SUGGESTIONS FOR THE DESIGN OF ELECTRICAL ACCESSORIES FOR PERMISSIBLE MINING EQUIPMENT

BY

L. C. ILSLEY and E. J. GLEIM

PRICE 15 CENTS
Sold only by the Superintendent of Documents, Government Printing Office
Washington, D. C.

WASHINGTON
GOVERNMENT PRINTING OFFICE
1926
# CONTENTS

<table>
<thead>
<tr>
<th>Topic</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction</td>
<td>1</td>
</tr>
<tr>
<td>Scope of paper</td>
<td>3</td>
</tr>
<tr>
<td>Acknowledgments</td>
<td>3</td>
</tr>
<tr>
<td>Inclosures in general</td>
<td>3</td>
</tr>
<tr>
<td>Terminology</td>
<td>4</td>
</tr>
<tr>
<td>Limitations of inclosures</td>
<td>4</td>
</tr>
<tr>
<td>General factors influencing design of permissible equipment</td>
<td>6</td>
</tr>
<tr>
<td>Type of machine</td>
<td>6</td>
</tr>
<tr>
<td>Place of operation</td>
<td>7</td>
</tr>
<tr>
<td>Size</td>
<td>7</td>
</tr>
<tr>
<td>Service</td>
<td>7</td>
</tr>
<tr>
<td>Accessibility of parts</td>
<td>8</td>
</tr>
<tr>
<td>Detailed study of features affecting safety</td>
<td>8</td>
</tr>
<tr>
<td>Type of permissible enclosure</td>
<td>9</td>
</tr>
<tr>
<td>Special protective devices</td>
<td>9</td>
</tr>
<tr>
<td>Total inclosure</td>
<td>14</td>
</tr>
<tr>
<td>Plane flanges</td>
<td>14</td>
</tr>
<tr>
<td>Cylindrical flanges</td>
<td>15</td>
</tr>
<tr>
<td>Step flanges</td>
<td>15</td>
</tr>
<tr>
<td>Irregular flanges</td>
<td>16</td>
</tr>
<tr>
<td>Advantages of flange joints over special devices</td>
<td>16</td>
</tr>
<tr>
<td>Main frames</td>
<td>16</td>
</tr>
<tr>
<td>Openings and their protection</td>
<td>18</td>
</tr>
<tr>
<td>Flange joints</td>
<td>18</td>
</tr>
<tr>
<td>Bolt and screw holes</td>
<td>18</td>
</tr>
<tr>
<td>Bearings</td>
<td>18</td>
</tr>
<tr>
<td>Lead entrances</td>
<td>24</td>
</tr>
<tr>
<td>Detailed study of features affecting safety—Continued.</td>
<td></td>
</tr>
<tr>
<td>Openings and their protection—Continued.</td>
<td></td>
</tr>
<tr>
<td>Handholes</td>
<td>24</td>
</tr>
<tr>
<td>Fastenings</td>
<td>27</td>
</tr>
<tr>
<td>Bolts and studs</td>
<td>27</td>
</tr>
<tr>
<td>Locks and seals</td>
<td>27</td>
</tr>
<tr>
<td>Locking of bolts, nuts, and screws</td>
<td>27</td>
</tr>
<tr>
<td>Nuts and washers</td>
<td>28</td>
</tr>
<tr>
<td>Terminals, lead entrances, and interconnections</td>
<td>29</td>
</tr>
<tr>
<td>Insulated studs</td>
<td>29</td>
</tr>
<tr>
<td>Stuffing boxes</td>
<td>32</td>
</tr>
<tr>
<td>Insulating bushings</td>
<td>33</td>
</tr>
<tr>
<td>Sealed-in leads</td>
<td>35</td>
</tr>
<tr>
<td>Connectors</td>
<td>38</td>
</tr>
<tr>
<td>Strain clamps</td>
<td>38</td>
</tr>
<tr>
<td>Apparatus needing special attention</td>
<td>39</td>
</tr>
<tr>
<td>Resistance boxes</td>
<td>39</td>
</tr>
<tr>
<td>Controllers and switches</td>
<td>39</td>
</tr>
<tr>
<td>Fuses and circuit breakers</td>
<td>40</td>
</tr>
<tr>
<td>Headlights</td>
<td>41</td>
</tr>
<tr>
<td>Ampere-hour meters</td>
<td>42</td>
</tr>
<tr>
<td>Battery boxes</td>
<td>42</td>
</tr>
<tr>
<td>Wiring of permissible equipment</td>
<td>43</td>
</tr>
<tr>
<td>Internal wires</td>
<td>43</td>
</tr>
<tr>
<td>External wires</td>
<td>43</td>
</tr>
<tr>
<td>Conclusion</td>
<td>47</td>
</tr>
</tbody>
</table>
### ILLUSTRATIONS

<table>
<thead>
<tr>
<th>Figure</th>
<th>Descriptions</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Gauze and grid type of protective device</td>
<td>10</td>
</tr>
<tr>
<td>2.</td>
<td>Plate type of protective device</td>
<td>12</td>
</tr>
<tr>
<td>3.</td>
<td>Oil valve</td>
<td>13</td>
</tr>
<tr>
<td>4.</td>
<td>Ventilated cover</td>
<td>13</td>
</tr>
<tr>
<td>5.</td>
<td>Types of flange joints</td>
<td>15</td>
</tr>
<tr>
<td>6.</td>
<td>Example of plane flange in main castings</td>
<td>16</td>
</tr>
<tr>
<td>7.</td>
<td>Example of irregular flange in main castings</td>
<td>17</td>
</tr>
<tr>
<td>8.</td>
<td>Example of plain bearings for controllers</td>
<td>19</td>
</tr>
<tr>
<td>9.</td>
<td>Examples of plain bearings for motors</td>
<td>21</td>
</tr>
<tr>
<td>10.</td>
<td>Example of single-row ball bearings for motors</td>
<td>22</td>
</tr>
<tr>
<td>11.</td>
<td>Example of double-row ball bearings for motors</td>
<td>23</td>
</tr>
<tr>
<td>12.</td>
<td>Example of insulated stud lead entrance and terminal, set-screw type</td>
<td>30</td>
</tr>
<tr>
<td>13.</td>
<td>Example of insulated stud lead entrance and terminal, nut and lock-washer type</td>
<td>31</td>
</tr>
<tr>
<td>14.</td>
<td>Example of insulated stud lead entrance and terminal, split-clamp type</td>
<td>32</td>
</tr>
<tr>
<td>15.</td>
<td>Example of stuffing box for lead entrance</td>
<td>33</td>
</tr>
<tr>
<td>16.</td>
<td>Example of intercompartment connections; long bushing, multiple conductor</td>
<td>34</td>
</tr>
<tr>
<td>17.</td>
<td>Example of intercompartment connections; short bushings, multiple conductor</td>
<td>35</td>
</tr>
<tr>
<td>18.</td>
<td>Example of intercompartment connections; short bushings, single conductor</td>
<td>36</td>
</tr>
<tr>
<td>19.</td>
<td>Example of intercompartment connections; sealing compound</td>
<td>37</td>
</tr>
<tr>
<td>20.</td>
<td>Example of lead entrance; plaster of Paris</td>
<td>37</td>
</tr>
<tr>
<td>21.</td>
<td>Example of strain clamp and bellmouth entrance for cables</td>
<td>38</td>
</tr>
</tbody>
</table>
SUGGESTIONS FOR THE DESIGN OF ELECTRICAL ACCESSORIES FOR PERMISSIBLE MINING EQUIPMENT

By L. C. ILSLEY and E. J. GLEIM

INTRODUCTION

The organic act under which the Federal Bureau of Mines was established contains a provision for the investigation of the safe use of electricity in mines. Congress each year appropriates funds for conducting this investigation. One of the bureau's duties is to study electrical apparatus used in mines in order to be able to render an opinion whether or not the apparatus is likely to introduce a hazard. To assist in the study of electrical apparatus certain safety standards have been developed. These standards, established with the aid of the manufacturer of the equipment and the operator using it, are published in schedules; and equipment that meets the requirements set forth in these schedules is known as "permissible" equipment. This term means that the bureau believes that the manufacturers of the equipment have adhered to certain minimum standards of safety, thus rendering the equipment safe for use in mines where inflammable gas or coal dust may accumulate.

The work of the Bureau of Mines for the increase of safety is entirely advisory and in no sense mandatory. For example, the bureau may advise a State mine inspector and often, at the request of an inspector, it gives its opinion of a given device. This advice, however, places no obligation on the State mine inspector. If, as a result of this advice, the State inspector issues regulations, that is properly a State matter which is usually covered by a provision in the State mining law.

In the same sense this paper on the design of apparatus is intended to advise manufacturers; it is in no sense mandatory. Manufacturers submit all equipment voluntarily, and the Federal Bureau of Mines has no right to say where such equipment as passes its tests shall be used, this again being a State matter entirely within the control of each State.

Every mining State has the privilege of having equipment tested by the bureau if it desires information on the safety of the equip-
INCLOSURES IN GENERAL

SCOPE OF PAPER

In the main the paper consists of a discussion of the design of accessories used in permissible mining outfits, most of which have been judged to meet schedule requirements. No reference has been made to the maker who submitted the apparatus, but naturally each will recognize his own design. Some of these designs are probably covered by patents; as to those that are not, the Bureau of Mines trusts there will be an interchange of ideas, and that those which seem to promise most for the increase of safety in mining will become common property.

The authors have freely discussed what seem to them the good and the bad features of the various designs shown, believing that such open discussion will in general tend to improve apparatus and thus advance the cause of mine safety.

ACKNOWLEDGMENTS


In their efforts to be of aid in this special field of design the authors have drawn on the experience gained in connection with these investigations, and from the drawings filed with the bureau they have selected examples of various methods of treating the several features of design that require attention. For these examples the authors gratefully acknowledge their indebtedness to the above-mentioned manufacturers.

INCLOSURES IN GENERAL

TERMINOLOGY

The operator purchasing electrical equipment for use in and about coal mines is confronted with a multiplicity of terms relating to inclosures. If he refers to any authority on electrical terminology he finds numerous classes of inclosures. For example, the American Institute of Electrical Engineers has the following standard terminology:² Open, protected, semi-inclosed, inclosed, separately ventilated, water-cooled, self-ventilated, drip proof, moisture resisting, submersible, and explosion proof. Several of these are defined under

---
“Classification of rotating machines relative to the degree of inclosure,” and are quoted below:

*Open machine.*—An "open" machine is of either the pedestal-bearing or end-bracket type where there is no restriction to ventilation, other than that necessitated by good mechanical construction.

*Totally inclosed machine.*—A "totally inclosed" machine is one so inclosed as to prevent circulation of air between the inside and the outside of the case, but not sufficiently to be termed "air-tight."

*Explosion-proof machine.*—An "explosion-proof" machine (or "flame-proof" machine) is a machine in which the inclosing case can withstand, without injury, any explosion of gas that may occur within it, and will not transmit the flame to any inflammable gas outside it.

In the reference quoted are included tentative definitions for terms relating to controllers, circuit breakers, switches, fuses, and accessories. Among these definitions are dust proof, gas proof, gas tight, and splash proof.

*Dust proof.*—Apparatus is designated as dust proof when so constructed or protected that the accumulation of dust within or without the device will not interfere with its successful operation.

*Gas proof.*—Apparatus is designated as gas proof when so constructed or protected that the specified gas will not interfere with its successful operation.

*Gas tight.*—Apparatus is designated as gas tight when so constructed that the specified gas will not enter the inclosing case.

*Splash proof.*—Apparatus is designated as splash proof when it is so constructed or protected that external splashing will not interfere with its successful operation.

*Permissible.*—This term, although not defined by the American Institute of Electrical Engineers, has been applied to apparatus approved by the Bureau of Mines. It may be defined as "apparatus listed by the United States Bureau of Mines for use in atmospheres which may inadvertently contain gas (methane) or coal dust in dangerous proportions."

The definition of "explosion proof" as given here is not strictly correct in that the word "any" is used. It is probable that certain gases, such as hydrogen or acetylene, are so sensitive and violent in their action that no practicable protection will properly safeguard electrical equipment in their presence, therefore this definition should be qualified.

**LIMITATIONS OF INCLOSURES**

A brief consideration of the limitations of different degrees of inclosures as viewed from the standpoint of a safety engineer follows:

The "open-type" machine which has not been designed to offer any protection and is therefore "wide open" in a dangerous sense is the least safe for service in gaseous mines. Such machines afford
the maximum ventilation to their windings and other electrical parts, but have no place in mines when safety is desired.

The “semi-inclosed” machine is just as dangerous as the open type; the partial inclosure is for mechanical protection of the electrical parts and offers no protection from ignition of gas.

The “totally inclosed” machine prevents free circulation of air and thus keeps a certain amount of dust from entering its interior. The covers over the openings of such machines are generally thin and the joints are not tight, hence gas can readily enter the interior and if it explodes there the covers, if not the entire apparatus, will be destroyed. This equipment, too, offers no protection from ignition of gas or dust.

The machine that goes by the term “flame proof” or “explosion proof” needs very careful consideration; often it is a “wolf dressed in sheep’s clothing.” It may be little better than a totally inclosed machine. The covers may have too few bolts, and if one of these bolts is left out, there may be an unprotected hole leading directly into the compartment. Between the joints the machine may be equipped with gaskets that are impossible to keep in good repair; it may have improper openings around the bearings or around the lead wires; it may be operated by an open-type switch, controller, or rheostat. There is no assurance that such a machine was ever tested in gaseous mixtures or ever given special attention at the factory. Whatever its condition, it is almost certain to be substandard as compared with a permissible machine.

The semipermissible outfit will be considered next. Usually this machine has some parts that have been passed upon by the Bureau of Mines, but the mine operator is either not willing to assume the responsibility of maintaining a permissible machine in safe condition or else he wishes to retain some practice or condition that has not been adjudged safe by the bureau. For example, the bureau does not approve a trolley pole on a storage-battery locomotive. Some operators want that combination and yet want all other parts on the locomotive approved; hence semipermissible outfits are found in service.

A permissible outfit represents the highest degree of safety. It has been more carefully designed than any so-called “explosion-proof” outfit. All of its accessories, including the wiring, were considered when its safety was approved. It receives more attention at the factory during construction than other equipment, and is the only equipment whose design has the benefit of inspection and check by a neutral testing department—that is, the United States Bureau of Mines. Permissible equipment is the only one that carries an approval plate testifying to its safety for use in mines.
A caution statement on this plate calls attention to points that need inspection if the outfit is to be maintained in a safe condition. Although at the top of the ladder with respect to safety, even permissible equipment will not be what it purports to be unless it is kept in good repair by the user.

GENERAL FACTORS INFLUENCING DESIGN OF PERMISSIBLE EQUIPMENT

A number of factors, such as type, size, and place of operation, influence the design of a permissible electric machine as a whole. These will be considered briefly.

TYPE OF MACHINE

Electric motors are usually classified under two main divisions, depending upon whether they are to be run by direct or by alternating current. In some applications the alternating-current equipment offers less difficulties in design than the direct-current machine because no starting or regulating resistance is required; also where the "Y" to "delta" method of starting is used the controller or starting switch is less complicated and is smaller than the direct-current controller. Direct-current motors of the open type make no pretense of being safe and are generally recognized as a hazard in a gaseous atmosphere because of the sparking at the commutator. If the sparking is intense enough it may become a hazard where clouds of coal dust are raised. This type of motor may have other dangerous features, such as loose connections at the terminals or burned-out armatures and field coils. These three troubles are more or less common to apparatus used in mines because it generally is subjected to hard service and frequently is worked at less than nominal voltage. In addition, some of the accessories to the motor, such as fuses, switches, and starting devices, may give trouble.

A synchronous alternating-current motor or an induction motor equipped with slip rings offers the same liability to sparking as the commutator of the direct-current motor.

Every induction motor has at least three possible sources of sparking, even though it is of the squirrel-cage type; these are (1) loose connections, and (2) and (3) failures in the primary winding or in the rotor. When bearings become worn the rotor may damage the primary or stator winding.

Because of the foregoing facts all types of motors intended for service with direct or with alternating current are required by the Bureau of Mines to undergo inspection and test before being approved for use in permissible outfits.
PLACE OF OPERATION

If an electric motor is to be used on the surface, as at an exhaust fan, one of two general lines of protection may be chosen, namely: (1) Bring a supply of fresh air to the motor compartment and its control or to a housing surrounding them so as to render the accumulation of an explosive atmosphere around them impossible, or (2) design the motor and its control so as to be safe in case dangerous conditions should accidentally arise.

If a machine is to be used inside a mine, conditions are usually such as to make it too expensive to bring a separate supply of fresh air into the mine for the sole purpose of ventilating the machine housing, as was suggested for a machine above ground. The alternatives are to set up the machine at a point where there is a constant supply of pure air, as in an intake airway, or to design it to be safe for use in a gaseous atmosphere if it should by chance have to work in such an atmosphere.

A portable outfit, such as a coal-cutting machine or coal drill that is in daily use at the face, is more likely to encounter explosive atmospheres than a pump motor that occupies a fixed place for long periods. Lengthening the suction pipe to the pump may permit taking the pump motor out of a gaseous place and putting it in a fresh-air intake.

SIZE

The size of a machine has an influence on safety design. The efficiency of a very large motor would be greatly impaired by inclosing the motor completely or in any way preventing the circulation through it of the surrounding air, which in many designs is relied on to keep the equipment at a safe operating temperature. Fortunately most of the motors needing special safeguards are not over 50 horsepower. Small totally inclosed motors have been and are being used successfully. As the size of the motor is reduced the problems of good machining, adequate flanges, and sufficient fastenings are simplified, and at the same time the rheostat, controllers, and other accessories necessary for operation are proportionately reduced in size.

SERVICE

Other things being equal, a machine for constant service must be more rugged and have a larger capacity than one built for intermittent work. Whether for constant or intermittent service the motor and its accessories should be designed with a good safety factor to insure against burn-outs or failure of insulation.

Portable machines are not as easily maintained as stationary machines. This is unfortunate because, as already stated, the port-
able machine is the one that usually has the greater need of safety features. In portable outfits not only are the motor and all its accessories to be watched and maintained for this harder service, but usually the trailing cable has to be considered. If not carefully handled and inspected, this cable will be a potential source of arcs and flashes because of excessive wear or of damage to the insulation.

ACCESSIBILITY OF PARTS

Motors, especially direct-current motors, have commutators to be cleaned, brushes to be renewed, and brush holders to be adjusted; fuse boxes have to be opened for renewal of fuses and adjustments have to be made of controller fingers, therefore a certain degree of accessibility is desirable. In many designs access to the inside of the motor or other casing for this purpose is afforded by handholes. The ease of access—that is, whether covers to these handholes should be bolted on or fastened in some more accessible way—is considered more a question of convenience than of safety. The Bureau of Mines has approved various degrees of accessibility, and believes that the particular designs are mainly a question to be adjusted by joint agreement between the users and the manufacturer.

DETAILED STUDY OF FEATURES AFFECTING SAFETY

General questions such as the size of machine, service, and place of operation have already been discussed. The designer's attention is now invited to questions that involve more detail.

An engineer about to design a motor or other permissible machine is confronted with many questions as to its detailed requirements, such as: (1) What type of inclosure is best suited for permissible machines? (2) How strong a casting is necessary? (3) What pressures will be developed within the casing? (4) Must there be a large factor of safety in the strength of the casting or will ability to withstand the explosion tests be the determining factor? (5) How can the wires be brought out through the casing? (6) Are insulated studs preferable to wires run through stuffing boxes? (7) What constitutes a satisfactory seal around a wire? (8) How about the bearings? (9) Must special housings be used? (10) How much clearance is allowable, and is this allowance fixed or is it to be determined by test? (11) What is the most effective joint? (12) What bolt spacing will be acceptable? (13) What is meant by no through holes into compartments? (14) Are there any exceptions to this requirement? (15) Are there other special requirements that should be considered?

These and other questions relating to specific details of design will be discussed in most cases with the aid of designs already accepted in order that the general plan followed in perfecting a permissible outfit may be better understood.
It is not the purpose of Bureau of Mines engineers to work out designs or to narrow the field of design. The idea back of this discussion is to get the designer to see the purpose of the requirements and become familiar with designs that have been adjudged acceptable, at least until a better plan is evolved.

Through this discussion it is hoped that the designer may be enabled to solve his particular problem quicker with less complicated parts and thus not burden the mining industry by the development of unnecessarily expensive designs.

**TYPE OF PERMISSIBLE INCLOSURE**

As already stated, a motor and its control can be safeguarded by having them operate in a nongaseous atmosphere or by bringing fresh air to them. Where such protection is not practicable several options remain. A gas-tight compartment is possible, although such a design is believed to be commercially impracticable for mine service. In the United States two general principles have been followed, namely: (1) To use special "protective" devices that will cool the flames from gas ignited inside the motor and quench them before they reach the outside of the motor or other casing; and (2) to inclose the motor or other part totally and to depend on closely fitting joints of a width sufficient to quench the flames before they can reach any explosive gas that may have accumulated outside.

**SPECIAL PROTECTIVE DEVICES**

**Gauze and Grid Protection.**—In early designs the first principle predominated. Designers hoped that the "protective" devices would give a certain degree of ventilation and also a relief of pressure if there was an internal explosion, and would at the same time quench any flames tending to issue through them. The devices used have been based on sound physical principles. Perhaps the "gauze and grid" or "screen and grid" type is the most familiar and the most widely used of any. Figure 1 shows clearly how it was applied to the motor of a mining machine.

In this motor there are 2 units or "mufflers" each made up of 24 screens and 25 grids built up alternately and held in place by 6 rivets. The purpose of the grids is to give mechanical strength and support to the screens, which offer a large amount of cooling surface to flame passing through them. The arrows in section A–B show the direction taken by gaseous products discharged from the motor after an internal explosion. In the tests with these devices explosion pressures averaging 75.9 pounds per square inch, gauge, were obtained when an explosive gas-air mixture contain-
Figure 1.—Gauze and grid type of protective device
ing 8.6 per cent of Pittsburgh natural gas—approximately the most explosive mixture—was used. When the motor was tested again with the mufflers eliminated and the machine totally inclosed, the average pressure obtained was 84.1 pounds per square inch or an increase of only 10.8 per cent. In another machine using the same type of protective devices the average pressure obtained with an 8.6 per cent mixture was 23 pounds per square inch, and when the machine was totally inclosed the pressure rose to 56.75 pounds. Although the percentage of increase is large, the final pressure is not excessive.

**Plate Protection.**—Another form of protective device that has been used in permissible mining machines is that based on the principle of “plate protection.” Figure 2 gives an example. In this machine two units are employed, one at each end of the motor. Each unit is made up of 57 sheet-steel punchings or plates, 3, 0.0187 inch thick, separated by 56 sets of 12 narrow spacers, 2, of similar thickness. The plates and spacers are riveted between malleable iron rings 1 and 4. The rings are ¼ inch thick but otherwise are of the same dimensions as the plates. Each unit thus has 672 radial apertures each 0.0187 inch thick, 2 ¼ inches long, and approximately 2 inches wide, through which flames or products of combustion must pass before reaching the surrounding atmosphere. Sections A–A and B–B of Figure 2 show clearly the direction of air currents circulating through the motor. If an internal explosion happens the direction of the arrows shown in section B–B is reversed. In the last tests with a machine equipped with this form of protective device the maximum pressure obtained in the motor with an 8.6 per cent gas-air mixture was 20 pounds per square inch. The tests indicate that this plate protection offers a more satisfactory relief of pressure than the gauze and grid type.

**Oil-Valve Protection.**—To accomplish certain ends, manufacturers have used various schemes to obtain a protected opening into their machines. In some instances a drain has been desired to prevent the accumulation of moisture or oil, to permit oiling the motor, or to allow some circulation of air to prevent “sweating” in a machine otherwise totally inclosed. One such scheme is an “oil valve,” shown in Figure 3. When screwed into the under side of a machine it serves as an overflow for oil or water. When it is put into the top of a bearing, oil may be admitted to the bearing through it. Figure 9, A, shows such a valve applied to the motor of a mining machine. The valve is normally held open by a light spring but closes tightly against its seat under the force of an internal explosion, as the arrows indicate.

**Labyrinth Opening.**—Another scheme that has been used is that of the “ventilated cover,” shown in Figure 4. This has been used to
close a handhole opening over the commutator in motors but as yet has not been approved. It consists of two parts, in one of which is cast a labyrinth or long, narrow, continuous groove (section B-B) over which is riveted a plate (section D-D) to close the top of the groove. Any gaseous products of combustion escaping from the motor enter the cover at its center, wind through the long passage,

and finally emerge from a narrow slot at the periphery. In comparative tests of a small motor using first this type of cover and then one cast solid—that is, without any labyrinth—the average pressure obtained was about 8 per cent less with the former than with the latter, although the same maximum pressure of 45 pounds per square inch was obtained in individual tests with each type. This result indicates that the resistance offered by the long tortuous passage is enough to prevent any rapid release of pressure.

Disadvantages of Special Devices.—The disadvantages of the special devices of the type described above are as follows:
1. Most of the devices require accurate machining, which increases the cost of manufacture.
2. Accumulations of dust, dirt, grease, and rust may interfere with or entirely prevent proper functioning.

3. Additional parts have to be inspected and maintained and the assuring of adequate inspection is difficult.

4. When the devices are taken out for inspection or cleaning, careless or indifferent handling may result in mechanical injury that makes their use unsafe. Parts may even be left out entirely by an employee who does not understand their purpose.

5. The size and weight of the entire machine may be increased by the addition of such devices.

Therefore, because of its regard for safety, the Bureau of Mines does not at present advocate the use of special contrivances for cooling flames.

**TOTAL INCLOSURE**

In designs brought out in recent years the second principle, that of totally inclosing the motor or other part and depending on closely fitting joints, has been widely adopted.

In the totally inclosed motor or other accessory the machined surfaces that constitute the joints through which internal flames might escape have been termed “flanges.” According to Bureau of Mines schedules now in effect these flanges must be metal to metal and form a path not less than 1 inch long on the shortest line from the inside of the casing to the outside. Gaskets should not be incorporated in the design of flanged joints; they are damaged too easily and add unnecessary complications.

Flanges may be classified as plane, cylindrical, step, and irregular. They are described as follows:

**PLANE FLANGES**

A plane flange simply consists of surfaces in one plane which have been finished by planer, shaper, boring mill, or other machine. In general, where the spacing of bolts exceeds 6 inches, a plane flange joint that will prevent the passage of flame is not easily obtained, because the force of the explosion tends to open the joint between the bolts. This weakness may be largely counteracted by making the castings heavy or ribbed, so that they will be rigid at the joints. Some manufacturers depend on short spacing of bolts and others resort to ground surfaces when using plane flanges. On a small motor or other accessory where the areas subjected to explosion pressures are not large the plane flange may be used without particular difficulty. In Figure 5, section 2 is an example of a plane flange. This shows a 2-inch flange; the measurement includes the bolt diameter. The portion at right angles to the joint is not a part of
the flange because it does not make contact with any other part. This flange, of course, may be for either a circular or a rectangular cover. Figure 6 shows the application of plane flanges to a mining machine. The smaller of the two openings gives access to the commutator and brushes; the larger opening permits removal of the armature. The reader should note that the spacing of bolts in this figure is considerably more than 6 inches; it is made possible by the use of a heavy end-plate casting, so shaped as to remain rigid under explosion pressures.

In Figure 5, section 5 shows a plane flange combined with threads; this makes a particularly effective joint.

**CYLINDRICAL FLANGES**

A cylindrical flange, as the name indicates, is one in which the two surfaces are close-fitting cylinders turned in a lathe or boring mill. This type is used almost invariably in combination with a plane flange and is applied widely in permissible equipment because accurate machining is comparatively easy. Section 1, Figure 5, shows a $1\frac{11}{16}$-inch flange composed of a plane flange $1\frac{1}{8}$ inches long and a cylindrical flange $\frac{7}{8}$ inch long.

**STEP FLANGES**

A "step" flange is a combination of two or more flanges not in the same plane that form right angles or steps with each other. In Figure 5, sections 1 and 4 are examples of simple step flanges that are a combination of plane and cylindrical flanges. Section 3 shows a step flange that is more complicated. This particular design is used where a cylindrical sliding cover is required to give access to a motor commutator. The step flanges of the types illustrated are particularly advantageous where it would be impracticable or undesirable, because of the small space or for other reasons, to use a simple plane or cylindrical flange. Also, a step flange, when properly made, is more effective in stopping the passage of flame.
The irregular flange is a combination of plane and cylindrical flanges either of which may not be continuous throughout. In Figure 7 a large part of the flange is plane, but on account of space requirements and the widely separated bolts it was necessary to use step flanges at section \( A-B \) in order to get the required width of flange.

**Advantages of Flange Joints over Special Devices**

The advantages of the flange joint over the special devices for the relief of pressure are simplicity, lower cost, and permanence. It is believed that these advantages more than outweigh the disadvantages of increased pressure and no ventilation.

**Main Frames**

Requirements of the Bureau of Mines for permissible machines are based on the assumption that by reason of the place of operation, the method of operation, and other conditions explosive mixtures of mine gas and air may accumulate within the casings and be ignited there. Tests are therefore made, as already mentioned, in explosive mixtures of Pittsburgh natural gas and air to determine whether those casings are strong enough to withstand the explosion pressures developed, and to determine whether the joints are capable of preventing the escape of flame. The pressures obtained vary widely according to the size and shape of the casings, but a general average will be about 90 pounds per square inch for casings of the totally inclosed type, although, as explained later, this value may be greatly exceeded. These pressures are of short duration and the strength of castings should be governed accordingly. If castings are to be used for the casings, the shifting of cores and the other variations in casting should receive
due allowance in order that the casings will always have the full required strength. Designs should be shaped to have the internal free space as small as practicable. The less the volume of gas that can explode within the casing the safer the equipment will be, all other factors being equal.

In the designing of the larger sizes of motor or other accessories it is advisable to avoid partitions and any form of construction that tends to divide the interior into pockets joined by restricted passages. The reason for this is that if the motor becomes filled with an explosive atmosphere and an ignition occurs in one pocket, the mixture in another pocket might be compressed by the first explosion before becoming ignited in turn as a result of that explosion. If the mixture in the second pocket were compressed enough its explosion might develop a pressure disastrous to the casing. In some tests a pressure of more than 280 pounds per square inch has been recorded.

High pressures are likely to be recorded in tests of coal-cutting machines or similar equipment in which the casings of the rheostat and controller are incorporated with the motor in the main casting, and the compartments are connected through small openings.

There are three ways in which this condition can be remedied, as follows: (1) Make the castings strong enough to withstand any explosion pressure that might develop; (2) completely isolate the several pockets or compartments from each other so that an ignition in one can not cause ignition in another; or (3) arrange the internal parts so that any ignition will assure the ignition of all the contained atmosphere as one volume.

During the Bureau of Mines tests of permissible machines several failures have resulted through the use of thin castings, and in nearly every instance these castings have been made of cast iron.
OPENINGS AND THEIR PROTECTION

For manufacturing reasons or for purposes of maintenance and inspection every machine has several openings or joints in its main housing. The housing itself is usually made in sections that are bolted together, therefore any opening or joint is a possible path through which the flame may reach and ignite an explosive atmosphere surrounding the machine.

FLANGE JOINTS

Flange joints have already been discussed in detail. With carefully machined surfaces and a sufficient number of bolts or studs, etc., these joints can be made tight enough to prevent the escape of flame.

BOLT AND SCREW HOLES

The next openings to guard against are bolt or screw holes. In most machines it is possible to eliminate all through bolts. They should be eliminated as far as practicable in any machine.

The Bureau of Mines has approved motors having bolts or cap screws through the motor walls for the purpose of supporting field pole pieces. In some designs the holes in the pole pieces did not extend entirely through them and therefore if one of the two bolts generally used were to come out, the metal of the pole piece would completely surround the hole through the motor wall. Use of studs securely fastened in the pole piece with nuts and lock washers outside would be preferable. Then if a nut came loose, the hole would still be filled by the stud. With respect to safety it would be better to fasten the pole pieces from the inside with cap screws so that no holes need be made through the motor wall. When cap screws are used for fastening commutator covers, etc., the boss provided should give metal enough to drill and tap into without cutting through the wall; in case a cap screw should be left out accidentally or purposely, no through opening into the interior of the casing of the accessory should result. By a little extra care in design and by strict compliance with drawings in the factory this danger can be avoided.

BEARINGS

The third class of openings comprises those through the bearing housings. By suitable design it is possible to stop all flames along the shaft, even if the oil or grease should be absent.

Plain Bearings.—All of the common types of bearings have been successfully used in the construction of permissible machines. Figure 8, A, shows the simplest form of bearing as applied to drum-type controllers. In this, as in any other type of bearing where close-
running fits are required, the limits specified for diameter of bore, shaft, etc., should be closely adhered to in manufacturing. Figure 8, B, shows a method of applying a bushing to controllers. In this particular design a plate over the upper ends of the bushings holds them in place.

**Figure 8.—Example of plain bearings for controllers**

A suitable bearing for a motor presents more of a problem than that for controllers, although its solution should not be particularly difficult, especially if space is not too restricted. In Figure 9, A is an example of a motor bearing with a brass bushing. This bearing does not extend all the way through the outside wall of the bearing housing. However, should the 2½-inch pipe plug be left out, the path for the discharge of any flame would be 4½ inches long, which
is ample for the extinction of the flame. In fact, in this type of bearing the length required for the weight to be carried is longer than is actually needed to prevent the discharge of flame. The tolerances to be allowed in machining should be specified in drawings. For example: In Figure 9, A, the 2-inch armature shaft may be made 0.005 to 0.007 inch "small" and the bearing bushing 0.000 to 0.003 inch "large." The maximum difference possible between the shaft and bushing diameters will be 0.01 inch.

Figure 9, B, shows a bearing in which the shaft extends out through the bearing housing. Here again a long path, 4 1/8 inches, must be taken by any flame tending to escape. If the 1-inch pipe plug were to be left out there would be a shorter path to the opening through the oil hole in the bearing bushing. This shorter path would probably not permit flame to pass.

**Single-Row Ball Bearings.**—Figure 10 shows how a single-row ball bearing was applied in the design of a motor for a storage-battery locomotive. With balls of the sizes shown the spaces between are comparatively large, but these spaces do not give an opening directly into the motor. On both ends of the motor the radial clearance between the armature shaft and the bearing housings is 1/32 inch for a distance of 1/8 inch along the shaft; also at right angles to the shaft there is a 1/16-inch space between the housings and the ball races. At the pinion end of the shaft there is a difference of only 1/32 inch between the shaft diameter and the bore of the bearing cap. The length of the bore along the shaft, including the groove, is 1 9/16 inch, which seems a little short for good safe practice, although this construction prevented the passage of flame in the tests. In some designs of bearings, felt rings in grooves at the bearing housing have been used to prevent the entrance of grease into the motor proper. The Bureau of Mines does not accept such rings as a means of protecting against the passage of flame; the rings may become hardened with grease and not maintain their original tight fit, or they may be left out by a repairman overhauling the motor. The designer will be more certain of his equipment passing the bureau's tests if he will make the bearing housing next to the shaft longer than is shown in Figure 10. Recommendation to this effect is made to him when he applies to the Bureau of Mines for information on openings at bearings. Generally it is desired to apply a standard motor or at least as many standard parts as possible to the machine being made "permissible." In such a case the designer may object to making special bearing housings. Actual tests in the bureau's testing gallery will furnish the final proof of the safety of the bearings or of any other part.

**Double-Row Ball Bearings.**—Figure 11 shows one way of applying double-row ball bearings to a motor. The bearing housings fit close
Figure 11. Example of double-row ball bearings for motors.
to the armature shaft for a longer distance than that shown in the example of single-row ball bearings (fig. 10). The clearance between the shaft and the housing, however, is also large at the pinion end; that is, for the double-row ball bearing, the difference between the diameters of the bearing housing and the shaft is $\frac{1}{16}$ inch, whereas for the single-row ball bearing the corresponding difference is $\frac{3}{32}$ inch at the bearing housing and $\frac{1}{16}$ inch at the bearing cap.

Lubrication.—The problem of safe openings for admitting oil or grease to bearings may at first trouble the designer, although it should not give any particular difficulty if one or two important points are kept in mind. It is, of course, essential that no opening be made directly into the interior of the motor. In some plain bearings the oil hole, as indicated in Figure 9, A and B, has been put about midway between the ends of the bearing bushing, thus insuring ample distance between the inner end and the edge of the hole. For many ball bearings a groove is made in the housing so that the grease is fed to the bearing from behind, as shown in Figures 10 and 11; then the grease hole is protected by the portion of bearing housing between the hole and the interior of the motor. Generally the testing engineers remove the grease cups in order to determine by actual test whether the protection is adequate.

LEAD ENTRANCES

The fourth class of openings includes those through which electrical connection is made between the interior and the exterior of the motor or other accessory. When electrical connections are made by means of properly fitted insulated studs there is little likelihood of trouble from flames escaping at the lead entrances. Openings around leads can be closed by asbestos-packed glands or by sealing the entrance with high-melting-point compound or plaster of Paris. If the second method is employed, extra precautions must be taken so that if the compound softens it can not flow and render the seal ineffective. If results in practice show that sealing is not as safe as other methods of closing openings, it may have to be rejected. The design of lead entrances has been discussed in detail under a separate heading.

HANDHOLES

The fifth class of openings includes those made for the purpose of inspecting or renewing of parts, and in some instances for assembly. Protection for handhole openings is generally provided in the form of a cast cover held by bolts, nuts, or screws. The degree of safety depends on the width and the type of the flange joint as well as the
number and the type of the fastenings. Other things being equal a straight path is the least safe; that is, more bolts are required to hold the parts together in such a way as to prevent flames from passing through the joints. On the other hand, thread joints have always proved very effective in stopping flames. Even one right-angle turn, that is, step flange, generally adds considerably to safety, and two right-angle turns usually make an effective joint.

Among the various methods that have been employed for protecting handhole openings, bolted covers, screw covers, clamped covers, and sliding covers may be mentioned. They are briefly discussed below.

**Bolted Covers.**—One large or several small covers bolted in place over openings of proportionate and suitable size have been more widely used than any other type of cover. Generally as the size is increased the number of bolts or other fastenings needed must also be increased in order to maintain tight joints. Therefore, the large cover will not be so desirable, and in addition it can not be so easily and quickly removed or replaced as the smaller one.

**Screw Covers.**—The screw type of cover (see 5, fig. 5) is generally used where a handhole 4 to 6 inches in diameter is large enough, although larger diameters have been manufactured.

The advantages of the screw type of cover when properly made are as follows: (1) There are no bolts, nuts, and lock washers to be lost or mislaid; (2) with the proper tool the cover can be quickly taken off or replaced; (3) the threaded joint is probably the easiest of any to make so tight that flames from an internal explosion will not escape; (4) usually one can tell by a visual inspection whether the cover is tight enough for safety; when the bolted type of cover is used, closer inspection is necessary to determine whether bolts are tight and all lock washers in place; (5) the screw cover is simple to lock in place with either a padlock or some form of seal.

The disadvantages of the screw cover are as follows: (1) Machining threads of such large diameter may present some difficulties, not so much with the cover itself as with the casting into which the cover fits; (2) the circular opening may not be adapted for use with the remainder of the design; (3) the ease with which the cover may be removed may tend to encourage opening the motor at times when opening would be unsafe.

**Wedged Covers.**—Small covers designed for wedging in place have been tried unsuccessfully. They consisted of rectangular castings with two opposite edges tapering in thickness and fitting into grooves tapered to correspond in the main casting. The intent was that the joints would close tight when the covers were forced into place.
difficulty with such a design is that extreme care is required in machining, otherwise the taper of the edges of the cover will differ from that of the grooves, and the cover will be tight in one place and loose in another. Dirt getting into the grooves or any rough spot on the cover edges may prevent the cover from closing tightly.

Clamped Covers.—Several manufacturers of storage-battery locomotives have designed controllers with special clamps instead of bolts or screws to hold the main cover. The object sought was ease of access for inspection and maintenance. As a controller for this service should have frequent inspection to insure that it is in proper operating condition, the removal of 10 to 20 bolts would obviously tend to encourage neglect of proper attention. Clamped covers that would permit the opening of a controller in about the same time that one or two bolts could be removed would possess a certain advantage over the bolted type of cover. The clamps, however, have not always proved successful; sometimes they failed to keep the flange joints tight enough to prevent the passage of flame; that is, the full benefit of the clamping action was not obtained where needed most.

Sliding or Ring Covers.—Still another form of construction used to give quick and easy access to the interior of motors may be termed a "sliding" or "ring" cover. It consists of an annular ring accurately fitted to the motor shell and easily rotated. When the motor is to be opened for renewal or adjustment or for cleaning, the annular cover is rotated until a radial opening in it matches with one of approximately the same dimensions in the motor shell. By making the metal around the openings wide enough there will be ample protection against the discharge of flames. This type of cover is held in the closed position by means of padlocks.

Advantages of the sliding cover are as follows: (1) There are no bolts and nuts to become lost or misplaced, and (2) a convenient means for obtaining an opening into the motor is provided, and this expedites inspection and cleaning.

The disadvantages of this type of construction are: (1) The difficulty and expense of machining thin castings accurately; and (2) unless the cover has been properly maintained by lubrication, etc., rust or corrosion may cause it to bind, and thus interfere with or entirely prevent moving it.

Some operators object to equipment with a large number of bolts because of the difficulty in keeping bolts tightly in place, but one might ask whether the same operators would maintain locks and seals any better. Where safety is properly regarded mine discipline and inspection will result in safe equipment with either method of fastening.
FASTENINGS

BOLTS AND STUDS

Covers and sections of casings must be held in place in a substantial and effective manner. Bolts, studs, and screws, especially those that are often removed, should be generously proportioned in order that there shall be no stripping of threads or failure because of the pressures developed within the accessory by the internal explosions to which the equipment may be subjected in a gaseous mine and will be subjected when being tested for approval by the Bureau of Mines. As the explosion pressure sometimes exceeds 100 pounds per square inch, the necessity for special attention to bolt sizes is obvious.

Not only is the size of fastenings important, but the spacing of fastenings is equally so. Fastenings should be spaced so that the casting covers will not spring between any two points and thereby leave an opening in the joint.

LOCKS AND SEALS

In some designs, such as for the sliding cover, bolts and studs are not needed to maintain a tight joint, and a lock or seal is relied on to keep the cover in place. This method when properly designed insures a readily accessible compartment, but it also places a key in somebody’s hand, so to speak, and the ultimate safety of the outfit depends upon the discipline the operator maintains in always having the key in the hands of reliable and responsible men. The same argument applies to the use of seals, except that tampering with a seal can be detected more easily, and to counterfeit the seal is more difficult than to fit an extra key to the lock. Neither lock nor seal should be removed in a gaseous section of a mine any more than bolts should be taken out to remove covers in such places.

In other designs the handhole covers are screwed into place instead of being bolted. Because of the ease of removing covers of this type, they also need sealing or locking after being screwed into place.

LOCKING OF BOLTS, NUTS, AND SCREWS

Of equal importance with adequate fastenings for the covers and sections of casings is the suitable locking of bolts, nuts, screws, and similar fastenings to prevent their loosening under vibration and strain. Various methods of accomplishing this end will therefore be considered.

The most common locking device is the spring lock washer. In many cases it is a simple and inexpensive yet effective means of locking bolts, nuts, and cap screws. Wherever the lock washer is
used to secure cap or machine screws that are threaded into blind or bottomed holes, care should be taken that the holes are tapped deep enough to allow the screw to be firmly tightened, even when the lock washer is omitted. The reason for this is that if the lock washer is lost or broken, as frequently happens, the making of a tight joint before the end of the screw strikes the bottom of the hole shall still be possible. The objection to lock washers has been that very close inspection is necessary to detect whether or not they are missing. On a large machine or where there are a number of machines to inspect and maintain in safe condition this is an important item.

Another method commonly used for cap screws, bolts, etc., has been to drill the heads at right angles to the axis of the bolt or screw and then pass iron wire through the holes. In this way an entire set of cap screws for a cover or end plate may be wired together or they may be wired in pairs, whichever proves more suitable or convenient. The ends of the wire are twisted together after the cap screws are wired. It may be argued that the wire will rust quickly. While this is more or less true, yet permissible equipment must be frequently inspected and have attention paid to its maintenance, and the renewal of parts when necessary, if it is to remain safe in case gas accumulates around it. This is the premium that must be paid if the insurance given by the safe use of permissible machinery is to be realized. Copper or brass wire might prove to be a satisfactory substitute for iron wire. The wired bolt is advantageous in that one can see at a glance whether or not the fastening of the bolt is missing. The wire may also serve to indicate tampering with the machine.

NUTS AND WASHERS

Many methods have been employed to prevent the loosening of nuts, but the one most generally used is the lock washer, already discussed. The castellated nut held with cotter pin or wire is probably the most effective and positive means for keeping a nut tight, as may be judged by its universal application on automobiles and steam locomotives, where the prevention of any loosening of parts is extremely important. This type of fastening is, of course, somewhat more expensive than the lock washer, but as a device for permitting reasonably quick and certain removal and tightening of nuts it can scarcely be excelled. A variation of the castellated nut is an ordinary nut drilled for a wire to go through both it and the screw or bolt.

A nut that does not have to be removed once it has been tightened may be securely held in place by prick-punching or by peening the end of the bolt or screw sufficiently. Occasionally an additional nut
or lock nut has been used to hold the main nut tight, but is not very satisfactory, because it can not of itself be relied on.

Special washers offer a variety of ways in which to lock nuts. In general these washers consist of a piece of soft metal, such as iron or brass, which is placed under the nut. The washer is then bent up at one or more points against a flat side of the nut and is bent downward at other points against flat spots on the casting or other part held by the nut. The latter bend prevents the special washer from turning, while the first bend keeps the nut from turning. A variation of this type of locking washer is used to secure a bearing nut on an armature shaft (see a, fig. 11). In this a projection on the washer fits into a keyway in the shaft and keeps the washer from turning. After the nut is pulled up tight a part of the washer is flattened against a side of the nut, thus holding it in place.

A form of lock that has been used to a limited extent is shown in Figure 15, which illustrates how a number of nuts in a straight line may be fastened. The method consists in turning one flat side of each nut so that these sides fall along one straight line. A strip of metal called a “locking bar” is then fastened down so that its edge comes against the flat sides of the nuts, thus fixing them in position.

Sometimes it becomes necessary or advisable to secure a cover at a point where a casting is comparatively thin. For such a place a stud bolt may be used in a hole that is drilled and tapped entirely through the wall of the casting, if the inner end of the stud bolt is thoroughly riveted over to prevent its loosening. Instead of being riveted, the end of the stud may be welded. As already stated, studs offer the advantage of keeping bolt holes filled up even though the nuts are missing.

Obviously, if rivets extend through the walls of permissible casings the riveting should be done very carefully so that there will be no possibility of the rivets working loose.

TERMINALS, LEAD ENTRANCES, AND INTERCONNECTIONS

INSULATED STUDS

A number of satisfactory methods and devices have been developed for the purpose of making electrical connection between the interior and exterior of motors, controllers, resistances, or other apparatus. Among these is the insulated stud with terminals. Early in its work on permissible machines the Bureau of Mines advocated this method of bringing circuits through the walls of permissible casings. In respect to safety it seemed to be as satisfactory as any device that had been proposed. In more recent years,
however, the insulated stud has been partly supplanted by other forms that seem to be equally safe if not safer.

Terminals within the motor or other accessory, although not nearly as hazardous as those outside, should be large enough and should have ample clearance from grounds or parts of opposite polarity. Permissible equipment is designed to prevent sparks and flashes within the casing from igniting explosive mixtures without, but only such sparking as can not be avoided should be allowed.

The position, security, and mechanical protection of terminals outside the compartment must not be overlooked; in fact, they should receive as careful attention as any part in the entire design. A spark at this point, resulting from a loose connection, from a ground, or from a short circuit, would be sure to ignite any surrounding explosive atmosphere.

**Figure 12.**—Example of insulated stud lead entrance and terminal, set-screw type

By using large clamping surfaces, lock washers, cotter pins, etc., terminals can be made reasonably secure. Any arrangement of terminals or scheme for bringing circuits through walls of enclosures that is of questionable safety should not be applied to permissible machines. If ample clearance, efficient insulation, and barriers are used, trouble from grounding can be eliminated. Substantial covers and housings cast as an integral part of the machine or suitably fitted to the contour of the machine should be designed to safeguard the terminals from outside injury and from contact with tools or other metal objects which might draw an arc or flash.

An example of the insulated stud as applied to a storage-battery locomotive is shown in Figure 12. In the design the studs are turned from hexagonal brass bars leaving hexagonal heads which are recessed into a block of insulating material on the outside of the motor
A bushing or tube of insulating material surrounds the stud in passing through the casing, and a washer of the same material separates the brass washer and terminal from the metal of the casing. Inside of the motor the conductors are soldered into terminals, while on the outside the conductor strands are soldered together and are held by a set screw of comparatively large diameter. Only friction prevents this set screw from loosening. In general, the Bureau of Mines now considers it necessary that a positive means shall be used to lock set screws of this type in place after they are tightened. The outside terminals are given mechanical protection by a cast cover held in place over them by means of three studs with nuts and lock washers.

**Figure 13.**—Example of insulated stud lead entrance and terminal, nut and lock washer type

Figure 13 shows another form of insulated terminal, designed for a locomotive motor. In this design three connections are brought out close together on 2-inch centers. The stud is made of brass, with a shoulder to rest upon the insulating bushing in the motor shell. On the inner end of the stud the conductor is soldered into place; at the outer end it is soldered into a terminal held to the stud with a nut and lock washer. Externally, the live parts of the terminals are completely incased in three fiber blocks which not only preclude the possibility of short circuits by parts of the terminals themselves coming in contact with each other, but also protect them from mechanical injury or from contact with metal parts. The fiber blocks are firmly secured to the motor by eight studs with nuts and cotter-pinned lock nuts.

A well-designed insulated stud, particularly adapted for use with controllers at which a large number of external connections have to
be made, is shown in Figure 14. The stud proper is a finished brass casting. It is insulated from the wall through which it passes by means of a fiber tube. Fiber washers on both sides of the wall insulate the head of the stud, and also the terminal nuts, from the wall. The split-clamp arrangement is placed on the outside of the controller or other accessory. The ends of the conductor are soldered into a brass sleeve which is firmly held by the clamp, thus making a good electrical contact, and also permitting quick removal or connection. A terminal of cast brass into which the lead is soldered is used on the inner end of the stud. By shortening the threaded portion of the stud and using a correspondingly shorter insulating bushing this design of stud may be applied to thinner walls.

![Figure 14.—Example of insulated stud lead entrance and terminal, split-clamp type](image)

**STUFFING BOXES**

One acceptable method of bringing a lead through a wall without breaking the continuity of the insulation is to pass the lead through a stuffing box packed with asbestos wicking. Figure 15 shows one form of the stuffing box as applied to a motor end plate. On this motor two groups of three leads are brought out, each lead having a separate stuffing box. A bushing that closely fits the conductor is threaded into the end plate. When the stuffing box is assembled after the lead is in place two or three turns of untreated asbestos rope or wick are wound around the lead and these after being pushed into place are compressed by tightening the packing nut which, in Figure 15, is labeled "cable-armor bushing." The shape of the recess in the bushing is such that the tightening of the packing nut forces the asbestos against the conductor, thus making a very tight joint. Where the thickness of the casting permits, the bushing may be eliminated by machining the main casting itself to fit the conductor, with a recess for the packing and with threads to take the packing nut. The stuffing box may be used in bringing a lead out of a machine or it
may be applied inside of a machine when the conductor is to pass through a wall that isolates one part from another. Provision should always be made to lock the stuffing-box nuts after they are tightened. One method of locking the nuts with a locking bar is shown in Figure 15 and was described under "Fastenings."

Although the stuffing-box lead entrance requires careful design in order to insure that the packing will close tightly around the lead passing through it, certain advantages resulting from its use make it seem very desirable with respect to safety. Use of a continuous length of conductor from the interior of one compartment to the interior of another is made possible with the stuffing-box lead entrance. Thus there need be no terminal connections outside of permissible compartments to protect against loosening, short circuiting, or other dangerous conditions. On a storage-battery locomotive having, say, eight compartments, with 2 to 15 or more electrical connections to be made at each one, one can readily see that, other conditions being equal, the greatest safety will be obtained when the greatest number of connections are made inside instead of outside of permissible casings.

**INSULATING BUSHINGS**

**Multiple Conductors.**—In one of the machines first approved by the Bureau of Mines connection had to be made between the motor and controller, which were separated by an end shield that carried one of the motor bearings. Figure 16 shows how the connection was made. An insulating tube or bushing with ends rounded so as not to cut into the insulation of conductors pulled through it fits tightly in the end shield 3. The conductors are "cabled"
together so that the tube is well filled. Thus with a constricted passage of sufficient length the propagation of flame from the motor 1 to the controller 2, or vice versa, is prevented.

When by the requirements of the design a number of conductors that must be kept close together have to be taken through a wall without allowing the passage of flame, the method illustrated in Figure 17 may be satisfactory. Shorter insulating tubes or bushings than those in Figure 16 are fitted into the wall, and the conductors are of such a number and diameter as to fit snugly in the bushings.

**Single Conductor**—If the space within a machine is so restricted that conductors can not be conveniently grouped together to be taken through walls in one bushing, a bushing for each individual conductor may suit the specific requirements. Such an arrangement is shown in Figure 18. The Bureau of Mines made special tests with this type of bushing to determine the allowable difference between the over-all diameter of the conductor and the inside diameter of the bushing. It tested a mining machine equipped with 13 bushings 2½ inches long and of three different diameters to ascertain whether flame was propagated through the bushings when conductors of various diameters were placed in them. The internal diameters of the bushings used were \( \frac{1}{16} \) inch, \( \frac{3}{32} \) inch, and \( \frac{5}{32} \) inch, respectively. The tests showed that flame was not propagated through the space around conductors even with a difference of \( \frac{1}{16} \) inch between diameters of conductor and bushing for the \( \frac{1}{32} \)-inch bushing, \( \frac{1}{8} \) inch for the \( \frac{1}{16} \)-inch bushing, and \( \frac{3}{32} \) inch for the \( \frac{5}{32} \)-inch bushing, but the bureau recommended that the manu-

---

**Figure 16**.—Example of intercompartment connections; long bushing, multiple conductor
facturer set $\frac{1}{8}$ inch as the maximum allowable difference. With the cables removed, propagation of flame through the bushings was obtained easily. It is probable that shorter bushings than 2$\frac{1}{2}$ inches might prove satisfactory, but none were available for the tests.

The examples given in Figures 16, 17, and 18 are not acceptable in permissible machines for entrances through outside walls, because they have openings through them that might be enlarged to an unsafe degree, either by accident or by the rewiring of the machine with smaller conductors than those originally specified. When each end of the bushing terminates inside of a permissible inclosure, an explosion in one of the inclosures will not necessarily be followed by an ignition in the second inclosure; but should the space around the conductor be large enough to permit flame to pass through the bushing, the flame would be discharged into the second inclosure rather than into the outside atmosphere.

**SEALED-IN LEADS**

**Multiple and Single Conductors.**—Some of the foregoing methods for bringing leads through walls of permissible machines may add considerably to the cost of manufacture, especially where, as in many controllers, a large number of leads have to be cared for. The use of a compound for sealing the leads in an opening from which they emerge was developed in an effort to fill the need for a more simple and inexpensive yet effective method of bringing out leads than some already described. One way of applying this idea is shown in Figure 19. It was used, because of excessive explosion pressures developed in tests, to isolate the resistance compartment from the motor compartment in a mining machine. A “pocket” or “well” 1$\frac{1}{4}$ inches deep was so cast in the frame that it extended halfway into both compartments, and the wall or partition between them came down into it for $\frac{1}{8}$ inch below its upper rim. When the wires were pulled through the opening, the partition caused them to “dip” down into the pocket, which was then filled with an asphaltic base.
compound of high melting point. In the example given (fig. 19) full advantage of the possibilities of effective sealing is not taken because only a little compound rests above the wires, and that underneath is entirely ineffective. If the compound is brittle a slight disturbance of the wires will break some of it out and either weaken or destroy the adequacy of the seal. When a seal is to be used it should be designed so that the wires will go to the bottom of the pocket, thus insuring the maximum depth of compound over the top of the wires. The path along the wires through the compound should be as long as practical. This type (fig. 19) of sealed passage, or modifications of it, has been used both as an entrance to permissible machines and as a connection between two isolated compartments.

Disadvantages inherent with seals of the type just described are as follows:

1. The sealing compound must not melt at low temperatures. Even so-called “high-melting-point” compounds have been found to “flow.” Therefore the pockets for seals should never be placed in any position except normally horizontal. Melted compounds of this character harden rapidly on striking a cool surface; consequently it is difficult to get them to flow evenly around the conductors to be sealed in, and considerable care must be taken to insure that the spaces around and between the conductors are completely filled. “Spark-plug cement” has been tried as a sealing material. Special care, however, is required to use correct proportions in mixing it, otherwise it will not harden enough to remain in place.

2. When a machine has to be rewired at the mine it may be impossible to obtain the special compounds without serious delay, and often the mine electrician will not have as good facilities as the manufacturer has for making a seal that is satisfactory and secure. If only one wire needs renewing the insulation on the other wires may possibly be damaged in removing the compound from the pocket to release the first wire.

3. If flame is necessary to melt the compound, either for removal or replacement, the work can not be done in a gaseous section of a
mine because no flame of any kind can be permitted there. Observance of this precaution requires that the machine to be rewired be moved to a nongaseous section of the mine or brought to the surface, a procedure that entails inconvenience and loss of time.

The foregoing objections are overcome in part by the use of plaster of Paris as a sealing material. Plaster of Paris is easily obtained and is cheap; it does not flow when heated; and it expands slightly on hardening. It can be mixed and poured cold, therefore no hazards attend its use in repair work in the mine.

Figure 20 illustrates the application of plaster of Paris in sealing the lead entrance of a mining machine. In this design a "pocket" is riveted to the outside of the motor frame. Insulating bushings in the pocket are placed opposite a set in the motor frame and, after the cables have been pulled through, the entire pocket is filled with plaster of Paris mixed with plenty of water in order that the mixture may flow freely into all interstices. The contour of the inside
of the pocket is such as to lock the mass tightly in place once it has hardened. Some tests made by the Bureau of Mines showed that when plaster of Paris was heated its mechanical strength was somewhat diminished; but further investigation may prove that plaster of Paris is as suitable as insulating compound, even where considerable heat prevails.

CONNECTORS

When leads are brought out of permissible machines in a manner similar to that just described it is necessary to provide some means for making connections with the external circuit. Connectors of various types have been used for the purpose.

Westinghouse Knuckle Joint.—A type that has been used is the Westinghouse "knuckle-joint" connector. This consists of two parts made from brass rod, in each of which an end of one of the cables to be connected is soldered. A pin on one part fits into a hole in the other part and serves as a pivot for the knuckle that the two parts form when put together at right angles to each other. When the knuckle is straightened out the connection is complete. A tongue and groove in one part match with a similar groove and tongue in the other, thus giving good electrical contact. A connector of this type need not be of much larger diameter than the cables connected. It is easily insulated with tape, and when supported in clamps of impregnated wood or other insulating material it forms a satisfactory connection. No tools are required either for making or breaking this type of connection. The objection to this type is that flame is required for soldering; hence the machine must be moved to fresh air or out of a mine before soldering can be done.

STRAIN CLAMPS

On portable machines such as coal cutters and drills, where a length of flexible cable is attached, a clamp of insulating material should be provided to relieve the terminals or lead entrances of mechanical strains such as those caused by jerks of the cable. Before the cable reaches the strain clamp from the outside it should
come through a bellmouth entrance that opens out with smooth rounded surfaces that permit flexure of the cable without cutting it. Figure 21 shows such an arrangement in section. This is an example of a three-conductor cable entering the bellmouth opening and held by the insulating clamp, from which it is divided into three separate conductors, each connected to a separate insulated stud. The casting to which the bellmouth is held (by two studs) gives protection to the terminals.

**APPARATUS NEEDING SPECIAL ATTENTION**

**RESISTANCE BOXES**

The same general rules that apply to covers, joints, lead entrances, and other parts already considered apply also to the design of casings for the resistances that are used to control the speed of motors. The chief hazard in resistances is arcing from broken or burned resistance elements. In recent years designers have directed their efforts toward producing resistance grids of material other than cast iron, which is easily broken. Grids of special alloys and punched-steel grids that do not break under ordinary operating conditions are now available; these reduce to a minimum the dangers of arcing from broken grids. The Bureau of Mines, however, requires a permissible inclosure for the resistance because there are other points besides a break in the grids where an ignition of gas might originate. These are as follows:

1. Arcing at loose terminals, a result of expansion and contraction when the grids are heated and cooled.
2. Arcing between grids, a result of the grids sagging together from overloading through careless operation.
3. Arcing when grids “open-circuit” by burning through after repeated overloading.

Resistance elements should be generously proportioned so as to have ample capacity to meet the severe conditions imposed on mining equipment. This is of especial importance where the resistance box is a separate unit and in consequence the conductors going from it to another accessory have to be run outside of a permissible casing. If the resistance elements are not large enough the heat will be carried out along the conductor, with probable damage to the insulation.

**CONTROLLERS AND SWITCHES**

The main problem in controller design is that of combining accessibility with adequate protection. From the operating standpoint
it is desirable that the controller be easily and quickly opened for inspection and repairs. If a cover of comparatively large area is used, a flange joint will require a large number of bolts or cap screws if it is to be kept tight. Therefore some designers have avoided the bolted joint as far as practical when designing controllers for storage-battery locomotives. In one design the joint is avoided by fastening the fingers and other parts to a frame joining two solid circular ends; a cylindrical shell with cylindrical step flanges at each end then forms the cover, which may be quickly slipped on or off.

When the top is cast integral with the controller frame the drum may be taken out or inserted if a screw cover having a greater diameter than the segments is used, as shown in Figure 8, A. If a box type of controller is desired, the main and reverse drums can be placed on the split between the two parts with brass bushings for shaft bearings, as shown in Figure 8, B.

In another design effective use is made of a large-diameter screw cover of aluminum alloy to obtain the desired accessibility from the front of the controller.

Every permissible machine should have incorporated in its design a switch or switches for cutting off the power supply from the motor or motors, independently of the controller. For a direct-current machine this provision requires the use of a double-pole switch or two single-pole switches. In other words, it should be possible to open each conductor of the feeding and return circuits at the machine, so that in case the controller can not be returned to the “off” position the motors can be stopped by opening the switch or switches. If insulation fails within the machine and the frame of the machine is thus made alive, the operator will have some protection from shock if he can open the circuit in this way.

**FUSES AND CIRCUIT BREAKERS**

The protection of a machine and its wiring, including cables that connect with the power circuit, should be carefully considered. Protection may be obtained by means of fuses or circuit breakers, but the general custom has been to employ fuses. Of itself, the fuse is easily adapted to permissible designs, but the specification in Schedules 2B and 15 of the Bureau of Mines that automatic circuit-interrupting devices shall be designed so that they “may be reset or renewed quickly and conveniently without meanwhile causing any of the permissible features of the equipment to be less effective,” generally complicates the design by the addition of interlocking mechanism. The necessity for opening fuse boxes is reduced by a multiple-fuse arrangement which permits the placing of two, three, or more new fuses in the circuit successively without opening the
box at each change. This arrangement is permitted, provided that
the fuse box is locked or sealed to prevent unauthorized persons from
tampering with the fuses; but when the last fuse has been used or
“blown,” new ones should be inserted only by the person authorized
to do so. If the fuses are not interlocked with the main switch so
that there is nothing to prevent their being inserted in or removed
from a live circuit when the fuse box is open, the machine must be
taken to fresh air where the work can be done without danger of
igniting gas. The multiple-fuse design may be made to be used as
a switch, thus combining two permissible casings in one. As with
switches, so with fuses—they must protect all the conductors in-
cluded in a circuit. The great objection to fuses has been that fuses
of larger capacity or even pieces of solid copper wire have been
inserted in the place of the regular fuses in order to obtain con-
tinuity of service without regard for the machine that is to be
protected.

A circuit breaker having a reset button that extends through the
wall of the permissible casing will tend to prevent continued over-
loading of a machine if it is so designed that the circuit breaker
can not be “held in.” Circuit breakers of the switchboard type are
complicated in design and delicate to adjust and are not suitable
for permissible equipment; their initial cost and the difficulty of
keeping them in repair are largely responsible for their not being more
generally applied to such equipment. Circuit breakers of the rail-
way type are more sturdy and therefore better suited for mining
equipment; one manufacturer has applied this type of breaker to
a permissible machine. An overload relay mechanism has also
been designed for use on a permissible machine; on this particular
machine it can not be reset except when the starting switch is in the
“off” position. Another manufacturer has made use of a tem-
perature relay in place of fuses. This relay can be set to operate at
a predetermined value of current so as to open a control circuit and
thus release magnetically operated contactors in the main circuit.

HEADLIGHTS

Since July 1, 1924, the Bureau of Mines has required that head-
lights be made permissible inclosures. The special problem in meet-
ing this requirement is that of making a satisfactory joint between
the lens and its frame or holder. The general practice has been to
machine a shoulder against which to seat the lens inside of the frame.
The lens may be cast or finished with sufficient accuracy of contour
to make a close fit against the shoulder when held by a retainer ring
screwed into the lens frame from the inner side. If desirable, the
lens may be made to seat against a lead ring to compensate for any
inequalities in the glass. In any case, the lens should be supported both front and back around its entire circumference and the joint between metal and glass should be at least 1 inch wide. The same thread that takes the retainer ring can be used to hold the lens frame to the body of the headlight. The retainer ring should be locked in place after it is tightened against the glass to prevent its loosening when the lens frame is taken off.

The glass preferably should not be less than ½ inch thick. Convex lenses have been made 1½ inches thick. For a flat glass it may be preferable to shape the lens frame so that it extends beyond the glass in such a way as to serve somewhat as a shield or mechanical protection for the glass.

If the lens frame is screwed to the body of the headlight, it should be locked in some manner. A sealing wire or padlock can be used for this purpose.

In one design of headlight the lens frame is held to the headlight body with cap screws and lock washers. This method necessitates the machining of a flange joint between the frame and the body.

The protection of the headlight as a whole should receive careful consideration. By this is meant that the headlight should be placed on the locomotive or other machine requiring it in a position where it will not be readily damaged by cars bumping the locomotive or machine.

AMPERE-HOUR METERS

Ampere-hour meters are now subject to the same requirements governing permissible inclosures as are headlight. The glass through which the meter dial is read can be supported and protected in the same manner as the headlight lens.

The meter should be insulated from the permissible inclosure which protects it, in order that failure of the insulation within the meter will not result in "grounding" the meter to the inclosure.

BATTERY BOXES

The battery box or housing for batteries used on permissible storage-battery locomotives probably presents more special features that concern safety than any other accessory used with permissible outfits.

The reader should note that the battery box is not considered an explosion-proof compartment and is not treated like one, for designers have deemed the construction of an explosion-proof battery inclosure impractical if not impossible because of the size of the box and the necessity of providing for release of gases and fumes given off by the battery. In spite of the limits set by the necessity of
ventilation many things can be done to make such a compartment safer than the boxes used on nonpermissible outfits.

The first step is to provide the battery box with adequate covers so insulated that they can not possibly short-circuit the battery, and so arranged that they can be locked in a closed position while the locomotive is in operation. The next step is to ventilate the battery box by providing holes through its walls and bottom for the free circulation of air. Ventilation tends to dissipate and dilute such hydrogen gas as the battery may give off during discharge. Any holes provided for ventilation should be guarded so that contact with the battery terminals can not be made by putting wires or other conducting material through the holes. A third step is to insulate the battery containers from the metal work of the box. If the containers are themselves metal, as in Edison cells, special care must be given to insulation. Wood or its equivalent must be provided under the trays. Lead-acid batteries have required no other insulation than the insulators supplied on the bottom of the trays. The fourth step is to give care to all wiring within the battery box. Because of the action of the electrolyte, only rubber-covered wire with a good grade of insulation should be used; it should be well cleated and so run that it will not be chafed or worn by passing over sharp metallic edges. Wiring between cells should be done with care so that wires will not come in contact with either the walls or the cover of the battery box. The wiring should be protected by fuses near a point where it leaves the battery.

**WIRING OF PERMISSIBLE EQUIPMENT**

**INTERNAL WIRES**

No special requirements for the insulation and protection of wires within permissible compartments other than those already accepted as good practice in the manufacture of equipment for mining service have been made by the Bureau of Mines.

**EXTERNAL WIRES**

In designing permissible apparatus too little consideration has been given to what may happen outside of permissible compartments. On the outside of compartments the electrical parts that need the most attention are the wires and the points where wires terminate. As terminals have already been discussed at some length, the question of adequate wiring will be considered here.

The factors governing safe wiring are many, depending upon the size, length, service, and liability to mechanical injury. Stationary
apparatus presents a less complicated problem than portable equipment.

Trailing Cables.—Portable equipment is usually provided with a cable termed a "trailing cable," generally 300 to 500 feet long. These cables if armored would be very expensive, practically impossible to reel, and not suitable for mine service. The custom, therefore, has been to leave such cables without mechanical protection. In its earlier approvals the Bureau of Mines did not attempt to approve the trailing cable, but left this question entirely to the judgment of the manufacturer and the user. The bureau only required that the strain on the cable should be so taken care of that there should be no pull on the terminals where the cable was connected to the machine.

As its approval work advanced the Bureau of Mines became convinced that more attention should be given to trailing cables, and in January, 1922, bureau engineers discussed this question with both machine and cable manufacturers at a conference held at the Pittsburgh experiment station.

As an outcome of this conference a better grade of trailing cable has been used on all permissible machines, and the bureau expects to be able to test cables to determine their suitability for this service. At present such cables as are recommended by the manufacturers of portable machines are tentatively approved. Since 1922 a requirement has been in force that all trailing cables must be protected by a fuse or circuit breaker, also that only approved cable is acceptable for renewals.

Cables having all-rubber insulation, with 60 per cent high-grade rubber on the outside, which serves as a wearing surface in the same way as the rubber on the tread of an automobile tire, are almost always used on permissible machines at present. These cables cost more than the former braid-covered cables but have proved to be more economical because they give much longer service; they are far more acceptable for permissible machines.

Another factor now considered in connection with trailing cables is the manner of attachment to the feeder circuit. Various kinds of attachment have been approved for use where arcs or flashes will not constitute a hazard. For such places the main consideration is that the end of the trailing cable shall be provided with a handle which will permit connection to be made without shock to the machine operator. Fuses may be assembled in the same handle, although this is not required by the Bureau of Mines if the operator protects the cable by a fuse or circuit breaker in some other manner. When the connection is not to be made in intake air, permissible junction boxes should be used. The short cable between the machine and the
reel of a coal-cutting machine is considered in the same light and is subject to the same requirements as the trailing cable.

Stationary machines such as room hoists and pumps often have feed wires in places beyond the intake air. These wires should be protected from falls of roof by ample timbering; where this protection is impracticable armored cable might be used. Each feeder should be protected by a fuse or circuit breaker.

Wires Between Permissible Inclosures.—Many stationary and portable machines have two or more compartments separated from each other, and wiring has to be outside of permissible inclosures. To meet the schedule requirements it is necessary to safeguard such exterior wiring by the use of some kind of a raceway for the wires. This raceway may take many forms but should be considered carefully or the wire may be more readily damaged by the raceway itself than if it were run in the open. In stationary equipment wires can be run in rigid conduit and terminated in suitable junction boxes near the point where they pass through the wall of a permissible compartment. If no rough edges are left at the ends of the conduit, and suitable junction boxes are provided, this method of handling wiring between compartments that are stationary, or at least are stationary with respect to the parts under consideration, should prove satisfactory. However, care should be taken not to injure the wires when placing them in the conduit and the conduit itself should be adequately fastened in place at frequent intervals along its length and secured at the points where it enters the junction boxes. Flexible conduit can be used in a like manner for stationary equipment.

When there is any considerable movement of one compartment with respect to another the problem of wiring between them is more difficult. To allow the wires to move with the machine, a certain degree of flexibility must be permitted and is generally obtained by using a flexible armor or an equivalent raceway for at least part of the wiring. Because of the movement more care must be taken to secure the ends of the armor to prevent strain on terminals and abrasion of the insulation.

If a cable has considerable movement—for instance, the cable on a turret machine—extreme care should be exercised to support the armor and cable properly and prevent strains on terminals or abrasions of the insulation within the armor. This wiring should be inspected frequently to insure that no unsafe condition has arisen.

On account of the electrolyte and its action on insulation and metals, storage-battery locomotives present special problems in
wiring. Where feasible, the wiring and its protecting raceway should be placed so as not to be in the path of spilled electrolyte or of water that drains from the battery when it is washed. The armor covering the wiring between compartments should be protected from mechanical injury, either by selecting paths that offer natural protection or by using special guards over the wiring.

Flexible Conduit.—A development in flexible conduit is the type made of two wires wound together spirally. This construction gives considerable flexibility and mechanical strength, but in common with all other metal conduit it is subject to corrosion. The use of rubber suction hose has been tried as a substitute for metal conduit. This hose has a rubber lining and an outer covering reinforced by either a round or flat wire with turns spaced approximately \(\frac{1}{4}\) inch apart and also by several layers of canvas. Thus in addition to their own insulation the inclosed cables have the insulation of the hose. The wire reinforcing in the hose is completely covered by rubber and canvas so that it can neither come in contact with any part of the machine to which it must be clamped nor with the conductors carried by the hose. The wire may tend to hold the conduit in a distorted shape if the walls in any way become mashed, but the insulation of the conductors would also have to be damaged at the same time or the wire reinforcement broken so as to pierce the insulation before a dangerous condition would result. The Bureau of Mines has recently permitted the use of a hose without wire reinforcement which had been advocated as an improvement over hose with wire. This hose offers the advantage of returning to its original shape after being flattened; in addition, the possibility of the wire breaking and piercing the conductor insulation is absent.

Conduit must be securely clamped or held at its ends and at other points where movement is undesirable; otherwise it may chafe and cut into the cable within it. This precaution is particularly essential for metal conduit. One method of holding conduit ends is shown in Figure 12, in which a special bushing is threaded internally to take the flexible conduit. In some instances soldering is done to prevent the conduit from "backing out" of the bushing. Figure 13 shows a form of split clamp used for the same purpose. The ends of the rubber conduit with wire reinforcement may be firmly held between the two parts of a cylindrical clamp held together by bolts or cap screws, and long enough to give a large area of gripping surface. The ends of the hose not having the wire reinforcement may be held by a flange coupling which is firmly held to the hose by a brass ferrule expanded inside against the coupling.
CONCLUSION

A bulletin as short as this can not cover all the points of design that might have to be considered in a single outfit. To one who bears in mind the multiplicity of uses for permissible motors and accessories, it will be evident that many of the problems that will arise from time to time have not been adequately covered here and will need individual attention. The authors trust, however, that the paper will be useful in interpreting the intent of Schedules 2B and 15 of the Bureau of Mines, and that designers will feel free to ask for a conference on any points still in doubt.