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MICROPROCESSOR-CONTROLLED, PRODUCTION-LINE, HIGH-RATE TESTING OF LEAD/ACID BATTERIES WITH DATA COLLECTION AND STATISTICAL-PROCESS-CONTROL EVALUATION OF RESULTS

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The production-line, high-rate discharge testing of wet automotive lead/acid batteries is an important quality control step to confirm the total integrity of the battery before it is shipped. This test ensures that all the plates are adequately formed, all cells are connected properly, the intercell welds are sound, the post-to-terminal burn is sound, the battery polarity is correct, and the acid specific gravity is in the correct range. In general, the test confirms the performance of the battery. All of these factors are evaluated in a short-duration, non-destructive test. The sampling is 100%; every battery is tested and all must pass to be acceptable.

Bitrode provides a flexible systems approach to high-rate testing that meets the needs of the simplest to the most sophisticated manufacturer. The basic unit is a light-duty discharge tester that utilizes a fixed resistor, solid-state load switching, and hand test probes. This is the Model HRD1500 that operates on the premise that the battery will be rejected if the discharge current falls below a pre-selected minimum amperage. The discharge is at 500 - 1500 A depending on the size of the battery. This unit can test about one 12 V battery per minute, on average.

The system for testing becomes more sophisticated in terms of quantity of batteries tested per minute, the degree of control of the test, the degree of automation of the test, and collection and interpretation of the results. The Model HRD2000 and HRD3000 high-rate testers provide excellent capability to test rapidly. In the U.S.A., it is common for batteries to be hand tested at a rate of up to 14 per minute with a 2 s discharge test. This can be accomplished by utilizing a unique, air-cylinder, counterweight system and a pivoting test head assembly for a moving conveyor. With the Model HRD2000 or 3000 it is possible to test the open-circuit voltage of the battery and then discharge at a switch-selectable-range of low, medium or high. This allows the discharge current to be configured consistent with a thorough load but not sufficiently high to damage the internal connections of the battery.

At this point, we can also observe an occurrence commonly referred to as surface charge. Present-day high cold-cranking batteries possess an ability to discharge at abnormally high currents when they are fresh from formation. In some instances, a battery may pass a high-rate test when fresh from

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formation, but not after standing. To counteract this characteristic, Bitrode provides an option to select a two-step discharge test. This involves a discharge to dissipate the surface charge, a rest period, and then a second discharge for accept/reject. This allows testing directly after battery formation.

For the manufacturer who requires test repeatability and compatibility from one shipping line to another, Bitrode provides the Model VRL1500 and 3000 high-rate testers. These are higher in sophistication compared with the Model HRD2000 and 3000. The VRL series features a phase-controlled power supply in series with the load resistor. The concept is to be able to control the battery voltage during discharge and to reproduce that discharge voltage to ± 0.02 V on successive tests. In short-duration, high-current discharges, the voltage can be controlled more easily than the amperage. By controlling the discharge voltage in a range of 2 - 7.5 V for a 12 V battery, the discharge current can be varied in the range of about 750 - 1500 A with the Model VRL1500. Thus, if it is desired to raise the discharge current slightly on a test, the control voltage is lowered until the desired discharge current is reached or surpassed. The VRL series also adds an internal ethylene glycol/water cooling system to prevent moisture condensation on internal parts, and a liquid/liquid heat exchanger to minimize cooling water requirements.

Either of the above production-line, high-rate testers can be automated by adding a battery test fixture that does not require an operator in regular attendance. This allows the actual high-rate testing to be done by a machine rather than by an individual. The test fixture can be relatively simple, requiring manual test-probe positioning adjustments and operated by a programmable logic controller. Alternatively, it can be highly sophisticated including full microprocessor control with data acquisition. The test fixture utilizing a programmable logic controller is available in a top-terminal-only model or a top-and-side-terminal model. It can process batteries up to 56 cm long with a maximum lengthwise distance between terminals of 41 cm. Maximum battery height is 28 cm, minimum height is 14 cm, and maximum width between battery terminals is 23 cm. High-rate testing must always be conducted utilizing explosion-proof vent caps to prevent an arc from igniting hydrogen gases commonly present in freshly formed batteries.

The more sophisticated version of the above automatic test fixture, the Model TF/M, features microprocessor control of all parameters and is ultimately designed to incorporate a bar code reader for the incoming battery to provide an unattended automated operation with data acquisition. The Model TF/M allows a battery to be identified by up to an eight digit number. All test and positioning parameters for this battery are pre-programmed. A touch panel keyboard is used for programming and operation. It includes a security key to prevent unauthorized program changes. All entries are via a fill-in-the-blanks menu. These parameters include the Lower Battery Cut-off Voltage which is an open-circuit voltage (OCV) set point below which the battery is not tested because of low open-circuit voltage. The OCV Setpoint is the minimum acceptable voltage for a battery to be tested. The Lower

Reject Current is the minimum acceptable discharge current for the battery. The Upper Control Limit is the maximum acceptable discharge current for the battery. A discharge in excess of this value will result in the battery being rejected. The Control Voltage is the discharge voltage of the battery and is held constant during the test. The Model TF/M units utilize the Bitrode Model VRL voltage-controlled discharge technology. The Terminal Type refers to top, side, or top-and-side terminals on the same battery. Polarity is reversible so that batteries do not have to be turned prior to testing. Case size determines which battery clamps are activated and whether the conveyor speed is slow or normal. Test time is the duration of the discharge and is adjustable from 1.0 to 3.0 s. When testing at normal speed and with a 2.0 s discharge, the test rate is about eight batteries per minute. The Move Probe Axis command allows the 5 cm top terminal or 1.9 cm side terminal copper test probes to be positioned for the specific battery number. When that battery is again selected, the probes will reposition to the previous location and testing can commence without further adjustment.

While testing, the screen will display the battery number, the test parameters, the test results for control voltage, open-circuit voltage, discharge current, and a comment if the battery is rejected. The test results of the last seven batteries tested are displayed on the screen.

The Model TF/M has an optional library maintenance feature that allows the test parameters and positioning data to be kept on floppy disc using an IBM AT compatible computer. Communication is through an RS232 interface. A number of test fixtures can communicate, utilizing a coaxial two-wire network. The test library can be down loaded from the test fixture to the floppy disc for safe keeping or can be uploaded to the test fixture for updates and corrections made on the personal computer.

In addition, the microprocessor of the test fixture has the ability to store 1000 lines of test data. The personal computer can be used to acquire the test data and present reports in summary format by battery type. One type is a Shift or Daily Production Report by finish line (Table 1). The report includes the test specifications for OCV, Minimum Reject Amperage and Control Voltage. Test results include Number of Batteries Tested, Number Failing OCV, Number Failing Minimum Discharge Current, Number Failing Polarity, and Number Passed. An Average, and Standard Deviation for OCV and Current are detailed for the batteries that passed the test. This report can be used for quality auditing as well as for inventory control.

Another Type Production Report is by Battery Type for a period of time such as a week or a month. The report can detail an average of the daily production runs of a battery type (Table 2). The report includes the Test Specifications for OCV, Minimum Reject Amperage, and Control Voltage. Test results include Number of Batteries Tested, Number Failing OCV, Number Failing Polarity, and Number Passed. An Average, and Standard Deviation for OCV and Current are detailed for the batteries that passed the test.

TABLE 1

Example of daily production report from TF/M1500 high-rate battery tester

Date _____ Bitrode model TF/M1500 finish line _____

Shift _____ Data time span _____

Test specs				Tested					Passed			
									OCV		Amps	
Battery type	Min. OCV	Rej amps	Control voltage	No. tests	Failed OCV	Failed amps	Failed polarity	No. passed	Avg.	S.D.	Avg.	S.D.
xxxxxxxx	12.75	1000	4.55	550	12	22	1	515	12.78	0.02	1031	27
xxxxxxxx	12.69	1250	4.00	1172	33	68	4	1067	12.74	0.03	1276	24
xxxxxxxx	6.32	850	3.80	223	9	17	0	197	6.41	0.04	889	36
Totals				1945	54	107	5	1779				

TABLE 2

Bitrode model TF/M1500 production report by battery type

Battery type _____ Date start _____ Date end _____

Test specs				Tested					Passed			
									OCV		Amps	
Date	Min OCV	Rej amps	Control voltage	No. tests	Failed OCV	Failed amps	Failed polarity	No. passed	Avg.	S.D.	Avg.	S.D.
xx xx xx	12.75	1000	4.55	550	12	22	1	515	12.78	0.02	1031	27
xx xx xx	12.75	1000	4.55	1582	27	40	2	1513	12.79	0.02	1035	28
xx xx xx	12.75	1000	4.55	1410	29	36	1	1344	12.78	0.03	1036	26
Totals				3542	68	98	4	3372				

The test results can also be selected by Battery Number for presentation in Statistical Process Control Format on either a daily basis or as a summary of each day's production on a weekly or monthly basis. The Tabular and SPC Format is menu driven allowing the test population to be selected for presentation. For example, this would allow presentation of data about a Specific Customer's Battery Type to be presented with the shipment in both Tabular and SPC Format. Alternatively, the results could include the Raw Test Data on every battery included in the shipment.