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CONSTRUCTION PLANT AND METHODS USED ON THE UHL RIVER HYDRO-ELECTRIC PROJECT.

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THE CONSTRUCTION PLANT OF THE UHL RIVER HYDRO-ELECTRIC PROJECT.

The production end of the Uhl River Hydro-Electric Project consists briefly of a couple of weirs diverting the water from the two main tributaries of the Uhl river, the Lamba Dag and the Uhl, located at an altitude of R. L. 6,100. The flow of the Lamba Dag is taken by a small flume and discharged into the Uhl river tributary above its weir and the combined discharge of both these tributaries screened through a couple of coarse and fine screens for elimination of logs and boulders, through a pair of intake gates into a double decantation chamber, each half containing two chambers in series, designed to remove gravel and coarse sand respectively ; the velocity in the second portion will be reduced to 1 foot a second. These decantation chambers during the flood season will operate with a continuous under-scour to ensure the continuous removal of the deposited matter. The outlet of the decantation chambers discharges into a high velocity flume, approximately 200 feet long, ending in the "Blue Pool" stilling pond, from which two 6 feet 3 inch diameter pressure ducts, 2,150 feet long, will convey the water across a nala bed to the upstream end of the upper main rapid. This drops the water by means of a rapid 190 feet long, through a grade of one in six through 31 feet head into the upper stilling pond, from which a gate in one side wall will enable 300 cusecs to be discharged at a later date, if required, into an upper emergency storage reservoir. The outlet of the upper stilling pond discharges into an open flume 200 feet long ; it then passes down another rapid 152 feet long, through a further drop of 37 feet into the main forebay, which also acts as a stilling pond. This forebay is provided with an overflow back into the river, a discharge gate and filling flume at one side for discharging up to 300 cusecs into the main diurnal reservoir, during the winter months when the water is clear, a 36″ diameter inlet for discharging up to 100 cusecs from the above mentioned emergency reservoir, and finally the main screened outlet into an 8 feet diameter pressure duct, connecting direct to the main tunnel, for use during the summer months when the water is too dirty to be safely stored in the diurnal reservoir, This 8 feet pressure duct runs under the floor of the diurnal reservoir straight into the tunnel, being controlled by an 8 feet butterfly valve at the entrance to the tunnel itself.

The diurnal storage reservoir 25 feet deep has a capacity of seven million c. ft. and is designed to store 150 cusecs for 12 hours a day, thereby enabling the minimum river discharge to be stored up at night, *i.e.*, during the hours of low demand, so as to provide peak discharges of double this quantity during the following day. This reservoir is provided with an overflow, a scour back into the river, and a screened offtake controlled by an 8 feet diameter butterfly valve leading direct into the above-mentioned pressure duct at its actual entrance into the tunnel.

It will thus be seen that there are two separate methods of supplying the tunnel as follows :—

(a) During the summer months when there is plenty of dirty water, direct from the forebay ;

(b) During the winter months when the water is clear but scarce, direct from the diurnal reservoir.

The above describes the arrangements for supplying the tunnel during the first stage, for which the normal winter supply of the river *i.e.*, 150 cusecs, is adequate. For the second and later stages of the project, an average flow of 300 and peak discharge of 600 cusecs will be required. To provide this extra quantity, storage during the winter months will be necessary. This storage will be obtained by the construction of a dam, approximately 270 feet high, located in a gorge half a mile downstream of the above mentioned diurnal reservoir. This will create a storage of 46,000 acre feet, which can be filled up during the months of August and September and will increase the winter supply from 150 to 300 continuous cusecs.

The conditions of the catchment area do not permit of this storage being maintained during the monsoon period, otherwise there is a risk of the reservoir being silted up in a few years. Arrangements have therefore to be made for bye-passing the dam and discharging the monsoon flow through the bye-pass during the summer months.

The intention is to provide a bye-pass which will only be capable of discharging the maximum floods under the maximum head. This means that during heavy floods, the reservoir will fill up and completely submerge the normal intake arrangements, and the alternative intake arrangements designed to supply the tunnel direct from the main reservoir would come into operation. During such periods however, the deposit of boulders and shingle at the upstream end of the temporary pond might entirely submerge the arrangements for drawing water from the river during the first stage and also during the summer months of the second. It is in order to avoid this that it has been deemed advisable to locate the intake arrangements above the junction of the two tributaries at R. L. 6,100 necessitating all the above described hydraulic works, connecting the decantation chambers with the forebay and diurnal reservoir. For controlling and shutting off the discharge through the tunnel after the construction of the dam, a valve chamber is being provided about 200 feet from the inlet, accessible (eventually after the dam is built) by a shaft from the surface, and containing an 8 feet diameter butterfly valve in the main tunnel itself designed to withstand the full head due to the height of the dam when closed.

In the second stage during the winter months the tunnel will be supplied from an entirely separate intake located just above the dam, for which a separate adit into the main tunnel will be provided, joining it just beyond the valve chamber. This separate adit is being utilised

at present in the first stage for construction purposes, and also (before the shaft is sunk) for access to the valve chamber.

The tunnel is approximately 14,200 feet long and will be 9 feet 3 inch internal diameter, lined with concrete throughout so as to provide reliable friction conditions and at the same time ensure its being watertight under the comparatively high hydrostatic head to which it will be subjected after completion of the dam in the second stage. The tunnel has two exits: one for scouring purposes only through the construction adit approximately 1,200 feet long, which has been driven in from the Wyer nala from R. L. 5,760 so as to reduce the total amount of main drive through the mountain range to 11,100 feet; the second and main exit into the surge shaft, where the tunnel proper ends. It then bifurcates into two 6 feet diameter steel pipes, each concreted up solid in one of two separate pipe tunnels, each 1,200 feet long, emerging at the surface at R. L. 5,635.

The surge shaft is 375 feet in depth from the ground surface to the centre line of the tunnel, is 12 feet and 16 feet in finished diameter in the upper and bottom portions respectively, the bottom portion forming the main chamber whence the two pipe tunnels emerge. This surge shaft will be of the Johnson differential type for the bottom 60 feet length, for which a reinforced concrete riser 60 feet high and 6 feet in diameter will be provided. Above the 60 feet level it will be of the simple type, 12 feet in diameter, with a modified contraction, formed by the riser and ports of the Johnson.

At the tunnel exit, the two main pipes each bifurcate again into two steel pipes of 4 feet 7 inch internal diameter. On each of these will be located an automatic self-closing stream line valve, backed by a butterfly isolating valve of the same dimensions.

During the first stage, two out of the four pipes are being installed and will be located on concrete supports, on the main Shanan spur, between the tunnel exit and the power station. All angles, both vertical and horizontal, will be embedded in massive concrete anchors which are being designed to take the resultant stress, with foundation pressures which are based upon the application of Rankin's formula, applied to hill slopes and a 30 degree angle of repose; this is rendered necessary owing to the nature of the soil of which this spur consists.

The four pipes in their lower halves will be gradually reduced in diameter from 4 feet 7 ins. at the top end to 3 feet 7 ins, just above the power station. The comparatively large diameter of the pipes at the bottom end necessitates their reinforcement by solid-drawn steel bands throughout the bottom half. Each of these pipes is designed to carry 200 cusecs at velocities varying from 12·2 feet per sec. at the top to 19·9 feet per sec. at the bottom. Immediately behind the power station, each pipe bifurcates into two of 2 feet 7 ins. diameter, each designed to carry 100 cusecs. There will thus eventually be 8 pipes entering the power

station, each carrying 100 cusecs. Each pipe will supply one single-jet pelton wheel turbine running at 428 r. p. m. and driving an alternator of 12,000 kw capacity at 11,000 volts.

The power station consists of two parts, the power house proper and the transformer station :—

The power house consists of three buildings :—

(a) The turbine room containing the 8 generators described above, with an annexe for auxiliary equipment.

(b) a control building containing the control room and auxiliary equipment connected therewith.

(c) a switch annexe containing the 11,000 volt switchgear controlling the output of the generators.

On a large flat space constructed on the higher ground immediately above the power station, will be located the transformer station, where the output of the generators will be stepped up to a pressure of 132 kv by transformers, and thence transmitted by transmission lines to Lahore and Kalka.

In the first stage of the project, four generating sets only will be installed with two transformers and the accompanying switchgear.

A general idea of the works area is given in drawings numbers one and seven.

For the building of these works a construction project had to be prepared, consisting briefly of the following :—

(1) Housing for both temporary and permanent staff for the construction and eventual operating establishment.

(2) Bridle paths, roads, railways and haulages, connecting up the various levels of work on both sides of the range.

(3) Provision of about 1,200 kw of power and a complete system for the distribution of power; and an automatic telephone system for about 24 subscribers.

(4) The provision of the usual construction plant consisting of mechanical excavators, winches, locomotives, rolling stock, cranes, concrete mixers and ordinary tools and plant.

(5) The special equipment required for the driving of the tunnel.

These will now be described in detail.

Little time need be spent on the ordinary housing and construction plant, and the bulk of the paper will be devoted to a description of (a) the communications between one portion of the works and the other by means of haulages : (b) the arrangements for the provision of power and its distribution ; and finally (c), the special equipment installed

for the driving of the tunnel, which forms the major work now under construction.

All housing was arranged as far as possible to be earthquake-proof and suited to the type of climate involved. During the early stages, for permanent buildings steel frames with hollow brick walls were adopted. This has been replaced later by expanded metal rough-casted outside and plastered inside, with an air space between.

Temporary buildings (roofed with 24 gauge C. G. I.) were constructed on poles fixed in the ground upon which all roof trusses and wall plates were supported. These were calculated to last about three or four years but it is anticipated that some difficulty may be experienced, due to the rotting of the poles in the ground, before the scheme is completed. White ants are not a serious menace in the district but they *do* exist and cause a certain amount of damage below R. L. 6,000. Housing has had to be provided for every man and cooly employed on the works, always including a piped water supply and complete sanitary arrangements. At the upper levels and in the Brot valley, snow is experienced for about three months in a year and on some occasions the quarters have been buried and the occupants have had to be dug out.

The chief features of interest in the construction plant are, an electrically driven one-yard excavator of the Marion type built by Ransomes and Rapier to the former's designs, electric winches, crushing plant and concrete mixers.

The Marion excavator is of that firm's standard design in which the characteristics associated with steam operation are obtained by means of direct current series motors, obtaining their supply from a motor generator located on the machine and driven by a 3 phase induction motor and fitted with a generator of special design giving a " drooping voltage " or constant current characteristic. The motors can actually be " stalled " and maintain their torque while stationary for a few moments without damage. The operation of the machine is simple and it has given good service under most trying conditions. The only serious replacements that have had to be made are associated with the breakage of the pads when traversing jagged pieces of broken rock, and the replacement of the compressor which had evidently been designed for use at sea level and whose capacity at 4,000 to 6,000 altitude necessitated it running almost continuously, so that it wore out after a few months' use. The conditions under which the machine has been working are no fair test of its ability. With inadequate rolling stock or arrangements for the disposal of spoil (which has always been the governing factor), the maximum output ever obtained in one day has been 3,500 cubic feet, working in two shifts of eight hours each. The material handled is broken-up rock and boulders of all sizes, bedded in a sandy loam alluvium. Boulders up to seven tons in weight are handled by rope slings, slung to the teeth of the bucket. The lowest cost in any one month (exclusive of interest and depreciation on the machine) was Rs. $34\frac{2}{3}$ per thousand cubic feet.

The electrical winches used are of the British Steel Piling Company's standard make and have the following characteristics :—

Size.	Speed of rope.	Size of rope.	Length of rope on drum.	H. P.
ton.	ft.-min.	diam.		
$1\frac{1}{2}$ ..	150	5/8"	750'	20
2 ..	50	5/8"	2,500'	10
4 ..	50*	7/8"	3,600'	25

*Converted latter to 100 and 50 HP. The 4 ton machines were not standard and were installed later on the Brot haulage : they are equipped with solenoid brakes.
The two ton winches have been converted to 150 feet per minute and 25 HP by using the motors removed from the 4 ton winches as explained above.

One of the two ton winches has been used for the sinking of the surge shaft; experience has proved the advisability of having machines used for sinking equipped with solenoid brakes; on more than one occasion the operator failed to stop a runaway, lost his head, and once threw in the pawl which wrecked the machine; fortunately no lives were lost

Two complete rock crushing and sand roll equipments have been installed, one at Brot and the other at the southern adit entrance. These are both Baxter standard machines, containing jaw crusher, conveyor, elevator belt, a large revolving screen, and two sand rolls. Both sand and aggregate of any required grading can be produced. These machines have so far given satisfaction, except for dust trouble for which no adequate solution has yet been found.

A standard specification for concrete for the whole project has been prepared based upon the standards of the American Society for Testing Materials, but with the chapter on proportioning entirely re-written so as to provide for the application of water-cement-ratio methods in the field. This problem has been satisfactorily solved by the use of certain items of equipment, especially designed for the purpose, consisting briefly of the following :—

Balance scales for weighing out cement with standard conical concrete counter-weights to which lead discs, (marked with the type of concrete) are added as well as smaller lead discs to compensate for each per cent of extra water in the fine aggregate; the amount of this is ascertained daily by means of a hydrometer and checked at intervals in the laboratory. For further particulars see Chapter V of the 3rd edition

of Hydro Electric Branch Specification No. 17. This method of proportioning and mixing has been specially designed for Indian conditions, is fool-proof and has proved satisfactory and is now standard throughout the works. All mixing is done in either quarter- or half-yard electrical mixers, in connection with each of which is a tank of fixed capacity, the contents of which cannot vary and upon which the proportioning of the whole batch depends, extra cement and aggregate being added as required (using the lead discs referred to above) to balance the extra water in the fine aggregate.

A chart is attached showing the fluctuations and steady improvement in test results of the standard mix used for ordinary reinforced concrete work.

For working the Hill Top Tramway, the Headworks Tramway and the various construction lines associated with the construction of the diurnal reservoir, seven ton super-Sentinel Steam Locomotives are used, burning wood of which large quantities are available from clearings for railways, roads and transmission lines. Light 4-wheel trucks of sturdy design have been found more convenient than bogies, they can be pushed about by hand and easily replaced after derailment. For the tunnel tramways, 10 ton mining type electric locomotives have been used, built to the specification of the Department by the English Electric Company. These can be driven either direct from a 200 volt overhead trolley, or by an Edison battery. These machines are of high grade make and are giving excellent service.

The above equipment is backed by a small permanent workshop containing the following equipment :—

1. Portable Electric Arc Welding Plant.
2. Band Saw.
3. Saw Gulleting machine.
4. Universal Joiner.
5. Wood turning lathe.
6. 13-inch Redman lathe.
7. 8-inch Turner Hoare lathe.
8. Milling machine.
9. Radial drilling machine.
10. High speed drilling machine.
11. Emery Grinder.
12. Grind Stone.
13. Power Hacksaw.
14. Screwing machine.
15. "Oster" light hand screwing machine 0-2.
16. "Oster" light hand screwing machine 2-6.
17. Shafting, hangers, and bearings.
18. Pulleys, counter-shafting, and main belting.
19. Marking-out table.
20. 40 H.P. motor.

21. Hammers, Wrenches, Forces, Tilting furnace, Moulders' tools, Vices, and other workshop equipment.
22. Sheet rolling machine.
23. Angle bending machine.
24. Rhodes slitting machine, slits up to $\frac{1}{4}$" M. S. Plates.

Of the above, the power hacksaw, drilling machines and lathes are naturally those most constantly employed. The electric welder, slitting machines, plate rollers, and angle bending machines have all proved particularly useful. This workshop is permanent equipment, located on the Shanan siding, level with the power station floor; associated with it is a large permanent store for the housing of spare parts and general stores.

Turning now to road and railway communications: the first thing to be done was the construction of a bridle path from Shanan up to the level of the tunnel adit: thence to Winch Camp at 8,000 feet and from there along the Hill Top Tramway to B's Neck and thence down to Brot. This formed the only means of communication on the works during the first two years of construction, prior to the completion of the haulageways.

The railway system is briefly as follows:—

A level 2'-6" gauge siding 1,300 feet long, from the terminus of the Kangra Valley Railway, past the permanent workshop and stores to the site of the power house, terminating at the bottom of the pipeline haulageway at R. L. 4,141. Thence the metre gauge pipeline haulageway hauls loads up to 15 tons past the tunnel exit at R. L. 5,635 up to a junction point at R. L. 5,810 immediately above it. This haulageway parallels the pipe line through most of its length and will be used for installing the main penstocks.

From the above mentioned junction at R. L. 5,810 the 2' 6" adit Tramway runs at a grade of 2·4 per cent. down to the "detonator spur" located in the Wyer Nala on which has been constructed the compressor station serving all the southern tunnel headings. From the detonator spur, the line runs up at a 2·8 per cent. grade to the adit entrance, a total length of 9/10th of a mile. This Tramway traverses some very bad ground and necessitated the removal of a large proportion of the hill in one section in order to secure the safety of the formation; many of the sidecuts are 140 feet in height and still give trouble during the monsoon.

Returning to the top of the pipeline haulageway at R. L. 5,810, a second metre gauge haulageway of five ton capacity continues up the spur to Winch Camp at about R. L. 8,000, which is the southern terminus of the Hill Top Tramway and contains the winch house, loco shed, storage space, transfer crane and a couple of subordinates quarters.

From this terminus at Winch Camp the 2'-6" Hill Top Tramway has been constructed for $1\frac{1}{2}$ miles at a compensated five per cent. grade across the south-west face of the hill to B's Neck where it crosses the hill

at R. L. 8,330, and thence continues level for a further 3/8 of a mile to the top of the Brot haulageway at R. L. 8,330.

At this terminus of the Hill Top Tramway is located the Brot Haulageway winch house, transformer station, crane and operators' quarters. The average slope of the hill side at this point is one in two and the Brot haulageway conveys five ton loads from this point down to the upper terminus of the headworks tramway at R. L. 6,130 on the bank of the Uhl river tributary, where a loco shed and transfer crane is located.

From this, the upper terminus of the headworks tramway (known as zero point), the headworks tramway runs for 1 3/8 miles at an average grade of five per cent. past the junction of the Lamba Dag tributary, the decantation chambers, crosses over the top of the two pressure ducts, past the west side of the upper emergency reservoir, where a permanent cement store has been located, and thence follows the bank of the main Uhl river to the upper end of the diurnal reservoir where the main Divisional store is located. At this point the line bifurcates into two branches, one running along the outside boundary of the diurnal reservoir to the stone dump and the site of the dam, and the other continuing at a down grade past the crusher plant and compressor station into the north tunnel heading, with a number of construction sidings now employed for the excavation of the main diurnal reservoir.

The most interesting feature of these communications is the three haulageways.

The Winch Camp and Pipeline haulageways are both the same type, except that the latter is designed to haul up to 15 ton loads (pipes) as against the normal five ton loads of the Winch Camp and Brot haulages.

The system of haulage adopted is that in which a rope slightly longer than the total length of the track, with a car at either end, makes three (or four) turns over a pair of sheaves, driven through gearing by means of an electric motor, and provided with the following brakes and safety devices :—

A post brake on the motor shaft operated by a weight which is tripped automatically by—

(*a*) a foot lever on the control platform ;
(*b*) a mechanical limit trip on the track ;
(*c*) a 15 per cent. over speed governor on the motor, and
(*d*) by an electric solenoid when the current fails or by the tripping of the main circuit breaker, which in turn is automatically tripped by—
  (*i*) a drop in voltage ;
  (*ii*) an excessive overload, or
  (*iii*) the movement of the operator off a spring-supported standing plate, which takes the place of the usual dead-man-handle ;
  (*iv*) by the car striking the limit switch on the track which acts as a back-up to item (*b*) above.

There is also a hand wheel which enables the gear to be locked at any time ; and finally electric regenerative braking : this is normal standard operation whenever the down load exceeds the upload, which usually takes place with balanced loads whenever the cars have passed the half-way point, (due to the unbalanced weight of the rope).

It was originally hoped to provide each car with the usual safety device to grip the head of the rail in the event of a failure of the rope. This equipment not only greatly increased the cost of the cars themselves (partly owing to the cost of the equipment and partly owing to the fact that they had to be made much heavier and sturdier to withstand the strain) but necessitated the use of a special type of patented rail head which nearly doubled the cost of the track. The cars are all however provided with a screw-on rail-head grip which is capable of holding a loaded car to the track on the steepest trade in order to prevent it shifting position due to the elasticity of the rope when being loaded or unloading at any intermediate point. This device is an essential when unloading Penstock Pipes for erection.

Particulars of the ropes actually supplied will be found in Appendix 8.

These ropes run on soft cast iron rollers and are prevented from rising more than 12 feet above the track by overhead guide frames to which similar hinged rollers are fitted.

The cars are of an ordinary four-wheel type with long wheel base. The wheels on each car on one side are double flanged and those on the other side flangeless, the flanged wheels on the two cars being on opposite sides. This enables the cars to be operated on a single track except at the passing place, where they automatically pass on to their correct tracks without points and without the necessity of attendance.

The tracks are the ordinary standard metre-gauge using 41¼ lb. rails and deodar wooden sleepers. The track is anchored to a carefully designed concrete anchor located at every 90 feet. These anchors are designed to take not only the thrust of the rollers and track under varying temperature conditions, but also that of a fully loaded car clamped to the track at any point. The anchors are located at the upper end of every 90 feet length of the rail : the three lengths of rail approximately 30 feet long being secured by fish-plates capable of taking the same tensile stress as the rails.

Owing to the distance apart of the anchors care had to be taken tc ensure the adjustment of the rail gaps to the correct amount depending upon the temperature of the day, for which the necessary information was supplied to the Overseer in charge, in the form of a temperature table.

Considerable attention has been paid to the drainage of the tracks so as to ensure the removal of all rain water from the track at intervals not exceeding about 100 yards. The drains which are fully pitched with stone on both sides and bottom, are carried away well over the water-shed on either side so as to ensure against any possibility of the water returning to the track at a lower level. The drainage arrangements have

so far been very successful ; no serious slips have occurred on any of the haulages and very little damage has been done during the last three monsoons.

The steep slopes upon which the track has been built preclude the possibility of using ordinary broken metal ; the stones tend to mount onto the sleepers and damage the rope. The track therefore has been pitched with hammer dressed stone throughout its length, the pitching being built up level with the top of the sleepers for the full width of the sleepers, outside which are located the two stone pitched drains already referred to. This system of packing and pitching has proved quite satisfactory from the point of view of erosion from rainfall, but is troublesome in connection with the maintenance of track levels. The track tends to settle after a few weeks' use and the pitching has to be removed before the track can be packed again. As the life of the deodar sleepers is also limited, it is open to discussion whether the more permanent method of construction standard in Switzerland would not have proved cheaper in the long run. This consists of a solid masonry wall under each rail connected by light steel ties at intervals. Their maintenance is practically nil and there are no sleeper renewals. Our system of construction, though cheaper in first cost, doubles maintenance, upkeep and renewals.

In designing haulages of this type several important points have to be provided for—

(*i*) First of all, all changes of direction have obviously to be made at convexities, otherwise it is impossible to keep the rope on the rollers. This has to be carefully borne in mind in the original location, and necessitated an examination of every spur for several miles around before suitable spurs could be found for constructing these haulages. This especially applied to the haulageway down to Brot on the northern side of the range, in fact the one finally selected was the only spur really suitable for the location of a haulageway and was only finally settled upon after three years' investigations.

(*ii*) The grade of the haulage in each section has to be so adjusted as to ensure that the ratio of the tension in the two ropes as they enter and leave the three or four-grooved sheaves, after providing for the loads on the cars, the cars themselves, the weight of the rope and the friction of the ropes on the rollers, does not exceed 3·7 for three wraps, and 6·6 for four. This allows a factor of safety of 1·5 as the rope is likely to slip on the sheaves if the ratio exceeds five with three sheaves or ten with four. This necessitates many adjustments of the profile (often completely upsetting any attempt at balancing cuttings and embankments) before the final profile can be decided. To enable this to be done, a diagram and calculation table has to be prepared, on which the load on the two ropes entering and leaving the drum are calculated for every position of

both cars. A sample of this diagram is given in Appendix I. This difficulty can under certain circumstances be got over by the employment of a ballast car, which is picked up by the upgoing car when nearing the upper end of the incline thereby balancing the additional weight of the rope of the lower car. This arrangement has been adopted with success on the Winch Camp haulageway, which otherwise would not have been operable.

(*iii*) A third condition, which must not be overlooked, is the necessity for maintaining the grade at not less than about 11 per cent., depending upon the position of the grade in question on the incline, and the relative stresses in the two ropes under the worst conditions. If this grade is not maintained, a lightly loaded down-going car may not be able to maintain its movement against the friction of its own rope.

(*iv*) Another point of importance is the possibility of a heavily stressed rope lifting up a lightly loaded car off its track and derailing it, when the latter is located at the lower end of a concavity on a comparatively flat grade near the top of the incline, the rope in question being heavily stressed at the time owing to its being attached to a heavily loaded car located on a steep grade near the bottom of the incline.

This danger arises because, in such conditions, the heavily stressed rope attached to the lower car has to pass under and be weighted down by, the upper lightly loaded car. This introduces further complications in the adjustment of the profile which in some conditions makes it impossible to operate certain profiles.

In the construction of the Pipeline haulageway, which has a comparatively straight track at an even grade, these restrictions did not affect the profile appreciably : except that they necessitated the provision "artificially" of two convexities, at the top and bottom of the crossing place, in order to provide for the horizontal change of direction of the rope at the turnouts associated with the crossing place. The insertion of these artificial convexities also affected the profile of the pipeline. This fact therefore points to the need for careful co-ordination between the profiles of the pipeline haulageway and the pipeline itself, the ideal conditions for which are often conflicting. For this reason it is very desirable to get as straight a pipe track as possible, so as to avoid the complications introduced by a heavily curved adjacent haulage.

These considerations became of governing importance in the design of the Winch Camp haulageway, which has to follow many curves both vertical and horizontal, in order to conform as nearly as possible to the surface of the spur before reaching Winch Camp. This in turn necessitated some very costly cuttings and banks which otherwise might have been avoided if a different system of haulage had been installed. Even

with these adjustments of the profile, a ballast car was found necessary and is in regular operation. The use of a ballast car necessitates a signalling arrangement when approaching the ballast car so as to slow down the car before buffing. The following horizontal and vertical curve radii were adopted :—

Pipeline 500 feet radius for both horizontal and vertical curves.

Winch Camp horizontal 500 feet, vertical 250, 500 and 1,000 feet.

When we came to design the Brot haulageway, where the country is much steeper, ending in a very steep stretch near the bottom end (incidentally one of the most difficult conditions to cope with, and one very common in the Himalayas), the conditions became even more formidable than those on the Winch Camp route. It was therefore decided to abandon this method of haulage altogether and to adopt a single drum winch hauling up one car at a time which system is not subject to any of the limitations described above. The size of the drum to hold the whole length of the cable was found to be excessive, moreover such a drum could not be transported to Winch Camp until the completion of the pipeline haulageway. A further consideration as to the type of winch to be installed was connected with the necessity of providing temporary winches which could be installed at intervals on the two southern haulages for their construction. These haulages were constructed as follows :—

Having excavated the formation, a hand winch was then transported in pieces and installed about 100 yards up hill. This was used for hauling up the track equipment until the track was installed up to the winch. The process was then repeated about three or four times until sufficient length of track had been installed to justify the installation of a light 1½ ton electric winch. This was then installed at intervals of about 1,000 feet, being hauled up in pieces by the hand winch. When two or three lengths of "electric haul" had been installed, these were then replaced by a larger electric winch of four ton capacity. These large electric winches then operated the haulageways for several months during the installation of the permanent winches and winch houses at the top. This arrangement necessitated the purchase of at least two four ton winches, capable of carrying about 3,000 feet of rope.

This fact, combined with the difficulty of transporting a larger drum to Winch Camp, led us to economise on the Brot haulage by the installation of two four ton drum winches, one at the top and one half way down, which could, in the meantime, be used for the construction of the other haulages. The employment of two such drum winches enabled us to adopt a comparatively cheap formation, practically following the surface of the ground, thereby saving a large sum not only on the formation but also on the winches. This system, however, necessitates the maintenance of two winch houses and two operating staffs and the transfer of the car from one rope to the other half way down. This immensely slows down the speed of operation and reduces the capacity

of the haulage. This system however is satisfactory for the first stage of the project but may have to be supplemented for subsequent stages *i.e.*, when the times comes for the construction of the dam. As however most of the loads will then be Portland Cement down hill, it may be possible to instal cheap rope chutes, as has been done on the southern side of the hill in connection with the delivery of timber and lime. (For the transport of fuel wood and limestone, for lime burning, surkhi and brick manufacture in the brick field below Harabagh village, two long span rope chutes were used for chuteing down fuel wood from the oak forest at 7,000 feet to the lime kilns and a double "travelling rope" gravity operated ropeway from the lime kilns to the brickfield. These operated steadily for about two years and gave satisfaction.)

The construction of the Hill Top Tramway presented most of the difficulties usually met with on hill roads, but in a somewhat exaggerated form. About one-third of the formation had to be cut out of vertical granite cliffs, involving cuttings up to 150 feet in height many of which had to be started from cradles. This work was carried on continuously throughout the winter by a gang of 50 specially clothed men using an oil engine driven portable compressor, which was hauled up by the bridle path by a gang of coolies in about a month. The compressor used was a Reavell driven by an Atlantic type paraffin engine started on petrol and was designed to enable the engine to be replaced by an electric motor when power became available. The conversion to electric drive was effected as soon as the Dhelu plant was put into operation, and the machine has since given good service as an electrically driven compressor.

The above described haulage system has now been completed and in operation a little over a year and it is possible to give some figures of capital and operating cost: see Appendices 2 and 3. The figures quoted in Appendix 3 are based upon continuous operation during the hours of daylight, using electrically operated transfer cranes at top and bottom terminals.

POWER SUPPLY.

Turning now to the arrangements for power; this is obtained from two water driven stations, one located at Dhelu on the Gugli Khad three miles from Shanan on the southern face of the range, and another in the Brot valley on the banks of the Uhl and using the waters of the Lamba Dug. The two stations are linked by means of an 11,000 volt transmission line which supplies 9 small outdoor substations located at the chief load centres on the works.

The Dhelu station is Pelton wheel driven consuming up to 24 cusecs on a head of 740 feet. The water is collected from two rain-fed nalas and delivered to a small forebay through a flume designed for 21 cusecs. The flume is of composite design consisting of cement plastered lime concrete where the ground is suitable, connected by short lengths of "armco" on timber trestles. The station is supplied by one 18" welded steel pipe with muff joints and contains two

Pelton wheel driven 3,300 volt 600 kva, 750 r. p. m. 3-phase alternators of standard design.

The Thuji plant contains one 500 kw Francis turbine driven 400 volt, 600 kva, 750 r. p. m. 3-phase alternator operating under a head of 98 to 198 feet and consuming 70 cusecs conveyed by an open masonry flume 4,100 feet long from a headworks of rather special design located on the Lamba Dag.

The pressure on both these stations is stepped up by out-door transformer stations of a design similar to that adopted for substations. For the transmission lines No. 5 copper wire supported on wooden H poles has been adopted as standard, except on 4 long spans on the south-west face of the hill at an altitude of 8,000 feet between Winch Camp and B's Neck, where spans of 2,500 feet have been employed using 7/·104" copper-clad steel cable supported on short steel towers of special design. The neutral is earthed and with the exception of the long spans referred to above, lines are protected by two high-tensile galvanised steel earth cables, earthed at every structure. Where the line crosses the hill at B's Neck, the highest point of the system, the insulation has been doubled and a set of oxide film arresters has been installed. The system has operated remarkably satisfactorily for the last 2 years, the chief failures being due to sheets of corrugated iron being blown off coolies quarters into the substation wiring.

Space does not permit of a more detailed description of the system but the following points may be instructive :—

The gaugings made in 1922 for the supply of the Dhelu power station gave two figures, one amounting to 12 cusecs based on the flow of the river with as many Kuhls as possible shut off, and one amounting to 19 based on the observed flows of all the Kuhls added together. An average of 15 cusecs was therefore, adopted for the purpose and arrangements made for a oil standby set. Subsequent experience indicated the possibility that considerable shortages might occur down to a figure of a 8 cusecs and possibly even lower, and the continuity of the supply for the pumps in the Northern heading (which is being driven down grade) being so vitally important it was decided to abandon the idea of a standby set, and to instal the Thuji plant in the Brot Valley. The two stations operate in parallel satisfactorily and the sub-division of plant into a station on each side of the hill has proved invaluable in maintaining continuity of supply.

The supply at Dhelu has dropped as low as seven cusecs for a week at a time. Owing to irregularities in the level of the flume (the whole installation was built in 15 months, the flume itself being built in 9 months) combined with the loss of head at the transitions from the masonry to the Armco flume and back, it has been found that the capacity, which was originally designed for 21 cusecs, has never exceeded 15, while lengths of the Armco, even in the straight, have been found to carry only 70 per cent. of the catalogued capacity of that particular size. This is partly due to the flume being operated too near its critical velocity, a point which was

overlooked in selecting the size from the maker's catalogue. The adoption of Armco has rendered it impossible to increase the capacity of the flume after completion. With this exception, the plant has given good service.

The Thuji flume traverses very bad ground and should have been covered for longer lengths than was done; this resulted in several wash-outs during the first monsoon till it was covered. The special type of headworks was on more than one occasion completely blocked by boulders, but it is hoped to rectify this by the use of a coarse screen at the weir. Some difficulty has also been experienced in controlling the output of the generator so as to prevent it exceeding the capacity at which the flume happens to be running at the time, with the resulting danger of suddenly emptying the forebay and throwing off its load without warning. This is being overcome by the installation of a load limiter on the governor which was not part of the standard equipment originally ordered. This necessity owing to the nature of the overflow flume, which, due to the nature of the country, has had to take the form of a timber chute, supported on trestles and lined with galvanized iron. In order to prevent the chute wearing out under the high velocities at which it operates, it is necessary to limit the discharge in the flume to that actually required at different times of the day. With the load limiter installed, it will be possible to adjust the discharge of the flume to the exact amount required and reduce the discharge down the chute to a negligible quantity. This method of operating the two stations in parallel, *i.e.*, with the Thuji plant more or less permanently fully loaded, is rendered difficult by the fact that the Thuji governor is a more modern and sensitive governor than those at Dhelu: the result is that the Thuji machine tends both to pick up and discard load in preference to those at Dhelu. This will necessitate the continual reloading of the Thuji machine by the operator after each reduction of load if the chute is to be kept empty. It is hoped to get over this difficulty by "setting" the Thuji governor above its synchronous speed but until the load limit device has been installed this cannot be tested.

To economise in operation, arrangements were made to enable the Thuji station to be operated by remote control from the compressor station about half a mile away where a permanent operating staff has to be employed in any case; arrangements are now being made to add a load limiter and thermostat on the bearings; experience has shown that without these it is inexpedient to leave the plant unattended.

The pipeline of the Thuji plant is of rivetted steel plate, manufactured in Calcutta, and has given entire satisfaction.

Particulars of the capital cost of these two plants and also the annual cost of operation and resulting cost of power will be found in Appendices 4 and 7.

Tunnel plant.

For driving the tunnel, the following equipment has been installed both at the northern portal in the Brot Valley and on the south side adjacent to the adit entrance; the latter serves all tunnelling and sinking operations on the south side of the range.

At the northern end the tunnel is being driven in one main heading 5,000 feet long. At the southern end, a 1,200 feet adit approximately eight feet diameter has been driven in from the Wyer Nala in a north-easterly direction to a point at the southern end of the tunnel 10,500 feet from the northern portal and approximately 3,200 feet from the surge shaft. From the head of this adit two main headings are being driven, one towards Brot and the other towards the surge shaft. Simultaneously two pipe tunnels, each 1,200 feet long, are being driven in from the tunnel exit to the surge shaft, and a surge shaft, 380 feet deep, sunk from the surface.

A compressor station has been established at each portal containing two and three 600 c. ft. min. reciprocating Brewett Lindley compressors, each compressor is driven by a direct—coupled induction motor of 120 B. H. P. at 363 r. p. m. supplied at 400 volts, 3-phase from the adjacent out-door substation. To each compressor is connected a receiver to store 160 c. ft. of air at 120 lbs./square inch from which a 6″ victaulic joint steel delivery pipe runs up to the heading, with (on the south face) a tee connection for the supply of the pipe tunnels and surge shaft where another receiver is located, from which the supply is continued down the pipeline, serving the power station and workshop area. When the two headings meet there will be five miles of compressed air piping installed guaranteeing a supply of air at 100 lbs. per square inch at practically every point on the works. This system has so far given good service and the victaulic joints have been found invaluable. In each compressor station is also located a pair of blowers of special design, driven by a direct coupled two speed induction motor located between the two individual blowers. The two individual blowers are of different characteristics; each is designed to deliver 3,000 c. ft. of air at 12″ and 20″ water gauge respectively when running at 1,500 r. p. m. They can exhaust 6,000 c. ft. of air per minute at $40\frac{1}{2}$″ and $65\frac{1}{2}$″ water gauge respectively, when run at 3,000 r. p. m. Both motor fans are provided with roller bearings and require 210 horsepower at full speed but only 39 B. H. P. at ·62 power factor at low speed. One blower alone is now being used during the early stages when the heading is short. As the heading lengthens, the other blower will be used and eventually both will be run in series. The two blowers cannot be operated in parallel owing to their different characteristics, which tends to cause surging and resulting loss of efficiency. The suction and delivery pipes are interconnected by a system of dampers which enables the blowers to be reversed and suck out fumes at 6,000 c. ft. per minute, if run at full speed immediately after a blast. Each of these pairs of blowers are designed to supply one *main* heading. The "adit-junction to surge shaft" heading (3,200 feet long) is ventilated by a smaller direct coupled blower capable of supplying 3,000 c. ft. of air per minute at 18″ W. G. at 3,000 r. p. m. This will eventually be placed in series with a second of similar design as the heading proceeds. The second machine is at present being used for the ventilation of the pipe tunnels. These two

machines are standard, *i.e.* not of special design, and are not reversible. Ventilation air is delivered by means of a 16" diameter sheet steel duct. Great difficulty was found in getting these manufactured in India and it was found more satisfactory to manufacture them locally of 1/8th inch thick steel sheeting welded and built up in the Shanan workshops. These latter, manufactured locally, have given entire satisfaction and are being used by degrees to replace the rivetted pipes of Calcutta manufacture which have never given satisfaction.

For driving the main headings light hammer drifters have been standardised. These are of the Ingersoll-Rand N-72 and 74 pattern capable of giving 1,500 to 1,800 strokes per minute and driving a $1\frac{1}{2}$" hole in granite, $8\frac{1}{2}$" deep in a minute. To enable the drills to be mounted and dismounted rapidly, a drill carriage of the Stearns-Roger type, (as found so useful in the Moffat tunnel) was obtained for each heading. These carriages enable four drifters to be run up to the heading and put into operation simultaneously, and are provided with air and water manifolds so that only one main connection has to be made for each service. For sinking, surface work, and driving in soft rock, medium weight hand hammer drills of the Consolidated Pneumatic Company's C. P.-5 pattern have been standardised and have given good service.

During the early stages several cases of miner's pthisis developed due to the use of dry drills of the light type purchased for use above ground. When the wet drills were first put into operation, difficulty was experienced owing to insufficient lighting due to fog and condensation. This disappeared on an improvement of the ventilation arrangements which at that time had not been extended up to the heading. It was originally hoped to operate with 33 per cent. spare, but our experience shows that progress cannot be assured with less than 100 per cent. spare drills; this then enables every drill to be entirely overhauled every seven days. The driving of the main headings has not yet reached the granite core of the hill and most of the driving has been in soft to medium mica schist, so that few opportunities have existed for a satisfactory try out of the heavy drifters, in fact some 80 per cent of the driving already done has been with hand hammer drills. Experience shows that in this country Indian labour prefers the use of hand hammer drills, in fact it is difficult to procure drill runners with any experience in the use of the drifters. These machines are heavy to lift about and handle and it is for this reason that the carriages were purchased. There is undoubtedly a prejudice against the heavier drills and disciplinary measures have at times been resorted to to enforce their use whenever conditions permitted. It is thought that some of this is due to difficulties in connection with the use of the drill carriages. These are mainly associated with the clearances required in the heading, to enable the mucking machine (described below) to pass the carriage, necessitating the partial dismantlement of the drills on the carriage, thereby defeating the main object for which the carriage was purchased. Certain modifications have been made, but until we have had several months' experience of driving

in the hard gneiss, it is impossible to express a reliable opinion on the use of these carriages.

Each heading is served by a 50 lb/yd 2′ 6″ gauge standard railway track. With this equipment derailments seldom occur, but the labour involved in connection with the dismantlement and re-erection of the turn-outs on the double track near the heading caused serious delays in progress. This difficulty has been overcome by using a 20 lb. turn-out and siding laid on the top of the 50 lb. with a pair of ramps.

This turn-out at the heading is a vital necessity to avoid long hand shunting of the individual tracks serving the mucking machine and until this was installed the output of the mucking machine was below estimate.

All rolling stock used on this tramway, including the mucking machine, electric loco and tip trucks, have to pass through a four feet square loading gauge in order to enable them to traverse the inside of the concrete centring car. One yard tip trucks of special design had therefore, to be made for this service. Several minor difficulties were experienced with the design supplied; these defects have now been rectified by modifications made at site, the most important of these being:—

(*a*) The centre of gravity of the tub as originally received was too low. This has necessitated the lowering of the trunnion on each side of the tub to raise the centre of gravity to enable the tub to be tipped by one man.

(*b*) The axle box straps were of too small section originally, and moreover were only secured by one bolt at either end. It was necessary to put in stronger straps and to secure them by two bolts at each end instead of one.

(*c*) The truck-bodies as delivered to us were carried on the axle box by springs. These springs fatigued and broke, and it was necessary to remove them altogether.

(*d*) Solid bar coupling made from loco to first truck.

(*e*) Coupling pin box on tubs cut away on each side.
(Above are to avoid derailments round sharp 55 feet radius curves.)

(*f*) Angle iron at the back of coupling pin box cut away so that links forced back when trucks are being pushed do not jam.

(*g*) One coupling link (the forward one) fixed to truck by putting a cross peg in the coupling so that latter can only be taken out by a fitter. (This ensures that link is always on the tub and has not to be hunted for.)

Tip trucks are removed and dumped in rakes of 12 at a time by the electric loco which has so far operated on its battery in the tunnel headings. As the lining is completed a semi-permanent trolley will be

installed so as to reduce the proportion of battery operation to the minimum. It has not hitherto been considered advisable to risk the installation of a 200 volt trolley in the unlined portion of the tunnel. Particulars of the electric locomotive used will be found in Appendix 9.

Electric firing has been standardised throughout on all main headings. The cut holes are fired instantaneously and the inner and outer rings in two stages of delay, for which special delay action electric detonators have been imported. These are all fired simultaneously but the delay detonators have short lengths of time fuse which take 5 and 10 seconds to burn before firing the detonator. The 10 second fuses are not very reliable. Power for firing is taken from the lighting main by a firing transformer reducing the pressure to 110 volts. This transformer is located about a thousand feet from the heading and moved on as the heading proceeds; the firing switch is kept under lock and key. The disadvantage of this method is that it is impossible to know when a misfire has occurred and on one occasion due to some bad explosive a charge was drilled through and blew up the whole drilling crew. This has been the only serious accident on the works to date and was traceable to deteriorated gelignite, imported direct from England and held in stock on the works for two years before use.

As the governing factor in all tunnel progress is the time taken to remove spoil after a blast, particular attention was paid to this matter. It was therefore decided to import two Myers-Whaley machines of the type which had been found so successful in the driving of the Catskill, Schandaken, and Hetch Hetchy tunnels. This machine consists of a shovel of about ¾ yard capacity, operated by levers and cams and mounted on a balanced hinged projecting arm in front of the carriage. It delivers its contents on to a travelling belt which in turn delivers to another belt on the main carriage, which again discharges into the tip truck located at the back end of the machine. The machine is electrically driven through clutches from one 3-phase induction motor supplied by a cable on a reel. The designs originally supplied were quite satisfactory until water was met with, when both the motor and electric equipment began to deteriorate. The conditions under which the machines have to work in a watery tunnel are indescribably bad for any machinery and it is found in practice that the machines have to be taken out and overhauled for at least 4 hours a day for cleaning and for 120 hours a month for replacement of worn parts, etc., with a complete overhaul once a year. This has necessitated the provision of duplicate equipment on all headings. Two additional machines have therefore been ordered for use one on either side of the hill; the later machines have been provided with complete water-tight equipment throughout and are of an improved pattern.

In order to enable any one machine to be used on either of the two headings driven from the adit, it was of course necessary to reverse the machine. This cannot be done on a turntable owing to its length and necessitated the construction of a triangle outside the compressor

station. Taking into consideration the appalling conditions under which the machines have worked in our wet and dangerous tunnels, the service has been excellent, the machines are popular with both labour and staff, and it is no longer possible to do without them.

For supplying power for the mucking machines, pumps, electric light, charge firing, and the loco trolley, four electric power services have been installed, one 3-phase 400 volt cable for lighting and firing and a 200 volt trolley for the locomotive. Each tunnel is also provided with a 2" pipe for water supply, and the northern heading with a 6" steel pipe for the drainage pump delivery. The erection, maintenance, dismantlement for lining and semi-replacement after lining, has presented one of the greatest problems in the project. The space taken up by all these services in the unlined heading is in any case considerable, and the space available is still less inside the finished lining; but in the centring car itself, where the space is even more restricted, the difficulty of finding room for all these services has necessitated the restriction of all rolling stock to a four feet square loading gauge. The arrangements finally adopted are shown on plates Nos. 1 and 2. For these reasons the very greatest care had to be exerted to ensure the services being properly and neatly erected in the positions assigned to them.

For the maintenance of plant, equipment, timbering, and the reconditioning of drill steel and repairing of drills, each heading is provided with a large smithy equipped with an Ingersoll-Rand forging machine and a furnace, the latter being charcoal and oil fired on the north and south faces respectively. At the north face, a small temporary workshop has been added to enable immediate minor repairs to be carried out at site. The two southern headings are self-draining, so the question of pumping has not arisen. In the north heading however, a semi-permanent pumping station had to be installed at the tunnel entrance to clear the water delivered by other pumps from the heading as well as the local drainage in the tunnel entrance ramp and the surrounding area. To reduce this latter to the minimum, two catch-water drains have been constructed on the hill sides above, and a third draining the hill below, and discharging in a flume across the railway cutting leading into the tunnel. This has reduced the amount of the drainage water to that in the actual heading itself plus the seepage and rainfall on an area of a few square yards only. This pumping station contains one 4" pump for normal use and one 8" emergency pump in case of floods. The seepage into the tunnel itself has hitherto been dealt with by means of 2 small 2" pumps. To meet the contingency of any heavier inflow, two four-inch pumps are kept in reserve. These pumps are all direct-coupled motor driven, on a self-contained bed plate, and can be dismantled and shifted without difficulty. Even with this comparatively small flow and the two 2" pumps referred to, the difficulties of water accumulation at the heading have interfered so seriously with the operation of the mucking machines, and driving generally, that it has been found necessary to drive up hill at a grade of 1/400 for 7 days and then to

adjust the floor levels before proceeding. The effect of this alteration in procedure was immediate and practically doubled the weekly progress ; it is now standard practice on this heading. The following maximum daily, weekly and monthly rates have so far been attained on the northern heading where the conditions have been most favourable :—

(*i*) Maximum in one day (November 13th, 1929), 13 feet.

(*ii*) Maximum in one week (ending August 17th, 1929), 62 feet.

(*iii*) Maximum in one month, (August 1929), 209 feet.

As the tunnel, when completed, will be subjected to considerable internal hydro-static pressure, it is of vital importance that the concrete lining should have a solid backing against the surrounding rock. This will be secured by grouting up the space between the concrete lining and the rock after the former has set, under pressure varying from 50 to 300 lbs. per square inch depending upon the condition of the rock and the ability of the lining to stand the grouting pressures. These conditions render it out of the question to leave any timber or organic matter between the lining and the rock. Where, therefore, the rock is so bad as to make it impossible to remove timbering before lining operations are started, steel frames of special design have been inserted in place of timber, backed with reinforced pre-cast concrete slabs in place of slabbing. These steel frames and concrete slabs will be left in and concreted up solid with the rest of the lining. In the two main southern headings, especially in that towards the surge shaft, this type of " timbering " has had to be adopted for over 2/3rds of the length so far driven. It provides an excellent temporary protection, except where the conditions are so bad as to necessitate continuous heavy timbering, as has occurred in the main southern heading at R. D. 530. Under these conditions the steel frames are too light, and once they get bent or out of shape it is impossible to rectify them. In such cases temporary wooden timbering has to be installed, being replaced afterwards by special steel frames of heavier section, in combination with the solidification of the surrounding rock by high pressure grouting. Up to date no attempts have been made to solidify the rock by this process but arrangements are being made to secure high pressure grouting pumps capable of forcing grout into the rock fissures to a considerable depth under pressures rising to 600 lbs. per square inch. This system practically converts fissured rock into a solid conglomerate for a depth of 50 to 60 feet all round the tunnel and is the only known method of rendering such rock impervious under hydraulic pressure.

The major problem in connection with the tunnel is associated with the arrangements for driving and lining simultaneously. The finished diameter of 9'3" is about the minimum that it is possible to drive and line simultaneously. The modern equipment necessary for rapid driving and the high standard of work needed for the heavy internal hydro-static pressures, is so complicated and elaborate that even with this diameter the problem becomes extremely difficult of solution. The following

is a brief sketch of the arrangements so far projected and completed for the lining. The system herein described was worked out in detail two years ago and forms the subject of a "Technical Memo," upon which the purchase of the equipment and the methods of driving and lining were based. Up to date no serious modifications of the system have had to be adopted but as it has not been put wholly into effect to date, it is too early to judge of its complete suitability.

No concreting is permissible within 1,000 feet of the heading. When the heading has proceeded for 1,000 feet clear straight, a series of 8" rolled steel joists are laid across, three feet apart extending for a length of 576 feet. Upon the frame a double track is laid at a level 2'-5" above the existing invert track. All traffic is then diverted on to the top of this frame by means of combined turn-out and ramp cars, one at each end. The original track is then dismantled and a 400 feet length of precast concrete invert pipe is then laid in a recess in the rock below the invert. This is then concreted up along with a corresponding length of invert. As soon as the front 80 feet length of this has set, a 40 feet length of R. S. J. frame is dismantled and re-erected ahead. On the newly laid invert, two new tracks of 5'-2" and 2'-6" gauge are laid, upon the wider of which the collapsible steel centring car is run. Inside this car there is then a single 2'-6" track continuous with that already laid on the new invert. Normal traffic can then continue through the inside of the car. The first 40 feet section of the lining is then completed round the centring while an additional 40 feet of the invert is laid ahead. When this has set, the joists over the new length of invert are shifted forward another 40 feet, the concreting car collapsed and shifted forward 40 feet and the process of laying and concreting repeated. For these arrangements, two special types of ramp cars and collapsible steel centring cars have been purchased, manufactured locally to the Department's designs and specifications by two firms in Bombay and Karachi. The laying and shifting of this equipment is comparatively simple: the real problem is associated with the breaking down of the services and their re-erection for a week at a time through the inside of the centring car. For this purpose each car will be equipped with a complete set of services forming part of and travelling with the car itself, and connection is made thereto, from the temporary services ahead and the semi-permanent behind, by means of flexible connections for air, ventilation and water; canvas ducts supported by internal wire spirals are used for ventilation. Similar arrangements for the electric supply would necessitate breaking and rejointing the cable at every 40 feet length; to obviate this difficulty arrangements have been made to thread all the electric conductor cables etc., through the car before starting to concrete.

Concrete will be proportioned and despatched dry from the depot at the tunnel entrance in concrete dump cars. It will be wet mixed in a quarter yard mixer of special design located in a place provided for it on the turn out ramp car which travels with the centring car; the actual carriage and placing of mixed concrete will be done by hand. At

the time of writing, the equipment is being installed for the first time in the northern heading : it may be possible to give the results of practical experience when reading the paper.

For the disposal of the drain water while laying arrangements are being made to instal a precast concrete drain pipe in a channel cut in the rock below and outside the lining. This will be laid in 40 feet lengths ; at the end of each a precast concrete man or hand hole will be inserted, into which weepers will discharge during the process of laying and which will afterwards be used for plugging the drain pipe at every 40 feet interval with concrete and grout, after the lining has set and is therefore capable of taking the ground water pressure.

In places where the rock is not strong enough to take the internal hydro-static pressure of the tunnel, when transmitted to it through the lining, the inside of the lining will be faced with a mantle of reinforced gunnite 6″ thick, capable of taking the full hydro-static pressure of the tunnel without support from the surrounding rock. The rings of reinforcing bars for this mantle will be jointed by arc welding at site and the gunnite applied by cement guns. The application of the gunnite to a complicated reinforcement and its building up to 6″ thickness in the inside of a tunnel requires special skill and experience, and arrangements will be made to have this carried out by contractors with previous experience of this type of work elsewhere. These contractors will supply their own cement guns and welding equipment, particulars of which are not at the present moment available.

For grouting up the rock and tunnel lining a standard high pressure Cannif grouting plant is being purchased, in connection with which a motor driven high pressure Booster compressor has been purchased. This will enable grout to be forced into the rock and into the small spaces behind the lining up to pressures of 300 lbs. per square inch. This machine has not yet been put into operation and no operating experience can therefore yet be quoted.

Further particulars of costs, horsepower etc., will be found in the appendices.

My grateful thanks are due to Captain Kenyon, Mr. Bruford, and Captain Guthrie for the assistance they have given me in providing the necessary information and data quoted in the paper, and to Mr. Heath for the interesting landscape sketch.

LIST OF APPENDICES TO ACCOMPANY COLONEL BATTYE'S PAPER FOR THE PUNJAB P. W. D. ENG. CONGRESS.

Appendix 1. Rope tension diagram and calculations.

,, 2. Capital cost of haulageways.

,, 3. Operating cost of haulageways.

,, 4. Capital cost of power plants.

,, 5. Cost of different types of plant and equipment.

,, 6. Horsepower of various types of plant.

,, 7. Operating cost of power plants.

,, 8. Particulars of haulageway ropes.

,, 9. Particulars of electric locomotive.

APPENDIX I.

METHODS OF CALCULATING ROPE TENSION AND MAXIMUM PERMISSIBLE RATIO.

The maximum permissible ratio of T to t is expressed by the following formulla :—

$$\left(\frac{T}{t} = {}_{e}Us\ \phi_{c.}\right)$$

Where e = Base of natural logs :

U_s = Friction coefficient of rope to sheave.

ϕ_c = Total radians of contact between rope and sheave.

Slip may occur at about $U_s = \cdot 10$.

For 3 and 4 wraps of the rope round the sheave $\phi c = 930°$ and 1320° *i.e.*, 16·23 and 23 radians respectively.

The limiting value of $\frac{T}{t}$ then is :—

$e^{1 \cdot 62} = 5 \cdot 07$ for 3 wraps.

$e^{2 \cdot 3} = 10 \cdot 0$ for 4 wraps.

The maximum working figures for $\frac{T}{t}$ actually adopted by us are :—

Pipe Line, 3·67, where there are 3 wraps.

Winch Camp, 6·55, with 4 wraps and a ballast car as well.

The rope tensions (T and t) are found as follows :—

The rope tension at the winch with car at any point X of the rope s the sum of the following 5 items :—

(1) Stress due to load of car on slope at point X .. $= W_c \sin \theta$.

(2) Rolling friction of car on track at 25 lbs per ton.. $= \frac{25}{2240} x \Sigma \sin \Theta$.

(3) Load due to the weight of the rope from the top of point X .. $= W_r\ \Sigma L \times \sin \Theta$.

(4) Friction of the rollers due to the weight of the rope. $= U_r\ W_r\ \Sigma L \times \cos \theta$.

(5) Friction of the rollers due to the stress of the rope on curves. $= U_r\ T_m\ \phi_c$.

Where T_m = items 1+2+ the mean of 3, 4 and 5, in that length, *i.e.*

T_m = items $1 + 2 + \frac{3 + 4 + 5}{3}$.

and where ϕ = Angle of slope.

W_c = Weight of loaded car.

W_r = Weight of rope per foot run.

ΣL = Total length of rope from top to the point X.

U_r = Coefficient of friction of rollers, usually taken as ·0315.

ϕ_c = Total curvature of rope (both vertical and horizontal) on rollers, added up from top to point X in radians.

Attached is a sample table showing how the rope tensions are conveniently calculated.

Owing to the low speed at which these haulages operate, (see table below) the starting acceleration is in any case very small. This is still further reduced by the effect resulting from the gradual tightening up of the rope on concavities which acts like a spring and brings stress onto the rope and winch very gradually. The following further particulars of the pipeline and winch camp haulages are of interest :—

Particulars.	Pipeline.	Winch Camp.
1. Speed	141′ per min.	219′ per min.
2. Time of trip	35′ mins.	30 mins.
3. Horsepower	106	107
4. Diameter of sheaves	9·85′	8·2
5. Net weight of car	4 tons	3·7 tons.
6. Net load	15·2 ,,	5·1 ,,
7. Gross load	19·2 ,,	8·8 ,,
8. Max. force on circumference of driving sheaves ignoring acceleration	9·7 ,,	5·7 ,,

Calculation form as standardised by Mr. E. S. Crump.

Apex point.	7 Sin θ.	$\frac{25}{2240} \times 7 \cos\theta$.	T=(2)+(3).	W ΣL sin θ.	U_r W ΣL cos θ.	$T_m = \frac{(4)+(5)+(6)+(9).}{3}$	$\Sigma\phi_c$.*	U_r T_m $\Sigma\phi_c$.	T=(4)+(5)+(6)+(9).	Remarks.
1	2	3	4	5	6	7	8	9	10	11
Top	..	..	..	0·000	0·000	2·269	0·0	0·000	2·269	
1/2 ..	2·198	0·071	2·269	0·082	0·008	2·316/ 2·983	2·9	·004/ ·005	2·363/ 3·030	
2/3 ..	2·864	0·071	2·935	0·344	0·026	3·144/ 3·720	27·7	·048/ ·057	3·353/ 3·934	
3/4 ..	3·439	0·068	3·507	0·490	0·034	3·810/ 1·644	39·7	·083/ ·036	4·114/ 1·924	
4/5 .. etc.	1·287	0·077	1·364	0·517	0·039	1·667/ 2·898	54·3	·050/ ·068	1·970/ 3·210	

*Includes horizontal angles.

APPENDIX 2.

Particulars of Haulageway Costs.

Item No.	Particulars.	Pipeline.			Winch Camp.			Brot.		
		Data.	Cost.	Rate.	Data.	Cost.	Rate.	Data.	Cost.	Rate.
Col.	1	2	3	4	5	6	7	8	9	10
1	Winch machinery and foundations, cars buildings, cranes and terminal equipment.	Net load in tons =15·2.	Rs. 1,97,000	Rs 12,950 per ton.	5·0 tons.	Rs. 1,37,900	Rs. 27,580	40 tons.	Rs. 1,01,900	Rs. 25,475
2	Track, formation, drainage and telephone lines.	Length in feet =4,963′	1,82,500	Rs. 36·75 ft.	6,476 ft.	1,97,400	30·5	5,563 ft.	1,14,100	Rs. 20·5
3	Ropes, Rollers and Guide Frames.	Ditto.	50,600	10·2 ft.	6,476 ft.	51,900	8·0	5,563 ft.	32,200	Rs. 5·8
4	Total capital cost of whole.	75,500 ft. tons.	4,30,100	Rs. 5·7 ft. ton.	32,380 ft. tons.	3,87,200	Rs. 11·9 ft. ton.	22,252 ft. tons.	2,48,200	Rs. 11·5 ft. ton.

APPENDIX 3.

Particulars of haulageway operating cost.

Item No.	Particulars.	Annual expenditure for all 3 haulageways lumped.	REMARKS.
Col.	1	2	3
		Rs.	
1	Operating Establishment ..	12,000	
2	Loading and unloading of goods at terminal stations	9,500	
3	Materials for maintenance of machinery	3,100	
4	Track maintenance establishment ..	11,900	
5	Materials for track maintenance ..	250	
6	Total of operating and maintenance	36,750	

APPENDIX 4.

Capital cost of power plants.

Item No.	Particulars.	Dhelu.		Thuji.		Remarks.
		Cost Rs.	Cost/Kw installed.	Cost Rs.	Cost/Kw installed.	
Col.	1	2	3	4	5	6
1	Kws installed ..	900 Kw.		480 Kw.		
		Rs.	Rs.	Rs.	Rs.	
2	Headworks, flume and forebay ..	1,64,005	182	1,47,492	307·5	
3	Pipeline ..	71,308	79·5	27,900	58	
4	Power Station buildings, cranes, tailrace, overflow etc.	52,195	58	41,804	87·5	
5	Generating plant, switchgear, transformers and machinery ..	1,47,084	163·5	90,834	189	
6	Total ..	4,34,592	483	3,08,030	642	

APPENDIX 5.

Cost of different types of Plant and Equipment.

Item No.	Particulars.	Cost in rupees.
Col.	1	2
		Rs.
1	Drilling and blasting plant for Headworks, Tunnel, Pipeline and Quarries	3,48,000
2	Ventilation plant for Tunnel	1,52,000
3	Tramway, Rolling Stock and Locos for Headworks, Tunnel and Power Station	6,53,000
4	Lifting and winding gear and winches for Headworks, Tunnel and Power Station	1,10,000
5	Unwatering pumps	63,000
6	Mucking machines, excavators for Tunnel, Power house and Headworks	1,91,000
7	Crushers and screens for Power House and Headworks	79,000
8	Concrete mixers for Tunnel, Headworks and Power Station	34,000
9	Concrete gun grouting machine and cement guns for Tunnel and Power Stations	38,000
10	Forms for Tunnel, Headworks and Power Station	90,000
11	Temporary workshop at Headworks	17,000
12	Rivetting plant for pipeline	10,000
13	General Tools and Plant	3,00,000
14	Temporary water supply for Headworks, Tunnel and Power Station	34,000
15	Lime mortar and mixing plant	6,000
	Gross Total ..	21,25,000

APPENDIX 6.

Horsepower consumed by various types of plant.

Item No.	Type of Plant.	Horsepower consumed.
Col.	1	2
1	Pipeline winch	120 HP.
2	Winch Camp winch	120 HP.
3	Each Brot Winch	50 HP.
4	Each electric loco	25 HP.
5	Each mucking machine	10 HP.
6	Each blower set	220 HP max. 38 HP min.
7	Each 600 feet compressor	140 HP.
8	Each rock crusher and sand roll equipment ..	60 HP.
9	Motor generator set	80 KW.

The total installed kilowattage of the system is 1,750 Kws. The maximum peak load so far experienced on the whole system is 600 Kws ; the resulting diversity factor actually experienced is therefore, 3.

With a peak load capacity of 1,080 Kws. and the same diversity factor, the maximum horsepower which can be installed on the system without additional plant is therefore 3,240 Kws.

APPENDIX 7.

Operating costs of power plant.

Item No.	Particulars.	Thuji.	Dhelu.
Col.	1	2	3
1	Peak load capacity	480 Kw.	600 Kw.
2	Capital first cost	Rs. 3,08,030	Rs. 4,34,592
3	Credits on completion	37,700	80,000
4	Net cost to project	2,70,330	3,54,592
5	Depreciation at 25 per cent. (so as to wipe off cost in 4 years of construction) ..	67,582	88,648
6	Interest on first cost at 5 per cent. ..	15,400	21,730
7	Annual operating cost	7,500	20,400
8	Total annual cost of generating power ..	90,482	130,778
9	Cost per Kw. year generated ..	188·5	218
10	Equivalent cost per unit generated on a 50 per cent. load factor basis ..	8·2 pies	9·5 pies.

APPENDIX 8.

Particulars of haulageway ropes actually installed.

	Pipe Line.	Winch Camp.
Length	1,600 metres	2,130 metres
Size	36 m/m diameter	28 m/m diameter
Quality of material	Best plough steel. Special acid grade 160/175 kilos per square m/m.	
Construction	Flattened strand 6/24 (9×12×3).	
Approximate weight per metre.	5·6 kilos.	3·41 kilos.
Actual breaking strain	78·67 tons	48·13 tons.
Diameter of wires 9 outer	3·2 m/m.	2·49 m/m
12 inner	1·3 m/m.	1·02 ,,
3 core	2·13 m/m.	1·68 ,,
Tests on individual wires	3·2, 1·3, 2·13 m/m	2·49, 1·02, 1·68 m/m.
Breaking strain lbs. (average)	2940, 483, 1302	1775, 294, 809
Elastic limit	60 % to 70 % of ultimate breaking strain of any one wire.	
Minimum elongation in 100 diameters.	1¼%	1¼ %
Minimum torsions in 100 diameters.	35	35
Minimum bends of 180° on 5 m/m radius.	4-5, 16-18, 9-10	7-8, 22-24, 15-17
Lay of rope	276 m/m.	210 m/m.
Lay of strands	114 ,,	95 ,,
Outside dimensions of Reels.	6′ 1″×6′ 1″×4′ 7″	5′ 11″×5′ 11″×3′ 9″
Gross weight of Reel packing for shipment.	9½ tons	7¾ tons.

Material.—The wire from which the above ropes were made was drawn in one continuous length without welds or brazes.

Lubrication.—The ropes were lubricated during manufacture with Craddock's special Rope Composition.

The maximum rope tension when ascending with an acceleration of 1/3 of a foot per second amounts to approximately 11,820 Kg. in the case of the Pipeline, and approximately 8,070 Kg. in the case of the Winch Camp Line, which gives the following factors of safety against breaking :—

Pipeline approximately	6·75
Winch Camp Line approximately	6·05

APPENDIX 9.

Particulars of Electric Locomotive.

The loco is of the combined battery—trolley mining type.

Battery.—112 cells, Edison Alkaline, Type A/6.

Voltage.—1·5 per cell on open circuit. Effective volts = 168. Line Voltage on trolley = 220.

Two motors of 25 HP. each.

Tractive effort.—Maximum=4,500 lbs., at 4.8 M. P. H. on 220 volts D. C.

Hauls 25 tons up a 3·5 per cent. grade exclusive of its own weight, or about 90 tons gross on the flat.

The motors which run at 850 r. p. m. are located with their axles parallel to the frame and the torque is transmitted to the main axle through single reduction phosphor bronze bearings with ball thrusts.

With the exceptions noted below, these locos have given entire satisfaction.

The trolley poles are too long to swing in the tunnel so that they are only able to run in one direction *on the trolley* in the tunnel. This difficulty has not yet been solved but is under consideration.

We originally specified Davies Centrifugally cast steel wheels. These were unobtainable in the size required and the wheels supplied are too soft and suffer from excessive wear.

The brake blocks are much too hard and are of a peculiar shape; they pressed on the flanges and wore them out. These are being modified and Lignum Vitae substituted.

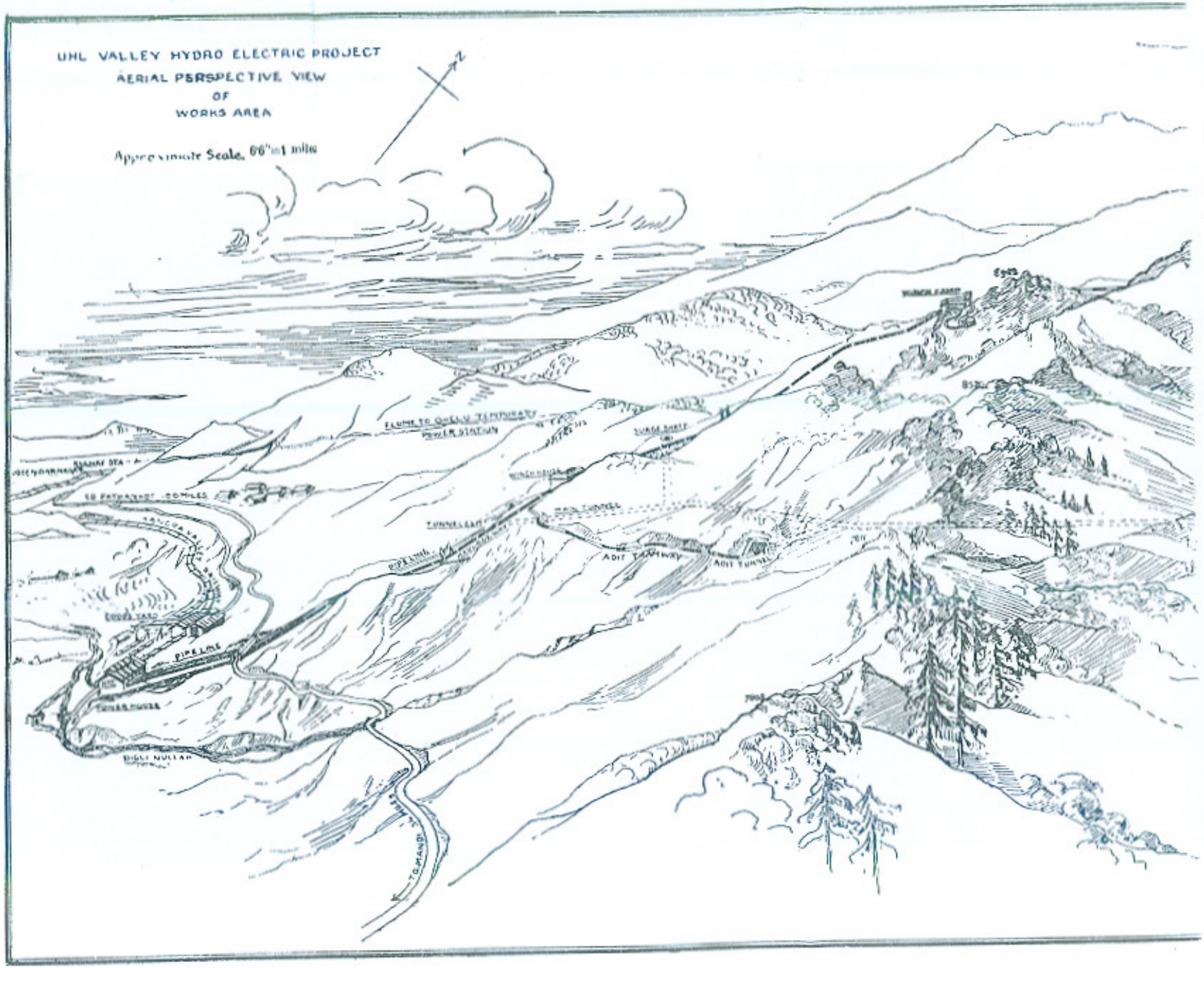
Weights of Loco:—

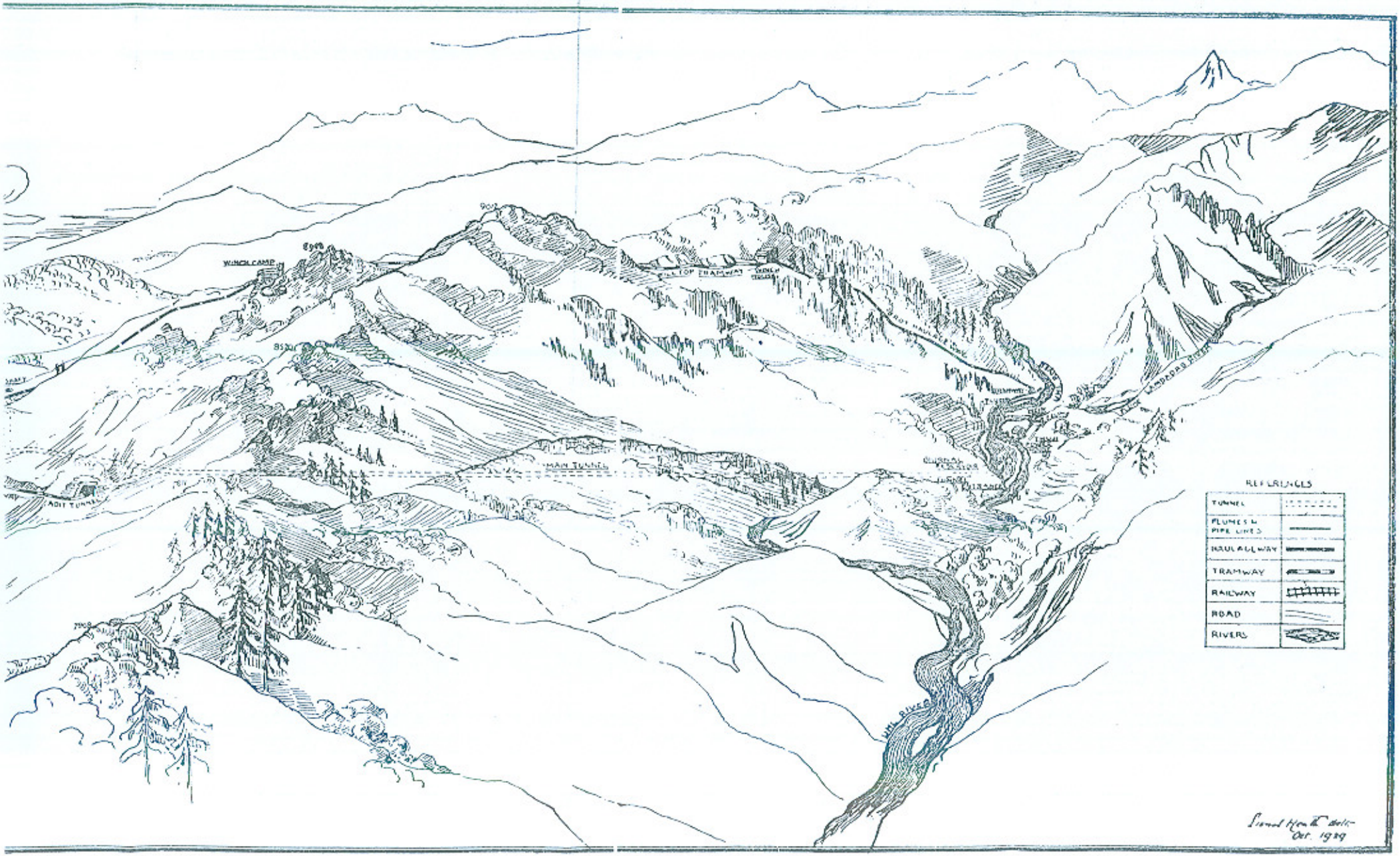
Loco with battery	..	..10 tons.
Loco (Trolley only)	..	..10 ,,

NOTE.—Counterweights and Battery weight—3 tons. Loco is not run without:—

(*a*) Batteries on the Battery-Trolley Type.

(*b*) Counterweights on the Trolley Type.


UHL VALLEY HYDRO ELECTRIC PROJECT
AERIAL PERSPECTIVE VIEW
OF
WORKS AREA
Approximate Scale, 66"=1 mile
FLUME TO OPEN TERMINAL
POWER STATION
SURGE SHAFT
TUNNEL EAST
ADIT TUNNEL
PIPELINE
TOWER HOUSE
TO MANDI


WINDY CAMP
8500
8300
MAIN TUNNEL
ADIT TUNNEL
REFERENCES
TUNNEL
PLUMES & PIPE LINES
ROAD & RAILWAY
TRAMWAY
RAILWAY
ROAD
RIVERS
Signed Hon. E. Beatty
Oct. 1929

PUNJAB PUBLIC WORKS DEPT.

HYDRO ELECTRIC BRANCH

PLAN OF UHL RIVER POWER STATIONS.

1 EQUAL TO 1 MILE

longs 8 7 6 5 4 3 2 1 0 1 2 MILES

—LEGEND—

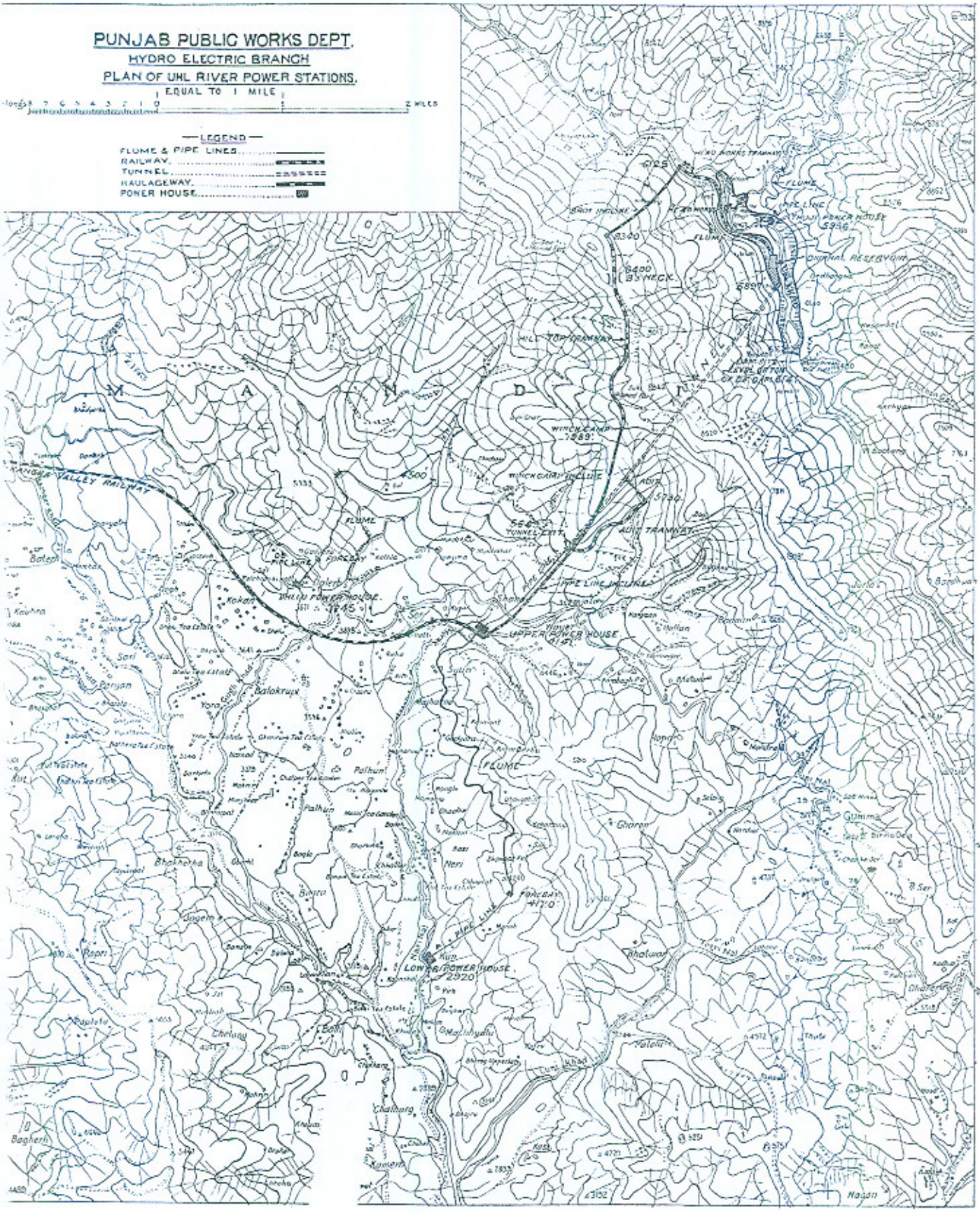
FLUME & PIPE LINES.....

RAILWAY.....

TUNNEL.....

HAULAGEWAY.....

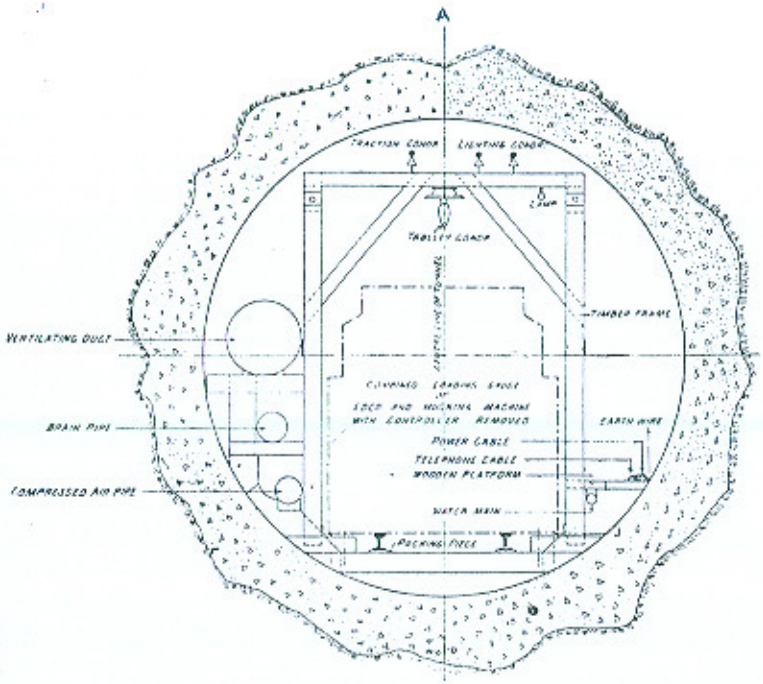
POWER HOUSE.....



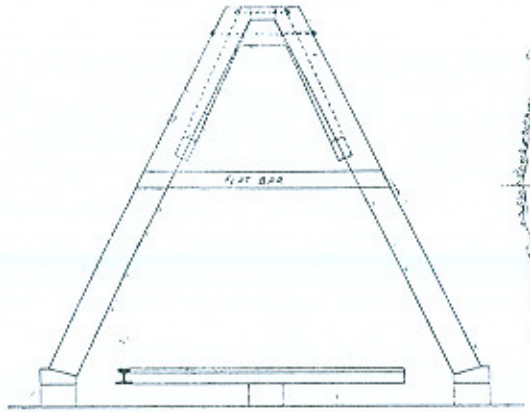
R DATED 24-3-1925

P.W.D
H.E.B
DRG. No U/P.M.4

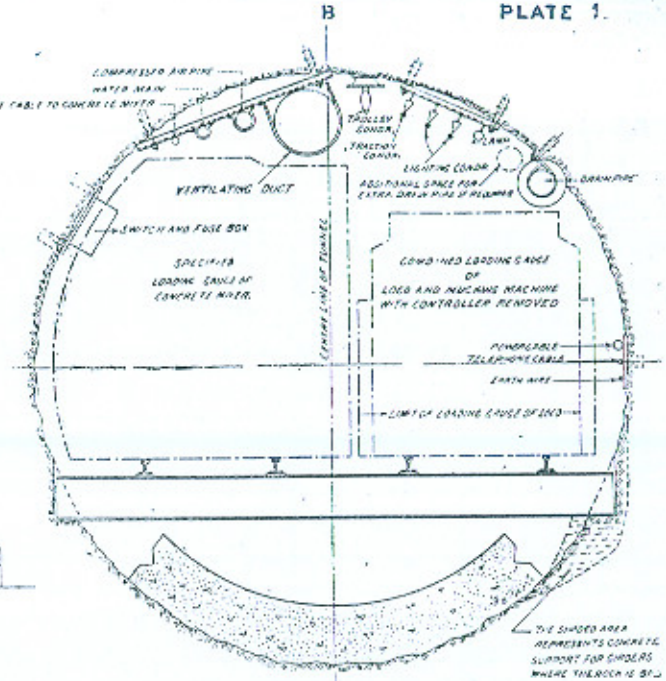
PLATE 1.



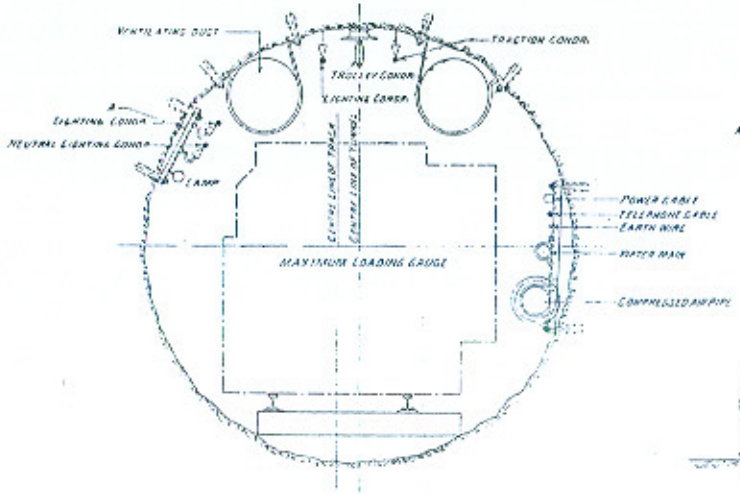
CROSS SECTION THROUGH LINED PORTION OF THE TUNNEL



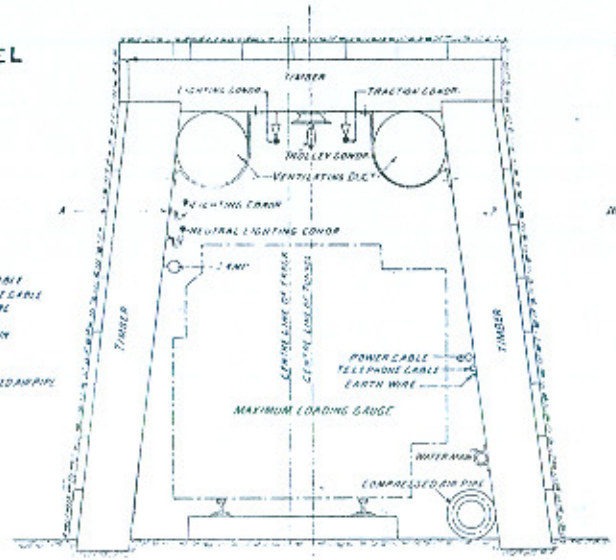
SIDE VIEW OF TIMBER FRAME



CROSS SECTION THROUGH LINED PORTION OF THE TUNNEL AT STEEL PLATFORM



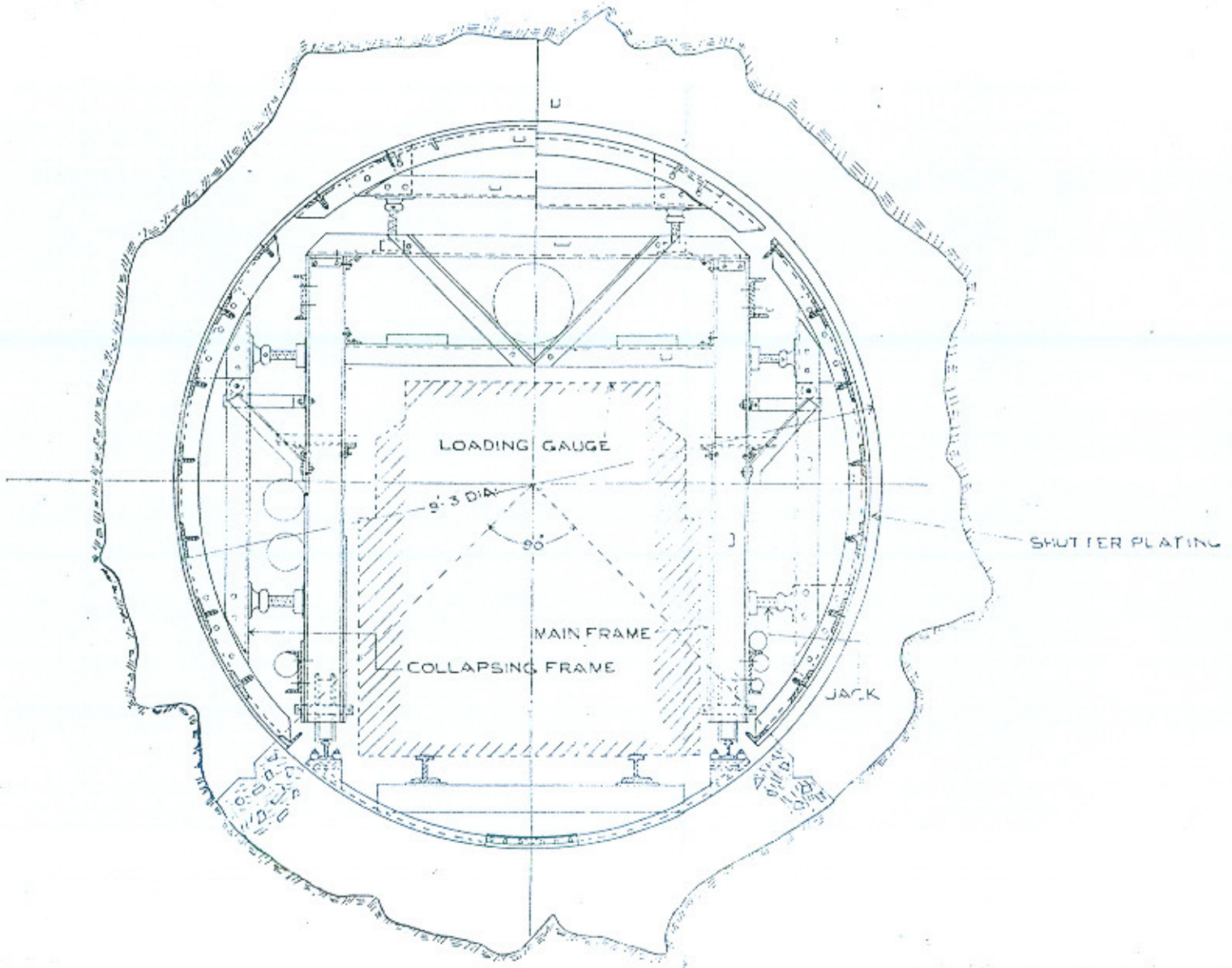
CROSS SECTION THROUGH UNTIMBERED PORTION OF ADIT



CROSS SECTION THROUGH TIMBER PORTION OF ADIT

NOTE — THE 3 BARE LIGHTING CONDUCTORS SHOWN ABOVE WILL BE SUBSTITUTED BY A TWIN V.I.R. CABLE TO BE FIXED AT A

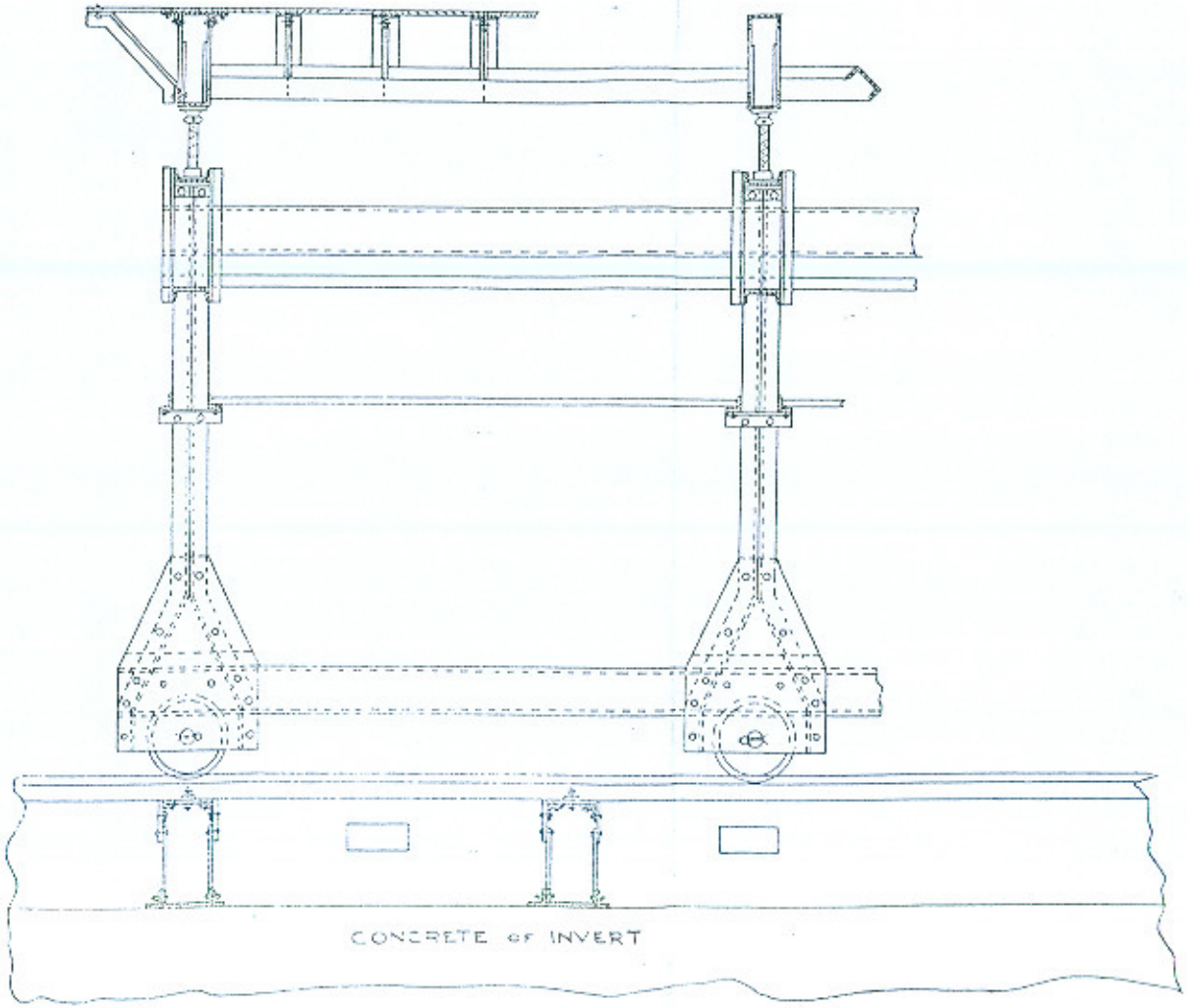
TUNNEI

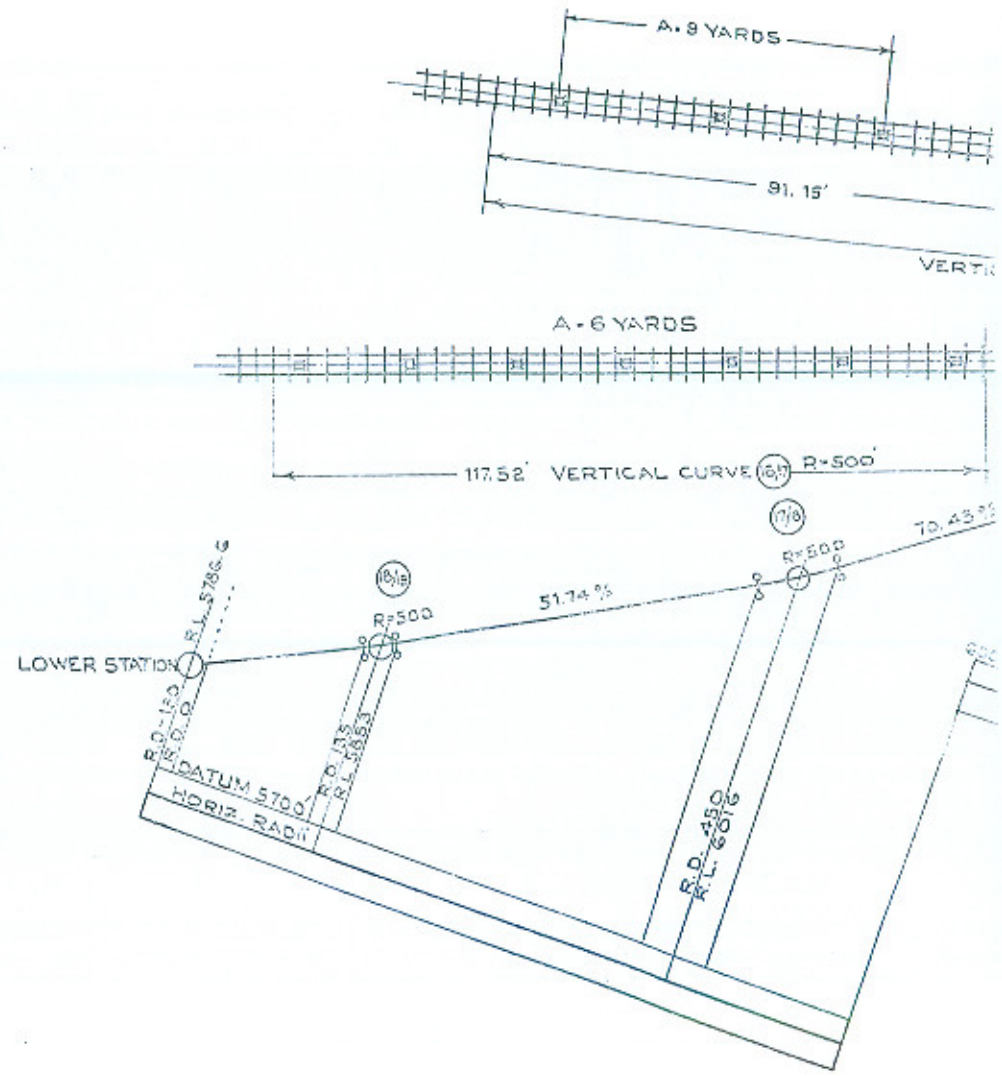

LOADING GAUGE
9'-3 DIA
90°
SHUTTER PLATING
MAIN FRAME
COLLAPSING FRAME
JACK

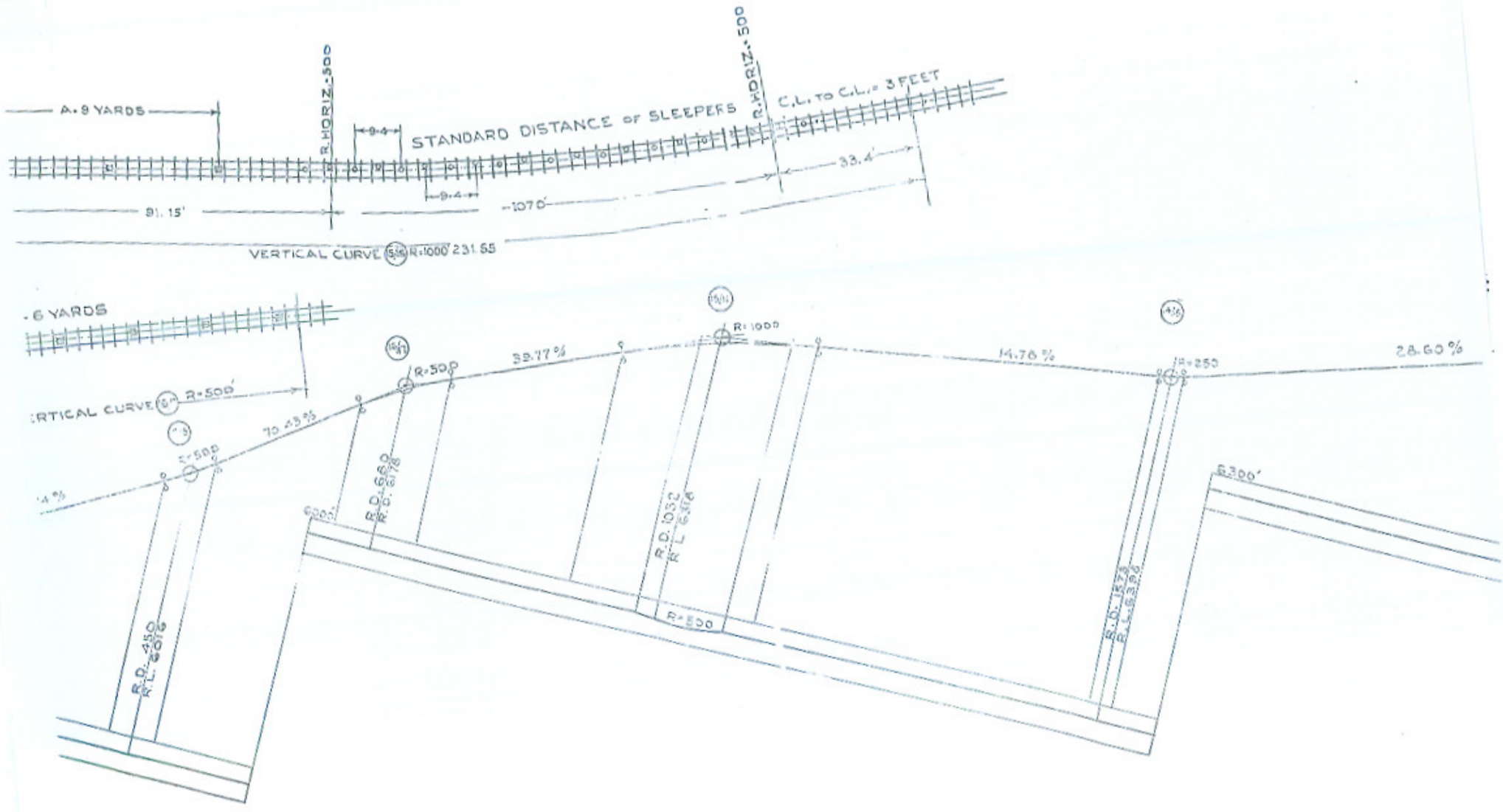
NEL CENTREING

PLATE 2.

ER PLATING

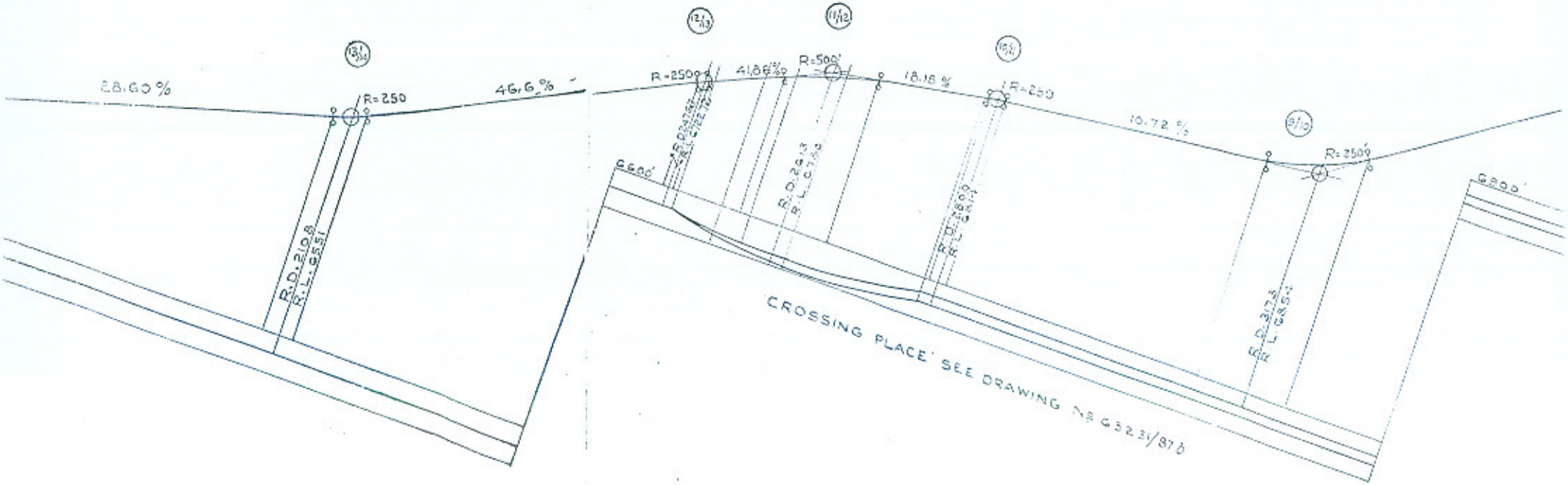



A-8 YARDS
91.15'
VERTI
A-6 YARDS
117.52'
VERTICAL CURVE
R=500
7/8
70.43%
R=500
51.74%
6/5
R=500
LOWER STATION
R.L. 578.6
R.D. 150
R.L. 570.0
DATUM 570.0'
HORIZ. RADII
R.D. 135
R.L. 585.3
R.D. 450
R.L. 601.2


A.9 YARDS
R.HORIZ.-500
9.4
STANDARD DISTANCE OF SLEEPERS
R.HORIZ.-500
C.L. TO C.L.= 3 FEET
33.4'
9.4
91.15'
107.0'
VERTICAL CURVE R=1000' 231.55
.6 YARDS
VERTICAL CURVE R=500'
R=500
38.77 %
R=1000
14.76 %
R=250
28.60 %
70.43 %
R=500
.4 %
600'
R.D. 660
R.L. 6178
R.D. 1032
R.L. 6414
R=500
R.D. 450
R.L. 6076
R.D. 1575
R.L. 6390
6300'

WINCH CAMP HAULAGEV
LONGITUDINAL SECTION

⊕ = BEGINNING AND



GEWAY
ION

NNING AND END OF VERTICAL CURVES

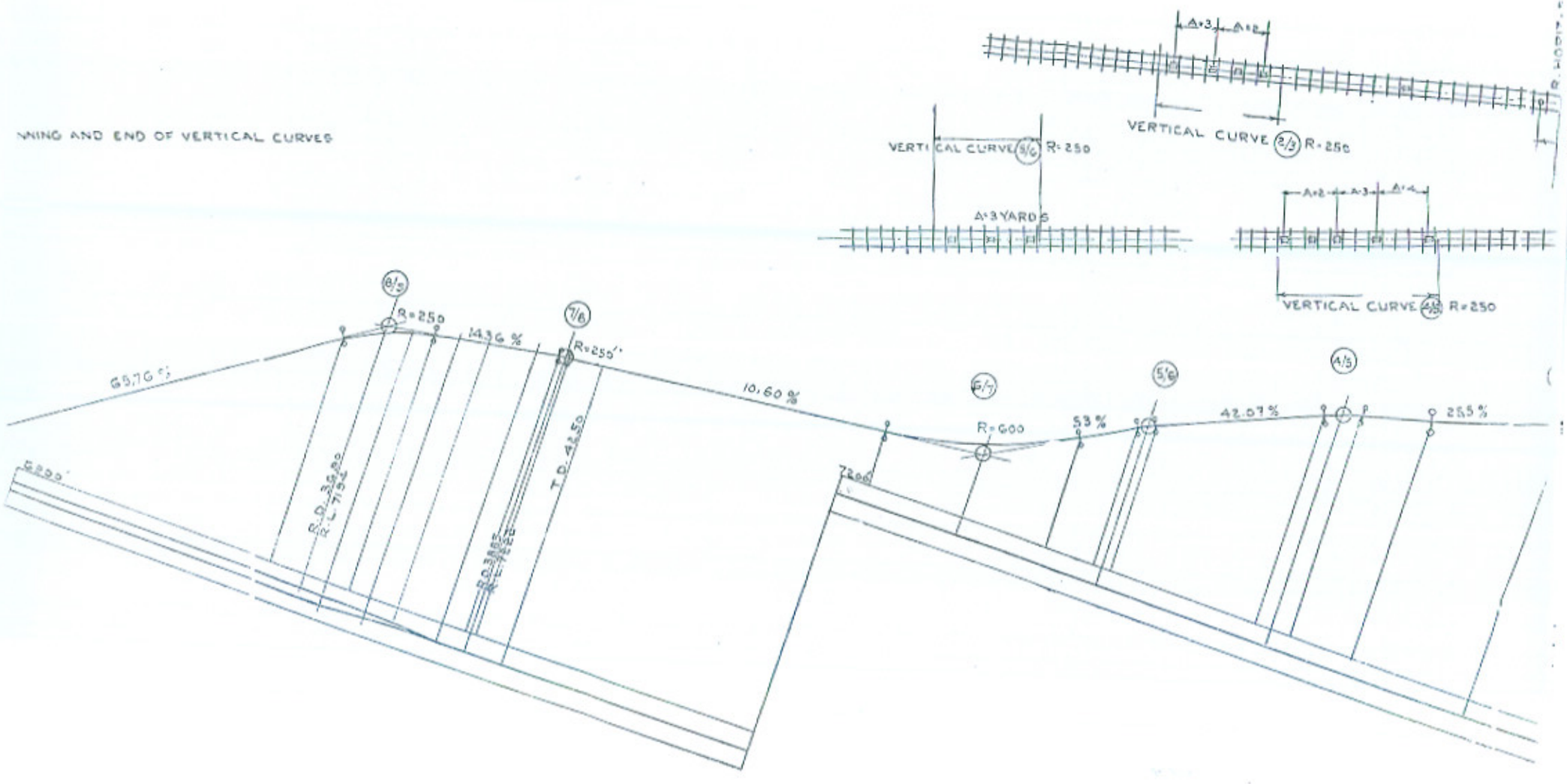


PLATE 3.

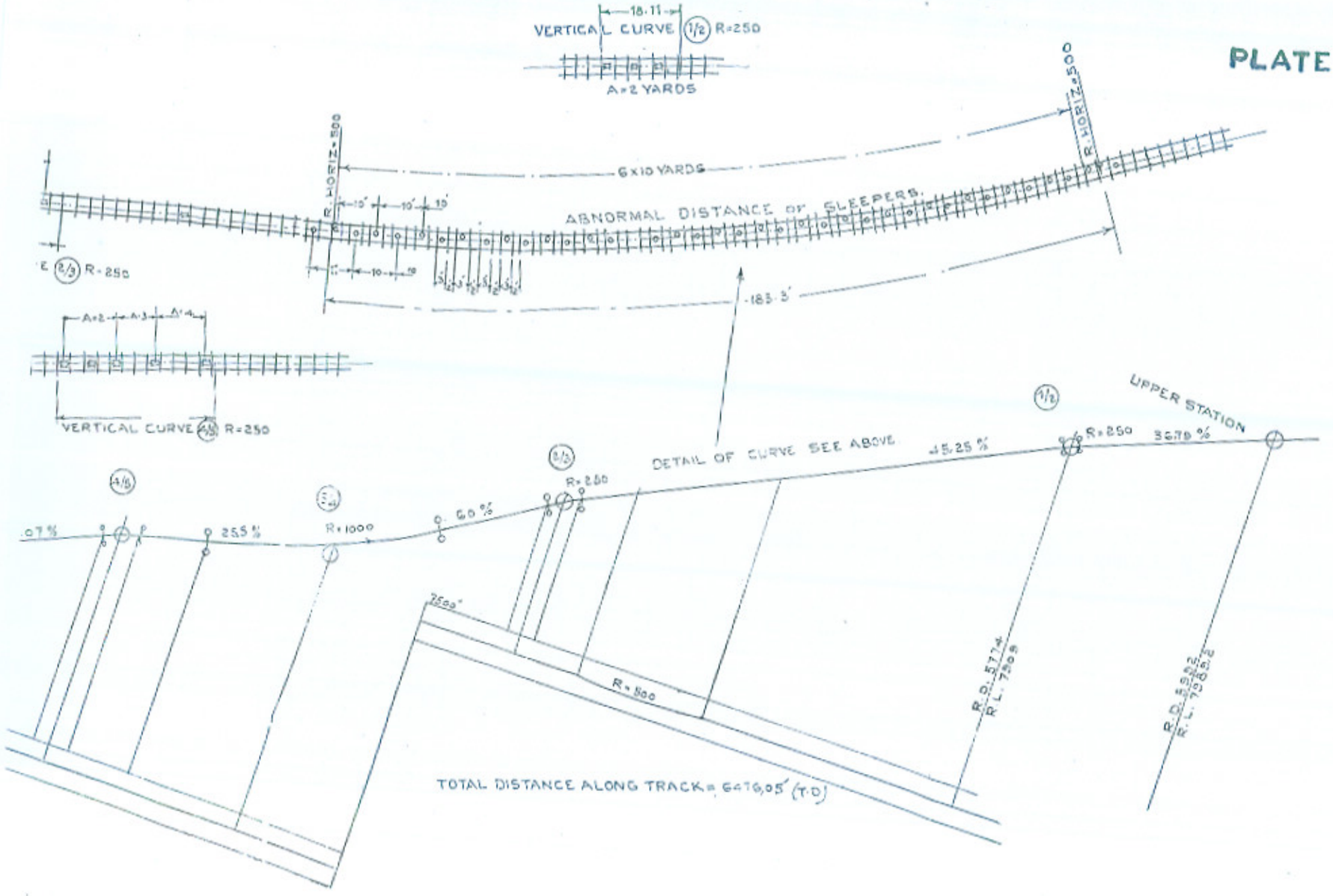
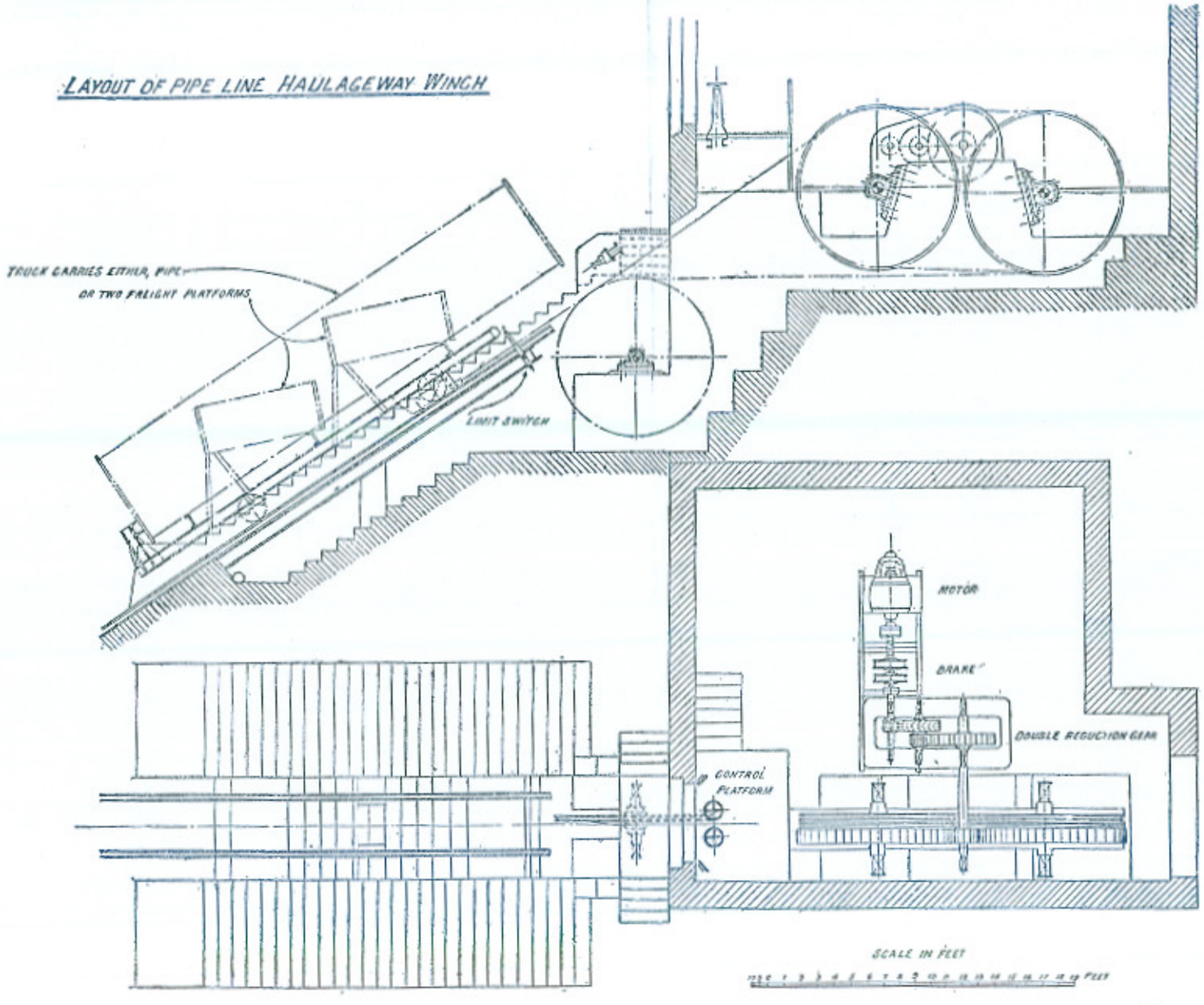
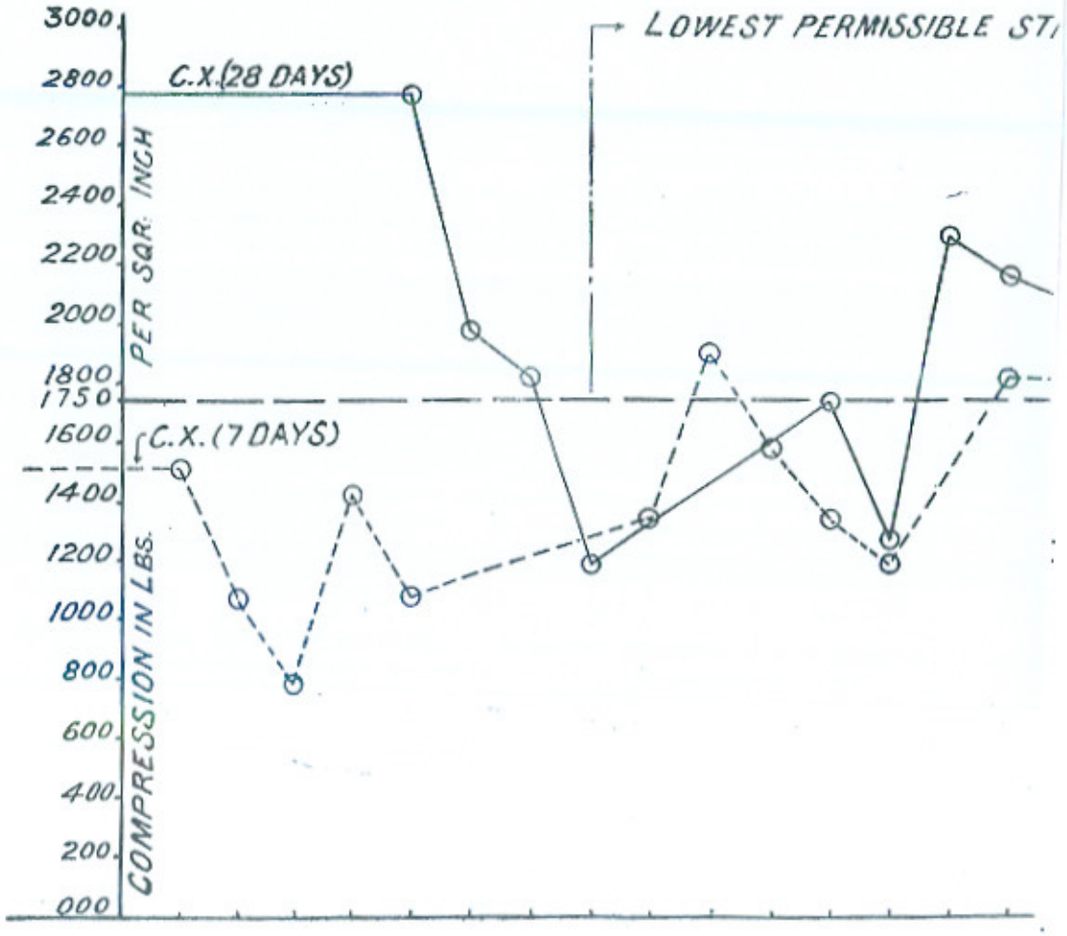

18.11
VERTICAL CURVE 1/2 R=250
A=2 YARDS
R. HORIZ. 500
6 x 10 YARDS
R. HORIZ. 500
ABNORMAL DISTANCE OF SLEEPERS.
E 2/3 R=250
183.3'
A=2 A=3 A=4
VERTICAL CURVE 4/5 R=250
UPPER STATION
DETAIL OF CURVE SEE ABOVE
45.25 %
R=250
36.79 %
4/5
3/4
R=1000
2/3
R=250
07 %
25.5 %
6.0 %
2500'
R=500
R.D. 5774
R.L. 7208
R.D. 5942
R.L. 7360
TOTAL DISTANCE ALONG TRACK = 6476.05' (T.D.)

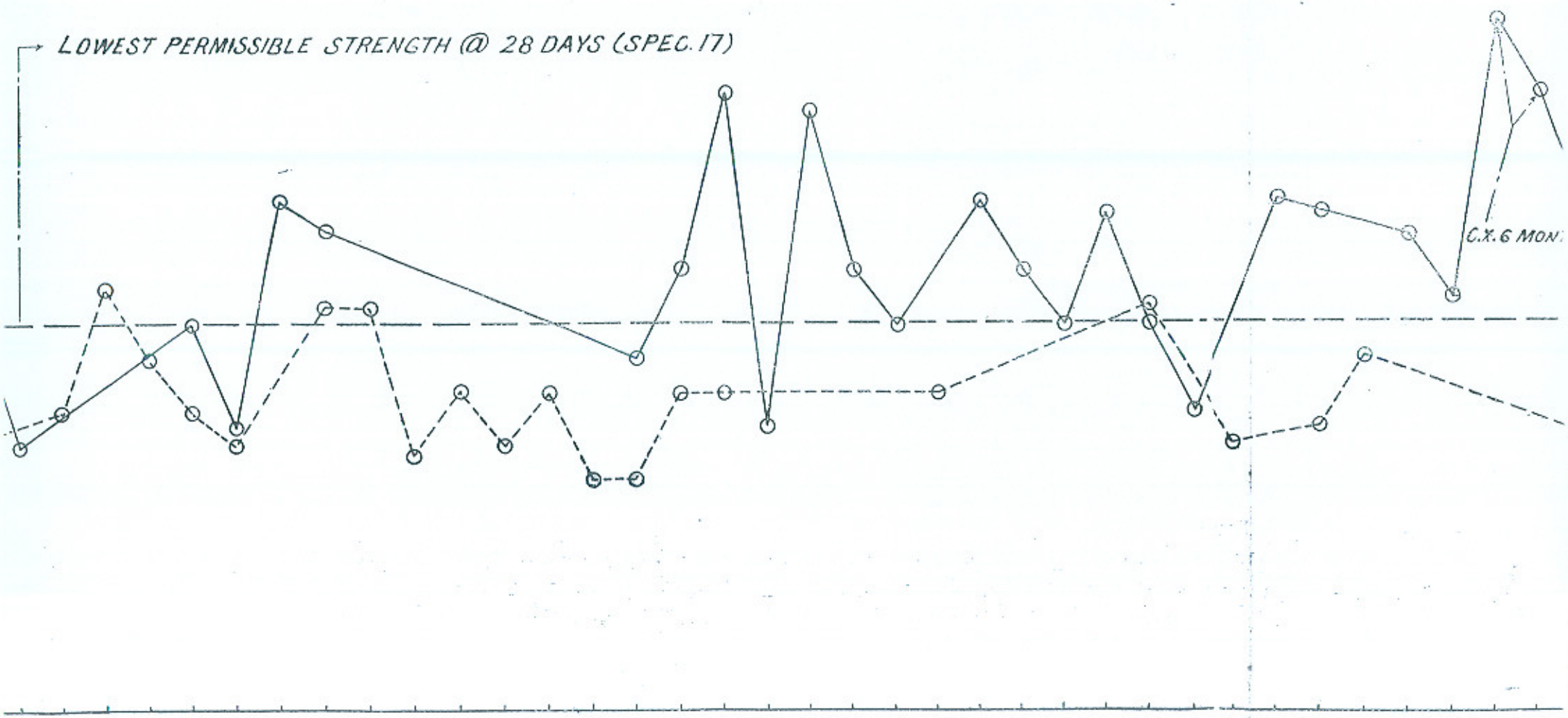
PLATE 4.

LAYOUT OF PIPE LINE HAULAGEWAY WINCH

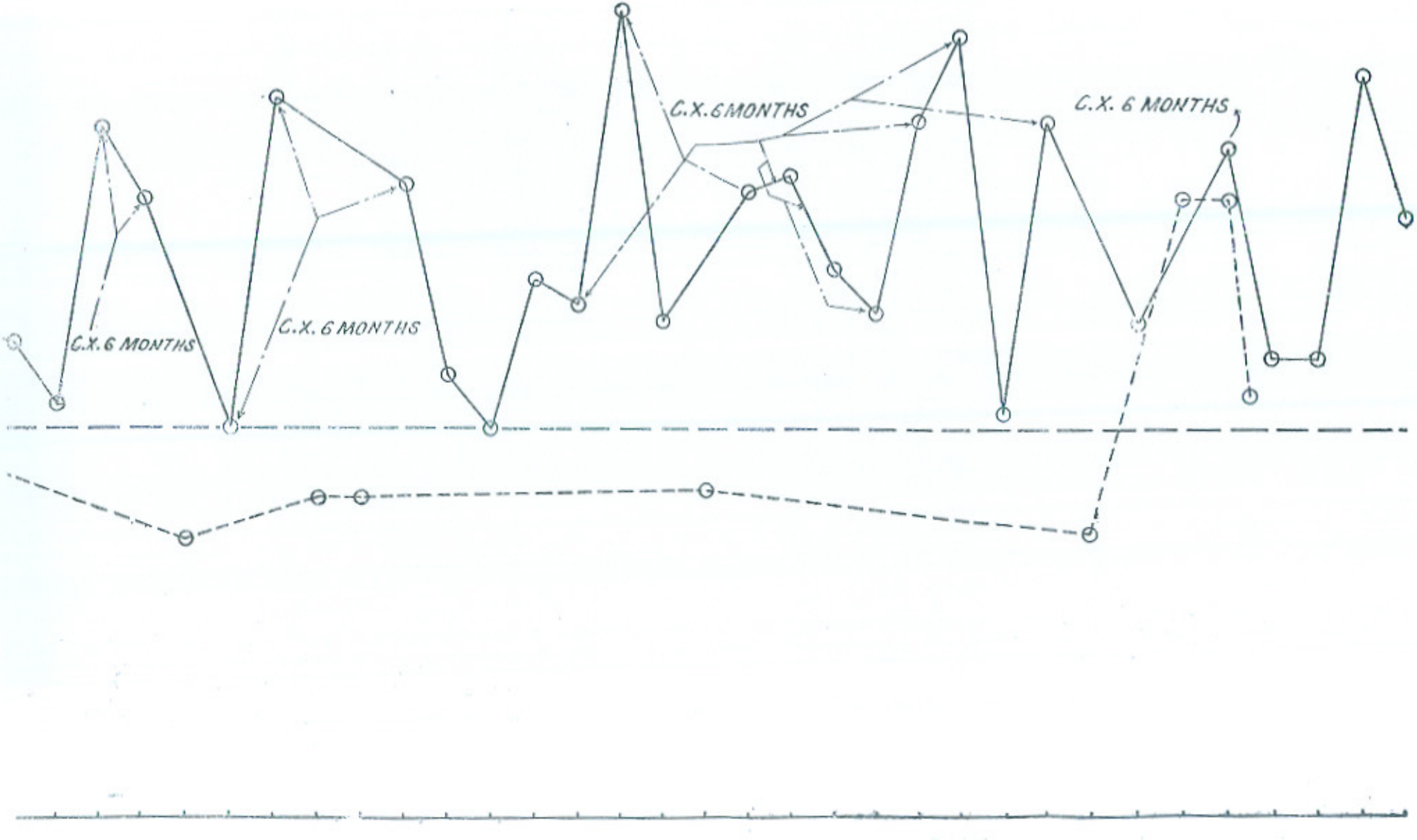


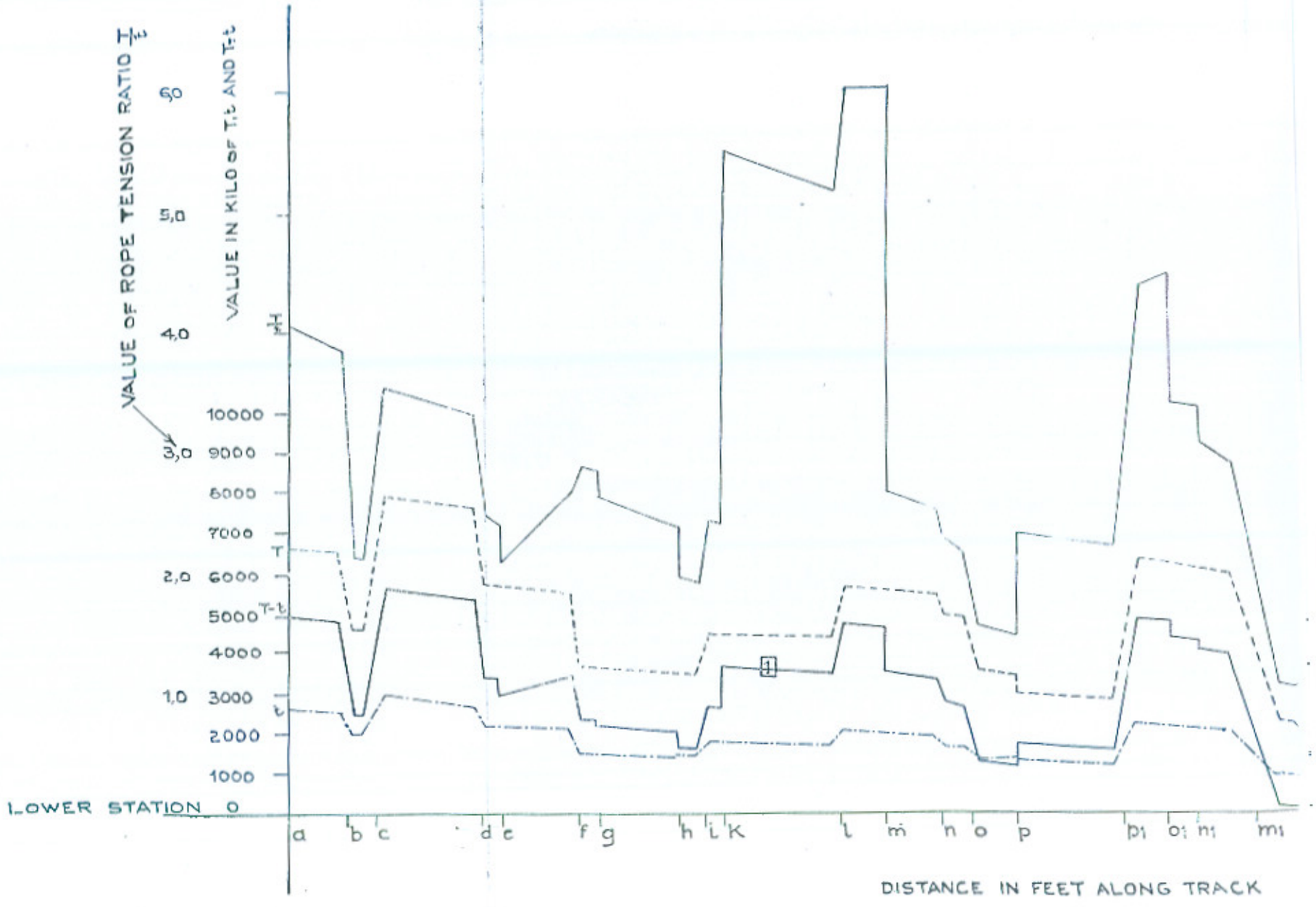

3000
2800
2600
2400
2200
2000
1800
1750
1600
1400
1200
1000
800
600
400
200
000
C.X.(28 DAYS)
C.X.(7 DAYS)
PER SQR. INCH
COMPRESSION IN LBS.
LOWEST PERMISSIBLE ST

TYPE C.X.



CONCRETE TEST CHART.




VALUE OF ROPE TENSION RATIO T/t
VALUE IN KILO OF T, t AND T-t
6,0
5,0
4,0
3,0
2,0
1,0
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
T
T-t
t
LOWER STATION 0
a b c d e f g h i K l m n o p p1 o1 n1 m1
DISTANCE IN FEET ALONG TRACK

APPENDIX 1.

UHL RIVER HYDRO-ELECTRIC PROJECT

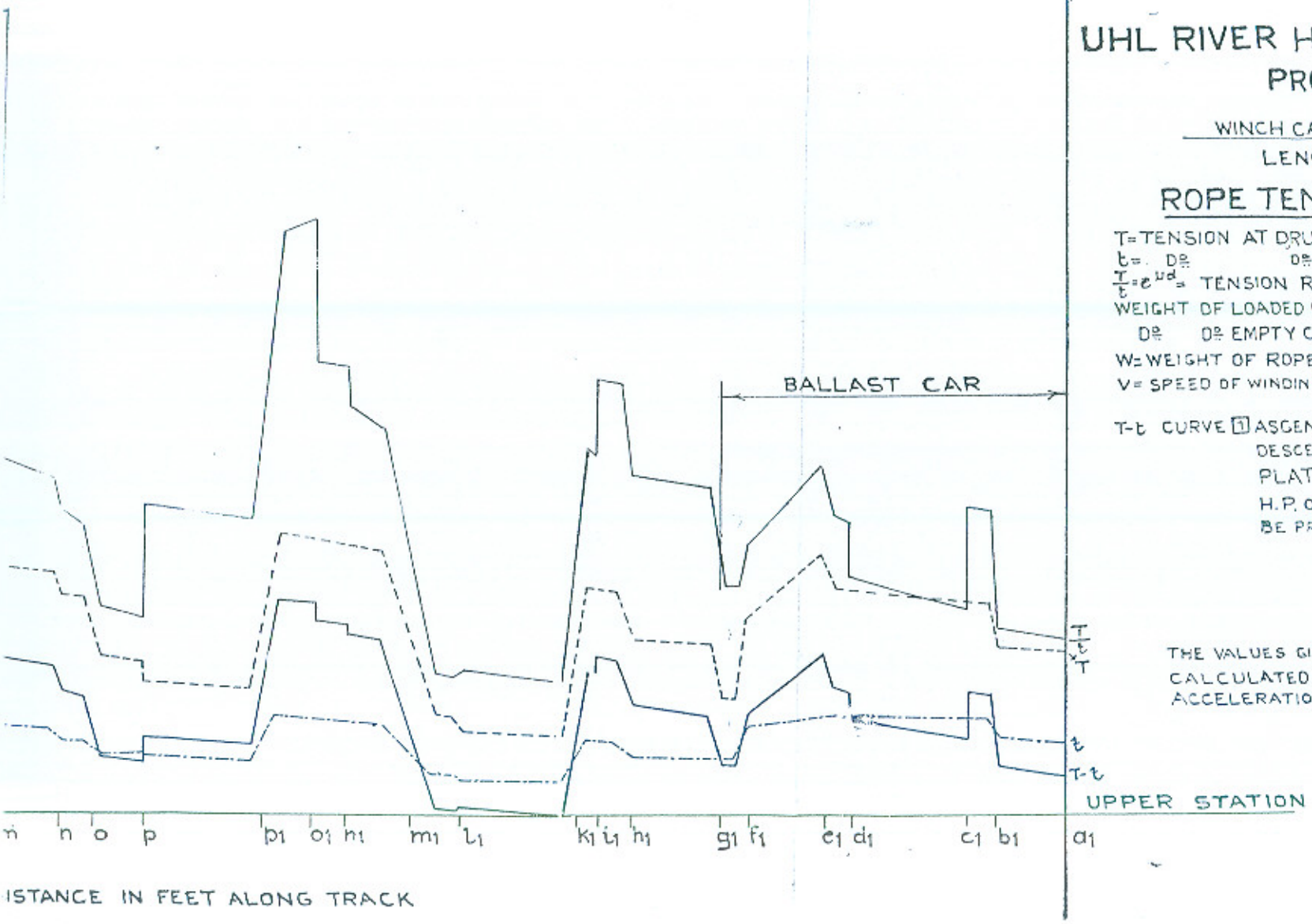
WINCH CAMP INCLINE. SCALE 1:5000

LENGTH OF TRACK 6560'

ROPE TENSION DIAGRAM

T = TENSION AT DRUM DUE TO ASCENDING LOADED CAR
t = 〃 〃 〃 DESCENDING EMPTY-CAR.
$\frac{T}{t} = e^{\mu\alpha}$ = TENSION RATIO
WEIGHT OF LOADED CAR WITH PLATFORMS = 8800 KILOS
〃 〃 EMPTY CAR WITHOUT 〃 = 2700 〃
W = WEIGHT OF ROPE PER FOOT = 2,28 lbs
V = SPEED OF WINDING, FEET PER SECOND = 3,67

T-t CURVE 1 ASCENDING CAR FULLY LOADED, DESCENDING CAR EMPTY WITHOUT PLATFORMS.
H.P. OF: 1 MILLIMETRE = 1,86 H.P. TO BE PRODUCED BY THE MOTOR.



THE VALUES GIVEN IN THIS DIAGRAM ARE CALCULATED WITHOUT REGARD TO THE ACCELERATION.

DISCUSSION.

Colonel B. C. Battye—In introducing his paper said that the main object of the paper was just to pass on to them the valuable experience that they had gained during the last three years in the designing and installation of their construction plant and in doing so he had endeavoured to put before the Congress the fullest possible facts, wherever they had made mistakes and wherever they had had trouble it was his experience that men learn little from success but much from failure, hence he had frankly put forward every feature of the construction plant used on the Hydro Electric Project. There were one or two things he had forgotten to which he wanted to draw attention.

Pressure of work had prevented his producing the chart or diagram of the hydraulic works on the north side of the hill, to which he had drawn attention, as Drawing No. 7 on page 6.

With regard to housing there was little to add except that they had had to provide housing accommodation for *every* man on the works as well as water-supply and sanitary arrangements.

Construction Plant.—There were a few comments to add to what he had already said. Since writing the paper they had been able to appreciate the value of the crushing plant and sand rolls and that by having weekly (and sometimes daily) tests made of the aggregate, they had been able by this means to produce an aggregate with a sieve analysis scientifically correct to specification.

Turning to roads and haulages, at the time of writing the paper, he was not in a position to give any definite information with regard to the causes which had led to the necessity for dismantling and re-erecting the pipe-line winch house on the new site. Nearly twenty months ago after having started to drive the headings of the two pipe tunnels, which run underneath the pipe line haulage winch house, and which is about hundred twenty feet above, having got in about 50 to 60 feet they noticed that the hill immediately above the portal had subsided, thereby endangering the foundations of the winch house. All tunnel driving was immediately stopped and a strong anchorage constructed in the heading to hold up the hill and prevent further subsidence. This consisted of bunches of 50 lb. rails, the joints between the bunches of rails being made by embedding them in concrete, and was designed for a ground pressure of 500 tons. This stopped all further movement and enabled the existing reinforced concrete portal to be installed during the next six months. Driving was then started again but three months later, the winch began to take far more power than was normally required and gave indications of being out of alignment. Levels were taken and it was discovered that the foundations had settled: meanwhile the winch house itself and the foundations had cracked in several different directions. It was immediately decided to dismantle the winch house and foundations and to re-erect the whole winch on top of the spur 200 ft. further back. This site deprives the driver of a view down the haulageway, but ensured a secure

foundation for the future. The new foundation had recently been laid and it was anticipated that the winch would be working again in a few weeks' time. It had been thought at one time that the damage was due to blasting but tests proved that this was not the case and there was now no doubt that the whole site had settled a fraction of an inch as a result of the cracks that had taken place 18 months before. The trouble was due partly to the absence of a portal, but more particularly to the cavitation that had taken place in the headings due to inexperience on the part of the tunnellers when timbering in that kind of ground. The Department's labour had now gained sufficient experience and could be trusted to drive through any bad ground without fear of cavitation.

One interesting thing that happened was that in shifting the winch house 200 feet back, they had had to add 200 feet to each end of the rope. They knew of no means of satisfactorily jointing such a rope; the Swiss Government did not allow passenger traffic on a spliced rope. The problem was to design a joint which would enable the rope to traverse the rollers or otherwise to purchase an entirely new rope 6,000 feet long. The difficulty was overcome by the introduction of a joint car at a point 200 feet in front of the main car: the joint car would stop at the winch leaving the main car to stop at the original transfer station, the site of which had not been shifted. This enabled all the additional rope to be obtained from spare lengths available at site and therefore, without any extra cost.

There was a misprint on page 17 of the paper where instead of "98 to 198" it should have been "98 to 108". Their power supply had so far been adequate and they did not anticipate any shortage of power: that was probably due to the diversity factor being higher than they had thought; it looked as if they should be able to get through without any additional power. The only trouble they had had was with the Thuji Flume: certain lengths of this traverse very bad ground: leakages had occurred with resulting settlement. This had caused several "shut-downs", but the difficulty had now been overcome and the amount of trouble had now been greatly reduced. They had had a little experience in the methods adopted for laying the invert without interfering with traffic, but it was too early to be able to give any final conclusions.

Mr. Freak.

Colonel Battye has described an elaborate method of concrete mixing by water cement ratio methods. These methods no doubt give a concrete of greater strength than the old fashioned mix such as 1 : 2 : 4 with the quantity of water undefined but the speaker would enquire whether the extra strength has not been obtained by disproportionately extra expense. Have higher allowable stresses been allowed, if so, what has been the saving in concrete and aggregate and what has been the cost of the special staff to run the mixing method with complicated weights, to use the hydrometer to test the quantity of water in the aggregate, to run the laboratory together with the cost of the laboratory equipment. He

would also ask what happens when the sun comes out or there is a shower of rain? Does concrete mixing have to stop while a fresh hydrometer test is made? He would enquire why mixing by the full bag method has not been used so as to avoid the weighing of the cement?

For running haulageways, electric power was required during construction, but the speaker would enquire whether the two temporary hydro electric power stations put in were the best means of getting that power. The hydro electric plant being only suited for the specific head and quantity of water will have practically no second hand value. The first hydro electric plant at Dhelu owing to an error in the size of the flume, cannot give the power for which it was designed, whilst the cost of the carriage of the second hydro electric plant to Thuji must have been very costly.

The speaker would suggest that oil sets on the Diesel or semi-Diesel principles such as were used at Sukkur should have been installed; with these the amount of power available would have been certain as against the doubtful quantity of power due to lack of water for the Dhelu hydro electric set. Oil driven sets of standard pattern could have been readily purchased and quickly installed and so allowed construction to have been put in hand quicker. Most important of all, oil driven sets would have had a useful second hand value on completion of construction. For the subsidiary machines such as air compressors, concrete mixers, the author had adopted electric drive in every case, which again will mean that the machines will have little or no second hand value in India. The usual practice is to have a separate oil engine for each machine and then the machines would have been standard and would have had a useful second hand value.

With electric driven machines, commencement of work had to be delayed until electric power was available.

The author mentions an eletric driven excavator; the speaker would enquire whether there has been sufficient work to justify an excavator at all. This again being electrically driven will have practically no second hand value. In the figures for the cost of the excavation with this machine, no detail of the lead has been given.

Lastly with regard to the housing, in the beginning brick panels were used and later plastered expanded metal. The speaker would ask which method has been the cheaper and why bricks were ever adopted with the bad brick earth available at the site?

Mr. Mool Chand Sharma.

He described the discharges of the rivers of the Punjab and compared them with the discharges of the Uhl (Beas). With reference to the working of the Dragline he wished to ask Colonel Battye what was the interest and depreciation referred to in the last sentence on page 7 of his paper: The lowest cost in any one month (exclusive of interest and depreciation on the machine) was Rs. 34-2-3 per thousand cubic feet. He

said that in Delhi he had been able to do similar work at Rs. 20 for the hardest sandstone.

L. Brij Mohan Lal.

He referred to Appendices 4 and 7 and enquired why the peak load capacity for Dhalu was 600 k.w. only when the k.w.s. installed were 900.

As regards the points raised by Mr. Mool Chand, about the excavation cost, he said that the usual rates for excavation of rock by blasting in the Kangra Valley were Rs. 40 per thousand cubic feet. In the Uhl River Project the cost was Rs. 34-8-0 per thousand cubic feet by the electric excavator excluding depreciation and interest charges. He said that the cost might come to Rs. 60 per thousand if the latter were included. Thus the work of the excavator was too costly.

Mr. Nicholson.

He referred to the methods adopted for the transportation of plant and machinery to the Headworks on the other side of the hill, and enquired if it would not have been preferable to have driven the tunnel heading first and take the material for construction of the works in the Brot Valley through it.

This would have saved the extra haulages over the hill.

Colonel B. C. Battye (reply).

Mr. Freak's points were in connection with concrete. He did not hope to save money by getting more highly stressed concrete and using higher stresses in the design ; the chief effect of this method was :—

(1) That they could get more uniformity in their concrete, the result of which was that they could be *certain* of their concrete. When lining pressure tunnels, where there can be no question of ever being able to carry out repairs, reliability of the concrete is of vital importance—far more so than economy.

(2) This method often resulted in a cheaper concrete, *e.g.*, in the building of the tunnel portal, they had found that, in actual practice by the adoption of these methods, it had been found that the actual mix, instead of being 1 : 2 : 4, it worked out to $1 : 2\frac{1}{4} : 4\frac{1}{2}$, so that an appreciable saving had been effected in the cost of the concrete by the adoption of these methods.

There was of course some extra cost involved in the laboratory staff, but that is the only extra cost : they do not find that any extra establishment had to be maintained for proportioning and mixing. Any intelligent overseer could pick up the idea without extra training and was able to control it without extra staff. The equipment costs a trifling amount compared to the value of the work that is handled.

As regard the question of having a hydrometer on the works, in a very short time the S. D. O. could tell by eye, whether to allow for 8 or 14 per cent. moisture, *e.g.*, in ordinary weather the moisture varied from about 7 to 10 per cent. and if he made an error of judgment of only 2 or 3 per cent. it was good enough. The S. D. O. checked his judgment once or twice a week (or get these checked for him) in order to keep the water cement ratio constant. The methods adopted were not highly abtruse or complicated and it was found in practice that an ordinary S. D. O. could be trusted to use his judgment.

With regard to electric power, Colonel Battye pointed out that the Appendix was an attempt to arrive at the actual cost of these plants after writing off the whole capital cost during the period of construction less the small credits noted, a considerable portion of which in the case of Thuji was a genuine credit because the whole of the electrical portion of this plant would afterwards be installed as auxiliaries in the main power station.

Their prices per unit were $9\frac{1}{2}$ pies. Now no fuel plant could possibly be installed on the works and hope to generate at these figures, from either oil or coal.

With regard to the electric drive, on all such works, concentrated in the area of a few square miles, direct electrically driven construction plant was, as every one knows, rapidly replacing all other types and could of course be sold and utilised elsewhere.

There was enough work for the excavator: it had been kept running for 16 hours a day for the last three years and expected to be used for another 2. There was plenty of work for it and it had undoubtedly speeded up work and enabled them to carry out all surface excavation more expeditiously. The excavator handled heavy stuff, *i.e.*, boulders from 4 to 6 feet in diameter, stacking them to one side upto 15 feet high. They had found in practice that the cost of working and maintaining the excavator was about equal to the cost of the actual bills paid to the contractor where small numbers of men were employed. The hills usually sloped 1 in 1 and they were perpetually faced with the problem of finding sites for housing men and foremen. The general feeling was that, putting aside the problem of housing and looking after labour on the one side, and depreciation and interest on the other, there was very little to chose either way: the general feeling was that the excavator had justified its use, and that labour saving devices in a country of this nature were justified every time, provided that hydro power could be obtained at a reasonable cost.

Referring to Appendix 4 this was an attempt to get at the cost of this type of installation, per kw. installed. Whenever water was available, provided the Armco flume was capable of carrying the full supply, the plant was capable of generating 900 kws. The cost of modifying the Armco flume so as to ensure its being able to give the full supply was trifling compared to the whole capital cost, so that the figure per kw. installed was correct within one or two per cent.

Mr. Nicholson's proposal to drive the tunnel through first and then use it to provide transportation facilities in to the Brot valley, had never been seriously considered. The time for driving the main tunnel was the governing factor on the whole project and even if they had been able to start driving a year earlier, which might have been possible if they had installed steam driven compressors in the valley below and piped the air to site, they would not have been anywhere near through the hill even by now and would not therefore, have been in a position to start the construction of the hydraulic works in the valley for at least another year. He thought that it was quite possibly true that if they had installed steam driven compressors in the valley below, they might have saved time in the completion of the project: but it must be remembered that they would have had to start driving the tunnel without proper surveys or transportation facilities neither of which had been completed by that date.

With regard to Mr. Sharma's enquiry, regarding interest and depreciation, the cost of the excavator plant had been charged straight off to the sub-head of the project concerned so that he regretted that he was unable at the moment to give exact figures for interest and depreciation on the cost of the excavator.