OCCASION

This publication has been made available to the public on the occasion of the 50th anniversary of the United Nations Industrial Development Organisation.

DISCLAIMER

This document has been produced without formal United Nations editing. The designations employed and the presentation of the material in this document do not imply the expression of any opinion whatsoever on the part of the Secretariat of the United Nations Industrial Development Organization (UNIDO) concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries, or its economic system or degree of development. Designations such as "developed", "industrialized" and "developing" are intended for statistical convenience and do not necessarily express a judgment about the stage reached by a particular country or area in the development process. Mention of firm names or commercial products does not constitute an endorsement by UNIDO.

FAIR USE POLICY

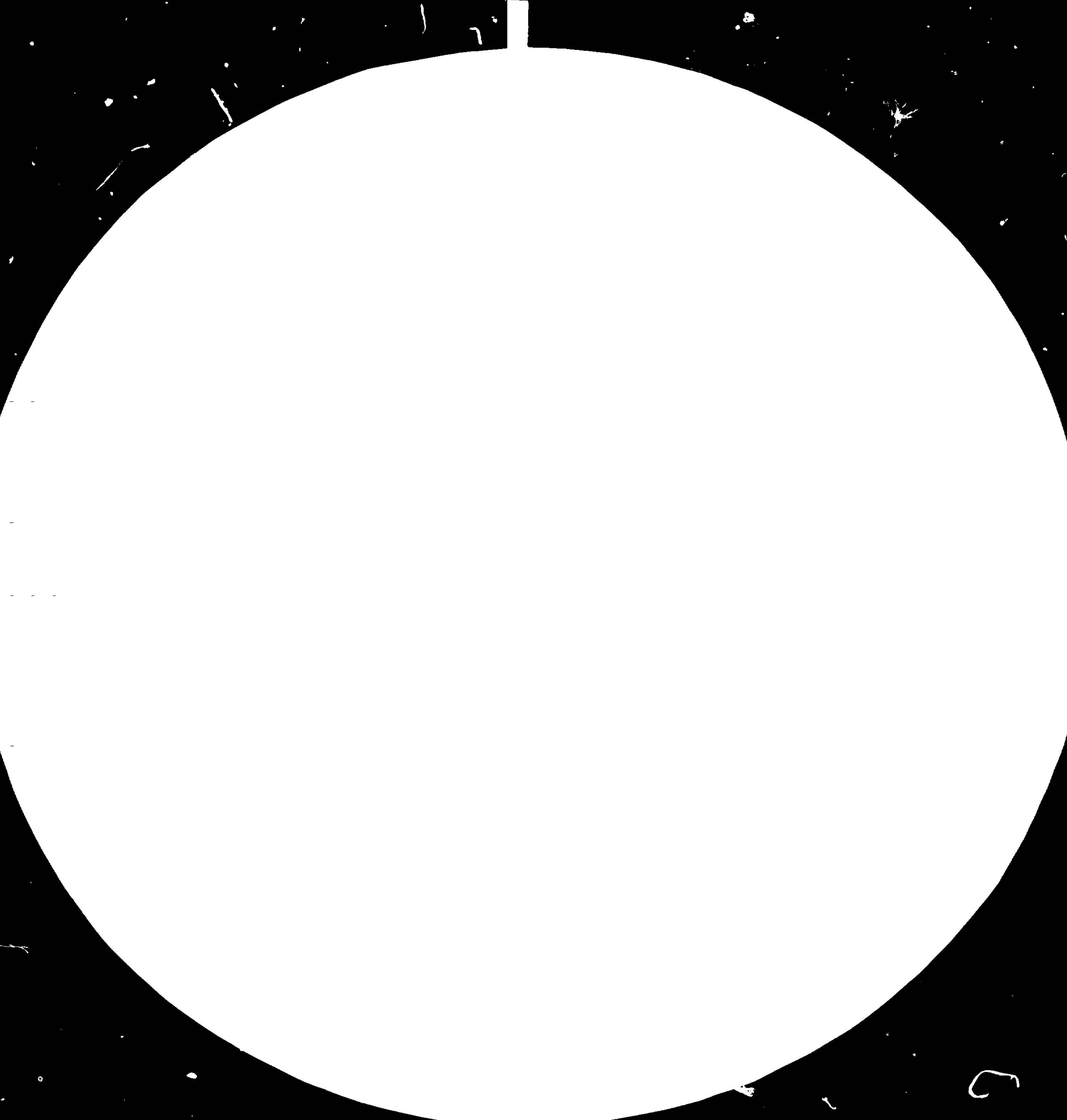
Any part of this publication may be quoted and referenced for educational and research purposes without additional permission from UNIDO. However, those who make use of quoting and referencing this publication are requested to follow the Fair Use Policy of giving due credit to UNIDO.

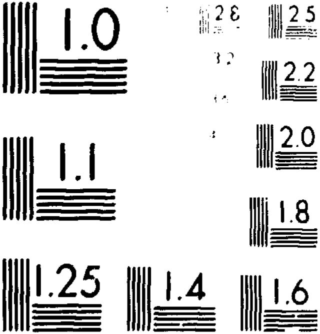
CONTACT

Please contact publications@unido.org for further information concerning UNIDO publications.

For more information about UNIDO, please visit us at www.unido.org

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna International Centre, P.O. Box 300, 1400 Vienna, Austria
Tel: (+43-1) 26026-0 · www.unido.org · unido@unido.org





MICROCOPY RESOLUTION TEST CHART

09749

Distr.
LIMITED

ID/WG.305/39
14 May 1980

ENGLISH

United Nations Industrial Development Organization

Seminar-Workshop on the Exchange of
Experiences and Technology Transfer
on Mini Hydro Electric Generation Units

Kathmandu, Nepal, 10-14 September 1979

CONSTRUCTION OF THE WATER POWER STATIONS ON BEIJING-MIYUN DIVERSION CANAL*

by

Beijing Design and Exploration Bureau
of Water Power

* The views expressed in this paper are those of the author and do not necessarily reflect the views of the secretariat of UNIDO. This document has been reproduced without formal editing.

80-39503

Contents

I. General Description of the Project

Beijing-Miyun Diversion Canal is a main canal for conveying water from Miyun Reservoir to Beijing. The head work of the canal lies in the downstream bank of the regulating reservoir of Bai River Water Power Station of Miyun Reservoir. It joins with the diversion canal of Yongding River at Yuyuan Tan and flows to Baijing City.

The cascade water power stations on the Beijing-Miyun Diversion Canal are for developing the water resources concentrated at the existing 8 drops within the range of 30 km from Gong Zhuang Zi head work to Xi Tai Shang downstream of Huairou Reservoir. The total head of this canal is 35 m.

In accordance with the development plan, the existing 8 drops were merged into 5 water power stations arranged at the inlet sluice of the main canal, at the drops No.2, No.3, No.6, and at one side of the Xi Tai Shang drop. The overall installed capacity is 11400 kw.

II. Engineering Geology

The geological survey of the cascade water power stations of Beijing-Miyun diversion canal was accomplished successively between the October of 1977 and the March of 1978. Two holes, 13-30^{m} deep for a single hole, were bored at each station. The overall length of boring was 228.76^{m}, of which 11.88^{m} were in the foundation rock; 156.88^{m} in the sand and gravel; 60^{m} in the cohesive soil.

Now, the foundation condition and the groundwater level on the site of the water power station No.3 is briefly described as follows.

Foundation conditions at the site of station No.3:

The surface layer is fine sand extending to a depth of 0-1.2 ^{m}. Its thickness varies slightly with the relief. The fine sand layer is underlain by a gravel stratum with more than 80 % of gravel and remaining of coarse sand. The gravel stratum above the depth of 12^{m} and that below the depth of 20^{m} mainly composed of gravels greater than 10^{cm} and the gravel stratum between 12 ^{m} and 20^{m} in depth mainly consists of gravels less than 10^{cm}. The gravels are largely composed of igneous rock and are more or less rounded in shape. The gravels are weakly weathered at their surfaces. The bearing capacity of the sand and gravel foundation is 4kg/cm^{2} and the internal friction angle of the gravel is 35^{0}.

Borings showed that the geologic structure within the site of the station changes very little, with similar condition of sedimentation, and that the stratigraphical structure and its material composition are stable.

From the observation of the nearby water wells, the highest groundwater level is 13 - 14 ^{m} below the ground surface and the minimum groundwater level is 18 - 19 ^{m} deep.

The permeability of the strata in the district is considerable. The continuous pump test offered a permeability coefficient of 100 - 200m/d.

III. Development Plan of Energy

(1) Annual diversion flow:

In accordance with the short-and long-term plans of water demand with the consideration of water consumption along the canal, the annual average flows for power generation vary for different cascade stations, as listed in Table 1.

From the statistical analysis of the data observed over many years on Beijing-Miyun diversion canal, the number of days for releasing water increases with increasing annual diversion flow. As the annual diversion flow is $5x10^{8}m^{3}$; the days of releasing water may reach 158 days and as the annual flow increases to $7.0 \times 10^{8}m^{3}$, the annual discharge days are expected to reach 200 days.

Table 1 Annual diversion flow

Item		Unit	Water power station				
			No.1	No.2	No.3	No.4	No.5
Annual average	Short-term	$10^8 m^3$	5	5	4.8	4.6	4.3
Diversion flow	Long-term	$10^8 m^3$	7	7	6.7	6.45	6.1

(2) Diversion discharge for power

Based on the diversion capacity of the existing canal and the need of consumption of water, the design discharges for the stations are 60-70 m^3/s.

(3) Design head

The main reason for adopting a scheme to merge the existing 8 drops into 5 power stations was that the difference between the maximum and the minimum water heads for the first 6 water drops was considerable. (see Table 2)

Table 2 The difference in water heads for the drops

Item \ Name of drops	No.1	No.2	No.3	No.4	No.5	No.6
Difference of water head	2.34	3.47	2.22	5.67	3.2	2.92

Except the water head of station No.4, which is rather big and reaches 5.67m, the heads of stations No.1, No.2, No.3, No.5, No.6 are all small. This is not favourable to the choice of the type of turbine. Through comparison of several alternatives, it was decided to combine the water heads of stations No. 1, No.3 and No.5 with the heads of stations No.2, No.4 and No.6 respectively. So, the development scheme of 5 cascades is reasonable from the point of view of economy. There is no much difference in the installed capacity and annual energy output while there is a decrease of 31 % in the capital investment. In such a way, the investment per KW may decrease by 24.9 %; especially, the quantity and variety of turbine units may decrease to the advantage of convenient management and maintenance during operation.

The design heads for cascade stations No.1-5 were determined as follows:

1. The head for station No.1 : . the design average net head 6.5 m, the maximum net head 8.7 m and the minimum net head 4.4 m.

2. The heads for station No.2-4: The gross heads for stations No.2 and No.4 are all 4.7 m and their design net heads are 4.5 m; the gross head for station

No.3 is 6.7 m; its design net head is 6.5 m.

3. The head for station No.5: Based upon the fluctuation of the water level in Huairou Reservoir, its design average net head is 4.5 m, but will be 6.0m in prospective period.

4. The choice of types of turbine-generator.

In order to decrease the variety and quantity of machines and the voltage level for the convenience of design, construction, operation and maintenance, in all the stations were installed type-ZD760-LH-200 water turbines, connected with 15 generators of two types, one with an output of 1000 KW (250r.p.m.) and the other with an output of 600 KW (214.3r.p.m.).

The parameters of the machine sets selected for all the water stations are listed in Table 3.

(5) Economical benefit:

According to the calculation, the diversion flow of $5\text{-}7 \times 10^8 m^3$ per annum will produce an annual energy of about 28000000kwh-39400000kwh. 5 cascade water power stations can economize a great quantity of fuels.

IV. General Layout of Power Stations and Design of Buildings

(1). General layout of power stations.

Table 3 The parameters of the chosen machine sets for all the power stations

Items	Unit	Water power station				
		No.1	No.2	No.3	No.4	No.5
Design head	m	6.5	4.5	6.5	4.5	4.5
Diversion discharge for power	m^3/s	66	57	66	57	57
Type of water turbine		ZD760 - LH - 200				
Type of generator		SF1250-24/2600	TSL 260/28-28	SF1250 24/2600	TSL260/28-28	
Installed capacity	KW	3 X 1000	3×500	3×1000	3×500	3×500

The principle of the general layout of the cascade power stations was that the existing Beijing-Miyun diversion canal should be kept in normal operation and the convenient construction of the station should also be ensured.

1. Water power station No.1:

On the right bank of the canal head work is located a power house with a downstream apron. Its tailwater channel is connected to the main canal. The development type of water power stations is diversion type power station. There are three service gates, (steel vertical-lift gates, each being 4.6 m x 2.7 m) with the provision of emergency gate slots trash racks. Downstream of the sluice gates are the 3 culverts with a section of 3.46 m x 2.5 m and a length of 19.6 m. The culvert outlet is connected to the inlet of the concrete spiral case of the power house through a 5 m long transition section.

3 water turbine-generators were installed on the foundation slab, which is 24.25m long and 14.5 m wide. The arrangement and the dimension of water power station No.1 were the same as those of stations No.2-NO.5. The access highway lies to the north of the power house and is connected with the inlet sluice highway. Owing to the limitation of the topographical condition, the power house is connected with a downstream apron of 16.8 m(L) X 20.4 m(W). There is a transition section with a twisted surface of a 1:5 inverse slope at the distance of 5 m from the outlet of the draft tube. And further downstream the 17.2 m long straight section of the tailrace is connected to the curved one. The base width of the tailrace is 8^{m}, the side slope is

1:2 and the tailrace is 73 m long.

A substation was installed on the right side of the power house and connected with the concentrated switching station of water power station No 3 through a 35 KV outgoing line.

2. Water power stations No. 2-5:

They were arranged respectively at drops No.2, No.4, No.6 and at one bank of the regulation sluice gate at XiTai Shang. The alignments of the power houses are all paralle with that of the canal. The distances between them range from 50 m to 55 m. After the regulation gate for the drop is closed, the water will be diverted through the entrance channel of the power house to generate electricity. The tail water returns to the downstream canal of the regulation gate. During the repairing or accident of the machine set of the water power station, the water may still discharge to the downstream by opening the regulation gate. The power houses of power stations Nos 2-5 are all water retaining structures, which are directly subjected to the water load and maintain their stability by their dead weights.

On the upstream side of the power house there are three 5^m x 3.2^m emergency gates and trash racks. The gates are controlled by fixed lift winches.

According to the characteristics of the water supply from the canal and the high suction head of the machine set, it was decided that no tailrace gate would be provided for the 5 cascade water power stations. The machine set may be checked and repaired according to plan, not in the irrigation period. The upper structure of the power house contains the main and auxiliary machine halls and installation bay. The control centre is located at station No.3. On the right side of the main machine hall was built a two-storey auxiliary machine hall, in which is the general control room.

In every cascade power house there are 3 water turbine-generators. Their spacings are 7^m. The crane span is 8 m. The dimension of the power house, including the installation bay is 30.52m(length) X 9.6 m (width) x 9.99 m(height). (The height from the foundation floor of the power house to the top of the generator floor is 13.67 m). Over the draft tube there is an auxiliary machine hall with a dimension of 24.25 m(length) x 4.7m (width) x 4.55 m(height).

Upstream of the power house is a pressure forebay with a rectangular section, Its bottom width is 19.8 m, the longitudinal slope of bottom floor 1:5, and the two retaining walls on either side are of gravity type. The upstream of forebay is connnected through the transition canal of the twisted surface to that of normal section. The bottom widths of the entrance canals for water power stations Nos.2-4 are 8 m. The side slopes of the canals are 1:2.5. The bottom width of the canal for station No 5 is 10 m. The side slope is 1:2. All their longitudinal gradients are 1/4000.

The downstream of the power house is provided with tail water apron with a rectangular section, a bottom width of 20.4 m, an inverse slope 1:5 and two gravity-type retaining walls on both sides of the apron. The apron is connected through the transition section to the normal section of the tailrace, Its sectional dimension is the same as that of the upstream entrance camal.

The substations for stations Nos. 2-5 are on the left side of the power stations. The access highways are also on the same side and lead to the installation bays.

3. <u>Safety measures for discharging water through the cascade stations</u>

Since the regulation capacity of the canal itself is very small (the canal top is about 1.5^m higher than the normal water level), when the machine set suddenly stops, on account of throwing off the full load because of fault, the inflow water along the canal will be obstructed and then will rise. Therefore, it is necessary to have reliable measures for discharging water. Otherwise, there will be a failure caused by overtopping of the levee. For this reason, the following measures have been used in the design of the stations:

(a). The existing regulation sluice is used for discharging the water. The sluice adjacent to the station has two gates and two lifting devices. Every Each is operated by a 3.5 kw electric motor and can lift the gate for discharging water within 2 minutes. In order to ensure reliability of power supply for operation, the existing 10 kv overhead line installed along the canal is used as a special external power source and the existing diesel-driven generator is also retained as emergency power source.

Under the extraordinary conditions the gate top of the stations will permit overflowing. When the water head is 1^m on the top of the gate, the overflowing discharge will be about $15m^3/s$.

(b). The regulation sluice of drop No 6 at the vicinity of station No 4 had to be reconstructed, since the embankment was raised and the height of the lift frame was not sufficient. The original electrically operated gates are replaced by hydraulic-operated gates, which can go up and down automatically with the water level of the canal. Thus, it is possible to ensure safe releasing of water through the sluice after the water rises in the canal. Two 3.6 m x 3.23 m radial gates are used for the sluice.

(2) Design of buildings

1. Grade of buildings:

According to the installed capacity of the stations, the power houses for these stations are designated as grade 4.

2 . Earthquake intensity:

The earthquake intensity of this district is 7 degree according to the seismic regionalization. In such district, earthquake resistant analysis might not be necessary in the design of the power house, but the aseismic measures were still considered for the upper framework of the power house and the connections between the prefabricated elements. To achieve a certain aseismic effect, the frameworks and all the elements were rigidly connected to form a monolithic structure and the walls were strengthened with girths.

3. Foundation stress requirement and foundation treatment for power house

On the basis of the exploration informations, one half of the foundation slab of power house of station No. 1 was constructed on the foundation rock, another half on sand and gravel. It was not possible to remove all the sand and gravel because of the restriction of topographical condition. Hence, the power house was not built on the same kind of foundation. To prevent the differential settlement of the foundation after completion of power house, grout pipes were embedded before the placement of foundation slabs. Consolidation grouting was not done until the turbine and spiral case floor had been concreted.

The foundation slabs of the power houses for stations Nos. 2, 3, 4 were built on sand and gravel foundation and that for No 5 was founded on alternate layers of clayey soil and clay. For buildings on foundations other than the rock foundation, it is necessary to keep the eccentricity as small as possible and stress distribution in the subsoil should be more uniform in order to ensure normal operation, that is, the ratio of maximum stress to minimum stress should not exceed 3 for sand;2 for dense clay; 1.5 for soft (plastic) clay.

During checking the overall stability of power house and the stress condition of foundation slabs for all the cascade stations under the normal operation condition (maximum water level upstream and corresponding maximum tail water level downstream) the stresses in the foundation soil and the ratio of maximum stress σ_{max} to minimum stress σ_{min} were within the permissible values (see Table 4).

Table 4

Name of stations	σ_{max} (kg/cm^2)	σ_{min} (kg/cm^2)	$k=\frac{\sigma_{max}}{\sigma_{min}}$
No.1	1.63	1.49	1.1
Nos 2,3,4	1.93	0.83	2.32
No.5	1.80	1.30	1.38

From Table 4 it can be seen that the foundation stresses beneath the power houses are not large, all of them do not exceed the adopted values recommended for foundation bearing capacity (4kg/cm^2 for sand and gravel, 2kg/cm^2 for clayey soil and clay). The ratio of maximum stress to minimum stress is also within the specified range. Therefore, the configuration dimension used for the power house can satisfy the stability requirement.

The upstream and downstream retaining walls, which were checked under both normal and abnormal conditions, can satisfy the stability requirement. The ratio of maximum stress to minimum stress also does not exceed the permissible value, and the eccentricity is very small.

4. Seepage control and drainage measures

The underground seepage path was designed according to the permissible exit gradient (J) of the foundation, which should not exceed 0.1.

The seepage control measures for all the joint connections of the structures within the upstream forebay and the downstream apron of power house were treated with plastic water stops of type-651 and with two layers of bituminous felts and three coatings of bitumen. The seepage control measures for the canal joint were filled with bituminous mortar and bituminous mastic. To prevent the seepage through the two abutments of the power house. two concrete keywalls were provided for increasing the seepage path.

The drainage measures in the foundation of downstream apron and those behind the walls were mainly determined according to the condition of groundwater level. Since the groundwater levels beneath stations No.1-4 were all lower than the foundation slabs of power houses, during excavation no groundwater appeared in the foundation pits of stations No.2, 3, and 4, except in the foundation pit of station No.1, in which there was a little quantity of seepage water. Therefore, it was decided that no filter drainage devices were provided under the downstream apron slabs and behind the walls.

As the groundwater level in the foundation of station No.5 was shallow, being about 5^m below the ground surface and 6^m above the bottom of the foundation slabs of power house, filter layers were placed under the downstream apron and drain holes were also provided in the slabs for decreasing the seepage pressure. In order to increase the stability of retaining walls and decrease their sectional size, drainage filters were placed behind the walls. This will lower the groundwater level and decrease the water pressure against the walls effectively.

5. Contruction standard

Prefabricated elements were used for the upper structure of power house. Crane beams, roof plates and eave plates were standardized elements supplied by the precast elements factory. Columns and girders were precast on the site. Some of the elements, for example, crane frame, girth and so on, were concreted in situ.

The external surfaces of the walls of power house were coated with cement mortar. Some parts of them were covered with terrazzo. Except that the floors of the generator storey, central control room and dispatching room were paved with terrazzo, all the other floors were coated with cement mortar.

The building configuration was designed on the principle of economic feasibility with due consideration of its prettiness and magnificence. The configuration arrangements were slightly different for different stations.

Windows are orderly controlled with window opening mechanism for ventilation. The accumulator room and the acid storage room can be ventilated with axial ventilators.

Steel windows, which were directly ordered from the steel window factory, were installed for their firmness and durability.

V. Hydro-Machineries. Electrical Connection with Power System and Automation

(1). Hydro - machineries

1. Water turbine

According to the choice of types of machine set, it was determined to use axial flow fixed blade vertical turbine. Its runner diameter is 200 cm. Its type, specification and characteristics indices are as follows:

Type : ZD 760-LH-200

Blade installation angle : 10°

Head :

Design head H_p = 7 m.

Maximum head H_{max} = 8 m.

Minimum head H_{min} = 4.5 m.

Rated discharge : Q_p = 20 m^3/s.

Rated speed : n = 250 r.p.m.

Rated output : N = 1150 kw.

2. Oil system :

Since the oil consumption in the machine set is not much, there is only one oil pump. Its overall oil quantity is 1.54 m^3. The capacity of oil sump for upper guide thrust bearing of generator was 0.24 m^3 and that for lower guide bearing was 0.025 m^3. Therefore, oil pipe lines for supply and outlet are not needed for stations. The oil can be fed with a movable oil bucket.

The storage and purification of turbine oil and insulating oil for 5 cascade stations are all concentrated on station No. 3. There are 2 Type LY-150 oil filters, one Type 2CY-3.3/3.3-1 oil pump and one Type 2CY-5/3.3-1 oil pump, one bucket with a capacity of 3 m^3 for insulating oil, one bucket with the same capacity for turbine oil and one movable oil bucket with a capacity of 0.2 m^3.

3. Pneumatic system

As the suction head of the machine set is H_s=+1.5 m, the tailwater level is 0.8 m below the centre of the runner during the full load of 3 machines, and therefore no consideration is given to air consumption in the tailwater in compensation regime. Low pressure compressed air of 7 kg/cm^2 is supplied only for braking and repairing. There are two Type 2V-0.6/7 low pressure air compressor with a 1 m^3 air vessel for every cascade station.

High pressure pneumatic system :

Each station has one Type CZ 20/30F high-pressure air compressor, which directly supplies the compressed air into the pressure oil sump of governor through the air-water separator.

4. Water supply system and drainage system

There are two Type 3 BA-9 water pumps for each station. They pump water from two spiral cases for cooling the bearings of the 3 machines of the whole station and for fire extinguishing. All the mechanical and electrical equipments are located above the maximum tail water level (Q = 68 m^3/s). There is one Type 1½-6 drainage pump used for pumping out the accumulated seepage water below the maximum tail water level, the pump is controlled by a water level-signalling device for automatic dewatering. Four Type 4 BA-25A water pumps were installed for the 5 stations. The pumps can be used temporarily to drain away the accumulated water for repairing the draft tube during the stopping of water in canal.

5. Measuring system

A water-level signalling device was installed upstream of the regulation sluice for each cascade station. When the water level rises over the high water level, the device gives out signal and automatically opens the existing gate on the canal. This will ensure no overtopping of the levee.

There are manometers for spiral cases and vacuum meters for draft tube for each machine set. Type DZ-II-flow-meters installed for the 3 machines of station No.1, can measure the transcient and accumulated flow through the machine sets.

6. Choice of Crane

Since the most heavy part to be lifted by the crane is the rotor of the generator. Its weight is 9.1 tons. Hence, each cascade station has a single-beam bridge crane with a capacity of 10 T, a span of 8 m and a lifting height of 16 m.

7. Machine repairing installation and oil test device :

All the equipments of the 5 cascade stations can be sent for repair to a repair workshop located at station No. 3.

The turbine oil and insulating oil are sent to the nearby Bai River water power station for examination, and no devices for oil test are installed at each station.

(2). Electrical connection with power system

A concentrated switching station is situated on station No. 3 which is the nearest station from the substation of the national system. Electrical voltage is separately stepped up on stations No. 1-4. Each of them has a step-up transformer converting the voltage from 6.3 kv to 35 kv. The power then flows through a 35 kv transmission line to the above switching station and from there to the national system.

Since station No. 5 is farther away from the switching station, its outgoing line with 10 kv is directly connected with the system.

(3). Automation level and design of electrical secondary circuit of the stations

At the present stage, the operation of the cascade station is mainly realized by men at respective control rooms and in future will be transitted to cascade concentration dispatching, that is, there will be a remote control of the other stations on station No. 3. Before realization of the remote control, water diversion for generation and irrigation will be centrally administrated by station No. 3 through communication dispatching in order to have a harmonic operation.

Every station has a central control room and a control console. A strong electron type one to one concentration contact control is used. Control switches, meters and signal lights are concentrated on the control console. Every machine set can be automatically started or stopped on the console by a command "start" or "stop". A room is reserved in the auxiliary machine hall of station No. 3 for cascade dispatching and telecontrol in the future.

The electromagnetic type compound relays are used as relay protection device. As for the synchronization regime, mainly the manual exact synchronization is used, and the automatical self synchronization is supplemented.

A self shunt excitation with thyristor is used for excitation system. Three-phase half control bridge connection with field suppression switch is used for station No. 2, 4 and 5. Three-phase full control bridge connection is used for stations No. 1and No. 3 without field suppression switch, but with thyristor controlled reversible field suppression system.

Direct current power source : in case of sudden throwing off the full load resulting in a failure caused by the surge because of obstructing the water flow in the canal, accumulators are used as direct current power source for stations No.2 and No. 3 which will produce great influence. The purpose is to ensure lighting for tracing out the cause of failure in time, to start the machine set for restoring the auxiliary power source,and to supply the lift winch of the regulation gate with power source. Alternating current rectifier and electric-capacitance storage device are used for other stations.

Reserve automatical reclosing device is connected between two bus-bars of the station power.

Control consoles and main control boards are all concentrated in the central control room. Relay protection board, automatical operation board and excitation board are arranged at the side of the machine. Except the two direct current boards, there is an empty place in the distribution board room (at the side of central control room) reserved for additional installation of secondary circuit boards when needed in the future development.

(4). Communication and lighting

In accordance with the characteristics of short term operation and prospective plan of the stations, at present time there is a Type DT-dispatching telephone general set in station No.3 for its communication with the substation of the power system and with the other stations.

As for the lighting of the stations, except station No.3, (being a dispatching centre) in which due attention is paid to prettiness of lighting arrangement in central control room and in dispatching room, the other stations only have general requirement for lighting in design.

VI. Construction and Operation Conditions about the Water Power Stations

Construction of these cascade stations began in March 1978; in November of the same year, station No.2 was completed and connected with electrosystem. At the same time, civil engineering works of power houses for stations No.1, 3, 4 and 5 were also nearly completed. In May 1979, the power from station No.3 was connected with system and the installation of machine sets had also begun at station No.1 and it is expected to be completed at the end of 1979. The stations No.4 and 5 are scheduled to be completed, connected with system and put into operation in 1980.

Since the stations No.2 and 3 were connected with the system and generated power, they have been basically in normal operation. Because that these cascade stations are seasonal ones, power generation is subordinated to irrigation demand and the stations do not bear the peak load, the power generation hours of these stations vary with the quantity of water diversion. The estimated annual energy hours are about 3800-4000 hours.

The whole engineering works of the above cascade stations are as follow:

Excavation of sand and gravel: $16.6 \times 10^4 m^3$;

Fill of sand and gravel: $25.5 \times 10^4 m^3$;

Concrete : $4.3 \times 10^4 m^3$;

Stone masonry laid with mortar: $0.6 \times 10^4 m^3$;

Reinforcement and steel materials: 800 T.

Note: Several drawings have been omitted because of the poor quality of reproduction.