OVERVIEW OF AUSTRALIAN LEAD/ACID BATTERY TEST PROGRAMMES

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Introduction

Following the energy crisis of 1973, Australia along with many other countries was reminded that the supplies of all types of fossil fuels, and of oil in particular, are finite. This realization, together with the concomitant effects it would have on the external balance of payments, prompted the Australian Government to seek ways of improving the nation's energy pattern. Accordingly, avenues were explored with a view to extending fossil-fuel supplies through the more efficient recovery and usage of resources, through the introduction of synthetic substitute fuels (*e.g.*, oil from coal; methanol; ethanol, etc.), and through the development of other forms of energy (*i.e.*, natural dynamic resources: solar; wind; tidal; geothermal, etc.).

Conservation of oil was pinpointed as the area of most urgent need. It was considered that a shift away from oil-based fuels could be achieved by the introduction of electric vehicles powered by secondary batteries that could be recharged from a coal-fuelled electric grid; coal is Australia's most valuable and lasting energy resource. Thus, scientific and technological programmes aimed at the development and testing of traction batteries were implemented in a number of governmental instrumentalities and tertiary educational establishments, and to a limited extent in industry. More recently, these programmes have been extended to cover secondary batteries employed in the storage and delivery of electricity derived from solar and/or wind "renewable" energy. It is considered that the development of satisfactory stand-alone power systems, incorporating renewable energy technologies, may provide a cost-effective alternative to grid connection in meeting the existing and future electricity supply needs of the numerous communities living in remote areas of the country. Finally, projected demand and load-management patterns have recently encouraged the various State electricity supply authorities to investigate the economic feasibility of using batteries for "peak shaving", *i.e.*, for the storage of electrical energy generated when demand is low, and its release when demand peaks on a daily cycle. To date, there has been no field or laboratory assessment of batteries in peaking applications.

In Australia, the main effort in battery testing has been directed towards studies of the lead/acid system, although it should be noted that developmental programmes have also been conducted on lithium-based cells, and on manganese dioxide/zinc, nickel/zinc, zinc/bromine and redox-couple cells. This review covers the testing of lead/acid batteries for electric road and track vehicles and for remote-area power supply systems.

Testing lead/acid batteries for electric road- and track-vehicles

Data on the performance of lead/acid traction batteries have been obtained from:

(i) laboratory test rigs developed by CSIRO, Flinders University of South Australia, and the Sugar Research Institute;

(ii) an electric road-vehicle test facility developed by the Energy Authority of New South Wales;

(iii) field trials on experimental and commercial electric road vehicles in demonstration programmes conducted by several Federal and State governmental intrumentalities and by several universities.

This review discusses the methodology and practice adopted for the laboratory testing of antimonial lead/acid batteries under duty loads that simulate electric road- or track-vehicle service.

In designing battery tests, decisions have to be made about:

(i) charging procedure;
(ii) profile (rate) of discharge;
(iii) depth of discharge before recharge;
(iv) useful life of the battery.

In Australia, there are no universally accepted standards for these parameters, and therefore test criteria differ between investigators. Once a test schedule has been devised, it has been generally agreed that it is essential to examine the effects on battery capacity and service life of the following electric vehicle variables:

(i) pulsed high-rate discharge, *i.e.*, "chopper" control conditions;
(ii) regenerative charging pulses during deceleration;
(iii) intervals at open-circuit corresponding to temporary halts of the vehicle;
(iv) boost charging during parking;
(v) temperature of operation;
(vi) level of vibration.

Many of these vehicle-system characteristics have been studied during the course of Australian battery-testing programmes.

Battery charging procedures

The underlying requirement in traction applications is a quick and efficient recharge without adverse effect on battery performance. To ensure the right balance of charge and discharge, correct charging should involve control of both the current and the time of charging, together with the battery voltage, to suit both the size and the design of battery, as well as the operating conditions (*e.g.*, state-of-charge, temperature, vehicle duty cycle, etc.). However, although it is recognized that a correct charging procedure is most important for satisfactory battery life and electrical performance, there is still no clear consensus of opinion in Australia on the "best" method of charging.

The Australian Standard AS 2548 for traction-battery chargers specifies a two-stage, tapered-current, charging regime. In the initial stage, the charging current tapers from a maximum value of 0.25 $C/5$ to a value of not more than 0.15 $C/5$ when the battery voltage has risen to 2.4 V/cell. The current then changes to a more gentle taper that terminates at a current $\leqslant$0.06 $C/5$ when the battery voltage has reached 2.75 V/cell. The amount of charge is controlled by means of a time switch that is set to operate at the commencement of the second current-taper stage and runs for a predetermined time (3 - 4 h) before switching off the device; the maximum recharge time is 8 h. The charger is provided with a facility for extending the normal charging period to equalize variations in the conditions of individual battery cells.

Tests conducted in the laboratories of the CSIRO Division of Mineral Chemistry on both commercial and experimental batteries have shown that application of the AS 2453 charging procedure results in poor battery life due to excessive overcharging and concomitant accelerated corrosion of the positive grids [1]. In mining operations, service-life problems have also been experienced when charging locomotive batteries with a two-step, tapered-current procedure [2].

The charging method preferred by the CSIRO and the Flinders University groups is based on a constant-current/constant-voltage (CI/CV) schedule. The CSIRO procedure involves initial charging at a current of 0.23 $C/5$, followed by a cross-over to constant-voltage control at 2.55 V/cell (average), with charge termination 3 h after a voltage of 2.4 V/cell (average) has been reached. The latter time is increased to 6 h every eighth cycle in order to provide a cell equalization charge. The voltage limits are not adjusted for changes in battery temperature. In the Flinders CI/CV schedule, the starting current is 0.28 $C/5$, the cross-over voltage is 2.43 - 2.48 V/cell (average), and the charging is terminated when the current has fallen to $\sim$0.03 $C/5$: the recharge time is $\sim$3.5 h.

Electric vehicle driving schedules and battery discharge profiles

Unlike the practice adopted in most other countries, the usual procedure in Australia for the laboratory testing of electric road-vehicle batteries involves the use of a current-profiled discharge rather than a constant-current discharge. It is considered that this approach allows batteries to be tested under simulated conditions that are more representative of actual operation in vehicles than the simpler constant-rate procedure. The current profile is obtained from road trials on vehicles operating over standard driving schedules. Whereas it is recognized that the ideal simulator would be one capable of a precision duplication of a given vehicle's power demands, for it is power and not battery current that is the determining factor limiting vehicle performance, it is considered that current-profiled discharge is a sufficiently good approximation for the simulation of battery behaviour in vehicle service. Furthermore, the latter procedure avoids the need for the complicated control circuitry and the more detailed testing that is demanded by power-profiled discharge.

On the other hand, in studies on the performance of battery packs under simulated canefield (track) locomotive service, the Sugar Research Institute discharges batteries to a preset power profile [3]. This profile (Fig. 1(a)) has been derived from measurements of the power required by a locomotive during canefield operations over a typical eight-hour shift. The test profile is a scaled-down version of the actual locomotive power requirements as, in the interests of economy and ease of operation, testing is conducted on 24 V battery packs rather than full-scale, 450 V, locomotive systems. On discharge, a computer controls the current to the load tank in relation to the power profile (Fig. 1(b)). The quantity of energy dissipated in the tank is computed from the current and voltage. The computer continuously cycles the battery pack through a 16 h charge/discharge cycle. To date, batteries have given over 600 cycles of service.

Careful consideration has been given to the development of a standard driving schedule for evaluating electric road-vehicles under conditions that typify service in an urban environment. The driving schedule chosen by

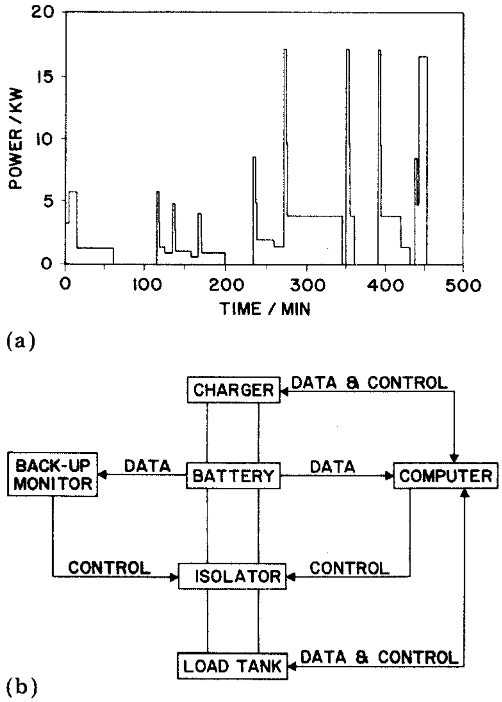

Fig. 1 (a) Scaled-down power/time profile for a canefield locomotive; (b) schematic diagram of test rig [3].

TABLE 1

Test schedule for AEVA driving schedule

Operation	Average acceleration ($m\ s^{-2}$)	Speed ($km\ h^{-1}$)	Time (s)	Cumulative time (s)	Distance (m)	Cumulative distance (m)
1. Accelerate	+0.83	0 - 30	10	10	42	42
2. Steady speed	0	30	5	15	42	84
3. Decelerate	−0.83	30 - 0	10	25	42	126
4. Idle	0	0	10	35	–	126
5. Accelerate	+0.83	0 - 45	15	50	94	220
6. Steady speed	0	45	15	65	188	408
7. Accelerate	+0.28	45 - 60	15	80	217	625
8. Steady speed	0	60	15	95	250	875
9. Decelerate	−1.11	60 - 0	15	110	125	1000
10. Idle	0	0	10	120	–	1000

CSIRO and Flinders University is that developed [4] by the Australian Electric Vehicle Association (AEVA). This schedule is derived in part from the Standards Association of Australia 27A Emission Testing Cycle and has been formulated after detailed analysis of actual traffic-flow data collected from a wide range of vehicles, experimental methods, and test routes. The AEVA driving schedule consists of a series of accelerations, constant speeds, decelerations, and idle intervals (Table 1; schematic given by dashed line in Fig. 2(a), (b)). The speeds and times for each operation are defined. The total time for the driving schedule is 120 s, the average speed is 30 km h^{-1}, and the vehicle travels a distance of 1 km exactly.

The AEVA driving schedule has many advantages over the US Society of Automotive Engineers (SAE) J227a driving schedules B, C and D, namely:

(i) The SAE J227a schedule is inconvenient in that the distance travelled per cycle by the vehicle is not specified; the range depends on vehicle-design characteristics and road/weather conditions. Thus, the distance travelled could vary from schedule to schedule as local driving conditions change. By contrast, the distance travelled in the AEVA procedure is fixed (*i.e.*, 1 km), and the total range of the vehicle (in km) is directly equal to the number of AEVA schedules completed before the vehicle can no longer meet the acceleration or speed requirements of the driving procedure. Thus, whereas performance in terms of vehicle range is meaningful when expressed as a given number of AEVA schedules, direct and accurate conversion cannot be made from the corresponding number of SAE schedules. This fact is important when expressing battery service-life as determined from laboratory measurements under simulated vehicle operation (see below).

(ii) The AEVA schedule is designed around metric speeds to take into account the fact that most countries have now adopted SI units. The maximum speed of the cycle (60 km h^{-1}) is the legal speed limit for

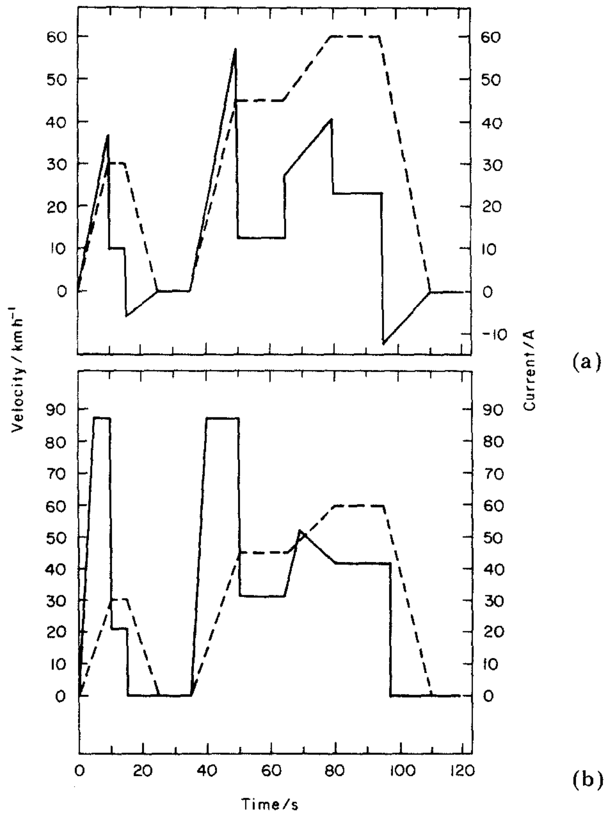

Fig. 2. AEVA driving schedule velocity (— — —) and battery current approximation (———) for (a) IMP and (b) Battronic electric vans. Currents scaled down for a 60 A h battery.

Australian urban driving (except freeways). Note, the maximum speed of the SAE J227a schedules B, C and D is 32.2, 48.3 and 72.4 km h^{-1}, respectively.

(iii) The SAE J227a schedule incorporates only one cruising speed; three cruising speeds are included in the AEVA procedure (Table 1). The AEVA constant-speed running represents 29% of the driving time and 48% of the distance covered. From ref. 5, the corresponding values for the SAE J227a schedules C and D are 25 and 41% of the time and 50 and 65% of the distance, respectively. Thus, in this mode, the AEVA schedule resembles the SAE J227a/C schedule.

(iv) The acceleration requirements are greater for the AEVA schedule (0.83 m s^{-2}) than for either the SAE J227a/C (0.75 m s^{-2}) or the SAE J227a/D (0.72 m s^{-2}) procedures.

(v) For a given distance travelled, the AEVA schedule has about the same number of stops (*i.e.*, 4) as the SAE J227a/C schedule, but the total idle period is shorter (17% *versus* 31% of total time). The SAE J227a/D schedule provides only one stop, but this is of about the same duration as the combined test periods in the AEVA procedure (21% *versus* 17% of total time).

From the above discussion, it can be seen that the AEVA driving schedule combines certain characteristics of the SAE J227a/C and J227a/D schedules, as well as introducing special features of its own, *i.e.*, defined range, more cruise speeds, and greater acceleration requirements. It is considered that the AEVA schedule is more representative of traffic flow than the SAE J227a procedure, and in this respect it is to be favoured. Indeed, the efficacy of the SAE J227a test procedure in addressing electric-vehicle service has recently been questioned by US testing authorities [6].

In order to test batteries in the laboratory under simulated electric-vehicle service, CSIRO obtained from road tests the current demands of two vehicles operating over the AEVA driving schedule. The vehicles involved were:

(i) a Battronic electric van manufactured by Boyertown Auto Body Works (USA);

(ii) an Induction Motor Propulsion (IMP) electric van developed in Australia [7].

The technology used in the Battronic van is over ten years old, whereas the IMP van is representative of present-day electric-vehicle design having a.c. motor drive and microprocessor-controlled operation with a regenerative braking facility. The current profiles of the two vans were scaled down from those experienced by the vehicle battery packs to equivalent rates for the test batteries used in the simulation studies (Fig. 2(a), (b)). The scaling factor was equal to the ratio of the test-battery capacity to the vehicle-battery capacity.

In similar studies, the Flinders University group has determined [8] the current/time profile for the Flinders Investigator Mk II vehicle [9] when operating over the AEVA schedule. This vehicle is a Fiat conversion and incorporates a linear control system that limits battery current to the range from −80 A (maximum discharge current) through to +80 A (maximum regenerative current). To accelerate battery testing, the idle periods of the AEVA schedule are omitted in the laboratory test procedure.

Battery service-life tests

Since the time taken to perform each AEVA driving schedule is 120 s and the equivalent distance is 1 km, battery service-life can be expressed in terms of the total equivalent distance travelled, as well as in terms of the total number of charge/discharge cycles performed. CSIRO scientists consider the former to be a better way of presenting battery performance, as equivalent numbers of charge/discharge cycles for different batteries may represent differing amounts of work performed by these batteries (note, capacity/cycle-number plots often vary from cycle to cycle and the overall relationship is not horizontal). In addition, vehicle operators find it more useful to be given battery life in terms of total expected service distance, rather than in terms of the number of charge/discharge cycles, as vehicles are not always driven over their maximum range during each working day, *i.e.*, batteries experience different depths of discharge from cycle to cycle.

In the CSIRO laboratory testing procedure, the voltage limit for discharge is taken as that value where fresh batteries yield a service equivalent (in km) to that given by fresh batteries in vehicle road trials under the AEVA driving schedule. For both Battronic and IMP simulation studies, this value is 1.6 V/cell (average) and in each test the batteries experience a 100% depth-of-discharge. The end of useful battery life is taken as the point at which the discharge capacity, converted to that at the nominal ($C/20$) rate, has fallen to a value $\leqslant 75\%$ of the nominal capacity at 25 °C. It should be emphasized that statements of battery performance are subjective, since the "end-of-life" stage is chosen somewhat arbitrarily. In a practical situation, the capacity cut-off limit will be determined by the particular service requirements of the vehicle in question and by the costs involved in maintaining the batteries.

In the Flinders University approach to battery testing, discharge is terminated when the battery voltage under load has fallen to 1.75 V/cell (average). A battery is considered to have failed when the discharge capacity has fallen to 70% of the initial value at the test rate.

Batteries under test in CSIRO are situated in thermostatically controlled water-baths maintained to within ±0.5 °C of the required temperature. Individual cell temperatures are monitored throughout the course of experiments; during battery charging and discharging, the electrolyte temperature does not increase above the set value by more than 4 °C except near the end of battery life. This procedure allows the effect of operating temperature (either fixed or profiled, see below) on battery performance to be determined. At Flinders University, batteries are not thermostatted, but are allowed to float thermally.

Each Australian research group — CSIRO, Flinders University, and Sugar Research Institute — has designed and developed its own purpose-built equipment for the testing of batteries [3, 8, 10, 11]. Some of the CSIRO equipment has entered commercial production.

Battery performance

By far the most extensive programme of traction-battery testing in Australia has been carried out in the laboratories of the CSIRO Division of Mineral Chemistry. The work has been supported by the Australian Government through the National Energy Research Development and Demonstration Programme (NERDDP), by the Australian Associated Smelters Pty. Limited, by the International Lead Zinc Research Organization, Inc. (ILZRO), as well as by CSIRO internal resources. The principal aim of the CSIRO research programme is to optimize electric road-vehicle lead/acid systems by correlating degradation in performance with changes in battery physicochemical characteristics and design such as:

- Active-material phase composition and distribution (at all stages of plate manufacture).
- Active-material crystal morphology, structure, size, and stability during battery service.
- Grid alloy composition and corrosion.

- Cell design, including novel types such as the Dunlop Pulsar system and recombination-electrolyte (RE) technology.

and with changes in electric vehicle design and operating conditions such as:

- Mode of current discharge.
- Regenerative braking.
- Temperature.

The methodology used in the testing of batteries has been described in detail above. The principal findings of the CSIRO programme have been:

- Optimization of the lead/acid battery can be achieved through closer attention to the positive active-material preparation stages of leady-oxide production [12], curing [11, 13] and formation [14, 15]; better control during oxide production gives a product with more consistent physico-chemical characteristics; better control during curing removes irregularities in plate performance; better control during formation results in an optimum α-PbO_2: β-PbO_2 ratio conducive to good battery performance.
- The degree of crystallinity of the positive-plate material, and the hydrogen content of crystalline β-PbO_2 in the positive plate material, have no marked effect on electrochemical activity [15 - 20].
- The use of low-antimony alloys (~ 2 wt.% Sb) can result in premature cell failure due to the irreversible formation of insulating, sulphur-rich zones at the grid/active-material interface [21].
- A positive-to-negative active-material weight ratio of greater than one yields superior service life [22].
- Decrease of electrolyte specific gravity in the range 1.28 - 1.20 decreases capacity but increases service life [23].
- Vehicle speed control through the use of chopper circuitry has no significant effect on battery performance [15].
- Regenerative braking extends battery service-life as well as vehicle range [15].
- With present battery technology, improved performance can be achieved by operation at elevated (fixed) temperatures up to 60 °C [24].
- Temperature profiling has been identified [24] as a more convenient and effective means of extending battery service-life than operation at elevated fixed temperature. Such treatment could have important ramifications in battery manufacturing and conditioning.
- Further research is required in a number of areas including:
  (i) cell design, *e.g.*, positive-to-negative active-material weight ratio, electrode geometry, grid alloy composition, separator technology, etc.;
  (ii) control and chemistry of paste production, plate curing and plate formation;
  (iii) method of charging;
  (iv) temperature regimes in battery production and operation.

Testing lead/acid batteries for remote-area power supply systems

The vast majority of people in Australia live in the coastal cities and towns. In these areas, the most efficient way of providing power for both telecommunication and domestic needs is through an electric power grid. Many people in Australia, however, do live in extremely remote areas with a very low population density. Since the nation's agricultural and mining industries depend on these isolated people, much effort is being devoted to developing stand-alone power systems as an alternative to the costly business of extending the mains supply. Australian remote-area power supply (RAPS) needs may be characterized according to size:

(i) Less than 1 kW: small, discrete function applications such as navigational aids, electric fences, water pumps and telecommunication links. Wind turbines and photovoltaic arrays coupled to large battery banks on float charge are extensively used in Australia to power navigational aids and telecommunication links. Water pumping is an extremely important activity in remote areas and may prove to be a major market for RAPS systems.

(ii) Between 1 and 25 kW: homestead applications. In remote areas, electricity is generally not required for cooking, water heating or space heating, but is required for lighting, cooling and powering domestic appliances as well as farm machinery. Diesel generators currently produce the bulk of the electricity generated for homestead use. A small number of RAPS systems are based on 32 V d.c. wind- and/or diesel-generated electricity.

(iii) Over 25 kW: small communities. These generally encompass the full range of consumer demands including electric cooking, water heating, and space heating. In addition to small towns, there are numerous isolated roadhouses, mining settlements, and small industries that fall into this size category.

Battery storage is a key element in many of the proposed RAPS applications. When used in conjuction with diesel generators, batteries enable the diesel to operate near its optimal load point, while photovoltaic and wind-generator systems require battery storage for meeting load demands occurring during periods of insufficient, or no, input energy. The battery has been identified as a major problem area where technological improvements are necessary. Thus, programmes have been implemented with the aim of improving battery economics and reliability through: (i) proper system sizing, *i.e.*, reducing battery reserve requirements; (ii) testing batteries to assess cell technologies and to obtain optimum service life.

Telecommunication systems for remote areas

Naturally, the major Australian developer of alternative power sources (notably wind and solar power) for remote telecommunications networks has been Telecom Australia. Wind-driven generators have been used as: (i) a back-up power source on the East–West Microwave Radio Relay System that provides telecommunication facilities between Perth and the rest of Australia; and (ii) the main power source (with diesel back-up) at the radiotelephone repeater stations on King Island and Three Hummock Island that provide a communication link between Tasmania and the mainland. All these systems employ batteries to store the wind-derived electrical energy.

The first major telecommunication trunk link in the world to be powered entirely by solar energy was installed by Telecom Australia between Alice Springs and Tennant Creek (580 km) in the Northern Territory in 1979. The link consists of 13 solar-powered repeater stations. Each station has thirty-six 12 V batteries giving a storage capacity of ~ 1500 A h, enough to keep the equipment operating for 10 - 15 days without sun. This technology has been recently used by Telecom Australia to install the longest solar-powered telecommunication route in the world, between Port Hedland in the Pilbara and Kununurra in the Kimberley region of Western Australia, some 1595 km.

The testing of batteries for the above applications is carried out in the Research Laboratories of Telecom Australia at Clayton, Victoria. Test programmes have been designed to investigate both the characteristics and the performance of batteries when exposed to simulated solar cycling conditions. Batteries with pure-lead positive grids are preferred as they have low self-discharge and long life under float duty — the operation that is considered to approach solar/telecommunication service. The test sequence adopted by Telecom Australia for 500 A h ($C/10$) batteries is as follows:

(i) two capacity tests at $C/10$ rate;

(ii) 100 (shallow) cycles involving discharging at 1.67 A for 13 h and charging at 2.17 A for 11 h on either fully charged batteries (simulated summer conditions) or half-discharged batteries (simulated winter conditions);

(iii) two capacity tests at $C/10$ rate;

(iv) repeat of sequences (ii) and (iii) but using differing numbers of shallow cycles.

The batteries are located in a constant-temperature water bath set at 30 ± 1 °C. Test data suggest that a battery life of 6 - 8 years is possible for solar applications. There have been no reports of the testing of batteries under simulated wind-generated electricity storage.

Power supply systems for remote-area communities

Since 1978, the Australian Government has provided (through the NERDDP) about A$10 million in support of projects involving the research, development and demonstration of components suitable for use in RAPS systems for homesteads, and for the demonstration of systems for entire communities. The programme has been broadly based, and has provided support for projects ranging from fundamental research and development of advanced photovoltaic cells and secondary batteries (*i.e.*, zinc/bromine, redox, but *not* lead/acid) to the development of prototype wind-generators suited to Australia's low inland wind speeds.

Unfortunately, there has been no development of facilities or standard procedures for the laboratory testing *per se* of lead/acid batteries under simulated RAPS service — despite the fact that the lead/acid battery is the only commercially available battery that is economically attractive for stand-alone power systems. It should be pointed out, however, that the CSIRO test facility for traction batteries (described above) could be readily adapted to RAPS studies. This would also be possible with the battery test facility developed by Telecom Australia for monitoring the performance of stationary lead/acid batteries used in the no-break power supplies of telephone exchanges and other equipment throughout the network. The Telecom facility provides for cyclic charge and discharge routines to determine battery capacity of six types ranging in capacity from 25 to 3200 A h. The facility has six distinct test bays, one for each type of exchange battery, arranged so that each battery can be tested readily at its 10-, 3- or 1-h discharge rates.

Field testing of batteries in homestead RAPS applications has been conducted by a number of Australian organizations. The Solar Energy Research Institute, Western Australia (SERIWA), has implemented the following remote-area field test programmes:

(i) 1.8 kW photovoltaic system at the Eyre Bird Observatory, having two battery banks, each of fifty-five 2 V, 500 A h ($C/20$) cells; cells in one bank utilize pure lead grids, those in the other bank have lead–antimony grids: after 5 years, two of the latter cells have failed.

(ii) 5 kW photovoltaic system on a pastoral station at Mt. Gibson, having a battery bank of eight 6 V, 1000 A h ($C/20$) batteries: after 2 years, two batteries have had to be overhauled.

(iii) 4 kW reverse-osmosis desalination unit (6 m^3/day) at Wannoo, having a battery bank of twenty-four 2 V, 750 A h ($C/20$) tubular-plate cells: the cells are kept at between 60 and 80% of charge and a manual equalization charge is applied every 10 days: after 2 years, all cells are healthy.

(iv) 750 W photovoltaic system at a remote aboriginal community, having a battery bank of twelve 2 V, 800 A h ($C/20$) tubular-plate cells: after 1 year, all cells are healthy.

The Energy Authority of New South Wales, with NERDDC funding, has recently commissioned three hybrid power systems for field testing:

(i) photovoltaic/diesel, giving 5000 kW h/year;
(ii) wind-generator/diesel, giving 5000 kW h/year;
(iii) photovoltaic/wind-generator, giving 3000 kW h/year.

All systems provide a 24 h supply of 240 V a.c. power and utilize battery banks and inverters.

Battery rating parameters

Authors making international overview presentations to this Workshop have been asked to include a table of battery capacity and cycle-life rating parameters for electric-vehicle, load-levelling and solar applications. In the case of Australia, this is difficult. There are no battery standards for electric road-vehicle, electric track-vehicle, load levelling or solar/homestead applications; the battery rating parameters for solar/telecommunication service have followed those for stationary/standby-power service, and the present standard for batteries in this latter application is currently under review. The

TABLE 2

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

Item	Electric vehicle			Stationary		Solar	
	Plant[a]	Road[b]	Track[c]	Load levelling[d]	Standby power[e]	Telecommunications[f]	Remote community[g]
Battery capacity rating							
Discharge rate at which capacity of battery is rated (C_x/X) X = ___ h:	5	20	5	–	3	10	3 - 5
Life cycle rating							
Type of discharge Constant current = *CI* Pattern = P:	*CI*	P	*CI*	–	*CI*	*CI*	*CI*
Discharge rate							
(C_x/X) X = ___ h:	3	3	3	–	3	3	3
I = ___ A:	0.25 $C/5$	0.33 $C/3$	0.25 $C/5$	–	0.25 $C/3$	0.25 $C/3$	0.25 $C/5$
Depth of discharge ___ %:	80	100	80	–	70	70	75 - 80
End of life criteria:	0.20 $C/5$ discharge every 50 cycles; failure if capacity $< 80\%$ $C/5$ before 1000 cycles	$< 75\%$ $C/20$	As per plant vehicles	–	To be decided	To be decided	To be decided
Expected life ___ years:	5	~ 2	3 - 4	–	15[h] (float conditions)	10 (shallow cycle) 1 (50% $C/10$)	5 - 6

[a] Official Australian Standard (AS 2402).

[b] Laboratory practice only.

[c] Usual to adopt plant-vehicle standard.

[d] No battery load-levelling facilities in Australia.

[e] Standard (AS 1981) under revision.

[f] Usual to adopt standby-power standard.

[g] Field practice only.

[h] To be lowered for RE batteries.

only Australian Standard in full operation is that for lead/acid traction batteries intended for installation in plant electric vehicles (*e.g.*, forklift trucks) or mechanical handling equipment, and having a prescribed minimum life of 1000 charge/discharge cycles. The information given in Table 2 is therefore a *pot-pourri* of official, empirical and crystal-ball statements.

Acknowledgements

The author is grateful to the Australian National Energy Research, Development and Demonstration Council and to the International Lead Zinc Research Organization, Inc. for their financial support and permission to publish the CSIRO work discussed in this paper; to his colleagues Dr R. J. Hill and Dr R. Woods for helpful discussion, and to Mr J. E. Manders (Australian Lead Development Association), Mr J. C. Howlett (Dunlop Batteries, Australia), Dr M. Watt (Energy Authority of NSW), Dr N. Pidgeon (State Electricity Commission of Victoria), Mr R. J. Dunstan (Solar Energy Research Institute, Western Australia), Dr W. McWhinney (Sugar Research Institute), and Mr J. Der (Telecom Australia), for technical information.

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