APPLIED SCIENTIFIC RESEARCH CORPORATION OF THAILAND

RESEARCH PROGRAMME NO. 6

EXPLOITATION OF MANGANESE ORES

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MANGANESE DIOXIDE AND LIFE OF DRY BATTERIES

REPORT NO. 2

ASSESSMENT OF THE PERFORMANCE OF DRY CELLS

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ASSESSMENT OF THE PERFORMANCE OF DRY CELLS

By Kasem Balajiva*,
Somphob Tantavichetkit*, and Precha Photiyarat*

SUMMARY

A satisfactory battery testing equipment has been designed for testing cells both under the proposed Thai National Standard Specification and the American Standards Association Specification ASA C18.1-1959. The results of tests on a number of experimental cells of varying quality suggest that the proposed Thai test is less sensitive to variation in cell performance than the American test and the latter test is more suitable for further studies on evaluation of manganese ores for dry cell depolarizer. Since certain cells can meet the Thai specification but fail to fulfil the requirements of the ASA specification, the proposed Thai test should not be employed to quality cells which may be used in areas where American specifications are the accepted standards.

INTRODUCTION

As part of an investigation to evaluate Thai manganese ores intended to be used as dry cell depolarizer, it has been planned to construct a reliable equipment for assessing the performance of dry batteries under different discharge conditions. The design of the equipment should be such that the influence of the testing conditions on the cell performance can be maintained as constant as practicable throughout the whole series of tests. It was intended that the equipment should serve two main purposes; firstly, to assess the performance of experimental cells made with different manganese ores in order to evaluate the depolarizing quality of the various ores. The other purpose was to study certain methods of assessing the performance of

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cells under different discharge condition and to compare the merits of some standard test methods used abroad with those of the method proposed in the Thai National Standard Specifiation for dry cells.

The present report is concerned with the construction of the cell testing equipment which can be used for a number of standard test procedures and with a comparison of some results obtained by the use of an American method and the proposed method for the Thai National Standard Specification.

Other reports in this series deal with the manufacture of experimental dry cells and the application of these techniques to evaluate the effectiveness of Thai manganese ores as dry cell depolarizer.

Various test methods have been used on dry batteries involving a variety of discharge conditions with recuperation periods of different durations. Most of the tests are aimed to simulate the various types of discharge which cells are subjected to under normal service conditions. The tests commonly used for the size of dry batteries concerned in this investigation, which is equivalent to the American Standards Association D size cell, include a light intermittent discharge such as occurs in the ordinary flashlight and a light discharge for prolonged periods as in the transistor radio circuit. Both these tests have been adopted in the American Standards Association, ASA designation C18.1-1959. Basically similar tests have been adopted in the British Standard B.S. 397:1960 for the same size battery but the resistance used in the discharge circuit and the discharge cycles are slightly different from the American method. In Thailand the discharge test similar to that of the British Standard method appears to be generally preferred mainly because an equipment suitable for such test could be simply constructed for use by the local industry which is represented by a number of relatively small companies who would not consider an elaborate or expensive test equipment justified. Consequently the Thai National Standard Specification for dry cell which is at present in the draft form awaiting consideration by a Technical Committee of the Centre for Thai National Standard Specifications has been prepared as an adaptation of the method used in the British Standard specification.

TEST METHODS

Two methods of test were chosen for further study: the ASA Light-Industrial Flashlight Cell Test and the Intermittent Test proposed in the draft Thai National Standard Specification for Dry Cells. Both methods involve connecting the cell under test to a fixed resistance of appropriate value for a specified period or periods each day and the performance of the cell is measured by the length of discharge time which elapses before the closed circuit voltage drops to a specified value. Details of the requirements of the two tests are set out below:

American Standards Association (ASA designation C18.1-1959) Light-Indistrial Flashlight Cell Test

Each cell shall be discharged through a resistance of 4 ohms for 4-minute periods, beginning at hourly intervals for 8 consecutive hours each day, with 16-hour rest periods intervening. (There are eight such discharge periods each day or a total daily discharge of 32 minutes).

The test shall be started within 30 days of the receipt of the batteries and the cells shall have been subjected to a temperature of $21^{\circ} \pm 1^{\circ}C$ for at least 24 hours before the test is commenced.

The following readings shall be taken: Initial open-curcuit voltage of the cell, initial closed-circuit voltage, and the closed-circuit voltage daily at the end of the last discharge period.

The test shall be continued until the closed-circuit voltage of the cell falls below 0.9 volt. The service of the light-industrial flashlight cell shall be reported as the number of minutes of discharge before the cell voltage falls below 0.9 volt, the required average performance being 850 minutes.

Proposed Thai National Standard Specification for Dry Cells

Each cell shall be discharged through a resistance of 5 ohms; the resistor shall be accurate to within 0.5 per cent of the rated value during the test. The test shall be made by discharging through the resistance for 30 minutes continuously per day for 5 consecutive days per week.

The test shall be made within 30 days of the receipt of the cell and the battery under test or awaiting test shall be subjected to a temperature between 25°and 30°C and a relative humidity between 60 and 85 per cent:

The closed circuit voltage of the cell under test shall be recorded at the end of the daily discharge period and the discharge test shall be taken as concluded when the cell voltage falls for the first time below 0.8 volt. The duration of discharge shall not be less than 750 minutes.

It will be noted that the American test does not specify a humidity value and the temperature of test for the Thai specification is higher than that for the American test. In applying both the test methods in the present study, however, the test temperature has been adjusted to 30° ± 1°C to suit the local conditions and the relative humidity value maintained at about 52 per cent. As a rule the tests were made on cells after they had been conditioned at the temperature and humidity for at least 24 hours but within one week from the date of manufacture, most of the cells being actually tested within 1-3 days.

THE EQUIPMENT

The general design of the test equipment follows that of the earlier Australian work* but the wiring circuit used for controlling the discharge has been adapted to suit the present requirements. It was decided that the testing equipment should provide for automatic timing of the discharge cycle to ensure a high degree of reproducibility and any influence of the testing conditions on cell performance can be maintained at a constant level. The batteries under test or awaiting test are kept in an air-circulating cabinet with temperature and humidity control, the humidity control being effected by incorporating a tray containing a saturated solution of potassium dichromate in the cabinet. The general appearance of the test cabinet and the

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* SKEWES, H.R., and WADSLEY, A.D. (1948).—The determination of dry cell performance. CSIRO Aust. Division of Industrial Chemistry Report Serial No. 67 (Mimeo.).

voltage measuring unit is shown in Figure 1.

The test equipment constructed is capable of discharging 85 cells mounted on two removable trays, the cells being divided into two groups and wired for two discharge schedules. The discharge schedule A corresponds to the Thai standard test method, i.e. discharge through 5 ohms for 30 minutes per day for 5 consecutive days per week. The schedule B applies to the American light-industrial flashligh cell test which is a daily discharge through 4 ohms for 4 minutes per hour for 8 consecutive hours per day.

The timing mechanism for controlling the intermittent discharge periods in automatic with the exception of a manual switch which isolates the cells for the discharge schedule A from the automatic circuit for two days a week. The circuit diagram is shown in Figure 2. The main timer is a synchronous motor which drives a 15 cm diameter bakelite disc at the rate of one revolution every 4 minutes. Two small cams on the periphery of the disc positioned at 180^{o} operate a micro-switch of the 12 volt circuit to provide an electrical impulse every 2 minutes for about 2 seconds duration. The impulse drives the 25 point rotary stepping switch A (Automatic Electric Type RB 10) which is made to "home" at the completion of the 15th step thereby making a complete cycle every 30 minutes. At the conclusion of each half-hour period, a second stepping switch B is operated. The switch B is made to "home" after making 24 steps thus completing its cycle every 12 hours. The power supplying these switches is from a 12 volt accumulator which also supplies the relays used for controlling the battery discharge circuits. For controlling the discharge period there are also a day timer and a manual switch. The day timer limits the discharge circuit to operate from 0600 to 1800 hour daily and the manual switch permits the operator to eliminate 2 days from the discharge cycle of the relays A. Usually Saturday and Sunday are eliminated leaving a five day week discharge schedule.

The relays used are of a normal telephone type (BGE type 3000) mounted close to the cells in the cabinet. The relays A which are for 30 minutes per day cycle are connected to the 3rd bank of the stepping switch B. Appropriate steps are selected so that the relays are

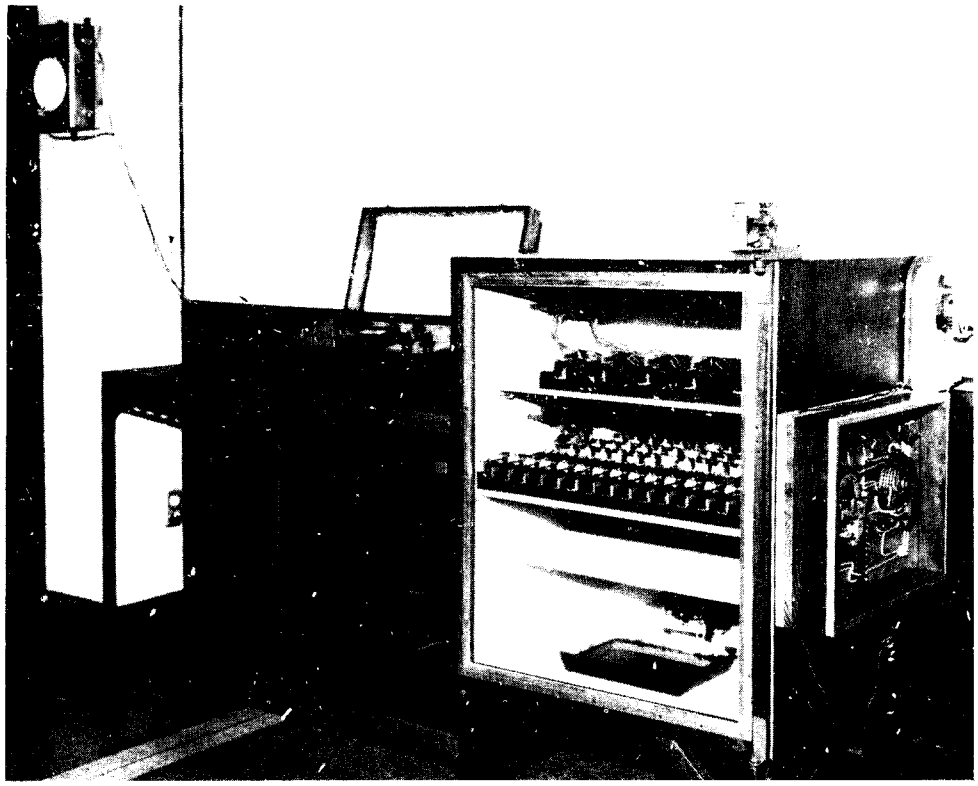

Figure 1.—The test carbinet and the voltage measuring equipment.

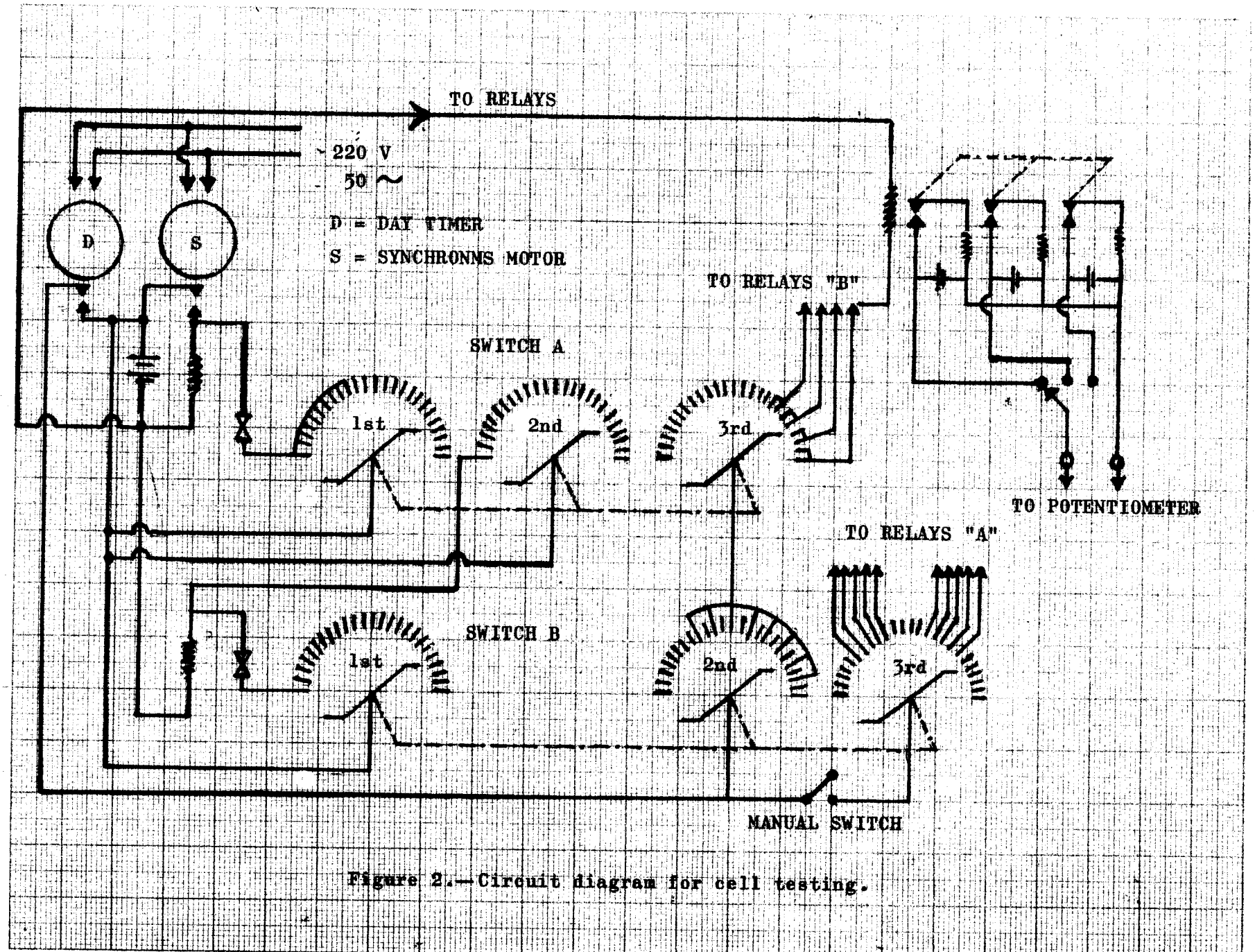

Figure 2.—Circuit diagram for cell testing.

operated at a chosen period of the day. In the diagram are shown connections for two sets of relays A, one set operating for the period 0900-1130 and the other for 1330-1600 hour.

The relays B which are operated daily for 4 minutes every hour for 8 hours a day are connected to the 3rd bank of the stepping switch A. Up to 7 relays operating successively can be incorporated in this system although only 4 are shown connected in the diagram. The period of the day for these relays to operate is controlled by the 2nd bank of the stepping switch B and can be selected for any 8-hour period between 0600 and 1800. The diagram shows the relays B operating from the beginning of each hour starting from 0700 hour.

In the event of a mains failure causing interruption of supply for the synchronous motor, an auxiliary vibrator power unit operated from a 6-volt accumulator drives the synchronous motor for up to 36 hours until normal power is restored. This auxiliary equipment was supplied to ASRCT by CSIRO of Australia.

The relays A and B which are used to operate the discharge circuits of the test cells are of multipole type and each relay causes a number of cell-resistor circuits to close simultaneously. Each cell under test is wired to a system of selector switches so that its voltage can be measured at any time required.

The cell voltage is measured with an accurate voltmeter which is a null-point instrument instead of the usual high resistance voltmeter. An external e.m.f. is balanced against the voltage of the test cell using the coarse and fine potentiometers as shown in Figure 3 and the voltage of the external e.m.f. is then measured. A calibrated 10 mA meter with two alternative series resistances are used for measuring the voltage giving full scale readings of either 2 volts or 1 volt with an accuracy of $\pm$ 0.5 per cent.

It should be stated that although the wiring circuit described above has been designed for the two methods of light intermittent tests which have been chosen for the present studies, the test equipment can, with some modification of the wiring system, be used for a number of other tests referred to in the American Standards Association or the British Standard specification.

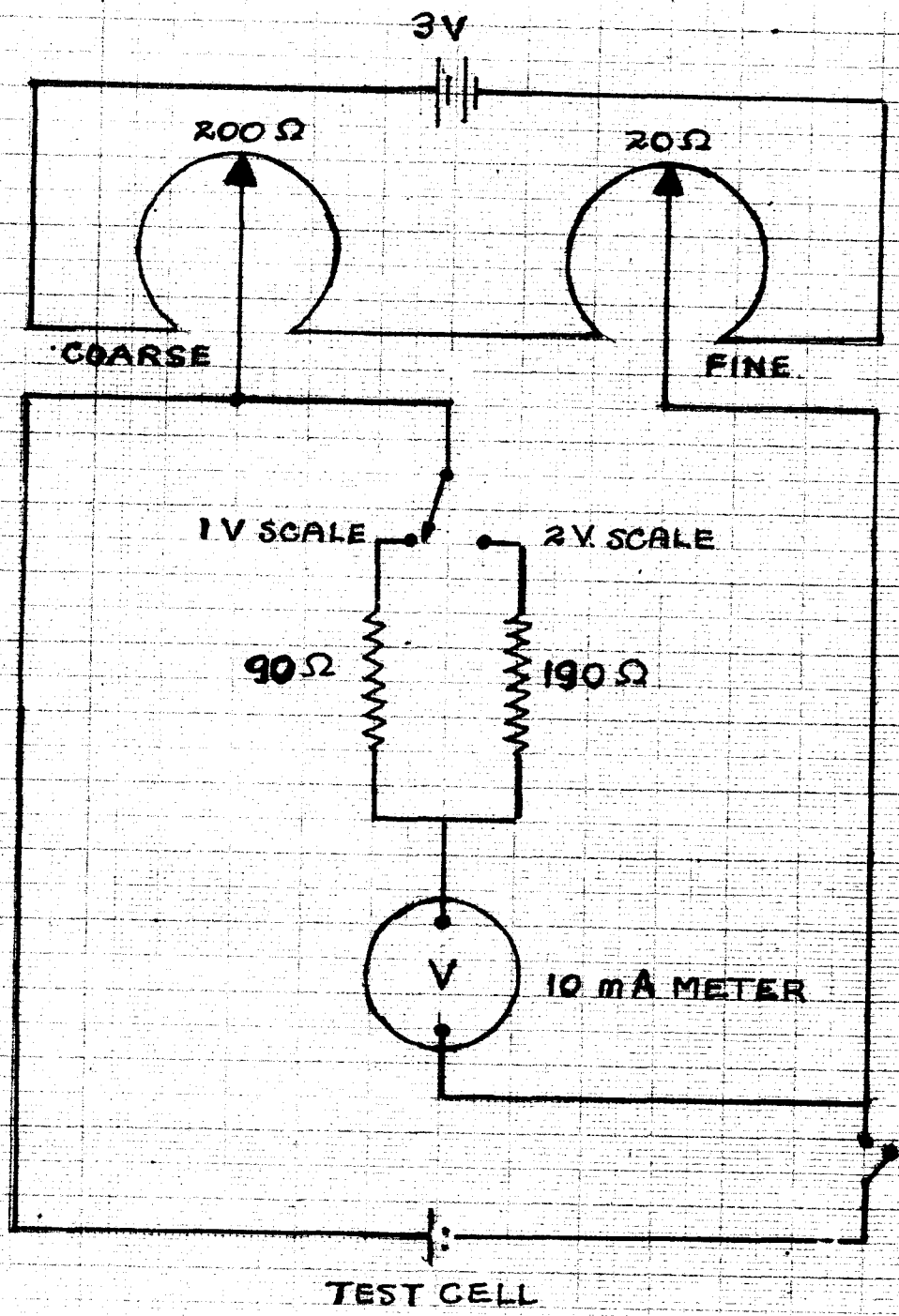

Figure 3.—Balance voltmeter circuit.

EVALUATION OF THE TEST METHODS

The two methods of test were applied to experimental cells prepared by the manufacturing technique established in an earlier investigation (see Report No. 1 of this series). For the purpose of evaluating the test methods, the cells were made with two different manganese dioxide contents in the black mix of 85 and 90 per cent to effect a variation in the cell performance. Two grades of manganese ores were used in order to provide confirmation of any findings on the tests.

The duplicate results for one of the manganese ores are shown in Figures 4 and 5, indicating the type of discharge curves under the Thai test and the American test schedules respectively. The test results for all the cells are summarized in Table.1. It will be seen that under the Thai test all the cells gave life values in excess of the specified minimum of 750 minutes, although for each grade of the manganese ore, a slightly longer life was obtained with 90 per cent MnO_2 than with 85 per cent MnO_2. Under the American test, on the other hand, the cells containing 85 per cent MnO_2 failed to meet the minimum requirement of 850 minutes whilst the cells made with 90 per cent manganese dioxide could pass the specified limit.

These data suggest that the two type of test schedules cannot be regarded as being equivalent and that the proposed Thai test is less sensitive to variation in cell quality than the American test procedure. The latter type of test is considered to be more appropriate to be adopted for further studies on the quality of manganese ores for dry cell depolarizer. The fact that certain cells can pass the proposed Thai specification but fail to meet the U.S. test requirements indicates that the Thai test is not suitable to be used as a qualifying test for cells which may be used in areas where the American specification is regarded as a standard measure of cell quality.

The difference in behaviour of dry cells under the two discharge conditions is not clearly understood but it appears to be related to the difference in the rate and duration of discharge and also in the recuperation period of the cell under the two test schedules.

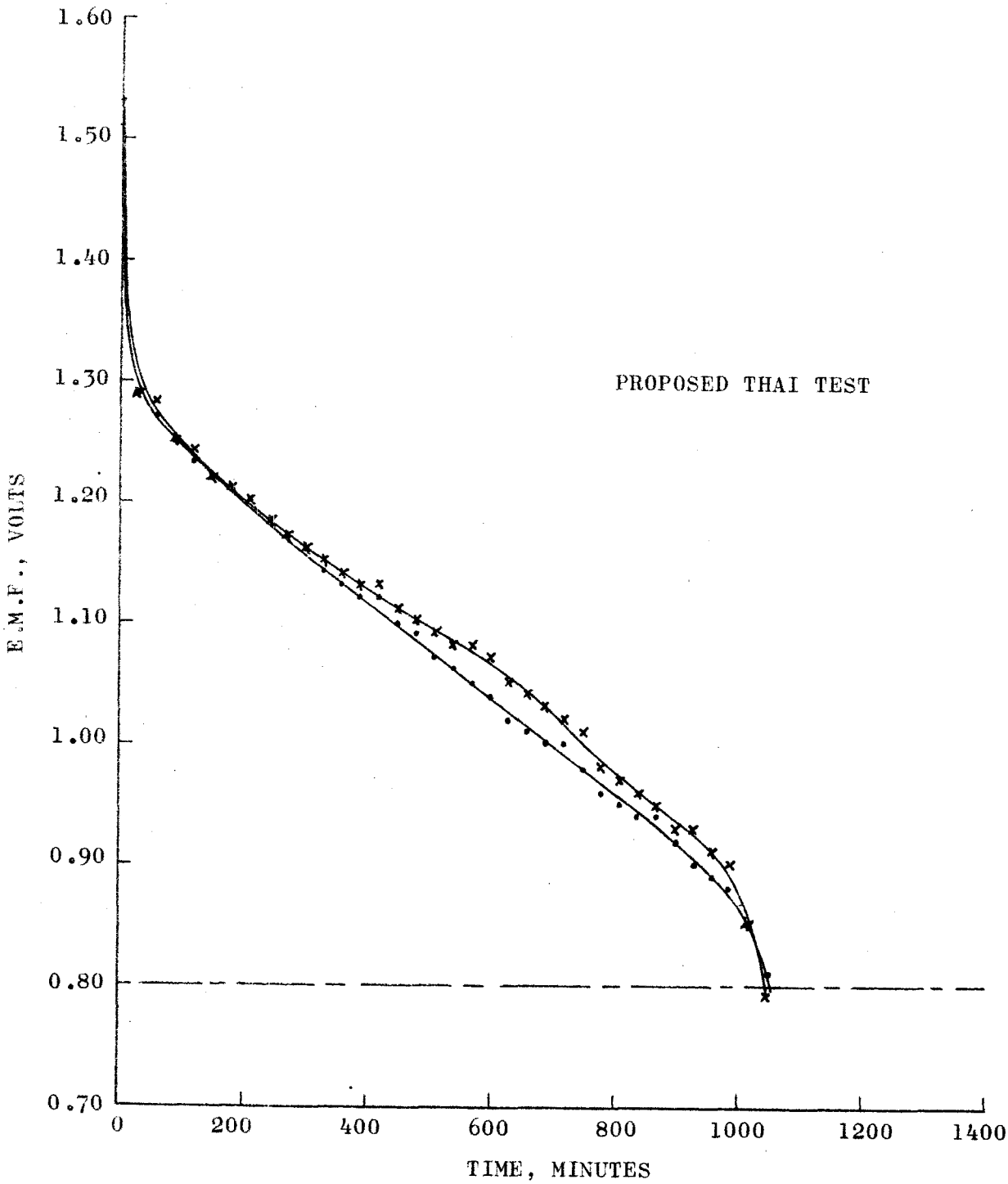

Figure 4.—Capacity test results for experimental cells made with 90 per cent Thai ore (lab. mark 6/3/14).

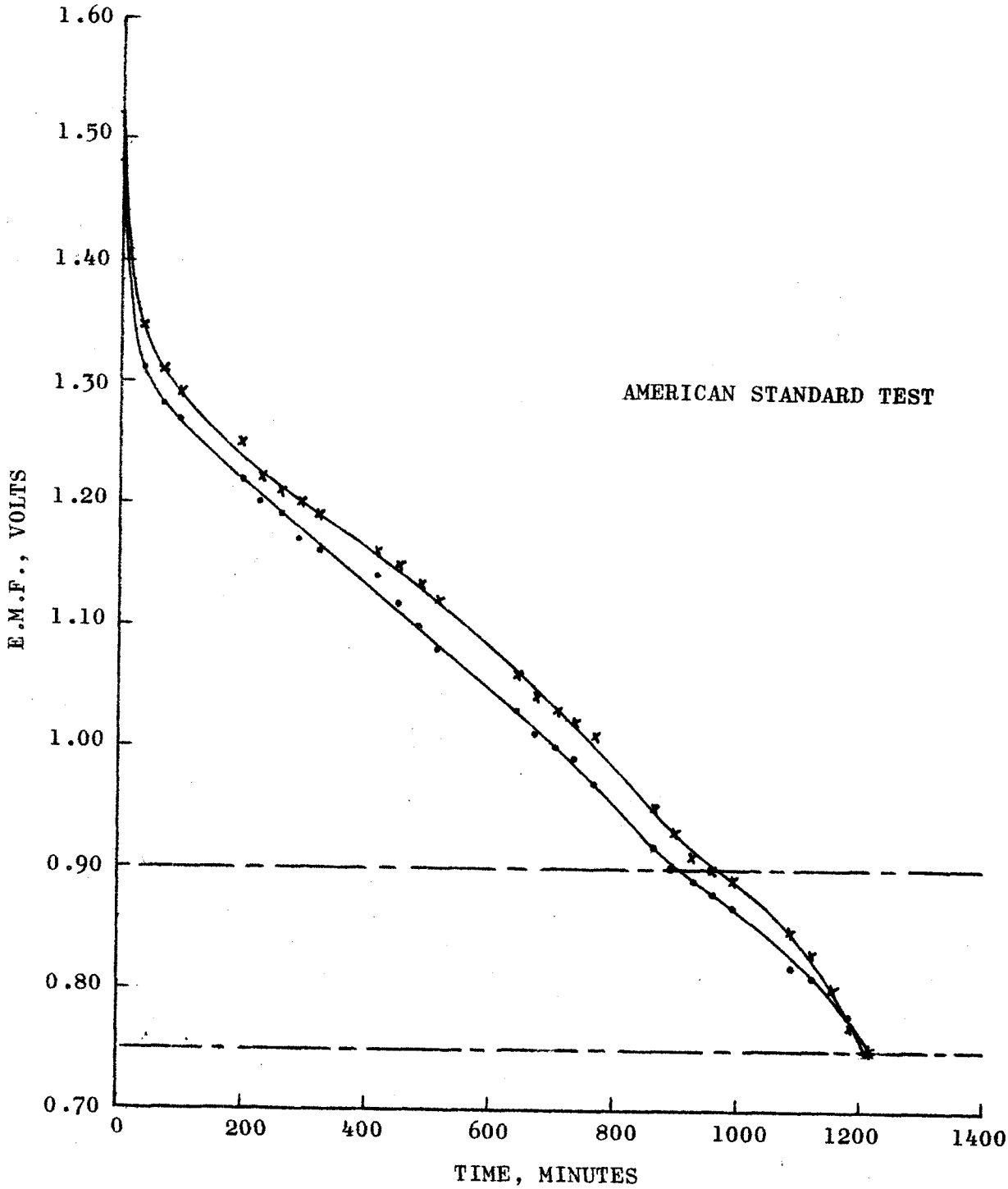

Figure 5.—Capacity test results for experimental cells made with 90 per cent Thai ore (lab. mark 6/3/14).

TABLE 1

COMPARISON OF TEST RESULTS
FOR MANGANESE ORE LAB. MARK 6/3/14

Type of test	Specified minimum life (minutes)	Mineral sample	MnO_2 in black mix %	Life to specified voltage (minutes)	
				Individual result	Average
Proposed Thai National Standard Specification	750 to 0.8 V	As received	85	1,030 1,020	1,025
			90	1,140 1,050	1,095
		-300 mesh	85	1,020 990	1,005
			90	1,080 1,060	1,070
American Standard C18.1-1959	850 to 0.9 V	As received	85	784 768	776
			90	960 928	944
		-300 mesh	85	656 592	624
			90	878 862	870

CONCLUSIONS

The following conclusions may be drawn from the above study:

1. A satisfactory battery testing equipment has been designed which is capable of testing cells both under the proposed Thai National Standard Specification for Dry Cell and the American Standards Association ASA C18.1-1959.

2. The results of tests on experimental cells of varying quality indicate that the proposed Thai test is less sensitive to variation in cell quality than the American test. The latter test is considered more suitable for further studies on evaluation of manganese ores for dry cell depolarizer.

3. Since certain cells may meet the requirements of the proposed Thai National Standard Specification but fail to fulfil the American specification, the former test should not be used for qualifying cells which may be used in areas where the American test is regarded as a standard measure of quality.

ACKNOWLEDGEMENTS

The authors wish to express their indeptedness to Mr. H.R. Skewes and his colleagues in the Industrial Chemical Laboratories of CSIRO Australia for advice and for providing the special components for the construction of the testing equipment. They also express their appreciation to Mr. A. Kalisky and the staff of the Instrument Repair and Calibration Centre of the ASRCT for advice on the design of the test circuit used for this investigation.