Veterans Administration

Journal of Rehabilitation Research and Development Vol. 25 No. 2
Pages 27–32

Testing of gel-electrolyte batteries for wheelchairs

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Abstract—A simple test rig was developed to measure the capacity of the lead-acid gel-electrolyte batteries used to power wheelchairs. Results of 166 tests revealed a wide scatter of battery life with different users and also showed that, in many cases, the two batteries used in a wheelchair became unequal in charge capacity after some time in use. It is recommended that pairs of batteries should be charged in series to overcome this problem.

INTRODUCTION

Batteries for powered wheelchairs are often a source of problems, and at Regency Park Centre are usually the largest material component in maintenance costs (1).

Liquid electrolyte, deep-cycle, lead-acid batteries are the most economical to use (2), but require regular attention to maintain electrolyte levels, are unpleasant to handle, and are not considered safe for transport in passenger vehicles. The gel-electrolyte version of the same kind of battery is more expensive, but is compact and neat in appearance, safe for transport, can be handled without risk of contact with acid, and can be operated in any position (allowing greater flexibility in storage on the wheelchair). For these reasons, gel-electrolyte batteries are increasingly preferred by powered wheelchair manufacturers and users.

At Regency Park Centre, gel-electrolyte batteries have been used in most of the powered wheelchairs for some years, whereas liquid-electrolyte batteries were previously used. The charge capacity of a liquid-electrolyte lead-acid battery can be determined by measuring the electrolyte density using a hydrometer, but this is not possible with gel-electrolyte batteries. Consequently, test equipment was developed to measure the charge capacity of gel-electrolyte batteries. The results are used to decide when wheelchair batteries should be replaced and to indicate if new batteries are within specification.

It has been shown that discharge testing with a simple resistive load is a good indicator of battery performance when fitted to a wheelchair (2). This paper describes the design and operation of a battery test rig and reports the results obtained during 18 months of use.

EQUIPMENT

The battery test rig (**Figure 1**) comprises a resistive load, a timer, and a box housing the control switches and electronics. The system was designed to

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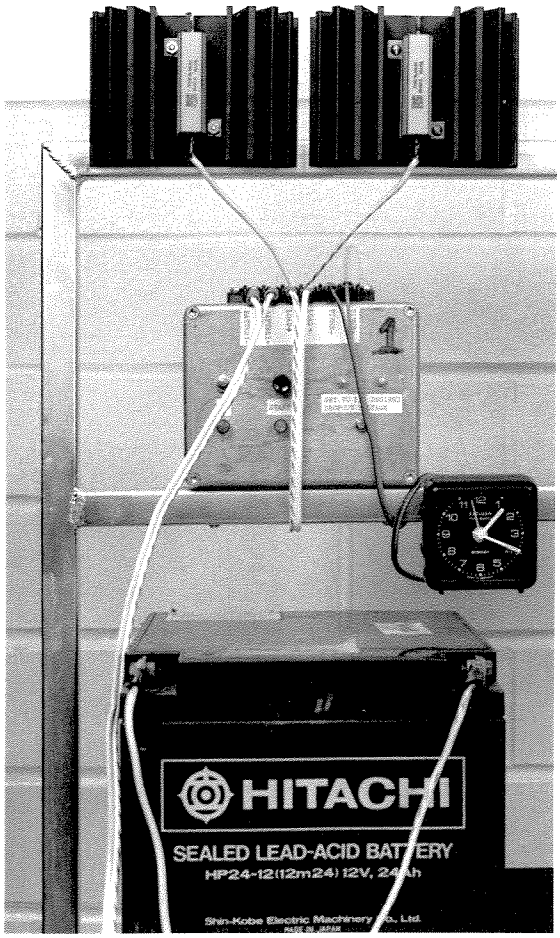


Figure 1.
General view of battery capacity test rig.

be simple to operate and suitable for use in the wheelchair maintenance workshop at Regency Park Centre.

Figure 2 shows the circuit of the test rig. In the circuit, the 5-volt regulator N1 (LM 340-T5) supplies the integrated circuits and is also the reference voltage from which the trip point is derived.

On power-up the relay coil is not energized. When the "Start Timer" button is pressed, the flip-flop formed by the cross-coupled NAND gates N3.2 and N3.1 is set, and the relay coil is activated via the Darlington pair transistors V1 and V2. In addition, the transistor V4 is turned on so as to illuminate the "Timer Active" yellow LED; and V8 provides approximately 1.4 volts to drive a clock that is normally powered by a 1.5-volt cell. When the battery voltage divided by R2 and R3 drops below the preset value set by R4, the output of the comparator goes low, resetting the flip-flop, removing the load, turning off the "Timer Active" LED and the supply to the timer, and terminating the test. R4 is set to terminate the test when the battery is discharged to 10.5 volts.

The test load has a resistance of 2 ohms, corresponding to a current of approximately 6 amperes for a 12-volt battery. This load was chosen to allow a conveniently short testing time: a battery with a capacity of 24 ampere hours can be tested in less than 4 hours.

BATTERY TESTING PROCEDURE

The test procedure is as follows:

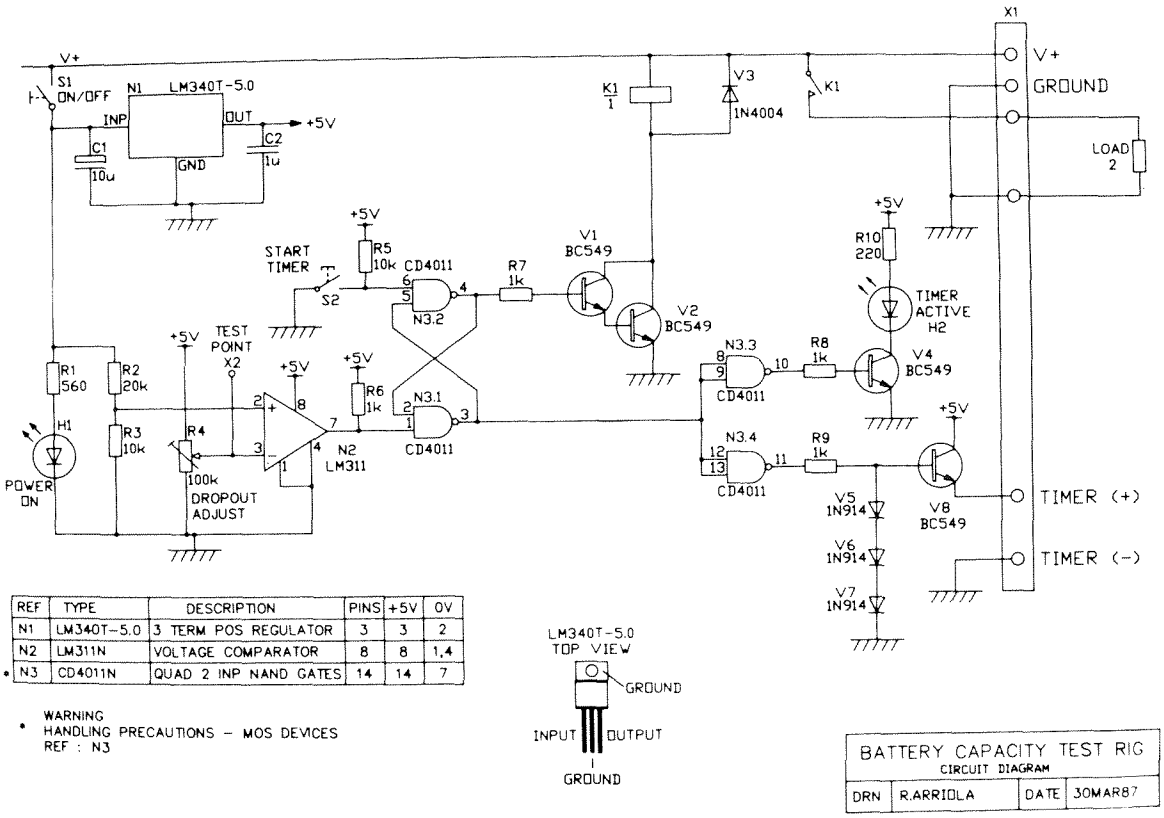
1. The battery to be tested is first fully charged at an ambient temperature of from 20 to 25 degrees Centigrade.
2. After charging, the battery is allowed to stand for 1 hour before testing.
3. The timer is zeroed, the battery is connected, and the test is started: upon completion of the test, the duration of the test is read and recorded.

The measured charge capacity of a lead-acid battery varies with the rate of discharge: an increased discharge rate (i.e., increased discharge current) results in a decreased capacity. The nominal capacity of batteries is usually determined in a test lasting 20 hours, but our test discharges batteries in less time and therefore the measured capacity is less than the nominal value.

For example, Hitachi HP 24-12 batteries, used on many powered wheelchairs at Regency Park Centre, have a nominal capacity of 24 ampere hours, but the manufacturer's data (4) shows that the same batteries will deliver 6 amperes for 190 minutes: a capacity of 19 ampere hours. Our test equipment discharges batteries at 6 amperes, so a test duration of 190 minutes for a Hitachi HP 24-12 battery indicates that the battery satisfies the manufacturer's specification.

In general, batteries used in powered wheelchairs at Regency Park Centre are replaced if their charge capacity is less than 60 percent of the nominal value. For most of our clients this is an appropriate compromise between loss of wheelchair range and the cost of batteries.

To obtain consistent results with testing, it is first necessary to ensure that all batteries are charged



REF	TYPE	DESCRIPTION	PINS	+5V	0V
N1	LM340T-5.0	3 TERM POS REGULATOR	3	3	2
N2	LM311N	VOLTAGE COMPARATOR	8	8	1,4
N3	CD4011N	QUAD 2 INP NAND GATES	14	14	7

* WARNING
HANDLING PRECAUTIONS – MOS DEVICES
REF : N3

Figure 2.
Circuit diagram of battery capacity test rig.

under the same regime before test. This is most easily done by using a charger of known performance to charge batteries before test. Charging and testing of batteries at a constant temperature is also recommended, and is most easily achieved by performing charging and testing in an air-conditioned room. After charging, batteries are allowed to stand for 1 hour before testing, as specified in standards for testing liquid-electrolyte batteries (3). Variations in the voltage at which a test is terminated will affect the results, but the controlling circuitry need not be overly sophisticated because the discharge characteristic is very steep toward the end of testing, and a variation of 0.1 volt in the terminating voltage will not cause significant errors.

TEST RESULTS

Regency Park Centre provides therapy and educational services to disabled children, and more than 90 powered wheelchairs are in use at the Centre, each fitted with two 12-volt batteries. Battery types and sizes vary according to the wheelchairs and needs of the users, but most chairs at the Centre use 24-ampere-hour, gel-electrolyte batteries, and most of these are Hitachi HP 24-12 batteries. Similar batteries marketed under the names Elkron, Exide, Century, Power-Sonic, and Portalac are used in smaller quantities.

Batteries are generally tested immediately after delivery and, in a few cases, have been found to be well below acceptable capacity in these tests. Most of the tests of batteries fitted to wheelchairs are performed when there is reason to suspect that battery capacity is a problem. The two batteries used in a wheelchair are tested separately.

Battery test results obtained over an 18-month period were examined for trends in battery life and performance. In order to reduce the number of variables involved, results are reported here only if: a) batteries were Hitachi HP 24-12 or Exide RE 12-24B (the most common types, both with 24 Ah

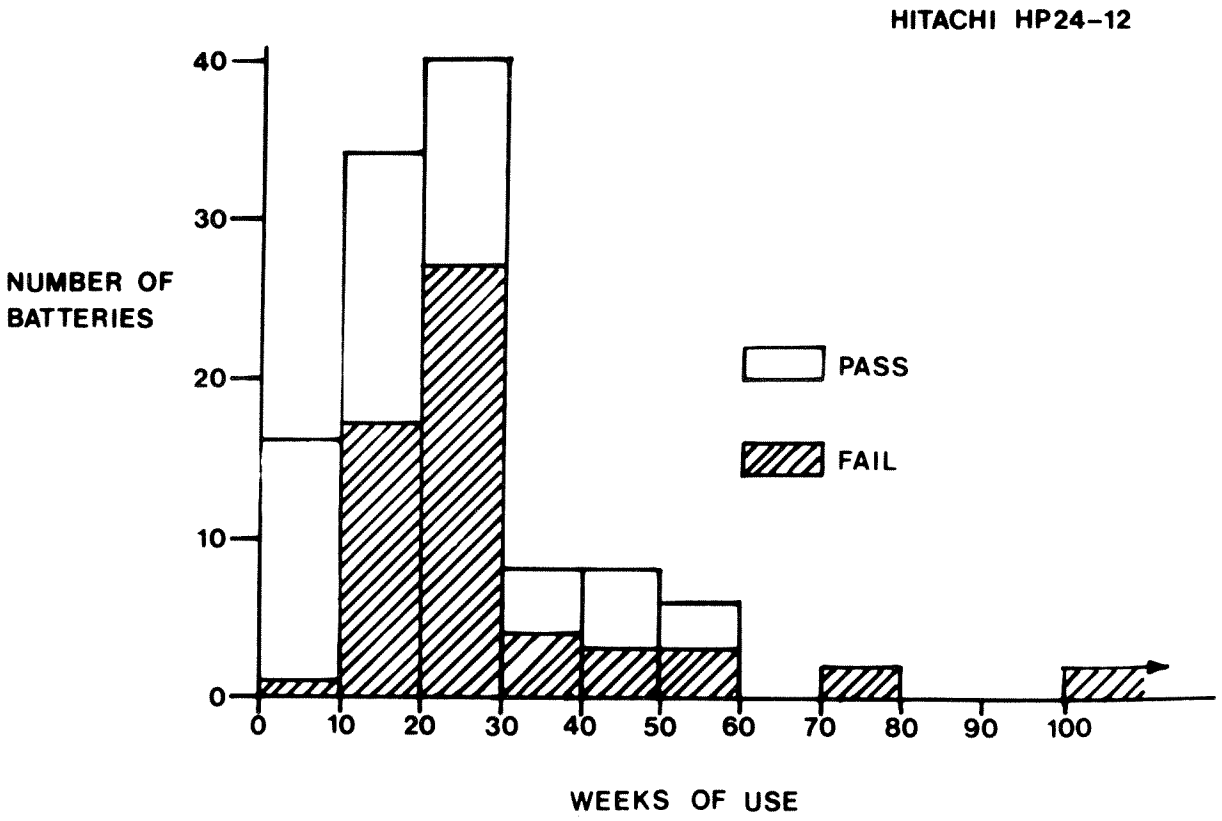


Figure 3.
Test results for 116 Hitachi HP 24-12 batteries used at Regency Park Centre. "Pass" indicates that batteries delivered at least 60 percent of their nominal capacity on test; "Fail" indicates that this was not achieved.

nominal capacity); and, b) batteries in a wheelchair set had been used as a matched pair since issue.

Results for 58 sets of Hitachi batteries and 25 sets of Exide batteries satisfied these criteria, representing a total of 166 individual battery tests. Results for Hitachi batteries are presented in **Figure 3**, and Exide batteries in **Figure 4**.

A scan of the raw data used to prepare **Figure 3** and **Figure 4** revealed that a significant number of battery sets showed a considerable difference between the capacities of the two batteries in the set, despite the apparently identical operating conditions of the two batteries. This is shown in **Figure 5**, in which the ratio of charge capacities of the two batteries is presented. The test results showed that batteries were well matched in capacity in the first 10 weeks of use, and results for this group were omitted from **Figure 5**. The histogram combines results for Hitachi and Exide batteries, which showed similar profiles when plotted separately.

DISCUSSION

The results presented raise several issues pertaining to the life of wheelchair batteries.

First, there is a very wide scatter of battery life, as measured by time in service. This reflects the wide variation in severity of use; for example, some users run their batteries into deep discharge every day, whereas others are very careful to avoid this.

The Exide batteries (**Figure 4**) appear to last longer than Hitachi batteries, but this cannot be demonstrated statistically. In addition, there is some bias in the results due to buying patterns which resulted in Exide batteries being issued to users who normally obtained long service from their batteries.

Compared with the manufacturer's expectations of battery use, wheelchair duty is severe. For example, the manufacturer of Hitachi batteries specifies a battery life of 260 cycles of complete discharge (down to 10.2 V at 4.8 A) before the

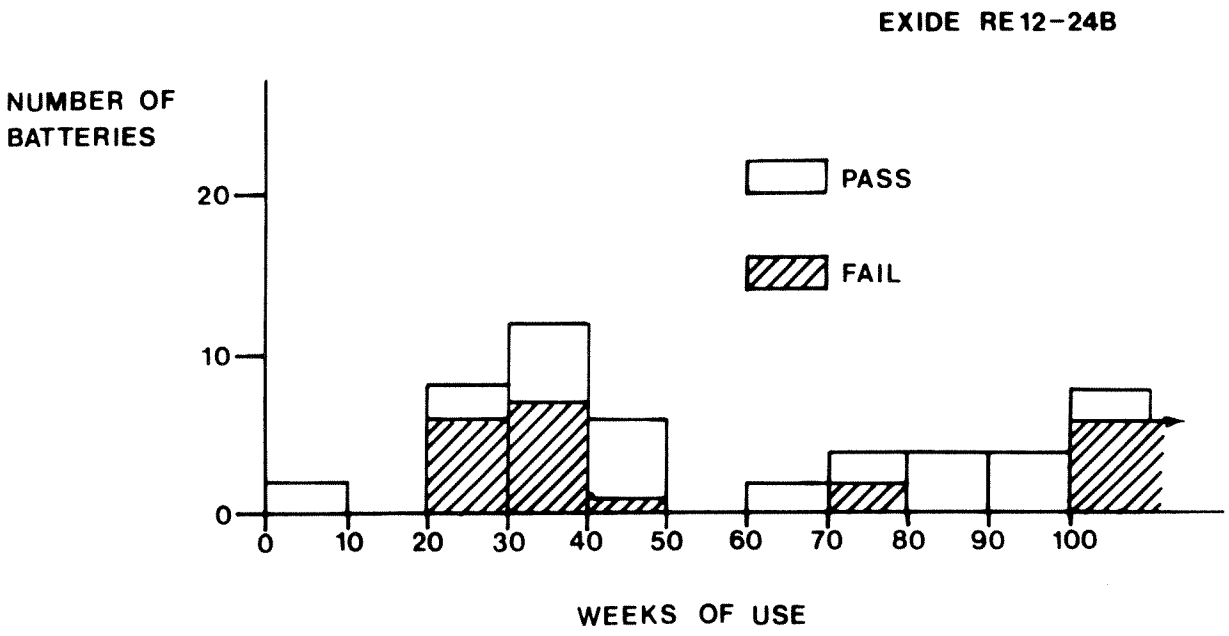


Figure 4.
Test results for 50 Exide RE 12-24B batteries used at Regency Park Centre. "Pass" indicates that batteries delivered at least 60 percent of their nominal capacity on test; "Fail" indicates that this was not achieved.

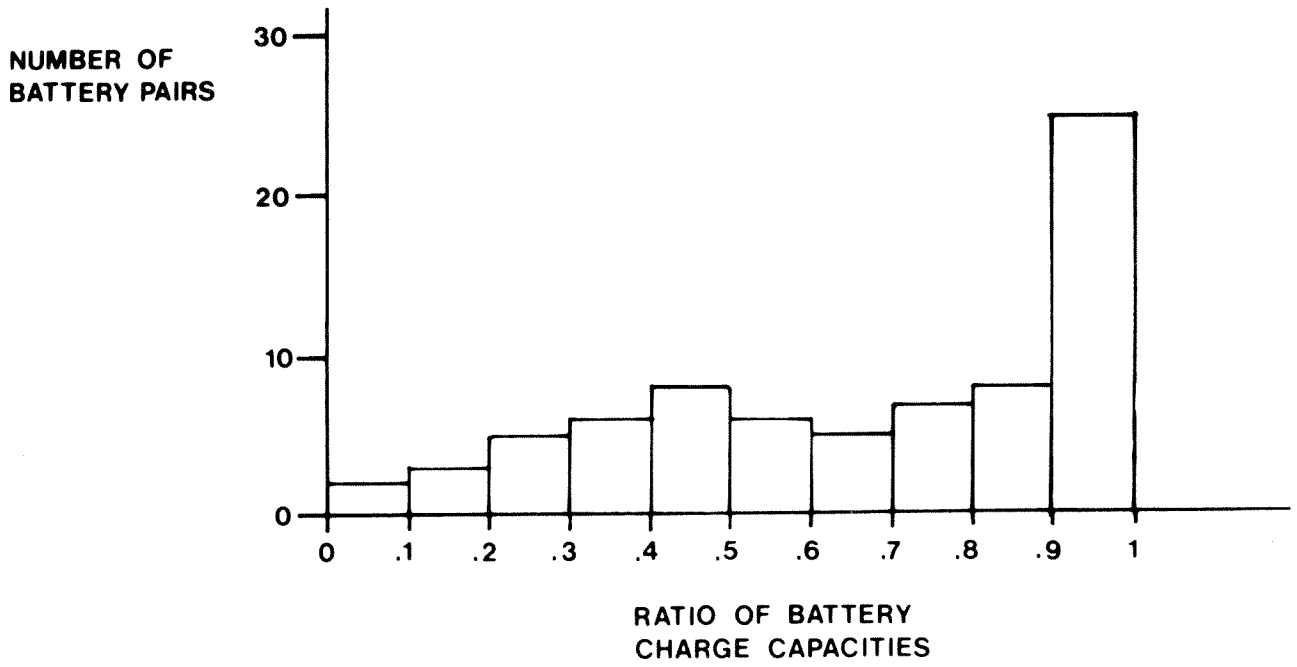


Figure 5.
Ratio of the charge capacities of 75 pairs of wheelchair batteries with more than 10 weeks' use.

charge capacity is reduced to 60 percent of the nominal value; this corresponds to about 37 weeks of use at one complete discharge every day. **Figure 3** shows that the majority of Hitachi batteries do not last for 37 weeks, so the operating conditions of these batteries are probably more severe than the manufacturer's test conditions. The precise nature of these apparently severe operating conditions is worthy of further investigation with a view to the extension of battery life. If, for example, regular discharge below 10.5 volts (a typical lower limit of operation recommended by battery manufacturers) was found to be related to short battery life, the development of devices to inhibit wheelchair operation at low voltages would be worthwhile. Another possibility is that the battery chargers supplied with the wheelchairs are unable to fully charge the batteries in the time available which may be only 8 to 10 hours.

It is clear from **Figure 5** that the two batteries fitted to a powered wheelchair frequently become unequal in charge capacity: the ratio of charge capacities was less than 0.7 for 47 percent of the battery sets tested. (Results for battery sets with less than 10 weeks use were not included in **Figure 5**.) Clearly this is most undesirable: the batteries are always discharged in series when used on the wheelchair, and the battery with less charge is likely to suffer excessive discharge which will, if repeated, lead to further reduction in charge capacity.

It is believed that unequal charging of the batteries is the source of this problem. Most of the powered wheelchairs in use at Regency Park Centre have 12-volt battery chargers, and the batteries are charged in parallel. Unequal charging can occur if there are poor connections between the charger and one of the batteries: a fraction of an ohm of resistance in the charging circuit can significantly reduce the charging current. This can be avoided by the use of a 24-volt charger, with the batteries connected in series. Any fault in the charging circuit then affects both batteries, and can therefore be more readily detected and corrected.

SUMMARY

The battery testing equipment has proved to be very useful for routine battery checking, and examination of the test results has shown that there is room for improvement in the life of batteries used on powered wheelchairs. More information is needed to determine aspects of battery service amenable to improvement that would also be effective in extending battery life.

ACKNOWLEDGMENTS

The battery test circuit was designed by Mr. Lyndon Durbridge to the authors' specifications.

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