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AUTOMATED SATURATED STANDARD CELL INTERCOMPARISON

B. E. Bell

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U. S. DEPARTMENT OF ENERGY
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B. E. Bell

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Automated Cell Intercomparison

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I would like to acknowledge technicians G. Blood and G. Brown. Without their programming expertise and extensive data taking this project would have taken much longer.

AUTOMATED SATURATED STANDARD CELL INTERCOMPARISON

B. E. Bell

ABSTRACT

A cost effective, highly efficient, and automatic method of intercomparing standard cells has been sought after and implemented, utilizing computer control and a commercially available scanner. This system reduces intercomparison time from 4 hours to 30 minutes using the standard National Bureau of Standards (NBS) 4x4 design.

INTRODUCTION

Manual intercomparison of saturated standard cells can yield very accurate results, on the order of tenths of parts per million. Typically our cells receive an uncertainty of ± 3 to ± 5 parts per million microvolts from the Primary Standards Laboratory (PSL).

Standard practice is to make intercomparisons monthly due to the long time involved in taking the measurements. However, occasions arise when more frequent intercomparisons are desirable. These include laboratory environmental upset, physical transfer of the cells, monitoring after cell bath general maintenance, and general historical data gathering.

With assigned uncertainties of ± 3 to ± 5 microvolts, a method was needed to intercompare cells in a time efficient manner without impacting these already wide tolerances assigned by the PSL.

The National Bureau of Standards (NBS) was contacted and queried regarding available scanners or automated systems. They confirmed the availability of a scanner, specifically applicable to standard cell intercomparison, that they had tested with encouraging results.

The designer and builder of the Data Proof scanner was contacted, technical information was supplied, and the scanner was chosen for implementation and evaluation.

COST TO IMPLEMENT AND BENEFITS DERIVED

Implementation was a rather painless task. After the scanner was received, it was connected to the cells and to the digital voltmeter input terminals using low thermal wire. Connection to the computer was accomplished using IEEE-488 cables. Interconnection was relatively simple.

Most standards labs use NBS-generated software. The same is true for Rocky Flats Plant, depending upon the application. For automated intercomparison, scanner channel selection and digital voltmeter commands had to be incorporated into the existing NBS software.

Once the system was fully assembled, and the software generated, evaluation and testing began. Various voltmeters were evaluated for best sensitivity and resolution. Types of physical connections were examined to reduce thermal electromotive force (emf) generation.

Table 1 shows the implementation costs. No new ancillary equipment was required - - costs only reflect the price of the scanner.

Tangible Benefit

Implementation of this system saves 44 hours of technician time per year.

TABLE 1. Cost to Implement Automated System

Data Proof Scanner	\$3,500
Modification of existing software (16 hr)	272
Software testing (6 hr)	102
Hardware testing (40 hr)	680
System testing (60 hr)	<u>1,020</u>
Total	\$5,574

Intangible Benefit

The new system has several intangible benefits. It promotes flexibility in use of personnel. Previously, only highly experienced and highly trained technicians could perform this measurement. Use of the new method with computer control and prompting allows most metrology technicians to perform this precise measurement with little or no specialized training.

It also provides for the maintenance of the most complete history possible. Previously, due to the lengthy nature of the measurement, only one standard cell intercomparison per month was possible or practical. Now, readings can be taken every half hour, if desired, to pinpoint inconsistencies between standard cells or to track single cell events.

Flexibility to evaluate the effects of various measurement variables is a noteworthy attribute. This could include data averaging (optimum number of points to average), effect of meter zeroing versus nonzeroing, and optimum time of day to make the intercomparisons.

Another positive feature is elimination of human error associated with reading measurements, transcribing data, and performing calculations.

Additional Benefit

Two additional benefits result from the new system. First, the system is expandable; it can incorporate a database management system linked to graphics software for total data manipulation and historical/statistical graphics. This would eliminate time-consuming plotting and the inevitable human errors involved.

Second, the new system provides a safer means of data storage to maintain historical control. This includes disk storage as well as hard copy in a localized file.

PROBLEMS ENCOUNTERED

Initially, meter selection posed a minor problem. Two Hewlett Packard 3456s worked quite well.

They were easy to program for and quite compatible with the HP86A computer controller, but they were used quite extensively for other measurements and could not be dedicated to a single system. The same held true for our two Solartron 7081 meters. However, a Keithley 181 nanovoltmeter had good sensitivity and resolution and was available for dedication to a single measurement system.

The main system components were selected and testing began. Straightforward measurements were tried at first; that is, a sequential selection of scanner relays linking various combinations of cells together per the NBS 4x4 design. Erratic results were produced. Cell values, left-right components, and standard deviations all fluctuated. To smooth out the errors, averaging 5 to 10 readings was attempted. Cell values appeared to be well within the limits set by the PSL. Readings were carried on almost daily for at least several months. No anomalies were apparent in the measured cell values. However, a fluctuating standard deviation did appear (ranging from -0.5 to $+0.5$ microvolts), as did a fluctuating left-right component (ranging from -0.2 to $+0.2$ microvolts). See Figures 1 and 2. In both figures, note the extreme excursion beginning around 3/27/86. This excursion occurred due to laboratory environmental upset, where temperature increased to a point well beyond laboratory specifications. Comparing these values and manual readings previously taken with the Guildline 9930 Direct Current Comparator Potentiometer, the latter clustered right around zero microvolts, and was generally much less than 0.2 microvolts, as shown in Figure 3.

The problem indicators had the same characteristics as those linked to induced thermal emfs caused by poor physical connections. However, there were no suspect problem connections, such as an external terminal block. The only physical connections were those tied directly to cell terminals. These connections should not have affected our readings to the extent observed.

To reduce the frequency of measurement excursions, we decided to change the measurement technique. The idea was to measure the difference of two cells, with cell "A" connected to one side of the meter, for example the positive side, and

FIGURE 1. Bank 3102 Versus Bank 3101: Standard Deviation and L-R Component

FIGURE 2. Bank 3102 Versus Bank 3101 Measured in Microvolts 8/19/85 Through 7/29/86

FIGURE 3. Manual Intercomparison: Bank 3102 Versus Bank 3101 Standard Deviation and L-R Component

cell "B" connected to the negative, and take a series of measurements. The final steps were to reverse the cells' connections to the meter (via the scanner), take another series of readings, average the magnitude of the readings, and assign the proper sign.

This appeared to work very well, and manual readings were halted, except to confirm measurement integrity. From July 1986 to January 1987, automatic intercomparisons were continually made. Excursions could still be periodically observed on the left-right component and standard deviation. The excursions appeared to be too infrequent to be thermals. Random line transients were our first suspects for investigation. Our less than clean power source has affected sensitive

measurements in the past. The main problem is that with manual measurements, the metrologist can pause for a transient to pass. By contrast, automated systems continue, despite the transient. Therefore, we decided to begin manual readings again, pair them up with the automated measurements, and compare the results.

During the manual measurement of one such session, when cell enclosure heaters came on, excursions occurred in the data, excursions dependent upon random occurrences of simultaneous measurement and heating. Apparently, AC line power causing inductive reactance in the heating elements, produced transients affecting the measurements. The solution proved simple. During all future intercomparisons, battery power will be used for heater element power. Figure 4

FIGURE 4. Automated Intercomparison: Bank 3102 Versus Bank 3101 Standard Deviation and L-R Component

shows the relative measurement stability upon implementing this policy in January 1987. To date, it appears that left-right component and standard deviation fluctuations have been eliminated, but we will continue to monitor the system for consistency.

CELL INTERCOMPARISON

The main difference between components of a manual intercomparison and an automated intercomparison is that to automate, the metrologist and manual switch are replaced by a computer and a bus controllable scanner, respectively. Figures 5 and 6 are block diagrams of the two intercomparisons. However, in this instance, since uncertainties were based upon the PSL intercomparison and since the Guildline 9930 was not bus controllable, it was replaced with a bus controllable voltmeter.

Manual Intercomparison

All cell banks being intercompared are connected to manual switches. From this point, they are connected to the Guildline 9930 potentiometer. When predetermined switch settings are selected, certain desired cells are bucked against one another. At this point, the technician must balance the bridge, note the dial reading, and record the data point as a difference reading. These steps must be accomplished for each cell in every bank used as a standard, and are dependent upon the NBS measurement design used.

After all readings have been taken, the temperature of each cell bank must be recorded. This record is needed for the temperature compensation factor used in the calculations -- the final step of the intercomparison (except for plotting).

Calculations are performed using NBS statistical analysis software. This software must be loaded into the computer with all manual measurements and temperature values typed in by the metrologist, as prompted. When the program finishes the

FIGURE 5. Standard Cell Manual Measurement Block Diagram

FIGURE 6. Standard Cell Automatic Measurement Block Diagram

computations, a final report is output containing saturated standard cell values to compare to assigned PSL values.

Automated Intercomparison

All cell banks being intercompared are connected to the scanner. From this point they are connected to the digital voltmeter. Both scanner and voltmeter are connected, via IEEE-488 bus, to a controlling computer. When predetermined scanner relays are selected (by computer), certain desired cells are bucked against one another and the computer controlled voltmeter measures the value and sends it to the computer. This is accomplished for each cell in every bank used as

a standard, and is also dependent upon the NBS measurement design used.

After all readings have been taken, the computer prompts the metrologist to input each cell bank temperature, as required in the manual inter-comparison, for temperature compensation used in the calculations.

Next, the computer automatically performs the NBS statistical analysis routine and a final report is generated. Please see Appendix A, the sample automated measurement program.

Comparison: Automated Versus Manual

As was shown in the previous section, the main difference between manual and automated

measurements is the replacement of switches, potentiometer, and metrologist with a scanner, voltmeter, and computer.

What benefit does automating standard cell intercomparisons provide a standards laboratory? It saves time. How much time is saved depends on the number of banks of cells being intercompared and how often the intercomparison is accomplished. In this application, using a typical 4x4 NBS design, automation was faster by a factor of 8 to 1.

To carry this on a bit further, time was saved, and at the same time, the integrity of the measurement was maintained. That is, accuracy did not suffer. Figures 3 and 4 provide a comparison of manual and automated measurements. Figures 4 and 7

FIGURE 7. Bank 3102 Versus Bank 3101 Measured in Microvolts 7/11/86 Through 3/30/87

show how well automated measurements preserve the stability, precision, and accuracy because they conform to the PSL-generated values and lie between the ± 3 and ± 5 microvolt tolerance bands.

CONCLUSIONS

A solution was sought to free up valuable measurement time and eliminate human error associated with saturated standard cell intercomparisons. The method tested utilized standard laboratory equipment and a commercially available standard cell scanner.

All evidence supports that when dealing with control limits on the order of ± 3 to ± 5 microvolts,

any random or systematic errors interjected by an automated system, properly employed, will be negligible.

An automated system such as that used at Rocky Flats Plant can decrease saturated cell intercomparison measurement time as much as 8 to 1. In addition to decreasing measurement time, decreasing human error becomes a very important side benefit.

The equipment selected was a computer controlled, Data Proof scanner and digital voltmeter system. Residual benefits from such a system include flexible use of personnel, isolation of measurement variables, ease of use, reduced human error, increased data collection for better cell history, and the following of cell recovery after shock.

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APPENDIX A.

Sample Automated Measurement Program

```

100 REM THE NAME OF THIS PROGRAM IS "CELLS"
120 REM 511398 08/12/85 RF 81774 PM-81774
140 REM THIS PROGRAM IS FOR THE HP86 COMPUTER AND EPSON TX-80 PRINTER
160 REM THIS PROGRAM INTERCOMPARES STD CELLS
180 PRINTER IS 8.80
200 OPTION BASE 1
220 DIM A$(200),D$(20),O$(20)
240 DIM S(18),L(30),P(100),R(30),Y(100)
260 ! GOTO 4000
280 DIM C(20,20),Z(20,20)
300 DIM Q(20),X(20)
320 DIM D(100)
340 DEF FNT(T) = (T-20)*(-40.6+((T-20)*(-.95+.01*(T-20))))
360 REM FROM 9845 TO 85 One1=O1;Oner=O2;Two1=J1;Twor=J2
380 DIM O1(20),O2(20),J1(30),J2(30)
400 F=0
420 MAT L=ZER
440 MAT R=ZER
460 MAT O1=ZER @ MAT J1=ZER
480 MAT O2=ZER @ MAT J2=ZER
500 GOSUB 7760 ! EXERCISE SCANNER
520 !
540 !
560 !
580 REM *****SETTING VARIABLES*****
600 E2,E3=0
620 S2=4 @ S3=4
640 N=16
660 S4=S2+S3 ! TOTAL NO. OF CELLS
680 S5=S4+1
700 S6=S4+2 ! TOTAL CELLS PLUS 2
720 IF F=0 THEN O$="3101/70990" @ M=8222.03 @ T1=28.08 @ T3=30.17
740 IF F=1 THEN O$="3102/70990" @ M=8231.88 @ T1=27.93 @ T3=30.17
760 IF F=2 THEN O$="3102/3101" @ M=8231.88 @ T1=27.93 @ T3=28.08
780 IF F=3 THEN O$="3101/3102" @ M=8222.03 @ T1=28.08 @ T3=27.93
800 !
820 !
840 !
860 REM *****TEST SETTINGS*****
880 !
900 ! IF F=0 THEN O$="3101/70990" @ M=8221.7 @ T1=28.07 @ T3=30.26
920 ! IF F=1 THEN O$="3102/70990" @ M=8231.8 @ T1=27.92 @ T3=30.26
940 ! IF F=2 THEN O$="3102/3101" @ M=8231.8 @ T1=27.92 @ T3=28.07
960 ! IF F=3 THEN O$="3101/3102" @ M=8221.7 @ T1=28.07 @ T3=27.92
980 !
1000 !
1020 !
1040 IF F=0 THEN GOSUB 7100 ! GET DATE AND CHECK WITH CELL CERT DATE
1060 !
1080 !
1100 !
1120 !
1140 REM *****ZERO MAT S*****
1160 !
1180 MAT S=ZER
1200 FOR I=1 TO S2
1220 S(I)=1
1240 NEXT I
1260 !
1280 !
1300 !
1320 REM *****ADD CELL NOS TO BANK RF NO*****
1340 !
1360 B$=O$(1,POS(O$,"/")+1)
1380 FOR I=1 TO S2
1400 A$(I)=B$&CHR$(45)&CHR$(I+48)
1420 NEXT I
1440 B$=O$(POS(O$,"/")+1,LEN(O$))
1460 FOR I=S2+1 TO S4
1480 A$(I)=B$&CHR$(45)&CHR$(I-S2+48)
1500 NEXT I
1520 !

```

```

1540 !
1560 !
1580 GOSUB 5300 ! CELL ORDER
1600 !
1620 !
1640 !
1660 REM *****LOADING CELL ORDER INTO MATRIX L AND R*****
1680 !
1700 IF S2=6 THEN 1780
1720 MAT L=O1
1740 MAT R=O2
1760 GOTO 1880
1780 MAT L=J1
1800 MAT R=J2
1820 !
1840 !
1860 !
1880 REM *****ENTER TEMP OF CELLS*****
1900 !
1920 IF F>0 THEN GOTO 2200
1940 CLEAR @ DISP "ENTER THE FOLLOWING REQUESTED TEMPERATURES IN CENTIGRADE."
1960 !
1980 !
2000 !
2020 DISP "What is the observed temperature of the RF 3101 cells?"
2040 INPUT T5
2060 IF T5<= 0 THEN 2020
2080 DISP "What is the observed temperature of the RF 3102 cells?"
2100 INPUT T6
2120 IF T6<= 0 THEN 2080
2140 DISP "What is the observed temperature of the RF 70990 cells?"
2160 INPUT T7
2180 IF T7<= 0 THEN 2140
2200 IF F=0 THEN T2=T5 @ T4=T7
2220 IF F=1 THEN T2=T6 @ T4=T7
2240 IF F=2 THEN T2=T6 @ T4=T5
2260 IF F=3 THEN T2=T5 @ T4=T6
2280 E2=FNT(T2)-FNT(T1) ! CORRECTION FOR TEMPERATURE
2300 E3=FNT(T4)-FNT(T3) ! CORRECTION FOR TEMPERATURE
2320 !
2340 !
2360 !
2380 GOSUB 5740 ! COLLECT DIFF READINGS
2400 !
2420 !
2440 !
2460 MAT Z=ZER (S6,S6)
2480 MAT C=ZER (S6,S6)
2500 MAT X=ZER
2520 MAT Q=ZER
2540 FOR I=1 TO N
2560 Y(I)=P(I)
2580 IF L(I)>S2 THEN 2640
2600 Y(I)=Y(I)-E2
2620 GOTO 2660
2640 Y(I)=Y(I)-E3
2660 IF R(I)>S2 THEN 2720
2680 Y(I)=Y(I)+E2
2700 GOTO 2740
2720 Y(I)=Y(I)+E3
2740 L=L(I)
2760 R=R(I)
2780 Q(L)=Q(L)+Y(I)
2800 Q(R)=Q(R)-Y(I)
2820 Z(L,L)=Z(L,L)+1
2840 Z(R,R)=Z(R,R)+1
2860 Z(L,R)=Z(L,R)-1
2880 Z(R,L)=Z(R,L)-1
2900 Z(S5,L)=Z(S5,L)+1
2920 Z(L,S5)=Z(S5,L)
2940 Z(S5,R)=Z(S5,R)-1
2960 Z(R,S5)=Z(S5,R)

```

```

2980 Z(S5,S5)=Z(S5,S5)+1
3000 Q(S5)=Q(S5)+Y(I)
3020 NEXT I
3040 FOR I=1 TO S4
3060 Z(S6,I)=S(I)
3080 Z(I,S6)=S(I)
3100 NEXT I
3120 MAT C=INV (Z)
3140 FOR I=1 TO S6
3160 FOR J=1 TO S6
3180 X(I)=X(I)+C(I,J)*Q(J)
3200 NEXT J
3220 NEXT I
3240 PRINTER IS 8,80
3260 !
3280 !
3300 !
3320 REM *****PRINT PAGE*****
3340 !
3360 PRINT "          LEAST SQUARES ANALYSIS OF STANDARD CELL DATA"
3380 PRINT
3400 V2=0
3420 FOR I=1 TO N
3440 L=L(I)
3460 R=R(I)
3480 D(I)=Y(I)-(X(L)-X(R)+X(S5))
3500 V2=D(I)*D(I)+V2
3520 NEXT I
3540 V3=N-S4
3560 W3=0
3580 V4=SQR (V2/V3)
3600 W2=1
3620 PRINT "DATE  ";D$:TAB (30);"RUN  ";O$
3640 PRINT "DESIGN  ";S2;"X";S3:TAB (29);N;"OBSERVATIONS"
3660 PRINT
3680 PRINT "STD DEV=";V4:TAB (30);"ACC STD DEV= .5"
3700 PRINT "DEG OF FREEDOM=";V3
3720 PRINT
3740 W1=0
3760 IF W2=0 THEN 3800
3780 GOSUB 5220 ! HEADING
3800 FOR I=1 TO N
3820 L=L(I)
3840 R=R(I)
3860 IF D(I)=0 THEN 3920
3880 X1=ABS (D(I))
3900 D(I)=D(I)/X1*INT (X1*100+.5)/100
3920 IF W2=1 THEN 3980
3940 IF ABS (D(I))<1.5 THEN 4000
3960 IF W1=1 THEN 4040
3980 PRINT I;TAB (6);A4(L);TAB (16);A$(R);TAB (33);P(I);TAB (45);Y(I);TAB (65);D(I)
4000 NEXT I
4020 GOTO 4120
4040 PRINT "          THE FOLLOWING DEVIATIONS EXCEED 3 SIGMA"
4060 PRINT
4080 GOSUB 5220 ! HEADING
4100 GOTO 3980
4120 IF W2=1 THEN 4160
4140 IF W1=0 THEN 4200
4160 GOSUB 5260 ! ----- LINE
4180 GOTO 4240
4200 PRINT "NO DEVIATIONS EXCEED 3 SIGMA"
4220 PRINT
4240 IF W2=1 THEN 4320
4260 W2=1 ! TO PRINT ALL OBS
4280 IF W2=1 THEN 3740
4300 IF W1=0 THEN 4360
4320 PRINT
4340 PRINT
4360 IF M(> 0 THEN 4420
4380 PRINT "MEAN OF GROUP WAS NOT GIVEN"
4400 GOTO 4440

```



```

4420 PRINT "REF GRP MEAN REDUCED BY 1.01 VOLTS. IN MICROVOLTS IS";M
4440 PRINT
4460 PRINT "LEFT-RIGHT COMPONENT =";X(S5)
4480 PRINT
4500 PRINT "TEMP GRP 1 =";T2;TAB (30);"TEMP GRP 2 =";T4
4520 PRINT "CORR GRP 1 =";-E2;TAB (30);"CORR GRP 2 =";-E3
4540 PRINT "GRP 1 CORR TO ";T1;TAB (30);"GRP 2 CORR TO ";T3
4560 PRINT
4580 PRINT "ESTIMATES OF DIFFERENCE FROM MEAN AND TEMPERATURE"
4600 PRINT "      CORRECTED EMFS IN MICROVOLTS"
4620 PRINT
4640 PRINT "NO          CELL          EST VALUE          EMF 1014"
4660 GOSUB 5260 ! ----- LINE
4680 P5=0
4700 FOR I=1 TO S4
4720 Z7=INT ((X(I)+M)*100+.5)/100
4740 PRINT I;TAB (8);A$(I);TAB (19);
4760 IF S(I)=1 THEN 4860
4780 PRINT "UNK";TAB (30);
4800 P5=P5+1
4820 W3=W3+X(I)
4840 GOTO 4880
4860 PRINT "STD";TAB (30);
4880 PRINT X(I);TAB (50);
4900 IF M=0 THEN 4960
4920 PRINT Z7
4940 GOTO 4980
4960 PRINT " "
4980 NEXT I
5000 IF M=0 THEN 5200
5020 W3=W3/P5
5040 W3=INT ((W3+M)*100+.5)/100
5060 GOSUB 5260 ! ----- LINE
5080 PRINT "MEAN OF UNK GRP REDUCED BY 1.01 VOLTS. IN MICROVOLTS IS";W3
5100 PRINT CHR$ (12)
5120 F=F+1
5140 IF F=1 OR F=2 OR F=3 THEN GOTO 420
5160 PRINT CHR$ (12)
5180 DISP "Program finished"
5200 STOP
5220 PRINT "OBS      LEFT      RIGHT      OBS      OBS      DCV"
5240 PRINT "NO      CELL      CELL      T-CORR"
5260 PRINT RPT$ (" ",80)
5280 RETURN
5300 END
5320 !
5340 !
5360 !
5380 REM *****MEAS ORDER OF CELLS*****
5400 RESTORE 5480
5420 FOR I=1 TO 16
5440 READ O1(I),O2(I)
5460 NEXT I
5480 DATA 1,5,3,5,3,7,1,7,2,6,4,6,4,8,2,8
5500 DATA 5,2,5,4,7,4,7,2,6,1,6,3,8,3,8,1
5520 FOR I=1 TO 24
5540 READ J1(I),J2(I)
5560 NEXT I
5580 DATA 1,7,3,7,5,7,5,9,3,9,1,9
5600 DATA 2,8,4,8,6,8,6,10,4,10,2,10
5620 DATA 7,2,7,4,7,6,9,6,9,4,9,2
5640 DATA 8,1,8,3,8,5,10,5,10,3,10,1
5660 RETURN
5680 !
5700 !
5720 !
5740 REM *****COLLECTING DIFF READINGS*****
5760 IF F=0 THEN RESTORE 6560
5780 IF F=1 THEN RESTORE 6640
5800 IF F=2 THEN RESTORE 6720
5820 IF F=3 THEN RESTORE 6800
5830 PRINT "DATE ";D$;TAB (30);"RUN ";O$

```

```

5835 PRINT @ PRINT
5840 OUTPUT 705 : "R2X" ! 20mV RANGE
5860 OUTPUT 705 : "D0X" ! DAMPING OFF
5880 OUTPUT 705 : "T0X" ! CONTINUOUS ON TALK
5900 OUTPUT 724 : "A16"
5920 WAIT 500
5940 OUTPUT 724 : "B16"
5960 WAIT 10000
5980 OUTPUT 705 : "Z1X" ! METER ZERO ON
6000 WAIT 1000
6020 FOR I=1 TO 16
6040 DISP I
6060 FOR K=1 TO 2
6080 READ A$,B$
6100 OUTPUT 724 : A$
6120 WAIT 500
6140 OUTPUT 724 : B$
6160 WAIT 5000
6180 P3=0
6200 FOR J=1 TO 5
6220 ENTER 705 : P2(J)
6240 P3=P3+P2(J)
6260 WAIT 1000
6280 DISP "J=";J;"DIFF READING = ";P2(J)*1000000
6300 NCXT J
6320 PRINT USING 6340 : I,P2(1)*1000000,P2(2)*1000000,P2(3)*1000000,P2(4)*1000000,
P2(5)*1000000
6340 IMAGE 10X,2D,3X,5(4D,2D,4X)
6360 P4(K)=P3/5*1000000
6380 NEXT K
6400 P(I)=(ABS (P4(1))+ABS (P4(2)))/2
6420 IF P4(1)<0 THEN P(I)=P(I)*-1
6440 DISP " AVE READING = ";P(I)
6460 OUTPUT 724 : "A00"
6480 WAIT 100
6500 OUTPUT 724 : "B00"
6520 WAIT 100
6540 NEXT I
6560 DATA "A01","B09","A09","B01","A03","B09","A09","B03","A03","B11","A11","B03",
"A01","B11","A11","B01"
6580 DATA "A02","B10","A10","B02","A04","B10","A10","B04","A04","B12","A12","B04",
"A02","B12","A12","B02"
6600 DATA "A09","B02","A02","B09","A09","B04","A04","B09","A11","B04","A04","B11",
"A11","B02","A02","B11"
6620 DATA "A10","B01","A01","B10","A10","B03","A03","B10","A12","B03","A03","B12",
"A12","B01","A01","B12"
6640 DATA "A05","B09","A09","B05","A07","B09","A09","B07","A07","B11","A11","B07",
"A05","B11","A11","B05"
6660 DATA "A06","B10","A10","B06","A08","B10","A10","B08","A08","B12","A12","B08",
"A06","B12","A12","B06"
6680 DATA "A09","B06","A06","B09","A09","B08","A08","B09","A11","B08","A08","B11",
"A11","B06","A06","B11"
6700 DATA "A10","B05","A05","B10","A10","B07","A07","B10","A12","B07","A07","B12",
"A12","B05","A05","B12"
6720 DATA "A05","B01","A01","B05","A07","B01","A01","B07","A07","B03","A03","B07",
"A05","B03","A03","B05"
6740 DATA "A06","B02","A02","B06","A08","B02","A02","B08","A08","B04","A04","B08",
"A06","B04","A04","B06"
6760 DATA "A01","B06","A06","B01","A01","B08","A08","B01","A03","B08","A08","B03",
"A03","B06","A06","B03"
6780 DATA "A02","B05","A05","B02","A02","B07","A07","B02","A04","B07","A07","B04",
"A04","B05","A05","B04"
6800 DATA "A01","B05","A05","B01","A03","B05","A05","B03","A03","B07","A07","B03",
"A01","B07","A07","B01"
6820 DATA "A02","B06","A06","B02","A04","B06","A06","B04","A04","B08","A08","B04",
"A02","B08","A08","B02"
6840 DATA "A05","B02","A02","B05","A05","B04","A04","B05","A07","B04","A04","B07",
"A07","B02","A02","B07"
6860 DATA "A06","B01","A01","B06","A06","B03","A03","B06","A08","B03","A03","B08",
"A08","B01","A01","B08"
6880 OUTPUT 724 : "A00"
6900 OUTPUT 724 : "B00"

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6920 WAIT 500
6940 OUTPUT 705 ; "Z0X" ! TURN ZERO OFF
6960 PRINT CHR$ (12)
6980 RETURN
7000 !
7020 !
7040 !
7060 REM *****CHECKING EXPIRATION DATE OF CELLS*****
7080 !
7100 CLEAR @ DISP "What is today's date? (MM/DD/YYYY)" @ INPUT D$
7120 IF LEN (D$) < 10 THEN 7100
7140 G=MDY (D$) ! CONVERTING TODAY'S DATE TO JULIAN DAY
7160 D1$="07/18/1987" ! DATE CELL CERTIFICATION EXPIRES
7180 IF LEN (D1$) < 10 THEN DISP "DATE CELL CERT EXPIRES NOT PUT IN PROGRAM CORRECTLY"
@ STOP
7200 G1=MDY (D1$) ! CONVERTING CELL EXPIRATION DATE TO JULIAN DAY
7220 IF G1 >= G THEN RETURN
7240 BEEP 30,500
7260 CLEAR @ DISP "Cell certification no longer valid" @ STOP
7280 !
7300 !
7320 !
7340 REM *****DATA FOR PROGRAM TESTING*****
7360 !
7380 IF F=0 THEN RESTORE 7540
7400 IF F=1 THEN RESTORE 7580
7420 IF F=2 THEN RESTORE 7620
7440 IF F=3 THEN RESTORE 7660
7460 FOR I=1 TO 16
7480 READ P(I)
7500 NEXT I
7520 RETURN
7540 DATA 97.14,99.46,97.84,95.54,103.33,99.01,96.77,100.99
7560 DATA -102.27,-93.07,-96.43,-100.62,-98.37,-100.87,-98.62,-96.02
7580 DATA 108.34,108.92,107.2,106.6,112.67,107.46,105.15,110.33
7600 DATA -111.53,-106.31,-104.58,-109.78,-109.5,-110.08,-107.7,-107.08
7620 DATA 11.31,11.93,9.54,8.87,9.5,4.22,8.42,13.68
7640 DATA -14.51,-9.27,-6.84,-12.12,-6.41,-7.02,-11.19,-10.6
7660 DATA -11.34,-9.06,-9.66,-11.95,-9.61,-13.82,-8.51,-4.35
7680 DATA 6.29,10.45,11.12,6.88,14.45,12.02,6.78,9.26
7700 !
7720 !
7740 !
7760 REM EXERCISE SCANNER
7780 !
7800 RESTORE 8040
7820 FOR I=1 TO 17
7840 READ A$
7860 OUTPUT 724 ; A$
7880 WAIT 1000
7900 NEXT I
7920 FOR I=1 TO 17
7940 READ B$
7960 OUTPUT 724 ; B$
7980 WAIT 1000
8000 NEXT I
8020 RETURN
8040 DATA "A01","A02","A03","A04","A05","A06","A07","A08","A09","A10","A11","A12",
"A13","A14","A15","A16","A00"
8060 DATA "B01","B02","B03","B04","B05","B06","B07","B08","B09","B10","B11","B12",
"B13","B14","B15","B16","B00"
8080 !
8100 !
8120 !
8140 REM *****LIST OF VARIABLES*****
8160 ! A$=CELLS
8170 ! A$( )=CELL NUMBER
8180 ! B$=RF NO. REF CELLS OR UNK CELLS
8200 ! C( )=
8220 ! D( )=
8240 ! D$=DATE
8260 ! D1$=CELL CERT EXPIRE DATE

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8280 | E2=CORR REF CELLS
8300 | E3=CORR UNK CELLS
8320 | F=WHICH BANK COUNTER
8340 | G=TODAY'S DATE TO JULIAN DATE
8360 | G1=CELL CERT EXPIRE DATE TO JULIAN DATE
8380 | I=LOOP COUNTER
8400 | J=LOOP COUNTER
8420 | J1()=
8440 | J2()=
8460 | K=LOOP COUNTER
8480 | L=
8500 | L()=
8520 | M=MEAN OF REF GROUP-1010000
8540 | N=NO. OF OBSERVATIONS
8560 | O1()=
8580 | O2()=
8600 | O4=RF NO. OF REF/UNK CELLS
8620 | P2()=DIFF READINGS(1-5)
8640 | P4()=AVE OF READINGS * 1000000
8660 | P3=SUM OF 5 READINGS
8680 | P5=
8700 | P()=DIFF BETWEEN OBS
8720 | Q()=
8740 | R=
8760 | R()=
8800 | S2=NO. OF CELLS IN REF GROUP
8820 | S3=NO. OF CELLS IN UNK GROUP
8840 | S4=TOTAL NO. OF CELLS
8860 | S5=S4+1
8880 | S6=S4+2
8900 | S()=
8920 | T1=CERTIFIED TEMP OF REF CELLS
8940 | T2=OBS TEMP OF REF CELLS
8960 | T3=CERTIFIED TEMP OF UNK CELLS
8980 | T4=OBS TEMP OF UNK CELLS
9000 | T5=OBS TEMP RF 3101
9020 | T6=OBS TEMP RF 3102
9040 | T7=OBS TEMP RF 70990
9060 | V2=
9080 | V3=DEG OF FREEDOM
9100 | V4=STD DEV
9140 | W1=FLAG
9160 | W2=FLAG
9180 | W3=MEAN OF UNK CELLS - 1.01
9200 | X()=
9220 | X1=
9240 | Y()=
9260 | Z(,)=
9280 | Z7=

```