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HYDROELECTRIC DEVELOPMENT ON KLAMATH RIVER

BY J. C. BOYLE.

View of Gorge and Proposed Dam in Outline.

The hydroelectric development now under construction for the California-Oregon Power Company, is situated on the Klamath River thirteen miles east of the Southern Pacific Railroad station at Thrall, Cal. It is near the geographical center of a territory of 10,000 square miles in Southern Oregon and Northern California over which the company is now distributing 20,000 horsepower and in which it will eventually develop 150,000 horsepower. The nearness of the installation to the central distributing station of the company makes it a valuable economical power acquisition.

The engineering structures, dam, power house and forebay, with all the smaller structures are combined under the name of Klamath River Dam No. 1. They are located together practically as a unit at the head of a canyon which has been formed by the Klamath River, eroding five distinct lava flows. Although the country surrounding the construction site is principally lava, and the walls of the canyon themselves vary to 250 ft. in height in lava, the river in its erosion has exposed a reef across the canyon at the location of the dam, approximately 130 ft. high. This reef is of andesite, apparently continuous for considerable distance on both sides of the canyon and considered the oldest exposed formation in the country.

Geographical conditions upstream from the site indicate that at one time the river ran over this reef, 130 ft. above its present bed. During the time that the river was at this height the water was backed up approximately 5 miles and formed a natural lake which varied in width to a mile at the widest part.

It is now proposed to fill the gorge made by the river in eroding the reef, with a concrete dam, and cover the old original lake bottom with a new artificial lake. The new lake will have a surface area

Map of Territory Served by California-Oregon Power Company.

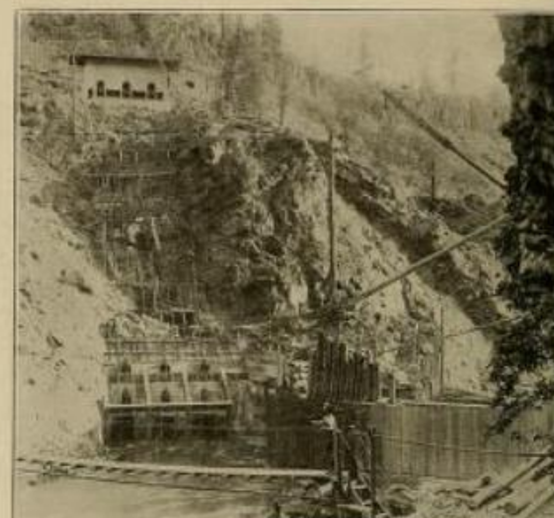
of 1000 acres and will have a catchment of 77,000 acre ft. This will be the third lake on the course of the Klamath River between its source and the construction site. Two large Klamath Lakes at present regulate the flow of the river at its source so that the high water mark at the construction site is never over 6 ft. above the low water mark, and the new lake with its regulation will control the floods of the river to a still greater degree. From gaugings taken for one and one-half years near the site, the maximum discharge of the river has been 4500 cu. ft. per second, and the minimum discharge has been 1450 cu. ft. per second. Taking the average for the same period as 2000 cu. ft. per second and allowing it to flow into the lake, it will take 20 days for the lake to fill. For utilizing a portion of this body of water allowance is being made for lowering the lake level 2 ft., thus supplying 2000 acre ft. of storage water to be used with the flow of the river for power during the low water season or to be used whenever a demand is made for it.

Construction Features.

Two of the most interesting construction features of this installation are, the diversion of the river from its channel while the foundations are being placed for the dam, and the procuring and delivering of material for the installation.

Diversion.

The width of the canyon at the base of the dam is 70 ft., all of which is taken up by the water of the river. For 150 ft. above the dam and for 350 ft. below the dam, the river channel has a grade of 2 ft. per hundred, producing a velocity in the water of about 20 ft. per second. The erosion produced by such a current would not permit winging the river from side to side, neither would blasting in the river bottom permit fluming the river, so a wing dam of



Side Hill Construction Already Accomplished.

rock-filled cribs, 30 ft. high was made 100 ft. upstream from the main dam.

This wing dam diverts the river from its original channel through an unlined tunnel around the east end of the dam. This tunnel is 356 ft. long with a cross section of 16 ft. by 18 ft. and a grade of 2 ft. per hundred.

On entering the tunnel the water passes through three sets of headgates, designed for 110 ft. pressure head and designed large enough to carry the average flow of the river under a head of 10 ft. Each set of gates consists of a clack valve covering the entrance to a 6 ft. depth by 30 ft. pipe, with a butterfly valve 6 ft. in diameter in the middle of the pipe and a 12 in. by-pass valve to the chamber between the large valves for equalizing the pressure behind the clack valve. Each valve is operated directly and independently by a specially designed operating wheel on an operating platform above the crest of the dam. The three pipes containing the three sets of valves are placed side by side horizontally in the direction of the tunnel and securely concreted together, thus forming a solid block to the entrance of the tunnel.

Delivery System.

In the delivering of materials, supplies and equipment to the site, a valuable acquisition has been made of a standard gauge branch railroad which extends up the Klamath River from Thrall. By building a spur track less than a mile in length to connect with this railroad, all the freight can be delivered directly from Thrall (13 miles) to the edge of the bluff overlooking the dam site. The construction camp, warehouses, machine shop, cement house, etc., are all located at the end of this railroad spur.

The top of the bluff overlooking the dam site is 100 ft. in elevation higher than the crest of the dam. The first 50 ft. of this elevation is taken up by a mixing plant, consisting of two sand machines, two rock breakers, and two mixers, all electrically operated. The output of this plant will be 720 cu. yds. of concrete per day of 9 hours.

Back from the edge of the bluff 400 ft. is a cinder cone of a consistent quality of black volcanic cinder, which, after analyses and extensive tests was found to be useful as a substitute for sand in the concrete. A gravity tramway to the edge of the bluff at the mixing plant, will handle the cinder directly to the two sand machines, which together will crush it to the required size and deposit it in a storage bin below.

The two rock breakers in the mixing plant will crush rock handled directly to them by the derrick from the quarry, and discharge the broken pieces into a storage bin beneath them.

All the cement used will be handled from the cars to the storage house or directly from the cars to the mixing plant and after passing a small storage bin will be measured into the charging hoppers of the mixers.

The ingredients thus passing into the mixers by gravity are mixed at the rate of 40 cu. ft. per batch into concrete. The concrete is discharged from the spouts of the mixers into open troughs in which it travels by gravity across the canyon or to any spot where it is to be placed. Remixers, boiling boxes and branch troughs can be placed where needed.

For delivering the rock to be laid with the concrete, a rock cableway with a traveling carrier has been provided. The rock will be quarried from a lava bluff down stream from the forebay but above it in elevation. That which goes into the dam as laid stone will be taken by gravity to the forebay level to be handled with the carrier to any place in the dam and the small rock quarried at the same time will be taken by the derrick directly from the quarry to the rock breakers above.

The economical value of such a gravity system can best be underestimated when the fact is considered that by means of it, all the concrete for the forebay, all the concrete for the power house and three-quarters of the concrete in the main dam can be placed, some 55,000 yds. in all, without elevating a yard of it.

The head gates, wing dam, mixing plant and smaller engineering structures have been completed, and in all probabilities concreting on the larger structures, dam, power house and forebay, will be started in the early summer of 1913. Upon completion of this installation the California-Oregon Power Company will have added to its power developments a hydroelectric plant capable of producing 53,000 horsepower. This along with the available storage for peak loads, within one and one-half miles of the central switching station at Fall Creek, will make it one of the controlling plants of the company's extensive distributing system.

The Dam.

The dam to be built will be of the arch-gravity type, 130 ft. in height above the bed of the river, 90 ft. thick at the base and 13 ft. thick at the top. The length of the crest will be 400 ft., curved on the arc of a circle of 356 ft. radius, curvature upstream. The center 200 ft. of the crest will be an overflow section capable of discharging the highest flood waters. At the upper toe there will be a cutoff wall 10 ft. thick extending below the foundation of the dam at least 10 ft., and at the lower toe there will be provided an apron which will discharge the overflow water in a horizontal position.

Owing to the position of the canyon walls at the dam site, it was found impossible to place the structure perpendicular to the river bed, the west abutment being further down stream than the east abutment. However, by making the dam curved with a 356 ft. radius the ends were found to strike the canyon walls nearly perpendicularly.

The total yardage of the dam will be about 35,000, of which between 40 and 50 per cent will be laid stone. To reinforce the dam on the bottom and on the upstream side, and to facilitate in handling forms, 30 lb. railroad rails will be imbedded in the concrete. These will be spaced 4 ft. centers, 4 ft. from the face of the concrete and laced together horizontally both across the dam and through the dam.

The Power House.

The power house will be of reinforced concrete with floor dimensions 70 ft. by 170 ft. and will eventually contain four complete hydroelectric units with exciters, switchboards and transformers.

Each unit will be made up of a 12,500 k.v.a., 10,000 kw. at 80 per cent power factor, 200 r.p.m., 2300 volts, generator, weighing 325,470 lb., connected with an 18,600 h.p. cylindrical type hydraulic turbine of 84 per cent efficiency, 20 per cent speed rise, 200 r.p.m., weighing 400,000 lb. and governed by an a.c. oil pressure type, fly ball governor of 75,000 ft. pounds capacity.

The penstocks for each unit will be a pipe 125 ft. long, 17 ft. in diameter, and on a hill slope of 37° 30' from the power house. The penstock will be made of sheet steel ½ in. thick at the upper end and ¾ in. thick where it enters the turbine. The water carried in it will have a velocity of about 5 ft. per second, depending on the load on the turbine.

The discharge from the turbine will be through a draught tube of special curved design located beneath the turbine and the generator floor. It will be made of concrete heavily reinforced on the top with I-beams. The area of the draught tube increases from 103.8 sq. ft. at the bottom of the turbine to 535 sq. ft. where the water leaves the power house.

The exciter units will consist of two trubine driven exciters and one motor generator exciter. The turbine driven exciters will be 200 kw., 720 r.p.m., 250 volts, and the turbine will be 300 h.p., 720 r.p.m., 83 per cent efficiency and connected with an oil pressure type, fly ball governor of 10,000 ft. pounds capacity. These units will be so connected that any one can be used on any four main generators.

For each unit in the power house there will be 3 single-phase transformers each of 4165 k.v.a., 2300 volts. The current from the generators will be run through a gallery switchboard to these transformers, thence out on a short line of one and one-half miles to the central switching and transforming station at Fall Creek.

The Forebay.

The forebay will be the supply reservoir for the penstocks for the power house. It is located at the west end of and adjoining the main dam and extends 200 ft. around the canyon to a position directly above the power house. Excavation has been made to a depth of 25 ft. below the ultimate crest of the dam, allowing 6000 cu. ft. per second to enter to the penstocks at a velocity of 5 ft. per second. An auxiliary spillway has been provided on the side of the forebay adjoining the dam, for relief when the water in the forebay rises above normal, and for taking care of any surge in the penstocks. A set of three gates will be provided for each penstock. These gates will be operated independently in sets so that any unit can be closed down without effecting the others. Racks and screens will be provided independent of the gates of sufficient size to allow the passage of the water and to take out all floating material.

The outer wall of the forebay, where the penstocks enter will be 10 ft. thick, 30 ft. high and anchored at the bottom. The inner wall will be a reservoir wall of 6 in. thickness with a batter of 1 in 10 and made continuous with the floor system. Both inner wall and floor system will be reinforced as a floor slab. Ample floor drains and side drains will be provided to take care of any seepage through the concrete.

The work is under the supervision of Mr. Sidney Sprout, superintending engineer of the California-Oregon Power Company, and Mr. A. C. Sprout, construction engineer of the California-Oregon Power Company, J. C. Boyle being engineer in charge.

TRAVELING AN ELECTRIC-HAULAGE ROAD.

In a discussion of accidents from mine cars and locomotives, the Bureau of Mines in its circular No. 11, thus describes dangers in traveling on an electric-haulage road:

The road you have to take in going to your working place is likely to be an electric-haulage road, because in the level mines of the United States, except in some gaseous mines, electric haulage is being used much more than any other mechanical means of hauling cars.

If you are carrying tools, such as a pick, a bar, or a drill, do not carry them over your shoulder. Many fatal accidents have happened because tools so carried struck the trolley wire. Even if the power is off the wire when you pass, get in the habit of not touching it.

TRANSFORMER CONNECTIONS.

BY W. A. HILLEBRAND AND E. R. SHEPARD.

(Concluded.)

Three transformers may be used with excellent results, on balanced or unbalanced loads, but only when the transformers used as the top of the T, a b of Fig. 15, are in multiple on the two-phase side. The

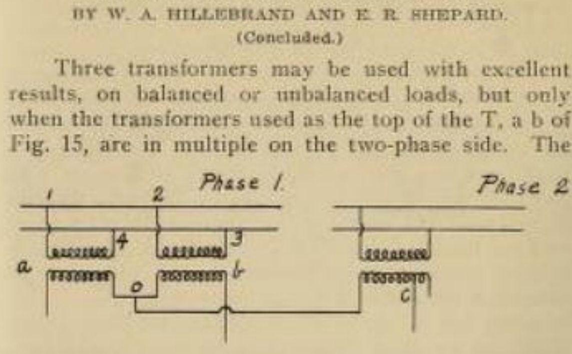


Fig. 15.

current in o c, which must divide at o and flow oppositely to a and b, induces in the circuit 1-2-3-4 a circulating current which prevents any choking effect.

An attempt to operate with coils 1-4 and 2-3 in series, as in Fig. 16, will lead to extreme unbalancing,

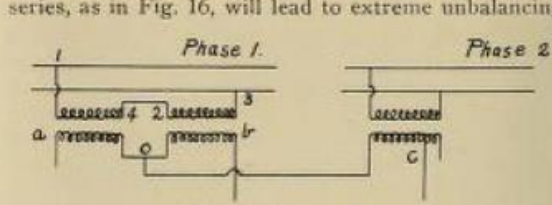


Fig. 16.

for currents cannot now flow in the circuit 1-4-2-3 to neutralize the choking effect of the currents flowing oppositely from o to a and to b.

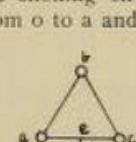


Fig 17

In Fig. 17 is shown a system for furnishing both two and three-phase service at a common voltage, using for the most part the same transformers and but four wires. The three-phase system is a, b, c; the two-phase ac and bd.

To obtain the two-phase system from the three-phase, all that is necessary is to add the voltage d e, equal to 13.4 per cent of the delta voltage a b, and of the phase position be. Practically this may be accomplished by any of the connections shown in Figs. 18 to 21 inclusive.

In the connection of Fig. 18, b d is an auto transformer or primary of a standard transformer, connected at e, an 86.6 per cent tap. Instead, a transformer may be employed having the ratios 2200:440:

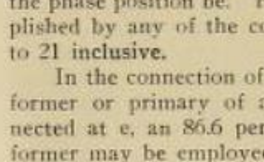


Fig. 18

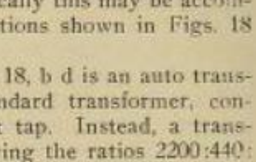


Fig. 19

220:110, in which case the full primary is used across b e and three-fourths of the secondary as e d. The rating of b d need only be 13.4 per cent of that of either of the others.

Fig. 19 requires for b e the full primary of an 11,000 volt transformer, and the secondary e d, three-fourths of a nominal 440 volt winding. The capacity of this transformer is also but 13.4 per cent of that of either of the others.

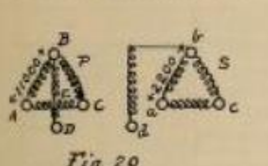


Fig. 20

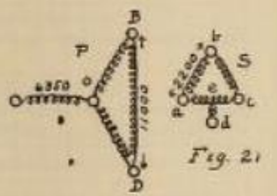


Fig. 21

B D of Fig. 20 is an 11,000:2200 volt transformer of the same capacity as each of the others.

In Fig. 21 B D has an odd ratio of 11,000:395 or 37.3:1, whence it is not to be considered as a practical case.

Technically, the behavior of all of these cases is similar so that only the connection of Fig. 18, repro-

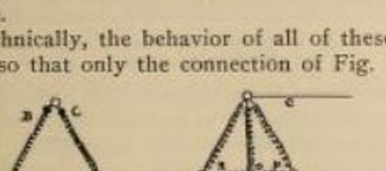


Fig 22

duced in Fig. 22, will be considered in analyzing the flow of currents in the transformers.

Single-phase current drawn by e g is supplied by transformers e d and e f and flows in opposite directions through n o and p o. With non-inductive load this current is 30 degrees out of phase with e d and

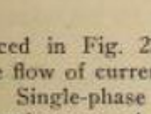


Fig 23

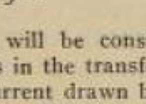


Fig 24

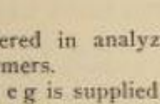


Fig 25

e f and 90 degrees out of phase with n o and p o. The vector diagrams are shown in Fig. 23 to 25 inclusive.

Single-phase current drawn by d f is principally furnished by transformer n o p but also in part by the parallel circuit d e f. On non-inductive load the current furnished by transformer n o p is in phase with voltage d f, whereas that furnished by circuit d e f is 60 degrees out of phase with e.m.f.'s d e and e f. The The vector diagram is given in Fig. 26 and 27.

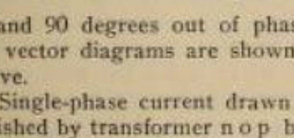


Fig. 26

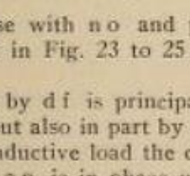


Fig 27

Any three-phase current supplied to a balanced load, flows equally in each of the delta connected transformers at the power factor of the load.

The two-phase load draws currents, some of which flow through the transformers at power factors other than that of the load. When these currents of various power factor combine with currents drawn by a three-phase load, the resultants in the different transformers or in the two secondary coils of transformer n o p will not be alike.

As an illustrative case, the vector diagrams for a balanced two-phase load of 12 amperes per terminal at unity power factor and a balanced three-phase load of 12 amperes per terminal at 86.6 per cent power fac-

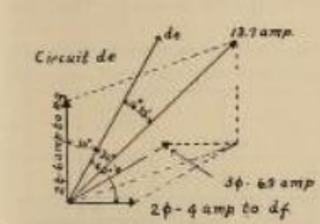


Fig. 28.

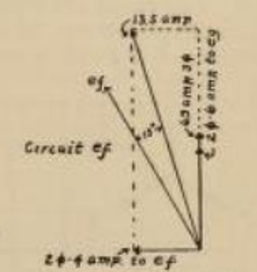


Fig. 29

tor lagging, are shown in Figs. 28 to 31 inclusive, for the four circuits d e, e f, n o, o p, of Fig. 22. The further assumption is made that of the 12 amperes two-phase load drawn by d f, 8 amperes flow through n o p and 4 amperes via d e f.

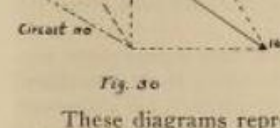


Fig. 30

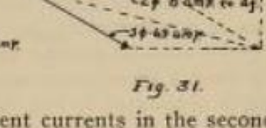


Fig. 31.

These diagrams represent currents in the secondaries, neglecting magnetizing and load current in current o e, the primary of the auto transformer. The primary current in transformer n o p is half the vector sum of currents in n o and o p, reducing to basis 1:1 transformation.

In an actual case the current distribution is altered by the fact that due to the different currents and power factors, the various sections will regulate differently, causing the ultimate distribution to depart from the simple law of Figs. 28 to 31, in a way that may be difficult to calculate. However, the following record of an actual test may serve to indicate what might be expected. Where two and three-phase loads were both applied, each was of the same value as when applied singly. The letter designations refer to Fig. 22 and primary currents are expressed in secondary terms.

Transformers e f, f d and e g are 7½ kw. 2200-220-110 volt, shell type, of the same make and period. Transformer e d is a 4 kw. core type transformer of same voltage rating but of an earlier period and different manufacture.

It would appear that with balanced two and three phase load, that transformer which is n o p of Fig. 22 carries somewhat the greater current. Any unbalancing of the two-phase load tends to overload this same transformer which carries the currents of both phases. When the power factors of the two and three-phase loads are equal, the total currents in each half of the secondary of n o p are equal.

If

I_3 = amperes per terminal 3-phase.

I_2 = amperes per terminal 2-phase.

an approximation to the maximum possible secondary current in either half of this transformer is

$$I = .57\,I_3 + .84\,I_2$$

Two-phase and three-phase service may also be furnished over four wires by means of the connection shown in Fig. 32, which requires however the use

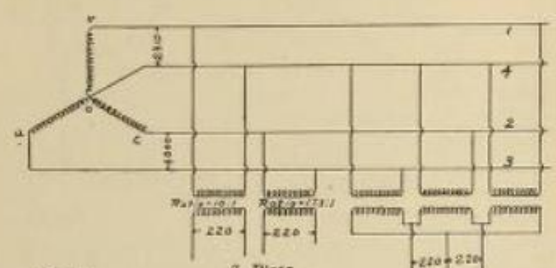


Fig 32

of a transformer with an odd ratio, 17.3:1, for each two-phase motor installation. Half of the two-phase power is furnished by transformer o b and half by the other two transformers, so that, in the proportion of the two-phase load to the total, o b should be 1.73 times as great as each of the other two. The excess volt-ampere capacity of a o and o c is due to the fact that the single phase current is furnished by o a and o c at a reduced power factor, 86.6 per cent when the load is non-inductive.

An unusual scheme for deriving a two-phase supply from a three-phase source, using three transformers, is illustrated in Fig. 33, in which o e is a separate

Fig 33

coil wound on the same core as d c. The two-phase voltages are b d and a c. Three-phase cannot be supplied. Referred to o b, voltages o e and e d may be derived as follows:

$$bd = ob + od = ac. \qquad (1.)$$

Calling $oe = ed = x$.

Then $ob + 2x \sin 30^\circ = 2\,(ob - x)\cos 30^\circ$.

$x = .267\ ob$.

From equation 1, $ob + .267\,(ob) = ac$.

$ac = 1.267\ ob$.

That is, the new two-phase voltage is 26.7 per cent greater than the three-phase neutral or 73 per cent of the original three-phase delta electromotive force.

The primaries of the system must be connected in delta. The three transformers are of the same volt ampere rating but this connection reduces the power output when fully loaded to 84.4 per cent of the aggregate capacity as single-phase apparatus.

No.	CURRENTS									VOLTAGES				LOAD
	A	B	C	d	e	f	g	n	p	de	ef	fg	eg	
1					15					light - 115 loaded - 114				Single phase non inductive on eg. Transformer ed open circuited
2					151					light - 119 loaded - 117				Same as No. 1. Transformer ef open circuited
3	3	116	6.0		153			115	73	[illegible]	[illegible]	205	180	Same as No. 1 All transformers in service
4	106	136	9.0	154	154	154	154	149	120	123	122	[illegible]	120	Balanced, non inductive 2 phase
5	38	124	100	155	150	145	0	90	91	121	120	120	119	3 phase induction motor
6	13	232	18	31	31	29	152	228	183	119	120	118	118	Combined loads of 4+5.
7	11	128	38	15	142	15	142	144	131	119	118	119	116	2-phase induction motor.
8	192	216	18	295	29	31	150	214	214	118	117	116	116	Two and three-phase motors of 5 and 7

Relationship of Currents, Voltages and Loads in Varying Circuits.

In conclusion, the authors wish it understood that they have not attempted to analyze all known or possible combinations for two and three-phase transformation, but only typical cases, with the purpose of presenting a general method for the determination of current distribution in interconnected transformers.

PULLING ELECTRIC CABLE IN PANAMA CANAL LOCKS.

Electric cables for the control, power, and lighting systems of the locks will be carried in vitrified clay duct, which has already been placed at Gatun and Pedro Miguel Locks and is being placed at Miraflores. For the control and power systems 246 miles of lead covered cable are to be pulled through these ducts, 40 per cent of the total amount that was placed by the largest power company in the United States during the twenty years preceding 1908. In addition there are 112 miles of wire of miscellaneous sizes from No. 12 up to 00 B. & S. gage for the lighting system.

This work in the locks was begun in October and will be finished in June. On account of the large amount of cable to be handled the expedient of laying it from an electrically driven winch has been resorted to. Before the operation is begun the ducts are carefully cleaned. Then a lead wire is pulled through, and by this means a manila cable is drawn through the duct. The electric cable is attached to the rope, and the winch is set in motion. By this method it is possible to pull 900 ft. lengths of No. 0000 B. & S. gage lead covered cable at one time, whereas the average length by other methods is about 300 ft. The outside diameter of this cable is a trifle more than 2 in. In such a length the cable passes through two intermediate manholes, and is greased at three points to aid in reducing friction. The advantage of pulling the long sections at one operation is that the making of two joints is saved, and this is a considerable economy. The winch used for the purpose is mounted upon trucks operated over the return tracks of the towing system. The cable is being placed directly below the floor of the operating tunnel, and therefore the pull by the winch is direct.