Incorporating the New Battery into the Telephone Plant

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The new Bell System battery has been designed to eliminate the problems experienced in applying the old cells. This article tells how the new cell will be incorporated into the telephone plant and describes a new plastic battery rack which has been specifically designed to accommodate the new cell in an optimum manner.

I. LEAD-ACID BATTERIES—EXISTING PRACTICES

Batteries have been an important part of the Bell System plant since the earliest days. Equipment arrangements have varied in size from a few dry cells in a wall telephone to installations occupying thousands of square feet of floor space in a modern telephone office. The design intent in each of these arrangements is fundamentally identical: to provide a mounting for the battery which protects it from its environment in such a way that neither the safety of operating personnel nor the reliability of the telephone plant is jeopardized. This intent has generally been well satisfied but not always in an economically optimum manner. Specifically, the present 180- to 1680-ampere-hour cells have certain characteristic faults which have severely limited the design options available to those charged with incorporating them into the plant.

1.1 *Equipment Problems with Present Cells*

1.1.1 *Multiplicity of Sizes*

The present product line includes eleven ampere-hour capacities, each of them purchased from three different manufacturers in both lead-calcium and lead-antimony. Since the specifications are of the "end-requirement" type, the manufacturer is free to vary many of the design parameters to suit his own product. As a result, the equipment designer must provide accommodation for 66 sets of physical dimensions.

This has been a major problem and has resulted in a proliferation of mounting arrangements with considerable confusion in the field.

1.1.2 *Cell Fragility*

Another major difficulty arises from the basic construction of the cell. The polystyrene case is fragile; the cover seal is weak; in time, electrolyte seepage can be expected in every installation. Leakage of electrolyte onto a battery rack can raise the potential of the rack sufficiently above ground to constitute a safety hazard. Leakage from two cells on the same rack can establish a current path sufficient to ignite the battery jar material. This has resulted in several disastrous fires and service outages. These characteristics leave the applications engineer very little latitude in mounting design. The cell must be supported over its entire base and can tolerate no continuous loads anywhere else on its outside surface.

1.2 *Dynamic Environments*

The impact of these constraints becomes apparent only when one considers the variety of dynamic environments to which the cells may be exposed in service. Roughly, these fall into these categories: normal service, earthquake areas, and sites hardened against nuclear attack with 2-psi overpressure, 10-psi overpressure, and 50-psi overpressure.

1.2.1 *Normal Service*

The normal service installations are typically as illustrated in Fig. 1. This "soft site" environment is quite benign and involves essentially no shock or vibration. The battery rack is designed as a "minimum cost" item and is only strong enough to support the heaviest cell. The structure consists of several welded steel upright supports and formed steel shelves of various lengths which are laid across the supports and bolted in place. The steel is protected by an acid-resistant paint and by polyethylene sheeting under the cells. The parts are shipped "knocked-down" and assembled on site by Western Electric Company installation personnel. The illustration shows a two-row, two-tier rack but a single-row, two-tier version is available for mounting against a wall and three-tier versions have been used in the past. The cells are supported on their bottom surfaces and are not otherwise braced. Options are provided to extend the upright support structure so as to allow the mounting of cable racks and bus bars over the stands.

These soft site racks are representative of the majority of battery racks used in the Bell System and generally give satisfactory service.

Fig. 1—Battery rack for normal service.

However, in the large areas of the country susceptible to earthquakes, racks require special attention. The entire West Coast has been classified in this category for some time and, because of recent wider recognition of the problem, the requirements for special treatment are gradually being extended eastward—in some cases as far as the Mississippi River.

1.2.2 *Earthquake Areas*

There are presently two battery racks being used in these earthquake areas. Figure 2 shows a modified soft site stand which has gained wide

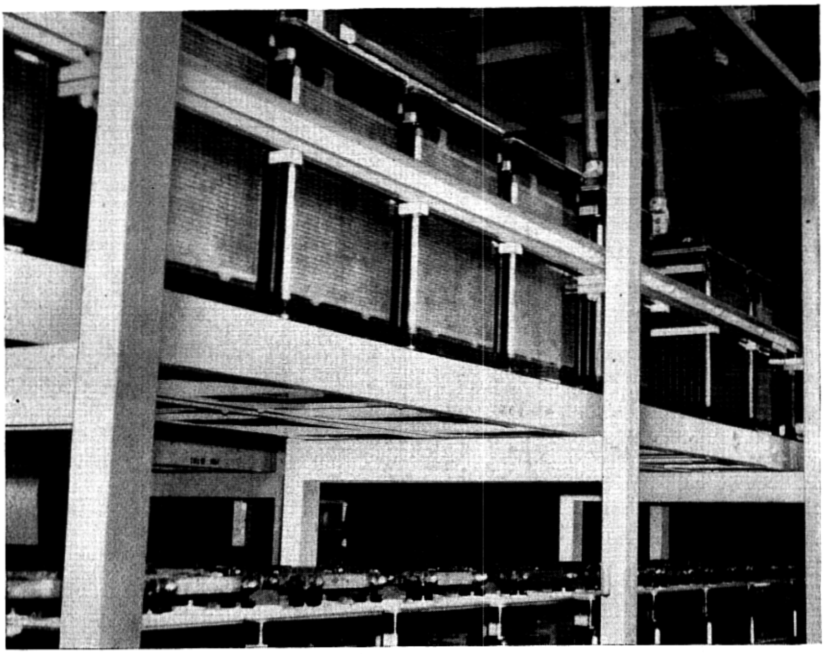

Fig. 2—Soft site rack modified for service in earthquake areas.

popularity. The modifications, which double the installed cost of the stand, consist mainly of "add-on" bracing to support the stand laterally from an overhead ironwork structure and support the cells on the shelves. The shelves themselves are stiffened by the addition of wooden blocks. The battery bracing, an "egg crate" structure bolted to the stand, provides lateral and longitudinal adjustments to accommodate the various sized cells. Because of case fragility, clearance must be provided around the entire cell; it is thus free to rattle around in response to ground motion. Nonetheless, the cell is held on the shelf. This arrangement is only marginally satisfactory but will withstand a mild tremor without damage and will probably ride out a moderate shock without collapse.

The frequently raised question of whether or not these racks would survive a major earthquake has remained unanswered because no Bell System area has experienced such an event since these stands were put into service. However, racks of identical design were in use in the Alaska Communications Building in Anchorage during the 1964 Good Friday earthquake. Figure 3 illustrates the damage sustained by one of these racks. This was a three-tier, two-row rack and employed the egg-crate bracing. Collapse was apparently caused by a lateral motion of the floor but there was certainly substantial coincident vibration. During collapse, the middle shelf came into contact with the terminals of the lower cells and caused a fire which destroyed some of the lower cells.

Shortly after this incident, a new rack (Fig. 4) was designed which provides additional stiffness and strength through the use of heavier

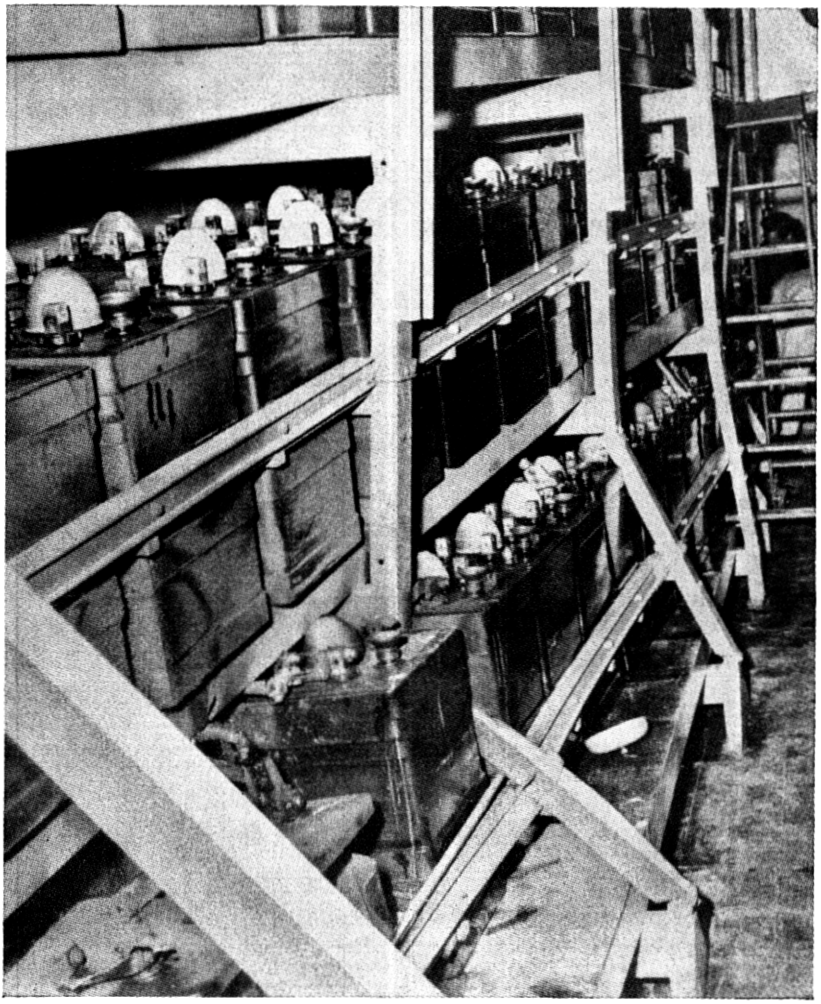

Fig. 3—Battery rack damage resulting from Alaska earthquake, Good Friday, 1964.

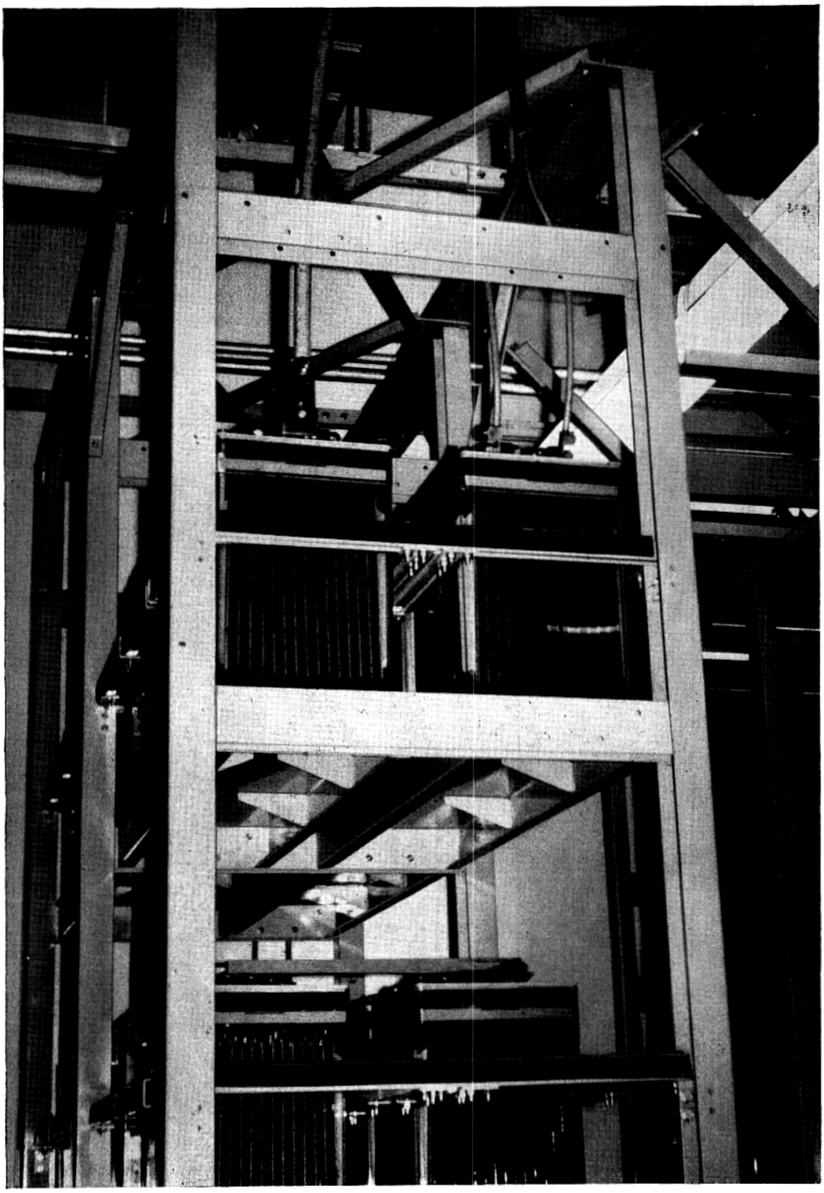

Fig. 4—Battery rack designed for earthquake areas.

steel with diagonal bracing within the rack structure and the welding of gussets under the shelves. The shelves are bolted between the uprights and the egg-crate has been strengthened. The cells must still be allowed to rattle, however, and thus would be thrown upward if substantial vertical acceleration were experienced. This rack is now the recommended standard rack for use in earthquake areas, but there has been considerable resistance to its general use because it costs three to four times as much as the earlier model.

1.2.3 *Hardened Sites*

The 2-psi hard sites impose vibration and shock loads which are of about the same acceleration level as a moderate earthquake and of shorter duration. It is anticipated that the rack illustrated in Fig. 4 will prove satisfactory for this service.

The 10- and 50-psi hard sites require a much higher order of protection. Dynamic loads during a nuclear attack are expected to exceed the capabilities of both the earthquake rack and the standard batteries themselves.

Figure 5 shows a battery modified for use in these sites. This is essentially the standard polystyrene cell enclosed in a glass-reinforced polyester frame to provide mounting details and shock protection. The cell is available in 1680- and 840-ampere-hour versions and is purchased with hardening details attached at a cost of two to three times that of the

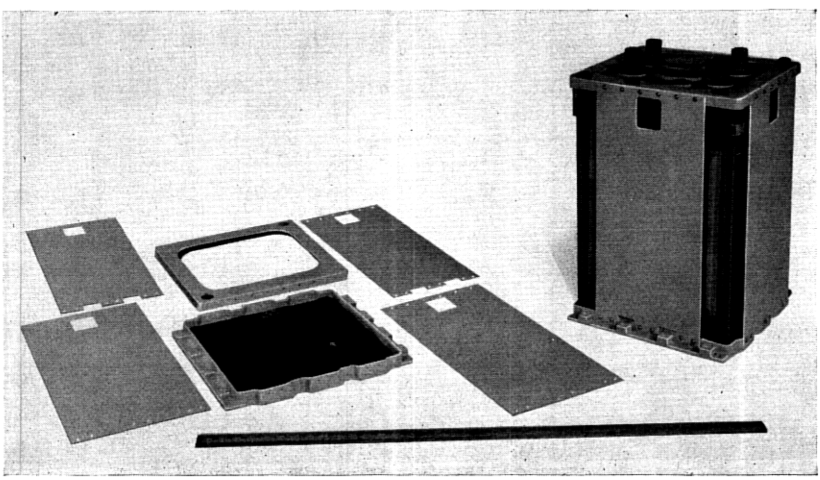

Fig. 5—Specially reinforced cell for service in sites hardened to resist nuclear attack.

regular cell. Unfortunately, many of these cells leak and, because of the reinforcing frame, they are extremely difficult and costly to clean.

Environmental tests were conducted on this design to assure that it could survive an expected 5-G shock when mounted in the 50-psi site. In order to make certain that the cell is never exposed to more than 5 Gs in service, a new battery rack was designed specifically for hardened site use (Fig. 6). This stand is much stiffer and stronger than the earthquake stand. It is made of heavier gauge steel and has added reinforcement welded to the uprights for additional horizontal strength. Two 2-tier, 2-row racks, separated by an aisle, are joined by a diagonally braced superstructure to provide lateral strength. The hardened cells are bolted to the shelves and are interconnected by means of fine-strand flexible cable instead of the usual rigid bus bars. This allows for some relative motion among the cells with minimal stress on the battery posts.

Since accelerations due to floor motions in a 50-psi hardened site

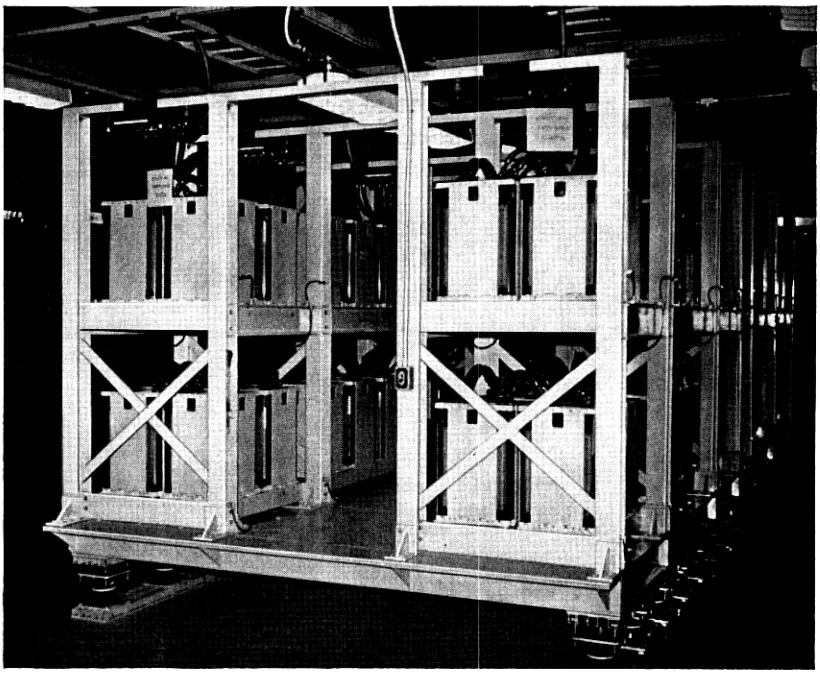

Fig. 6—Spring-mounted battery rack for service in sites designed to withstand 50-psi overpressure.

are expected to exceed the 5-G capability of the cells, the stands in these sites are mounted on a rigid steel platform which in turn is supported on a system of steel or rubber springs. The mass of the stand is matched to the stiffness of the springs to provide an overall natural frequency of about 4 cycles per second. This effectively decouples the stand from the building and assures a sharply defined shock and vibration regime for the cells with expected peak acceleration never exceeding 5 Gs. Because motions in the 10-psi sites are expected to be far less severe and not to exceed 2 Gs at any frequency, the stands in these sites are bolted directly to the floor without a steel platform or suspension springs.

The special cells, stiffened stands, flexible connectors, platforms, springs, and low production rates make these installations 10 to 20 times as expensive as the normal installation. Fortunately, they involve only a small percentage of the total number of batteries being used.

II. THE NEW CELL

Let us now consider the advantages and disadvantages of the new battery from a plant viewpoint.

The most significant feature is the degree of design control which will be established for the new cell. All parts and materials will be controlled by separate Bell System specifications. Fabrication and assembly procedures will be carefully delineated and will be under the surveillance of Western Electric inspection personnel. This assures uniformity in cell size and performance and allows standardization of plant equipment and procedures to accommodate a reasonably stable product line.

2.1 *Reduction in Number of Sizes*

Instead of the present 66 physical sizes, the new cell will be available in only four sizes. Table I lists the present sizes and the replacing new sizes. These four capacities will be packaged in the same diameter jars with four different heights. All corresponding internal parts will be identical for the four sizes, but the number of plates will differ. Terminals and cover details will be identical for all sizes. These sizes have been selected as a compromise between economies deriving from high volume manufacture and those attendant to buying the minimum battery needed for a given installation.

2.2 *New Cell Configurations*

This reduction in available sizes is not without penalty. Figure 7 compares the outline configurations of the new cells with those of the

TABLE I—COMPARISON OF PRESENT-CELL SIZES AND REPLACING-CELL SIZES

Present Cell	Replacing Cell	Projected Annual Purchases
180 A.H.* 240 A.H.	240 A.H.	14000
300 A.H. 420 A.H.	420 A.H.	25000
540 A.H. 680 A.H. 840 A.H.	840 A.H.	18000
1080 A.H. 1320 A.H. 1680 A.H.	1680 A.H.	52000

* In some installations it may be more economical to replace the 180-ampere-hour cell with parallel strings of the present 100-ampere-hour cell.

old cells. It is apparent that, while total volume is approximately the same, there is a substantial change in geometry. Except for the largest size, the new cells are lower than those they replace but have a larger "footprint."

This change in geometry poses no problem for the 1680-ampere-hour cell in either new installations or in the replacement of existing cells. Figure 8 shows a trial installation in a New Jersey Bell office in which a string of new cells was installed in space previously reserved for 1680-ampere-hour cells of the old design. These field-trial cells have smaller capacity but the outside dimensions are equivalent to the new 1680-ampere-hour cell. There is sufficient space on the shelves for the new cell and the additional height is readily accommodated by the existing stand.

For the smaller sizes, the problem is considerably more difficult. The new cells cannot be exchanged on a one-for-one basis without changing the stand. Also, the present stand design would demand excessive floor space if it were made long enough for the new cells. The solution here is to provide a completely new stand design which takes advantage of the geometry of the new cell to permit three- and four-tier arrangements. Present practice limits battery racks to two tiers because air tends to stratify into layers of different temperature. As a result of this temperature differential, cells near a ceiling connected in a series with others near the floor would self-discharge under normal float-voltage

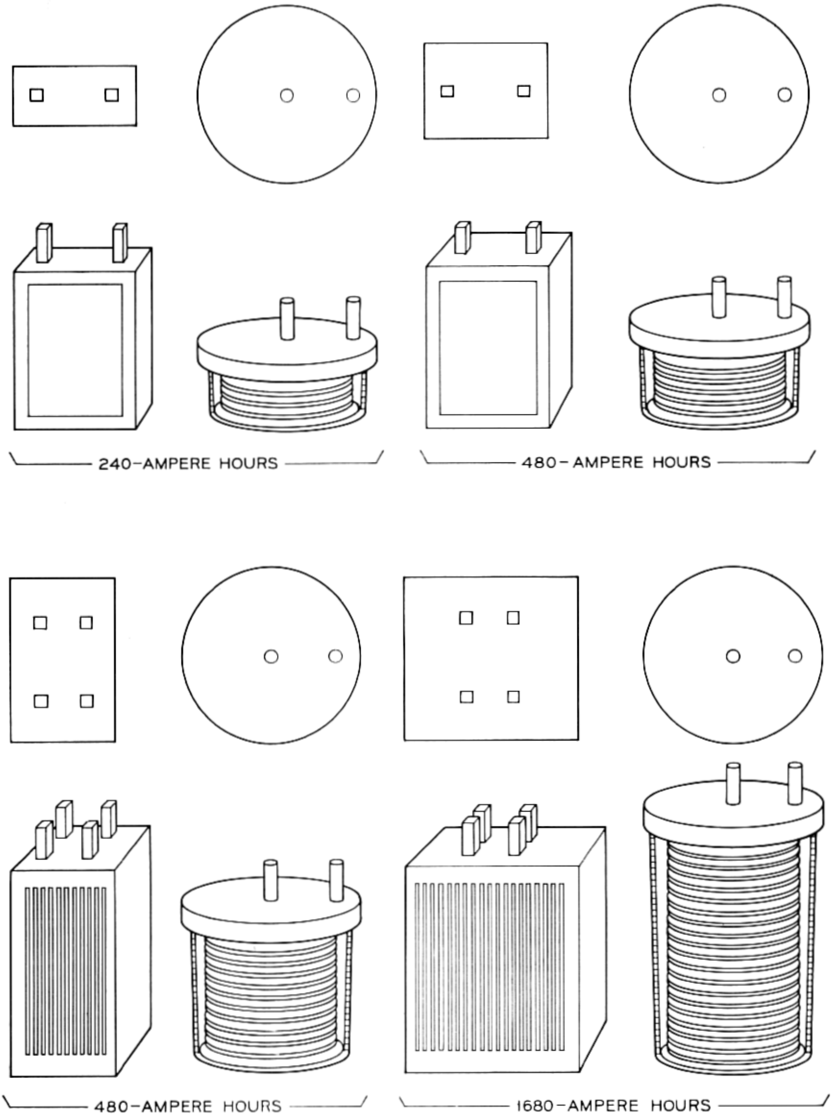

Fig. 7—Comparison of new round cells with old cells.

Fig. 8—Early trial installation of new cells.

conditions.[1] The new cells will be short enough so that three tiers of the 840- and 420-ampere-hour size and four tiers of the 240-ampere-hour size will be less than 7 feet high (Fig. 9). It is expected that temperature differentials within this height will be acceptable.

Using this approach the stands for the new cells will be only slightly longer than the existing standard arrangements. (Nine inches longer for a 48-volt battery—Fig. 10.) It is expected that this will cause no difficulty in new installations and in most existing sites.

2.3 *Plastic Battery Rack*

The physical characteristics of the new cell permit far greater design latitude than the present battery structure. The cell case has excellent impact strength and can also be subjected to moderately high continuous stresses. Thus it can be safely handled, mounted and clamped by any of its surfaces, including the underside of the cover seal lip. This will permit the elimination of the large variety of present battery stand designs and the development of economical and practical mounting

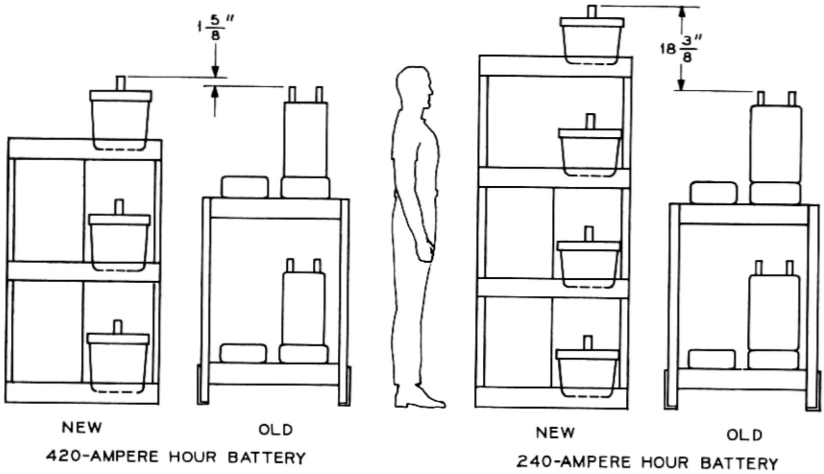

Fig. 9—Three- and four-tier arrangements for smaller sizes of new cells.

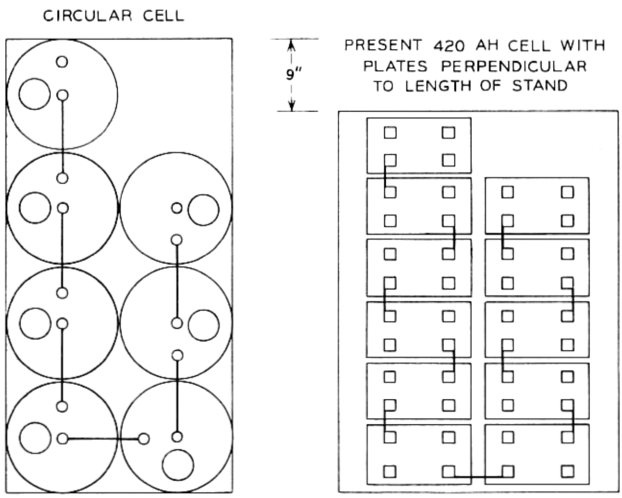

Fig. 10—Plan view of three-tier rack compared with equivalent existing rack.

arrangements which, with small variations, can be used in soft, earthquake and hardened sites. The design of such a stand is now essentially complete and models are being fabricated for a field trial.

2.3.1 *The Parts*

The two parts from which the stand is assembled are shown in Fig. 11.

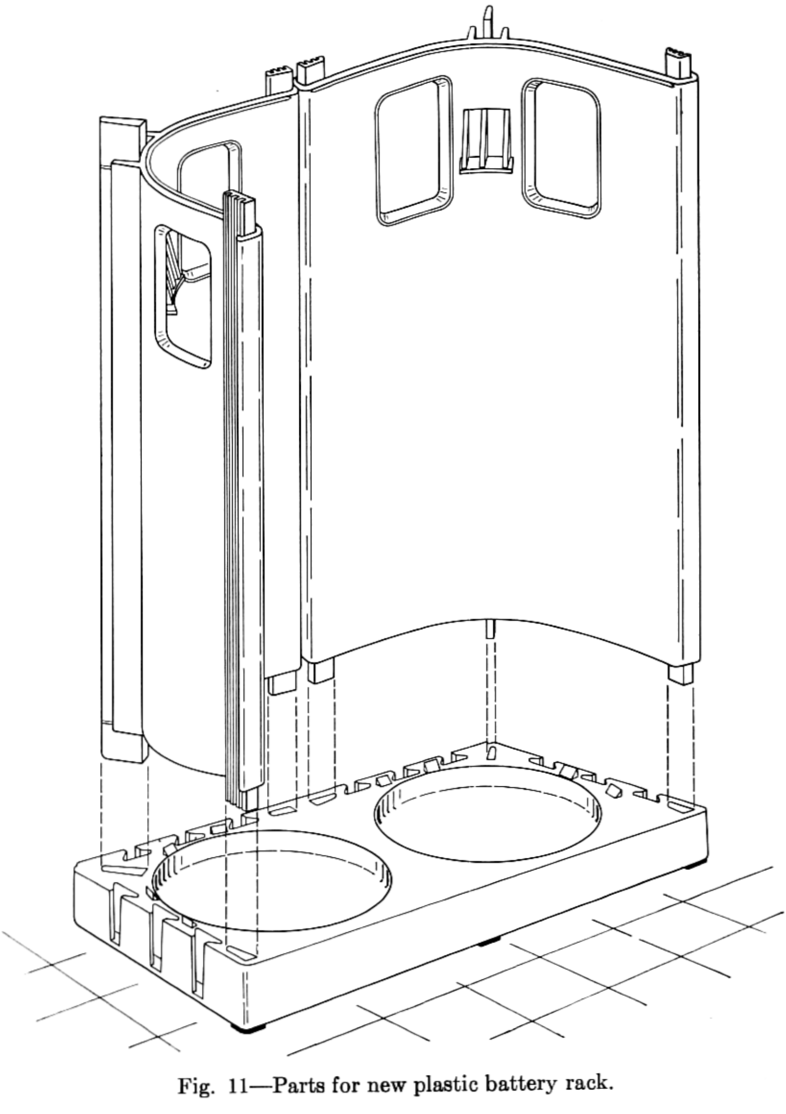

Fig. 11—Parts for new plastic battery rack.

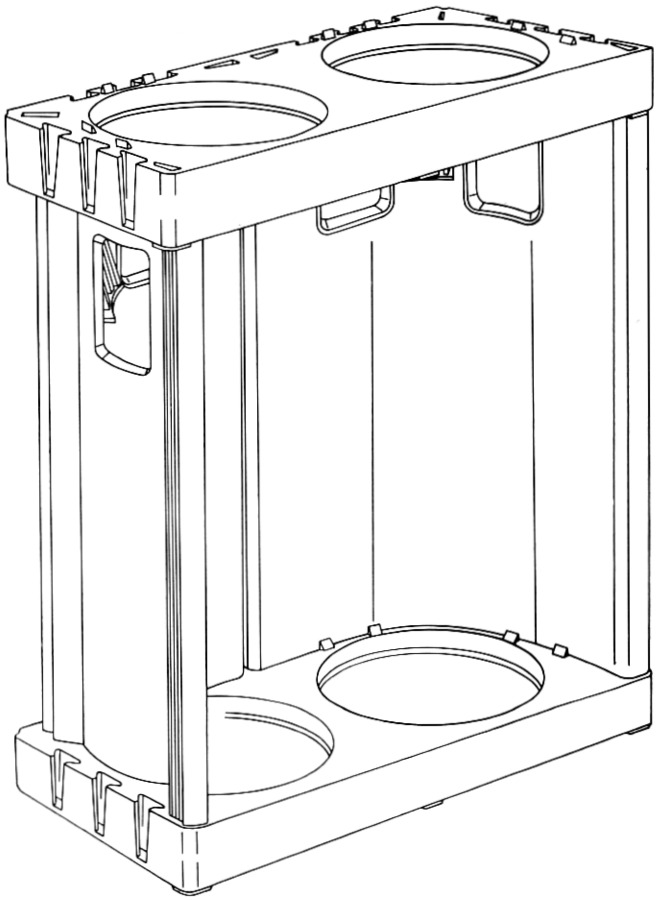

Fig. 12—Assembled basic module of new rack.

These parts are compression molded of fibreglass-reinforced polyester. This material was selected because it is strong, stable, relatively inexpensive and a non-conductor. A non-conductor is desirable for this application to avoid the safety- and fire-hazards alluded to earlier. The plastic is nonflammable in air and acid-resistant and will have color molded in to harmonize with the remaining plant.

To provide positive cell retention, the base part contains two $1\frac{1}{2}$ inch deep wells into which the cells are set. For added rigidity, the back is curved to follow the contour of the cells with access holes provided for cell interconnections. Both the base and the back have deep, molded-

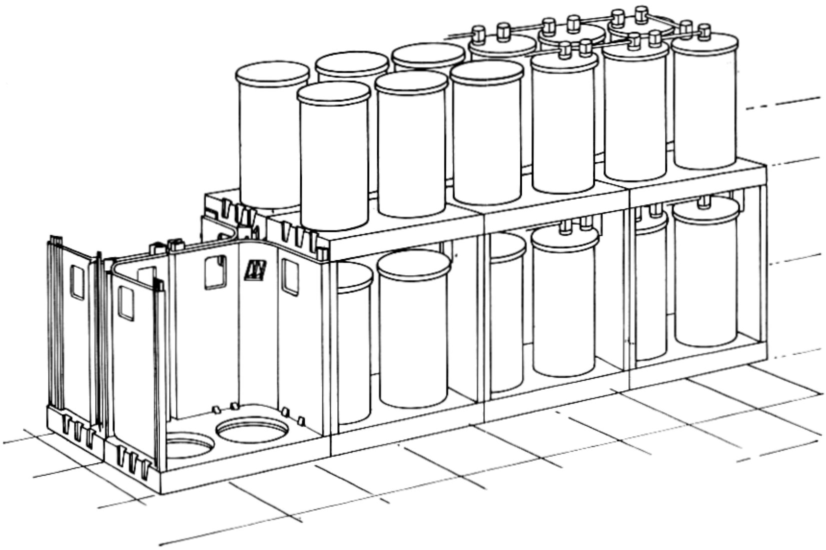

Fig. 13—Free-standing two-row rack.

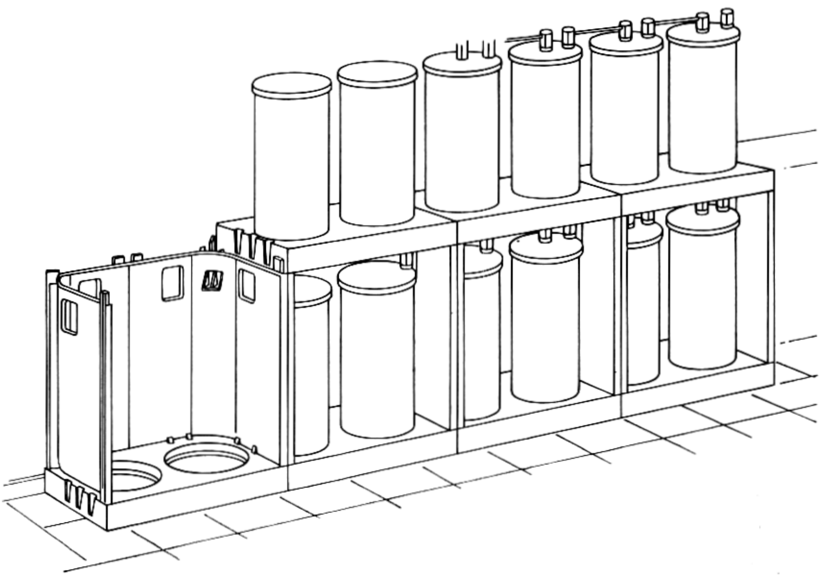

Fig. 14—Single-row rack for wall mounting.

in ribs to provide stiffness and strength. The backs will be available in four different heights to accommodate the various cell sizes. These parts will be shipped loose and assembled on site.

2.3.2 *The Assembled Soft Site Rack*

A basic module comprises two bases and two backs, assembled as shown in Fig. 12, and provides mounting space for four cells. The backs have projections top and bottom which cement into wells provided in the base using an epoxy cement with toothpaste-like consistency.

The modules can be further assembled to provide as many mounting positions as needed. They can be used as either a free-standing two-row stand (Fig. 13) or a single-row stand (Fig. 14) for mounting against a wall.

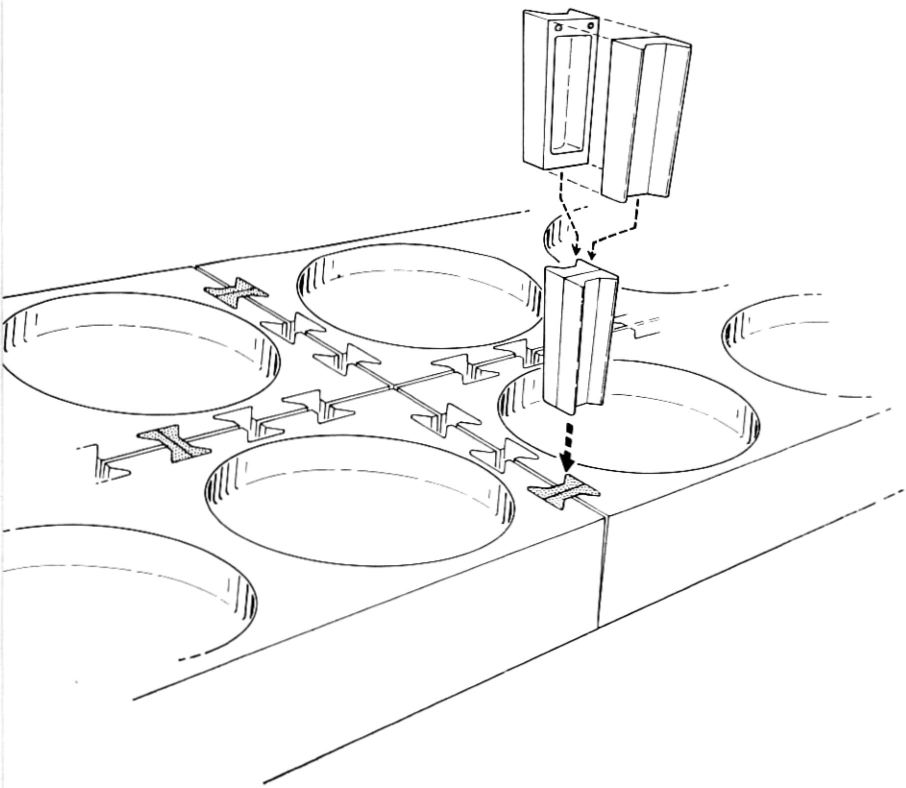

Fig. 15—Interlocking with dovetail keys.

For soft sites, the basic module has sufficient strength to carry its four cells independently. However, for added stability the modules will be interlocked using dovetail keys as shown in Fig. 15. The keys consist of two identical pieces molded of the same material as the rest of the stand and epoxied in place. Although space is provided for up to 12 keys per base, it is expected that 3 will suffice for a soft site.

2.3.3 *Cell Installation*

These stands will be mounted directly on the floor to reduce height and will allow the installation and removal of individual cells when necessary. Installation procedures are currently tailored to the fragility of the old cell. The cells are wrestled out of their shipping container onto a platform hoist. The platform is then positioned next to the stand at the proper height and the cell pushed onto the stand by hand. To remove a cell, the procedure is reversed, the cell being pulled onto the platform using a strap. This method is effective but on occasion has resulted in cell damage. Since the weight of the new cell can easily be supported by the strength of its cover-to-jar seal, a new hoist is being developed in conjunction with Western Electric installation engineering which will grasp the cell by its cover lip for lifting and positioning during installation and removal.

2.3.4 *Earthquake Areas*

While designed primarily for soft site use, the stand illustrated in Figs. 13 and 14 does provide some degree of earthquake resistance. Because of the ribs and the shape of the backs, there is sufficient shear strength to avoid stand collapse during a mild shake and the wells in the base will also keep the cells from vibrating off the shelves.

In areas where severe earthquakes are expected, a full complement of dovetail keys will be used and another layer of backs and bases will be added as shown in Fig. 16. Molded into the backs is a small ribbed shelf which is used to lock the cell into the stand by means of a snap-in retainer. This retainer will be injection-molded of the same material as the battery case and will be used only in earthquake and hardened sites. Simple steel brackets and $\frac{5}{8}''$ threaded rods are used to bolt the stand to the floor and, via diagonal bracing, to overhead ironwork. This is very similar to present practice and should find ready acceptance in the field. While dynamic tests are incomplete at the present time, it is expected that this arrangement will be suitable for 2- and 10-psi hard sites as well as the earthquake sites.

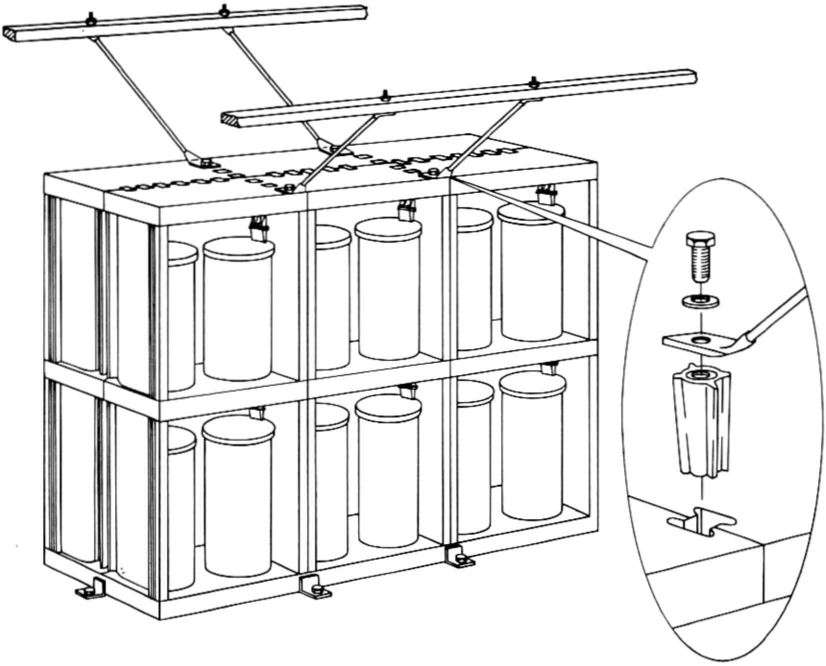

Fig. 16—New rack as installed for service in earthquake areas and in 2-psi and 10-psi hard sites.

2.3.5 *50-psi Hard Sites*

The 50-psi sites require additional modification as illustrated in Fig. 17. Shown is the earthquake stand with channel sections added top and bottom. The stand is raised off the floor and suspended from the ceiling by means of presently available, standard shock isolators. Standard restrainers, which limit the swing during normal service but break during a severe shock, are installed at the bottom. Sufficient clearance is provided around the stand to allow free motion. These arrangements will limit the dynamic loads to about 3.5 Gs in a vertical direction and 1 G in the horizontal direction. It is expected that this will be within the capability of both the new stand and the new cell.

2.3.6 *Costs—New Stand Versus Old*

Present estimates are that the new soft site stand will cost about the same as the old soft site stand but the new earthquake stand will cost only about one-third as much as its present equivalent. Cost of

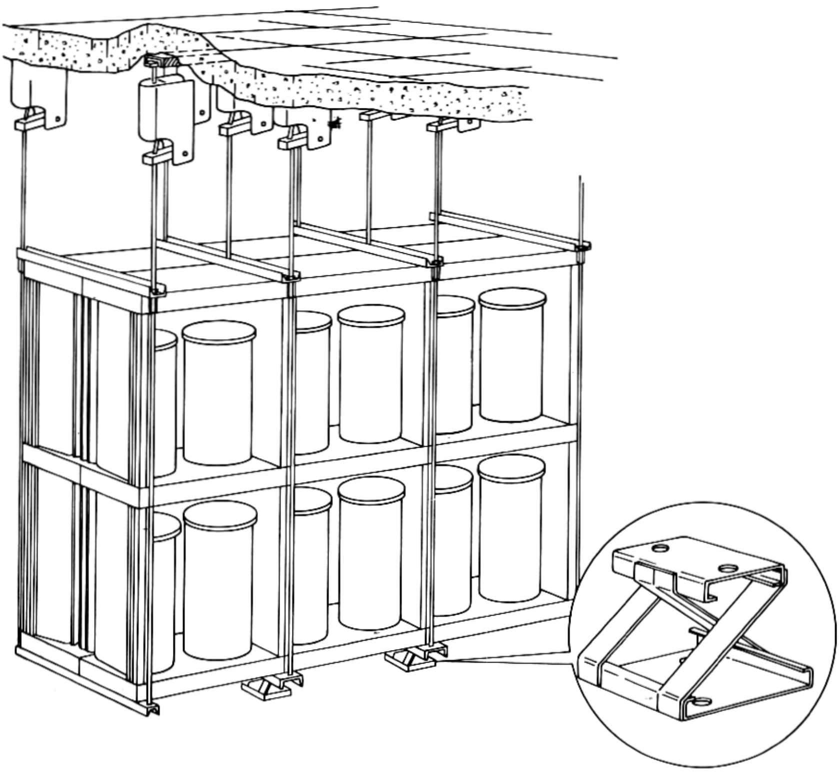

Fig. 17—New rack ceiling-suspended for service in a 50-psi hard site.

the 2- and 10-psi hardened site stands will be similar to that of the earthquake stands and the cost of the 50-psi stand will be about one-fifth that of the present arrangement.

2.4 *Cover Details and Cell Interconnections*

The cells used in early field trials are shown in Fig. 8. They provided only one mounting position for the filling funnel and explosion-proof vent. This caused some difficulty in accessibility for maintenance since the funnel could not be positioned near the aisle in all cases. Additional problems were encountered in interconnecting these cells. Flexible cables with crimped-on lugs were clamped by means of lead-plated nuts to $\frac{1}{2}''$ threaded copper rods which had been cast in place in the positive and negative posts. The stress of tightening the nuts was sufficient in many cases to bend the rods and damage the threads.

As a result of these experiences cells for later field trials will be modified as shown in Fig. 18. The fill tube will be shipped loose and installed in one of two mounting positions after the cell is in place on the stand. This assures that the funnel will always be near the aisle for accessibility. The other mounting position will be plugged (they are both plugged during shipment).

The present standard cell interconnection employs lead-plated copper bus bars bolted to both sides of the post. Depending on the size and configuration of the cell, up to 4 bus bars are used. The later field trial cells will allow a similar arrangement except that only one positive post and one negative post are provided. However, the posts are higher and can still accommodate up to 4 bus bars. This design permits the

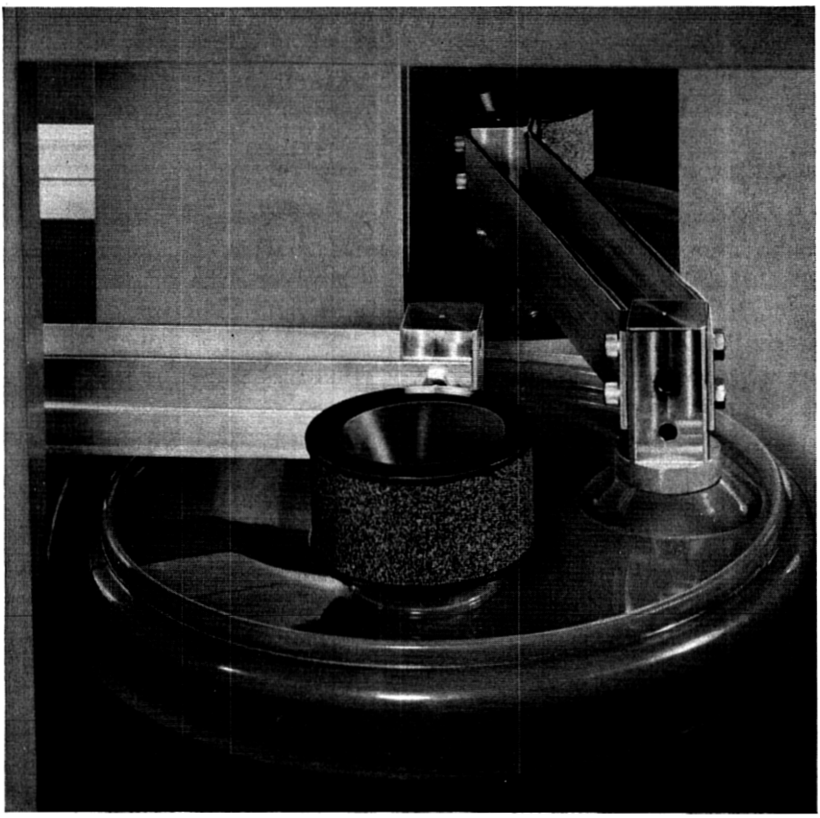

Fig. 18—Top view of new cell showing cover details.

removal of connectors for post cleaning without breaking the electrical connection of the string, and is arranged so that connections can readily be made from either of two perpendicular directions. The post is of lead-antimony alloy and is cast as part of the center-pour operation.

Since the new cell is expected to have a service life which is essentially as long as the equipment it services, consideration is being given to more permanent means of interconnecting cells. Several such methods are presently under development in conjunction with the Western Electric Engineering Research Center, Princeton, New Jersey. The joints will be acid-tight and will provide a reliable, permanent, low-resistance, maintenance-free connection for the lifetime of the battery. It is expected that overall voltage drop within the string will be substantially reduced, thus allowing the cells to be discharged to a lower potential while still maintaining adequate plant voltage. Provision will be made to allow removal and replacement of single cells in case of early failure. It is expected that these techniques will be employed on some of the later field trial cells.

2.5 *Battery Plants Within Equipment Lineups*

The Operating Companies will also benefit from reduced maintenance due to improved cover seal and post seals. In the past, frequent cleaning of cells has been necessary because of electrolyte leakage and post corrosion. The presence of acid has made it desirable to keep the batteries physically separated from the rest of the telephone equipment. The improved seals will eliminate this objection and allow the installation of power plants within the lineups of the power-using equipment. This would provide shorter and smaller power cables without excessive voltage drop. The new battery stand is designed to be placed in equipment lineups. A single row stand can be installed in a 15-inch-deep lineup with front access only (Fig. 19), and a two row stand in a 30-inch-deep lineup with front-and-rear access. As shown in Fig. 20, doors can readily be provided as an optional add-on accessory where appearance is a factor.

2.6 *Testing and Field Trials*

We are now engaged in an extensive test program to prove in these new concepts. The cells and stand are being subjected to a series of environmental tests including shock and vibration tests to simulate the shipping, handling, earthquake and nuclear site environments. Preproduction models of the new stands will be installed in several

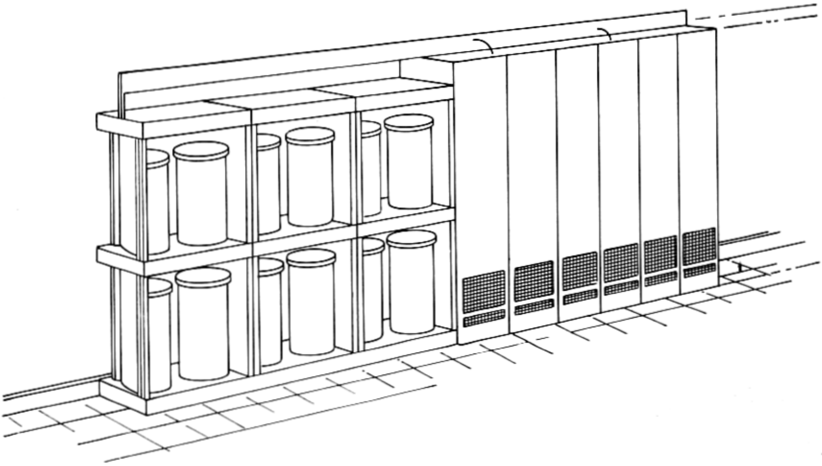

Fig. 19—Single-row rack installed in an equipment line-up.

field trial locations by Western Electric personnel with the new permanent cell interconnections used in some of these sites.

As these tests proceed, we expect to learn more about the advantages and flexibility of the cells and mounting arrangements. These results might considerably temper the approach outlined here, but we expect

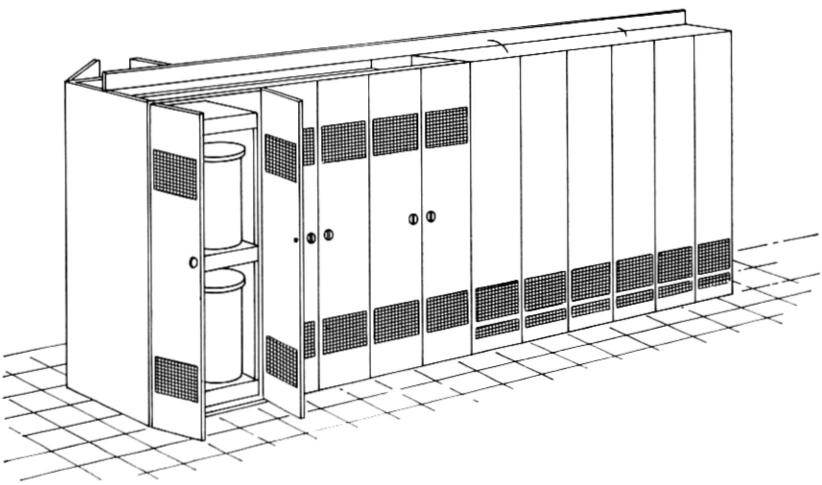

Fig. 20—Two-row stand in an equipment lineup with doors added to improve appearance.

that the integrated systems approach used in the development of the cells and their introduction into the plant will yield immediate and long-term benefit to the Bell System by providing more reliable service at substantially reduced cost.

REFERENCE

1. Milner, P. C., "Float Behavior of the Lead-Acid Battery System," B.S.T.J., this issue, pp. 1321–1334.