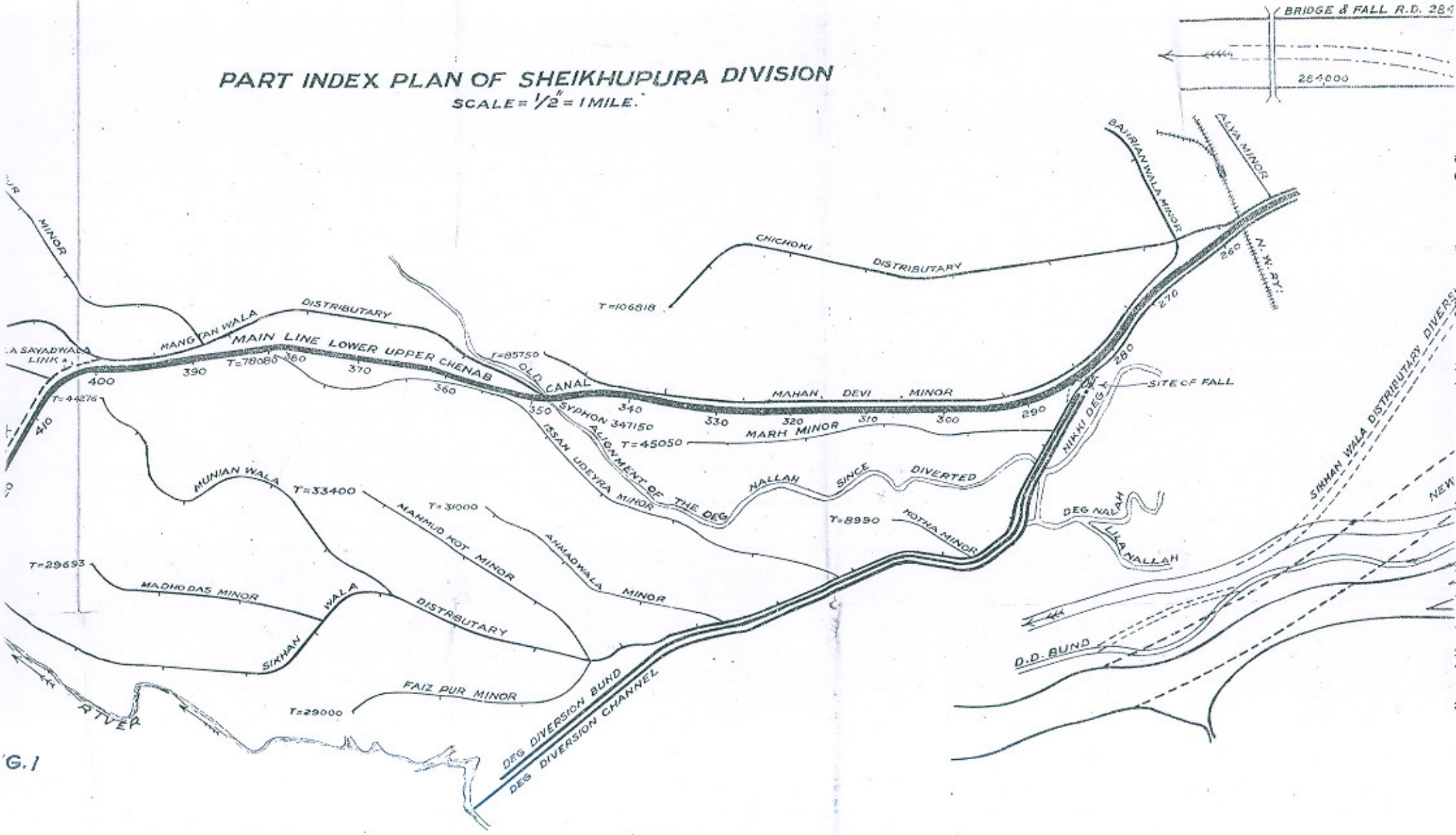
PART INDEX PLAN OF SHEIKHUPURA DIVISION

SCALE = 1/2" = 1 MILE.



G.1

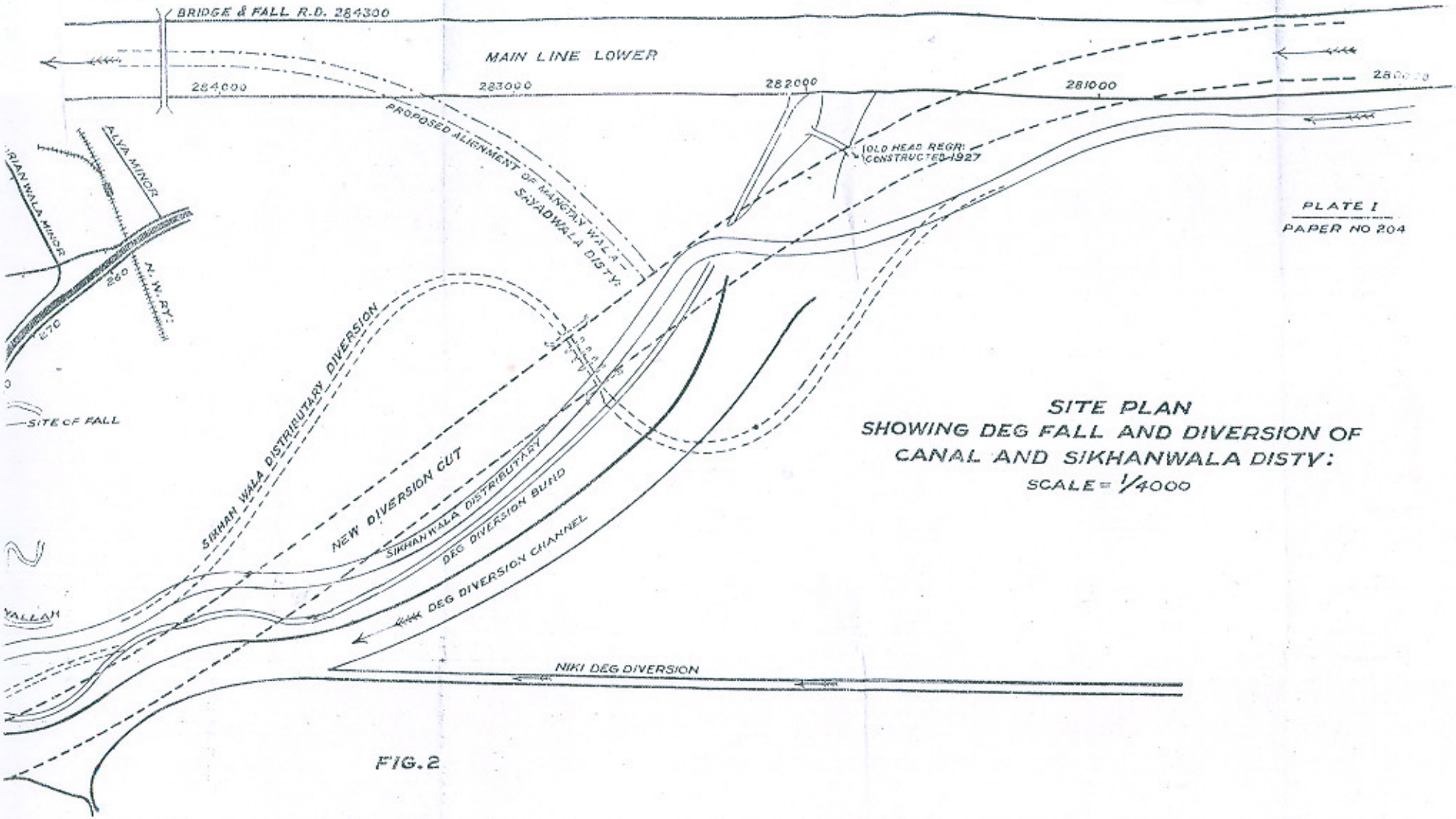

BRIDGE & FALL R.D. 284300
MAIN LINE LOWER
284000
283000
282000
281000
PROPOSED ALIGNMENT OF MANGTAN WALA SIYADWALA DISTY:
OLD HEAD REGR: CONSTRUCTED 1927
PLATE I
PAPER NO 204
AAYA MINOR
N. W. RY:
SITE OF FALL
SIKHAN WALA DISTRIBUTARY DIVERSION
NEW DIVERSION CUT
SIKHANWALA DISTRIBUTARY
DEG DIVERSION BUND
DEG DIVERSION CHANNEL
NIKI DEG DIVERSION
SITE PLAN
SHOWING DEG FALL AND DIVERSION OF
CANAL AND SIKHANWALA DISTY:
SCALE = 1/4000

FIG. 2

PLATE II
PAPER NO 204

PLAN OF DEG FALL AND AQUEDUCT
AS CONSTRUCTED IN 1927
SCALE = 1/250

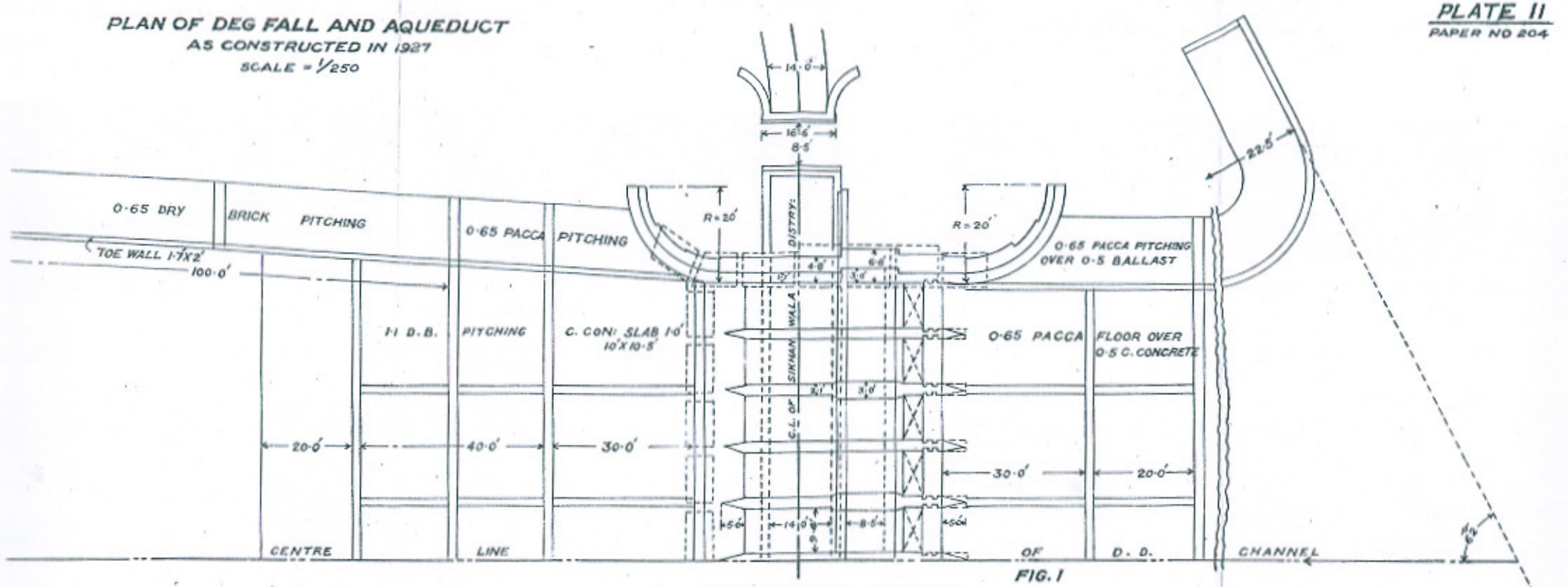


FIG. 1

LONGITUDINAL SECTION

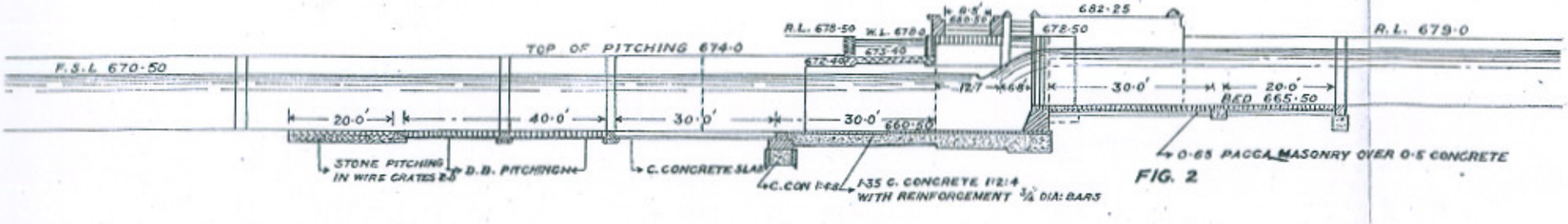


FIG. 2

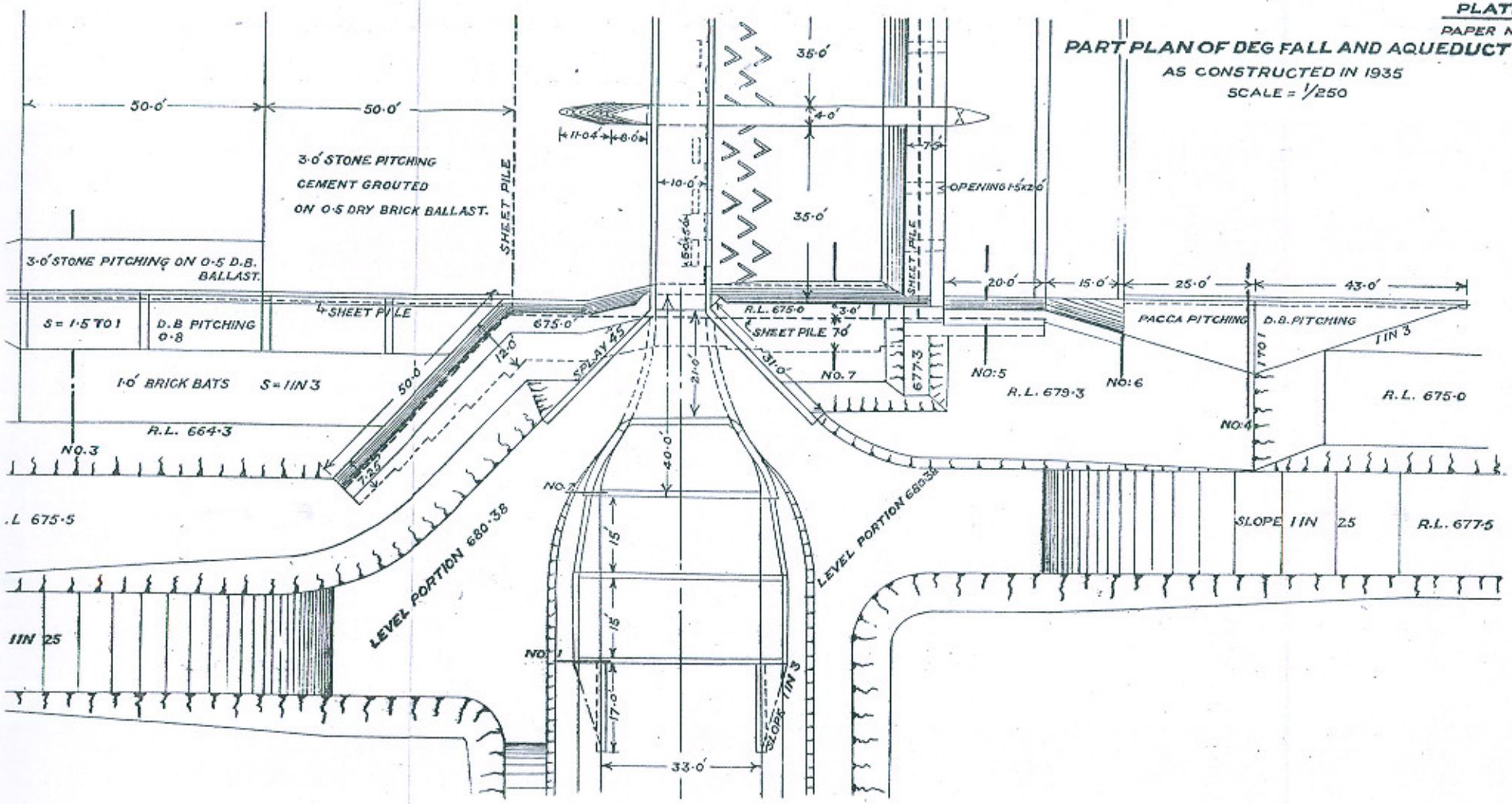
PLATE III

PAPER NO 604

PART PLAN OF DEG FALL AND AQUEDUCT

AS CONSTRUCTED IN 1935

SCALE = 1/250



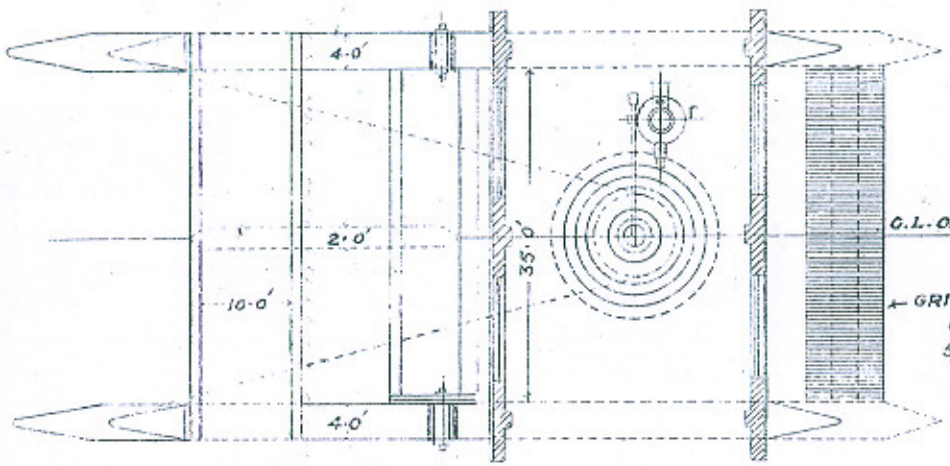


FIG.2

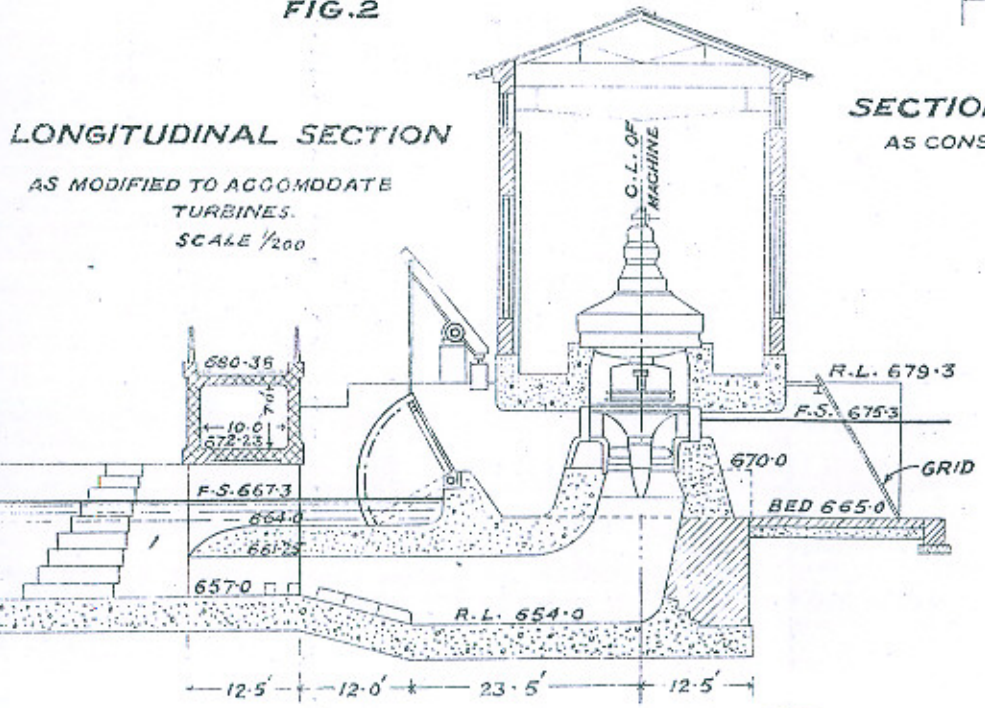


FIG.3

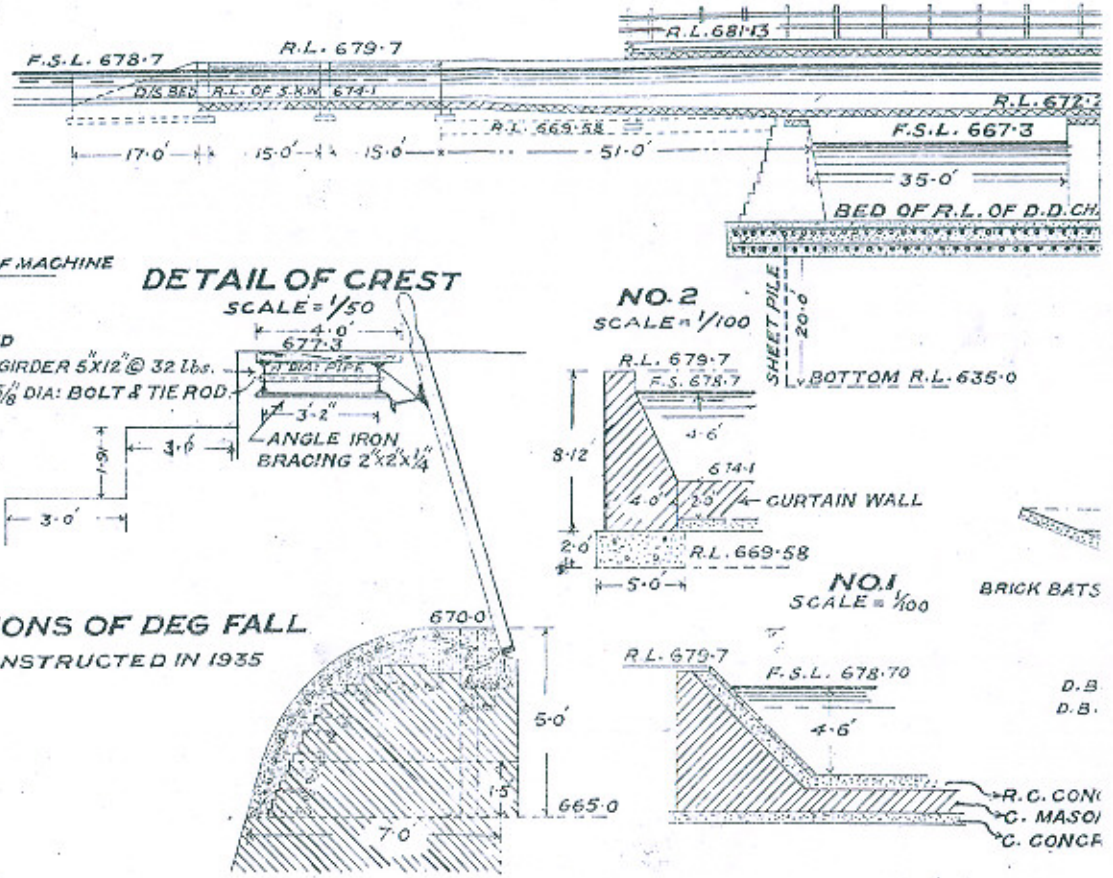
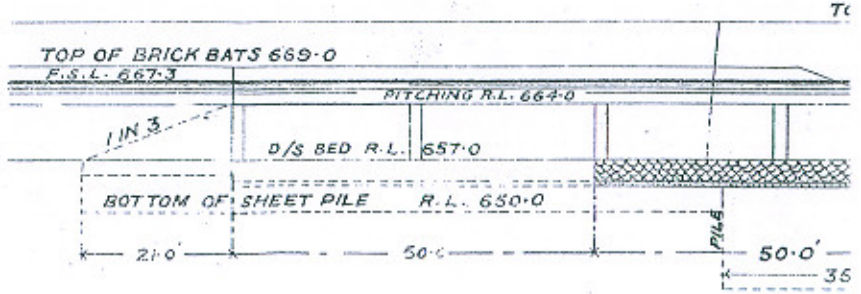


FIG.1



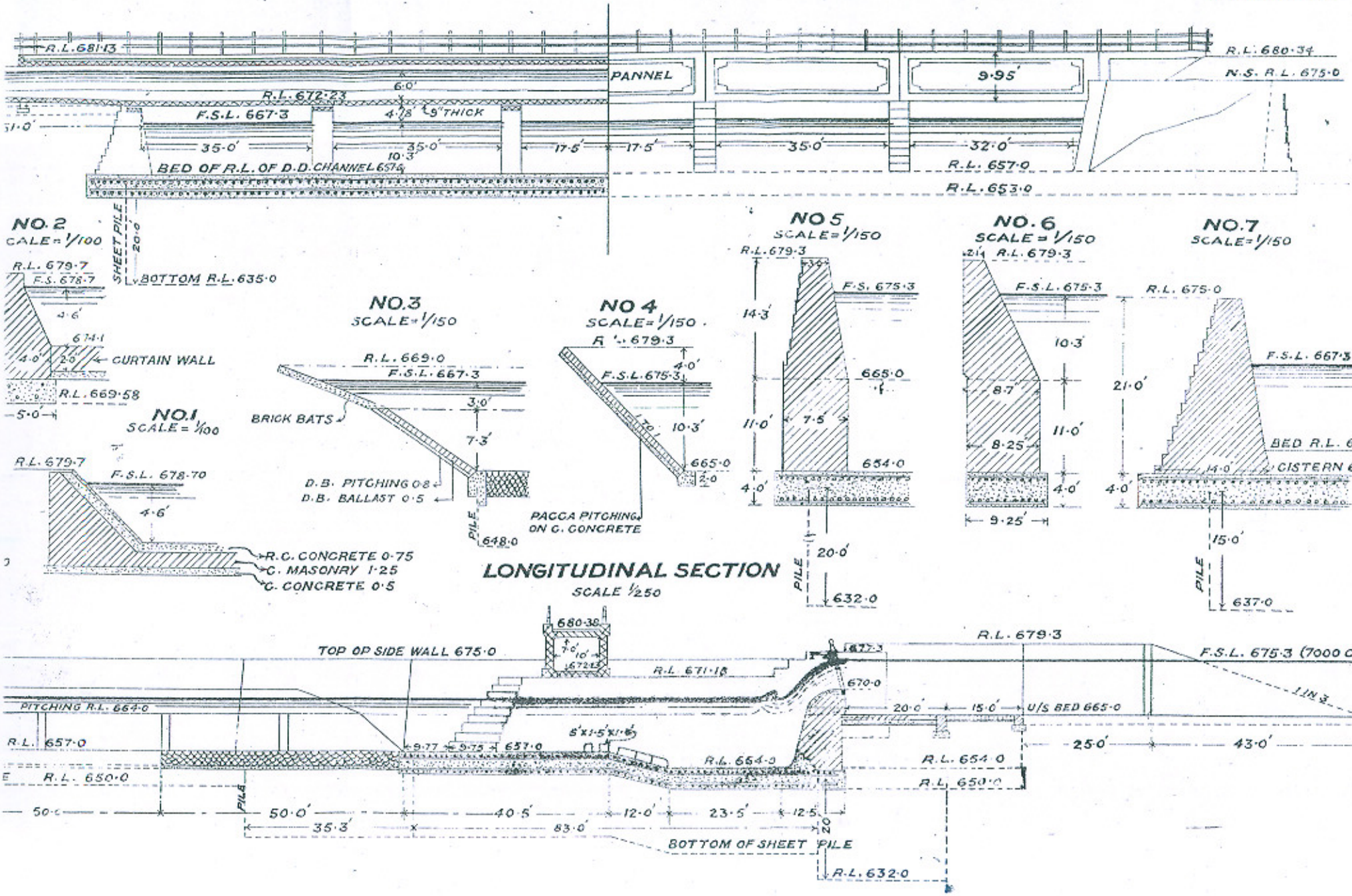

R.L. 681·13
R.L. 672·23
F.S.L. 667·3
6·0'
4·18
9" THICK
35·0'
35·0'
10·3'
17·5'
17·5'
PANNEL
9·95'
35·0'
32·0'
R.L. 680·34
N.S. R.L. 675·0
R.L. 657·0
R.L. 653·0
BED OF R.L. OF D.D. CHANNEL 657·4
SHEET PILE
20·0
BOTTOM R.L. 635·0
NO. 2
SCALE = 1/100
R.L. 679·7
F.S. 678·7
4·6'
6 7 4·1
4·0'
2·0
CURTAIN WALL
R.L. 669·58
5·0'
NO.1
SCALE = 1/100
R.L. 679·7
F.S.L. 678·70
4·6'
R.C. CONCRETE 0·75
C. MASONRY 1·25
C. CONCRETE 0·5
NO.3
SCALE = 1/150
R.L. 669·0
F.S.L. 667·3
3·0'
BRICK BATS
7·3'
D.B. PITCHING 0·8
D.B. BALLAST 0·5
PILE
648·0
NO 4
SCALE = 1/150
R.L. 679·3
4·0'
F.S.L. 675·3
10·3'
2·0
665·0
PACCA PITCHING ON C. CONCRETE
NO 5
SCALE = 1/150
R.L. 679·3
F.S. 675·3
14·3'
11·0'
4·0'
7·5'
668·0
654·0
20·0'
PILE
632·0
NO. 6
SCALE = 1/150
R.L. 679·3
F.S.L. 675·3
10·3'
8·7'
11·0'
8·25'
4·0'
9·25'
NO.7
SCALE = 1/150
R.L. 675·0
F.S.L. 667·3
21·0'
BED R.L. 657·0
14·0'
CISTERN 654·0
4·0'
15·0'
PILE
637·0
LONGITUDINAL SECTION
SCALE 1/250
680·38
7·0'
10'
672·4
TOP OF SIDE WALL 675·0
R.L. 671·18
PITCHING R.L. 664·0
R.L. 657·0
9·77
9·75
657·0
5'x1·5'x1·5'
R.L. 664·0
R.L. 654·0
R.L. 650·0
R.L. 650·0
PILE
50·0'
50·0'
40·5'
12·0'
23·5'
12·5'
35·3'
83·0'
20
BOTTOM OF SHEET PILE
R.L. 632·0
R.L. 679·3
F.S.L. 675·3 (7000 CUS:)
1 IN 3
670·0
20·0'
15·0'
U/S BED 665·0
25·0'
43·0'

FIG. 1

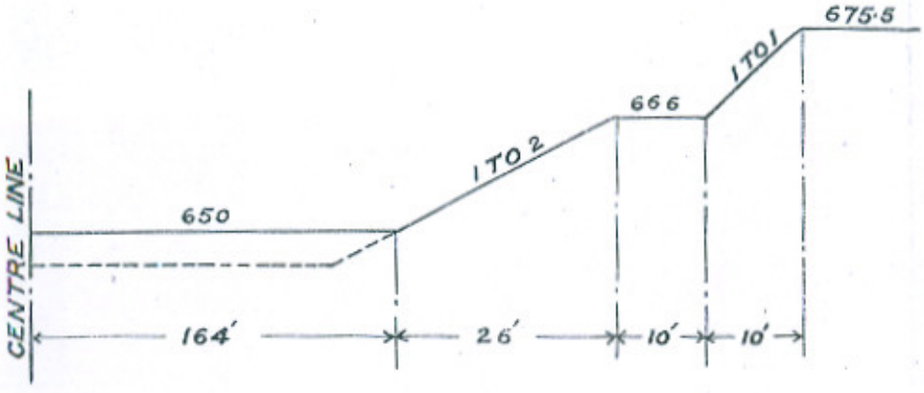


FIG. 2

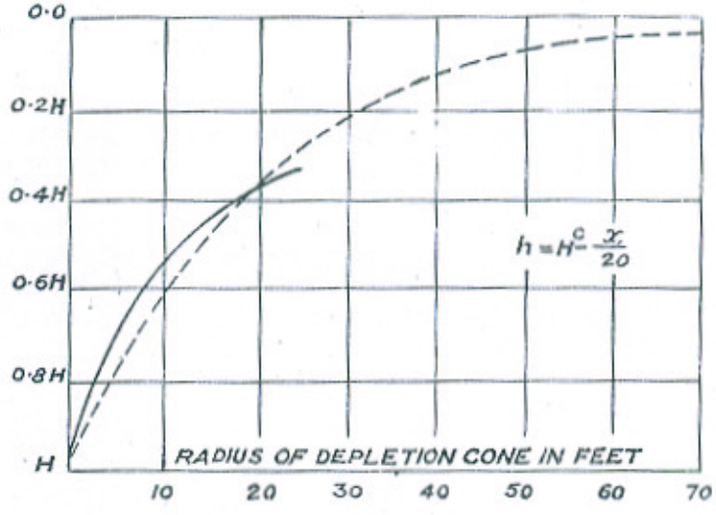


FIG. 3

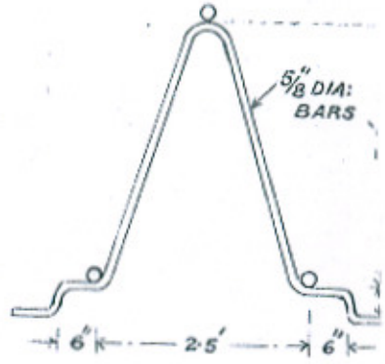


FIG. 6

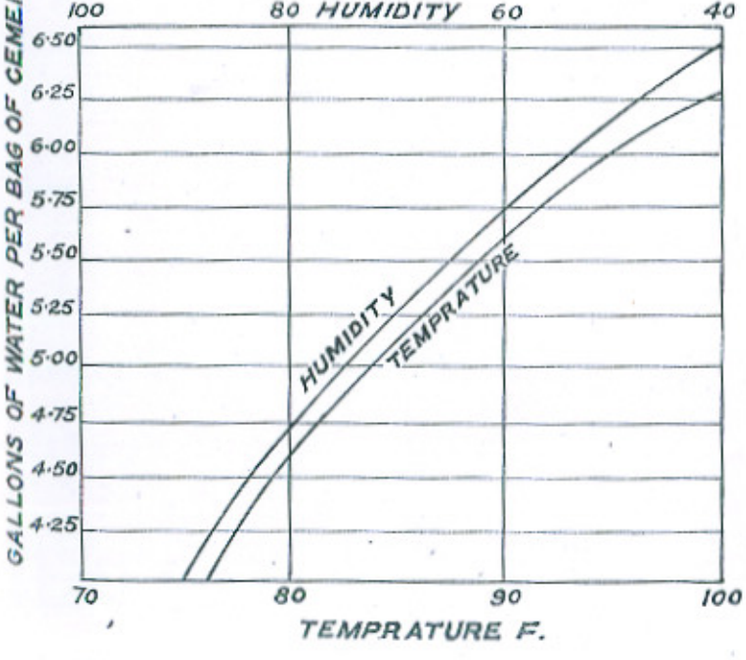


FIG. 7



FIG. 8



FIG. 9

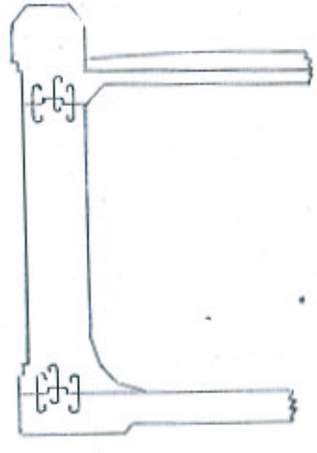


FIG. 3

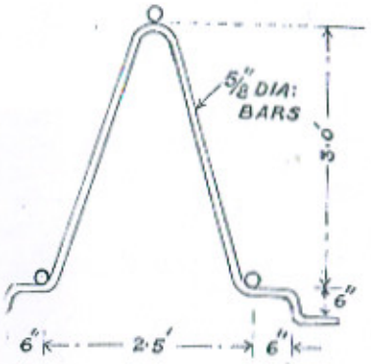


FIG. 4

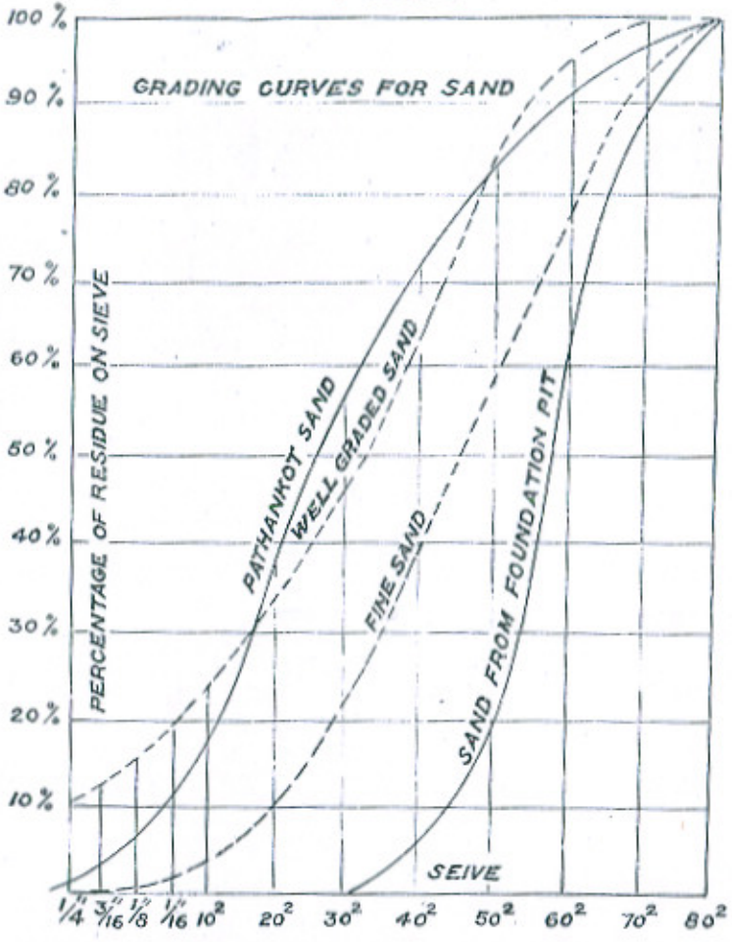


PLATE. V
PAPER NO 204

FIG. 5

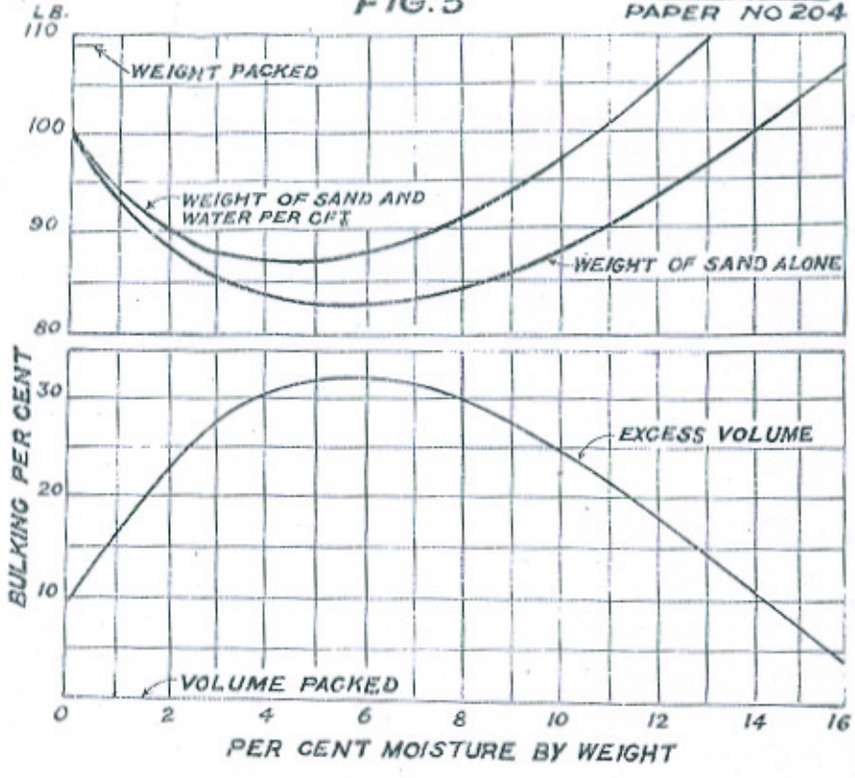
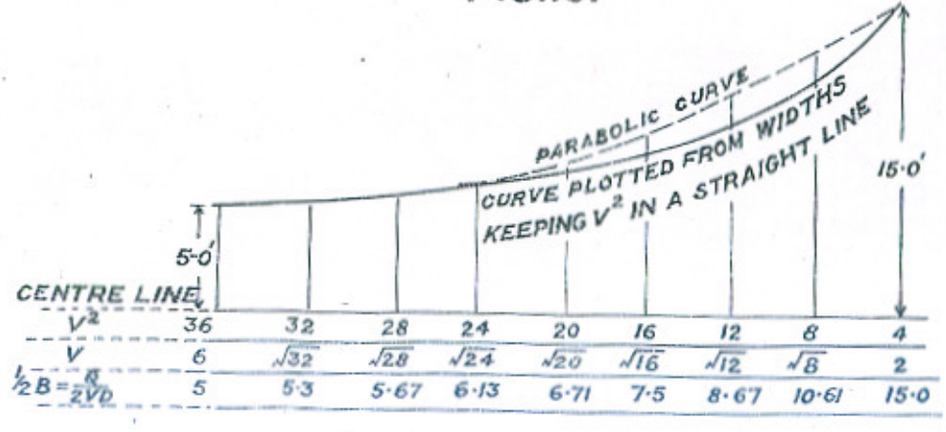


FIG. 10.



V PIPE
L

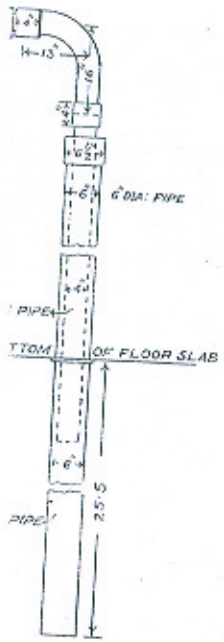


FIG. 1

PLAN SHOWING PUMPING ARRANGEMENT

SCALE 1/200'

PLATE VI
PAPER NO 204

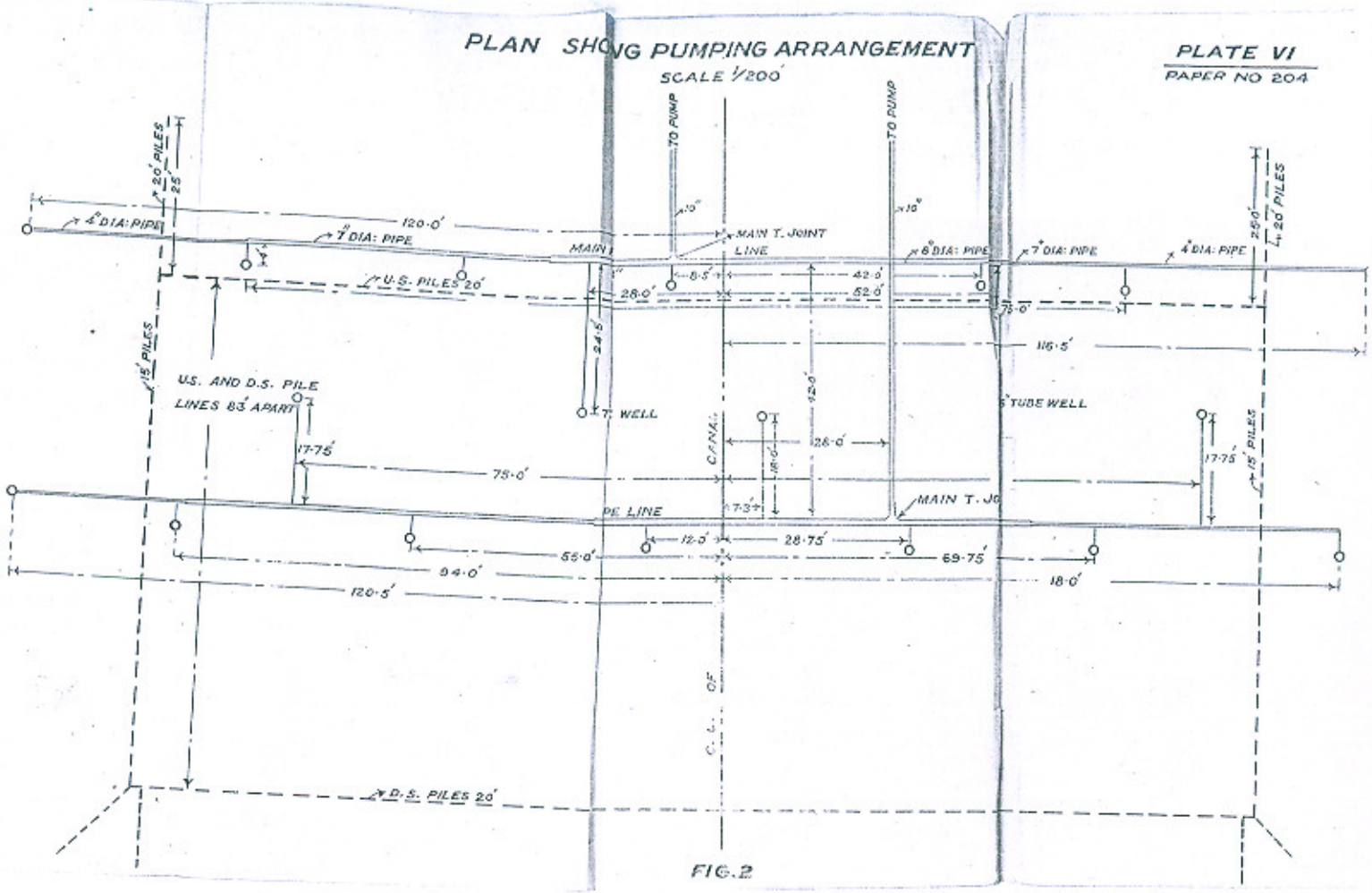


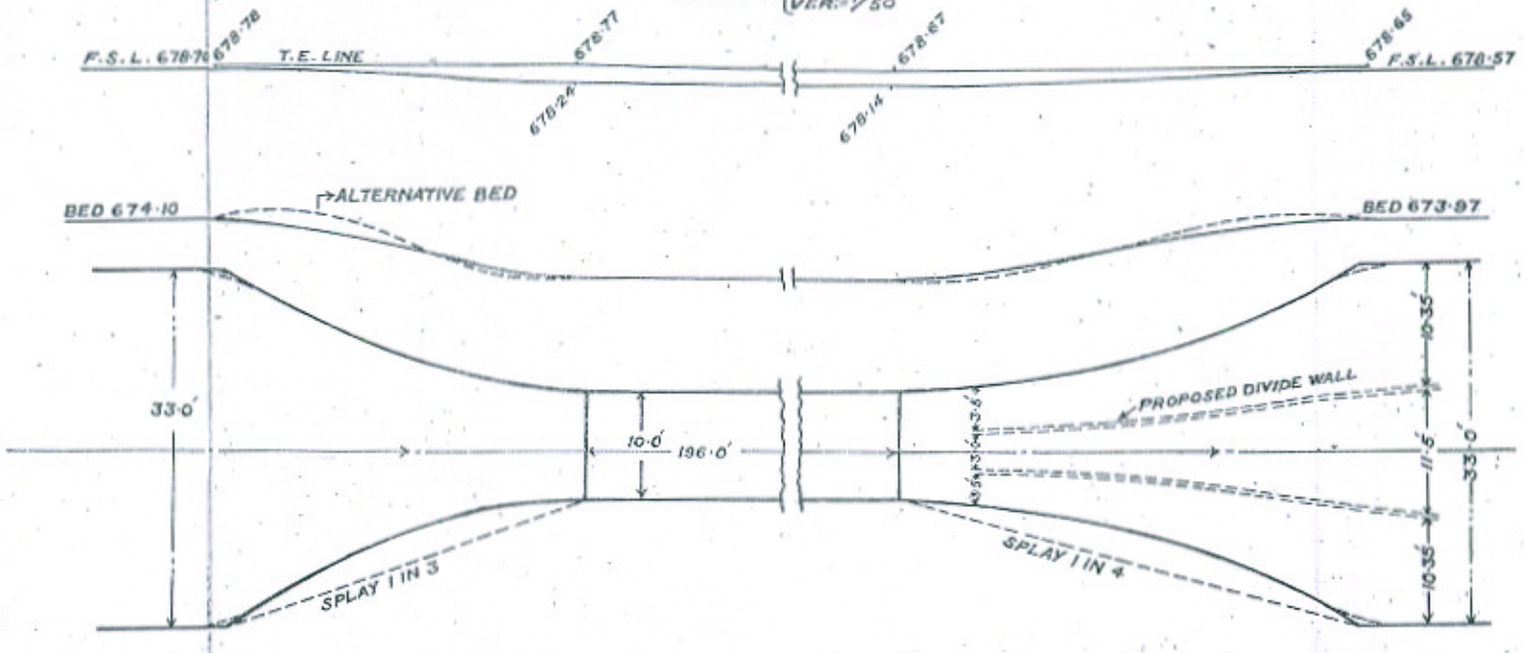
FIG. 2

PLATE VI
PAPER NO 204

DEG FALL AND AQUEDUCT

PLAN SHOWING ENTRY AND EXIT CURVES OF AQUEDUCT FOR SIKHANWALA DISTRIBUTARY

SCALES { HOR = 1/150 VER = 1/50



F. S. LEVEL	678·76	678·78	678·63	678·57	678·57	678·42	678·37	678·27	678·17	678·84
R.L. OF BED	674·10	673·80	673·72	673·70	673·67	673·67	672·72	672·37	672·34	673·97
VELOCITY	4·66	4·75	4·85	5·10	5·35	5·70	5·90	6·00	6·53	5·83
DEPTH	4·66	4·78	4·77	5·10	5·35	5·70	5·90	6·00	6·53	5·83
R.L. OF T.E.LINE	678·76	678·78	678·77	678·77	678·77	678·77	678·77	678·77	678·77	678·67
Ef	4·66	4·90	5·05	5·30	5·70	6·05	6·49	6·53	6·53	6·67
q	10·6	12·9	15·9	20·0	24·5	29·6	33·9	35·0	35·0	35·0
BED WIDTH	34·53·0	27·2	22·0	17·6	14·32	11·92	10·46	10·0	10·0	10·0
DISTANCE	3·5	3·0	2·5	2·0	1·5	1·0	·5	0		

F. S. LEVEL	678·67	678·67	678·67	678·66	678·66	678·66	678·66	678·66	678·66	678·66
R.L. OF BED	672·34	672·27	672·41	672·41	672·71	672·84	673·26	673·41	673·56	673·90
VELOCITY	5·83	5·76	5·40	5·40	5·07	4·60	4·03	4·03	3·61	2·68
DEPTH	6·0	6·9	6·77	6·66	6·35	5·85	5·15	4·80	4·80	4·75
R.L. OF T.E.LINE	678·67	678·67	678·67	678·66	678·66	678·66	678·66	678·66	678·66	678·66
Ef	6·53	6·40	6·25	6·05	5·70	5·24	5·10	4·95	4·95	4·85
q	35·0	34·0	31·6	28·0	24·7	20·0	17·7	15·0	15·0	12·8
BED WIDTH	10·0	10·28	10·08	12·44	14·20	16·60	18·8	23·32	27·40	45·46
DISTANCE	0	5	10	15	20	25	30	35	40	45·46

DEG FALL AND AQUEDUCT

DETAILS OF AQUEDUCT REINFORCEMENT AND SHUTTERING

SCALE = 1/50

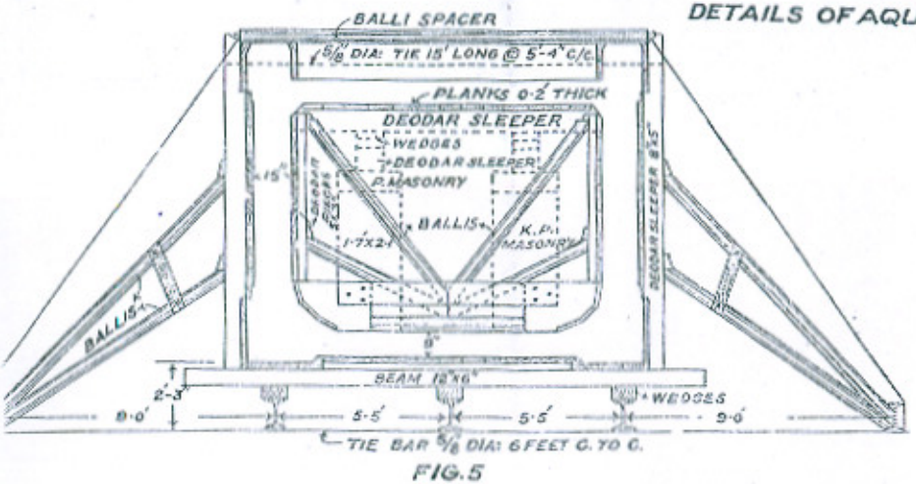


FIG.5

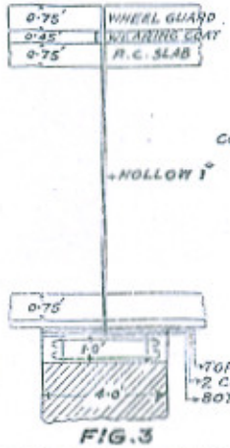


FIG.3

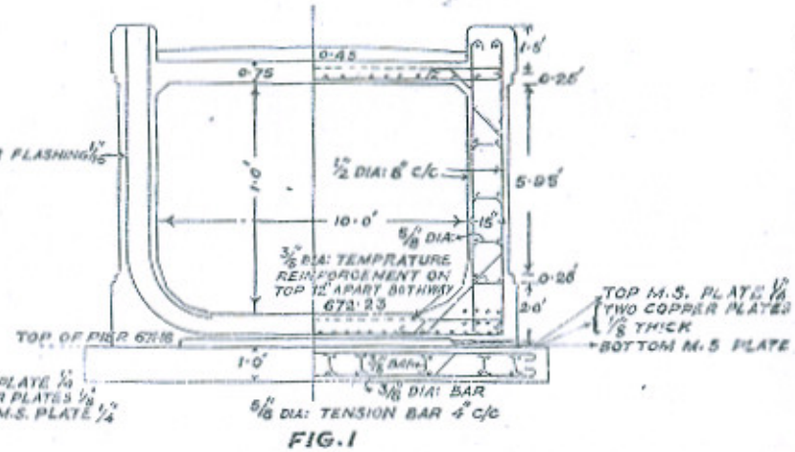


FIG.1

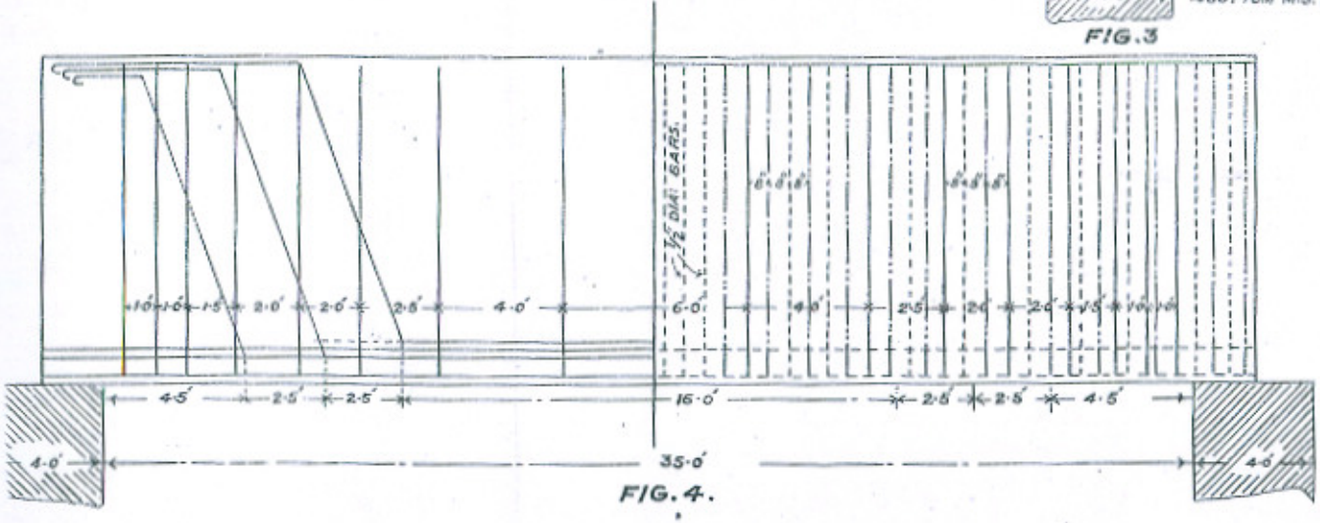


FIG.4.

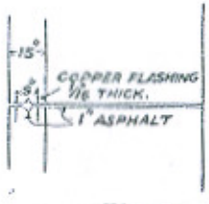


FIG.2

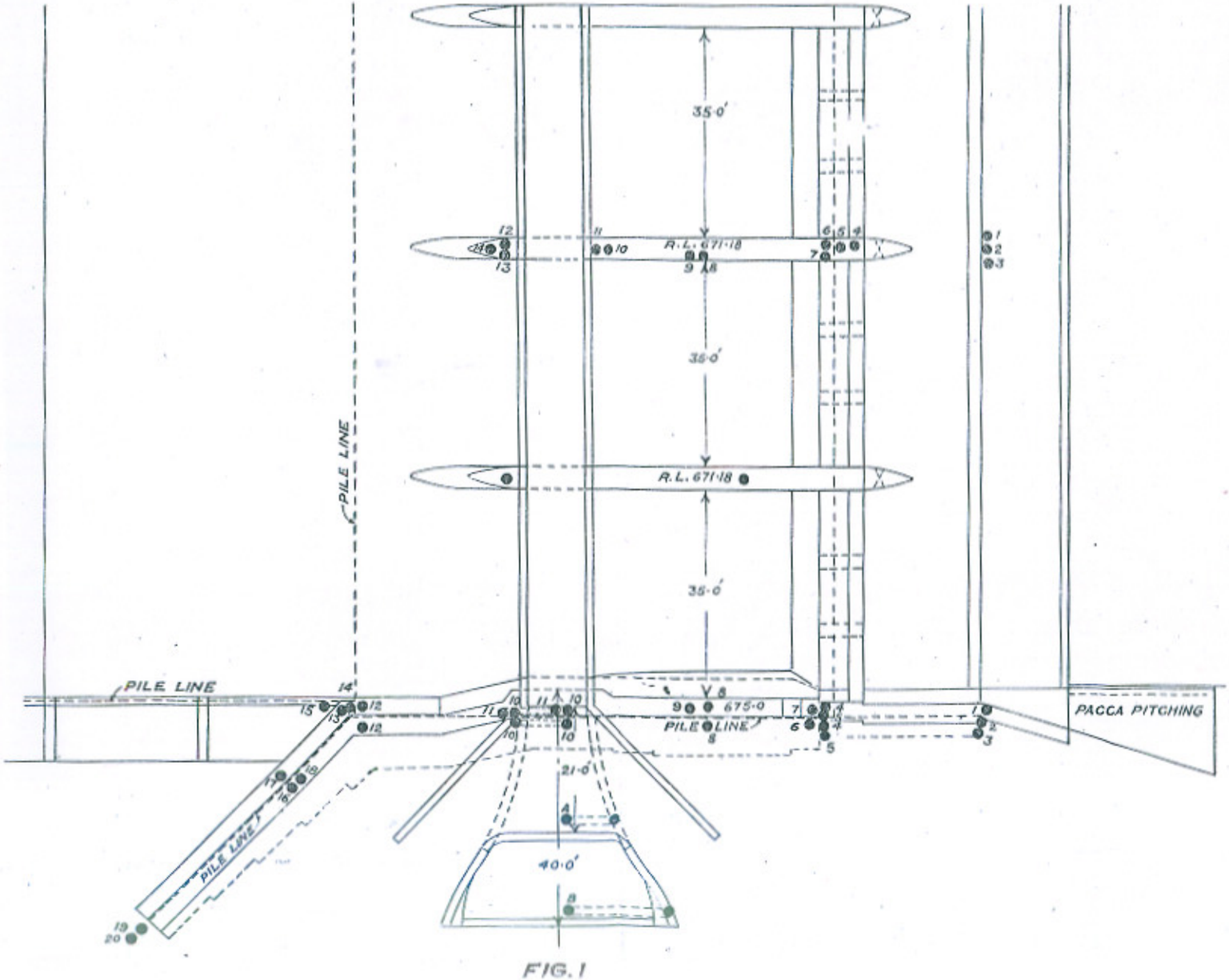
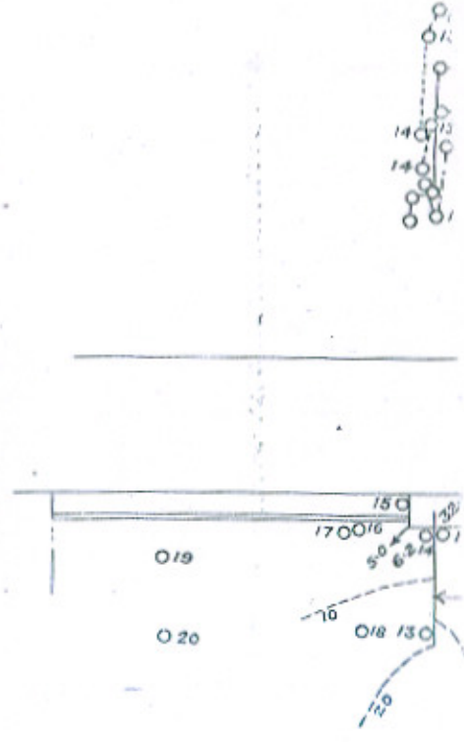


FIG. 1

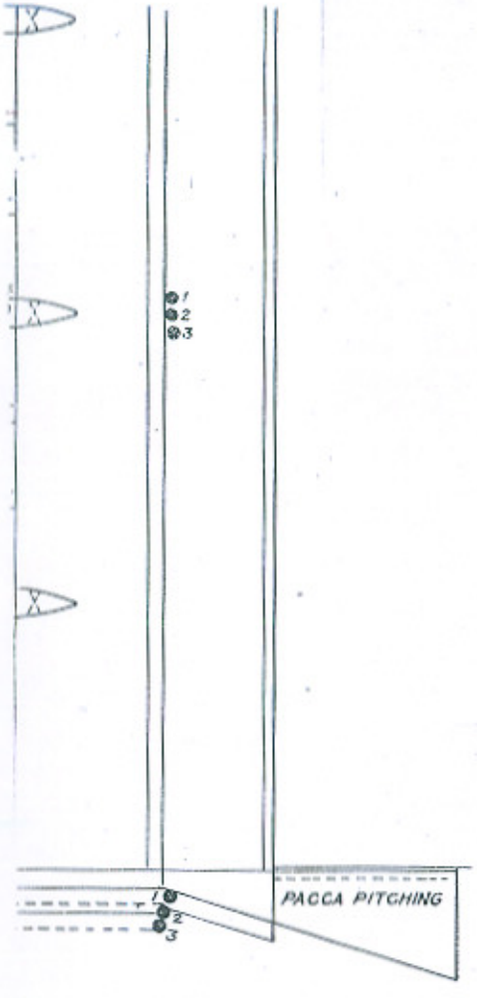
DEG FALL AND ,

PLAN SHOWING PRE

SCALE =



DEG FALL AND AQUEDUCT
PLAN SHOWING PRESSURE PIPES
SCALE = 1/250



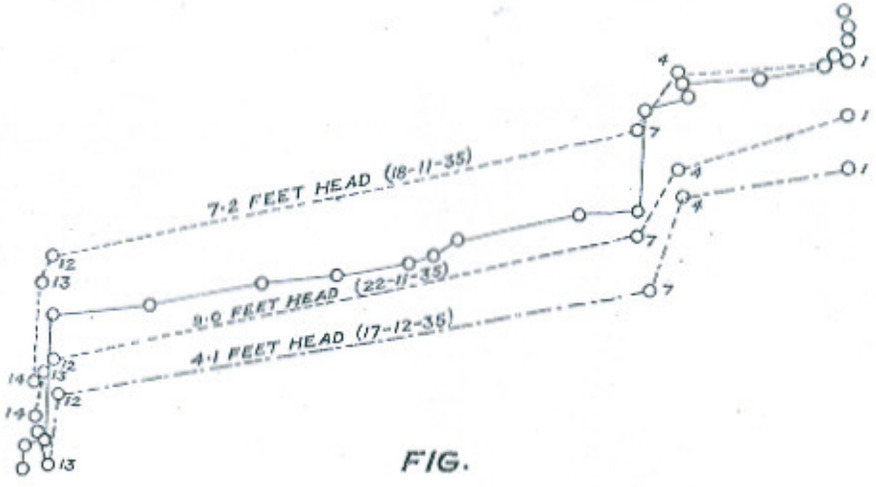


FIG.

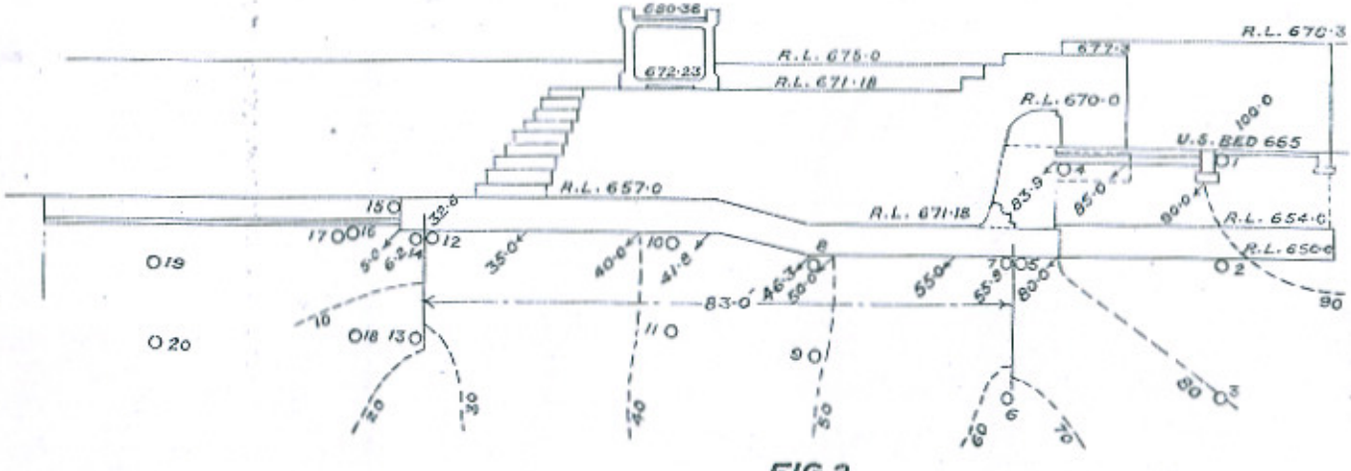
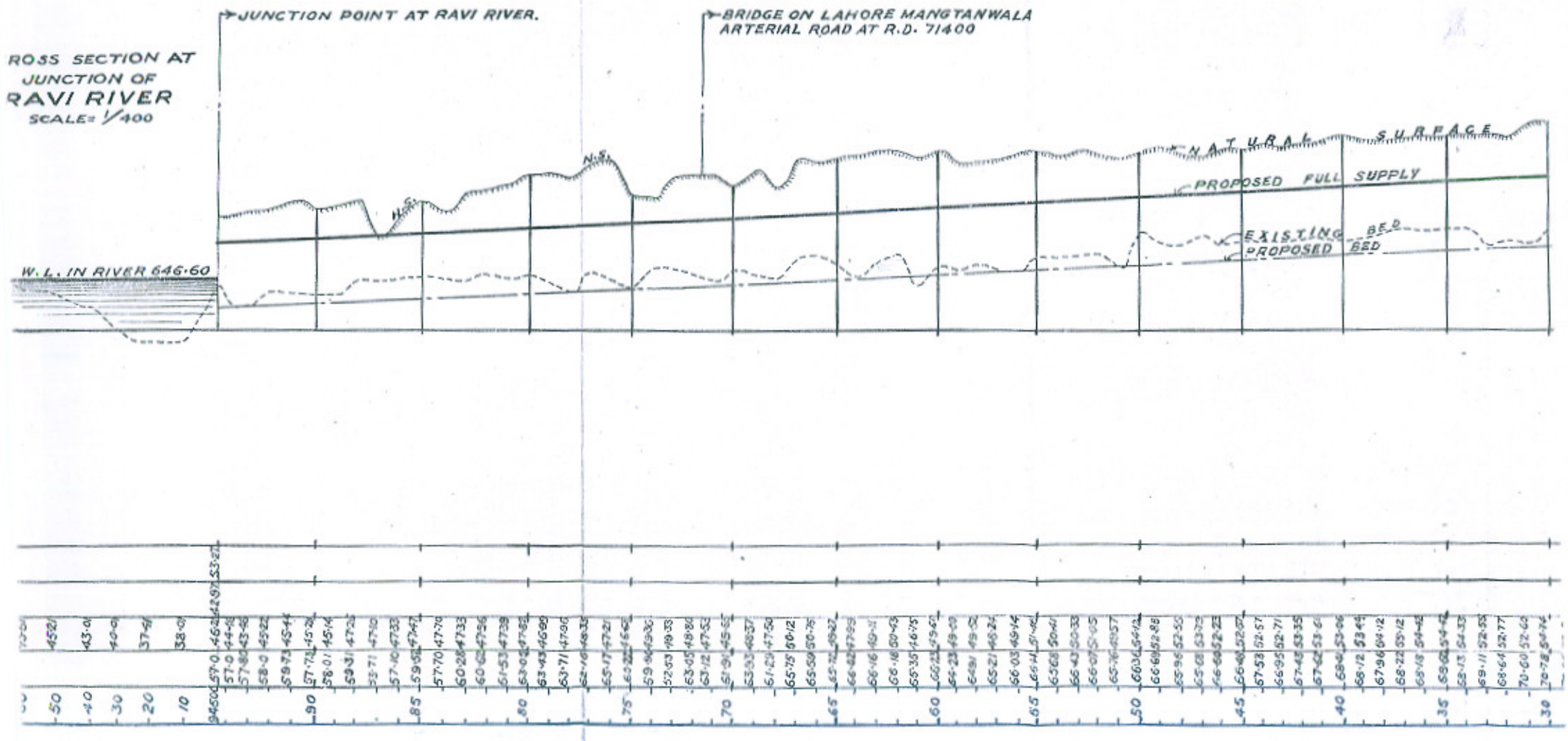


FIG.2

LONGITUDINAL SECTION OF DEG DIVERS

SCALE { HOR:- 1 INCH = 1 MILE
VER:- 1/200



ECTION OF DEG DIVERSION CHANNEL

SCALE { HOR:- 1 INCH = 1 MILE
VER:- 1/200

PLATE X
PAPER NO 204

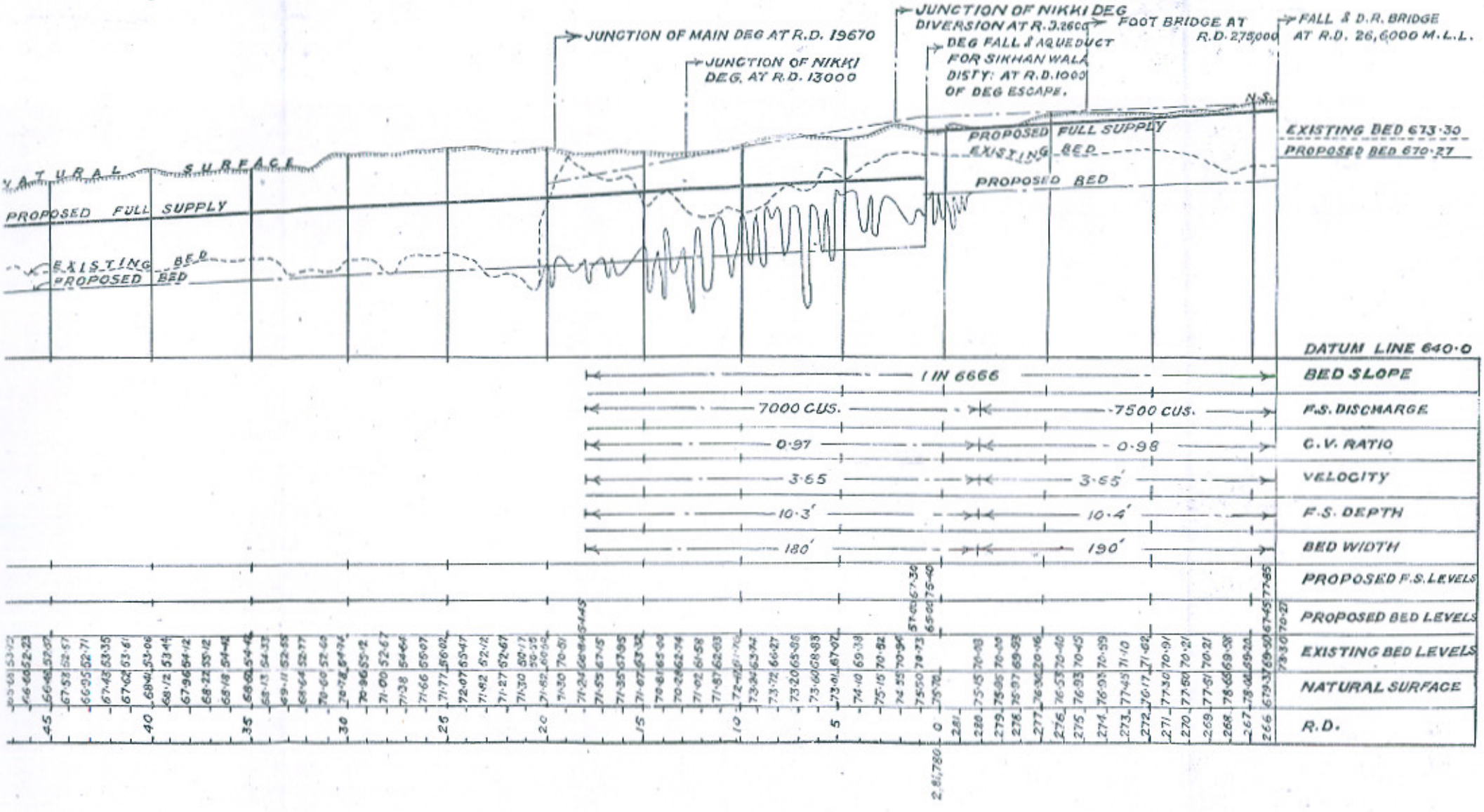
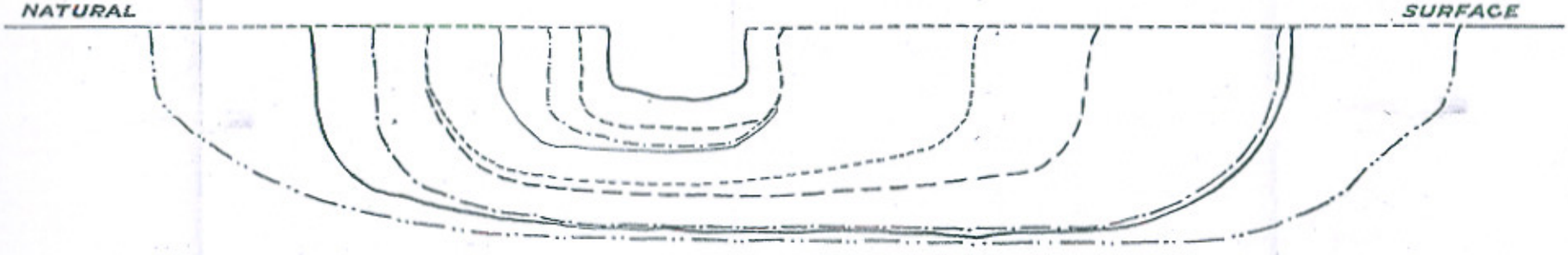


PLATE XI
PAPER NO 204

TYPE CROSS SECTION
SHOWING THE DEVELOPMENT OF THE DEG DIVERSION CHANNEL

SCALE 1/100



DISCUSSION.

In introducing the Paper on the Deg Diversion and the combined Headfall, the Author remarked that the diversion of the Deg Nalla into the Ravi below Sharakpur and about 10 miles above its junction with this river, *i.e.*, opposite Gugera, was originally carried out in the year 1914, to protect about 1,00,000 acres of irrigated area of the Upper Chenab Canal from spills, to which the Deg Nalla was subject.

The flood discharge of the Deg in pre-canal days was over 30,000 cusecs against about 3,000 at present. Thus the utility of the Deg Diversion as a carrier of flood waters of the Deg was greatly lost on account of the absorption of most of the rain water in the cultivated lands in its catchment; and by the present scheme, this same channel had been put into use for a more important protective purpose, *viz.*, that of ridding the irrigated area of the Upper Chenab Canal from the scourge of waterlogging.

As would be seen from the excellent Paper on waterlogging, read before this year's Congress, most of the anti-waterlogging measures so far adopted had either proved ineffective or had been only partially successful. The Deg Diversion Scheme was the greatest measure of all in the history of waterlogging in this Province and it was hoped that it would produce correspondingly great results.

The Deg Diversion Channel when it was fully developed would have a fall of 8 feet at its head and would carry the entire supply of the Upper Chenab Canal into the river which was from 6 feet to 9 feet below the natural surface. At present the spring level was only about 9 feet below ground so that the supply level would be very close to the sub-soil water level. Moreover, the length of the diversion was only 18 miles, against 36 miles of the Upper Chenab Canal beyond the offtake of the diversion. Thus, both due to the reduced length of the channel and the lowering of its level, great improvement in the waterlogging conditions of the last 36 miles of the canal tract might be confidently expected.

The constructional details of the work had been fully described in the Paper, of which the following might be specially mentioned :—

(1) The desirability of thoroughly examining, by means of trial bores, the foundation areas of all important works to be built in waterlogging tracts.

(2) The desirability of making comprehensive arrangements for the pumping of water, so that the foundation concrete could be laid in the dry without the risk of mortar being washed away by seepage water, leading to the possible failure of the work, as perhaps actually happened in the case of the old Deg Regulator.

(3) The desirability of mixing concrete by mechanical mixers in preference to hand mixing in all works of any magnitude, on account of the uniformity of the mix and the greatly increased strength obtained in the finished concrete.

Particular mention had been made in the Paper of the development of the channel connecting the canal with the old Deg Diversion, situated 4 miles lower down. This channel, which was originally made capable of carrying about 20 cusecs of water, and was carrying 3,500 cusecs in October 1936 (at the time of writing of the Paper) was now carrying about 5,000 cusecs, and in a few days time, it would be carrying its full supply discharge of over 6,000 cusecs.

All this development of the channel had taken place by the simple process of retrogression of levels upstream from a fall, the soil to be eroded being alluvium.

This formation of the channel by natural processes might possibly furnish some clue to the natural relationship between the discharges of channels and their shapes and dimensions and might be of interest to investigators of the laws of flow of water in alluvial channels.

In conclusion, the Author said that this was perhaps the first work of its kind to be undertaken by the Punjab Irrigation which had been designed on the basis of data obtained from model experiments carried out in the Punjab Irrigation Research Laboratory, thanks for which were due to Dr. McKenzie Taylor and other officers of the Institute who made many valuable suggestions.

Mr. **Kanwar Sain** said that the Paper under discussion contained very valuable information on details and costs of working and to anyone who may be forced to carry out a similar work the Paper would prove of immense benefit. There were several features in which methods employed on this work were in distinct advance of those previously employed in the Province. One of these features was the use of tube-well pumping instead of open pumping, employed to dry the foundations. The Author had deliberately kept back his definite opinion whether he preferred the tube-well system of pumping or the usual open sump method. The very fact that open pumping had to be resorted to would indicate that tube-well pumping was not found to be sufficient to cope with the work. In America the tube-well system had been used very successfully in fine sand and loam against heads of as much as 24 feet. With the tube-well system there were no open sumps to collect chips which, in spite of the foot-valves, did occasionally choke the pumps. There was no gritty and muddy water to wear the pumps out. The tube-well system lowered the general ground water-level below the subgrade of the excavation; thus stabilizing the material and making it easy for the workmen to work. In America, filters used on this kind of work were of a special

pattern which had much more filter capacity as compared to the ordinary filters available in the market for domestic use. The inlets were usually placed 3 to 5 feet apart and were electrically welded to the header pipe. At each inlet a filter point was jetted into the ground with a water pressure of about 50 lb. to the inch, which took only about 4 to 5 minutes to go down its full length. Headers were laid along one side or on both sides of an excavation. Tees, elbows and joint fittings with necessary valves were installed in the header line where necessary. Generally, a centrifugal pump with a priming pump to keep the air out of the line was used for pumping. The same set could be taken out and used on another job. It was necessary that each filter point be provided with a shut-off valve so that any point could be cut out for removal or shut off if taking air, without interfering with the continuous operations of the remaining system. Would the Author point out what he thought to be the defects in the tube-well method employed by him?

On page 114 the Author had stated that cement was not stocked at the work for more than one week before it was used. This seemed to be open to objection as there might be chances of delay in transit between the cement factory and the work due to unforeseen circumstances and it might appear desirable to have more cement in hand than would last for only a few days' work. Many authorities were now of the opinion that the storage of cement under ordinary care improved the strength of the cement and did not cause deterioration.

Naturally on a job of this kind with previous failure staring one in the face one would hesitate to cut things too fine but on the following points economy could have been exercised:—

The abutments, 13 feet wide at the base, might well have been designed of reinforced concrete which would have cost, perhaps, only one-third of the design actually provided. Similarly the reinforced concrete aqueduct could be designed as a box instead of designing the side walls and slabs independently.

Mr. **R.K. Khanna** said that two points of outstanding interest in Mr. Kapur's Paper were (*i*) his reference to the probable effects of the diversion of the Upper Chenab Canal into the Deg on the waterlogging conditions of the tract of land below the point of diversion and (*ii*) his reference to the formation of a four-mile length of the diversion channel by the action of flowing water.

Up to now, no appreciable effect on the subsoil water levels near Mangtanwala, which is 25 miles from the point of diversion of the canal, had been produced. But this need not discourage the Department. The sub-soil reservoir is an immense store-house of water; and even if there were to be some effect from the diversion of the canal on the subsoil water levels of the adjoining tracts of land, it would take considerable time for that effect to be amenable to measurement of sub-soil levels.

But the more important point to be considered was whether one could expect waterlogging conditions below the point of diversion definitely to improve as a result of the diversion of the canal. The Mangtanwala and Sayadwala distributaries and all the smaller irrigation channels were remaining there as before; so, if irrigation channels and irrigation of lands were the principal sources of supply of the subsoil reservoir, then little or no improvement in waterlogging conditions could be expected from the Deg Diversion Scheme. But, as was generally well recognized, infiltration from the main canal was always the principal source of supply of the subsoil reservoir; and as such, great improvement could be expected to result from the action taken. Before the execution of the Deg Diversion Scheme, water percolated from the canal into the sub-soil under a head of about ten feet of water, almost all the year round. This percolation had now been completely eliminated from the portion of the canal below the diversion. Percolation from the diversion channel and from the upper portion of the canal would tend to keep up the sub-soil levels in the Mangtanwala area to some extent; but in spite of this tendency, great improvement in waterlogging conditions was sure to take place in time. Thus, the Deg Diversion Scheme as an anti-waterlogging measure could be expected to prove highly successful.

The other point of paramount interest, not only to the practical engineer but also to the scientist, was the method adopted by Mr. Kapur in excavating about four miles length of the diversion channel by the action of flowing water itself. Although the action taken by Mr. Kapur, of employing water to do excavating for itself, was entirely on his own initiation, the feasibility of such action must have occurred to him as a result of his discussion with the Speaker during their hydraulic tour to the valleys of the Sutlej and Beas rivers just before the Deg Diversion was taken in hand. One or two extracts from the Speaker's pamphlet entitled "Silt theory of flow of water," which was published shortly after their return from that tour were illustrative of the views formed by the Speaker and the Author about the processes of formation of channels in Nature:—

Page 16. "The whole process of formation of rivers, streams and the smallest rivulets of water consists in this, that the edges of falls and rapids gradually wear away or give way, thereby forming or deepening the channel for the flow of water. This process, which is termed 'retrogression of levels' is always at work at falls and rapids and in the steep stretches of channels and is working backwards from the sea to the mountains."

Again in the same connexion on page 17:—

"The softest rocks wear away the quickest, and after that progressively harder rocks give way; so that the number of falls and rapids goes on decreasing, the remaining falls go on receding towards the mountain and the vertical drop at some of the remaining falls and rapids goes on increasing by the disappearance of the intervening cascades."

So it must have been some such ideas which the Author carried from their frequent discussions during the tour that made him decide to try the experiment of making water cut its own channel. And this experiment had been remarkably successful inasmuch as a 5,000-cusec channel has been formed within a short time from a 20-cusec cunette.

The Speaker had mentioned his indirect association with Mr. Kapur in his experiment to stress, at least in one respect, the practical utility of this theory of flow of water, which had been evolved not by algebraic manipulations of complex mathematical formulae but from a first-hand study of natural processes in the great workshop of Nature. He was not sure if Mr. Kapur had complete data of the formation of the diversion channel at its various stages as illustrated by him on Plate XI of his Paper. But if he had, then it would furnish a valuable clue to the natural relationship subsisting between the discharges of flow, and slopes and dimensions of channels in various kinds of soils.

Mr. **K. L. H. Wadley** said that Mr. Kapur had dealt very fully with the Deg Scheme in his Paper, and for its size the work was remarkably full of engineering interest. He did not propose to make a long commentary on the Paper which contained all the essential points of interest to Punjab engineers, but he wanted to enlarge on one or two items from which he learnt something during the course of the construction.

Some years ago, it was probably a difficult matter to get borings done cheaply in out of the way places. But now that the hand pump was so common throughout the Province, it was a comparatively easy matter to get men from the nearest town who were willing to sink bore holes at very cheap rates. It helped tremendously to be able to have an accurate forecast of the subsoil conditions at and around the proposed site of a new work. The borings could show that by quite a small alteration of the site originally proposed money, time and trouble might be saved.

For works with foundations below spring level, it would pay hands down to leave plenty of room round the main work and not to be stingy in respect of the area proposed to be opened up.

Figure I, Plate V gave a cross-section of the excavation as it was actually opened up at the Deg Fall.

Whereas the size of the finished work was some 200 feet × 200 feet, the area opened up for excavation measured about 400 feet × 400 feet at ground level, and this large area was found to be none too big.

As excavation got below spring level, there was a continuous infiltration of water from round the toes of all the side slopes as the water

drained into the pumping sumps. This water brought material with it and the sides got undermined and started dropping in. This dropping in and the consequent cutting back of the sides could be checked by piling spoil from the bottom of the excavation back on to the eroded side slopes.

By keeping on doing this as fast as erosion of the sides took place, the excavation could be left open for a reasonably indefinite period. This was so in the case of sandy slopes at any rate. One could, however, adopt this method only if there was adequate room inside the pit round the foundations proper.

The Author would probably agree that experience at the Deg Fall showed that the area as opened up (*vide* Figure I, Plate V) was just about as small as would allow of keeping a safe control on the side slopes.

The Tube-well pumping was a most interesting experiment, and in the Speaker's opinion, most successful. It gave a dry floor for laying the concrete, and better still, it ensured that the sand under the floor was absolutely undisturbed, both during and after the laying of the concrete—a very important point on an hydraulic work of this nature.

In cases where the water was made to gravitate to a sump or sumps situated round the outside of the floor slab there was a grave risk of drainage tunnels forming undetected, under the completed floor, unless the open pumping was very skilfully conducted and supervised. It was difficult to exercise this amount of supervision night and day, especially at a time when so much supervision was needed for the proper mixing and placing of the concrete.

Tunnels under an hydraulic floor are of course a grave source of danger. It was for that reason that the tube-well system had great possibilities for works with foundations laid below spring level.

At the Deg Fall, there was an excellent sub-stratum of sand from which water drained easily into the tube-wells. It would be very interesting to see how the system behaved if given a less porous sub-stratum. It would probably necessitate a closer spacing of the wells.

As the Author had stated, it was considered best to use, as far as possible, material and plant available in the Department. Although, as the Author had remarked, this plant was rather costly and inefficient to run, it did its job amazingly well and the scheme reflected great credit on the Drainage Division

As a Sub-Divisional Officer on the job, the Speaker said that although he did not like the long suction pipes, they worked ; but they needed rather careful nursing to prevent leaks.

If it were decided to use tube-wells on further works, the speaker had in mind small electrically driven centrifugal pumps (one for each well), so arranged that each pumping unit clamped neatly on to the tube well with a suction pipe and foot valve dangling down inside the well. These small pumps could be made to discharge into pressure pipes through which the water could be delivered up to ground level.

Alternatively, if pressure pipes were not available, the pumps could be made to discharge into G. I. sheet flumes, which could easily be made locally and the water in the flumes would gravitate to the main pumping sump, well away from the foundations. Electric current for the motors would be from a generator driven by an oil or steam engine.

These small tube-well pumps could be kept in the Irrigation Department and loaned to whichever Division might require them.

It might have occurred to some that it might have been possible to draw out the tube-wells as concreting advanced and so to salvage them for use on other occasions. This was thought of and in fact one well was pulled up. It was, however, found to have too marked an effect on the surounding spring level to permit of others being drawn. Also it was decided that it would tend to leave cavities or, at any rate, tend to unsettle the soil under the floor, which of course was undesirable.

It could be assumed that the tube-wells would have to remain in any work on which they were used, and be plugged solid with concrete.

It might also be mentioned that for purposes of digging the excavation, open pumping was all that was needed. Once the bottom of the foundation level was reached the tube wells should be installed and brought into action for keeping the floor of the foundation dry for laying the impervious slab.

The Speaker had nothing to add to the Author's description of the concreting operations except to emphasize the need for close supervision at all stages and of impressing on one's staff the necessity for great care.

The bulking of damp sand was an important point and the test described was equally applicable to small works or large. Undersanded mixes were particularly objectionable on hydraulic works

Mr. **W. C. Chopra** said that it was really fortunate that the Deg Diversion happened to be in the Sharakpur region, so as to be handy for diverting the tail reach of the Main Line Lower of the Upper Chenab Canal into it. It might interest this audience to know that, for getting rid of the Deg floods, several other schemes were considered and abandoned, the foremost being that of leading the Deg into the Basantar, a

tributary of the Ravi, situated in Shakargarh Tehsil of Gurdaspur District; yet another being somewhere between the Basantar and the Raya Branch. Looking back now, the Speaker said that he remembered that for the final discussion Sir John Benton came down to Lahore from Simla, the other officers who joined the discussion being Mr. Bennett, Chief Engineer, Messrs. Rose and Ives, Superintending Engineers and Mr. Muller and the Speaker, Executive Engineers. What he would like to ask the Author (as he did not find it mentioned in the Paper) was whether or not it had been necessary to raise the Deg Diversion Bund in order to take up the combined monsoon flood of the Deg and the 7,000-odd cusecs of full supply discharge of the canal.

With regard to the development of a cunette from the canal to the deep Deg Nalla mentioned on page 128, he might inform the Author that in connection with the construction of the Bhimber Weir of the Upper Jhelum Canal in 1917 he succeeded in diverting the winter supply of the canal to the deep channel below the weir, in the same manner, at small cost. It was very wise of the Author to have adopted this cheap method.

Mr. **C. L. Handa** said that Mr. Kapur had dealt with the interesting work of the Deg Fall construction so very thoroughly that there was not much room for amplification. There were however a couple of points of which he had personal knowledge, due to his association with this work, and these might interest the members.

Mr. Kanwar Sain and Rai Bahadur Khosla had commented on the system of tube-well pumping which was employed on this work on a large scale with great success. Regarding this, it was to be noted that the suitability of open pumping versus tube-well pumping was largely dependent upon the nature and the extent of the area under operations. At the Deg Fall the whole work was located within a pit of about 400 feet by 300 feet and involved an excavation of over 20 feet. Except for tube-well pumping, it would have been necessary to open more than twice this area if the foundations were to be drained by open pumps alone. The cost of this would have been prohibitive. On the other hand in the case of the work at Marala Weir, which had already been visited by many of the members of this Congress, it was more expedient and economical to depress the general water-table within the area of working by a large number of open pumps. The water level outside the work having been lowered a couple of feet below foundation level, concreting of a bay was started from both ends towards the centre without any local pumping. Two or three tube-wells were then sunk in the centre of the bay to dry up the area locally without blowing any sand. By this means the final sealing of the concrete was effected in the dry. Wholesale tube-well pumping over such a large area would naturally have been expensive, and the final stage of the work would not have been satisfactory with outside pumping alone. It was only by a happy combination of the two

methods that the best results were obtained most economically. It might be said that among other things pumping by either way was a function of the area that had to be opened and the superiority of one or other method could only be judged by conditions on the spot.

The second point the Speaker wished to talk about was the pressure pipe observations described by Mr. Kapur on page 127 of the Paper. The observations on the 18th and 22nd November, 1935 with heads 7·2 feet and 9 feet were made by the Speaker, and members would be interested to know the peculiar conditions attending these observations. On one of these days water had just been admitted into the Fall after the stoppage of pumping on the downstream side. Head was created by means of the needle dam, but there was considerable leakage through the needles and the unwatering openings in the crest. This resulted in a rapid rise of downstream water level as the cistern below was filled and the leading cunette was still undeveloped. On account of an insufficient time-lag, the rise of water level in the pipes naturally could not keep pace with the outside rise, and the effective pressure indicated by the readings therefore was exaggerated.

It would thus be seen that the conditions were not steady enough to give reliable results. Moreover, since the channel below the Deg Fall had not scoured down to the designed levels it would be some time before these big heads of 7 feet to 9 feet could again be obtained at this fall. At present the drop across the fall was less than a foot. The full value of the pressure pipe readings under big heads would be available after the process of erosion of the 4 miles of channel below the headfall was completed.

Before he closed the Speaker wished to say a few words about the development of the Deg Diversion channel from the Deg Fall to the point of its junction with the Deg Nallah. In his opinion the process of development could be further expedited if the initial cunette had been dug a little more liberally. In that case the kankar bars and the stiff strata that were encountered after a month's running, could have been removed before water was let in. It was true that the work of deepening the initial cunette was not easy but it was certainly practicable without prohibitive expense. A few more thousands of rupees spent in the initial stages would not only have materially quickened the rate of development, but would also have removed any anxiety that might now exist regarding the period that would be required for the complete development of the Deg Diversion channel which would enable the lowering of the canal full supply in the vicinity by 8 feet.

Mr. **S. I. Mahbub** said that the very valuable Paper of Mr. Kapur not only dealt with the history and design of the Deg Fall but also enumerated the constructional details of reinforced concrete work and work below spring level. The observations regarding fluming and the development of the Deg Diversion Channel were also of scientific interest.

The Speaker said he had recently to make a new Head Regulator for a 500-cusec channel, within a thousand feet of the Deg Fall, where the foundations had to be taken only 12 feet below spring level. Two 6-inch pumps, working with 8 H. P. Petter Engines were kept going day and night in a pit measuring about 70 ft.×100 ft., *i.e.*, about 1/20th of the size of the pit in the case of the Deg Head and yet it was not found practicable to lay the concrete without boxing. It could thus be imagined that it would have been quite impossible to lay the concrete in the dry in the foundations of the Deg Head, if only open pumping had been resorted to.

In the case of the flume over the Deg Fall, a divergence of 1 in 4 on the downstream side had, in spite of parabolic curves, been found to be excessive in actual practice. This had caused a scour hole on the right side about 5 or 6 feet deep, some 20 feet from the end of the pacca floor. Two divide walls had since been inserted, as described by the Author, to ease off this divergence. These had, however, not yet been tested and it would be of interest to know how far these were effective in reducing the downstream scour.

The development of the Deg Diversion channel from a 20-cusec cunette to its present capacity of 5,000 cusecs furnished an interesting scientific study and threw great light on the methods by which Nature formed her channels.

The Speaker had been in charge of the Deg Diversion channel for the last six months and the progress obtained in this period had been really phenomenal, the increase in discharge being from 2,000 to 5,000 cusecs. A longitudinal section of the channel, prepared recently, showed that with the exception of a few narrow humps, the central portion of the channel had scoured backwards to the designed bed levels from R.D. 20,000 to R. D. 5,500. This had been successfully accomplished by fixing spurs about 500 feet apart, with a water jet leaving a gap of 50 feet for the flow of water. These spurs created a series of small falls which effectively scoured the bed between them. After the scour had gone sufficiently deep, the end ballies started falling in, thus automatically widening the channel.

The drawbacks in this method, however, were that the development took considerable time and the water level had to be kept high in its initial stages, which naturally raised the water-table of the adjoining area for that period.

The whole of the Upper Chenab Canal had since been diverted into the Deg Diversion channel which marked the completion of one of the biggest anti-waterlogging measures taken in hand in this Province. This was bound to arrest any further deterioration of land in the 36 miles tract below the offtake of the Deg Diversion channel, but how far it would

help in ameliorating the condition of the area already stricken with *thur* had yet to be seen.

Mr. **S. L. Kumar** said that the Author stated on page 114 that the compressive strength allowed in the calculations was 600 lb. per square inch for 1 : 2 : 4 concrete. To have adopted this figure in these days for the design when 750 lb. per square inch was adopted for the ordinary grade concrete of 1 : 2 : 4 mix was certainly wasteful. Was this done just to save the comparatively trifling expense of using some grit with fine sand?

Regarding the allowance for bulking of sand, although the Author clearly stated on page 114 that this bulking depended " partly on the degree of packing or consolidation by shaking but the main factor was the moisture content of sand." Yet while determining bulking experimentally as detailed in paragraph 1 on page 115, he made allowance for the moisture content only but not for the first factor, *viz.*, bulking due to loose packing. Experiments made by the Speaker with hard sands showed that the weight of loose sand per cubic foot was about one-sixth less than that of an equal volume of dry rodded sand. Similar results were obtained with other sands.

Cement when loosely packed might weigh from 60 lb. to 70 lb. per cubic foot while the dry rodded weight of ordinary cement was 90 lb. cubic foot and that of rapid hardening cement was 40 lb. Thus, while on works, it was the dry rodded weight of cement that was allowed for when each bag of ordinary cement was considered equal to 112/90, *i.e.* 1¼ cubic feet, there seemed to be no reason why a similar allowance should not be made for the bulking of sand and shingle due to their measurement in a loose condition. Thus, in a 1 : 2 : 4 mix when using dry Haro sand, for each cubic foot of cement, one should use 2⅓ cubic feet of loose sand and not 2 cubic feet. If the sand was not dry, further allowance for the bulking due to the moisture would be necessary.

The author evidently felt satisfied when he stated in the first line of page 115 that bulking tests were made at least twice a day. Actually on works, where sand was being washed simultaneously with the laying of concrete and where it was bound to be used with greatly varying degrees of moisture, the results of test for moisture content, described by the Author, applied only to the batch for which it was used. Hence, two or even half a dozen tests were not of much value. The only possible method to attain uniformity of the mix was to use such apparatus as had been recently placed on the market by Messrs. Hall & Sons, London. In this apparatus, if moist sand was placed in a container, a calibrated scale automatically gave the volume of the damp sand required for a certain mix. A second method was to vibrate saturated sand in a vibrator for 30 seconds. The vibrated sand contained a definite percentage of moisture; thus the bulking due to the

moisture became a constant factor. The third method and much the simplest, though not easily applicable to big works, was to dry the sand beforehand. The hot sun in India would effectively dry up the sand in a few days after it had been washed and spread in stacks of about one foot depth and raked up occasionally.

In paragraph 5 on page 115 in connection with mixing the Author stated that an attempt was made to turn out one batch every 3 minutes from the mixer. Considering that it took at least one minute for charging the mixer and another for removing the mixed stuff from the mixer only one minute was actually allowed for mixing the sand, cement and shingle. This was not in the Speaker's opinion adequate to ensure a uniform mix.

In Appendix II, the Author gave on page 134 the details of running costs of a 12 H. P. portable steam engine for 12 hours, amounting to a total of Rs. 26-12-0. A number of 12 to 14 H. P. portable Lister oil engines had been used by the speaker with welding generators. Their cost for a shift of 9 hours was as follows:—

	Rs.	A.	P.
Diesel oil 4 gallons	0	12	0
Mobil oil, 1 lb.	0	2	6
Driver	1	8	0
Coolie for one hour to fill up cooling water tank.	0	1	0
Spares and consumable stores	0	8	0
	2	15	0 say, Rs. 3

Thus the cost of a diesel oil engine for 12 hours would be Rs 4 *i.e*, one-seventh of the cost of a steam engine. It would have been certainly economical in the long run if the uneconomical steam engine had been scrapped and a new oil engine had been purchased at a cost of Rs. 1,600 approximately.

In his opinion with the small diesel oil engine of 12 to 15 H. P. it was not necessary to have oilmen. The lubrication was automatic. The driver had quite an easy job without an oilman. A coolie was needed for one hour in every shift to fill up water in the cooling tank.

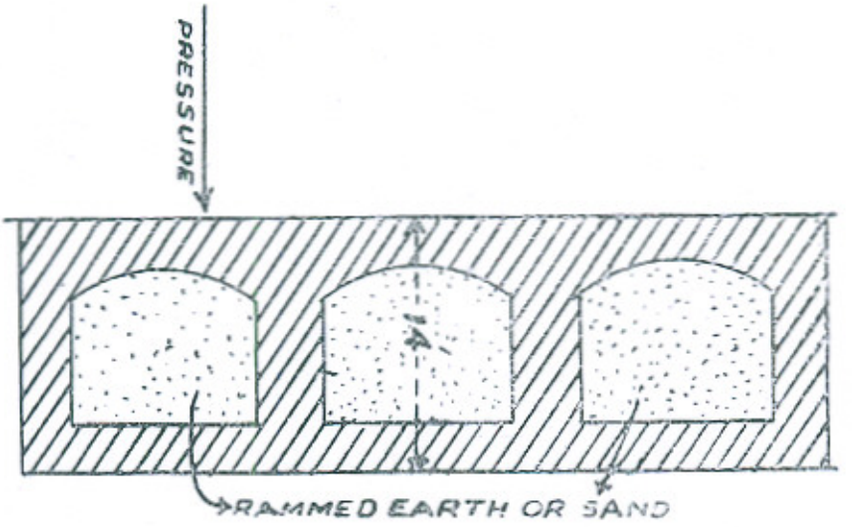
On pages 134 to 136, the Author took kerosene oil at Re. 0-4-0 a bottle and also at Re. 1 a gallon. As a gallon contained 6 bottles, one of these rates was evidenty incorrect.

Mr. **Indra Sen** said that looking at the two designs, the old and the the new, one felt that if the old was weak, the new was unnecessarily strong.

For example, take the wing wall at section No. 7, Plate IV.

The width at the base was 14 feet for a backing 21 feet high. Apparently it had been designed on Rankine's theory to withstand wet sand with an angle of repose 20°. This thickness could be reduced (*i*) partly because Rankine's Theory did not take into account the cohesion between particles of soil of the backing and (*ii*) partly by providing suitable weep holes, pressure due to high spring level being reduced to some extent.

In any case it would have been cheaper as pointed out by Mr. Kanwar Sain to design wing walls in reinforced concrete when there was so much pressure from the backing. For section 7, the speaker had worked out the design and the stem of the reinforced concrete wall came to 2·5 ft. only, against 14 feet masonry. The thickness of the masonry walls was more than five times that of the reinforced concrete one, but masonry was only thrice as cheap as reinforced concrete. Hence, reinforced concrete wing walls could have been built at 60 p.c. of the cost of masonry walls and to stand the same pressure. Even if it were necessary to provide masonry wing walls, their cost could have been reduced by making them hollow and filled with rammed earth or sand as per sketch.



The excavation of foundations 20 feet below spring level was a remarkable achievement. The ingenious idea of temporarily lowering the spring level in the foundation area by means of tube-well pumping was conceived by Mr. Murphy soon after the failure of the old Head Regulator.

As pointed out by Mr. Khosla, our knowledge of earth pressure was very limited and it was very desirable that experiments should be carried out both in the laboratory and the field. When he was a student at Roorkee in 1922-23 experiments were being made in the

laboratory, under the guidance of Sir William Stampe, then Professor of Civil Engineering, to determine earth pressures and angle of repose of various soils. The Speaker did not know what the results were, but it would be advisable to get the results of these experiments for future guidance.

Mr. Khosla told the Speaker in 1928 that if the Deg Head Regulator were to be rebuilt, the floor and foundations would be laid in the dry. It appeared that tube well pumping was the only safe method for executing work of this nature.

Another feature of the design was the very economical combination of the aqueduct and the road bridge. Provided the sharp kinks in the road were not objected to, the design was quite satisfactory.

It was difficult to foretell the results of the scheme as an anti-waterlogging measure. It might lower the spring level in the vicinity of the old abandoned channel, but it could not reclaim vast areas where salt and *thur* had already appeared on the surface. The hope was that fresh areas would not be thrown out of cultivation along the new diversion channels.

Storing of cement was a very important thing. In the interest of timely execution of works, it was extremely desirable to keep large quantities of cement in store to guard against emergencies such as delay in supplies, rains, etc., and to avoid possible risk of deterioration the consignments might be ordered in paper lined bags, the difference in cost being negligible.

Mr. **B. S. Wadhera** said that he would like to know if there were any special circumstances which necessitated the adoption of a rather elaborate and expensive form of shuttering for the inside of the aqueduct. Normally it would be much cheaper to use false work consisting of side walls of kacha pacca masonry with plaster for the inside, and the work of concreting could be finished in about a half to a third of the time spent in this case.

R. B. **A. N. Khosla** said that the scheme was essentially an anti-waterlogging measure, but the Author had not clearly stated in the Paper how this object was to be achieved and he asked the latter to explain this aspect of the scheme in greater detail.

The Speaker remarked that the design and execution of the work left nothing to be desired. The reinforced concrete aqueduct was a feature of the new structure and had called for high technique and skill in execution. The arrangement for accommodating a series of turbines for power development at a later date was a wise and timely provision. The boxing-in of foundations by interlocked steel sheet

piles, besides providing for the security of the structure, facilitated construction and laying of open foundations. The necessity of the downstream pile line as a cut-off had been fully appreciated.

Referring to the design of wing-walls the Speaker stated that full earth pressure for dry earth with a 20° angle of repose had been taken and in addition 50 to 70 per cent. of water pressure. The tests carried out in America indicated that this assumption was reasonable.

Another important feature of this constructional work was the use of a series of tube-wells for pumping out water from within the cofferdam which was made by the steel sheet piles This enabled the foundation concrete to be laid practically in the dry. In large works, however, exclusive use of tube-well pumping was likely to be prohibitive in cost and slow in operation. A judicious supplementing of the open pumping by pumping from tube-wells would prove most effective and economical.

The Speaker remarked that it was always desirable and highly useful to make slump and bulk tests on a large job but the results obtained from such tests could be accepted as a general guide only for the water-cement ratio. Judgement by eye of the engineer must still control the proportions. The requirements of water varied considerably during the day with changes in air temperature and humidity. It had always to be remembered that a comparatively dry mix might give a high tensile strength in laboratory tests but was likely to produce spongy concrete.

The approaches to the aqueduct had been designed with the minimum loss of head. The outside appearance and finish of the work was very pleasing.

The Author had in short produced a Paper which would prove of very great value to the designer and the construction engineer.

CORRESPONDENCE.

Mr. **T. Blench** congratulated the writer on his lucid practical exposition and asked if he would care to give a short appendix dealing with the design, including the following points.

(1) Did the design that failed fail only because of the absence of a pile line ? Was a model tested in the Irrigation Research Laboratory either before or after construction ? Would a plate showing the design be included in the appendix, showing the reason for failure ?

(2) How was the diversion channel designed ? With Q=7000 and S=0·15 per 1000, *f* (the silt factor) worked out to 1·1, which seemed

to be about what one expected from the Upper Chenab Canal from general information. But the section of 180×10·3 corresponded to Q=6,000 and f=0·7. Dimensions from 7,000 cusecs and f=1·1 should be 210×9·5.

As the channel was in cutting it might quite possibly run to the dimensions chosen; but it would be interesting to know if they were taken from the existing canal or guessed or designed.

(3) Was it considered likely that the Deg Diversion might affect the f of the Lower Bari Doab Canal? Under the old conditions the Upper Chenab Canal discharged just above the undersluices, and apparently its silt never went to the Lower Bari Doab Canal which had a very low f of about 0·7 at the most. Now that the discharge was upstream the Upper Chenab Canal silt might be carried into the Lower Bari Doab Canal.

(4) How was cistern depth calculated? At about half discharge, headed up, the Central Board of Irrigation Publication on The Standing Wave,* Plate V showed that about 6·5 feet was required, against 10 feet provided in the design. This was just a reasonable extra allowance for retrogression, effect of needles and other disturbing causes. Was the depth actually found from the Central Board of Irrigation Publication?

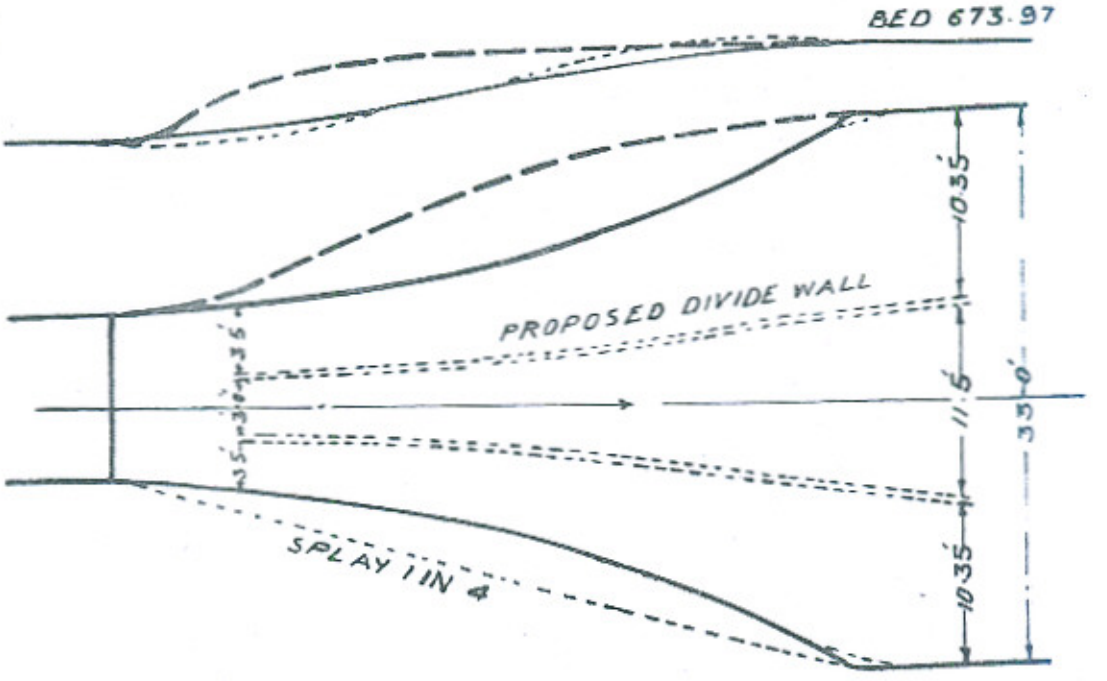
(5) Were the calculations for the reinforced concrete aqueduct design available? Fairly simple assumptions about the section over the piers showed that, with full aqueduct, there was a large negative bending moment at the bottom corners, which did not seem to have been allowed for. Away from the piers it probably did not exist. A design of this type was tricky and well worth putting on record.

Mr. Blench suggested a divergence on the general lines of Sketch A (see page 142q) which would give divergence to the water where the aqueduct was of small breadth. The idea was to give the water a good divergence by a fairly, but not too abrupt, rise of the bed just outside the throat, and use the major portion of the side splay as a means of bringing back the flow parallel to the channel centre-line. Friction blocks would be useful in the divergence. They did not seem to be of any use in the Fall cistern, as they neither needed to nor on account of the piers could give any divergence there. Their real use was in adding friction to a jet so as to help it to diverge to full channel breadth at which place absorption of energy was negligible compared with that of the standing wave, without whose formation the work would fail. The use of friction blocks was described by their inventor, Mr. Montagu, in the Central Board of Irrigation on Falls.†

* C. B. I. Publication No. 7.

† C. B. I. Publication No. 10.

SKETCH A



The **Author** in replying to the discussion said that R. S. Kanwar Sain wanted to know whether the Author preferred the tube-well system of pumping to the usual open sump method. Experience on the Deg work showed that for the excavation of earthwork, the usual open sump method was much cheaper than the tube-well pumping to start with. As the foundation was excavated lower down, it became necessary to combine both systems.

For getting a dry bed for concreting, tube-well pumping was invaluable and should be insisted on. It prevented the cement being washed away and also saved the raw concrete from being subjected to the strain of water pressure from below which was bound to be very harmful.

It was the Author's definite opinion that with the greatest care possible with open pumping, some of the cement from the bottom concrete was bound to be washed out and this might result in leaving a layer of practically dry ballast under the work which was extremely dangerous. He, therefore, strongly advocated a combination of the two systems of pumping, in the manner done at the work under discussion.

The defects in the tube-well method employed at the Deg Fall were :—

(1) The tube-well units employed were too big and the Author recommended smaller units, spaced closer.

(2) The installing of the pipe lines at a high level and subsequent lowering by stages caused leaks in the pipe line and thereby substantially reduced their efficiency.

The Author thought that the following system used by the construction of an incinerator plant in New York, where the foundations were 24 feet below Spring Level, were well worth adoption on similar works:

"A series of well points were installed around all four sides of the proposed foundation pit, outside the line of sheet piles. Points were spaced at 3 feet intervals along the sides and at 6 feet intervals across the ends. Two pumps were hooked into the 8-inch pipe header circuit. The point units were 25 feet long, made up of a 1½-inch pipe, 22 feet long with a 3-feet screwed point at the lower end.

This system lowered the water sufficiently to permit an 8-foot cut, after which the sheeting was drawn 5 feet below the ultimate bottom. The well points were then jetted down about 3 feet farther, lowering the header lines at the same time. This placed the tips of points about 1 foot below the bottom of the sheeting.

As excavation progressed downwards, the first installation of well points proved inadequate to keep the ground dry. This trouble was overcome by installing another set of well points inside the sheeting, jetting the units down to 5 feet below the bottom of the sheeting. These points spaced at 6 feet intervals, were connected to header lines and were served by a single pump.

The well points used were of a new design (Complete Machinery and Equipment Co. system). Their chief departure from other designs is a fluted sleeve inside an octagonal bronze and perforated brass-pipe covering. The fluted sleeve is sealed at the top, forcing the water to travel down the outside of the sleeve to the point before it can enter the pipe. A ball valve on the tip is used for jetting purposes, and seals the bottom of the point when in action. The points are self jetting and do not require driving." *Engineering News Record.*

As regards the storing of cement, the work was not a closure work and a week's supply in hand was ample, considering that the whole of the foundation concrete was finished in about two weeks.

The abutments, as designed, no doubt looked very wide to a superficial observer, but considering that pacca masonry cost only Rs. 0-6-0, per c. ft. against Rs. 2 per c. ft. for reinforced concrete, the cost could not be reduced by a change to reinforced concrete, as the average thickness of the abutments was only 8 feet, and a reinforced concrete abutment could not be less than 1·5 feet in thickness in addition to the counterforts.

Mr. Khanna's remarks were interesting. The data required by him was not collected as the changes in the cross section were too rapid to give accurate results.

The Author expressed his thanks to Mr. Wadley for coming all the way from Simla, to take part in the discussion. He agreed with Mr. Wadley's remarks about the studying of subsoil conditions, which point had already been stressed in the Paper.

He also agreed with him in that the foundation pit as excavated was just enough to work it. Any further cutting down of this area would have been extremely troublesome during the progress of the work.

Regarding his remarks about a less porous sub-stratum the Author thought that it was only in sand that tube-well pumping could be successful. In clayey soil, open pumping should be much cheaper and quite safe.

He did not agree with Mr. Wadley that electric pumping sets would be more efficient. The method described in reply to R. S. Kanwar Sain's remarks of having small well points closely spaced, appeared to be decidedly better.

If small well points were used, there should be no difficulty in removing them after completion of the work, particularly from the outside of sheet piles.

In reply to Rai Bahadur W. C. Chopra's enquiry as to whether it had been necessary to raise the Deg Diversion bund in order to take the combined monsoon flood of the Deg and the Upper Chenab Canal, the Author stated that so far only a small bund had been constructed on the left of the Deg Diversion from its Head to about Mile 5. The Deg Diversion bund on the right was very high and there was no chance of its being overtopped by the combined supply. Moreover, during the monsoon months, when the Deg was in flood, the supply running in the tail reach of the Upper Chenab Canal was less than 5,000 cusecs, which was sufficient to feed all the Upper Chenab Canal channels, the Lower Bari Doab Canal getting the rest of its supply from Ravi water.

In reply to Rai Bahadur A. N. Khosla the Author stated that the method by which the object of the scheme was to be achieved had been outlined by him in his introductory remarks.

He agreed with Mr. Handa that tube-well pumping should be judiciously combined with open pumping according to the requirements of each work.

Considering that the development of the cunette was to go on for a considerable time, he did not think any further expenditure on the original cunette was justified, as it was not possible to dig much below spring level. The progress in the development of the Deg Diversion

in its early stages had amply justified the belief that the cunette as excavated was sufficient.

The only reach which had not developed was from R. D. 3,000 to R. D. 5,000 where an old channel existed whose bed was below spring level. This reach was so marshy that it was not possibe to do any work, although an estimate for a cunette was actually sanctioned for work in this reach.

Sh. Mahbub Ilahi made a reference to the two divide walls, inserted downstream of the flume to ease off the divergence.

Mr. Merrington who was at present in charge of the works wrote that the divide walls had been quite successful in their function of preventing scour below the walls and there had been no trouble in this connection. The flow was now quite smooth and due to the disappearance of the eddies the loss of head through the flume was also less.

In reply to Mr. S. L. Kumar the Author stated that the Punjab Irrigation Department had not so far changed its specification regarding the compressive strength of concrete as the works on the canals were generally carried out in very out of the way places where the required quality of work was not always certain. Grit was not specially mixed with sand as the samples of bajri obtained later contained the required quantity of grit. For the floor slab, a minimum thickness of 4 feet having been fixed for other reasons, it would have made little difference increasing the compressive strength to 750 lb.

Mr. Kumar took exception to the method employed by the Author for measuring the bulking of sand. The bulking, no doubt, depended partly on the degree of packing but the sand was loosely packed in the experiment as well as when actually measuring and therefore the error on this account was cancelled. The apparently dry Haro sand used by the speaker was evidently not quite dry, for perfectly dry sand could be reduced in volume by rodding it. The cement was used in whole bags and therefore no allowance was necessary in bulking.

The sand at the Deg Fall was excavated from the foundation pit and had been lying in stacks for over one month before it was used on the work. The Author therefore considered that two tests carried out each day were sufficient in that particular case.

The only "possible method" recommended by Mr. Kumar was the use of the apparatus recently placed on the market by Messrs. Hall & Sons, London. Perhaps he had not seen this apparatus, otherwise he would not have made the remarks regarding the "degree of packing of the sand". As per instructions received with this apparatus, the container, or canister as the makers called it, was filled with the damp

material to be tested, gently shaking the canister while the material was being poured in. Thus the degree of packing in this case would depend entirely on the shaking, which brought in an error, but this error was negligible as compared to the bulking caused by moisture.

As stated in paragraph 5 on page 115, one batch was turned out every minute. The time spent in feeding the mixer was not more than half a minute, and 1½ minutes were allowed for mixing which was considered ample. In this connection Mr. Kumar was referred to " Concrete Engineering ", by J. Singleton Green, Volume, I pages 204 to 206 which he would find instructive.

Mr. Kumar, in his criticism had given details of the working cost of a 12 H. P. portable Lister oil engine and had compared it with a 12 H. P. portable steam engine. He seemed to forget that while the engines were rated by their B.H.P's., the N.H.P. in the case of a steam engine was 3 to 5 times the B. H. P.

The prices of diesel and mobil oil as given by Mr. Kumar were only Rs. 0-3-0 and Re. 1-8-0 per gallon respectively. A reference to page 135 of Appendix II would show that the cost of crude and mobil oil at the Deg fall were Re. 0-7-0 and Rs. 2-4-0 per gallon respectively. The difference was due to railway freight at full rates and the carriage charges from the railway station to site which had to be paid. Moreover, the portable steam engine could be safely relied upon to work continuously twenty-four hours a day for months at a stretch, while oil engines were known to give trouble very frequently if worked continuously in the summer heat of June and July in this locality.

Mr. Indra Sen had drawn attention to the unnecessary strength of the wings, floors, foundations, piers, etc. The author assured him that the work had been designed scientifically and that none of these dimensions could be reduced. The wings might have to withstand slush, the floor might have to withstand uplift pressure caused by a head of 24 feet, the foundations rested on sand and the piers had to carry the aqueduct when full of water (7 feet depth), a road-way on top and the heavy electric generators and turbines which were proposed to be installed.

In reply to further remarks by Mr. Indar Sen, the Author stated that in comparing the thickness of masonry walls with reinforced concrete, Mr. Indra Sen had taken the thickness of the former at bottom, instead of the mean or average thickness which was only 8 feet. Thus, while the thickness of a masonry wall was less than 4 times the thickness of a reinforced concrete wall, the cost of reinforced concrete was about 5 times the cost of masonry. It was, therefore, cheaper to have masonry walls.

Regarding his suggestion of making the walls hollow, the Author was of opinion that the saving in cost was not worth the risk involved, as the sand filling may be washed out through any hollow joints left in the masonry.

As regards the sharp curves in the roadway on top of the aqueduct flume, the Author stated that the road approaches were marked on the ground to a full scale and tested before deciding on the design for the approaches.

In reply to Mr. Bhim Sen Wadhera, the Author stated that the false-work consisting of side walls of kacha pacca masonry was not used as the fresh concrete at the bottom could not stand their heavy load without being damaged. Besides it would have been necessary to make the walls very thick to withstand the pressure caused by a 7-feet column of concrete.

In reply to the communication from Mr. Blench, the Author stated that the main features of the design had already been described in the Paper. The rest of the calculations were ordinary routine which any one could do with the help of a simple text-book on reinforced concrete. The other points raised by Mr. Blench were dealt with below :—

(1) The Author's opinion, as regards the cause of failure had already been given in the Paper, and a plan of the work had also been given *vide* Plate II. As far as the Author was aware the work was constructed. The work had not been tested on a model after its failure.

(2) The diversion channel was designed by Mr. Murphy with the help of Kennedy's Hydraulic diagrams.

(3) It was not considered likely that the Deg Diversion would affect the silt in the Lower Bari Doab Canal.

(4) The Deg Fall was a vertical fall and it was not intended to have any cistern downstream, but a 3 feet deep cistern was introduced at the request of the Hydro Electric Department.

The depth of cistern was 3 feet and not 10 feet as stated.

(5) The calculations for the reinforced concrete aqueduct were available. As stated above these were fairly simple. The assumptions made and the method of calculation had been described in the Paper.

The side beams of the aqueduct were freely supported and the negative bending moment at the supports were $\frac{wl^2}{20}$. This had been provided for by carrying half of the 12 reinforcing bars straight through and bending up the remaining half at three points, *vide* Figure 98 page 292, of " Reinforcement Concrete ", by Taylor and Thompson, Volume I, Fourth Edition.

Mr. Blench suggested a divergence even steeper than 1 in 4. In this connection the Author suggested his visiting the site and seeing for himself that the high velocity jet through the flume did not stick to the sides as they existed at present and the divergence suggested by him was sure to make matters much worse.