Pumping Installation for the Warsak Lift Irrigation Scheme

By

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I. GENERAL

1. The Warsak Lift Canal Pumping Station, located 10 miles to north-west of Peshawar town, in Tribal Territory of Khyber Agency (R. L. 1255) is accessible by three different approximately equidistant routes. (See location map plate 1):—

(*i*) Peshawar to Jamrud along Jamrud-Warsak road mile 5 along link road to the pumping station (16 miles).

(*ii*) Peshawar to Warsak along Michni Road along Michni Shahgai to Jamrud-Warsak road 7½ miles along link road to Pumping station (15 miles).

(*iii*) Peshawar along Jamrud Road to R.D. 58,000 Gravity Flow Canal then along the Canal boundary road to R.D. 23,600 along link road to Pump House (14 miles).

2. Before describing the Pumping installation and the Lift Canal itself, it would perhaps be of interest to know the salient features of the Warsak Multi-Purpose Project.

3. This Project was conceived originally by the Public Works Department of the former N.W.F.P. Government in the year 1947-48. After carrying out preliminary investigation and studying the hydrological data, the department had recommended to the Central Government to arrange for technical appraisal of that proposal by some outstanding Consultants. The Central Government readily agreed to the proposal and engaged Messrs Merz Rendel Vatten (Pakistan) Consultants and Design Engineers, Stockholm (Sweden). The Consultants submitted an interim report in 1949. After conducting further detailed site studies, including actual drilling and discharge observations extending over a period of 2½ years, the Consultants submitted the preliminary project report in 1951. The report discussed in detail the various alternative sites and types of dam to be constructed.

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4. The one serious limitation, that stood in the way of maximum exploitation of the hydel power potential of Kabul river, was the proximity of Pak-Afghan International border—about 20 miles along the river course—upstream of the dam site. In order not to violate the international requirements in such matters care had to be taken to fix the height of the dam in a manner that would prevent the inundation of Afghan area due to afflux. The Consultants accordingly recommended the construction of a rock fill dam 150 feet high from the average bed level of the river channel and development of power potential of 2,40,000 K.W. installed capacity.

5. The Central Government on receipt of the Warsak Hydro-electric Project report took some time to decide whether Warsak or the Mianwali Hydel Project, sponsored by the ex-Punjab Government, should be implemented first. The examination of the two alternative proposals naturally took some time before it was eventually decided that Warsak Hydro-electric project should get first priority. Meanwhile the Canadian Government got interested in aiding the Project under Colombo Plan. And so an agreement between the Pak Central and Canadian Governments was signed about the end of 1954. The Canadian Government engaged Messrs H. G. Acres & Company as their Consultants for the project. Contract for the construction work was entrusted to Messrs Angus Robertson Limited, a Canadian construction firm. The Consultants finally decided to go in for masonry instead of a rock-fill dam recommended by the M.R.V.P. It was also decided that in the first instance only four generating sets, totalling 1,60,000 K.W. installed capacity, should be installed making provision for installation of additional two generating sets each 40,000 K.W. The scheme also provided for irrigation facilities to 1,40,766 acres area (gross) located on the left and right banks of Kabul river. The Irrigation Department—who were in charge of the whole Project till the end of 1955—transferred the superintendence of the Hydel Power portion of the Project to the Warsak Dam Organization early in 1956 after the arrival of Canadian Project Director and his team, retaining the charge of construction of Warsak High Level Canals.

6. After the reservoir draw down levels and power requirements were determined by the Consulting Engineers, from the point of view of maximum power production, the share of irrigation supply was prescribed as 500 cusecs and 350 cusecs in Kharif and Rabi respectively.

7. The Consultants thereafter fixed the exit level of the Right Bank Irrigation Tunnel at 1244.00. From this level the gravity command of the two channels on the left and right banks of Kabul river worked out to be gross/C.C.A. of 81,307/69,594 acres. The balance of the area viz. 1,40,766—81,307=59,459 acres gross, had therefore to be provided for under Lift canal,

The static head necessary for commanding the area worked out to be 162 feet and the total head to 196 feet. This lift, although unusually high, has been made possible due to the availability of cheap power, (2 pies per unit envisaged in the original project report of 1951) and the existence of suitable high level spur (necessary for locating the exit structure of the Rising Main) within a short distance of one mile from the Pumping station.

8. The irrigation supply of 455 cusecs—passed down the Right Bank Canal, through a 17,000 feet long tunnel—is carried to the bifurcation point R.D. 20,130 through a Gravity Canal. At this point the channel bifurcates into two branches, namely the Gravity Flow canal and Lift canal. Similarly on the left bank 45 cusecs irrigation supply is drawn from the Reservoir into the Left Bank canal through four tunnels aggregating in length to 10,414 feet.

9. The Right Bank Gravity Flow Canal—commissioned in 1961—has a discharge of 255 cusecs and a length of 45.2 canal miles. This channel serves an area of 58,641 acres (C.C.A.) out of which 33,000 acres is already under irrigation and the rest is being reclaimed gradually. The slow development is due to lack of adequate earth-moving equipment.

10. The Left Bank Gravity canal is virtually complete. It has a capacity of 45 cusecs and a length of 18.5 miles. It irrigates an area of 10,953 acres (C.C.A.) located in the Mohmand Agency area. The channel, aligned through an extremely difficult terrain, has necessitated the construction of numerous costly and intricate cross-drainage works.

Warsak Lift Canal

11. This channel, with a capacity of 200 cusecs and length of 37 miles, is aligned along the mid slope of Khyber hills at an elevation of 1400 above M.S.L. The supply for this channel, drawn from the Main Gravity Flow Canal at R.D. 20,130, is conveyed into sumps of Pumping station through a feeder channel (2500 feet length). From this point the water is pumped, by means of 4 giant Centrifugal pumps—perhaps the biggest pumping units of their kind in the country—(each 50 cusecs capacity and 1340 H.P. with Motor power of 1582 H.P.) connected to a mild steel Rising Main, 5′-9″ dia and 5,500 feet long to R.D. 0 of Lift Canal located at R.L. 1400. The Rising Main has been manufactured by Messrs Herman & Mohatta Limited, from imported 3/8 inch thick M.S. Plates. The Lift Canal commands an area of 46,100 acres. This channel too is aligned through a most difficult terrain necessitating construction of a large number of costly and intricate cross drainage works. The estimated cost of the Lift canal—inclusive of cost of Pumping equipment—is 3.7 crores which is about 46% of the total cost of the Project. This incidentally reflects the importance of this component of the irrigation Project.

12. Since there is a general feeling both in the public and the Government circles that implementation of this project has been delayed unnecessarily, some explanation would appear to be necessary. Initially the work on the Warsak High Level Canals Project was to be started simultaneously with the commencement of the work on the Warsak dam itself *i.e.*, in early 1956 and was to be completed in five years *i.e.*, by end of 1961 which incidentally was also the scheduled target for the completion of the Warsak dam.

13. Unfortunately the Irrigation Department ran into serious difficulties from the very start of the Project, in that the Irrigation tunnel exit level—which was to be determined by Messrs H. G. Acres & Company—was not intimated to the department till the beginning of 1958, despite the fact that the department moved in the matter early in 1956. Further, within a few months of the commencement of the work, on the construction of the Warsak canals, the progress was seriously hampered due to scarcity of construction materials like cement and steel on account of stoppage of steel imports following Suez crisis which situation was further complicated by the allocation of priorities to Projects like Warsak Dam and Korangi Housing scheme in Karachi. The scarcity lasted for almost three years *i.e.*, from the beginning of 1958 to the end of 1961. In October 1961 after the work had made some progress the contractors served the department with notices of termination of contracts on the plea that they had already completed work to the extent specified in their agreements and that they were also being put to loss on account of continuous rise in prices of material and cost of labour. Since the issue had legal implications it took the department two years to resolve the same. Finally it was decided in July 1963 to rescind the existing contracts and to call fresh tenders. It took the department another six to eight months to go through the pre- and post-tender formalities and eventually entered into agreements with the fresh contractors. This processing of the contract documents took us to March 1964 when new contractors were selected and start work orders were given.

14. The magnitude of work in terms of quantities of structural material used, amount of earthwork and masonry works handled and the measure of economic impact resulting from providing irrigation facilities to the project area is self-evident from the figures given below :

(*i*) Quantities of major structural materials used in the scheme.

Cement	..	35,000 tons.
Steel	..	3,000 tons.

(*ii*) The extent of work.

1. The latest revised cost of the project including cost of irrigation tunnel and share cost of Warsak Dam .. 803.72 Lacs.

2. Earthwork	..	220.0	M.Cft.
3. Cutting in rock and conglomerate	...	15.0	M.Cft.
4. Masonry work	..	5.5	M.Cft.
5. R.C.C. work	..	0.5	M.Cft.

(*iii*) Prospects

The Project area after full development would yield about 50,000 tons of additional food grain which will help reduce the present food deficit margin. In terms of cash there will be an addition of Rs. 3.5 crores in the national income which will also help raise the per capita earnings and consequently the living standard of the people in the area. Another important factor that must follow the development of the Project area would be the change in the climate for the better on account of the afforestation in the barren area through the provision of irrigation facilities.

History shows that the whole area covered by the Project—even up to the time of Babar, who shot a Rhinoceros somewhere here—was once a great forest and it would redound to the credit of this great scheme and its sponsors—the Government of Pakistan—for having provided means of restoring the area to its original condition.

II. DESIGN OF PUMP HOUSE FOUNDATION

1. The design of the Pump house foundation presented difficult, though quite interesting, engineering problem, for the clay and silt soil on which the pump house has been erected had low bearing capacity which was likely to decline further in course of time under damp conditions resulting due to general rise of ground water table and seepage from feeder channel and sump walls. The foundations have, therefore, been designed for damp conditions and the complex stresses both direct and indirect. The direct forces constitute the load of pump house structure and weight of pumping units—each weighing nearly 10 tons—and the indirect stress comprise the live load due to high speed of pumping units and the resonance effects of the nearly identical frequencies of pumping units (12.2 cycles per second) and the low compact foundation soil critical frequency. The critical range in which increase in settlements is greatest seems to extend from $\frac{1}{2}$ to $1\frac{1}{2}$ times the natural frequency which for soils varying from loose fills to dense medium sands varies from 19.1 to 21.3 cycles per second. It was anticipated that the natural frequency of the pump units may approach the critical range and cause excessive settlements of the foundation.

2. In view of the conditions stated in para 1 above, it was decided to have competent analysis of the foundation soil of the pump house for determining its safe bearing pressure before proceeding to design the Raft foundation—

2. Earthwork	..	220.0	M.Cft.
3. Cutting in rock and conglomerate	...	15.0	M.Cft.
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covering an area of nearly 150×43 feet—which was the obvious answer. Test bores were drilled, one on each side of the pump house to determine the present depth of ground water table at the pump house site. The test holes showed that the water table in the area was over 80 feet from the N. S. whilst the foundation base of the pump house was to be located at 20 feet below N.S. Although the moisture content of the sub-soil, at foundation level, is only 5% at present, it is liable to increase due to seepage from the Pump House sump wells and subsequent rise of the ground water table. Moreover, as the clay is of the plastic nature its bearing capacity would decline when the soil gets damp in due course of time.

3. Three samples were obtained one each from 1st, 3rd and 5th Auger holes (see Fig. 1) as the sub-soil strata appeared to be fairly uniform up to a considerable depth from N.S. and the samples so taken from the foundation level represented the foundation material on good approximation. These specimens were tested in the Hydrology and Soil Mechanics Section of the Irrigation Research Institute, Lahore and the following laboratory results were obtained:—

Average angle of Internal friction (ϕ)	..	8.5°
Average Cohesion (C)	..	1307 lbs/sq. ft.
Average moisture content due to capillary rise		26%
Average dry density	..	93.3 lbs/cft.
Average wet density (r)	..	$\frac{93.3 \times 126}{100}$ = 117.5 lbs/cft.

Ultimate bearing capacity (q_u) according to Terzaghi's formula:

$$q_u = C\,(2/3\ Nc) + rb\,(1/2\ Nr) + rd\,(Nq) \quad .. \quad (i)$$

where b=width of foundation of Main Raft, say 20 ft.

d=depth of foundation=4.66 feet.

Nc, Nr, & Nq are Terzaghi's coefficients depending upon angle ϕ.

The following values of the coefficient have been obtained from the charts in the present case:—

$Nc = 7.5$

$1/2\ Nr = 0.08$

and $Nq = 1.10$

Substituting these values in (i) above we get

$$q_u = 1307\,(2/3 \times 7.5) + 117.5 \times 20 \times 0.08 + 117.5 \times 4.66 \times 1.1$$

$$= \frac{6535 + 188.00 + 602.3}{2240} = 3.29 \text{ tons/sq. ft.}$$

Applying safety factor of 3, the safe bearing capacity value

$$=\frac{3.29}{3}=1.096 \text{ ton/sq. ft. Say } 1.1 \text{ ton/ft}^2.$$

The ultimate bearing capacity of cohesive soils according to Wilson formula is given by the following relation:—

$$Cu=5.5\times C\,(1+0.38\,\frac{d}{b}) \qquad .. \qquad (ii)$$

$$=\frac{5.5\times 1307}{2240}\left(1+\frac{0.38\times 4.66}{20}\right) \text{ tons/sq. ft.}$$

$$=\frac{7188+635}{2240}=3.5 \text{ tons/sq. ft.}$$

and with factor of safety=3, the safe value=1.16 tons/sq. ft. ..(B)

Based on the above analysis of the results a safe bearing pressure of 1.1 ton per sq. ft. was recommended by the Irrigation Research Institute, Lahore for adoption in the design of the Raft foundation of the Pump house. In order to effect economy in the cost of the pump house foundations as well as to ensure stability of the structure, two one inch clear construction joints—one on each side of the manifold trench (Plate 2)—have been provided in the pump house floor to prevent transmission of vibrations from the section in which the pumping sets are located, as well as from the manifold trench which is also subjected to severe vibrations due to induced pressures.

Likewise this one inch clear joint has been continued in the end walls of the pump house. The recommendation assumed that the moisture content would not exceed the capillary range which was nearly 12% below saturation. In addition, provision of a Filter below the foundation was recommended to ensure the minimum bearing pressure of 1.1 ton per sq. ft.

II. Before adopting the above recommendations of the Irrigation Research Institute it was considered necessary to get second opinion from Messrs Harza Engineering Consultants working with WAPDA. The Consultants suggested carrying out sub-surface density test, and the taking of undisturbed samples from the foundation base for consolidation void ratio tests, moisture content tests for Atterberg's units and other tests in WAPDA Soil Laboratory at Warsak. The soil results obtained in the Irrigation Research Institute, Lahore were passed on to the Consultants for their use and for advising on the following three main issues involved in the design of the foundation:—

(*i*) Effect of reduction of soil cushion between the upstream sump wells and the pump house foundation to dampen the effects of vibrations.

(*ii*) Safe bearing pressure of the soil under the Raft foundation.

(*iii*) Extent of compaction necessary for achieving safe bearing capacity visualized in (*ii*) above.

(*i*) *Soil Cushion*. Originally a 3 feet wide soil cushion was provided between the upstream confining wall of the Raft and the walls of the circular sump well. This cushion was provided with the intent to help neutralize the effects of the vibrations due to running of the pumps and thereby relieving the over-stressing on the sump well structure. In the revised design, based on the advice of the Consultants, the following modifications were made:—

(*a*) The confining wall was totally omitted.

(*b*) R.C.C. circular wells were adopted with a view to withstanding the additional stresses due to vibrations caused by the pumping units.

(*c*) The soil cushion between the end of the Raft and the nearest point of the sump wall was reduced from 3 to 2.35 feet as a result of adopting modifications (*a*) and (*b*).

(*ii*) *Safe Bearing Pressure*. In order to determine the soil characteristics in the area under the Raft foundation 5 Auger hole bores were sunk up to a maximum depth of 25 feet, which was the limit of the penetration of the hand auger available for test. The position of auger holes is marked in Fig. 1 and the soil profile sections are shown in Fig. 2. The boring had to be discontinued when a very hard and dry stratum was met and the Auger could not go down deeper than what is shown in Fig. 2. The Auger holes No. 4 and 5 had consequently to be left at 12 and 15 feet respectively due to the fact that in one case the Auger got stuck in the foundation and could not be pulled out manually and in the other case the rod broke down whilst being pulled out as a result of jacking. In fact in a foundation of this type full penetration could only be achieved if powered Auger or drill was available.

The material from each Auger hole was classified according to the unified soil classification system and index tests. The compaction tests were performed on representative material. The natural moisture content and *in situ* dry and wet densities were also determined in the Soil Laboratory at Warsak and the results are illustrated in Table No. 1. The results of various samples in respect of grain size curves were duly plotted. Similarly the moisture density relationship for various materials and the variation in the natural moisture content, wet and dry density, void ratio and porosity with depth for different Auger holes were plotted on graphs, numbering in all over 70, which have not been reproduced in this paper due to lack of space.

The results of experiments carried out on the Soil Specimens of the five Auger holes show the following variations of the moisture content:—

1. Auger Hole AH-1 .. 3.41 to 7.19%
2. Auger Hole AH-2 .. 2.54 to 10.02%
3. Auger Hole AH-3 .. 3.50 to 6.42%
4. Auger Hole AH-4 .. 2.68 to 8.44%
5. Auger Hole AH-5 ... 6.20 to 6.72%

In Auger Hole AH-1, the dry density at a depth of 2′-1″ is given as 95.7 lbs/cft. and at a depth of 4′-2″ as 88.5 lbs/cft. which is very low. The dry density at a depth of 10′-8″ is given as 96.4 lbs/cft. at a depth of 20′-8″ as 114.1 lbs/cft. and at a depth of 24′-0″, it is given as 119.9 lbs/cft.

Referring to Tables 1 and 2, and comparing the dry densities with the maximum proctor densities, it will be noticed that in all the five cases, the dry densities are lower by nearly 4 to 16% than the maximum proctor densities up to a depth of about 8 feet, which indicates that the layer of soil up to 8 feet depth is low compact, and quite dry which is therefore not suitable as a base for the loads of the Motors and Pumps.

Similarly the classification of the material Fig. 2, shows that up to a depth of approximately 8.5 feet, it consists of either fine silt or clayey silt (ML) of zero to low plasticity, and from 8.5 feet to 17.5 feet depth it varies from clayey silt to silty clay of low to medium plasticity. Below 17.5′ depth it consists of fine silt (CL—ML to CL) to clayey silt (CL) which is again of low plasticity. The depth up to 8½ feet is therefore more critical both from the point of view of bearing capacity as well as susceptibility for settlement under applied loads.

As regards the lower clayey silt layer of low plasticity, it is otherwise quite compact, and the only difficulty in this layer would be the swelling effects due to saturation in due course of time. This however is considered of less importance as due to higher pressures at this depth and the omission of the Boxed-in condition the vertical swelling effect will be negligible.

Shear Tests

As it was not possible to obtain undisturbed samples from the upper silty material layers, the same being in a very dry state and partly due to lack of necessary equipment at that time, it was only possible to carry out consolidated quick direct shear test on compacted samples of the material taken at a depth of 4.0 ft. from Auger Hole No. 5. Since the upper layers in the foundation are not very dense it was expected that tests on compacted samples of the silt materials at densities close to the values in the field would give an approximate idea of the strength parameters of the material in the foundation.

The samples were initially prepared at a moisture content, varying from 25% to 27%, which is slightly on the wetter side as compared to optimum moisture content of 22.5%. The resulting initial dry densities were between 90.0 lbs/cft. and 92.0 lbs/cft.

The idea in placing these samples at wetter than optimum conditions was to obtain quick saturation and to have samples at densities close to the field densities. The samples were then consolidated under respective normal pressures of 1.0, 3.0 and 5.0 tons per sq. ft. at initial moisture content and then saturated and further allowed to consolidate. After the consolidation was completed, the samples were sheared rapidly without allowing any loss of moisture.

The apparent shear strength envelope of the material is shown in Graph No. 1 and gives an apparent cohesion as 0.24 tons per sq. ft. and an apparent angle of friction of 25.5 degrees.

It is thus clear that the silty material is capable of mobilising fairly high frictional shear strength provided it is consolidated under adequate applied pressure. The cohesion of this material cannot, however, be relied upon, but on the basis of the test result, an angle of internal friction of 22°, can be safely assumed for the material.

In the meantime due to heavy rainfall the foundation area was completely flooded. Therefore the foundation, which was initially dry, became in upper parts nearly fully saturated. In this case the bearing capacity will, therefore, be a function of the unconfined compressive strength of the material. Consequently unconfined compression tests were performed on compacted samples of the materials at different moisture contents. The result of these tests have been shown in Table 3.

It will be seen that the unconfined compressive strength of the material at an average dry density of 95.45 lbs/cft. is given as 0.94 kg/Cm^2, for an average moisture contents of 19.26%. Similarly the unconfied compressive strength of the material at an average dry density of 88.8 lbs/cft. is given as 0.77 kg/Cm^2 at an average moisture content of 25.22%.

The variation of compressive stress with percentage axial deformation for the two representative tests are given on Graphs 2 and 3.

At 25.22% moisture, the material is still not fully saturated, the percentage degree of saturation being 75%.

With samples fully saturated, the unconfined compressive strength would be lower. The lowest densities recorded in the upper layer of the foundation which consists of fine silt are from 83.4 lbs/cft. to 88.5 lbs/cft. which can be safely applied to the actual foundation layer up to 8½ feet depth.

The bearing capacity may, therefore, be determined as follows:—

CASE I. **Foundation in its existing state of compactness and saturated**

The unconfined compressive strength of the material would not be greater than 0.77 kg/cm^2. Therefore the ultimate net bearing capacity would not be greater than 2.85 times the unconfined compressive strength which is equal to 2.195kg/cm^2. The allowable net bearing capacity with a factor of safety of 3 would not be greater than 0.732 kg/cm^2 or 0.67 tons/ft^2. The bearing capacity is therefore too low. Assuming a wet unit weight of soil of

113 lbs./cft. with depth of foundation of 6.5 feet, the gross allowable bearing capacity would be 0.67+0.33 or 1.0 ton/ft^2.

CASE II. **Foundation consolidated under an applied load of 1.1 tons/ft^2 and then saturated**

Consolidation test on undisturbed sample No. 1 taken at a depth of 1.0 ft. near auger hole AH-1, shows the final change in void ratio to 0.755 under a load of 1.1 tons/ft^2 as can be seen from the plot of log consolidation pressure varying with void ratio. (Graph 4). Similarly the consolidation test on undisturbed sample No. 2 taken at a depth of 4.0 feet near auger hole No. AH No. 5 shows a final change of void ratio to 0.769 under a pressure of 1.10 tons/ft^2. This corresponds to a dry density for the material of 96.4 lbs/cft.

In this case the material will be able to mobilize its frictional shear resistance. Assuming a friction angle of 22° for the material, and the depth of foundation (D*f*) of 6.5 feet and neglecting 'Boxed in position' the ultimate bearing capacity for general shear failure,

$=(\gamma D_f N_q + 1/2\ \gamma B N_\gamma)$

When, γ = Wet unit weight with % moisture content of 27.6%.
= 88.4×1.276=113.0 lbs/cft.

N_q = 8.0

N_γ = 2.0

B = 22.0 feet

Ultimate Bearing Capacity =(113×6.5×8.0+1/2×113×22×2.0)
=(5870+2482)=8352 lbs/fr^2.
=3.73 tons/ft^2

Net allowable bearing capacity with a factor of safety of 3.0.

$=\frac{3.73}{3}=1.24$ T/ft^2 Gross allowable bearing capacity =1.56 T/ft^2

However, the 'Boxed in' condition would prevent a general shear failure of the material. With the 'Boxed in' position, the ultimate bearing capacity, assuming a local shear failure of the concrete wall, depth of foundation =16.5 feet.

Wet density, assuming percentage moisture content of 27.6%
=94.0×1.276 = 120.0 lbs/cft.

Width of foundation = 28.0 feet (say).

N_γ' = 1.1

N_q' = 3.5

Depth of foundation = 16.5

Bearing capacity = $(\gamma D_f N_q' + 1/2\ \gamma B N_\gamma')$

$$= 120\times16.5\times3.5+1/2\times120\times28\times1.1$$
$$= 6925+1850$$
$$= 8775 \text{ lbs/ft}^2$$
$$= 3.92 \text{ T/ft}^2$$

Net allowable bearing capacity with

a factor of safety of 3 $= \frac{3.92}{3} = 1.306$ tons/ft^2

Gross allowable bearing capacity $=1.306+0.885=2.191$ T/ft^2

Therefore the foundation would be safe to withstand a bearing pressure of 1.10 tons/ft^2 as already recommended by the Irrigation Research Institute, provided the upper low compact layer of 8.5 feet depth is consolidated properly. The material below 8.5 feet depth is already fairly compact and even in saturated condition is expected to take the allowable bearing pressure of 1.10 tons/ft^2.

Settlement under the Base Slab

Consolidation tests were also performed on two undisturbed samples of the soil, one at 4.0 ft. depth near Auger Hole AH-5 and the other at 1.0 ft. depth near Auger Hole AH-1. The consolidation test data is given in Table No. 4.

The samples taken at 4.0 depth had an initial moisture content of 2.83%. It was subjected to a consolidation pressure of 0.25, 0.50 and 1.0 ton per sq. ft. at its natural moisture content.

The samples were then saturated and allowed to consolidate further. It was then subjected to a load of 2.0 tons per sq. ft.

The final per cent water content at the end of the test was 27.60% corresponding to a per cent degree of saturation of 83.5%. The change in void ratio as a result of saturation under 1.0 tons/ft^2 was from 0.772 to 0.77. The vertical collapse of the material as a result of saturation being 0.02% of the initial height of the sample. Therefore there is no danger of a collapse of the material if the consolidation of the material in its dry state is complete and the foundation is later on saturated.

The sample taken at 1.0 ft. depth was initially allowed to saturate. On saturation the sample tended to swell and the swelling pressure as determined was very low, it being 22.8 lbs/sft. which is very low. After saturation, the sample was successively subjected to a load of 0.25, 0.50, 1.0, 2.0 and 4.0 tons/ft.^{2} The average value of compression index as obtained from these two samples is 0.039 and shows that the material has low compressibility characteristics. The maximum settlement in a depth of 8.5 feet of the foundation under a load of 1.1 ton/ft^2 would be as follows:—

Coefficient of compressibility $= av = \frac{e_0 - e}{\Delta P}$ ft^2/ton

$$= \frac{0.91 - 0.758}{1.1}$$

$$= \frac{0.152}{1.1} = 0.138 \text{ ft}^2/\text{ton}$$

Coefficient of volume compressibility $= m_v = \frac{av}{1+e_0} = \frac{0.138}{1.91} = 0.0722 \text{ ft}^2/\text{ton}.$

Settlement $= H \Delta P m_v$
$= 8.5 \times 1.1 \times 0.0722, \quad \Delta P = 1.10 \text{ ton/ft.}^2$
$= 0.675$ feet
$= 8.10$ inches.

The magnitude of maximum settlement is excessive. The running of the Pumps and Motors would create further settlement due to vibrations in the foundation. However, the frequency of impulse has already been calculated as 1.4 times the natural frequency of the system, and therefore any additional settlement due to vibrations would be relatively low, as the maximum load, acting due to vibrations, is calculated as only 0.088 kips/ft^2 which is quite low.

The only defect therefore would be the excessive settlement if the structure is built on the soil foundation of 8.5 ft. depth in its present loose state. The maximum tolerable total settlement for raft foundation is limited to 2" which allows a tolerable differential settlement of 0.75". Since in this case the total settlement greatly exceeds the allowable limit of 2", the allowable differential settlements would be excessive and unsafe.

The final course, which was adopted as a result of the above noted detailed investigations, was therefore to remove this soft soil to a depth of 8.5 feet and to replace it with material of specified grading and texture to be artificially compacted to the desired dry densities, when it can safely be made to withstand the allowable bearing pressure of 1.10 tons per sq. ft. and which would, therefore, not undergo excessive total or differential settlements.

Consolidation under the Base slab

The final recommendations concerning the Pump House foundation were discussed amongst the Irrigation Department and the Consultant, of Messrs Harza Engineering, at Lahore during December, 1962 and the following decisions were taken:

(*i*) The 8.5 feet thick loose silt/clay layer underlining the Pump House foundations be excavated and replaced with compacted sand fill.

(*ii*) The confining walls below the Raft which were proposed by Central Design Office, Lahore, be entirely eliminated as they would not be required now because of the improved foundation.

(*iii*) A representative from Harza Engineering was to visit the area and decide on a suitable source of aggregate which should be of sand but close to gradation for concrete fine aggregate having the required dry density.

Trial samples were therefore obtained from different natural drainages and tested in laboratory. The material from the dry nullah—within 2 furlongs of the Pump House—was considered most suitable for the sand fill. The material consisted of 30% of gravel size particles and 70% of sand in depths varying from 1.75 feet to 5 feet. The material—in its natural form—was quite suitable for use, thus obviating the necessity of washing and grading.

The compaction of the $8\frac{1}{2}'$ thick sand fill was to be done by means of vibratory compactors in 4″ to 6″ layers and the degree of the compaction had to be not less than 116 lbs. per cft.

The compaction was accordingly carried out at site after excavating and removing the loose soil and the field density values were checked at Wapda Soil Laboratory at Warsak for each 100 cubic yards of the placed material. As many as 40 field tests were carried out during the compaction process and it was found that the material used had actually a maximum standard proctor dry density of 128.60 lbs. per cft. with an optimum moisture content of 10% for the fraction minus No. 4 sieve. The theoretical maximum dry density for the entire material, including particles coarser than No. 4 sieve, was found to be 144.0 lbs. per cft. with a theoretical optimum moisture content of 6%. The theoretical maximum dry density for the entire material with maximum particle size as $1\frac{1}{2}''$, as deduced from dry density moisture relationship for the material minus No. 4 sieve, compares favourably with the approximate maximum dry density for the material as determined by carrying the tests in the mould of volume of 0.1 cft. The maximum proctor dry density for the entire material has therefore been adopted as 139.0 lbs. per cft. a figure which is quite on the conservative side. It has been assumed that the minimum desirable density for the material attained by compaction should not be less than a value corresponding to 95% of the dry density value of 139.0 lbs. per cft. which would give us a relative density of at least 75% in the field.

Comparing the values of the field dry densities attained after compaction for the total material with the maximum dry density of 139 lbs. per cft. it was evident that in almost all the cases the degree of compaction attained in the field was 95% or greater. A few instances where the dry densities were slightly lower were re-compacted at site. Since the material consisted essentially of granular material, it possesses good shear strength and as such there is no danger of any bearing capacity failure.

With the attainment of a relative density of 75% in the field enough safeguard exists against any danger whatsoever of differential settlement.

The maximum settlement under a load of 1.1 ton per s. ft. would be very small and achieved soon after the application of the load.

III. PUMPING—INSTALLATION

1. The choice of pumping units for Warsak Lift Canal was influenced by the following considerations:—

(*i*) The capacity of the pumps was determined so that they would conform to the standard commerical sizes or be as near the marketable size as possible, for any departure from such a course would not only have meant extra cost but also delay in the delivery period, which the department could ill afford.

(*ii*) The five number of pumping units—selected from the view-point of the maximum flexibility of operation—permit the running of one or more than one set singly or in series in keeping with the day to day and period to period irrigation water requirements.

2. The tentative design and lay-out plan of the Pumping station and the equipment (see Plate 2)—issued with tender enquiries—was evolved by the Irrigation Department in light of the past experience of similar works in the area. The successful tenderer Messrs K.S.B. Pumps Company Limited, West Germany, adopted the design and specifications, outlined in the tender enquiries, except that they suggested some modification like replacement of Foot Valves by Vacuum Priming Pumps and provision of pump protection equipment, that will afford protection to the Pumping plants against undesirable water hammer effects—due to induced pressure surges in the Rising Main—and also facilitate draining of the Rising Main itself. These modifications were accepted by the Department.

3. **The Pump Unit**

The Pumps finally selected are Messrs K.S.B. RDXL 717 heavy duty type. They are horizontal Centrifugal type with split casing which arrangement permits dismantling and withdrawal of rotating element, without disturbing the pipe connection or pump alignment. They are directly coupled to electrical motors by means of flexible couplings. The pump Impeller Blades have been manufactured of cast chromium steel, to withstand the abrasion due to river water (specific gravity of 1.06) carrying sand, silt and clay of grain sizes between 0.005 mm to 0.15 mm.

4. The Pump casing, manufactured of closed grain quality cast iron, is designed for test pressure of 150% above the actual working pressure. The Pump shaft, manufactured of the best steel, is completely protected from fluid effect by renewable sleeves of cast chromium steel. Each Pump (1340 H.P.)

is capable of lifting 50 cusecs discharge against the total head of 196 feet. Since full supply discharge of the Lift Canal in Kharif is 200 cusecs and that in Rabi is 150 cusecs, four and three pumps, respectively, would operate normally leaving the 5th one as a stand-by. The vacuumetric suction lift of the Pumping unit is 11.75 feet. The pumps—with 42″ suction and 36″ delivery bores—are connected to 57′ inches dia manifold pipe, which in turn is connected to 69″ diameter Rising Main 5,500 feet long. The Rising Main has been manufactured from 3/8″ thick M. S. Plate.

5. **The Motor Unit**

Each Pump is coupled with 11 K.V., 3 Phase, 50 cycles asynchronous squirrel cage slippering induction type Siemens Motor (1582 H.P). The Motors are air-cooled with the inlet and exit cabins having a minimum area of 6 sq. feet. They have been designed to withstand temperature of 122°F. The winding of the motors have class III insulation to suit moist and tropical atmospheric conditions obtaining at site. The Motors with a rated capacity of 1180 K.W. and speed of 744 R.P.M. are capable of running the pumps for full output at the rated speed, without overloading when a set is running singly or in parallel in groups of 2, 3 or 4 simultaneously according to requirements.

The motor units have been provided with a unique automatic control system, complete with sound and light flash warnings. The system is such that motors trip automatically and immediately in case of emergency and in the event of the water level dropping in the suction channel below a certain specified level and re-start when required level is reached.

6. **Sluice Valves**

The delivery pipes of pumps are fitted with 36″ dia, electrically operated Sluice Valves. The valves are of oval shape body, and are suitable for handling water up to a temperature of 104°F. They have been tested against the following hydraulic pressure:—

390 feet head of water (gates open).

196 feet of water (gates closed).

The Sluice Valves have been provided for regulating the Pumping unit discharge, in accordance with the irrigation requirement and with a view to ensuring that the Pumping sets and transmission lines would not be subjected to undue stresses and strains occasioned by a full load start. A special feature of these valves is that they are fitted with torque clutches which facilitate the closing of the circuit when unexpected obstacles hamper the closing movement. For emergencies a hand wheel is also provided which does not in any way interfere with the electrical operation of the valve.

7. Reflux Valves

The Pump delivery pipes are also fitted with 36″ dia Reflux valves, of the tilting disc type. The valves are capable of withstanding hydraulic pressure of 524 feet and 328 feet head of water when the gates are open and closed respectively. The discs are eccentrically pivoted on two trunnions and bronze bushes at their bearing points which can be inspected through an opening provided on the upper part of the downstream section. The Reflux valve protects the pumping unit against the pressure in the event of sudden stoppage. It also prevents pressure on the idle units due to back flow.

8. Surge Suppressors

Referring to Plate No. 2, it will be noticed that a Y-piece has been installed at the end of manifold pipe, which is fitted with two surge suppressors 24 inches dia, for draining the water from the Rising Main back into the Feeder channel through two 18 inches dia over flow lines. Each of the two surge suppressors is capable of discharging a maximum quantity of 100 cusecs at an effective pressure on inlet flange of approximately 162 feet static head and a total head of 196 feet. The surge suppressor device provides protection both to the Rising Main and the Pumping Plant against undesirable water hammer effects due to induced pressure surges in the Rising Main.

The inertia of the water column in the Rising Main gets disturbed, due to sudden stoppage and re-starting of the pumping units, resulting in pressure oscillations which are a source of great danger to the pumping units. In the present case the quantity of the water in 5,500 feet long, 69″ dia Rising Main is so large that the effects of oscillations are bound to be quite pronounced.

What happens in actual practice is that due to sudden stoppage of the pumping units the speed of the pump is reduced to such an extent that, within a reflection period of the pressure wave of approximately 4 seconds, a pressure vacuum is created at the beginning of the discharge pipe, which results in steam generation causing the breakdown of the liquid column.

After reversal of the flow in the pipe line and reformation of the water column, there would be a sudden deceleration of the back-flow velocity, which would cause a water hammer of more than 20 times the atmospheric pressure, if no by-pass was provided.

In the extreme case, when all the four Pumping units stop, due to current failure, both the by-pass pipes have to be opened immediately, so that, in a period of 9 seconds, after the stoppage of units and reversal of flow, the by-pass lines are fully open. The maximum back-flow of 200 cusecs is likely to occur after a lapse of about 20 seconds, from the moment of disconnection of power supply, whereafter the surge-suppressors will automatically start closing so slowly that no dangerous pressure peaks will be caused. The surge-suppressors have been so designed that they take only 45 to 60 seconds for the entire operation of opening and closing.

The mode of operation of the surge-suppressors (by-passes) is explained with reference to schematic diagram (Plate No. 6) as under:—

(*i*) When the pumping units are in service the surge-suppressors are closed. The closing body, which has been designed as a differential piston, is kept in closed position by the operating pressure, marked by an arrow. The opening of the differential piston is effected by the movement of an auxiliary control valve (3), which is actuated by the opening weight (15), through a crank gear (13). Tripping in the event of current failure releases the opening weight (15) by means of a Magnet (17) which actuates a release system consisting of the tripping elements 19 to 22, thus initiating its falling movement.

(*ii*) The Cam-plate (27) fixed to the shaft (14) works the sprocket wheel (29) which swings out the check lever (lock) (32) through a lever apparatus and releases the toothed rack (31), so that the closing weight (16) then begins to sink. A relatively slow closing movement of the auxiliary control valve (3) and consequently the slow closing movement of the differential piston is effected by means of a fan brake which runs in an oil, bath (45).

(*iii*) When the opening weight (15) has returned to its initial position, the surge-suppressor is closed. To be ready for another operation, the closing weight (16) must also be brought back to its initial position. This could be accomplished either by hand or hydraulically by means of cylinder (40) for which the water is taken from the Main Line by means of a magnet valve set (38), (41) and (47) and eventually the lock (32) automatically engages the closing weight (16) in its original position.

9. Vacuum Pumps for Priming Purposes

Another special, in fact, an outstanding feature of the Pumping installation is the provision of complete electrical equipment for priming of the five pumping units which comprise two Vacuum Pumps each built in with a water Filter and 9.1 K.W. 400 volts motor capable of delivering 123.2 cft. air per minute at 0.4 atmosphere. The Vacuum Pumps can suck water at the rate of 0.53 cft. per second at 1.5 atmosphere running pressure.

This equipment replaces the conventional Foot Valve system of priming the pumps. The conventional method of priming has been discarded in favour of the Vacuum priming device for the reason that the latter is much more efficient and economical than the former. Efficient in that, in the foot valve arrangement if it sucks air on account of either loose joint or unevenness in rubber seal, the pumping unit would be difficult to start and if it does, it would not pump to capacity. Moreover the vacuum system is comparatively cheap, for, whereas the foot valves would have cost Rs. 60,000, the Vacuum priming units have cost only Rs. 8,500.

10. **Overhead (Hand Operated) Travelling Gantry**

The crane has a capacity of 15 tons and has been provided to facilitate the initial erection of the heavy pumping equipment as well as subsequent periodical repairs. The overall span of the cross girders carrying the crane is 31.5 feet. The gantry is capable of being shifted to any position in the Pump house. The one special feature of this gantry is that the worm gear hoist is provided with an automatic effective load pressure brake capable of holding full load at any height, and offering no resistance in further lifting or preventing it from running down.

11. **66/11 K. V. outdoor Sub-station**

The 66/11 K.V. out-door sub-station, manufactured and supplied by Messrs Siemens of West Germany has all the modern equipment. The sub-station steps down the 66,000 volts supply from WAPDA Shahi Bagh Grid station to 11,000 volts for which the pumping unit motors are designed. There is yet another transformer which steps down the current from 11,000 volts to 400-440 volts for lighting purposes of the Pump house and the colony. The electrical system from the sub-station, through the Panel room, to the motors is shown in the Schematic diagram Plate 4.

The 66 K. V. overhead line as well as the sub-station is protected from atmospheric lightning by means of lightning arrestors, which are effective up to a length of 3,280 feet. These lightning arrestors are connected directly to the main line, and are always in the circuit, whether the line is dead or alive, which therefore affords protection at all times.

Next to the lightning arrestors, has been placed the Earth Isolator to discharge the line at the time of shut down of the motors, which provides safety to the workmen.

The Main Isolator fixed between the Potential transformer and the Earth Isolator, gives extra safety in isolating the entire system, whenever maintenance work is required to be carried out on the Potential Transformer, Current Transformer, and the automatic circuit breaker. This arrangement obviates the necessity of shut-down of the Main 66 K. V. WAPDA line.

The Earth Isolator and the Main Isolator are interlocked pneumatically as well as mechanically, in such a way that if one is closed the other opens automatically, safeguarding earthing of the main line.

The Potential Transformer of 600/2000 V.A. capacity and a transformation ratio of 66 KV/110 V provides control voltage for Energy Meters, safety protection relays and volt meters.

The Current Transformer, which is located next to the Potential Transformer, supplies the energy to the current coils of energy ampere meters and protection relays.

The automatic Circuit Breaker of 600 Amps rating and 1000 MVA rupturing capacity, has oil-immersed contacts and includes safety devices for overload, short circuit and earth leakage. The Bus Bar Isolator isolates the 66 KV 3 Phase Bus Bars from the automatic Circuit Breaker.

The automatic Circuit Breakers and Isolators are controlled pneumatically, for which the equipment is housed in a Control Cabinet installed inside the sub-station which is in turn connected with a compressor which supplies and maintains constant compressed air supply.

Main Transformers

(*i*) There are two 3-phase Siemens oil immersed transformers each having a transformer rating of 3 MVA at 50 cycles and a transformation ratio of 66/11 KV + 7.5% in 5 steps, star to star connection with a delta compensatory winding. The star point is fully insulated on the high and low voltage sides and each can be loaded with 100% of the rated current.

The two transformers are of outdoor type suitable for an ambient temperature of 113°F and are self-cooled. These are fitted with Siemens on-load tap changer on the low voltage side, the voltage being capable of setting, in steps, under load. The transformers have the safety devices for controlling development of high pressure gases called Buchholf-Relays due to defective oil or in case of falling of the oil level when they trip the automatic circuit breaker.

(*ii*) *Low Tension—Power—Lighting Supply Transformer*. One additional house transformer has been provided in the end room of Main Pump House building for supply of low tension power current supply for lighting and other purposes in the Pump House itself. There are four spare outlets available for supply to the colony.

This transformer is also 3-phase oil immersed type, having a transformer rating of 250 KVA at 50 cycles, at an ambient temperature of 45°C, and a transformation ratio of 11000 + 2.5% + 5% stepping down to 400/230 volts.

It has delta star switching connection with off load tap changer switch to be worked from outside.

(*iii*) 66 *K. V. Switch Gear*. The outdoor 66 K. V. Switch gear has single bus bar of copper rope of 0.185 in.^{2} cross-sectional area with outgoing feeders of copper rope of the same size. The switch gear is designed for an ambient temperature of 113°F at 1000′ Elevation above sea level.

The short circuit rating of the switch gear is 1000 MVA having three bays and is equipped with the following equipment:—

(*a*) One Incoming bay has three cathode drop lightning arrestors with Isolating and Earthing Switches and one expansion type Circuit Breaker having rupturing capacity of 1000 MVA with compressed air drive.

It also has one additional Isolating Switch with three voltage transformers, Siemens type VTOF 60 and three current transformers Siemens type ATOF 60.

(*b*) Two transformer bays each of which has one Isolating Switch with compressed air drive and three current transformers Siemens type ATOF 60.

(*c*) In addition to the above, all material, which include suspension and Tension Insulators, Bushing Insulators, Valves, Terminal Panels, etc. and measuring, protection and signalling equipment for the 66 KV/11 KV, has been fully provided. One outdoor compressed air equipment having 3-Phase motor 400 volts at 50 cycles has been provided, to supply compressed air to the electrical equipment.

(*iv*) 11 *K. V. Switch Gear.* The 11 K.V. Switch Gear which consists of 10 Panels is located inside the Panel Room of the Pump House, has rupturing capacity of 200 MVA and is designed for a continuous single busbar system suitable for 11 KV—50 cycles.

The specifications of the ten individual panels and their functioning are as follows:—(Plate No. 5).

(*i*) *Two Panels Nos.* 1 & 7. There are two incoming Feeder Panels, each consisting of one busbar Isolating Switch, with an expansion type circuit breaker having a rupturing capacity of 200 MVA at 11 KV for manually on-operated and automatically off-operated condition with three built-in primary releases with time lag for over-current tripping.

Also fixed in these panels are two potential transformers 11000/110 volts in V-Switching and three current transformers Siemens type ATQ 200/5A, with measuring and relay cores. There are in addition 3 moving Iron Ammeters, one moving voltmeter, and one Transformer differential protection Relay.

The on and off signalling lamp in the face of the Panel indicates when the Transformer Panel is on, the switching off being achieved simply by pressing a push-button.

(*ii*) *Five Motor Panels Nos.* 2 *to* 6. There are five Motor Panels, one for each Motor. Each panel consists of one Bus-bar Isolating Switch and one Expansion Circuit Breaker manual drive with no-voltage releases and a cut off switch. Also fitted in, are one Earthing Isolator, three current transformers and three moving Iron ammeters. The equipment is protected by means of a three pole Bimetallic secondary overload relay which has a built in quick acting magnetic short circuit protection. A kilowatt hour meter has been installed in each motor panel for recording the energy consumption of each individual motor.

(*iii*) *One Station Supply Panel No.* 8. This Panel consists of a Load-Breaker-*cum*-Isolating switch for connection to the 250 KVA Transformer. It houses a Distribution Box for 400 volts-50 cycles supply, with an automatic circuit breaker and quick short circuit releases. The Panel controls internal lighting of the Pump House Colony and connections to welding plugs etc.

(*iv*) *Two Control Panels Nos.* 9 *and* 10. Panel No. 10 is for the 66 K.V. Transmission and consists of moving voltmeter, ammeter and Impedence Protection equipment for the 66 KV Feeders. The kilowatt hour meter records the total energy consumption on the 66 K.V. Incoming Main. On the face of the Panel there are five check back switches and a Blinker Relay.

Panel No. 9 houses the alarm signal and battery charging equipment. If there is any fault anywhere in the Transmission line, the outdoor substation, the panels or the individual motors, a loud alarm is automatically sounded and it keeps on until switched off after locating the trouble spot.

Similarly the luminous panel (Fig. 3) which has various lamps, indicates the entire functioning of the electrical equipment. The whole alarm system and other inter-panel controls are worked directly from D.C. current which is supplied from the adjoining battery room, through a rectifier and a set of 53 cell-batteries connected in series. The Rectifier is of solenium dry type and is suitable for connection to 3-Phase 400 volts—50 cycles. The capacity of the batteries is 8 amps. permanently or 12 amps. for short durations.

TABLE NO. 1

Table showing Field Moisture Content and Densities in the Foundation below the Base Slab.

S. No.	Auger Hole No.	Depth Ft. Inch.	Field moisture content.	Wet density Lbs/Cft.	Dry density Lbs./Cft.	Void ratio.	Porosity.
1	2	3	4	5	6	7	8
1	A.H-1	2′—1″	7.19	102.8	95.7	0.768	43.50
2	,,	4′—2″	3.41	91.50	88.5	0.91	47.6
3	,,	10′—8″	4.01	100.20	96.40	7.46	42.75
4	,,	20′—8″	5.46	121.0	114.10	0.49	32.85
5	,,	24′—0″	5.21	126.40	119.9	0.43	30.05
6	A.H 2	7′—5″	2.54	86.00	83.80	1.06	51.5
7	,,	10′—3″	10.02	108.90	99.00	0.746	42.75
8	,,	16′—9″	8.34	107.0	98.60	0.765	43.30
9	,,	22′—0″	4.34	100.00	95.80	0.769	43.50
10	A.H-3	3′—0″	6.42	89.20	83.80	1.00	40.0
11	,,	7′—0″	5.05	109.5	104.2	0.632	38.7
12	,,	9′—7″	5.00	114.8	109.1	0.546	35.40
13	,,	15′—4″	4.00	112.20	108.0	0.565	36.00
14	,,	20′—6″	3.50	114.19	110.40	0.53	34.65
15	A.H-4	10′—6″	8.44	102.34	94.5	0.8	44.5
16	A.H-5	3′—0″	6.20	99.21	93.40	0.824	45.10
17	,,	9′—0″	6.72	108.4	101.6	0.70	41.20
18	,,	12′—10″	6.37	121.49	114.0	0.527	34.50

Note:—At 11′—2″ depth of Auger Hole AH-2 the field moisture content was found to be 2.68%.

Table No. 2

Table showing Results of the Soil Tests of Samples from Pump House, Warsak High Level Canal.

S. No.	Auger Hole No.	Lab. Samples No.	Depth Ft. Inch.	Specific Gravity.	Liquid limit%.	Plastic limit%.	Plasticity index.	Optimum moisture content % O.M.C.	Proctor Max. dry density Lbs/Cft.	Grain Size Analysis			Remarks
										Gravels 3	Sand %	Silt Clay%	
1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	A.H-1	808/1	0′—0″/5′—11″	2.71	..	..	..	17.50	101.00	..	4.9	95.1	
2	,,	809/1	5′—11″/8′—4″	2.69	...	..	..	20.00	98.5	..	5.30	94.7	
3	,,	810/3	8′—4″/9′—8″	2.71	42.45	30.45	12.0	20.50	101.00	..	1.30	98.7	
4	,,	811/4	10′—0″/12′—8″	2.70	39.80	24.52	15.28	22.00	96.50	..	2.7	97.3	
5	,,	812/5	12′—8″/15′—8″	2.67	27.73	22.68	5.05	17.00	106.50	..	7.0	83.0	
6	,,	813/6	15′—8″/17′—8″	2.72	29.56	21.8	8.08	19.50	102.30	..	11.2	88.8	
7	,,	814/7	17′—8″/19′—6″	2.74	31.22	36.08	5.14	17.50	104.50	...	15.2	84.8	
8	,,	815/8	19′—6″/22′—8″	2.74	..	..	..	17.05	105.0	..	22.4	77.06	
9	,,	816/9	22′—8″/25′—0″	2.75	27.50	23.36	4.14	17.5	106.00	..	19.70	80.3	
10	A.H-2	873/1	0′—0/6′—5″	2.73	..	..	..	19.00	98.20	..	7.2	92.8	
11	,,	874/2	6′—5″/8′—2″	2.77	29.48	29.62	9.86	21.50	98.80	..	1.7	98.3	
12	,,	875/3	8′—2″/12′—3″	2.74	36.60	27.30	9.30	..	..	..	2.8	97.2	
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	16.00	110.00		22.5	77.5	

13	A.H-2	876/4	12′—3″/17′—5″	2.70	36.50	18.68	7.82	16.00	110.00	..	22.5	77.5
14	,,	877/5	17′—5″/19′—0″	2.79	30.63	25.59	5.04	...	...	..	12.73	87.27
15	,,	878/6	19′—0″/21′—0″	2.71	27.00	22.43	4.57	16.00	110.20	...	11.7	88.3
16	,,	879/7	21′—0″/23′—10″	2.72	24.85	20.80	4.05	15.00	113.30	...	19.6	80.4
17	,,	880/8	23′—10″/24′—2″	2.76	27.10	21.81	5.29	15.00	114.20	..	18.7	81.3
18	A H-3	881/1	0′—0″/5′—6″	2.69	..	...	...	19.50	102.30	...	6.5	93.5
19	,,	882/2	5′—6″/8′—8″	2.67	27.60	25.20	2.4	20.00	103.40	...	4.1	95.9
20	,,	883/3	8′—7″/10′—6″	2.68	35.00	25.25	9.75	19.5	104.80	...	4.9	95.1
21	,,	884/4	10′—6″/13′—6″	2.69	31.10	22.60	8.5	17.00	108.20	...	12.5	87.5
22	,,	885/5	13 —6″/17′—4″	2.71	40.95	30.58	10.37	22.50	96.50	...	2.2	97.8
23	,,	886/6	17′—4″/19′—2″	2.63	31.65	25.49	6.16	20.00	104.20	...	11.1	80.9
24	,,	887/7	19′—2″/21′—5″	2.71	24.25	21.25	3.00	17.50	109.60	..	17.7	82.3
25	A.H-4	888/1	6′—0″/4′—3″	2.65				19.80	101.00	...	2.7	87.3
26	,,	889/2	4′—3″/5′—6″	2.65				20.00	100.00	..	13.0	87.0
27	,,	890/3	5′—6″/7′—6″	2.73	32.01	27.32	4.69	19.00	102.00	...	3.6	96.4
28	,,	891/4	7′—6″/8′—6″	2.69							3.80	96.2
29	,,	892/5	8′—6″/9′—6″	2.71	40.83	30.87	9.96				0.5	99.5
30	,,	893/6	9′—6″/10′—6″	2.73	41.80	29.28	12.52				1.8	98.2

[*Contd.*

TABLE No. 2 [*Contd.*]

Table showing Results of the Soil Tests of Samples from Pump House, Warsak High Level Canal.

S. No.	Auger Hole No.	Lab. Samples No.	Depth Ft. Inch.	Specific Gravity.	Liquid limit %.	Plastic limit %.	Plasticity index.	Optimum moisture content % O.M.C.	Proctor Max. dry density Lbs/Cft.	Grain Size Analysis			Remarks
										Gravels 3	Sand %	Silt Clay %	
1	2	3	4	5	6	7	8	9	10	11	12	13	14
31	A.H-4	894/7	10′—6″/12′—0″	2.74	39.35	23.49	15.86	19.0	105.80	..	2.8	97.2	
32	A.H-5	895/1	0′—0″/6′—0″	2.73	29.24	26.54	2.70	20.00	99.70	..	8.2	91.8	
33	,,	896/2	6′—0″/8′—0″	2.71	32.40	26.19	6.21			..	0.4	90.6	
34	,,	897/3	8′—0″/11′—10″	2.75	41.30	25.75	15.55	22.55	101.60	...	0.9	99.1	
35	,,	898/4	11′—10″/13′—5″	2.79	35.23	24.53	10.70	25.00	96.35	...	1.4	98.6	
36	,,	901/7	13′—5″/15′—0″	2.68	27.94	19.36	8.68	15.80	108.80	...	1.3	78.7	

TABLE NO. 3

Table showing Results of Auger Hole A-H-5 Unconfined Compression tests on Disturbed Samples.

S. No.	Sample No.	Depth.	Wet density.	Dry density.	Void ratio.	Porosity	Unconfined compressive strength.	%Moisture content.
		Ft. Inch	Lbs/Cft	Lbs/Cft		%	Kg/cm²	%
1.	1	4.0	114.0	95.0	0.792	44.1	0.98	19.91
2.	2	4.0	113.4	95.9	0.79	44.1	0.902	19.35
3.	3	4.0	111.5	89.1	0.91	47.6	0.826	25.01
4.	4	4.0	111.2	88.6	0.92	48.0	0.713	25.41

TABLE NO. 4

Consolidated Test Data of Undisturbed Samples.

Sample No.	Depth	Initial % moisture content.	Initial wet density	Initial dry density	Initial void ratio.	Void Ratio Under Load T/FT² 0.25	0.5	1.0	2.0	4.0	Moisture at the end of the test	Compression index
	Ft. Inch		Ibs/Cft.	Ibs/Cft.							%	Cc
1.	4.0	2.83	97.5	95.0	0.79	0.785	0.778	0.77	0.756	..	23.15	0.046
2.	1.0	27.6	116.4	91.1	0.85	0.796	0.78	0.75	0.74	0.71	33.9	0.033

Cc=Average compression index = 0.039

BASE SLAB SHOWING POSITION OF AUGER HOLES

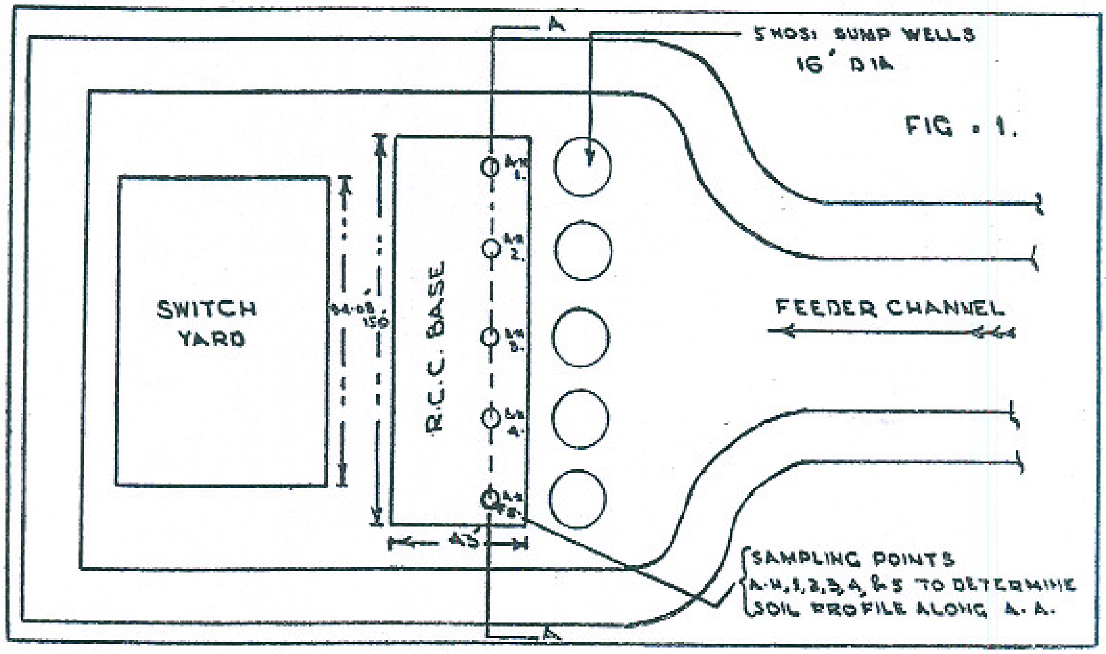


FIG. 1.

SOIL PROFILE OF AUGER HOLES AT BASE SLAB FOUNDATION OF PUMP HOUSE

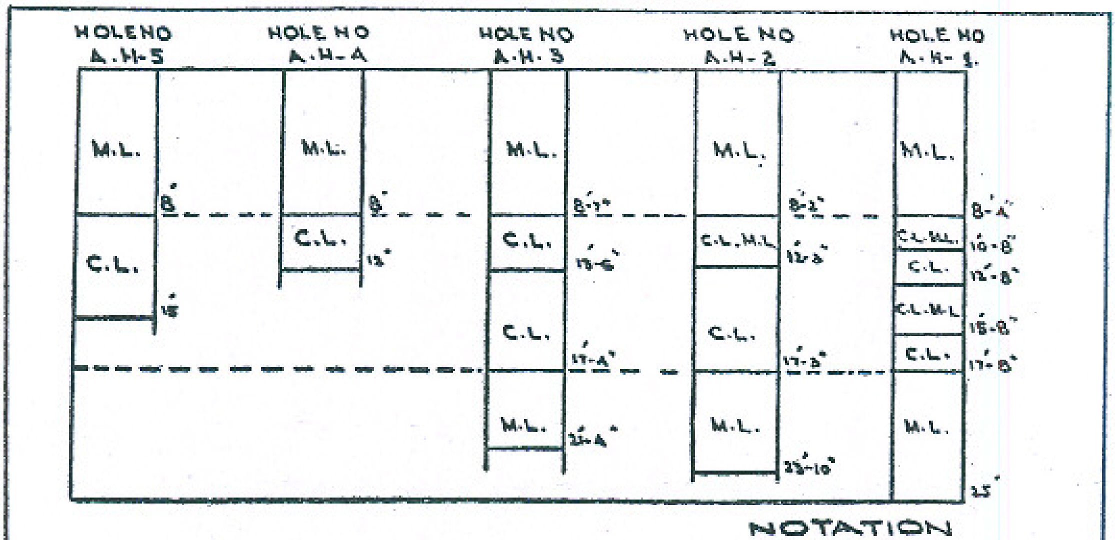
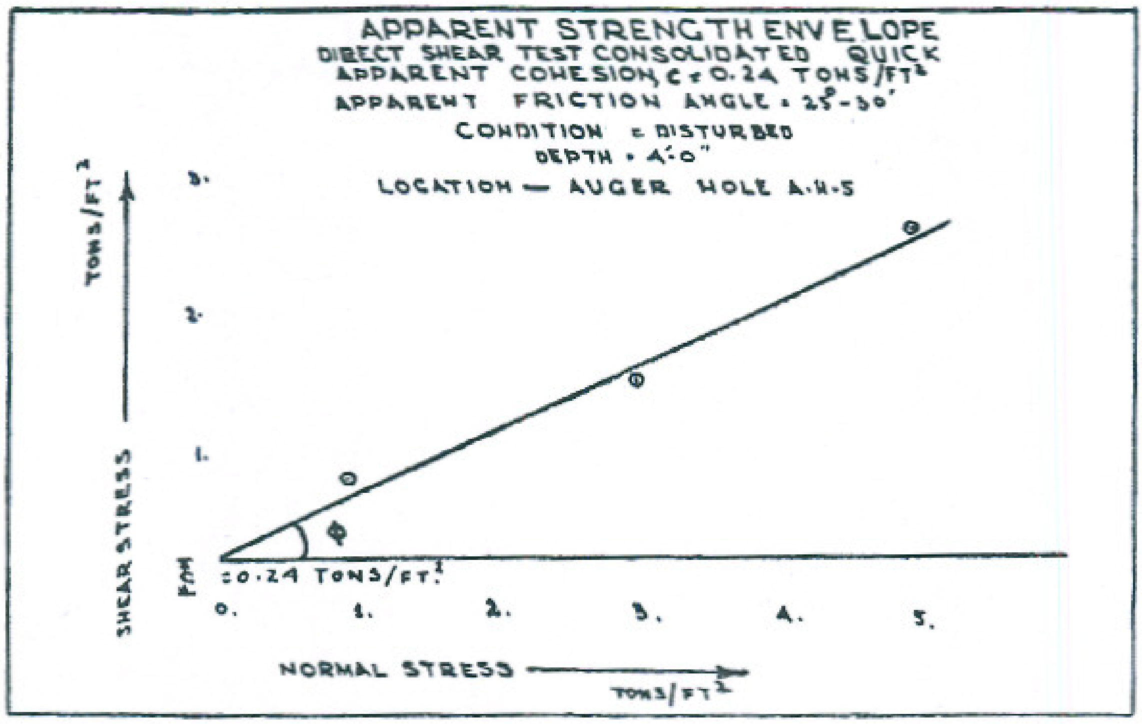


FIG. 2.

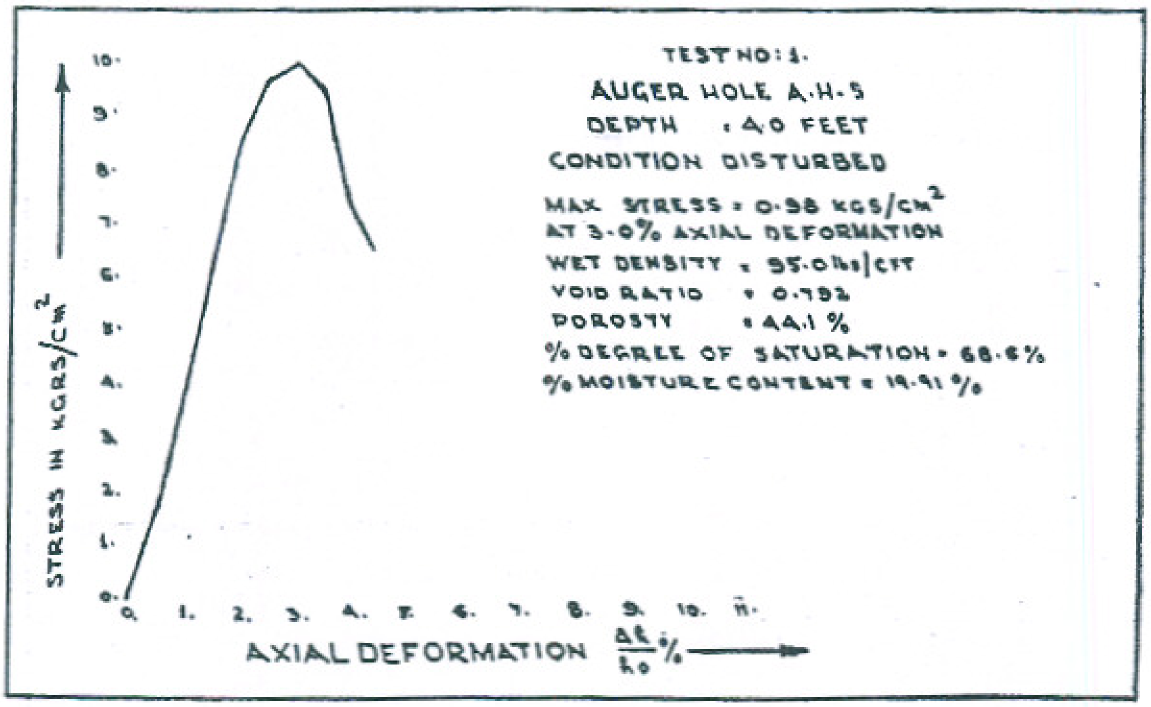
FRONT SIDE VIEW OF PANEL NO:9
FAULT INDICATOR

66KV IMPEDANCE TRIPPED	66 KV VOLTAGE FAULT
AIR SET FAULT	400 V FAULT
11 KV INPUT I FAULT	11 KV INPUT II FAULT
TRANSFORMER I FAULT	TRANSFORMER I WARNING
TRANSFORMER II FAULT	TRANSFORMER II WARNING
WATER INPUT TO LOW	BY-PASS MOTOR-VALVE NOT FULLY OPEN
WATER INPUT IN ORDER	PUMP MOTOR 1 OUT OF ORDER
PUMP MOTOR 2 OUT OF ORDER	PUMP MOTOR 3 OUT OF ORDER
PUMP MOTOR 4 OUT OF ORDER	PUMP MOTOR 5 OUT OF ORDER
MOTOR 1-5 OVER LOAD	MOTOR 1-5 EARTH FAULT

FIG: NO.3.



GRAPH NO:1.



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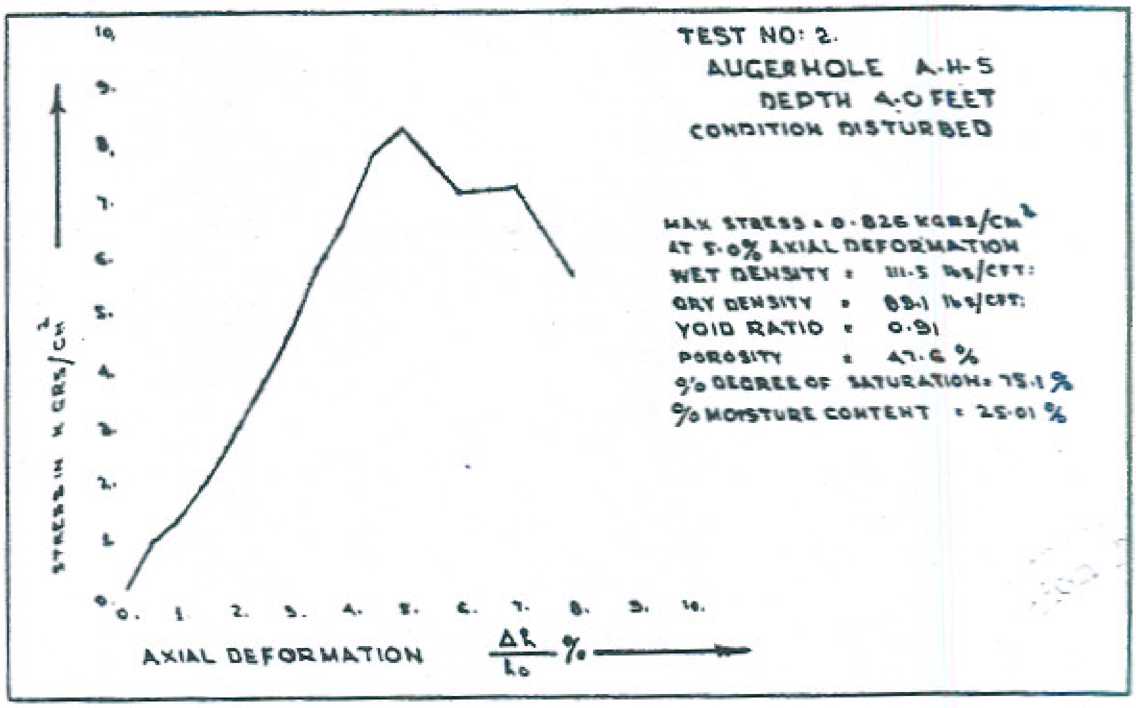
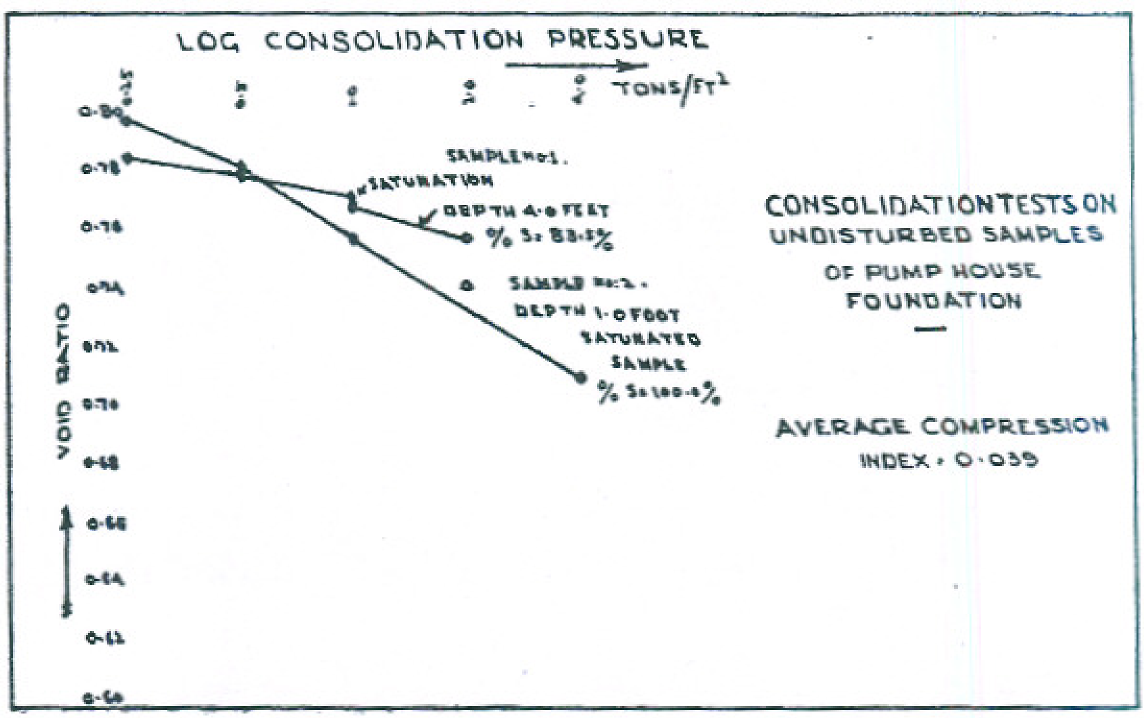
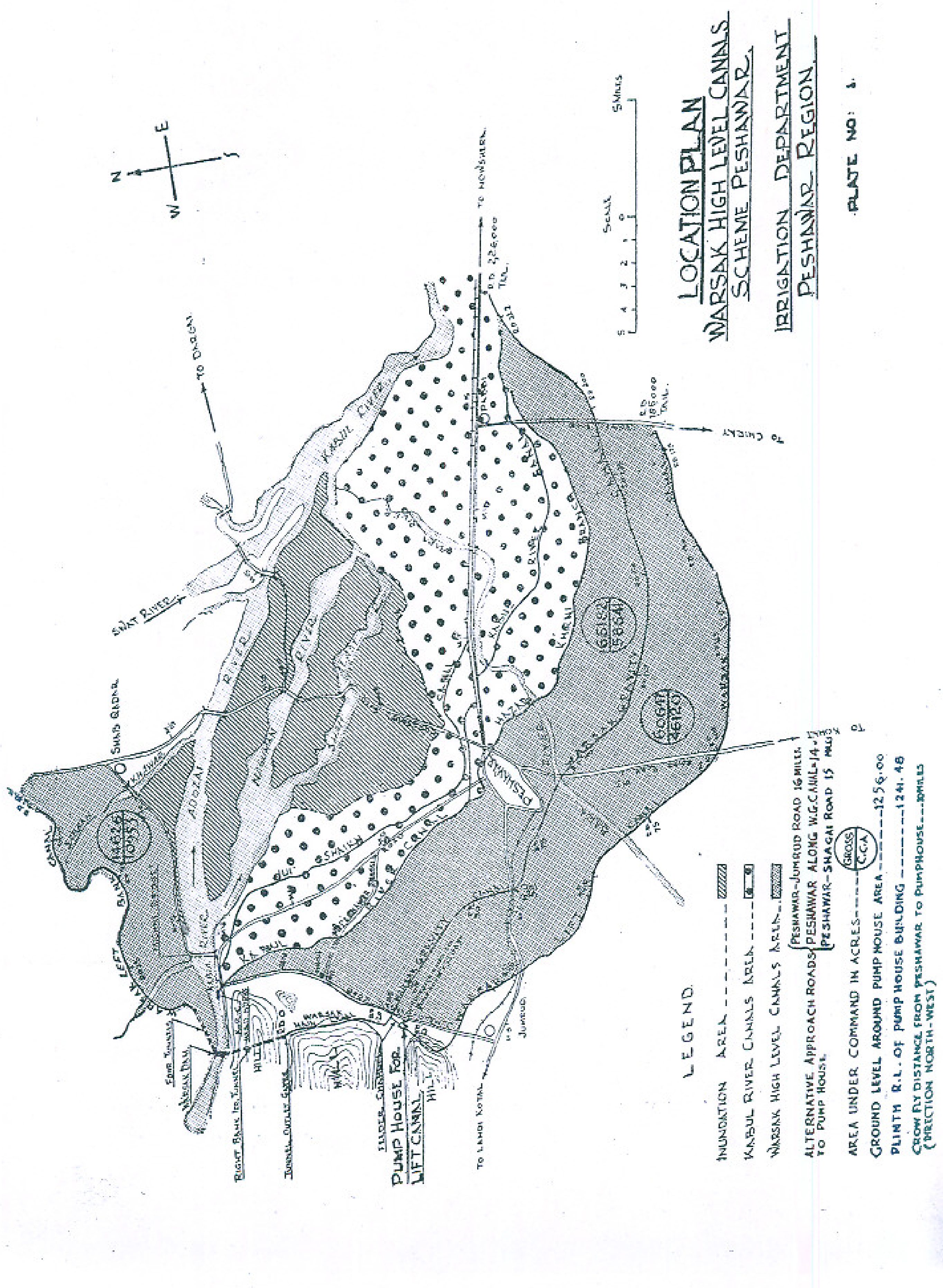
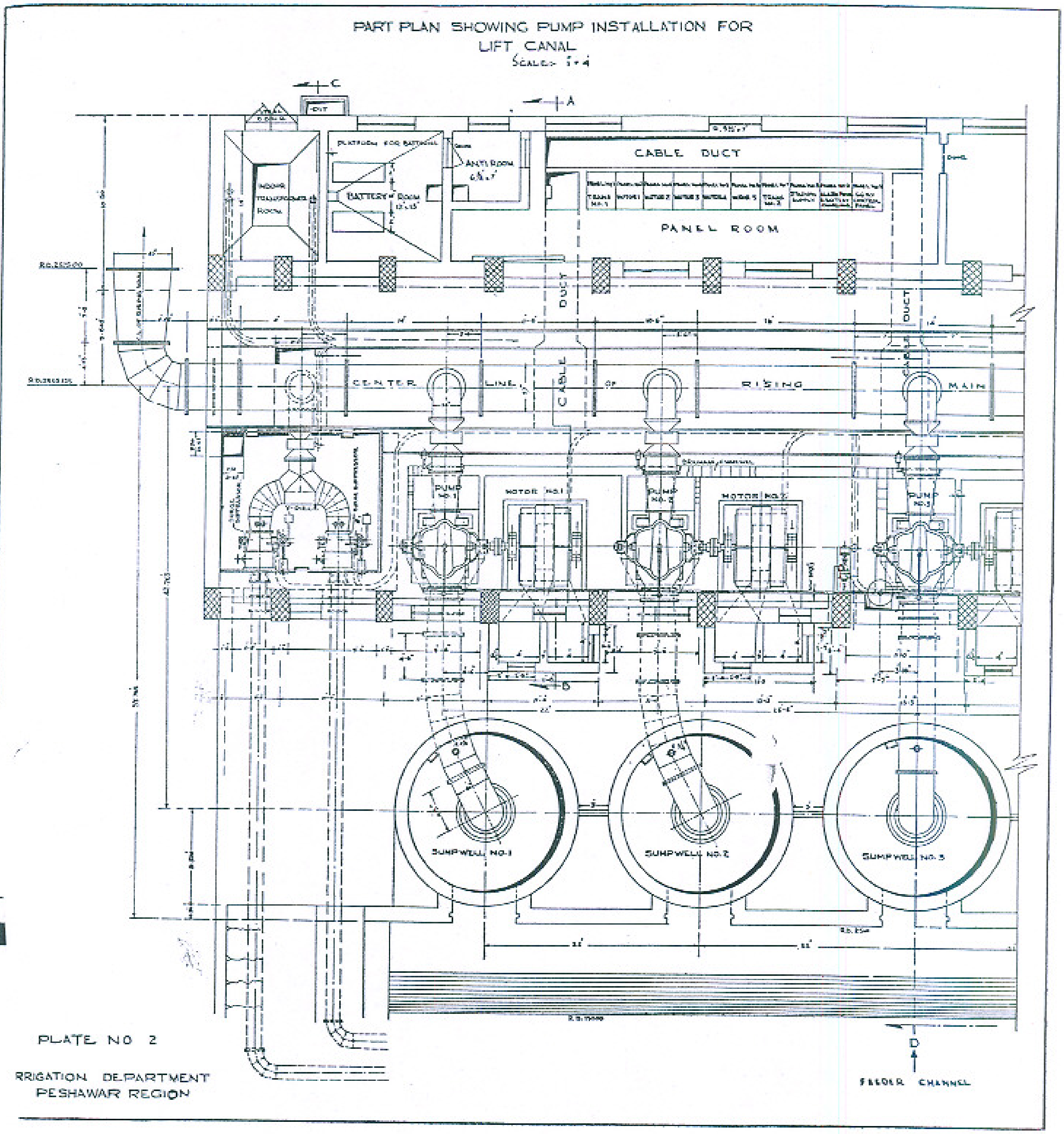


GRAPH NO: 3.



GRAPH NO: 4.


LOCATION PLAN
WARSAK HIGH LEVEL CANALS SCHEME PESHAWAR.
IRRIGATION DEPARTMENT PESHAWAR REGION.
PLATE NO: 1.
SCALE
5 MILES
LEGEND
INUNDATION AREA
KABUL RIVER CANALS AREA
WARSAK HIGH LEVEL CANALS AREA
ALTERNATIVE APPROACH ROADS TO PUMP HOUSE.
PESHAWAR–JUMRUD ROAD 16 MILES.
PESHAWAR–SHAGAI ROAD 15 MILES
AREA UNDER COMMAND IN ACRES
GROSS
C.C.A
GROUND LEVEL AROUND PUMP HOUSE AREA 1256.00
PLINTH R.L. OF PUMP HOUSE BUILDING 1241.48
CROW FLY DISTANCE FROM PESHAWAR TO PUMPHOUSE
(DIRECTION NORTH-WEST)
PUMP HOUSE FOR LIFT CANAL
TO LANDI KOTAL
KABUL RIVER
SWAT RIVER
TO DARGAI
TO NOWSHERA
SHAB QADAR
PESHAWAR
JUMRUD
HILL
N
S
E
W


PART PLAN SHOWING PUMP INSTALLATION FOR
LIFT CANAL
CABLE DUCT
PANEL ROOM
BATTERY ROOM
ANTI ROOM
CENTER LINE OF RISING MAIN
PUMP NO. 1
MOTOR NO. 1
PUMP NO. 2
MOTOR NO. 2
SUMPWELL NO. 1
SUMPWELL NO. 2
SUMPWELL NO. 3
FEEDER CHANNEL
PLATE NO 2
RRIGATION DEPARTMENT
PESHAWAR REGION

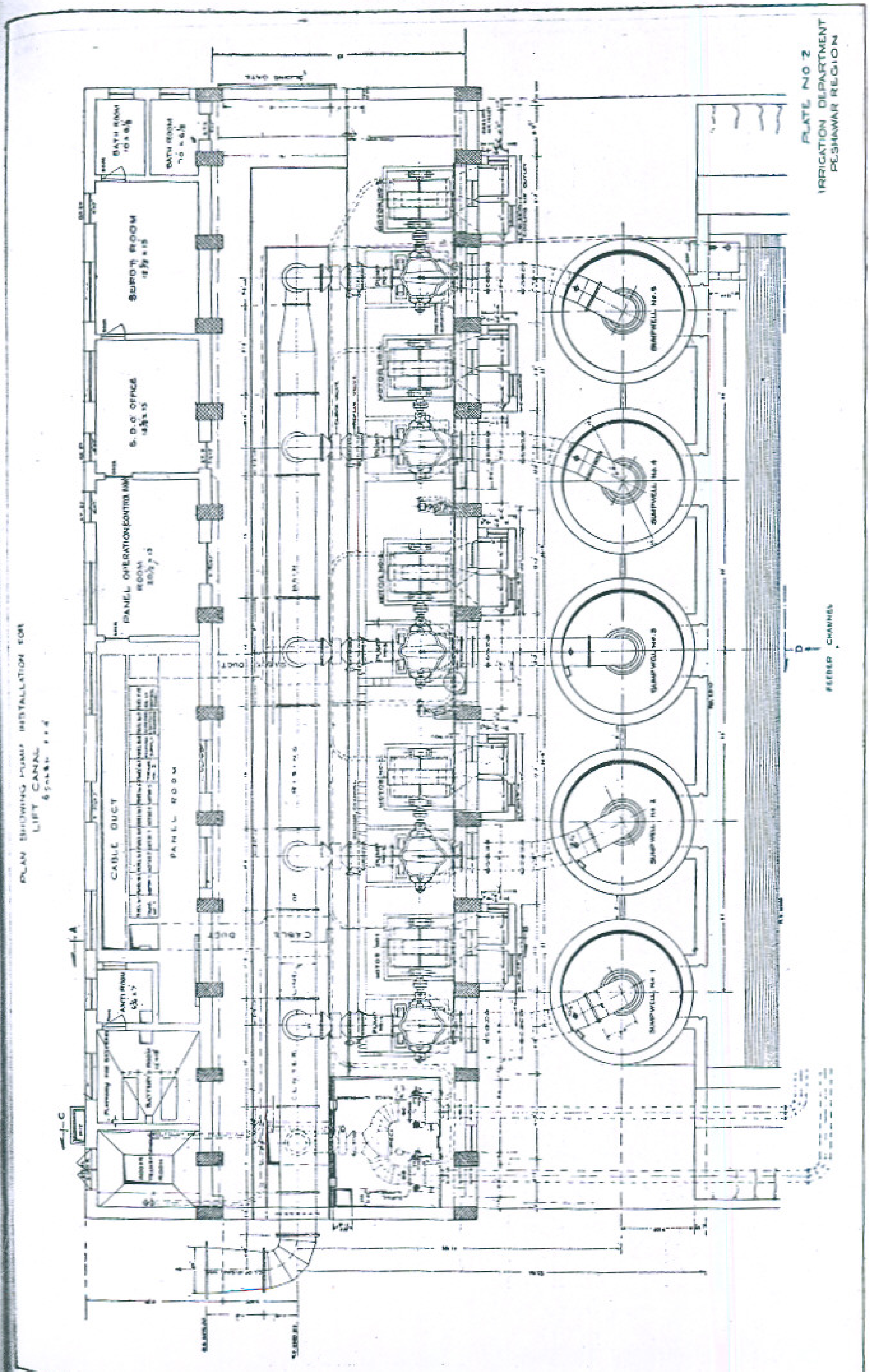
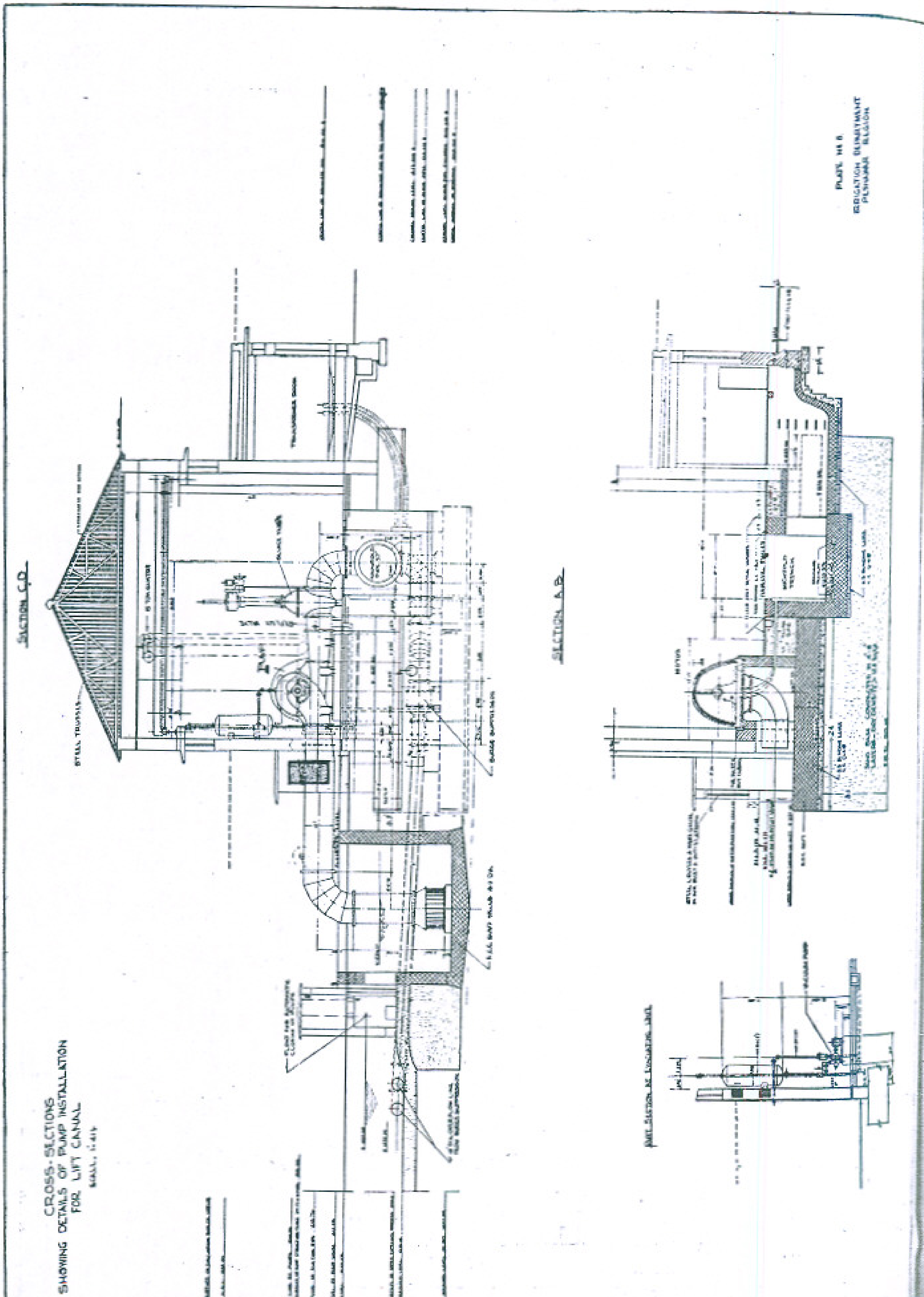
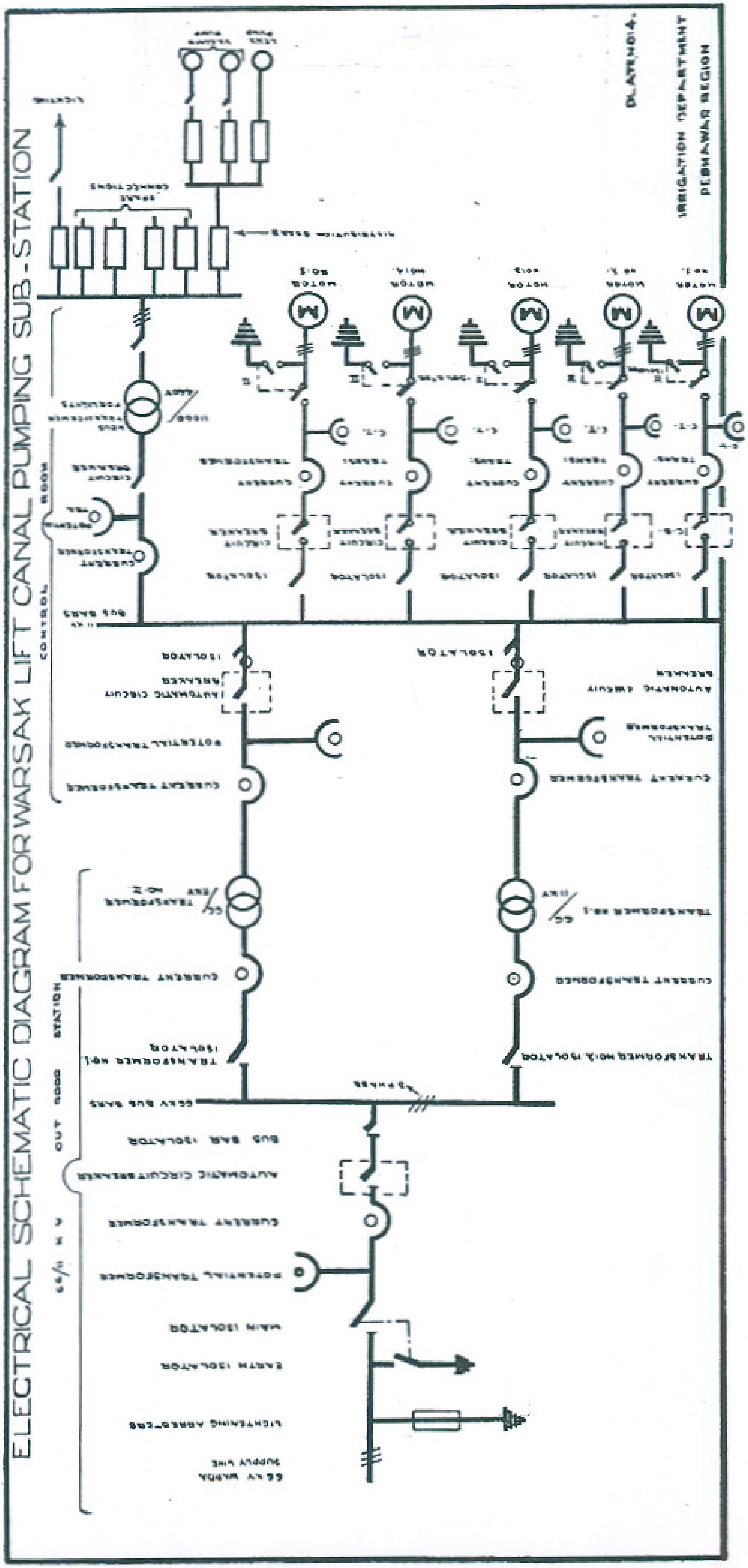
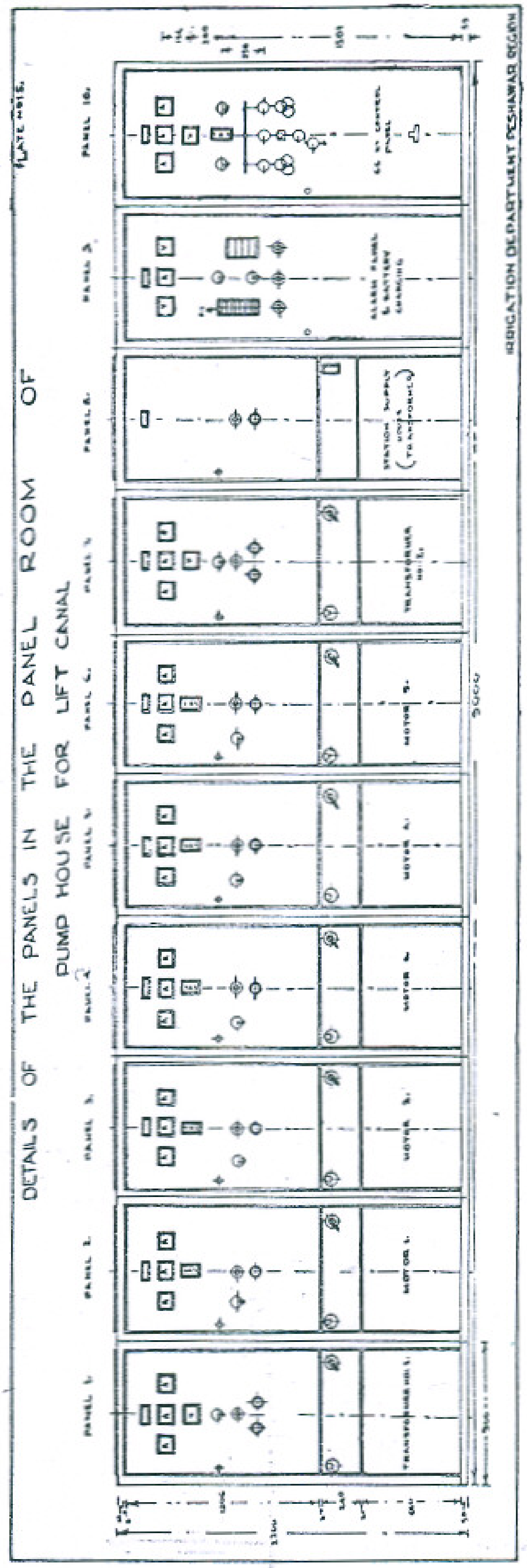
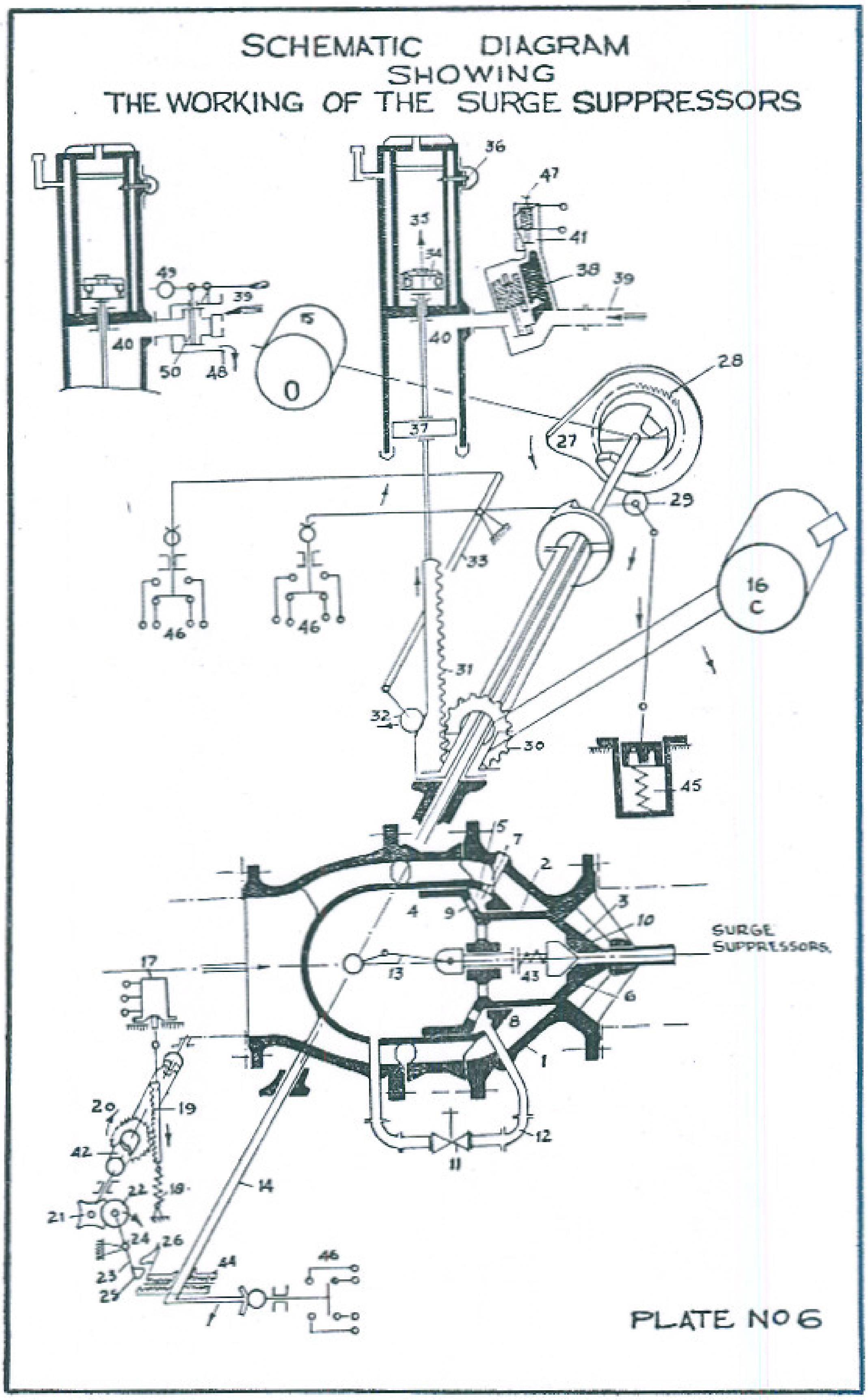


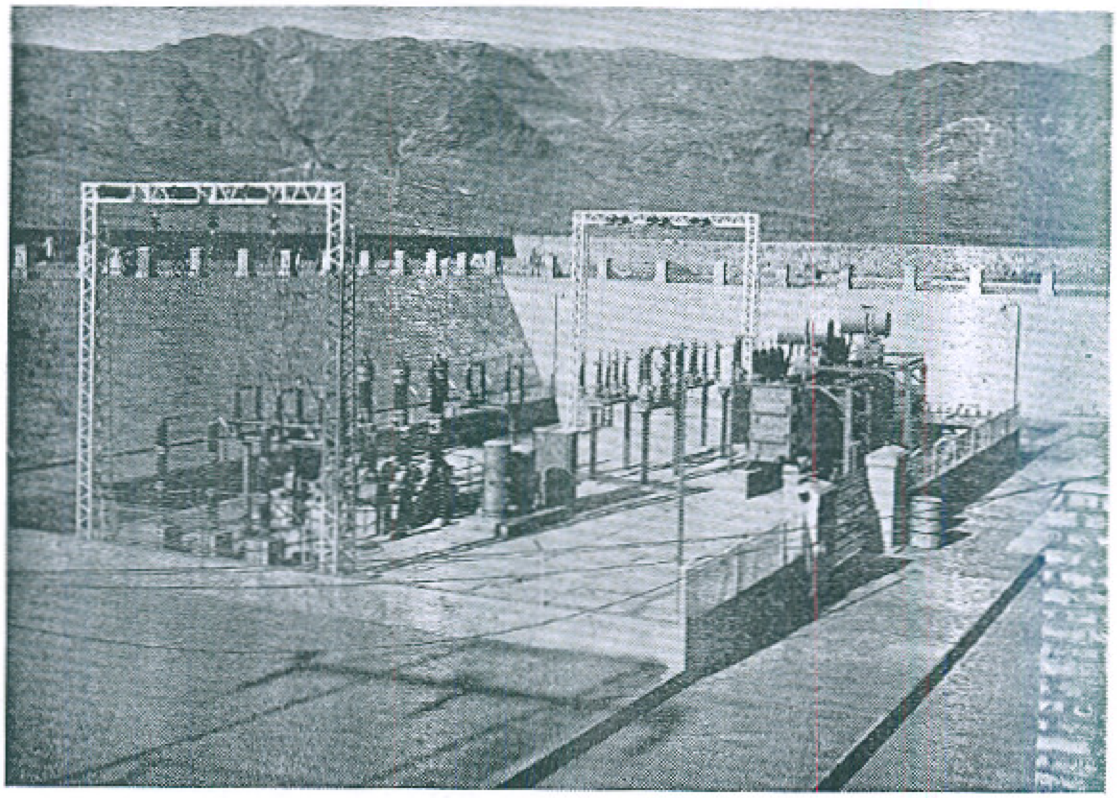
PLATE No 2
IRRIGATION DEPARTMENT
PESHAWAR REGION
PLAN SHOWING PUMP INSTALLATION FOR
LIFT CANAL
BATH ROOM
SUPDT. ROOM
S.D.O. OFFICE
PANEL OPERATION (CONTROL) ROOM
CABLE DUCT
PANEL ROOM
SUMPWELL No. 1
SUMPWELL No. 2
SUMPWELL No. 3
SUMPWELL No. 4
SUMPWELL No. 5
FEEDER CHANNEL


CROSS-SECTIONS
SHOWING DETAILS OF PUMP INSTALLATION
FOR LIFT CANAL
SECTION C.D
SECTION A.B
STEEL TRUSSES

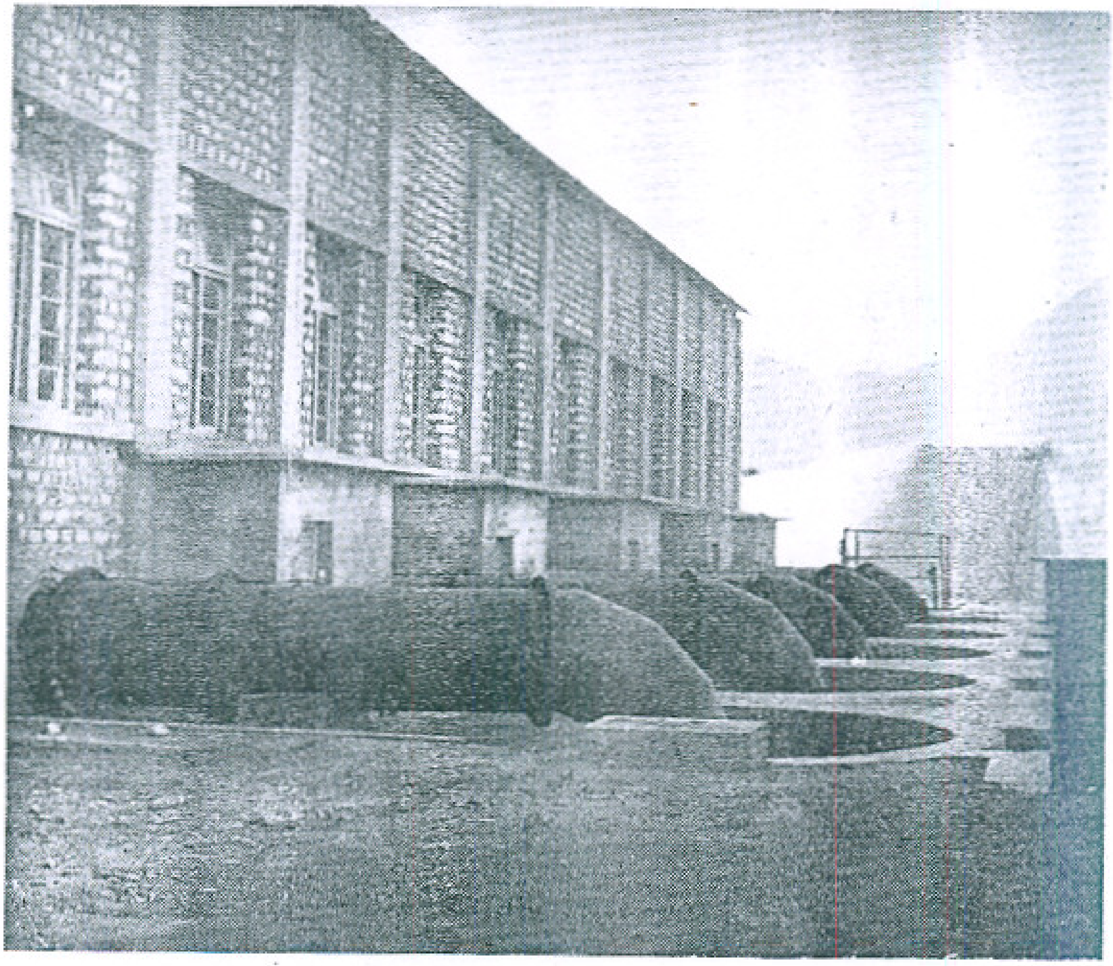

ELECTRICAL SCHEMATIC DIAGRAM FOR WARSAK LIFT CANAL PUMPING SUB-STATION
IRRIGATION DEPARTMENT
PESHAWAR REGION


DETAILS OF THE PANELS IN THE PANEL ROOM OF
PUMP HOUSE FOR LIFT CANAL
IRRIGATION DEPARTMENT PESHAWAR REGION

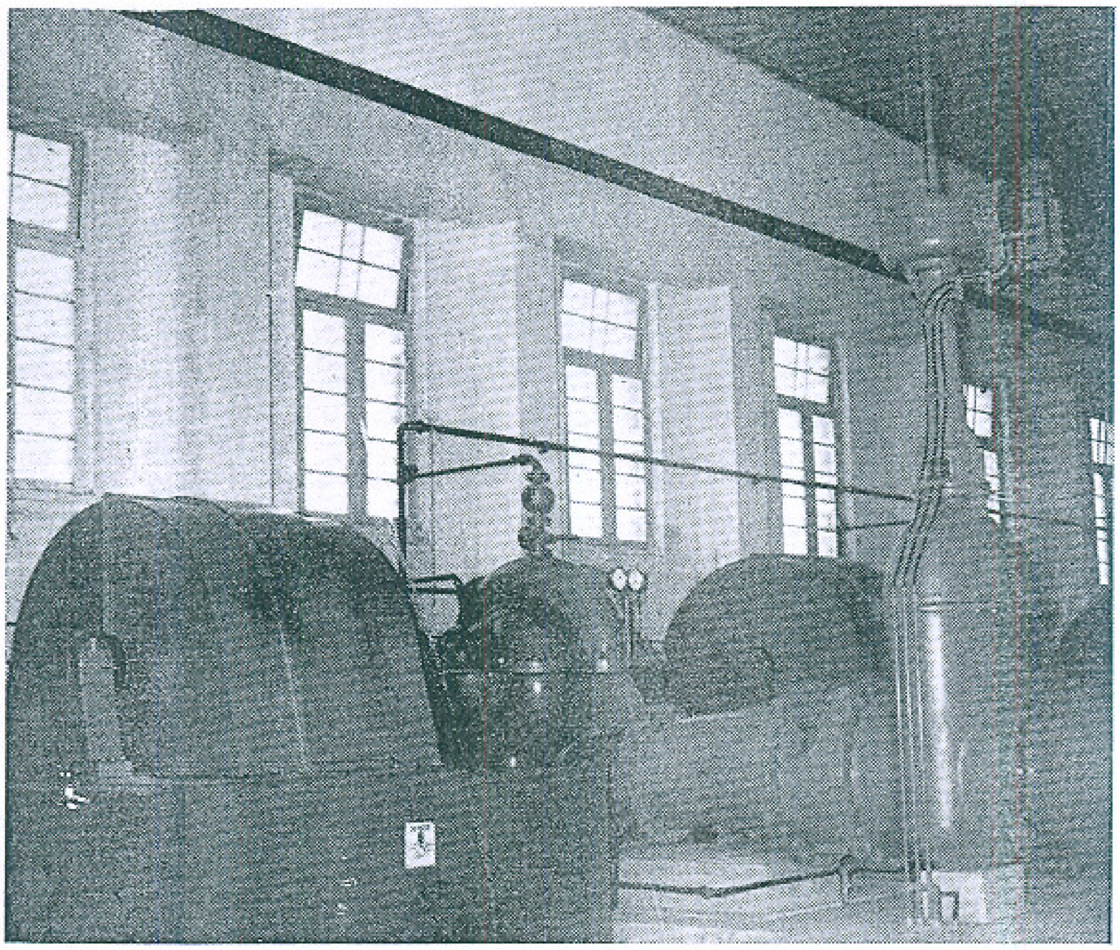

SCHEMATIC DIAGRAM
SHOWING
THE WORKING OF THE SURGE SUPPRESSORS
SURGE SUPPRESSORS.
PLATE No 6



66 KV Outdoor Sub-Station for Warsak Lift Irrigation Scheme



Pump House for Lift Canal showing Sump-Wells and Suction Pipes



One of the Pumping Units showing the Motor, Pump and Sluice Valve