

Chapter Ind 6

TUNNEL, CAISSON AND TRENCH CONSTRUCTION

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Ind 6.001 Scope. These orders shall apply to all tunnels, caissons, accessory shafts and trenches while under construction with the exception of tunnel construction in connection with mines.

Ind 6.01 Definitions. For the purpose of these orders the following items are defined.

(1) **Tunnel** is a subterranean passage or chamber constructed without the removal of superincumbent material.

(2) **Shaft** is an excavation made from the surface of the ground, the longer axis of which is steeper than 45 degrees.

(3) **Trench** means a narrow excavation made from the surface of the ground.

(4) **Constructor** means the person, firm or body corporate in immediate control of the construction of any tunnel or its accessories and as such responsible for the condition and management thereof.

(5) **Superintendent** means the person resident on the work having general supervision and responsibility.

(6) **Foreman** means a person in charge of a subdivision of the work or of the entire work at any one time and under the instructions of the superintendent.

(7) **Works** means any or all parts of a tunnel excavated or being excavated as well as shafts and approaches, power houses, lumber yards, storage yards and structures of all kinds, which are in the immediate vicinity of and used in connection with the excavation or the immediate disposal of excavated material or in connection with the construction of the tunnel lining.

(8) **Magazine** means any building or other structure or place in which explosives are stored or kept, whether above or below ground.

(9) **Explosive or Explosives** means all explosive compounds commonly used in blasting practice, including the dynamites, gelatin dynamites, ammonium-nitrate dynamites, blasting powders, black powders and all detonators.

(10) **Person** means a firm or body corporate as well as natural persons.

(11) **Underground** means within the limits of any shaft or tunnel.

(12) **Employes or Persons Employed** means all persons receiving compensation from the constructor or others for labor or services performed on the works.

(13) **Approved** (unless otherwise specified) means approval by the industrial commission.

(14) **Pressure** means gauge pressure in pounds per square inch.

(15) **Open Air** shall be defined as well ventilated under normal atmospheric pressure.

(16) **Close Sheathing** means planks shall be abutting.

Ind 6.02 Inspections. (1) Tunnels, shafts, trenches, timbering and equipment shall be inspected daily. All dangerous conditions or defects shall be made safe.

(2) Every reasonable precaution shall be taken to insure the safety of the workmen in all cases whether or not provided for in these orders.

Ind 6.03 Care of the injured. (1) It shall be the duty of employers to keep at such place or places as shall be convenient and accessible to employes in shafts or tunnels a wire basket stretcher and a woolen blanket for use in carrying any person who may be injured. At all times there shall be kept and maintained an approved supply of first aid material in a dust and moisture proof box.

(2) It shall be the duty of the employer, on all tunnels where work is in progress, to designate certain employes to be trained in the application of first aid, and at least one employe who has had first aid training shall be present throughout each shift. It shall be the duty of the employer to secure the services of a competent person to instruct such employes from time to time, but not less than once each year in the proper handling and treatment of injured persons before the arrival of a physician.

Ind 6.04 Fire protection. (1) Every reasonable precaution shall be taken against fire in and about tunnels and adequate fire protection shall be provided.

(2) Fire hose connections where water is available with at least 50 feet of hose attached shall be provided at the shaft opening.

(3) Fire extinguishers of 2½ gallon capacity protected against freezing shall be installed in all power plants and at shaft openings.

(4) Head frames built of combustible material shall be of open framework. At or about the surface landing there may be a head house if built of fire resisting material.

(5) Any container used for pouring gasoline shall be provided with a closed top, flexible spout and a safety screen and no open light shall be permitted within a 10 foot radius of the gasoline tank, while filling operations are in progress.

(6) Where fire is used for heating hoppers, any enclosure shall be of incombustible material.

Ind 6.05 Flammable material. (1) Gasoline, naphtha, distillate, fuel oils and other dangerous flammable materials shall be stored in a building kept solely for such storage and the location of which is at least 100 feet away from any shaft, tunnel or approaches, or any building directly connected with the tunnel opening and at least 300 feet distant from any explosive magazine.

(2) If oil or gasoline storage places are so located that leakage would permit oil or gasoline to flow in the direction of the shaft means to prevent such flow shall be provided.

(3) Not more than one day's supply of lubricating oil or grease shall be kept in underground workings.

(4) The storage of gasoline, naphtha and other distillates in underground workings is prohibited.

(5) Waste or decayed timbers shall not be stored in the tunnel, but shall be promptly removed therefrom. Empty boxes, wooden chips, paper and combustible rubbish of all kinds shall not be allowed to accumulate underground.

(6) In all shafts and tunnels, no naked lights or smoking shall be permitted.

(7) Combustible materials in an amount greater than one day's normal requirement shall not be stored or kept within 20 feet of tunnel shafts.

Ind 6.06 Lighting. (1) All lighting in tunnels and shafts shall be by electricity only. While work is in progress tunnels, stairways, shafts, ladderways and all places on the surface shall have a light intensity in foot candles of not less than 0.25.

(2) All places where hoisting, pumping, or other machinery is erected and in the proximity of which persons are working or moving about shall be so lighted when the machine is in operation that the moving parts of such machine can be clearly distinguished.

(3) The exterior of all lamp sockets shall be entirely non-metallic.

(4) Lamp cord, where used for temporary lighting connections, shall have extra heavy insulation. Portable electric hand lamps shall be equipped with a keyless socket of non-combustible, non-absorbent insulating material, large handle of non-absorbent insulating material (such as impregnated wood), basket guard and proper cord.

(5) All incandescent lamps shall be so placed that they cannot come in contact with any combustible material.

(6) When wires used for light and power in tunnels and shafts are uncased, heavy type S rubber covered cable shall be used. Cables shall be supported on insulators except when not possible to do so in tunnel headings or when used in connection with portable hand lamps. Separate uncased wires shall be kept at least 3 inches apart.

(7) Wires which are not armored shall have mechanical protection wherever exposed to injury.

Ind 6.07 Electrical equipment. (1) **DEFINITIONS.** (a) *Potential of a circuit.* The potential or voltage of a circuit, machine or any piece of electrical apparatus is the potential normally existing between the conductors of such circuit or the terminals of such machine or apparatus.

(b) *Grounding.* Grounding any part of an electrical system shall consist in so connecting such part to the earth that there shall be no material difference of potential between such part and the earth.

(c) *Underground station.* The term "underground station" as used herein shall mean any place where electrical machinery is permanently installed in the tunnel.

(d) *Carrying capacity.* The term "carrying capacity" shall be taken to mean carrying capacity of a given wire as prescribed by the Wisconsin state electrical code.

(e) *Guarded.* The term "guarded" shall mean effectually covered, inclosed or otherwise guarded by means of suitable covers, casings, screens or barriers so as to prevent accidental contact with live parts of apparatus or circuits.

(2) **CARE OF EQUIPMENT AND PRACTICES.** No person shall be allowed to install or handle electric wires, lights, or conductors, or work on or with electrically driven apparatus, unless he shall be competent and shall have been previously instructed in the performance of his duties by the tunnel superintendent, tunnel foreman, or someone authorized by them.

(3) **GROUNDING.** All non-current carrying metal parts of electrical equipment, including frames and bed plates of generators, transformers, compensators, rheostats and motors shall be permanently and effectively grounded. All metallic fittings, coverings and armoring of cables are included. The central wire of a three wire system and some point of any low voltage system shall be grounded. See the Wisconsin state electrical code.

Note: This order requires the grounding of the non-current carrying parts of portable tools, such as drills. An additional conductor in the portable cord and a grounding contact in the plug and receptacle will provide the best means of permanent and effective grounding.

(4) **SUPPORT OF CABLES AND WIRES.** All underground cables and wires, unless provided with grounded metallic covering, shall be supported by efficient insulators. The conductors connecting lamps to the power supply shall in all cases be insulated.

(5) **OVERHEAD LINES ABOVE GROUND.** Overhead transmission lines between the generating station or sub-station and the tunnel entrance shall be supported upon insulators, which shall be adequate in quality, size and design for the voltage transmitted. Where such line is more than 500 feet in length, lightning arresters shall be installed in connection therewith. All overhead lines, except in the case of trolley wires, shall be maintained not less than 14 feet above the ground at the lowest point, except at the point of entrance to the tunnel.

Note: If wires cross areas accessible to vehicles or if the voltage exceeds 300, greater clearances shall be provided as required by the Wisconsin state electrical code.

(6) **BRANCH CIRCUITS.** Every branch circuit shall be provided with a switch and fuses of ample carrying capacity on each phase within 50 feet of the point where it leaves the main circuit.

(7) **POWER WIRES AND CABLES.** (a) In all shafts, the angle of inclination which is above 45 degrees from the horizontal, and in all hoisting shafts or manway compartments, all power wires and cables shall be amply protected by insulation and substantially fixed in position. All shaft cables shall be supported on insulators that cannot cause abrasion of the covering or insulators, so spaced that no part of the cable shall be under a tension greater than one-fourth of its ultimate strength. The cable shall be held in position at points between the insulators by grips or cleats that cannot cause abrasion of the covering or insulation. Where the cables are not completely boxed in and protected from falling material, space shall be left between them and the side of the shaft so that they may yield and lessen a blow from falling material. This rule shall not be construed to prevent the installations of efficiently insulated wires in metal conduit to transmit power underground.

(b) Where the cables or feed wires in tunnels cannot be kept at least 12 inches from any part of the tunnel, car or locomotive, they shall be especially protected by proper guards.

(8) **CABLES ENTERING FITTINGS.** (a) The exposed ends of cables where they enter the fittings of any description shall be so protected and finished off that moisture cannot enter the cables or the insulating material leak out, if of an oily or viscous nature.

(b) Where unarmored cables or wires pass through metal frames or into boxes or motor casings, the holes shall be substantially lined with insulated bushings.

(9) **JOINTS IN CONDUCTORS.** All joints in conductors shall be mechanically and electrically efficient and whenever of a permanent nature, shall be soldered. All joints in insulated wire shall, after the joint is complete, be reinsulated to the same extent as the remainder of the wire.

(10) **JOINTS IN CABLES.** Where cables are joined, suitable junction boxes shall be used or the joints shall be soldered and the insulation, armoring or lead covering replaced in as good condition as it was originally.

(11) **FUSES, CIRCUIT BREAKERS AND SWITCHES.** (a) Fuses and automatic circuit breakers shall be constructed so as effectually to interrupt the current when a short circuit occurs or when the current through them exceeds a pre-determined value. No open type or link fuses shall be used.

(b) Fuses shall be stamped or marked, or shall have a label attached, indicating the maximum current that they are intended to carry. Fuses shall be adjusted or replaced only by an authorized and competent person.

(c) The capacity of fuses used to protect feeders shall not exceed the current capacity of the feeder by more than ten per cent.

(d) All points at which a circuit has to be made or broken shall be provided with suitable switches, which shall be so installed that they cannot be closed by gravity.

(e) All switches, circuit breakers and fuses shall have non-combustible bases and shall be properly enclosed.

(f) All cartridge fuses, and plug fuses larger than 15 amperes capacity, shall always be so arranged that they may be disconnected from the supply circuit by properly placed switches. An individual switch shall be installed in each branch circuit of capacity larger than 15 amperes.

(g) All manual switches, including service switches, shall have suitable casings or inclosures of such design as to permit of operation without opening the inclosure and so that the operator is at all times protected against danger. Cases shall be locked, sealed or made inaccessible to other than qualified persons by other suitable methods.

Exception. Switches on switchboards and panel boards which are properly guarded or locked or in underground stations or other similar places not accessible to other than qualified persons are exempted.

(12) **MOTORS.** Every motor together with its starting device shall be protected by a fuse in each phase or (in the case of motors of more than 40 horse-power) by a circuit breaking device on at least one line of direct current systems and on two phases of three-phase alternating current system and by switches arranged to cut off entirely the power from the motor. The above devices shall be installed in a convenient position near the motor and in sight of it.

Ind 6.08 Scaling and inspection for loose material. (1) In rock tunnels, shafts or trenches frequent inspections shall be made by a competent person whose duty it shall be to see that all loose rock so located that it may fall is removed.

(2) After a blast is fired these requirements for inspection and removal of loose rock shall be complied with before proceeding with the work.

Ind 6.09 Timber requirement for tunnels. (1) Every shaft or tunnel excavation not located in solid rock in which men are permitted to work shall be kept adequately and securely timbered to prevent injury to any person from falling materials, or collapse of the sides or roof of the working place.

(2) All timbers used in the support of shafts and tunnels shall be of good quality, reasonably straight grained and free from weakening knots and other defects.

(3) All timbers shall, when placed for the support of the roof and sides of the tunnel or in the shaft, be properly fitted and wedged in place. Timber sets in tunnels and sheathing planks in shafts shall be abutting. All void spaces in back of timbers shall be filled with blocking or other suitable material.

(4) Face boards shall be placed in all tunnel headings at end of mining shifts.

Exception. Face boards need not be placed in stable ground if mining operations are continued without interruption by the succeeding shift.

(5) Knee braces, cleats and spreaders shall be nailed in place with not less than two nails for any one piece. No nail smaller than the

following shall be used for the various thicknesses of materials as follows:

1 inch (nominal)	8 d common	[2½ inches x No. 10¼]
2 inch	" 16 d "	[3½ inches x No. 8]
3 inch	" 30 d "	[4½ inches x No. 5]
4 inch	" 50 d "	[5½ inches x No. 3]

(6) No tunnel excavation shall be carried more than 24 inches in advance of the timbering.

(7) In solid stable soil tunnel sections shown in figures 1 to 8 may be used if timbered within the following limitations.

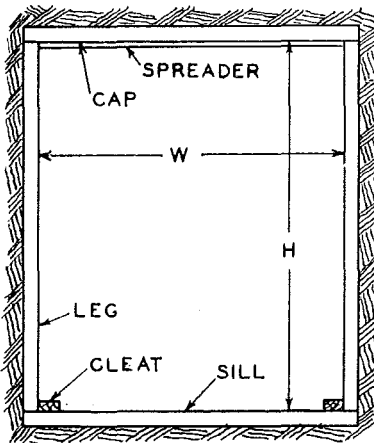


Fig. 1 Box Type of Timbering

Width Maximum in Feet W	Height Maximum in Feet H	Dimensions of Timbering		
		Caps, Legs, Sills Thickness in Inches	Spreaders (One to every set) Inches	Cleats Inches
3	4	2	1x4	2x4
5	6	3	1x4	2x4

Note: The use of either spreaders or cleats in figure 1 is required. Cleats shall consist of 2 x 4 inch lumber not exceeding 3 feet in length.

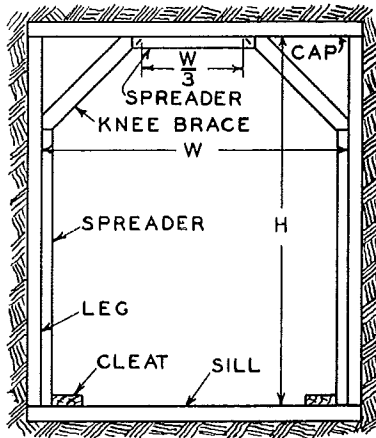


Fig. 2 Box Type of Timbering

Width Maximum in Feet W	Height Maximum in Feet H	Dimensions of Timbering		
		Caps, Legs, Sills, Knee Braces, Thickness in Inches	Spreaders (One to every set) Inches	Cleats Inches
8	8	3	2x6	2x6
10	10	4	2x6	2x6

(a) Knee braces shall be spaced not exceeding 2 feet center to center and may be removed immediately preceding concrete or masonry work at that point.

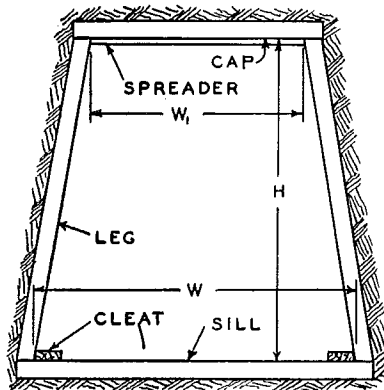


Fig. 3 Modified Box Type of Timbering

Width Maximum in Feet		Height Maximum in Feet H	Dimensions of Timbering		
W_1	W		Caps, Legs, Sills Thickness in Inches	Spreaders (One to every set) Inches	Cleats Inches
3	5	4	2	1x4	2x4
5	7	7	3	2x6	2x6
8	10	10	4	2x6	2x6

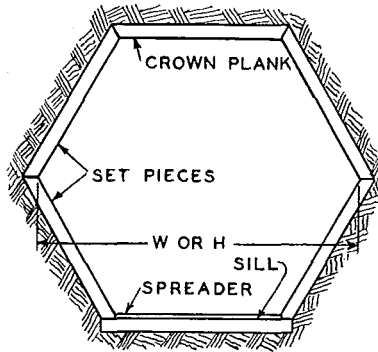


Fig. 4 Hexagonal Type of Timbering

Width Maximum in Feet W	Height Maximum in Feet H	Dimensions of Timbering	
		Crown Planks, Set Pieces, Sills Thickness in Inches	Spreaders (One to every set) Inches
10	10	3	2x6

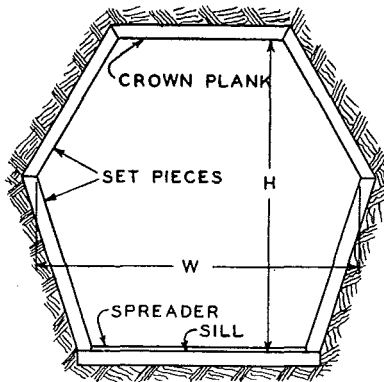


Fig. 5 Modified Hexagonal Type of Timbering

Width Maximum in Feet W	Height Maximum in Feet H	Dimensions of Timbering	
		Crown Planks, Set Pieces, Sills Thickness in Inches	Spreaders (One to every set) Inches
10	10	3 ⁽¹⁾	2x6

(1) Use 4 inch plank if length of any piece exceeds 6 feet.

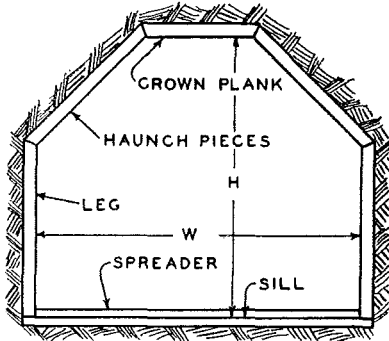


Fig. 6 Arched 6-Piece Timber Set

Width Maximum in Feet W	Height Maximum in Feet H	Dimensions of Timbering	
		Crown Planks, Legs, Haunch Pieces, Sills Thickness in Inches	Spreaders (One to every set) Inches
5	6	3 ⁽¹⁾	2x6
10	10	3 ⁽¹⁾	2x6

(¹) Use 4 inch plank if length of any piece exceeds 6 feet.

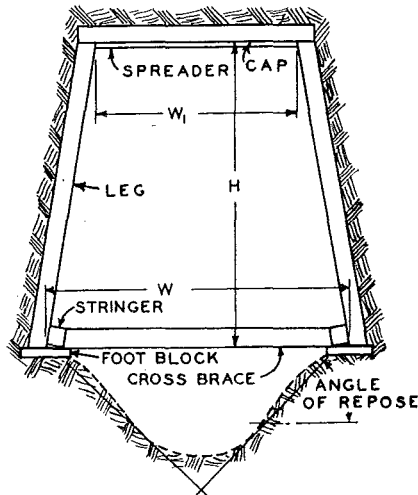


Fig. 7 Cap and Leg Type of Timbering

Width Maximum in Feet		Height Maximum in Feet H	Dimensions of Timbering			
W ₁	W		Caps, Legs, Thickness in Inches	Stringers Cross Braces (4 feet c-c) Inches	Spreaders (One to every set) Inches	Foot Blocks Inches
3	5	4	2	4x6	1x3	(1)
5	7	7	3	4x6	2x6	
8	10	10	4	4x6	2x6	

(¹) Foot blocks shall not be less than 2 inches thick or less than 12 inches long and the width shall equal that of the leg pieces.

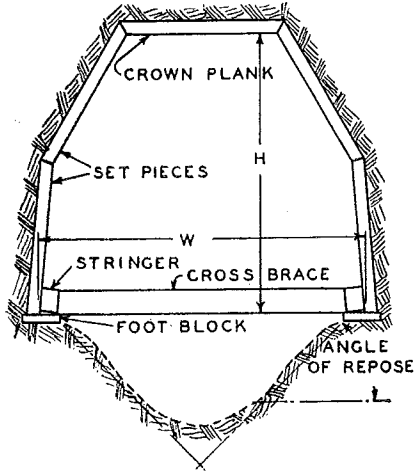


Fig. 8 Arched 5-Piece Timber Set

Width Maximum in Feet W	Height Maximum in Feet H	Dimensions of Timbering		
		Set Pieces Inches	Stringers Cross Braces (4 feet c-c) Inches	Foot Blocks Inches
10	10	3	4x6	(1)

(1) Foot blocks shall not be less than 3 inches thick or less than 12 inches long and the width shall equal that of the leg pieces.

(b) Sections shown in Figures 7 and 8 are only permissible when concrete or masonry follows tunnel excavation within a distance of not exceeding 25 feet from the face of the tunnel and the tunnel section does not remain open for more than 48 hours; provided, however, that the bench shall not be removed unless the concrete or masonry is placed immediately thereafter.

(c) When excavating below the level of the foot blocks the angle of repose of the material at the particular place shall govern the permissible depth.

(d) Stringers and crossbraces are required only when excavation extends below base of foot blocks. They may be removed when masonry or concrete reaches the elevation of the cross braces.

(8) In excavating heavy soil which cannot be held in place with timber sections shown in Figures 1 to 8 inclusive, then timber sections shown in Figures 9 and 10 shall be used within the following limitations.

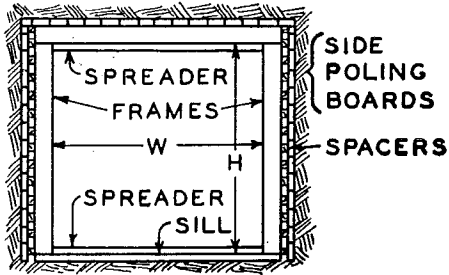
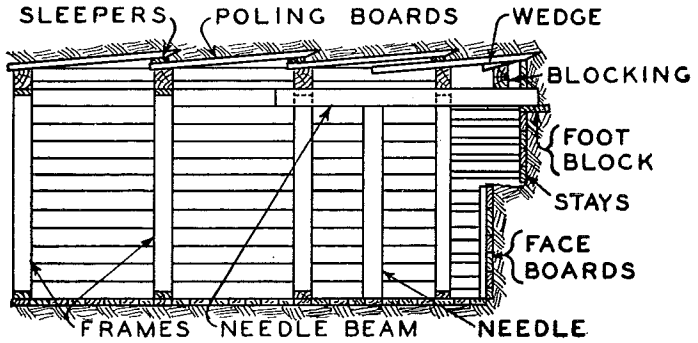


Fig. 9 Poling Board Method of Timbering

Width Maximum in Feet W	Height Maximum in Feet H	Sheathing Thickness in Inches	Framing Timbers	
			Dimensions in Inches	Maximum Spacing in Feet
5	5	2	6x6	4
7	7	2	8x8	4
8½	8½	2	10x10	4
10	10	2	10x10	3½

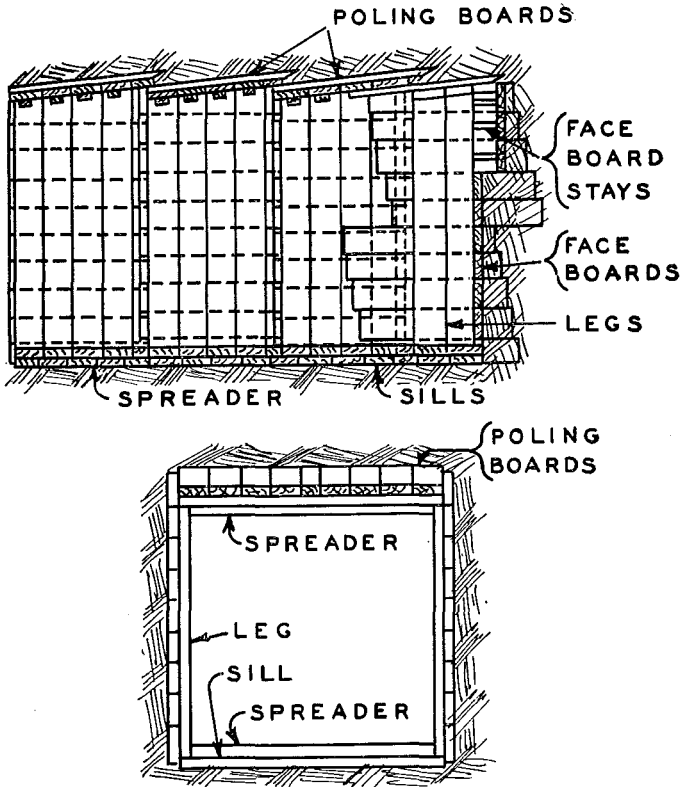


Fig. 10 Poling Board Method of Timbering

Width Maximum in Feet W	Height Maximum in Feet H	Sheathing thickness in Inches	Set Pieces thickness in Inches	Spreaders Inches	Cleats Inches	Knee Braces Inches
4	3	1	2	1x4	2x4	---
5	6	1	3	1x4	2x4	---
8	8	1	4	1x4	2x6	3
10	10	1	6	1x4	2x6	4

(9) For tunnels of greater dimensions than indicated in Figures 1 to 10 or for the modification or combination of sections of timbering for the same, or for the use of metal liners in lieu of timbering, plans and specifications shall be submitted to the industrial commission for approval.

(10) Tunnel excavations in which men are permitted to work shall not be less than 3 feet wide nor less than 4 feet in height. These measurements apply to distances between timbers.

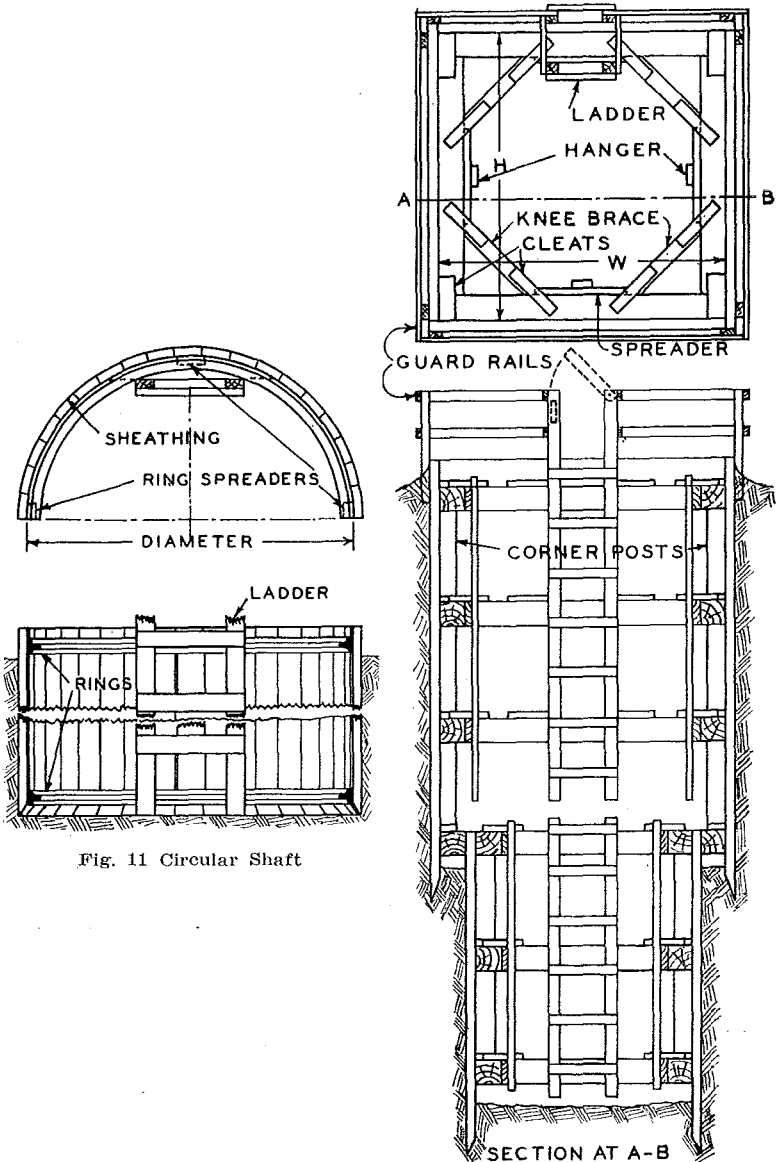


Fig. 11 Circular Shaft

Fig. 12 Rectangular Shaft
Timbering

(11) Shafts exceeding 5 feet in depth in which men are permitted to work shall be timbered. Shaft sections shown in Figures 11 and 12 may be used within the following limitations:

(a) Linings shall not be less than 2 inch close sheathing.

(b) Rings and frames shall not be spaced greater than 48 inches center to center.

(c) Cleats, hangers, spreaders and corner posts shall not be less than 2 x 6 inches.

(d) For circular shafts, the diameter of which shown in Figure 11 does not exceed 6 feet and the depth does not exceed 10 feet, ring sections shall not be less than $\frac{1}{2}$ x 4 inches.

(e) For rectangular shafts shown in Figure 12, in which W or H does not exceed 6 feet and the depth does not exceed 10 feet, not less than 4 x 6 inch framing members shall be used.

(f) For circular or rectangular shafts larger than the above, ring sections or timber frames shall be proportionately increased so as to maintain an equivalent factor of safety.

(g) Staging or scaffolds shall be provided in shafts for workers when installing equipment or driving sheathing. All scaffolds shall be constructed or installed so as to support any maximum material load which may be placed on them as well as weight of the men.

Ind 6.10 Timber requirements for trenches. (1) All trenches over 3 feet in depth shall be kept adequately and securely timbered to prevent injury to any person from falling or caving ground.

(2) Timbers shall be installed according to the tables of trench timbering requirements contained in section Ind 6.10 (3) to (14).

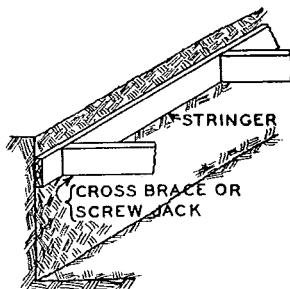


Fig. 13 Trench Timbering

(3) All timbers used for supporting sides of trenches shall be of good quality, reasonably straight grained and free from weakening knots and other defects.

(4) Trenches of 3 feet to 5 feet in depth in which men are permitted to work shall be timbered, except as provided for in section Ind 6.10 (6 to 10). (6)

(5) In hard solid soil timbering shall be of not less than 2 x 6 inch stringers held in place by 2 x 6 inch cross braces or screw jacks spaced not exceeding 6 feet center to center as shown in Figure 13. In soil that splits easily, gravelly or filled in ground, sand or very wet soil, timber requirements shall be the same as for trenches over 5 feet and not exceeding 10 feet in depth.

(6) When the sloping of trenches to the angle of repose does not extend to the bottom of the trench, level benches 2 feet wide shall be provided adjacent to and between the top edges of the vertical walls and the toes of the slopes.

(7) The vertical part of the trench shall be timbered. For vertical walls more than 5 feet in height the timbering shall conform to the requirements in tables for trenches 42 inches or less in width.

(8) For vertical walls less than 5 feet in height 2 x 6 inch uprights spaced 6 feet center to center with two 2 x 6 inch cross braces for each set shall be the minimum requirement.

(9) Uprights in all partially sloped excavations shall extend not less than 2 feet above the vertical portion. Toe boards 12 inches wide shall be placed behind all uprights to prevent material from falling into the vertical portion of the trench.

(10) Trenches 3 feet and over in depth need not be timbered if excavated in solid rock or whenever the sides of the trench are cut down to the angle of repose. The angle of repose shall not be considered greater than one to one-half (measuring one foot of rise to each one-half foot horizontal) for dry or moist soils and not more than one to one for wet or heavy soils.

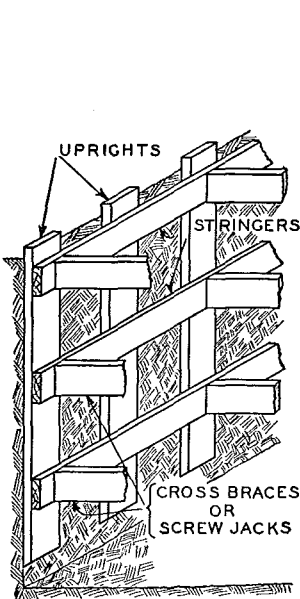


Fig. 14 Trench Timbering—
Solid Soil

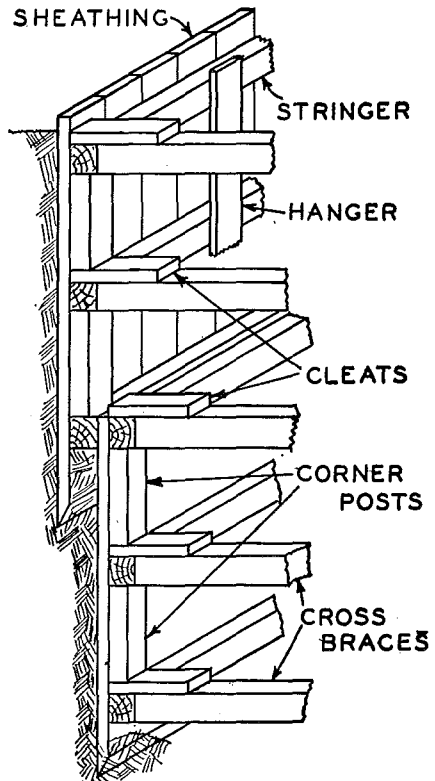


Fig. 15 Trench Timbering

TABLE OF TRENCH TIMBERING REQUIREMENTS

For Trenches Over 5 Feet and Not Exceeding 10 Feet in Depth and Width Not Exceeding 42 Inches

	Kind of Soil	Uprights	Cross Braces	Stringers**
Where no parallel excavations exist or have existed within 10 ft.	Hard, solid soil	2x6 inch planks space 6 ft. c—c	*2—2x6 inch planks or equivalent for depths under 7 ft.; 3 for depths 7 ft. to 10 ft.	None
Previous excavations 5-10 ft. from trench	Hard, solid soil	2x6 inch planks space 4 ft. c—c	*2—2x6 inch planks or equivalent for depths under 7 ft.; 3 for depths 7 ft. to 10 ft.	None
Previous excavations less than 5 ft. from trench	Hard, solid soil	2x6 inch planks spaced 3 ft. c—c	*2—2x6 inch planks or equivalent for depths under 7 ft.; 3 for depths 7 ft. to 10 ft.	None
Irrespective of any previous excavation	Soil that splits easily	2x6 inch planks space 3 ft. c—c	*2—2x6 inch planks or equivalent for depths under 7 ft.; 3 for depths 7 ft. to 10 ft.	1x6 inch boards placed back of uprights near top of trench
Irrespective of any previous excavation	Gravelly or filled in ground	2x6 inch planks spaced 2 ft. c—c	*2—2x6 inch planks or equivalent for depths under 7 ft.; 3 for depths 7 ft. to 10 ft.	1x6 inch boards placed back of uprights near top of trench
Irrespective of any previous excavation	Sand or very wet soil	2 inch close sheathing	3x6 inch timbers or equivalent horizontally spaced not exceeding 6 feet	3x6 inch timbers or equivalent—2 for depths under 7 ft.; 3 for depths 7 ft. to 10 ft.

For Trenches over 10 Feet and Not Exceeding 15 Feet in Depth and Width Not Exceeding 42 Inches

	Kind of Soil	Uprights	Cross Braces	Stringers**
Where no parallel excavations exist or have existed within 15 ft.	Hard, solid soil	2x6 inch planks spaced 4 ft. c—c	*3—2x6 inch planks or equivalent for depths under 13 ft.; 4 for depths 13 ft. to 15 ft.	None
Previous excavations 10 to 15 ft. from trench	Hard, solid soil	2x6 inch planks spaced 3 ft. c—c	*3—2x6 inch planks or equivalent for depths under 13 ft.; 4 for depths 13 ft. to 15 ft.	None
Previous excavations less than 10 ft. from trench	Hard, solid soil	2x6 inch planks spaced 2 ft. c—c	*3—2x6 inch planks or equivalent for depths under 13 ft.; 4 for depths 13 ft. to 15 ft.	None
Irrespective of any previous excavations	Soil that splits easily	2x6 inch planks spaced 2 ft. c—c	*3—2x6 inch planks or equivalent for depths under 13 ft.; 4 for depths 13 ft. to 15 ft.	1x6 inch boards placed back of uprights near top of trench
Irrespective of any previous excavations	Sand, gravel filled in ground or very wet soil	2 inch close sheathing	3x6 inch timbers or equivalent, spaced 6 ft. c—c	3x6 inch timbers or equivalent—3 for depths under 13 ft.; 4 for depths 13 ft. to 15 ft.

For Trenches Over 15 Feet in Depth and Width Not Exceeding 42 Inches

Irrespective of any previous excavations	Any soil	2 inch close sheathing	4x12 inch timbers or equivalent horizontally spaced 4 ft. c—c	4x12 inch timbers 48 inches c—c
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Note: c—c means center to center.

*In lieu of these cross braces for each upright, 3x6 inch stringers may be used with substantial cross braces spaced horizontally sufficient to give equivalent protection, but in no case exceeding 6 feet.

**Where stringers are used they shall be properly supported by posts or cleats.

FOR TRENCHES OVER 42 INCHES IN WIDTH UP TO AND INCLUDING 12 FEET IN WIDTH

Depth of Trench	Uprights	Cross Braces	Stringers
Over 5 ft. to 10 ft. incl.	(1)	4x6 inch timbers spaced horizontally 7 ft. face to face	4x6 inch timbers spaced 4 ft. c—c
Over 10 ft. to 20 ft. incl.	(1)	6x6 inch timbers spaced horizontally 7 ft. face to face	6x6 inch timbers spaced 4 ft. c—c
Over 20 ft. to 30 ft. incl.	(1)	6x8 inch timbers spaced horizontally 7 ft. face to face	6x8 inch timbers spaced 3 ft. c—c
Over 30 ft. to 40 ft. incl.	(1)	8x8 inch timbers spaced horizontally 7 ft. face to face	8x8 inch timbers spaced 3 ft. c—c

(1) Uprights shall consist of 2 inch planks and spaced to comply with specifications for trenches less than 42 inches in width.

(11) For trenches exceeding 40 feet in depth or 12 feet in width, plans for timbering shall be submitted to the Industrial Commission for approval.

(12) Any other method of supporting the walls of an excavation will be approved if designed and constructed to afford equivalent protection.

(13) A temporary guard railing or other effective guard or barricade shall be provided at or near the sides of trenches and shall be kept in place at all times, except at such times when safe-guards will interfere with excavation or other work.

(14) All trenches to which employes or frequenters may be exposed at night shall have red lanterns or torches placed along the exposed side or sides.

Ind 6.11 General safety precautions. (1) **PROJECTING NAILS.** All spikes and nails with points projecting shall be bent down or removed from lumber lying in or about working places.

(2) **SAFETY BELTS.** Approved, tested and regularly inspected safety belts or harnesses and ample lengths of $\frac{3}{4}$ inch diameter rope shall be provided for emergency use.

Note: Lists of approved safety belts can be secured from the industrial commission.

(3) **CLAM SHELL BUCKETS.** No man shall be permitted to work in a shaft when excavation is being done with a clam shell bucket unless the least dimension of the shaft is twice the length of the bucket when fully opened.

(4) **DRIVING SHEATHING.** When sheathing is driven by power equipment, drivers especially designed for the purpose shall be used.

(5) **PROTECTIVE HATS.** All underground workers in tunnels and shafts shall wear protective hats or caps of approved design and manufacture.

(6) **PROTECTIVE FOOTWEAR.** Approved hard toed boots or shoes shall be worn by all underground or surface workers exposed to toe injury hazards.

(7) **SOLITARY EMPLOYMENT.** During periods of temporary shut-downs, solitary employment shall be prohibited in shafts over 20 feet in depth unless an extra man is on duty outside of the shaft.

Ind 6.12 Mechanical haulage. (1) When mechanical haulage is used, care shall be taken that the speed is not excessive depending upon the grades and condition of the tracks. No cars shall be pushed underground where it is practical to draw and all locomotives shall be equipped with headlights and gongs. Trolley poles shall be trailed whenever it is possible to do so. No locomotive shall be operated by a person under 18 years of age. No gas locomotive shall be used in any tunnel.

(2) Approved means shall be provided to prevent the run away of standing cars.

Ind 6.13 Sumps. All sumps shall be securely covered or fenced except when being cleaned or repaired.

Ind 6.14 Ventilation. (1) There shall be provided in each shaft or tunnel at least 30 cubic feet of free air per minute for each person in the shaft or tunnel.

(2) Precautions shall be taken after blasting and at the beginning of each shift for the detection of explosive gases and insufficiency of oxygen in the air. Further precaution shall be taken from time to time to see that the noxious gases are exhausted from the working face so that at no time when working in the shaft or tunnel will the gases exceed the following limits:

Carbon monoxide to be less than -----	.005%
Carbon dioxide to be less than -----	1.00%
Methane to be less than -----	.25%
Hydrogen sulphide to be less than -----	.001%
Oxygen to be more than -----	19.00%

(3) If tests show an excess of these limits for any of the gases, mechanical ventilation shall be provided and operated which will give a minimum of 1,000 cubic feet of free air per minute in each tunnel and sufficient air in addition to dilute said gases with pure air to comply with the limitations of the above table.

(4) Gasoline engines shall be so located that the exhaust gases will not enter the shaft or the air intake of compressors. Gasoline engines shall not be operated in any tunnel or shaft.

(5) Harmful dusts shall be removed from the air breathed by workers sufficiently to cause the air to be safe to breathe.

(6) The maximum silica dust concentration in the air breathed by workmen at any point in the normal breathing zone shall not exceed 15 million particles under 10 microns in longest dimension per cubic foot of air when the quartz content of the dust is 35%. Variations in free silica content will make proportional inverse changes in this standard.

Ind 6.15 Shaft protection. (1) During shaft sinking operations, the tops of all shafts shall be guarded by a suitable barricade that will keep unauthorized persons away from the opening. At night there shall be an additional protection of torches or red lights. After a

depth of 16 feet has been reached a standard railing and toeboard and equipped with necessary gates shall be provided and such gates shall be kept closed when access to the shaft is not necessary.

(2) Where cages are installed in shafts, automatic gates shall be used at the top landing. All intermediate landings shall be provided with a fence and gate or gates, the members of which shall not be more than 4 inches apart and not less than 5 feet high. The gates at such landings shall not be more than 12 inches from the openings, which gates shall be kept closed at all times except when persons or material are entering or leaving the cage.

(3) Means for blocking cars shall be provided at all landings and also for blocking cars on cage.

(4) Landing dogs shall be provided at all landings where cars enter or leave cage or where material is taken on or off cages.

(5) The tops of all bins or hoppers around which men are required to work shall be provided with a temporary guardrail.

Note: Guardrail installations, if of wood construction, will comply with this order if made according to the following specifications:

Guardrails of not less than nominal 2 x 4 inch material fastened to posts and not more than 42 inches or less than 36 inches above the working level;

Posts of not less than nominal 2 x 4 inch material, spaced not more than 8 feet apart, fastened and braced in place;

Where the top of the guardrail is more than 36 inches above the working level, an intermediate rail of not less than nominal 1 x 6 inch material is to be placed midway between the top guardrail and the working level.

Equivalent strength and stiffness is to be provided if material other than wood is used.

(6) Collars of all shafts shall be provided with efficient dams to prevent influx of water during heavy rains. Dams shall be formed by extending shaft lining not less than 10 inches above surface ground level and banking with clay or other plastic material.

Ind 6.16 Stairways and ladders in shafts and caissons. (1) All shafts leading to tunnels, and all shafts in caissons where men are working, shall be provided with ladders or stairways which are to be kept clean and in good condition at all times.

(2) Where the depth of the shaft exceeds 40 feet, ladders shall be provided with landings, the area of which shall not be less than the equivalent of 18 x 24 inches, and such landings shall not be spaced more than 20 feet apart.

(3) The distance between the centers of rungs of a ladder shall not exceed 14 inches and shall not vary more than one inch in any one ladder length. The rungs of the ladder shall in no case be less than 6 inches from the wall or any obstruction in the shaft or opening in which the ladder is used. Under no circumstances shall a ladder inclining backward from the vertical be installed.

(4) Should it be necessary to offset any section of a ladderway, the top of the ladder section shall extend not less than 3 feet above the bottom of the section above, or hand holds shall be provided.

(5) A suitable ladder shall be provided from the tops of all locks to the surface, the side rails of such ladder to extend at least 3 feet above the landing.

(6) Vertical air locks used for the passage of men shall be provided with platforms of sufficient area to accommodate all men admitted to the lock.

(7) Fixed ladders of standard construction shall be provided for access to cable sheaves on head frames located over tunnel shafts. A

runway or platform equipped with guardrails and toeboards shall also be provided next to cable sheaves.

Note: A ladder is a framework consisting of 2 or more approximately parallel stringers to which are attached horizontal cleats or rungs uniformly spaced, used for ascending to and descending from elevated places.

Ind 6.17 Cleaning of ladderways. Timbers and projections on which debris may lodge in ladderways and stairways in daily use shall be kept cleaned of all loose rock and other debris.

Ind 6.18 Hoisting engineer. Only experienced operators familiar with the details of hoisting equipment shall be employed to operate such equipment. Learners may be taught the operation of hoisting equipment at such time and under such restrictions so as to not endanger other workers. Hoist operators shall be familiar with the requirements of section Ind 6/19.

Ind 6.19 Duties of hoisting engineer. (1) It shall be the duty of every hoisting engineer to keep a careful watch over his engine and over all machinery under his charge.

(2) He shall, while on duty, be in immediate charge of his engine, and shall not at any time delegate any of his duties to any other person, except to apprentices duly designated, as provided in these rules.

(3) He shall familiarize himself with and use the signal code posted in the engine room, as hereinafter provided.

(4) He shall not run his engine unless the same is properly provided with brakes and distance marks on hoisting ropes or cables.

(5) It shall be the duty of the hoisting engineer to exclude every person from his engine room except any person or persons whose duties require their presence therein.

(6) He shall hold no conversation with any one while his engine is in motion or while attending to signals.

(7) He shall not hoist men out of, or lower men into, any tunnel or shaft at a speed greater than the rate posted in the engine room.

(8) He shall inspect all hoisting machinery and safety appliances connected therewith and shall immediately report any defects found therein.

(9) After any stoppage of hoisting for repairs, he shall run the bucket, skip, cage or other conveyance, on which no men shall ride, up and down the working part of the shaft at least once, and shall not permit the bucket, skip, cage or other conveyance to be used for hoisting or lowering men until the hoisting machinery and shaft shall have been found to be in safe condition.

(10) He shall do no hoisting in any compartment of a shaft while repairs are being made in the said hoisting compartment except such hoisting as may be necessary to make such repairs.

(11) He shall not turn over the charge of the engine to his relief at change of shift or at any other time while the bucket, skip, cage or other conveyance is in motion.

Ind 6.20 Hoisting. (1) The superintendent of the tunnel shall establish for each shaft rates of speed for the cages, skips, buckets or other conveyances that shall not be exceeded in the hoisting or lowering of men, and he shall post a notice of such limitation in a conspicuous

unwound; at least 2 full turns shall remain always on the drum or reel. The end of the rope attached to the conveyance in the shaft shall be bound around an oval thimble and then fastened to itself by the use of three or more clamps, or shall be securely fastened with a tapered socket.

(7) No open hook shall be used with a bucket, cage, or skip in hoisting, but some approved form of safety hook or shackle hook shall be used.

(8) Every sheave and every idler under which is led any hoisting cable shall be provided with a guard that will keep the cable on the sheave or idler if the cable becomes slack.

Ind 6.24 Cages for hoisting. (1) In all shafts over 40 feet in depth cages shall be used for conveyance of men. This requirement shall not apply to the following conditions:

(a) Shafts in the process of sinking.
 (b) Shafts when being dismantled after work in tunnel is substantially completed.

(c) In caissons or vertical locks.

(2) In shafts less than 40 feet in depth cages will not be required when men are made to use approved ladders and in no case shall be lowered or hoisted with swinging hooks, buckets or other device.

(3) Cages shall be provided with bonnets consisting of 2 steel plates not less than 3/16 of an inch in thickness sloping toward each other and so arranged that they may be readily pushed upward to afford egress to persons therein, and such bonnet shall cover the top of the cage in such manner as to protect the persons on the cage from falling objects.

(4) Cages shall be entirely enclosed on two sides with solid partitions or wire mesh not less than No. 8 U. S. standard gauge, no opening in which shall exceed 2 inches.

(5) Cages shall be provided with hanging chains or similar devices for hand holds.

(6) Every cage shall be provided with an approved safety catch of sufficient strength to hold the cage with its maximum load at any point in the shaft.

(7) A safety device shall be provided for blocking cars while on cage.

(8) All parts of hoisting apparatus, cables, brakes, guides and fastenings shall be of the most substantial design and shall be arranged for convenient inspection. The efficiency of all safety devices shall be established by satisfactory tests before the cages are put in service and at least once every three months thereafter and a record thereof kept.

(9) The test of the safety catch shall consist of releasing the cage suddenly in such manner that the safety catches shall have an opportunity to grip the guides.

Ind 6.25 Sanitation. (1) It shall be the duty of the employer to provide dry closets, water closets, or closet cars on all working levels for the use of all men employed in tunnels. At least one such closet shall be provided for every 40 men employed within the tunnel. No closets shall be constructed without adequate provision for the effectual cleansing and removing of the contents thereof, which shall be

removed and disposed of at least twice each week. A disinfectant or deodorizer shall be supplied and sprinkled upon the contents thereof. Provided, however, that this order shall not apply to any tunnel when the employer or superintendent prefers to permit the men to go to the surface and requires the men to do so. Such exit and entrance to tunnel or caisson shall be in accordance with decompression and compression. Sections Ind 6.27-Ind 6.28.

(2) One outside toilet and urinal shall be provided for every 20 men employed on each shift and protection from the weather shall be provided.

(3) A safe quality of drinking water shall be supplied for the use of all men employed in the tunnel. The supply of drinking water shall be adequately protected from contamination by dust, and from promiscuous drinking from the supply vessel on the part of the men.

(4) A dressing room or change house shall be provided for the purpose of drying clothes of persons employed in and about the tunnel. Not less than four square feet of floor area shall be available for each employee. Adequate means of heating and lighting shall be provided and a temperature of not less than 70 degrees F. shall be maintained at all times. Dressing rooms or change houses shall be cleaned daily of all refuse or accumulation. Lockers or hangers shall be provided for clothing. Tools, equipment or other supplies shall not be kept in change houses.

WORK IN COMPRESSED AIR

Ind 6.26 Hours of labor. (1) The working time in any 24 hours shall be divided into two shifts under compressed air with an interval in open air; except that when pressures of 15 pounds per square inch or less are employed; the rest interval need not be spent in open air unless it is convenient to do so.

(2) The limits of hours as herein specified shall apply according to the maximum pressure attained at any time during any shift.

(3) Persons who have not previously worked in compressed air shall not work more than one shift in the first 24 hours. No person shall be subjected to pressure in excess of 50 pounds per square inch except in emergency.

SHIFTS AND INTERVALS OF WORK FOR EACH 24 HOUR PERIOD

Pressure			Hours		
Maximum Number of Pounds	Maximum Number of Pounds	Maximum Total	Maximum First Shift in Compressed Air	Minimum Rest Interval in Open Air	Maximum Second Shift in Compressed Air
Normal	15	8*†			
15	21	8	4	1	4
21	26	6	3	1	3
26	33	4	2	2	2
33	38	3	1½	3	1½
38	43	2	1	4	1
43	48	1½	¾	5	¾
48	50	1	½	6	½

*Rest period need not be spent in open air unless it is convenient to do so.
 †Thirty minute rest period to be taken in middle of shift.

Ind 6.27 Period of compression. When workmen enter the lock, air pressure shall not exceed 5 pounds during the first minute, then the pressure shall be held constant for an interval long enough to ascertain whether workmen are affected, and a similar pause shall be made after each 5 pound raise in pressure.

Ind 6.28 Decompression. (1) No person shall be permitted to pass from the place in which work is being done under pressure to normal air except after decompression in the intermediate lock as follows:

(Pressure in workings)	(Minimum time to decompress)
Normal to 15 pounds -----	5 minutes
15 pounds to 20 pounds -----	10 minutes
20 pounds to 30 pounds-----	20 minutes
30 pounds and above -----	1 minute for each pound of pressure

(2) The reduction of pressures during the time intervals required in the above table of decompression rates shall be accomplished at a rate as uniform as possible.

(3) The decompression table shall be posted conspicuously inside of and at the entrance to each man lock. Violations of the above schedule shall be noted on the record of the individual involved.

Ind 6.29 Gauges. (1) A recording gauge to show the rate of decompression shall be connected to each man lock. The dial shall be of such size that the amount of rise or fall in the air pressure within any 5 minutes shall be readily shown.

(2) There shall be on the outer side of each working chamber at least one pressure gauge, which shall be accessible at all times and shall be kept in accurate working order. Additional fittings shall be provided so that test gauges may be attached at all necessary times. Pressure gauges shall be tested every 24 hours and a record kept of such test.

(3) Whenever men are working under a lake or stream a competent man shall be placed in charge of the valves and gauges which regulate and show the pressure in the working chamber. He shall not be employed more than 8 hours in any 24. At no time shall he operate more than 2 separate air lines.

Ind 6.30 Exhaust valves. Exhaust valves shall be provided, having risers extending to the upper part of chamber, if necessary, and shall be operated at such time as may be required and especially after a blast, and men shall not be required to resume work after a blast until the gas and smoke have cleared.

Ind 6.31 Communication. Suitable means of communication shall be maintained at all times between the working chamber and the power house and the surface.

Ind 6.32 Safety screens. (1) In the construction of tunnels when the tunnel heading extends beyond the shore line, screens shall be installed when necessary, in which case screen shall at no time be at a distance of more than 500 feet behind the face.

(2) Wherever in the prosecution of caisson work in which compressed air is employed, the working chamber is less than 12 feet in

length and when such caissons are at any time suspended or hung while work is in progress so that the bottom of the excavation is more than 9 feet below the deck of the working chamber, a shield shall be erected therein for the protection of the workmen.

Ind 6.33 Locks. (1) Each bulkhead in tunnels of 12 feet or more in diameter or equivalent area, shall have at least two locks in perfect working condition, one of which shall be used as a man lock. An additional lock for use in case of an emergency may be required by the industrial commission.

(2) The man lock shall be large enough so that those using it are not compelled to be in a cramped position, and shall not be less than 5 feet in height. Emergency locks shall be large enough to hold an entire heading shift.

(3) All locks used for decompression shall be lighted by electricity and shall contain a pressure gauge, a timepiece, a glass "bull's eye" in each door or in each end.

(4) Valves shall be so arranged that the locks can be operated both from within and from without.

Ind 6.34 Compressor plants. (1) A good and sufficient air plant for the compression of air shall be provided to meet not only ordinary conditions, but emergencies, and to provide margin for repairs at all times.

(2) This plant shall be capable of furnishing to each working chamber a sufficient air supply for all pressures to enable work to be done as nearly as possible in the dry.

(3) There shall be two complete compressor plants to supply air for the compressed air work. The power supplies to each unit shall be from independent sources.

(4) Duplicate air feed pipes shall be provided for the compressor plant to a point beyond the lock whenever work is being constructed under ponds, rivers and lakes or other bodies of water.

Ind 6.35 Sinking of caissons. No caisson shall be dropped by the method of removing the air pressure therein for a greater depth than 24 inches, and then only by the person in charge at the time.

Ind 6.36 Bracing. All caissons shall be properly and adequately braced before loading with concrete or other weight.

Ind 6.37 Sanitation and ventilation. (1) Absolutely no nuisance shall be tolerated in the air chambers; containers shall be provided when necessary.

(2) No smoking shall be permitted in the air chamber.

(3) The supply of fresh air to the working chamber shall be sufficient at all times to permit work to be done without danger or discomfort. All air supply lines shall be equipped with check valves and carried as near to the face as practicable when used for ventilation. The air shall be analyzed as required and a record kept of the same.

(4) Care shall be taken to keep all parts of tunnel, caissons, and other working compartments, including lockers, dry rooms, rest rooms and other equipment in a sanitary condition and free from refuse, decaying, or other objectionable matter.

(5) When temperatures in underground workings exceed 95 degrees Fahrenheit, effective means shall be employed to reduce such temperatures. This requirement does not apply to tunnels extending less than 50 feet from shafts.

Ind 6.38 Health requirement for compressed air operations. (1) **CHANGING CLOTHES.** Men working in compressed air shall be required to change clothes at the start and termination of shifts.

(2) **COFFEE AND UTENSILS.** A sufficient supply of hot coffee and sugar shall be supplied to men working in compressed air at the termination of shifts and during rest periods. Coffee shall be heated by means other than direct steam. Coffee containers and cups shall be kept in a clean and sanitary condition at all times. All containers shall be kept covered at all times.

(3) The following persons shall not be permitted to work under compressed air:

(a) Persons addicted to the excessive use of intoxicants or drugs.

(b) Persons suffering with general arteriosclerosis, high blood pressure, heart lesions (valvular or muscular), disturbances of blood circulation, chronic or acute respiratory diseases, or any disease of the kidneys. Every applicant for employment should submit a specimen of urine for analysis.

(c) Fat individuals, undernourished, or anemic persons.

Ind 6.39 Medical attendance and regulations. (1) Any person or corporation carrying on any work in the prosecution of which men are employed or permitted to work in compressed air, shall employ one or more qualified medical officers, who shall have had experience, or shall have familiarized himself with compressed air work, whose duty it shall be strictly to enforce the following:

(a) No person shall be permitted to work in compressed air before he shall have been examined by the physician in compressed air and reported to the person in charge thereof, to be physically fit to engage in such work.

(b) In the event of absence from work of any employe for 5 or more successive days due to illness, he shall not resume work until he has been re-examined by the physician and his physical condition reported to be such as to permit him to work in compressed air.

(d) After a person has been employed continuously in compressed air for a period of three months, he shall be re-examined by the physician and he shall not be permitted to work until such re-examination has been made and he has been reported as physically qualified to engage in compressed air work.

(e) The physician shall at all times keep a complete and full record of examinations made by him, which record shall contain dates on which examinations were made and a clear and full description of the person examined, also a statement as to the time such person has been engaged in like employment. A uniform examination blank, prescribed or furnished by the industrial commission, which shall contain a record of examination in every case of compressed air workers, shall be used by each medical examiner, and the record of such examinations shall be kept on file at the place where the work is in progress and shall be subject to inspection by the industrial commission.

(f) In cities and communities in which no hospital or health institution maintains a medical air lock, such a lock shall be established in connection with all work in compressed air when the maximum pressure exceeds 17 pounds. Such locks, if cylindrical, shall not be less than 5 feet in diameter, and if rectangular, shall not be less than 5 feet in width and 5 feet in height. The lock shall consist of two compartments, each compartment long enough to accommodate a cot with sufficient clearance to permit opening and closing of doors. Each door shall be provided with a bull's eye and fitted with air valve so arranged to be operated from within and without. Such lock shall be kept properly heated, lighted and ventilated, and shall contain a gauge, a telephone and cot. Such lock shall be under the control of the physician in charge and there shall be maintained in close proximity a first-aid room, which shall contain medical and surgical appliances necessary for first aid in case of accident.

(g) An identification badge shall be furnished to all employes advising police officials that the employe is a compressed air worker; stating location of medical lock, and stating that in case of emergency an ambulance surgeon shall remove the patient to the medical lock and not to the hospital.

(h) All cases of compressed air illness shall be reported to the industrial commission on a uniform blank furnished by the commission and copies of all such reports shall be kept on file at the plant where the work is in progress.

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