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March 3, 1997

REPORT OF DISCOVERY

HARNESS/POSITIVE PLATE LUG DISCONNECT IN ROUND CELL BATTERY

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03/03/1997

REPORT OF DISCOVERY

Observation

On February 12, 1997 a four cell string of high gravity Round Cells failed a capacity discharge test The test was carried out at the C&D Technical Center in Conshohocken PA., as part of the Nuclear Round Cell User's Council test program. The discharge test failed because one cell went into reversal immediately following the start of the discharge. This cell was manufactured in 1991 (serial # R9105-97461) and used in a spare battery at McGuire's Nuclear Generating Station. The remaining three cells in the string were new cells recently manufactured. The discharge was done at a constant current of 508 amps, corresponding to a 2 hour discharge rate, to an end voltage of 1.75V/cell. The reversed cell reached a potential of -2.63 volt within 1 second and -3.32 volt after 47 seconds, at which time the discharge was terminated. During this time the reversed cell was gassing heavily and produced a smell of hydrogen sulfide. Subsequent autopsy of the failed cell revealed that the harness of the positive electrode was completely disconnected from the four lugs connected to the top positive plate.

Cell history

The failed cell from the McGuire spare battery had been subjected to the same discharge testing as the batteries in service at McGuire. During a total number of five tests consisting of a combination of capacity discharge testing and service load profile testing, no additional voltage loss associated with poor harness/lug connections had been observed. After the cell was transferred to Conshohocken the first capacity discharge test using a two hour rate, showed an additional voltage loss of approximately 100 mV and a delivered capacity of approximately 80% of rated capacity. In the subsequent discharge done under the same conditions the cell was driven into reversal.

Cause of failure

Further examination of the disconnected harness and positive plate lugs pointed towards incomplete welds as the most likely contributor to the disconnection. The weld burns were narrow and shallow. The fact that no discharge problems were experienced during testing done at the McGuire Nuclear Generating Station indicates that extensive handling with associated mechanical and thermal stresses possibly contributed to the final failure.

Consequences of such failure

Consequences of such a cell reversal, if it occurs in a battery servicing a load, are loss in capacity and excessive gassing. The major factor in excessive gassing is the generation of hydrogen gas which can form explosive mixtures in air. Smaller amounts of hydrogen gas can also be formed during cell reversal, especially when the cell temperature is raised. Although this gas is highly toxic its smell can be detected at very low concentrations. The extent of capacity loss and gas generation depends on the specific application, such as battery configuration, battery cut-off voltage and most importantly initial discharge current in the load profile.

Capacity loss

The Coup de Fouet, which is a rapid voltage loss occurring at the very start of the discharge of a lead-acid battery, is critical when the initial discharge current is very high. The service load profile for the Nuclear Generating Plant is characterized by a high initial current, which generally lasts approximately one minute. If the initial discharge current is high enough to lower the Coup de Fouet discharge voltage below the battery cut-off voltage, then the battery will shut down almost immediately and the deliverable capacity is very small. In this case the amount of hydrogen gas generated during reversal is also limited.

Hydrogen gas generation

Assuming that water decomposition is the main electrochemical reaction following cell reversal, then the total amount of hydrogen gas generated in the reversed cell can be estimated based on the discharge current and battery string capacity delivered before the cut-off voltage is reached, according to:

Volume of hydrogen in liters = 0.42 × delivered capacity in Ampere-hours.

Summary

Based on the available data, values for delivered capacity and the volume of hydrogen gas, generated is estimated for two different initial discharge currents. The lower current represents the case where the Coup de Fouet voltage is above the battery cut-off voltage, while the higher current represents the case where the Coup de Fouet voltage is below the battery cut-off voltage. This example is based on one reversed cell in a 60 cell string battery with 100% capacity and a cut-off voltage of 105 volt.

initial current	**available battery capacity**	**amount of hydrogen gas generated**
500 A	60%	250 liters
1000 A	< 1%	< 4 liters

Conclusion

Test records from the manufacturer show that cell serial # 97461, did pass the bond resistance test as per Round Cell specification KS-20724 drawing L-905503. This test is required to evaluate the harness to positive plate lug weld. The cell also passed a subsequent discharge test specified by McGuire Nuclear Generating Station. Most importantly in the entire Round Cell manufacturing history of 800,000 cells and 25 years this is the first time that a complete disconnection of harness and positive plate lugs have been reported as the cause of failure. From this Round Cell manufacturing history, combined with the weld test results at the manufacturer, it is concluded that the cell failure described in this ROD is an anomaly, occurring extremely rarely.