Zeitschrift: IABSE structures = Constructions AIPC = IVBH Bauwerke

Band: 7 (1983)

Heft: C-25: The Itaipu Dam: Design and construction features

Artikel: Powerhouse arrangement and design

Autor: [s.n.]

DOI: https://doi.org/10.5169/seals-18270

7. Powerhouse Arrangement and Design

7.1 General Arrangement

The general arrangement of the Powerhouse is shown in Fig. 16. The total length of the Powerhouse is 968.0 m, and includes from the right bank to the left:

- *Right Assembly Area* with a length of 151 m and the transverse equipment unloading building.
- *Powerhouse* portion in the river channel, 544.0 m long, consisting of 15 blocks with generating units and one empty block. All blocks are 34 m wide. The Central Control Room and administrative complexes will be located in blocks U9A and U10.
- *Central Assembly Area* 98.0 m long and another equipment unloading building.
- *Powerhouse* portion in the Diversion Channel, 136.0 m long, with 3 generating units and one unit block reserved for the future.

7.2 Design and Foundations

7.2.1 General

The distance between the axis of the Main Dam and the centerline of the Powerhouse units is 111.50 m. The dam and the Powerhouse structures are separated from each other by a contraction joint.

Each block of the Powerhouse is an independent structural unit, separated from the adjoining blocks by open contraction joints. Below the turbine deck, vertical keys were formed in the transverse contraction joints between blocks.

7.2.2 Loading Conditions

For structural design and stability analyses of the various blocks of the Powerhouse, four classes of loading conditions were used:

- *Construction Loading Conditions* included various possible combinations of loads during construction, such as exceptional live loads due to movement or installation of construction or permanent equipment, loads imposed during testing of permanent equipment, and loads imposed by fresh concrete on existing lifts or incomplete members.
- *Normal Loading Conditions* covered various combinations which would be imposed on the structure during normal operation of the Powerhouse, such as hydrostatic loads with reservoir level at El. 220.0 and the tailwater varying between El. 92.0 and 105.4, temperature changes, uplift pressures, normal wind loads and dynamic loads due to mobile equipment or due to normal operation of the permanent equipment.
- *Exceptional Loading Conditions.* Along with the normal loading conditions, they included combinations of infrequent statistically loads, such as hydrostatic loads due to a reservoir level at El. 223.0 and tailwater at El. 122.0, seismic loads due to an acceleration of 0.05 g, high wind loads and dynamic loads due to emergency operation of the equipment.

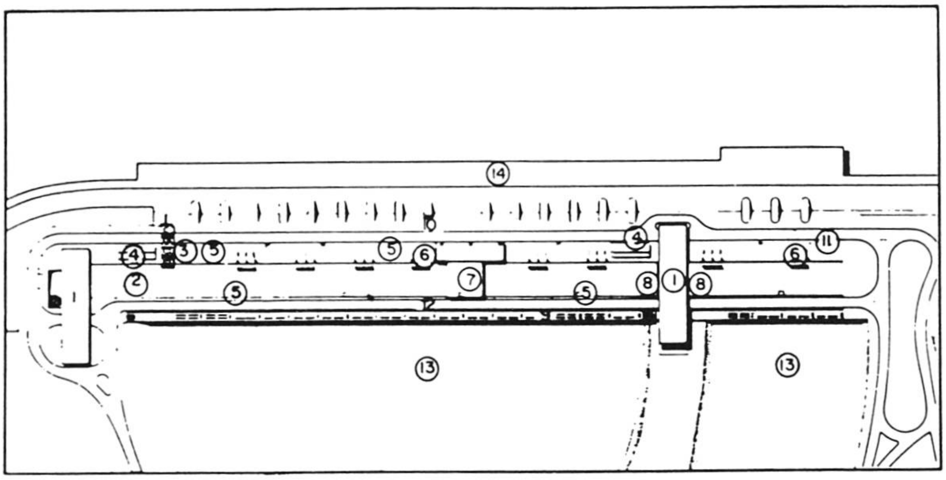


Fig. 16 Powerhouse General Plan

1. *Equipment unloading building*
2. *Right assembly area*
3. *Transformer unloading location*
4. *Auxiliary services transformers*
5. *Vertical circulation access*
6. *Transmission line take-offs*
7. *Central control room*
8. *Central assembly area*
9. *Draft tube gate hatches*
10. *Penstocks*
11. *Upstream road*
12. *Downstream road*
13. *Tailrace*
14. *Dam and power intakes*

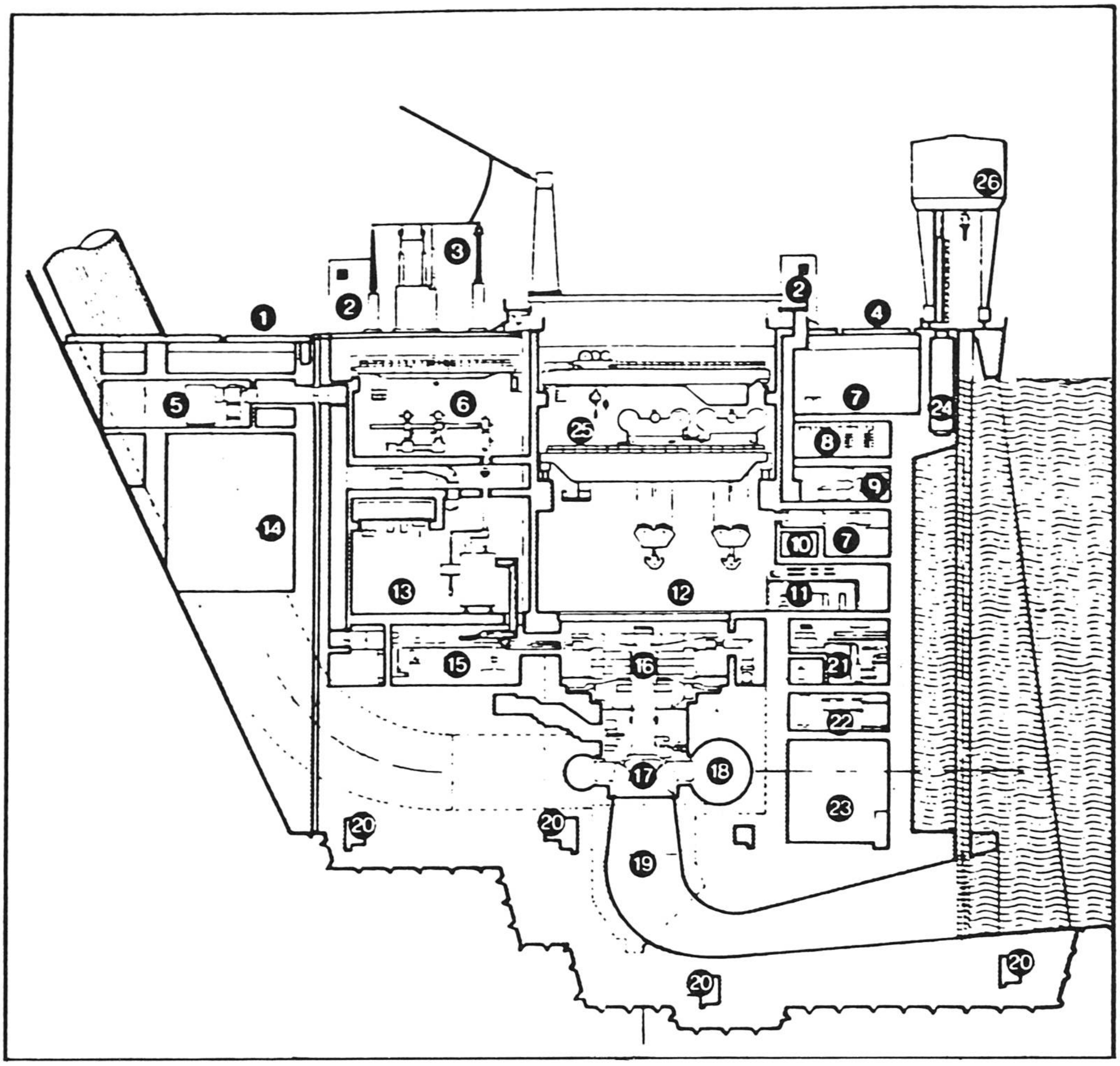


Fig. 17 Powerhouse Section General Arrangement

1. *Upstream road*
2. *Vertical access*
3. *Trans. line take-offs*
4. *Downstream road*
5. *Upstream ventilation*
6. *SF6 substation*
7. *Electrical equip. gallery*
8. *Cable gallery*
9. *Ventilation equip. gallery*
10. *Battery room*
11. *Local unit control*
12. *Generator hall*
13. *Transformer gallery*
14. *Penstock*
15. *Upstrm. elmech. equip. gallery*
16. *Generator*
17. *Turbine*
18. *Spiral case*
19. *Draft tube*
20. *Drainage gallery*
21. *Mechanical equip. gallery*
22. *Pumps*
23. *Anti-flooding gallery*
24. *Draft tube gate storage*
25. *Main powerhouse crane*
26. *Gantry crane*

– ***Limit Loading Conditions,*** combined highly improbable loads, such as a reservoir level at El. 223.0 and tailwater at El. 138.0 (corresponding to the passage of a probable maximum flood through the Itaipu reservoir), with extremely severe wind loads and a seismic event equivalent to an acceleration of 0.08 g.

7.2.3 Powerhouse Foundations

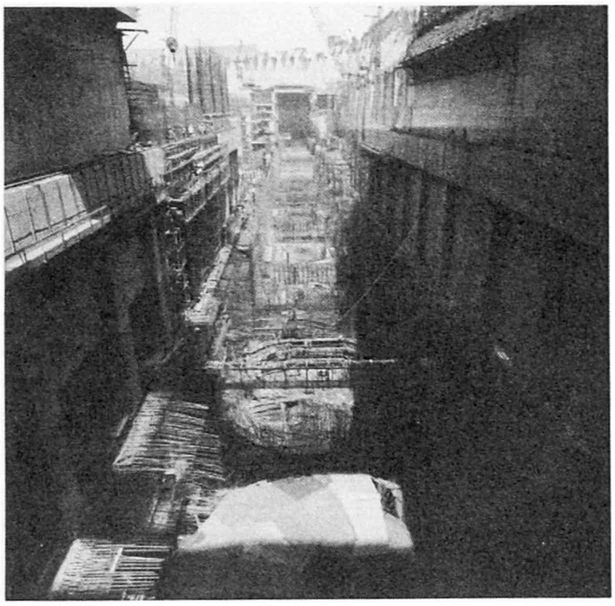
Except for the central six blocks, U6 to U10, all Powerhouse blocks are founded on sound, dense basalt. For the six central blocks, where the river bedrock was about 25 m lower, backfill concrete was placed below the normal foundation level of the structure.

The stability of the central Powerhouse blocks and their foundation, against shear sliding, was studied jointly with the central blocks of the Main Dam.

Conventional and finite element methods were employed. The comprehensive geomechanical model also evaluated the stability of the Powerhouse jointly with the dam, particularly with respect to the weaker zones in the foundation.

7.3 Structural Concept and Design

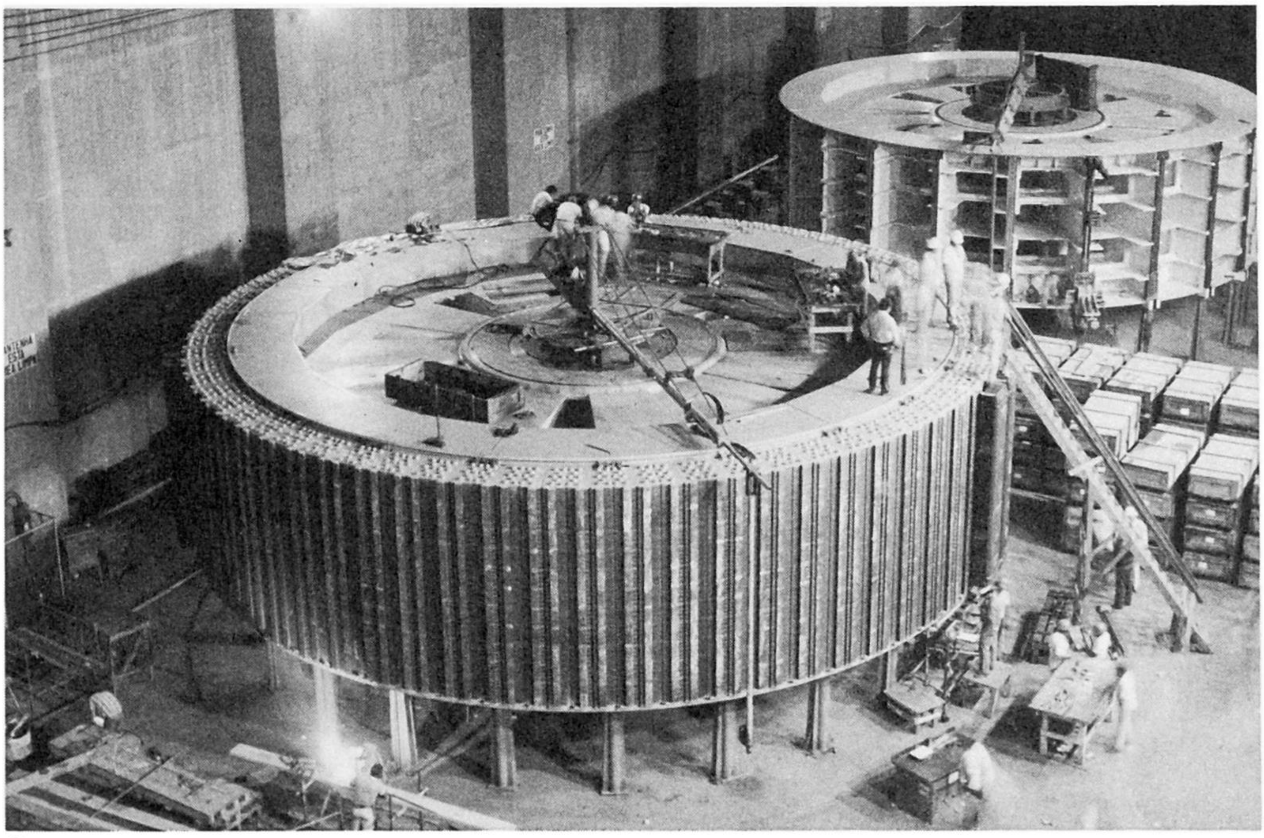
The Right Assembly Area was mostly carved out of sound rock and is therefore almost entirely rigidly confined. The foundation slab has a thickness of 5.0 m. The upstream and downstream walls, 36 m high (El. 108 to El. 144) were placed directly against the excavated faces of the rock. Because of the average 0.1 H : 1.0 V slope of excavation, the thickness



Powerhouse

of these walls varied from 6.0 m at the base to 10.0 m at the top. The 151.0 m long Right Assembly Area was divided into three structurally independent blocks.

While the Central Assembly Area is similar in layout to that at the right bank, its structural concept was different because it was not excavated into the abutment. On the contrary it is completely free on the upstream side. Therefore, the Central Assembly Area was designed as a composite structural frame.



Generators

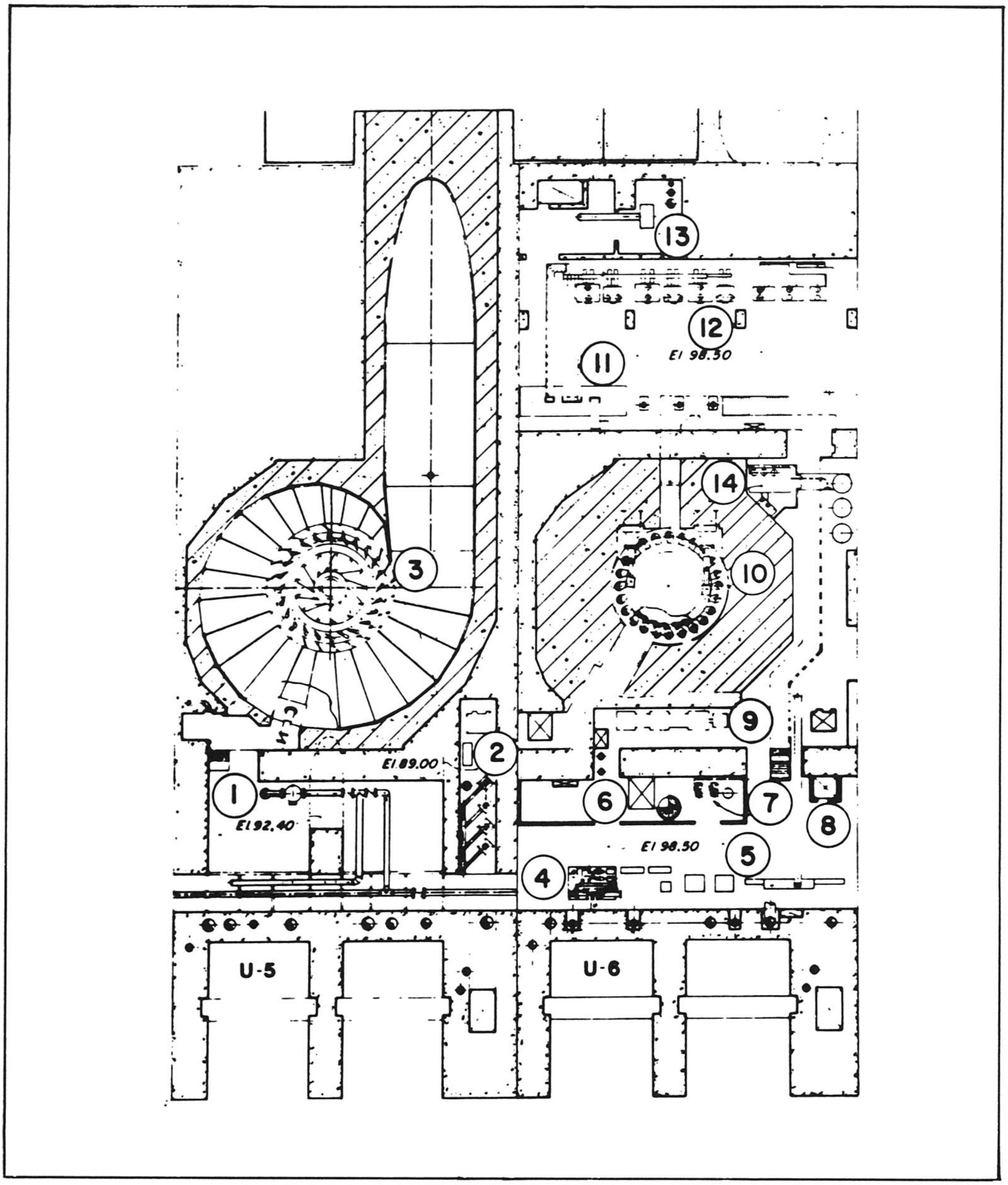


Fig. 18 *Powerhouse Equipment Arrangement Floors at El. 92,40 and El. 98,50*

1. *Cooling water filters*
2. *Pumps for anti-flooding gallery*
3. *Turbine (Section of El. 87,50)*
4. *Plant for treatment of generator demineralized water*
5. *Unit motor control center*
6. *Air tanks for generator brakes*
7. *Governor air compressors*
8. *Elevator shaft*
9. *Neutral cubicle of generator*
10. *Turbine (Section of El. 92,10)*
11. *Excitation system*
12. *Transformers for generator auxiliary services*
13. *Ventilation system for lower galleries*
14. *Turbine governor system*

To establish the general structural configuration of a typical unit block, a three-dimensional FEM analysis was made with the estimated dimensions of the principal load-carrying members (substructure, external walls and main floors), including foundation rock down to El. 0.0. In this phase of the analysis only the Normal Loading Conditions were used, with the principal objective to understand the tendencies of structural behavior of the various parts of the block.

Thereafter, the locations of construction joints in the substructure were determined, considering the construction equipment and methods to be employed. From this, a division of the substructure into various structural members was possible and the design of each member, including reinforcement, was carried out.

The portion of the Powerhouse downstream of the centerline of the units consists essentially of an L-shaped structural monolith, with the substructure slabs and the draft tube forming the horizontal part of the L and the downstream breast wall and the counterfort piers supporting it forming the vertical member. This monolith was designed as an inverted dam to resist the hydrostatic pressure from tailwater at El. 138.0, which may occur during a probable maximum flood. The downstream wall and piers were constructed ahead of the floor slabs of the downstream galleries, in order to protect the incomplete unit blocks when the first unit starts operation in 1983. The piers or counterforts were slip-formed.

One important aspect of the design of the structure below El. 98.5 is the large amount of second-stage concrete which was placed after the installation and pressure testing of the spiral case and the lower bend of the penstock.

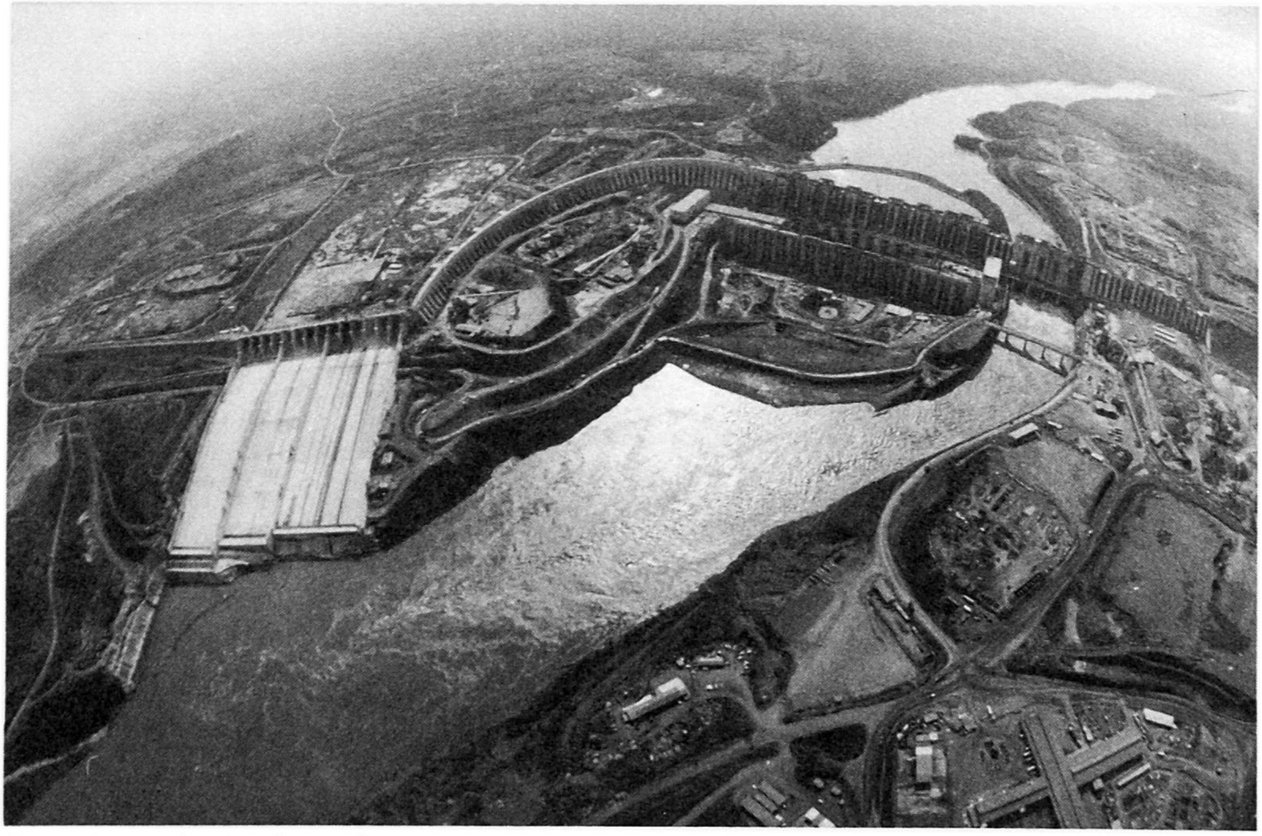
7.4 Layout of Equipment Galleries

The Itaipu Powerhouse is of the indoor type. Because of the 46 m variation between the minimum and probable maximum tailwater levels, the top service deck of the Powerhouse is located 36 m above the floor of the generator hall.

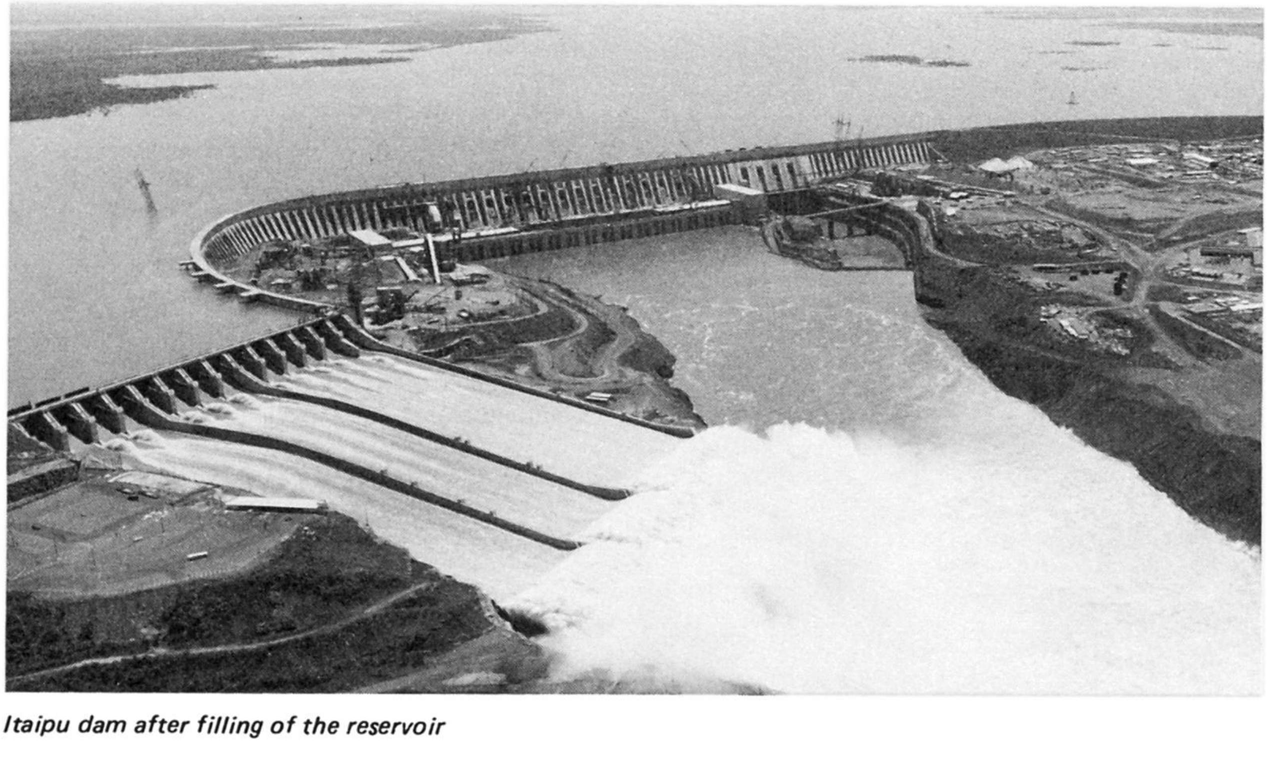
Several alternative layouts were analysed to optimize the utilization of space between El. 108 and 144. In one of the earlier arrangements, most of the electromechanical auxiliary equipment was located in the downstream galleries, and the main step-up transformers were located on the top deck at El. 144 on the upstream side. With the selection of gas insulated (SF6) switchgear which could be located indoors, it was decided to place the main transformers indoors in a gallery upstream of the generator hall and at the same level, as indicated in Fig. 17. The 500 kV SF6 switchgear is located in the gallery above the unit step-up transformers.

The disposition of the various equipment is shown in a typical floor plan in Fig. 18, and described below:

- ***El. 92.4, downstream:*** filters for raw water supply, water pressure controls for cooling oil for transformers and piping for distribution of water for cooling and services.
- ***El. 98.5, upstream:*** unit terminal cubicles, cubicles for excitation equipment for the units, and bus bars from the generators to the step-up transformers.
- ***El. 98.5, downstream:*** turbine governor, demineralization unit for cooling water fot the stator of the generator, air compressor for partial load operation of turbine and for the governor, compressed air tanks, and control panels for the unit motor.
- ***El. 108.0, upstream:*** main (unit) step-up transformers located in individual cells, and protected by transverse fire protection walls.
- ***El. 108.0, downstream:*** local control and protection panels for the units and for the 500 kV line take-offs.
- ***El. 115.0, downstream:*** CO_2 cylinders and fire-fighting equipment, distribution switchboards for auxiliary services in AC and DC, and battery room.
- ***El. 122.0, downstream:*** ventilation plant for the downstream galleries.
- ***El. 127.6, downstream:*** cable trays, cubicles and auxiliary equipment for the emergency diesel generators.
- ***El. 128.2, upstream:*** gas insulated (SF6) switchgear.
- ***El. 132.0, upstream:*** ventilation plant for the upstream galleries.
- ***El. 133.2, downstream:*** Central Control Room and administrative facilities, frequency converters for serving station auxiliaries, distribution panels for auxiliary services and the air conditioning plant for the Central Control Room and Unit Control Rooms.
- ***El. 144.0, upstream:*** banks of 500/13.8 kV transformers for auxiliary services and the EHV equipment of the 500 kV line take-offs.



General view of Itaipu dam in final construction phase



Itaipu dam after filling of the reservoir