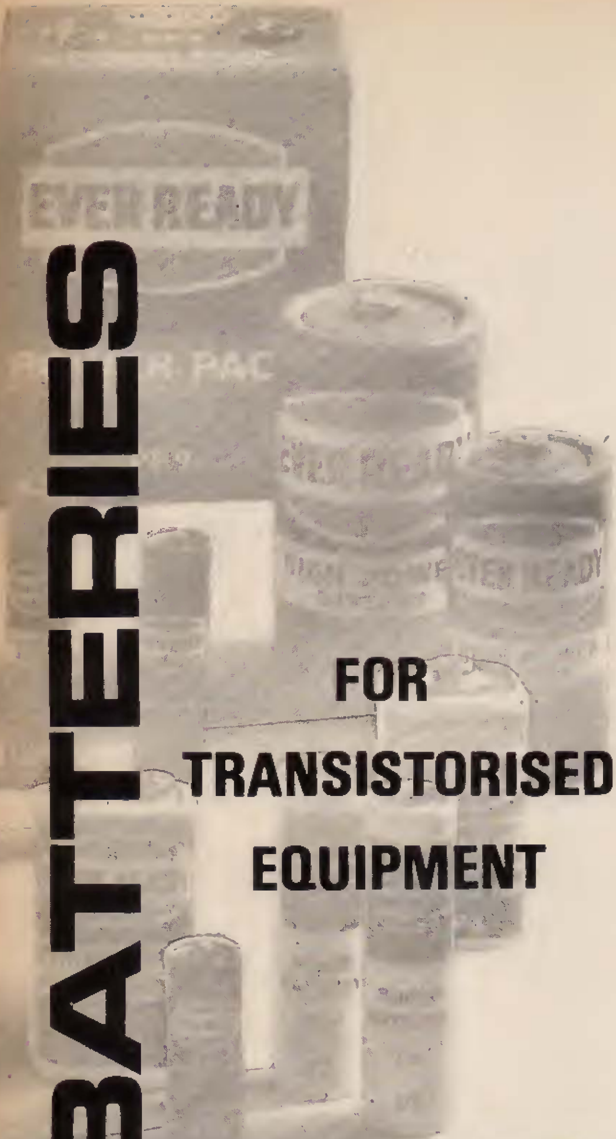
# BATTERIES FOR TRANSISTORISED EQUIPMENT

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MODERN techniques in electronics, in particular the increasing use of transistor circuitry and portable equipment, call for a discriminating choice of power supplies to satisfy the electrical and physical demands of such equipment. For convenience of size and weight per unit capacity the primary cell has largely superseded the secondary (or wet) cell where low wattages and currents are required.

Widespread use is made of "dry batteries" for transistor circuits, particularly where portability is an essential requirement. The most commonly used type of dry cell is a development of the Leclanché cell, two or more of which constitute a "battery" when suitably connected together and jacketed or boxed.

Since there is a variety of sizes and shapes of dry battery on the market, this article is aimed at providing a guide for constructors and users so that the most appropriate cell or battery can be selected for a particular purpose.

## BASIC CONSTRUCTION

Let us first look at the basic construction of a dry Leclanché cell. Fig. 1 shows a cut away section of a "leak-proof" cell. The electrolyte is normally a paste made up from ammonium chloride with moisture retaining agents added. In a completely dry state the solution cannot function properly. The depolariser is a mixture of manganese dioxide and carbon which is held between the electrolyte and the carbon rod or the positive electrode (anode). The negative electrode is normally a zinc cup which contains all the necessary ingredients outlined above.

In the case of a "leak-proof" cell (Fig. 1) a leak-resistant tube is wrapped round the outside of the zinc cup and fixed to a steel plate at the bottom and plastic cover at the top.

The term "leak-proof" is used advisedly since it is possible for the electrolyte to seep out under severe abnormal conditions, but in a normal working environment little or no leakage should be experienced.

Cells of the type described above can be classified under a general term "round" cells for obvious reasons.

## HIGH PERFORMANCE BATTERIES

High performance batteries are relatively new and have extended the range of equipment which can be economically operated from low cost primary batteries. They derive their improved performance from both constructional modifications and changes in the materials used. The construction is similar to that of conventional round cells, using a zinc can, separator, electrolyte, depolarising mix (manganese dioxide and carbon) and a carbon rod collector.

The thick paste separator of the conventional cell has been replaced in h.p. cells with a specially developed low resistance paper. This allows for a much greater weight of active materials to be included.

The effect of these changes are very obvious at the higher rates of discharge as is seen in the various curves and tables illustrating the typical performances. Voltages are maintained at higher levels and the voltage fall is far less rapid than with standard cells.

## LAYER CELLS

Layer cells have certain unique advantages over round cells:

(1) They have greater potential capacity per unit volume;
(2) They are conveniently assembled into high voltage stacks where intercell connections are made automatically.

They are unable however to deliver heavy currents as will be shown in the examples to follow. The basic construction of a layer type cell is illustrated in Fig. 2.

## CORRECT CHOICE

There are characteristics which are common to all varieties of Leclanché dry cells which must be fully understood if full use is to be made of the potential energy available.

These characteristics are:

(a) Nominal voltage per cell is 1·5 volts;
(b) Voltage falls on discharge;
(c) If the discharge is intermittent the battery will "recharge" itself during the rest period.

There are other life parameters which can be neglected for the majority of amateur work; these are:

(d) Ambient temperature during discharge;
(e) Storage conditions before use.

To choose the correct battery for a particular application the following must be known:

(1) Space available and life required;
(2) Working voltage range of the equipment;
(3) Current consumption and period of use per day.

The tables given later in this article show the common batteries available and their life-current performance. This is a convenient method of showing battery capacity because for power supplies of 6–9 volts or above, where the current drawn will give a life of 20 hours or more,'a layer type cell battery would be used.

For voltages below 6–9 round cells may be more conveniently used. For life values of less than 20 hours high performance round cells should be used for all voltages as they are specially formulated for high rates of discharge.

Whilst it is appreciated that mercury cells are also available, for the purposes of this article examples to illustrate how selection should be made are based on high-performance round, standard round, and layer types of conventional zinc-carbon cell.

The figures quoted for equipment operating conditions are not necessarily applicable to a particular item but are only assumptions for finding the most suitable battery.

## TRANSISTOR MEASURING EQUIPMENT

There are a host of these devices which, with the advent of transistors, have enabled equipment to be powered very readily from dry cells. To name just a few: signal generators, transistor voltmeters, pre-amplifiers, transistor testers, noise analysers. In general these operate well from voltages between 6 and 24, are used intermittently, and the current drawn during operation is relatively low, about 5 to 50mA. Many commercial devices available use one or two PP9s to give 9 or 18 volts as required. Smaller layer "Power Pack" batteries may be used if space is limited.

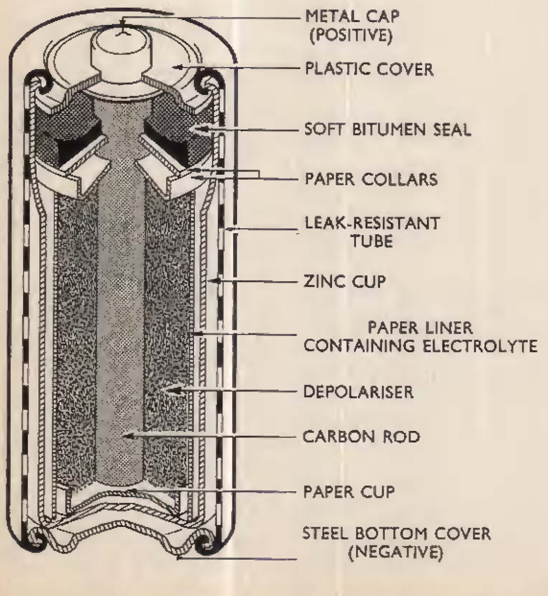


***Fig. 1. Section through a typical "leak-proof" dry cell***

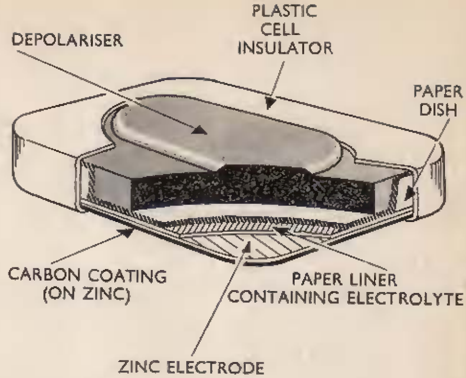


***Fig. 2. Section through a layer type cell***

Estimates of the life to be expected from the various batteries listed can be made from column (a) in the current guide tables on the next page.

The current values listed represent the currents at which the battery will give 350 hours life. Approximate estimates of life at other currents may be made by *pro rata* calculations. They will, however, become inaccurate as the life falls below the 100 hours. Examples are given here for three batteries to illustrate these points and to further illustrate the difference in characteristics of the layer, round and h.p. batteries.

*Layer type PP9* — *350 hours at 17mA*

At 34mA we would expect $\frac{350}{2} = 175$ hours.
Actual life = 150 hours

At 68mA we would expect $\frac{350}{4} = 87{\cdot}5$ hours.
Actual life = 57 hours

At 102mA we would expect $\frac{350}{6} = 58$ hours.
Actual life = 29 hours

*High performance type HP2* — *350 hours at 21mA*

At 42mA we would expect 175 hours.
Actual life = 175 hours
At 105mA we would expect 70 hours.
Actual life = 65 hours
At 210mA we would expect 35 hours.
Actual life = 30 hours
At 420mA we would expect 17 hours.
Actual life = 9 hours

*Conventional round type LPU2* — *350 hours at 20mA*

At 40mA we would expect 175 hours.
Actual life = 170 hours
At 80mA we would expect 87·5 hours.
Actual life = 56 hours
At 160mA we would expect 43·8 hours.
Actual life = 15 hours

These figures illustrate the versatility of the h.p. range and the limitations of the other types and will guide you into the use which can be made of the figures in columns (a) and (b) of the current guide tables. It should still be borne in mind that the figures in the table are for voltages down to 0·9V per cell and that corresponding reductions in life can be expected if higher end points are used.

| Battery type | Current Guide Milliamps (a) | (b) | (c) | Weight lb. | oz. | Dimension Inches Length | Width | Height | Price s | d |
|---|---|---|---|---|---|---|---|---|---|---|
| **1·5 VOLT BATTERIES** | | | | | | | | | | |
| U16 | 2 | 16 | 200 | — | 0·3 | 0·406 dia | | 1·75 | 0 | 5 |
| HP16 | 2 | 20 | 250 | — | 0·4 | 0·406 dia | | 1·75 | 1 | 0 |
| HP7 | 4·5 | 40 | 500 | — | 0·5 | 0·563 dia | | 1·984 | 0 | 7 |
| LPU11 | 9 | 70 | 500 | — | 1·4 | 1·031 dia | | 1·969 | 0 | 8 |
| HP11 | 10 | 140 | 1000 | — | 1·4 | 1·031 dia | | 1·969 | 1 | 3 |
| LPU2 | 20 | 150 | 750 | — | 3 | 1·344 dia | | 2·406 | 0 | 10 |
| HP2 | 21 | 275 | 2500 | — | 3·5 | 1·344 dia | | 2·406 | 1 | 6 |
| **4·5 VOLT BATTERIES** | | | | | | | | | | |
| 1289 | 7 | 55 | | — | 4 | 2·438 | 0·875 | 2·625 | 1 | 3 |
| 126 | 24 | 180 | | — | 13 | 4·063 | 1·375 | 3·438 | 3 | 0 |
| PP11 | 34 | 260 | | 1 | — | 2·563 | 2·063 | 3·594 | 5 | 6 |
| AD28 | 35 | 200 | | 1 | — | 4·0 | 1·375 | 4·188 | 3 | 6 |
| **6 VOLT BATTERIES** | | | | | | | | | | |
| PP1 | 17 | 130 | | — | 10 | 2·563 | 2·188 | 2·188 | 3 | 0 |
| 996 | 35 | 200 | | 1 | 4·5 | 2·656 | 2·656 | 4·0 | 4 | 0 |
| **9 VOLT BATTERIES** | | | | | | | | | | |
| PP3 | 1·2 | 14 | | — | 1·3 | 1·047 | 0·688 | 1·906 | 2 | 6 |
| PP4 | 1·5 | 16 | | — | 1·8 | 1·0 | 1·0 | 1·969 | 2 | 3 |
| PP6 | 4 | 40 | | — | 5 | 1·422 | 1·359 | 2·75 | 2 | 9 |
| PP7 | 8 | 55 | | — | 7 | 1·813 | 1·813 | 2·438 | 3 | 3 |
| PP9 | 17 | 130 | | — | 15 | 2·594 | 2·047 | 3·188 | 3 | 9 |
| **12 VOLT BATTERIES** | | | | | | | | | | |
| TV1 | 42 | 550 | | 3 | 8 | 5·25 | 2·688 | 5·375 | 14 | 0 |
| **15 VOLT BATTERIES** | | | | | | | | | | |
| B154 | 0·25 | 2 | | — | 0·6 | 0·625 | 0·594 | 1·375 | 2 | 0 |
| B121 | 0·4 | 5 | | — | 0·75 | 1·031 | 0·625 | 1·469 | 2 | 0 |
| **22·5 VOLT BATTERIES** | | | | | | | | | | |
| B122 | 0·4 | 5 | | — | 1·13 | 1·031 | 0·625 | 2·0 | 2 | 6 |
| **60 VOLT BATTERIES (Tappings at 45–30–15 volts)** | | | | | | | | | | |
| B1702 | 17 | 130 | | 6 | — | 7·688 | 2·625 | 5·75 | 38 | 9 |
| **67·5 VOLT BATTERIES** | | | | | | | | | | |
| B101 | 2·1 | 15 | | — | 12 | 2·813 | 1·375 | 3·719 | 11 | 0 |
| **90 VOLT BATTERIES** | | | | | | | | | | |
| B126 | 2·1 | 15 | | 1 | — | 2·781 | 1·969 | 3·844 | 9 | 0 |
| **300 VOLT BATTERIES** | | | | | | | | | | |
| B1489 | 0·4 | 5·0 | | — | 15 | 2·688 | 2·219 | 3·906 | 42 | 6 |

## CURRENT GUIDE VALUES

- **Discharge.** Fixed resistance
- **Current.** Milliamps at 1·5 volts
- **Temperature.** 20 degrees C
- **Storage.** Fresh batteries
- **End-point voltage.** 0·9V per cell. The lower the voltage end point the more energy will be available from the Battery. In addition to this, as the load increases the initial working voltage will drop. At the highest currents quoted end point voltages above 1·2V per cell will not be practicable. In these cases much lower end points such as 0·8V should be used if possible.
- **Column (a)** 350 hour rate—4 hours per day. Currents shown in this column will exhaust the battery after approximately 350 hours. At this rate the apparent ampere hour product (350 × current) may be used to obtain an approximate indication of service life on discharges of different periods per day including 24 hours per day.

Calculation can also be made at higher rates as in the examples shown. Capacities on much lower drains or shorter periods per day will be reduced by shelf deterioration.

- **Column (b)** 20 hour rate—4 hours per day. Current shown in this column will exhaust the Battery in approximately 20 hours. At this rate changes in period per day will materially effect the service life.
- **Column (c)** 1 to 2 hour rate. 5 minutes per day. Shown for 1·5V batteries only. Figures show the order of magnitude of maximum current which the Battery can deliver. These figures apply as previously stated to fixed resistance load discharges. Half the currents shown in this column could be the transmitter current in a TxRx that is 1,250mA for an HP2. This battery would deliver the 2·5 amp peaks which could well be required in the application.

Table 1: BATTERY COMPARISON FOR TAPE RECORDER EXAMPLE

| Battery type | Calculated life to 0·9V per cell (hours) | Actual life (hours) at 100mA 4 hours per day to | | Weight (ounces) | Cost | Cost per hour for actual life down to 1V per cell |
|---|---|---|---|---|---|---|
| | | 1·0V per cell | 0·9V per cell | | | |
| 6 × LPU2 | $\frac{20 \times 150}{100} = 30$ | 30 | 35 | 18 | 5s | 2d |
| 6 × HP2 | $\frac{20 \times 275}{100} = 55$ | 60 | 65 | 21 | 9s | 1·8d |
| 6 × LPU11 | $\frac{20 \times 70}{100} = 14$ | 8 | 11 | 9 | 4s | 6d |
| 6 × HP11 | $\frac{20 \times 140}{100} = 28$ | 24 | 27 | 9 | 7s 6d | 3·75d |
| 1 × PP9 | $\frac{20 \times 130}{100} = 26$ | 25 | 30 | 15 | 3s 9d | 1·8d |
| 2 × PP9 (in parallel) | $\frac{20 \times 130}{50} = 52$ | 80 | 95 | 30 | 7s 6d | 1·13d |

## SMALL PORTABLE TAPE RECORDERS

Assume the following operating conditions of the recorder:

| | |
|---|---|
| Nominal operating voltage | 8V |
| Maximum acceptable voltage | 10V |
| Minimum acceptable voltage | 6V |
| Average current on "playback" | 75mA |
| Average current on "record" | 100mA |
| Average current on "rewind" | 300mA |
| Minimum life approximately | 20 hours. |

Let us assume a mean current of 100mA for calculation purposes but bear in mind that for rapid rewinding there should be ample reserve of power to supply up to 300mA.

To start with one simple characteristic requirement can be ascertained, i.e. the nominal battery voltage, which would be 9 volts. Since all dry cells are nominally 1·5 volts when new, the battery would have six cells. This can be one self-contained battery or six individual cells connected in series.

The tables on the previous page show the characteristics of a variety of dry batteries (other types are given in manufacturers' literature). It will be seen that the current range column is divided into three categories:

(a) 350 hrs at 4 hours per day;
(b) 20 hrs at 4 hours per day;
(c) 1 to 2 hour rate, 5 minutes per day (1·5V cells only).

Explanations of these characteristics are shown below the tables.

Referring again to the example in hand, Table 1 above summarises the characteristics of six combinations. The current drain time in the second column is calculated on the basis of the 20 hour rate, after which time the voltage of *each cell* has dropped to 0·9V.

The third column indicates the actual life assuming a consumption of 100mA at 4 hours per day until the battery "end-point" voltage is (a) 1·0V per cell; (b) 0·9V per cell. The figure of 100mA is taken as the average maximum current during normal running.

Although the "rewind" current is higher it is unlikely to be a strain since this operation is on for only about a minute or two.

It can be concluded from Table 1 that if a small tape deck is used the HP11 battery is most suitable particularly if weight is of prime importance. The HP11 will cater easily for the extra current required on rewind.

### *CURRENT GUIDE VALUES continued*

Columns (a) & (b) *Pro rata* estimations on intermittent drains. Estimations of life of LPU2 and HP2 batteries when discharged at 60mA 4 hours per day to 0·9V

LPU2 From 20 hour figure $\frac{20 \times 150}{60} = 50$ hours

From 350 hour figure $\frac{350 \times 20}{60} = 117$ hours

Actual figure is 90 hours

HP2 From 20 hour figure $\frac{20 \times 275}{60} = 92$ hours

From 350 hour figure $\frac{350 \times 21}{60} = 122$ hours

Actual figure is 117 hours

## ACCOMMODATING THE FALLING VOLTAGE

The higher the discharge rate the more important is "end-point" voltage. Comparing capacities of the LPU2 down to 1·1 and 0·8 volts we have a difference of 25 per cent at 20mA 4 hours per day but at 150mA 4 hours per day there is an extra 180 per cent available as follows:

| | | 1·1 | 1·0 | 0·9 | 0·8 | volts |
|---|---|---|---|---|---|---|
| Life down to | | | | | | |
| LPU2 | 150mA | 9 | 12 | 18 | 25 | hours |
| | 20mA | 315 | 350 | 370 | 395 | hours |

At high rates if the end point seems high the circuit voltage limitations should be reconsidered.

The life figures in the current guide tables are all down to 0·9 volts per cell, this is of course 5·4V for a 9V battery. If the circuit is designed round 8V as in the case of the small tape recorder exemplified here, and this was assumed to be the maximum, the nearest battery voltage to this would be 7·5 volts. A 6V battery would represent 6/5V per cell (1·2V). Probably less than $\frac{1}{8}$ of the potential energy of the cell would be realised.

If high voltage end-points are necessitated by circuit limitations, h.p. batteries are essential as they give a considerable proportion of their energy output above 1·1V. It is possible that in this particular tape recorder seven cells could be used in series to give a nominal voltage of 10·5V. The circuit should be analysed and the maximum on-load voltage determined for playback, record, and rewind. For example, these might be (a) Rewind 12V; (b) Playback 12V; (c) Record 10V.

If the 100mA record current will lower the voltage to 10 volts, seven cells may be used in series and extra life will be obtained. There is however not much useful energy left in the cell below 0·8V. Extra cells in series to give end voltages below this will therefore not necessarily give extra life.

## MORE SEVERE TAPE RECORDER DISCHARGES

The discharge curves in Fig. 3 show the results of the HP2 and LPU2 battery when discharged on a fixed

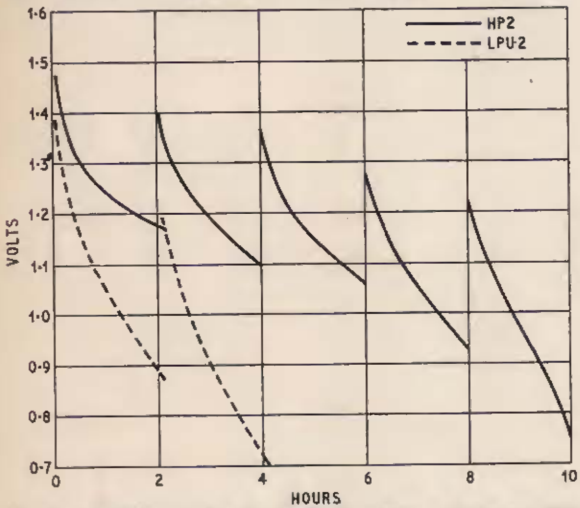


*Fig. 3. Graph showing the fall of voltage across an HP2 and LPU2. Discharge rate 3 ohms per battery, 2 hours per day*

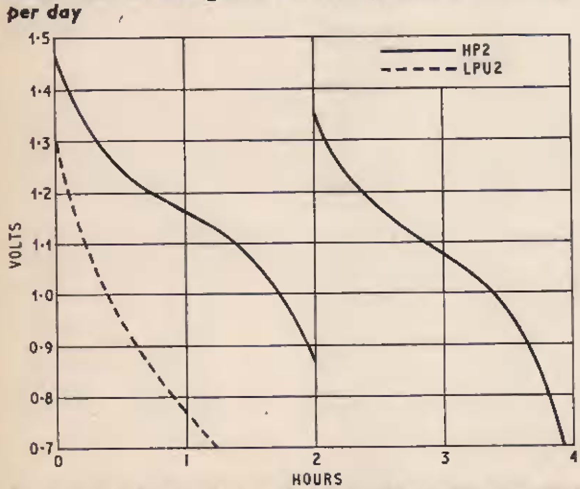


*Fig. 4. Graph showing the fall of voltage across an HP2 and LPU2. Discharge rate 500mA constant current, 2 hours per day*

resistance of 3 ohms for 2 hours per day. The current at 1·5V will be 500mA.

The other graph (Fig. 4) shows the same batteries when discharged at a fixed current of 500mA. The latter discharge is of course more severe and the batteries last a correspondingly shorter time. It should be borne in mind that an equivalent discharge for many transistor devices and electric motors would be somewhere in between fixed resistance and constant current.

## PORTABLE TRANSMITTER-RECEIVER

Transmitter-receivers are rather different from the preceding examples because normally the power required by the transmitter is considerably in excess of that required by the receiver. However, h.p. batteries accommodate these variations reasonably well.

As a guide, some current values are given here which correspond to about 12 hours life from the selected batteries. Assume conditions of discharge as follows:

Transmit current is 10 times receive current. End point voltage is 0·9V per battery. Battery is discharged continuously alternating from transmit to receive with one minute on transmit and nine minutes on receive.

| Battery | Tx | Rx | |
|---|---|---|---|
| HP2 | 1,250mA | 125mA | All life 12 hours |
| HP11 | 500mA | 50mA | |
| HP7 | 250mA | 25mA | |

Very approximate estimates of life at other rates can be made from the average of the transmit and receive current. Taking, for example, the HP2

$$\text{Average current} = \frac{1{,}250 + (9 \times 125)}{10} = 237{\cdot}5\text{mA}$$

At this average current drain until each cell is 0·9V, the life is 9 hours.

This calculation could of course have been made much more accurately if the life was 20 hours or more. However, it is obvious that reasonably worthwhile estimates may be made with h.p. cells at even these high rates of discharge.

## INTERMITTENT DISCHARGE

These figures are for continuous discharge of 12 hours. If discharged 4 hours per day as in the tables (more likely for amateur use) the life would be increased to the order of 20 hours and calculations could be made more accurately from the tables. The period of use per day materially affects the life when the discharge rate is fairly high. The effect is more noticeable with layer cells and least noticeable with h.p. cells as one would expect. Table 2 below shows three examples at the higher rates of discharge.

All figures are for voltages down to 0·9V per cell. ★

**Table 2: COMPARISON AT HIGH DISCHARGE RATE**

| | HP2 at 400mA | LPU2 at 20mA | LPU2 at 150mA | PP9 at 50mA |
|---|---|---|---|---|
| 1 hr/day | 14 | 295* | 40 | 100 hours |
| 4 hr/day | 10 | 370 | 18 | 95 hours |
| 12 hr/day | 4·5 | 320 | 12 | 65 hours |

* LPU2 begins to show a slight loss of life due to the extended period of use.