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Unwatering Tresavean Mine

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TRESAVEAN is a famous old Cornish mine which is recorded as having first been worked some 150 years ago, and to have yielded profits exceeding £800,000 on a paid-up capital of only about £2000. During the first half of the nineteenth century Tresavean held a leading position in the county as a copper mine, and its richness is illustrated by the following figures taken from a book published in 1855, entitled "Cornwall: Its Mines and Miners": - From 1829 to October, 1888, the value of ore produced was £703,182. 14s. 7d; dues paid to the lord of the manor, £85,458. 14s. 7d; cost of labour and material, £316,962. 16s. 9d; profits divided, £344,186. Tresavean is also interesting as having had the first "man engine" in the county installed there. In the early fifties the lode was becoming poor in copper and expensive to work with the plant then in use. It had not yet been recognised that good copper lodes in Cornwall often turn to good tin lodes as depth is attained, so that though a good deal of tin was discovered in the lower workings no one thought much about it. Finally, in 1857, owing to a dispute between the landlord and mine owners and the reasons given above, the pumps were drawn up and the mine allowed to fill with water.

An attempt was made to unwater the mine by means of a Cornish pump between the Years 1881 and 1887. A very great deal of money, about £100,000 was spent in the venture, and the company only succeeded in lowering the water a little further than the 166-fath. level below adit.

When the present company acquired the mine in 1907, none of the old pit work left by the last company was to be seen, and it was locally reported that the old column pipe had been blasted in more than one place below adit, so that it was thought the old work would be of little use as it stood. Moreover, it was considered that there would be a great advantage in having a larger space available in the Shaft for winding purposes than would be possible if the old pit work were left there, or new Cornish pit work of a similar kind put down in its place. It was, therefore, decided to unwater the mine by means of temporary electrical pumps, to be replaced by permanent electrical pumps later, rather than by installing a Cornish pumping plant. Other important advantages considered were, that by putting in an electrical power-generating plant, the extra power available after completing, the unwatering could be conveniently used for milling, winding, or any other purposes required about the mine, and one good central power plant could be run more economically and efficiently than several smaller independent plants scattered about the property. Again, it was thought that Harvey's shaft would be found in fairly good Condition and practically free from chokes from a short distance below adit, in which case it was considered that the work could be carried out more expeditiously with electrical sinking pumps than by means of an ordinary heavy Cornish pumping plant.

Fig 29 shows a vertical section of Harvey's shaft and Rogers' shaft, and the chokes, partial or complete, in the former are marked at their respective positions.

The unwatering has now been successfully carried out by means of electrical high-lift turbine pumps, in spite of serious obstacles, down to beneath the 248-fath. level below adit, which was the first object of the Company and as it is, I believe, the largest and most successful operation of the kind yet achieved in the county with an electrical plant, some account of the work and difficulties overcome may perhaps be of interest. Up to the present date, eight

electrically driven high-lift turbine pumps have been used in the work, but never more than three have been worked together at the same time, the others merely acting, as spares.

Six of the pumps are designed for a delivery of 600 gal. per min. through a lift of 600 ft. when running at a normal speed of 1450 rev. per min. An extra 60ft head is allowed for suction lift and friction head.

Three of the pumps are used for sinking purposes and five are used as station pumps. The sinking pumps are of the vertical type and the station pumps horizontal. The impellers and diffusion vanes are all made of phosphor bronze, and with the exception of the last sinking pump, which has its casing made of gunmetal, the other pump casings are made of special cast iron. The impeller shafts are made of nickel steel, and provided with water-cooled white metal thrust bearings. Each pump has a throttle valve attached to regulate the discharge, and immediately above this there is fitted a check valve to support the weight of water contained in the rising main when the flow of water ceases for any cause.

Similar check valves are placed in the rising main at distances apart of about 40 fath.

Each combined set consists of pump and motor, bolted to the same bedplate in the case of the horizontal pumps, and to the same channel iron frame in the case of the sinking pumps. The motors are of the squirrel-cage induction type for sinking pumps, and slip-ring type for station pumps, all arranged for three-phase alternating current, 50 cycles; 550 volts. At full load, with a maximum current of 210 amperes, the motors are designed to give an output of 190 bhp. The motors for the vertical pumps are of the enclosed type, water-cooled, and ventilated internally by means of a revolving fan attached to the rotor shaft. The fan causes the air to circulate internally through the body of the motor, continually passing it next to the water-cooled sides. This method has been found very satisfactory, as it keeps the motor cool without danger of allowing the moisture in the shaft to enter the windings. The weight of the rotor is carried by a compound ball-thrust bearing on the rotor shaft, which is connected to the impeller shaft by a flexible coupling, the two ends being fastened together by 16 small bolts enclosed in rubber washers. Plate XI shows No. 1 sinking pump at surface.

The power plant consists of three high-pressure Lancashire boilers and three Bellis & Morcom compound two-crank high-speed engines, directly coupled to British Electric Plant Co. alternators, the last set having been only quite recently installed as a spare.

The alternators are of the revolving field-magnet type, with stationary armature, each capable of developing 250 kW., at 550 to 600 volts, three-phase 50 cycles, 875 rev. per min. The steel rotor is mounted on a steel shaft. The exciter is of the open shunt-wound multipolar type, directly coupled to the alternator. There are two methods of regulation, by shunt resistance in exciter field, and by resistance between exciter and alternator field; the former being the only one used at present.

There are two switchboards, one facing the first two engines, and the other the third engine. The first and larger board contains two generator panels and four feeder panels, one feeder for the winding engines, one for lighting, one for the sinking pumps, and one for the station pumps. The second switchboard has one generator panel, one feeder panel, and one panel with a three-pole two-way switch for connecting No. 3 alternator with No. 1. or No. 2. Both switchboards are supplied with the necessary ammeters and voltmeters. Each feeder is controlled by a three-pole oil switch fitted with overload release on two phases.

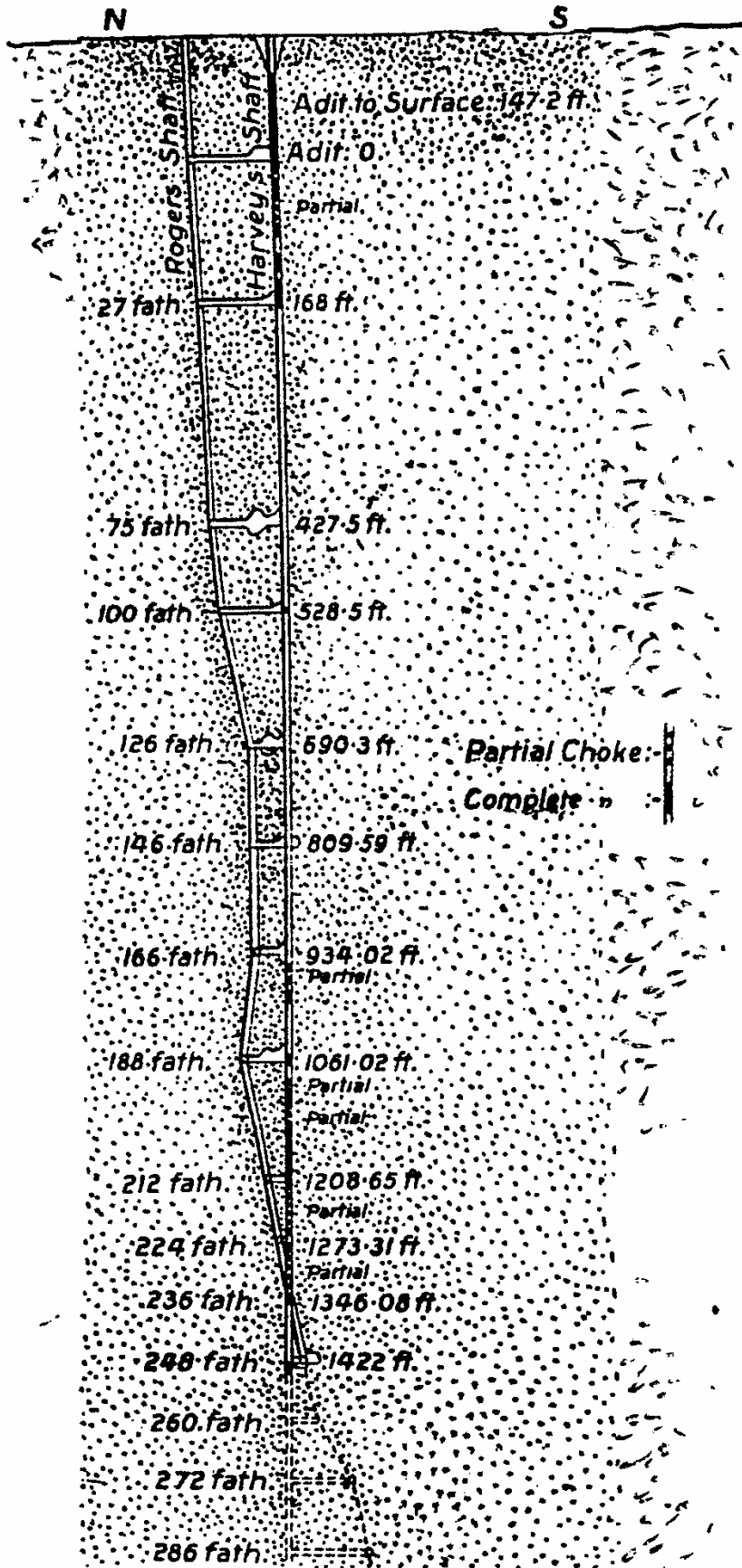


FIG. 29.—Vertical Section, Harvey's and Rogers' Shafts.

Two varieties of cables are used for the pumps: the smaller more flexible type is used for the sinking pumps and lowered intermittently down the shaft, and the larger and heavier type is securely fixed in the shaft and connected with the station pumps. As the sinking pump cables are only for temporary use the conductors were allowed to be of smaller cross-section than usual for the maximum current which might be used. Each cable is 7.4 in. in circumference, three-core pattern, 0.15 sq. in. section, pure and vulcanized rubber insulated, double wire armoured, braided and compounded over all. Weight about 1240 lb. per 100 yd. Each cable for station pumps is 10-in. circumference, three-core pattern, 0.217 sq. in. section, bitumen insulated, double wire armoured, braided and compounded over all. Weight about 3210 lb. per 100 yd.

Each of the sinking pump cables is wound on a light-built steel drum, 6 ft. diam., 6 ft. 6 in. between flanges, which are 9 1/2 in. deep. The inner end of the cable was originally connected with slip rings at the end of the drum axle, but the rings being found rather small for the purpose a plug is now used. The other end of the plug is connected with a short length of cable leading from an oil switch at the feeder panel. The further ends of both cables, together with the wire rope, which supported them, pass over three 6-ft. diam. pulleys at the shaft collar and thence down the shaft to a junction box suspended at the end of the wire rope. The suspending rope is made of plough steel, 3 7/8-in. circumference, and is attached to both cables by means of wooden-lined iron clamps so as to support the entire weight of both cables. The clamps are fixed about 40 ft. apart, and are designed to run on wooden guide rods fastened to the dividers of the shaft.

The two station pump cables are securely fastened in the shaft by a series of wooden iron-bound cleats about 4 ft. long and 10 in. wide, which are themselves bolted to the wall plates or other strong timbers in the shaft. These cleats are placed about 15 yd. apart. The lower end of each cable is connected with an oil switch placed at the pump station, and the upper end is connected directly with the oil switch of the feeder panel.

The winding machinery for pumps, cables and men is driven by two electric motors, and also by a small steam winch which is used as a convenience in lowering the pumps slowly, and it could be employed in case of emergency if the electric power should fail.

The skip and man-cage hoist has a single drum 6-ft. diam. and 8 ft. 8 in. wide, between flanges 9 in. deep. It can raise three tons 800 ft. per min. Post type of brake, drum speed 16 rev. per min., connected with motor by gearing and raw hide pinion; electric motor, synchronous speed 500 rev. per min., 90 bhp. slip ring induction type. Speed is regulated by standard reversing controller with crane-rated resistances.

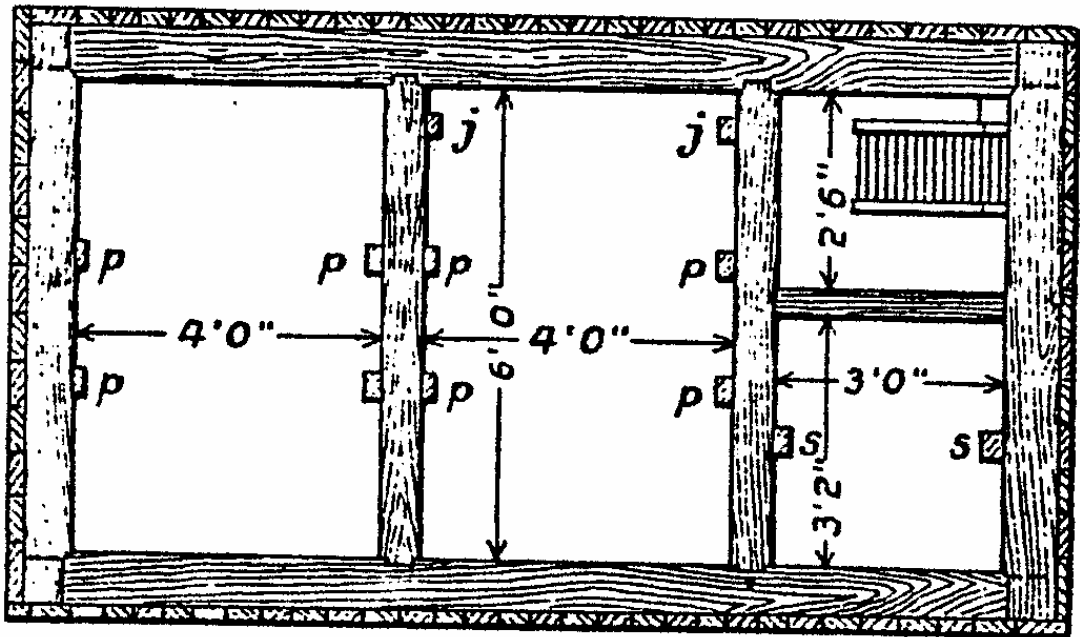
For raising and lowering the pumps and cables there is a combination three-drum hoist driven by a 30 b.h.p. electric motor; drum A, 6 ft. diam., 4 ft. wide between flanges, 12 1/2 in. deep; drum B, 6 ft. diam., 3 ft. between flanges, 10 in. deep; drum C, the same as B. The three-drum hoist is shown in Plate XII.

The main hoist rope is ordinary lay, special plough steel, 2 7/8 in. circumference; of the two pump ropes, the larger is .52 in. circumference, 340 fath., and the shorter 4.8 in. circumference, 240 fath. long. Both the ropes are of the ordinary lay, patent plough steel. The rope for supporting the electric cables is 3 7/8 in. circumference, ordinary lay, special improved plough steel. The man hoist and pump hoist ropes were designed to have a factor of safety of eight above the maximum dead load, and the cable support rope a factor of safety of six above the maximum dead load.

When the writer first came to the mine he found at Harvey's shaft an inverted cone-shaped excavation 40 ft. in diam. at the surface, tapering down to the dimensions of the shaft, where the first solid choke began at about 46 ft. below the surface. The necessary timbers were put across this hole, a windlass set up and the work of clearing began without delay. Good solid rock was found about 40 ft. below surface, and the first set of shaft bearers were put in at 46 ft. from the top. It was soon discovered that the shaft was evidently about 12 ft. by 6 ft. within the old timbers, and the writer then decided to make the new shaft in three compartments, two of them 6 ft. by 4 ft. within timbers, and the third compartment at the west end 6 ft. by 8 ft., the centre dividers being each 6 in. wide. The top frame sets were all made of 8 in. by 8 in. pitch-pine timbers with the bevelled mitre joint; dividers 6 in. by 8 in., with dovetailed ends, are mortised into the wall plates; the studdles are 6 in. by 8 in., and the corner posts 8 in. by 8 in.; outside lagging 2 in. thick. The shaft timbering was designed with the object of first suiting unwatering operations, and afterwards permanent working conditions. The two large compartments were first arranged to each take one of the sinking pumps with all the necessary cables, tackle, etc., as well as the temporary 6 in. rising main. The third compartment is at present divided into two parts, one 3 ft. by 8 ft. 2 in. for the skip or man cage, the other only 3 ft. by 2 ft. 6 in. for ladder way. After the unwatering is finished and the proper hoisting arrangement has been installed in the two large 6 ft. by 4 ft. compartments then the small skipway will no longer be required, and the whole west compartment, 6 ft. by 8 ft., can be used for the ladder way and permanent rising main.

Fig. 30 is a plan of the shaft, 17 ft. below surface, showing positions of skip, pump, and junction-box guide rods. The regular timber sets with 2 in. lagging are only carried up to about 17 ft. below the timber collar at surface, the intervening space being entirely secured by a 2-ft. concrete lining, in which 6 in. by 8 in. dividers and end pieces alone are set to carry the necessary guide rods. The concrete lining is built from solid rock to surface, and the depths to which it goes down on the four different walls are as follows: -south side 86 ft., north side 80 ft., east end 291 ft. west end 46 ft. The proportion of cement used to the aggregate concrete mixture was about 1 to 7. Although the actual dimensions of the concrete wall were purposely varied a good deal according to conditions, the extremes being from 3 ft. 6 in. down to 9 in. it can be roughly stated as averaging about 20 in. thick with inside dimensions 13 ft. 8 in. by 7 ft. 8 in. In many places large loose rocks were built into the concrete wall, making it wider than 2 ft., and giving it more strength; but on the other hand, where the shaft was also completely timbered and the surrounding country fairly well settled, the concrete lining was allowed to be considerably less than 18 in. thick. The opening between the concrete wall and the old sides of the cone-shaped hollow was carefully filled and rammed, and the headgear foundation was built up of reinforced concrete resting on rough masonry covering a large base.

The headgear was designed by the writer with a view to making it amply strong and suitable for the double purpose for which it might be required, that is to say, first for unwatering operations, and afterwards for regular mining work. The chief conditions which it had to suit were as follows:-(1) To carry two sinking pumps with weight of attached suspending ropes, making total loads of 12 tons and 14 tons respectively, maximum speed of winding 20 ft. per min. (2) To carry a 4-ton load in temporary skipway at a maximum speed of 800 ft. per min. (3) To carry 5-ton loads for regular winding in large compartments at a speed of 1500 ft. per min. (4) To allow as high an opening as possible in one direction through the headgear, so that the sinking pumps with their long, hanging frames could be easily handled. . The pump pulleys were arranged to be fixed 42 ft. above shaft collar, the temporary skipway pulley at 581 ft., and the regular winding pulleys at 60 ft. above shaft collar. The opening left for the sinking pumps was 36 ft. high. The headgear fulfils all the required conditions.



j. Junction box guides. *p.* Pump guides. *s.* Skip-way guides.

FIG. 80.—Plan of Harvey's Shaft, Tresavean Mine.

It is very rigid and has been cheaply built, the largest timbers used being only 12 in. by 12 in., with the exception of the two old pieces, 15 in. by 15 in., which remained over after having been used as original supports across the 40 ft. excavation. Views of the headgear are shown in Plates XI and XIII.

A temporary rock-bin and shoot has been built on the headgear to take all material discharged from the temporary skip during unwatering operations, and a small tram line leads northerly from the rock-shoot out over the dumps in one direction, and another small line leads southerly from the skipway, its object being to facilitate the handling of all heavy and bulky material such as the old pit work, which is drawn up through the shaft by means of the rider frame alone, without the skip being attached. The tram rails extend over folding doors which open and close over the skipway, so that wagons can pass directly under the rider frame and skip when required, and the skip is removed from the rope coupling by this means.

The skip and rider frame arrangement was specially designed by the writer to fit the peculiar conditions and requirements of the case, and as it has been found to answer most satisfactorily from the start, to have much facilitated the work, and so proved a saving in time and labour, a detailed description may perhaps be of interest.

Fig. 31 herewith shows elevations and plans of the sinking skip and the rider frame. The channel irons J, which form the chief portion of the rider frame, act as guides and run on 4 in. by 2-in. guide rods fixed in the skipway. The rectangular iron frame L encases the skip or any other large and heavy body which is to be raised or lowered in the shaft. The top horizontal bars I are used to stiffen the frame and also as a safe step on which two men can stand to ride on the frame when it is travelling in the shaft. C is the top connection of the rider frame, which, when unbolted, allows the frame to be taken off the rope; it also encases the beechwood bushing B, in the form of a reel, through which the wire rope passes. E is a

rubber pad which fits into the cast iron easing F, and forms with it a buffer between the rope socket and the rider frame. The iron casing, F is made a comfortable fit for the rope socket G.

The sinking skip has a capacity of 24 cub. ft., and is made with a sloping bottom so that the contents may be easily discharged after merely knocking up the door catch. The special features about the skip are that it has no guides of its own, but is dependent upon the rider frame to carry it safely through the skipway, and, being rectangular in shape, it cannot revolve in the frame like an ordinary sinking bucket with crosshead.

For the size of the shaft compartment it is able to be of much larger dimensions and capacity than an ordinary sinking bucket could be, and it is more easily discharged. The skip is made to pass easily in and out of the rider frame by the suitable shape of the bail H with the trunnion shields P and the sloping top ends M and N. The small rings T at the bottom of the skip were put there to pass a rope through in case it was required to help in guiding, the skip into the frame when moving up from the bottom of the shaft, but it was never found necessary to use a rope for this purpose.

This particular form has the following advantages over an ordinary sinking bucket:-(1) It has a larger capacity; (2) It is more easily discharged; (3) It will not revolve in the frame, and hence is safer and better for men to ride on, and not so injurious to the rope. The rider frame has the following advantages over the ordinary crosshead bucket guide:-(1) It is a safer guide in a confined space; (2) It has sufficient weight to travel down the shaft on the end of the rope by itself; (3) Two men can quite safely ride on it alone; (4) It is particularly suitable for drawing up large materials, such as pump rods, column pipes, etc., in a confined space. An ordinary skip would, of course, be most inconvenient and unsuitable for working continually below the guide rods and repaired portion of the shaft, as is the case with unwatering operations, and, as already explained in the present case, with the very small space left for temporary winding purposes an ordinary bucket and crosshead guide would have been very inefficient and inadequate.

It can be easily understood how safely and conveniently other large and heavy materials can be drawn up instead of the skip, providing it is possible to make one end enter the frame of the rider. By means of the rider frame and rope passing through it we were able to draw up the old pit work from the shaft quickly and conveniently. The combination skip and rider frame carries eight men, divided as follows:-Four inside skip, one standing on top of front end N, one on top of back end M, and two facing each other on crossbar I. This number makes a fairly close fit, but is quite safe for travelling, in the skipway compartment of the shaft.

Plate XIV shows the skip and rider resting, on the small bogie, which is used to remove them from the skipway whenever the man cage is attached to the rope, which, however, is very rarely done. The weight of the skip is about 61 cwt. and of the rider frame about 4 1/2 cwt.

The preliminary work at the mine consisted chiefly in clearing and repairing the adit level, opening up Harvey's shaft down to adit level, erecting headgear, repairing old buildings and putting up new ones, getting the reservoir into shape and bringing in the new water supply, also any of the foundation work that could be decided upon before the final plans of the plant had been made. The adit was found in bad condition and it was cleaned out and repaired from Williams' shaft to the mouth, that is, for a length of about 4500 ft., before pumping started; since then it has been cleared and repaired from Williams' shaft northerly to Comford lode, along Caddy's lode to Boyes' shaft, and westerly of Williams' to the extreme end, making an additional length of about 4000 ft. and a total of about 8500 ft., or more than one and a-half miles. The 4-in. iron pipe carrying the chief boiler water supply comes through the fields and over the dumps for a distance of about 5100 ft., and a number of small branch lines had to be laid from it to various water tanks which were put in for the benefit of farmers through whose land the main pipeline passes. The second water supply, carried through 7-in. stoneware pipes, is laid in the same trench as the first for a distance of about 3850 ft.

Harvey's shaft was cleared, secured and equipped down to adit level and the headgear erected long before the pumping plant was ready to start operations. The work of the first 80 ft. or so below surface was carried out with an ordinary hand windlass and bucket, and from this depth to water level, 150 ft. below surface, the work was carried out with the help of a small steam winch and tip bucket, the wire rope passing over the pulley of a small temporary headgear which was erected on the platform over the shaft excavation. The adit level was opened at a depth of 147 ft. below top of shaft collar, and the station was enlarged here to take two V-notch delivery tanks, each fitted with Lea's patent water recorder. Down to this point the work was easy and plain sailing, in spite of the large excavation at surface and solid choke extending from 46 ft. downwards. The shaft was cleared and secured from surface to adit in about three months time, and the men taken away to open up another lode on the property while waiting for the pumping plant to be installed. During this period much work was done in the way of clearing, and repairing the adit, two independent ladder ways in different parts of the mine were put down from surface to adit, and various explorations carried out on the main lode and other parts of the mine.

Before pumping operations began the choke was cleared down to a few feet below water level, and after the first day's pumping we were again troubled with severe chokages which lasted, with only short clearances between, all the way down to the 27-fath. level, where the last of the chokage was found resting on doors at the level 168 ft. below adit. Regular pumping began about 1 p.m. April 26th, 1909, and the 27-fath. level was not reached until August 9th, the slow rate of progress being due to great difficulties with the chokes. The pumps were not designed to handle the broken rock, gravel, crushed timber, and grit found in all the chokes, and we were obliged to resort to special means to safeguard and spare the sinking pump as much as possible.

At this time we found the best way out of the difficulties, sometimes by getting the suction down through the holes in the chokes, whenever we could make them, into the clearer water below, and sometimes by putting our suction pipe down in the old pump column, which was still standing in place in the shaft. In the latter case it was occasionally necessary to blast out the sides of the old column to let in the water, after having first secured it firmly with chains and timber.

One blast was fired electrically at a depth of 57 ft. below the top of the pipe, which projected two or three feet above water level. A special strainer had to be made to put down inside the column pipe, with special connections across the shaft to the pump; also, since the blast completely severed the old column pipe, it was necessary to secure and support the length of column above the blast with chains below each 9 ft. length, as it was taken off before lowering the pump. In one instance, when the old column pipe was itself choked with debris, we overcame the difficulty by driving down a 2-in. pipe through it to the bottom, a distance of 18 ft., and then blasting out the bottom, which fortunately also cleared the debris and left a clear passage for our suction.

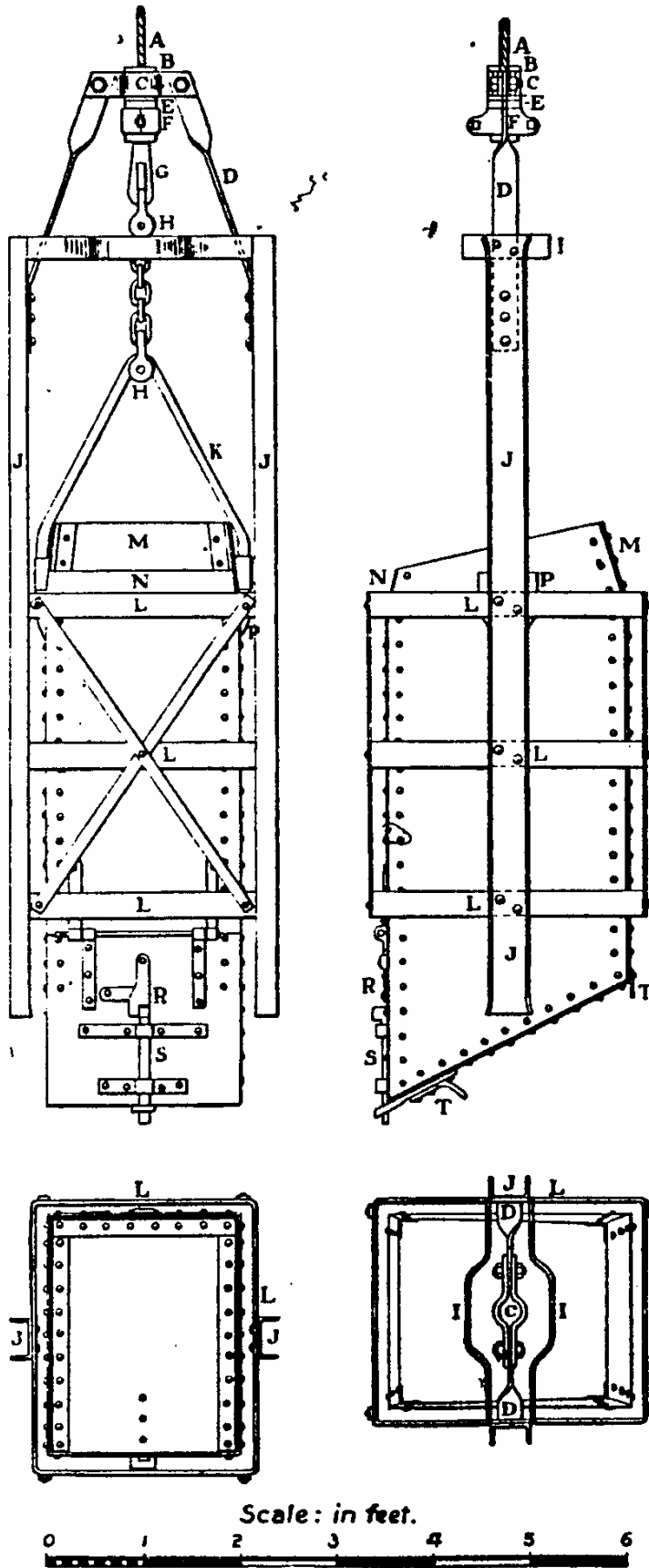


FIG. 81.—Sinking Skip and Rider Frame.

When we got near the doors of the 27-fath. level we resorted to a method which has since been found most satisfactory for all deep solid chokes. The method consists in substituting for an ordinary suction pipe a special one with a sharp point at the lower end, to enable it to be driven down through the choke, and with a connection at the upper end to which a special valve box containing a strainer can be fitted. The conical point is made of mild-steel, and can be welded on or screwed to the lower end of suction pipe. The iron suction pipe should preferably be made in convenient lengths, to suit the convenient distance for each lowering of the pump, that is to say, in about the same lengths as each section added to rising main. But although this may be a convenience it is not a necessity, as the suction pipe, after having been driven through the choke, can generally be raised or lowered a little without difficulty to suit the position of the pump. As the pump is lowered, and each length of suction pipe uncoupled, a screwed flange is taken off the last length which has just been removed, and screwed to the upper end of the next length remaining on the suction, in place of the coupling which was used to connect the two lengths together. The valve box is fitted with connections, so that the bottom may be bolted to the flange at top of the special suction, and the top bolted to the flange of short pipe connection to pump. Inside the box there is an ordinary clack valve in the middle, and a strainer fastened below, which is bent into a synclinal fold so as to expose as large an area as possible to the inflowing water. The box is divided in the middle, and can be easily opened out to examine and clean the strainer or valve. In the first instance this method was used to pump through a choke only a few feet thick resting on doors at the 27-fath. level, and the steel-pointed pipe was easily driven down through some eight feet of debris and through the wooden doors which were supporting it. After having driven the end of the pipe a few feet below the platform, the point was blasted off, the upper end was connected to the valve box, and the valve box connected to the suction end of pump by a short length of pipe forming a reverse bend. The special suction pipe used was 4 in. in diam., and the pump worked very satisfactorily with this arrangement, keeping the water well down below the top of the choke and enabling the men to conveniently clear it away.

At the 27-fath. level an extra quantity of old pump work had to be removed, including cistern, H-piece and supporting timbers, plunger barrel, etc; but, in spite of this extra work in clearing the shaft, the water was lowered and the shaft cleared and repaired for a distance of 24.9 ft. during the week ending August 14th. During the next week a good deal of work was done in clearing the remainder of heavy timber from the 27-fath. level and putting in a new collar there; the running was, however, good, as a distance of 29.6 ft. was made. The following week a little obstructing timber was found in the shaft, but this was easily removed, and the suction put down so that we managed to make 33.6 ft. The next week a little debris and old timber was found resting, on doors about 260 ft. below adit, also the regular run of old timbering finished here. New bearers were put in at 268 ft. to take up the timbering, and carry pumps; but in spite of a good deal of extra shaft work, the water was lowered a further 28.9 ft.

The progress made during the first four weeks from the 27-fath. level downwards is shown in Tables I and 11. The measurements given in the first three columns were taken for each day at 9 a.m., and the water level recorded is the distance below adit collar. The number of gallons pumped, and the hours during which the pump was working were automatically marked on the charts supplied with Lea's ' water recorder, and the figures given in the tables have been taken from these charts. Measurements for suction length and distance of water level below adit were taken every day except Sunday at 9 a.m., and the omission to do so on that day is the reason for the queries shown for the Sunday records of water level below adit. During the week ending September 11th the sinking pump began to fail, and it became evident that it would have to be taken to surface for repairs

TABLE I.

Date, 1909.	Gal. Pumped	Time Pumping.		Av. Gal. per min.	Water Level, Ft. below adit.	Length Suction, Ft.
		Hrs.	Mins.			
Aug. 7th...	—	—	—	—	170.5	9.6
" 8th...	462,614	14	55	517.1	174.5 ?	19.6
" 9th...	475,924	16	0	495.1	178.2	17.8
" 10th...	291,222	13	35	357.1	174.7	13.8
" 11th...	513,088	16	10	529.1	183.0	10.8
" 12th...	595,153	20	50	476.1	189.4	17.2
" 13th...	584,260	17	30	556.4	195.8	13.0
" 14th...	370,019	13	45	448.5	195.4	12.6
" 15th...	427,755	14	45	483.3	196.0 ?	13.2
" 16th...	407,420	13	10	515.9	198.3	15.5
" 17th...	502,558	18	25	454.9	204.1	13.0
" 18th...	605,684	17	20	582.5	212.7	12.6
" 19th...	558,478	22	35	412.2	216.8	16.7
" 20th...	665,962	18	30	599.9	223.8	9.0
" 21st...	471,329	16	20	481.0	225.0	10.2
" 22nd...	718,977	20	25	587.1	231.0 ?	6.3
" 23rd...	574,092	17	25	549.5	237.7	13.0
" 24th...	632,191	24	0	439.0	242.8	18.1
" 25th...	425,939	15	0	473.2	243.8	8.6
" 26th...	730,234	24	0	507.1	251.6	16.4
" 27th...	468,061	14	0	557.2	252.7	8.4
" 28th...	602,779	22	25	447.5	258.6	14.3
" 29th...	620,208	18	30	558.7	265.0 ?	11.7
" 30th...	632,554	24	0	439.2	271.3	18.0
" 31st...	372,561	24	0	258.7	270.7	17.4
Sept. 1st...	385,633	11	55	539.6	272.7	12.5
" 2nd...	648,532	24	0	450.3	279.7	19.5
" 3rd...	487,670	22	40	358.6	281.8	21.6
" 4th...	594,090	19	45	501.3	287.5	15.6
Aug. 7th to Sept. 4th	14,824,387	515	55	478.9	—	—

TABLE II.

Date, 1909.	Gal. Pumped.	Time Pumping.		Av. Gal. per min.	Water Lowered, Ft.
		Hrs.	Mins.		
Aug. 7th to 14th ...	3,291,680	112	45	486.6	24.9
" 14th ,, 21st ...	3,639,186	121	5	500.9	29.6
" 21st ,, 28th ...	4,152,273	137	15	504.2	33.6
" 28th ,, Sept. 4th	3,741,248	144	50	430.5	28.9
Aug. 7th to Sept. 4th	14,824,387	515	55	478.9	117.0

. The distance made during this week was only 12.8 ft., and the quantity pumped 3,210,704 gal. No. 1 sinking, pump was finally stopped at 8.50 a.m. on September 18th, and was raised to surface during the day. When it was stopped it was delivering about 300 gal. per min. No. 2 sinking pump was made ready, moved into place, lowered down the shaft, connected up and set to work early in the morning of the 23rd, when the water level stood at about 273 ft.; it did not, however, run steadily until the night of September 24th, when the water level was about 275 ft. below adit. At 9 a.m. on the 25th the water level was 280.5 ft., and by October 16th it had been lowered to 420.7 ft. below adit. The record for the three weeks is as given in Tables III and IV.

TABLE III.

Date, 1909.	Gal. Pumped.	Time Pumping.		Av. Gal. per min.	Water Level.	Length Suction.
		Hrs.	Mins.			
Sept. 25th...					280.5	9.5
" 26th...	597,695	16	25	607.0	-- ?	—
" 27th...	764,367	21	0	606.6	297.9	11.75
" 28th...	868,946	24	0	603.4	307.2	21.0
" 29th...	606,773	16	10	625.7	311.1	6.5
" 30th...	858,778	24	0	596.3	319.0	14.75
Oct. 1st...	860,957	24	0	597.8	327.0	22.75
" 2nd...	495,658	13	30	611.9	329.8	6.8
" 3rd...	874,392	24	0	607.2	— ?	—
" 4th...	803,584	24	0	558.0	346.7	23.7
" 5th...	405,241	12	0	562.8	348.5	19.7
" 6th...	638,728	18	35	572.9	356.3	10.7
" 7th...	820,651	24	0	569.8	368.2	22.5
" 8th...	266,893	8	50	503.7	368.0	22.25
" 9th...	455,352	14	40	517.6	369.6	—
" 10th...	874,013	10	45	579.8	— ?	—
" 11th...	783,612	24	0	544.1	383.4	19.5
" 12th...	583,896	18	15	533.2	390.7	8.25
" 13th...	709,536	24	0	492.7	401.6	19.5
" 14th...	481,134	22	50	351.2	404.1	22.0
" 15th...	496,021	14	15	580.1	411.2	10.25
" 16th...	762,552	24	0	529.5	420.7	20.1
Sept. 25th } to Oct. 16th }	13,508,779	403	15	558.3	—	—

Tables III and IV show the best records made during the unwatering operations. The average rate for the full three weeks comes out at 6.676 ft. per day, and during the weeks ending October 2nd and October 16th the average rate per day was over 7 ft.

The 75-fath. level was exposed at 427.5 ft. below adit. An old balance-bob was found in place here with the front end projecting several feet over the north side of the shaft. We

considered the question of removing it to surface, but finally decided that under the circumstances it would be cheaper to cut the end off, which was accordingly done.

There was much heavy old pit work to be removed from here, including the usual plunger barrel, H-piece, cistern and timber supports, and this work caused some delay in the rate of sinking, so that only 13.8 ft. was made during the week ending October 23rd; 26 ft. was made during the following week, and 26.7 ft. during the week ending November 6th. Suction lengths of 24.5 ft. and 24 ft. respectively were recorded for these two weeks. At this time the increase in inflowing water from 250 gal. per min. to 450 gal. per min. began to delay the work somewhat. On November 6th the water level was down to 487.2 ft., and on the 20th down to 527.2 ft., so that up to this date the average progress for the 208 days since starting pumping works out at a little more than 2.58 ft. daily, including all stoppages from any cause whatever. On November 20th No. 2 motor short-circuited, due to leakage of a small cooling water pipe, which had been corroded through and had then been spraying water into the motor windings for some time without being noticed. No. 2 pump was taken to surface on the 22nd and the motor removed, and No. 1 motor coupled to the pump in its place. The pump was then lowered again and set to work at 8.45 p.m. on the 26th, when the water level had risen up to about 440 ft.

TABLE IV.

Date, 1909.	Gal. Pumped.	Time Pumping.		Av. Gal. per min.	Water Lowered.
		Hrs.	Mins.		
Sept. 25th to Oct. 2nd	5,058,174	139	5	605.5	49.8
Oct. 2nd " " 9th	4,264,841	126	5	568.8	39.8
" 9th " " 16th	4,190,764	138	5	505.8	51.1
Sept. 25th to Oct. 16th	13,508,779	403	15	558.3	140.2

By December 4th it had been reduced to 495.9 ft., and by the 18th to 528.7 ft., just 1 1/2 ft. lower than the depth reached on November 20th. At this depth the floor of the so-called 100-fath.level was uncovered.

It had been originally intended to install the first station pump at the 100-fath. level, but as the incoming water increased to 535 gal. per min. on December 13th, and up to 660 gal. per min. on the 28th the sinking pump was unable to hold it and was driven back up the shaft, so that by January 1st, 1910, the water had risen to 463 ft. below adit, and by January 14th up to 447 ft. below adit. As soon as it was found that the sinking pump could not hold the water it was decided to alter, cut out, and fit up the 75-fath. station so as to install a duplicate set of horizontal pumps there instead of at the 100-fath. level. Also as a large portion of the inflowing water could be caught at this level by putting in a line of launders about 700 ft. in length, work was immediately started for this purpose. One of the large cables for station pumps was lowered down the shaft and fixed in position, and the second 6-in. rising main carried down to the 75 station. The old balance-bob hole was dammed up and made into a good reservoir to take the water from the 75-fath. level and also from the sinking pump

below, both these water supplies being first passed through strainers and V-notch measuring boxes.

The first station pump was installed with all the necessary electrical and water pipe fittings and set to work on February 4th with one impeller removed, when the water level stood at 462 ft. below adit. This pump had at first to be throttled down to take only the water from the 75-fath. level, which was then about 200 gal. per min., but this sufficiently relieved the sinking pump, so that the water level was reduced down to 494 ft. by February 14th. Unfortunately it was then found necessary to take No. 2 sinking pump to surface for repairs, leaving only the new station pump to, pick up the water at the 75-fath. level. The newly repaired No. 1 sinking pump was lowered down and set to work at 9 p.m. February 17th, and from that date until March 13th it delivered up to adit. The station pump and the sinking pump then ran in parallel from February 17th to March 18th, each delivering its separate supply of water to adit, and during this period the water level was reduced from 438 ft. to 575 ft. below adit, that is to say, for a distance of 137 ft. in 24 days, in spite of the fact that the incoming water ranged from 613 gal. per min. on February 15th to 735 gal. per min. on February 26th, and had only decreased down to 580 gal. per min. by March 15th.

On February 21st and 22nd the two pumps together were delivering, over 1025 gal. per min. to adit. From March 18th onwards the station pump received its supply of water from the sinking pump as well as from the 75 level; the fifth impeller was replaced, and at first it delivered as much as 715 gal. per min. to adit from the cistern at the 75 station.

Good, steady progress was made from March 18th to May 21st, the water level and distance made each week being as given in Table V.

The average rate of sinking made during this period of ten weeks comes out at 85 ft. per week, or 5 ft. each day. The 126-fath. level was uncovered at a depth of 691 ft., and the 146-fath. level at a depth of 810 ft. For the four weeks ending April 16th the average speed was 42.1 ft. per week, or just over a fathom each day.

Up to May 21st, 1910, the average speed for the 390 days since the start of pumping comes out at about 2.37 ft. each day, or say 16.2 ft. each week, including all stoppages. At the beginning of June, No. 1 sinking pump was working near the limit of its hydro-static head, and its delivery was consequently small, finally decreasing so much as only to equal the quantity of incoming water. On the 18th it was stopped about 8.45 a.m. and taken to surface for repairs, and No. 2 sinking pump was lowered and at work by 4.25 a.m. on June 16th.

The 166 level was uncovered at a depth of 934 ft. below adit. From the 27-fath. level down to the 166-fath. level no bad solid chokes were encountered, although interfering timbers and a small amount of debris had to be constantly cleared away. Between the 166 and 188 levels, however, we passed through three nearly solid chokes each from about 10 ft. to 15 ft. thick, and the rest of the way was partly choked, and with bad rotten walls to the shaft. Fortunately we found weak spots in these chokes, and by means of various grab hooks we managed to make holes in different places, through which we were able to put down the suction and so keep the water level down to or below the top of the choke. We did our best to protect the strainer, which had to be constantly cleaned, sometimes with a long-handled brush used under water, but often it was necessary to raise it out of water to clean it properly. Working through chokes in this way causes severe wear to the pump, as a certain amount of grit will continually pass through the strainer and up the suction pipe into the pump chambers.

TABLE V.

Date, 1910.	Water Level.	Distance made. Ft.
March 12th	571.5	—
„ 19th	594.8	23.3
„ 26th	641.5	46.7
April 2nd	675.7	34.2
„ 9th	720.2	44.5
„ 16th	763.2	43.0
„ 23rd	786.0	22.8
„ 30th	818.3	32.3
May 7th	854.2	35.9
„ 14th	890.7	36.5
„ 21st	921.2	30.5
March 12th to May 21st ...	—	349.7

The thrust bearings are also liable to become heated on account of the small cooling water pipes getting choked and thus preventing free water circulation through the water jacket. The strainer used is made of copper sheeting with 1/8-in. punched holes, which, however, soon wear to a slightly larger diameter.

A cross-course first touches the shaft at the 166 level, and from there down to the 236-fath. level the shaft has been badly broken up and disturbed by it. A good deal of work had to be done at the 166 station in order to make a suitable room for two station pumps and a cistern to take the delivery from the sinking pump, as well as the small amount of water picked up at the level. The water supplies from the sinking pump and 166 level are led through strainers and V-notch measuring boxes as is the case at the 75 level station, and there is an arrangement of pipes by means of which the water delivered from either station pump can be circulated back through the cistern. This arrangement has been occasionally used for testing purposes. There is also a branch from the sinking pump delivery taking the water back in the level, and this pipe, which is controlled by a throttle valve, can be used whenever it happens that, from some cause or other, the delivery from sinking pump exceeds the delivery from the station pump. There is only one rising main from the 166 to the 75 station, and each station pump is independently connected to it. The electric cable supplying current for either of the pumps at the station is securely attached to the north wall of the shaft in the same way as the cable to the 75 station.

No. 2 sinking pump took the water down to 1085 ft. below adit, while delivering up to the 75 level, so that the shaft was cleared and repaired down to this depth at the same time as preparations were made at the 166 level for the new station pumps. Unfortunately, neither of the new horizontal pumps for the 166 station was delivered until long after the time promised, and the first one could only be started on regular work by September 17th. The conditions then were: No. 2 sinking pump delivering to 166 station; No. 3 station pump taking water from 166 level and from the sinking pump, and delivering to the 75 station; No.

1 or No. 2 station pump taking water from 75 level and from No. 3 station pump, and delivering to the measuring tanks at adit level.

A great deal of exploration work was done at this time and during the following months, when we had much trouble with pumping operations. Also much work was being carried on in the adits, and a dam was being built at the 75 level to hold back the large quantity of inflowing water which collected there.

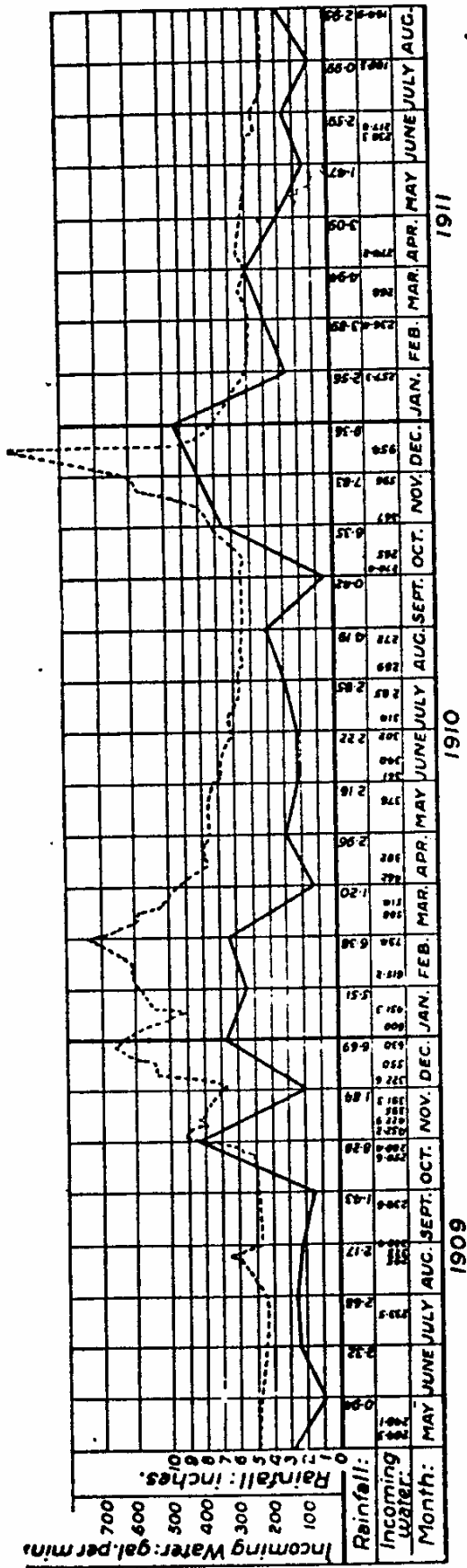
On October 10th No. 2 sinking pump was stopped on account of continual failure of thrust bearing, and brought to surface for repairs. No. 1 sinking, pump was put down for its third campaign and started work early in the morning of the 14th. The incoming water, which had decreased to 265 gal. per min. in the early part of October, began to increase towards the end of the month. At the beginning of November the quantity had increased to 867 gal. per min., and by the beginning of December to 600 gal. per min.

The rainfall during December was exceptionally heavy, totalling 9.36 in. and this following on the two very wet months, October and November, gave a total of 23.54 in. for the three months. This is the heaviest fall of rain recorded in this district for the same three months during any year since 1892. The rainfall for 1910 was as much as 51.58 in., which is the second highest record in 28 years.

Fig. 32 gives curves showing the effect of rainfall on incoming water at Tresavean from May, 1909, to the end of August, 1911. The great increase of incoming water up to about 950 gal. per min. on December 17th, when the dam was first closed, caused a set-back in the pumping operations, as the water rose in the shaft, driving the pump back 133 ft., from the 4th to the 17th of December. From that date onwards, however, steady, although sometimes slow, progress has been made. Table VI gives the progress made for each four-weekly period from the start of pumping, April 26th, 1909, up to September 9th, 1911.

It will, perhaps, be advisable now to briefly discuss a few points which either have not been touched upon at all, or which may not have been sufficiently explained. First, then, with regard to the way the sinking pumps are supported in the shaft. The author has seen four other mines using high-lift turbine pumps for unwatering purposes. In one of these cases the pump was slung by a four-fold rope system and in three cases by a two-fold rope system. The four-fold system requires two pulleys on each pump and two pulleys for each pump on the headgear; the two-fold system requires only one pulley on each pump and one pulley for each pump on the headgear. We decided to use a single fall larger rope attached to a pair of triangular plates carrying, a two-fold rope sling passing round the pulley wheel of pump. The single fall of rope, although double the strength, has, of course, only to be half the length of a two-fold rope, and consequently, there is only half the length to be looked after and greased. The short sling, which is of just sufficient length to clear comfortably the bend of delivery pipe, makes a convenient way of supporting the pump frame without straining it. In our case, taking into consideration the comparatively great depth the water would have to be lowered, we decided to support the rising main along the walls of the shaft, connecting the bottom of it by means of a short reverse bend with the top of pump delivery, a telescopic expansion joint being inserted above the top of pump delivery and just below the bend to rising main.

We further decided that the pump should always be supported by chains as well as by the rope, except when it was actually being lowered or raised in the shaft. In order that the weight of the pump should be taken up quickly and conveniently, two adjustable stretching screws were obtained for each pump, and the writer had $\frac{3}{4}$ in short link chains made in lengths of 25 ft. and 9 ft., each chain having a large hook at one end and a large link at the other end. The 9-ft. lengths were made with special large links set about the same distance apart as the adjusting length of each stretching screw.



The higher and dotted curve indicates the Incoming Water in gallons per min.

The lower and heavier curve shows the Rainfall in inches per month.

NOTE.—The Dam was closed in the 75-fathom level, Dec 17th, 1910.

Fig. 82.—Effect of Rainfall on Incoming Water at Tresavean, May, 1909—August, 1911.

TABLE VI.
TRESAVAN PUMPING RECORD SUMMARY 26-4-09 TO 9-9-11.

No.	PERIOD.		Gallons Delivered at Adit.	LENGTH OF RUN.			WATER LEVEL.	
	From.	To.		Sinking Pump.	75 Sta. Pump.	166 Sta. Pump.	Lowered.	Ft. Below Adit.
				Hrs. Mins.	Hrs. Mins.	Hrs. Mins.		
1.	26-4-09	22-5-09	11,693,993	424 5	—	—	41.6	44.6
2.	22-5-09	19-6-09	12,240,646	421 25	—	—	57.5	102.1
3.	19-6-09	17-7-09	12,181,212	451 20	—	—	48.2	150.3
4.	17-7-09	14-8-09	10,954,593	442 50	—	—	45.1	195.4
5.	14-8-09	11-9-09	14,743,411	535 40	—	—	104.9	300.8
6.	11-9-09	9-10-09	12,790,890	428 15	—	—	69.3	389.6
7.	9-10-09	6-11-09	16,123,233	533 15	—	—	117.6	487.2
8.	6-11-09	4-12-09	15,073,825	511 10	—	—	8.7	495.9
9.	4-12-09	1-1-10	20,956,367	641 55	—	—	-82.4	468.5
10.	1-1-10	29-1-10	21,454,731	644 5	—	—	11.7	475.2
11.	29-1-10	26-2-10	27,127,942	572 55	506 0	—	34.4	509.6
12.	26-2-10	26-3-10	27,950,806	630 30	611 15	—	131.9	641.5
13.	26-3-10	23-4-10	21,464,735	614 5	687 20	—	144.5	786.0
14.	23-4-10	21-5-10	19,182,162	625 5	662 40	—	135.2	921.2
15.	21-5-10	18-6-10	14,140,243	571 45	597 45	—	8.3	929.5
16.	18-6-10	16-7-10	15,191,111	556 40	567 0	—	79.8	1009.3
17.	16-7-10	18-8-10	11,895,800	496 30	496 25	—	10.7	1020.0
18.	18-8-10	10-9-10	10,724,008	412 5	411 45	—	-10.6	1009.4
19.	10-9-10	8-10-10	12,848,986	530 0	520 5	413 25	51.8	1061.2
20.	8-10-10	6-11-10	12,538,882	496 35	481 22	180 15	24.6	1085.8
21.	6-11-10	3-12-10	20,502,470	651 5	659 55	643 35	23.8	1109.0
22.	3-12-10	81-12-10	19,843,769	618 20	650 5	611 55	-110.0	999.6
23.	81-12-10	28-1-11	16,325,135	581 45	573 45	574 25	108.8	1108.4
24.	28-1-11	25-2-11	10,893,686	533 0	504 7	508 25	27.2	1185.6
25.	25-2-11	26-3-11	10,265,390	518 15	505 55	508 25	20.9	1156.5
26.	25-3-11	22-4-11	10,630,324	560 24	531 8	533 22	21.5	1178.0
27.	22-4-11	20-5-11	10,830,046	614 47	598 35	602 23	35.0	1213.0
28.	20-5-11	17-6-11	10,391,039	622 48	606 0	609 24	52.3	1265.8
29.	17-6-11	15-7-11	10,299,537	630 32	617 50	616 30	70.3	1336.1
30.	15-7-11	12-8-11	9,714,185	562 55	562 25	562 41	68.4	1404.5
31.	12-8-11	9-9-11	8,551,475	552 37	551 0	552 58	60.3	1464.8

This arrangement, together with two large S-shaped books about half the length of straining screw, make it possible conveniently to tighten up the chains supporting the pump for any position of the pump.

The upper ends of the chains are slung round temporary horizontal timbers securely supported in the shaft, and the pump may be suspended 200 ft. or so below these supports on a series of chains hooked together, the special 9 ft. lengths only being used at the bottom. Each tightening screw is shackled to the eye at the top of each of two steel plates, which are securely bolted to the two channel irons of the pump frame. Two sets of chains are attached to each pump, and these are sufficiently strong to carry the full weight of pump and water column in the rising main, although the chains are never tightened so as to take the full weight, but only sufficiently to take the greatest strain off the supporting ropes. Each time the pump is lowered it only takes a few minutes to hang the new chains and tighten them up to the proper position.

The rising main used for unwatering operations is only considered to be for a temporary purpose. It is a 6-in. internal diam. lapwelded steel pipe with loose Albion flange joints packed with a single rubber washer. The regular length of each pipe is 18 ft., but a few lengths of 9 ft., 6 ft., 4 ft., 3 ft., 2 ft., and 1 ft. are used as a convenience when occasion requires it. There are two independent 6 in. rising mains fixed in the shaft from the adit to the 75-fath. level, one in each pumping compartment, but below the 75-fath. station there is only one, which is carried down the east pump compartment. It was originally intended to use two pumps and two rising mains in the shaft while unwatering down to the 200-fath. level, but it was soon found by experience that the old pit work left in the west end of shaft would seriously interfere with such a proceeding, and, owing to the very confined space in the shaft, it was never found advantageous to lower the two sinking pumps at the same time. Moreover, as a general rule the capacity of one sinking pump was sufficient to lower the water fast enough to keep up with the work of clearing, securing and repairing the shaft until the 75 level was reached. After installing the two station pumps at the 75 level, each one with its separate rising main, it became possible, until the new pump was started at the 166 station, to run either the sinking pump and one station pump in parallel, or the two 75 station pumps in parallel, and this was done during February and March, 1910, when the quantity of inflowing water from the 75 level was very heavy.

Earlier in this paper it was mentioned that these high-lift centrifugal pumps are not suitable for handling the rough material which can be passed through an ordinary Cornish pump without difficulty, and to save unnecessary wear and tear as much as possible we used a very fine strainer. A strainer of ample superficial area, made of copper-plate with 1/4-in. punched holes, was found to answer the purpose very well. With a strainer of this kind the sinking pumps have worked satisfactorily, using a suction length of over 25-ft. The usual length of pump suction during the whole period covered by this paper varied from about 10 ft. to 20 ft., giving an average length of about 15 ft., and 25.2 ft. was the greatest length recorded.

The extreme length of suction lift that can be used depends chiefly upon the condition of the strainer, which, of course, should be clean, and upon how near the limit of its hydrostatic head the pump is working; the nearer the limit the less the suction lift allowable. When using a long 4-in. pipe, driven through choke, the friction of water passing through the suction pipe has a considerable effect in reducing the actual height of suction lift, and this is particularly the case when the quantity being pumped is sufficient to cause a high velocity of the water passing through the pipe, that is to say, when the friction head in the suction pipe becomes an important factor. At one time, when we had 73 ft. of 4-in. suction pipe through the choke, the theoretical head, due to friction in the pipe and entry of water into the pipe, amounted to about 11 ft.

The thickest choke encountered in the shaft below water level was that occurring at and above the 212-fath. level, where it was found to be over 70 ft. deep and so compact that the water could only percolate slowly through it. When at first pumping above this choke, the water level in the shaft was continually taken down several feet below the level of the main body of water in the mine; also, when first starting the pumps, the water level would be very rapidly reduced the first 8 or 10 ft. in the shaft, and after stopping the pumps the water would rise abnormally fast to begin with. Again, when the 4-in. pipe was first driven through this choke, and the end blasted off, although the upper end stood 2 or 3 ft. above the water level in the shaft, water began to overflow from the top of it. All these phenomena proved the choke to be stopping up the shaft something like a rather porous cork in a pipe full of water.

3/4-in. to 1 1/4-in. round iron, were used, also a kind of iron scissors for lifting large rocks or timbers from under water was occasionally used. (2) A drop-screw was used more than once in the work of dismantling and taking up the weight of the old pit work. It was used, for example, in drawing out each pole-piece from its plunger barrel, for taking apart some of the heaviest pieces of ironwork, and raising the bottom lengths of column pipe in which the old bucket of the lift pump had worked, before removing the supporting timbers. (3) A large steel-pointed harpoon and heavy iron rammer were both tried, in the way of breaking through and penetrating chokes, but this method of attack was not found satisfactory. (4) The old cast iron column pipe was made up of standard lengths of 9 ft. each, with a few odd lengths and matching pieces. The upper portion was 18-in. diam. and the remainder 16-in. diam. The weight of each length ranged from 81 cwt. to 16 cwt., the average being a little over 1 ton. The wrought iron strapping plates connecting the wooden pump rods together ranged from 161 ft. to 21 ft. long and averaged about 6 cwt. each. Each length of column pipe, as well as other heavy pieces of old iron work, were raised through the shaft with the rider frame. Each length of pipe was slung on four short pieces of chain, the lower ends being bolted loosely to the upper flange of pipe, and the four pieces of chain were gathered together at the top by one large circular link, which was fastened by a shackle to the eye of the rope socket.

The pieces of pump rod, 14 in. by 14 in. pitch-pine, cut into various lengths from 10 ft. to 40 ft., were connected to the rope socket by means of a special large steel U-shaped clevis, a hole having been bored through each piece of timber to take the long bolt of the shackle. After having raised the old pit work to surface by means of the rope and rider frame, the doors over skipway were closed and two small bogie wagons with swivel bolster and steel stanchions, were run on an 18-in. gauge track in the proper position to conveniently carry the material to be removed from the rope. The front wagon would take the weight of the lower end of pipe or heavy timber, and as the rope was eased so would the front wagon move forward, until the upper end of the material would gradually be let down into the second wagon. The iron chains or special shackle would then be unfastened, and the heavy material could be easily removed from the shaft by the two trucks over the tramway and the process could be repeated. The rider frame would either descend empty or heavy shaft timbering could be sent down in it, or the skip could be attached and sent down for the usual work of clearing and repairing the shaft.

(5) In the worst place of the shaft, that is, above the 212-fath. level, where the ground is badly disturbed by a crosscourse, it was found advantageous to drive in a few rows of pointed iron rods from 5 ft. to 9 ft. long. Each row was put in just above the last easterly end-piece of a set after it had been firmly secured. The rods were placed about 8 in. apart and driven in their full length, inclined slightly upwards. This method, together with ordinary wooden spills driven down the sides as the choke was cleared, was found to answer very well, and prevented further heavy runs of loose ground into the shaft, as had occurred when the spilling method had been used without the addition of these iron rods. The object of using iron rods instead of ordinary wooden spills was two-fold; firstly, because the rods placed horizontally took up so little room, that the nearly vertical timber spills could still be conveniently driven

downwards between them; secondly, because wooden spalls were not strong enough for the work, and could not be successfully driven horizontally through the mixture of loose decomposed granite containing hard boulders. At this part of the shaft every square foot of ground had to be carefully held by temporary timbering while preparing to put the permanent timbers in place. In a few places in the shaft it was found possible to make use of some of the old timber sets, usually about 9 in. by 8 in. cross section, also a little of the old lagging, but as a rule it was found to be broken or too rotten for our purpose. For only very short distances have the walls of the shaft been found sufficiently strong to stand safely without close lagging. A certain portion of the shaft at first appeared to be strong enough, but after the water had been lowered and it had stood for some weeks or months exposed to the air, the walls began to crack and flake away, badly, so that much of it had to be re-timbered and closely lagged. The timbering is usually made up of 8 in. by 8 in. sets with 2-in. lagging, but in places where the walls are fairly good, 6 in. by 6 in. sets placed a little closer together have been used with 1-1/2in. lagging.

It may be interesting, to note that the throttle-valve of pipe through the dam in the 75-fath. level was entirely closed on December 17th, 1910. The valve was partly closed on December 2nd, and this caused a rather curious affect, which may be worth mentioning here. The valve was partly closed and the water allowed to rise inside the dam to a height of about 92 ft., giving a pressure of about 40 lb. per sq. in., which was as high a pressure as we thought it safe to allow, until December 17th, when we considered the concrete would be sufficiently set. After the water under pressure had been running from the pipe for about ten days, it was found that the cross-cut level, leading to the dam contained a great quantity of carbonic acid gas which was increasing rapidly every day, and soon became so bad that it was impossible for a man to get in safely as far as the dam. A lighted candle would not burn within about 500 ft. of the face, nor acetylene lamps within about 300 ft. An air pipeline and ventilating fan were quickly put in, and the bad air drawn out so that men could conveniently get in again to the dam. It was found, after completely closing the valve and stopping the flow of water which had been spraying out

from the mouth of the pipe with great force, that the quantity of carbonic acid gas no longer increased. The condition remains the same to the present time, and there has never been any need to resort to artificial ventilation since the discharge pipe was closed. It therefore seems reasonable to suppose that the great quantity of carbonic acid gas, found in the cross-cut throughout a distance of over 700 ft., may have been set free by the water as the pressure was released, while spraying out from the mouth of the pipe on the near side of the dam, the action being probably much the same as that of soda water in a bottle after the cork has been drawn and the pressure thus released. The carbon dioxide which was dissolved in the water under pressure may perhaps have been picked up in the backs of old stopes, as the water rose against the roof. The author would be glad to hear if anyone has had a similar experience, or from anyone who can offer a better explanation of this rather peculiar occurrence.

Concerning the efficiency of the whole pumping plant, it may be said that when new and at full load the efficiencies were about as follows -

Engines and alternators	86 %
Cables to pumps.....	97%
Motors of pumps.....	91%
Pumps	72%

Engine to pump delivery- $86 \times 97 \times .91 \times .72 = 55\%$

The efficiencies of alternators, cables and motors are practically unaffected by constant use, but wear and tear on steam engines and pumps affect their efficiencies considerably, if they are allowed to get out of repair. This is particularly the case with high-speed turbine pumps when handling acid water full of gritty material.

The parts of the pump most easily affected and which wear out soonest are the white metal shaft bushes and impeller rings. The white metal thrust bearings are also apt to heat up suddenly, due to temporary stoppage of the cooling water, or from some other cause. In this connection it has been found a good plan to arrange a little strainer and attach it to the water cooling pipe in such a way that it can be periodically cleaned, and thus lessen the danger of sudden chokage and stoppage of circulating water round the thrust bearing. The phosphor-bronze impellers and guide vanes may occasionally become damaged after a very hard and rough campaign, but repairs and renewals in this respect are seldom required. The effect of acid gritty water passing through the body of the pump at a high velocity is to soften and wear away portions of the cast iron, so that the life of a cast iron pump is very limited under these conditions. However, if a pump is required for Ion, service, this difficulty can be overcome by making the body of gunmetal instead of cast iron, at an extra cost of 20 % more or less.

In the unwatering operations this company has so far made use of three sinking pumps and five station pumps, of which up to date never more than three have been running at the same time. The third sinking pump is the only one made with gunmetal body, but this pump, as well as the last two station pumps, are in a different style from the first ones. The chief feature of the new type is the use of only one single diffusion vane for each impeller, instead of a series of diffusion vanes in the chamber for each impeller. The third sinking pump has also the advantage of being so constructed that each chamber and impeller can be easily removed or replaced. This is a great advantage as the pump can be taken apart, impellers removed or added, and all ordinary repairs carried out down in the shaft, instead of having to raise the pump to surface for repairs and alterations. Some figures are shown in Table VII which will give an idea of the work done by the first two sinking pumps and station pumps up to March 4th of this year. Exact measurements were automatically taken of all water pumped to adit, but not of the quantities pumped by each pump to the 75 level station, so that those figures preceded by a x mark may only be considered as approximately correct. When the white metal shaft bushes and impeller rings become worn, the water in the pump is able to pass in a wrong direction between the different chambers or stages of the pump. This leakage of water from the right passages not only causes wear and tear to other parts than the phosphor bronze impellers and diffusion vanes, but it also is very apt to throw the pump out of balance and cause serious trouble with the thrust- bearings. It is important that, if possible, the pump should be repaired before the shaft bushes and impeller rings become too much worn, otherwise the efficiency of the pump will fall badly, the pump will get unnecessarily scoured and worn, and there will probably be trouble with the thrust-bearing.

It should, perhaps, be mentioned that we had had no previous experience with turbine pumps, and, under the existing conditions, feared to attempt making any repairs down in the shaft on the internal parts of our first two sinking pumps, also, on account of having to take them to surface for repairs, and the consequent loss of time, they were not re-bushed as often as they should have been. The third sinking pump, made to a different design, is an improvement in this respect, and so far it has been possible to keep it in good repair without any long stoppage and without having to bring it to surface.

With regard to the rate of progress it will have been noticed that in part of September and October 1909, a speed of over 7ft. a day was attained for two weeks, or an average of nearly 7 ft. a day for three weeks. Also in 1910, during a period of ten weeks from March 12th to May 21st, an average speed of 5 ft. a day was maintained while unwatering the mine, and clearing, securing and equipping the shaft. On the other hand, three periods of four weeks

each actually show losses. Again, if we divide all the periods of four weeks into two classes (a) in which more than 50 ft. were made, and (b) in which less than 50 ft. were made, we find 14 periods in class (a) and 17 periods in class (b). Under class (b) it will be found that slow progress was always due to one or more of the following causes

(1) Failing pump having to come up for repairs, and time taken before new pump is working satisfactorily in its place.

(2) Extraordinary quantity of inflowing water due to exceptionally heavy rains.

(8) Unforeseen delay in delivery of pumps at the mine.

(4) Bad chokages in the shaft.

(s) Exceptionally bad condition of shaft walls.

(6) Stoppage of machinery.

(7) Removal from the shaft of extra heavy old pitwork and interfering old timbers. Cutting out and preparing room for pump stations.

Item No. 1, although a serious cause of delay to us in the past, should no longer be a serious hindrance to anyone in the future, since by using a pump of similar or equally good design to our last one, the ordinary small repairs can be easily carried out promptly in the shaft, and with a gun-metal body the pump should last a long time before having to be taken to surface for extensive repairs and renewals.

We feel that we are now safe from any more bad troubles due to cause 2 for several reasons. Firstly, because the adit level by the beginning of this year had been cleared and repaired from end to end, and all the water possible is caught there; secondly, because the dam in the 75-fath. level shuts off a large proportion of the water that, formerly troubled us; thirdly, because all the water in the mine down to the 248 level will soon be conducted to a sump, feeding a station pump at this level, so that any sinking pump below this level will only have a very small quantity of water to deal with.

The only safe way to prevent trouble from cause 8, is when possible, to order the plant to be delivered a long time before you expect to require it.

With regard to item 4, although chokages cannot, of course, be prevented, and they must delay unwatering operations somewhat, nevertheless we feel that we have solved the problem, to a very great extent, by the method of using a pointed suction pipe with special valve box on top. With a little experience, this method can be made to work so well, that to my mind one of the greatest causes of anxiety formerly, in unwatering operations with high-lift turbine pumps, has been removed. Much credit is, I think, due to our engineer, Mr. F. Thompson, for having worked out this method so successfully. Troubles due to cause 6 cannot be avoided if an old shaft is tackled, but the nature of the country rock, the proximity or otherwise of disturbing influences such as cross-courses, and the length of time the shaft has stood under water, will all help as a guide to how much trouble may be anticipated in this respect. Item 6 is a very exceptional cause of delay, and should never be a serious one. Under heading No. 7 three causes are mentioned. The first one, the removal of heavy old pitwork would not occur in most undertakings and it did not trouble us after the last of the old pit work was passed below the 166-fath. level. Interfering old timbers in the shaft was not a serious cause of delay, and the cutting out and preparation of pump stations would of course be equally necessary in any kind of a pumping scheme.

The author would be very pleased if this paper should be the means of provoking another interesting discussion* on the relative merits of the electrical turbine pump compared to the Cornish pump for unwatering operations. The author fully recognises a drawback in having generally to engage more skilled, and consequently higher paid men to successfully operate electrical and high-speed machinery than would be required for ordinary slower running steam engines, but, in his opinion, there are many points in favour of using electrically driven high-lift turbine pumps for unwatering operations.

Some of the advantages of using the latter system instead of the Cornish pumping system for unwatering may be stated as follows :

(1) Much less space is taken up in the shaft, and by installing electrically -driven station pumps for permanent work, after the unwatering has been accomplished, the space is still left, so that a shaft of a given size will leave more room for hoisting purposes than if a Cornish pump had been installed.

(2) Given good conditions in the shaft for making speed, the turbine pump, with its rising main, can be lowered more quickly to follow down the water than can the Cornish pump, with its massive equipment in the shaft.

(8) After the unwatering has been finished, the conditions are suitable for installing permanent electrically driven station pumps of the ram type, arranged to work economically with variable speed motors.

(4) With regard to the question of first cost, the author is not at liberty to give figures, but in this connection it should be remembered, that the surplus power of the generating plant, after the unwatering has been completed, can be used to great advantage for other purposes on the mine. The adaptability of electric power for various purposes is a strong point in its favour, and by centralising the generating plant, instead of making use of several steam engines scattered about in different places, much loss and waste of power is avoided. Furthermore, it would now be possible in many districts to purchase economically the requisite electric power from a neighbouring power supply company, and thus avoid having to put up any generating plant on the mine. This might be a great advantage with an unproved property.

The author believes there are still several old mines in Cornwall well worth unwatering and reopening, and for this reason the question of the most suitable system of pumping for unwatering purposes is of particular interest. In some cases, where an old mine is to be unwatered and there appears to be no suitable shaft for the purpose, it might be advisable to sink an entirely new shaft clear of the old workings and cross-cut back to them, after having installed the necessary pumping plant, as has been successfully done recently at the Phoenix Mines. But where it is decided to make use of an old shaft 100 fathoms or more in depth below adit, and to use the electrical system of pumping, the author would recommend that special attention be paid to the following points:

(1) No effort and expense should be spared in clearing and securing all adits as quickly as possible.

(2) A good power plant should be put in, of ample capacity for all probable requirements, unless the power supply can be economically purchased from elsewhere.

TABLE VII.

SUMMARY OF PUMP CAMPAIGNS, 26-4-09—4-8-11.

Description of Pump.	Number of Campaign.	Reason of Stop.	Period.		Gallons Pumped.	Length of Run.	
			From	To		Hrs.	Mins.
No. 1 Sinker	First	Failing duty	26-4-09	18-9-09	64,494,125	2415	10
No. 2 "	First	Failing thrust-bearing	28-9-09	14-2-10	95,895,858	9001	85
No. 1 "	Second	Failing duty	17-2-10	13-6-10	× 71,494,675	2588	0
No. 2 "	Second	Failing thrust-bearing	16-6-10	10-10-10	× 46,400,217	2078	85
No. 1 Station West	First	Thrust-bearing seizing	4-2-10	29-9-10	59,210,685	2419	0
No. 1 " East	First	General repair	25-4-10	19-11-10	90,259,195	8405	0
No. 1 Sinker	Third	Failing duty and thrust-seizing	14-10-10	4-8-11	× 59,997,021	8028	10

NOTE.--The figure preceded by a × mark under the column "Gallons Pumped" could not be obtained very accurately, since exact measurements were only taken of all water delivered to wharf.

Generally speaking, all campaigns were stopped on account of wear and tear to pump, which caused a falling off in the duty, and a tendency for the thrust-bearings to heat up.

(3) Pumps should be made and delivered a long time before they are required, so that there need be no danger of having to wait for them.

(4) Centrifugal pumps should be of such a type that the separate stages can be easily removed and added as required, and the pumps so arranged that the stages can be added and all ordinary repairs conveniently carried out down in the shaft.

(5) The rising main should be secured to the shaft instead of being carried on top of the pump.

(6) Small removable strainers should be placed on the pump fittings to prevent the water-cooling pipes round the bearings from becoming choked. The water-cooling pipes should be made of copper to prevent corrosion.

(7) At the bottom of the suction pipe a copper strainer should be used, of ample superficial area, with small openings.

(8) If a bad choke should be encountered, a special pointed suction should be driven down through it, as described in this paper.

(9) Duplicate pumps should be available, both for sinking and station purposes, so that there may always be a spare pump to fall back upon when either a sinking pump or a station pump is undergoing extensive repairs.

(10) Ordinary spare parts for repairs and renewals should be made interchangeable between all station pumps, and all sinking pumps, and where possible also between station pumps and sinking pumps. In the case of badly acid water the inside body of the pump should be made of gunmetal or some other metal suitable for resisting the corrosive action of the water.

When the unwatering operations were started no one at the mine had had any previous experience with turbine pumps, and the author hopes that the description which he has given of the plant used, and the way in which difficulties have been overcome, will be of interest to many, and some help to those with a similar undertaking before them.