

Module 5

HYDROPOWER ENGINEERING

LESSON

3

HYDROPOWER EQUIPMENT AND GENERATION STATIONS

Instructional objectives:

On completion of this lesson, the student shall learn about:

1. Equipment employed for converting water energy to electrical energy
2. Different types of turbines
3. Guidelines for selecting a specific turbine
4. layout of power houses

5.3.0 Introduction

The powerhouse of a hydroelectric development project is the place where the potential and kinetic energy of the water flowing through the water conducting system is transformed into mechanical energy of rotating turbines and which is then further converted to electrical energy by generators. In order to achieve these functions, certain important equipments are necessary that control the flow entering the turbines from the penstocks and direct the flow against the turbine blades for maximum efficient utilization of water power. Other equipments necessary are couplings to link the turbine rotation to generator and transformers and switching equipment to convey the electric power generated to the power distribution system.

A powerhouse also accommodates equipment that are necessary for regular operation and maintenance of the turbine and power generating units. For example, overhead cranes are required for lifting or lowering of turbines and generator during installation period or later for repair and maintenance. For the crane to run, guide rails on columns are essentially required. The maintenance of a unit is done by lifting it by the crane and transporting it to one end of the power house where abundant space is kept for placing the faulty unit. A workshop nearby provides necessary tools and space for the technicians working on the repair of the units.

A control room is also essential in a powerhouse from where engineers can regulate the valves controlling water flow into the turbines or monitor the performance of each unit to the main power grid.

Power houses that receive water from a reservoir through a penstock may be termed as power generating units detached from head works. There is another class of powerhouse that utilize the water head directly from the water body. These are usually the run-of the river type power houses mentioned in Lesson 5.1, which are located as a part of a barrage in a river or those which utilize the head difference of a canal fall.

The detached power houses may be surface or underground types depending upon its position with respect to the ground surface. In-stream or run-of-river power houses are mostly surface type.

Turbines are of different types like reaction or impulse-types. They may also be divided as with horizontal or vertical axes. This lesson discusses all the salient features of a

hydropower generating station including the layout, structural components and mechanical parts.

5.3.1 Hydraulic turbines

These form the prime mover which transforms the energy of water into mechanical energy of rotation and whose prime function is to drive a hydroelectric generator. The turbine runner and the rotor of the generator are usually mounted on the same shaft, and thus the entire assembly is frequently referred to as the turbo-generator.

Hydroelectric plants utilize the energy of water falling through a certain difference in levels which may range from a few meters to 1500m or even 2000m. To handle such a wide range of pressure heads, various turbines differing in design of their working is employed. Modern hydraulic turbines are divided into two class - impulse and reaction. An impulse turbine is one in which the driving energy is supplied by the water in kinetic form, and a reaction turbine is one in which the driving energy is provided by the water partly in kinetic and partly in pressure form. The basic types of impulse and reaction turbines are given in the following table.

Turbine types	Class	Head range
Propeller turbines: Fixed blade turbines	Reaction	10-60m
Adjustable blade (Kaplan turbine)	Reaction	10-60m
Diagonal flow turbines	Reaction	50-150m
Francis turbine	Reaction	30-400m (even up to 500 to 600m)
Pelton turbine	Impulse	Above 300m

Each turbine has a water passageway which incorporates a turbine casing, stay vanes for support, wicket gates for flow control, a runner that rotates the generator, and a draft tube or the exit channel downstream of the turbine.

Figure1 shows the typical positioning of a reaction and impulse turbines with respect to the incoming water conducting system and the draft tube, which is the exiting duct of the flowing water.

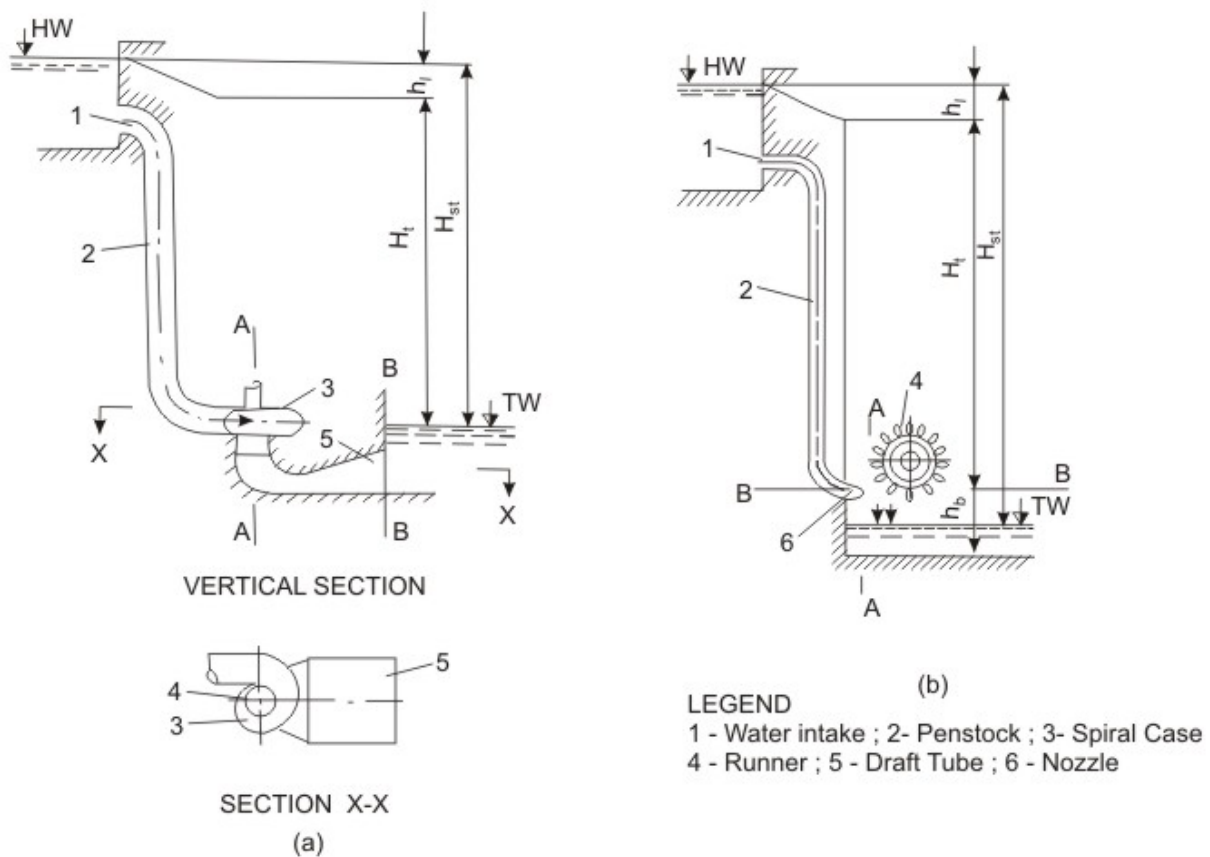


FIGURE 1 Layout for (a) Reaction Turbine ; (b) Impulse Turbine.

For the reaction type of turbine, (Figure 1a), the turbine section is assumed to begin at the entrance to the turbine case (section A-A in the figure) and end at the exit from the draft tube (section B-B). It may be noted that this setting for a reaction turbine ensures the following characteristics:

1. The wheel passage remains completely filled with water
2. The water acting on the wheel vanes is under pressure greater than atmospheric
3. The water enters all round the periphery of the wheel through the scroll case
4. Energy in the form of both pressure and kinetic is utilized by the wheel

In the Figure1, H_t is the head of water on the turbine and is the difference in water specific energy between beginning and end of the turbine section.

For the impulse type turbine (Figure1b), the following characteristics of the turbine setting differentiates it from the impulse type of turbines:

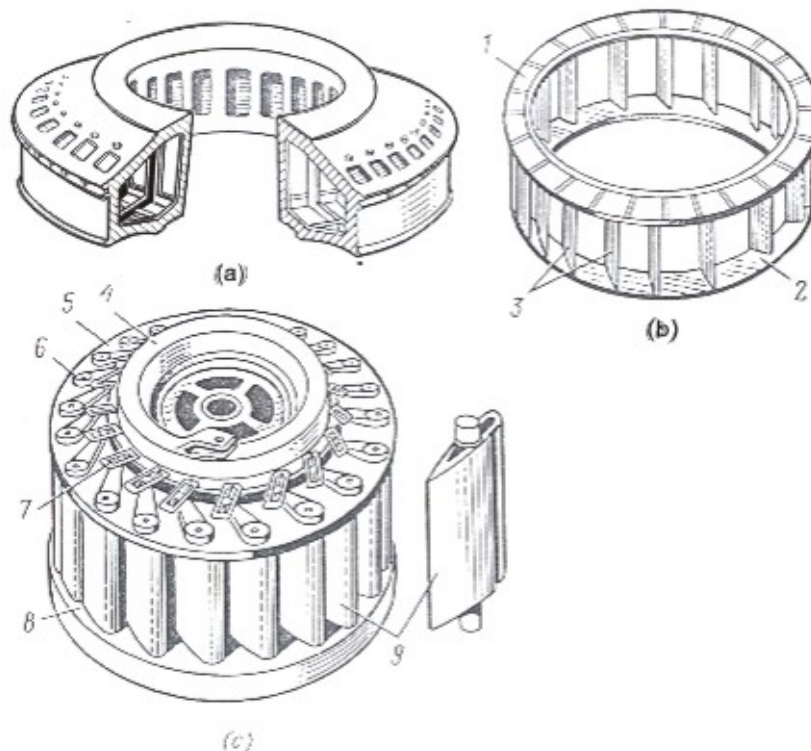
1. The wheel passages are not completely filled with water since a jet emanating from the penstock nozzle strikes the buckets of the runner
2. The water acting on the vanes or buckets located at the wheel periphery is under atmospheric pressure
3. The water impacts on the runner at one point or at a few discrete points, depending upon the number of nozzles

4. Energy applied to the wheel is completely kinetic

The components of the different types of turbines are discussed in the following paragraphs.

Reaction turbines

A turbine has stationary as well as rotating members. The stationary components of a reaction turbine with vertical axis are shown in Figure 2.



1=Upper circular plate of stay ring ; 2=Lower circular plate of stay ring; 3=Stay vanes; 4=Operating ring
5=Upper ring of wicket gates; 6=Levers; 7=Slotted guides; 8= Lower ring of wicket gates; 9= Gates

FIGURE 2. Stationary components of a reaction turbine
(a) Cover ; (b) Stay ring ; (c) Wicket gates

The purpose of each part is as follows:

1. Stay ring, which forms the outer support of a turbine case. It resists heavy loads imposed by the equipment and the concrete of the power house structure. It consists of an upper and lower circular plates joined by 10 to 16 stay vanes of streamline shape. The stay rings of some turbines may have no lower plate.

2. Wicket gates, which are provided inside the stay rings regulate the discharge and direct the water flow towards the runner by their angle. Also, the wicket gates serve to start

up and shutdown the turbine and to control its power output and rotational speed. Wicket gates also have an upper and lower rings resting in recesses provided in the circular plates of the stay ring. The rings of the wicket gate are joined together by 20 to 32 blades (or gates) of streamline shape.

3. Operating ring, to which the gates are connected by slotted guides and levers rigidly fastened to their top pins. The function of the operating ring is to open or close the gates which can rotate about their axes.

4. Turbine cover, The operating ring is installed in a recess provided in the turbine cover which, in turn, rests in a recess made in the upper ring of the wicket gates. The turbine cover gives support to the turbine bearing and separates the water passageway through the turbine from the dry turbine pit.

The rotating or movable parts of a reaction turbine comprises of the runner and the shaft. The shape of such part differs for different types of reaction turbines, as described below:

1. Axial flow reaction turbines

Figure 3 shows the Kaplan type of adjustable blade axial flow turbine, where the stream of water flows in the direction of the axis of the turbine.

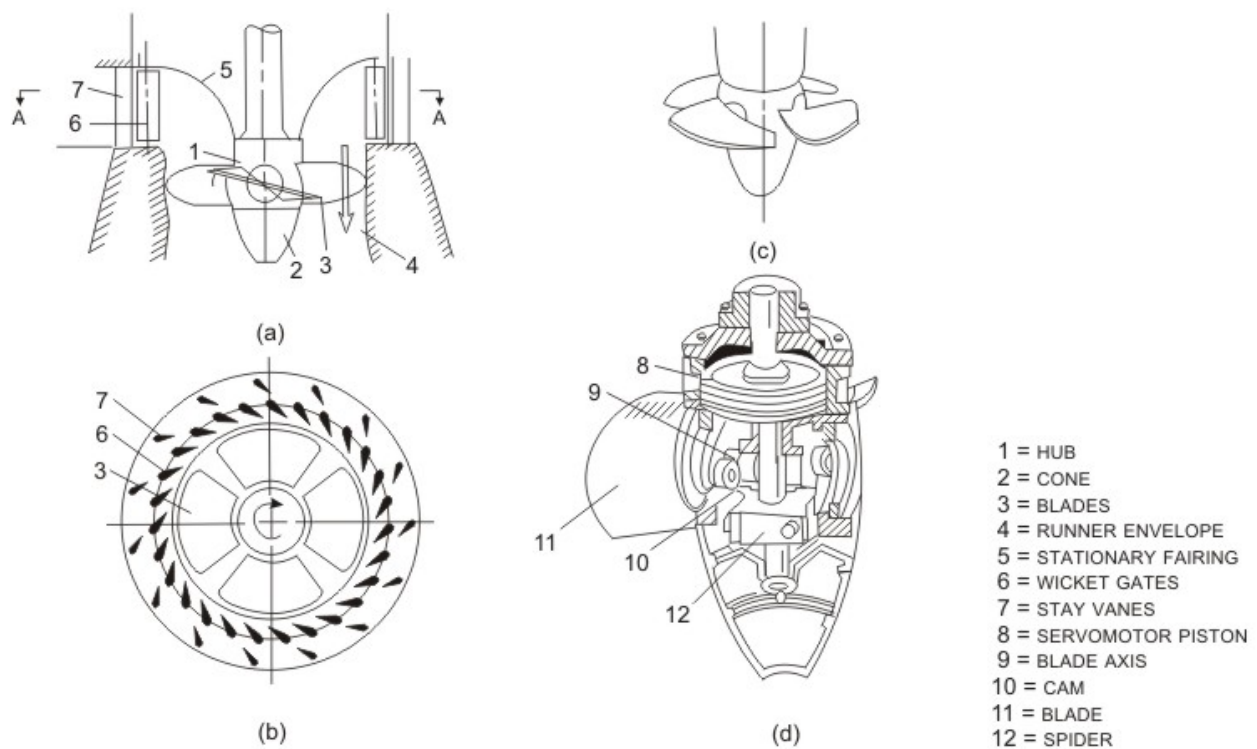


FIGURE. 3 Adjustable - blade propeller (Kaplan) turbine
 (a) Cross-sectional elevation ;
 (b) Horizontal section A-A through runner ;
 (c) General appearance of runner ;
 (d) Section through blade adjustment mechanism

The axial flow turbine resembles the propeller of a ship and hence is also termed as the propeller turbine. The runner of such a turbine has three to eight blades, cantilever-mounted on a spherical or cylindrical hub equipped with a cone (Figure 3c). In a fixed blade propeller turbine, the blades are rigidly fastened to the hub at a permanent angle. In the adjustable-blade propeller (or Kaplan) turbine, the blade angles can be adjusted by a hydraulic operated piston located within the hub (Figure 3d). The advantage of having an adjustable-blade for a propeller turbine, as for the Kaplan turbine, is that the fixed blade wheels show peak efficiency at only a small range of load. If load is slightly higher or smaller than this range, its efficiency drastically decreases. On the other hand, the blade adjustable turbines can be operated in such a way that their efficiency remains high over a very large range of load.

2. Radial flow reaction turbines

Figure 4 shows the runner of a Francis turbine, where the flow of water from the stationary part into the turbine runner is in a radial direction.

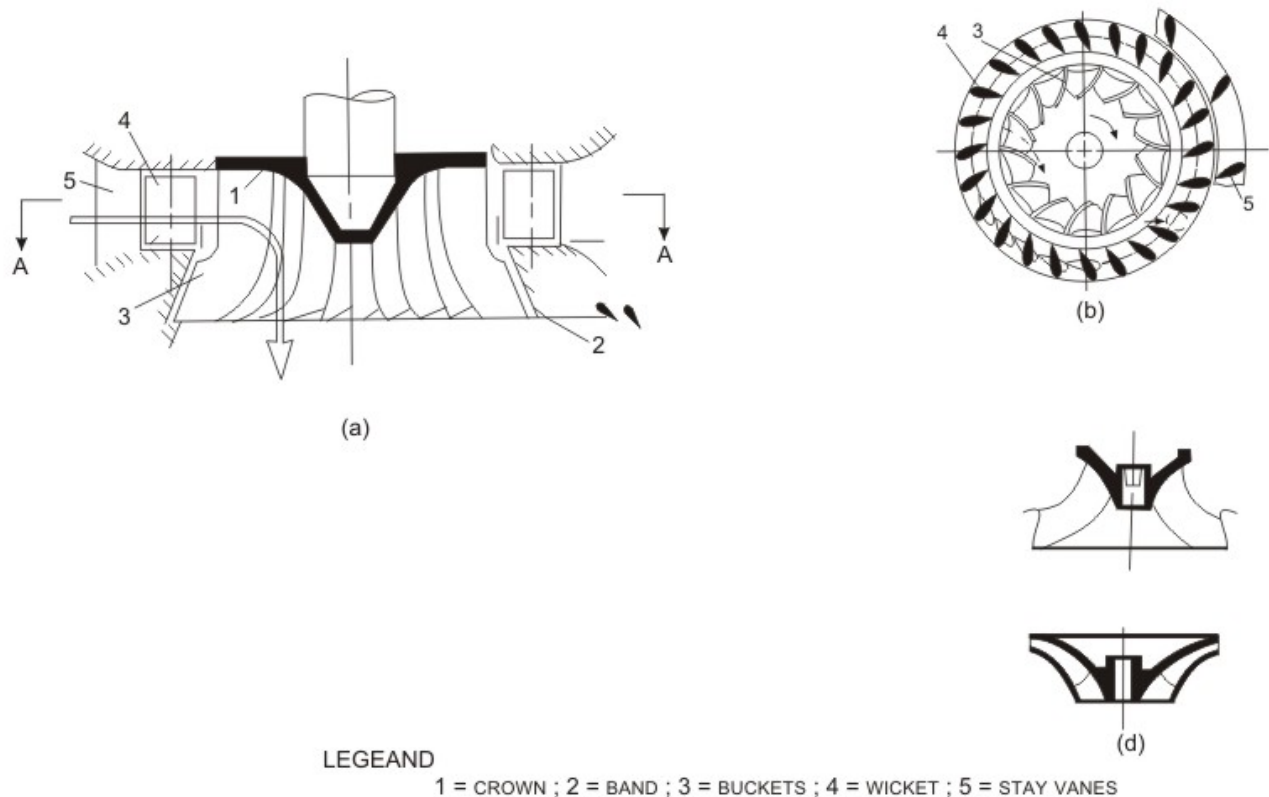


FIGURE 4. Francis turbine ; (a) Cross sectional elevation ; (b) Horizontal section A-A through runner ; (c) General appearance of runner ; (d) Runners for various heads

Once inside the runners, the flow direction changes and gets directed downward. The runners of a Francis turbine are attached at their upper ends to a conical crown and the lower ends to a circular band. The shrouded buckets make an angle with the radial planes

and bend at the bottom. The number of blades usually ranges from 14 to 19 (Figure 4c). As with the propeller turbine, the runner shape depends upon the head, as shown in Figure 4d.

3. Diagonal flow reaction turbines

Figure 5 shows the runner of a Deriaz turbine, which is the adjustable-blade modification of a diagonal turbine.

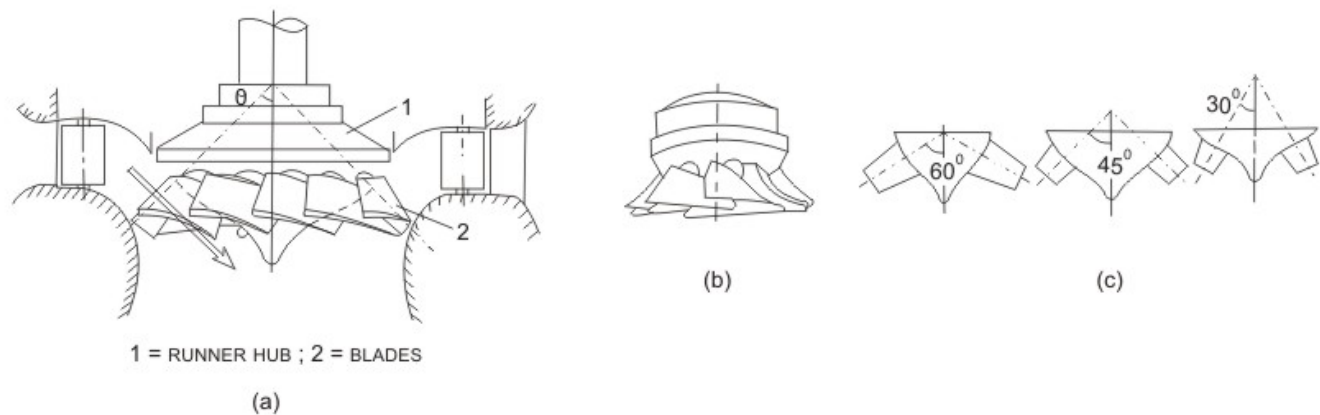


FIGURE 5. Adjustable - blade diagonal (Deriaz) turbine
 (a) Cross sectional elevation
 (b) General appearance of runner
 (c) Runners for various heads

Here, the flow of water against the turbine blades is neither axial nor radial, but at an angle. The angle θ made by the blade axes with the main shaft decreases with increasing head and ranges between 30° and 60° . As with Kaplan turbines, the mechanism for adjusting the blade angles is located within the hub.

Reaction turbines with the turbo-generator axis placed vertically, as described before, causes the stream of water to change by 90° from the point where it leaves the stationary part and the water enters the turbine runner. Again, the water turns by 90° as it leaves the runner and enters the draft tube before finally joining the tail water. This turning of flow twice – results in a loss of energy. Another inconvenience is that vertical turbo generators require extra head room in low-head power plants and thus becomes inconvenient to place there. Under these circumstances, a horizontal axial-flow (propeller type) arrangement of reaction turbine has been often adopted like the bulb type turbine (Figure 6). It has the generator in series with the turbine runner at a submerged elevation and enclosed in a

streamlined water tight housing located in the water passageway on either upstream or downstream side of the runner.

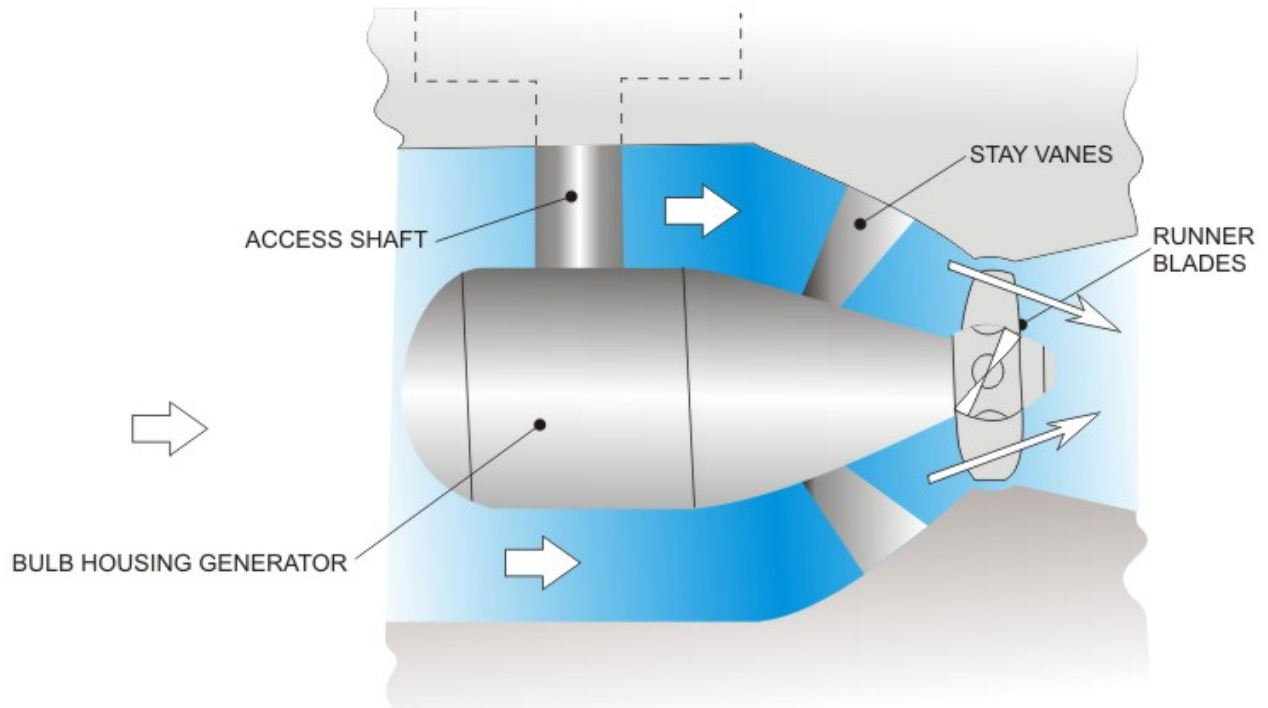


FIGURE 6. Axial - flow bulb turbine

The S-type tubular turbine (coupled to an open-air generator) is also favoured for very low head range and designed as a low capacity unit (Figure 7). The blades of the turbine can be fixed (propeller) or movable (Kaplan).

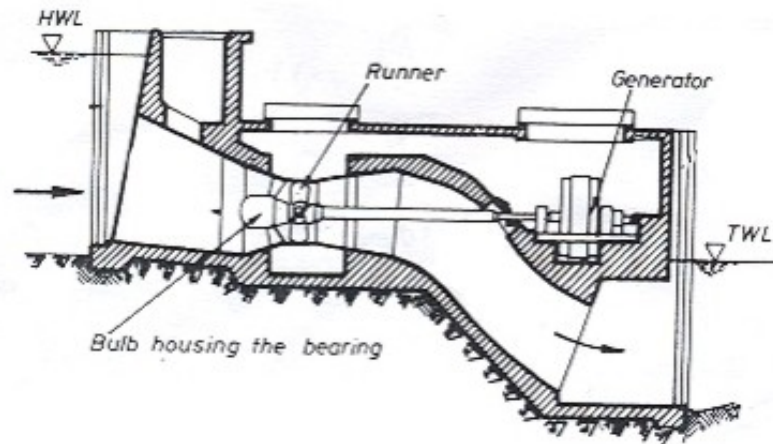


FIGURE 7. Low capacity S-type tubular turbine

Impulse turbines

As mentioned above, the Pelton turbine is an impulse turbine that is used commonly in hydro power projects world wide for very high head installations. The runner of a Pelton turbine (Figure 8) consists of a disk with buckets attached around its periphery. The buckets can be integrally cast with the disk or welded or bolted to the wheel centre. The buckets may vary in details of their construction but in general they are bowl-shaped and have a central dividing wall, or splitter, extending radially outward from the shaft. The runner is enclosed in a housing and is mounted on the same shaft with the rotor of the water-wheel generator, placed either vertically or, more frequently, horizontally. The water is supplied from the upper pool through penstocks which end with one or several tapering nozzles. The water jet escaping from the nozzles hit the dividing wall which splits it into two streams, and the bowl-shaped portions of the buckets turn the water back, imparting the full effect of the jet to the runner. The quantity of water through the nozzle is controlled with the help of a spear-valve. The used water flows down a conduit into the lower pool.

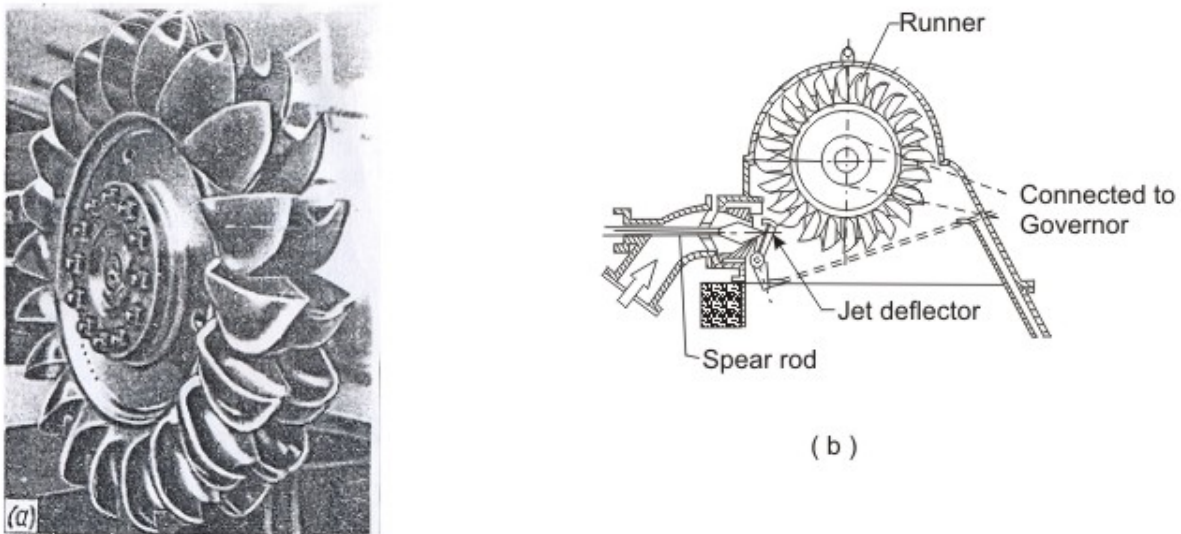


FIGURE 8. Pelton - type impulse turbine
 (a) General view
 (b) Section through water passage showing spear - type flow control valve

5.3.2 Choice of a turbine

The water power designer has to make a choice on the type of turbine that can be adopted for a particular project. After the range of head to be handled by a turbine has been evaluated by stream flow analysis and the installed capacity determined from the analysis of the power-generating capacity of the proposed plant, the task of the designer is to choose an optimum turbine type and series, the number of power generating units, the runner diameter, rotational speed, and runner axis elevation. Knowing the total installation at the power station, the number of units can be decided. The capacity of the plant should be fixed as high as possible with adequate care on efficient running and low initial costs, and available transport and shipping facilities.

The following Bureau of Indian Standard Codes of practices may be referred to for the detailed design of hydraulic turbines and their selections:

1. IS:12837-1989 "Hydraulic turbines for medium and large power houses - guidelines for selection"
2. IS: 12800-1993 " Guidelines for selection of turbines, preliminary dimensioning and layout of surface hydro-electric power houses":

- Part 1: Medium and large power houses
- Part 2: Pumped storage power houses
- Part 3: Small, mini and micro hydroelectric power houses

One of the important parameters of a turbine is the Specific Speed denoted as n_s , which and defined as the speed in r.p.m. at which a turbine of homologous design would operate, if the runner were to reduce to a size which would develop one metric horse power under one metre head. It is given by the following relation:

$$n_s = \frac{n\sqrt{P \times 1.358}}{H^{5/4}}$$

where

- n_s = Specific speed of turbine in revolutions per minute(r.p.m.)
- n = Rated speed of turbine in revolutions per minute
- P = turbine output in kW, and
- H = Rated head in metres.

Once the specific speed (n_s) is determined, the chart given in IS: 12837-1989 and reproduced in Figure 9 may be used to determine the type of turbine that may be adopted for the particular project.

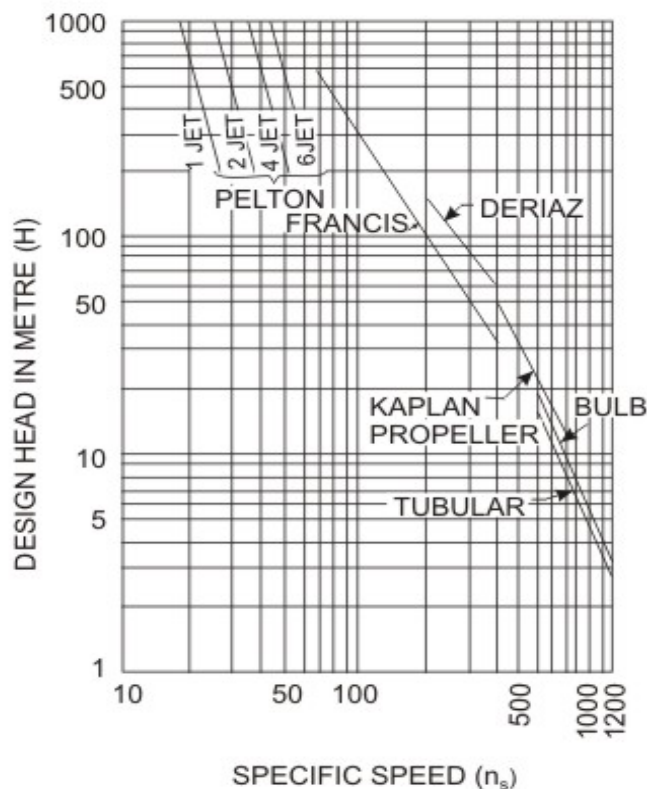


FIGURE 9. Chart for determining the selection of turbine

The type of turbine selected also depends upon techno-economic considerations of the generating equipment, power house cost and relative benefits of power generation. The factors given in the following table determine the type of turbine to be used depending upon site conditions.

Type of Machine	Head variation percent of rated head (m)	Load variation percent of rated outlet	Specific speed (m-mhp)	Peak Efficiency in percent
Pelton	120 to 80	50 to 100	15 to 65	90
Francis	125 to 65	50 to 100	60 to 400	93
Deriaz	125 to 65	50 to 100	200 to 400	92
Kaplan	125 to 65	40 to 100	300 to 800	92
Propeller	110 to 90	90 to 100	300 to 800	92
Bulb	125 to 65	40 to 100	600 to 1200	92

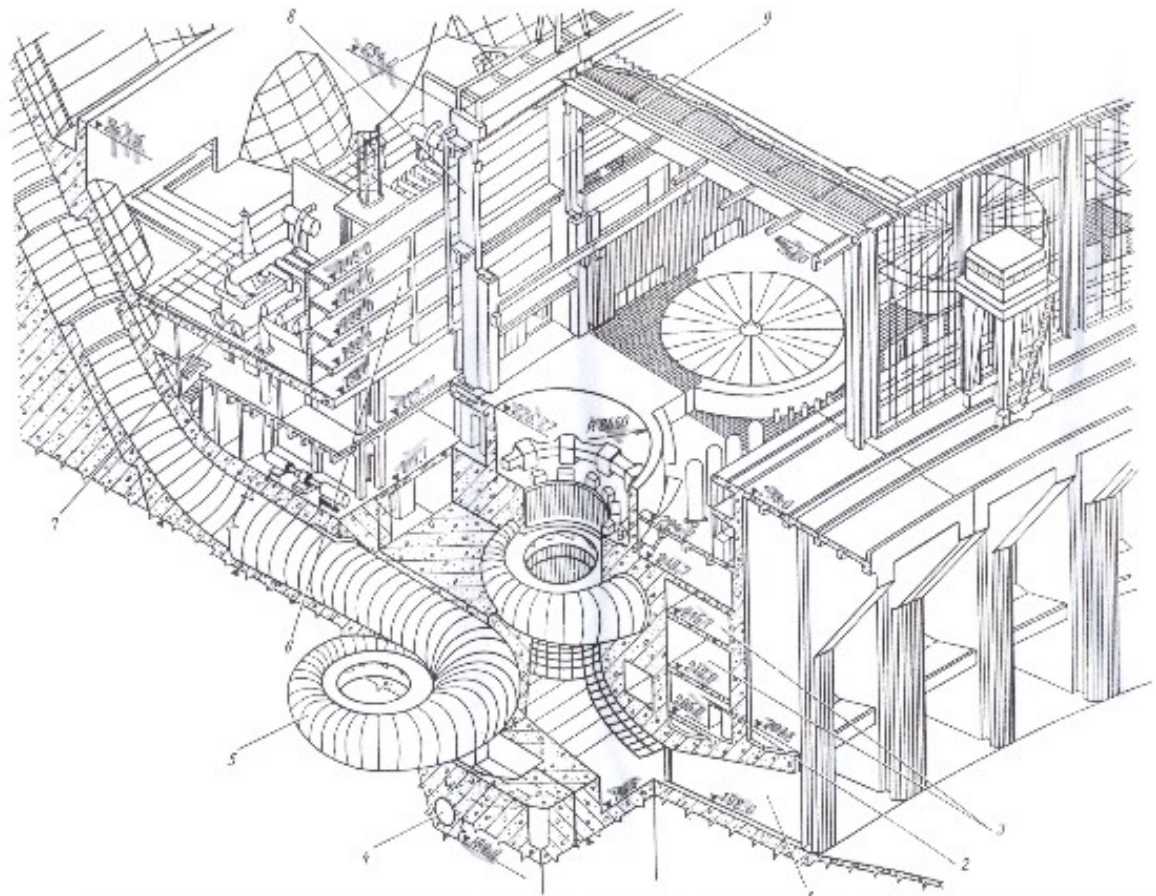
The following points may additionally be noted:

1. The performance of a turbine is ideal at the design head. Fall of efficiency in case of Pelton, Kaplan and Bulb turbines is much less in comparison to Francis and Propeller types. Therefore in overlapping head ranges selection of type of turbine should consider the head variation existing at site.
2. Turbine efficiency varies with load. Fall of efficiency at part load for Francis and Propeller is much steeper in comparison to that for Kaplan and Pelton turbines. Therefore, necessity of operating turbines at part loads for longer time influences the choice of turbines in the overlapping head ranges. Thus in the head ranges where both Kaplan and Francis are suitable. The requirement of large pressure head and electrical load variation dictates, Kaplan turbine to be superior to Francis turbine from considerations of higher power generation on account of better overall efficiency. Similarly, in the overlapping head ranges where both Francis and Pelton could be used, Pelton has advantages over Francis in overall performance level when variation of load and head is higher.
3. Highest specific speed of turbine resulting in higher speed of rotation for generator with consequent reduction in cost of generator. This criteria is very important for selecting-type of turbine from cost consideration in the overlapping head ranges.

5.3.3 Appurtenant structures for reaction turbines

It was mentioned earlier that the power output of a reaction turbine depends upon the hydro-net pressure head, that is, the effective head available for power generation. This is calculated by deducting the losses in the water conductor system (including penstocks) from the gross head evaluated between the head water or reservoir level and the tail water

level. Further, the entire water passage from the intake to the outlet is completely filled with water. In fact, there should not be any water nor the water pressure be so low that it turns into vapour, which may create cavitation damage to the turbine and the water passage. Hence, it is important to design the path of water from its distribution to the runner at the periphery of the stationary part to the existing passage.



1=Draft tube ; 2=De-watering-system pumps; 3=Process water-supply system; 4=Discharge gallery
5=Special case; 6=Cable gallery ; 7= Transformer; 8,9= Columns

FIGURE 10. Cut-out view through the water passage and powerhouse of a reaction turbine

In Figure 10, a three dimensional cut-out view through the power house of a reaction turbine has been shown. The turbine and generator units have been removed to give a better view of the water passage. It may be observed that the penstock, which is a uniform diameter tube shapes in to a spiraling pipe near the turbine that reduces in size towards its tail end. This section, called the Spiral or Scroll Casing, is provided to distribute the conveyed water all around the periphery of the turbine runner through the stay rings and

wicket gates as uniformly as possible. At the bottom, the water passage bends up from vertical to a horizontal alignment, and this passage is known as the draft tube. The functions of a Draft Tube are two-fold: (a) Achieves the recovery of velocity head at runner outlet, which otherwise would have wasted as exit loss, and (b) Allows the turbine to be set at a higher elevation without losing advantage of the elevation difference. The second objective allows easier inspection and maintenance of the turbine runners.

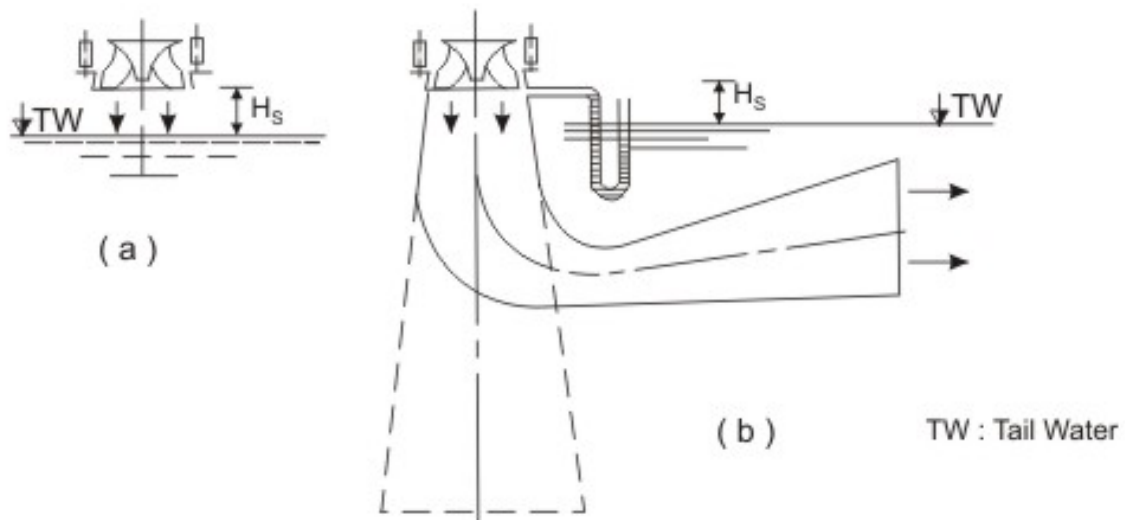


FIGURE 11. Principle of operation of a draft tube

Figure 11 explains the reason why a reaction turbine enjoys the energy available between the runner end and the tail water level (H_s) with the help of a draft tube (Figure11b). In the absence of a draft tube (Figure11a), the head difference (H_s) would have simply been lost. As shown in Figure11b, in the presence of a draft tube, therefore, there exists a sub-atmospheric pressure at the bottom of the runner. It may be noted that though Figure11 shows a typical Francis turbine in place, the draft tube is not very different in case of a propeller or Kaplan turbine, as shown in Figure 12.

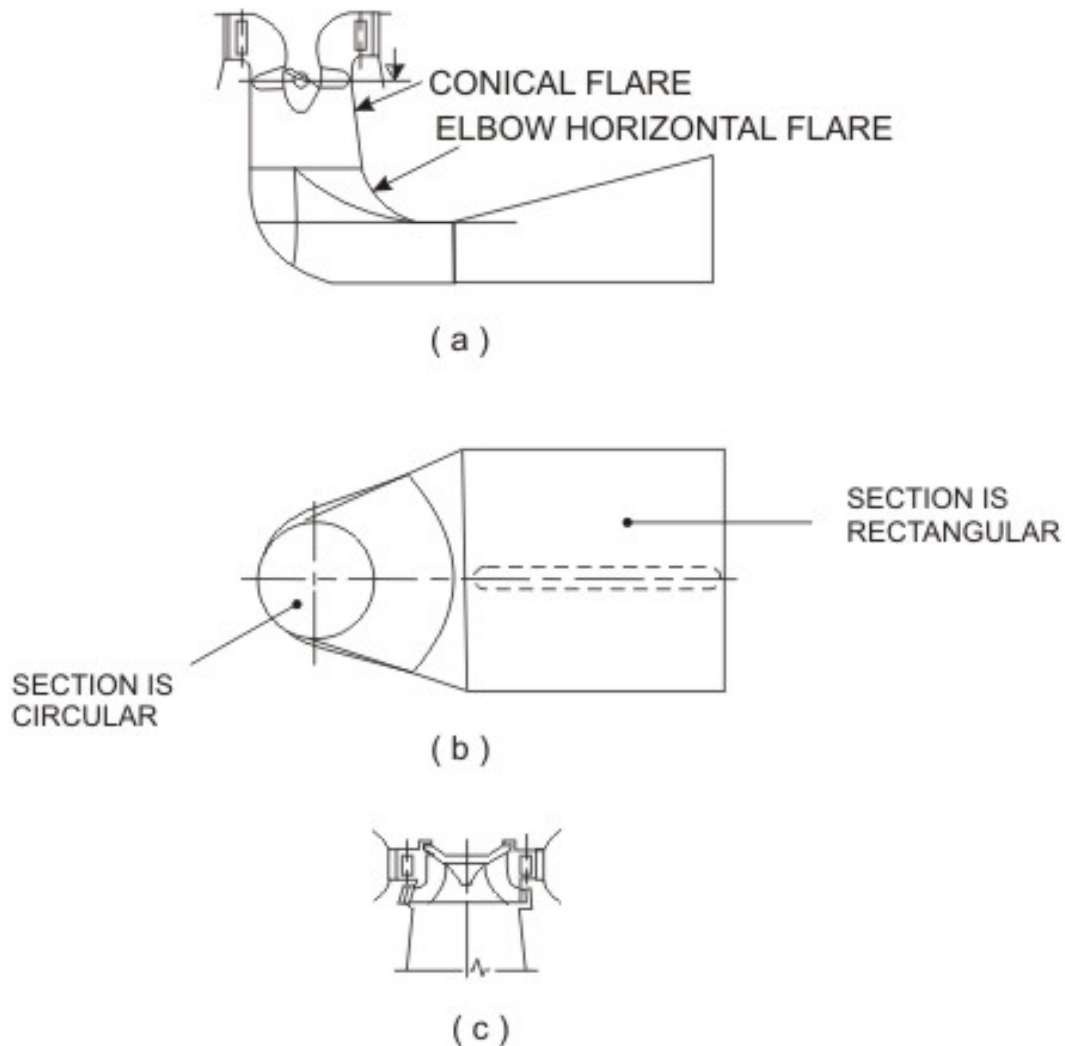


FIGURE 12. Standard draft tube shapes

- (a) Vertical section through a Kaplan unit, showing draft tube
- (b) Plan of a draft tube
- (c) Section through a Francis unit & conical flare

It may be observed from the figure that in the 'Elbow-type' draft tube, the vertical section is circular but gradually changes to a rectangular section as it becomes horizontal. This is because at the end of the draft tube, there is usually a rectangular shaped gate that is sometimes required to shut off tail water during maintenance. However, the change in shape of the elbow increases the turbulent losses in the draft tube. The magnitude of this loss depends upon the magnitude of flow.

A sectional view through the water passage and turbine of the power house shown in Figure 10 would be as shown in Figure 11, which shows a typical Francis runner installed.

Of course, one may replace the runner with a Propeller or Kaplan unit without changing much of the inlet and exit water passages, the spiral casing and draft tubes.

Both the spiral casing and draft tubes have to be designed carefully, in order to reduce the head loss as far as possible and also to avoid cavitations. The following Bureau of Indian Standards codes can be referred to for carrying out a detailed design of these units:

IS: 7418-1991 "Criteria for design of spiral casing (concrete and steel)"

IS: 5496-1969 "Guide for preliminary dimensioning and layout of elbow type draft tubes for surface hydel power stations".

5.3.4 Power house layouts

Classifying by the way the water from the head water pond or reservoir is applied to the turbine, one may differentiate powerhouses as belonging to one of the following categories:

1. In-stream, as for low-head run-of-river plants (Figures 13 and 14). Here, the intake head works are incorporated as a part of the power house.

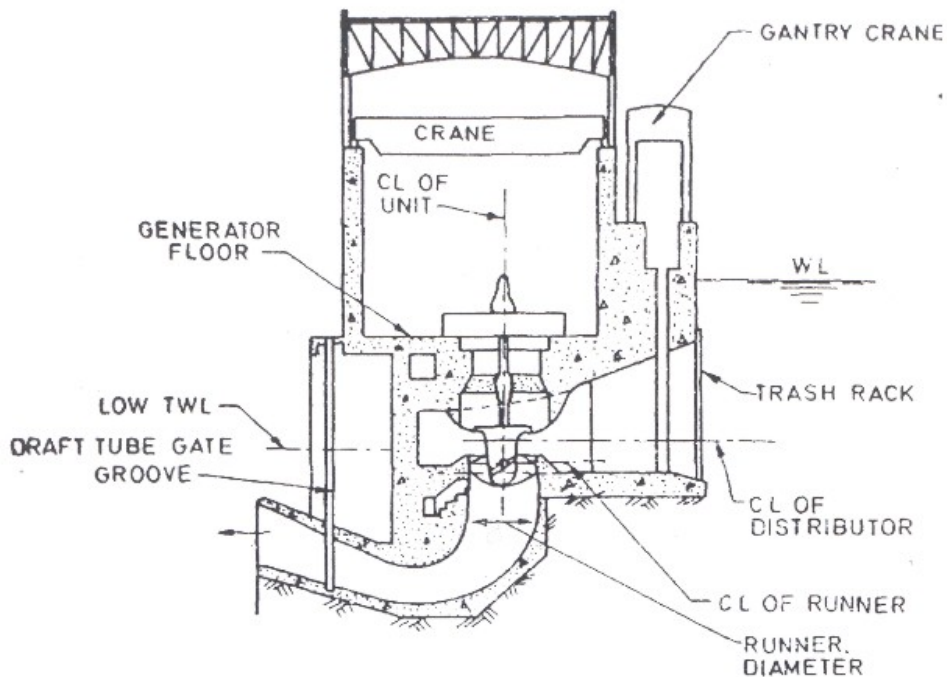


FIGURE 13 . Vertical section through a powerhouse Built as a structure integrated with intake and employing Kaplan turbine

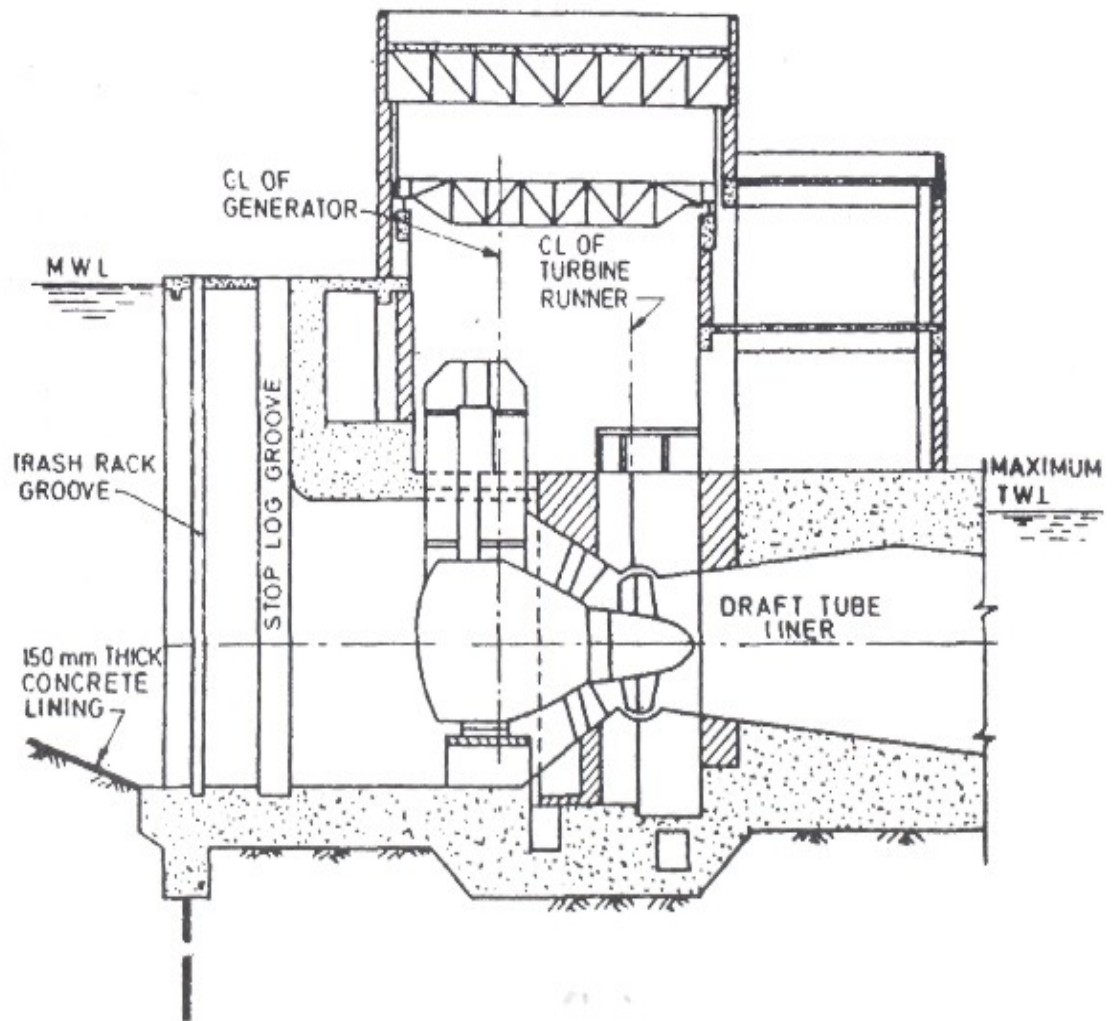
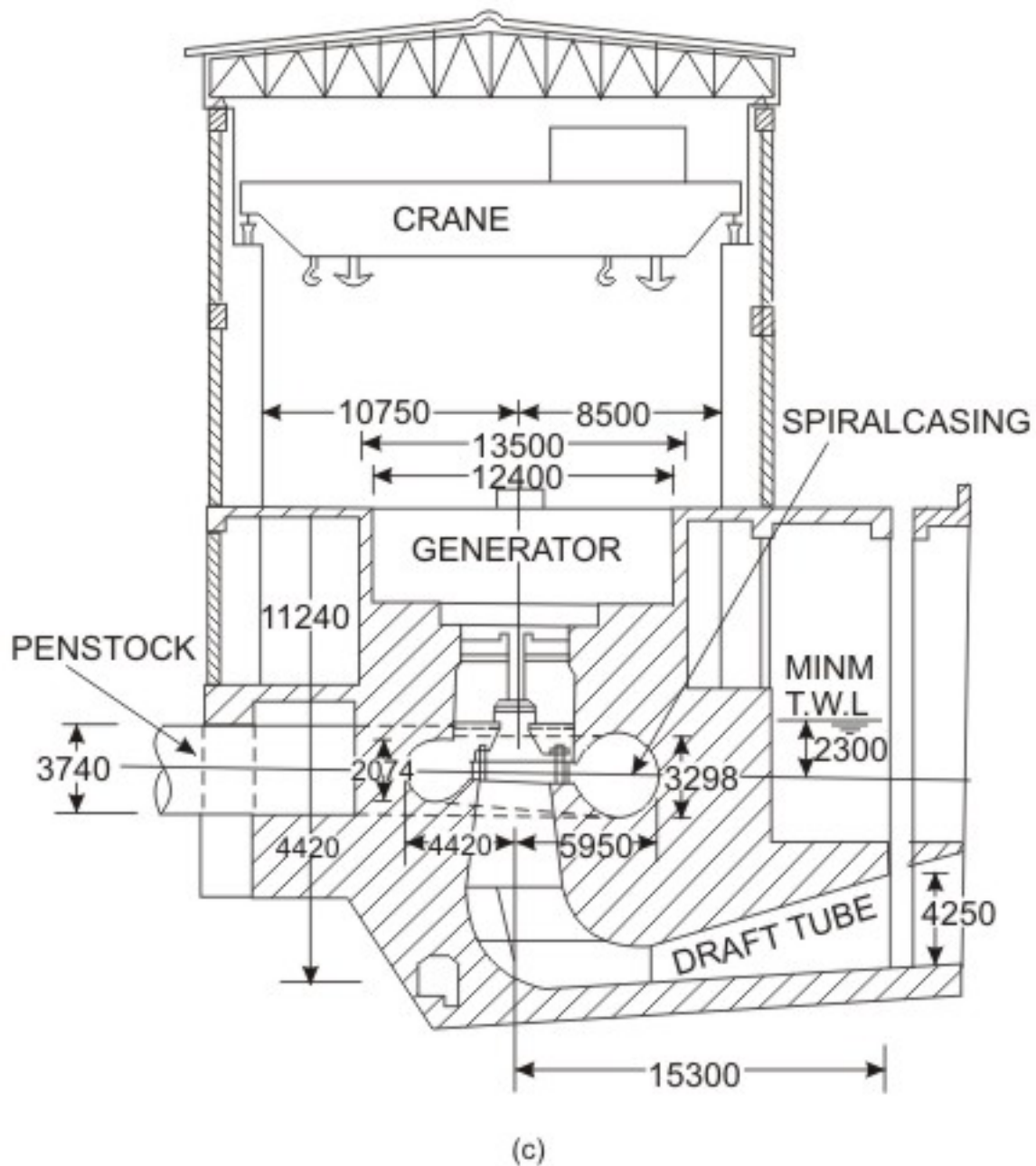


FIGURE 14 . Vertical section through a powerhouse built isolated Built as a structure integrated with intake intake and employing bulb turbine

2. Detached, as for turbines receiving water through an intake from the head water via a penstock (Figure 15).



All dimensions in millimetres.

FIGURE 15. Vertical section through a powerhouse built isolated from head works (intake) showing typical dimension in mm. The turbine unit may be either Kaplan or Francis

Power houses may also be classified as surface or underground types, depending upon its location with respect to the natural ground surface. An example of each may be cited for the powerhouses of the Sardar Sarovar, which actually consists of two sets, the first being the main river power house, which is underground (Figure 16) and the other at the intake of the canal, which is over ground (Figure 17).

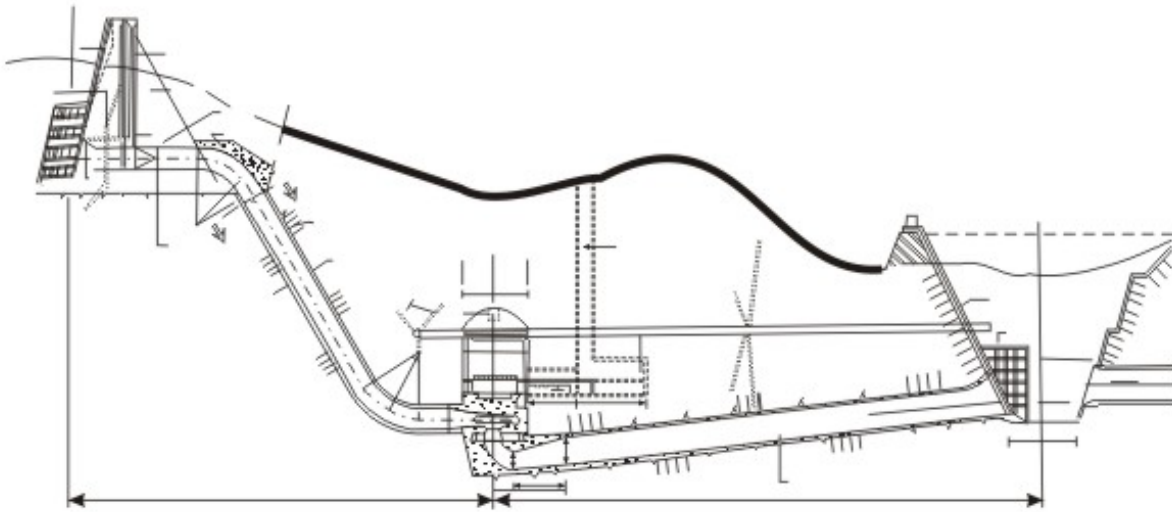
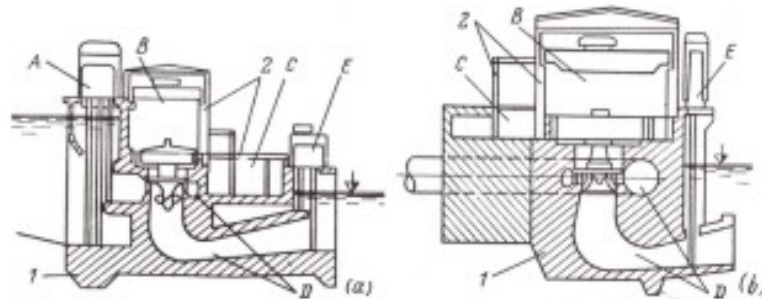


FIGURE 16. Section through riverbed powerhouse underground of Sardar Sarovar Dam project



LEGEND:
 1-SUBSTRUCTURE ; 2- SUPERSTRUCTURE ;A-JURKE-GATE ROOM
 B-GENERATOR ROOM ; C- AUXILIARY ROOM; D-WATER PASSAGEWAYS;
 E-DRAFT-TUBE GATE ROOM

FIGURE 18. Structural components of a powerhouse
 (a) In-stream ; (b) Isolated

Usually, the power house can be divided into a Substructure (marked 1 in Figure 18) and the Superstructure (marked 2). The substructure contains water passageways (D) and serves as a hydraulic structure and the Superstructure houses the service rooms such as a intake-gate room (A), generator room (B), auxiliary room (C), and draft-tube gate room (E).

A typical plan of the machine hall for a large power house shows the units arranged in row with the service bay, central room and worked usually provided at one end (Figure 19).

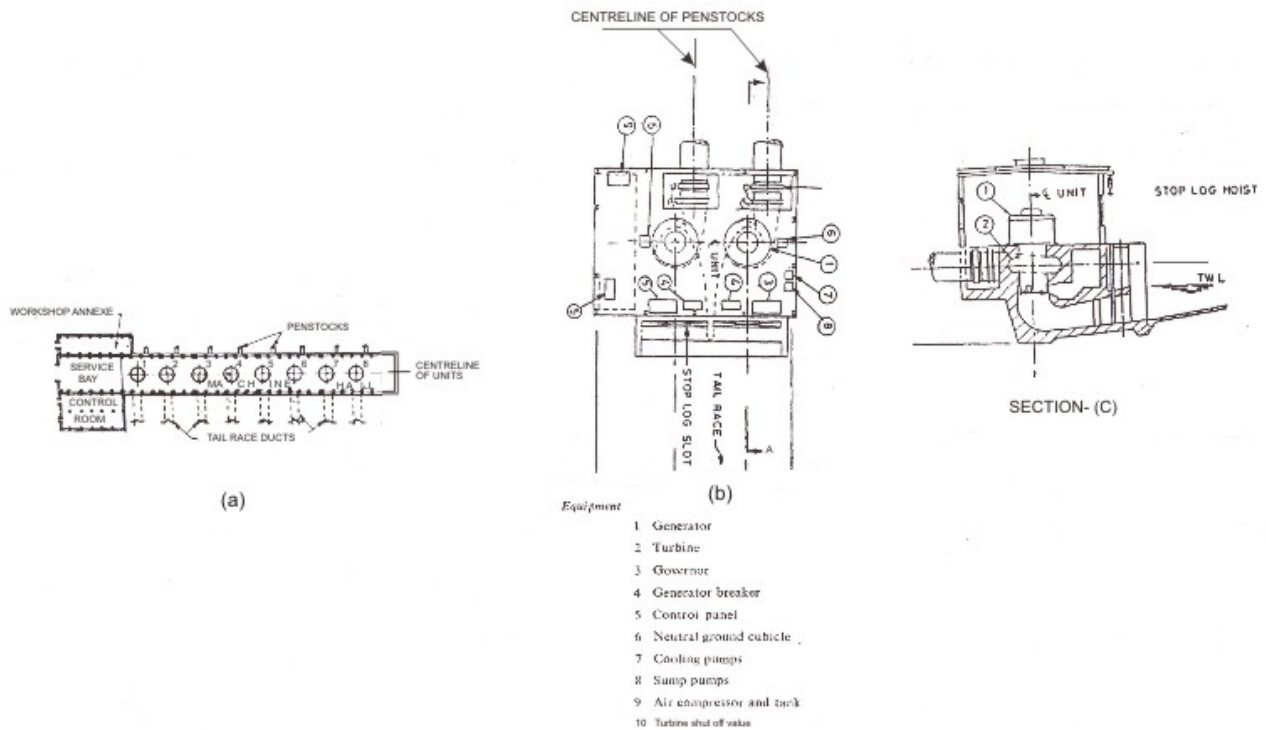


Figure 19. Typical layout of a large power home for Francis or Kaplan turbines
(a) General plan; (b) Details of two units; (c) Cross section A-A

The length of a power house mainly depends upon the unit spacing, length of erection bay and the length required for the overhead crane to handle the last unit. The total length (L) of the power houses may be determined from the following formula:

$$L = N_0 \times (\text{unit spacing}) + L_s + K$$

where

N_0 = Number of units

L_s = Length of erection bay

K = Length required for overhead gantry crane to handle the last unit

The length of erection bay may be taken as 1.0 to 1.5 times the unit bay size as per erection requirement. The width of the power house depends on the dimensions of the spiral casing and the hydro generator. Superstructure columns which are required to carry the weight of the rails supporting the overhead gantry crane are usually spaced at about 2.0 to 2.5 metres.

The height of the power house from the bottom of the draft-tube to the centerline of spiral casing (H_1 in Figure 20) has to be determined from the dimensions of elbow type draft tube. The thickness of the concrete below the lowest point of draft-tube may be taken from 1.0 to 2.0m depending upon the type of foundation strata, backfill conditions and size of the power house. The height from the center line of the spiral casing up to the top of the

generator (H_2 in Figure 20) can be determined from the height of the generator's stator frame and that of the load bearing bracket.

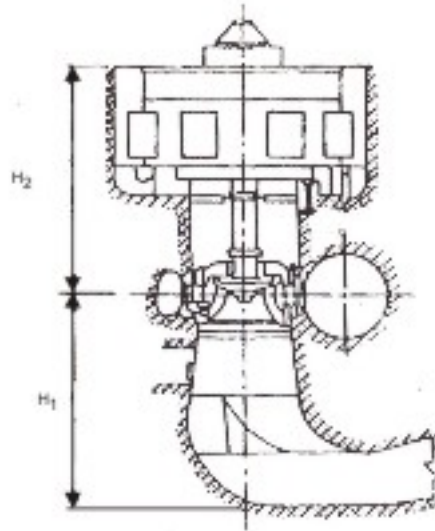
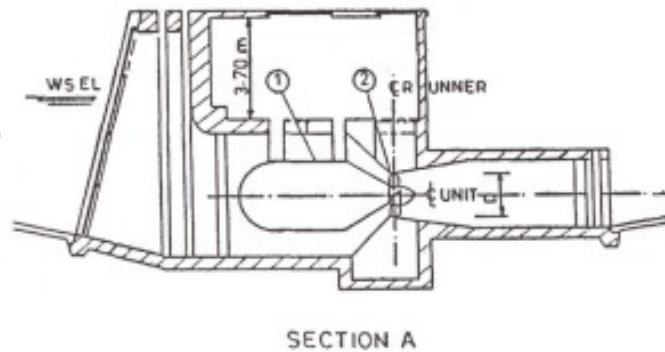
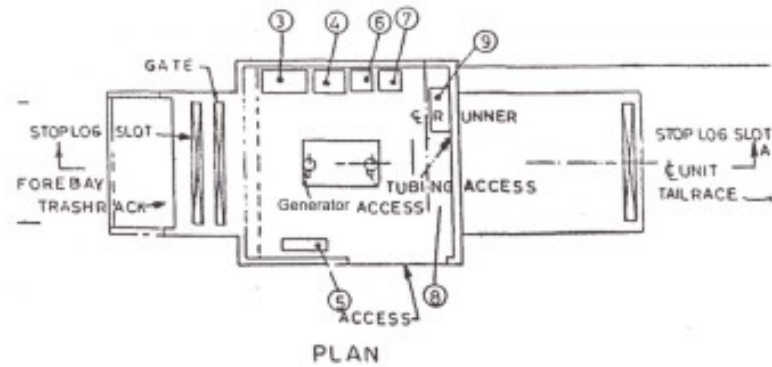


FIGURE 20. Cross section through generating unit showing relative heights of substructure divisions. H_1 : From bottom of draft tube to centreline of spiral case: H_2 : From centreline of spiral case to top of generating unit

The height of the machine hall above the top bracket of the generator depends upon the overhead cranes hook level, corresponding crane rail level, and the clearance required between the ceiling and the top of the crane.

The layout of an in-stream power house with a bulb turbine is shown in Figure 21.



Equipment

- 1 Generator
- 2 Turbine
- 3 Governor
- 4 Generator breaker
- 5 Control panel
- 6 Neutral ground cubicle
- 7 Surge and protection cubicle
- 8 Sump pumps
- 9 Air compressor and tank

Figure 21. Layout of an in stream power house with bulb turbine

The detailed dimensions for the any of the above power houses may be done from the following Bureau of Indian Standard codes:

IS: 12800-1993 "Guidelines for selection of turbines, preliminary dimensioning and layout of surface hydro-electric power houses"

Part 1: Medium and large power houses

Part 2: Pumped storage power houses

Part 3: Small, mini and micro hydroelectric power houses

5.3.5 Structural design of power house

As indicated, a hydropower generating station essentially composes of a substructure and a superstructure, when viewed from a vertical section. In plan, each single turbo-generator unit or a few of these units are constructed monolithically as a block with vertical joints between two adjacent block.

Stability and analysis of forces

The stability of the entire power house largely depends upon the construction of the substructure foundation which is in direct contact with water. Primarily, the structure has to be checked for overturning, sliding and uplift pressures. The different expected loads for the substructure of two types of powerhouses-instream and dam based are shown in Figure 22(a) and (b) respectively.



FIGURE 22. Loads to be considered for the analysis of the substructure of a power house
(a) Instream power house; (b) Dam based power house

For the in-stream power house, the principal force here is the upstream (head water pressure) H_u . It is partially balanced by the downstream (tail water pressure) H_d . Sliding is resisted at the base by friction due to the weight of the structure (W) and the weight of water within the power house V_1 and V_2 on the upstream and downstream of the two gates considering the gates to be closed and the scroll case and draft tubes as empty. From the bottom of the structure, the uplift pressure (u) and the net base reaction pressure from the foundation (R) balance the vertical forces. Sliding and overturning checks for the stability of

the powerhouse may be then done according to the laws of mechanics. The corresponding stresses calculated at the base may be checked against the safe bearing pressure of the foundation.

For powerhouses not built as an integral part of the headworks (intake), the stability check need not include that of sliding as there is no direct hydrostatic pressure to resist from the upstream over a large surface area as that for in-stream power houses. The upstream water pressure is now considered as that offered by the water within the penstock (P in Figure 22b). Since the substructure is located below the tail water level, the foundation may be considered saturated and the upstream and downstream pressures (H_u and H_d) may be considered same and they cancel each other. The uplift pressure may, therefore, be considered to be uniform throughout. The self weight of the structure (W) and the weight of water on the downstream of the structure (V) are balanced by the base reaction pressure (R).

Structural design and construction

The substructure concrete encasing the draft tube has to support the machinery load over the cavities and has to transmit the same to the foundation such that the pressure at the base remains within permissible bearing pressure of foundation. The substructure and the frames of the power house are sometimes constructed as one single stage of concreting, as shown in Figure 23. The substructure mass concrete portion housing the draft-tube has to be checked for loads and streams which may be done by a three dimensional stress analysis software package. Necessary reinforcement has to be provided according to the analysis.

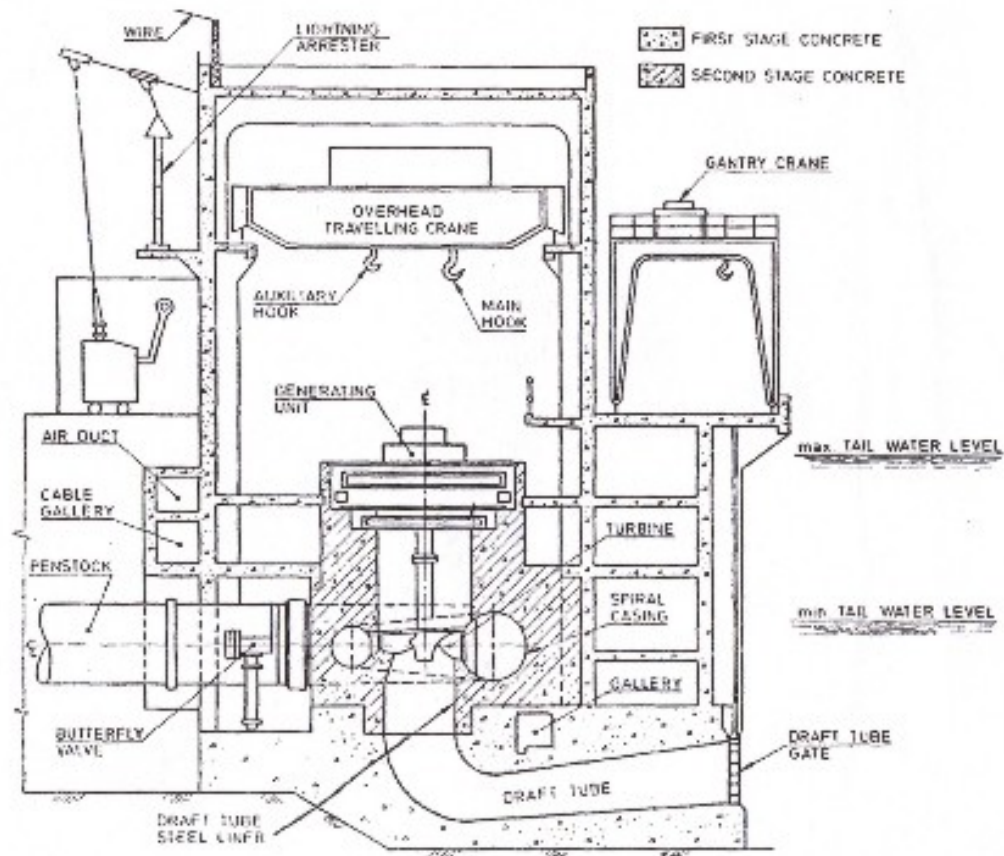


FIGURE 23. Sequence of construction of a power house

Above the substructure concrete encompassing the draft tube lies the concrete housing the scroll case which supports the load of an annular concrete block that acts as the foundation for the heavy generator load. Both these concrete blocks (second stage concrete shown in Figure 23) to be analyzed for forces, static as well as dynamic, caused by the rotation and vibration of the turbines. Reinforcements have to be provided according to the stresses obtained from the analysis, preferably using a three dimensional stress analysis software package. The Bureau of Indian Standards code IS: 7207-1992 "Criteria for design of generator foundation for hydroelectric power stations" may be referred to for guidance on the respective analysis.

The superstructure of a power house consisting the structure associated with the machine hall of the generating units, other places for electrical and auxiliary equipment, and

structures to support cranes for servicing the turbo generators during installation and repair. For analyzing the superstructure of a surface power station, the Bureau of Indian Standards code IS: 4247 (Part2)-1992 “Code of practice for structural design of surface hydroelectric power station” may be referred to for further details. For an underground power house, the superstructure components remain much the same, except the roof and walls, which are then taken care of by the power house cavity itself.