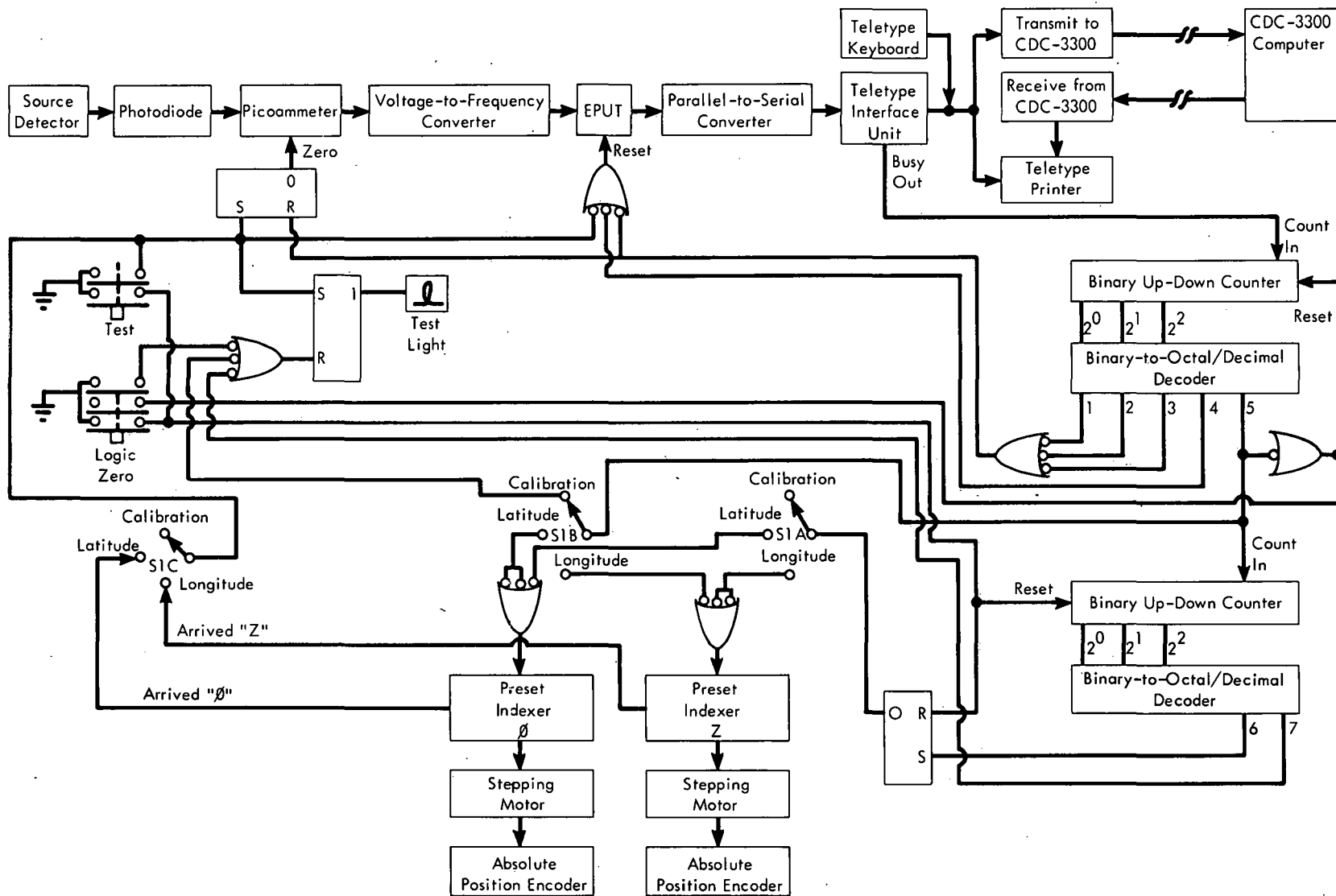


Figure 3. DXT TEST STATION.

PART NUMBER: 1234-56-7890

BULK DENSITY: 2.986 GM/CC

SCAN	DENSITY, GM/CC	DEVIATION, PERCENT
Ø.2 IN. LATITUDE		
	2.927	- 2.0
	2.925	- 2.0
	2.956	- 1.0
	2.906	- 2.7
	2.953	- 1.1
	2.970	- 0.5
	2.906	- 2.7
Ø DEG. LONGITUDE		
	2.891	- 3.2
	2.890	- 3.2
	2.877	- 3.7
	2.921	- 2.2
	2.922	- 2.1
	2.884	- 3.4
	2.985	- 0.0

INSPECTION COMPLETED.

Figure 4. TYPICAL PRINTOUT OF TEST RESULTS

In Block ③, a least-squares straight line is fitted to the averaged and zero-corrected readings from three standards of known, different DXT characteristics. This line then provides a means of comparing an unknown sample to the known standards.

In Block ④, a simple linear drift in the readings with time (due to instrument drift) is considered to have occurred, or:

$$\text{Drift} = \frac{R_2 - R_1}{N},$$

where:

- N represents the total number of latitude and longitude data points (in the present case, 14),
- R<sub>1</sub> the reading taken on the standard immediately before beginning the latitude scan, and
- R<sub>2</sub> the reading taken on the same standard immediately after ending the longitude scan.

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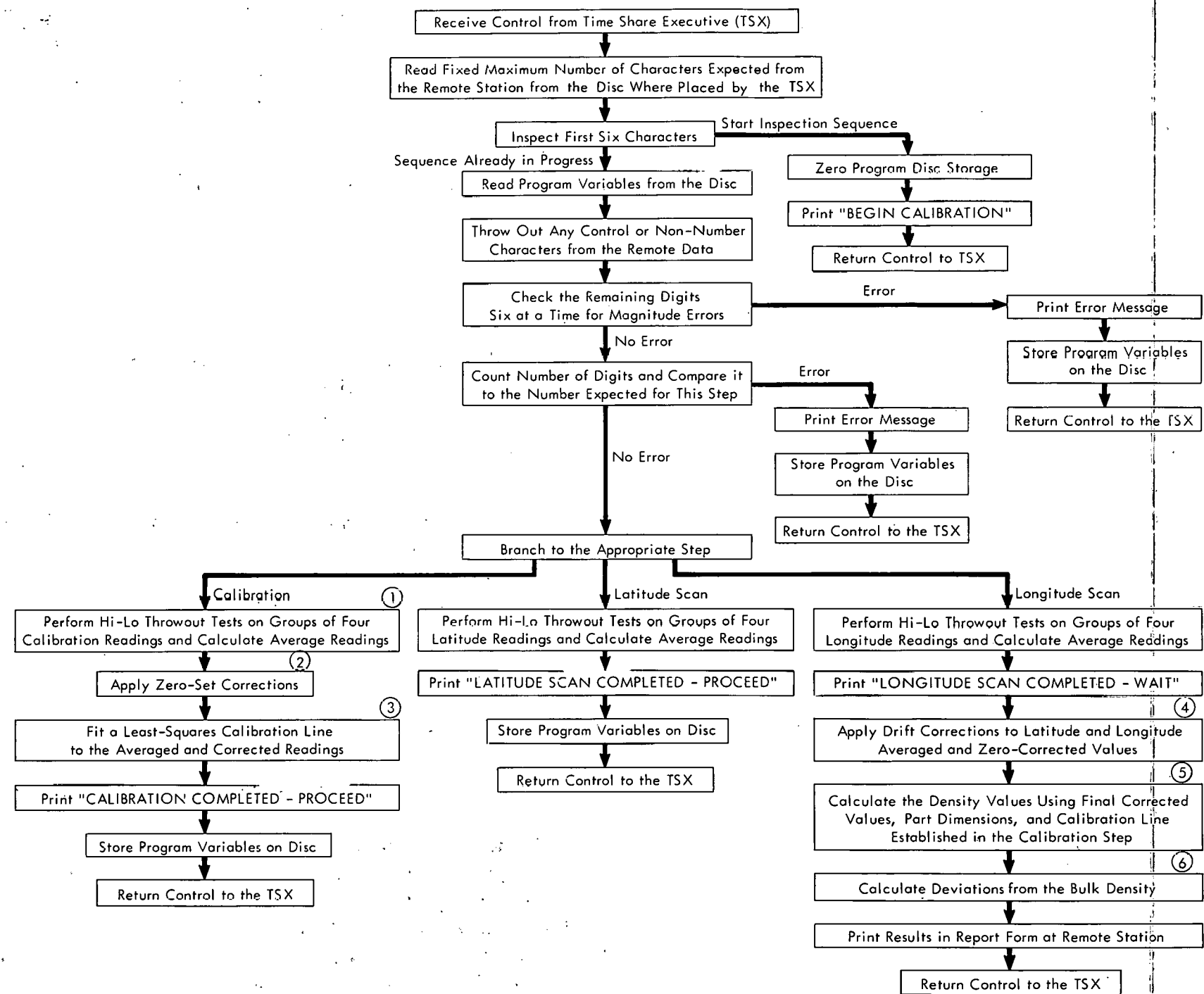


Figure 5. ABBREVIATED SOFTWARE FLOW CHART.

Then, the  $i$ th reading in the sequence corrected for drift is:

$$R_{i\text{corr}} = R_i + (i) \times \text{Drift.}$$

This expression was used for simplicity. A more realistic scheme would consider a nonlinear drift and would take into account the time expended between the latitude and longitude scans.

In Block (5), the density at the  $i$ th data point is calculated from:

$$\text{RH0}_i = (A R_{i\text{corr}} + B) / t_i,$$

where:

A and B represent calibration constants obtained from the least-squares fit in the calibration step,

$R_{i\text{corr}}$  the corrected DXT reading at the  $i$ th point calculated previously, and

$t_i$  the part thickness at the  $i$ th point obtained from the part dimension specifications.

Deviation from the bulk density, Block (6), is calculated from:

$$\text{Deviation (\%)} = \frac{(\text{RH0}_i - \text{Bulk Density})}{\text{Bulk Density}} \times 100.$$

#### TIME-SHARE EXECUTIVE PROGRAM

The DXT gage was connected to the computer, as indicated in Figure 6. Use of the Teletype interface permitted analog signals from the gage to be converted into digital signals, which are acceptable by the 321 data set adapter. The Model 33 Teletype was used as a receive-only station. After manipulating the data received from the DXT gage, the results are then sent back to the Model 33 Teletype for utilization by the gage operator.

The logic path taken by the gage data is outlined in Figure 7. The time-share executive (TSX) program controlled the data transfer between the two remote terminals (gage and Teletype) and the application program. The functions

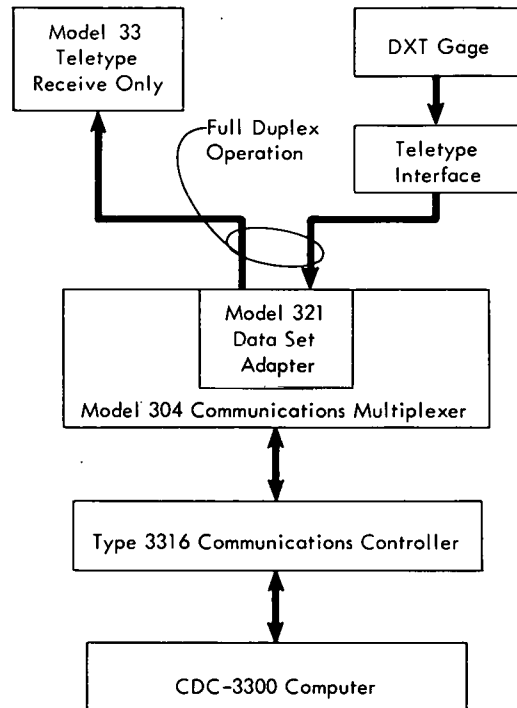


Figure 6. HARDWARE CONNECTION OF THE DXT GAGE.

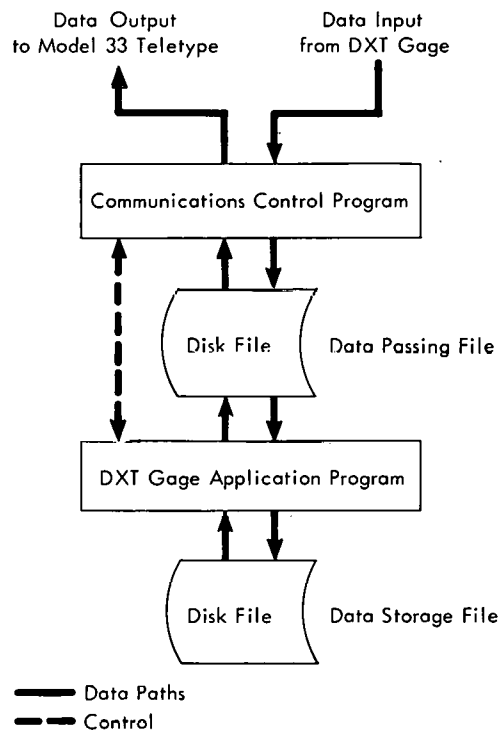


Figure 7. DATA FLOW FOR THE DXT GAGE.

performed by the control program consisted of: (1) opening (activating) the two lines of a full-duplex system, (2) reading data from the DXT gage, (3) writing data to the Model 33 Teletype, (4) checking and recovering errors for the reading and/or writing of data, (5) writing the data received onto the data passing file, (6) reading any results from the data passing file, and (7) calling the application program into memory.

Upon being called into memory, the application program: (1) retrieved any data on the data passing file, (2) manipulated the data received, (3) stored onto the data storage file any data needed for future data manipulation, and (4) returned any intermediate or final results to the control program via the data passing file.

The TSX and application programs were set up in a job environment with the control program being permanently resident and the application program coming into memory only when needed. This approach permitted other jobs to be multiprogrammed along with the DXT gage program.

The results of the test showed that the DXT gage could be connected to the CDC-3300 computer; that the TSX and application programs could communicate with the DXT gage and the Model 33 Teletype; that there was only about a one or two-second delay between the end of the data input to the beginning of the results; and there was no noticeable degradation of running time when other jobs were submitted for multiprogramming.

## PROJECT RESULTS

All of the objectives were realized as the project was carried from inception to completion. In the five-week period of the project, approximately 200 man-hours of development labor were spent on the hardware and 80 manhours on the software. Another 24 manhours were consumed by Data System's personnel in marrying the application program to the telecommunication data. The surprising aspect of the job was that it actually proved to be simpler than anticipated. The system was demonstrated to management and personnel from several departments. Feasibility of the real-time analysis of gage data with the CDC-3300 computer has been established.

## CONCLUSIONS AND RECOMMENDATIONS

The present utilization of small computers throughout the Plant offers strong evidence that decentralization of computer power is a very real solution to

many equipment control and data problems. Since a small computer is approximately as fast as a large one, it should be applied where fast data acquisition is required (ie, fast, single, nonrecurring events), where fast data analysis is needed (ie, computations required to make real-time on-line decisions), and where control functions are being performed (eg, positioning a machine tool in accordance with adaptive control measurements).

Based on the findings of the project, the production control computer is recommended as a strong candidate for solving all future data problems where fast responses (less than a few milliseconds) are not required.

Advantages for the larger computer approach versus a small one are:

1. A more powerful central processing unit is available for increased efficiency in computations.
2. A higher-level language (eg, Fortran) can be effectively applied to reduce the software effort threefold over machine language.
3. Time-share executive (TSX) software enables a multitude of stations, such as the one covered in this report, to be handled.
4. Peripherals, such as several magnetic tape transports, disk files, line printers, and a card reader, are available, whereas a single station with a small, dedicated computer may have trouble economically justifying such devices.
5. The solution to data problems described herein encourages standardization and interchangeability of hardware.

### ACKNOWLEDGEMENTS

The authors wish to thank R. C. Crowe, D. R. Fletcher, and W. H. Moehl of the Y-12 Physical Testing Department for defining the nondestructive test requirements and for operating the gage; R. A. Tannert of the Data Systems Department for allowing the use of the production control computer in making this feasibility study; and W. E. Skold of Control Data Corporation for connecting the transmission lines to the computer.

APPENDIX A

DETAILED ENGINEERING DRAWING

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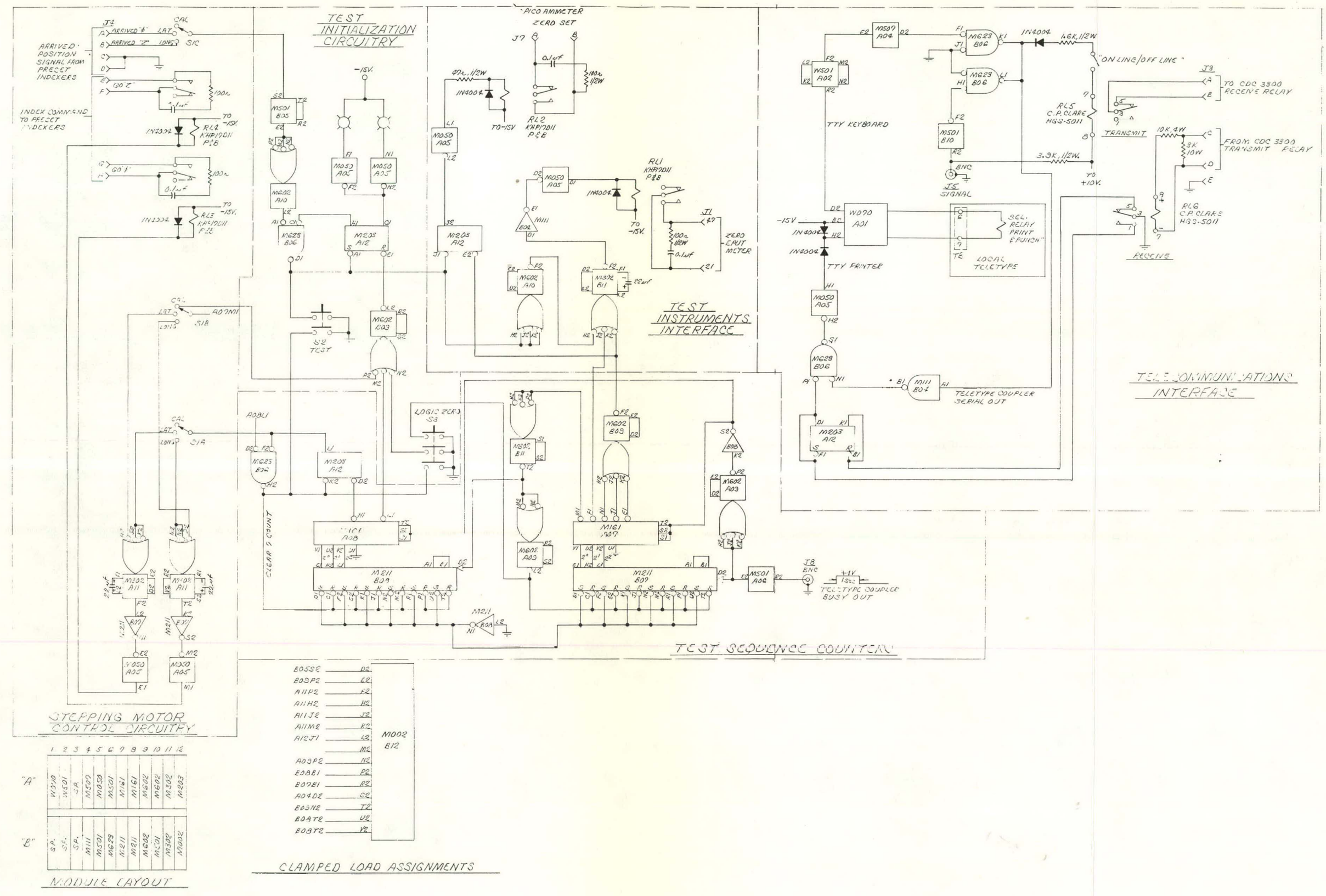


Figure A 1. DXT GAGE LOGIC DIAGRAM.

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APPENDIX B

SOFTWARE LISTING

## FORTRAN (3.2)/MASTER

```

PROGRAM PQ67
C
INTEGER BUFFER(81)
CHARACTER CBUFFER(324)
EQUIVALENCE (BUFFER,CBUFFER)
CHARACTER CKCHAR
COMMON/DATA/IFMT999(2),THICKNSS(14)
DATA (IFMT999=4H(01I,4H6) )
DATA (THICKNSS=8(0.267875),0.313077,0.387666,0.492549,0.629051,
2 0.799034,0.949976)
INTEGER VALUEARR(41),DAT(50)
INTEGER DRF1,DRF2,DRIFT,EOT,ZROSET,TEMP
DIMENSION N(4),NAVG(20),RHOT(20),DEV(20)
CKCHAR=11B
EOT=99999
MCAL=20
MLAT=35
MLONG=40
RHO1=2.986*0.252731
RHO2=2.986*0.507240
RHO3=2.986*0.759971
RDENS=2.986
ISTAT=0
BUFFER IN (6,0)(BUFFER(1),BUFFER(81))
01 GO TO (01, 02, 02, 02), UNITSTF(6)
02 DECODE(6,99,BUFFER(1))NX
99 FORMAT(I6)
IF(NX.EQ.99997)442,444
444 CALL LOCATE(6,1,JM,0)
CALL FORTDUMP (BUFFER(1),BUFFER(81),1,4HCBUF)
READ(7,500)A,B,DRF1,ISTAT
500 FORMAT(2E15.8,2I6)
READ(7,505)(NAVG(I),I=1,20)
505 FORMAT(20I6)
CALL LOCATE(7,1,JM,0)
GO TO (870,880,890),ISTAT +1
870 NCHAR=126
IFMT999 = 74020131B
GO TO 875
880 NCHAR=216
IFMT999 = 74030631B
GO TO 875
890 NCHAR=246
IFMT999 = 74040131B
875 IDELETE=0
DO 1010 I=1,324
IF(CBUFFER(I)-CKCHAR)1005,1005,1000
1000 IDELETE=IDELETE+1
GO TO 1010
1005 IDEL=I-IDELETE
CBUFFER(IDEL)=CBUFFER(I)
1010 CONTINUE
ISTART=325-IDELETE
IF(ISTART.GT.324)1025,1015
1015 DO 1020 I=ISTART,324
1020 CBUFFER(I)=01B
1025 WRITE(61,1030)IDELETE
1030 FORMAT(1X,I6)
DECODE (NCHAR,IFMT999, BUFFER(1)) VALUEARR

```

```

WRITE (61,931) ISTAT, NCHAR, CKCHAR
931 FORMAT(1X, I1, I6, 4X, A1)
CALL FORTDUMP (VALUEARR(1), VALUEARR(41), 2, 4HVALA)
M=1
5 NX=VALUEARR(M)
IF (NX.GT.99999) 34,6
6 IF (NX.EQ.EQT) 10,7
7 IF (NX.EQ.99998) 4,8
8 DAT(M)=NX
M=M+1
GO TO 5
34 CALL LOCATE(6,1,JM,0)
READ(7,500)A,B,DRF1,ISTAT
READ(7,505)(NAVG(I),I=1,20)
CALL LOCATE(7,1,JM,0)
GO TO 44
4 CALL LOCATE(6,1,JM,0)
WRITE(8,3)
3 FORMAT(1H~,1H+,1H~,29HEXITING PROGRAM - START OVER.,1H~,1H+,1H~)
CALL LOCATE(6,1,JM,0)
CALL LOCATE(7,1,JM,0)
RETURN
442 CALL LOCATE(6,1,JM,0)
A=B=0.
DRF1=ISTAT=0
DO 446 JK=1,20
446 NAVG(JK)=0
WRITE(7,500)A,B,DRF1,ISTAT
WRITE(7,505)(NAVG(I),I=1,20)
WRITE(8,450)
450 FORMAT(1H~,1H+,1H~,18HBEGIN CALIBRATION.,1H~,1H+,1H~)
CALL LOCATE(6,1,JM,0)
CALL LOCATE(7,1,JM,0)
RETURN
10 CALL LOCATE(6,1,JM,0)
M=M-1
WRITE(61,932)M
932 FORMAT(1X,I6)
IF (M.EQ.MCAL) 1100,41
41 IF (M.EQ.MLAT) 1200,43
43 IF (M.EQ.MLONG) 1300,44
44 IF (ISTAT.EQ.0) 12,45
45 IF (ISTAT.EQ.1) 14,46
46 WRITE(8,16)
16 FORMAT(1H~,1H+,1H~,34HDATA ERROR - RERUN LONGITUDE SCAN.,1H~,1H+,
2 1H~)
WRITE(7,500)A,B,DRF1,ISTAT
WRITE(7,505)(NAVG(I),I=1,20)
CALL LOCATE(6,1,JM,0)
RETURN
1100 GO TO (100,14,46), ISTAT+1
1200 GO TO (12,200,46), ISTAT+1
1300 GO TO (12,14,300), ISTAT+1
12 WRITE(8,17)
17 FORMAT(1H~,1H+,1H~,31HDATA ERROR - RERUN CALIBRATION.,1H~,1H+,1H~)
WRITE(7,500)A,B,DRF1,ISTAT
WRITE(7,505)(NAVG(I),I=1,20)
CALL LOCATE(6,1,JM,0)
CALL LOCATE(7,1,JM,0)
RETURN
14 WRITE(8,18)

```

```

18 FORMAT(1H^,1H+,1H ,33HDATA ERROR - RERUN LATITUDE SCAN.,1H^,1H+,
2 1Hv)
WRITE (7,500) A,B,DRF1,ISTAT
WRITE (7,505) (NAVG(I),I=1,20)
CALL LOCATE(6,1,JM,0)
CALL LOCATE(7,1,JM,0)
RETURN
100 LL=1
DO 24 I=1,16,5
DO 19 IL=1,4
ILI=IL+I
19 N(IL)=DAT(IL I)
ZROSET=DAT(I)
DO 22 J=1,3
J1=J+1
DO 22 K=J1,4
IF(N(J).GE.N(K))22,27
27 TEMP=N(J)
N(J)=N(K)
N(K)=TEMP
22 CONTINUE
IF(N(1)-N(4).LT.50)50,52
52 IF(N(1)-N(3).LT.50)60,53
53 IF(N(2)-N(4).LT.50)70,54
54 WRITE(8,26)
26 FOPMAT(1H^,1H+,1H 55HTOO MUCH VARIATION IN COUNT VALUES - RERUN CA
2LIBRATION.,1H^,1H+,1Hv)
CALL LOCATE(6,1,JM,0)
CALL LOCATE(7,1,JM,0)
RETURN
50 NAVG(LL)=(N(1)+N(2)+N(3)+N(4))/4-ZROSET
GO TO 75
60 NAVG(LL)=(N(1)+N(2)+N(3))/3-ZROSET
GO TO 75
70 NAVG(LL)=(N(2)+N(3)+N(4))/3-ZROSET
75 LL=LL+1
24 CONTINUE
DRF1=NAVG(4)
A11=3.0
A12=FLOAT(NAVG(1)+NAVG(2)+NAVG(3))
A21=A12
A22=FLOAT(NAVG(1))*FLOAT(NAVG(1))+FLOAT(NAVG(2))*FLOAT(NAVG(2))
+FLOAT(NAVG(3))*FLOAT(NAVG(3))
B1=RHO1+RHO2+RHO3
B2=RHO1*FLOAT(NAVG(1))+RHO2*FLOAT(NAVG(2))+RHO3*FLOAT(NAVG(3))
B=(B1*A22-B2*A12)/(A11*A22-A21*A12)
A=(A11*B2-A21*B1)/(A11*A22-A21*A12)
ISTAT=1
WRITE(8,11)
11 FORMAT(1H^,1H+,1H ,32HCALIBRATION COMPLETED - PROCEED.,1H^,1H+,
2 1Hv)
WRITE(61,500) A,B,DRF1,ISTAT
WRITE(7,500) A,B,DRF1,ISTAT
WRITE(7,505) (NAVG(I),I=1,20)
CALL LOCATE(6,1,JM,0)
CALL LOCATE(7,1,JM,0)
RETURN
200 LL=1
DO 124 I=1,31,5
DO 119 IL=1,4
ILI=IL+I

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```

119 N(IL)=DAT(ILI)
    ZROSET=DAT(I)
    DO 122 J=1,3
      J1=J+1
      DO 122 K=J1,4
        IF(N(J).GE.N(K))122,127
127 TEMP=N(J)
    N(J)=N(K)
    N(K)=TEMP
122 CONTINUE
    IF(N(1)-N(4).LT.50)150,152
152 IF(N(1)-N(3).LT.50)160,153
153 IF(N(2)-N(4).LT.50)170,154
154 WRITE(8,126)
126 FORMAT(1H~,1H+,1H ,57HTOO MUCH VARIATION IN COUNT VALUES - RERUN L
      2ATITUDE SCAN.,1H~,1H+,1Hv)
    CALL LOCATE(6,1,JM,0)
    CALL LOCATE(7,1,JM,0)
    RETURN
150 NAVG(LL)=(N(1)+N(2)+N(3)+N(4))/4-ZROSET
    GO TO 175
160 NAVG(LL)=(N(1)+N(2)+N(3))/3-ZROSET
    GO TO 175
170 NAVG(LL)=(N(2)+N(3)+N(4))/3-ZROSET
175 LL=LL+1
124 CONTINUE
    WRITE(8,111)
111 FORMAT(1H~,1H+,1H ,34HLATITUDE SCAN COMPLETED - PROCEED.,1H~,1H+,
      2 1Hv)
    ISTAT=2
    WRITE(7,500)A,B,DRF1,ISTAT
    WRITE(7,505)(NAVG(I),I=1,20)
    CALL LOCATE(6,1,JM,0)
    CALL LOCATE(7,1,JM,0)
    RETURN
300 LL=R
    DO 224 I=1,36,5
      DO 219 IL=1,4
        ILI=IL+I
219 N(IL)=DAT(ILI)
    ZROSET=DAT(I)
    DO 222 J=1,3
      J1=J+1
      DO 222 K=J1,4
        IF(N(J).GE.N(K))222,227
227 TEMP=N(J)
    N(J)=N(K)
    N(K)=TEMP
222 CONTINUE
    IF(N(1)-N(4).LT.50)250,252
252 IF(N(1)-N(3).LT.50)260,253
253 IF(N(2)-N(4).LT.50)270,254
254 WRITE(8,226)
226 FORMAT(1H~,1H+,1H ,58HTOO MUCH VARIATION IN COUNT VALUES - RERUN L
      2ONGITUDE SCAN.,1H~,1H+,1Hv)
    WRITE(7,500)A,B,DRF1,ISTAT
    WRITE(7,505)(NAVG(IG),IG=1,20)
    CALL LOCATE(6,1,JM,0)
    CALL LOCATE(7,1,JM,0)
    RETURN
250 NAVG(LL)=(N(1)+N(2)+N(3)+N(4))/4-ZROSET

```

```

      GO TO 275
260  NAVG(LL)=(N(1)+N(2)+N(3))/3-ZROSET
      GO TO 275
270  NAVG(LL)=(N(2)+N(3)+N(4))/3-ZROSET
275  LL=LL+1
224  CONTINUE
      WRITE(8,211)
211  FORMAT(1H~,1H+,1H ,32HLONGITUDE SCAN COMPLETED - WAIT.,1H~,1H+)
      L1=LL-1
      DRF2=NAVG(L1)
      DRIFT=(DRF2-DRF1)/14
      DO 320 I=1,L1
320  NAVG(I)=NAVG(I)-I*DRIFT
      DO 325 I=1,L1
      RHOT(I)=(A*FLOAT(NAVG(I))+B)/THICKNSS(I)
325  DEV(I)=((RHOT(I)-BDENS)/BDENS)*100.0
      WRITE(8,330)
330  FORMAT(3H+++,1H ,25HPART NUMBER: 1234-56-7890,1H~,2H++)
      WRITE(8,331)
331  FORMAT(1H ,25HBULK DENSITY: 2.986 GM/CC,1H~,2H++)
      WRITE(8,332)
332  FORMAT(5H ,4HSCAN,8H ,14HDENSITY, GM/CC,3H ,
2 18HDEVIATION, PERCENT,1H~,2H++)
      WRITE(8,333)
333  FORMAT(1H ,16H0.2 IN. LATITUDE,1H~,1H+)
      WRITE(8,335) (RHOT(I),DEV(I),I=1,7)
335  FORMAT(20H ,F6.3,14H ,F5.1,1H~,
2 1H+)
      WRITE(8,340)
340  FORMAT(1H+,1H ,16H0 DEG. LONGITUDE,1H~,1H+)
      WRITE(8,335) (RHOT(I),DEV(I),I=8,14)
      WRITE(8,350)
350  FORMAT(4H++++,1H ,21HINSPECTION COMPLETED.,1H~,1H+,1H~)
      RETURN
      END

```



APPENDIX C

DETAILED PROGRAM FLOW CHART

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