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MODIFIED AN/PSM-13 FOR FIELD TESTING BA-4386/PRC-25.(U)

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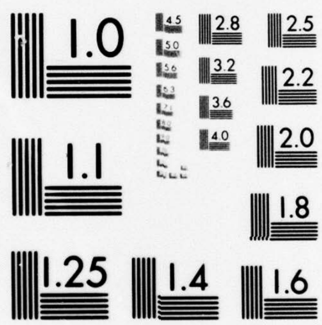
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Research and Development Technical Report

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MODIFIED AN / PSM-13 FOR FIELD TESTING BA-4386 / PRC-25

Donald B. Wood

Electronics Technology and Devices Laboratory

January 1977

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Test set, Battery, AN/PSM-13, using the loaded voltmeter technique, was designed to predict minimum remaining capacity for a number of zinc-carbon batteries. When the magnesium Battery BA-4386/PRC-25 was introduced into the military supply system, Test Set Battery AN/PSM-13 was used with this battery but with inaccurate results. A program was established to determine the factors that influence the operation of the AN/PSM-13 with the magnesium Battery BA-4386/PRC-25 and to design and fabricate a modified version of the tester which would adequately test the battery. Two loaded voltage — (CONT)

20. ABSTRACT (CONT)

values were selected to predict the battery state-of-charge relative to its use in Radio Set AN/PRC-77. The upper voltage point indicates that at least 85% of the battery's fresh capacity is remaining; the lower point no less than 15%. A reading between the two points indicates the battery has at least 15% of its capacity remaining; however, it could have up to 100%. The results of the evaluation to determine the accuracy of the modified AN/PSM-13 in predicting the capacity remaining in Battery BA-4386/PRC-25 are presented.

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MODIFIED AN/PSM-13 FOR FIELD TESTING BA-4386/PRC-25

INTRODUCTION

Test Set, Battery, AN/PSM-13, was designed to be used with six military type zinc-carbon batteries, including Battery BA-386/PRC-25, to indicate their capacity or state-of-charge at a certain minimum capacity level. It consists of Test Set Battery TS-1301/PSM-13 and six adapter connectors. The AN/PSM-13 uses the loaded voltage technique to estimate the capacity of a battery. With this technique the battery is placed under an appropriate resistive load and the voltage registered on a voltage scale calibrated to reflect the condition of the battery. The test set indicates whether a battery is in good or bad condition, or in an intermediate condition that would provide at least eight hours of service in normal use. The battery condition is shown on a meter located in the TS-1301/PSM-13. The arrangement shown in Figure 1 is similar to that used for the BA-386/PRC-25.

When the Magnesium Battery BA-4386/PRC-25 entered the supply system and replaced the BA-386/PRC-25, the adapter connector used for testing Battery BA-386/PRC-25 was employed for the new battery. This proved to be faulty since data accumulated during use showed that the AN/PSM-13 did not provide accurate data relative to the condition of or the capacity remaining in Battery BA-4386/PRC-25. Subsequently, a program was initiated to determine if the inadequacies of the AN/PSM-13 could be overcome with modifications so that it could be used to reliably predict the capacity remaining in Battery, BA-4386/PRC-25.

The AN/PSM-13 Improvement Program consisted of the following three phases:

1. Study of the battery performance variables that would have an influence on the loaded voltmeter technique employed in the AN/PSM-13.

2. Design and fabrication of a Modified AN/PSM-13 (PSM-13) for adequately testing Battery BA-4386/PRC-25.

3. Determine the influence of various factors on the modified AN/PSM-13 on its ability and suitability in predicting the state-of-charge of Battery BA-4386/PRC-25. This was investigated using different applications and by assessing the influence of stand time between use on the battery's remaining capacity itself.

The program to modify the AN/PSM-13 for use with Battery BA-4386/PRC-25 was initiated in July 1973 under Contract DAAB07-73-C-0300 with Barnes and Reinecke, Inc. The contractual effort addressed the variables that influence the tester operation and the design and fabrication of a modified tester. Several typical rates of battery discharge and various storage periods and temperatures were used to generate the data on which the redesign of the test set was based. Analysis of these test data were performed at ECOM. The relationship that existed between the remaining capacity of the battery and the loaded voltmeter test reading was determined and used as a basis for developing the redesign rationale.

The evaluations conducted at ECOM established the limits of use of the modified AN/PSM-13 relative to the influence of discharge load, use patterns, battery manufacturer, and battery storage. During the evaluation, lots of five batteries were subjected to various lengths of discharge (different stages of discharge) under loads representing the operation of the AN/PRC-77, the KY-38 with the AN/PRC-77, and the AN/PPS-15. The batteries were then screened, i.e., subjected to the loading of the PSM-13 and the battery voltage observed. The batteries were then stored at 21°C for periods of one or seven days, screened again with the PSM-13, and discharged to end voltage under the respective loading. The capacity-screening voltage data were then evaluated to determine their correlation. This procedure was repeated on the AN/PRC-77 use condition with batteries that had been stored for four weeks at 71°C. The influence of 12 hours on, 12 hours off type discharge was also determined with the AN/PRC-77 loading.

EVALUATION PROGRAM AND RESULTS

Phase 1. Determination of Variables Influencing Loaded Voltage Readings

Experimental Procedure (Phase 1)

Under the Barnes and Reinecke program, BA-4386/PRC-25 batteries that were "as received" from Army storage depots and others that were stored four weeks at 71°C after receipt were divided into groups as follows for use with the discharge loads and duty cycles shown:

		Predischarge Storage Conditioning Code			
		A		D	
		Maker Code			
Discharge Loads	Duty Cycle	K	L	K	L
9.0 Ohms/ 227 Ohms	2 min/18 min	3	3	6	6
14.2 Ohms/ 291 Ohms	2 min/18 min	4	4	4	8
30.0 Ohms	Continuous	-	-	6	6

A = as received
D = Stored 4 weeks at 71°C
K = Batteries made by Union Carbide
L = Batteries made by Ray-O-Vac Division
Number represents the number of batteries.

The batteries were first discharged at 21°C to remove 50 to 70% of their capacity under the loads and duty cycles indicated. Following this initial discharge, the batteries were stored for 1 day at 21°C and then subjected to a loaded voltage screening thru 30 ohms, 14 ohms, 9 ohms, and 4 ohms, respectively, for thirty seconds. After this loaded voltage reading, the batteries were stored an additional six days at 21°C and then subjected to another loaded voltage screening as described. The batteries were then discharged to end voltage (10.0 volts) employing the loads and duty cycles indicated.

Discussion and Results (Phase 1)

Presented in Figures 2, 3, and 4 are the data obtained by Barnes and Reinecke. The data points shown represent the capacity obtained after the seven day stand versus the loaded voltage reading after a one day stand. The one day data were plotted because it had less variance than the seven day data. The solid lines trace the outer limits of data while the broken lines allow an estimate of the variance in capacity at a selected voltage level.

First, the data shows that near the end of a discharge there appears to be a linear response of voltage with respect to capacity. The slope of this response would allow one to select a level of screening voltage that would indicate whether a battery had a predetermined level of capacity remaining. For example, in Figure 3 a reading of 9.0 volts or more thru a 4.0 ohm screening resistor would indicate that the battery had 15 or more hours of capacity remaining if it were to be used under the load conditions shown.

Second, the data of Figure 3 shows that with the 4 ohm screening load the variance in capacity is less than that obtained with a 9 ohm screening load. In Figures 2 and 4 the variance is only slightly larger with the 4.0 ohm screening load than it is with the 9.0 ohm screening load. It was judged that the steeper slope obtained with the 4.0 ohm load makes the readings more sensitive. Data for the 30 and 14.2 ohm screening loads are not shown because there was less slope in their voltmeter reading vs capacity plots.

On the basis of this data and the observations made, it was determined that a 4 ohm screening load would be used in the design and fabrication of the PSM-13.

Phase 2. Design and Fabrication of a Modified Test Set, Battery, AN/PSM-13

The modified test set consists of a new adapter connector, which applies the 4 ohm screening resistance to the battery being tested, and a decalcomania to be applied to the meter face of the present TS-1301/PSM-13. Both items, which can be seen in Figure 1, were fabricated by Barnes and Reinecke.

The schematic of the new adapter connector is shown in Figure 5. The 4.0 ohms of resistance is shown as R1 to R5, each resistor being 20 ohms. An LVA75A diode, made by TRW, is shown as VR1. This diode suppresses the first 7.5 volts not to register on the meter, thus improving the accuracy of the voltage readings. The 44.2K ohm resistor, R6, acts in parallel with the 4.0 ohm resistance so that the meter of the TS-1301/PSM-13 will read the voltage of the battery being tested between 7.5 and 12.5 volts.

The details of the decalcomania are shown in Figure 6. As originally designed, the two points labeled F and G are used to indicate the capacity remaining in the battery under test and will be discussed in detail under the Phase 3 program where the data used in establishing their location was obtained.

These modifications do not alter the normal operation of the AN/PSM-13 for testing other batteries, since all of the components used to screen Battery BA-4386/PRC-25 are located in the new adapter connector and the new voltage scale, located on the top of the meter face glass as shown in Figure 1, allows the original meter face to be used.

Phase 3. Determination of Factors Influencing Accuracy of the Modified AN/PSM-13

Experimental Procedure (Phase 3)

An extensive program was pursued to determine the factors that would influence the accuracy of the modified AN/PSM-13 in predicting the capacity of Battery, BA-4386/PRC-25 in the more widely used applications. Six groups of batteries, identified as Groups A thru F, were subjected to the evaluation plan shown in Table 1. Except as indicated under pre-discharge storage for Group D, the program was carried out at an ambient temperature of 21^{o}C.

All batteries were screened with the PSM-13 prior to the start of a discharge. For Groups A thru D the following also applied:

1. The batteries were subjected to an initial discharge for the indicated period using the designated load and duty cycle.

2. Following the initial discharge, i.e., within five (5) minutes after the discharge was interrupted, each battery was screened with the PSM-13.

3. The batteries were then stored on open circuit. For storage designated as one day, the actual time varied between sixteen and twenty-four hours.

4. After storage, the batteries were screened with the PSM-13 and subsequently discharged to 10.0 volts with the indicated load and duty cycle.

Table 1. Evaluation Plan

Group A

Initial Discharge Time									
0 Hrs	8 Hrs	16 Hrs	20 Hrs	24 Hrs	32 Hrs	40 Hrs	48 Hrs	52 Hrs	Storage Following Initial Discharge
X	X	X	X	X	X	X	X	X	1 day
	X				X	X	X		7 days

Discharge Load applied: 14.2 ohms for 2 minutes, 291 ohms for 18 minutes, cycle repeated - simulates operation of the AN/PRC-77.

Group B

Initial Discharge Time							
0 Hrs	5 Hrs	12 Hrs	20 Hrs	24 Hrs	28 Hrs	32 Hrs	Storage Following Initial Discharge
X	X	X	X	X	X	X	1 day
X		X	X				7 days

Discharge Load applied: 9 ohms for 2 minutes, 227 ohms for 18 minutes, cycle repeated - simulates operation of the KY-38 with the AN/PRC-77.

Group C

Initial Discharge Time				
4 Hrs	8 Hrs	11 Hrs	15 Hrs	Storage Following Initial Discharge
X	X	X	X	1 day

Discharge Load applied: 30 ohms, continuously - simulates operation of the AN/PPS-15.

Table 1. Evaluation Plan (CONT)

Group D

Pre-discharge Storage	Initial Discharge Time: 8 Hrs	32 Hrs	40 Hrs	45 Hrs	Storage Following Initial Discharge
4 weeks @ 71°C	X	X	X	X	1 day

Discharge Load applied: Same as Group A.

Group E

Five batteries discharged to cut-off voltage of 10 volts under the load conditions shown for Group A. Discharge was interrupted every 12 hours at the end of an 18 minute period, left on open circuit for 5 minutes, and screened with the PSM-13 before resuming the discharge.

Group F

Five batteries discharged under the load conditions shown for Group A on a 12 hour on, 12 hour off basis. The batteries were screened with the AN/PSM-13 before and after each 12 hour period. Ten volts was the end voltage.

X - indicates 5 batteries submitted to the indicated discharge.

Usually each set of five batteries used in the evaluation contained 3 made by Union Carbide Corporation (UCC) and 2 made by Ray-O-Vac (ROV). Various dates of manufacture for the batteries were employed, as shown in the following tabulation, to determine if the age of the battery had an influence on the results:

Union Carbide		Ray-O-Vac	
Date of Manufacture	Quantity	Date of Manufacture	Quantity
10/72	22	09/73	2
12/72	24	12/73	6
10/73	50	01/74	9
		02/74	8
		03/74	2
		07/74	8
		08/74	12
		09/74	8
		10/74	4
TOTAL	96	TOTAL	59

GRAND TOTAL 155

Discussion and Results (Phase 3)

Plots of the PSM-13 voltage reading (VR) with the Modified Adapter Connector versus hours of capacity remaining (HCR) in Battery BA-4386/PRC-25 for the various discharge conditions are presented in Figures 7 thru 14.

Group A

In Figure 7 the data for the 14.2 ohm/291 ohm discharge on a 2/18 minute program show a scatter indicating some broadly distributed response between HCR and VR. This data plot is judged to be the most representative curve of the various groups and programs investigated. The broken line, labeled C, represents an estimate of the mean of the data and is presented to show the following: The region between 20 and 45 HCR is essentially level, i.e., the slope is near zero. With this characteristic, it is impossible to accurately predict the HCR using a four ohm loaded voltage reading in that capacity region. Only near both ends of the discharge, i.e., below 20 hours and above 45 hours, is there magnitude to the slope of the VR-HCR plot. It should be stated that for the purpose of this analysis it was assumed that the VR-HCR relationship in the region below 8.4 volts and 10 hours capacity remaining is linear and follows the broken lines shown. This assumption is supported by the data in Figure 3 below the 10 hour capacity level. Because of the slopes shown, the VR in the end regions can be used to predict the HCR in the battery; however, even in the end regions only an estimate of the HCR can be made because of the amount of scatter in the data.

The rationale used in selecting the VR in these regions and how it can be used in predicting the HCR follows: The two broken lines in Figure 7, labeled A and B, represent what is selected to be the upper limits of the data in the 0 to 20 HCR. Both broken lines were drawn since there is a difference between the same day reading, labeled A, and the reading taken either after 1 day or 7 days stand, labeled B, relative to the deviation in the data; however, it is estimated that the mean of each of the groups of data is about the same. Based on these patterns of VR versus HCR, it is proposed that two voltage levels can be selected. One voltage level, for example F, is near the end of the discharge where, if the modified PSM-13 reading falls below that value, the battery has less than what is considered to be a usable amount of capacity. The other voltage level is near the beginning of the discharge, and if the VR is above that value the battery is capable of providing most or all of its original capacity. The voltage levels selected are considered safe, i.e., a certain percentage of batteries will give more than the selected minimum capacity, but nearly none will give less. The price that must be paid in order to insure that a user have confidence in the meaning of the reading obtained is that some usable batteries will be rejected as unusable.

The readings selected for Group A are 8.4 volts, labeled X, for the same day readings and 8.6 volts, labeled F, for the 1 or 7 day readings. These represent about 9 hours or 15% of a 60 hour capacity battery. The lines for the upper limit were selected to insure that 85% capacity would be remaining if the 10.0 volt (same day) (line Y) or 10.2 (1 or 7 day) (line D) reading were used. Because of the lack of slope in between the selected readings, a reading that falls in that region only signifies that the battery has at least 15% of its capacity remaining and it could have a lot more, up to 100%.

Each of the other Group's results will now be discussed individually and the results summarized following the discussion. It has been assumed that each group follows the general pattern just described for Group A, although the data obtained is not as extensive for some of the groups and the shape of the curve is not as evident as it is with Group A.

<u>Group B</u>

Presented in Figure 8 is the data representing the 9.2 ohm/227 ohm discharge on a 2/18 minute program. In the 5 to 10 HCR region the two broken lines, A and B, represent an estimate of the upper limits of the response curve for the same day VR and the 1 or 7 day VR's, respectively. A voltage reading of 9.2 volts, labeled E, based on the same day readings, was selected to indicate that any battery giving this reading or more will provide at least 15% of its original capacity. The capacity in this case is 6 hours based on a mean total capacity of 40 hours. The value selected on the basis of the 1 or 7 day readings is 8.9 volts, labeled F. Using the 1 or 7 day readings with this voltage would result in more usable batteries being rejected as unusable.

The VR provided at the high end indicated by the lines C and D also vary depending on whether one studies the readings taken immediately after discharge (line C) or if a period of 1 to 7 days is allowed to elapse before the reading is taken (line D). The VR value selected is 10.2 volts based on the same day data. It can be stated that no battery rendering this reading or better will give less than 85% of the original capacity of the battery, under the loading cited, based on a total capacity of 40 hours. The deviation in the 1 or 7 day readings raises the high capacity assurance voltage level to about 10.8 volts. The use of this higher value would result in more batteries not being judged in excellent condition when they actually would be.

Presented in Figures 9 and 10 are the same data that are presented in Figure 8, but sorted as to manufacturer and as to storage period after which the second PSM-13 reading was taken, as indicated. The mean voltage is substantially lower for UCC batteries, based on same day readings, as indicated by the unlabeled broken line over drawn on the ROV data (Figure 10). The difference in mean voltage level is attributed in part on the difference in the age of the batteries. The month and year of manufacture is noted on both figures. The evaluations were conducted in December 1974 and January 1975 when the two groups of UCC batteries were over two years old and the ROV batteries were, for the most part, less than a year old. However, in the important region around 6 or 7 hours of remaining capacity, the slope of the upper limit line, labeled A for ROV and B for UCC, is about the same for both supplier's batteries, especially if the same day readings are compared.

The UCC battery voltage falls during storage after the first discharge and for the most part the ROV battery voltage rises. The only drops in the ROV data are in the 10 hour region where the UCC battery voltage falls the most and appreciably more than ROV's batteries. Also, in the same region the seven day voltage is clearly lower than the one day voltage. It is assumed that in this region of discharge the battery inhibition system may have broken down.

The differences between suppliers evident in Group B were also noted in Group A.

Group C

In Figure 11 the VR versus HCR data is presented for the 30 ohm discharge program. The upper limit of the same day reading, line A, is above the 1 or 7 day reading line B. This indicates that because of the lower current drain during discharge (as compared to Groups A and B), the cell recovery process is not having as much influence on the battery voltage as was experienced in the other discharge programs. The 15% point, corresponding to 3 hours of service remaining, is 8.0 volts, labeled E, for the same day reading and 7.5 volts, labeled F, for the 1 or 7 day readings. The natural break point at the higher end occurs at about 14 hours of service with a reading of 10 volts. This corresponds to at least 75% capacity remaining, based on a 20 hour capacity battery.

Group D

In order to assess the influence of storage on the VR, batteries were stored 4 weeks at 71°C followed by a 14.2 ohm/291 ohm discharge on a 2/18 minute program (as in Group A). The results are presented in Figure 12. The mean VR versus HCR, line B, is depressed as can be seen when it is compared to the readings obtained from fresh batteries, shown by line A, employing the same loading. The same day readings are depressed even more. The upper limit lines are shown for the 1 or 7 day readings (line C) and for the same day readings (line D). These lines are well below that (line E) obtained for fresh batteries. The screening values selected for 15% HCR are 7.8V (same day), labeled F and 8.05V (1 or 7 day), labeled G, while 9.7V, labeled H, was selected to represent at least 85% capacity remaining.

Group E

Figure 13 shows the voltage vs capacity response when Battery BA-4386/PRC-25 is discharged continuously on the 14.2 ohm/291 ohm, 2/18 minute program with a VR taken every twelve hours. The upper limit point, labeled A, for 15% minimum capacity remaining was selected as 8.2 volts while the reading to show at least 85% capacity remaining, labeled B, was selected as 10.1 volts.

Group F

Presented in Figure 14 is a plot of the VR taken immediately after discharge was interrupted and after a twelve hour stand, versus capacity remaining as indicated. The capacity was removed in twelve hour increments on the 14.2 ohm/291 ohm, 2/18 minute discharge program. The spread of the voltage readings is greater and the mean is lower after the twelve hour stand period when compared to readings taken right after the discharge is interrupted. The upper limit, labeled A, to be used to predict a minimum capacity of 15% remaining was judged to be 8.2 volts. The capacity point, labeled B, representing at least 85% capacity remaining, is not well defined, but was selected to be 9.9 volts.

Summation (Phase 3)

Presented in Table 2 is a summary of the VR's selected for at least 15% capacity remaining and at least 85% capacity remaining in Battery BA-4386/PRC-25 for the programs studied. The voltage level for the 15% capacity point depends upon the rate of discharge. If the rate of discharge is high, it results in a larger recovery of the battery voltage after a partial discharge. The Group C discharge, which is considered to be the lowest rate discharge, gave the lowest reading in comparison to Groups A and B. The discharge rates of Group A and B batteries are considered higher because of the polarization taking place during the two minute portion of the discharge (six and four hour rate for Group A and B, respectively). As indicated by the Group D results, storage for four weeks at 71°C before discharge depresses the loaded battery voltage when compared to batteries not subjected to this storage.

The 85% capacity remaining response values do not depend on rate as much as the 15% values do if the Group C data is ignored. The lack of a natural break in Group C data may have lead to the lower voltage values. The reason for this behavior cannot be assessed from the data gathered, but it is probably current drain rate dependent since the voltage level does not drop as fast with the lower discharge rate.

Table 2. Minimum Voltage Reading With Modified AN/PSM-13 Required to Obtain Indicated Capacity

% Minimum Capacity Remaining	Reading Day	GROUP A	B	C	D	E	F
15	Same	8.4	9.2	8.0	7.8	8.2	8.2
	1 or 7	8.6	8.9	7.5	8.05	N/A	N/A
85	Same	9.9	10.2	11* /10**	9.7	10.1	9.9
	1 or 7	10.1	10.8	ND	ND	N/A	N/A
Rate of Discharge in Hours	-	6.0	4.0	20	6.0	6.0	6.0
Fresh Mean Capacity in Hours	-	60	40	20	60	60	60

Notes: ND - Indicates no data was available on which to base an estimate.
N/A - Indicates not available.
* - 17 Hours - 70% capacity
** - 14 Hours - 85% capacity

To simplify the tester for the user a value of 8.4 volts was selected for the conditions described herein to provide a criteria for a battery with a usable amount of capacity remaining relative to mission life. Ten (10.0) volts was selected to indicate the value above which a user would be assured of at least 80% capacity remaining. These points are shown on the decalcomania of Figure 6 as F and G, respectively. A summary of the estimates of what a battery will provide in terms of minimum capacity in hours, percent of capacity, and mean capacity for each of the above readings, based on use and previous history, is indicated by the following data.

Modified AN/PSM-13 Reading	8.4 Volts			10.0 Volts		
	Minimum		Mean*	Minimum		Mean*
Group	Hrs	%**	Hrs	Hrs	%**	Hrs
A	9	15	16	49	82	55.5
B	2.5	6	7	34	85	40
C	4	20	7	14	70	16
D	22	36	26	55	92	61
E	11	18	15	48	80	ND
F	11	18	ND	ND	-	ND

* - Based on indicated PSM-13 reading.

** - Based on total mean capacity in hours presented in Table 2.

The values of 8.4 and 10.0 volts are shown in Figures 7, 8, 11, 12, 13 and 14 by the broken lines labeled X and Y drawn perpendicular to the ordinate and where applicable to the abscissa. If each of the cited curves are inspected, a quantitative judgment of the number of usable batteries that may be discarded is obtained. All of the batteries below the 8.4 volt line do not meet the minimum voltage requirement and, therefore, will be rejected as unusable. The selection of this value is made to assure the user that he has a usable battery, i.e., one that will function for about a nine hour mission life on the AN/PRC-77 drain under the conditions studied and for some lesser period on the other drains studied. Based on the data obtained, the test method should not accept or pass any batteries that would give less than nine hours service on the AN/PRC-77 drain.

The minimum capacity values for the AN/PPS-15 and the KY-38 drains are not as long in terms of mission life as those selected for the AN/PRC-77 drain, but if a higher capacity level, and hence a higher voltage value, was selected for the AN/PPS-15 and the KY-38 then a larger quantity of usable batteries would normally be discarded by the higher voltage value when the AN/PRC-77 alone was being considered. This was judged to be inappropriate, since the major use of Battery BA-4386/PRC-25 is with the AN/PRC-77. An alternate approach would be to assign different values for different drains or use modes. This could be done if the complexity introduced for the user was judged warranted.

Inspection of Figures 7, 8, 11, 12, 13 and 14 will also provide an indication of what would happen if 1 or 7 days were allowed to elapse after a battery was used before a loaded voltage reading was taken. For the most part, more usable batteries would be rejected as not usable, since the data has more variance, i.e., for any particular voltage reading the possible capacity remaining is more. It is, therefore, more advantageous to take a reading immediately after use to predict capacity remaining. If the one or seven day reading is selected a value of 8.6 volts would have to be used as the 15% voltage level.

Incidently, in place of using the hours of capacity remaining, the capacity in ampere-hours for the conditions studied was also used with very similar results. The voltage reading showed just as large a deviation when they were plotted versus capacity remaining in ampere-hours; and more importantly, the loaded voltage readings were still discharge rate dependent.

CONCLUSIONS

A 4.0 ohm loading was selected on the basis of preliminary tests as the best loading to be used in the AN/PSM-13 for use with Battery BA-4386/PRC-25. A technique employing diodes to expand the voltage scale of the AN/PSM-13 improved its voltage reading accuracy considerably.

For the conditions studied, the voltage reading obtained with Modified Test Set, Battery AN/PSM-13 designed to be used with Battery BA-4386/PRC-25 yields a broadly distributed response curve when it is plotted against hours of capacity remaining. The central portion of that response curve is a region with near zero slope, which provided no meaningful information relative to predicting hours of capacity remaining. Both ends of the curve do provide a response that allows predictions of battery capacity. Loaded voltage reading levels have been selected that indicate a battery will provide at least a certain minimum capacity. The value at the low end is 8.4 volts meaning that for the conditions studied a battery having a PSM-13 reading above that value will provide at least 15% of its original capacity on the AN/PRC-77 discharge regime. Similarly, a reading of above 10.0 volts indicates a battery capable of providing at least 85% of its original capacity under the same discharge conditions. Voltage values between 8.4 and 10.0 volts signify any capacity level above 15% and up to 100% of its original capacity for the conditions studied in this program. Because of the flatness of the capacity response in the voltage region between 8.4 and 10.0 volts, the loaded voltage cannot be used to predict accurately the capacity of the battery between 15% and 80%.

The loaded voltage values are influenced by the rate and type of discharge, by the conditions under which a battery is stored, and by when after a partial discharge is completed the loaded voltage reading is taken. For the conditions studied, a reading immediately after a discharge is completed is the most meaningful in predicting remaining capacity because the deviation is less than that obtained after one or seven days open circuit stand. The lower value (15%) voltage reading is not influenced greatly by battery manufacturer.

The Radio Set AN/PRC-77 was selected as the keystone application, since more BA-4386/PRC-25 batteries are used with it than with any of the other applications studied. However, the values selected can also be translated into meaningful capacity remaining responses for the other applications and for the conditions studied although the corresponding usable time increments are shorter.

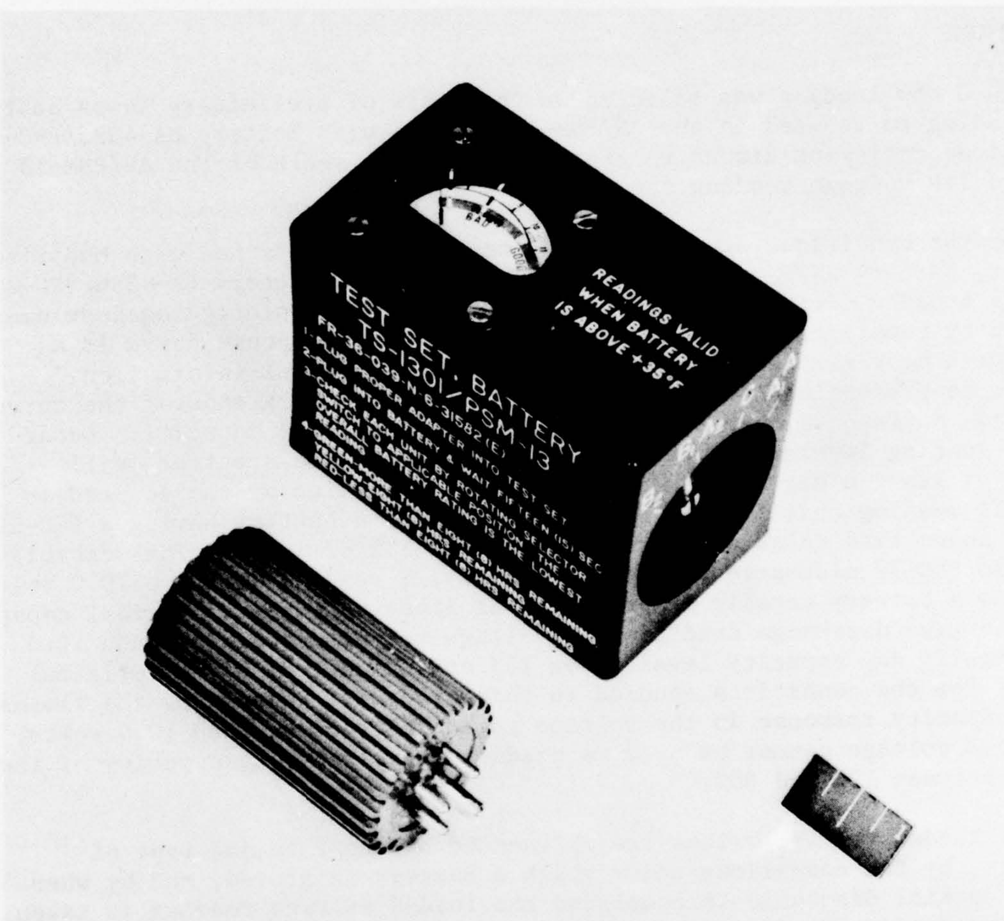

Figure 1. Modified Test Set, Battery AN/PSM-13

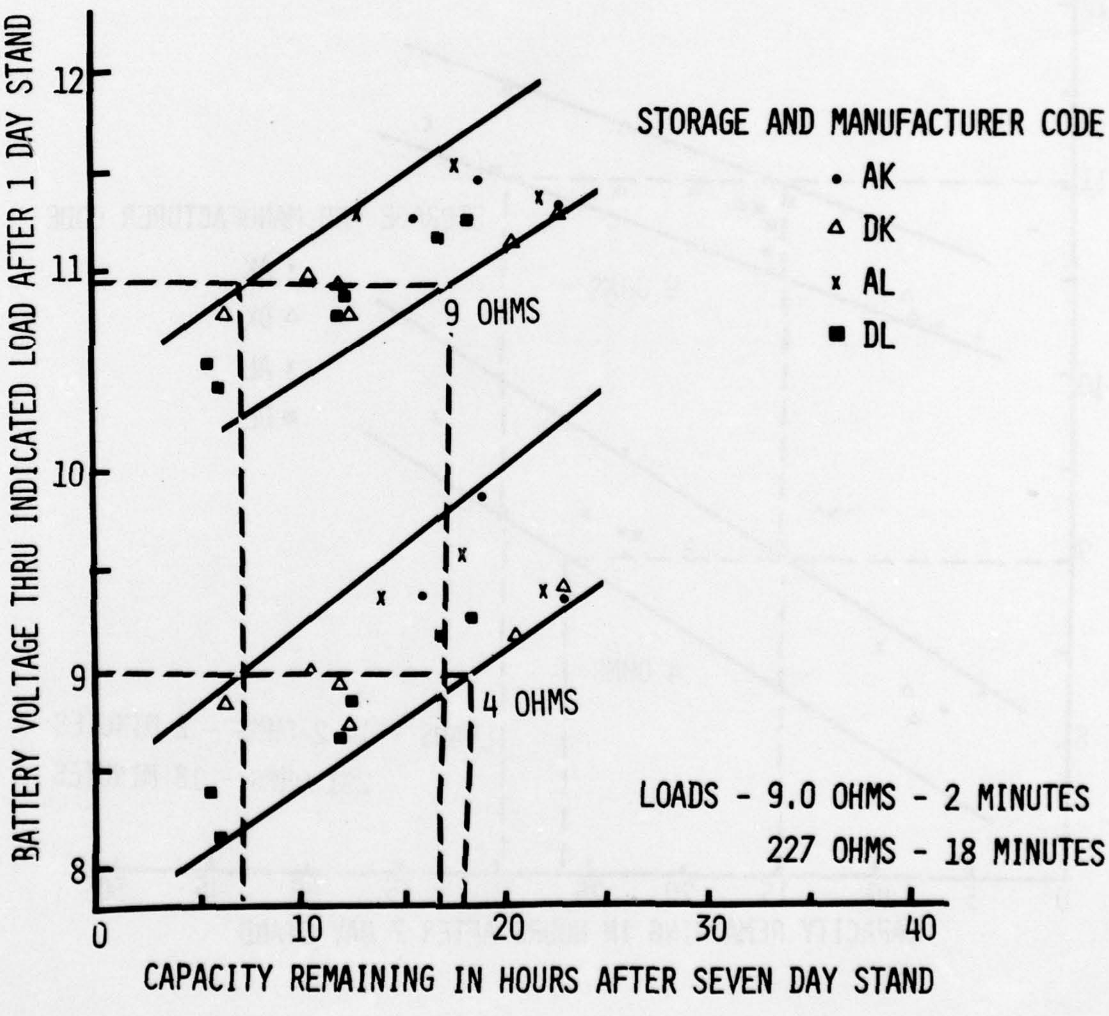

Figure 2. Capacity Remaining Versus Loaded Voltage Reading - KY-38 Drain

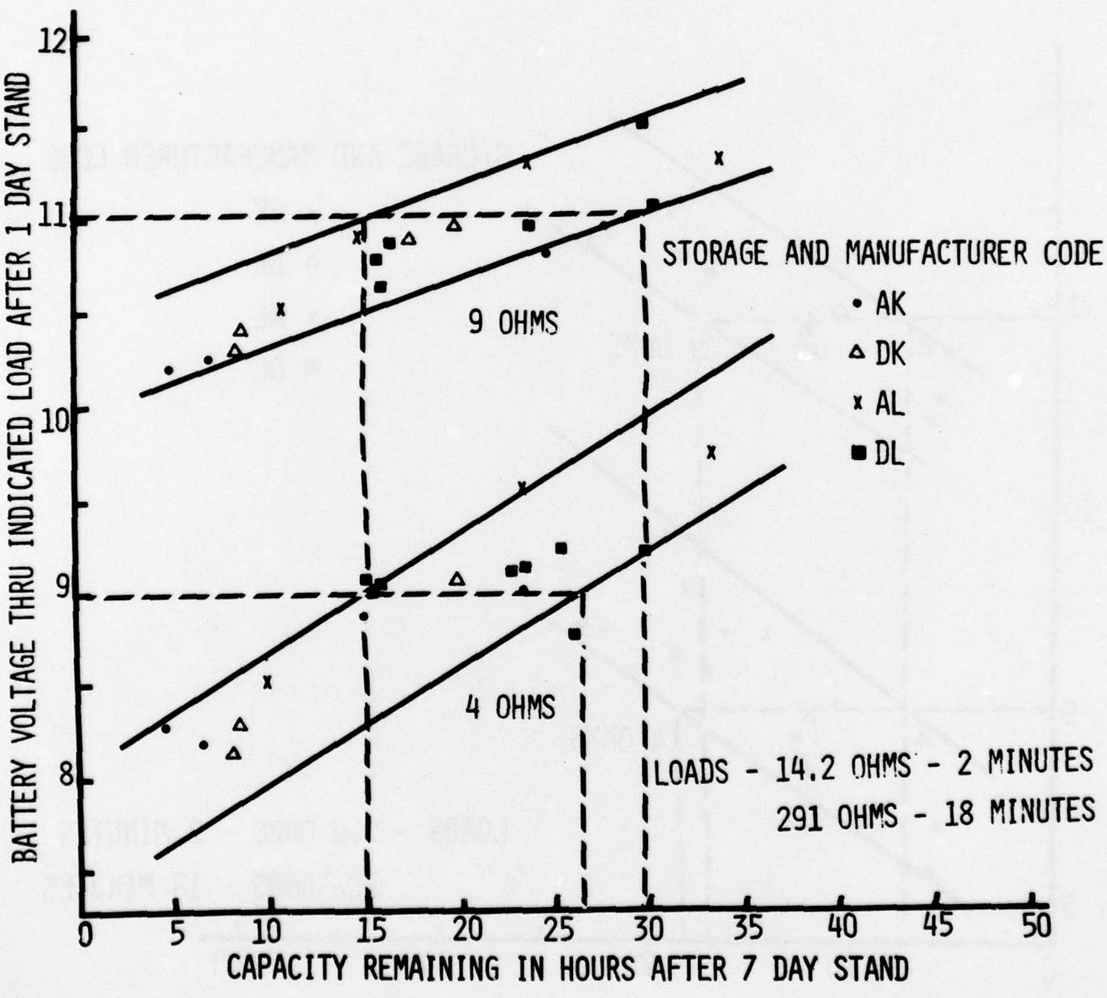

Figure 3. Capacity Remaining Versus Loaded Voltage Reading - AN/PRC-77 Drain

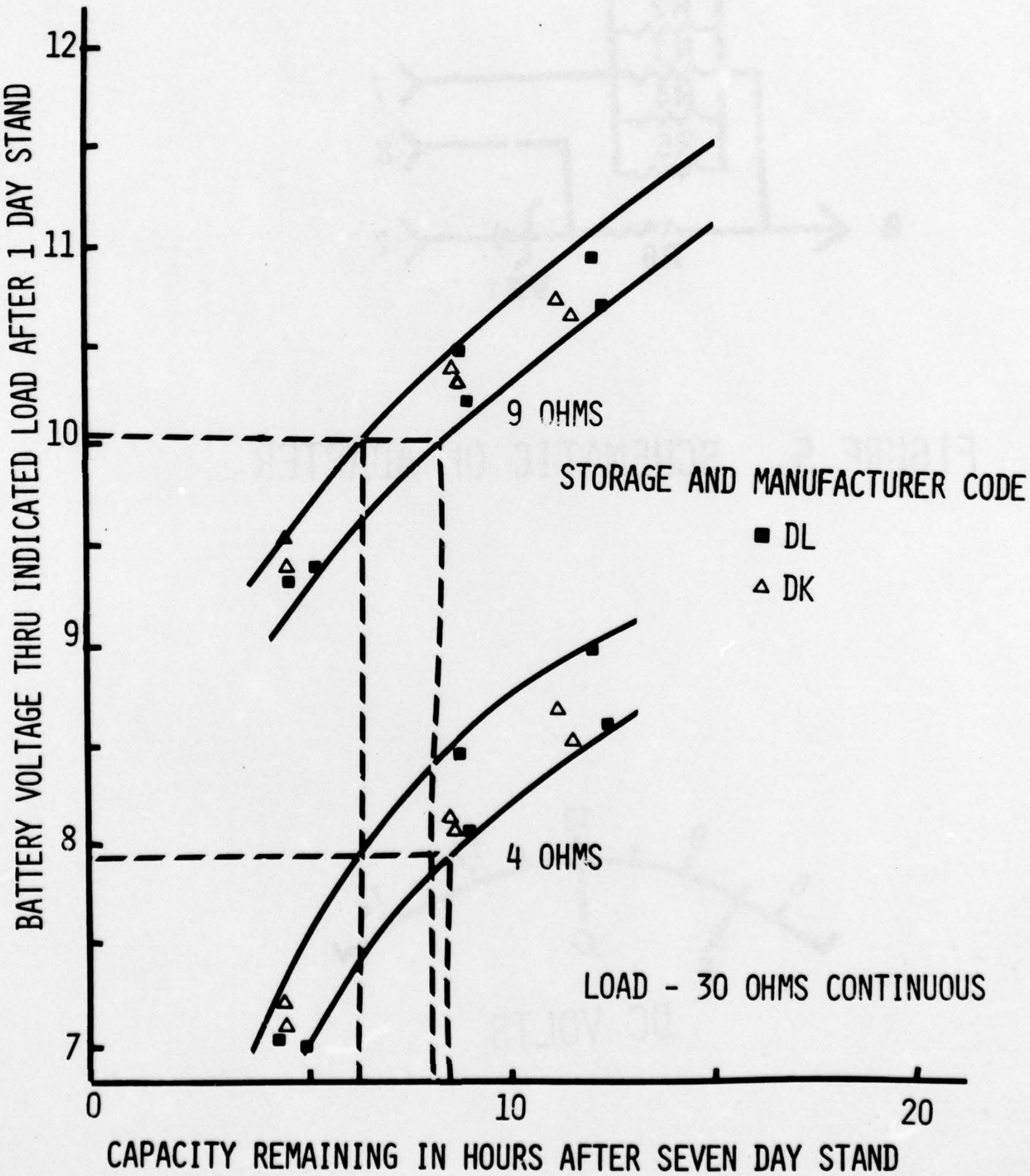

Figure 4. Capacity Remaining Versus Loaded Voltage Reading - AN/PPS-15 Drain

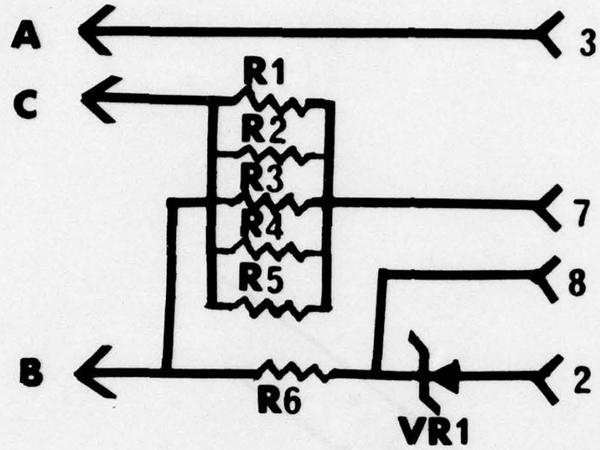

FIGURE 5. SCHEMATIC OF ADAPTER

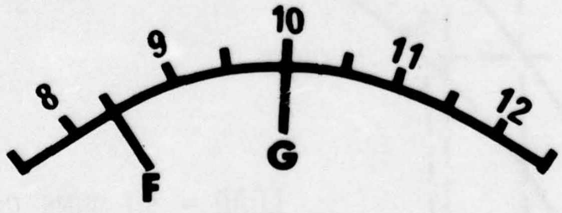

FIGURE 6. DECALCOMANIA SCALE DESIGN

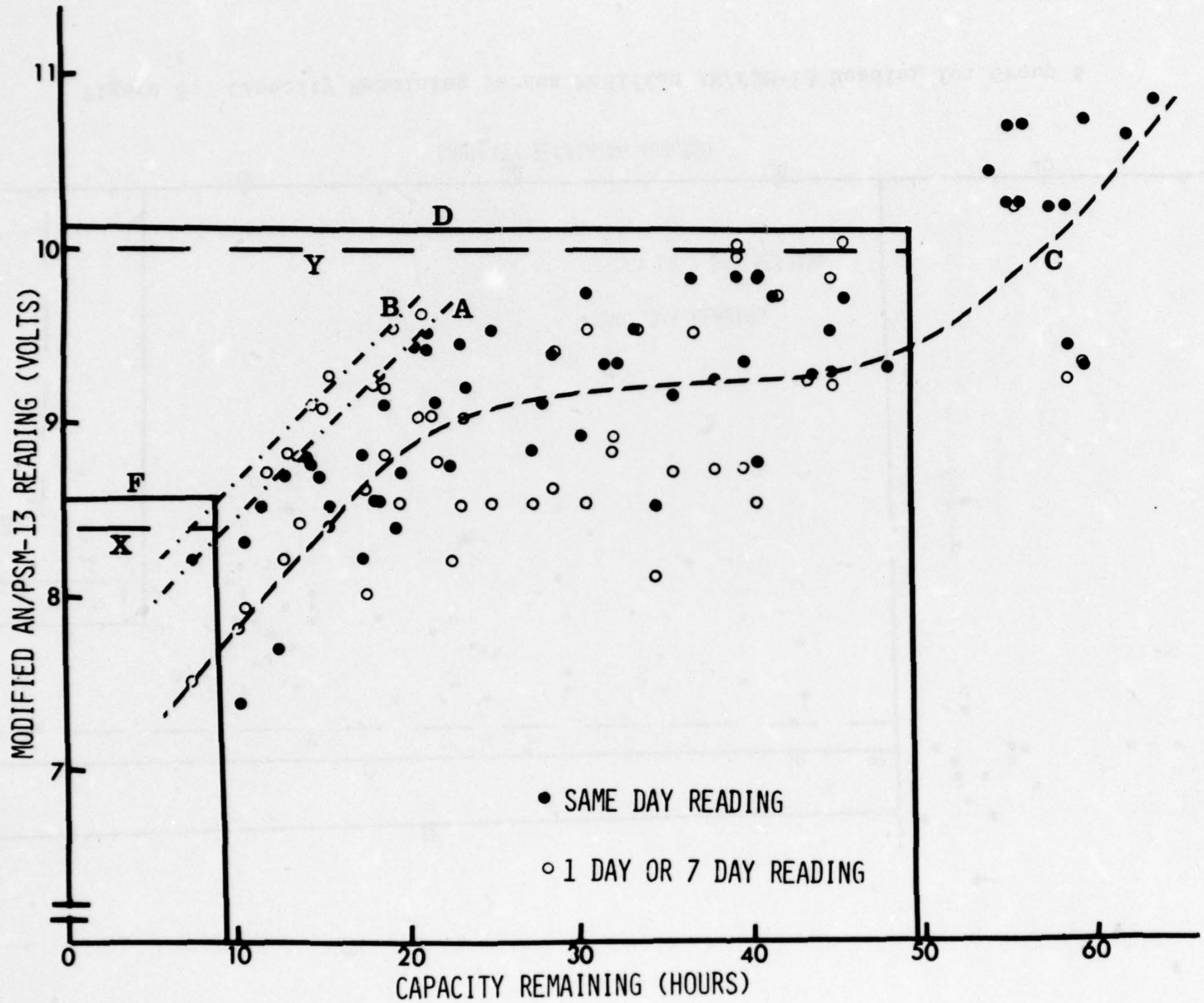

Figure 7. Capacity Remaining Versus Modified AN/PSM-13 Reading for Group A

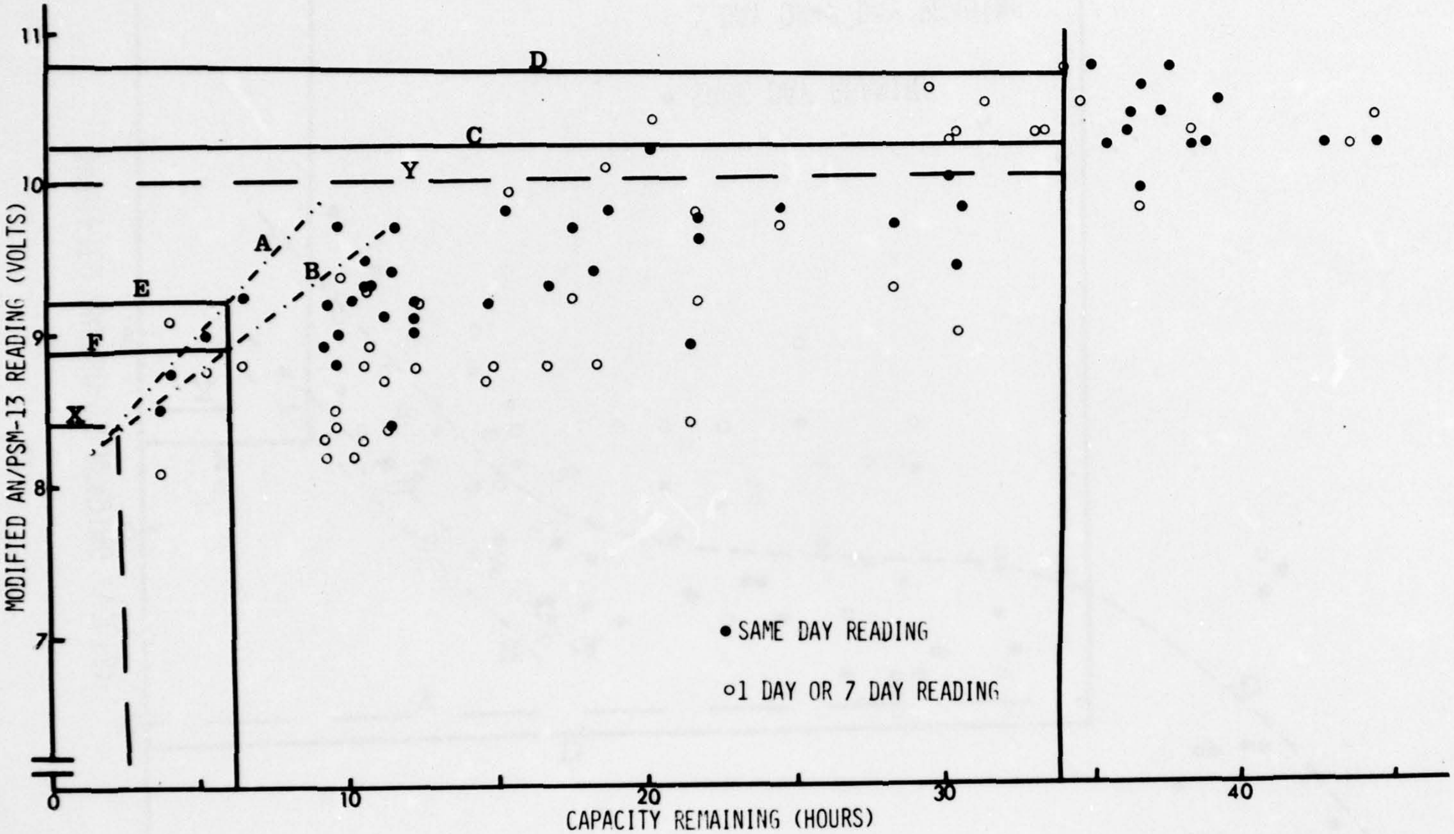

Figure 8. Capacity Remaining Versus Modified AN/PSM-13 Reading for Group B

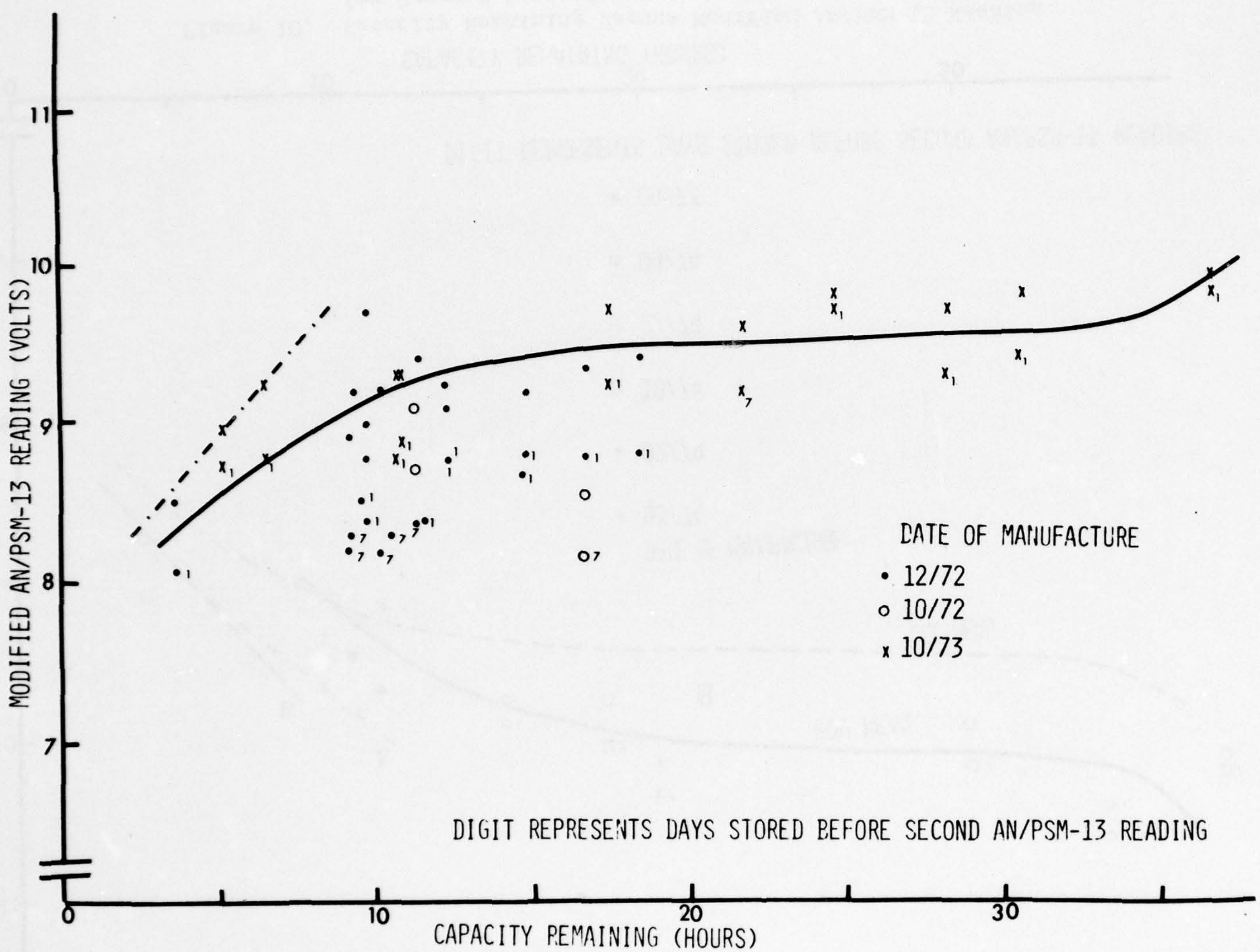

Figure 9. Capacity Remaining Versus Modified AN/PSM-13 Reading for Group B Batteries Made by UCC

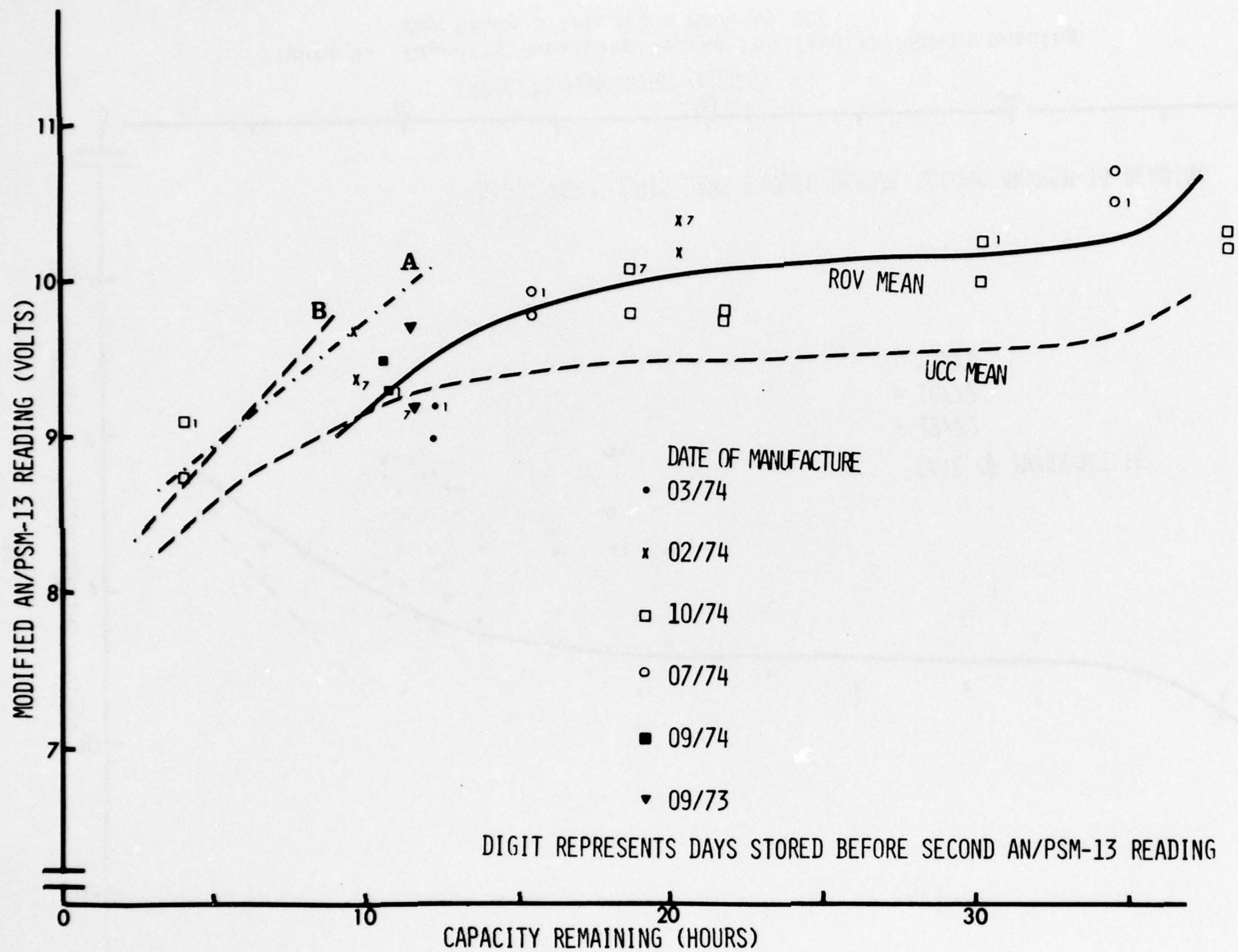

Figure 10. Capacity Remaining Versus Modified AN/PSM-13 Reading for Group B Batteries Made by ROV

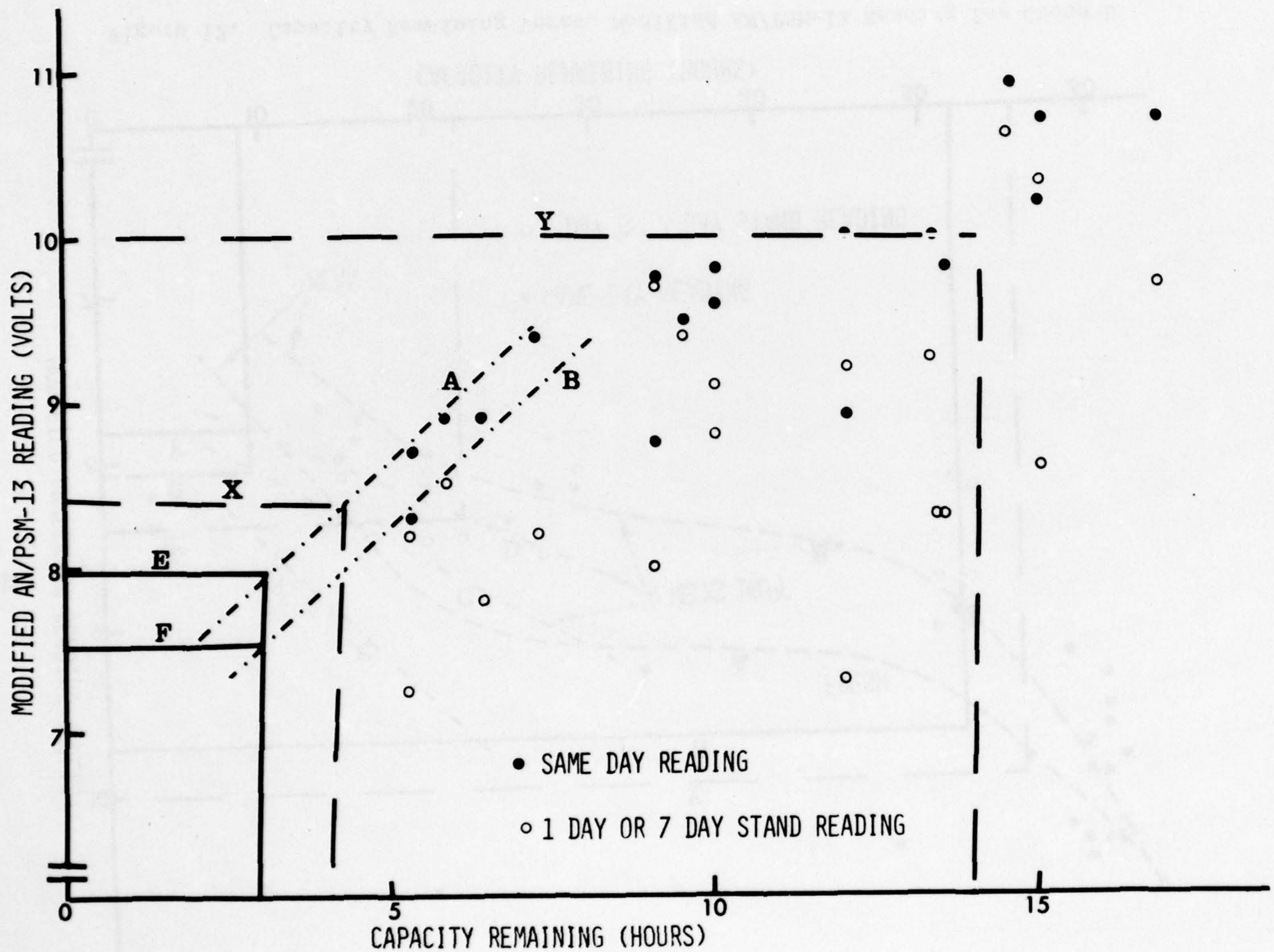

Figure 11. Capacity Remaining Versus Modified AN/PSM-13 Reading for Group C

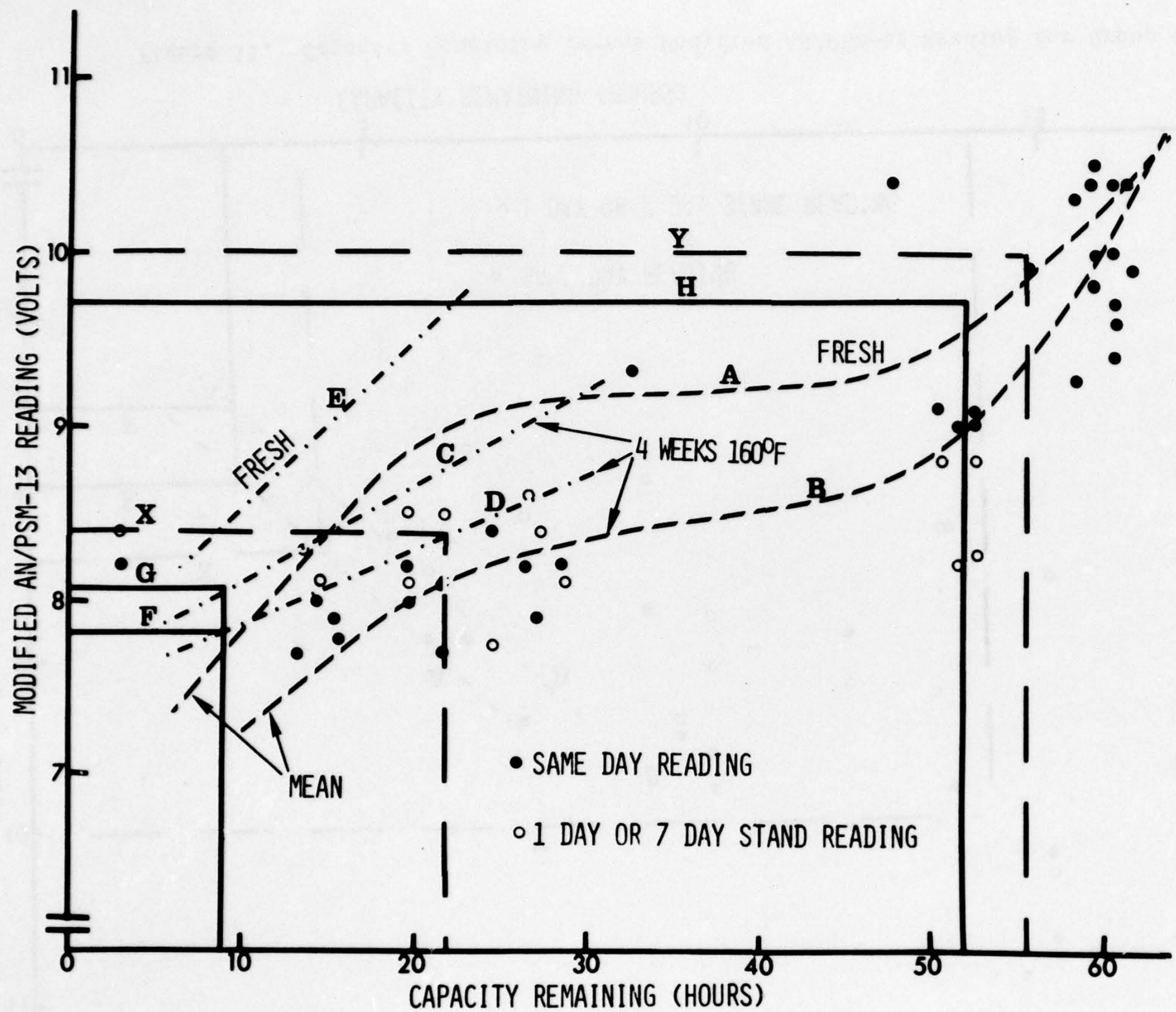

Figure 12. Capacity Remaining Versus Modified AN/PSM-13 Reading for Group D

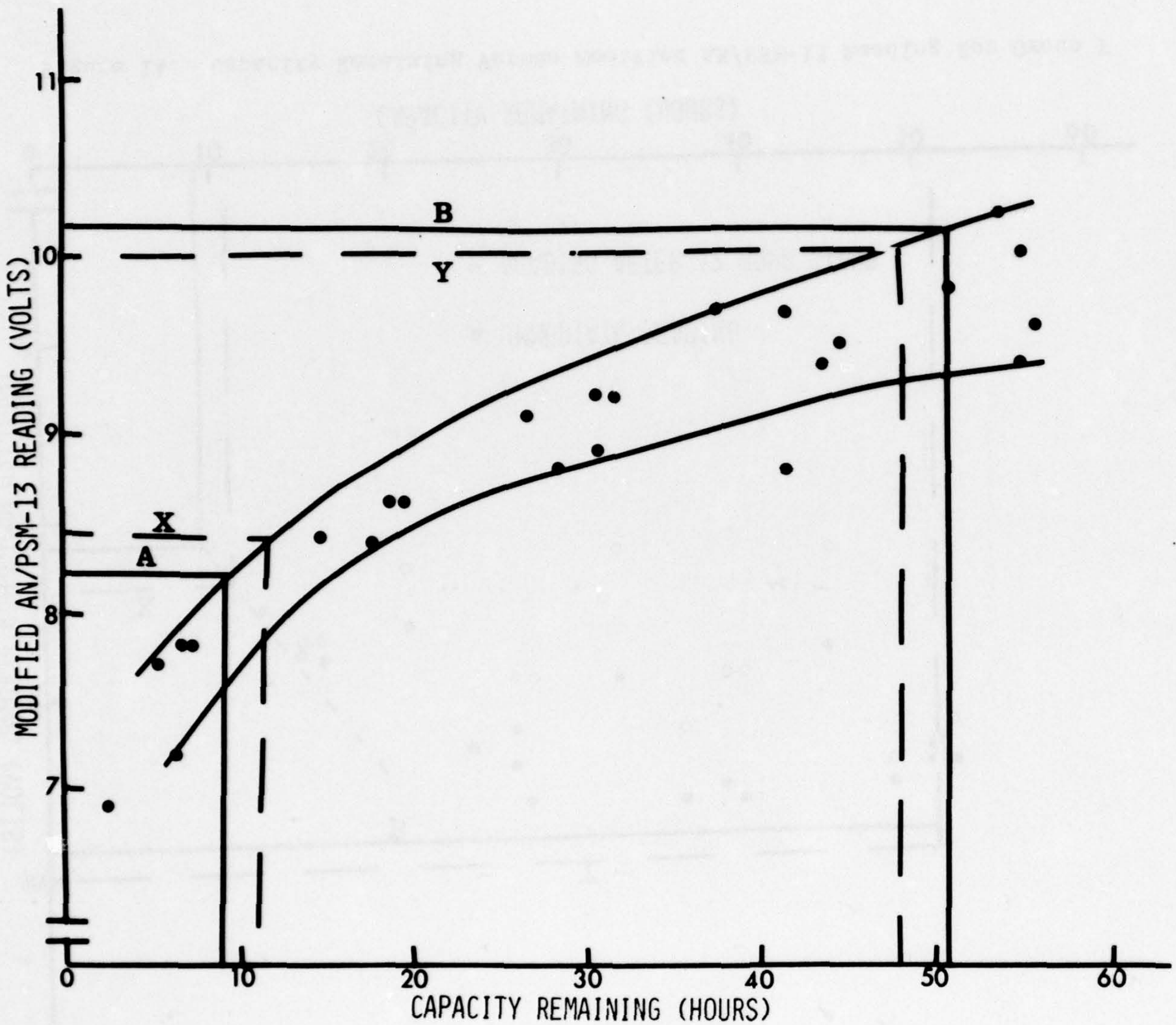

Figure 13. Capacity Remaining Versus Modified AN/PSM-13 Reading for Group E

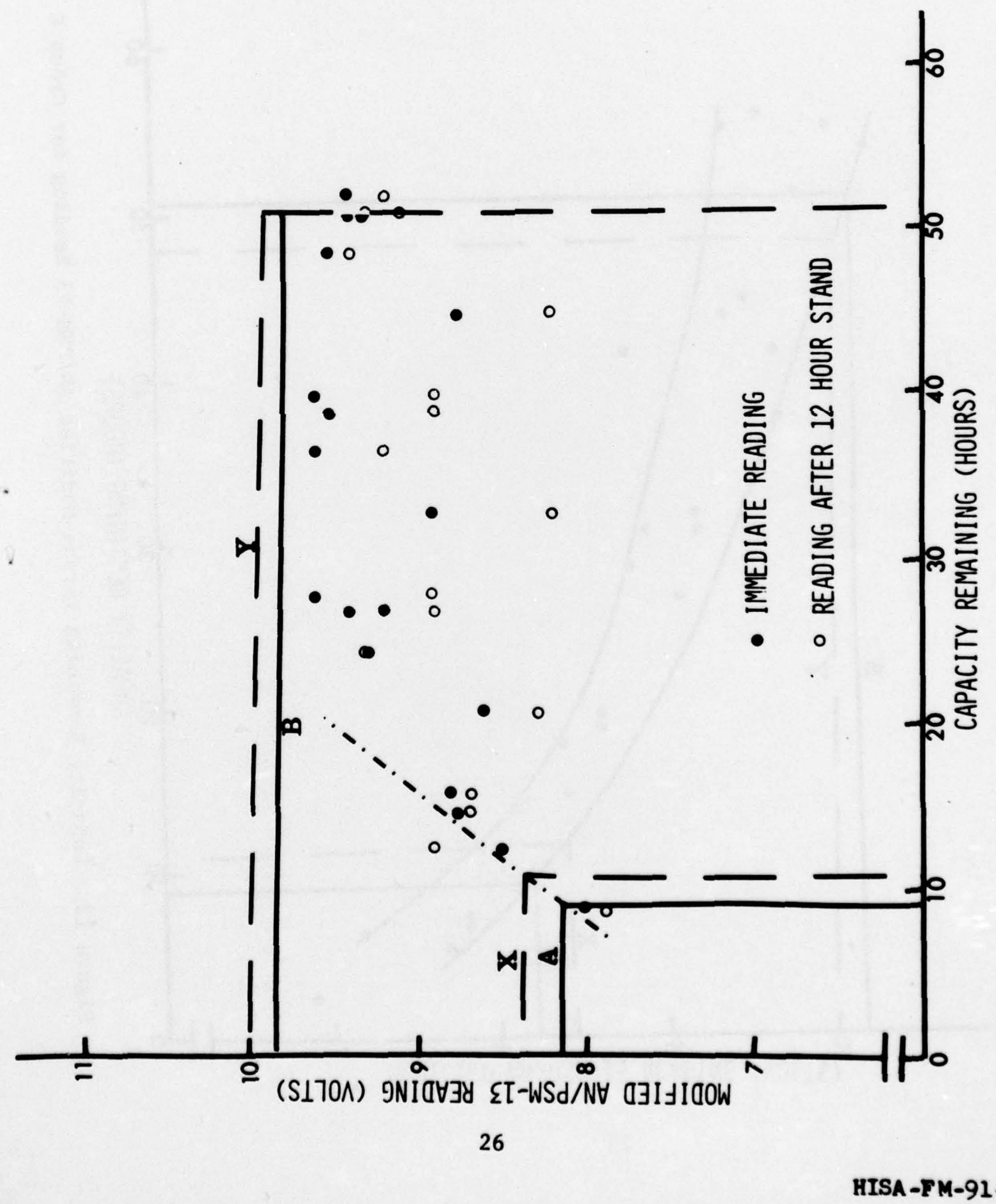

Figure 14. Capacity Remaining Versus Modified AN/PSM-13 Reading for Group F