OVERVIEW OF RECHARGEABLE BATTERY TESTING IN JAPAN

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Summary

In Japan, advanced batteries, Na–S, $Zn-Cl_2$, $Zn-Br_2$, and the Cr–Fe redox–flow battery, aiming for utility load-leveling applications have been actively developed in the "Advanced Battery Electric Power Storage System Project" of the Agency of Industrial Science & Technology (AIST), Ministry of International Trade and Industry (MITI). This project was started in FY 1980 and scheduled to be continued to FY 1990, and a 1000 kW demonstration plant is planned to be constructed and tested. Regarding batteries for vehicular applications, relatively small-scale projects have been carried out by Japan Electric Vehicle Association (JEVA) and the Electric Vehicle Engineering Research Association (EVERA) after the "Electric Vehicle Project (FY 1971 - 1976)" of AIST, MITI. In this paper, an outline of these projects and the battery testing practices involved are reported.

A. Advanced Battery Electric Power Storage (EPS) System Project

1. Introduction

In Japan, the difference between day and night electricity demand has increased in recent years, and the annual load factor has decreased by about 50%. On the other hand, large capacity nuclear and coal fired power plants have become popular. Their power output is hard to control, as efficiency has priority. Controlling the electricity according to the power demand increases the load factor and improves the generation efficiency. Pumped hydrogeneration as a means of storing electric power for load leveling has already been commercialized. This has some shortcomings, however: the location of the power plant is, generally, remote from consumers and is restricted to preserve the natural environment in national parks, etc. Plants of the EPS system can be installed in or near cities.

Thus, the EPS system using advanced batteries is expected to be the most promising for commercialization as a substitute for pumped-up power generation.

2. Outline of the project

2.1. Basic research and development plan

Table 1 shows the development goal to be achieved by the electric power storage system demonstration test.

TABLE 1

Goal of development

Item	Target performance
Output (kW)	1000
Standard charge/discharge time (h)	8 charge/8 discharge
Overall energy efficiency (%)	Over 70 (at a.c. input/output terminal)
Service life (charge/discharge cycles)	Over 1500 (service life: about 10 years)
Countermeasures for environmental protection	Conforming to all environmental quality standards (applicable laws and regulations)

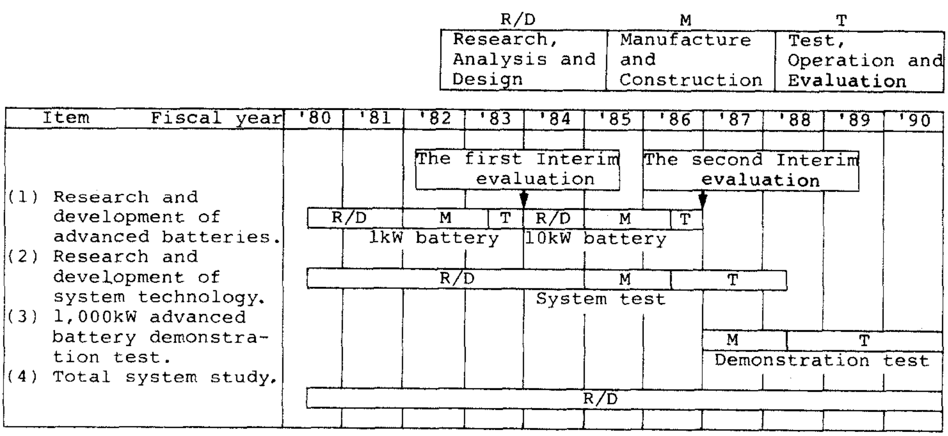

Fig. 1. Development schedule.

Figure 1 shows the project schedule, and the following items are being or will be investigated.

(i) Research and development of advanced batteries is being undertaken for Na–S, Zn–Cl_2, Zn–Br_2, and Cr–Fe redox–flow batteries. A performance evaluation method for these batteries is also being developed.

(ii) System tests using a 1000 kW improved lead–acid battery are programmed to establish system technologies. The facility for the tests will be constructed by the end of September 1986, and test programs are now under discussion.

(iii) By using advanced batteries, a 1000 kW class power-storage-system will be operated to test comprehensively and demonstrate its performance and functions.

(iv) To support the above research and development, the complete system is being systematically studied to optimize its practical applications.

2.2. Organization

Figure 2 shows the organization of the project for the FY 1985. The New Energy Development Organization (NEDO) is taking charge of the development of advanced batteries, system techniques, and total system studies, and has consigned the practical research and development work to private enterprises.

National research institutes, Electrotechnical Laboratory (ETL) and the Government Industrial Research Institute, Osaka (GIRIO) support research for advanced batteries and evaluate the battery performance. ETL developed a Cr–Fe redox–flow battery, up to March, 1984 but its technology was transferred to Mitsui Eng. & Shipbuilding Co., Ltd. in May, 1984.

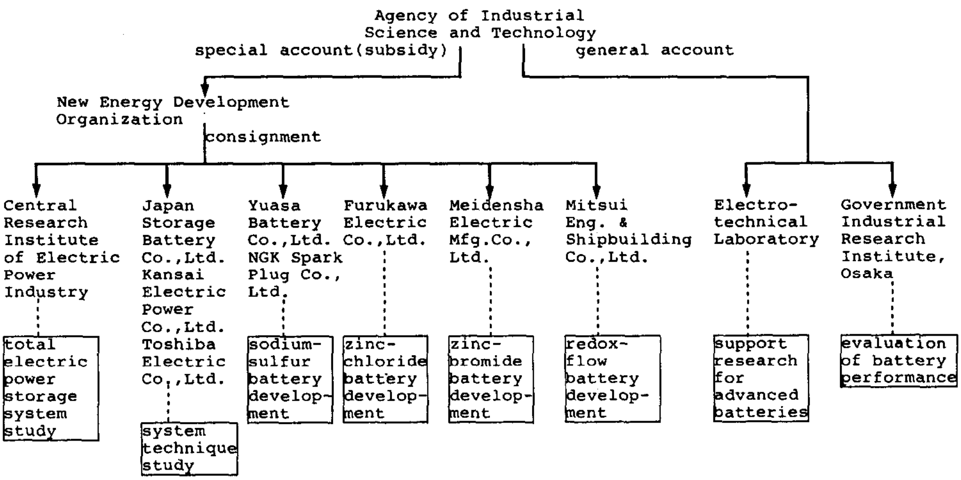

Fig. 2. Organization of the project (FY 1985).

3. The first interim evaluation test

3.1. Conditions of the evaluation test

The following tests were conducted, mainly in the first interim evaluation test.

(i) Capacity tests at various discharge rates. — Measurement of retained capacity at 8, 6 and 4 h rate discharges. Table 2 shows the conditions.

(ii) Self discharging rate test. — Measurement of the self discharge rate by the capacity test after setting aside the full, charged batteries for 2 and 4 weeks.

TABLE 2

Conditions for the first interim evaluation test

Battery		Sodium–sulfur	Zinc–chloride	Zinc–bromide	Redox–flow
Capacity test at various discharge rates	Charging power (kW)	1.70	1.40	1.25	1.34
	Cut-off voltage or duration*	2.4 V	8.0 h	8.0 h	8.0 h
	8 H.R. Discharging power (kW)	1.46	1.00	1.00	1.00
	Cut-off voltage or DOD*	1.40 V	1.00 V	1.00 V	DOD 81%
	6 H.R. Discharging power (kW)	1.95	1.31	1.30	1.20
	Cut-off voltage or DOD*	1.25 V	0.9 V	1.00 V	DOD 81%
	4 H.R. Discharging power (kW)	2.92	1.91	1.90	1.70
	Cut-off voltage or DOD*	1.00 V	0.8 V	1.00 V	DOD 81%
Self discharging rate test	Ambient temperature	Room temp. (battery temp.: *ca.* 350 °C	Room temp.	Room temp.	Room temp.
Period (weeks)		2 & 4	2 & 4	2 & 4	2 & 4
Life test	DOD for nominal capacity (%)	100	100	100	100
	End of life	when mean value of energy efficiency of every ten cycles falls to 80% of energy efficiency of initial ten cycles or fails to maintain 8 h discharge and cannot be recovered.			

*Voltage for unit cell and DOD for inherent capacity.

TABLE 3

Specifications of advanced batteries for the first interim evaluation test

Battery	Sodium–sulfur	Zinc–chloride	Zinc–bromide	Redox–flow
Configuration	6 cells in parallel × 10 in series	30 cells in series × 2 in parallel	16 cells in series × 4 in parallel	30 cells in series
Unit cell voltage	1.8	2.0	1.67	0.90
Unit cell capacity	130 A h/8 H.R.	75 A h/8 H.R.	75 A h/8 H.R.	320 A h/8 H.R.
Open circuit voltage	20.8	63.0	29.6	31.2

TABLE 4

Results of capacity test at various discharge rates

		Sodium–sulfur	Zinc–chloride	Zinc–bromide	Redox–flow
8 H.R.	Discharged (W h)	16 345	7993	8024	7890
	Energy efficiency (%)	85.9	71.1 (76.1)	80.1	76.7 (83.2)
6 H.R.	Discharged (W h)	15 711	7947	7951	8070
	Energy efficiency (%)	82.3	70.7 (75.9)	79.3	78.4
4 H.R.	Discharged (W h)	14 428	7666	7736	8200
	Energy efficiency (%)	76.5	68.3 (72.5)	77.2	79.8

Note 1. Energy efficiencies shown in parentheses are the values obtained from tests by the battery developers after the official test at GIRIO.

2. Auxiliary power consumptions are excluded.

(iii) Life test. — Measurement of the life of the batteries after repeating an 8 h charge and an 8 h discharge at an 8 h rate.

The respective tests were conducted at room temperature (25 ± 10 °C). The tests were restricted to the batteries (auxiliaries, *i.e.*, heaters, pumps, etc. were excluded).

3.2. Specifications of advanced batteries for the first interim evaluation test

Table 3 summarizes the specifications of the advanced batteries for the first interim evaluation test.

3.3. Results of the first interim evaluation test

3.3.1. Capacity test at various discharge rates

Table 4 shows that every battery has sufficient capacity, even at the 4 h rate discharge. The ratio of discharged W h and the energy efficiency of the redox–flow battery rise as the hour rate increases. This is not a result of the inherent characteristics of the battery, but the operational conditions were optimized one by one during the test in the order 8 H.R., 6 H.R. and 4 H.R.

3.3.2. Life test

The life of the battery is one of the important elements in evaluating its performance. It takes a long time to obtain substantial data, however. Life tests are continuing, as shown in Table 5, and the results are planned for inclusion in the second interim evaluation.

4. The first interim evaluation of AIST

In the first interim evaluation of AIST, all the batteries were regarded as having been developed to a high level. It was decided that each battery should be developed to the 10 kW scale. Therefore, parallel and competitive

TABLE 5

Results of life test

Battery	Mode	Cycle life (∞)	Energy efficiency (%)	
			Initial stage	Present stage
Sodium–sulfur (as of June 24, 1985)	No. 1 constant power	551	*ca.* 85	*ca.* 79
	No. 2 constant current	600	*ca.* 86	*ca.* 78
Zinc–chloride (as of June 21, 1985)	No. 1 constant power	380	*ca.* 77	*ca.* 66
	No. 2 constant current	340	*ca.* 73	*ca.* 66
Zinc–bromide (as of June 16, 1985)	No. 1 constant power	520	*ca.* 79	*ca.* 62
	No. 2 constant current	525	*ca.* 80	*ca.* 36
Redox–flow (as of June 15, 1985)	No. 1 constant power	192	*ca.* 76	*ca.* 75
	No. 2 constant current	224	*ca.* 71	*ca.* 72

development of the four types of batteries is being continued until FY 1986, and they are planned to be tested from October 1986 in GIRIO, and evaluated in March 1987 by AIST. Testing items and conditions are now being prepared.

B. Testing on Vehicular Batteries

1. Electric route bus demonstration project

In 1977, Japan Electric Vehicle Association (JEVA) started an electric route bus demonstration project. In the initial stage of this project, 6 bus units, 18 sets of batteries, 10 chargers, and an automatic battery exchanging facility were manufactured, and the operation of the buses was entrusted to the Kyoto City bus-office. After several years of operation, 18 sets of batteries (four manufacturers shared the construction of these batteries) were renewed and the operation has been continued to date. Figure 3 shows the reasonable correlation between the accumulated mileage of the buses and the bench-tested cycle life of the installed batteries.

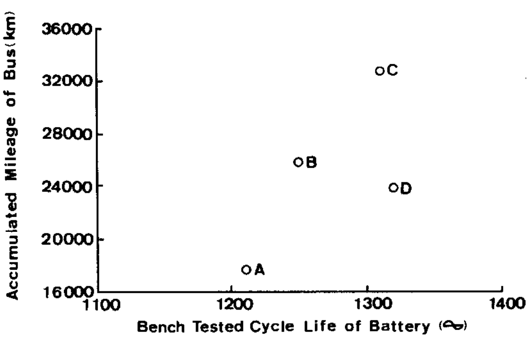

Fig. 3. Relation between the accumulated mileage of buses (average of 4 - 6 sets of batteries) and bench-tested cycle life (0.25 *C*, DOD 75%) of lead–acid batteries (A, B, C, and D) made by different manufacturers.

2. Electric Vehicle Engineering Research Association project

The Association was established in 1978, its object being to research and develop mass-producible commercial electric vehicles. Tables 6 and 7 show the test results of the first trial of the manufactured vehicles and the installed lead–acid batteries in 1982.

TABLE 6

Performance of the 1st trial manufactured vehicles of EVERA

Type of vehicle Installed battery*	Van type		Pick-up type	
	H-type	L-type	H-type	L-type
Passenger capacity (persons)	4		2	
Maximum loading capacity (kg)	150		300	
Mileage per charge (km) (at 40 km h^{-1} constant speed)	141	108	143	109
Maximum speed (km h^{-1})	77		79	
Acceleration (s) (0 - 40 km h^{-1})	7.6		7.3	

*H-type, high energy density type; L-type, long life type.

TABLE 7

Performance of the EVERA installed battery

Type of battery	H-type	L-type
Energy density (0.2 C, W h kg^{-1})	48.1 - 49.0	42.2 - 42.6
Cycle life (0.2 C, DOD 60%, ∞)	625 - 700	over 1000

C. Battery Capacity and Cycle Life Rating Parameters for Various Applications

TABLE 8

Battery capacity and cycle-life rating parameters for various applications (Japan)

Item	Application		
	Electric vehicle	Load leveling	Solar
Battery capacity rating			
Discharge rate at which capacity of battery is rated, (C_x/X) X = ___ h:	5	8	–
Life cycle rating			
Type of discharge, Constant current = *CI* Constant power = *CP* Pattern = P:	*CI*	CP, *CI*	–
Discharge rate, (C_x/X) X = ___ h:	4 - 5	8	–

(continued)

TABLE 8. *(continued)*

Depth of discharge, (%)	60 - 70	100	–
End of life criteria:	Cycling will continue until module can no longer deliver 60 - 70% (value is determined in individual cases) of rated capacity before the voltage per unit cell decreases to 1.7 V and cannot be recovered.	As shown in Table 2	–

Lead–acid batteries are used for solar applications. In Japan, however, their testing methods have not been officially determined.
For vehicular and load-leveling use, battery testing methods are determined for individual cases, as testing standards have not yet been authorized.