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# LIFE CYCLE MONITORING OF TUBULAR PLATE LEAD ACID BATTERIES WITH CADMIUM ELECTRODES

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Tubular plate lead acid batteries are extensively used in long life industrial applications at different duty cycles (float with occasional deep discharge or deep discharge). Normally, the life cycle tests take about a year to complete and the satisfactory completion of the set number of cycles is taken as the end test.

An attempt has been made to regularly monitor the cadmium potential of both positive and negative plates during cycling and assess the progressive deterioration of the battery in the life cycle test for stationary and traction applications. Comparison of the life performance of different batteries with other data (capacity, storage efficiency, etc.) has been made to correlate and predict performance aspects. Modification of the life cycle test based on the above data is also aimed at to cut short the testing duration without sacrificing the real life evaluations. Results on batteries from different sources are presented here.

**Key words: Tubular lead battery, life test, cadmium potentials**

## INTRODUCTION

Tubular plate construction increases the life of the positive plate in lead acid battery. However, the high rate discharge performance is reduced due to higher internal resistance offered by such a fortified construction. This type of construction is very well suited to several industrial battery applications with moderate drains as in stationary and traction purposes. The duty cycle involves either float service with occasional deep discharge or deep discharge cycles. In the latter case the battery is subjected to continuous cycling and the life, inspite of the tubular plate construction, can be limited thanks to contributions from the negative plate.

The authors have earlier presented performance of several types of lead acid batteries [ 1 ]. The testing of stationary and traction batteries for life is based on several specifications — both Bureau of Indian Standards (BIS) and Research Designs and Standard Organisation (RDSO) of the railways. This paper deals mainly with testing of stationary cells (IS 1651 with life cycle test based on RDSO specification) and traction cells (IS 5154).

The life cycle test procedures for the tubular plate cells is different for the two types of applications as given in Table I.

The life cycle for stationary cells involves 76.5% discharge and 90% recharge for every cycle. While charging is nearly at the 10 hr. rate, discharge is at 6 hr. rate. This works out to (87% discharge at $C_{10}$ rate and charging is 108% at $C_{10}$ rate) about 20% excess charge in every cycle. On the other hand, the corresponding figures for traction cells are 86.4% charge and 94% discharge ($C_5$ rate) creating an imbalance. In the case of traction cells, the discharge is for 3 hours at 0.25 $C_5$. Hence of the two tests cited, the life cycle test on the traction cell is severe. The test results reported bring forth this aspect.

## EXPERIMENTAL

The tests on batteries were conducted as per specifications at 300 ± 2K for stationary cells (20 to 500 Ah) and at 306K to 316K for traction cells (290 Ah). The cells were monitored during cycling periodically by measurement of cadmium potentials. Several types of batteries from various sources were tested and typical results presented. The control tests were also performed by monitoring cadmium potentials. Traction cells were assembled in polyethylene container while stationary cells were in hard rubber container. The performance of the cells under life cycle tests are presented here.

TABLE - I Life cycle test procedure

| Specification | Discharge rate and duration | Charge rate and duration | Control test & requirement | Life expected & approx. duration for for completion of test |
|---|---|---|---|---|
| IS 1651 (RDSO) | 0.17 x $C_{10}$ for 4½ hrs. | 0.12 x $C_{10}$ for 7½ hrs. | $C_{10}$ test every 50 cycles. 80% of rated capacity | 500 cycles 10 months |
| IS 5154 | 0.25 x $C_5$ 3 hours | 0.096 x $C_5$ for 9 hours | $C_5$ test every 50 cycles. 80% of rated capacity | 1000 cycles 20 months |

### Stationary cells

The performance of a typical battery during periodic capacity tests in life cycle is presented in Fig.1. It may be seen that the cells are very healthy even at the end of the 500 cycles and cadmium potentials of positive and negative vary slightly during life. The failure trend is difficult to predict from this curve unless the studies are continued. However, it can be concluded that this mode of cycling is not severe on the cells as most of the batteries subjected to this test have completed 500 cycles without failure. The study will be extended by having a cycling pattern as follows to accelerate the test and introduce failure modes:

| | | |
|---|---|---|
| Discharge | $0.15 \times C_{10}$ | 5 hrs |
| Charge | $0.12 \times C_{10}$ | 7 hrs |

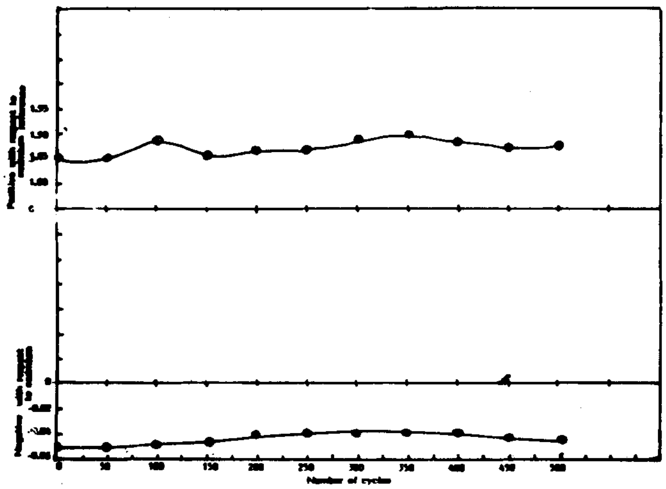

*Fig.1: Stationary cell 2V/80 Ah - Life cycle vs plate potentials at 80% of the rated capacity*

Other conditions remaining same. This works out to equal levels of discharge and charge. The tests will be taken to completion.

**Traction cells**

Traction cells present interesting results as presented in Figs 2-5. Fig.2 represents the performance of 2V/290 Ah traction cells during the capacity test after various cycling regimes viz. 100,500,750 and 1000. The cadmium potential values of the positive plates change gradually and remain in a narrow regime indicating their healthy state. But the life limitation is due to progressive negative plate failure during the cycling. This is clearly seen by the negative cadmium potentials. As cycle life increases the negative cadmium potential rises sharply leading to failure.

Fig.3 indicates the variation of the cell voltage with cycling at 80% discharge stage during capacity test (since 80% is the minimum required of rated capacity). Progressive fall in voltage due to wear-tear failure mode is seen in the case of cell B. Cell A has failed prematurely. The same results are depicted with respect to cadmium voltage in Fig.4. The sharp rise in negative cadmium voltage brings out the negative failure mode especially after 500 cycles in the case of cell A. Cells A and B show similar positive plate potentials. Cell B shows gradual negative plate failure.

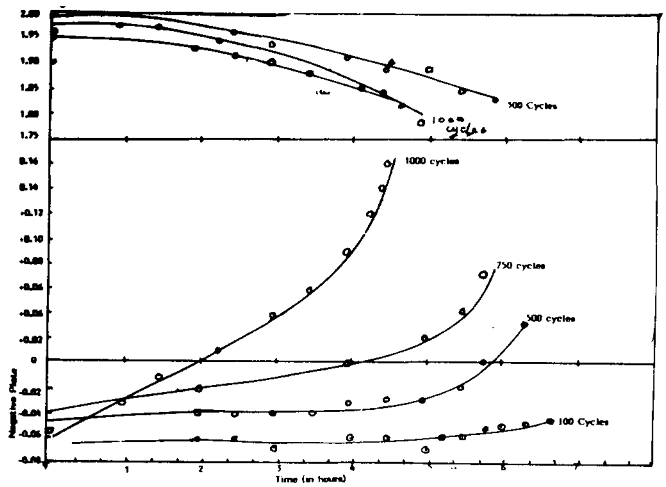


*Fig.2: Traction cell 2V/290 Ah — Capacity test at 80% of the rated capacity- plate potential vs time at different cycles*

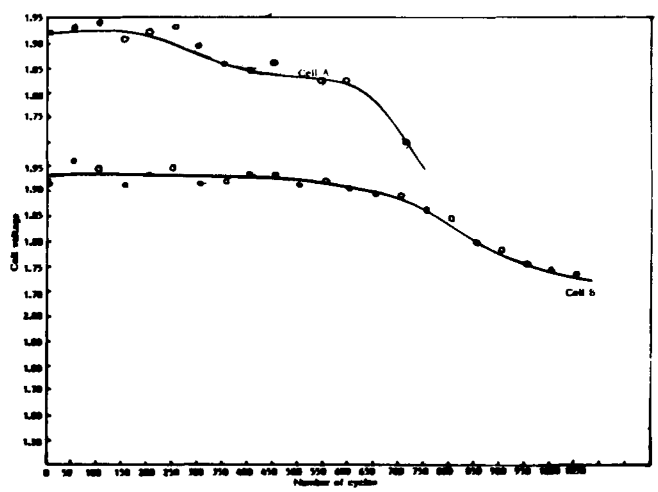


*Fig.3: Traction cells 2V/290 Ah: Life cycles vs cell voltage at 80% of the rated capacity*

Fig.5 represents the performance of a prematurely failed cell compared to a healthy cell at 650th cycle capacity test. Failure is predominantly negative oriented in this case — the negative potential rising very sharply.

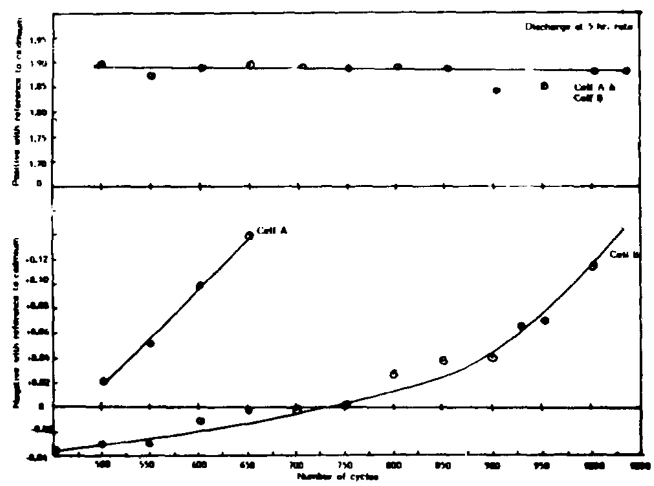


*Fig.4:Traction cell 2V/290 Ah — Life cycle vs plate potential at 80% of the rated capacity*

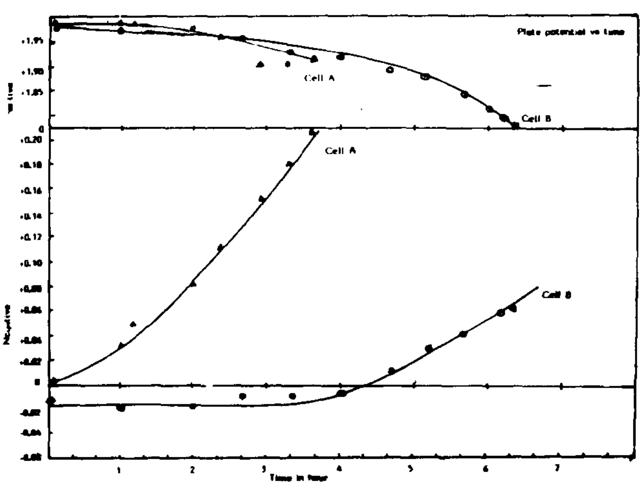


*Fig.5:Traction cell 2V/290Ah capacity test at 650 cycles*

The results indicate that though the stationary and traction cells are nearly similar, the life cycle performance is widely different due to variation in severity in the cycling as already mentioned. Traction cells which are subjected to heavy discharge regimes suffer by failure of the negative plate. The positive plates retain their performance upto 1000 cycles. This brings out the necessity for improving the design and fabrication of the negative plate. However, the wide temperature range allowed for life cycle test of traction cells may give different data at different test periods [2]. However, it is also seen that the test itself is rather severe as indicated and it is proposed to modify the test as follows and study the performance of the cells

| | |
|---|---|
| $0.20 \times C_5$ | 4 hrs. |
| $0.10 \times C_5$ | 8 hrs. at 300 $\pm$2K |

other things remaining same. Here again the discharge/charge are evenly balanced and still is accelerated deep discharge cycle.

An examination of the traction cell which has completed 1000 cycles revealed that negative plates were intact. Positive plates on examination showed that the grid spines were nearly corroded and reaching the end of the life.

## CONCLUSIONS

(i) Traction cells fail during life cycle tests due to severity of the test and failure of negative plate. (ii) The positive plates of cells that completed life cycle tests show extensive corrosion of positive grid indicating impending failure. (iii) Modified test routines are suggested.

## REFERENCES

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