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TABLE

1. Number and causes of accidents, 1933 to 1942, inclusive, in quarries and related outside works. 4
INFORMATION ON THE PREVENTION OF QUARRY ACCIDENTS


INTRODUCTION

The primary objective of this paper is to discuss the hazards and furnish a list of recommendations for the safe operation of quarries and related works. They have been compiled from Bureau of Mines publications covering the safety experience of engineers before and during the war in the mineral industry, from a publication of the National Safety Council, Inc., from explosives recommendations made by various explosives manufacturers, and from suggestions obtained from quarries visited.

The second objective is to describe and illustrate safety devices, practices, and quarrying methods.

The quarrying and related industries of the United States had a lower accident-frequency rate than either the metal- or coal-mining industry as reported for 1942. However, the quarry industry ranked eleventh in 15 major industries during 1942 in lost-time accident frequency; metal mining ranked fourteenth and coal mining fifteenth.

According to published accident statistics, the accident-frequency rates for both fatal and nonfatal accidents in the quarrying and related industries dropped rapidly from about 1916 to 1932. From about 1933 to 1942 the rates fluctuated, showing only slight improvement over the entire period.

During the war the increased demand for critical material produced by some non-dimension-rock quarries, such as those producing rock for the manufacture of portland cement and others producing rock for aggregate, necessitated increased mechanization to maintain production in spite of dwindling manpower. The mechanization and the
employment of green labor required additional safeguards and safety measures to prevent a sharp rise in accident-frequency rates. Accident statistics for the entire quarrying industry during the war period have not been published, but from partial unpublished statistics it appears that, though a slight rise is indicated, the precautionary measures taken by the quarrying industry did prevent an undue rise in the number of accidents.

ACKNOWLEDGMENTS

Grateful acknowledgment is made to the various companies and their officials for the many courtesies extended while their operations were visited and for their cooperation and assistance in obtaining the material in this paper.

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ACCIDENT DATA

The recommendations and suggestions for the prevention of quarry accidents in this paper are discussed insofar as possible under the principal causes of quarry accidents as given in the Bureau of Mines yearly statistics of such accidents. Since this paper does not include underground quarry operations, accidents that occurred in such operations are not included in table 1, but accidents that occurred in outside works related to quarries are included.

QUARRY TYPES AND METHODS

There are two general types of surface quarries, open-cut and side-hill excavations. The open-cut quarries are pits excavated below the surface of the ground, and the sidehill excavations are used in hilly or mountainous areas where the material to be mined is above the general ground level. The height of the operating face in either type of quarry varies greatly; some quarries have a single, relatively high face, and others have two or more benches or faces. The height of the face is regulated by such factors as the type of equipment used, the condition of the walls, the dip of the strata in a stratified deposit, the necessity for having a fairly uniform product after blasting, and the wishes of the operators. Quarrying is done by underground methods where there is excessive overburden or where the deposit dips steeply. The term "quarry" is used as defined by Webster, "an open excavation, usually for obtaining building stone, slate, or limestone."

The drilling and blasting method used depends largely on the physical characteristics of the material to be quarried—whether it is flat-beded or the bedding dips steeply, whether it is massive or contains many fractures, and whether it is a hard or relatively soft and disintegrated material. Figure 1, A, is a typical example of a flat-beded limestone quarry containing numerous vertical fractures.
Figure 1.—A, Typical flat-bedded eastern limestone quarry; B, boom of dragline used in scaling quarry face; C, overburden sloped back from stripped area above quarry face.
TABLE 1.—Number and causes of accidents, 1933 to 1942, inclusive, in quarries
and related outside works

<table>
<thead>
<tr>
<th>Cause of accidents</th>
<th>Number of total accidents</th>
<th>Percentage of total</th>
<th>Number of nonfatal accidents</th>
<th>Percentage of total</th>
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</thead>
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<tr>
<td>Falls or slides of rock, walls, or overburden</td>
<td>137</td>
<td>19.8</td>
<td>2,688</td>
<td>5.4</td>
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<td>Drilling and channeling</td>
<td>5</td>
<td>0.7</td>
<td>1,520</td>
<td>3.0</td>
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<td>Explosives</td>
<td>106</td>
<td>15.3</td>
<td>561</td>
<td>1.1</td>
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<td>Falls of persons</td>
<td>90</td>
<td>13.0</td>
<td>4,853</td>
<td>9.7</td>
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<td>Machinery</td>
<td>107</td>
<td>15.5</td>
<td>5,190</td>
<td>10.3</td>
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<td>Haulage</td>
<td>79</td>
<td>11.4</td>
<td>3,303</td>
<td>6.6</td>
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<tr>
<td>Electricity</td>
<td>40</td>
<td>5.8</td>
<td>405</td>
<td>1.1</td>
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<td>24</td>
<td>3.5</td>
<td>12,490</td>
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<td>Flying objects</td>
<td>28</td>
<td>4.0</td>
<td>6,083</td>
<td>12.2</td>
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<tr>
<td>Falling objects (other than No. 1)</td>
<td>5</td>
<td>1.2</td>
<td>6,083</td>
<td>12.2</td>
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<tr>
<td>Burns</td>
<td>16</td>
<td>2.3</td>
<td>1,678</td>
<td>3.4</td>
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<tr>
<td>Other causes</td>
<td>52</td>
<td>7.6</td>
<td>8,519</td>
<td>17.2</td>
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<tr>
<td>Total</td>
<td>692</td>
<td>100.0</td>
<td>49,897</td>
<td>100.0</td>
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CAUSES AND PREVENTION OF ACCIDENTS

FALLS OR SLIDES OF ROCK, WALLS, OR OVERBURDEN

Falls or slides of rock from walls or overburden, one of the principal causes of both fatal and nonfatal accidents in quarries, accounted for 20 percent of all quarry fatalities and for 5 percent of all nonfatal accidents in quarries during the period 1933–42 (see table 1).

Falls and slides of rock depend largely on the condition of the quarry face. This includes: (1) Natural characteristics, such as angle of bedding, dip, hardness, and extent and nature of fracturing; (2) the method of drilling and blasting, which includes the spacing of holes and the kind and amount of explosives used; and (3) scaling of the face after blasting.

SCALING METHODS

Scaling of quarry faces by hand, especially high faces, is a hazardous operation even when safety belts and lines are provided to protect scalers. In steep-beded deposits, fracturing parallel to the face may prevent adequate scaling, and slides of rock may occur after all apparent loose rock has been scaled down. When inspection of the top of the bank above the face discloses such slips or fractures, the material should be blasted down before men are allowed to work under the face. Vertical walls are recommended in relatively flat bedded deposits, but they are generally hazardous in steep-beded deposits.

Mechanical scaling by means of the shovel dipper is probably the safest method of scaling, but this can be employed only where the height of the quarry face is within the shovel-dipper reach. Mechanical scaling of high faces may be done by using a dragline bucket under certain conditions, but the terrain above the quarry face must be such that the dragline may be placed on the bank above the quarry face. At one large limestone quarry where a single vertical face about 125 feet high was being quarried, a dragline was utilized for scaling; the face was extremely ragged and contained boulders that might have fallen and injured or killed the shovel operator. Scaling this face by hand would have been extremely hazardous, and operating the
CAUSES AND PREVENTION OF ACCIDENTS

shovel at the face was considered dangerous unless the face was scaled. An accident had previously occurred in this quarry in which a shovel operator was pinned in the shovel cab by a large rock falling from the face; fortunately, he was not injured. Figure 1, B, shows the boom of the dragline extending over the face of the quarry.

Quarry walls should be inspected daily, and persons should not be allowed to work under places where falls or slides of rock or overburden might occur. Walls should be inspected and scaled, where necessary, of loose rock after every blast, rain and freeze, or thaw before men are allowed to work under quarry faces. Life lines and belts should be used during all scaling operations and should be inspected frequently to be sure that they are in safe working condition. Life lines should be securely anchored and frequently tested.

Abandoned quarries or quarry faces that are inactive and therefore not subject to inspections or scaling should be fenced or barricaded, and signs should be posted warning persons of the danger of falling rock.

OTHER PRECAUTIONS

Slides or falls of overburden are a potential source of accidents, especially in sidehill quarries. The overburden should be stripped to bedrock at least 10 feet back from the face. Sidehill quarries should have the overburden removed at least 15 feet from the face of the quarry. The overburden should then be sloped to its angle of repose throughout its entire length, and precautions should be taken to prevent wash and slides from falling into the quarry. Figure 1, C, shows such a condition at a limestone "glory hole" operation. Quarries located on steep hillsides, where there is danger of rolling or sliding material, should be protected by the use of baffle boards, screens, cribbing, or other effective method.

Persons, except those assigned to make it safe, should be prohibited from working at the face of a pit or quarry where the material slopes at an unsafe angle. The persons designated should be required to use safety belts and life lines while so employed. The management should furnish and maintain in a safe condition safety belts and life lines used in this work. The life lines should be held by a second employee or securely lashed to a fixed object in such a manner that the employee cannot fall.

All persons employed on ledge operations in deep-pit quarries should be required to use life lines and safety belts on the top cut, when cleaning ledges, when within 15 feet or less of the edge on ledges inclining toward the pit or any cut, when within 3 feet of the edge on ledges pitching away from the pit, or at any other time when life and limb are in danger while working on the ledge.

Life lines may be used as belts. Snub tenders watching life lines should keep the lines snubbed at all times to a fixed object.

All deep-pit quarries with faces over 100 feet high should be provided with shelters or refuge places a safe distance from the working face. These shelters should be large enough to accommodate all men working in danger zones.

In quarries where the multiple-bench method is used, the benches should be at least 10 feet wide, and the outer edge of each bench should be protected against material falling over the edge, with possible
injury to workers below. The preferred method of working multiple benches is to stagger the working places so that men will not be working directly below each other.

**DRILLING AND CHANNELING**

Although the statistics in table 1 show drilling and channeling as a relatively slight cause of both fatal and nonfatal accidents in the quarrying industry, they are important phases of quarrying. Many accidents connected with drilling or channeling probably are charged to other causes. For example, particles of rock or steel in eyes, although readily connected with drilling, probably would be charged to flying objects; injuries sustained from workers slipping or stumbling while drilling could be charged to falls of persons; and sprains caused from improper lifting of drills or drilling equipment might be charged to handling material. Such accidents will therefore be discussed under drilling and channeling, although they could be classed under other causes.

Table 1 shows that there were only five fatal accidents in quarries attributed to drilling in the 10-year period 1933–42, amounting to 1 percent of all fatal accidents. There were 1,520 nonfatal accidents attributed to drilling, amounting to 3 percent of all nonfatal accidents in the quarrying industry.

**WELL (CHURN) DRILLS**

The well or churn drill is probably the most widely used type of drill in non-dimension-stone quarries. Its use is limited to vertical holes, and it is not generally used on steep hillsides where preliminary benches or roads are required on which to place the drill. Both electric and internal-combustion engine-powered well drills are in use, the electric drills being the most common. Well drills are used for drilling deep holes and are not generally considered economical for drilling holes less than 20 feet deep. The principal advantage of using well drills is that relatively large diameter holes are drilled which hold a sufficient amount of explosives to break the burden of rock; for the same reason, holes may be spaced at greater intervals than those drilled with other types of drills that make smaller-diameter holes.

Generally, a larger tonnage of rock is broken when blasting with well drill holes than when small-diameter drill holes are used; thus primary blasts are required less frequently. In some types of rock better fragmentation is obtained when closely spaced, small-diameter drill holes are used; however, this depends largely on the characteristics of the material blasted. Some quarries spring the drill holes in order that a larger charge of explosives may be loaded in the bottom of the drill hole; this permits a wider spacing of the drill holes, and in some instances better fragmentation results.

When well-drill holes are being drilled, workers should never work under a suspended string of tools. The tools should be lowered to the level of the platform. If the heavy wrenches and other tools used around drill rigs are dropped, they may cause serious foot injuries. The use of protective footwear will aid in preventing such accidents. Drillers should remove all unnecessary tools and equipment from the platform before changing bits. Falls of persons from the operating
platforms of well drills have caused accidents; such accidents can be reduced by providing guardrails around the edge of the platform. Figure 2, A and B, shows guardrails on well-drill platforms. C is another view of the same well drill shown in B and shows the necessity for guardrails, since a workman falling from the front edge of the platform might drop to the quarry floor, a distance of over 125 feet.

The well drill should be stopped before the machinery and parts are greased; moving parts should be guarded where possible. To prevent accidents from broken, flying cables on well drills, the cables should be inspected frequently and replaced promptly when found to be unsafe.

Men working at the top of the mast on well-drill rigs should wear safety belts as a protection against falls. Handrails provided on the sides of the ladderway to the top of the mast on some types of drills afford protection against falls from slipping. Figure 3, A, shows cables used for handrails on a well-drill rig of this type.

Accumulations of drill sludge in pools at or near the drill should be avoided when it is practicable to do so. Splashing mud from a drill hole is a frequent cause of eye injury; employees should be required to wear safety goggles when working at the front end of the drill, or they should be cautioned to keep their heads away from the collar of the hole after drilling water is added.

Well-drill holes that are left open are hazardous; drillers should be required to block the finished drill hole before moving to a new location.

Electrical repairs should be made only by a qualified electrician and not by the driller or helper. Electric drills should be grounded when in operation. The electric power cable should be kept out of water as much as possible; slack cable should be coiled in a safe place and protected from damage. Insulated tongs or insulated cable hooks should be used in handling the electric power cable when the power is on.

Good housekeeping is essential around well-drill rigs for preventing accidents caused by stumbling.

**WAGON DRILLS**

A wagon drill consists of a heavy pneumatic hammer drill mounted on a long drill guide or mast. The whole assembly is mounted on a steel chassis, and drilling may be done from any angle from vertical to horizontal. The chassis usually is mounted on two automobile-type rubber-tired wheels and is equipped with a smaller rubber-tired wheel in the rear for steering the rig. At a western quarry, air-operated, self-propelling devices were installed on the wagon-drill rigs to assist in moving them over rough ground. The device, shown in figure 3, B and C, consists of an air motor direct-connected to an automobile-type rear-end assembly, which in turn is connected by chain-and-sprocket drives to the two rubber-tired wheels. It is also provided with a clutch so that the drive may be disengaged when the rig is being towed. It was stated that many accidents had occurred from rigs getting out of control and turning over while being moved before the installation of these devices.

Wagon drills are somewhat top-heavy because of the high mast or drill guide, and accidents caused by the drill rig upsetting while
Figure 2.—A and B, Guarded platform of well drill; C, well drill above 125-foot vertical face.
being moved are not uncommon. The drill should be lowered to the bottom position on the mast before the drill rig is moved and when the drill is not in operation. To prevent the drill from falling when in a raised position and possibly injuring the operator, the hoisting rope or chain should be inspected frequently and replaced promptly when it shows signs of deterioration.

Wagon drills are used quite extensively in quarries for drilling vertical down-holes, which are similar to those drilled by well drills, except they are much smaller in diameter. The holes are usually not over 3½ inches, while well-drill holes are from 5½ to 12 inches in diameter. Wagon-drill holes rarely exceed 40 feet in depth, while well-drill holes 150 feet or more in depth are not uncommon.

Well drilling and wagon drilling are about equally hazardous, but the use of wagon drills is becoming more extensive because of the trend toward using lower quarry faces, which in some instances is a safer operation. The depth of holes necessary for average benches is within the drilling limits of wagon drills. Because of the faster drilling speed of the wagon drill, more holes may be drilled in the same length of time than when using well drills. Holes may be spaced closer, and this may result in better fragmentation and less secondary blasting.

Wagon drills are frequently used for drilling nearly horizontal toe holes from quarry floors. Such drilling is frequently done under relatively high faces, and the drill operator is exposed to the hazard of falling or sliding rock. When drilling in such places, the driller should have an assistant to watch for rock falls or slides of rock from the face. Figure 4, A, shows a high quarry face where falls and slides of rock are apparently imminent and where a wagon drill is operated under the face. In this case an assistant was on duty and evidently needed.

Toe-hole drilling, especially under high faces or banks, is unusually hazardous, and care should be taken to trim the bank before a hole is started. When blowing out a hole with a blow pipe, the driller and helpers should wear goggles. Soft metal hammers should be provided to loosen drill steel in the hole. Drillers should be prohibited from using hard-faced hammers to hammer the drill steel.

**JACKHAMMER DRILLS**

Jackhammer-type drills are used quite extensively in quarries for both primary and secondary drilling. In some hillside quarries and in "glory hole" operations their principal use is in the drilling of down-holes from narrow benches. They are used to some extent in drilling toe holes from quarry floors and are used almost exclusively in the drilling of boulders, or blockholing.

Jackhammer drilling in quarries is generally a more hazardous occupation than drilling with other types of drills. Various accident hazards are present when drilling down-holes with jackhammers from narrow benches which often are only about 4 feet wide; these benches afford insecure footing which may result in serious falls. Falls of persons caused from insecure footing or from overbalancing are likely to occur when deep down-holes are drilled with jackhammers. The holes often are 20 or more feet in depth and changing drill steel is difficult under these conditions. Safety belts and life lines should be a must when drilling in such places. The hazard from rocks rolling
down from bench to bench and causing injuries to drillers is serious; strict supervision should be maintained to see that all benches are trimmed after blasting and before drilling operations commence. Bars used in trimming banks should be blunt on one end. Protective footwear will aid in preventing injuries from rolling and falling rock.

Figure 4.—A, High quarry face where a wagon drill is used for drilling toe holes; B, typical blockhole drilling on a quarry floor.
and, from a safety standpoint, quarry planning should eliminate the necessity for drilling in dangerous places.

Drilling of boulders, or blockholing, is done with jackhammers, both on the slope of the blasted material below the quarry face and on the quarry floor. Drilling of boulders on the slope is particularly hazardous because of the proximity of the vertical face above the driller who might be injured from falling rock or from loose rock rolling or sliding down the slope; such drilling is frequently done from insecure footing. The driller should stand facing the bank to observe better any movement of rock above him. Figure 4, B, shows a typical blockholing operation on the floor of a western quarry. Drilling from insecure footing may result in sprains from slipping while drilling or while removing stuck drill steel from the hole.

In some quarries the hazards from blockholing on the slope of blasted material are eliminated by removing the boulders from the slope to the quarry floor, whenever possible, by the dipper on the shovel. In some quarries the boulders are then pushed a safe distance from the face and slope by a bulldozer so that they can be drilled from a more secure footing, and the drillers will be out of the way of falling or rolling rocks. Drillers working close to the bottom of the face or at the foot of a bank of broken rock should be required to wear hard hats. Protective footwear should be worn by all blockhole drillers to prevent foot injuries from falling rock and drills or other drilling equipment. In some quarries protective clothing such as safety hats and shoes is mandatory for all quarry workers. Drilling in the "boots" of old drill holes should be prohibited as unexploded dynamite may be concealed in the boot.

Eye injuries caused from flying objects, such as particles of rock or steel, are common to blockhole drillers who do not wear safety goggles. The use of soft metal-faced hammers for removing detachable bits from drill steel will aid in the prevention of accidents from flying particles of steel. Safety goggles will protect the eyes from flying rock particles when blowing out drill holes with compressed air.

Insecure or faulty connections of compressed-air hose present an accident hazard. Connections should be made secure, and the couplings should receive frequent inspections; defective couplings should be replaced promptly. No attempt should be made to adjust or repair air connections until after the air pressure has been removed from the line.

OTHER TYPES OF DRILLS

Rotary drills are sometimes used in quarries in place of churn drills; the drilling speed is considerably faster than with well drills in most rock formations. Most of the recommendations for safety in well drilling apply to rotary drilling.

Drills used in granite and other dimension-stone quarries are pneumatic hammer drills of the heavy "drifter" type, mounted on a heavy, cylindrical steel quarry bar, 5 to 6 inches in diameter and 10 to 12 feet in length. Two drills often are mounted on the same bar. The bar, known as a quarry or channel bar, is attached at each end to a pair of steel legs adjustable in length and pointed on the bottom ends. The bar, when mounted on the four legs, has the appearance of a sawhorse. The drill is equipped with an attachment for holding a broaching tool so that both drilling and broaching can be done. Since
the complete assembly is heavy, weighing more than a ton in some instances, it cannot be moved by hand and usually is moved to new locations in the quarry by means of the stiff-legged derricks normally used for hoisting stone from the open pit.

The pointed ends of the steel legs are designed to prevent the drill rig from slipping, but instances have been reported of the drill slipping and upsetting on inclined surfaces, causing serious injuries to the operator. A safety rule for preventing accidents of this type is in effect at one granite quarry; the rule stipulates that shallow holes should be moleed in the granite base and that each leg of the rig should be set in such a hole before drilling operations were commenced.

EXPLOSIVES

During the 10-year period 1933–42, 106 fatal and 561 nonfatal accidents in quarries were caused by explosives. This was 15 percent of all the fatal accidents but only 1 percent of all nonfatal accidents (see table 1). The severity of explosives accidents is shown by the above figures—approximately one fatality for every five nonfatal accidents, which is by far the highest ratio of fatal to nonfatal accidents in the quarry industry. Because of the high percentage of fatalities, it is essential that adequate safety rules for the storage, transportation, and use of explosives be rigidly enforced. The various explosives manufacturers have published much valuable information relating to the storage, handling and use of explosives, including numerous recommendations which, if strictly followed, would prevent many of the accidents caused by explosives.

The Bureau of Mines over a period of several years has conducted much research in its laboratories and in its Explosives Testing Station at Bruceton, Pa., on the safe use of explosives; and, in addition, it has acquired much valuable information on the safe storage, handling, and use of explosives from field engineers. Data from the above sources have been freely used in compiling the following recommendations:

STORAGE

Detailed descriptions of recommended construction of explosives magazines are found in Standard Storage Magazines, published by the Institute of Makers of Explosives, and in Bureau of Mines Information Circulars 7307, Surface Storage of Explosives, and 7380, Safe Storage, Handling, and Use of Commercial Explosives in Metal Mines, Nonmetallic Mines, and Quarries. Three general types for permanent magazines are described: Brick; filled construction; and portable steel, lined with brick or other material. Recommendations are made also as to the construction of box-type magazines.

The following precautions apply to magazines:

1. Magazines should be constructed of bullet-resistant material, unless they are to be used exclusively for storing black blasting powder.

2. Magazines should be well-ventilated, both in the roof and in the foundations, to protect the explosives from heat and extreme changes in temperature that may cause the explosives to deteriorate. The openings for ventilation in the foundation should be
enclosed in such a manner as to prevent the entrance of persons, animals, rubbish, sparks, and firebrands, or the direct penetration of bullets that can detonate the explosives.

3. A box-type magazine may be used for storage of small amounts of explosives or as an operations storage box for a daily supply.

4. Magazines should not be used to store material other than explosives. Blasting caps, electric blasting caps, or any type of igniter should be stored in a separate magazine and not with high explosives or black blasting powder. Fuse and detonating fuse can be stored safely in an explosives magazine.

5. Open flames of any kind should not be permitted in or around a magazine; and if artificial light is needed, only electric flashlights or electric lanterns should be used. Oil-burning and chemical lamps or lanterns, candles, and matches should be prohibited.

6. The premises on which a permanent magazine is situated should be marked conspicuously by signs containing the words "EXPLOSIVES—KEEP OFF."

7. Barricades around magazines greatly reduce the extent of the danger to persons and property in the surrounding area as the force of an explosion is directed upward by the barricade. All permanent magazines should be barricaded.

8. Smoking should not be permitted in or around magazines.

9. A site for the magazine should be chosen which will comply with the American Table of Distances insofar as feasible. Non-conforming existing magazines should be made to conform to the American Table of Distances, if feasible, by the construction of barricades. The magazines should not be located within 200 feet of any vital building or structure or from any mine shaft, tunnel, or slope opening. Figure 5, A and B, illustrates concrete and dirt barricades. The barricades were required in order to comply with the American Table of Distances.

10. The interior of the magazine should be kept clean and dry at all times.

11. The floors of magazines should be constructed of nonsparking material, preferably of wood with no exposed metal.

12. There should not be any exposed sparking metal on the inside of the magazine that will come in contact with explosives.

13. To prevent brush fires from reaching magazines, trees should be kept trimmed; grass, weeds, and underbrush should be cut; and the open ground around magazines should be kept free of dry leaves or other combustibles for a distance of 25 feet from the magazine (see fig. 6, A).

14. Explosives should be stored in such a manner as to assure the issuance of the oldest stock first, and the cases should not be stored on their ends.

15. Detonator magazines should be at least 50 feet from explosives magazines if barricaded and at least 100 feet if not barricaded.

Figure 6, B, illustrates a well-built, semi-dugout-type explosive-storage magazine.
TRANSPORTATION

Much information on the safe transportation of explosives is available in regulations of the Interstate Commerce Commission, from the Bureau of Explosives of the American Railway Association, the Bureau of Mines, the National Safety Council, and other organizations. Nevertheless, transporting explosives from the railroad car to the storage magazine and from the storage magazine to the point of use is sometimes done with little consideration of safety. Such transportation is very often poorly supervised, if at all, and the safety of the operation depends almost entirely on the dependability and knowledge of the men involved.

The following minimum standards should apply for transporting explosives by vehicle, both from magazines to near point of use and from railroad or manufacturer to magazines:

1. Any vehicle transporting explosives should be marked or placarded on the front, each side, and the rear with the word "EXPLOSIVES" in letters not less than 4 inches high in colors contrasting with the background, or the vehicle should carry in a conspicuous place a red flag not less than 24 inches square with the word "EXPLOSIVES" in white letters at least 3 inches high or the word "DANGER" in letters 6 inches high.

2. The floors of all vehicles used for transporting explosives should be tight. Any exposed sparking metal on the inside of the body that might come into contact with any package of explosives should be covered or protected with wood or other non-sparking material.
FIGURE 6.—A. Explosives-storage and detonator-storage magazines. Construction, distances, housekeeping, and sign all comply with recommendations for safe storage; B. a well-built, semi-dugout-type explosives-storage magazine; C, opening a wooden case of explosives with wooden tools away from the magazine.
3. Explosives should not be transported in any form of pole-type trailer; no such trailer should be attached to a vehicle hauling explosives.

4. Vehicles transporting explosives should not be overloaded, and in no case should the explosives containers be piled higher than the closed sides of the body.

5. Vehicles transporting explosives should be inspected to determine that the vehicle is in condition for safe transportation of explosives. This inspection would include the brakes, steering mechanism, electric wiring, fuel tank and fuel lines (to be sure that the latter are not leaking), and the body or chassis (to check against accumulations of oil or grease).

6. Vehicles transporting explosives should be driven only by authorized, competent persons.

7. Packages or containers of explosives should not be thrown, dropped, or otherwise roughly handled while being loaded or unloaded. All explosives should be transported in the original shipping containers or in some other suitable container.

8. Blasting caps, electric blasting caps, and any form of igniters that are not in the original shipping container should not be hauled in the body of a truck with explosives.

9. Metal, metal tools, oils, matches, firearms, acid, or flammable substances should not be carried in the body of a vehicle transporting explosives.

10. Unauthorized persons should not ride on a vehicle transporting explosives.

11. Smoking or carrying matches should not be permitted on or around a vehicle transporting explosives.

Many commercial companies have additional rules governing their employees while engaged in the transportation of explosives. Transportation of explosives by hand in quarries is generally part of the loading operation of drill holes and is done by the blasting crew. The qualifications and duties of blasting crews are discussed under “General Use.”

GENERAL USE

Three essentials for avoiding accidents in the use of explosives are: (1) Competent blasters, (2) exposure of only the men necessary to handle explosives, and (3) enforcement of regulations for the safe handling of explosives. Blasting crews should be composed of careful, experienced men who understand the hazards of explosives and who can be relied upon to observe all safety precautions while handling explosions. The number of men used in loading operations should be kept to a minimum, and all persons not engaged in loading should be prohibited from entering the loading zone. To lessen the time of exposure and to prevent confusion, the blasting crews should be well-organized, and each man assigned to a specific task.

A premature explosion in a Pennsylvania quarry in which 31 men were killed is an example of unnecessary exposure of a large number of men; other unsafe practices were also involved. The premature blast occurred while the loading crew and several other quarry workers who were not connected with the loading of a row of well-drill
holes were eating lunch in the vicinity of the holes being loaded. The cause of the premature explosion was not determined definitely; the boxes of explosives piled at each hole were detonated, as well as a roll of Primacord that was near the hole being loaded. As all persons in the vicinity of the blast were killed, exactly what caused the detonation will never be known.

The following covers recommended practice in the use of explosives in quarry blasting:

OPENING EXPLOSIVES CONTAINERS

1. Kegs or wooden cases of explosives should not be opened with metallic tools; a wooden wedge and a wooden, rubber, or fiber mallet should be used for this purpose. (See fig. 6, C.) A metallic slitter may be used for opening fiberboard cases, provided it does not come in contact with the metallic fasteners of the case.
2. Boxes of explosives or kegs of black blasting powder should not be opened inside a magazine.
3. Boxes containing pellet powder should be opened in the same manner as recommended in No. 1. This also applies to free-running or “bag” powder when packed inside wooden cases.

CHARGING HOLES, GENERAL

1. Explosives that are so hard that a punch cannot be inserted for priming or that are believed to be substandard in any other respect should not be used.
2. Low-freezing or nonfreezing explosives should always be used. If explosives are believed to be frozen, no attempt should be made to use them or thaw them, but rather the manufacturer should be notified.
3. All holes for blasting should be checked before attempting to charge explosives.
4. High explosives in small boreholes should be tamped with only enough force to collapse the cartridge. Excess ramming should be avoided. The primer cartridge should never be tamped.
5. Tamping sticks should be made of wood, with no exposed metal parts. Jointed wooden tamping sticks, with exposed couplings of nonsparking material, may be used in long holes.
6. Blasting caps and/or electric blasting caps should be kept separate and apart from other explosives until ready to be used.
7. The diameters of dynamite cartridges should be small enough so that the cartridge can be pushed or lowered readily into a drill hole. Loose-fitting cartridges may be compacted by using the tamping stick for this purpose.
8. Smoking should be prohibited while explosives are being handled or used.
9. Open-flame lamps, or other source of fire, flame, or sparks should not be allowed where explosives are being handled or used.
10. Explosives should not be transported on the quarry property, handled, or used immediately before or during an electrical storm.
11. Safe shelters should be provided to accommodate all employees in the danger zone when secondary blasting is being done.
12. All drill holes should be stemmed to assure maximum efficiency from explosives.

13. Drill holes for secondary blasting should be drilled deep enough to accommodate the charge of explosives as well as sufficient stemming to confine the charge.

14. Rocks so large as to require more than one hole to break them should be blasted electrically or with detonating fuse so the charges will explode simultaneously.

15. A blast should not be fired until all surplus explosives are in a safe place, all persons and vehicles are at a safe distance or under sufficient cover, and a definite period has elapsed after adequate warning has been given.

**PRIMERS**

A primer consists of a cartridge of explosives with some means of firing it attached to the cartridge.

Primers should be made carefully, in accordance with the data published by the makers of explosives, and should satisfy the following general requirements:

1. The detonator (blasting cap or electric blasting cap) or igniter should be placed in the safest and most effective position in the primer cartridge and should be attached to it in such a manner that it cannot be readily pulled loose from the cartridge.

2. The detonator should be placed in the primary cartridge of explosives in such a manner that the fuse or leg wires of electric blasting caps are not strained while the hole is being loaded.

3. The primer assembly of cartridge and detonator should be made so that it can be loaded safely, easily, and in the correct position in the charge.

4. The primer should be made waterproof if used in wet work. This can be done by sealing the openings in the primer cartridge with soft soap or wax.

Certain definite standards are recognized as increasing the efficiency of the primer in blasting operations and also definitely decreasing the hazard attending the preparation of the primer and its placement in the charge. Some of these are listed below, but they should be considered as only the minimum requirements:

1. Dynamite cartridges used for primers should not be slit, as the whole cartridge is necessary to hold the detonator in position and to protect it from abrasion or blows during loading.

2. Fuse should be cut squarely across with a clean, sharp blade or cutter and seated lightly against the cap charge. The cap should be crimped tightly, using only a hand or bench-type crimper. Crimping caps with the teeth, a knife, or any tool other than a crimper should be prohibited.

3. The long axis of the detonator should lie as nearly as possible in line with or parallel to the long axis of the primer cartridge, and in small drill holes the detonator preferably should point toward the bulk of the charge of explosives.

4. Primers made with fuse and blasting caps should be assembled so that the cap is in the center of the primer cartridge and the fuse has no sharp bends, kinks, or knots. Two recom-
mended methods for assembling this type of primer are shown in figure 7.

5. Primers made with electric blasting caps should be assembled so that the leg wires will not slip off or permit the cap to be pulled out of the cartridge, and there are no sharp kinks, knots, or overlaps in the wires that may cause the wires to break or to cut into each other through the insulation. Two assembly methods are shown in figure 8.

6. Detonating fuse, if used to fire a column of explosives, should extend the full length of the column of explosives. The detonating fuse may be lowered to the bottom of the hole by attaching it to the first cartridge loaded.

DETONATING WITH FUSE AND BLASTING CAPS

The use of fuse and blasting caps for detonating primary blasts in quarries is limited. Primacord, electric detonators, or a combination of both is considered to be safer as well as more efficient for detonating large quarry blasts.

The principal use of fuse in quarries is in blockholing and mudcapping; however, some operators consider electric detonators safer and more efficient for this type of blasting. Electric blasting is replacing, to some extent, the use of fuse and blasting caps in secondary blasting. In quarries where fuse and blasting caps are used, there are many safety precautions that should be observed to prevent accidents from explosives.

Using too short a fuse has been a common cause of accidents. The minimum length of fuse should comply with requirements of State law or company management, but no fuse should be less than 30
inches in length. The length of fuse to be used where more than one fuse is spit at a time should be determined by the management. Normally, not over 12 fuses should be lighted by each blaster.

Commercial fuse is manufactured with two standard burning speeds; the fuse most commonly used has a burning speed of 40 seconds per foot and the other a burning speed of 30 seconds per foot. The burning rate of fuse should be tested at frequent intervals, and the rate conspicuously posted where it will be observed readily by users. One desirable advantage of posting is to familiarize users with the normal burning rate of fuse. A considerable number of workmen engaged in blockholing have been asked regarding the burning rate of fuse, and many answered "a foot a minute." This dependence on "a-foot-a-minute" rate, plus a possible variation of 10 percent in the normal burning rate of 40 seconds per foot, could

Figure 8.—Recommended methods for making primers with electric blasting caps.
readily cause accidents from blasts occurring before the blaster had retreated to a safe distance. As an example, take a 4-foot fuse that burns 10 percent faster than the normal burning speed; its burning time would be 160 seconds less 10 percent or 144 seconds (2 minutes, 24 seconds). Using the "a-foot-a-minute" belief, the assumed burning time would be 4 minutes, and the blaster would therefore believe, erroneously, that he had 1 minute and 36 seconds longer time to reach safety than he actually had. Many accidents that are blamed on fuse burning too fast are probably due to not knowing the actual burning speed of fuse.

In some quarries precautions are taken to prevent accidents that are caused by blasters staying too long after spitting several fuses in blockhole blasting. A fuse, 2 feet shorter in length than the fuse used in blasting, was attached to a blasting cap and was spit at the same time the blasters received the signal to start spitting the round. When the blasting cap on the warning fuse detonated, another signal was given the blasters warning them to cease spitting and to retreat to a safe place. Figure 9, A, shows a warning fuse and blasting cap being spit and placed in an iron pipe. The warning whistle is also shown as well as the iron shelters into which the blasters retreat after spitting the fuses.

Fuse that has been stored in too warm a place may cause misfires, as the weatherproofing material may have melted and penetrated the powder train or the fuse may have dried out enough to cause cracks through which water can penetrate the powder. Fuse should not be uncoiled when cold as it may crack and allow moisture to reach the powder train. Cold fuse should be warmed at 70° to 80° F. before uncoiling it. Fuse should be cut with a sharp instrument to prevent the waterproofing material from smearing over and sealing the freshly cut end. The fuse should be cut squarely across the end, as a long, diagonal cut may not permit the powder train to be in close enough contact with the detonating material in the blasting cap; the long end may even bend over in the cap so that the powder train is sealed off from the detonating charge in the blasting cap.

Grease should not be used for waterproofing, as most greases contain light oils that may penetrate to the powder train or to the detonating material in the cap and cause misfires. Paints containing light oils should not be used for the same reason. The use of a cap-sealing compound, miner's soap, or wax is recommended. Sharp bends and kinks should be avoided in handling fuse.

Some of the commonly recognized safe practices in fuse blasting, which are minimum standards, are listed below:

1. Blasters or shot firers should know the burning speed of the fuse that is being used.
2. Blasters or shot firers should always use sufficient fuse and an adequate warning signal or system that permits those present to reach a safe place before the first hole fires.
3. An effective lighter should be used in lighting fuse. Several types of good lighters are on the market.
4. The use of cigarettes, burning paper, or improvised torches for lighting fuse should be prohibited.
5. Fuse should not be allowed to come in contact with oils, paints, kerosine, gasoline, distillates, or similar solvents.
6. In wet work, the joint between the fuse and cap should be made waterproof; no substance containing oil should be used for this purpose.

7. When charges of explosives are to be fired in rotation, a good practice is to dip the uncapped ends of the fuse in a contrasting color of paint or dye, for example, black paint on white fuse.
The blaster trims the painted ends of the fuse and thereby eliminates the chance of trimming a fuse twice.

8. Safety fuse and cap blasting should not be used for firing two or more shots which must detonate simultaneously.

9. The end of the safety fuse should be freshly cut and clean before an attempt is made to light the powder train.

10. Precaution should be taken to prevent sharp bends in fuse which may cause a misfire or a rupture in the cover of the powder train whereby a spark may cause a premature explosion.

**DETONATING ELECTRICALLY**

The use of electric detonators in quarries for detonating primary blasts is quite common, especially in the detonation of explosives in wagon-drill holes. They are used to some extent in well-drill-hole blasting, but detonating fuse is generally considered to be a more efficient and safer method for such blasting. The detonating fuse is detonated by either electric detonators or by fuse and blasting caps.

The most important consideration in blasting, either with electric or fuse and blasting cap, is to prevent premature explosions. Probably the next most important consideration is the prevention of misfires or delayed fires, both of which present accident hazards.

One of the hazards encountered in electric blasting is "stray" electric currents, which may be strong enough to fire the cap. The stray currents are caused by poor bonding of the rails if electric haulage is used, by poorly installed electrical equipment, or by other causes.

Some of the safe practices (these are suggested minimum standards only) regarded as standard for electric blasting follow:

1. Electric blasting caps should be protected from electric currents by shunts or by short-circuiting the cap by twisting together the ends of the leg wires until they are ready to be connected into the blasting circuit.

2. Electric blasting caps should be tested individually with a blasting galvanometer before being used. The circuit should be tested with a blasting galvanometer before the shot is fired. No means other than a blasting galvanometer containing a silver chloride cell manufactured for the purpose should be used for testing electric blasting caps or blasting circuits.

3. The insulation on all firing lines and/or leading lines should be adequate and in good condition.

4. Blasting circuits should not be grounded at any point, and bare spots in the wire should not be permitted to touch the ground.

5. A power circuit used for firing should not be grounded.

6. When firing from a power circuit, a master switch should be used. It should be locked in the "open" position at all times except when firing. Keys to the master switch should be entrusted only to the person designated to fire the shot.

7. When firing from a power circuit, one or more safety switches should be placed in the permanent firing line in addition to the master switch used for firing.

8. As a protection from lightning, an air gap at least 5 feet long should be in both wires of the firing line or between the firing lines and the leading lines.
9. All blasting switches should be short-circuited in the "off" position but not grounded.

10. When firing electrically, a two-conductor circuit should be used throughout; that is, the earth, rail, or pipe should never be used as a return circuit.

11. All blasts detonated with electric blasting caps should be fired from a source of current of ample capacity.

12. Electric blasting caps used in well-drill-holes or long, small boreholes should be tested several times during the loading of the hole and should be short-circuited again after each test. Two electric blasting caps are frequently placed in each well-drill hole.

13. Stranded wires should not be used in a blasting circuit.

14. Duplex leading wire should not be used except for firing single electric blasting caps.

USE OF A BLASTING MACHINE OR BATTERY

1. When firing with a blasting machine, the machine, its detachable handle, or the key for its lock should be kept in the possession of the person designated to fire it during the connecting of the blast and until it has been fired.

2. When firing with a blasting machine or battery, the leading wires should not be connected until immediately before firing and should be disconnected immediately after.

3. When firing with a blasting machine, the holes should be connected in series-parallel as recommended by the manufacturer.

4. The number of detonators connected in series should not exceed the rated capacity of the blasting machine.

5. The blasting machine should be kept in good condition and should be tested at regular intervals. The use of a rheostat for testing is recommended.

Misfires in electric blasting frequently are caused by improper handling of the leg wires of the electric blasting caps. Care should be taken not to break or damage the insulation of the wires; they should not be kinked or tied. If the electric blasting caps have enameled leg wires, the connections should be made at the tinned ends; the enameled leg wires should not be cut unless it cannot be avoided. The enamel must then be thoroughly scraped off the leg wires before connecting.

SPRINGING OF BOREHOLES

The springing of well-drill, wagon-drill, or other types of boreholes is a hazardous operation and should be done only by experienced men who are familiar with the hazards involved and who will follow rigid safety rules. Boreholes near loaded holes should never be sprung, as many serious accidents, including fatalities, have occurred from premature explosions where the springing blast has propagated to the loaded hole through underground crevices that were not apparent on the surface. During the construction of a mountain highway the springing of a churn-drill hole adjacent to a line of loaded holes resulted in propagation to all of the loaded holes; the premature blast killed six men.

A rather common but unsafe practice of determining whether a sprung hole is cool enough to permit loading explosives is to insert
the tamping stick or dolly in the hole, remove it, and, if the end is cool to the touch, conclude that the bottom of the hole is cool enough for loading. In such cases smoldering roots, bits of paper from explosives wrappings, or other smoldering debris may be in the hole and ignite the loading charge. Blowing out boreholes with compressed air after springing is recommended as a material aid in cooling the bottom of the hole; water is also used to good advantage in cooling holes. Explosives manufacturers generally recommend ammonia dynamites, preferably gelatinous types, for springing holes. The temperature at the bottom of a sprung hole should be less than 80° F. before it is safe to load additional charges of explosives in the hole. The time required to cool a sprung hole is variable, depending in part on the amount and kind of explosives used in springing and on the nature of the rock. When relatively large springing charges are used, additional explosives should not be placed in the hole until it has been allowed to cool for 24 hours. Electric blasting caps are recommended as the safest method for detonating springing charges; the use of "short fuses" should be prohibited when detonating the springing charge with blasting caps.

**LOADING AND BLASTING WELL-DRILL HOLES**

Loading explosives in well-drill holes is one of the major accident hazards connected with quarry blasting. Generally, several holes are shot at a time, entailing the use of relatively large quantities of explosives and requiring the services of a comparatively large crew of men to load and stem the holes. The workers are exposed for a considerable period to the hazard of premature explosions which, when occurring, usually result in fatalities to a large proportion of the loading crew. Well-drill holes should be loaded under the supervision of an experienced man who is well versed in the many hazards present and in the safety measures necessary for the prevention of accidents. The loading crew should consist of men, trained in such work, who can be relied upon to observe at all times the safe methods of loading that are essential if accidents from premature explosions and misfires are to be avoided. The work should be organized so that the loading will be completed in the shortest possible time consistent with safe loading, and thus reduce the time of exposure. Some of the recommendations considered necessary for safe loading of well-drill holes are:

1. All holes for blasting should be checked before attempting to load explosives. Well-drill holes may be checked with a dolly, tamping block, or by visual inspection with the aid of a mirror.
2. Water standing in well-drill holes should be bailed out, if possible, and the holes loaded with an explosive of adequate water resistance.
3. Blasting crews should be carefully organized and should consist of the minimum number of experienced men to do the work in an efficient manner. Each man should be assigned to definite tasks to avoid confusion.
4. A blast should be planned before loading is started. The planned charge for each hole should be recorded. This will permit the blasting foreman to give his attention to the actual work of loading and the safety of the men engaged in loading.
5. The condition of each hole to be loaded and the quantity, height, and position of the explosives charge or charges placed in the hole should be recorded on the loading chart. The distance from the top of the last charge loaded in the hole to the collar of the hole should be measured accurately, as it is of great value in determining the quantity of stemming that must be removed from a hole in case of a misfire.

6. Members of loading crews engaged in loading well-drill holes should be prohibited from wearing hobnail or steel-plated shoes to avoid striking sparks on rocks.

7. Large dynamite cartridges may be dropped in smooth well-drill holes, but they should not be dropped into a hole unless the hole is free from obstructions throughout its entire length.

8. Large dynamite cartridges should not be dropped in well-drill holes containing excessive water until the charge is above the water level.

9. The lowering of large cartridges of explosives into well-drill holes by the use of a tripod and rope is recommended (fig. 9, B).

10. Large dynamite cartridges that have wedged in a well-drill hole should not be tamped with a dolly, but after water has been poured into the hole attempts to dislodge or pierce them should be made with a spear-shaped wooden tamping block or a small-diameter wooden pole such as is recommended by the explosives manufacturers.

11. Rough or ragged holes and holes partly closed by an obstruction that cannot be removed readily should be loaded with cartriged dynamite lowered with a rope, with free-running powder, or with dynamite cut in small pieces.

12. When a long line of holes is being loaded by more than one loading crew, the crews should be separated by the greatest practical distance that can be maintained as the loading operations progress and is consistent with efficient operation and supervision of the crews. Every effort should be made to keep the loading crews a minimum of 25 feet apart and to prevent simultaneous loading of adjacent holes.

13. When drill holes are to be loaded for blasting, the explosives containers should be stacked in piles at least 25 feet, preferably farther, from the nearest drill hole to be loaded. For a given total amount of explosives in a loading area, it is preferable to have a few piles, each containing relatively large quantities of explosives, rather than to have a large number of piles, each containing small quantities.

The containers should be opened at the piles as needed, and the opened containers carried one at a time to the loading station. This station should be at least 6 feet from the hole to be loaded or from any unstemmed loaded hole and at least 25 feet from the main pile. The quantity of explosives at this point should not exceed 100 pounds.

From this station the explosives should be passed one cartridge or unit at a time for loading into the hole. Empty cases and lining paper should be removed immediately to a waste pile.

14. Excessively large amounts of explosives should not be delivered to the loading area at one time. If deliveries of ex-
Explosives are made by truck, the quantity permitted at or near the loading operations should be limited to one truckload. Other trucks loaded with explosives should wait or be unloaded in separate safe places away from the loading operations.

15. When explosives for a blast cannot be delivered to the loading area by truck or railroad and must be carried to the holes by men, the same care should be taken to avoid having excessively large amounts of explosives in one area.

16. Explosives should be delivered first to the hole farthest from the truck to avoid driving or walking among piles of explosives.

17. Explosives in excess of immediate requirements, when delivered in the vicinity of a blasting operation, should be stored until used in a portable magazine, in a small building if protected by a guard, or in other suitable places properly protected against theft.

18. An ample quantity of suitable stemming or tamping material should be placed by each hole before the delivery of explosives to the holes is started. The stemming material should be screened or free from excessively coarse pieces.

19. Stemming should be placed in each hole as soon as practicable after the loading of the explosives has been completed, being careful to protect the detonating fuse or leg wires of electric blasting caps from damage.

20. Explosives should not be loaded into well-drill holes when there is any danger from sparks, flame, or other sources of ignition. All equipment that emits sparks should be removed or closed down during loading operations.

21. Explosives in well-drill holes may be tamped with a dolly when tamping is required, but the use of a dolly should be kept at a minimum. Extreme care should be taken not to damage the detonating fuse or leg wires of electric blasting caps.

22. Tamping sticks and dollies should not be used when they become badly worn. They should be replaced with new ones before this occurs.

23. Dollies should be checked frequently to insure against the metal weight becoming exposed.

24. Wooden tamping sticks tipped with nonsparking metal should not be used. Metal pipes with a wooden plug in the end should not be used for tamping explosives.

25. Free-running powder that is not loaded in bags should be poured into the hole through a copper funnel. The copper funnel will help to prevent spillage of explosives around the collar of the hole where they might be ignited accidentally or exploded by friction.

26. Detonators, blasting caps, or other explosive material foreign to the proper loading of explosives should not be allowed in the vicinity in which loading is done.

27. As soon as the loading of well-drill holes has been completed, all persons should leave the blasting area except those required to connect the blast for firing.

28. Only those holes that are to be blasted should be loaded.

29. While explosives are being loaded for primary blasts, all
persons not needed to help with loading should be kept away from the area.

DETONATING FUSE

1. Detonating fuse, when used for priming well-drill holes, should be lowered to the bottom of the hole either by attaching it to the first cartridge or by other means. It should then be cut from the reel, and the reel moved well away on to the next hole before any other explosives are loaded.

2. The detonating fuse should extend 1 to 3 feet from the hole to compensate for subsidence. It should be drawn taut and made secure on the top, where it will not interfere with loading or come in contact with explosives on the ground. Before stemming material is used, the detonating fuse should be checked to make certain that it has not been broken.

3. When detonating fuse is used, main or trunk line splices should be factory splices or tight square knots. No splices should be used in the drill hole.

4. Branch-line connections and all connections in the main line other than splices should be tight and at right angles.

5. Main or trunk line should be laid out free of kinks or coils, and all connections should be inspected before the blast.

6. When connecting a blasting cap or an electric blasting cap to detonating fuse, a connector should be used for the purpose, or it should be taped or otherwise fastened securely alongside and at the end of the detonating fuse, with the end of the cap containing the explosives charge pointed in the direction in which the detonation is to proceed.

Caps should not be brought to the loading area or attached to the detonating fuse until all is in readiness to fire the blast.

7. Plain detonating fuse may be used for trunk lines or in shallow drill holes, but reinforced or wire-protected types should be used in deep or ragged holes.

LOADING AND BLASTING SMALL BOREHOLES

The loading of small boreholes, such as wagon-drill and jackhammer-drill holes, probably is less hazardous, insofar as major accidents from premature explosions are concerned, than the loading of well-drill holes. Such holes are generally shallower and much smaller in diameter, requiring smaller amounts of explosives for loading; moreover, a smaller crew of men is required for loading and tamping. The number of men exposed and the time of exposure to premature blasts are therefore considerably less. However, most of the hazards present during the loading of well-drill holes are also present during the loading of small boreholes, and the same precautions should be taken to prevent accidents. To avoid repetition, safety recommendations applying to both types of loading, which have previously been given under "Loading and Blasting of Well-Drill Holes," are not repeated.

Some additional recommendations applying more particularly to the loading and blasting of small boreholes are:

1. Before being loaded drill holes should be blown out with compressed air to remove as much of the drill cuttings as pos-
sible from the hole. Grit is one of the sources of danger when explosives are being tamped in drill holes.

2. The wooden tamping stick should be cut squarely across the end so that it will not puncture the cartridge during tamping.

3. All drill holes should be stemmed with screened material, such as sand, clay, or soil. Soil containing combustible matter, such as leaves, twigs, or other organic matter, should not be used. Stemming not only aids in more efficient blasting but may prevent a premature explosion by stray sparks from fuse or igniters.

4. Electric blasting caps are generally recognized as one of the safest methods of detonating small boreholes in primary blasting. Detonating fuse is not in common use for this purpose.

5. Drill holes should not be loaded while adjacent holes are being drilled.

**TUNNEL OR COYOTE-HOLE BLASTING**

Tunnel blasting is practiced to some extent in certain sidehill-type open quarries, generally where the hillside above the quarry floor is too high or too steep to permit the use of well drills without extensive road work.

Loading of tunnel blasts presents the hazard of accidents from premature explosions. Many of the recommendations for handling of explosives while loading well-drill holes, previously given under “Loading and Blasting Well-Drill Holes,” are applicable to the handling of explosives in tunnel blasting and, therefore, are not repeated.

The following precautions should be taken when loading tunnel or coyote holes for blasting:

1. All members of the loading crews in tunnel or coyote-hole blasting should be required to wear rubbers or shoes without nails.

2. Leading wires should be installed before the loading operations are begun. The leading wires should be suspended from the roof or placed in slotted wooden boxes or troughs with a wooden cover. Copper or brass nails should be used to fasten the covers.

3. Leading wires should be protected at all times from stray currents or from other possible sources of electricity. The outer ends of the leading wires should be kept short-circuited, but not grounded, at all times until the shot is ready for firing.

4. All electric connections inside the tunnel should be covered with insulating tape.

5. Circuits should be tested at least every 10 feet if stemming is placed in the crosscuts, or before each explosives charge is placed in position.

6. Loading operations should be suspended during the approach or progress of an electrical storm.

7. Before the primer is made, electric blasting caps should be tested with a blasting galvanometer. When electric blasting caps are used for primers, two caps should be placed in each explosives charge.

8. Electric blasting caps should have enameled leg wires or equivalent insulation.
9. Detonating fuse, when used, should be suspended from the roof of the tunnel or placed in slotted wooden boxes or troughs with wooden tops.

10. When a tunnel blast is fired with detonating fuse, a double line should be used throughout.

11. All detonating fuse connections should be made tight, at right angles, and otherwise in the manner recommended by the manufacturers.

12. If explosives containers are carried by men, the roadway should be kept free from obstructions that would be a stumbling hazard.

13. If explosives containers are passed from one man to the next, the men should be cautioned against dropping the containers.

14. If explosives containers are slid on board slides to the loading operation, frequent inspections should be made for protruding nails.

15. Only copper or brass nails should be used in constructing a slide, unless it is blind-nailed with wire nails.

16. If wheelbarrows are used to carry explosives to the loading operation, the wheel tire should be made of rubber or other nonsparking material.

17. Electric flashlights with insulated bodies or approved battery cap lights should be used for illumination when explosives are being loaded in tunnels or coyote holes.

18. Electric lighting circuits should never be permitted in a tunnel or coyote hole that is being loaded with explosives.

19. Illumination of blasting tunnels by reflectors is not recommended as a general practice.

20. Unauthorized persons should be prohibited from approaching tunnel or coyote holes while loading operations are in progress.

21. The area being loaded for blasting should be plainly marked both in front and on top of the bank to be blasted.

22. Employees engaged in loading operations should not be permitted to eat lunch in the loading area.

TOE-HOLE OR SNAKE-HOLE BLASTING

The following additional precautions should be observed during the loading of toe holes, often referred to as snake holes:

1. The charge of explosives should be pushed to the back of the hole with a wooden pole, using care not to block the hole.

2. Care should be used in placing stemming in the holes, especially if loose explosives are on the bottom of the flat hole.

3. Only wooden or bamboo poles should be used in loading snake holes. Metal pipes or rods should not be used.

The use of compressed-air blowers for loading flat holes is not discussed in this paper, and no recommendations are made. Investigations have been made relative to the use of blowers for loading explosives, but the hazards have not been definitely determined.
BLOCKHOLING AND MUDCAPPING

Whenever possible, blockholing rather than mudcapping should be used in secondary blasting. The practice of mudcapping is not recommended except in emergencies or under special circumstances. When mudcapping is done, only one mudcap should be placed on a boulder, unless electrical blasting is used. When detonating with fuse and blasting caps, there is the danger of one of the mudcaps being blown off the boulder and resulting in a misfire.

When fuse and blasting caps are used for detonating a series of blockholes, the holes should be stemmed to prevent possible premature explosions caused by sparks from fuse or igniters contacting the exposed explosives in the hole. Flying rock from one shot may cut the burning fuse off from a nearby hole, causing a missed hole. Explosives from such holes, if undetected, may explode when the blasted material is being loaded by a power shovel or while the material is being crushed. In one quarry all blockhole blasts were inspected before the blasted material was loaded, and any boulders found to contain explosives or primers were conspicuously marked with red paint. The shovel operators were instructed not to move boulders so marked.

Blasting shelters, built strong enough to resist flying debris from quarry blasts, should be provided at strategic points on the quarry floor for the protection of workers. Figures 10 and 11, A, show different types of blasting shelters used on the floors of some quarries.

HANDLING MISFIRES

Many preventable accidents have occurred from mishandling of misfires and from returning too soon to blasted areas where misfires may have occurred. Some of the precautions for the prevention of such accidents are:

1. Each misfire should be handled under the personal supervision of the blasting foreman or quarry foreman. Extreme care should be used in handling misfired holes.

2. In case of a misfired hole the stemming should be removed to within approximately 12 inches of the explosives when possible, using a jet of water or compressed air when water is not available. A primer should be placed in the hole and fired as usual. This generally will detonate the unexploded charge.

3. If a misfire occurs when an electric blasting cap is used, test the cap with a galvanometer; and if it shows a circuit, connect the lead wires, and fire in the usual way. If no circuit is shown by the galvanometer, the misfire should be handled as described in No. 2.

4. If compressed air is used for blowing out stemming from a missed hole, it should be done with a stiff rubber hose equipped with a regulating valve within reach of the operator. The regular metal blowpipe used for blowing drill cuttings from a drill hole should not be used, even if it is tipped with rubber.

5. If water is used to remove the stemming from a missed hole, the water stream should have considerable force and should be used only with a rubber hose in the hole. Water will destroy some types of explosives, but wetting the explosives should not be depended upon to make the missed hole safe to handle.
Some States require misfired well-drill hole blasts to be reported to the State department of mines, which instructs the management on the procedure to be followed.

Further suggestions in regard to handling misfired holes will be found in the pamphlet, Safety in the Handling and Use of Explosives,

published by the Institute of Makers of Explosives, 343 Lexington Avenue, New York, N. Y.

KINDS AND TYPES OF EXPLOSIVES TO USE

Protection against blasting accidents is partly afforded by the selection of the right kind and type of explosive. Representatives of the explosives manufacturers can give helpful advice regarding type of explosive best suited. The Institute of Makers of Explosives recommends gelatin dynamite and low-density ammonia explosives as the safest types for use in well-drill-hole blasting. Except in very shallow holes, both gelatin and ammonia dynamite will compact sufficiently when dropped into drill holes; and little, if any, tamping is required. The impact of large cartridges, 16 to 24 inches in length and 5 to 7 inches in diameter, will cause them to pack more solidly when dropped

Figure 10.—A, Blasting shelter on quarry floor, made of boulders and railroad ties; B, steel blasting shelter, floor of eastern limestone quarry.
in well-drill holes than smaller, lighter-weight cartridges. The advantage of using relatively long cartridges is that they are not as likely to stick in the borehole as shorter cartridges.

**FALLS OF PERSONS**

Falls of persons, as shown in table 1, have accounted for 13 percent of all fatalities and 10 percent of all nonfatal accidents in quarries and outside works during the 10-year period 1933–42. Preventing such accidents is primarily the responsibility of the employer. Adequate safeguards should be provided, warning signs should be erected where safeguards are not feasible, and employees should be taught the falling hazards connected with their work.

**GENERAL RECOMMENDATIONS**

1. Falls over quarry faces or benches caused by walking too close to the edge can be prevented by fencing quarry faces or benches where such accidents may occur. Where fencing is not feasible, warning signs should be posted. Abandoned quarries and parts of quarries not in active operation should be fenced.

2. Accidents caused by persons slipping or overbalancing while working on narrow benches or other high places and on places having insecure footing usually can be prevented by the use of safety belts and life lines. Some of the places where such equipment should always be worn are:
   - (a) When drilling on narrow benches.
   - (b) When scaling quarry faces.
   - (c) When working on elevated structures.
   - (d) When working above crusher openings.
   - (e) When working on high scaffolds.

Safety belts and life lines should be furnished by the company for use in such places, and their use should be made mandatory. The equipment should be personally examined by the user, and if found in an unsafe condition it should not be used. The life lines should be anchored securely, and the anchorage should be inspected frequently. Figure 11, B and C, showing men drilling on narrow benches high above the bottom of a glory hole, illustrates the necessity for safety belts and life lines for the prevention of accidents from falling.

3. Safe means of access should be provided to all working places in any pit or quarry.

4. Walkways into a quarry should be graded and properly guarded with handrails where needed.

5. Whenever icy or slippery conditions exist, all roads, paths, and walks should be well-sanded or otherwise suitably protected.

6. Men subject to dizziness should not be permitted to work in high places.

7. The floor boards of staging, platforms, and scaffolds should be of sound timber, not less than 2 inches thick, and closely laid.

8. Temporary openings or excavations should be guarded or covered.

9. Good housekeeping is essential to prevent stumbling accidents. Tools, materials, and debris should not be left where persons may stumble over them.
Figure 11—A. Portable blasting shoring constructed from an old air receiver; B. Drilling with jackhammers on narrow benches on side of "gorey hole" type quarry; C. Bottom of "gorey hole" over 300 feet below where men are shown drilling in B.
10. Good lighting goes far toward preventing accidents from falling, stumbling, and tripping. Good lighting should be provided at all night operations.

LADDERS

1. Ladders used as manways from deep pits or quarries should be constructed according to the following specifications: Stringers or sides, 2- by 6-inch oak or its equivalent in strength, notched or mortised full depth into sides of stringers, and fastened by a 1- by 2-inch strip or batten nailed with not less than tenpenny nails.

Such ladders should be permanently and substantially fastened. All ladders should be provided with ladder backs or cages. (See sec. 2 for exception.)

2. Ladders built in staggered sections of less than 30 feet each, with a platform between each two sections, can be constructed of 2- by 4-inch sound lumber. The ladders should extend through the platform at least 30 inches. This type of ladder construction does not require ladder backs or cages.

3. Rungs of ladders should be spaced not over 12 inches apart.

4. Stringers or sides should be spaced not less than 12 inches apart, inside measurement.

5. The back side of the rung should be not less than 6½ inches from any obstruction.

6. Steel ladders and combination steel and wood ladders can be used in place of the wooden ladders.

7. Landing platforms should be of such size as to permit free and easy movement from one ladder to another, and open sides should be equipped with substantial guardrails.

LADDERS (IN AND AROUND SURFACE PLANTS)

1. All ladders should be substantially constructed and maintained in a safe condition at all times.

2. Wood for side rails and treads should be thoroughly seasoned, smooth, and free from decay, faults, splinters, or sharp edges. It should be red, white, or Sitka spruce, or wood of equivalent strength.

3. Wood for rungs or cleats should be white ash or wood equivalent in strength and resistance to wear.

4. Wood treads should be inset in the side rails not less than three-eighths of an inch. All steps should be securely fastened at both ends.

5. Wooden ladders or ladder parts should not be painted. Paint may conceal defects in the wood and may promote dry rot. Linseed oil, clear varnish, or clear lacquer form satisfactory protective coatings.

6. Portable ladders should not exceed 30 feet in length. Hooked-top ladders are recommended where practicable.

7. Ladders should be equipped with nonslip bases.

8. Stepladders should not exceed 20 feet in height.

9. The spacing between the rungs of a ladder should not exceed 12 inches and should not vary more than 1 inch in any ladder.
10. Ladders with parallel sides should have a minimum inside width of 12 inches between the sides.
11. The rungs of a ladder should, in no case, be less than 6½ inches from the wall or other obstruction against which the ladder is resting.
12. Ladders should be considered unsafe for use while covered with ice, mud, or snow.
13. Ladders should be inspected regularly for defects and should not be used until any defects are repaired.
14. Persons ascending or descending ladders should use both hands and should not carry materials.

STAIRWAYS

1. All stairways should be equipped with handrails not more than 34 nor less than 30 inches high, measuring from the top of the rail to the surface of the tread in line with the face of the riser at the forward edge of the tread.
2. Flights of stairs having four or more risers should be provided with handrails as follows:
   (a) On all open sides.
   (b) On one side of enclosed stairways less than 44 inches in width.
   (c) On both sides of enclosed stairways 44 inches or more, but less than 88 inches in width.
   (d) On both sides and in the center of stairways 88 inches or more in width.
3. All stairways should be sufficiently lighted, either naturally or artificially, to show stumbling hazards.
4. The treads of stairways should present a minimum slipping hazard, should be of uniform height and width, and should be kept in good repair.
5. Stairways should have at least 6½ feet overhead clearance when they are enclosed.
6. Surface stairways should not be set on an angle of more than 45 degrees from the horizontal.

RUNWAYS, ELEVATED WALKS, PLATFORMS

1. Railings should be provided on all runways, elevated walkways, and platforms, except on the loading and unloading sides, as follows:
   (a) Railings should be 42 inches high, with an intermediate rail halfway between the top rail and the floor, and should be permanent, substantial, smooth, and free from protruding nails, bolts, or splinters.
   (b) Posts should not be more than 8 feet apart.
   (c) If the height exceeds 6 feet above the floor level, a toehold at least 3 inches high, preferably 6 inches, should be provided.
   (d) Railings should be:
      1. Wooden railings, posts—2 by 4 inches or larger.
         Upper rail—2 by 4 inches, or 1½ by 4-inch strip on top of the post and a 1½ by 4-inch strip on the side of the post.
      2. Pipe railings—not smaller than 1½-inch iron pipe.
      3. Metal shapes or bars—equivalent to 1½ by 1½ by 3½-inch angles.
   (e) Intermediate rails may be omitted when the panels are fitted with substantial expanded metal or wire mesh.
2. Permanent platforms in frequent use should be equipped with a permanent stairway or stationary ladder.

TRESTLES

1. Any trestle on which persons are required to travel should have a walkway on one side at least. The walkway should have a standard railing.
2. The walkway should provide for a minimum clearance of at least 3 feet between the railing and the widest rolling stock used.
3. Where dumping is done on trestles, both sides of the track should be accessible either by means of walkways or working platforms, portable or stationary.
4. Regular walkways or passages under trestles should be suitably protected. The use of metal gratings, screens, or a wooden platform is recommended.
5. Hoppers beneath tracks for the unloading of coal or other materials should be protected by a grizzly, grating, or other suitable covering to prevent persons from falling into the hopper.
6. Safety belts and lines should be used by men working around the hoppers if the opening is not protected.

FLOOR OPENINGS

1. All floor openings should be enclosed, guarded with standard railings and toeboards, or protected by safety covers with flush hinges.
2. Safety covers, when open, should provide protection equivalent to standard railings.
3. Railings or enclosures may be hinged to open inwardly but should be so fastened that they cannot be removed entirely.
4. Hatch openings should be protected by:
   (a) Standard railings and toeboards.
   (b) Hatch covers,
   (c) Solid, slat, or grille gates 42 inches high.
5. If it is not practical to use hinged railings, sockets may be used.

MACHINERY

Machinery is one of the major causes of fatal and nonfatal accidents in quarries and related outside works. Table 1 shows that machinery was the cause of 16 percent of all fatalities and 10 percent of all nonfatal accidents during the 10-year period 1933–42.

Proper safeguards and the strict enforcement of safety rules will prevent many of the accidents from this cause. Training employees in the safe methods of operating machinery will also help in reducing the number of accidents.

GENERAL RECOMMENDATIONS

1. Machines should not be operated without authorization from the foreman or other person in charge.
2. Machines should be manned with competent operators; un-
skilled persons should be instructed by competent operators during the training period.

3. Repairs or adjustments on machinery in motion should not be permitted; if necessary, the machinery should be blocked securely against motion. Power switches should be locked in the open position while repairs or adjustments are being made. To prevent machinery being started while men were working on it, one cement plant provided each employee with a padlock to place on the power switch controlling any machinery he was to work on. As many as 10 padlocks were observed on one switch controlling the power for a rotary kiln that was being repaired.

4. Oilers and other persons working around machinery should be required to wear snug-fitting clothes.

5. All machinery should be adequately illuminated.

6. Steps, handrails, grab irons, and floors should be kept free of grease, wire, and debris.

7. All machinery and belting exposed to possible personal contact should be adequately guarded as indicated below:

   (a) Gears, sprockets, friction devices, and couplings, with protruding nuts or bolts, should be completely guarded.
   (b) Shafting and shaft ends within 6 feet of the floor or platform level should be completely guarded.
   (c) Vertical or inclined belt, chain, or rope drives should be suitably guarded to a height at least 7 feet from the floor.
   (d) Horizontal belt, chain, or rope drives within 7 feet of floor or platform level should be guarded.
   (e) All flywheels should be guarded with a closed guard to a height of 6 feet or to the top of the flywheel.
   (f) Circular or band saws and planers should be adequately guarded.
   (g) Locomotive and truck repair pits should be guarded or covered when not in use.
   (h) Guards on machinery removed for oiling or repairs should be replaced before the machinery is put in operation. This should be made the responsibility of the person who removes the guards.
   (i) The use of projecting setscrews should be prohibited. Collars with countersunk setscrews, are recommended.
   (j) Overhead shafts should not be lubricated while the shaft is in motion.

SHOVELS, DRAGLINES, CRANES, AND STIFFLEG DERRICKS

1. Each shovel, dragline, crane, or stiffleg-derrick operator should be made responsible for the mechanical condition and the safe operation of the equipment under his control. He should make daily inspections of all vital parts of the equipment, such as cables, sheaves, brakes, and other parts essential to its safe operation. The equipment should not be operated when inspection shows defective or unsafe parts until they are replaced or repaired.

2. Men should not be permitted to work under the moving load or bucket.

3. No one except car spotters or brakemen should be allowed to board any shovel, dragline, or crane while it is in motion. Figure 12 shows an unusual arrangement for boarding a shovel at an eastern quarry. Extension ladders and guarded landings such as shown are worth while safety features.

4. No one except authorized attendants should be permitted on an operating shovel, dragline, or crane.

5. Revolving shovels, draglines, and cranes, when moving,
should be swung so that the operator is facing in the direction the machine is traveling. After the machine has been moved the operator should make a test swing to assure that the cab will clear both the bank and track or truck side. If the cab will not clear a track or truck road, suitable warning signs should be placed immediately.

6. Buckets should be lowered for repairs. Men should not work under a suspended bucket.

7. Trucks should not be loaded by a power shovel until the truck driver is out of the cab and in a safe place, unless the truck cab

![Figure 12.—A, Extension ladder for mounting to cab of shovel; B, ladder in raised position. Note guarded landing.](image)

has been specifically designed for power-shovel loading. (See fig. 13, A.) The truck driver should never remain in the cab while the truck is being loaded if the dipper is swinging over the cab. (Many quarries prohibit loading trucks at any time while the driver is in the cab, even if the truck cab is protected with a steel canopy.)

8. Shovel operators should be prohibited from swinging a loaded bucket over the top of a locomotive or truck cab.

9. Shovels, draglines, and other equipment, where the operator has limited vision, should not be moved until the groundman, craner, or oiler, or other competent person is on the ground where he can supervise the movement. In some quarries power shovels are provided with conveniently placed push buttons either on the ends or sides of the cabs to operate a warning signal, such as a Klaxon horn, in the cab. A groundman or other person in danger of being caught between the swinging cab and bank or other obstruction can signal the operator by touching the push button. It
Figure 13.—A, Truck with steel canopy designed for loading with power shovel; B, push button mounted on rear of shovel cab for emergency signal to operator; C, truck and trailer at a western quarry; capacity, 72 tons. Note pusher truck used on empty return trip for increased speed.
is claimed that several potential accidents have been averted by the use of these signals. Figure 13, B, shows one such installation.
10. The operator of loading equipment should be made responsible for loading the car or truck properly, with the load balanced and with no overhanging rocks.
11. Oil and grease should not be allowed to accumulate on the floor around the machinery, as it is both a slipping and a fire hazard.
12. The wire rope guys supporting the mast of a derrick should be inspected semimonthly. Particular attention should be given to the fastenings at each end of the guy.
13. Electric power cables should be handled with insulated cable tongs or insulated cable hooks. Rubber gloves can be used if in good condition.
14. Shovel power cables should not be moved to the next outlet while the power is on.
15. Operators of power shovels should be warned of danger when the shovel is working near power lines.
16. Firemen of steam-powered shovels should be required to see that all persons are out of danger before blowing down a boiler.
17. Pitmen on locomotive-type shovels should be required to wear safety (hard) hats.
18. Boom suspension cables should be inspected at regular intervals but not less than once each month.

CRUSHERS

1. Trucks should not be dumped into crushers without a signal from attending operators.
2. Crusher men should be prohibited from working in a crusher pit while the crusher is operating.
3. A safe place should be provided for crusher men while cars or trucks are dumped into the crusher. The crusher man should not stand in front of a car dumping directly into the hopper.
4. Crusher pits heated with salamanders during cold weather should not be entered until they have been blown out or otherwise satisfactorily ventilated.
5. Warning signs should be placed at the hoppers of all crushers undergoing repairs to prevent material being dumped into the hopper by mistake.
6. Men working around crusher openings should be protected from falling into the crusher by the guarding of openings so far as practicable, by having a dumping procedure making inadvertent access of men to opening impossible, and by the use of hooks attached to overhead hoists which permit dislodgment of hung-up rock. If such hooks are provided, railings can be installed around crushers. A chain across dumping opening when car or truck is not being dumped often is a practicable guard. The use of a baffle plate attached to an overhead hoist and opposite the dumping opening serves as a guard, prevents flying rock during dumping operations, and assists in dislodging hung-up rock.

A safety belt and life line should be worn when working over the feed opening of any operating crusher or in any car unloading
into a crusher. The life line should be tied short enough to prevent the workman from being caught in the moving parts of the crusher.

7. Crusher men should be required to wear goggles while the crusher is operating and when sledding oversize rock.

AIR COMPRESSORS

1. Excess oil or the wrong type of oil used in lubricating the valves of air cylinders should be avoided; a fire or explosion may be caused.

2. Air receivers should be fitted with a drain valve at the lowest point, and the receivers should be drained at least once a shift.

3. All air receivers should be provided with safety valves and should be tested daily to assure that they are in good working condition.

4. Fuel tanks on gasoline-engine-powered air compressors should not be filled while the engines are running.

5. Tightening of compressed-air-pipe connections or other repairs or adjustments should not be made until the air pressure has been removed from the line.

OVERHEAD CRANES

Overhead cranes on rock-storage bins or piles are a frequent cause of accidents. The following rules are regarded as good practice at many plants:

1. A strongly built footwalk, with standard railing and toeboard, should extend the entire length of the bridge, preferably on the motor side. The walk should be at least 18 inches wide and should clear the bottom of all overhead construction under which the crane passes at least by 5 feet, preferably by 6 feet 6 inches.

2. Cranes equipped with a cab should be provided with a fixed ladder or stairs with handrails to afford safe passageway from ground or floor to crane cab and from crane cab to bridge footwalk.

3. An effective warning signal, securely fastened, should be placed within easy reach of each crane operator.

4. Every crane cab should be equipped on all sides with a railing or with an enclosure equivalent to a standard railing and toeboard.

5. A crane bumper extending one-third of the truck-wheel diameter above the rail should be fastened securely at each end of each rail of the crane runway.

6. Every crane trolley should be provided with a solid floor or pan extending under the entire trolley.

7. Fenders designed to push or raise a hand, arm, or leg out of danger should be fastened to the bridge or truck. One such fender should extend in front of each bridgetowel to a point below the rail.

8. A switch in the main power circuit which can be locked open should be placed above each crane cab within easy reach of the bridge or walk.

9. In connection with each hoisting block there should be provided an overtravel cut-off switch that will automatically stop the up-travel of the block before it strikes the bridge.
10. Only authorized persons should be permitted to ride on cranes.

11. Trolley lines should be located on the opposite side of the runway from the cab and should be protected from contact with swinging hoisting cables.

12. Mechanical inspection of crane machinery and equipment should be made daily, and a detailed inspection by a competent person should be made weekly. A written record of the weekly inspection should be made to the management.

13. Tower-type crane bridges should not be permitted to move over tracks partly covered with loose material that has slid from the banks.

14. Cranes should not be permitted to operate over men working in the storage pit or bin.

STORAGE OF MATERIAL

Rock-storage bins and piles may be hazardous unless precautions are taken. The following recommendations apply particularly to rock-storage bins:

1. Permanent ladders or stairways should be provided to the top of all rock-storage bins.

2. Steel ladders of substantial construction should be placed on the inside of rock-storage bins. Removable chain ladders can be substituted for stationary ladders, if not over 50 feet long.

3. Ladders should be constructed as recommended under “Ladders,” except that steel construction should be used in place of wood.

4. Safety belts and lines should be used by all persons entering rock-storage bins.

5. Loading devices should be locked so they cannot be operated while men are working inside rock-storage bins.

6. Conveyor belts or bucket conveyors should not be crossed by employees except at regular crossings.

7. Riding on conveyor belts and bucket conveyors should be prohibited.

8. Nonslip walkways should be provided alongside conveyor belts and bucket conveyors for use of inspectors and attendants.

9. All persons should be prohibited from walking on the inside of a trommel screen while it is in motion.

10. Power shovels used in loading rock from storage piles should be governed by the recommendations under “Shovels.”

11. Persons should be prohibited from working under or in front of overhanging frozen top material during loading operations. The pile should be sloped properly or scaled after each freeze or thaw, and a safe working slope should be maintained at all times.

HAULAGE (INCLUDING HOISTING)

Haulage accounted for 11 percent of all fatal accidents and for 7 percent of all nonfatal accidents in open quarries and related outside works during the 10-year period 1933-42, as shown in table 1. So many types of haulage are used in quarries, with each type having
its own peculiar accident hazards, that accident recommendations for haulage are discussed under each principal type of haulage.

TRUCKS

Truck haulage is gradually supplanting rail haulage in many quarries because of its greater flexibility. Trucks can be used on much steeper grades than the ordinary rail-haulage equipment and are much more flexible for loading.

Many of the recommendations for safe haulage by trucks are also applicable to shovel loading of trucks and, in some instances, have already been given under the heading "Machinery." However, as they are important safety rules, it will only emphasize them the more to repeat some of them.

1. The truck driver should be made responsible for the safe condition of the truck. He should test all vital parts pertaining to the safe operation of the truck, such as brakes, clutch, steering mechanism, and horn, at the start of each shift. Should the inspection or test show any defective or unsafe parts, the truck should not be placed in operation until such defective parts are replaced or repaired.

2. Trucks should be under control at all times. Driving a truck with the gears out of mesh (coasting) should be prohibited.

3. Before ascending or descending a steep grade the gear should be selected that will assure control of the truck on the grade and will make changing of gears on the grade unnecessary.

4. When necessary to leave a truck on a grade the driver should head or back it into the bank, if possible, and leave the truck in gear and the brakes securely set.

5. Trucks loaded by power shovels should be equipped with overhead protection for the cab and driver.

6. A truck driver should leave the cab and retreat to a safe distance when the truck is being loaded by a power shovel, unless the truck has been specifically designed for such loading, having a steel canopy extending over the cab.

7. A truck driver should always leave the cab if it is necessary for the shovel bucket to swing over the cab.

8. Only authorized persons should be allowed to drive trucks.

9. Truck drivers on public highways should not exceed local speed limits and should drive slower where unsafe road conditions require it.

10. Only helpers or other authorized persons should be allowed to ride with truck drivers.

11. No person should be permitted to ride on the running board of a truck.

12. Mounting or dismounting from moving trucks should be prohibited.

13. No smoking or open lights should be permitted during refueling operations, and the truck engine should be stopped.

14. No repair work of any nature should be permitted on dump trucks when the truck box is in dumping position, unless the box has been properly blocked.

15. Trucks should not be moved backward unless the driver has
a clear view of the area behind the truck or unless a watchman has signaled that it is safe to move.

16. Truck drivers should not pull away from the loading shovel until the load has been balanced. Rock should not be permitted to project or overhang from the sides of the truck.

17. Fire extinguishers of the carbon tetrachloride or carbon dioxide type should be kept on the truck at all times in an easily accessible place.

18. Trucks should not be dumped into crusher chutes, hoppers, or bins without a signal from the attending operators.

19. A substantial bumping block to stop a truck backing or a safety hook designed to engage the front axle should be provided at all places where a rear dump truck is to discharge its load, unless the load is being dumped on level ground for spreading.

20. When necessary to crank the truck engine, the person performing this operation should stand on the ground and not on the bumper of the truck; the gearshift lever should be placed in the "neutral" position.

21. Automotive equipment should include necessary tire tools and jacks, as well as other small tools for minor adjustments, unless each equipment can be obtained quickly and easily from a central supply point.

22. When the crusher is located on the surface, traffic should be one-way where the truck roads lead from the pit to the crusher, particularly if the road is steep. If this is not practicable, the road should be wide enough to accommodate the free passage of the truck at all points, or definite turn-outs and waiting points should be designated.

Figures 13, C, 14, and 15, A and B, show types of automotive haulage at several quarries.

RAIL HAULAGE

1. Tracks should be well-laid and properly ballasted. All switches should be equipped and laid in conformity with A. S. A. standards (M-7-1-1935) and (M-7-2-1935).

2. Inspectors and repair men should be the only persons permitted to walk on tracks during working shifts.

3. An approved signal system should be installed on any railway where more than one locomotive is operated.

4. Bumping blocks or the equivalent should be provided on all dead-end tracks. Similar protection should be provided for elevated spur tracks.

5. Grade crossings should be eliminated as far as practicable. The crossings should be planked or filled between the rails and should have "Stop" signs on each side of the track. The track should be visible in both directions from the crossing.

6. The minimum clearance for standard-gage tracks should be:

(a) From the gage line of the nearest rail to loading or unloading docks, walls of depressed tracks, and wheelbarrow platforms, 3 feet 4 inches.

(b) From the gage line of the nearest rail to all stockyards, 5 feet on tangent track and 5 feet 6 inches on curved track.

(c) From the gage line on nearest rail to all other structures not noted above, 6 feet.
Figure 14.—A, Truck shown in figure 13, C, dumping into cars; B, semi-trailer-type truck, capacity, 20-25 tons, used on long haul at western cement quarry; C, loading truck with shovel. Note truck driver out of cab, although cab is protected with steel canopy.
Figure 15.—A, "Buggy"-type conveyance with 16 wheels, 25-cubic yard capacity, pulled by caterpillar, and used at a western cement quarry; B, "buggy" shown in A being unloaded into crusher hopper; C, a 60-ton Davenport, 0-6-0-type locomotive used for hauling rock from three quarries to a cement plant.
(d) The minimum distance between the nearest gage lines of adjacent tracks should be 8 feet 6 inches.

7. The minimum overhead clearances should be as follows:

(a) From top of rail to any wire or structure, 22 feet.
(b) From top of rail to any transmission line carrying up to 15,000 volts when men are permitted to ride on top of standard freight cars, 28 feet.

8. Where it is impracticable to have an overhead clearance of 22 feet or more above the top of the rail, suitable “head tappers” should be erected at proper distance on each side of the structure.

9. The minimum clearances for narrow-gage tracks, less than 4 feet 8½ inches, should be regulated by the maximum width of equipment in use. The clearance between the equipment and stationary objects should not be less than the minimum requirements for standard-gage tracks.

10. Tracks having less clearance from buildings, poles, or other structures for a man on the side of a car than is specified in rule 6, a and b, should have suitable warning signs erected to indicate the danger of inadequate clearance.

11. All guardrails, lead rails, and frogs should be provided with protective blocks of wood or metal to prevent pedestrians’ feet from being caught between the rails.

12. Switch stands should be constructed so that the level will be thrown parallel to the track.

13. Switch throws should be installed to provide adequate clearance for the switchmen.

14. The rod extending from the bridle bar to the switch throw should be covered or otherwise guarded to avoid a stumbling hazard.

15. Where one track crosses another track, a rule should be established giving trains on one track precedence over those on the other tracks at point of intersection.

16. Cars should not be left on side tracks, unless ample clearance is left for mainline transportation.

17. Railroad cars should be left standing within limits designated by clearance signs or posts.

18. Derail devices should be installed, where necessary, on all side tracks near the junction with the main line.

19. A safety switch or derailing device should be provided on incline tracks to prevent run-away cars from going back into the pit.

20. Cars left on a grade should always be well-blocked, and the hand brake should be set tightly. If the grade leads into a place where men are working, a derailer or derail switch should be provided.

21. Workmen required to do repair work under equipment such as locomotives or cars should be protected by a portable derailer and suitable signals to warn trainmen from making a coupling.

22. Cars of materials or supplies being loaded or unloaded should have danger signs placed at both ends of the car or train to warn trainmen from making a coupling.

23. Cars not coupled to locomotives should be securely blocked while being loaded.
24. “Poling” or moving a car on another track with a pole should not be done except in an emergency. When “poling,” one end of the pole should be held against the car while the locomotive is slowly moved to position where it will engage the other end of the pole and will hold it in position until all persons are in a safe place. “Poling” a car should not be done while anyone holds the pole in place.

25. Where operations require that persons frequently pass over a track, a warning signal should be provided. An overpass or underpass is preferred when it is practical.

26. Road crossings should be guarded when cars are being moved across the roadway.

27. Employees should be prohibited from climbing over or crawling under cars in order to cross tracks. Sitting under cars should be prohibited.

28. Locomotives, whether steam, gasoline, Diesel, or electrically driven, should be equipped with bells or whistles capable of producing loud and clear warning signals.

29. Locomotives, whether steam, gasoline, Diesel, or electrically driven, should be equipped with railers, track tools, track supplies, and track jacks at all times, unless such equipment can be procured quickly and easily from a central supply point.

30. Locomotives should be equipped at both ends with footboards of an approved railroad type, with grab irons, handrails, and nonslip steps.

31. All locomotive boilers and their appurtenances should be thoroughly inspected semiannually, internally and externally, and under operating conditions by a competent inspector. The locomotive should not be operated at pressures in excess of the safe working pressure authorized by the inspector.

32. Locomotives operating at night should be equipped with front and rear headlights. The lights should be used from sunset to sunrise.

33. No person without proper authority should be permitted or allowed to ride on a locomotive or train.

34. All persons should be prohibited from boarding or riding the leading footboard of a locomotive.

35. Persons whose duties require them to ride on a locomotive should ride in the cab or on the trailing footboard, never on the front footboard.

36. Brakemen, firemen, and others whose duties require them to ride should remain on the locomotive and should be prohibited from riding on cars of the “rocker” or “cradle” type. There is danger of this type of car dumping while in transit.

37. “Rocker”- or “cradle”-type dump cars should be equipped with an efficient, positive locking device.

38. Steam locomotives under pressure and left unattended should be blocked securely to prevent run-aways should the throttle valve leak.

39. When cars are moved by hand they should be pushed and not pulled.

40. Flying switches should be prohibited. Trains should be brought to a full stop before cars are cut loose.
41. Railroad-car hand brakes should be tested before an attempt is made to move the car. If defective brakes are discovered, the car should be marked appropriately for immediate repair and moved only with a locomotive or attached to another car having good brakes.

42. Starting a car on a grade by “pinching” should be prohibited, except when a man is stationed at the brake wheel.

43. Railroad-car brakes should not be manipulated by the hands alone. A heavy brake stick, preferably a hooked bar, should be used. The brake stick should be pulled toward the inside of the car to prevent the person from falling from the car should the stick or the chain break.

44. Automatic couplers should be provided on new installations as far as practicable and equipped with extension handles so couplers can be operated without danger of catching hands in the jaws.

45. No person other than a member of the train crew should be allowed to couple or uncouple cars.

46. Trainmen should not go between cars to pull coupling pins while the cars are in motion.

47. Links should not be guided into the drawhead by hand; a stick or another pin should be used for this purpose.

48. Drawheads or “knuckles” should not be shifted with the foot when the cars are in motion. The trains should be standing still when the drawheads or “knuckles” are shifted.

49. No attempt should be made to pull the coupling pins or to make couplings on the inside of a curve.

50. Only authorized, qualified persons assigned to the work should be permitted to operate a locomotive.

51. Haulage employees and ground crews should be instructed to exercise precautions to prevent accidents to themselves from dumping of cars by the shovel while being loaded or while in transit.

52. Cars loaded by power shovels should not be moved until after the load is balanced and there are no protruding rocks or rocks that are likely to fall off while the car is in transit.

53. When descending an incline, the engineer should have the train under control and be prepared to stop at any time.

54. Where the vision is obstructed, trains should not be pushed around curves without first ascertaining that the track is clear.

55. A trainman should be required to ride the front end of trains that are being pushed.

56. All haulage equipment should be inspected frequently by competent persons and all defects repaired promptly. This is particularly necessary when locomotives and air-brake equipment are used.

57. Brakemen should wear safety hats and snug-fitting clothes.

58. Safety latches should be provided on electric locomotives to hold trolleys or pantograph away from the wires.

Some types of locomotives used in quarries are shown in figures 15, C, 16, A and B, and 17, A.
Figure 16.—A, An old-type gasoline-powered locomotive used at a western gypsum quarry; B, a 20-ton electric locomotive used at a western cement quarry. Note hand-brake wheels and air-brake couplings on side of each car; C, view of large cement rock quarry using conveyor belt haulage to cement plant.
Figure 17.—A, Electric locomotive hauling trains from tunnel under "glory hole" at a western cement quarry; B, conveyor from stock pile shown in figure 18, A; C, conveyor shown in B to secondary crusher and conveyor extending into background.
CONVEYOR BELTS

In recent years there has been increasing use of conveyor belts in quarries. They are used by themselves or in conjunction with flight or bucket elevators in many open-pit operations. They are also used for relatively long hauls at some sidehill quarries where the terrain is too rough for economical truck haulage. At a large western quarry a series of long conveyor belts is used for conveying the crushed rock from the quarry to a large stock pile adjacent to a cement plant. The quarry floor is over a thousand feet higher than the stock pile, and advantage has been taken of this difference in elevation to generate power; the conveyor system is equipped with regenerative motors which generate sufficient power to operate the quarry well drills and power shovels. The primary crusher is at the edge of the quarry floor, and the first belt conveyor carries the crushed rock from underneath the crusher to a stock pile. The rock is fed from this stock pile to another conveyor belt having its feed end in a tunnel, lined with concrete, underneath the stock pile. This second belt feeds the rock to a secondary crusher, whence it is carried by a third conveyor belt to a screening tower near and above the final stock pile at the cement plant. Three conveyor belts carry the different sizes of screened rock to three different stock piles. Conveyor belts with their feed ends in concrete-lined tunnels under these stock piles carry the crushed rock to the cement plant. Figures 16, 17, B and C, and 18 show views of the quarry and of the different conveyor belts used.

Many of the recommendations listed under machinery are applicable to the safe operation of conveyor belts, such as the safeguarding of moving parts and hazards connected with starting machinery while being repaired. Some such recommendations will bear repetition and will be found in the following list for the safe operation of conveyor belts:

1. Persons should be prohibited from riding on conveyor belts.
2. Conveyor-belt drives should not be greased while in motion.
3. All persons working around conveyor belts should wear snug-fitting clothing.
4. Gears, sprockets, friction devices, and couplings with protruding bolts or nuts should be guarded completely.
5. Shafting and projecting shaft ends within 6 feet of floor or platform level should be guarded completely.
6. Vertical or inclined belt, chain, or rope drives should be suitably guarded at least 7 feet above the floor or platform.
7. Horizontal belt, chain, or rope drives within 7 feet of a floor or platform should be guarded.
8. When guards are removed for oiling or repairs they should be replaced before the conveyor belt is started.
9. Projecting setscrews should be prohibited. Collars with countersunk setscrews are recommended.
10. Repairs should not be made to conveyor belts or their mechanism until after the power has been cut off.
11. Power switches controlling the movement of conveyor belts should be locked in the open position before repair work is begun on conveyor belts; the key to the lock should be in the possession of the person in charge of the work.
Figure 18.—A, Conveyor belts, carrying crushed material from primary crusher to stock pile, shown in lower left center; B, other end of conveyor shown in figure 16, C, discharging into screening tower; C, showing three suspended conveyor belts carrying rock from screening tower to stock piles at cement plant.
12. If feasible, belt dressing should not be applied to conveyor belts while in motion; utmost care should be taken if this dressing must be applied while the belt is in motion.

13. Belt conveyors should not be crossed over, except at designated cross-overs, which should be well-guarded.

14. Railed, nonskid walkways should be provided wherever persons are required to travel alongside conveyor belts. Stairs, platforms, and landings should also be well-guarded.

15. Walkways, landings, stairways, and platforms adjacent to conveyor belts should be kept free of all stumbling and slipping hazards.

16. Operators should not start conveyor belts until they are positive that all persons are in a safe position.

INCLINED TRAMWAYS AND VERTICAL HOISTING (DERRICKS)

Inclined tramways, on which the rock is hoisted in cars, are used in many open-pit quarries. Accidents connected with this phase of quarry operation are usually severe; causes of the accidents include being struck by run-away cars or riding in run-away cars. Prevention of such accidents depends on strict observance of adequate safety rules, frequent inspections of equipment, providing safe equipment, and good supervision.

Some of the recommendations previously given under rail haulage also apply to safe operation of inclined tramways. The principal hazards inherent in this type of haulage are in connection with the hoists and hoisting equipment. Since most of the hoisting recommendations for inclined tramways are applicable to hoisting stone with stiff-legged derricks, recommendations for both are listed together.

1. The track and roadbed of inclined tramways should be well-laid, properly ballasted, and maintained in good condition.

2. Employees should not be allowed to walk on the track or right-of-way of inclined tramways, if cars are or may be set in motion.

3. Cars should not be hoisted or lowered while maintenance crews are working on the track.

4. Where there is danger of cars running off the end of inclined tracks at either top or bottom, a positive stop block should be provided at each end and a derailing device near each end.

5. Men should be transported in special cars equipped with safety devices to prevent cars from running away in case of hoist failure, or cable, coupling, or drawbar breaking. The safety device should be tested at frequent intervals to assure that it is in working condition and that it will stop the car.

6. The man-cars should have level seats and should be provided with handholds.

7. No tools, explosives, or other material should be carried in cars transporting men.

8. Man-trips should be operated at a safe speed.

9. All hoists should have ample power to hoist the loaded car, trip of cars, or vertically suspended load.

10. Hoists should be equipped with brakes capable of stopping
and holding the loaded car, trip of cars, or vertically suspended load at any point.

11. The sides (flanges) of the drum should extend not less than 4 inches radially beyond the outer layer of rope when the rope is fully wound on the drum.

12. On inclined tramways the hoist should be provided with an accurate and reliable indicator showing the position of the car or trip at all times. The indicator should be so placed that it is in constant view of the engineer.

13. All electric hoists should be equipped with protective devices that will stop the hoist within a reasonable distance upon failure of the power.

14. Hoists should be provided with positive overwind and overspeed controls, or a second engineer should be in attendance at all times when men are being transported.

15. Hoists should be so placed that the noise of other machinery will not prevent the engineer from hearing signals.

16. Hoisting equipment should be inspected daily, and a written record should be made of such inspection.

17. No person should be allowed in the hoist house except the hoist engineer or other person especially authorized by the management.

18. Hoisting engineers should be physically fit and should be required to take an annual physical examination.

19. The hoisting engineer should immediately report any defect in the hoist or signaling system and record it in the daily log. When defects are found that might make further operation of the hoist unsafe, the hoist should not be operated until the defect has been remedied.

20. Hoisting engineers making any change in or adjustment of the clutches, brakes, etc., on drums, safety devices, or on any part of the hoisting equipment should report such change or adjustment to the relief hoisting engineer and record them in the log.

21. A trial run should be made on inclined slopes before lowering men at the beginning of a shift.

22. All violations of hoisting rules should be reported to the foreman.

23. Hoisting ropes should be of adequate size to handle the maximum load to be hoisted, with a large factor of safety for such load as defined in American Standards Association pamphlet M-11.

24. At least three full laps should remain on the drum when the rope is extended to its maximum distance; the rope should make at least one full lap on the drum shaft or around a spoke of the drum (in case of a free drum), and the end should be fastened securely, preferably by cable clamps.

25. The rope should be fastened to its load by means of a spelter-filled socket, a thimble and clamp, cable clamps, or other approved means.

26. Wire ropes of less than three-fourths of an inch in diameter that are used for hoisting men should be fastened with not less than four cable clamps; for larger ropes the number of clamps
specified in American Standards Association pamphlet M-11 should be used. The spacing between clamps should conform to approved practices.

27. Bridle chains that serve as a secondary safety connection between the rope and the car should be provided.

28. Hoisting cables, used in hoisting or lowering men, should be inspected at least once each day while the rope is traveling not over 50 feet a minute.

29. A record showing length of service of each hoisting rope and amount of tonnage hoisted should be kept by a designated competent person. A rope should be replaced as soon as there is evidence of undue weakness or any indication that the rope might fail.

30. A rope should not be used for hoisting:

(a) That shows more than six broken wires in any single pitch, length, or lay of rope.

(b) When the wires in the crown of the strand are worn to less than 65 percent of their original diameter.

(c) When inspection discloses a dangerous amount of corrosion or distortion.

31. Not less than 5 feet of cable should be cut from the end of a hoisting rope when changing fastenings. The interior of the rope should be carefully checked for deterioration before fastenings are replaced.

32. At regular intervals every hoisting rope in vertical or nearly vertical shafts should be lubricated from end to end with oil or suitable rope lubricating compound, and the date of each lubrication should be recorded in the log book.

33. Slate and other deep-pit quarries should provide at least two man-boxes for hoisting and lowering men in the pit or quarry. These boxes should be not less than 1 foot 2 inches high, 4 feet wide, and 6 feet 6 inches long. They should be equipped with four corner chains. All corner chains should be permanently fastened to the man-box and should be connected with a king ring which should be attached to the cable hook when men are being hoisted or lowered in a pit or quarry. Man-boxes should be built of best-grade materials and should be strong enough to carry six persons safely.

34. All chains and cables used in and about all pits and quarries should be large enough to sustain the maximum load hoisted out of a pit or quarry, with a factor of safety of not less than 5. The use of chains or cables which do not meet the above requirements should be prohibited.

35. All block, rubbish, and man-box chains used in deep-pit quarries should be inspected at least once a week by a competent blacksmith or hook-on man.

A granite (deep-pit) quarry in an eastern State adopted a fixed rule that all hoisting cables must be replaced after 3,000 hours of service. The safe life of a hoisting cable in such operations is necessarily short because of the excessive bending of the wires in the rope due to the small diameter of the sheaves in the blocks used for hoisting stone. The company did not consider replacing of hoisting ropes at such short intervals as being uneconomical, as the ropes that were
discarded were used for making slings. These slings were used for attaching stone, weighing up to 20 tons, to the hoisting cable. All stone weighing over 20 tons was attached to the hoisting cable by rope slings made of new cable. The use of chains for attaching heavy stone had been discontinued at this quarry, as rope slings are believed to be safer. Several potential accidents had been caused by chain slings breaking when used for lifting heavy loads; usually, these breaks were the failure of welded links. Some operators prefer wire-rope slings to chain slings from a safety standpoint.

In most deep-pit quarries it is not feasible to set the hoist in such a position that the hoisting engineer can see the bottom of the pit. Hoisting signals at such operations are generally given by the derrick man, who is stationed near the derrick where he can see all parts of the pit and can readily be seen by the hoisting engineer. Signals are given by movements of the hands and arms according to a prearranged code. These “arm and hand” signals are more or less standard in any one locality or district but vary considerably in different districts or States. During the war, when there was considerable migration of quarry workers from one district or State to another, some hoisting accidents occurred because of a misunderstanding of the signals given. It is desirable for the quarrying industry to formulate a signal code that would be used at all quarry operations where the hoisting engineer must rely on relayed signals.

36. In quarries where signals are relayed to the hoisting engineer by the derrick man or some other authorized person, the hoisting engineer should not operate the hoist or move the derrick boom except when relayed signals are given and are understood. The hoisting engineer should make certain that the man relaying the signals is using the code to which the hoisting engineer is accustomed.

37. Warning signaling devices, such as whistles or sirens, should be provided at deep-pit quarries to warn workers of loads being hoisted or lowered so that they may stay in a safe place.

AERIAL TRAMWAYS

Aerial tramways are used as a means of haulage from quarries where the terrain is too rough or too steep to permit the use of other types of haulage. Two types of aerial tramways are in common use: (1) The single-rope track type on which the bucket travels underneath and suspended by trolley wheels to the rope cable, and (2) the 2-cable track type on which the conveyor pans ride on the cables. Figure 19, A, shows an aerial conveyor of the 2-cable track type used to transport gypsum rock from a quarry to the plant at a western quarry.

Most of the recommendations previously given under “Machinery” apply also to the safe operation of aerial tramways and are not repeated. Some additional recommendations for the prevention of accidents in the operation of aerial tramways are as follows:

1. Persons, except members of maintenance and repair crews, should be prohibited from riding on aerial tramways, unless they are designed to transport men.
2. Crossings should be protected with steel-mesh nets or other adequate protection where aerial tramways pass over public highways, railroads, or other places where persons might be injured from falling rock from tramway buckets or from falling buckets.

3. Employees should receive instruction for the proper spacing of tramway buckets or pans so as not to overload any span of the tramway, unless the buckets or pans are spaced automatically.

4. Precautions should be taken not to overload buckets or pans.

5. Aerial tramways should not be started until the operator is sure that everyone is in a safe position.

**ELECTRICITY**

Nonfatal accidents caused by electricity in quarries and in related outside works during the 10-year period 1933–42, as shown in table 1, were of minor importance, amounting to only 1 percent of nonfatal accidents from all causes. Fatal accidents from electricity, however, accounted for 6 percent of fatal accidents from all causes. The ratio of fatal to nonfatal accidents caused from electricity was relatively high, as there was 1 fatality for about every 10 nonfatal accidents. As so many electrical accidents result in fatalities, it is evident that all known safety precautions should be taken for preventing such accidents. Education of employees as to the seriousness of the shock hazard from the improper or unsafe handling and use of electrical conductors, which generally carry high voltage in quarry operations, will go far toward eliminating electrical accidents. One of the major factors in the prevention of such accidents is the provision of approved
safe electrical wiring and equipment, properly installed and maintained.

The following recommendations are given for the prevention of electrical accidents:

ELECTRIC POWER LINES AND WIRING

1. All electric wiring should conform to the National Electrical Code, and all line work should conform to the rules recommended by the National Electric Light Association.
2. Overhead high-potential power lines should be placed at least 15 feet above the ground, 20 feet above driveways, and supported and guarded to prevent contact with other circuits.
3. Guy wires from poles supporting high-potential transmission lines should be grounded unless equipped with insulators. If insulators are used, they should be installed near the poles.
4. Electrical equipment and overhead power circuits should be protected against lightning or voltage surges.
5. High-potential power lines should be protected by circuit breakers.
6. All electric circuits should be of ample capacity for the current carried.
7. Power wires should be supported on or by well-designed and installed insulators.
8. Lighting circuits should be provided with adequate fuses.
9. Electric lights should be so placed that they cannot come in contact with combustible material.
10. Portable extension lights should be equipped with lamp guards at all times.
11. Fallen high-tension wires should not be left unguarded, unless it is definitely known that it is safe to do so.

TRANSFORMERS

1. Transformers should be placed on poles at least 15 feet above the ground. When this is not practicable, the transformers should be enclosed by substantial fences at least 6 feet high.
2. The gate or door to the transformer enclosure should be kept locked to prevent the entry of unauthorized persons.
3. "DANGER—HIGH VOLTAGE" signs should be placed on transformer enclosures.
4. Transformer houses should be constructed of fireproof material, well-lighted and ventilated.
5. Transformer stations should be equipped with a dry, insulated stick or other equally safe method for operating disconnect switches.
6. Signs warning against pulling switches while power is being used should be placed in all substations and at switch stations.

Figures 19, B, and 20, A, show two methods for guarding portable transformer stations at western quarries.

GROUNDING

Grounding electrical equipment in quarries is vital to the protection of persons against shock hazards and is also necessary for the protec-
tion of the equipment. Lack of grounding, insufficient grounding, and poor maintenance of grounds are common causes of electrical accidents. The following safety rules should be rigidly enforced for

![Image of a portable transformer in wooden fence used at a western gypsum quarry. (Figure 20A). Portable metal towers with wooden poles on top for supporting trailing cable across truck road. (Figure 20B). Lightweight, hinged wooden supports equipped with saddles and snatch blocks for elevating trailing cable above crossings. (Figure 20C).]

the protection of quarry workers:

1. Cases of all transformers that are within 8 feet of the ground should be grounded.
2. All metallic frames, casings, and coverings of motors, generators, switchboards, and other electrical equipment that can
become "alive" through any cause, such as failure of insulation or by contact with energized parts, should be grounded.

3. All metallic coverings and armor of cables and all conduit should be grounded.

4. Ground connections should be tested frequently to determine their continuity and occasionally to determine their resistance.

5. The grounding of electrical equipment on electric shovels should be maintained in accordance with the manufacturers' standards. The failure to maintain proper grounding is a frequent cause of accidents.

Grounding should be done by an experienced electrician, as superficial or inadequate grounding does not afford protection. The erroneous belief that connecting the ground wire to rock or soil will always provide a proper ground is too prevalent. In many instances rock and soil are not good enough electrical conductors to carry off the ground current, and their capacity for such purposes can only be determined by tests. The size of the wire or cable used for the grounding circuit also determines its efficiency, and it must be of ample size to carry the current if proper protection is to be afforded by the ground. It is recommended that at least No. 0 copper wire be used in grounding.

SWITCHES AND CIRCUIT BREAKERS

The proper use, installation, and type of switches and circuit breakers on electrical circuits are all necessary for the prevention of electrical accidents. The following recommendations are applicable for safe operation of electrical equipment in quarries:

1. Switchboards should have:

   (a) Ample working space around and back of them, free of rubbish and stored material.
   (b) An entrance at each end to permit authorized persons to inspect, adjust, or repair apparatus back of the switchboard.
   (c) Adequate light.
   (d) Control readily accessible for emergency shut-down.
   (e) A disconnecting switch on incoming circuit at or near the entrance to the rear.
   (f) Entrances to rear guarded against unauthorized entrance.

2. All principal switches should be marked so that they may be found readily in case of emergency.

3. Officials, haulage crews, electricians, and persons connected with electrical maintenance should be familiar with the location of cut-out switches.

4. Circuit breakers should be provided to protect all power circuits; if they are automatic, they should be set so that the circuits cannot be overloaded.

5. Switches and circuit breakers should be so installed that they are readily accessible and can be operated without danger of contact with moving or live parts.

6. Switches and starting boxes used to control electric circuits should be of a safe design.

7. Electric motors, switches, and controls exposed to dust or water should be of tight construction.
8. Lines or circuits should be disconnected by the electrician in charge or by the authorized switchboard or substation attendant. They should be closed only by the electrician who disconnects them or, at his direction, by the switchboard or substation attendant.

9. Switches on the line or circuits that have been disconnected to make repairs or adjustments should be locked out and placarded "DANGER—MEN WORKING ON THIS CIRCUIT—DO NOT CLOSE."

10. No person other than the man opening or ordering the circuit opened should close it or give orders for closing it.

11. A circuit switch should not be closed, unless it is positively known that no one is working on the circuit.

12. Disconnecting switches should not be thrown until after the load has been taken off.

13. Insulated hooks should be used to open and close high-voltage switches.

14. Switchboards should be made of incombustible material and should be kept free from moisture.

**TRAILING POWER CABLES**

High-tension power cables are in common usage in many quarries for transmitting power to electric shovels. Since these trailing cables must be moved frequently on the quarry floor, they are subject to abrasion, deterioration from weather, being cut by flying rock, inadvertently run over, etc. They should be of such construction as to resist damage and should be properly maintained and handled to prevent serious accidents from shock. The following safety rules for the use of trailing cables should be rigidly enforced:

1. All portable cables for electric shovels, cranes, drills, or other machinery should be well-insulated with such material as will prevent injury to workmen. All cables should be waterproofed and rubber-covered.

2. Portable cables should be connected to transmission lines at the nearest outlet to avoid trailing unnecessary lengths of cable over the quarry floor.

3. Power cables should be mounted on high poles, horses, or otherwise adequately supported where they pass over railroad tracks and truck roads. Where pass-overs are not feasible, the cables should be placed in conduit and passed under such places. Figures 20, B and C, and 21 show several of the different types of overhead crossing supports for cables at various quarries.

4. Low poles, wooden horses, or other suitable supports for elevating trailing cables from quarry floors are recommended. Figure 22 shows the low supports used in some quarries.

5. Electric cables should not lie in water but should be supported where necessary.

6. Splicing of power cables while the power is on should be prohibited.

7. Temporary cable splices should be made in a workmanlike manner, mechanically strong, and well-insulated. Preferably, when a cable is found defective, a stand-by cable should be used,
Figure 21.—A, Wooden supports shown in figure 20, C, supporting trailing cable across railroad track on quarry floor; B, portable ladder-type metal supports for trailing cables at road crossings; C, portable pole-type support for elevating cable across road crossing.
Figure 22. — A, Saddle on wooden “A” frame fastened to adjustable metal leg, used for supporting trailing cable above quarry floor; B, self-supporting pedestal-type wooden supports for elevating trailing cable above wet quarry floor; C, showing trailing cable supported above quarry floor.
Figure 23.—A, Moving trailing cable attached to power shovel with insulated cable hook; B, pan built on rear of electric shovel for coiling excess cable and for keeping cable away from caterpillar treads; C, reel on side of electric well drill for coiling excess trailing cable.
and the defective cable should be sent to the shop for permanent splicing and vulcanizing.

8. Insulated cable tongs or insulated cable hooks should be used in handling high-tension cables. The cables should never be handled with bare hands. Rubber gloves, if they are in a safe condition, may be used. Figure 23, A, illustrates method of handling cable with insulated cable hook.

At one quarry it is the practice to tie loops of 1-inch hemp rope to the trailing cable at about 25-foot intervals, starting near the rear of the power shovel. It is claimed that the loops are of value in moving the cable, as the cable tends to slip when grabbed with cable tongs or hooks. Cable hooks engaged in the rope loops would move the cable without it slipping.

9. A trailing cable should be fastened firmly to the shovel in such a way that it will not be pulled by the terminal connections when the shovel is moved.

10. Reels or other suitable methods for storing excess trailing cable should be provided on power shovels, well drills, or other electrically operated machinery using trailing cables.

Figure 23, B, shows a pan built on the rear end of an electric power shovel for storing excess cable. Note that the cable is clamped to the front end of the box to prevent strain on the shovel terminal. A roller is provided on the rear end to facilitate the uncoiling of the cable. The pan was installed primarily to permit the shovel to back up in emergencies without running over the cable.

Figures 23, C, and 24, A, show two types of reels used on well drills for coiling excess trailing cable.

FUSING ELECTRICAL CIRCUITS

The correct fusing of electrical circuits is done to protect electrical equipment (such as to prevent the overloading of circuits that might result in burnt equipment or in fires in buildings and to protect persons from electrical accidents. The following safety recommendations are made to prevent accidents due to lack of or improper fusing:

1. All electrical equipment should be protected against excessive overload by fuses or equivalent protective devices of the correct type and capacity.

2. Wire or other conducting material should not be used as a substitute for properly designed fuses.

3. All lighting circuits should be provided with the correct capacity fuses.

4. Fuses should not be inserted in a circuit until after the switch has been opened.

5. The practice of overfusing either power or light circuits is hazardous and should be prohibited.

MISCELLANEOUS RECOMMENDATIONS

1. Combustible material should not be stored or allowed to accumulate under power lines.

2. Dry wooden platforms, rubber mats, or other electrically non-
conducting material should be kept in place at all switchboards and machinery where shock hazards exist.

3. Electric wiring in all buildings should be so installed as to present the minimum fire and contact hazards.

4. All electric appliances, machines, and conductors should be large enough for the work that is required of them. Overloading is hazardous.

5. Rheostats and electric heaters should be so installed as to prevent electric shock, burns, and fires.
6. Electrical equipment should be repaired only by a competent electrician.

7. Employees should not depend entirely on the insulation of electric wires as a protection against shock.

8. No work should be done on electrical circuits and apparatus when the current is on, unless conditions make it absolutely necessary, in which case adequate precautions should be taken.

9. Precautions for working on live circuits should include insulated foot supports, such as rubber boots, dry ladders, or insulated platforms, approved rubber gloves, approved shields, and blankets for covering live parts and grounds.

10. Safety goggles and masks should be worn when working with a soldering pot and ladle.

11. Linemen should fasten safety belts around the pole and not around the arm or brace.

12. Instructions for the resuscitation of persons suffering from electrical shock should be placed and maintained at switches and at other places where shock hazards are apparent.

13. Employees working in and around electrical equipment should be trained in the resuscitation of persons suffering from electrical shock and in general first-aid procedures.

14. Insulated platforms should be used when operating high-tension switches. Figure 24, B, shows a platform used for operating a control switch furnishing power to an electric shovel.

15. "DANGER" signs should be placed in the vicinity of high-tension power cables where there is danger of trucks running over them. Figure 24, C, shows a type of portable "DANGER" sign used on the quarry floor at an eastern quarry.

**Handling Materials**

Handling materials is one of the minor causes of fatal accidents in quarries and related outside works. During the 10-year period 1933-42 it was the cause of only 4 percent of fatalities resulting from all causes as shown in Table 1; however, it was the chief cause of nonfatal accidents during the same period, accounting for 25 percent of all lost-time nonfatal accidents in quarries and related outside works.

Handling materials enters into virtually all phases of quarry operation, and it is a question whether or not many accidents that have been reported as caused from handling materials could not have been as accurately reported under other causes; for example, suppose two men are carrying a timber and the lead man stumbles and falls, causing the other man to drop his end of the timber on his foot, mashing a toe. The primary cause of the accident was stumbling and would be charged to falls of persons. However, the man was hurt by the timber dropping on his foot, which might be charged to falling objects, but as the accident occurred from handling material it is possible that it was so reported.

A great many of the recommendations already given under other causes of quarry accidents apply to the safe handling of materials. Probably some of the general recommendations which would be of the most value in the reduction of such accidents are:
1. Employees should be taught the proper way to lift and carry material.
2. Employees engaged in handling materials should wear suitable clothing, such as snug-fitting clothes, hard hats, safety-toe shoes, and, where needed, suitable gloves and safety goggles.
3. Employees should be warned against lifting or carrying loads that are too heavy and might cause injuries from strains; in such instances they should request assistance.
4. Employees should be instructed in the proper method of using bars for lifting or prying to prevent injuries caused from overlifting or from bars slipping.
5. Employees should be cautioned against dropping materials or tools on men working below them; and, where possible, men should not be assigned to work where they might endanger men working below them.
6. Safeguards should be provided wherever possible to eliminate hazards which may cause accidents from the handling of materials or from other causes.
7. All employees should be given physical examinations, and those not physically qualified should not be assigned to tasks beyond their ability.

**FLYING OBJECTS**

"Flying objects," as shown in table 1, was near the bottom of the list of causes of fatal accidents in quarries and related outside works during the 10-year period 1933–42, accounting for only 1 percent of fatalities from all causes. It was, however, second from the top in single causes of nonfatal accidents during the same period, accounting for 12 percent of nonfatal accidents from all causes.

Flying objects also enter into practically all phases of quarrying. Although the flying object may be the material object that made the injury, the primary cause was the operation, machine, or tool that caused the object to fly. Crushers, drills, loose-handled tools, breaking cables, and grinding wheels are some of the primary causes of accidents from flying objects. The blasting of rock is also one of the principal causes of such accidents. The adoption of recommendations already given under other causes of accidents will help in the reduction of accidents from flying objects. Other specific recommendations for protection against injury from flying objects are as follows:

1. Adequate shelters should be provided for all employees who might be injured from flying rock during blasting operations, and all such employees should be required to use these shelters.
2. Wherever hazards exist from broken cables, guards should be provided to protect the operator or other person who might be injured.
3. All employees should have safety goggles, with corrective lenses when necessary, if their work at any time requires such protection. The use of goggles should be made mandatory on work requiring such protection.

At operations where the use of goggles in certain types of work has been made compulsory, the reduction in the number of eye accidents has been very gratifying. The following data from one of the large
copper mines\(^{10}\) give the results obtained from the compulsory use of goggles:

<table>
<thead>
<tr>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eye injuries in year before the use of goggles was enforced</td>
</tr>
<tr>
<td>Eye injuries in first year the use of goggles was enforced</td>
</tr>
<tr>
<td>Eye injuries in second year the use of goggles was enforced</td>
</tr>
</tbody>
</table>

The types of work where the use of safety goggles was enforced and the penalties given for not wearing them are quoted as follows:

Goggles are without exception to be worn by every workman while doing the following kinds of work:

IN THE MINE


ON THE SURFACE

Using cold chisel to cut or scrape any class of material. Breaking rock or concrete. Using either electric or acetylene welders. Cutting with lathe running at high speed. Cutting cables with cold chisel. Handling acid. Cleaning with compressed air. Cutting cold steel. Grinding drill shanks. Using emery wheel. Sandblasting. Babbitting. Soldering. Creosoting timber. Pouring in foundry. Any man disobeying this rule will be given a 3-day lay-off for the first offense, 10 days for the second, and permanent dismissal from the service for the third.

The conclusion of the article from which the above quotation was made is also worthy of quote:

Of all classes of injuries, none leaves the workman in a more helpless and pitiful condition than blindness. I believe the policy most beneficial to workmen and employers is to put teeth into rules and insist that workmen wear goggles while doing certain kinds of work and save their eyes.

4. Warning signs should be posted at all places where there exists a hazard from flying particles.

FALLING OBJECTS (OTHER THAN FALLS OR SLIDES OF ROCK)

Falling objects, not including falls or slides of rock, are a minor cause of both fatal and nonfatal accidents in quarries and related outside works. Table 1 shows that during the 10-year period 1933–42 falling objects accounted for 4 percent of fatalities and 5 percent of nonfatal accidents from all causes. The following suggestions or recommendations are offered as a means for reducing the number of accidents caused by falling objects:

1. Hard hats should be used by all employees working near the bank or in any place where falling objects might strike them.
2. Materials should be stored in such a manner as to prevent them from falling.
3. Materials should not be carried on ladders.
4. Tools, drills, drill steel, or other material should not be left on scaffolds at the end of the shift.
5. Persons should not be allowed to work or pass under scaffolds on which men are working. Warning signs should be posted; and, if feasible, the area beneath scaffolds should be roped off to

prevent persons from coming close enough to be injured by falling objects.

6. The use of hard-toe shoes by all employees is recommended.
7. Men should not walk under suspended loads.
8. Toeboards should be provided on all elevated floors, platforms, landings, or other places where tools or material might fall or be pushed over the edge, with possible injuries to persons below.

**BURNS**

Table 1 shows that burns caused 2 percent of all fatal accidents and 3 percent of all nonfatal accidents in quarries and related outside works during the 10-year period 1933–42.

The number of fatalities from burns was divided evenly between quarries and related outside works, eight fatalities occurring in each. Of the eight fatalities in outside works, six were in outside works relating to limestone quarries, such as lime kilns. The total number of nonfatal burn accidents was divided as follows: 21 percent in quarries and 79 percent in outside works. Of the total number of nonfatal burn accidents in outside works, 70 percent were in outside works related to limestone quarries, such as lime kilns. From the above statistics it is evident that hazards causing burns are more prevalent in outside works related to lime quarries than in quarries or in outside works other than those connected with limestone.

The principal causes of burn accidents, other than around lime kilns, are the improper use of gasoline and accidents connected with welding operations. Electrical burns connected with the operation of switches and from other causes are not uncommon. Recommendations for the prevention of accidents from burns are as follows:

1. Gasoline should not be used for cleaning.
2. Gasoline, oil, or kerosine should not be used for starting fires.
3. Fuel tanks attached or adjacent to machinery or automotive equipment powered by gasoline engines should not be filled while the engines are running.
4. Gasoline cans kept on power equipment should be painted red and marked “Gasoline.” The cans should be kept tightly capped at all times when not in use and should be inspected frequently for leaks.
5. Smoking and open lights should be strictly prohibited in all places where gasoline is being used, dispensed, or stored.
6. Stoves, radiators, and other heating devices should be shielded to prevent personal contact.
7. Open lights and all other sources of ignition should be kept a safe distance from carbide containers.
8. Gas-welding equipment should be used in conformity with the manufacturer's safety rules furnished with such equipment.
9. Electric welding should be shielded to prevent the electric arc from being seen by other employees; otherwise serious eye burns may result.
10. Goggles should be worn to prevent serious eye burns when gas and electric welding is done. Goggles with the correct lenses for each type of welding should be provided.
11. Electric welders should wear welding masks to protect the eyes and face. Gauntlet gloves should be worn to protect the wrists and hands.

12. High leather shoes should be worn by welders and welders' helpers to protect the ankles and feet.

13. Welders and their helpers should wear aprons and long sleeves made of asbestos, leather, or other equally fire-resistant material.

14. Welders' trouser legs should be worn over high shoes and should not have cuffs.

15. Vessels or containers should not be welded until precautions have been taken to allow the confined air to escape.

16. Vessels or containers that have been used to hold combustible gas or liquids should be cleaned thoroughly with steam and then filled with water before welding is started.

17. Extreme caution should be used if welding is to be done in any coal-handling or coal-pulverizing space. The coal dust should be kept thoroughly wet down.

18. Enclosed-type safety switches should be used for protection against arcs and flashes.

OTHER CAUSES

Other causes, including hand tools, stepping on nails, and boiler and air-tank explosions, accounted for 8 percent of all fatal accidents and 17 percent of all nonfatal accidents in quarries and related outside works during the 10-year period 1933-42, as shown in table 1.

HAND TOOLS

Defective or unsafe hand tools and the improper use of hand tools have caused many accidents. Education and training of employees in the correct use of tools will prevent many such accidents. Some of the recommendations applicable to the prevention of accidents from hand tools are as follows:

1. Defective tools, such as hammers, axes, chisels with mushroomed heads, and tools with loose handles, should not be used. Files without handles should not be used. Wrenches with sprung jaws should not be used.

2. Only wrenches of the proper size should be used on any job, and employees should be trained in the proper use of wrenches. Improvised extension of wrench handles to obtain more leverage should be prohibited.

3. Whenever there is enough room men holding tools that are being struck with a sledge by another person should be on the opposite side from the man wielding the sledge.

4. Heavy bars should be laid flat and not left standing on end.

5. Tools should be put away immediately after use and not left where they might be a hazard, such as falling on a person or causing someone to trip over them.

6. A foreman or other authorized person should frequently inspect hand tools, and any that are found defective or unsafe should either be immediately repaired or replaced.
CAUSES AND PREVENTION OF ACCIDENTS

STEPPING ON NAILS

Many minor injuries are caused by stepping on nails. Such injuries may readily become serious by infection, unless they are treated promptly. The elimination of such accidents can be attained by rigid observance of the following:

1. Protruding nails in boards or other materials either should be removed or bent so that they will be flush with the material from which they were protruding.

BOILER AND AIR-RECEIVER EXPLOSIONS

Although boiler and air-receiver explosions do not occur frequently, they are a source of serious accidents. Recommendations for preventing accidents from boiler and air-receiver explosions and from other causes connected with their operation are as follows:

1. All stationary steam boilers should receive at least one internal inspection annually; the inspection should be made by an authorized boiler inspector, and a written record of each inspection should be kept.
2. A safety-valve escape should not discharge lower than 7 feet from the floor; the discharge should preferably be piped to a safe location outside of the building.
3. Safety valves should be tested frequently.
4. Steam gages should stand at zero when the pressure is off and should show the same pressure as the safety-valve setting when the safety valve is blowing off.
5. The water-gage glass should be kept clean and the passages kept open to prevent incorrect water-gage readings.
6. Repairs or adjustments to boiler or boiler fittings should never be made until the pressure has been removed.
7. Steam valves should be opened slowly.
8. Men should never enter a boiler until all valves have been closed, the fireman in charge notified, and danger signs have been placed on the boiler and at all valves which, if opened, would permit steam to enter the boiler.
9. At least two safe means of exit from all parts of the boiler room should be available; the doors should open outward.
10. A stairway or fixed ladder should be provided to give easy access to the top of boilers or runways between boilers.
11. Compressed-air receivers should be equipped with suitable pressure gages and safety valves.
12. Air receivers should be equipped with a drain cock at the lowest point, and the accumulation of sludge should be drained from the receiver at least once each working day.

MISCELLANEOUS HAZARDS

1. Horseplay or pranks should not be permitted.
2. Good housekeeping is essential to safe operation and is reflected in the safety records of quarries and plants.
3. Some of the requisites for good housekeeping are:

(a) Suitable receptacles should be provided and used for rubbish; metal cans with tight metal covers should be provided for oily waste and rags.
(b) Rubbish receptacles should be covered, and the contents removed at suitable regular intervals.
(c) Storage of materials should not be stumbling, falling, and fire hazards, and should provide adequate aisle space.
(d) Adequate lighting is essential.

4. Men should be prohibited from having liquor on the job and from coming on the job under the influence of liquor.
5. The leg muscles should be used in lifting, keeping the back straight and the shoulders higher than the hips.
6. Men working with picks, shovels, sledge hammers, etc., should be placed far enough apart to avoid the possibility of striking one another.
7. Gas and acetylene tanks should not be dropped, bumped, or otherwise roughly handled. Precautions should be taken to fasten gas cylinders so that they will not fall over when standing on end.
8. Horseplay with compressed air should not be permitted.
9. Persons handling wire rope should be required to wear heavy leather gloves.
10. Whenever possible, experienced men should work with new men.

HEALTH CONDITIONS

DUST CONTROL

The control of dust in quarries and related outside works is essential to the health of employees. The principal source or cause of dust in quarries is drilling dry with percussion-type air drills, such as jackhammers and wagon drills. Another common source of dust is the loading of trucks or cars by power shovels. Loading from chutes and the dumping of trucks and cars are also dust producers.
The three ways or methods of protecting employees from breathing dust-laden atmospheres are as follows:

1. Allay the dust at its source, use water in drilling, or use water to wet down blasted material before loading. Sprays may also be used to advantage in chutes for allaying dust. Wetting agents are sometimes used to advantage in allaying dust at its source.
2. Remove dust from the atmosphere by dust-collecting equipment which consists of suction fans, filters, and the necessary hoods and piping.
3. Prevent dust from entering the lungs by the use of approved-type dust respirators.

Wet drilling, although being used in some quarries where the rock contains a high content of free silica, is not generally used in quarries. Some quarry operators contend that in limestone and other rock quarries where the free silica content is within allowable limits there is no hazard involved from breathing the dust. However, exhaustive studies of the effects of breathing excessive amounts of most all dusts, made by numerous well-known authorities, including the Bureau of Mines, summarize the effects on health as follows: 11

As regards types of dust injurious to health, it appears that any dust insoluble or difficultly soluble in the fluids of the respiratory passages and in sufficiently finely divided form to float in the air and be breathed by workers in considerable quantities over long periods ultimately will be harmful.

Wet drilling is therefore recommended in all places where conditions will permit.

Wet drilling is not considered satisfactory or feasible in some quarries and in some rock drilling in connection with construction work because of freezing temperatures or other conditions. In such places where dry drilling is done, dust collectors should be used for collecting the dust at the collar of the drill hole before it becomes disseminated into the atmosphere. If dust collectors are not used, all drillers and other persons breathing the dust-laden air should be required to wear the proper type of respirator for protection against dust. Such respirators should also be worn when it is not feasible to allay dust by wetting in loading and dumping operations. Several manufacturers are now making dust-collecting equipment suitable for collecting dust at the collars of drill holes. This equipment is apparently doing a satisfactory job at some operations, although it is probably not as effective in all cases for eliminating dust as wet drilling.

Several types of equipment connected with outside works of quarries may cause the air to become burdened with excessive amounts of dust; these include crushers, vibrating or revolving screens, storage bins, elevators, and various types of conveyors. Many efficient dust-collecting systems are available for removing the dust at or near the source of such operations. For protecting the health of employees an efficient dust-collecting system should be installed and properly maintained in all parts of plants and crushers where excessive amounts of dust are being disseminated into the air. In places where such installations are not feasible, all employees should be furnished with suitable respirators, and their use should be made mandatory.

SANITATION

1. Change houses:
   If practicable, change houses should be provided with showers and an adequate supply of hot and cold water. Lighted carbide lamps should be prohibited to prevent fires. The change house should be:

   (a) Kept clean and sanitary.
   (b) Provided with at least two exits.
   (c) Well-illuminated.
   (d) Provided with clothes lockers, hangers, or both.
   (e) Kept well-heated, and, if necessary, the heating equipment guarded against contact hazards.
   (f) Properly ventilated.
   (g) Provided with facilities, properly maintained, to prevent the spread of foot infections.
   (h) Provided with sanitary toilet facilities.

2. Drinking water:
   (a) An adequate supply of pure drinking water should be furnished for all employees in quarries and plants.
   (b) The use of the common drinking cup should be prohibited; suitable sanitary cups should be provided.
   (c) Drinking water should be protected against contamination at all times.
   (d) Drinking water should be tested at frequent intervals to assure its suitability for drinking purposes.

3. Toilet facilities:
   (a) Each quarry should be provided with a sufficient number of tightly constructed insect- and rodent-proof closets for the convenience of employees.
(b) Adequate dry closets should be provided where suitable pits cannot be made.

(c) Proper arrangements should be made for the effectual cleansing of all dry closets. A disinfectant or deodorizer should be used; quicklime is recommended.

(d) Care should be taken that the excrement in dug closets does not contaminate the drinking water.

(e) Employees should be penalized for defecating on the surface, especially on the quarry or pit floor, when toilets are provided.

SAFETY ORGANIZATION

Safeguards will not, by themselves, prevent accidents; suitable safety rules, properly enforced, must also be provided. Training and education of employees concerning the hazards connected with their individual jobs and the safe methods by which their work can be done are of material assistance in reducing accidents. Safety consciousness will go far toward eliminating many accidents. This can be instilled into workers through the display of safety posters and encouraging their attendance at regularly held safety meetings at which the various accident hazards are discussed and remedies found for their elimination. Emphasis should be made in safety meetings on the mental and physical anguish and financial loss suffered not only by the injured but also by his family as a result of accidents. Suitable awards for no-accident records, if properly planned, often give valuable assistance in reducing the number of accidents. Compulsion alone will not prevent accidents but must go hand in hand with the cooperation of both management and employees. The employees must recognize that compulsory rules are made solely for their protection and that it is to their advantage to assist in seeing that they are enforced, even if, as individuals, they sometimes feel the brunt of disciplinary measures.

The following suggestions, some or all of which if incorporated in any safety organization, should materially aid in reducing accidents in quarries and related outside works:

1. A full-time safety engineer should be employed where there are 100 or more employees. (The practice of delegating numerous duties other than safety to the safety engineer, which became prevalent during the war, should be discontinued as soon as possible. Full-time duty on safety work is essential in plants or quarries employing 100 men or more.)

2. A safety organization of officials and employees should be established if practicable.

3. Joint safety meetings of men and officials should be held at least each month.

4. A bulletin board should be provided and posted with suitable bulletins and posters; safety posters should be replaced by new material from time to time.

5. Accidents involving injury to persons and other serious accidents should be investigated, and a record kept of such investigations.

6. Responsibility for accidents should be ascertained when possible.

7. A safety committee composed of workmen and officials should make periodic inspections of quarries and related outside...
works. They should submit suitable recommendations for correcting the hazards observed.
8. A record should be kept of all accidents; these should be summarized monthly, as well as annually, and studied with a view to correcting bad practices, conditions, or hazards.
9. Special company rules regarding quarry and plant safety should be formulated and adopted; preferably, they should be published so as to be made available to all employees.
10. All employees, especially new employees, should receive copies of the safety rules and should be encouraged to study them.
11. Employees should become conversant with the State laws for quarries and related plants; this should be done by instructions and assistance as may be obtained from the company or available educational agency.
12. All employees should be given first-aid training as soon as possible after being employed.
13. Additional first-aid training should be given all employees annually or at other periodic intervals.
14. Adequate first-aid materials should be provided in quarries and plants and should be kept in clean, usable condition.
15. A stretcher, woolen blanket, and waterproof blanket should be maintained in good condition in a place convenient and accessible to employees.

CONCLUSION

Quarries and related outside works are quite diversified in type, methods, and nature of material produced; each has its own peculiar accident hazards. The suggestions for the prevention of accidents in this paper do not completely cover all the various types of quarries, and some of the recommendations given may not be applicable to an individual quarrying operation. It is believed, however, that if the suggestions and recommendations are studied, and those applicable to a particular operation be adopted, either in whole or in part, the results obtained will be reflected in an improved accident record.

There is no question as to the astonishing results that can be and are being obtained in the lowering of accident rates where management takes enough interest to provide safe working conditions and obtains the cooperation of employees through active safety organizations. This is evidenced by the increasing number of large companies who, through their interest and investment in safety, have attained records showing millions of man-hours worked without a single lost-time accident. Such records not only reflect accident reduction but also a material saving in operating costs. Frequently, the savings have amounted to more than the cost of providing a safe operation.

BIBLIOGRAPHY