DEPARTMENT OF COMMERCE

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SAFEGUARDING WORKMEN AT OIL DERRICKS

BY

H. C. MILLER

PRICE 40 CENTS

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

UNITED STATES
GOVERNMENT PRINTING OFFICE
WASHINGTON
1927

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By H. C. MILLER

INTRODUCTION

Safety methods and devices in the oil fields are in a state of continual development; each year many changes and improvements are made for the greater protection of workers. Progress toward safety has been especially rapid in the improvement of derrick construction and in methods of safeguarding those whose duties take them into derricks. More operators are beginning to realize that safety is essential to efficiency, that efficiency results in lower costs, and that no successful operator can afford to produce oil without protecting those in his employ.

Employees should feel that they have a part in the safety movement, and should welcome every provision made to safeguard working places and conditions. They must do their share by always being careful, avoiding risks, using the safeguards and safety devices furnished, and discouraging carelessness and insisting that others do likewise. To the employee an accident means physical pain, loss of time with resultant loss in wages, and often privation in his family or among his dependents; to the employer an accident results in decreased production and higher unit costs.

Men working in a derrick that lacks proper safeguards and safety devices are constantly faced with the danger of falling from the working platforms or from the ladders that they must use in going to and from places above the derrick floor. Those men remaining on the floor are exposed to the machinery hazards and also to the risks of being struck by tools or materials dropped from above. Working thus in an atmosphere of danger, employees can not maintain the efficiency otherwise possible. This condition is reflected in the increased cost of labor.

Falls of workers can be avoided by railings placed around the exposed edges of platforms, or, if the platforms are inside the derrick where railings are not practicable, the use of safety belts and life lines will greatly reduce the number of falls. Many falls from derrick ladders can be prevented by constructing ladders properly, inclosing them in cages of wire netting, and offsetting them at short

intervals. Toe boards on exposed edges of all outside platforms will in a large measure prevent tools and materials from falling on those below.

At many derricks other inherent dangers exist because of conditions that usually are beyond the control of the drilling and producing crews. Partial or total collapse of the derrick, although relatively infrequent, is the most serious danger of this kind. The major causes of collapse are improper design of the derrick, faulty materials and construction, deterioration through age and vibration, and the softening of the ground under the derrick footings by water. These causes, either singly or in combination, are responsible for a large number of the derrick failures that cause injuries to oil workers.

Improper design can not be tolerated as an excuse for accidents. If competent and reliable rig builders are employed, they can be relied on to reject all faulty materials and to erect a derrick in a workmanlike manner and according to the best engineering construction. Deterioration from age can not be avoided entirely, but it can be reduced materially. The life of a wooden derrick will be prolonged by building it of proper lumber coated with a preservative where rotting is likely. Scraping off the rust and painting the exposed metal where it has rusted will prolong the life of steel derricks and will tend to maintain their original strength. Much of the deterioration due to vibration can be eliminated by renailing a wooden derrick when necessary and by keeping the bolt nuts on a steel derrick tight. Proper maintenance of wooden and steel derricks also requires guys with turnbuckles or other tightening devices to take up small amounts of slack without putting such sharp bends in the guy wires as are made with the ordinary board tighteners in which the line is twisted around a couple of 20-penny spikes.

A serious and insidious cause of derrick failure is the softening of the ground under the derrick footings by water, which may come from hosing off derrick floors, rains, flowing water sands, or other sources. Water filtering through the soil often reduces its safe bearing power by the actual solution or removal of fine soil particles. Frequently this softening is not accompanied by any perceptible settling until the derrick is loaded by a pull on the casing. Then the footings give and throw a twist into the derrick that causes it to collapse. The derrick may collapse straight in on the floor or it may collapse in any direction.

It is good business to construct substantial and permanent guards over all hazardous exposures. There is no economy in constructing makeshift guards that must be replaced or repaired frequently.

Safeguards will not prevent all accidents caused by machinery, but an organization emphasizes the importance of self-preservation

by installing safeguards and proves to its employees that it takes an interest in protecting them.

In addition to guards for the machinery at pumping wells, a safe means of getting to and from the belt-house roof should be provided. There should be a railed platform on the belt-house roof so that the walking-beam bearings and the pitman bearing can be oiled in safety. A ladder on the side of the derrick, extending from the railed platform on the roof of the belt house to the top of the walking beam, will allow workmen to climb on the beam in safety. A hand-rail on that part of the walking beam which is inside the derrick will assure safety to the man who must go out on the end of the beam to work on the temper screw or the equipment from which the sucker rods are suspended.

This bulletin presents some of the methods and devices used in the oil fields of the United States for reducing the number of accidents at derricks. The author hopes that this presentation will aid the petroleum industry in some of its safety problems, and will assist employer and employee alike in stimulating greater activity and interest in safety work. The data have been presented by text and photographs, and working drawings have been used to show the details of construction of a number of approved methods, guards, and devices.

This paper is the second in a series on safety work in the oil fields; it deals entirely with safe principles of derrick construction and the safety devices and safeguards found on and in the derrick. The first paper¹ in the series deals exclusively with the mechanical guards used in rotary drilling.

ACKNOWLEDGMENTS

For many of the data and photographs contained in this report, the writer is deeply indebted to the following organizations: The Associated Oil Co.; the Carter Oil Co.; the Empire Gas & Fuel Co.; the Hope Natural Gas Co.; the Humble Oil & Refining Co.; the Midwest Refining Co.; the Shell Co. of California; the Sinclair Oil Co.; the Standard Oil Co. of California; the Union Oil Co. of California; and the Industrial Accident Commission of the State of California.

Recognition for helpful information is due the following persons: N. C. Susan of the E. D. Bullard Co., San Francisco, Calif.; C. C. Scharpenberg, A. L. Tietze, Wallace Canfield, and Arthur Johnson of the Standard Oil Co. of California; H. A. Matier and G. F. Prussing of the Union Oil Co. of California; T. W. Osgood

¹ Miller, H. C., *Mechanical Safeguards in Rotary Drilling*: Tech. Paper 369, Bureau of Mines, 1925, 38 pp.

and J. Wesley Gebb of the Industrial Accident Commission of the State of California; Tracy Shaw and R. E. Carron of the Midwest Refining Co., Midwest, Wyo.; B. A. Myers of the Carter Oil Co., Salt Creek, Wyo.; J. J. Evans, Jake Meridith, Al. Taylor, and A. C. Perry of the Hope Natural Gas Co., Clarksburg, W. Va.; V. H. Hayslip of the Humble Oil & Refining Co., Houston, Tex.; A. J. Leonard and L. A. Ogden of the Empire Gas & Fuel Co., Oil Hill, Kans.; R. M. Carr of the Sinclair Oil Co., Enid, Okla.; H. C. Fowler of the United States Bureau of Mines, Bartlesville, Okla.; J. C. Ross of the United States Geological Survey, Midwest, Wyo.; and F. C. Gregory of the United States Bureau of Mines, Duluth, Minn.

For their constructive criticism of this paper acknowledgments are due to G. F. Prussing, H. A. Matier, and Allan MacDonald of the Union Oil Co. of California; C. C. Scharpenberg, C. W. Scholefield, Arthur Johnson, and R. A. Donovan of the Standard Oil Co. of California; R. W. Kelly, J. A. Jones, and H. A. Mallman of the Associated Oil Co.; E. L. Adams of the General Petroleum Corporation; E. G. Sheibley, T. W. Osgood, G. Chester Brown, and J. Wesley Gebb of the Industrial Accident Commission of the State of California; F. B. Tough and T. T. Read, formerly of the United States Bureau of Mines; and to the following members of the bureau: H. H. Hill, F. M. Brewster, C. P. Bowie, and H. C. Fowler.

Grateful acknowledgment is made to other members of the United States Bureau of Mines who aided in the preparation of this paper.

DERRICK FOUNDATIONS

The object in having foundation piers under an oil derrick is to provide such a solid base for the derrick that its corners will not settle unequally when long strings of drill pipe or casing are lifted. When foundation piers settle unevenly, the stability of the derrick is endangered and the lives of the men under the derrick are jeopardized. Unequal settling of the foundation piers throws the crown of the derrick out of line with the hole that is being drilled. A half-inch settling of a foundation pier will throw the crown blocks of a 114-foot derrick 3 inches out of alignment; also a twist will be thrown into every girt, brace, and leg of the derrick, and will tend to loosen them. A nailed or riveted joint will often fail if subjected to a sudden twist, even though it is amply strong to resist straight shearing, thrust, or tension. An unequal settling will throw stresses into some of the guy wires and slack into others; this unequal tension reduces the power of the guy wires to combat the overturning pressures of wind blowing against the derrick.

It is impossible to drill a straight hole when the derrick crown is out of line with the hole. Not only will the hole be crooked, but line cuts, line wear, and, in rotary drilling, "twists off" will result. When the derrick is considerably out of plumb, the load is unevenly distributed on the four legs and there is danger of pulling in the derrick.

A slight displacement at the derrick crown, when it is parallel to the crown-block I-beams, can be corrected by shifting the pulley boxes. Steel I-beams usually have a number of extra bolt holes, or the pulley boxes have hook bolts that grip the under side of the web of the I-beam, so that the boxes can be shifted to any desired position along the beams. Such practice is permissible and safe because the shifting is so slight that no serious change will take place in the distribution of the loads on the four legs of the derrick.

When the displacement of the derrick crown is too great for correction by shifting the pulley boxes, or if the movement has not been parallel to the I-beams, many drillers shift the crown blocks in their entirety in order to make the sheaves again line up with the hole being drilled. This practice is dangerous because the I-beams should at all times have a full bearing on the bumper timbers. Shifted crown blocks, resulting in broken bumper timbers, falling crown blocks, and collapsed derricks have been the cause of many oil-field accidents. Such accidents can be averted by jacking up and shimming the low corners of the derrick. After the derrick has been brought back to plumb, all guy wires should be inspected for kinks and weak spots and made taut. Unequal settling of derrick foundations can be largely prevented by greater care in the design and construction of foundation piers.

FACTORS DETERMINING SIZE AND DESIGN OF FOUNDATION

Virtually every site for a derrick offers conditions that make the establishing of foundation piers a problem different from that at the last site; usually the design and size of derrick foundations to meet these conditions are left to the head rig builder. At Goose Creek, Tex., some of the derricks are built out in the bay (fig. 1), and in the Summerland field in California derricks built on piling extend some distance into the Pacific Ocean. Many derricks at Huntington Beach, Calif., are built on boggy land that is only a few feet above sea level, and many are on dirt that has been hauled in or on concrete foundations supported by piles (fig. 2). In the hilly parts of West Virginia, Wyoming, California, and elsewhere some derricks are built on hillsides and have one or more foundation piers resting on filled ground. Most of the derricks in the United States, however, are constructed on relatively dry ground

where the soil conditions are such that properly proportioned piers make satisfactory foundations.

The area of the base of foundation piers should be proportioned to the load to be carried and the bearing power of the soil on which they are to be built. The maximum load that may come on each of the foundation piers is problematical and can not be determined exactly, because it depends upon the type of derrick, whether wood or steel; the height of the derrick; the depth of the well being

FIGURE 1.—Oil derrick erected in the bay, Goose Creek, Tex.

drilled; the size and weight of the casing handled; and the method of drilling, whether it is by cable or rotary tools. Wood is generally used for derricks, although steel derricks are rapidly coming into general use, especially in congested districts where a fire hazard exists and in localities visited by frequent windstorms. The drill pipe used in rotary drilling comes in lengths about 20 feet long, and the number of lengths of drill pipe to the stand determines the height of the derricks in rotary-drilling practice. When other conditions are equal, the fewer the stands per depth of hole the greater the speed at which a well can be drilled. Derricks

for rotary drilling generally range in height from 96 to 122 feet. In cable-drilling practice, where the height of the derrick is determined by the length of the string of drilling tools, heights range from 62 to 84 feet. In California, where rotary drilling is almost always used, a depth of 7,936 feet² has been reached by the drill, and well depths more than 5,000 feet deep are common. In Pennsylvania, where wells are drilled by cable tools, a well was sunk a depth of 7,756 feet.³ Prepa-

² California Oil World, "C. C. M. O. Olinda test loses bit cutters at 7936": Vol. 19, Aug. 19, 1926, p. 1.

³ Garrison, R. H., "Deep-drilling practice in California": Oil and Gas Jour., vol. 24, Jan. 1926, p. 76.

rations have been made in West Virginia to drill a well by cable tools to 10,000 feet unless oil or gas is found at a less depth.

The size and weight of the drill pipe and casing used in drilling a well, the amount of friction between the pipe and the sides of the hole, and the unascertainable stresses that may come on the derrick legs when the driller attempts to free a string of frozen casing by loading his engine to the limit are factors that must be taken into account in the design of foundation piers for derricks.

As previously mentioned, the controlling load factor to use in designing derricks and derrick foundation piers is problematical and can not be determined exactly. Many practical oil men have always been of the opinion that a derrick should be strong enough

FIGURE 2.—Driving used 11 $\frac{3}{8}$ -inch casing, 10 feet long, to support foundation piers of 122-foot derrick at Huntington Beach, Calif. Casing filled with concrete after driving. Ten piles to each foundation pier

to counteract the strain necessary to pull the stoutest casing in two. Recent practice in designing steel derricks is to consider that less damage and loss of property and life will result from the breaking of a wire line than from pulling in the derrick. The breaking strengths of those sizes of drilling and casing lines that are used in the oil industry are given in Table 1. This table agrees with the standards adopted by the United States Bureau of Standards and by the wire-rope manufacturers. The figures for the minimum breaking strengths given in the table should be divided by 5 in order to obtain the recommended safe working load. Manufacturers recommend a factor of safety of 5 for wire rope used in drilling for oil and gas.

TABLE 1.—*Minimum breaking strengths of wire drilling and casing lines*

Nominal diameter	Cast steel	Extra strong cast steel	Plow steel	High-grade plow steel
	<i>Pounds</i>	<i>Pounds</i>	<i>Pounds</i>	<i>Pounds</i>
$\frac{3}{4}$ inch.....	35,000	40,400	46,000	52,600
$\frac{7}{8}$ inch.....	46,000	52,000	58,000	80,000
1 inch.....	60,000	68,000	76,000	90,000
$1\frac{1}{8}$ inches.....	76,000	86,000	94,000	112,000

In determining the maximum load that the foundations of a 114-foot and a 122-foot heavy California type derrick should carry without appreciable settling, it is assumed that nine ⁴ 1-inch lines are the most used at any time for hoisting drilling tools and casing. On this basis the maximum load on each foundation pier is found as follows:

Breaking strength of 1-inch-diameter plow-steel wire line=76,000 pounds. $9 \times 76,000 = 684,000$ pounds=total breaking strength of 9 lines. 56,000 pounds=approximate weight of wooden derrick, crown blocks, etc. $684,000 + 56,000 = 740,000$ pounds=total actual weight on the 4 foundation piers. $\frac{740,000}{4} = 185,000$ pounds, or the weight on each pier.

As very few derricks are absolutely plumb the load is not always equally divided on the four piers, and some allowance must be made for this fact. Just how great this added weight may be is indeterminate, but a total load of 200,000 pounds, or 100 tons, on each foundation pier is considered to be within the limits of safety.

SOIL

After determining the approximate weight to be supported by each footing, it next becomes necessary to consider the soil on which the derrick is to be erected. Clay soils range from undecomposed or partly decomposed slate or shale rock, which will support the derrick load on foundations having a small bearing area, to soft clay, which will squeeze out in every direction under load. Derricks to be built on a soft clay soil require footings of relatively large area. Coarse sand and gravel in the clay increase its supporting power, and a sandy or gravelly clay is less liable to ooze away when pressure is brought on it. Gravel and coarse sand, when confined laterally so that the finer particles can not be washed away, make an excellent

⁴ In exceptional cases more than nine lines are sometimes used. According to F. M. Brewster, Bureau of Mines, recently in West Virginia a company used thirteen 1-inch lines in lowering a string of special 6-inch casing 6,824 feet long. This casing weighed 249,000 pounds and was not floated in, as is the practice in rotary drilling.

foundation soil and require foundation piers of relatively small area to support the derrick loads safely.

A large amount of water used in drilling a well, particularly by the rotary method, runs through the derrick floor to the ground underneath and into the foundation soil; therefore, it is best to regard a clay soil with doubt and to construct the foundation accordingly. If the soil underneath the derrick is of such texture that water used in drilling will seep into it and endanger the stability of the foundation piers, the surface of the ground under the derrick should be concreted. (See fig. 4.) When the derrick is to be erected on a hillside, precautions must be taken to prevent the foundation piers from sliding. Foundations should be carried to such depths that drainage water from the derrick floor and elsewhere can be excluded from the soil underneath the foundation piers. Clay soil, especially when wet, will ooze from under the footings and cause settling and sliding.

In designing foundation piers for derricks, some elasticity must be given to the values shown in handbooks for the bearing power of soils, because derrick foundations are subjected to shock and jar. Table 2 gives the bearing area of safe foundation piers for 114 and for 122 foot derricks for the various soils found in the oil fields. The values for the safe bearing power of soils on which oil derricks are built have been derived from the practice of operators in California and elsewhere. The bearing area in square feet of foundation piers for shorter derricks can be determined by dividing the total weight on one of the piers by the safe bearing power of soils given in Table 2. For economy in labor and materials, concrete

TABLE 2.—*Bearing area of foundation piers for 114 and for 122 foot oil derricks for various soils, and the safe bearing power of those soils*

Kind of soil	Safe bearing power ¹	Bearing area of foundation piers
	<i>Lbs. per sq. ft.</i>	<i>Feet</i>
Quicksand, alluvial soils, etc.	1, 100	² 14 by 14
Soft clay	1, 400	12 by 12
Ordinary clay and sand together in layers, wet and springy	2, 500	9 by 9
Loam, clay, or fine sand, firm and dry	3, 000	8 by 8
Very firm, coarse, stiff gravel or hard clay	5, 500	6 by 6
Rock (shale)	6, 600	5½ by 5½

¹ Oil-field practice.

² Piling recommended in quicksand.

foundations for wooden derricks are built so that their tops are usually not more than 6 inches above the surface of the ground. Wooden blocks or posts are used on top of the concrete piers to bring the derrick sills to the desired height.

Concrete foundations for steel derricks are usually carried up to the bottom of the steel floor beams; these beams are bolted directly to the concrete piers.

The depth to which derrick foundation footings must be carried to support the load safely, without settling or sliding, depends largely on the slope of the ground and the depth of the soil. No derrick should be built on a hillside on filled ground unless the footings extend through the fill to the firm soil underneath, except where the fill has such a large area that it may be considered natural soil. Precautions must be taken to prevent water from reaching the under side of the footings, if the underlying soil on which the foundations rest is clay in layers that dip down the slope of the hill. The water that seeps down around the footings will soften the clay and thus allow the foundation piers to slide.

FIGURE 3.—Details of derrick foundations suitable for 114 and 122 foot wooden derricks on a soil composed of clay and sand: A, concrete; B, wood

Excavations for concrete piers are usually carried to depths of 3 to 5 feet below the surface of the ground, unless soil conditions necessitate going to a greater depth to obtain a satisfactory and safe footing. When lumber is used instead of concrete, only the loose top soil is scraped away, and then a place is

leveled for the footing. On hillsides the tops of these piers will not necessarily be at the same elevation. There is no objection to posting up under the derrick floor if the posts are properly braced.

FOUNDATION PIERS

Figure 3 illustrates two types of foundation piers designed for a 114-foot and a 122-foot derrick for rotary drilling. Such piers will support a load of 200,000 pounds on a soil composed of sand and clay, with a bearing power of 2,500 pounds to the square foot.

(See Table 2.) The bearing area in square feet of a foundation pier for shorter derricks can be found by dividing the total load on that foundation by the bearing power of the soil on which the derrick is to be built.

In constructing timber foundations for oil derricks, 3 by 12 inch planks should be used. The planks of the lower course, after being coated with a wood preservative, should be laid close together on the leveled ground. On top of these planks the next course, equal in length to the width of the lower course, should be spiked. Each succeeding course should then be laid on in a transverse direction and be well spiked to the course below. Foundation piers should have anchor bolts, by means of which the side sills of the derrick can be bolted to the piers. The best woods for timber foundation piers are oak, Georgia pine, Oregon pine, and California redwood. Wooden footings are easily constructed and inexpensive, and if properly protected will last for decades.

Concrete footings have many qualities to recommend them. When the materials of the concrete have been properly selected, proportioned, mixed, and placed, the durability of the footing is practically everlasting. By bolting the side sills to the concrete footings, weight is added at the derrick corners. This weight is an aid in holding the derrick erect in a windstorm.

In those localities, particularly hillsides, where the surface soil is liable to be washed away by the water used in drilling, especially rotary drilling in which a great deal of water gets under the derrick, the ground between the foundation piers should be covered by a layer of concrete 1 to 2 inches thick. This concrete blanket prevents water from finding its way around and underneath the foundation piers and prevents the washing away of the soil underneath the derrick floor; it is important, because seepage of water around derrick foundations is the commonest cause of their settling. The surface of this concrete should be so sloped that water will drain to a common point, whence it can be carried off in a pipe or flume.

Figure 4 shows a typical concrete foundation for a derrick on a gently sloping hillside. Here a layer of concrete 2 inches thick keeps the loose, sandy soil from washing away.

DERRICK CELLARS

Many derricks have cellars measuring 8 by 8 to 10 by 10 feet and 8 to 16 or more feet deep. The depths depend on the opinions of different operators and on which of the two methods of drilling is employed. For rotary drilling, a depth of 10 or 12 feet below the sills of the derrick is adequate and provides ample headroom for all the

casing connections and fittings that may be required. Operators who use the cable-tool method of drilling excavate their cellars to depths of 16 to 20 feet. Deep cellars are advantageous for cable-tool work, especially in localities where unconsolidated sands are encountered. Under such conditions the driller is often compelled to work the casing far enough below the derrick floor to give sufficient clearance for screwing on another joint.

Whenever the depth of cellars in loose or cavey ground is more than 5 feet the sides should be protected by sheeting and shoring to keep them from caving and thus entombing or injuring the workers. The sides of all deep cellars, and of all shallow cellars that are liable to cave, should be protected permanently. Square frames placed

FIGURE 4.—Concrete foundation for derrick, showing 2-inch concrete blanket between foundation pliers

horizontally with vertical lagging planks, or walls of concrete thick enough to hold back the ground, are the two means best suited to prevent cellar walls from caving. When concrete is used for wall material, the floor should likewise be made of concrete. If the ground tends to cave, the derrick cellars are usually dug by hand and shored as depth is gained. In sandy and swampy areas it is often necessary to use wooden sheet piling from the surface down. Figure 5 shows the sinking of a derrick cellar in wet and running ground. The earthy material and water were ejected from the cellar excavation by means of a steam jet. Double rows of 2 by 12 inch wooden sheet piling held back the running ground; they were driven by hand as excavation progressed.

Every cellar should have a means of exit from its bottom to the surface of the ground.⁵ This may be a stairway (fig. 6), an inclined runway (fig. 7), or a ladder. Experience shows that stairways and

FIGURE 5.—Sinking a derrick cellar in wet and running ground with a steam jet. Wooden sheet piling protects the sides of the cellar against caving. Huntington Beach field, Calif.

runways are safest and best for cellars over 16 feet deep. Stairways and runways should be at least 3 feet wide, and there should be a minimum clearance of 7 feet between the floor of the stairway, or

FIGURE 6.—Concrete cellar for derrick: *a*, Stairway to surface of ground and to derrick floor; *b*, steam line to jet; *c*, discharge line from jet

runway, and the derrick sills. According to the Industrial Accident Commission of the State of California, the angle of the slope of cellar stairways should not exceed 50° from the horizontal. The

⁵ Industrial Accident Commission of the State of California, General Petroleum Industry Safety Orders for Drilling and Production: 1924, p. 7.

Department of Labor, Bureau of Factory Inspection, State of Oklahoma, Petroleum Industry Safety Orders: Order No. 57, 1925.

maximum slope for inclined runways should not exceed 20°. The sides of the runway and the excavation for the stairway should be protected against caving by sheeting and shoring. Exits of derrick cellars should provide at all times an unobstructed passage out of the cellar.

Ladders may be used only in cellars that are 16 feet or less in depth. When ladders are built out of thoroughly seasoned, straight-grained lumber, free from knots or other serious structural defects, they are considered a safe means of exit. To assure the highest degree of stability and safety, the ladder rails should be 2 by 6 inches in section, and the 1 by 6 inch rungs should be nailed securely.

Ladder and stairway openings in the derrick floor should have trapdoors or covers that can be kept closed except when men are working in the cellar. In cable-tool drilling it is also important to

FIGURE 7.—Inclined runway from derrick cellar

have well-fitted floor boards in the cellar opening through which the blocks travel. These boards should be kept in place at all times, except when pipe is being handled. Many men have been injured by falling into derrick cellars through floor openings.

DRAINAGE

Figure 6 shows a concrete cellar at a rotary-drilled well. This cellar has walls higher than the surface of the surrounding ground. Such construction is advantageous, because the portion of the concrete walls above ground acts as a barrier to surface drainage water from the derrick floor and elsewhere. No water, except that which may come through the derrick floor directly above, can run into the cellar. The derrick floor shown in Figure 7 is sloped both ways

from the center in order that the water will run off rapidly and less water will find its way through the floor into the cellar. It is important to keep water from getting into cellars lagged with lumber—especially cellars in loose and pervious strata. The walls of such cellars will not always prevent water from seeping into pervious strata that may underlie the foundation piers of the derrick. Many soils contain soluble salts, and often the percolating water from the derrick cellar will remove or dissolve the fine soil particles of the pervious strata beneath the foundation piers and thus cause the derrick to settle.

Drillers should be cautioned against allowing water, mud-laden fluid, and oil to accumulate in derrick cellars. A few years ago a fatal accident occurred when an oil worker went into a derrick cellar to repair a plugged steam jet. Enough steam had leaked under the seat of a defective shut-off valve in the steam line to the jet to heat to a high temperature the mud-laden fluid that had accumulated in the cellar. The workman accidentally fell into the hot fluid and was fatally burned.

Cellars not equipped with a gravity drain can be kept dry by means of a steam jet when steam is available. When a well is being drilled by electricity and steam can not be had, a small motor-driven pump can be used. A manually operated diaphragm pump will keep a cellar dry when no mechanical power is available. To accommodate the jet or pump suction, a pit about 18 inches square and 12 inches deep is built in the floor of the cellar at one corner. In order that the floor can be kept dry, it slopes from all directions to the suction pit.

Steam lines to jets in derrick cellars, especially lines placed near the ladders and stairways, have caused many burns. Men who lose their balance and fall from cellar ladders or stairways unconsciously grab at anything within reach, and many have had their hands severely burned in this manner. There are records also of men working in the cellar being burned seriously by backing against hot steam lines. Such accidents can be guarded against by placing the steam line in the cellar corner diagonally opposite the ladder or stairway. If for some reason it is impossible to do this, then that part of the steam line in the cellar should be covered with an insulating material or otherwise inclosed.

BREATHING APPARATUS AND MASKS

During the drilling of many wells so much gas collects in the derrick cellar that it is dangerous for men to go down to handle spider slips, drive clamps, and tools. This gas may be petroleum vapors or hydrogen sulphide, or a mixture of the two. Hydrogen sulphide is

much more poisonous than petroleum vapors and quickly causes unconsciousness and death. Fortunately, only a few petroleum, such as some found in Mexico, Canada, the Pan Handle oil field, Texas, and the Lima field, Ohio, contain hydrogen sulphide in solution and give it off when exposed to the air.

A few years ago two men were asphyxiated by "poison gas" in the cellar of a well being drilled in the Sunset field in California. This gas, which probably was hydrogen sulphide, was present at a number of locations within a certain area in such quantities that it was extremely dangerous for a man to enter a cellar without fresh air being first supplied. At these wells, blowers were set on the derrick floors with pipes leading to the bottom of the cellars, and air was forced into the cellars to drive out or to dilute the gases so that men could enter safely. If this gas was hydrogen sulphide gas, it is indeed fortunate that other men did not lose their lives by inhaling it. Though hydrogen sulphide has an exceedingly disagreeable odor when greatly diluted in air, it is odorless in deadly concentrations. Unless they are equipped with suitable gas masks or hose masks, men should not enter derrick cellars containing hydrogen sulphide gas or petroleum vapors until the cellars have been freed of all noxious gases. In using gas masks, however, the wearers should remember that the effectiveness of the canister type of mask is restricted to certain definite atmospheres and does not protect against concentrations of petroleum vapors in air that exceed 5 per cent by volume, or concentrations of hydrogen sulphide that exceed 2 per cent.⁶ Unless it is definitely known from chemical analysis that the vapors do not exceed these concentrations, canister gas masks must not be used.

Self-contained oxygen breathing apparatus protect against all deficiencies of oxygen. They are not dependent on the surrounding air and therefore protect against any concentrations of petroleum vapors or hydrogen sulphide. In the oil fields oxygen breathing apparatus are seldom used; they are bulky and heavy, only trained men can use them, and they require frequent attention to insure their maintenance in good working condition.

Hose masks, because their use is not limited to certain concentrations or kinds of vapors or gases, are especially adapted for work in petroleum vapors and hydrogen sulphide gas in derrick cellars. Fresh air is either drawn through a rubber hose by the wearer himself or it is forced to him by a manually operated blower through the hose from a source uncontaminated by irrespirable gases or vapors. Although the distance the wearer may go from pure air is

⁶ Katz, S. H., and Bloomfield, J. J., Gas Masks for Gasoline and Petroleum Vapors: Tech. Paper 348, Bureau of Mines, 1924, p. 24.

limited by the length of the hose, the length required for work in derrick cellars seldom exceeds 50 feet. No chemicals are required for hose masks, men do not have to be specially trained in their use, and there is virtually no upkeep expense.

Workmen who wear hose masks should be cautioned against using any other hose than that supplied with the masks or that made especially for hose masks. These hose are made of a special grade of treated rubber and cloth and are fitted inside with an embedded stiff-metal spiral that prevents collapse. Bastard connections are now being placed on this type of hose so that garden hose can not be substituted for it or used with hose masks when additional length is required. Garden hose is penetrated quickly by petroleum vapors; there is also the danger that flowers of sulphur will form in improperly treated rubber hose and will clog the inside passages.

Sometimes men have to enter a derrick cellar when no hose or gas masks are available. At such times fresh air should be blown into every corner and along the floor of the cellar through a hose or pipe until it is reasonably certain that the cellar has been freed of gases and vapors. A rope long enough to reach the bottom of the cellar should then be made fast to each man before he enters the cellar. One or more attendants should hold onto the other end of the rope at a place of safety, where they can keep watch over the man in the cellar and pull him out if he is overcome by gas. A man that has been overcome by gas should be removed to fresh air immediately and artificial respiration started.

DERRICKS

WOODEN DERRICKS

Only material that is structurally sound, free from serious defects, and properly proportioned to the load requirements should be used for derricks. The members of the derrick must be well put together with nails long enough and in such numbers as to give the fabricated structure its maximum strength. During drilling operations a loosely built derrick will vibrate considerably and nails become loosened; winds of high velocity and the alternate swelling and shrinkage of the lumber through changes of weather also tend to weaken derricks. A weakened derrick is a dangerous structure in which to work.

A wooden derrick under construction is usually squared and plumbed only by the eye of the head rig builder. If the derrick is built, as often happens, with even a slight twist, the crown of the finished derrick will not square up with the base. When the load is applied, the structure is very liable to corkscrew and collapse. Often the crown of a derrick does not line up with the hole, and

the crown blocks are shifted to take care of this discrepancy. This shifting throws unequal stresses on the derrick members by unevenly distributing the load on the four legs. Such a derrick will not stand the same pull as one that is plumb. The additional time and labor required to plumb and square a derrick carefully as it is being run are well spent and a farsighted economy. Too much emphasis can not be put on the necessity of building derricks plumb and square. If the head of the rig-building crew is competent, such errors will seldom if ever get by.

PROVISION FOR STRESSES

Derricks should be substantially constructed to provide against any unforeseen stresses, such as those caused by the driller endeavor-

FIGURE 8.—Wreckage of a collapsed derrick. Failure to keep this derrick in good repair cost two lives

ing to free a string of frozen casing, drill pipe, or tools. The combined mechanical efficiency of the ordinary band wheel, calf wheel, and casing block is about 144 times the lifting force of the engine. This enormous force with the engine "wide open" is usually enough to pull the casing or the wire line in two, or to collapse the derrick. Invariably workers on the derrick floor are injured, even fatally, when a derrick collapses. There is less danger when the line breaks or the casing parts than when the derrick collapses; the workers may escape uninjured if they are cautious and stand back away from the calf wheel and hoisting tackle when a heavy pull is taken on the casing.

Figure 8 shows the wreckage of a collapsed derrick, which failed between the first and second girts above the floor. Investigators

from the Industrial Accident Commission of the State of California found that the cause of the collapse was an insecure foundation and the weakened condition of the derrick itself because of missing girts and braces. The investigators also found that the derrick had been guyed with only one guy wire and that that wire had been loose. Neglect to keep this derrick in repair cost two lives.

Drillers often realize the weak condition of the derrick under which they are working and try to play safe by operating the hoisting equipment from the engine house. This practice can not be commended. If a derrick is known to be weak, it should be repaired before a heavy pull is attempted. Wooden derricks deteriorate rapidly with use and age; hence they are much weaker after a well has been drilled with them and they have stood several years unprotected from the elements. Redrilling and deepening jobs frequently necessitate strengthening the legs of the derrick before the increased loads can be handled. Legs are strengthened by additional 2 by 12 inch members (doubler) nailed against the derrick legs, to a height of 20 to 40 feet above the floor, or by 2 by 8 inch lumber nailed against the girts and braces along the edges of the derrick legs. Missing girts and cross braces should be replaced. When the derrick must be strengthened, additional cross braces should also be nailed on.

Figure 9 shows a derrick reinforced for deeper drilling. As the additional girts and cross braces have been nailed on over the derrick ladder, the rig builders certainly gave little thought to the safety of the crews that were to redrill the well. To ask a derrickman to climb to the crown of this derrick would be criminal, but with the companies that employ rig builders as inefficient and thoughtless as those who worked on this derrick, it might cost the man his job if he complained about the ladder. Figure 9 illustrates a deplorable condition of unsafe practice.

PULLING CASING

Pulling a string of casing that is fast in the hole throws a severe strain on the derrick. To attempt this operation under a weak derrick is dangerous for there is no way of knowing how severe is the strain on the derrick. Some companies operating cable-tool rigs in West Virginia require the use of shear poles whenever it is thought that the derrick may not stand the strain of a heavy pull. These shear poles have two legs of heavy 10-inch, or larger, casing, 40 feet long. Sometimes heavy wooden poles are used for the legs of shear poles. Each leg stands on a 12 by 16 inch timber 8 to 12 feet long, bolted crosswise of the derrick sills to the floor timbers.

These timbers are placed parallel to each other and about 7 feet each way from the hole. Across the top of the two legs is a 12 by 16 inch or larger timber, 5 feet long; the hoisting tackle is suspended from it. The top of the shear pole is held in position over the center of the hole by guy wires running to the four corners of the derrick.

FIGURE 9.—Derrick reinforced with additional girts, cross braces, and uprights along derrick legs. Note unsafe practice of nailing braces and girts over existing derrick ladder. Smackover, field, Ark.

The hoisting outfit consists of a two-sheave casing pulley and a three-sheave traveling block. The casing pulley is made fast to the top cap of the shear pole by wrapping wire rope around the cap and through the becket of the pulley. The dead end of the casing line is fastened to the lower becket of the casing pulley. The fall line passes over a casing pulley in the crown-block assembly, then down to the calf-wheel shaft. If there is no calf wheel, the bull-wheel shaft is used. With this hoisting arrangement, about 70 per cent of the load is taken off the derrick crown. Shear poles of a similar design are also used with drilling and pulling machines when the mast is not strong enough to carry a heavy load.

As has been stated, it is best to consider the casing line the weak part of the drilling equipment and to build the derrick to carry a load greater than the line will hold. The load that will part the casing line is the breaking load of one line multiplied as many times as there are lines strung between the hoisting block and the derrick crown. Safe design requires that the derrick sustaining this load shall be perfectly safe under all conditions. Some allowances, however, must be made for defects in material and workmanship. To take care of these unknown quantities, a factor of safety of not less than 4 is used in

designing derricks. A factor of safety means the ratio in which the breaking load exceeds the safe load, or, in other words, each piece of material entering into the construction of the derrick should be able to resist stresses at least four times greater than what may be required under ordinary conditions.

MAINTENANCE OF SAFE CONDITIONS

Many advocates of better derricks recommend bolting the girts and braces to the derrick legs, in addition to nailing them. This practice is not necessary if the derrick is properly erected, and if it is renailed when inspection shows renailing is necessary. Wooden derricks made of seasoned lumber bolted together without the use of nails are used in some parts of the country. They have the advantage of being moved easily, as they can be quickly taken down and reerected. Nailed derricks should not be allowed to stand year after year without the nails being redriven, for the strength of the entire structure depends upon the holding power of the nails. No redrilling or deepening job should start until the derrick has been carefully inspected and reconditioned if necessary.

Drilling crews should realize that each and every member of the derrick is there for a purpose. Each member sustains a certain load and by its being there strengthens other members. Under no circumstances should a member be sawed away or its cross sectional area be reduced by notching or chipping unless the member is to be immediately replaced. If an opening must be cut in the side of the derrick for the purpose of bringing in tools and materials that can not be brought in otherwise, those members should be replaced immediately, because their removal has reduced the strength of the derrick as a whole.

Too much emphasis can not be placed on the need of frequently inspecting the derrick for loosened members and unsecured material. Many accidents have been caused by derrick members falling on men at work on the derrick floor. It has often happened that members loosened by the vibrations of the derrick and struck by a swinging cable or string of tools have dropped on those below. A careful driller will never start his tour or shift until his derrickman or tool dresser has thoroughly inspected the derrick and every loose member has been made secure. Only by constant vigilance and effort can the number of such accidents be reduced.

STEEL DERRICKS

So far as safety is concerned, steel derricks are superior to those built of wood. Steel derricks with concrete foundations and corrugated-iron housing are practically fireproof. This fact not only re-

duces the risk of property losses, but avoids the possibility of injury to workmen from burning wooden derricks. When too great a load is put on them, steel derricks twist and buckle rather than collapse, and in consequence the danger of injury to the men working on the floor of the derrick is much reduced. Failures of steel derricks in the past have been due primarily to the unknown loads and conditions which derricks have to withstand. The knowledge gained from

a study of these failures has been used in the design of later derricks, with the result that properly erected steel derricks to-day rarely fail.

Bolted steel derricks should be inspected frequently for loose bolt nuts. Many men on derrick floors have been injured when struck by nuts that had dropped from derrick bolts. Inspection of steel derricks, followed by the tightening of loose nuts, is especially important and necessary during the first few days that derricks are in use.

Painted steel derricks should be inspected for rusty spots, for those parts of steel derricks that are unprotected by paint rust rapidly. All rusty spots should be cleaned thoroughly with a wire brush and a steel scraper and

FIGURE 10.—Tubular steel derrick. Note bent brace and legs caused by tubing hook catching derrick brace

then coated with red lead, graphite, or other metal-preserving paint. In many localities, especially in the oil fields near the seacoast, painted derricks must be painted every year or two. Even the zinc coating on some galvanized derricks flakes off and exposes the bare metal to corrosion unless it is protected by paint. Steel derricks that are not protected against corrosion soon lose much of their original strength. Not only do such inspections and corrective measures lengthen the life of a derrick, but they reduce the possibility of workmen being injured because of its failure. To know that the structure

under which they are working is entirely safe and that loose nuts and other materials are not likely to fall on them gives the workmen a feeling of security which they otherwise would not enjoy.

Drillers, when hoisting tubing and rod hooks, should be careful that swinging hooks do not catch on derrick girts or cross braces. Figure 10 shows the damage done to two legs of a tubular steel derrick when a tubing hook caught and bent a derrick brace. Figure 11 illustrates what happened when a tubing hook caught on a member of a turnbuckle derrick. The upper half of the derrick was completely torn away from the lower section before the engine could be stopped. An accident like this means almost certain death to the man up in the derrick; he has practically no chance to save himself.

Crews working in steel derricks should take care that derrick members are not bent or otherwise deformed. Treading on the small steel braces, girts, and turnbuckle rods bends them and shortens the distance between their fastenings. Such bending throws added stresses into these members and into those immediately adjacent to them. By walking on the girts of a light steel derrick of the type used in many fields for drilling shallow wells and for pumping wells, a heavy man can bend them and thus cause the legs at the ends of the girt to bend toward each other. When the legs bend the strength of the derrick is impaired, and the derrick may buckle at that point when loaded.

When bull ropes at steel derricks are stretched too tightly they will bend the derrick leg nearest the tug pulley of the bull wheels; such bending should be guarded against because it weakens the derrick at that point.

FIGURE 11.—Turnbuckle derrick with upper half completely torn away from lower section by tubing hook catching on derrick girt

DERRICK GUYS

WIND STRESSES

The importance of properly guying derricks is underestimated. In nine years, 1916 to 1924, inclusive, windstorms in the United States leveled over 9,000 derricks. Derrick-leveling windstorms are frequent in the Mid-Continent and Gulf oil fields. California experienced the greatest windstorm disaster recorded in oil-field annals when in January, 1916, two windstorms leveled 1,870 derricks in the San Joaquin Valley, causing a loss of over \$500,000.

The destructiveness of a derrick-leveling wind, however, can not always be measured by its monetary losses alone; often such a wind leaves in its wake many persons who have been injured and killed. The proper guying of derricks has, therefore, a humanitarian aspect aside from its value as a precaution against financial losses. The importance of guying derricks in accordance with good engineering principles increases as derricks are built to greater heights. Most derricks leveled by heavy winds in the past have been short—few have been over 106 feet high. The attention given to properly guying the tall derricks recently erected is largely responsible for their standing up better in spite of their greater exposure to the wind.

In the design of derricks it is customary to consider 80 miles an hour as the maximum velocity of wind. Experiments on lattice structures similar to an oil derrick showed that the pressure per square foot on flat surfaces of relatively small area is 0.0032 times the square of the wind velocity in miles per hour.⁷ From this empirical formula, an 80-mile an hour wind will exert a pressure of slightly more than 20 pounds per square foot on flat surfaces. The overturning effect of such a wind on an oil derrick must be resisted by guy wires.

NUMBER OF GUY WIRES NECESSARY

WOODEN DERRICKS

Different opinions are held as to how a wooden derrick should be guyed and as to the number of guy wires necessary to protect a derrick from overturning in a heavy wind. A canvass of many oil fields shows that some operators consider guy wires unnecessary, and that others use one, two, three, or four to each derrick leg. Experience in the industry indicates that four guy wires to a leg are necessary to guy 106, 114, and 122 foot derricks safely against an 80-mile an hour wind. Three wires to each leg of 72 to 96 foot

⁷ Mansfield, Merriman, American Civil Engineer's Pocket Book. New York, 1916, p. 493.

derricks and two to each leg of shorter derricks are necessary to resist the overturning stresses of a strong wind. Table 3 represents good practice, brought out by experience in oil fields, as to the number of guy wires necessary for wooden derricks of various heights and the approximate height above the derrick floor of the tying point on the derrick leg.

TABLE 3.—*Number and size of guy wires and approximate height above the floor of the tying point on the derrick leg for wooden derricks of various heights*

Height of derrick, feet	Number of guy wires per leg	Diameter of guy wire, inch	Approximate tying point on derrick leg above derrick floor, feet			
			No. 1	No. 2	No. 3	No. 4
122.....	4	$\frac{3}{8}$	26	50	74	¹ 106
112-114.....	4	$\frac{3}{8}$	26	50	74	¹ 98
106.....	4	$\frac{3}{8}$	26	50	74	90
96.....	3	$\frac{3}{8}$	26	50	82	-----
82-84.....	3	$\frac{3}{8}$	26	50	74	-----
72-74.....	3	$\frac{3}{8}$	26	50	66	-----
62-64.....	2	$\frac{3}{8}$	26	50	-----	-----

¹ $\frac{1}{4}$ -inch-diameter guy wire recommended.

The first guy wire should be attached well down on the derrick leg. Because the guy was tied too high, heavy windstorms usually have caused derricks to fail at a point about halfway between the derrick floor and the point where the lower guy was attached to the derrick leg. Derricks have actually "blown out" from under the guys when too great a distance above the derrick floor was left unsupported. For this reason the lower guy should be tied to the derrick leg at the third girt.

STEEL DERRICKS

Because of the smaller surface exposed, steel derricks withstand the overturning force of winds of high velocity more successfully than wooden derricks do. This fact was one of the outstanding features of the windstorm that leveled nearly 1,300 derricks in Arkansas, Oklahoma, northern Louisiana, and Kansas on March 28, 1924. Although many steel derricks stood in the path of the storm, only a few were blown over. (See figs. 12 and 13.) Figure 12 shows that two of the foundation piers were pulled out of the ground when the derrick overturned. This derrick would not have been blown over had more care been taken to proportion the size of the piers to the height of the derrick, bury the piers at least 3 feet in the ground, and guy the derrick properly.

Steel derricks are not self-sustaining in a heavy wind unless they are bolted to foundation piers of adequate weight and size to give

ample stability to the structure. Even then many operators guy them to rigid deadmen for additional protection. Small piers, such as those shown in Figure 12, are of little value in resisting the overturning effect of a wind against the derrick. Experience shows that fewer guy wires are necessary for steel derricks and that the wires

FIGURE 12.—Steel derrick blown over because of inadequate foundation piers, Oil Hill, Kans.

can be tied higher on them than on derricks of wood. The customary practice in constructing 74-foot derricks is to tie the guy wires to the legs at the fourth and eighth girts (see fig. 14). In guying 122-foot steel derricks in California, the guy wires are usually tied to the legs at the ninth and thirteenth girts.

FIGURE 13.—Steel derrick blown over because of inadequate deadmen, Oil Hill, Kans.

METHOD OF ATTACHING GUY WIRES

The method of tying guy wires to the derrick legs should be given consideration, as it has much to do with the ultimate strength of the wire. A poorly attached guy wire, full of kinks, knots, and sharp

bends, can not be expected to develop its maximum holding power. A good method ⁸ to use is to pass the wire at least three times around the derrick leg and to place a three-bolt clamp on the wire so that it will be about 3 feet from the derrick when the guy is taut. The free end of the wire should then be fastened below the clamp by a lineman's "make-up," which consists of wrapping the free end to the line itself with one or more of the galvanized wires composing the line; such a "make-up" should carry the load even without any clamp. A better

FIGURE 14.—Seventy-four-foot steel derrick guyed at fourth and eighth girts with used sucker rods for guy lines, Oil Hill, Kans.

way to fasten the guy wire to the leg of wooden derricks is to use the derrick-leg clamp shown in Figure 15. This clamp eliminates the sharp turns in the wire at the derrick leg, and as a result the full strength of the wire is not impaired.

Guy wires should be fastened to the derrick legs where these are joined by girts and braces, for the legs are stiffer there than anywhere else. All guy wires should be free from knots and sharp bends. When strung they should be taut so that the tension in each wire will be the same. Provision should be made for the pumper or roustabout to keep the guy wires tight, preferably by having each wire fitted with a turnbuckle at the

ground end. Many derrick guy wires are tightened by twisting the wire around two spikes driven through two pieces of 2 by 6 inch boards, 3 to 4 feet long (see fig. 16). These boards are placed on opposite sides of the wire and two spikes are driven through them. The wire runs between these spikes, which are about 2 inches apart. The guy wire is twisted taut by using the boards as levers, and a third spike is then driven through the boards to prevent unwinding. Guy

⁸ Tough, F. B., "Prevention of oil-derrick failures in windstorms by improved method of guying": West. Eng., vol. 8, February, 1917, p. 63.

FIGURE 15.—Oil derrick leg-clamp for guy wire

wires thus tightened will develop only a small part of their original strength.

Figure 17 shows the three common methods of guying oil derricks. Combinations of any two or all three of these are to be seen in the fields, plain evidence that the proper guying of derricks is something not generally understood. The method shown in Figure 17, C, has proved the most practical. Experience has demonstrated that cross guying as shown in Figures 17, A, and 17, B, will cause the derrick to twist and rack in a windstorm.

In Figure 17, A, a wind against the side d is resisted by the two guy wires acting through the sides a and c , and the entire structure is held together by compression—the ideal condition. A wind from the direction S, however, puts the nails holding the sides b ,

FIGURE 16.—Poor substitutes for derrick guy-wire turnbuckles and deadmen, Goose Creek field, Tex.

c , and d in shear, and the derrick is liable to fail. A diagonal or quartering wind from the direction Q, striking equally against the sides a and b , will likewise tend to weaken the structure by loosening the nails and deforming it, as shown by the dotted lines. This throws extra tension in girts b and d , and this tension must be resisted by nails in shear.

Figure 17, B, shows an effort to tie the structure together still further by extending the guy wires around and past one leg of the derrick and tying them to the next leg. In a broadside wind against any side the tendency of the wires to hold the structure together is realized, but, as in Figure 17, A, a quartering wind from the direction Q will tend to deform the structure in the manner shown by the dotted lines. The guy wires may also slacken by slipping and thus allow the derrick to sway. To try to hold derricks together by wrapping them with guy wires is not good practice. Oil-derrick

guy wires have but one purpose—to take up wind stresses that tend to overturn the structure. A derrick should be built as an integral structure, strong enough to withstand the maximum drilling loads;

FIGURE 17.—Incorrect methods (A and B) and correct method (C) of guying an oil derrick

then it should be properly guyed to prevent any appreciable swaying which would tend to weaken it by wrenching the corners and joints.

In Figure 17, C, the guy wires are placed diagonally at each corner and run from the derrick legs directly to the deadmen. In a wind against the side *a*, the inside of the side *c* will also receive windage that will tend to tear the sides *b*, *c*, and *d* away from the side *a*. As the derrick is a nailed structure, those three sides will be held to the side *a* entirely by nails in shear. In a newly erected, well-nailed derrick, in the designing of which consideration has been given to the wind stresses on each member and the number of nails necessary to overcome these stresses, this condition is not serious. A derrick with loosened nailing, however, may be badly damaged.

To forestall any possibility of a derrick pulling apart at the guy-wire tie points, the opposite sides of the derrick can be bolted together by horizontal tie-rods, as shown in Figure 17. For this purpose, used sucker rods can be employed. They can be cut to suitable

FIGURE 18.—Concrete deadman for oil derricks; 2-rod type

lengths and threaded in the shop or warehouse yard, delivered at the derrick location with other derrick material, and put in place as the derrick is being run. Each rod should have one cast washer and two nuts at each end. The threads back of the nuts should be "jimmied" after the nuts have been tightened, and the rods should be slightly upset to prevent the nuts from coming off. Derricks that are bolted and guyed as shown in Figure 17, C, will not pull apart in any wind.

MATERIALS USED FOR GUY WIRES

The usual guy wire for derricks is a galvanized-wire strand of seven wires without a fiber core. Because of its construction, such wire will resist static loading when there is little impact but will

lose much of its original strength when kinked, knotted, or bent around sharp corners. Guy wire is galvanized to resist corrosion.

Their desire to use available salvaged material has led some operators to use sand lines, casing lines, and sucker rods for derrick guys. Used sand lines can be easily put on and are good for a time, but they corrode rapidly and soon become so weak as to be unfit for use. Casing lines are unwieldy to handle, their installation cost is usually greater than that of regular galvanized guy wire, and, like sand lines, they corrode very rapidly. In parts of Kansas and Oklahoma, sucker rods of $\frac{3}{4}$ -inch diameter are used with much success. (See fig. 14.)

CONSTRUCTION AND LOCATION OF DEADMEN

The same care should be taken in selecting the materials and in making the deadmen used to anchor oil derricks as in building the derricks. After deadmen are once in place and covered with 3 to 6 feet of earth they can not be readily examined and inspected; they should therefore be constructed of materials that are sure to have a long life. Wooden deadmen, unless properly treated with some wood preservative, will decay in a relatively short time, the rate of decay depending somewhat on the kind of wood and on the soil in which they are buried. Properly constructed deadmen should outlast the derrick itself. Although to-day there are oil derricks in the United States that have been standing for more than 40 years, no estimate can be given of how long deadmen may be expected to act as anchors in holding derricks erect against heavy winds. Wooden deadmen decay gradually and give no evidence of their reduced holding power until a heavy wind demands of them their initial holding power. When they fail either the central part of the wood pulls out or the wire or rods pull through the deadmen.⁹

There are no better materials for the construction of deadmen than concrete and steel. No limit can be placed on the life of concrete; and if the iron and steel that come in direct contact with the soil are given a coating of asphaltum or tar, they will not rust for a long time. As concrete preserves iron and steel, many operators have adopted as their standard an anchor made of 6-inch casing, 6 feet long, embedded in the middle of a block of concrete 6 feet 4 inches long, 16 inches wide, and 12 inches thick. Sometimes concrete blocks 10 feet long and 18 inches square, into which the lower ends of metal anchor rods have been cast, are used.

Figures 18, 19, and 20 illustrate three common types of deadmen in whose design the ultimate life of the anchorage has been con-

⁹ Tough, F. B., "Prevention of oil-derrick failures in windstorms by improved method of guying": West. Eng., vol. 8, February, 1917, p. 63.

FIGURE 19.—Concrete and pipe deadman for oil derricks; 4-rod type

sidered. In each type asphaltum or other corrosion-preventing material is used to protect the iron and steel wherever it is exposed to the soil. In the construction of the deadmen shown in Figures 18 and 20 metal that comes in contact with the soil is coated with preserving material after the concrete has been cast in place and before the hole is back filled. In the construction of the deadman shown in Figure 19 hot asphaltum is poured down the cover pipes,

filling them completely, after the guy wires have been made taut. To coat the metal anchor rods (fig. 18) is important in many fields where buried iron and steel corrode rapidly.

The deadman shown in Figure 20 is particularly suitable for derricks in congested districts where low guy wires obstruct or endanger the movement of trucks, teams, or materials. This type of deadman has another advantage; it can be set 10 to 20 feet nearer the derrick without changing the slope of the guy wires, and hence it is used where derricks are near a thoroughfare or close to a property line. Two precautions, however, must be taken in the construction of deadmen of this type: The pipe used must be in good condition and must be heavy enough to resist bending and possible breaking at a point just above the concrete footing; also, the concrete block must be

FIGURE 20.—Derrick deadman used in congested fields

buried deep to keep it from being lifted out by the forces exerted on the pipe through the guy wires.

In all types of deadmen the resistance to lift depends primarily on the depth and bearing area of the anchor, and on the weight and cohesion of the overlying soil. The depth and size of the anchor itself are limited only by the means available to place it, but the weight and the cohesion of the soil differ from place to place and from season to season. The effectiveness of any given type of dead-

man therefore depends upon the soil and the soil conditions. The deadmen shown in Figures 18, 19, and 20 are designed for a loose, clayey soil. Their design can be changed slightly to meet other soil conditions, but any large reduction in the size of the anchors or in the depth to which they are buried is not recommended.

Pipes driven into the ground, as shown in Figure 16, do not make good deadmen. They pull out easily and are of little value in a heavy windstorm. To keep guy wires to such deadmen taut is almost impossible, and a slack guy wire that allows a derrick to sway is almost as bad as no wires at all.

Deadmen should be placed on a line through opposite legs of the derrick and at a distance from the corner of the derrick about equal to the height of the derrick.

GUY WIRES AS EMERGENCY EXITS

Guy wires have many times been a means of escape from the derrick when the regular exits were cut off by fire or gas. Men have come down the wires by using their caps, hats, coats, pieces of waste, or life belt to protect their hands. Usually the shoes and clothing are enough protection for the feet and legs. Guy wires should be smooth and free from obstructions, so as to prevent any injuries other than frictional burns to workmen who must seek safety thus. As guy wires are too steep for men to descend in safety, some operators suspend additional wire cables, fastened within easy reach from the working platform, between the derrick leg and the ground. The ground end of these cables is fastened to a deadman 150 or more feet away from the derrick. Such emergency cables afford safer and easier descent than is possible by the regular guy wires.

To provide a safe and practical means of escape from the derrick platform when an emergency demands a quick get-away, a satisfactory device has been developed that is built on the principle of a pair of pliers¹⁰ (fig. 21). Positive control over the speed of descent on the guy wire is made possible by a hand clamp with which the grip of the safety device on the wire between its halves is controlled. From the lower end of the device hangs a permanently attached wire loop through which the workman places one of his legs when about to descend. Tests have shown that the guy wire on which this safety device is to be used must not be too steep; best results are obtained when the angle that the wire makes with the ground is not more than 45°

¹⁰ Osgood, T. W., "An oil derrick emergency exit": California Safety News, vol. 6, August, 1922, p. 5.

Recently another safety guy-wire slide¹¹ has been perfected. It consists of a platform suspended by metal hangers from two grooved wheels that fit over the guy wire. The derrickman sits on the platform and controls the speed of descent with a braking lever which acts against the guy wire. This guy-wire slide has been approved by the engineers of the Industrial Accident Commission of California.

A 4-foot piece of garden hose, slit its entire length so as to slip

FIGURE 21.—Oil-derrick emergency guy-wire slide

over the guy wire, is an excellent homemade guy-wire slide. Such a device keeps the wire from burning or cutting the hands. The hose should not be larger than $1\frac{1}{2}$ inches in outside diameter in order that it may be firmly gripped by the hands and the speed of descent controlled. As a substitute for the manufactured devices described above, a piece of slit hose should be kept in readiness on all working platforms from which the guy or emergency wires can be reached. An excellent practice followed by some companies is to tie the hose over the wire to a derrick leg with twine. The twine keeps the hose, when not in use, from sliding down the wire, but breaks easily without the necessity of having to be untied in case of emergency.

In territories of high gas pressure where wells may blow out during drilling or "bringing in," and the ejected gas or oil may be ignited through friction of sand on the casing or through external means, either of the safety devices described may save lives.

Special life lines are recommended for use at steel derricks that ordinarily are not guyed or have guy wires that are not within reach of the working platforms. At some steel derricks the operators suspend $1\frac{1}{4}$ -inch manila-rope lines from the double and fourble platforms to the ground, as Figure 22 shows. These lines are large enough to let a man control the speed of his descent without receiving frictional burns when coming down hand over hand. There are several objections to the use of manila-rope life lines—objections serious enough to prejudice a person against their use. Manila rope

¹¹ Oil Bulletin, "Safety in the old fields": Vol. 11, Sept. 25, 1925, p. 943.

deteriorates rapidly when exposed to the weather, and at the crucial moment, when a man must use it, it may part and allow him to fall. Should the gas and oil blowing out of an uncontrolled well catch fire, the rope may burn in two before the man reaches the ground. A wire cable with a guy-wire emergency slide is more dependable and satisfactory.

FIGURE 22.—Steel derrick with $1\frac{1}{4}$ -inch manila-rope life lines from double and fourble platforms to dead-man at *a*

GIN POLES ON DERRICK CROWNS

Safety in gin-pole construction demands the abolishment of the one-stick type of gin pole and the general use of a framed structure to handle safely the loads that must be raised to the top of the derrick. A gin-pole structure consisting of two uprights and a cross timber is required by law in California and Oklahoma. This type, illustrated in Figures 23 and 24, consists of two 2 by 12 inch lumber

uprights, notched at their tops to receive a 2 by 12 inch wooden cross-piece; wooden blocks 12 inches square and 2 inches thick are nailed below the notches to keep the upright pieces from splitting. Such gin poles will safely handle loads up to 3,600 pounds. Gin poles for steel derricks are usually of steel. The uprights are either straight pieces of channel iron, or are an A frame made from angle iron. (See fig. 29.) The clearance between the water table and

FIGURE 23.—Derrick crown equipped with safety platform, safety railing, and safety gin pole, as used in California, Kansas, and Oklahoma. In California a 12-inch toe board is now required around the crown platform. Note caged ladder used by some California operators

the under side of the cross-piece should be not less than 7 feet. This minimum is necessary in order to allow enough headroom in which to hang the set of blocks and tackle used in hoisting the sections of the crown blocks to their position on the bumper timbers. Many operators insist on a clearance of 8 feet between the water table and the under side of the crossbeam, in order that when the crown blocks are in place men can stand without striking their heads against the crosspiece while working on the crown blocks and I beams.

OUTSIDE DERRICK PLATFORMS

One of the most important points in accident prevention in the oil fields is to eliminate falls of workmen from derricks.

In California during 1923, 65 oil workers fell from derricks;¹² 8 of the men were killed. The total time lost through these accidents was 56,263 days. In Wyoming recently, within several weeks two men fell from the crown of oil derricks. One was killed instantly and the other received injuries that confined him to the hospital for months. Both were working on the crown blocks of derricks not equipped with

¹² Miller, H. C., and Steidel, C. E., Accidents in the California Petroleum Industry in 1923: Tech. Paper 382, Bureau of Mines, 1926, p. 7.

working platforms and railings. A gust of wind blew off one man; the other man lost his balance and fell off backward.

Similar accidents can be prevented by providing platforms and railings at the crown of every derrick on which men work. Good practice also calls for an outside platform at each level of the oil derricks where there is an inside working platform. For a man to step off a ladder and walk along a derrick girt to reach an inside platform is a hazardous practice; experienced men, as well as those not so accustomed to working in a derrick, may become dizzy and fall. Their handhold may give away or they may slip.

For rotary drilling there should be outside platforms across the ladder side of the derrick at the double, triple, and kelly levels.

FIGURE 24.—A type of derrick-crown platform and railing used in Kansas and Oklahoma. For greater protection the midrail should be 18 inches above the platform and a toe board placed around the edge of the platform

At these levels the inside platforms are on the ladder side of the derricks, and safe access to them from the outside platforms can be had through the open spaces between the derrick girts and braces. An outside platform encircling the derrick should be built at the fourble level, for derrickmen may have to work in any one of the four inside corners of the derrick.

At pumping wells, when the sucker rods are hung in the derrick instead of being "laid down," an outside platform is required to reach the inside rod platform safely. In the 114 and 122 foot derricks this inside rod platform is about 90 feet above the derrick floor. Because it is on the side opposite the derrick ladder, workmen in the past have been compelled to walk on the derrick girts to reach it. This exceedingly hazardous practice has been eliminated at

many derricks by building a platform that extends around the outside of the derrick from the ladder to the opposite corner. The first platform below the derrick crown shown in Figure 27 is a good example of this type.

In cable-tool drilling, an outside platform across the ladder side of the derrick at the rod and tubing board will prevent workmen from falling while getting on and off the derrick ladder at this level. Though rod and tubing platforms are not needed while a well is being drilled with cable tools, and are seldom installed until the tubing or rods have to be pulled, nevertheless it is economy to construct the outside platform at the rod and tubing board level at the time the derrick is being built.

FIGURE 25.—Tubular-steel derrick with railed crown at a well in West Virginia. For greater safety there should be a platform around the crown. Handrails should have an intermediate rail and toe board

Railed platforms completely surrounding the crown of derricks give workmen the protection needed at this elevation (figs. 25 and 26). A person who considers the hazards of working on a derrick crown that is not equipped with a safety platform can have no argument against building railed platforms at every derrick crown. Two or more men often work simultaneously

at this level, changing sheaves or bearing boxes or stringing a new cable over the sheaves. A platform at the crown gives them a safe walkway for getting from one side of the crown blocks to the other. Standing on crown-block I-beams and stepping around and over sheaves is not good practice.

Many men have lost fingers and toes when stringing sheaves on derricks not equipped with crown platforms. Oiling sheaves is easy and safe for the derrickman who has a platform to stand on.

Fewer tools are dropped from derrick crowns when derricks are equipped with platforms, because the platforms provide a temporary resting place on which to deposit the tools. The handrailing on crown platforms will prevent workmen from falling off or being blown off; it will also prevent them from falling from the platform when wrenches slip and they lose their balance; and it will safeguard them if they trip or stumble when walking on the platform.

All outside derrick platforms should be at least 2 feet wide. Those on the ladder side of the derrick should have a 2 by 2 foot opening to permit the free passage of men climbing the ladder. On the outer edge of all outside platforms there should be a substantial railing 42 inches high, with an intermediate rail 18 inches above the floor. Railing uprights should not be more than 8 feet apart. Toe boards placed at the outer edges of the platforms will keep loose material and tools from falling off the platform on men below. Toe boards 6 inches high are recommended for all except the crown platform; for it a 12-inch toe board is desirable, as several recent accidents have indicated. Drilling crews when changing sheaves have leaned crown sheaves against 6-inch toe boards. These are not high enough to prevent the large-diameter sheaves now used in rotary drilling from overbalancing and falling to the derrick floor. Such accidents have been entirely eliminated in California, where 12-inch toe boards are required on all crown platforms.¹³ The prac-

FIGURE 26.—Turnbuckle derrick in the Salt Creek field, Wyo., equipped with a pipe handrail at the crown. A platform around the crown and one across the ladder side of the derrick at the rod and tubing platform is necessary for safety

¹³ Industrial Accident Commission of the State of California, General Petroleum Industry Safety Orders for Drilling and Production: 1924, p. 8.

tice of leaning sheaves, bars, tools, and materials against platform toe boards should be discouraged. All loose materials and tools should be laid flat on the platforms, so that if kicked or made to roll they will bump against the toe boards and will in no wise endanger the men below.

Figure 27 shows an excellent outside platform installation for a wooden derrick. The well was completed and on the beam when this

FIGURE 27.—122-foot derrick with outside safety platforms opposite all inside working levels, Torrance field, Calif.

picture was taken. The lower section of the derrick ladder ran up the side of the slush-pump shed while drilling was in progress but had been moved to a derrick leg when the shed was torn down. An outside platform was then built along the second girt from the corner of the derrick to the derrick ladder. The crown and fourble platforms encircle the derrick; the double and kelly platforms are across the ladder side of the derrick; and the rod platform, which may be seen between the fourble and crown platforms, is built along two and one-half sides of the derrick.

Figure 28 shows a steel derrick for rotary drilling, which has wooden safety platforms. With the exception of a rod platform, this installation is com-

plete as far as platforms are concerned. The figure shows the method followed in adding safety platforms to the earlier types of steel derricks, whose specifications included no material for platforms. The material for virtually every steel derrick for rotary drilling now erected in California and Oklahoma (where the law requires platforms on derricks) includes channels, angles, and bars for outside safety platforms with railings and toe boards. (See fig. 29.)

INSIDE DERRICK PLATFORMS

In some parts of the country little attention is being given to the construction of safe platforms inside the derrick. At some wells (fig. 30) a platform consists of two 2 by 12 inch planks laid side by side across the derrick girts. At many wells now being drilled in various parts of the country a 2 or 2½ inch board, 12 inches wide, constitutes a working platform. A narrow inside platform with open spaces between it and the side of the derrick is not a safe working place. Men on derrick platforms must be able to reach the casing, tubing, rods, or tools hanging in the center of the derrick without leaning out too far; consequently the working edges of platforms must be well out toward the center of the derrick. If the platforms are narrow, open spaces between the platforms and the side of the derrick are left through which men may fall. Injury and death can be prevented by widening platforms to fill the entire space between their outer edges and the sides of the derrick. Wide platforms give men a freedom of movement they do not have on such narrow platforms as those shown in Figure 30; also they enable men to work better and faster. Economy in drilling will result from their use.

FIGURE 28.—114-foot steel derrick with safety platform at 16-foot intervals and offset ladder, Signal Hill field, Calif.

PLANKING

Table 4 gives the number of thicknesses of planks necessary for safe inside derrick platforms of various spans; the figures are based on a combined live and dead load of 500 pounds concentrated at

the center. Experience shows that a derrick platform capable of sustaining such a combined load is safe. When more than one thickness of planks is used for the platform the plank of each course should be nailed to the course below. When the platform is two or more planks wide the courses should be spiked to a 2 by 12 inch plank across the under side at the center. This crosspiece will prevent one course, when deflected by the weight of a man, from sagging lower than the next beside it.

TABLE 4.—*Number of thicknesses of 2, 2½, and 3 inch by 12 inch Texas yellow, Oregon, and Georgia pine planks necessary for safe inside derrick platforms for various spans*

Span, feet	Thickness of planks, inches			Span, feet	Thickness of planks, inches			Span, feet	Thickness of planks, inches		
	2	2½	3		2	2½	3		2	2½	3
6.....	1	1	1	12.....	2	2	1	18.....	3	2	2
7.....	1	1	1	13.....	2	2	1	19.....	3	2	2
8.....	2	1	1	14.....	2	2	1	20.....	3	2	2
9.....	2	1	1	15.....	3	2	1	21.....	3	2	2
10.....	2	1	1	16.....	3	2	1	22.....	4	3	2
11.....	2	1	1	17.....	3	2	2				

Safe practice in rotary drilling with 114 and 122 foot derricks demands at least double thickness of 2-inch planks for the floors of the rod and fourble platforms. As the double and kelly platforms are longer, greater thickness is needed for their floors. The span between girts at the double and kelly platforms is nearly 21 feet for the 114 and 122 foot derricks having a 24-foot base, and although a sound 2 by 12 inch plank of Texas yellow, Oregon, or Georgia pine with a span of 21 feet will support a 200-pound load at its center, it will not safely support the weight of a man moving back and forth, as he does when working at these levels. To avoid accidents—there have been many—from failures of these platforms, experience shows that three thicknesses of 2-inch, or two of 2½-inch or 3-inch planks spiked together should be used for double and kelly platforms.

Decking planks of inside platforms are often struck and torn off or broken in two by drilling tools and by materials raised and lowered in the derrick. The broken pieces are likely to fall and injure workmen on the derrick floor, unless the ends of the decking planks have been securely fastened to the derrick girts. To spike decking planks to girts is not enough, for the nails pull out when the broken pieces sag; U or J bolts with large washers have proved better suited to this purpose. One bolt should be placed at each end of the decking planks, as shown at *b* in Figure 41. The remaining platform planks should be nailed securely to the girts of wooden derricks and bolted to the girts of steel structures.

SAFETY BELTS

In rotary drilling, falls of workers from double and kelly boards have been frequent, and many of them have been fatal. An investigation of the causes of many of these accidents showed that nearly always the employee was at fault. Most operators willingly provide safety belts for use at these platforms, but employees do not always use them, partly because work on these platforms is intermittent and seldom lasts more than a few minutes at a time. Furthermore, the height of double and kelly platforms does not impress derrickmen, accustomed to working at higher elevations, with the necessity of using safety belts.

Many operators realize the small regard some men have for their own safety when working on double and kelly platforms, and stretch a wire line, usually a sand line or a sucker rod, about 3 feet above the platforms across the working edge. They advise their employees, however, that safety belts must be worn, whether or not a wire line or metal rod is stretched across the platforms. Stretching a manila rope, wire line, or sucker rod across the working edge of derrick platforms is good practice but is not approved by the men using the platforms. Their objection is that such a line or rod interferes with their work and is unnecessary when life belts are used. One company using cable tools in Kansas tried wooden railings with toe boards across the working edges of tubing platforms. Additional hazards arose—fingers were pinched between pipe and railing, the wooden bars of the railings often broke, and

FIGURE 29.—122-foot steel derrick equipped with safety platforms at the kelly, fourble, and crown platforms. Derrick ladder offset every 16 feet, with landings at offset points, Inglewood field, Calif.

the falling pieces of lumber endangered those at work on the derrick floor.

After employers have done everything possible in the way of providing safeguards, safety belts, and life lines, the employees should do their part by using this equipment. Some operators hold their drillers responsible for the enforcement of safety-belt rules, and derrickmen and others who disobey are subject to discharge. Some men,

FIGURE 30.—Steel derrick with platforms of a single thickness of 2 by 12 inch plank at kelly and triple levels, Smackover field, Ark.

however, are always willing to take chances, and will attempt to “get by” without using safety belts. This fact led some operators in California and some in Texas and elsewhere to abolish double and kelly platforms. The work formerly done on these platforms is now done on the derrick floor. This change has eliminated an accident hazard and has increased the speed of drilling.

“RAT HOLES” AS A SAFETY MEASURE IN ROTARY DRILLING

Drilling by the rotary method without the use of double and kelly platforms is done by using two “rat holes”—shallow holes drilled beneath the floor of the derrick. One is drilled deep enough to receive the kelly (drill or grief) stem, and the other the double stem (two joints of drill pipe screwed together). The holes are lined with pipe to prevent caving, and this pipe extends from the bottom of the holes up to the under side of the derrick floor. When the “rat holes” are not in use, the openings in the floor are closed with wooden covers, set flush with the floor so as not to present a stumbling hazard.

The kelly “rat hole” is on a line between the two slush pumps and about 2 feet out toward the center of the derrick. This hole

customarily is drilled to such a depth that when the kelly is set in it, as shown in Figure 31, the swivel of the kelly is 10 to 12 feet above the derrick floor. There it is out of the way and does not interfere with the work of the men. Moreover, the traveling-block hook can be hooked into and unhooked from the swivel bail without striking the floor or the rotary table with the long elevator links which are often allowed to hang from this hook. Many operators seldom take the elevator links out of the casing hook while drilling. When the kelly is hooked on, the elevator links hang at one side and do not interfere with the operations of the swivel. This allows greater speed in drilling, as it is not necessary to stand the elevators on the derrick floor or to run the blocks down so that the elevator links can be hooked on. Accidents that result from the links of elevators standing on the derrick floor becoming unbalanced are thus eliminated.

Before the rotary table is set in its drilling position on the derrick floor it is placed over the proposed location of the "rat hole." In drilling the kelly "rat hole" the side of the table toward the slush pumps is elevated 2 inches by placing a 2-inch board under the table stringer so that the hole will be drilled a few degrees off vertical. This hole is then lined with $11\frac{5}{8}$ or $12\frac{1}{2}$ inch casing (used casing ordinarily), the bottom opening of which has been closed, by welding on a steel plate to prevent loose gravel and sand from working up into the "rat hole."

The "rat hole" for the double is on the opposite side of the derrick, a foot or so in front of the rotary drum. It, too, is drilled

FIGURE 31.—Kelly stem standing in "rat hole"

at a slight angle by blocking up the side of the rotary table that is toward the draw works. This hole is also lined with casing that has been closed at the bottom. When the double is set in its "rat hole," its upper joint, which is about 20 feet long, projects above the floor. When the elevators are to be unlatched they are allowed to slide down this joint until they can be reached from the floor.

Thus all operations incidental to hooking on or unhooking the kelly stem, or to latching or unlatching the elevators on the double, can be accomplished by the derrickman without leaving the floor of the derrick; double and kelly platforms can therefore be eliminated advantageously. There is no "setting back" of the kelly stem and the drilling double when "rat holes" are used. Time is saved, there is no delay while the derrickman climbs up and down the ladder to and from the platforms, and he is always available for work on the derrick floor. Thus the accidents from falls of derrickmen from double and kelly platforms are eliminated.

Although derrickmen wear safety belts when working on double and kelly platforms, they are sometimes dragged off the platforms, belt and all, when the kelly is being shifted. The hazardous work done by the cathead man when setting the kelly stem back is also eliminated. Many cathead men have lost their arms and even their lives when swinging kelly stems back, because the driller could not see what was going on at the cathead on the opposite side of the draw works. Many times the driller is not aware of the fact that the cat line has fouled, or that the cathead man has got his arm or hand between the cat line and the cathead, until it is too late to prevent a serious accident. Wherever "rat holes" are used, the drilling crews are unanimous in their praises for this method of eliminating a hazardous operation and at the same time speeding up the work.

NEED OF PLATFORMS AT CABLE-TOOL WELLS

The usual practice at wells drilled with cable tools is to do without inside platforms until it becomes necessary to pull tubing and rods after the wells are drilled. Casing is still set without the use of platforms. When casing is set, the cotter key is pulled out of the wrist pin, and the end of the pitman is set on the floor. This tilts the walking beam at an angle of about 18° from the horizontal, and brings the derrick end about 20 feet above the floor. The casing stabber stands on the end of the beam and swings the top of the casing around until the threads of the pipe engage in the collar of the pipe in the hole. This work is hazardous; many men fall and are injured when stabbing casing from the end of the walking beam. Such work should be done from a platform built at the second girt.

The platform need not be more than 2 or 3 feet wide, and need be only long enough to enable a man to reach the joint of casing to be screwed on. The most convenient place for the platform would be over the bull ropes. There the platform would not interfere with casing being raised in the derrick; it could be hinged to the second girt, and the end toward the center of the derrick could be supported by tie-rods from a girt above. At derricks where the floor is roofed over, the platform could be hinged to a derrick girt and the outer edge supported on posts whose lower ends rest on the roof. Between casing jobs, such a hinged platform could be swung back against the side of the derrick, where it would be out of the way.

DERRICK LADDERS

During the past few years the derrick ladder has been the object of much study by those interested in the safety of oil workers. This interest was stimulated when compilations of accident statistics showed that many of the accidents in the oil fields were falls from derrick ladders. The importance of good derrick ladders can not be emphasized too strongly. Poor ladders are worse than none at all, for a ladder, regardless of its condition, invites a workman to use it when he must climb a derrick. Ladders with loose or missing rungs, split stringers, or stringers insecurely fastened to the derrick have no place in industry. Climbing derrick ladders is hazardous at best. Some men find it difficult to climb even good ladders to unaccustomed heights and fall because they lack confidence and a feeling of security when at any great distance above the ground. When experienced climbers fall, it is usually because they become careless or overconfident or because the ladders are in poor condition. A man should always make sure that a ladder is safe before using it.

Derrick ladders should extend from the floor to the crown of the derrick. When ladder sections are offset, it is necessary for safety to build railed platforms or landing places between the offset sections. The ladder shown in Figure 32 is not safe; there should be a landing platform at the bottom of the upper ladder to prevent the worker from misjudging his step and falling when descending the ladder; furthermore, the workmen, to get from one section of the ladder shown in Figure 32 to the other, must walk on the 2-inch edge of the derrick girt and depend upon a diagonal cross brace for a handhold. Two rig builders, using approximately 100 board feet of lumber, could make a railed platform along the girt between the ladder sections in about one hour's time. The cost of such a platform will not exceed \$5 or \$6.

The frequent practice of running the circulating pipe up the center of the derrick ladder in the manner shown in Figure 33 can not be indorsed. At the lower end, the circulating pipe is usually 6 to 8 inches in front of the ladder, and a person climbing the ladder has to straddle the pipe. Often, too, the top of the pipe leans to one side of the ladder and a man has diffi-

FIGURE 32.—Unsafe derrick ladder

culty in getting a foothold on that side. In many ladders the rung at the top of the pipe is cut out, as shown in Figure 33, to allow the pipe to enter the derrick. What can be more dangerous than a missing rung in a derrick ladder? Many men have been killed by falls from derrick ladders, and many more have been injured, some of them permanently. These crippled men and their families have become objects of charity, or have had to do without the pleasures and advantages they formerly enjoyed. Such negligence as shown in Figure 33 is almost criminal. There is a good reason for placing the circulating pipe in the center of the side of the derrick, because the pumps are hooked up in pairs; but there is no reason for placing the lower section of the ladder in the exact

center of the side of the derrick; it could just as easily be 1 or 2 feet to one side, and thus eliminate a hazard that is common in the oil fields.

WOODEN LADDERS

The following specifications for wooden ladders for oil derricks are being followed by most rig builders in the oil-producing States:

1. Lumber to be of straight grain free from all structural defects.
2. Minimum cross section of ladder stringers, 2 by 4 inches.
3. Minimum cross section of ladder rungs, 1 by 4 inches.

4. Minimum distance between stringers (center to center), 12 inches.
5. Maximum distance between centers of rungs (center to center), 16 inches.

Many operators prefer 2 by 6 stringers and 1 by 6 rungs, and much can be written in favor of these sizes. The safest ladders to climb have the 2-inch edges of the stringers placed against the derrick so that there is at least 4 inches between the rungs and the derrick members. Care should be taken to avoid any obstructions that would decrease this clearance and interfere with a safe foothold on the rungs. Ladder stringers should extend at least 42 inches above the platforms. Such construction promotes safety by providing a handhold for the climber when he steps on and off the ladder.

Experience shows that it is good practice to bolt the top and bottom of ladder sections to the derrick members so that reliance need not be placed on the uncertain holding power of nails. Nailing or stapling two-strand coppered or galvanized twisted wire along the ladder stringers and over the ends of the rungs will prevent the rungs from pulling away from the stringers (see fig. 34); box strapping is also used for this purpose. The wire or metal strapping should be continuous from top to bottom of the ladder section. Some operators cover the ends of ladder rungs with narrow strips of lumber. Figure 36 shows a section of a derrick ladder; the ends of the rungs have been covered with 1 by 4 inch lumber, nailed on. If strips of lumber are used in place of wire or strapping to keep the rungs from pulling off, no strips smaller than 1 by 3 inches in cross section should be used. Some operators drive tenpenny nails about half their length into the ladder stringers, just above and

FIGURE 33.—Unsafe practice of having the circulating pipe along the center of the derrick ladder

below the rungs after the rungs have been nailed on. The projecting part of the nails is bent against the outside face of the rungs as a precaution against the rungs splitting and pulling off. This is good practice when twisted wire or strips of lumber are not available.

Many companies that use rotary tools are building derrick ladders in sections and are offsetting these sections every 16 feet up the side of the derrick, because ordinarily the shorter the distance

FIGURE 34.—Section of derrick ladder, showing twisted wire nailed over the ends of the rungs

a worker falls the less severe is his injury. Between each of these 16-foot sections is a railed landing, as shown in Figures 27 and 29. Offset ladders have not as yet been used on cable-tool derricks. Figure 35 illustrates an offset ladder on an 82-foot derrick and is given here to encourage adoption and general use of this type in cable-tool fields. Operators of rotary equipment have appreciably reduced the number of falls from derrick ladders by offsetting derrick ladders at 16-foot intervals. Cable-tool operators can do likewise by equipping their derricks with ladders of similar construction.

CAGES FOR LADDERS

In addition to offsetting the ladder sections at regular intervals, some operators inclose the ladders in a cage, as shown in Figures 37 and 38 and in the detail drawing, Figure 39. In this construction a cage, consisting of a series of parallel bars of lumber covered with wire netting, incloses anyone using the ladder. A man can not fall beyond the next platform below from a caged ladder. Such construction imparts a sense of confidence to the climbers; the trained or the untrained workman has no difficulty in rapidly climb-

ing such a ladder. Should his foot slip, his handhold will probably prevent him from falling; should his hands lose their hold or a rung pull off, his shoulders will merely drop back a few inches and wedge him in between the ladder and the screen on the back of the cage so that he can not fall. The greatest distance a man can fall from a caged ladder is the distance between the platforms, or 16 feet. This is in striking contrast with what might happen on the ordinary uncaged ladder, whether or not it is offset. Although there are railed platforms at 16-foot intervals, a person who loses his handhold and falls backward off an uncaged ladder will not necessarily land on the next platform below and stop there; in turning over and over, as he does when falling off a ladder, he may miss this and other platforms entirely and drop to the ground.

Only the back of the cages shown in Figures 37, 38, and 39 is covered with screen or wire netting. Some operators deem this protection adequate; others place wire netting over the back of the ladder cage between the platform to the underside sides from a point 7 feet above the floor of every platform to the underside of the platform above.

Caged ladders can also be used on steel derricks. Figure 40 shows a caged offset ladder on a 122-foot steel derrick equipped with outside platforms for rotary drilling. This type of derrick ladder is the result of a great deal of thought and study by safety and designing engineers, and is by far the safest.

FIGURE 36.—Section of derrick ladder, showing strips of lumber nailed over the ends of the rungs. The 2-inch edge of the ladder stringers should be against the derrick to give the climber a safer foothold on the ladder

FINGER BOARDS

Many accidents at oil derricks can be attributed directly to faulty finger boards at the fourble platform. In drilling deep wells where 60 or more stands of drill pipe or tubing may be stacked in the derrick at one time, sturdy finger boards against which to lean the pipe are necessary. One can easily imagine the result should a

FIGURE 37.—114-foot wooden derrick with caged offset ladder, Huntington Beach field, Calif.

finger board give way and allow the stacked pipe to fall against the opposite side of the derrick. Although such accidents are not frequent, many men have been injured by the fall of torn-off finger boards or parts of finger boards. Traveling blocks and elevators, when going up or down the derrick, often hit and break off the finger boards. As they must necessarily project a considerable distance out beyond the working edge of the platforms, finger boards should be made of structurally sound timber, not less than 6 by 6 inches in cross section, well bolted to the platform. Some operators tie the end of the finger board to a derrick member with a wire line, and thus prevent the broken finger board from falling to the derrick floor. (See *a*, fig. 41.) Ordinary $\frac{3}{8}$ -inch line, such as is used for derrick

guy wires, is well suited to this purpose and will keep a broken finger board from falling. Sometimes the unsecured part between the decking plank of the platform and the end of the finger board, tied by wire to the derrick, is broken and falls to the derrick floor; therefore, it is advisable to prepare for such an occurrence by nailing or stapling wire along one entire side and the bottom of the finger board. If the loose end of the wire is then securely tied

to a derrick girt or brace, there is little possibility that any part of the finger board will fall.

Figure 42, a drawing of a fourble platform, shows the relative position of the two finger boards, the bumper blocks, and the corner platforms. Two finger boards are customarily used in derricks where the work requires stacking drill pipe or tubing on both sides of the derrick. Ordinarily, pipe having right-hand threads is stacked on one side of the derrick, and tubing or left-hand threaded drill pipe is stacked on the other side. The decking plank on the working side of the fourble platform is built from three thicknesses of 2-inch plank, bolted at each end to the derrick girts by J bolts. The finger boards are bolted to the decking planks by $\frac{3}{4}$ -inch-diameter bolts. When the finger boards are not in use they can be swung sideways around the bolt as a pivot and are out of the way. Bumper timbers are bolted to the platform by two $\frac{3}{4}$ -inch-diameter bolts. Each finger board is tied to the derrick girt below the platform by a $\frac{3}{8}$ -inch wire line (not shown), which is nailed to the under side of the finger board at its pointed end.

Figure 41 shows one corner of a fourble platform. At *a* is the wire that prevents the broken-off finger board from falling, and at *b* is one of the J bolts holding down the decking plank. In the background is a caged safety ladder with a screened back. Examination of the figure will reveal that the outer edge of the decking plank between the finger board and the derrick girt has been cut back for a distance of a few inches. Originally this board was 12 inches wide from girt to girt, as in Figure 42, but was notched to make room for another row of drill pipe behind the finger board. Such a practice is not common, though special conditions sometimes make it necessary to add space for stacking more drill pipe. After the decking plank was chipped away, as the photograph shows, it was necessary to support the center of the platform by tying it to a derrick member. Tying a wire line across a derrick platform is not good practice; derrickmen are liable to trip on the wire and fall.

FIGURE 39.—106-foot wooden derrick with caged offset ladder, Midway Sunset field, Calif.

SAFETY BELTS AND LIFE LINES

In the California oil fields during 1923, 10 per cent of the days lost through accidents were attributed to falls of workers from derrick platforms.¹⁴ In 1922 and 1923 falls from derrick platforms caused 14 out of 93, or 15 per cent, of the deaths from accidents in

the drilling and producing oil fields of the State. Available information indicates that all of these fatalities could have been avoided if a safety belt and life line had been used.

Safety belts and life lines should be provided at every working platform and at every point above the derrick floor where men work. A wire cable or metal rod, to which the life line can be attached, should be strung from one derrick leg to the adjacent leg, completely around the inside of the derrick. Experience in the oil fields has shown that a man can most readily attach a life line to these wire cables or metal rods when they are placed 3 or 4 feet above the platform levels. Used sand line and sucker rods are most frequently employed for this purpose. Sucker rods are best because they can be bolted to the derrick legs and will not sag or give.

FIGURE 40.—122-foot steel derrick equipped with caged offset ladder, Maricopa field, Calif.

The flexible life line from the safety belt is attached to the cable or rod by a large harness snap or similar device. When attached thus it can be quickly taken off and snapped on. The snaps should be large enough to slide freely along the cable or rod from one derrick corner to the other; this gives the wearer freedom of movement

¹⁴ Miller, H. C., and Steidel, C. E., Accidents in the California Petroleum Industry in 1923: Tech. Paper 382, Bureau of Mines, 1926, pp. 4-13.

FIGURE 41.—Fourble platform: *a*, Wire that prevents the finger board from falling when broken off; *b*, one of the decking plank J bolts, by means of which the platform is fastened to the derrick girts

FIGURE 42.—Fourble platform: *a*, Finger boards; *b*, bumper blocks; *c*, corner platforms

from one derrick corner to the next, with a uniform length of life line. When men work on walking beams or other places where there are no inside platforms the life line should be tied securely to a derrick girt or brace.

Life lines should not be longer than is absolutely necessary to allow free and unhampered movement of the person wearing the safety belts to which the lines are attached. A length of 5 feet is usually ample. In a recent accident a man fell from the fourble platform and dropped 18 feet before the life line checked his fall. The abrupt stopping of his fall by the single-strap safety belt caused severe internal injury. In addition, he received a painful injury to his head when he was jerked against drill pipe standing in the derrick. Had there been but 5 feet of slack in the life line, he might not have been injured.

FIGURE 43.—Safety belt without a belt tongue, designed for quick removal

Single-strap belts.—Two distinct types of safety belts are in use in the oil fields—a single-strap belt and an improved belt equipped with shoulder straps. The single-strap belt is 2 to 6 inches wide. It is fastened around the wearer and adjusted to fit with a buckle. The life line is attached to the belt by an iron ring through which the belt passes. If loosely strapped around the wearer, this belt will

slip up under his arms when he falls and hold him suspended by his armpits; if it is tightly strapped it will grip him around the abdomen and hold him suspended with his head and feet down; either way the belt may cause severe internal injuries. Wide belts, when they are tightly strapped around the wearer, are hot and uncomfortable in warm weather; for this reason, if for no other, they are regarded with disfavor by many derrickmen.

Improved type.—The improved type of safety belt, Figure 44, which is being adopted by many companies, has a chest strap 2 inches wide and 48 inches long, with shoulder straps 1½ inches wide riveted to the chest strap in the back. These shoulder straps pass through a D ring where they cross in the back and are looped around the chest strap in front and there riveted. The life line can not slide on the belt, but is attached to the D ring, where it is out of the way and does not interfere with the work of the wearer. In case of a fall, the belt grips the wearer around the chest, and the shoulder

straps hold him in an upright position, with free use of his hands, arms, and legs.

Objection to belts.—One objection frequently voiced to the use of safety belts by derrickmen, especially at wells in areas of high gas pressure, is the length of time required to take off the belt if a quick get-away must be made from the derrick. To meet such objections, two types of quick-opening safety belt buckles have been designed, in which the old-style buckle and tongue have been eliminated. The belt shown in Figure 43 is designed so that the wearer can remove it in an instant by pulling the loose end of front strap *a* out of ring *b*. As soon as this is done, the belt opens up and can be thrown off the shoulders. The life line is attached to **D** ring *c*, an objectionable feature, because when a man falls he is held suspended by the belt around the center of his body; his head and feet hang down, and he is unable to avoid striking pipe or other objects standing in the derrick.

Figure 44 shows a belt that meets this objection. The ring to which the life line is attached is so placed that when a man falls he hangs erect and has the free use of his hands and feet. The belt can be taken off quickly by pulling forward the clasp wing, which allows the belt to open up and slide off the wearer's shoulders.

INSPECTION OF SAFETY BELTS AND APPURTENANCES

Safety belts, life lines, and all attachments should be inspected frequently. The engineers of the Industrial Accident Commission of California recommend that such equipment be strong enough to withstand the strain caused by a weight of 200 pounds falling a distance of 5 feet. An easy and quick way to make this test is to strap the belt around two full 100-pound sacks of cement and, with 5 feet of slack in the life line, push the sacks off an elevated platform.

DERRICK LIGHTING

VALUE AND AMOUNT OF ILLUMINATION REQUIRED

Proper lighting is a very important safety measure, because it applies to all parts of the derrick and thus differs from many other safety measures that are needed only to meet special hazards. Good light is required by every member of the crew, no matter where he is working or what his duties. Insurance companies know that 15 to 18 per cent of all preventable accidents at industrial plants are a result of poor lighting; it is reasonable to suppose that these figures will hold good in the drilling of oil wells. Though first of all a safety measure, good lighting has an economic advantage, because

it allows the men to perform their duties in less time and in a more satisfactory manner.

A properly lighted drilling derrick is one in which the crown blocks, working platforms, derrick floor, engine houses, casing rack,

FIGURE 44.—Clamp type of quickly detachable safety belt

suction pit, and circulating ditch are so lighted that the efficiency of the crews by night will be as nearly that by day as is reasonably possible. This calls for a minimum illumination of about 2 foot-candles on the derrick floor and surroundings,

The measurement of the intensity of illumination is the foot-candle, or the amount of illumination falling on a perpendicular wall or surface from a standard candle set 1 foot away. The intensity of light varies inversely as the square of the distance from the source; thus a 16-candlepower light, which has an intensity of 16 candle-feet at a distance of 1 foot, will have 4 candle-feet at a distance of 2 feet, and 1 candle-foot at a distance of 4 feet. Daylight intensity ranges as high as 10,000 foot-candles outdoors on a clear day, 5,000 on a cloudy day, 2,000 in the shade, and 3 in machine shops; it should be 2 to 3 foot-candles for reading ordinary print. A standard of 2 foot-candles on the derrick floor is about the low limit for efficient and safe work.

SOURCE OF ELECTRICITY FOR LIGHTS

Electric lines serve many oil fields in the United States, and good illumination is inexpensive; in fact, when interpreted in terms of time saved, either through decreased number of accidents or increased efficiency, the equivalent in wages of this time saved will more than balance all the contributing costs of a good lighting system. Where electricity can not be purchased or brought from a central generating station, many operators use portable generating outfits to supply electric energy for lighting oil derricks.

The generators ordinarily used are rated at 1 to $1\frac{1}{2}$ kw. These outfits may be electric generators driven by direct connected steam turbines or by gas or gasoline engines. They are efficient, simple to operate, and eliminate the fire hazards from open-flame lights at oil derricks. Steam-driven turbogenerator sets are usually placed near the boilers to reduce condensation losses in the steam lines. The wires running from such units to the derrick should be placed on insulators fastened to poles—not hung on nails driven into trees or along the side of the engine house, as is so often done. Gas or gasoline driven units should not be on the derrick floor or in the engine or belt house where escaping gas from the well might be ignited by back fire from the engine. Figure 45 shows a portable gas-engine-driven generating unit that supplies electric light for a derrick. Note the safety railing in front. The open knife switch fastened to the wall above the generator should be replaced by an inclosed safety switch. Open knife switches arc across their contacts when opened under load, and such arcing will ignite inflammable gas.

ARRANGEMENT OF LIGHTS

In addition to the minimum requirement of two foot-candles of illumination on the derrick floor, the arrangement and situation of the

lights must be such that the driller when looking up into the derrick will not have the glare of a light or of a polished reflector directly in his eyes. Improper lighting causes as many accidents as inadequate lighting. Drillers should be able to follow the traveling block from the floor of the derrick to the crown, without the discomfort

FIGURE 45.—Portable gas-engine-driven generator at an oil derrick. Note unsafe open wiring and knife switch

or annoyance of glare. Glare is objectionable because it causes eye fatigue and tends to disturb the nervous system. Any interference with clear vision reduces efficiency and increases the risk of accidents.

An ideally lighted derrick, therefore, would not only have the proper amount of illumination, but also have the lights so placed that the driller will never be compelled to focus his eyes against their glare. Because of the limited size of the interior of the derrick above the fourble platform, it is impossible to arrange the lighting system so that drilling, redrilling, pulling, and cleaning jobs can each be done without the man at the throttle being subjected to some discomfort by the glare of the lights in the upper third of the derrick. The lights below the fourble platform, however, should be placed

against the leg of the derrick that is at the driller's back, so that he will have light on his work and not in his eyes.

No one system of derrick lighting can meet all requirements. If the lights are correctly placed with respect to the rotary driller, they are not in the right place for the cable driller, or for redrilling, pulling, and cleaning-out jobs. In fields where rotary drills are used, most of the derrick lights are along the derrick leg at the driller's corner. The combination system of derrick wiring, in

which the derrick-light sockets are placed in each of the two derrick legs that are nearest the draw works, is seldom installed; with this system, the lamp globes during rotary drilling are inserted in the sockets placed along the derrick leg at the driller's back. After the well has been drilled the globes are moved over to the sockets in the other corner, to keep the lights behind the man at the throttle.

Some operators install what may be termed a "compromise lighting system" that has given good results and has been approved by drilling and producing crews. Figure 46 explains it. With this system the rotary driller, and later the well puller or cable-tool driller, never has to look directly into the glare of any lamps except those above the fourble platform—a condition that can not be remedied in any system. These upper lights, however, are so far away that they do not cause a great deal of eye fatigue. No permanent lights are placed over the circulating pumps; none are needed there, for their presence only irritates the eyes of the driller. If the reflectors of the lights on the second girt are tilted downward, there will be plenty of illumination at the pumps for all ordinary needs. For repair work on or near the pumps, or for other work requiring close illumination in that locality, a plug receptacle and extension cord are provided. The size and the arrangement of the lights in Figure 46 give perhaps the maximum of illumination with the consumption of a minimum of wattage and also cause a minimum of eye discomfort to those working in the derrick and on the derrick floor. In determining the size and position of the lights in the engine houses, belt house, casing rack, and circulating ditch, as shown in Figure 46, consideration was given primarily to safety. The fundamental requirement of a good artificial lighting system is safety; economy in the use of current is a secondary consideration.

ELECTRIC WIRING FOR DERRICK LIGHTS

Improper or defective wiring for lights in and around oil derricks is a hazard that is especially dangerous where gas may be present. At many derricks the wires of lighting systems are hung on nails driven into the derrick girts and braces; there they rub against wood and may be injured and broken by tools and materials run in the derrick. At a wooden derrick such wiring is hazardous whether gas is present or not, because a short circuit between two wires may set the derrick afire.

Many operators use the same wires at more than one derrick and do not always cut out or tape worn parts. Failure to do this has caused many fires at oil derricks. For safety, all electric light wires in and around the derrick, with the exception of the portable extension cords and the service line from the transmission system to the

FIGURE 46.—Diagrammatic drawing of a lighting system for 114 and 122 foot derricks

derrick, should be placed in iron-pipe conduits with metal switches and metal junction boxes. Lamp sockets should be mounted in steel boxes to which the conduits can be secured. Conduits should be grounded. The practice of wiring derricks with conduit is compulsory in California.¹⁵

All wires should be double or triple braided, rubber covered, and of ample size to carry safely the required load without overheating. Joints in the wires and all places where taps are made should be soldered; then rubber insulation should be wrapped around the connection and covered with friction tape. It is further recommended that the contacts of all switches be within gas-tight inclosures.

Wherever electric bulbs may come in contact with gas in combustible proportions they should be covered with heavy glass outer globes with metallic guards. These guards and outer globes ward off small pebbles and sand that may be blown out of the well with enough force to break the thin globes of the lamps and thus permit the glowing filaments to come in contact with the escaping gas. Another precaution taken by many companies is to place the main switch for the derrick lights on the first power-transmission pole away from the derrick, or on a pole near the boilers, instead of in the derrick. Then the lights can be turned off at a point of safety if the crew must leave the derrick floor without first turning off the lights.

All operators do not agree as to the best methods of supplying artificial light to those who work in the derrick cellar. Some, and perhaps the majority, use an extension cord. Because of the danger of electric shock and of short circuits that might ignite inflammable gases only the very best flexible cord should be used; portable extension cords should be heavily insulated and should be fitted with an electric lamp in a gasproof globe protected by a metal guard. Portable lamp guards should have a wooden or rubber handle and a hook. Outer globes of heavy glass with metal guards over them reduce to a minimum the possibility of breaking the thin globes of the electric lamps. Extension cords should have gasproof connections to plug receptacles installed in the derrick lighting system.

Extension cords for use at oil derricks should be made up by competent electricians. The cords should be inspected frequently while in use, and if repairs are needed only the electrician should make them. Worn spots in the insulation covering the wires should not be repaired by workmen at the derricks. The use of adhesive tape, from first-aid cabinets, for temporary repairs of worn insulation should be condemned. Generally speaking, the extension electric

¹⁵ Industrial Accident Commission of the State of California, Orders 713-5a, 713-5b, 713-5c: Electrical Safety Orders, 1925, p. 162.

cords used at oil derricks are much abused. Workmen often disregard the fact that such cords are merely continuations of live wires and must be handled with the same care. When extension cords are handled, the current should be cut off. The cords must not be placed on grounded surfaces, or where they may be injured by tools, materials, or machinery when the current is on. The cords should always be placed before the plug is inserted in the receptacle; when the current is on, no part of the cords other than the insulated handles should be touched. Lamp globes should never be changed unless the plug has been withdrawn.

REFLECTING QUALITIES OF INTERIOR OF DERRICK

The intensity of illumination on the floor of a derrick depends not only upon the arrangement and size of the lights, but also upon the reflecting qualities of the illuminated surfaces. Dark surfaces strongly absorb light instead of reflecting it, and with all lighting conditions equal, a new or clean derrick will be much better illuminated than one sprayed or covered with oil. Large variations in foot-candles of illumination on the derrick floor have been noted in comparing the lighting of clean and oily derricks. These variations have led to experiments on the effect of painting or brightening up the interior of an oil-sprayed derrick. A mixture of lime and water (whitewash) has been tried, sprayed against the interior of the derrick by machine. Although the immediate improvement in the lighting of the derrick floor was quite perceptible, it was not lasting, for the lime flaked off and the derrick was soon as blackened as before. The falling flakes of lime also caused a new hazard by injuring the eyes of those working on the floor of the derrick. Further experiments to develop a suitable paint or wash that can be sprayed on the inside of the derrick to increase its reflecting power should be encouraged. The economic importance of this measure has been demonstrated, not only in providing better illumination on the derrick floor, with a resultant decrease in accidents, but in reducing production costs by speeding up the work.

OPEN-FLAME LIGHTS ON DERRICK FLOOR

Although gas lights, lanterns, and other open-flame derrick lights have been largely displaced by electric lights at drilling wells, many operators still use them. At some wells in Pennsylvania, West Virginia, and Ohio where natural gas is cheap, gas lights are used as a matter of economy. Even though every precaution is taken to extinguish such lights when the drills approach gas sands, they have caused many derrick fires when unknown gas pockets were tapped.

There is no real economy in using open-flame lights in the derrick. Electric lighting units are inexpensive, and when the wiring in a derrick has been properly installed and is in good condition it is a protection against the accidental firing of gas. Open-flame lights do not give a steady light; light winds cause them to flicker and flare, and the resultant variation in the intensity of illumination on the derrick floor is conducive to accidents and poor work.

LOOSE MATERIAL IN DERRICK

Accidental dislodging of loose materials and tools that are left on the platforms or hung on nails driven into derrick members has caused many injuries to men on the derrick floor. Lumber, tools, crown sheaves, and other materials should never be left unsecured on any of the derrick platforms, or on any place overhead. The enforcement of this rule and the one requiring all loose material for which there is no immediate use to be removed from the derrick will reduce the number of accidents from falling objects.

In the California oil fields alone, during 1923, material and tools falling from the derrick onto those below caused 159 lost-time accidents¹⁶ resulting in the loss of 5,795 days and 6 fatalities. In other words, 10 per cent of the fatalities in the drilling and producing division of the California oil industry in 1923 were caused by tools or materials falling out of the derrick. The records of these accidents show that many accidents could have been avoided had care been taken to fasten securely or to remove all loose material above the derrick floor.

Pipe hooks dropped from working platforms in the derrick have injured many floormen. When pipe hooks are used above the derrick floor they should be tied to the derrick with a rope to keep them from falling.

Greater care should be taken in building windbreaks and shelters at the working platforms in the derricks. Many of them are of flimsy construction, built of scrap corrugated iron or lumber picked up around the derrick. Wind pressures of 20 pounds per square foot are common in the oil fields, and a 2 by 10 foot sheet of corrugated iron may be required to withstand a total wind force of 400 pounds. It is doubtful whether many platform shelters will resist a wind pressure of 20 pounds to the square foot. That many will not is verified by the numerous sheets of iron and pieces of lumber that sail through the air when an oil field is visited by a hurricane or a tornado.

¹⁶ Miller, H. C., and Steidel, C. E., Accidents in the California Petroleum Industry in 1923: Tech. Paper 382, Bureau of Mines, 1926, pp. 4-13.

CROWN SHEAVES

Accidents caused by crown sheaves jumping out of their bearings can be avoided. Sheaves that were cast integral with the trunnions (gudgeons) or those into which the shaft was forced under a pressure of not less than 15 tons can not jump out of their bearings when bearing caps or covers are securely bolted over the ends of the trunnions. Neither can a sheave of this type move far enough laterally to allow either end of the trunnion to drop out of its bearing. All bearing-box bolts should have two nuts, or one nut safeguarded by a cotter pin, to prevent the caps of the bearings from working loose, coming off, and possibly falling on somebody. If this precaution is taken, the vibrations caused by the drilling or

FIGURE 47.—Crown sheaves with metal straps welded over the gudgeons

casing line running over the sheave will not unscrew the nuts. A loosened nut falling from the bearing box can severely injure a man on the derrick floor. With the bearing cap in place, securely held down by the bolt nuts, the sheave can not jump out of the bearings and thus be the contributing cause of one of the many possible accidents.

Trunnion bearings not fitted with caps or covers can be used with assurance of safety after metal straps have been welded over the ends of the trunnions across the tops of the bearings, as shown in Figure 47. These straps should be $2\frac{1}{2}$ to 3 inches wide and one-half inch thick; they should be securely welded to the bearing blocks to prevent a sheave with an integral trunnion, or a sheave into which the shaft has been forced under pressure, from jumping out of its bearings. This makeshift arrangement, however, should

never be used with loose-pin crown sheaves unless some means have been taken to make it impossible for the trunnion or shaft to move lengthwise and drop out of its bearings. The bearings of all loose-pin sheave trunnions should have boxes that completely inclose the ends, sides, and tops of the sheave shafts. These will entirely eliminate the possibility of a loose-pin sheave jumping from its bearings.

Falls of crown sheaves, trunnions, bearing boxes, and bearing-box caps have caused fatalities and numerous injuries in the oil fields. To be the contributing cause of a fatality or injury to a worker in the derrick, however, crown sheaves do not always have to fall after jumping out of their bearings. Recently ¹⁷ a driller's helper was fatally injured when a loose-pin crown sheave with bearings open at the ends jumped out of one of its bearings and allowed the drilling line to slip out of the sheave past the end of the sheave trunnion. The traveling block and suspended string of pipe fell and in falling tore loose the line spooling device from the draw-works headboard above the hoisting drum. The cathead man on the derrick floor was hit by the spooling device and injured fatally; the driller, who was standing at the engine throttle, was also injured by flying equipment. Fortunately the sheave and its loose trunnion did not fall, and the other members of the drilling crew escaped injury.

Every driller should insist that his derrickman carefully and thoroughly inspect the equipment at the derrick crown at the beginning of every tour or shift. Crown blocks should never be used until inspection shows they are safe and are properly oiled.

STAIRS TO DERRICK FLOORS

Stairs, substantially built and properly proportioned, should be provided when derrick floors are more than 1½ feet above the ground. The rise (the distance between the top of one step to the top of the next) for a comfortable stair should be 7 to 7½ inches; stairs having a greater rise are so steep that they cause men to stumble. The run (the horizontal distance from the face of one riser to the face of the next) must bear a certain relation to the rise; for a comfortable stair the sum of the rise and run should be 17 to 17½ inches. Stairs with a total rise of 4 feet or more should have handrails. The proper height for handrails is 2½ feet above the tread, measured vertically.

HANDRAILINGS AROUND DERRICK FLOORS

When the floor of a derrick is 4 or more feet above the ground the open sides should be fenced in with a two-rail railing. Such railings

¹⁷ Gebb, J. Wesley, "Safety order violated—father of six killed": California Safety News, March, 1925, p. 6.

are needed on producing wells, especially at night. Many pumping wells are but dimly lighted or are not lighted at all, so that the pumpers sometimes walk too close to the edge of an unprotected floor and fall off. Railings should be substantially built, 42 inches high, with a mid rail 18 inches above the floor. Figure 48 shows an excellent railing at a producing well.

GUARDS FOR BULL WHEELS AND BULL ROPES

Bull wheels to apply power in hoisting drilling tools out of the well are used with cable tools. The drilling cable is spooled on the bull-wheel shaft and is unwound as the depth of the well increases. At producing wells, bull wheels are used for pulling tubing and rods and for redrilling with cable tools. In drilling with rotary tools, bull wheels are seldom used. Rotation is imparted to the bull wheels

FIGURE 48.—Railed floor and runways to belt-house door at a producing well, Signal Hill field, Calif.

by one or two lines of bull ropes, which may be $2\frac{1}{4}$ or $2\frac{1}{2}$ inch diameter manila rope or 1-inch wire cable. These ropes connect the tug pulley on the band wheel with the rim of the tug or left-hand bull wheel; they are crossed between the tug pulley and the bull wheels to reverse the direction of power.

Bull-wheel and bull-rope hazards are of several kinds. Men may fall across the bull ropes and be carried into the bull wheel, may be caught on the bull-wheel pegs when treading the wheels, and may be injured or killed if a bull wheel is torn from its bearings.

Most of the serious injuries caused by bull ropes result from men trying to climb through bull ropes that are moving; many of these injuries prove fatal. Numerous attempts have been made to provide protection from these hazards. Various types of railing guards have been constructed along the side of the bull ropes that is toward the

center of the derrick, but such guards have proved impractical because they interfere with the work of the crew on the derrick floor.

BULL-WHEEL GUARD

A lightweight portable bull-wheel guard that in no way interferes with the work of floormen has been developed. (See figs. 49 and 50 and the detail drawing, fig. 51.) If a man falls across the bull ropes, as shown in Figure 50, he is carried by the ropes or the cable against the guard and is not crushed between the bull wheel and the ropes. He may receive frictional burns from the ropes or cable, or he may get cut by the cable clamps or wire wickers, but he can not be drawn into the bull wheel to almost certain death.

To install this guard, two holes whose diameters equal the outside diameter of 2-inch pipe are bored in the derrick floor about 6 inches in front of the tug wheel and $18\frac{1}{2}$ inches apart, center to center. Sections of 2-inch pipe, about 1 foot longer than the distance between the derrick floor and the ground, should be driven through these holes and into the ground until their tops are flush with the upper side of the derrick floor. The guard is set into these pipes. One guard for each well-pulling, cleaning, and redrilling crew is enough, as the portability of the guard allows it to be carried from well to well with other tools and equipment. Wells can be equipped beforehand to receive these guards, consequently there need be no delay in installing them when the bull ropes have to be used.

Oil workers must not think that such a guard in front of the bull wheel makes the practice of climbing through the ropes safe and permissible. The installation of such guards, however, will save

FIGURE 49.—Bull-wheel guard in position in front of bull wheel and over the bull rope: a, Bull-rope throw-off

the lives of thoughtless and careless workers who persist in the hazardous practice of climbing through moving bull ropes.

GUARDING BULL-WHEEL PEGS

Treading on bull-wheel pegs with one or both feet often leads to serious injuries. Such practice is especially dangerous just as the rope goes on. Unless the tool dresser or floorman moves quickly out of the way of the bull-wheel pegs, they may catch his clothing and cause serious injury. With his feet on the pegs, it is often impossible for the workman to get in the clear; his clothes are caught by the pegs, and he is whirled around on the wheel. With only his hands on the pegs and both feet on the floor, the workman is in a better position to get out of the way of the bull-wheel pegs. Educating the worker to pull on the bull-rope pegs with his hands and not to tread on them will eliminate this cause of accidents.

FIGURE 50.—Men can not be drawn into bull wheel when this guard is used

Figure 52 shows a combination splashboard and bull-wheel peg guard. The splashboard prevents the water used in cooling the bull-wheel brake from flying out on the floor of the derrick across the path of the workers; this is a safety device, in that workers who

must dodge a spray of water are likely to stumble and fall or run into something on the derrick floor. Also the water from the rim of the wheel may carry particles of dirt or scale into the eyes of the workers. Another advantage of a spray arrester is that the comfort and health of the men are increased if their clothes are kept dry. The 1 by 12 inch board hinged to the side of the splashboard prevents men from coming in contact with the pegs in the rim of the brake wheel. This board can be turned back against the splashboard when someone has to turn the bull wheel by pulling on the pegs.

FIGURE 51.—Bull-wheel guard

BULL-ROPE THROW-OFF

Often during the manipulation of tools the bull rope has to be thrown from its grooves in the tug wheel. A crowbar, a piece of pipe, or a 2 by 4 inch board is frequently used as a lever to give the side thrust necessary to lead the bull rope off the tug wheel, but such practice is dangerous and causes accidents. A mechanical device

FIGURE 52.—Combination water splashboard and bull-wheel peg guard

for doing this work safely is shown in Figure 53, and at *a* in Figure 49. Figure 53 is a detail drawing of a steel bull-rope throw-off. The long handle at the end of the tripping arm allows the man manipulating the bull-wheel brake lever to stand in a place of safety away from the bull ropes and bull-wheel pegs when he throws the bull ropes off the tug pulley. The pivot pipe shown at *a* in Figure 54 should be flush with the top of the tripping arm. At many wells the top of this pipe is burred or mushroomed and projects up above the wooden arm. Projecting and burred pivots are dangerous, especially when men follow the hazardous practice of treading on the bull-wheel pegs to start the wheel. Recently at a well in West Virginia a man's foot slipped off a peg, was

caught between a mushroomed pivot and the rim of the bull wheel, and was badly mutilated before the bull wheel could be stopped.

GUARDING AGAINST BULL-WHEEL DOGS CATCHING IN LOOSE BULL ROPES

When bull ropes have been thrown off the tug pulley of the bull wheels, they should be hung immediately on a hook or holder against the bull-wheel post or brace, before the wheels are again in motion; they should not be left hanging loose on the bull-wheel shaft. When

FIGURE 53.—Bull-rope throw-off

suspended from a hook or holder the ropes are away from the tug pulley and there is no danger of the dog on the bull wheel catching them when tools are being run into the hole. Deaths and many serious injuries have been caused by bull ropes being picked up by bull-wheel dogs just as workmen were stepping across the ropes or were trying to hang them on the hook while the wheels were in motion. Figure 55 shows a method used at some wells in West Virginia and Ohio to eliminate this hazard. The sections marked A, B, and C are bolted to the arms of the bull wheels, whether the wheels are of wood or steel. The shape of these sections is such that the loose bull ropes are kept 8 inches away from the face

FIGURE 54.—Wooden bull-rope throw-off: a, Dangerous projecting pivot

of the tug pulley when the bull wheels are moving. At this distance the dog can not pick up the ropes, and the tools can be run into the hole safely.

GUARDING AGAINST BURSTING BULL WHEELS

Bull wheels run at excessive speeds sometimes "blow up." Steel, as well as wooden bull wheels, burst (see fig. 56) when the speed of rotation exceeds the safe limit. Just what the safe speed is depends generally on factors over which the tool dresser or workman on the derrick floor has no control. A good rule to follow when lowering tools into the hole is to keep the maximum speed of rotation of the bull wheels such that slight pressure on the brake lever will slacken descent of the tools. Faulty brakes, loose brake bands, and brake bands insecurely fastened to the sills underneath the floor are contributing causes of the blowing up of bull wheels.

To reduce the possibilities of material damage and of human injury, the braking equipment should be frequently inspected and all faulty parts repaired promptly.

GUARDING AGAINST BULL WHEELS LEAVING THEIR SUPPORTS

Occasionally bull-wheel shaft gudgeons come off or the posts spread apart, and the bull-wheel shaft slips out. If the tools are

FIGURE 55.—Wooden arms (A, B, C) fastened against bull-wheel spokes to prevent bull rope from accidentally catching on the dog

not on bottom when this happens, their weight may pull the bull wheel up the derrick. Girts and braces are broken as the bull wheel travels upward, and the workmen on the floor must seek safety from falling timbers. Most of these accidents occur at derricks that have stood for many years and at derricks that were not properly built. Weathering loosens the joints of derricks, girts and braces warp and twist, and bull-wheel posts become loose. The bull wheels at such

a derrick should not be used until the derrick has been reconditioned and made safe. As an added precaution, two cable loops of 1-inch-diameter wire rope, fitting loosely around the bull-wheel shaft 1 or 2 feet in from the inside faces of the bull wheels and securely fastened to a sill under the derrick floor, will prevent descending tools from pulling bull wheels into the derrick.

GUARDS FOR BULL-WHEEL SPREADERS

Wooden bull-wheel spreaders on bull-wheel shafts dry out and become loose after exposure to the weather for a time. Frequently such spreaders fly apart when the bull wheels are used, and the flying

FIGURE 56.—Wreckage that resulted when a pair of steel bull wheels "blew up" because of a faulty brake, Burbank field, Okla.

pieces injure workers on the derrick floor. To prevent such accidents, all wooden bull-wheel spreaders on bull-wheel shafts should be bound to the shaft with small cable or heavy wires and so secured that the parts of the spreaders can not fly away when the shaft rotates.

DAMAGE TO STEEL DERRICKS BY TIGHT BULL ROPES

Every driller wishes the bull ropes to be as tight as possible. A common practice is to allow a hose to play on a manila bull rope; the water makes the fibers shrink and thus shortens the rope. Sometimes the rope purposely is spliced short, so as to be excessively tight when run on the tug pulley. At steel derricks the bull ropes must not be so tight as to put a bend in the girt to which the bull-wheel posts are fastened. Bending this girt will twist and bend the two derrick legs to which it is fastened and thus weaken the entire

derrick. Derricks with bent and twisted legs will not carry the load for which they were designed and will "pull in" much easier than derricks that have not been damaged by excessively tight bull ropes.

CALF-WHEEL DRIVE-CHAIN GUARDS

Calf-wheel drive chains are subjected to enormous strains when long strings of casing are lowered, lifted, or suspended in the well. Often these strains are so great that links break or pins fail by shear. When many calf-wheel drive chains break under stress, pieces of chains or the ends of parted chains fly out on the derrick floor. The links and pins of the chains do not always fly in a tangential direction from the tug sprockets when the chains break. Often they fly toward the center of the derrick floor and injure

FIGURE 57.—Calf-wheel guard

workmen standing in their course. Calf-wheel chain guards should therefore be of such design and construction that broken parts of chains can not fly out on the derrick floor in any direction.

Some calf-wheel chain guards are made from flat steel, such as is used for calf or bull wheel brake bands; others are made from casing. Most operators prefer to use casing, as they can utilize salvaged material. Figure 57 shows a calf-wheel drive-chain guard made of 6 1/4-inch casing. The 1/4-inch by 6-inch steel plate on the calf-wheel shaft side of the guard keeps broken parts of chains from flying out on that side. As the guard is placed close to the face of the calf wheel, no side skirt is needed on the brake side of the guard.

A fundamental requirement for guards over machinery on the derrick floor is that the guarded machinery must be readily accessible

for repairs or replacements. The guard shown in Figure 57 can be lowered to the floor by pulling the top hinge bolt. Too much time is lost when 8 or 10 bolt nuts have to be unscrewed before a guard can be removed, as happens when the guard is bolted direct to the floor and headboard. Guards that are hinged at the top are usually raised away from the calf wheel by means of the cat line,

and are suspended above the floor. Sometimes they are raised by hand, and the lower end is propped up with a stick of lumber. Men have been injured when the cat line slipped or the wooden prop was knocked out and the guard fell on them. The author recommends the hinging of calf-wheel drive-chain guards at the bottom, so that when it is necessary to get at the tug sprocket or drive chain the guards must be lowered to the floor instead of raised above it.

The hinges of calf-wheel chain guards should be securely bolted to the floor and headboards, for breaking chains often tear insecurely attached guards from their fastenings. Bolts with washers should be used in preference to lag screws to hold down guards. The bolts through

FIGURE 58.—Guard over the calf-wheel sprocket chain

the hinges at the top of the guards should extend through both headboards. It is good practice to bolt the floor hinges of guards to steel plates or angles on the under side of the derrick floor; these will distribute the upward pull of the bolts over a larger area than will washers alone.

Figure 58 shows a calf-wheel drive-chain guard made from flat steel. Note how completely it covers the tug sprocket and chain above the derrick floor.

CALF-WHEEL TIE-RODS

Calf-wheel shafts are subjected to great strains when long strings of casing are set or pulled. Unless the calf-wheel jack posts are held down securely, they will tear out. At wooden derricks the best practice is to bolt the calf-wheel headboards to the main sill under the derrick floor with iron or steel rods, at least 1 inch in diameter, placed against the inside face of both calf-wheel jack posts. No tie-rods are necessary at steel derricks in which the jack posts are riveted or bolted at the top to a derrick girt and at the bottom to the derrick sill.

Instructing workmen to stand to one side of the brake handle when applying the brake will avert many serious injuries. Leaning over the handle or putting a leg over the handle when applying pressure to the brake has caused broken jaws, loosened and broken teeth, fractured skulls, broken legs, and other injuries, many of them fatal. Experience shows, however, that men frequently get hurt because they do not practice what they know. Some operators, reluctant to rely entirely upon the caution of the workmen, are endeavoring to design brak-

FIGURE 59.—“Nonkick” calf-wheel brake

ing machinery so men can not get hurt by it. Several noteworthy attempts, one of which is shown in Figure 59, have been made to build bull-wheel and calf-wheel brakes with bands that are pulled at both ends simultaneously when pressure is applied at the handle. The arrangement and multiplicity of levers through which the brak-

ing force is applied is being worked out to eliminate "kick backs" at the lever handle. These attempts are still in the experimental stage, but the results are promising.

BAND-WHEEL AND DRIVE-BELT GUARDS

The belt-house runway leading from the derrick floor to the engine house is rarely more than 2 or 3 feet wide. Occasionally the band-wheel shaft extends into this passageway or the shaft key projects beyond the end of the shaft and presents a hazard to those using the passageway. At many derricks the side of the walkway next the drive belt is open, so that men can fall on or against the belt or into

FIGURE 60.—Band-wheel platform with guard rails and steps to the band wheel; side view

the belt way along the side of the belt. When the drive belt is in motion such falls bring workmen where they can be struck and injured by the belt clamps. The bolted-type belt clamps used in oil fields are dangerous also because they catch on loose clothing and sometimes carry workmen into the pulley wheels of the engines.

A two-rail wooden or pipe railing, 42 inches high, built along the inside edge of the passageway from the engine or motor to the band wheel and around the end of the band-wheel shaft to the calf-wheel post will prevent such accidents. A guard of this kind is shown in Figures 60 and 61. In Figure 60 a railed platform with steps leading to it has been built along the side of the band wheel. This platform gives the men a safe place on which to stand when putting the

belt on the band wheel or the bull ropes on the band-wheel tug pulley. The band-wheel shaft in Figure 61 has been boxed in so as completely to cover the dangerous exposed key seat in the shaft. Some operators are now building narrow belt houses with no run-way along the belt. Other operators are boarding off the inside passageway along the drive belt between the sand-reel post and the engine house; this is good practice and will eliminate the accidents which otherwise would occur in that vicinity.

SAND-REEL AND PITMAN GUARDS

SAND-REEL GUARDS

To guard the sand reel of the oil derrick effectively, so that no one can run into or fall against it, is a simple matter requiring a few pieces of lumber and an hour's labor. A good sand-reel guard is shown at *a*, in Figure 62; this guard also takes in the walking-beam counter-weight shown at *b*.

At many derricks the sand-reel guard is made of 2-inch lumber and is placed so that it clears the flanges of the sand reel by about 6 inches. With a solid wall of 2-inch lumber

FIGURE 61.—Railing guard along inside edge of belt-way passage. Guard prevents contact with band wheel and drive belt; view from derrick floor

42 inches high on the exposed end and sides of the sand reel, the workmen can not come in contact with the moving reel. If the guard is built of 2-inch stuff, the boards on the rear side of the sand reel can slip into grooves along the corner post and at the belt-house wall; these boards can then be lifted out when a man has to work on the sand reel. Safety makes it desirable to build sand-reel guards not over 15 inches away from the flanges, for if the guard is too far from

the sand reel, men are liable to climb over the guard and get caught between it and the moving flanges. When placed closer than 15 inches, the guard should be a solid panel or a heavy frame covered with wire netting having openings not over 2 inches square, or the equivalent in any other design. The railing guard shown in Figure

63 affords protection when the guard is 15 inches from the flanges of the sand reel.

PITMAN GUARDS

Guards around pitman cranks are necessary to prevent accidents there. Men have been injured by the crank when they stepped back too far after coming down the Sampson-post brace ladder. Such accidents present an excellent reason for doing away with ladders along Sampson-post braces. The larger sizes of pitman cranks circumscribe a circle having a radius of about 40 inches, so not much standing room is left between the foot of the Sampson-post ladder and the circle made by the crank.

One day a man sat down near the foot of the Sampson-post ladder to eat his lunch, not realizing how close he was to the pitman crank. The machinery in

FIGURE 62.—Sand-reel and pitman-crank guard: *a*, Sand-reel guard; *b*, walking-beam counterbalance; *c*, pitman-crank guard. Note handrail along Sampson-post ladder

the derrick was idle during the noon hour, but in a short time enough steam accumulated in the steam chest of the engine, through a leaky throttle valve, to turn the engine over. The pitman crank revolved and hit the man on the head. He was killed instantly.

Such accidents and many others caused by the pitman crank can be prevented by suitable guards, such as the one shown at *c* in Figure 62, and in Figure 63. These guards are made of 2 by 4 and 1 by

6 inch lumber, and are hinged to the sand-reel post in the manner shown in Figure 63. Provision must be made to swing or lift the pitman guard out of the way, as there are times when the jerk line has to be used. If the guard is hinged to the sand-reel post, it can be easily and quickly swung back into position when the work that required its removal is finished. If the guard is not hinged, it is often thrown off the derrick walk and not replaced immediately after the completion of the work requiring its removal.

A pitman guard made of salvaged sucker rods welded into a frame and covered with wire netting is shown at *a* in Figure 64. This guard is hinged back of the pitman to a 2 by 4 nailed to the belt-house wall, and can be swung aside when the pitman has to be taken off.

FIGURE 63.—Sand reel and pitman guard

CONNECTING PITMAN TO WRIST PIN ON BAND-WHEEL CRANK

Attempting to put the pitman back on the crank without counterbalancing the pitman by the rods or by other means has caused accidents, most of which resulted in strained backs and pinched fingers and toes. Recently, however, a worker was killed because he was unable to hold the unbalanced pitman up after once having it off the floor. The weight threw him down and the end of the pitman crushed his chest. Workmen should not attempt to lift anything that they can not handle with safety. When the pitman is to be put back on the crank it is safest to employ mechanical means to counterbalance the weight of the pitman, or else to wait for some one to help lift the pitman onto the crank pin.

GUARDS FOR COUNTERBALANCES

WALKING-BEAM COUNTERBALANCE GUARDS

The unbalanced load of the column of sucker rods in the well causes an uneven motion of the engine, which is largely overcome by suspending a counterweight from the pitman end of the walking beam. The usual method of counterbalancing is to extend the walking beam beyond the pitman hanger and to suspend a heavy block of concrete from the end of this extension. The vertical travel of the counterweight varies with the length of the stroke of the pitman

FIGURE 64.—Pitman-crank guard: *a*, Guard around pitman crank; *b*, guard around walking-beam counterbalance

and the distance between the Sampson post and the point of suspension of the counterweight.

Every walking-beam counterweight should be so guarded as to prevent men from getting hurt underneath it. The sand-reel guard at *a* in Figure 62 prevents workmen from getting injured by the counterweight *b*. The guard at *b*, Figure 64, similarly protects them. The panels of this guard are salvaged sucker rods covered with wire netting.

COUNTERBALANCES FOR CASING TONGS

Casing tongs are counterbalanced because of their weight. When they are counterbalanced, tongs weighing 450 pounds or more can be handled with ease on the derrick floor. Wooden boxes filled with

scrap iron (fig. 65), or pipe collars and thread protectors filled with concrete, similar to the counterweight shown in Figure 66, are used.

When wooden boxes such as that shown in Figure 65, filled with scrap iron, stones, or dirt, are used as tong counterweights, they should be bound with wire or box strap to keep the sides from coming off or the bottom from dropping out; this should be done in addition to tying them so that they can not fall. Counterweights made of casing collars or thread protectors filled with concrete are better than wooden boxes; many operators use them because they are safer and more economical. They are convenient to handle, can be made of various diameters and lengths, and can be used in drilling more than one well. Figure 66 shows a tong counterweight designed to hang in the corner of the derrick. Counterweights hung outside the derrick do not, as a rule, run up and down on a guide rod, and consequently do not need guide-rod pipe sleeves. When filled with concrete, 8¼-inch casing collars weigh approximately 70 pounds; 10-inch weigh 100 pounds; and 12½-inch weigh about 130 pounds. Concrete-filled protectors weigh about half as much as concrete-filled collars of the same diameter. The weights of casing tongs can be matched closely by adding enough sections.

FIGURE 65.—Safe method of suspending tong-counterweight box *a* less than 5 feet above the ground

Figure 33 (p. 51) shows a hazardous practice of suspending counterweights above the level of the derrick floor. Should the cables or fastenings fail or become detached, the heavy weights would crash through the pump-house roof and perhaps injure workmen. Counterweights that are suspended above working places should be so tied that they can not fall. A 10-foot piece of wire cable, such as a piece of sand line, given just enough slack to allow the tongs to

function and securely fastened to the counterweight and to a derrick girt, will keep the counterweight from falling through the pump-house roof.

FIGURE 66.—Concrete counterweight for tongs

Suspending counterweights near the ground, preferably in some place unfrequented by workmen, is better than hanging them above the level of the derrick floor. Many operators are now doing this. There is little possibility that workmen will get hurt by a falling

counterweight, or by material falling out of a counterweight box, when it is suspended so as to hang not more than 5 feet above the ground, as shown in Figure 65. If, by necessity, a counterweight must hang in a place frequented by workmen, a railed inclosure for it will keep it from inflicting injury.

WRENCH POLES

Wrench poles are used chiefly at wells drilled with cable tools, where it is customary to balance the tool wrenches from poles fixed across a derrick girt. (See fig. 25, p. 40.) The tool wrench is suspended from the short end of the pole by a rope or a wire cable, and the counterweight to balance the wrench is tied to the other end. Care should be taken to tie the poles to the derrick girts securely, so that they can not become loose and fall. To keep them from falling, counterweights should be secured to the wrench poles with wire, in addition to the usual manila-rope fastening.

FIGURE 67.—Extension oil line for pitman-crank bearing; horizontal type

PITMAN CRANK-SHAFT AND WRIST-PIN OIL LINES

To oil the pitman crank-shaft bearing when the crank is in motion is hazardous. If the pitman crank is guarded as in Figure 62, a workman may reach too far, overbalance, and fall head first into the inclosure, where he is in imminent danger of being struck by the crank or pitman. For the workman to move the pitman-crank guard so that he may get to the bearing to oil it is not the solution of the problem. The purpose of guards is to keep workmen away from moving machinery; under no conditions should a guard be moved while the machinery is in motion. Extension oil lines, installed as shown in Figure 67, will allow a man to oil the pitman crank-shaft bearings safely without shutting down the engines or taking the guards away. The position of the filling cups of the horizontal extension oil lines in Figure 67 is satisfactory and safe when the pitman-crank guard extends no farther than the one shown there, for a man has room to stand between the guard and the Sampson-post brace. When the pitman-crank guard extends from the sand-reel post to the Sampson-post brace, the filling cup must be placed elsewhere. If there is a runway on the belt-house

roof, many operators put the filling cup near the edge of the roof, vertically above the crank-shaft bearing (fig. 68). Pumpers can then oil the pitman-crank bearing while they are on the runway to oil the walking-beam bearings. Figure 68 has been retouched to bring out more clearly the position of the extension oiler; the oil line is $\frac{1}{2}$ -inch pipe, fitted with a swaged nipple on top for a funnel. At some wells the operators have made it possible to oil the wrist pin also from the belt-house runway; this is accomplished by fastening an oil line along the outer side of the pitman. The lower end of the pipe reaches the wrist pin, and the top end is bent around one side of the pitman so that the can or funnel into which the oil is poured can be reached conveniently from the belt-house runway.

FIGURE 68.—Extension oil line for pitman-crank bearing; vertical type

Many accidents will be prevented by the adoption of extension oil lines for the pitman crank-shaft bearing and wrist pin. Pumpers can assemble and install the extensions in a short time, and their cost will rarely exceed \$1.

To oil the center iron bearing of the walking beam that is on the side of the beam opposite the belt-house roof runway, one operator in California bores a $\frac{7}{8}$ -inch hole through the walking beam directly above the oil wells in the bearing caps. This hole is started on the belt-house side of the walking beam, about 4 inches above the bottom of the beam, and comes out on the opposite side an inch or so above the top of the bearing-cap oil well. Thus the inserted pipe has such a grade that the oil runs readily from the filling side above the belt-house runway to the outer bearing on the opposite side of the beam. On the belt-house side of the walking beam the pipe is bent upward to permit oil to be poured in conveniently. The outlet end of the pipe projects beyond the side of the beam just far enough to let the oil fall into the bearing-cap oil well.

Both bearings can then be oiled safely from the runway on the belt-house roof, even while the walking beam is in motion. Thus there is no need to reach or to climb under or over the walking beam—a dangerous practice. Furthermore, as this outer bearing can be easily and safely oiled there is some assurance that it will receive

the required amount of lubricant at frequent intervals. At present, because of their inconvenient position, many center iron bearings, especially those that are on the side of the beams opposite the belt house, rarely get oiled.

BELT-HOUSE ROOF LADDERS, STAIRS, AND RUNWAYS

Every oil derrick should have a ladder or stairway from the derrick-floor level to the belt-house roof. Workmen, especially those at

pumping wells and at wells being drilled by cable tools, must get on the belt-house roof frequently. The walking-beam bearings, pitman hanger, and the T hanger on the derrick end of the walking beam must be oiled, and there is much other work that can be reached only by way of the belt-house roof.

FIGURE 69.—Unsafe ladder along Sampson-post brace

LADDER TO BELT-HOUSE ROOF

At most oil derricks a ladder along the Sampson-post brace provides access from the derrick-floor level to the roof of the belt house. Most of these ladders have only one stringer—the Sampson-post brace—to which the rungs are nailed. This practice is poor. It is difficult to keep the rungs from splitting and tearing off

when only one stringer is used. (See fig. 69.) Every ladder should have two stringers. If the Sampson-post brace is utilized for one stringer, there should be another stringer parallel with it, to which the other end of the rung is nailed (fig. 68). If it is nailed against the side of the belt-house wall, this second stringer may be a piece of 2 by 4 inch lumber; otherwise, for a rigid ladder, a 2 by 6 inch stringer is necessary. A minimum clearance of 12 inches between stringers, with the rungs 16 inches on centers, is recommended for

ladders along the Sampson-post brace. Rungs of structurally sound 1 by 4 inch lumber, well-nailed to the stringers, are safe; but 1 by 6 inch rungs are much stronger, have a greater nailing surface, and are also less likely to split when nails are driven through them near their ends. A handrail along the Sampson-post ladder (fig. 62, p. 84) will be a help to the pumper, who must frequently carry tools or a can of lubricating oil to and from the belt-house roof.

FIGURE 70.—Handholds on Sampson post and walking beam: *a*, Sampson-post handhold; *b*, walking-beam handhold

Safe practice demands that the stringers of a permanently attached ladder terminate 42 inches above the upper landing, in order that the climber may have a secure handhold when stepping off. A ladder along the Sampson-post brace can not be so built, because the brace, which is used as one of the stringers, is framed into the Sampson post on a level with, or slightly below, the eaves of the belt house. At some derricks a short vertical ladder is built along the Sampson post above the ladder along the brace (fig. 68), or a handhold is provided on the side of the Sampson post as shown at *a* in Figure 70. Otherwise, in order to get from the ladder to the roof or runway, the men are compelled to hang onto the Sampson post or on the belt-house roof as best

they can, and consequently are liable to slip and to fall from the ladder.

Running the reverse rod of the engine and the wires from the throttle wheel along the outside of the belt-house wall to the headache post on the derrick floor is the usual practice at oil derricks. Usually the rod and wires pass between the stringers of the Sampson-post ladder. Where this condition exists, workmen descending the ladders often trip on the wires or rod and fall. At or near a ladder

there should be nothing that will interfere with the free movement of men going up or down. The reverse rod and throttle wires should run between the ladder and the belt-house wall—not through the spaces between the rungs and stringers.

Ladders along the Sampson-post brace can not be deemed safe unless they have two stringers with good rungs securely fastened to them, and unless a handhold or a short ladder has been provided on the side of the Sampson post above the eaves of the belt house. Safe use depends on the absence of the reverse rod, throttle wires, and other interferences between the stringers, and on the presence of a guard around the pitman crank.

FIGURE 71.—Stairway leading from derrick walk to belt-house roof runway

Stairs from the derrick-floor level to the belt-house roof, as shown in Figures 71 and 72, are safer and easier to use than ladders along the Sampson-post brace. Stairs allow workmen to face in the direction in which they are going—an important advantage over ladders—and are especially safer at night, when a pocket flashlight is the pumper's only source of light.

The stair built along the side of the belt house that is opposite the pitman crank (fig. 72) is the better of the two shown. In this position the stair is out of the way of any extended walking-beam counterweight that may be required; also, a more comfortable stair can be built because the run is not limited to 4 or 5 feet, as it is at the location shown in Figure 71. Stairway stringers and treads should be 2-inch lumber, not less than 8 inches wide. A rigid stair can be made if the treads are supported on cleats of 1 by 4 inch lum-

ber nailed against the inside of the stringers, and if spikes are driven through the stringers into the ends of the treads. The height of the handrails for derrick stairways should be $2\frac{1}{2}$ feet above the tread, on a line with the face of the riser. The best handrails are made of surfaced 2 by 4 inch lumber. Smooth lumber is preferable, because there is less danger of workmen getting splinters in their hands.

BELT-HOUSE ROOF RUNWAYS

Runways on belt-house roofs are important safety aids. Corrugated iron, which is commonly used for belt-house roofs, is extremely

FIGURE 72.—Stairway leading from derrick floor to belt-house roof runway

slippery and hazardous to walk on. The slight pitch of the roof adds to the danger of slipping, and a little rain or a few inches of snow increases it many-fold. Wooden roofs, like those of corrugated iron, are similarly hazardous; and when the spaces between the roof boards are covered by battens, or when the boards are lapped, there is the additional hazard of tripping.

Belt-house roof runways (see fig. 71) should be built at every derrick. They should be along the walking-beam edge of the roof and extend from the derrick to a point at least 2 feet beyond the stirrup end of the walking beam.

Similar runways should connect the runways along the walking beams with the top of the stairs leading from the derrick-floor level. A width of 2 feet is common for belt-house roof runways. Guard rails 42 inches high on all exposed sides of runways, except at stairways, prevent injuries to workmen who might otherwise fall off or inadvertently step off the runways.

WALKING-BEAM GUARDS

Frequently a man has to get out to the derrick end of the walking beam to hook the crosshead on or off, to bolt down the adjuster T board, oil the T bearing, or for some other purpose. In order to

get out to the end of the walking beam a man usually straddles the beam in a sitting posture and by raising himself with his hands works his way out to the end. A few men defy danger and ignore safety by walking out. To walk the beam is exceedingly dangerous, and the danger is greatly increased when the beam is coated with oil. Although straddling the beam is safer, it also has disadvantages. Frequently splinters run into the hands and legs; these wounds may become infected, and it has happened that the infected member had to be amputated.

No workman should go out on the walking beam until the fly-wheel has been blocked and the engine can not turn over. Many men have been thrown from the beam when their added weight upset the balance of the beam and allowed the engine to turn over. Throttle valves on steam engines at derricks are seldom tight; steam gets

FIGURE 73.—Handrail on derrick end of walking beam

by them and gradually accumulates in the steam chest until the slightest jar on the engine belt, walking beam, or pitman is enough to start the engine. Several instances can be cited of vibration opening throttle valves, thus causing the engines to turn over and continue to run while men were out on the beam oiling the T bearing. The men hung to the walking beam with much difficulty until help arrived and the engines were shut off. Securely blocking engine flywheels with crowbars, pipe, or heavy sticks of timber, and opening the relief valves in the steam chests will prevent recurrence of such accidents.

Some operators fasten a metal rod along the side of the walking beam (see fig. 73) in order to give a man a handrail to hold to when going out on the beam. This railing is made of $\frac{7}{8}$ -inch sucker rods with the ends flattened and drilled for 20-penny spikes.

The distance between the horizontal part of the railing and the top of the walking beam is 24 inches. In order to keep the guard rail from jamming against the side of the derrick when the pitman is taken off the wrist pin and the well end of the beam is raised, that part of the railing nearest the Sampson post is spiked to the beam at an angle of approximately 50° with the horizontal. This simple safeguard should be installed on every walking beam to abate

a hazard to which every pumper is fairly sure to be exposed some time.

A safe means for getting on the walking beam should be provided. If no ladder is provided for getting from the roof of the belt house to the top of the walking beam, a handhold should be attached to the walking beam, as shown at *b* in Figure 70. The ladder shown in Figure 70 is too short; men are compelled to step on the walking-beam bearing in order to climb on top of the beam. Figure 74 shows an excellent ladder that affords a safe and practical means of access to the top of the walking beam. Note the neat and substantial construction.

FIGURE 74.—Ladder from belt-house roof to top of walking beam

Also note the handrail.

Well-built safeguards show

employees more than anything else the sincere interest that employers are taking in the prevention of accidents. When workers use safety devices they think of safety not only as something that is to keep them from getting hurt, but also as something that makes their work easier. Their enthusiasm is aroused, and they become safer workers.

ENGINE GUARDS FOR CABLE-TOOL DRILLING AND PUMPING

Good engine guards should be simple in design and construction but strong enough to withstand ordinary use. The materials used for these guards at oil derricks are wood, steel bars, steel pipe, and woven wire. Wooden guards are much used because rig builders, carpenters, or workmen can make them of surplus material from the construc-

tion of derricks. Metal guards are used by operators who have machine-shop equipment—mainly welding outfits—or can have the guards built in commercial shops. However, the material is not a matter of consequence if the guards are properly built, installed, and used.

The amount of clearance possible between the moving machinery and the guard has a great deal to do with the selection of the most suitable type of guard. If the clearance is less than 15 inches, the spaces between the frame of the guard should be covered with woven wire. If the clearance is less than 4 inches, the largest opening or the mesh of the wire should not exceed one-half inch; if it is more than 4 inches but less than 15 inches, the largest opening should be 2 inches square, or the equivalent in any other style of mesh. Adherence to these specifications for size of openings in the wire filler for engine guards will save fingers and hands from injury.

Means should be provided for moving the guard from before the flywheel of drilling and pumping engines. Steam-engine flywheels frequently must be “kicked off center,” and gas engines are started by spinning the flywheel. That section of the guard directly in front of the flywheel should be hinged, or otherwise fastened so that it can be moved and replaced quickly and easily.

Guards around pulley wheels should allow enough room for a parted belt to drop off and free itself from the pulley. One oil company in California lost a derrick by fire because the clearance between the engine pulley and guard was too small. The belt failed to free itself from the pulley and wound itself around the clutch; then the belt parted; the engine ran wild. This fact was verified after the fire by the marks on the metal guardrail where the belt clamps had hammered it, and was further substantiated by the engine casting being broken where the clamps had struck innumerable blows. When the belt failed to free itself from the pulley wheel it whipped and frayed, filling the engine house with ravelings that were ignited by a spark struck from the engine casting or metal guard by the belt clamps.

STEAM-ENGINE GUARDS

The steam-engine guard shown in Figure 75 is a railing guard, 42 inches high; it has a mid rail and also a toe board. The L-shaped section of the guard is hinged at *a*, and is so hung that it will close by gravity. This feature is commendable because the workman who “kicks the flywheel off center” is usually in a hurry to get back to the derrick floor and will not always take time to swing the guard back and latch it. The clearance between this guard and the flywheel is 15 inches. Figure 75 shows an open-panel type of guard

which, when placed not closer than 15 inches to the machinery, affords adequate protection to all who work around the engine.

The wooden frame of the guard shown in Figure 76 has been covered with woven wire of 2-inch mesh. This is good practice, because the guard is less than 15 inches and more than 4 inches from the flywheel. The guard is hinged at its farther end (not shown) and hung so that it closes by gravity. A guard of similar construction adequately guards the pulley and belt on the opposite side of the engine.

FIGURE 75.—Hinged wooden guard in front of a steam-engine flywheel: a, Hinges

GAS-ENGINE GUARDS

To be effectively guarded, a gas engine at an oil well needs a more elaborate guard than that usually built around a steam engine. A gas engine has more parts to be kept oiled and in adjustment and many more places where workmen can get hurt. Usually two flywheels must be guarded, as well as a clutch pulley, jacket-water pump pulleys, and belts. As pumpers and oilers must get to the engine and its auxiliaries to oil and adjust the individual parts, a railing guard around the entire engine is not adequate.

The framework of many gas-engine guards is made of $\frac{3}{4}$ -inch pipe or $\frac{7}{8}$ -inch used sucker rods, covered with woven wire (fig. 77). Because of the small clearances between the moving parts and the guards, it is imperative that the mesh of the woven wire shall not exceed $\frac{1}{2}$ inch. Certain other requirements must be considered in the design and construction of gas-engine guards. The guard over the outer flywheel should be so built that it can be moved out of the way so as not to interfere with the manual starting of the engine. The guard over the clutch pulley should be movable, as frequent adjustments are necessary for efficient operation of the engine. The oiler should be able to oil every part of the engine without having to remove the guard.

Figure 79 is a detailed drawing of a guard for a Union Tool Co. 40-horsepower type A gas engine with type N-UB reverse gear. This typical California gas-engine guard will serve, with slight modifications, as a pattern for guards for other makes of gas engines. The reader should note that the section of the guard in front of the outer flywheel is suspended from two rods along the wall of the engine house and is free to move along them. When the engine has to be started by hand this section is slid along the rods until it is out of the way. The guard over the clutch pulley can be removed when repairs or adjustments to the clutch are necessary. The pump guard rests on four legs and can be moved intact when work is to be done on the water pump or its belt. The pipe and rods comprising the frames of the various sections are welded together, making a fin-

FIGURE 76.—Wire-covered guard for steam-engine flywheel

FIGURE 77.—All-metal guard over clutch-type gas engine

ished guard which is light in weight, efficient, and of pleasing appearance.

ELECTRIC MOTOR GUARDS

Electrically driven pumps require guards over the exposed motor pulley, belt, jack-shaft pulleys, and band-wheel belt. In Figure 78 note the guard around the jack-shaft pulley and belt. The frame of this guard is made of $\frac{7}{8}$ -inch sucker rods, welded together and

covered with woven wire of $\frac{1}{2}$ -inch mesh. Floor plates are welded to the bottom of the legs, so the guard can be easily slid away from the pulley.

FIGURE 78.—Metal guard around pulley wheel at electric motor oil-well pumping installation

PROTRUDING KEYS IN ENGINE SHAFTS

The many accidents caused by protruding keys in the flywheel shafts of steam and gas engines demonstrate the need of having shaft keys flush with the ends of shafts or else covered with a suitable protector. Shaft-key and key-seat protectors should be fastened to the end of the shafts by countersunk cap screws. Cap screws that are not countersunk flush with the end of the protector can catch clothing

and are as dangerous as projecting shaft keys. Protruding keys, such as the one shown in Figure 80, often catch the clothes of workmen starting gas engines or tramping flywheels in order to move steam engines off center. Some men have been killed and many have been injured at drilling and pumping wells where this unsafe condition existed.

ENGINE EXHAUSTS

STEAM-ENGINE EXHAUSTS

Steam from steam-engine exhausts causes many accidents. Men working in front of an exhaust pipe or passing the exhaust pipe when

no steam is coming out are sometimes badly scalded if the driller, not knowing they are there, starts the engine. Horizontal exhausts for steam engines should not be used where men may, at some time or other, work or pass within 25 feet of the outlet. When a derrick is near a road, street, or other thoroughfare every precaution should be taken that the steam from the engine is not blown into or across the line of travel of men and vehicles. Recently the exhaust steam from a drilling engine threw such a cloud of vapor across a street that the driver of an approaching automobile did not see a workman from the derrick. The car hit the workman, who later died from his injuries. Many instances can be cited of men injured and scalded by exhaust steam because the only provision made to take care of it had been piping it out of the engine house.

To prevent recurrence of such accidents is easy, as Figures 81 and 82 show. From the tee, screwed to the end of the 4-inch line from the engine (fig. 81), a 5-foot section of 4-inch pipe leads the exhausted steam upward to a point level with the eaves of the engine house. From the bottom of the 4-inch pipe below the tee, an outlet pipe, 2 inches in diameter, carries the condensation to a sump or hot well.

The exhaust stack shown in Figure 82 was built of 1 by 12 inch lumber and is 14 feet high. The 4-inch exhaust line from the engine enters the stack 4 feet above the platform on which the stack rests. A series of holes in the four sides of the stack 1 inch above the bottom allows the condensed water to escape and run to a sump.

FIGURE 80.—Protruding keys of flywheel shafts should be sawed off flush with end of shaft or covered with suitable protector

GAS-ENGINE EXHAUSTS

The exhaust gases from gas engines at derricks should escape through a vertical pipe, as is shown in Figure 83. To make an installation of this kind absolutely safe, the construction of a railing guard around the pipe is advisable. With the pipe in the center of a 4-foot inclosure, 42 inches high, there could be no excuse for anyone being burned by contact with the hot pipe or the gases.

FIGURE 81.—Steam-engine exhaust made of pipe

TREATMENT OF BURNS AND SCALDS

So many men are burned and scalded by steam and hot water from engine exhausts and by contact with hot steam lines at oil derricks that some knowledge of the proper method of first aid treatment of burns may prevent infection and relieve much pain.

Every burn should receive immediate treatment. Many slight burns are neglected, and severe burns that are not properly treated invite infection. Burns are infected more frequently than wounds, because they partly destroy the tissues and thus lessen the resistance to infection.

Destroyed tissues are in themselves a source of poisoning, as they are absorbed by the blood around the wound.

In all cases of burns, loose clothing, except that which adheres to the skin, should be removed, and the air should be excluded from the burned surfaces as quickly as possible by the application of picric acid gauze moistened with steam or clean water. Picric acid gauze should be in every first aid cabinet.

After the dressing is applied to exclude the air, the burn should be covered with a loose bandage; the bandage must not be so tight that it will rub off the burned skin. Burned fingers and toes should be separated, and the backs of the ears should be kept away from the head with sterile gauze when bandages are applied.

If the tissues have been deeply burned or scalded, or if the blisters are extensive, medical treatment should speedily follow first aid.

PIPING FOR GAS-ENGINE INTAKE VALVES

Many disastrous gas explosions and fires have occurred at oil wells where gas engines are used, and many of these were caused by back-firing at the air-intake valves. A section of pipe, screwed into the intake valve and extending upward through the roof of the engine house, will prevent the flames from igniting gas within the engine house when a back fire occurs at the intake valve.

VENTILATION OF ENGINE HOUSES

Buildings that house gas engines should be ventilated. A ventilator in the roof of an engine house at an oil well will furnish an outlet for gases that might otherwise accumulate in dangerous quantities. Ventilators not only reduce the fire and explosion hazard at wells, but eliminate the danger of men being asphyxiated when they have to enter engine houses to oil or repair engines. Roof ventilators are especially needed at wells in cold climates where most engine houses are made nearly air-tight for the sake of warmth.

FIGURE 82.—Wooden stack for steam exhaust

CLEANLINESS AT DERRICKS

Cleanliness is characteristic of those derricks at which few accidents occur. Cleanliness and neatness tend to make men careful, whereas dirty, oily, cluttered derrick floors breed carelessness and increase the liability to accidents. A clean derrick floor is one of the best safeguards against accidents to the well crews. Men can

not work safely on derrick floors having tools, materials, boards with up-ended nails, wire cable, and accumulations of rubbish strewn about. Tools and materials out of place make men stumble. Up-ended nails cause abrasions and subsequent infection. Bruises, skin abrasions, and fractures result when unprotected openings are left in derrick floors. Not only should the derrick be tidy—the tools hung on racks or neatly arranged in corners and out of the way places, floors scraped clean, openings closed, and unused material piled elsewhere—but material should not be scattered about the ground outside. Material and tools strewn over the derrick yard

FIGURE 83.—Gas-engine exhaust stack: A railing around the stack would prevent workmen from being burned if they came in contact with the stack

present a great hazard at night, or when derrickmen are forced by a blow-out, fire, or pulled-in derrick to make a quick get-away.

Figure 84 illustrates a deplorable condition of untidiness. Boards, barrels, pipes, and materials used in drilling the well lie scattered about the derrick yard. Pools of mud-laden fluid and oil add to the general unkept condition of the surroundings. What chance would the workmen have of reaching a point of safety away from the derrick should something happen at the well that required them to leave quickly?

Figure 85 illustrates an unsafe derrick floor of a producing well. Boards with up-ended nails may be seen back of the casing-head valve. Openings such as those in this derrick floor should not be tolerated; men can not work safely where such unprotected openings exist.

The derrick floor shown in Figure 86 is unsafe. The posts and floor timbers are badly rotted; the floor boards are broken and

loose. The hazard of tripping on the floor of this pumping jack is great because of loose boards, pipe, rock, and other materials scattered about. Pipes extending upward a few inches to a foot through

FIGURE 84.—An example of "poor housekeeping" at a well in the Smackover field, Ark.

a floor on which men have to walk are dangerous. They not only trip men, but their mushroomed tops cause abrasions of the skin.

FIGURE 85.—Derrick floor at a well in Wyoming. Note holes in floor and boards with up-ended nails

Every precaution must be taken, no matter how trivial, if accidents in the oil fields are to be reduced in number and severity. Lack of cleanliness at derricks is not always the fault of the man-

agement. Some workmen are careless and allow conditions in and around the derrick to become unsafe. The management, through its tool pushers and foremen, should call the attention of the workmen to such unsafe practices. Constant effort should be made to

FIGURE 86.—Derrick floor at a pumping jack in Pennsylvania; floor supports and sills badly rotted; floor boards weak and broken through in many places. Pipes stick up through floor, and loose material on the floor increases the stumbling hazard

prevent accumulations of tools, materials, and rubbish on the derrick floor or yard. Experience has shown that many accidents are eliminated and the efficiency of workmen is increased by keeping the derrick and its surroundings in an orderly condition.

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