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Volume 45 OCTOBER 1954 Part 10

PROCEEDINGS AT THE FOUR HUNDRED AND FORTY-NINTH GENERAL MEETING

Held at Kelvin House, corner Marshall and Hollard Streets, Johannesburg

Thursday, 28th October 1954

J. P. ANDERSON (President) was in the Chair and declared the meeting open at 8 p.m.

There were present 55 members and visitors and the Secretary.

MINUTES

The minutes of the monthly general meeting held on the 23rd September 1954, were taken as read, and were confirmed.

MEMBERSHIP

The Secretary announced that in terms of By-Law 5.2.4, the Council had elected the undermentioned candidates to membership of the Institute in the following grades :—

Member : STANLEY MCCRACKEN.

Graduates : WILLIAM ROBERT CHARLES BURLEY, MICHAEL FREDERICK LAUBSCHER, SELWYN LIPSCHITZ, JOSEPH LODEWYK ROTHMAN.

Associates : GEORGE STEPHEN BAKER, REX MICHAEL HOWES MIDDLETON, DONALD MACKENZIE POWIS, DESMOND WILLIAM SMITH.

Students : BERNARD ARTHUR CHAMBERLIN, HILTON FITZ-HUGH ELLIOTT, DAVID JOHN HALL, ANTHONY WILLIAM LOCKE MANDY, WALTER MARCEL VERPOORT.

Transfer from Associate Member to Member : JOHN DINWOODY WILLIAMS.

Transfer from Graduate to Associate Member : DAVID DAVIDSON, JOHN DOUGLAS DAWSON.

Transfer from Associate to Associate Member : CORNELIUS ALWYN JOHANNES BORNMAN.

Transfer from Student to Graduate : COLIN CREWS URQUHART.

GENERAL BUSINESS

Annual Banquet

The President said that the Institute's Annual Banquet would be held in the main Hall, Kelvin House, on Friday, 26th November, at 7 for 7.30 p.m. Booking for that function had been exceptionally heavy, and he would suggest that if there were any members who intended going to the banquet and who had not yet obtained their tickets, they do so without delay.

PAPER AND DISCUSSION

The paper entitled ' The lead-acid battery and its associated control gear : a survey of applications and operating principles,' by

R. A. Harvey and V. A. Lord, was presented on behalf of the authors by A. B. Parsons.

The President proposed a vote of thanks to the authors for their paper and congratulated Mr Parsons on the manner in which it was presented. The following contributed to the discussion : A. H. Durr (Associate Member), J. C. Macfarlane (Associate Member), G. H. Kohler (Associate), G. J. Muller (Member) (communicated), E. N. Johnson (Associate Member) (communicated), G. A. Dalton (Past President) and J. E. T. Cogle (Member).

There was no further business and the President declared the meeting closed at 9.30 p.m.

Institute Notes

Cape Western Local Centre

Members of the Institute visiting Cape Town are cordially invited to attend general meetings of the Cape Western Local Centre which are held in the Demonstration Theatre, Electricity House, Strand Street, Cape Town, on the second Thursday of each month.

A general meeting of the Cape Western Local Centre was held in the Demonstration Theatre, Electricity House, Strand Street, Cape Town, on Friday, 15th October 1954.

Mr C. G. Downie (Chairman of the Centre) was in the Chair and declared the meeting open at 8.10 p.m. Fifty-seven members and visitors were present.

The Chairman extended a cordial welcome to Professor M. J. Meek, D.Eng. (Liverpool), M.I.E.E., Professor of Electrical Engineering at Liverpool University, who presented the Fourth Bernard Price Memorial Lecture entitled 'High voltage spark discharges.' This lecture was originally presented at the Annual Joint Meeting between the Institute and the University of the Witwatersrand, Johannesburg, on Thursday, 26th August 1954.

Professor R. Guelke proposed a vote of thanks to Professor Meek which was seconded by Professor A. F. P. J. Heydorn (Member).

The following contributed to the discussion : Dr H. D. Einhorn (Member), Dr J. L. N. Bessling (Associate Member), H. Flederman (Associate Member), Col. G. H. Webster (Associate Member) W. J. M. Emery (Associate Member), The Chairman and F. D. Opperman (Member).

Professor Meek replied to a number of the questions raised by the contributors.

The Chairman mentioned that the Association of Professional Scientists and the Royal Society of South Africa had extended invitations to members of the Centre to attend their general meetings.

Continuing the Chairman said that he was very pleased indeed to see Mr J. A. F. Michell (Past President) among the members that evening and he hoped that he would be a regular attender at the meetings of the Centre now that he was resident at the Cape.

There being no further discussion the Chairman declared the meeting closed at 10.30 p.m.

[*Institute Notes—continued on page 324*

THE LEAD-ACID BATTERY AND ITS ASSOCIATED CONTROLGEAR; A SURVEY OF APPLICATIONS AND OPERATING PRINCIPLES

By R. A. HARVEY,* B.Sc.(Eng.) and V. A. LORD*

Paper received on 23rd August 1954

SUMMARY

This paper gives a brief description of present-day designs of Planté and pasted-plate cells. Reference is made to the floating and trickle charging of Planté batteries and the modern applications of this type of battery are examined. These applications include batteries for switch-operating purposes in power stations and substations, batteries for operating telephone exchanges and for emergency lighting purposes.

The portable battery applications are divided into two categories, straight charge and discharge, and 'system governed' applications. Reference is made to battery sizes for mining locomotives and the flameproofing of these locomotives. A description is given of the charging methods for electric trucks and road vehicles. Railway applications include train lighting and diesel-starting duties. The paper deals with the control of batteries on vehicles and aircraft.

CONTENTS

1. INTRODUCTION

The first electric storage battery was produced in 1859 by Gaston Planté, a Frenchman, when he invented the reversible lead-acid cell. This cell was quite different from any other type which had previously been made, in that it could be brought back to a fully charged state after a discharge by means of an electric current. All cells made before that time were of the 'primary' type which could not be recharged electrically.

A second invention of considerable importance was made in 1881 by another Frenchman, M. Faure. Whereas Planté had used pure lead for the preparation of his plates, Faure conceived the idea of coating the surface of the plates with a compound of lead. This enabled a lighter construction of plate to be used.

Planté's pure lead plates were the basis of present-day stationary battery manufacture and Faure's pasted plates were the forerunner of the modern portable battery.

The storage battery industry has grown from these two important inventions and in less than one hundred years its products have penetrated into every part of the world.

The methods used for charging batteries have undergone several changes since 1859. For the first twenty years or so the charging current was obtained principally from primary cells; but following the rapid development of dynamo-electric machinery in the 1880's engine-driven d.c. generators were increasingly used for the purpose. Such generators are still the standard method of charging batteries on motor-cars, buses, lorries, aircraft etc., and in isolated stationary lighting plants, but the public electric supply mains are being utilized to an increasing extent for battery charging.

In the early days, when the mains were d.c., charging would normally take place direct from the mains with a charging resistance in circuit. Now that a.c. mains are almost universally employed for distribution, some method of rectification to d.c. is essential for battery charging, and motor-generators, commutating rectifiers, mercury-arc rectifiers, hot-cathode valves, copper-oxide rectifiers and selenium rectifiers have all been used from time to time. The selenium

* Mr Harvey and Mr Lord are Research Engineers with Chloride Batteries, Limited, Manchester.

rectifier is now the type most commonly used for small-scale charging because it has no moving parts and is very flexible in design. The mercury-arc rectifier and hot-cathode valve are used for medium-scale battery charging.

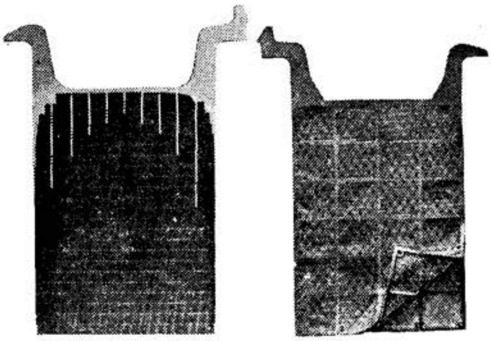
Although there are many alternative metals and electrolytes which can be employed to make up a reversible storage battery the lead-acid cell is, by an overwhelming majority, the type which is in most common use to-day. Its supremacy is due to a combination of technical and commercial reasons. It is completely reversible and can be made to give many hundreds of cycles of charge and discharge. This is due mainly to the fact that the products of reaction, both on charge and discharge, are all insoluble in the electrolyte and thus remain on the electrodes. Other characteristics are low internal resistance, low rate of loss of charge on standing, high voltage and working efficiency, good mechanical strength for the duty involved, and reasonable first cost, weight and volume.

In both classes of lead-acid cells, i.e. the Planté and pasted-plate types, the essential components are lead peroxide for the positive electrode, spongy lead for the negative and dilute sulphuric acid for the electrolyte. This gives an open-circuit voltage of just over 2 volts. On discharge the active material of both electrodes combines progressively with the electrolyte to form lead sulphate. On recharge the chemical reactions are exactly reversed, i.e. the plates and the electrolyte are restored to their original chemical condition.

2. PLANTÉ CELLS

The Planté cell is used principally for stationary duties. Its positive plates (see Fig. 1a) are made from pure-lead castings and their design is such that the surface area is developed to have an area equal to seven or eight times the nominal plate area. This is done by means of a series of lamelles covering almost the whole casting. The plates are electro-chemically 'formed' and this gives them a surface skin of active material. They have an exceptionally long life, in either years or cycles of charge and discharge. This is due to the fact that they contain a reserve of pure lead inside the skin of peroxide which is progressively converted into fresh peroxide to compensate for wear and tear in use. The plates are heavy and bulky for their capacity and are unsuitable for continual handling or vibration; but for stationary work they are supreme.

The negative plates, which are of the pasted 'box' type (see Fig. 1b), are also designed for maximum life rather than mechanical strength or low weight.



(a) (b)

Fig. 1—(a) Typical Planté positive plate; (b) Typical negative (unfilled)

The separators may consist of glass tubes or (more usually) of specially treated wood veneers reinforced with wood or plastic dowels. In certain cases it is more convenient to use diaphragm separators of inert material (such as microporous plastic) where dry storage is necessary for some time before filling in with acid. As regards stationary batteries, however, such materials show no outstanding advantage over wood for separators once the cells are in commission. This is in direct contrast with the usual design of portable cell where the wood separator is now rapidly becoming obsolete. The reason is that Planté separators do not touch the positive plates and there is consequently no danger of the lead peroxide from these plates affecting the wood veneer.

The electrolyte in Planté cells has the fairly low specific gravity of 1·210 when the battery is fully charged. This is much lower than the usual design of portable battery and the fact that the acid is comparatively weak tends to lengthen the life of the cells. It means, however, that a large volume of electrolyte is necessary in order to keep the fall of specific gravity within reasonable limits when the cells are discharged.

The smaller Planté cells are usually made up into glass boxes but the large ones are assembled in wood lead-lined boxes. Sealed-in glass cells are available in the smaller ranges.

2·1 *Charge/discharge routine*

From 1880 onwards Planté batteries were extensively used in d.c. power stations and isolated lighting plants for duties involving regular cycles of charge and discharge. For example, in an isolated plant the battery would be charged during the daytime and would discharge in the evening to the lights. The life of the Planté plates under these strenuous conditions is very long indeed. With a duty of three to four cycles of charge and discharge per week the positive plates will last from eight to twelve years (or say 2 000 cycles), and the negative plates twelve to sixteen years (or say 3 000 cycles).

Nowadays this class of duty (whilst still important) is less common than it used to be, because of the widespread availability of public supply mains. Planté batteries are now used principally for stand-by duties where an instantaneous supply of electricity is required in the event of a mains failure. Examples are to be found in power stations and substations, emergency lighting in cinemas and hospitals, stand-by telephone supplies, etc. A very important additional application is that of circuit-breaker closing and tripping in power stations and substations.

These duties may involve the battery in very few cycles of charge and discharge, but nevertheless the Planté battery is generally chosen for this work because of the ease with which it can be kept in condition by floating or trickle charge and, of course, for its very long life.

2·2 *Floating operation*

With this method of operation the load is normally supplied from the a.c. mains through a rectifier with the battery 'floating' across the d.c. output terminals. (By floating it is meant that the battery neither discharges nor receives any charge other than, in some cases, a trickle charge). When the main supply fails the battery immediately discharges to the load without any break whatever in the continuity of supply.

This general method of working is frequently used in telephone exchanges where it is vital that there must be absolute continuity of supply. For power-station work, too, the indicating lamps, healthy trips, etc., are often supplied on the floating-battery principle. It should be noted, however, that the heavy switch-closing current is designed to come direct from the battery and not immediately from the charging plant. This applies whether the mains are on or off.

The best floating voltage from the battery point of view is to float at about 2·25 to 2·3 volts per cell. At this voltage the battery absorbs a small trickle charge which keeps it in good condition indefinitely without the need for periodical freshening charges. Furthermore, the cells are maintained in such a healthy condition that it is unnecessary to bring the voltage right up to 2·75 volts per cell on recharge after an emergency discharge. Recharges can be completed merely by temporarily increasing the float voltage to 2·4 volts per cell. On many power-station installations the permissible voltage limits on the load circuits are sufficiently wide to cater for such an arrangement. This simplifies the control apparatus and also the maintenance routine.

At other classes of installations such as telephone exchanges where the voltage limits are more critical, it may be necessary to float at, or slightly below, the true equilibrium voltage of about 2·06 volts per cell (in 1·210-specific gravity acid). Generally this means the use of two batteries, one being on float whilst the other is receiving a freshening charge.

The life obtained on float operation may be anything from twelve to sixteen years or more depending upon how closely the conditions approximate to those of continuous trickle charging.

2·3 *Trickle charging*

A Planté battery on stand-by duties can be kept in a fully-charged condition for many years by means of a trickle-charge current. This is a very small current flowing in the 'charge' direction which just balances the losses which occur in the battery circuit. The current required is approximately 1 milliampere per ampere-hour capacity at the 10-hour rate for batteries up to about

100 Ah, but for batteries above that size the rate per ampere-hour gets progressively less.

This method of controlling stand-by batteries was first introduced commercially about 1927 and the results obtained since that date have fully justified its adoption. Numerous tests have been carried out on trickle-charged batteries which have been in service for twenty years or more and the capacity obtainable from these batteries is generally found to be even higher than their nominal catalogue capacity.

There is every reason to expect a properly maintained trickle-charged Planté battery to have a life in the region of twenty to thirty years.

Under ideal conditions a trickle-charged battery should be disconnected entirely from the load, except in an emergency, and this is the usual method adopted for pure emergency-lighting installations. A good approximation to this state of affairs is, however, obtained if floating is carried out at between 2·25 and 2·3 volts per cell as mentioned in a previous paragraph. If the battery is held at this voltage it will automatically take the trickle charge it requires.

It must be emphasized that trickle charging is suitable only for Planté batteries; it is not recommended for pasted-plate batteries because the continuous flow of current tends to attack the partly exposed grids of the positive plates. In the case of Planté plates there are no such grids and the difficulty does not arise.

3. STATIONARY BATTERY APPLICATIONS

3·1 *Power stations*

In the period from 1880 to 1900 many d.c. generating stations were installed in Great Britain and elsewhere for the purpose of giving a public supply within a limited area. A large storage battery was almost a standard fitting in such stations. It served as a stand-by in case of engine failure and it enabled the engines to be shut down completely at night, leaving the battery to supply the load. A further important application was load-levelling where the battery helped to supply the peak loads.

The use of alternating current in modern power stations and the enormous growth in the size of the generating plant have made these applications obsolete except in the case of small isolated d.c. power stations. Nevertheless, stationary batteries still have important duties to perform in every power station which is built to-day. The main difference is that the battery supply is used only for internal services in the station and none of it is sent out to the consumer.

The two principal functions of the present-day power station battery are circuit-breaker closing and tripping, and emergency lighting. It is usual for one battery to deal with both duties and the calculation of a suitable capacity for the battery is rather a complex matter. An essential feature in such calculations is that the battery must have sufficient capacity to close the breakers at the end of the specified emergency lighting discharge (usually of three hours duration).

Separate batteries are commonly employed for each of the subsidiary duties in a power station such as telecommunications, impulse-type electric clocks, summation gear, fire alarms, etc. These devices require widely differing voltages and it is quite wrong to endeavour to operate them from the main station battery.

Planté cells are standard practice in power stations and they are normally of the sealed-in or closed-top cells where the capacity is within the range obtainable. The main advantages of the lids are the elimination of acid spray and the reduction in the quantity of topping-up water required. In dusty atmospheres, too, the lids effectively prevent sand and other impurities from dropping into the cells. The limit of capacity with sealed-in cells was at one time 180 Ah at the 10-hour rate but this was extended to 240 Ah a few years ago. A recent innovation has been the 450-Ah closed-top cell as illustrated in Fig. 2. This was developed primarily for the South African market, because of the dusty conditions in some of the power stations, but it is now being used extensively in other parts of the world. The advantages of the closed-top cell are so great that some engineers use two in parallel to get the capacity required, rather than employ open-type cells.

3·1·2 Control of power-station batteries

At one time it was common practice for the main station battery (or batteries) to be worked on a charge and discharge cycle in the belief that this work was beneficial to the plates. Now that the principles of trickle charging and floating have been established there is no need for such regular cycling of the battery and the battery-charging gear is designed to supply the d.c. required for the continuous load, from a rectifier with the battery floating across the load terminals. In

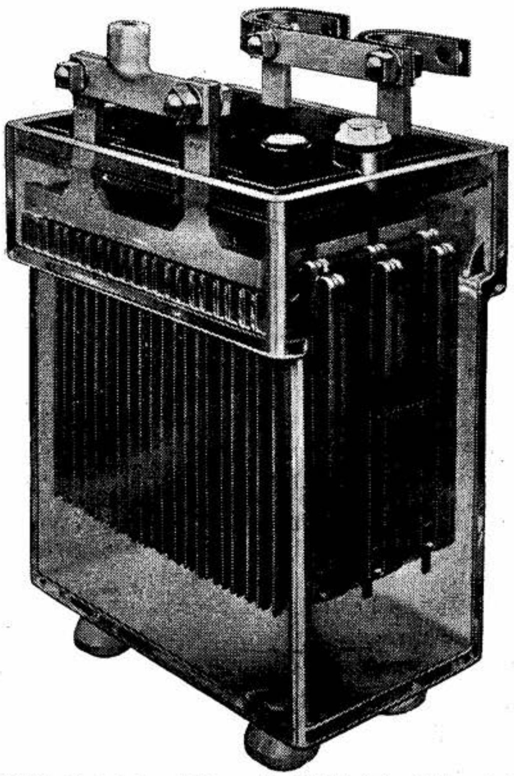


Fig. 2—Sealed-in cell (Capacity 450 Ah at the 10-hr rate)

this way, the battery is relieved from supplying such load except in an emergency, and excessive wear and tear on the battery is avoided. If the continuous load is comparatively small and is likely to vary from hour to hour, an automatic constant-voltage charger of the selenium-rectifier type is installed. This is often achieved with saturated choke control.

In other cases where the continuous load is fairly high a mercury-arc rectifier with automatic voltage regulation is usually employed. The regulator in such a rectifier must be fitted with a time-lag device to avoid 'hunting.'

The method to be used for recharging the battery after a discharge requires careful consideration because of the increased battery voltage.

In a really large power station the best solution is to use two main batteries, one being in service whilst the other is on trickle charge or quick charge. In this way the high voltage of quick charge (2·75 volts per cell) can readily be kept away from the load circuit. Where only one battery is justified, a simple method is to use the reduced charge voltage of 2·4 volts per cell mentioned in an earlier paragraph. Only as a last resort should battery tappings or end-cell regulators be used to keep down the battery voltage applied to the load.

Emergency-lighting circuits should preferably be under the control of an automatic contactor with its coil energized from the main supply. If these lights are connected to the battery by means of a manually-operated switch there is always the danger that the battery may be found to be discharged just when it is most wanted.

3·2 *Substation batteries*

The big majority of substations are nowadays unattended and the battery-control gear must therefore be of a type which can operate for long periods without attention.

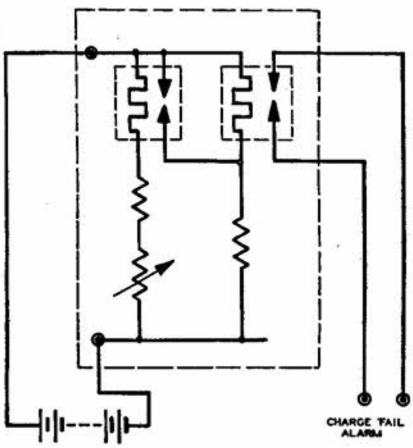


Fig. 3—Diagram of typical charge-fail alarm relay

In the larger substations the battery is used for circuit-breaker closing, tripping and a constant number of healthy trip lamps. The charger can therefore be of the simple manually-controlled type set for a given constant output. It supplies the steady load and also a small surplus for trickle charging the battery. Recharging after a discharge is carried out by manual operation of a quick-charge switch.

In the smaller distribution substations a battery is required for breaker-tripping purposes only. This is commonly a 16-cell 10-ampere-hour battery housed in a wood or steel cabinet. The charging gear is incorporated in the cabinet itself and provides a trickle charge only. Useful features of such a cabinet are a resistance to act as a test load, and also a voltmeter. These are used to check that the battery will, in fact, supply the tripping loads required without the voltage dropping below a pre-determined value.

An important point in the design of such tripping batteries is that they must be properly insulated against earth faults. If such faults do occur there is a danger that incorrect tripping of the breakers may take place. In the wood cabinets this insulation is automatically ensured by the woodwork of the cabinet. In the case of steel cabinets, however, the cells are mounted on wood boards (on the steel shelves) in order to get proper insulation from earth.

3·2·1 Charge-fail alarms

The battery room in a power station is usually located at some distance from the control room and it is inconvenient for the operating staff to make regular hourly visits to the battery controlgear. It is, nevertheless, important that the staff should have early information if the battery should start to discharge. Steps can then be taken to put the matter right before the whole capacity of the battery has been lost.

A charge-fail alarm device which is frequently used for this purpose is a voltage-operated relay connected across the battery terminals. (A typical diagram of such a device is shown in Fig. 3.) As soon as the battery voltage drops below some predetermined value the relay contacts close and give an alarm in the control room. Sometimes change-over contacts are used so that both ' normal ' and ' alarm ' conditions are indicated. A voltage-operated device is generally preferred to a current-operated relay because it gives a more reliable indication of the battery condition. It is, for example, possible for the rectifier to be supplying a current which is insufficient to balance the load current so that the battery is actually on discharge. This set of conditions would cause the battery-voltage relay to give an alarm but would not necessarily affect a current-operated relay.

Any charge-fail alarm device must be time-lagged to prevent fictitious indications during breaker-closing operations.

The alarm system described has been extended in some cases to unattended substation batteries so that an indication of ' charge fail ' can be immediately reported back to the control room through pilot wires.

3·2·2 Earth test relays

Most power-station batteries (except the telecommunication battery) are insulated from earth on both poles and means are frequently provided on the battery controlgear to determine whether the insulation resistance of the battery (and its associated circuits) is satisfactory. One method is to connect a sensitive relay between the mid-point of the battery and earth. Another similar method is to create an artificial centre point by putting a high resistance across the battery and connecting its centre point through a relay to earth. Excessive earth leakages on either pole are immediately signalled back to the control room by the relay. A high resistance and pushbutton for giving a temporary earth fault should always be provided in such cases to enable testing of the relay to be carried out from time to time.

3·3 *Telephone exchanges*

In the early telephone systems each subscriber had his own battery for supplying the speech current, and signalling was carried out by means of a magneto. The maintenance of these local batteries became a very expensive matter as the telephone systems increased in size, and a technique was consequently developed whereby both the speech and signalling currents could be derived from a central storage battery at the exchange.

When automatic telephones were introduced there was a substantial increase in the size of battery required in any given exchange because it had to supply not only the speech and signalling currents, but the automatic mechanisms as well.

The standard practice in the British Post Office for many years was to have two batteries in each exchange, one being on discharge to the load whilst the other was on charge from the public supply mains. This method of control led to considerable wear and tear on the batteries since they operated on a straight charge/discharge cycle. Furthermore each battery had to be capable of supplying the load for the requisite stand-by period (usually 24 hours) since the other battery might have been completely discharged when a mains failure occurred.

The Post Office therefore decided in 1938 to change over to a floating routine for the larger telephone exchange batteries, and a modified semi-floating routine for the smaller batteries. From the beginning Planté type batteries have been used almost exclusively for telephone duties in Great Britain.

3·3·1 Floating scheme

The pure floating scheme is applicable to those exchanges where the consumption is from 2 000 to 10 000 ampere-hours per day. It is known as the 'divided-battery float system' and is illustrated in Fig. 4. Two

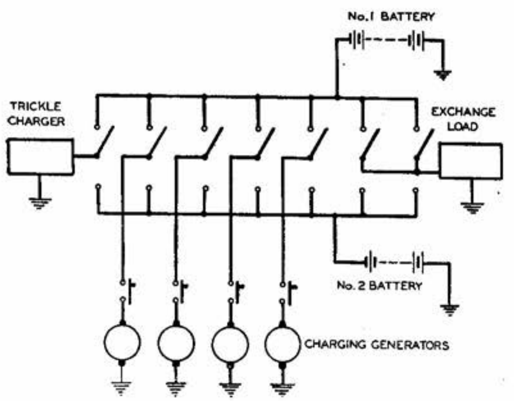


Fig. 4—Simplified diagram of the divided-battery float scheme for telephone exchanges

batteries are used each consisting of 25 cells and the capacity is so selected that the two together can supply the exchange load for the requisite 24-hour stand-by period.

Motor-generator sets, driven from the main supply, produce all the energy for the exchange when conditions are normal but one battery is floating across the d.c. busbars. The voltage is held at 2·02 to 2·07 volts per cell corresponding approximately to the open-circuit voltage of the battery. Under these conditions the battery very slowly loses some of its capacity and after a week the second battery is put in its place so that the first one can be given a freshening charge. The duties are changed over from one battery to the other in this way every week. In the event of a mains failure the battery which is floating immediately takes over the load and the second one is paralleled to it as soon as possible by the attendant.

A floating-trickle charge routine at 2·3 volts per cell is not permissible as this would lead to an excessive voltage being applied to the exchange load. If fewer cells were installed to compensate for this higher voltage, this too would not be permissible because the voltage on discharge during a mains failure would be too low for the automatic telephone gear in the exchange.

3·3·2 Semi-floating schemes

The amount of manual supervision required for the above scheme is not justified for medium exchanges taking from 100 to 2 000 ampere-hours per day, and the British Post Office have developed a system of semi-floating control for such exchanges. It is known as the 'parallel-battery automatic system.'

The load is normally supplied from the mains through two or sometimes three rectifiers and both batteries are connected across the d.c. busbars with an ampere-hour meter in circuit (as shown in Fig. 5). This meter is of the usual battery-charging type, i.e. it is reversible and runs 'slow' on charge.

It has three contacts at—

i the fully-charged position (zero),
ii the 4 per cent discharge position and
iii the 30 per cent discharge position.

When first connected the batteries supply the load and the rectifiers are shut down. The ampere-hour meter integrates the discharge current until the 4-per cent position is reached. A contact on the meter then starts up the rectifiers. These supply current to the load and the batteries until the zero position on the ampere-hour meter is again reached. The contact on the meter then shuts the rectifiers down. This cycle of operations continues indefinitely.

It may so happen that at busy times the rectifier output is not sufficient to meet all the demands of the exchange. In these circumstances, the battery discharges in

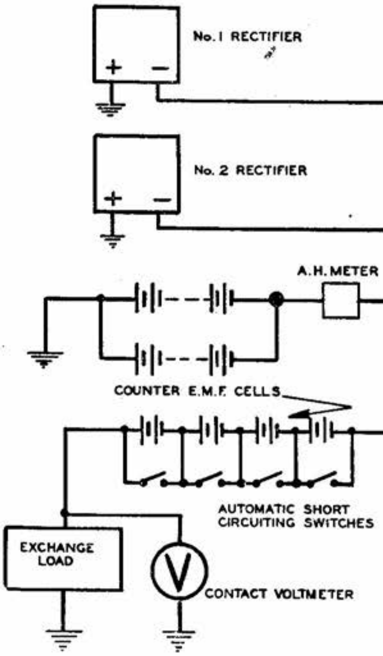


Fig. 5—Simplified diagram of the parallel-battery automatic system for telephone exchanges

order to make up the deficit and is recharged under the control of the ampere-hour meter when the exchange load is reduced. If, however, the discharge should exceed 30 per cent of the combined battery capacity then a contact is made in the ampere-hour meter which sounds an alarm. This is a warning to the attendant that extra rectifier capacity is required or, alternatively, that the batteries are discharging to a considerable extent because of a mains failure. Two batteries in this control system are used so that one can be taken out of service for overhaul when required.

The voltage of the batteries during charge is higher than the exchange apparatus can tolerate. Counter-e.m.f. cells are consequently inserted in the load circuit by automatic means during charge in order to drop the surplus voltage. These cells are specially designed to have a fairly constant counter-e.m.f. over a wide range of current. They have a very low capacity and are normally short circuited when not required.

The smallest exchanges taking up to 200 ampere-hours per day operate on the 'single-battery automatic system.' This is generally similar to the scheme detailed before but only one battery and one rectifier are used. Voltage control is still maintained automatically with the aid of counter-e.m.f. cells.

3·4 *Emergency lighting*

Batteries are now frequently installed in cinemas, hospitals and public buildings for the purpose of providing emergency lighting in the event of a mains failure. The principal developments in this battery application have taken place in the last 25 years and its present widespread use is due to two main causes :—

i Trickle charging of stand-by batteries reduces supervision to a minimum and furthermore a battery life of 20 years or more can be obtained with such control
ii Static rectifiers of the valve or selenium type are very convenient for the charging of emergency batteries from a.c. mains. Rotating machinery is no longer required.

Modern electric-supply networks are very reliable, and breakdowns are rare, but

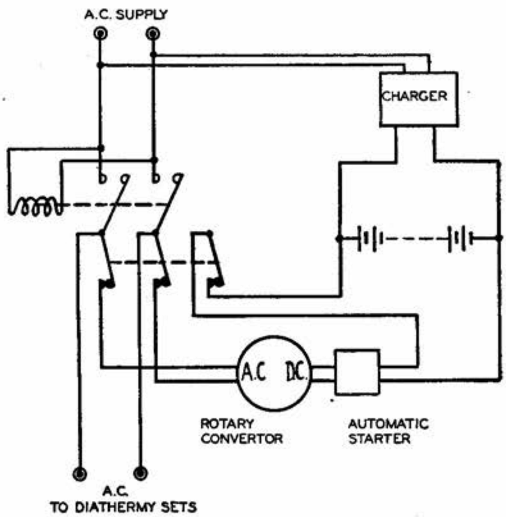


Fig. 6—Simplified diagram of emergency-lighting plant to supply a.c. to diathermy sets

nevertheless power failures do occur from time to time, and a local battery on the consumer's premises is undoubtedly the best method of dealing with emergency lighting problems.

In Great Britain, every commercial cinema is compelled by law to have emergency lighting. Gas lighting is used for this purpose in some of the older cinemas, but all the modern ones have storage batteries. Hospitals are not compelled to have emergency lighting but practically all the British ones are equipped with batteries. The minimum requirement is lighting protection in the operating theatres but many others extend the system to the wards, staircases, etc. A recent innovation has been the installation of a battery with a rotary converter for supplying a.c. to diathermy equipment during an emergency. This is illustrated in Fig. 6.

The simplicity of the apparatus now available has enabled the scope of emergency lighting to be extended to large departmental stores, schools, banks, swimming baths, factories, hotels, dance halls, etc. A new development has been the use of emergency lighting on football grounds. Many of these grounds are being equipped with floodlighting to enable matches to be played at night. Emergency lighting of staircases, passageways, etc., is an essential requirement in such cases because of the large crowds involved and the danger of panic in sudden darkness.

The Planté battery is used exclusively for emergency lighting in Great Britain and many

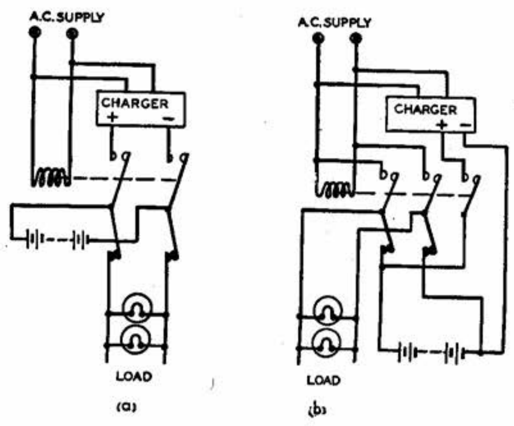


Fig. 7—Simplified automatic emergency-lighting diagrams
(a) **Non-maintained circuit.** (b) **Maintained circuit**

places abroad because it lends itself to trickle charging and has such a long life in service. The usual arrangement is for a selenium rectifier to be installed for continuous trickle charging of the battery and for recharging the battery after a mains failure. This latter charge, known as a 'quick charge,' is controlled by a manually-operated switch and is put into action as soon as possible after the mains have been restored after an interruption of supply. The battery must be brought back to a fully-charged state before being put back on to trickle charge.

The lights themselves are under the control of an automatic switch, or contactor, and there are two distinct systems which can be used :—

i The non-maintained system illustrated in Fig. 7a. In this scheme the emergency lamps are normally 'dead' and are illuminated in an emergency only. It is mainly applicable to hospitals

ii The maintained system illustrated in Fig. 7b. Here the emergency lamps are normally illuminated from the mains but obtain their supply from the battery in an emergency. This scheme is particularly applicable to cinemas where it is a statutory requirement (in Great Britain) that the emergency lamps must be illuminated during the whole of a performance. In many cases the battery is of 50 or 100 volts only and the emergency lamps are, therefore, illuminated at the required voltage, under normal conditions, by means of a step-down transformer.

In either of the above schemes the automatic switch has its coil energized from the main supply. It is only when this supply fails that the switch changes to the emergency position and the battery is connected to the load. The battery is automatically disconnected again when the mains are restored, but quick charging of the battery is under manual control as mentioned before.

The floating-battery system is another method sometimes used for the control of emergency batteries. In this case the load is normally derived from a rectifier, with a battery floating across the rectifier terminals. When the mains fail the battery automatically takes over the load without the need for any automatic switch. Battery maintenance is not so simple with this method of control and it is used in only a few areas where the local authorities demand it by their regulations.

Operating-theatre lighting in hospitals is of vital importance and special apparatus is necessary for the emergency lighting because of the design of the lanterns in use. These are generally arranged to have one main lamp only and the light is concentrated from this lamp on to the patient by means of an extensive system of lenses and mirrors. This construction means that a minimum of heat is projected on to the surgeon's head and furthermore his head does not cast a shadow on the patient.

This illumination is, however, dependent on one lamp only, and the automatic switch for the theatre is therefore of the series type which detects whether current is flowing to the lamp. If this current should cease to flow due to mains failure, local fuse failure or lamp-filament failure, the emergency lamps in the fitting are automatically illuminated from the battery.

4. PASTED-PLATE CELLS

The pasted-plate type of cell is used mainly for portable duties. Whilst cells of this type work on the same fundamental principle as Planté cells there is a considerable difference in plate construction. In the pasted-plate type both positive and negative plates are of the same general construction and are cast in the form of lattice grids from lead/antimony alloy (see Fig. 8a). The active material is applied to the grids in the form of a lead-oxide paste which is then converted electro-chemically into lead peroxide and spongy lead for the positive and negative plates respectively.

In comparison with the Planté type the plates form a more rigid structure and are more robust mechanically. The positive plates contain a higher proportion of active material but they possess no reserve from which fresh active material can be formed. Generally, therefore, cells of the pasted-plate type have not the same degree of durability (particularly in terms of cycles of charge and discharge) but they possess a number of advantages over Planté types for certain uses.

The chief advantages to be claimed for the pasted-plate type are considerably reduced weight and bulk for a given capacity. This is made possible by the use of a compact assembly and a reduction in acid volume by employing a higher working specific gravity—usually 1·250 or 1·280. As minimum weight and bulk are of primary importance in most portable battery applications, it is easy to see why the pasted-plate type of lead-acid cell is invariably chosen for this class of duty.

4·1 *Principles of cell design*

The present-day uses of pasted-plate cells cover a much wider and more varied field than those of the Planté type; consequently there is a correspondingly wide variation in methods of construction and design. In view of this it is important that the user should choose a type which has been specifically designed for the duty in question.

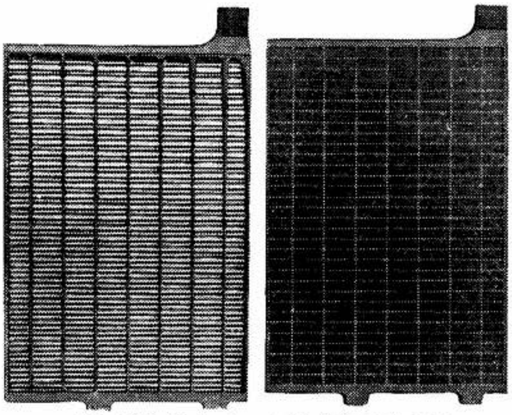


Fig. 8(a) Typical pasted-plate and grid

The designs available are, at one extreme, represented by the use of thin unarmoured plates which achieves minimum cost, weight and bulk with maximum performance at high rates of discharge. At the other extreme the use of thicker and armoured plates achieves maximum durability (in years and cycles) with maximum robustness and resistance to vibration.

4·1·1 Thin-plate types

The cheaper and less durable types of lead-acid batteries usually employ thin flat pasted plates with grooved wood, or inert micro-porous separators between them. They are assembled in containers of glass, celluloid, plastic material, hard rubber or bituminous composition. These types are used for radio, handlamps and in 6-volt and 12-volt units for starting and lighting on private cars.

Aircraft batteries also use thin plates, but in this case the ruling factors in design are light weight and reliability rather than low initial cost.

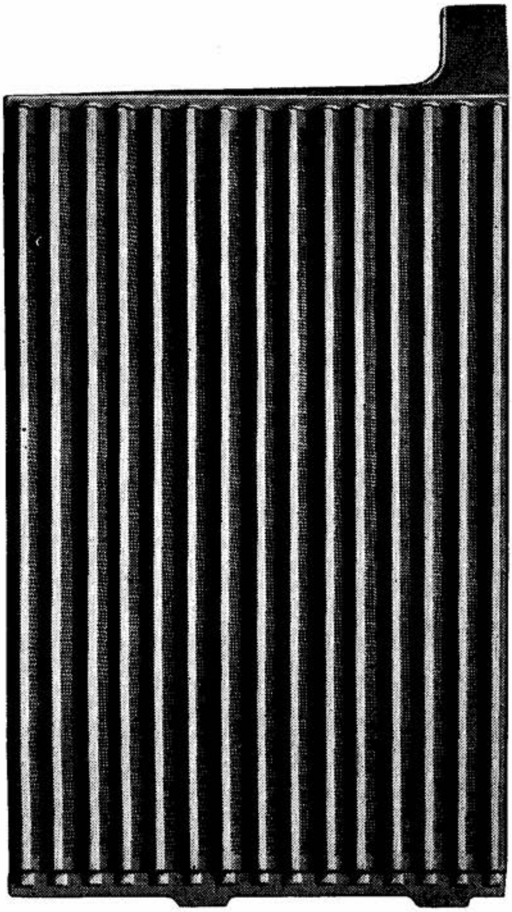


Fig. 8(b)—Tubular positive plate

4·1·2 Armoured-plate types

The more durable types of pasted-plate cells use thicker plates having some form of armouring for the positive active material. One particular design employs positive plates of a tubular construction (see Fig. 8b), with separate vertical pencils of active material each contained in a finely slitted tube of hard rubber and having a central core of lead alloy joined to the top and bottom bars of the plate. Batteries employing plates of this type are extensively used for train lighting, cooking and air-conditioning and also for vehicle propulsion.

Other designs use thick flat pasted plates with sheets of glass wool to support the positive active material. The glass wool is in addition to the normal separators. These types are mainly used on passenger and commercial vehicles, also for submarine and other marine applications.

Cells of the armoured-plate type are usually assembled in moulded hard-rubber containers or in thinner containers of similar material which are suitable for assembly in wood or steel trays.

4·2 *Progress and development*

The most important development in recent years in the portable battery field is the introduction of the inert microporous separator which has largely superseded treated wood as a separating material in most types of pasted-plate cells. Several types are in use including microporous rubber, microporous plastic and bonded fibre reinforced

Fig. 9—New design of radio cell with polystyrene container and absorbent fibre separators

with glass wool. These separators are in every way as efficient as wood and (in the case of the microporous plastic type) are so much more chemically resistant that their durability exceeds that of the battery plates by a considerable margin.

The new-type separators make possible an all-dry assembly so that new batteries may be stored in a dry unfilled condition for long periods without deterioration before charging.

Another development on small portable cells where unspillability is a desirable feature is the introduction of absorbent-fibre separators. The use of this material enables compact unspillable cells to be produced, with none of the drawbacks of the so-called 'jelly acid' types.

Other developments in design have centred around the use of acid-resistant plastic materials. Polystyrene is already in use for containers in certain sizes of radio cells (Fig. 9) and also for vent plugs in most portable cells. Polythene is in use for aircraft-battery containers on account of its lightness, strength and good characteristics when exposed to extremes of temperature.

Improved alloys and manufacturing techniques have also been introduced in recent years and this incorporation in present-day manufacture has resulted in increased durability.

5. PORTABLE BATTERY APPLICATIONS

The early uses of portable batteries were of a widely varying nature but invariably the charging source was at a static point. To some extent this limited the use of batteries on moving vehicles because of the inconvenience of removal of the batteries for charging. As the railway companies were among the first organizations to use batteries on a commercial scale it is perhaps fitting that they conceived the idea of charging the batteries on the vehicle itself.

On all later types of vehicles using batteries for auxiliary duties this same principle has been followed although many different forms of charging control have been tried up to the present day.

Generally, therefore, the uses of portable batteries fall into one of two categories :—

i Straight charge and discharge
ii 'System-governed' applications.

i Straight charge and discharge

This method of operation as applied to portable batteries will always represent a basic application. It covers the use of batteries which are regularly cycled involving charging at one place and discharging at another. Radio, deaf-aid and portable lamps are amongst the applications in the smaller types and for armoured types the propulsion of electric road vehicles, factory trucks, surface locomotives and mining locomotives.

Batteries on submarines and for many other marine applications also operate on the straight charge and discharge system.

ii System-governed applications

This method of operation covers in general the batteries used on vehicles to provide continuity of lighting and to perform other auxiliary duties including engine starting. In such systems the battery operates 'on balance' in conjunction with a generator which can supply the various loads only when the vehicle is travelling above a predetermined speed. In these cases the operating routine of the battery is necessarily of an irregular and intermittent nature.

Some of the more important applications in both categories are described in greater detail in the following paragraphs.

5·1 *Mining locomotives*

Battery-powered locomotives for underground haulage are widely used in South Africa and have also been used in British collieries for over thirty years mainly in sizes between 2 and 8 tons with one or two larger sizes. During the last few years there has been an increasing growth in the use of locomotives generally for underground haulage and this is likely to continue. With this prospect in view manufacturers in Britain have developed larger battery-powered locomotives of about 13 tons weight and equipped with motors having a total rating of 60 to 90 h.p. (1-hr rating). Fig. 10 shows a locomotive of this type. These were the first locomotives of their type comparable in performance with the 15-ton 100-h.p. diesel locomotives which were made available by a number of British manufacturers some five or six years ago.

Performance under identical conditions indicates that there is little to choose between the two types in hauling power and time to complete a given duty. Operating experience over the last six to eight years in British mines indicates that the battery-operated locomotive has definitely gained favour. This

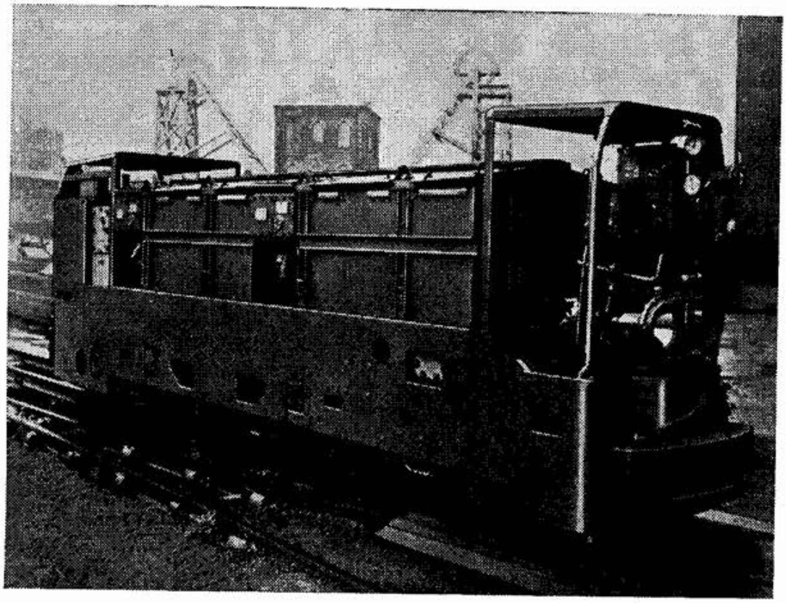


Fig. 10—13-ton flameproof mining-type battery locomotive

is mainly due to comparative freedom from trouble in service.

The 13-ton battery locomotives are each fitted with 100-cell batteries of the armoured type, capacity 412 Ah at the 5-hr rate of discharge. These cells are specially designed for mining applications and have increased headroom to eliminate acid spillage. Double-terminal pillars reinforced with copper inserts are provided to assist cooling and carry the heavy currents without risk of overheating.

As the locomotives nowadays are in almost continuous service it is customary to provide two or even three batteries per locomotive. Normally where one battery is sufficient to drive the locomotive through a full eight-hour shift only two batteries and one charger are required and these are so operated that each battery receives three complete cycles of discharge and recharge every two working days. Where the duty is such that one battery is insufficient to provide a full shift working it is necessary to provide for three batteries with charging capacity for two batteries simultaneously.

5·1·1 Calculation of battery sizes for mining locomotives

Because of the numerous variable factors involved, the calculation of locomotive-battery performance presents a difficult task. From the battery point of view the variable factors are—

i reduction in available capacity with increases in rate of discharge

ii recuperative properties of the battery during off-load periods.

If the nominal 5-hr capacity is taken as 100 per cent, the capacity available when discharging continuously at the 1-hr rate is reduced to 65 per cent. This class of duty calls for intermittent discharges at rates usually of the order of the 1-hr rate for the battery, but as these discharges are evenly spread over a full shift period, the off-load time is comparatively long and permits a reasonable amount of recuperation.

The recuperative property of a battery is a complex quantity but a simple practical formula for the calculation of battery capacity (which includes for recuperation) giving reasonably accurate results is—

$$C = AN\left(F_2 + \frac{F_1 - F_2}{3}\right) F_3 .\ F_4$$

where C = the capacity of the battery required at the 5-hr rate of discharge in ampere-hours

A = the ampere-hours discharge per duty cycle

N = the number of cycles required on one charge of the battery

F_1 and F_2 are correction factors allowing for the difference between the capacity available under the actual conditions of discharge and the nominal capacity at the 5-hr rate

F_3 = a factor allowing for the depreciation in battery capacity towards the end of life

F_4 = a factor allowing an extra margin to cover emergency requirements.

The composite factor $\left(F_2 + \frac{F_1 - F_2}{3}\right)$ can be further explained in that F_1 is the factor which would have to be used if the total ampere-hour output required for the duty were taken at the maximum current. Similarly F_2 is the factor which would have to be used if the discharge were spread evenly over the whole working period, i.e. if the whole ampere-hour output were taken at the mean current.

The resulting value of the composite factor is intermediate between the two factors F_1 and F_2 but rather nearer to the smaller factor F_2.

In order to simplify the actual method of calculation of battery size, curves can be drawn showing the value of the composite factor for different periods of time relating to factors F_1 and F_2. The time factor relating to F_1 is the total ampere-hour capacity (AN) divided by the maximum current, and the time factor relating to F_2 is the total shift period concerned.

A further simplification can be made by assuming that the time factor relating to F_2 is 5 hours and provided the shift periods concerned are between 4 and 8 hours the error in the final calculated ampere-hour capacity will be within 5 per cent.

5·1·2 Flameproofing of battery electric locomotives

The flameproofing regulations applicable to British collieries require ordinary electrical controlgear to be housed in steel cases with wide flanges. This standard design of flameproofing is neither suitable nor necessary for battery housing. Quite apart from the fact that the battery is a static apparatus without moving parts, the traces of hydrogen evolved from the cells would render the normal type of enclosure ineffective. Batteries used on locomotives which operate in hazardous atmospheres are therefore fitted in ventilated enclosures with special precautions to ensure that—

i each cell is fitted with at least double pillars and connectors

ii the undersides of the battery covers are adequately insulated to prevent short circuits on the tops of the cells

iii insulators are fitted between the cells and the steel trays

iv end cables have fireproof insulation.

All associated battery controlgear on the locomotive, including the external battery terminals, is mounted in its own flameproof chamber.

5·1·3 Methods of charging mine loco batteries

Batteries charged underground in Britain are subject to special regulations which state that the batteries may be charged and changed only at the appointed places. The charging stations must be constructed of non-flammable material and must be properly ventilated. The ventilating air must discharge direct from the battery racks to the return airways.

The chargers in use are mainly of the rectifier type which provide a two-step current output of approximately the starting rate for the particular battery at the com-

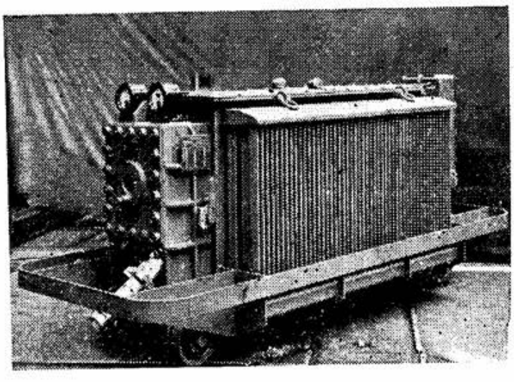


Fig. 11—Mining-type flameproof charger—oil-immersed rectifier

mencement of charge, with provision for automatic reduction of the charging current to the finishing rate when the cells begin gassing. Automatic termination of charge is also provided in the form of a voltage/time relay or ampere-hour meter.

Rectifiers are generally of the oil-immersed type (Fig. 11) with flameproof protection of all associated controlgear. The chargers are normally mounted on bogies for easy movement in charging stations.

5·2 *Electric trucks and road vehicles*

One of the first applications of storage batteries was for the propulsion of road vehicles. However, the rapid development of the internal combustion engine and increased production of petrol and oil have enabled vehicles of the latter type to supersede the former in all except certain special applications.

The main uses for battery-propelled road vehicles in Britain lie in local milk- and bread-delivery services and the production of such vehicles has increased steadily over the last 25 years or so. With the increase in production technical improvements have been made and these have helped to make battery-operated vehicles advantageous in their proper sphere.

A more recent development has been the battery-propelled 'pram' or pedestrian-controlled vehicle used mainly for milk delivery. Such vehicles are employed in built-up areas and operate within reasonable distance of the depot.

During the last few years the use of battery-propelled works trucks has extended at a much more rapid rate than the use of road vehicles. This applies particularly to fork-lift trucks and is probably due to the enormous emphasis now devoted to the art of materials handling as a prime factor in improving productivity.

The earlier trucks included the fixed-platform type, tractor type and elevating-platform type with batteries consisting of up to twenty cells averaging about 250 ampere-hours at the 5-hr rate. Fork-lift trucks on the other hand have been developed to handle much heavier loads with correspondingly larger batteries.

5·2·1 Charging methods

All these applications require batteries of the armoured type for the rather arduous duty consisting of regular discharging and charging, together with the ability to withstand severe vibration.

Generally, the duty is such that about 12 to 14 hours per day are available for charging and this enables standard vehicle chargers to be used. In some cases the vehicle may operate on a shift system and in such cases more than one battery per vehicle is required.

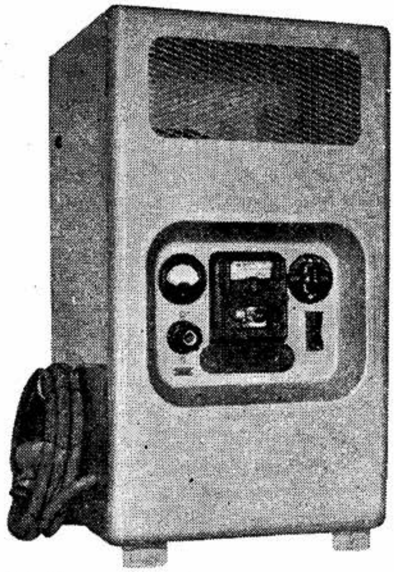


Fig. 12—Standard vehicle battery-charging rectifier

The standard vehicle charger is of the metal-rectifier type as shown in Fig. 12, suitable for operation from a.c. mains. It is usually of the completely-enclosed type suitable for wall mounting and is complete with input and output control switches, ammeter and voltage/time relay for terminating the charge automatically. The output characteristic is such that the maximum output current is available at a battery voltage corresponding to 2·1 volts per cell falling to half the maximum value at a battery voltage corresponding to 2·6 volts per cell. Most battery manufacturers specify a recommended maximum charge rate at 2·5 volts per cell for taper charging and in selecting a charger its output is considered suitable if within plus or minus 10 per cent of the recommended rate at 2·5 volts per cell.

On this basis the time required for a complete recharge after a full discharge will be approximately 10 to 12 hours.

For shorter charging times chargers of the two-step type will be required. Generally these chargers provide an average charging rate equal to the recommended starting rate up to 2·4 volts per cell at which point the charging current is reduced automatically. For the remainder of the charge the average current is approximately equal to the recommended finishing rate. By employing the recommended charge rates the time required for a complete recharge after a full discharge will be approximately 7½ to 8 hours. Typical charging curves are shown in Figs. 13 and 14.

Other methods of charging are at the manufacturer's recommended constant current rates or by the modified constant voltage method, both systems operating from d.c. generators.

Where an a.c. supply is available the separate rectifier method of charging gives greater flexibility and generally better results from the point of view of battery life. This may be partly due to the incorporation of the voltage/time relay which ensures that the battery receives the correct amount of charge.

This device consists of a sensitive voltage relay and time switch. The function of the relay makes use of the fact that irrespective of the depth of the previous discharge the ampere-hour input required will be constant after the battery has reached a certain

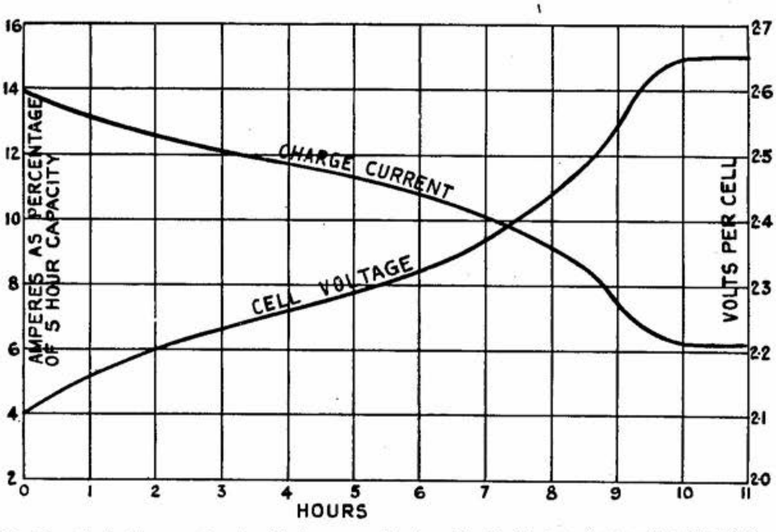


Fig. 13—Typical current and voltage curves for traction batteries when recharging (after a complete discharge) from a standard vehicle charger

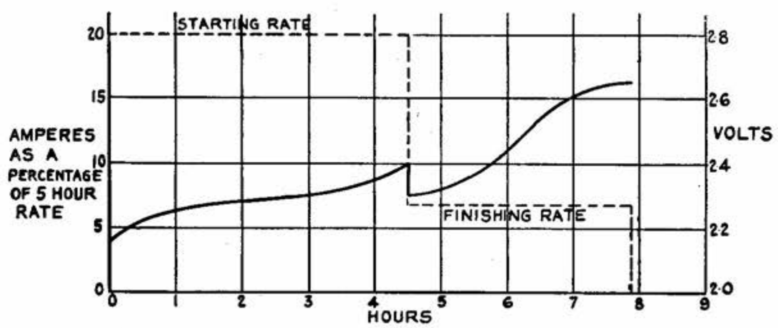


Fig. 14—Typical current and voltage curves for traction batteries when recharging (after a complete discharge) from a two-step charger

voltage at a predetermined charging rate. The function of the voltage relay in standard taper chargers is to detect when the battery voltage reaches 2·35 volts per cell at which point the timing motor begins to operate. This allows charging to continue for a pre-set time which is calculable from the ampere-hour capacity of the battery and the average charging rate during the timed period. When this time has elapsed charging ceases automatically.

These relays have time scales which can be pre-set between 1 and 6 hours and once adjusted for a particular combination of battery and charger further adjustment is seldom necessary. The tripping device is re-set by hand at the commencement of each recharge.

Reversible ampere-hour meters are sometimes fitted to vehicles for automatic charge control but generally they are not as reliable in operation as the relay type described above.

5·3 *Railway applications*

Although the first record of the use of secondary cells for train lighting in Britain goes back to 1881 it was not until 1894 that the first really successful scheme embodying battery and dynamo fitted on the railway coach was developed.

The first air-conditioning apparatus on trains which incorporated refrigerating plant was supplied in America in the mid-1930's. Air conditioning is now extensively used on many railways operating in tropical climates and generally such plants derive their power supply from axle-driven generators and batteries on each coach. In many respects they are a direct development of the ordinary train-lighting schemes.

Electric cooking was introduced on British railways in 1924 and is in use on certain routes.

5·3·1 Types of batteries

As train lighting was one of the early applications of lead-acid storage batteries practically every type of cell has been used in this service. Even to-day there are more different types employed for this duty than for any other single application. Standardization is gradually cutting down the number of types of cells used for this duty and present developments show a swing towards the armoured type of pasted-plate cell. In South Africa and India there is a definite preference for the tubular armoured type.

Cells of this type are assembled in thick-walled hard-rubber containers. One design extensively used in South Africa and illustrated in Fig. 15 consists of two or four cells in a moulded hard-rubber container of the monobloc type. The two-cell unit has a capacity of 300 ampere-hours at the 10-hr rate and weighs 165 lb. The four-cell unit has a capacity of 150 Ah at the 10-hr rate and weighs 186 lb. The cells are designed specially for railway service with adequate headroom above the plates to prevent spillage of acid. The design also provides for efficient cooling and good electrical contact between cells or units. Floats are provided in each cell to give visual indication of the acid level and to facilitate maintenance.

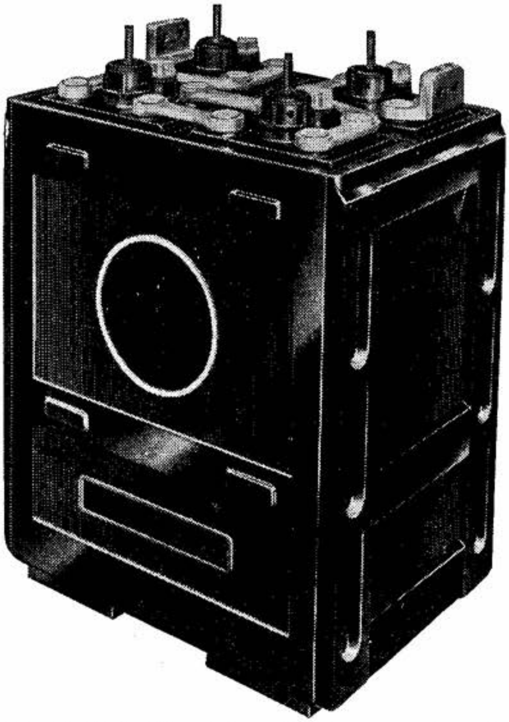


Fig. 15—Four-cell monobloc 150-Ah battery for train lighting etc.

Single cells of this type are in use on the Blue Trains and described in Mr J. P. Anderson's Presidential Address.[1] Cells of similar design are used for air-conditioning equipment, but as the heavy loads demanded cannot be handled at the usual lighting voltage of 24 volts a new standard of 110 volts has been adopted and is almost universally employed for this duty. The corresponding lead-acid battery for this voltage consists of 56 cells.

A typical battery used for electric cooking on the British Railways consists of 90 cells, capacity 180 Ah at the 10-hr rate.

5·3·2 Control systems

The control systems used in conjunction with train-lighting batteries have been as widely varied as the types of batteries themselves. However, they fall into two main categories, one employing a single battery and the other duplicate batteries.

In the single-battery scheme provision has to be made to reduce the voltage on the lamps during charging periods. With the double-battery scheme one battery is on charge while the other is floated across the lights. This scheme gives excellent voltage control on the lamps where individual switching of lights is limited. A feature of this scheme is that both batteries feed the load when the train is stopped and furthermore the batteries are charged alternately, i.e. after every other stop.

5·3·3 General

In connection with railway signalling, etc., batteries are used for the operation of electric-point motors, signal motors, interlocks on signal and point levers.

5·3·4 Diesel locomotives

Diesel-engine locomotives have been in use for shunting purposes for some years and in recent years this form of propulsion has been extended quite considerably to passenger services. Generally, there are two distinct types, namely diesel/electric locomotives for main-line operation and diesel-mechanical railcars for suburban work.

Diesel/electric locomotives are generally equipped with a battery specially designed for diesel-engine starting. A typical lead-acid battery for this duty would consist of 48 cells capacity 185 Ah at the 5-hr rate. Cells of this type use flat-pasted plates armoured with glass wool with additional microporous plastic separators. Terminal pillars and connectors are reinforced with copper inserts to carry the heavy starting-current demands of the diesel engines.

Batteries of this type operate in conjunction with constant-voltage generators driven from the engine, and voltage settings of between 2·2 and 2·3 volts per cell are recommended for satisfactory operation of the battery.

Diesel-mechanical railcars are generally similar to buses in operation and are usually equipped with 24-volt electrical systems. Batteries used may be of the diesel-starting design or other armoured design including the tubular type. The charging and control system is similar to that used on diesel road vehicles.

5·4 *Vehicle starting and lighting*

For this duty the battery is required to provide continuity of lighting and to perform engine starting and other auxiliary duties. On private cars the batteries fitted are of the thin-plate type with separators of wood or microporous material. Cells are assembled in monobloc units of 6 or 12 volts in hard rubber or bituminous composition material. On commercial and passenger vehicles batteries having thick pasted and armoured type plates are used with additional separation. Cells are assembled in monobloc containers or made up from individual cells and fitted in wood trays. System voltages are usually 12 or 24 volts and batteries consist of a number of 6- or 12-volt units.

On private cars the 'third-brush' system of regulation was used up to about 1936, but between this date and 1939 a general change was made to the separate generator and compensated - voltage - control (c.v.c.) regulator. The adoption of this form of charge regulation has led to longer battery life with less maintenance. With a correctly set regulator there is virtually no overcharging as the battery takes what it requires from the system. For example a discharged battery will take a comparatively heavy charging current which will be reduced automatically as the battery approaches the fully-charged state (see Fig. 16). A fully-charged battery will take only a relatively small current from the system at a voltage which permits only slight gassing.

The present tendency is to fit lower-capacity batteries on private cars yet the auxiliary loads have been increasing steadily over the last few years. This policy would seem to be contradictory and the net result is that the smaller batteries do not provide the additional reserve which has been so useful in the past in assisting the users in emergency and particularly in the winter months.

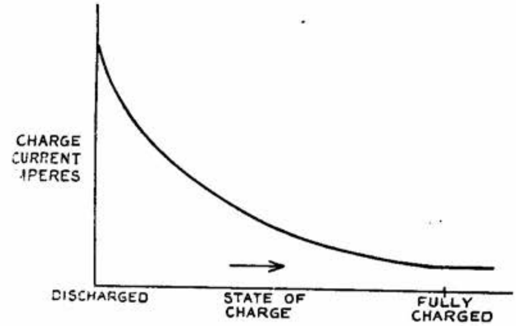


Fig. 16—Curve showing variation in charging current with state of charge. Battery charging from c.v.c. regulated system

On commercial and passenger vehicles the c.v.c. system of control has been a standard fitment almost since its inception. Further developments include the current-voltage regulator system which permits charging at a constant current rate up to a predetermined voltage. At this point the constant-voltage regulator takes control so that the charging current is reduced progressively as the battery approaches the fully-charged state. This system is intended to recharge a discharged battery in a shorter time.

Another development is the combined alternator/rectifier equipment which is claimed to give a considerable weight reduction and a saving in maintenance. This system has not yet been very widely used.

Because of the comparatively heavy lighting loads on passenger vehicles it is necessary to allow extra capacity for this specific purpose in determining a suitable battery size.

Trolley buses may have batteries for manoeuvring and low-voltage lighting. For manoeuvring, a 60-volt battery is used and for charging, this battery is usually divided into two 30-volt units connected in parallel. A constant-voltage generator supplies the charging current. The batteries are invariably of the armoured type.

Motor cycles and minicars generally use 6-volt batteries of about 12-Ah capacity. Charging is from a generator and c.v.c. regulator except on the smaller types which use an a.c. generator and metal-rectifier arrangement.

5·5 *Aircraft*

Modern aircraft are dependent on an adequate supply of electric power for their numerous electrically-operated devices. It would be impracticable to attempt to supply all the various loads from batteries alone, and in order to keep such batteries to the minimum possible weight and size only limited duties are required to be carried out and these under conditions of extreme emergency.

Two essential duties which the battery must be capable of performing are the operation of radio and other instruments to effect a safe descent should the aircraft's engines fail in flight, and also to operate the fire extinguishers on crash landing.

On medium-sized civil aircraft the most commonly used system employs 24-volt batteries with one or more engine-driven d.c. generators. On larger aircraft the battery may consist of 54 cells in 12- or 24-volt units operating on a nominal 120-volt d.c. supply system. These are two of a number of different systems in use on various types of aircraft, and although the systems may be varied, some degree of standardization

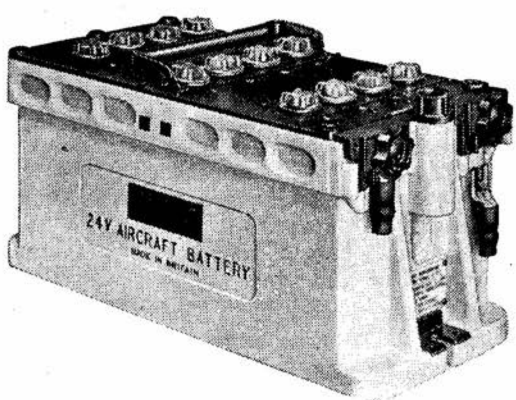


Fig. 17—Typical civil aircraft 24-v 25-Ah battery

has been achieved in the design and types of batteries used for this class of duty. The design of these batteries has had to take into consideration the fact that the whole electrical equipment of aircraft has to withstand conditions more arduous than for most other applications.

The batteries used are of the thin pasted-plate type and designed to give maximum performance at high rates of discharge. Both 12- and 24-volt batteries are available in either special-grade hard-rubber or polythene monobloc containers, the capacities available ranging from 15 to 63 Ah. A typical aircraft battery of 24 volts, 25 Ah at the 10-hr rate weighs 45 lb (see Fig. 17).

All these batteries are of the semi-unspillable type and can be installed on any non-aerobatic aircraft. They can be tilted through an angle of 60° from the vertical without risk of spilling the electrolyte, and a special feature of all types is that the tops of the batteries are protected against accidental short circuits by the inclusion of an insulating cover. Normal servicing can, however, be carried out without removing the cover. Special facilities are provided for holding down the containers and usually the holding-down device is an integral part of the container. Special insulated terminals of a modified plug-and-socket type are also provided which ensure correct polarity and these can be manipulated without fear of accident or short circuit in restricted space.

Although batteries of this type are capable of supplying power for engine starting under emergency conditions, on normal service this duty is invariably carried out from ground starter batteries mounted on a trolley. Battery trolleys carrying twelve cells having a capacity of some 100 to 275 Ah at the 5-hr rate can be seen at most airports and the use of these devices avoids the need for discharging the battery on the aircraft itself.

Ground starter batteries are also of the thin-plate high-performance type but do not embody the special features of aircraft batteries themselves.

6. CONCLUSION

The applications of storage batteries are so wide and varied that it has been possible to deal only with the principal uses in this paper. However, enough has been written to illustrate the important part played by storage batteries in the electrical industry and the field of transport.

During the last 25 years steady progress has been made in the design and manufacture of storage batteries, and in the same period fundamental changes have taken place in charging and control methods. These improvements have resulted in longer battery life with less manual attention required during service, and consequently more and more batteries are being used for standby and emergency duties.

Mention has been made of choosing the correct type of storage battery for the particular application and this cannot be sufficiently emphasized. The same degree of selection also applies to charging and control-gear, particularly if a new application is involved. This precaution will generally ensure satisfactory and reliable operation, together with long battery life.

7. ACKNOWLEDGMENTS

The authors desire to express their thanks to C. P. Lockton, Chief Engineer, Chloride Batteries Limited, for his permission to use the information included in this paper. They also acknowledge with thanks information and illustrations from Messrs Bruce Peebles Ltd., Metropolitan Vickers Electrical Co. Ltd., Partridge, Wilson & Co. Ltd. and Westinghouse Brake & Signal Co. Ltd.

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DISCUSSION

A. H. Durr (Associate Member): The authors have given a very complete account of the various types of stationary and portable batteries in commercial use and I should like to add a few remarks, especially in regard to the pasted-plate type of battery used for vehicle starting and lighting.

In battery manufacture, quality control is perhaps more important than in any other process. Experience has shown that two batteries manufactured on the same day may have quite different characteristics, and the following factors should be particularly controlled :—

a Purity and consistency of lead, pastes and expanders
b Such conditions as temperature and humidity during curing or drying of the pased plates, and duration of drying
c Inspection of separators
d on the completed battery, control should be exercised to check the performance of the battery, i.e. capacity, high-rate discharge characteristics, retention of charge and life cycling
e Battery cases should be checked for cracks (dielectric strength test), mechanical strength (pneumatic test), chemical inertness and resistance to acid.

Expanders

The authors have made no mention of the use of expanders in the paste which are claimed to improve the high-rate discharge characteristics of the battery and which therefore provide better starting or cranking ability. This is due probably to the prevention of sulphate films on the active crystals which thereby reduce the capacity. Although most expanders in use are trade secrets the two main classes are the inorganic types (generally barium sulphate) and the organic types (such as derivatives of lignen). These types act in different ways and their effect if used together is more or less additive. It would be interesting to have the authors' views on the effects of expanders.

Types of motor vehicle batteries

It is interesting to note the similarity between the American S.A.E. Standard and the South African Standard in regard to battery sizes and capacities and on the other hand the divergence as regards test methods for high-rate discharge and life cycling. These differences are :—

(*a*) *High-rate discharge*

The South African Bureau of Standards (S.A.B.S.) specification prescribes a discharge for a period of 4 minutes 20 seconds at a rate in amperes equivalent to three times the rated capacity. The voltage of the battery is determined after 5 seconds and after 4 minutes 20 seconds, and the voltage after these periods shall be not less than 1·66 and 1·33 volts per cell respectively.

The American S.A.E. Standard prescribes a discharge at 300 amperes at 0°F to a terminal voltage equivalent to one volt per cell. The criterion is the time taken for the battery to reach a voltage of one volt per cell and the time prescribed varies with the size of battery.

b Life cycle

The S.A.B.S. specification life test is as follows :—

i Discharge for 4½ hours at a rate in amperes equivalent to 16 per cent of the rated capacity
ii Charge for 7½ hours at a rate in amperes equivalent to 11 per cent of the rated capacity
iii After every twenty cycles recharge the battery and determine the ampere-hour capacity
iv The life test is regarded as completed as soon as the capacity obtained on one of the test discharges fails to reach 80 per cent of the rated capacity.

The S.A.E. life test is as follows :—

i Discharge for one hour at approximately 40 amperes for a total of 40 ampere-hours
ii Recharge at the rate of approximately 10 amperes for 5 hours for a total of 50 ampere-hours
iii One complete capacity discharge test is made each week at 40 amperes
iv When the capacity of the battery on a complete capacity discharge cycle, at

the 40-ampere rate, drops below the ampere-hours rated by the manufacturer at the 20-hour rate, the life test of the battery shall be considered as completed

v The number of life cycles prescribed for a battery varies according to the size of the battery

It will be noted that the American life-cycle test takes on an average twelve to twenty weeks to complete depending on the size of the battery. Similarly the S.A. life-cycle test takes about fourteen weeks to complete. Considerable delay is therefore inevitable in testing batteries for the purpose of adjudication of tenders and there appears to be a need to investigate a faster life test either on a high-rate discharge test of short duration and high-rate charging to simulate cranking and charging conditions in practice.

The American specification covers the heavy duty or double-separation type of battery which is not included in the existing South African Specification S.A.B.S. 2-1952. The S.A.B.S. has appointed a committee to revise its specification and it has been suggested that the double-separation type should be included.

It has been suggested also that batteries should be further subdivided as follows :—

a Batteries, for private cars and light commercial vehicles, fitted with thinner plates (positives up to approximately 0·095 inch thick) and usually with single separation

b Heavy-duty batteries, for goods-carrying vehicles, fitted with medium thickness plates (positives between about 0·095 inch and 0·190 inch) normally fitted with double separation

c Heavy-duty batteries, for public service vehicles, fitted with thick plates (positive more than 0·190 inch thick) and with double separation.

It will be noted that the foregoing classification is according to plate thicknesses and single or double separation and that the thin-plate batteries with single separation are recommended for private cars and light vehicles. This recommendation fully agrees with the authors' recommendation in regard to thin plates for private cars. It also supports the theory that the thin-plate battery with single separation is best suited for private cars, since it gives good cranking characteristics which are considered more important than lighting and other services. On the other hand, the thicker-plate batteries with double separation are better suited to supply a consistent steady drain and are therefore able to supply the lighting and accessory loads taken by public vehicles.

J. C. MacFarlane (Associate Member): As I am associated with the mining industry, it is that aspect of the paper that is of most interest to me.

Small lead-acid batteries are used in the mines for telephones, bell systems, tripping devices and a variety of other uses. As the lead-acid battery lends itself ideally to trickle charging, it requires very little maintenance and gives long battery life. As a cap-lamp battery the lead-acid cell has proved very satisfactory, as it has the advantage of less weight than other types.

As regards traction underground there are a large number of battery locos in use on the Rand: it has been found that when lead-acid batteries are used the only satisfactory method of charging is the modified constant potential. The ampere-hour method is apt to result in overcharging due to the loco driver putting a half-charged battery on charge for the full period. Unfortunately the constant potential system requires a reasonably sensitive voltage relay and must be maintained carefully underground. Battery locos have been used with success in mines with which I am associated, in conjunction with trolley line. The battery is trickle-charged while the loco is using power from the overhead line enabling the loco to be used beyond the end of the line and increasing considerably the time between charging.

With the unskilled African driver being driven by an enthusiastic miner, running a battery flat is not an uncommon occurrence and is detrimental to the life of a lead-acid cell. To overcome this low-voltage relays are installed which, by means of red lights, warn the driver to have the batteries re-charged without delay.

As ambient temperature in deep level mining is an important feature, it would be most interesting to see curves showing the variations of charging rates against different ambient temperatures. Due to the high temperatures encountered, such troubles as cell cases buckling and cracking and the battery tops distorting have been experienced especially when the battery is not under the constant supervision of an experienced attendant. Could not some more efficient method be devised for cooling these cells? This refers not only to charging but also to discharging. Recently, by increasing the cooling of a 6-ton loco underground, it was possible to more than double the amount of work per charge.

The lead-acid batteries do not lend themselves to simple cooling arrangements as do the nickel-iron batteries, on account of the non-metallic cases. Generally, lead-acid batteries require more careful handling than nickel-iron batteries but this disadvantage is offset to some extent by the very much higher cost of the latter.

High temperature results in rapid evaporation of distilled water and much damage has been caused to batteries underground by the level in the cells running low during a shift.

Adequate ventilation at the charging station is of great importance as damage has resulted underground when open lights have been in the vicinity of freely charging cells.

In my experience, taking into account all differences and with the employment of the unskilled African on the mines, the nickel-iron battery is preferable, for underground traction, to the lead-acid battery. I should like to hear the authors' comments on this subject.

G. H. Kohler (Associate): Although the lead-acid battery was invented a long time ago and is used extensively, there is still a lot of mystery about some of its characteristics. Perhaps this is due to, rather than in spite of, its early origin!

The application which interests me most is the power station battery. An enquiry for such a battery usually states the nominal voltage and the conditions of loading, i.e. the steady load (signal lamps), the largest breaker-closing and -tripping currents, emergency lighting load (with charger off) for two hours and final battery terminal voltage required for sequential reclosing of breakers for a period of one minute duration with charger off. This information is passed on to the makers. From some secret safe, no doubt, the battery maker takes out some curves and formulae to which he can apply the given loads to obtain the number of cells and ampere-hour capacity of the battery required. The secret documents are then returned to safe keeping. Perhaps the authors have access to this information which they may be willing to release for publication. The information would be very useful in estimating and checking battery requirements.

The authors appreciate that the calculation of a suitable capacity for the battery in a modern power station is rather a complex matter but do not enlighten us further on this point. The problem is not as simple as it seems as will be seen from the following notes concerning the difficulties facing the power station designer in the selection of a suitable battery.

In an Escom power station the station battery comprises two separate batteries of sealed-in type cells normally connected in parallel and normally kept at a floating voltage of 2·25 volts per cell by an automatic constant-voltage type of charger. As the emergency load (emergency lighting plus steady load) and final load (emergency load plus breaker-reclosing load) may be required at any time without notice it is obvious that the battery must be maintained at full capacity at all times, and this can be achieved by floating at 2·25 volts per cell. British Standards require that closing devices shall operate at 80 per cent rated supply voltage. After such an emergency discharge one battery at a time would be taken off load and given a high-rate charge. The number of cells in the battery is thus tied up with its floating voltage which is 2·25 volts per cell.

To ensure correct operation of carrier-communication equipment the floating voltage should not vary by more than plus or minus 5 per cent. Signal lamps are specially made to cover a wide voltage range but valves should not be operated under overvoltage conditions exceeding 5 per cent. There does not appear to be a provision under British Standards to cover overvoltage conditions in closing-coil circuits nor continuously rated coils but it seems reasonable to assume that for low-current coils on contactors and relays these can stand an overvoltage of 5 per cent without harm. It should be noted that in the case of oil circuit-breakers, the supply arrangement, according to B.S. 116 shall limit the voltage to the designed normal voltage (nominal). It is desirable that the same nominal d.c. supply voltage be specified for all related gear in the same power station and the floating voltage must be as close to the nominal voltage as practical. On light-current circuits the voltage drop permitted is of the order of $1\frac{1}{2}$ per cent whereas on heavy-current circuits such as on large closing-coil circuits a voltage drop of 5 per cent may be allowed. Applying the foregoing to a 220-volt (nominal) battery system the permissible voltage range for correct operation is :—

Maximum voltage = 220 + 5 per cent overvoltage + 1·5 per cent voltage drop = 234·3 volts.

Minimum voltage = (220 × 80 per cent) + 5 per cent voltage drop = 187 volts.

Table A has been calculated on the voltage-per-cell figures given by a well-known battery manufacturer for the conditions mentioned therein :—

for breaker-reclosing purposes the battery must still carry a fair charge at the end of the emergency load period.

An examination of Table A suggests that 102 cells would suit the voltage requirements. Battery makers however, invariably offer 108 or 110 cells for the same duty. Perhaps the authors can throw some light on this matter. Perhaps also, the secret documents in the care of the battery maker would throw some light on the question of ampere-hour rating of the battery. As explained above the capacity required for the emergency load is not the only factor determining the ampere-hour capacity of the battery. This is also affected by the minimum voltage required for the final breaker-closing load, even though the ampere-hours required for one minute of this load are usually less than 5 ampere-hours. Obviously the greater the ampere-hour capacity of the battery in relation to the emergency load, the less difference will there be between the floating voltage and the voltage after supplying the emergency load. The basis suggested is a

TABLE A

No. of cells	110	108	106	104	102	100	98
No-load fully charged volts (charger off) (2·01 volts/cell)	221	217	213	209	205	201	197
Floating volts* (2·25 volts/cell) (charger on)	247 (252)	243 (248)	238 (243)	234 (238·5)	230 (234·5)	225 (229)	220 (224)
Volts after two-hour emergency load (charger off) (1·87 volts/cell) ...	206	202	198	194	191	187	183

* Figures in brackets indicate plus 2 per cent d.c. voltage variations due to variations of a.c. voltage on charger.

The figure of 1·87 volts/cell after emergency load with the charger off given in Table A has been taken as the voltage after two hours of discharge on the 3-hour rate at an average current equal to the emergency lighting plus steady loads. A study of typical battery discharge curves suggests this method—for want of something better—of selecting the number of cells required to ensure that after the 2-hour load its voltage is above that necessary for breaker-reclosing duty.

Different factors would have to be used for emergency loads of other durations. In other words in order to obtain correct voltage compromise between the economics of the case and reliability. The authors may be able to put forward a better and more general formula for all types of mixed loads. In this connection the formula given by the authors for determining the battery capacity for a mine locomotive does not appear to apply to the particular case of a power station battery where the minimum permissible voltage after an emergency discharge is comparatively high, unless factor F_4 is intended to cover this condition. If so, it would be instructive to have some idea of the values to be assigned to the four factors in the formula.

There is yet another aspect on which additional information would be very welcome. Could the authors give particulars on the internal resistance of a lead-acid battery from which it would be possible to calculate the voltage per cell at any instant on any discharge rate? This formula would also give the maximum current which could be taken from a battery at any time.

Before concluding, it would be interesting to have the views of the authors concerning the best arrangement of stationary batteries with glass containers when placed in rows. With a type of battery recently supplied to a power station and the arrangement of inter-cell connectors provided by the makers the end plate is seen from the side instead of the edges being visible. It would seem that a view of the edges is more useful than a view of the end plate from the battery attendant's point of view as he can then see the colour of each plate in each cell.

E. N. Johnson (Associate Member): This is a subject which, when one reads the paper, one realises really needed airing as the various types of batteries and their charging characteristics are not as well known as might be expected from their wide application.

The authors state that by an overwhelming majority the lead-acid cell is in most common use to-day. This is true but I cannot agree with their statement that it is supreme. Its wide application is due largely to its cheapness relative to other types of batteries and to technical attributes which make it suitable for many purposes. It is stated that it is completely reversible which again is not quite factual in that in every reversal a certain amount of shedding of active material takes place hence the large cavity left below the plates to accommodate this material. The nickel-iron and nickel-cadmium batteries, particularly the former, find very wide application for traction and stand-by plant uses. This type of cell has theoretically an almost infinite life and in practice the life is very much longer than can be obtained from the lead-acid type cell. If it were not for the initial cost its application would undoubtedly find far wider use.

The internal resistance of the nickel-iron cell is relatively high which prevents its application on starting duties but the nickel-cadmium cell has an internal resistance comparable to the lead-acid battery and as such has a wide application and is frequently used for starting duties.

The authors have given very useful information on the Planté cell. At the present time, however, this type of cell, as far as I am aware, is not available from local manufacture in South Africa although it is made in England and Australia. I am not certain of its cost relative to that of nickel types but it would probably be comparable.

It would be useful if the authors would give information on the cost of this type of cell together with its capacities in relation to the nickel types.

G. A. Dalton (Past President): Since the incorporation of this Institute only twice have storage batteries formed the subject matter of a paper presented to the membership.

The first was read by Mr Pleass before the Wireless Section during December 1922, under the caption of 'A few notes on high-tension batteries,' but with the advent 17 years later of the second paper entitled 'Lead-acid storage batteries and their application,' presented by A. C. Tilley, some considerable advance in battery design and practice was recorded, and the membership was treated to a very fulsome technical discourse on, to use Mr Tilley's words, 'the evolution of the modern storage battery.' This excellent paper and the author's detailed replies to the queries raised in the discussion, given in June 1941, set a standard for this Institute.

The late C. T. Cocks in his paper 'Some train-lighting systems,' delivered in October 1922, referred briefly to the application of accumulators for the lighting of trains. He did not dwell on their technical aspects, confining himself mainly to statistics of lead-acid and alkaline cells in service on the South African Railways. Mr Cocks did, however, bring to light an interesting facet of battery manufacture in South Africa, which, in view of the rapid growth of industries in this country, is worthy of recapitulation. Resulting from very gratifying experiments during World War I, carried out by the Railways, in the re-pasting of old plates and the fabrication of new ones, the Railway Administration started a factory in Bloemfontein which, to quote Mr Cocks, 'formed the birth of the manufacture of accumulator plates in this country.' With a return to normal trading conditions this factory ceased to function.

Thirteen years have gone by since Mr Tilley closed the debate on his paper. Is it that engineers, prone to think in terms of megawatts, have relegated batteries, their faithful ally to the commonplace? The late Mr Cocks in discussing Mr Tilley's paper stated, *inter alia:* 'The subject of storage batteries is usually regarded by engineers (particularly power engineers) as being beneath their notice,' but immediately proceeded to ameliorate this by stating that this was probably due to 'the formidable array of chemical equations which usually accompanies any explanation of their working.'

It might be that the accumulator in its fundamental design has remained somewhat static through the years and, as such, has lost much of its quondam glamour.

We have listened this evening with a great deal of interest to Messrs Harvey and Lord's paper. After a close reading of this paper and that delivered by Mr Tilley and drawing a comparison between them—the scientific approach disposes of indecency—one is forced to the conclusion that the conjecture, anent accumulator designs remaining static, cannot be lightly dismissed. Apart from the introduction of inert microporous and absorbent fibre separators and the use of acid-resistant plastic materials for containers and vent plugs, Mr Tilley's survey still remains, in the Institute's archives, the standard work of reference. There is no intention of detracting from Messrs Harvey and Lord's commendable effort in bringing batteries to the fore again. They have made in their rendering of the twice-told tale a matter of great interest but in view of what has gone before very little remains to engender factual criticism or provoke original thought in discussing their paper. Planté and Fauré certainly built better than they knew. There are, however, some minor points concerning which clarification by the authors would be very much appreciated.

The authors' attention is drawn to Section 2.2, paragraph 3, and Section 3.1.2, paragraph 4, relating to quick-charge voltage. The point at issue is not exactly a contradiction, but some qualification appears to be necessary as to why either 2·4 or 2·75 volts per cell may be used, and what special considerations apply to using 2·4 volts.

With regard to Section 3.1.2, paragraph 1, is it not a fact that most automatic selenium rectifiers now installed employ static phase conversion to give constant voltage output and that saturated choke control, or more correctly a development of it, is less common?

In connection with Section 2.2, paragraphs 3 and 4, what is the recommended frequency of freshening charges associated with various floating voltages between 2·08 and 2·25 volts per cell?

Referring to Section 4.1.2, paragraph 1, the inference seems to point to the exclusive use of tubular armoured type cells for vehicle propulsion. As there are probably a very great number of the flat-plate glass wool-armoured type in use for vehicle propulsion, do the authors agree that the vehicle propulsion application ought rightfully to have been included in paragraph 2 of the same section?

In Section 5 *i*, 'Straight charge and discharge,' paragraphs 1 and 2, the wording implies that batteries on submarines and ships are removed from their locations for charging but the authors will agree that this is not the case.

In their reference to 'Types of batteries,' Section 5.3.1, paragraph 1, the authors make mention of the fact that for train-lighting purposes present developments show a swing towards the armoured type of pasted-plate cell, but in South Africa and India there is a definite preference for the tubular armoured type. It would be interesting to have from the authors the underlying reasons governing this decided preference. With the tubular armoured type cell, is there any build-up in capacity with cycling, and, if so, to what extent? Does not the flat-plate glass wool-armoured cell, with its special separation assembly, possess marked advantages over the tubular type in this respect?

With regard to 'Mining locomotives,' Section 5.1, paragraph 3, it would be interesting to learn which of the two types of armoured cells, tubular or flat plate, are fitted to the 13-ton battery locomotives operated by the British mining industry. Possibly both types are in use but will the authors clarify the issue, as well as similar issues raised in Section 5.2.1, paragraph 1, and Section 5.4, paragraph 7 ?

The authors mention in Section 5.3.3, paragraph 1, that batteries are used for railway signalling, etc., but it would be interesting to learn the types of batteries favoured for the specific purposes enumerated.

In their reference to diesel-mechanical railcars in Section 5.3.4, paragraph 4, the authors state that batteries used may be of the diesel-starting design, or other armoured design including the tubular type. In what respect does the diesel-starting type differ from the armoured types, and does it possess any inherent advantages over the latter ?

Relative to Section 5.5, paragraph 2 the authors kind indulgence is craved in putting the following question. Are the fire extinguishers on an aircraft, which function electrically from a battery, brought into operation immediately before the aircraft crashes, or automatically on impact ?

Finally, it is noted that the authors have not made mention of the means for overcoming the spillage of acid. In batteries destined for use in vehicles, trains, aircraft, floating craft, etc., special precautions must of necessity be taken. Have there been any recent developments in this respect ? Has the design of the vent cap materially altered, and, if so, could the authors provide details ?

J. E. T. Cogle (Member): The authors have presented an interesting and informative paper and it is apparent that much ingenuity and effort has been expended on the improvement of lead-acid batteries and associated control equipment.

There are, obviously, difficulties in reducing the size of cell without sacrifice in performance and size reduction would appear to result in compromises in design. Having reduced the amount of solid matter to a minimum, reduction in the volume of electrolyte to produce a smaller cell seems to call for acid of higher specific gravity than that which may be the optimum for long life. Is any information available co-relating length of life with quantity and specific gravity of electrolyte for any particular type of cell with the plate area and thickness kept constant ?

Changes from the use of alkali batteries to lead-acid batteries have sometimes been made for certain purposes. Is the reason for this associated with improvements in performance of lead-acid cells and control equipment, or is it a question of economics such as cost of raw materials and manufacture ? It seems to have been generally accepted that alkali batteries would stand up to almost any abuse, so any preference for the lead-acid battery would not seem to be merely a question of robustness and ability to withstand ill-treatment.

Where rapid charging is required as in the case where less than about seven hours are available for charging, as sometimes happens with electric trucks, the alkali battery would appear to be the answer as use of lead-acid batteries seems to necessitate having a second battery on charge whilst its companion is in use.

I feel that the authors might have given some up-to-date comparisons of the two types of cell so as better to emphasize any improvements in lead-acid cells in recent years.

With regard to separators, the authors state that, in the case of stationary batteries, the microporous type shows no advantage over wood once the cell is in commission. It would appear that it might be easier to control the consistency of synthetic material than to control the vagaries of nature in producing just the right timber for separators and the best wood for the purpose has not always been freely available. The synthetic material has definite advantages when it comes to storage without acid and also when the top of the separator happens to become uncovered in service.

More details of correction factors in Section 5.1.1. as well as curves or an example illustrating the use of the formula in typical cases would give some idea of what could be expected in calculating the value of C.

In the manufacture of pasted plates, is litharge generally used for both plates or is litharge used for reduction to spongy lead and a higher oxide for oxidation to lead peroxide ? Are quick-formation agents such as chlorates and acetates used to any extent ?

The authors do not recommend trickle charging for pasted plates as continuous flow of current tends to attack the partly exposed grids of the positive plates. Is this really very detrimental when trickle charging is carried out for limited periods and is not almost continuous ? In what way does the plate suffer ? Does the material become loose in the grids, do the plates buckle or are there other effects ?

Institute Notes

NEW PUBLICATION ARRANGEMENTS FOR THE *JOURNAL* AND *PROCEEDINGS* OF THE INSTITUTION OF ELECTRICAL ENGINEERS, LONDON

The Institute has been advised by The Institution of Electrical Engineers, London, that new arrangements for the publication of the *Journal and Proceedings* have been made. The details are as follows :—

The Journal

In place of the present *Journal* (which has hitherto been available only to members of The Institution) and Part I (General) of the *Proceedings*, there will be only one general publication, in the form of the improved *Journal* of The Institution. This will be designed to be of interest not only to members but also to non-members *who can now subscribe in the same way as for the Proceedings.* It will still be called the *Journal* and will appear monthly, but in a more attractive form.

In the new *Journal* much of the present material will still be published, but less formally, and it will be supplemented by such items as special articles on current Institution papers or events ; engineering reviews of wider appeal than Progress Reviews (which will continue to appear in the *Proceedings*) ; correspondence on engineering subjects ; and some of the general material at present appearing in Part I of the *Proceedings*.

The Proceedings

Part I of the *Proceedings* will be discontinued at the end of 1954, and thereafter the *Proceedings* will be divided into three parts only :—

Part A ' Power Engineering '
(issued in alternate months—February, April, etc.)

This will resemble the present Part II, but the only measurements papers it will contain will be those which are of interest to power engineers.

Part B ' Radio and Electronic Engineering '
(issued in alternate months—January, March, etc.)

This will resemble the present Part III, but will contain measurements papers on electronics, which at present appear in Part II.

Part C ' Monographs '
(issued twice a year—in March and September)

This will be a continuation of the present Part IV, and will contain monographs, as before.

Most of the material previously published in Part I will appear either in Part A or Part B, but occasionally lectures or papers on highly specialised advances in physics or mathematics, previously published in Part I, will be treated as monographs and will appear in Part C. Thus, Part A will cover power engineering and Part B will cover light-current engineering. Part IV will continue virtually unchanged as Part C.

The *Journal* and the three parts of the *Proceedings* will be available to members of the South African Institute of Electrical Engineers at half the published rates as follows :—

	Published rate	*Reduced rate to members of co-operating societies*
	Per annum	Per annum
Journal	... £1 5s. 0d.	12s. 6d.
Proceedings, Part A	... £1 15s. 0d.	17s. 6d.
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