DEPARTMENT OF THE ARMY TECHNICAL BULLETIN

US ARMY VOLT PROGRAM FOR CALIBRATION ACTIVITIES

Headquarters, Department of the Army, Washington, DC
26 November 1987

REPORTING OF ERRORS

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1. Purpose. This bulletin provides the guidance and procedures to be utilized for:

a. Disseminating the volt from the U.S. Army Primary Standards Laboratory (APSL) to the Calibration and Repair Centers (CRCs).

b. Reducing data as necessary for surveillance of CRC standard cells.

c. Determining the EMF/temperature corrections for saturated standard cells.

*This bulletin supersedes TB 43-177, 24 April 1985, including all changes

2. Scope

a. This bulletin applies to all CRC's that participate in the US Army Volt Program.

b. This bulletin applies specifically to the following saturated cell models:

(1) Standard cells with temperature Enclosure, Eppley Laboratories, Inc., Model 106-4 (APN 7909096).

(2) Saturated standard cell Enclosure, Guildline Instruments, Inc., Model 9154 ( ) (all models).

3. Definitions. In addition to the definitions in AR 750-25 and AR 310-25, the Following definitions apply:

a. **Saturated Standard Cell**. A chemical cell in which the electrolyte is kept ;saturated at all times by the presence of an excess of solid crystals.

b. **Transport Standard**. A group of standard cells used to compare the unit of voltage maintained at one location to that maintained at another location. A transport standard can either be used to calibrate a reference standard or to disseminate the colt from the reference standard to other lower level standards.

c. **Reference Group**. A designated group of cells used only for maintaining the volt in a calibration facility. This group is lot normally used in performing routine calibrations.

d. Working Group. A designated group of cells which may be used as a standard for performing routine calibrations in a calibration facility.

e. Observation. A noted occurrence involving a measurement with a standard or test system. An observation is the simplest piece of information (data) that has independent significance in a calibration.

f. Run. A sequential group of observations in a test procedure or measurement design.

g. **Test**. A process by which data is accumulated to serve as a basis for assessing the degree that a system meets, exceeds, or fails to meet the technical or operational specifications assigned to the system.

h. Measurement. The process of comparing an instrument or test system to an accepted standard.

i. Measurement Design. A design selected to intercompare a group of standards. Designs are selected to provide maximum information with a minimum number of observations.

j. Thermal EMF. The thermoelectric potential generated by leads and/or binding posts of the reference device when connected into a circuit with pure copper connections.

k. Calibration and Repair Center (CRC). A functional organization established for the purpose of providing single source Calibration and Repair Service (C&RS) for general purpose and selected special purpose TMDE.

4. General. Figure 1 indicates an ideal flow of the volt within the calibration system. It indicates an ideal traceability chain from the "Legal Volt" at the National Bureau of Standards (NBS) to the lowest level of the Army Calibration System. As the chart indicates, the US Army Volt is linked to the US Legal Volt at NBS with procedures of the NBS Volt Transfer Program and transportable standard cell enclosures. The CRC Volt is linked to the US Army Volt at the APSL with procedures of this technical bulletin and transportable standard cell enclosures supplied and controlled by the APSL. Local surveillance of cells in the reference and working groups at the CRC will be performed in accordance with procedures of appendix B.

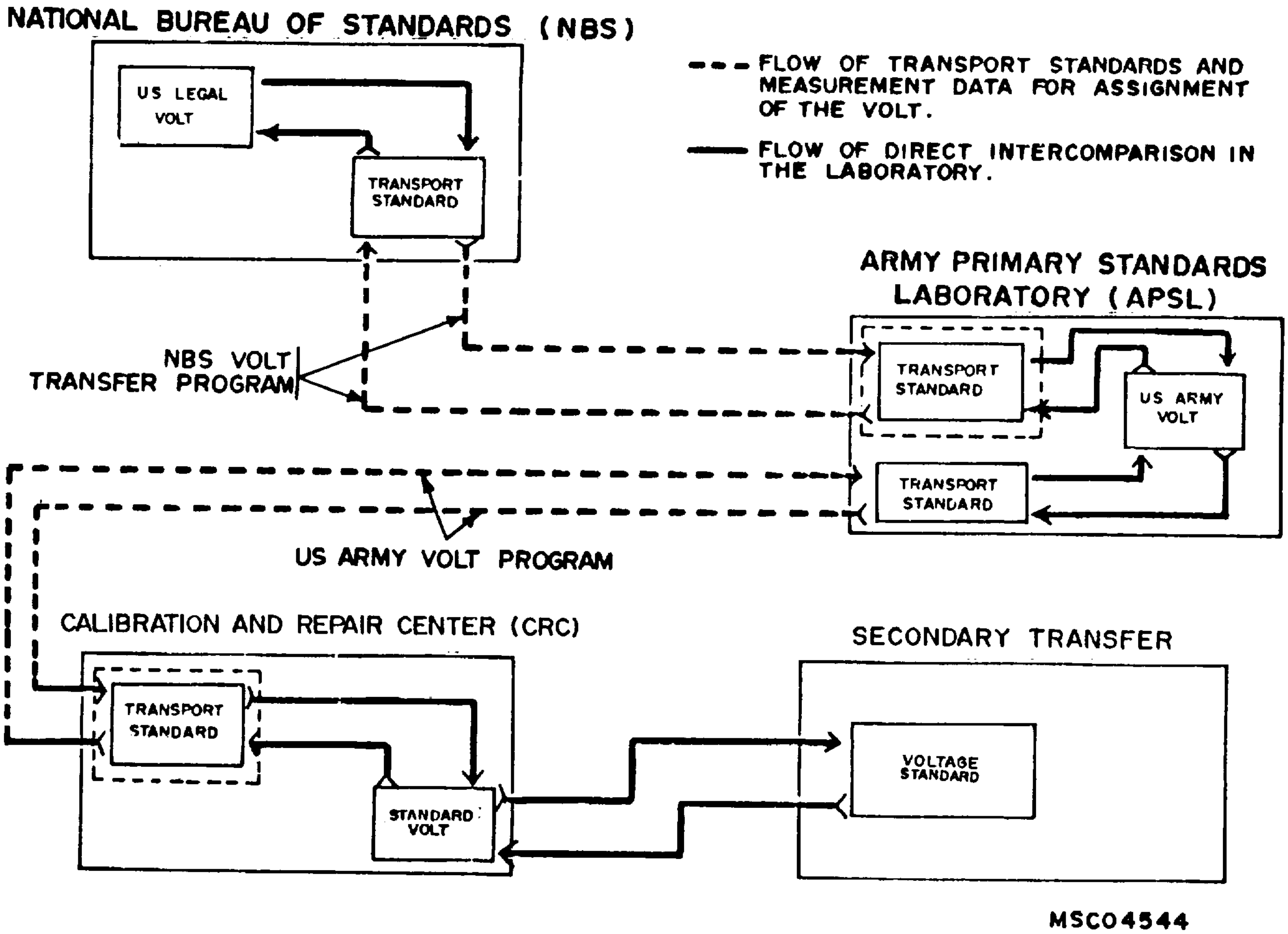

Figure 1. Flow chart for the US Amy Volt.

5. Responsibilities

a. The U. S. Army Primary Standards Laboratory will schedule, disseminate, and assign the values to the CRC voltage standards as outlined in paragraph 1**a** above and appendix A of this technical bulletin.

b. The CRCs, using saturated standard cells, will obtain and transmit the data as required to implement the program provided in paragraph 1**a** above and appendix A. They will also implement the programs provided in paragraph 1**b** above and appendix B of this technical bulletin.

6. Equipment and Accessories Required.

Table 1 lists minimum use specifications of equipment required for performance of calibration covered by this technical bulletin. Table 2 lists required accessories. When any equipment listed in table 1 is not available, equivalent items may be substituted provided that they meet the minimum use specifications.

Table 1. Minimum Specifications of Equipment Required

Item	Common name	Minimum use specifications	Manufacturer and model (part number)
A1	POTENTIOMETER	Range: 0.0 to 10000.0 μV Resolution: 0.1 μV	Guildline, Model 9931/9771 (MIS-10416)
A2	STANDARD CELLS W/ TEMPERATURE ENCLOSURE	Range: 1.018 V nominal Accuracy: ±3 μV with calibration report	Eppley, Model 106-4 (7909096) or Guildline, Model 9154 (MIS-10364)
A3	VOLTAGE REFERENCE STANDARD	Range: 1.018 V Stability: 2 μV per hour	John Fluke, Model 730A/AB (MIS-10358)

Table 2. Accessories Required

Item	Common name	Description (part number)
B1	WIRE CONDUCTOR[1] SHIELDED PAIR	Shielded pair, solid conductor, untinned copper (MIS-10312)
B2	GALVANOMETER	Guildline, Models 9460/9461 or 5214-SR21 (7907452)

[1] Fabricate to length; approximately 6 feet per unit length with common joined at junction and insulated. Junction to be formed in a fashion to yield minimum thermal EMF.

7. Procedure

a. Calibration of Cells at the CRC

(1) Program schedules, methods of shipping the transport standards, observation forms, and data transmission instructions will e controlled by the APSL to assure calibration of the CRC standard cell as required by TB 43-180. Program intervals nay be shortened or extended by the APSL to satisfy emergency needs or to meet individual requirements.

(2) Upon receipt of the transport standard at the CRC, it shall be inspected while on battery power to ascertain that it is maintaining operating temperature (periodic cycling of front panel meter). If front panel meter does not cycle, contact the APSL for guidance. If periodic cycling is evident, the transport standard shall then be connected to 115-V ac line power in the laboratory environment area in which measurements are to be made. The batteries of the transport standard shall be checked and recharged as necessary to bring them to a full-charge condition. The battery charge switch should be placed in the "Lo-Charge" position during normal operation.

(3) The transport standard shall be allowed to stabilize in the laboratory environment for at least 24 hours before observations are begun. The first set of observations will then be made using instructions of appendix A. These instructions contain a typical format for a four-cell by four-cell comparison which consists of 16 observations taken in the order specified in the observation sheet (fig. A-1, Appendix A). A series of eight observations will be taken with cells connected as in figure A-2 of appendix A, and a series of eight observations will be taken with cells connected as in figure A-3 of appendix A. For clarity and to eliminate confusion in the measurement process, the transport standard cells are designated 1 through 4 and the laboratory standards A through D.

The first set of observations shall be transmitted to the APSL immediately for analysis to determine a go or no-go condition for the transport loop.

(**a**) A go-condition will be assumed by the CRC and intercomparisons shall continue at a rate of not less than two per week until notification by the APSL.

(**b**) If a no-go condition exists, the APSL will advise the CRC to discontinue the observations and will provide further instructions as necessary.

(**c**) Data sheets will be mailed directly to the APSL, ATTN.: AMXTM-SE.

(4) Upon completion of the observations at the CRC and return of the transport standard to the APSL, the cell values shall be redetermined with respect to the US Army Volt. If this redetermination and the CRC intercomparison data are conclusive, a test report and DA Label 80 will be completed and transmitted to the CRC calibrating the enclosure(s).

(5) If upon return of the transport standard to the APSL, either the cell value redetermination or the observation data are found to be inconclusive, a rescheduling for calibration will be made and the procedure repeated.

b. Internal Surveillance of the CRC Saturated Cells

(1) Surveillance of the reference and working groups of cells will be maintained by the method outlined in appendix B. Surveillance will consist of monthly comparisons of the reference and working cells and plotting the computed value of each cell and the mean of the groups.

(2) The following computations and graphs are required:

(**a**) The value of each cell and the mean of the working group based on the mean of the reference group (compute and graph).

(**b**) The value of each cell in the reference group based on the mean of the reference group (compute and graph).

(**c**) Left-right component (compute only).

(**d**) The data sheets of the monthly comparisons of the reference and working cells used to compute **a**, **b**, and **c** above.

(3) Upon receipt of the calibration report from the APSL, the CRC will construct graphs similar to sample table B-3 of appendix B and in accordance with (**a**) through (**c**) below:

(**a**) Enter the calibration report value for each of the cells and the mean of each group at the appropriate point on the graphs at time zero and enter the date at the bottom of the graph.

(**b**) Enter the upper and lower control limits. These limits will be supplied by the APSL in the calibration report.

(**c**) At monthly intervals following calibration, use the technique of appendix A and compare the reference and working cells. Use the technique of appendix B and compute the value of all cells in terms of the mean of the reference group. Enter the computed data in the graphs.

(4) Surveillance plots are considered within control if plotted data is within upper and lower control limits.

(5) Out-of-control conditions and actions will be determined in the following manner:

(**a**) The average left-right component (residual EMF) is 0.10 µV for systems used in the CRCs. Any computed left-right component exceeding 0.30 µV indicates a requirement for determining system errors (sources of thermal EMF, cell instability, potentiometer errors, etc.). In situations where left-right component computations exceed 0.30 µV and the sources of errors cannot be traced locally, guidance should be requested from the APSL.

(**b**) Control limits on the surveillance charts signal out-of-control conditions for the cell. Individual out-of control cells in the working group should not be used as standards for calibration; however, surveillance should continue. In some cases, the condition will be temporary and will return to an in-control condition. In the event of an out-of-control working group mean, request guidance from the APSL. The reference group mean will track a straight line by definition. In the event as many as two reference group cells drift out-of-control, request guidance from the APSL.

APPENDIX A

PROCEDURE FOR CALIBRATION OF STANDARD CELL ENCLOSURES AT CALIBRATION AND REPAIR CENTERS (CRCs) BASED UPON A TRANSPORT STANDARD CELL ENCLOSURE AND INTERCOMPARISON DATA TAKEN BY CRC PERSONNEL

A-1. The CRC will complete one US Army Volt Program observation sheet (fig. A-1) for each run according to the following instructions.

a. **CUSTOMER UIC**. Enter the six-character user identification code assigned to your calibration facility.

b. TECHNICIAN. Enter the last name of the technician performing the measurements.

c. INSTRUMENT. Enter the model number of the instrument used to obtain the measurements.

d. DATE. Enter the date the measurements were made.

e. RUN NO. Enter the number of the run. (The first set of data on a cell enclosure is run number 1, the second is run number 2, etc.)

f. ENCLOSURE SERIAL NUMBER. Enter the serial numbers for the transport standard and the reference or working group in the appropriate column.

g. NOMINAL TEMPERATURE. Enter the nominal temperature of each enclosure in the appropriate column. (The nominal temperature is the "set-temperature" of the enclosure and is usually stamped near the temperature dial or on the nameplate of the enclosure. Guildline, Model 9154B enclosures have a nominal temperature of 32°C.)

h. MEASURED TEMPERATURE. Enter the measured temperature of each enclosure in the appropriate column. (Temperatures should be measured to the nearest .001°C. It is important that this data be entered in the proper blocks.)

i. **OBSERVATIONS**. Enter the observed readings in microvolts. (Resolution should be at least 0.1 µV. Example 12.3 µV).

j. REMARKS. Remarks are optional but give the technician a place to record any conditions that might have affected the data. (Example: heavy traffic in measurement area, changing environment, etc.)

A-2. Measurement Instructions

a. Caution should be exercised when connecting and disconnecting cells. Handling of wires and connectors should be minimized to keep thermal EMFs as low as possible. When observations are begun, there should not be extended delays in completing the total observation series. Observations must be made in the order specified by the numbers under the observation blocks on the observation sheet. This conserves the trend-eliminating feature of the measurement design.

b. Connect equipment as shown in figure A-2 and measure the difference between cell 1 of the transport standard and cell A of the reference or working group. Enter the observed value, with proper sign, in observation block number 1 (this is the value of cell 1 - (minus) cell A).

c. Move leads from cell 1 to cell 2 of the transport standard and measure the difference between cell 2 of the transport standard and cell A of the reference or working group. Enter the observed value, with proper sign, in observation block number 2 (this is the value of cell 2 - (minus) cell A).

d. Move leads from cell A to cell B of reference or working group and measure the difference between cell 2 of the transport standard and cell B of the reference or working group . Enter the observed value, with proper sign, in observation block number 3 on the second line (this is the value of cell 2 - (minus) cell B).

US ARMY VOLT PROGRAM

OBSERVATION SHEET

CUSTOMER UIC	TECHNICIAN	INSTRUMENT	DATE	RUN NO.

	TRANSPORT STD	LAB STD
ENCLOSURE SERIAL NUMBER		
NOMINAL TEMPERATURE		
MEASURED TEMPERATURE		

LEFT CELL	RIGHT CELL	OBSERVATION	LEFT CELL	RIGHT CELL	OBSERVATION
1	A	1	2	A	2
2	B	3	3	B	4
3	C	5	4	C	6
4	D	7	1	D	8
A	3	9	A	4	10
B	4	11	B	1	12
C	1	13	C	2	14
D	2	15	D	3	16

REMARKS: ______________________________

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Figure A-1. Sample observation sheet.

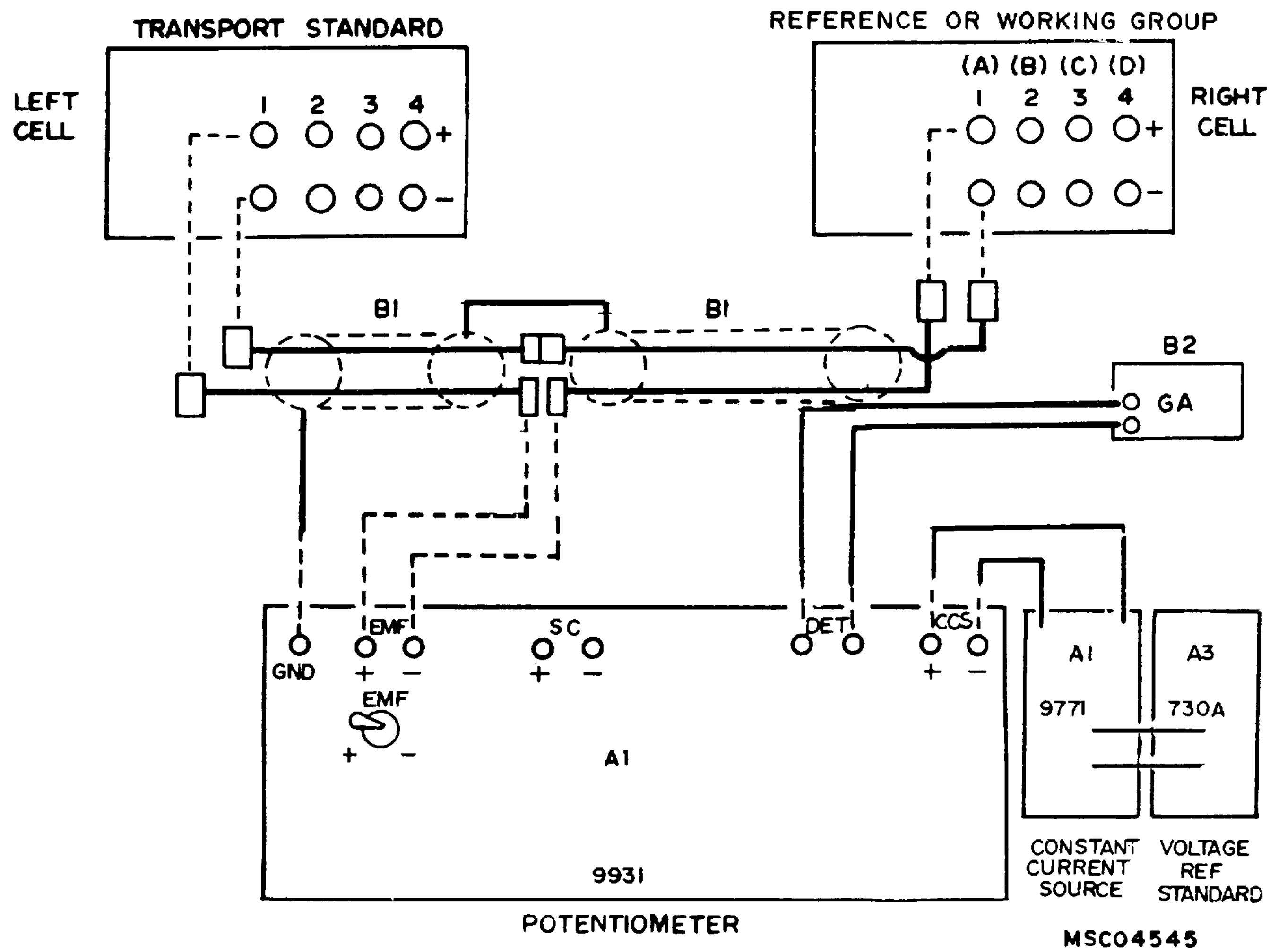


Figure A-2. Equipment setup for normal observations.

e. Alternately move the leads and make the measurements as required to obtain observations four through eight to complete the remaining five observations of this series.

f. Connect equipment as shown in figure A-3 and measure the difference between cell A of the reference or working group and cell 3 transport standard. Enter the observed value, with proper sign, in observation block number 9 of the next line (this is the value of cell A-(minus) cell 3). Note that the positive EMF lead of the potentiometer is now connected to the reference or working group and the negative lead to the transport standard.

g. Alternate move the leads and make the measurements as required to obtain observations number 10 through 16 to complete the remaining seven measurements of this series.

NOTE

The position of the potentiometer EMF-REVERSAL switch is governed by the actual difference between the cell EMFs. When the switch is the "+" position, the sign for the observation is positive (+), when in the "-" position the sign is negative (-). Figures A-2 and A-3 reflect typical switch positions for observations when the temperature of the transport standard is significantly lower than that of the reference or working group.

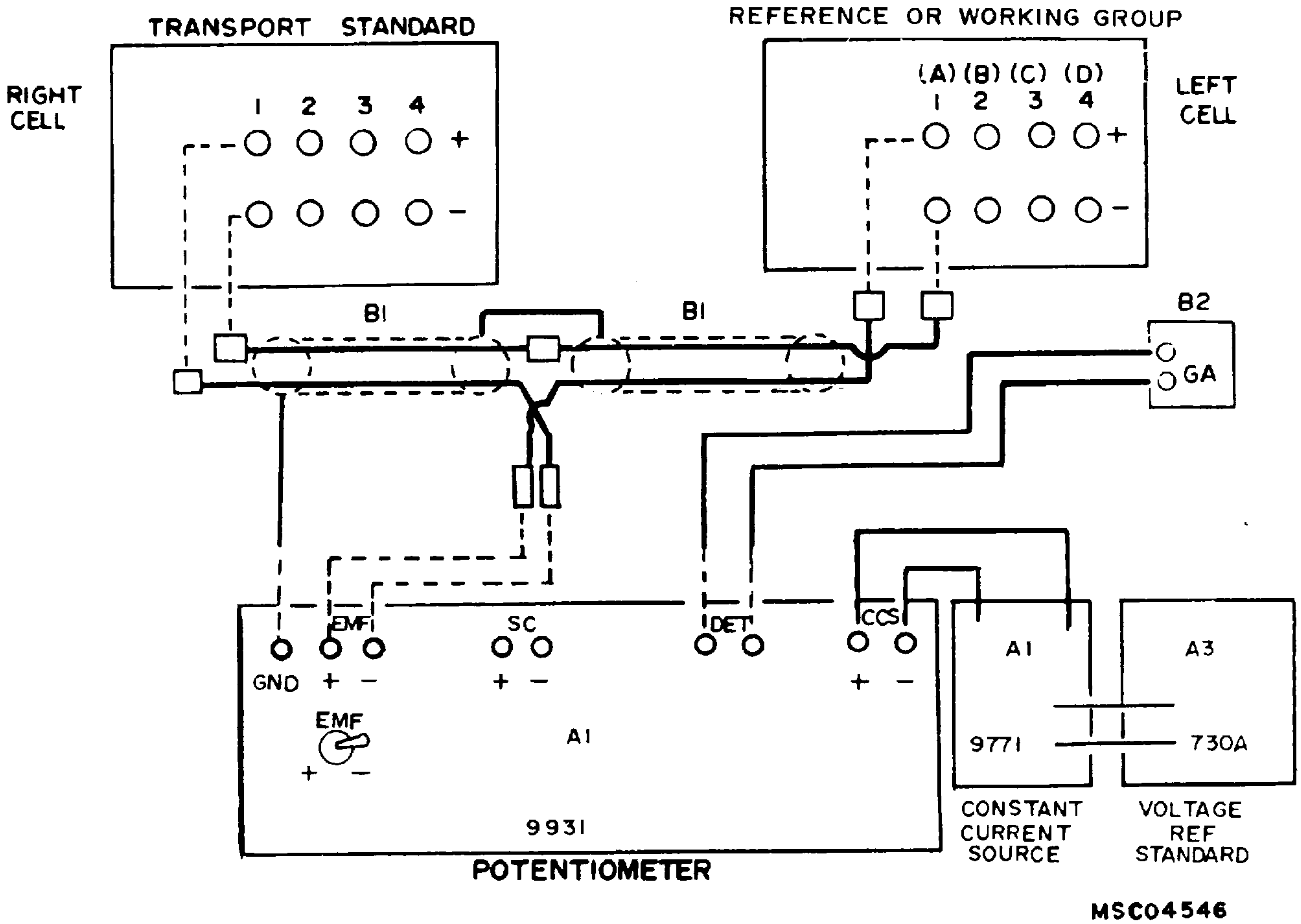


Figure A-3. Equipment setup for reverse observations.

APPENDIX B

PROCEDURE FOR REDUCTION OF DATA FOR

SURVEILLANCE AND CALIBRATION OF STANDARD CELLS

B-1. General. Data produced as a result of measurements for the APSL (Reference: Appendix A of this technical bulletin) is reduced by computer at the APSL. When surveillance measurements are made in the in terms of the CRC Volt, manual reduction of data is required. This appendix provides the method to be used for this manual data reduction and will provide the same level of accuracy as the computer program if care is taken that no errors enter the manual computations. However, in of the higher probability of errors involved in manual computations, the method should be programmed into local computers, if available, to eliminate as much as possible human-error component. Table B-1 presents a sample computer printout.

B-2. A single run containing 16 observations in a measurement design and computed (calculated) as instructed herein provides information on:

a. The EMF of each cell used in the design relative to the mean of the reference group.

b. The left-right component (the residual EMFs of the measuring system).

c. The deviation of each observation from the predicted value.

d. The standard deviation of a single observation.

B-3. Definitions of terms used for manual calculations:

a. Vref = Mean voltage of reference group.

b. Vx = Mean voltage of working group.

c. tc = Temperature EMF correction for reference and working enclosures.

d. Obs-D = Observed difference.

e. Corr-D = Corrected differences, calculated from the observed difference value and temperature EMF correction. Corr -D for observations 1 through 8 = (obs-D)-(tc). Corr-D for observations 9 through 16 = (obs-D) + (tc).

f. P = Left-right component (residual EMF), calculated from the summation of the observed differences divided by the number of observations.

$$P = \frac{\Sigma \text{obs-D}}{16}$$

g. ΔVp = The EMF difference between computed values of the cell at left and the at right.

$$\Delta Vp = EMF_L - EMF_R$$

h. DEV. = The deviation of the observed difference from the predicted difference.

$$DEV = (\text{corr-D}) - (\Delta Vp) - (P)$$

i. Sx = The observed standard deviation of a single observation.

$$Sx = \sqrt{\frac{\Sigma(DEV)^2}{N-M}}$$

Where N = number of observations, and number of cells. For two groups of 4 cells, N = 16 and M = 8 resulting in N - M = 8.

B-4. The certified mean voltage (Vref) of the reference standard cell group must be known use the computed values of the individual of the working and reference groups will terms of the reference mean and the observed differences. The nominal temperature and measured temperature at time of test for both the reference and working enclosure is also required. The measurement equation for cells of the working group appears as follows:

Table B-1. Sample Computer Printout

US ARMY TMDE SUPPORT GROUP
ARMY PRIMARY STDS LAB
STANDARD CELL ANALYSIS DATE 4121

WSACSD ---- RUN NUMBER S

	SERIAL NO.	NOM. TEMP.	MEAS. TEMP
REF GROUP	36776	32	32. 004
TEST GROUP	35926	32	32.009

CELL	EMF	DIFF (UV)
1	1. 0103374	-.27
2	1.01803451	+.50
3	1.01803295	-1.06
4	1.01803484	+.83

MAN OF REFERENCE CELLS = 1.01803401

CELL	EMF	DIFF (UV)
1	1. 01802962	+5.96
2	1.01802173	-1.92
3	1.01802133	-2.32
4	1.01802194	-1.72

MEAN OF TEST CELLS = 1.01802365

OBSERVATION NUMBER	OBSERVE DIFFERENCE (UV)	DEVIATION (UV)
1	+4.62	-00.02
2	+5.39	-00.01
3	+13.29	+00.00
4	+11.73	+00.00
5	+12.12	-00.01
6	+14.02	+00.00
7	+13.41	00.00
8	+12.32	+00.00
9	-3.41	-00.01
10	-5.32	-00.03
11	-13.15	+00.03
12	-12.10	-00.02
13	-12.48	+00.00
14	-13.25	+00 00
15	-12.65	-00.01
16	-1 .03	+00.00

STANDARD DEVIATION = .02 UV
LEFT-RIGHT COMPONENT = - 22 UV

$$Vxi = Vref + vi + tc$$

Where Vxi is the computed voltage value for the i^{th} cell in the working group; Vref is the certified mean voltage of the reference standard cell group at nominal temperature, vi is the measured differences (small between cells obtained from the measurement design, and tc is the net temperature correction for both the reference and working enclosures.

B-5. The measured data from the observation sheet is substituted into the following equations to obtain the value for each cell of the working group at nominal temperature:

$$\text{Cell A} = \overline{V}ref + \frac{(obs) + (obs10) - (obs1) - (obs2)}{4} + tc$$

$$\text{Cell B} = \overline{V}ref + \frac{(obs11) + (obs12) - (obs3) - (obs4)}{4} + tc$$

$$\text{Cell C} = \overline{V}ref + \frac{(obs13) = (obs14) - (obs5) - (obs6)}{4} + tc$$

$$\text{Cell D} = \overline{V}ref + \frac{(obs15) + (obs16) - (obs7) - (obs8)}{4} + tc$$

$$Vx \text{ (Mean of UUT Group)} = \frac{(\text{cell A})+(\text{cell B})+(\text{cell C})+(\text{cell D})}{4}$$

B-6. To obtain the value for each cell of the reference group, substitute the measured data from the observation sheet and $\overline{V}x$ from 4 above into the following equations:

$$\text{Cell 1} = \overline{V}x + \frac{(obs\ 1)+(obs\ 8)-(obs\ 12)-(obs\ 13)}{4} - tc$$

$$\text{Cell 2} = \overline{V}x + \frac{(obs\ 2)+(obs\ 3)-(obs\ 14)-(obs\ 15)}{4} - tc$$

$$\text{Cell 3} = \overline{V}x + \frac{(obs\ 4)+(obs\ 5)-(obs\ 9)-(obs\ 16)}{4} - tc$$

$$\text{Cell 4} = \overline{V}x + \frac{(obs\ 6)+(obs\ 7)-(obs\ 10)-(obs\ 11)}{4} - tc$$

B-7. Temperature Corrections

a. Temperature corrections must be computed for both the reference and working group when the temperatures of the enclosures at the time of test are different from their nominal temperatures. These corrections may be closely approximated by the following equation.

$$Tc = \Delta t\, C_t$$

Where: Tc is the temperature correction
Δt is the actual temperature minus nominal temperature
C_t is the temperature coefficient at the nominal temperature

The most common nominal temperatures for standard cell maintenance are 28°C, 30°C, 32°C, and 35°C. Temperature coefficients at these temperatures are given below.

C28 = -54 µV/°C
C30 = -57 µV/°C
C32 = -59µV/°C
C35 = -62 µV/°C

b. For an example, consider the data in figure B-1. Nominal temperature of the transport standard is 32°C. Measured temperature is 32.004°C.

Then $Tc = \Delta t\, C_t$
Tct = .004 x (-59)
Tct = -.236 µV for the transport standard

Nominal temperature of the lab standard is 32°C. Measured temperature is 32.009°C.

Then $Tcl = \Delta t\, Ct$
Tcl = .009 x (-59)
Tcl = -.531 µV for the lab standard

c. The correction tc used in this technical bulletin corrects voltages to the nominal temperature of both enclosures and is computed as follows:

tc = Tct - Tcl

For this example:

tc = -.236 - (-.531)
tc = +.295 µV

This is the quantity that would be substituted in the equation (B-4 above) for tc.

B-8. Sample computations for the data in figure B-1.

US ARMY VOLT PROGRAM
OBSERVATION SHEET
(SAMPLE)

CUSTOMER UIC	TECHNICIAN	INSTRUMENT	DATE	RUN NO.
WSAC SD		9931	30 APR84	5

	TRANSPORT STD (REFERENCE GROUP)	LAB STD (WORKING GROUP)
ENCLOSURE SERIAL NUMBER	36776	35926
NOMINAL TEMPERATURE	32.000	32.000
MEASURED TEMPERATURE	32.004	32.009

LEFT CELL	RIGHT CELL	OBSERVATION	LEFT CELL	RIGHT CELL	OBSERVATION
1	A	+4.62 (1)	2	A	+5.39 (2)
2	B	+13.29 (3)	3	B	+11.73 (4)
3	C	+12.12 (5)	4	C	+14.02 (6)
4	D	+13.41 (7)	1	D	+12.32 (8)
A	3	-3.41 (9)	A	4	-5.32 (10)
B	4	-13.15 (11)	B	1	-12.10 (12)
C	1	-12.48 (13)	C	2	-13.25 (14)
D	2	-12.65 (15)	D	3	-11.08 (16)

REMARKS: ______________________________

Figure B-1. Sample observation sheet completed.

a. Computation of Cell Values for Working Group

Cell A =

$\overline{V}ref$ + $\frac{(obs\ 9)+(obs\ 10)-(obs\ 1)-(obs\ 2)}{4}$ + (tc)

= $\frac{1018034.01+ (-3.4\ 1)+ (-5.32)-(4.62)-(5.39)}{4}$ +(.295)

= 1018034.01 - 4.685+ .295

= 1018029.62µV = 1.01802962 V

Cell B =

$\overline{V}ref$ + $\frac{(obs\ 11)+(obs\ 12)-(obs\ 3)-(obs\ 4)}{4}$ +(tc)

= $\frac{1018034.01+ (-13.15)+(-12.10)-(13.29)-(11.73)}{4}$ +(.295)

= 1018034.01- 12.567+ .295

= 1018021.74 µV = 1.01802174 V

Cell C =

$\overline{V}ref$ + $\frac{(obs\ 13)+(obs\ 14)-(obs\ 5)-(obs\ 6)}{4}$ +(tc)

= 1018034.01+(-$\frac{12.48)+(-13.25)-(12.12)-(14.02)}{4}$ +(.295)

= 1018034.01- 12.9675 + .295

= 1018021.34 µV = 1.01802134 V

Cell D =

$\overline{V}ref$ + $\frac{(obs\ 15)+(obs\ 16)-(obs\ 7)-(obs\ 8)}{4}$ +(tc)

=1018034.01+ $\frac{(-12.65)+(-11.08)-(13.41)-(12.32)}{4}$ +(.295)

= 1018034.01. - 12.365+ .295

= 1018021.94 µV = 1.01802194 V

b. Calibration of Cell Values for Reference Group

Cell 1 =

$\overline{V}x$ + $\frac{(obs\ 1)+(obs\ 8)-(obs\ 12)-(obs\ 13)}{4}$ - (tc)

= $\frac{1018023.65+ (4.62)+(12.32)-(-12.10)-(-12.48)}{4}$ -(.295)

= 1018023.65 + 10.38 - .295

= 1018033.74 µV = 1.01803374 V

Cell 2 =

$\overline{V}x$ + $\frac{(obs\ 2)+(obs\ 3)-(obs\ 14)-(obs\ 15)}{4}$ - (tc)

= $\frac{1018023.65+ (5.39)+(13.29)-(-13.25)-(-12.65)}{4}$ -(.295)

= 1018023.65 + 11.145 - .295

= 1018034.50 µV = 1.01803450 V

Cell 3 =

$\overline{V}x$ + $\frac{(obs\ 4)+(obs\ 5)-(obs\ 9)-(obs\ 16)}{4}$ - (tc)

= 1018023.65+$\frac{(11.73)+(12.12)-(-3.41)-(-11.08)}{4}$ -(.295)

= 1018023.65 + 9.585 - .295

= 1018032.94 µV = 1.01803294 V

Cell 4 =

$\overline{V}x$ + $\frac{(obs\ 6)+(obs\ 7)-(obs\ 10)-(obs\ 11)}{4}$ - (tc)

= 1018023.65+ $\frac{(1\ 4.02)+(13.41)-(-5.32)-(-13.15)}{4}$ -(.295)

= 1018023.65 + 11.475 - .295

= 1018034.83µV = 1.01803483 V

c. Computation of Deviations (Table B-2). The deviations of a single observation are computed and the 16 deviations are then squared and summed, $(DEV)^2$, the sum is then utilized to compute the standard deviation of a single observation (appendix B, paragraph 2**i**). These computations are useful only in that they signify a good run as opposed to a bad run. If the deviations or standard deviation exceed 0.3 µV, the run is usually suspected and a new run is made (optional for surveillance).

Table B-2. Computation of Deviations

Observation	EKF_L	EKF_R	ΔVp	(Corr-D)-(ΔVp)-(P)	DEV (µV)
1	1.01803374	1.01802962	4.12	(4.325)-(4.12)-(.22)	-0.02
2	1.01803450	1.01802962	4.88	(5.095)-(4.88)-(.22)	-0.01
3	1.01803450	1.01802174	12.76	(12.995)-(12.76)-(.22)	+0.02
4	1.01803294	1.01802174	11.20	(11.435)-(11.20)-(.22)	+0.02
5	1.01803294	1.01802134	11.60	(11.825)-(11.60)-(.22)	+0.01
6	1.01803483	1.01802134	13.49	(13.725)-(13.49)-(.22)	+0.02
7	1.01803483	1.01802194	12.89	(13.115)-(12.89)-(.22)	+0.01
8	1.01803374	1.01802194	11.80	(12.025)-(11.80)-(.22)	+0.01
9	1.01802962	1.01803294	-3.32	(-3.115)-(-3.32)-(.22)	-0.02
10	1.01802962	1.01803483	-5.21	(-5.025)-(-5.21)-(.22)	-0.04
11	1.01802174	1.01803483	-13.09	(-12.855)-(-13.09)-(.22)	+0.02
12	1.01802174	1.01803374	-12.00	(-11.805)-(-12.00)-(.22)	-0.03
13	1.01802134	1.01803374	-12.40	(-12.185)-(-12.40)-(.22)	-0.01
14	1.01802134	1.01803450	-13.16	(-12.955)-(-13.16)-(.22)	-0.02
15	1.01802194	1.01803450	-12.56	(-12.355)-(-12.56)-(.22)	-0.02
16	1.01802194	1.01803294	-11.00	(-10.785)-(-11.00)-(.22)	-0.01

d. Computation of Standard Deviation of a Single Observation

$$Sx = \sqrt{\frac{\Sigma(DEV)^2}{N-M}}$$

$$= \sqrt{\frac{.0063}{8}}$$

e. Computation of Residual EMF

$$P = \frac{\Sigma obs-D}{16}$$

$$P = \frac{3.46}{16} = .216\mu V$$

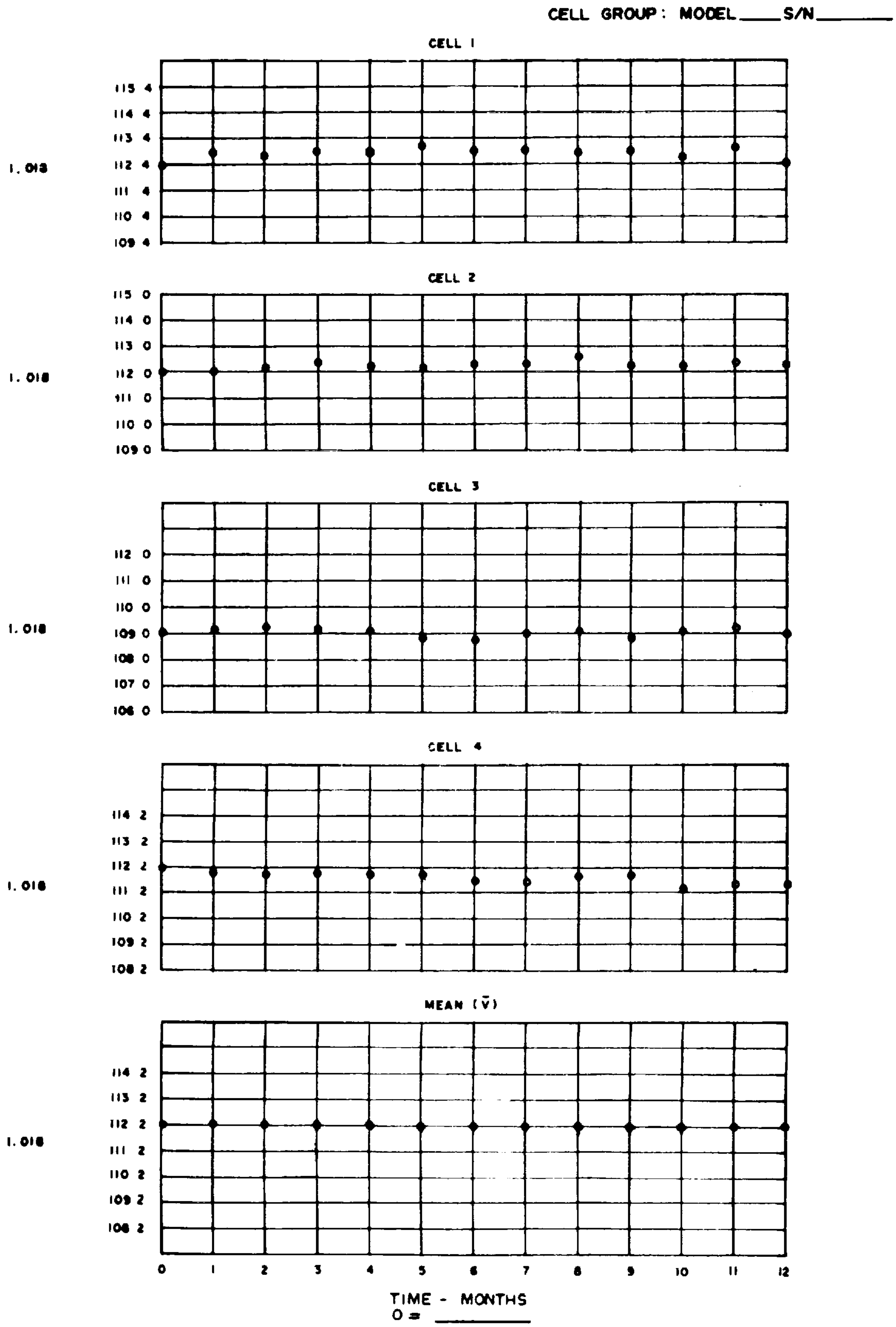
NOTE

Paragraphs c and d above are provided only for facilities that calibrate standard cells. These computations need not be performed during surveillance of ACF standard cells.

NOTE

Values may vary slightly from the computer analysis due to rounding of numbers.

Table B-3. Sample Plot of Saturated Standard Cells



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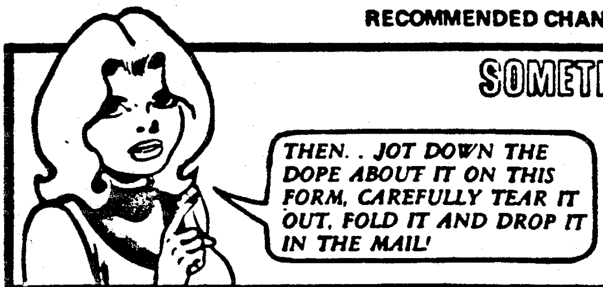

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