Mono Craters Tunneling a Struggle with Water and Ga

Major feature of the project to develop a supplemental water supply for the City of Los Angeles has been the driving of the 11-1/3-mi. bore through the crest of the Sierra Nevada

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DRIVING of the 11⅓-mi. Mono Craters tunnel represents the principal construction feature in the Mono Basin project being carried out by the Los Angeles Bureau of Water Works and Supply to bring supplemental water supply through the crest of the Sierra into the Owens River, so that the present aqueduct can be operated at its full capacity of 480 sec. ft. throughout the year. Tunneling operations were started in 1934, and during the four year construction period the work has developed the following features of unusual interest: shaft sinking and tunnel driving through heavy, glacial material with large flows of water; carbon dioxide gas flows averaging about 1,000 c.f.m. requiring extensive ventilating equipment; and the trucking of bulk cement in 1,500 lb. sacks. A general description of tunnel driving and lining operations is presented in this article.

Features of the Mono Basin project, the need for this supplemental supply, sources and method of diversion were reviewed briefly in *Western Construction News,* June, 1936. A collecting system of conduits in the basin will deliver into a storage and regulating reservoir to be formed by the Grant Lake dam. The discharge from this reservoir will flow through the Mono Craters tunnel and enter the water-shed of the Owens River for delivery into the existing aqueduct system of the City of Los Angeles.

The tunnel has a finished cross-section providing an area of 74 sq. ft., which is nearly equivalent to a circular section of 9 ft. 8½ in. in diameter. The gradient is 0.0005, which provides a capacity of 365 sec. ft., based on a coefficient of $n = 0.012$.

The tunnel excavation is more than 90% completed, only about 5,000 ft. remaining (see profile) to be driven on Oct. 31, 1938. At the rate of progress made in the two remaining headings for the past few months, the tunnel should be holed through in March of next year.

Points of access and headings

Construction work began in September, 1934, at the west portal (heading 1), and subsequent excavation has been carried on in a total of six headings. The accompanying profile drawing shows the points of access and the designation of the headings. Work at the east portal began in November, 1934, and headings 5 and 6 (see profile) were holed through July 7, 1936, after driving 9,927 ft. toward shaft 2.

The sinking of shaft 2 was begun Feb. 9, 1935, and tunnel grade was reached four months later, June 13, 1935. The depth is 299 ft. from collar to tunnel invert. Driving was begun in heading 4, August 28, and in heading 5, Sept. 7, 1935. A total of 2,808 ft. was driven in heading 5 before holing through to heading 6.

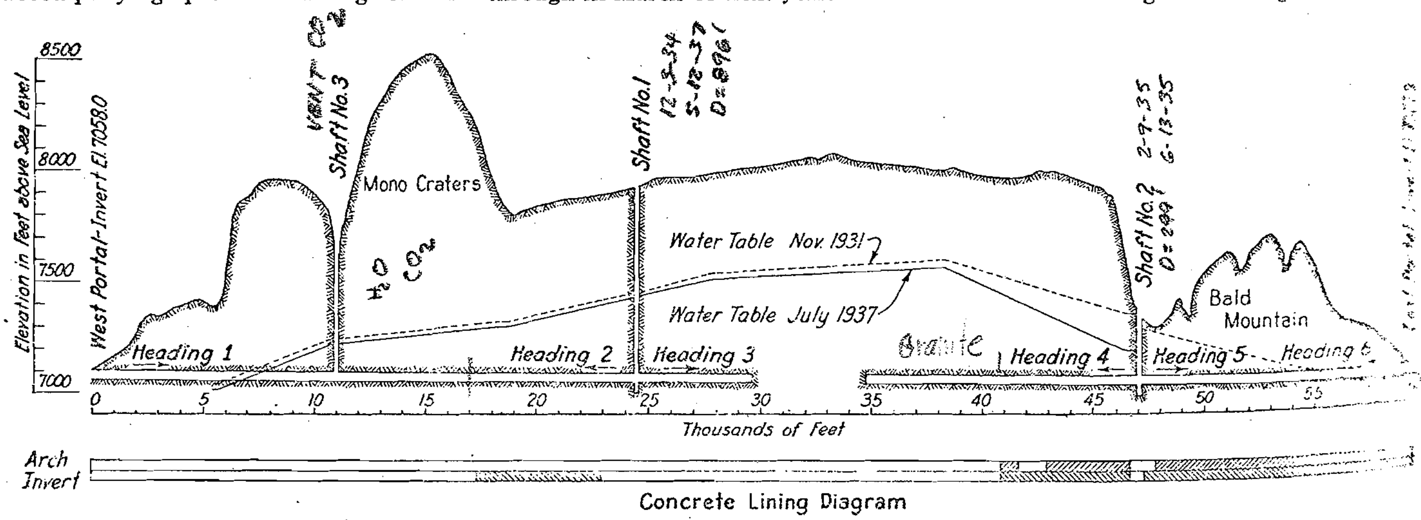
Shaft 1 sinking was begun Dec. 3, 1934, and tunnel grade was not reached until May 12, 1937. The depth is 896 ft. from collar to tunnel invert grade with a 48-ft. sump below tunnel grade. This shaft penetrates volcanic ash and rhyolite for 563 ft. and from 563 to 871 ft. the formation was unconsolidated glacial material. The water table was struck at a depth of 492 ft. As the shaft was sunk deeper into the glacial material the increasing head of water made it extremely difficult to hold the sand encountered in the bottom of the shaft against boiling up. Several runs of sand and gravel into the shaft occurred at various times. Each run would relieve the pressure for a time but there was a tendency for the gravels immediately surrounding the shaft to be gradually sealed up by the fines with a resulting diminished flow of water and increased pressure until another run-in would occur.

Shaft sinking problems

Drifts were driven out from the shaft at the 632, 709 and 739-ft. levels to intercept some of the water courses and relieve the pressure at the shaft. These drifts undoubtedly relieved the pressure somewhat but were not entirely satisfactory due to the tendency of the material to seal up with fines and obstruct free drainage.

The shaft was lined with reinforced concrete from the 530-ft. depth to the bottom. Both shaft 1 and shaft 2 have three compartments, the two skipways being 5 ft. x 5 ft. 2 in., and the manway and utility compartment 5 ft. x 6 ft. The over-all excavated dimensions are 7 x 20 ft. The concrete lining in shaft 1 was made octagonal through the glacial

PROFILE showing points of access and designation of the six headings used in driving the Mono Craters tunnel. Shaft 3 was sunk for the special purpose of permitting supplemental ventilation for the section between headings 1 and 2, which was subject to heavy inflows of carbon dioxide. Note the 5,000-ft. section remaining to be driven, which is scheduled to be holed through in March of next year.



...as Involved ...as Flows

VITAL UNIT of equipment in any tunnel project is the drill carriage. Mounted on 24-in. gauge trucks this carriage, shown in front and rear view, has a frame of four 4½-in. heavy pipes as the main horizontal members each carrying a drifter drill on the cantilevered forward end. The pipes are used to store wooden tamping sticks and blow pipes.

...terial in order to obtain the necessary ...ength. The lining was designed to ...stand a hydrostatic pressure of 50 lb. ... sq. in. Material at the bottom of the ...ft in which the station and muck ...ket were cut is a soft sandstone with ...clay-like gouge in the seams giving it ...pronounced tendency to squeeze. On ...count of the difficulty of holding this ...eezing ground the station and muck ...ket were made considerably smaller ...originally planned and as actually ...structed at shaft 2.

...t shaft 2 the station was cut 30 ft. ...opposite the shaft, the center line ...ich is 20 ft. off the tunnel center ... A surveyors drift 7 ft. wide was ... from the ends of the shaft parallel ...e tunnel, 45 ft. both directions, with ...ht angle cross cut over to the tun... A pump station and sump were ...ted out from the shaft opposite ... the tunnel, and an equipment re... drift 13 ft. wide and 50 ft. long at right angles from the tunnel on the opposite side of the tunnel from the shaft. The tunnel was widened to 16 ft. for a length of 200 ft. to provide room for the battery charging station and switching facilities.

At shaft 1 the repair drift and surveyors drift were eliminated and the width of the station reduced to 13.5 ft. The muck pocket capacity was made 30 cu. yd. The pump stations were also located a few hundred feet from the shaft.

Materials encountered

The material encountered in heading 1 for 17,300 ft. was volcanic rock, principally rhyolite, and then a sandstone or shale to the holing through point. The rhyolite offered no particular difficulties until well under the craters where the heavy water pressure and large quantities of carbon dioxide gas gave considerable trouble. Numerous fracture zones were encountered where the water and gas, both under pressure, would tend to carry in sand and small fragments. A considerable amount of the driving was done with the face fully breastboarded and the sides and arch spiled tightly. Heading 2 (west from shaft 1) was either in unconsolidated glacial material of the type that caused the difficulty in sinking shaft 1, or in soft sandstone and shale.

Heading 3 has been mostly sandstone and shale, some areas of which had a tendency to squeeze the same as the material at the station for shaft 1. This type of material gave no great difficulty in driving but had to be relieved frequently until it finally attained a degree of stability. Squeeze posts were used back of the steel sets in these areas and relieving was done by removing some of the material between the lagging. About a mile east from shaft 1, heading 3 has passed into a diorite with indications that it may soon enter granite.

Heading 4 has been driven through granite from a point 6,000 ft. west from shaft 2, and is still in granite at 12,500 ft. Most of the granite, however, is blocky and requires support. Driving west from shaft 2, the bottom of which is in hard basalt, the tunnel was in basalt and andesite for 3,650 ft. from which it entered unconsolidated glacial material which continued until the heading entered granite at 6,000 ft. A large portion of heading 6 west from East Portal was driven through lake bed material which gave considerable difficulty by "heaving." Several feet of this material gradually squeezed up from the floor and had to be removed from time to time. This area had become fairly well stabilized by the time the concrete lining was ready to be placed in the summer of 1937. The total tunnel excavated to Oct. 31, 1938, was 54,808 ft. Of this amount two-thirds is timbered. The last 18,000 ft. driven, however, is all timbered except 2½%.

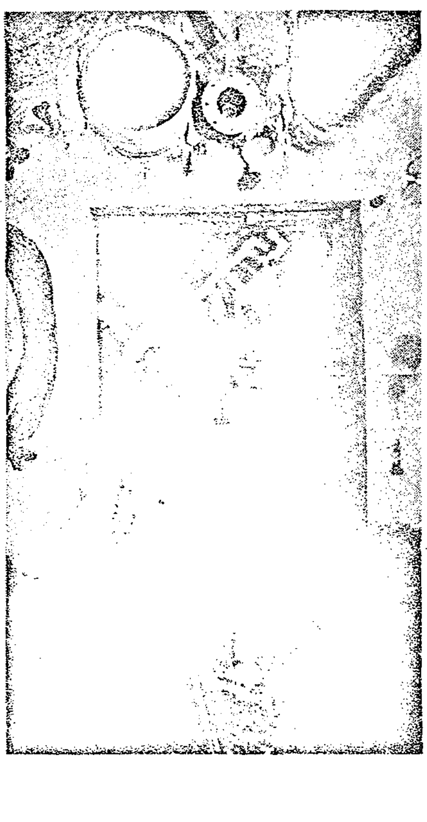
The maximum month's progress was 1219 ft. made in heading 1 in April, 1935. The maximum days progress was 90 ft. in 16 hr. on July 15, 1935, on which date one shift was lost on account of the tunnel being flooded by a cloudburst at West Portal.

Driving Operations

The drill carriages (see illustration) used in the tunnel were made in the Department shops. Standard equipment in sufficiently compact units was not available at the time of beginning tunnel construction. The frame of the carriage is made of 4½-in. extra heavy pipe mounted on 24-in. gauge trucks. Four of these pipes constitute the horizontal members and extend forward to serve as cantilever supports for the four drifter drill mountings. Each drill is mounted on a short length of pipe attached by clamps to one of the four longitudinal pipes of the frame. This mounting permits each drill to swing in two planes by merely loosening nuts on the clamps.

Centrally mounted in the frame is an air receiver of 15 in. dia. and 5 ft. long with six outlet connections, one each for the four drifter drills and two extras for jackhammers. The working platforms on either side which fold up against the carriage when not in use have plank floors 24 in. wide. The planks are less slippery than metal would be. The longitudinal pipes of the main frame form excellent storage space for the wooden tamping sticks and blowpipes. The front of the carriage is mounted on four-wheel trucks with a kingpin, while the rear, where there is less weight, is carried on a single pair of wheels. Ingersoll-Rand and Gardner-Denver automatic drifter drills with 3½-in. piston and 50-in. shell are used.

RISK of flooding shaft 1 from a possible flow of water in excess of the pumping capacity was avoided by the construction of two concrete bulkheads equipped with steel doors in headings 2 and 3. Bulkheads were designed for a head of 350 ft. of water and the doors consisted of 12-in. I-beams welded edge to edge.



The accompanying diagram shows the typical arrangement of drill holes. This diagram is based on a 38-hole round. The number of holes varies considerably, but usually runs between 24 and 40. The usual advance per round is 5 ft., although in sound rock 6 ft. and sometimes 7 ft. are pulled when possible.

The mucking machines used are Conway Type 50A. Hauling is done by Atlas battery locomotives using 48 cell Exide batteries of 340 ampere hour capacity at 110 volts. In addition, trolley locomotives are used as boosters for 9,600 ft. in from the west portal. Track gauge is 24 in. and 40 lb. rails are used.

The muck is hauled in nine car trains. Cars are of the side dump mine type of 70 cu. ft. capacity. Switches are installed every half mile, alternately 200 and 300 ft. in length. For switching behind the mucking machine a California switch is used, constructed with four rails making three 24-in. gauge tracks. Empty and loaded muck cars use the outer tracks, but the drill carriage and mucking machine can be taken to and from the face only on the center track due to clearance limitations.

The mucker operates on 440 volt 60 cycle current, with power taken into the tunnel at 2200 volts in marine and mono cables. Transformers are located every thousand feet.

Method of supports

With the exception of the immediate vicinity of the two portals where 8 x 8-in. timber tunnel sets were used, steel I-beam and H-beam sets have been used almost entirely. Five inch 12¼-lb. I-beam sets were employed at first, and later 6-in. 12½-lb. I-beams and finally 6-in. H-beam, both 20 and 30-lb., were adopted as standard. In very heavy ground where the 30-lb. sets are required, steel spreaders are used across the invert. These spreaders are of 6-in. 20-lb. H-beams, curved to a radius of 19 ft. 4 in. It has not been necessary to replace any tunnel sets where the spreaders were used. The supporting sets are normally placed on 5-ft. centers, although in many places they are much closer, sometimes a few inches apart.

The soft condition of a considerable portion of the material encountered necessitated the driving of spiling. The spiling driven was usually 4 x 6 in. or 6 x 6 in. timber driven ahead of the face set at least 7 ft. or more, depending on the tendency of the material to run. Spiling is ordinarily driven by the mucking machines serving as a sort of battering ram. An 8 x 8-in. timber with a collar and plate on each end is held against the end of the spiling being driven while the other end is rammed by the mucking machine. One of the battery locomotives with a special coupling for holding the ramming timber has been used ... satisfactorily for the same purpose ... heading 4.

In extremely heavy ground where ... spiling must be driven blind, 6 x ... 10.5-lb. steel channels have been ... successfully. The channels are driven with the legs alternately outward and inward and overlapped so that the ... of the last channel driven serves as a guide for the next, thus preventing ... channels drifting apart while driving.

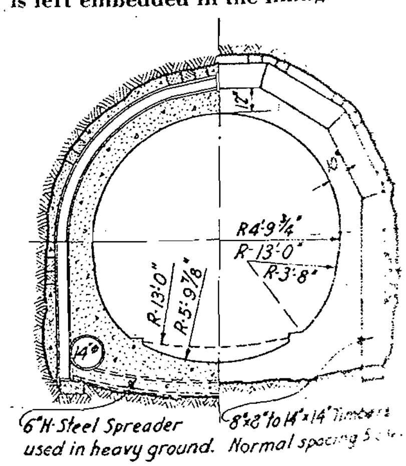
Control of gas

As the tunnel driving proceeded ... the craters, carbon dioxide gas was ... countered in increasing quantities ... 13,000 ft. from West Portal the quantity of gas became too great to be handled with the ventilation equipment then installed. Tunnel driving in heading ... then temporarily suspended (May ... 1936) while a ventilation shaft known as shaft 3 (see profile) was sunk at 11,... ft. from the portal. This shaft has a depth of 535 ft. and was sunk from the top and raised from the tunnel level simultaneously. The sinking of this shaft was accomplished in a period of 38 days from May 16, 1936, to June 23, 1936.

The total blower capacity which was installed at shaft 3 is a little over ... c.f.m. of air. The fans are electrically operated and so connected that any ... them can be operated either blowing into or sucking out of the shaft. In addition to the electric drive, the fans ... connected to auxiliary gasoline motors installed for emergency in case of interruption in the power supply. As emergency blowers the total capacity is approximately equal to that of the electrically driven equipment.

The quantity of gas released into the tunnel has averaged about 1,000 c.f.m. since the tunnel reached the approximate center of the craters. The quantity fluctuates from about 850 c.f.m. to 11... 1200 according to the barometer. ... flow depends more upon the rate of change of barometric pressure rather than on the magnitude of the pressure itself. This fact can probably be ex...

SECTION of tunnel indicating the typical supporting system. To facilitate the handling of water during concrete lining operations one of the pumping bases is left embedded in the lining.



plained ... crevices ... surge ch... stant ba... sure in t... pressure ... den drop ... duces a ...

By ... c.f.m. of ... maximum ... been hel... of the h... respirati... nel beco... dioxide ... over 2½ ...

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Since ... west po... ventilat... shaft 1 ... the rem... of whic... shaft 3 ... To regu... flowing ... under t... ft. apar... stalled ... have 20 ... proxim... drawn ... portal.

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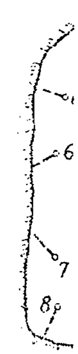
TYPIC... holes ... though ... betwee... eter of ... 5 ft. pe... in soun...



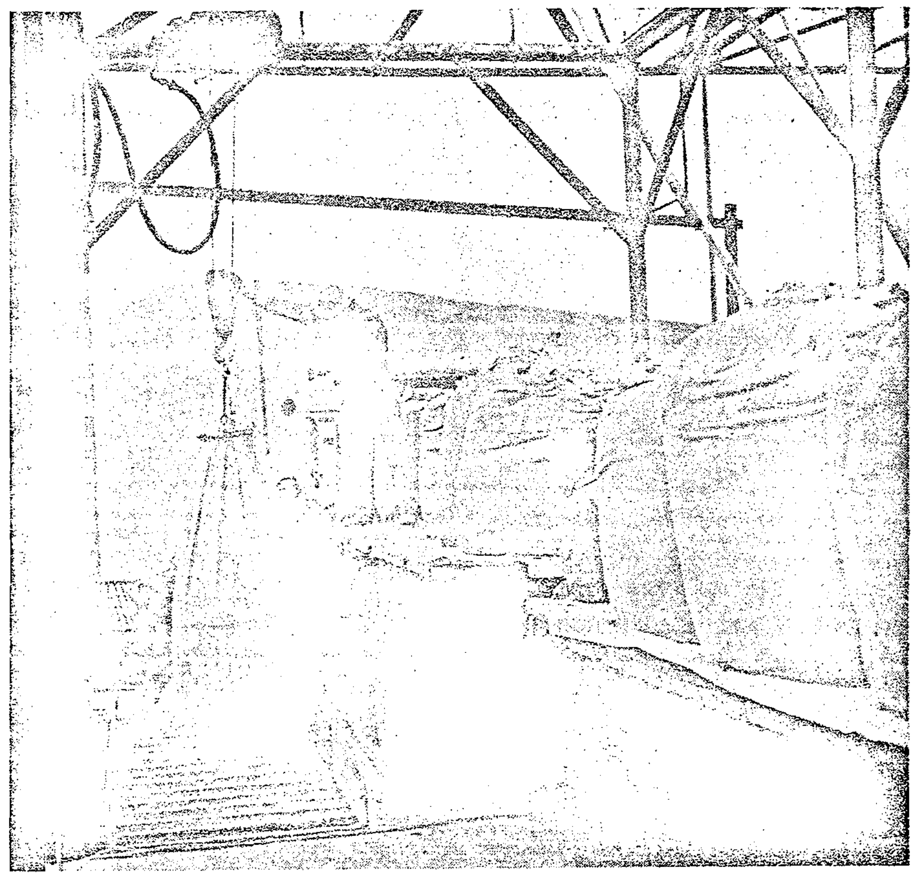
...ned by the assumption that the ...ces in the rhyolite act as a sort of ...e chamber for the gas. At any con... barometric pressure the gas pres... in the crevices and the atmospheric ...ssure reach an equilibrium and a sud... drop in the barometric pressure pro...es a surge of gas into the tunnel.

...y blowing approximately 24,000 ... of fresh air into the tunnel, the ...ximum carbon dioxide content has ...n held to not over 2% in the vicinity ...the heading work. The effect on the ...piration of those working in the tun... becomes noticeable when the carbon ...xide concentration becomes a little ...r 2½%.

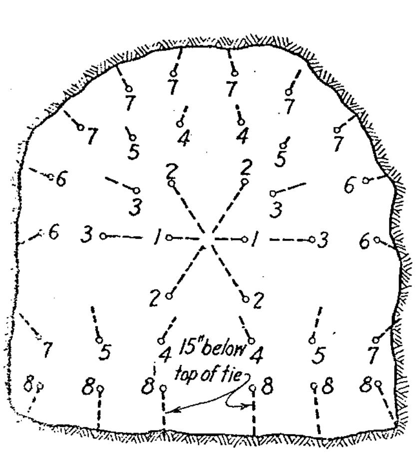
All those working in the tunnel are ...ructed to assemble at the man train ...mediately in case the power goes off ...d proceed toward the portal. This pre...ution is taken in addition to starting ...e emergency gasoline operated blow...s. A mine rescue squad is maintained ...ong the regular tunnel workers. ...ese men receive two hours training ...ch month. Those serving on the mine ...scue squad received additional com...ensation for being available for mine ...scue work at any time. In spite of an ...casional power interruption of short ...ration, there have been no injuries ...ffered due to the effect of the gas.

Since the holing through between the ...est portal and shaft 1, the system of ...entilation has been to suck the air down ...aft 1 and up shaft 3, thus permitting ...e removal of all the ventilating pipe ...f which there were three east from ...aft 3 during the driving of heading 1. ...o regulate the relative amount of air ...owing from shaft 1 and the west portal ...nder this system, two steel gates 160 ... apart forming an air lock were in...alled just west of shaft 3. These gates ...ave 20 in. dia. holes which permit ap...roximately 10% of the air which is ...awn up shaft 3 to come from the west ...ortal.

These gates are hydraulically operated ...d electrically controlled so that they ...an be opened and closed by the motor...en by pulling the electric switches in ...equence as the train passes through. They are so controlled that it is not possible to have both gates opened simultaneously. If both gates were open, most of the air would be drawn from the west portal due to lesser resistance to flow and since about 95% of the gas is made between shaft 3 and shaft 1, the concentration would become too high in that area. The relative flow of air from the portal and shaft 1 can be regulated if desired by changing the size of the orifices through the air locks.



SACKS of 1,500-lb. capacity were used in trucking bulk cement to the job. These sacks are bottomless, and before filling the bottom is tied with sash-cord. A steel ring in the top is used to lift the sack over the discharge hopper and the pulling of the tie cord releases the sack load. A truck and trailer load of 30 sacks can be unloaded in about 15 min.



TYPICAL drilling round consisted of 38 holes spaced and fired as indicated, although the number of holes varied from between 24 and 40 depending on the character of the ground. Average advance was 5 ft. per round, but 6 to 7 ft. were pulled in sound rock.

Problem of handling water

The dewatering of the tunnel has been a serious problem during most of the operations. Water was first encountered in heading 1 at about 6100 ft. and continually increased until over 9000 g.p.m. or 20 sec. ft., were being pumped from the heading at the time of holing through at a little over 22,000 ft. from the portal. The water was pumped out through three 14-in. lines, two of them running out at the portal and one up shaft 3.

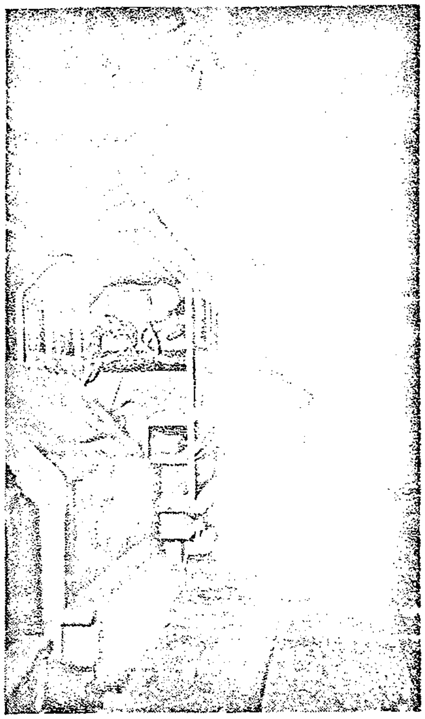
In addition to the pick-up pumps along the line wherever water is being made, there are booster pumps at 7,800 ft., shaft 3 which is at 11,000 ft., 13,500 ft. and 15,000 ft. The station at 15,000, which is practically under the center of the craters, is elevated sufficiently above the tunnel grade that it would be above the water in case the tunnel should become flooded. The pumps, consisting of two 4,500 g.p.m. units designed to operate against 210-ft. head, can be operated by remote control from shaft 3.

Pumps at shaft 3 are also located high enough above tunnel grade that they cannot be flooded. These pumps, consisting of two 6,000 g.p.m. units, are not connected to the dewater pipes on the suction side but pump directly from a sump into which any or all three of the 14-in. lines can be discharged.

The total flow from shaft 1 has been somewhat over 5,000 g.p.m. since midsummer of 1938 when the seasonal fluctuation reached its peak. There has been a seasonal fluctuation reaching its peak each summer just after the snow melts. The surface water affects the tunnel flow quite readily, especially in the vicinity of shaft 1. The total installed capacity of the pumps at shaft 1 is 12,500 g.p.m. consisting of five 2,500 g.p.m. units designed to operate against a head of 1,000 ft. The pumps at shaft 2 are two 2,500 g.p.m. and one 4,500 g.p.m., 380-ft. head units.

The dewatering pipes are 14-in. 12 gauge laid against the floor and side wall of the tunnel. Two pipes are laid in heading 1 as far as shaft 3 and three lines from shaft 3 eastward to the 15,000-ft. pump station. One pipe was carried all the way to the holing through point at 22,400 ft. One dewatering pipe has been sufficient for each of the other headings.

To facilitate the handling of the water during concrete lining operations, one of the lines is left in place and buried in the lining. The nearly circular form of the finished section provides 10 in. of concrete between the buried pipe and the surface of the concrete.



THREE 18-in. lines of ventilating pipe were required in the handling of carbon dioxide gas encountered in the section of tunnel under the Mono Craters. Flow of gas averaged about 1,000 c.f.m. A fully equipped mine rescue car is shown at the left.

To reduce the risk of shaft 1 being flooded in case a flow of water was encountered in excess of installed pumping capacity, concrete bulkheads with heavy steel doors were installed in headings 2 and 3. These bulkheads, constructed of reinforced concrete, were designed to withstand a pressure equivalent to a hydrostatic head of 350 ft. against the side away from the shaft. The steel doors were made of 12-in. 31.8-lb. I-beams with flanges welded edge to edge. The clear opening of the doorway is 5 ft. wide by 7 ft. high. The water pipes, conduits, and ventilation lines and a 20-in. pipe serving as an emergency manway pass through the bulkhead. The bulkhead of heading 3 was placed behind a welded sheet steel form which remained in place. The movement of equipment through the tunnel was not interrupted by the placing of the concrete.

Concrete lining

At the present time (Oct. 31) approximately 16,500 ft. of concrete lining has been completed. From shaft 2 to the east portal, it is all completed with the exception of 670 ft. adjacent to the shaft. In addition, 4,400 ft. have been completed west from shaft 2 in heading 4. Concreting the floor west from shaft 1 toward west portal was begun in September, and by the end of October had been completed a distance of 8,100 ft. It is now planned to pour the arch in this area and pressure grout behind the lining in order to seal off as much water and carbon dioxide as possible.

The first step in placing the concrete lining is to pour the floor, which is monolithic with a curb on either side, used later to support forms for placing the arch. The floor is given only a rough screeding since considerable material is later spilled on it during the placing of the arch. The final step will be the placing of a trowelled mortar finish on the floor.

Control of the tunnel water is a difficult problem in the placing of the concrete lining. A drain consisting of one or more 5-in. perforated sheet metal pipes is placed in a trench in the subgrade and backfilled with gravel. These drains lead to the pump sumps which are located partly outside the normal excavation line of the tunnel. Forms are placed on the tunnel side of the sumps so that they are kept open and in service after the floor is poured.

Where excessive quantities of water fall from the roof of the tunnel, sheet metal is placed between the tunnel sets to carry the water around the periphery of the tunnel to lateral drains connected with the longitudinal invert drains.

The concrete placing unit consists of a carriage on which is mounted a ramp, conveyor belt and a 1 cu. yd. mixer. The carriage is provided with its own locomotive power and is mounted on nine 24-in. gauge trucks. The aggregate cars are pulled up the ramp by a small electric hoist and each compartment dumps automatically onto the conveyor belt which feeds into the mixer. The switching of loaded and empty cars is done on a California switch in the same manner as the muck cars are handled during excavating.

In pouring the floor, alternate ties are first removed from under the track just ahead of the mixer carriage. Then, as soon as the carriage has passed completely off a pair of rails, they are lifted by chain blocks suspended from the tunnel sets, the ties removed and temporarily stored along the side of the tunnel just outside the curb. Steel forms are used for the inner surface of the curb. The forms are supported on 1-in. steel pins driven into the subgrade. The pins are pulled at the time of stripping the forms. A twist with a wrench loosens them so that they can be easily pulled.

Steel forms are used for placing the arch. These forms are assembled in 30-ft. sections and moved on a carriage mounted on two pairs of trucks. The forms are lifted into place or lowered by hydraulic jacks mounted on each end of the carriage, and when lowered and folded will easily pass through the sections which are set up in position. Concrete is placed through a 6-in. extra heavy discharge pipe from a 1-yd. Ransome gun mounted on trucks and coupled to the mixer carriage.

The floor is ordinarily poured one shift per day, the other two shifts being used for trimming and installing drains. The arch is placed continuously in three shifts of eight hours. The pour averages 400 to 450 cu. yd. per day which lines 200 to 300 lin. ft. of tunnel depending on the over-breakage. The tunnel lining averages about 2 cu. yd. of concrete per lineal ft.

Aggregate is produced by th[…]reau's own screening plant locate[…] Rush Creek 3½ mi. from the portal. [...] gravel is of granitic origin, is good [...] sound, having a specific gravity of [...] 2.65. Yield of concrete runs about [...] sacks per cubic yard for a 28 day stre[ngth] of 3,000 to 4,000 lb. per sq. in. by test [...] the mix is arbitrarily raised to 7 [...] where excessive quantities of water [are] encountered.

Batching plant

The portion of the lining comp[...] from the east portal to a point [...] 6,000 ft. west of shaft 2 was all [...] at the portal. The batching plant [...] now been moved to the west portal [in] order to concrete the section from [...] portal to shaft 1 while driving is co[ntin]ued in Headings 3 and 4.

The batching plant consists of a [...] and gravel tunnel from which the [ma]terial is carried by conveyor belt [...] 60 cu. yd. bin divided for sand and gr[avel] beneath which are the weighing [...] pers dumping directly into the aggre[ga]te cars. A bulk cement storage plant [has] been installed to store 2,500 bbl. Cem[ent] is weighed automatically by photo e[lec]tric cells mounted in such a manner [...] the screw conveyor feeding into [...] weighing hopper is stopped automatical[...]ly when the correct weight of mat[erial] is in the hopper. When the cement is dumped from the weighing hopper into the car the conveyor is automatica[lly] started so that the weighing hopper is always filled and ready to dump. Two men operate the batching plant.

Cement in 1500-lb. sacks

A new method of transporting bulk cement has been devised by the engi[...]neers of the Monolith Cement Co., wh[ich] has the contract for furnishing cement. The cement is hauled in canvas sacks holding 1,500 lb. These sacks are fitted at the top with a heavy steel ring about 10 in. in diameter and are left open at the bottom. Before filling, the bottom is tied with a piece of sash cord in such a manner that by pulling the loose end the knot will untie.

A crane has been installed over the hopper at the batching plant, and sacks are hoisted off the trucks by the crane. The mono-rail is sloped (see illustra[...]tion) so that the loaded crane rolls to a spot over an opening in the cover of the hopper. By pulling the cord the entire 1,500 lb. of bulk cement is dropped [...] the hopper from which it is carried [...] the two elevated cylindrical storage tanks by a series of screw conveyors a[nd] bucket elevators. A truck and trailer [...] of cement can be unloaded in approxi[...]mately 15 min. Thirty 1,500-lb. sacks [...] cement are hauled in one truck a[nd] trailer load, eighteen sacks on the tra[iler] and twelve on the truck.

Organization

The project is being done by force ac[...]count under the direction of H. A. V[...] Norman, chief engineer and gen[eral] manager, Los Angeles Department [of] Water. H. L. Jacques, engineer of ma[...] construction, is superintendent of [the] project, and the writer is in charge [of] engineering.