Bulletin of Electrochemistry 7 (8) August 1991, pp 362–363

0256-1654/91/$ 3-50

PERFORMANCE CHARACTERISTICS OF 5 AH SODIUM SULPHUR CELL

M Kamaludeen, N G Renganathan, M Raju, H P Sarma, A Visuvasam S Sriveeraraghavan
G Periaswami*, S Rajan Babu* and C K Mathews*

Central Electrochemical Research Institute, Karaikudi - 623 006, INDIA
* Indira Gandhi Centre for Atomic Research, Kalpakkam - 603 102, INDIA

[Received: 1991 April; Accepted: 1991 July]

As a part of developmental activity towards the goal of testing prototype 20 Wh sodium sulphur cell preliminary studies on 5 Ah cells have been carried out. The cell with central sodium design has been fabricated. Beta alumina tube after helium leak test was assembled in the designed cell. High purity sodium was filled and reformed sulphur electrodes were assembled. The cells, after TIG welding of both sodium and sulphur compartments, were tested for their performance.

Key words: Sodium-sulphur, β-alumina, charging and discharging cell

INTRODUCTION

Sodium sulphur battery has a lot of potential applications in load levelling, vehicle propulsion and satellite power [1]. As a part of the developmental activity towards the goal of testing prototype 20 Wh sodium sulphur cell, preliminary studies on 5 Ah cells have been carried out and the results are presented.

EXPERIMENTAL

The cell with central sodium design has been fabricated [2] in such a way that sodium has to be accommodated in a reservoir and the cell volume is given by

$$V_c = \frac{\pi D^2}{4}\left\{L + L_t + \left[\frac{23 \times 3600E}{2\eta F\delta_{Na}} - \frac{\pi(d-2t_e)^2 L}{4}\right] \frac{4}{\pi(d+2t_s)^2}\right\} \quad \ldots (1)$$

where V_c = cell volume, L = Length of the cell case, L_t = Length of the terminal, η = Voltage efficiency, F = Faraday, δ_{Na} = density of sodium, D = Maximum diameter of the cell, d = Electrolyte tube diameter, t_e = Electrolyte thickness, t_s = Sulphur electrode thickness.

The cell is shown in Fig 1. Beta alumina tube (obtained from National Physical Laboratory, New Delhi), was used as the solid electrolyte and the specifications of the tubes in general (and not to any particular batch) is given in Table I. Helium leak tightness tests were made (at B.H.E.L. Trichy) and results for some of the tubes are given in Table II. Minimum leak rate tubes were filled with high purity sodium (at I.G.C.A.R., Kalpakkam) and the compartment was TIG welded. Equal weight ratio of sodium to sulphur was maintained. Then, preformed sulphur impregnated carbon matrix electrodes were assembled and again sulphur compartment was also TIG welded. Carbon content was varied from 10 to 20% in carbon sulphur compact and design of sulphur electrodes had been patented. The cell was placed in a heating chamber which was maintained at 623± 10K with suitable temperature controller. Performance characteristics of the cells viz. life cycle, charge and discharge current densities and causes of failure were studied.

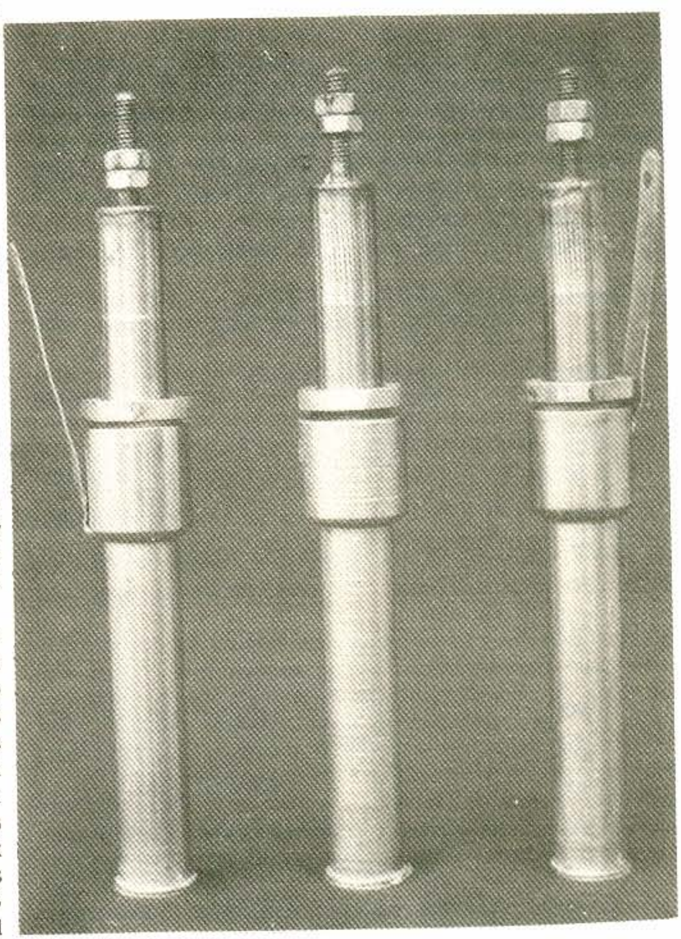

Fig. 1: Sodium sulphur cells

TABLE-I: Characteristics of beta alumina

1. Diameter of the tube (mm)	10
2. Thickness (mm)	1–3
3. Conductivity (ohm cm)	5–10
4. Mechanical strength (M.Pa)	100–200
5. Ovality/Inclined to the base	Slightly

TABLE-II: Helium leak tightness of some of the beta alumina tubes

Tube No.	Helium leak rate (Std cc. sec^{-1})
B–79	2.7×10^{-6}
B–90	1.89×10^{-4}
B–94–5	1.89×10^{-4}
B–94–3	More than 10^{-3}
B–94–6	More than 10^{-3}
B–92	8.1×10^{-5}
B–93–5	2.43×10^{-5}

* None of the tubes withstood standard specification viz. helium leak rate of 1×10^{-8} Std cc sec^{-1}

RESULTS AND DISCUSSION

Typical charge/discharge curves are given in Fig. 2. It is quite obvious that cell resistance seems to be higher than the reported values. This may be mainly due to the structure of sulphur electrode and steps have been taken to reduce this by the modification of the sulphur electrode design. Data observed on the cell failure over the period 1988–1990 are given in Table III. Generally, physical degradation and electrical degradation are the two main modes of cell failure. Due to physical degradation, fracture occurs at the alpha alumina/beta alumina/seals. Due to electrical degradation, capacity loss or resistance increase occurs. 50% of the failure seems to be due to fracture at the alpha alumina, beta alumina interface viz. glass seals. It seems that the penetration of sodium dendrites initiated cracks in beta alumina and sometimes getting enlarged are the main reason for premature failure of sodium sulphur cells. Cracks isolated in the main body of beta alumina are typically of a circumferential type. There is little correlation between the crack patterns and the longitudinal shape of sulphur electrodes used in the cells [3]. Tubes having initially micro cracks as is evident from the poor helium leak tightness data from (Table II), may be the cause for abrupt failure of most of the cells.

The other main contribution to the cell failure is due to the electrical degradation resulting in capacity loss/resistance increase. There are several reasons for increase in cell resistance. Among them the design of sulphur electrode plays a vital part. In some of the cells with single mat sulphur electrode, increase in resistance is understandable. However, in some of the cells with dual mat design consisting of a thin layer of oxide coated carbon fibre formed by decomposing $Al(NO_3)_3$ [4] and $Al_2(SO_4)_3$ impregnated carbon at 1273K [5], increase is resistance was again noticed. It was found that in the $Al_2(SO_4)_3$ route, the sulphate remains as a residue even after prolonged heating and this may be responsible for the increase in cell resistance.

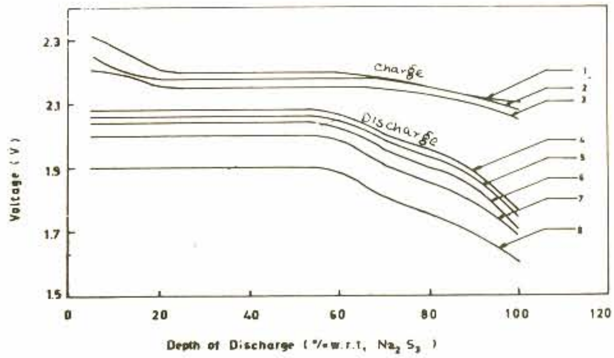

Fig. 2: Charge discharge curves at different current densites (1) 30 (2) 20 (30 10 (4) OCV (5) 10 (6) 20 (7) 30 (8) 50 $mA.cm^{-2}$

TABLE-III: Data on the observed cell failure over a period of one year

Total No. of tubes	158
Tubes found to be defective before assembling	70
Total No. of cells tested	88
Failure due to equipment breakdown	10
Failure due to handling	5
Abrupt failure	
(i) Cracked alpha alumina	10
(ii) Cracked beta alumina	10
(iii) Seal failure	15
(iv) Combinations of (i), (ii), & (iii)	13
Poor performance	
Capacity loss/resistance increase	25

CONCLUSION

Cycle life achieved with 5 Ah cell was 73 at an operating discharge current density of 50 $mA.cm^{-2}$ and a charge current density of 25 $mA. cm^{-2}$.

Acknowledgement: *The authors acknowledge the financial support from D N E S for this project.*

REFERENCES

1. R W Minck and C R Halbach, *Proc* 17th IECEC, Vol. **2** (1982) p 557
2. J L Sudworth in *The Sodium Sulphur Battery*, (Ed) J L Sudworth and A R Tilley, Chapman and Hall, New York (1985)
3. J Baso, EPRI Report, EM 2579 DE 82, 096459, 6–23 (1982)
4. G J Janz and R M Murphy, *J Electrochem Soc*, **125** (1978) 1605
5. R W Powers and B R Karas, *ibid*, **136** (1989) 2787