A CRITICAL STUDY ON DIMENSIONING OF HYDRO POWER STATIONS WITH PELTON TURBINE

A DISSERTATION

Submitted in partial fulfillment of the requirements for the award of the degree

of

MASTER OF TECHNOLOGY

in

HYDROELECTRIC SYSTEM ENGINEERING AND MANAGEMENT

By

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CANDIDATE'S DECLARATION

I hereby declare that the dissertation titled **"A Critical Study on Dimensioning of Hydro Power Stations with Pelton Turbine "** which is being submitted in partial fulfillment of the requirement for the award of Degree of **Master of Technology in Hydroelectric System Engineering and Management** at department of Water Resources Development and Management (WRD&M), Indian Institute of Technology, Roorkee is an authentic record of my own work carried out during the period of June, 2004 to June, 2005 under the supervision and guidance of **Professor Devadutta Das and Professor Gopal Chauhan,** WRD&M, IIT, Roorkee.

I have not submitted the matter embodied in this dissertation for the award of any other degree.

Place: Roorkee.

Dated: June, 2005

....

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This is to certify that the above statement made by the candidature is correct to the best of our knowledge.

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Place: Roorkee

Sandip Kumar Dev

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Notations / Symbols:

- D_2 = Wheel pitch diameter (m)
- D_j = Jet diameter (m)
- H_n = Turbine net design head (m)
- K_u = Runner peripheral velocity coefficient
- H_s = Distance between wheel centerline and maximum water level within the casing (m)
- N = Turbine rotation frequency (rev/min)
- N_f = Turbine runaway rotation frequency (rev/min)
- N_{sj} = Turbine specific speed per jet
- i = Number of jets
- η = Turbine efficiency (p. u.)
- Ø= jet efficiency (p.u.)
- P_t = Turbine rated capacity (kW)
- Q = Turbine rated flow (m^3/s)
- v = water velocity at spiral case inlet (m/s)
- g = gravitational acceleration (m/s)
- D_g = air dap diameter
- D_o = outer stator core diameter
- D_f = stator frame diameter
- D_b = inner diameter of generator barrel
- L_c = core length of stator
- L_f = length of stator frame
- D = outer barrel diameter
- W_r = weight of generator rotor
- W_{tr} = weight of turbine rotor
- H_t = height of load bearing bracket
- H_1= height of center line of turbine from the bottom of draft tube
- H_2 = height of generator top from the center line of turbine

ABSTRACT

The hydro turbines convert the potential energy into mechanical energy for its further conversion into electrical energy by use of electrical generators. In a hydro power station, the hydraulic turbine is the centre, or in other words the heart, as all the dimensional parameters are dependent upon its dimensions. Therefore, during the planning stage, the dimensioning of the hydro power plant begins with the selection and sizing of the hydro turbine.

Project planning involves proper analysis of stream flow and waterpower studies, reservoir levels, location, foundation conditions, determination of capacity, number and size of units and layout and *dimensioning of hydro power station.* The estimates of cost much depend upon the preliminary planning which determines the scope of the project and forms the basis for judgment of its feasibility and for authorization of the expenditure of the funds required. After such authorization the final design and construction will necessarily follow closely along the lines of the general plan in order to remain within the limits of the estimated cost.

As the hydropower stations have very costly electro-mechanical equipments and civil structures therefore it is essential to be extremely careful about its *dimensioning* and layout.

Power studies preceding the *preliminary dimensioning and design of hydro power stations* will generally furnish information on the maximum and minimum heads prevailing at the site under consideration, average head during a period of low stream flow and desirable total installed capacity at the station. At this early stage of the planning, multiplicity of the possibilities of different combinations of numbers and size of units are to be studied. At such crucial stage, preliminary dimensioning of hydro power station is to be carried out based upon the experiences of previous installations of hydro power projects. It is imperative that the preliminary dimensioning of the power station should be made in such a manner that requirements can be met by the manufacturers without much deviation.

The selection of the turbines in the overlapping range of Pelton and Francis turbines through the comparison of installations of different capacity and head has also been done

to delineate head ranges governing specific type of turbine, viz. Pelton or Francis, can be used.

As there is no IS code available for the preliminary dimensioning of hydropower station with Pelton turbine, the present work is an effort to develop and present certain useful guidelines and develop a set of relationships for the Dimensioning of Hydropower Stations with Pelton Turbine as in the case of reaction turbines. For this purpose, work done by De Sievro and Lugarsi, on the Modern Trends in Selecting and Dimensioning of Hydropower Station with Pelton Turbine [5], has been extended by collecting data of power stations with Pelton Turbine in India and have been analyzed to reach at the conclusion.

INTRODUCTION

1.1 HYDRAULIC TURBINES:

Flowing water has two forms of energy that is kinetic and potential. The kinetic energy depends on the mass of water flowing and it's velocity while the potential energy exists as a result of difference in water level between two points known as head. The water or hydraulic turbine, as it is sometimes named converts the kinetic and the potential energies possessed by water into mechanical power. The hydraulic turbine is, thus, a prime mover which when coupled to a generator produces electric power.

For the utilization of high heads Pelton turbines are commonly used. But in the overlapping operating head ranges of Francis turbine and Pelton turbine, Low specific speed Francis turbines may also be used.

Among the impulse (or action) water turbines, Pelton turbine is the type used extensively for all high-head applications with unit output exceeding about 2 MW. It is also called free jet turbine and operates under a high head of water and, therefore, requires a comparatively less quantity of water. The water is conveyed from a reservoir in the mountains to turbines in the powerhouse through penstocks. The penstock is joined to a branch pipe or lower bends fitted with a nozzle at the end. Water comes out of the nozzle in the form of free and compact jet. The number of nozzles required for a turbine depends on its specific speed. All the pressure energy of water is converted into velocity head. The water having a high velocity is made to impinge, in air, on buckets fixed round the circumference of a wheel, the latter being mounted on a shaft. The impact of water on the surface of the bucket produces a force which causes wheel to rotate, thus, supplying a torque or mechanical power on the shaft .The jet of water strikes the double hemispherical cup shaped buckets at the center and is deviated on both sides, thus eliminating an end thrust. The water jet after impinging on buckets is deflected through an angle of about 165 degrees, instead of 180 degrees, so that it may not strike the back of incoming bucket and retard the motion of the wheel. After performing work on buckets water is discharged into tailrace. The wheel must be so located that the buckets do not splash into the tailrace water when the wheel revolves.

As stated above Pelton turbine is best suited for high heads. It is efficient and reliable when employed under the conditions. It will remain no more efficient for low heads, because for a given power if the head is reduced, the rate of flow has to be increased. Increased flow will require bigger jet diameter, consequently the runner diameter will also be increased. On the other hand the jet velocity and consequently peripheral velocity of runner will be reduced because of low head. These two factors i.e., increase the runner diameter and decrease of runner velocity will make the turbine bulky and slow running for low heads.

1.2 CLASSIFICATION:

1.2.1 General:

Classification of modern hydro turbines are made according to [7]:

(1) the name of the originator

(2) the head water available

(3) the action of water on the moving blades

(4) the direction of flow of water in the runner chamber

(5) the disposition of turbine shaft

(6) the specific speed, N_s or non-dimensional factor, K_s

1.2.2 Classification Depending Upon the Name of the Originator:

Depending upon the name of originator, the hydro turbines can be classified as

(a) Pelton turbine - named in honor of Lester Allen Pelton of California, USA, is an impulse type of turbine, used for high head and low discharge.

(b) Francis turbine – named after James Bichen Francis of USA, is a reaction type of turbine for medium high to medium low heads.

(c) Kaplan turbine – named in honor of Dr. Victor Kaplan of Germany, is a reaction type of turbine for low heads and large quantities of water flow.

1.2.3 Classification Depending Upon the Head of Water Available:

It is quite difficult to classify the turbines according to head and discharge, as for the same head or discharge many types of turbine can be employed. But in general, they can be grouped as high head, medium head and low head turbines. Table 1.1 gives the head ranges for different type of turbines.

Table 1.1

Ranges of Head for Different Type of Turbines [7]:

Type of turbines	Normal range of maximum net head
Pelton	above 300 m.
Francis	30 - 400m.
Kaplan	10 – 60 m.
Deriaz	50 – 150 m.

1.2.4 Classification according to Action of Water on the Moving Blades:

Figure 1.1 shows classification of hydro turbines according to action of water on the moving blades.

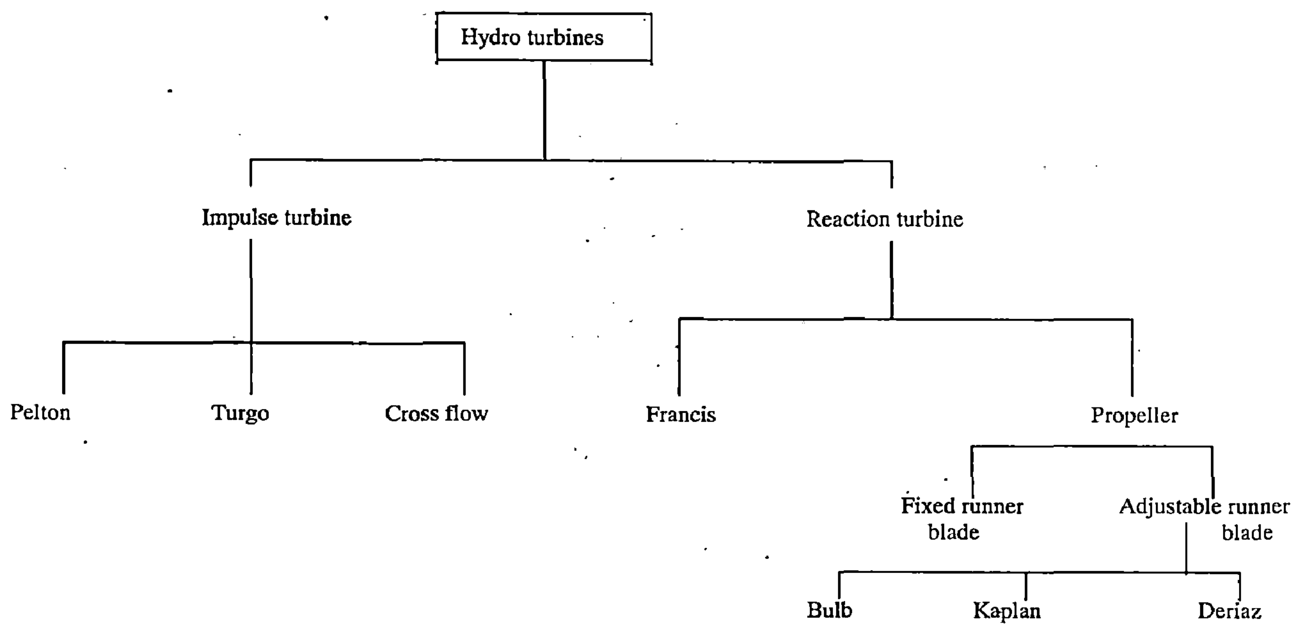

Figure 1.1 Classification of hydro turbines according to action of water on the moving blades [7].

1.2.5 Classification According to the Direction of Flow of Water in the Runner:

Figure 1.2 shows classification of hydro turbines according to direction of flow of water in the runner.

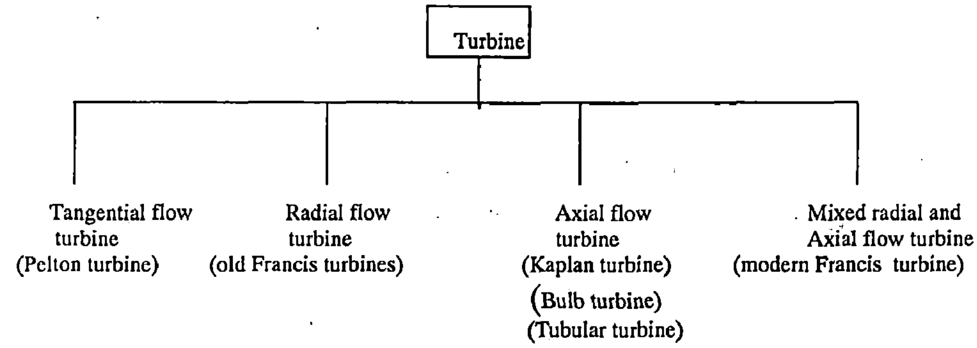

Figure 1.2 Classification of hydro turbines according to direction of flow of water in the runner [7].

1.2.6 Classification According to the Disposition of Turbine Shaft:
According to the disposition of shaft turbines can be classified as vertical or horizontal. In modern practice, Pelton turbine one or two jets have horizontal shaft whereas multi jets Pelton and rest large units have vertical shaft.

1.2.7 Classification According to Specific Speed N_s and Non Dimensional Factor K_s:

Turbines fall under a natural order when classified according to their specific speeds. The specific speed of a turbine is the speed of a geometrically similar turbine that would develop one horse power (BHP) under a head of one meter.

Specific speed,

$$N_s = N^* (P_t)^{0.5} / (H)^{5/4}$$

Where, N = the normal working speed of the turbine in rpm

P_t = the turbine output in BHP

H = the net or effective head in meter

The specific speed Ns is a dimensional quantity but a non-dimensional factor K_s could also be deduced for turbines in place of N_s as follows:

$$K_s = Q^*N^2 / v^3$$

Where, Q = rate of flow in m^3s^{-1}
N = speed in rpm
v = velocity of water in ms^{-1}
$= (2gh)^{0.5}$

Most modern method to classify the water turbines would, therefore, be according to the non-dimensional factor K_s. The values of factor K_s are given in the table below:

Table 1.2

Values of specific speed N_s and non-dimensional factor K_s for different turbines [7]:

Type of turbine	type of runner	specific speed	dim.less.factor K_s
	Slow	10 – 20	0.098-0.39
Pelton	Normal	20 – 28	0.39-0.76
	Fast	28 – 35	0.76-1.2
	Slow	60 – 120	3.5-14
Francis	Normal	120 – 180	14-31.5
	Fast	180 – 300	31.5-88
Kaplan	–	300 – 1000	88-980

Messrs Gilbert Gilkes and Gordon Ltd. (England) have patented Turgo Impulse Wheel, where the water form the jet which strikes the buckets tangentially, bridges the gap between the specific speeds of Pelton and Francis, that is between 35 and 60.

1.3 HEAD AND SPECIFIC SPEED FOR VARIOUS TURBINES:

Choice of the type of turbine and preliminary specification regarding technical features is always based upon the data of successfully operating plants on the basis of which numerous curves and tables have been prepared and establishing relationship between the ranges of heads and corresponding specific speed within which runner of different types work satisfactorily.

These head ranges are not rigid on account of continuing development in the design of the runner.

It can be observed from the above that for very high heads above 800 m. or so, the choice is restricted to only Pelton turbines. In other ranges adoption of more than one may be possible.

1.4 SCOPE OF STUDY:

In a hydro power station, the hydraulic turbine is the centre, or in other words the heart, as all the dimensional parameters are dependent upon its dimensions. Therefore, during the planning stage, the dimensioning of the hydro power plant begins with the selection and sizing of the hydro turbine.

Project planning involves proper analysis of stream flow and waterpower studies, reservoir levels, location, foundation conditions, determination of capacity, number and size of units and layout and *dimensioning of hydropower station.* The estimates of cost much depend upon the preliminary planning which determines the scope of the project and forms the basis for judgment of its feasibility and for authorization of the expenditure of the funds required. After such authorization the final design and construction will necessarily follow closely along the lines of the general plan in order to remain within the limits of the estimated cost.

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At the early stage of the planning, multiplicity of the possibilities of different combinations of numbers and size of units are to be studied. At such crucial stage, preliminary dimensioning of Hydropower Station is to be carried out based upon the experiences of previous installations of Hydro Power Projects. It is imperative that the preliminary dimensioning of the power station should be made in such a manner that requirements can be met by the manufacturers without much deviation.

The selection of the turbines in the overlapping range of Pelton and Francis turbines through the comparison of installations of different capacity and head has also been done to delineate head ranges governing specific type of turbine, viz. Pelton or Francis.

1.5 METHODOLOGY:

As there is no IS code available for the preliminary dimensioning of hydropower station with Pelton turbine, the present work is an effort to develop and present certain useful guidelines and develop a set of relationships for the Dimensioning of Hydropower Stations with Pelton Turbine as in the case of reaction turbines. For this purpose, work done by De Sievro and Lugarsi ,on the Modern Trends in Selecting and Dimensioning of Hydropower Station with Pelton Turbine [5], has been extended by collecting data of power stations with Pelton Turbine in India and have been analyzed to reach at the conclusion.

wheel increases, the spear is pushed into the nozzle thereby reducing the quantity of water striking the buckets. If the speed of the wheel falls, the spear is drawn back allowing the greater quantity of water to pass through the nozzle. Sometimes a sudden decrease in load takes place. Consequently water requirement of turbine suddenly falls. This necessitates the immediate closure of the nozzle with the spear, which may cause the pipe to burst due to sudden increase in the pressure of water. In order to avoid such occurrences, an additional nozzle is used. Water can pass through the nozzle, without striking the buckets. This nozzle is called the Bypass Nozzle and is opened when the main nozzle is being closed on a reduction in load taking place.

The modern practice is to provide the guide mechanism with a deflector (fig). The deflector is a plate connected to the spear rod by means of levers. The plate is located between the nozzle and the buckets. When a sudden reduction in load takes place, the governor brings the deflector in front of the buckets thus deflecting the water jet and preventing it from striking the buckets

With the sudden fall in load, the blade instantly go forward into stream, causing it to whirl and converting the compact jet into a hollow-cone broken into spray, thus destroying the energy by diffusion. For the normal operation, the blades are withdrawn and their ends flushed with the cover, leaving a clear passage for the water to go out the nozzle.

2.1.3 Hydraulic Braking System:

After shutting down the inlet valve of the turbine, the large capacity runner wil go on revolving for a considerable period, due to its inertia. This has necessitated the development of a brake to bring the turbine to a standstill in a shortest possible time. The brake consists of a small nozzle fitted in such a way that on being opened, it directs a jet on the back of the buckets to bring the revolving runner quickly to rest (fig). The least diameter of the brake jet has been found to be equal to 0.6 times the least diameter of the main jet.

2.2 DIFFERENT LAYOUTS OF PELTON TURBINE:

(a) *Arrangement of jets*: ordinarily the pelton turbines have a single jet and horizontal shaft, as shown in figure. However, the number jets depend upon the specific speed. It is, therefore, possible that more than one jet may be employed. Fig. 2.2(a), (b) and (c) show the arrangements of single jet, double jet with horizontal shaft and four jets with vertical shaft respectively.

(b) *Arrangements of runner*: The runner of the turbine as well as the rotor of the generator to be driven by the turbine are keyed on the same shaft. The rotor of the generator is generally heavier than the Pelton runner, and is, therefore, supported in two bearings while the turbine runner is keyed on the length of the shaft respectively. This is known as *single–overhung* unit if runner.

If the turbine is designed for greater power or higher speed, two turbine runners keyed to a single horizontal shaft are installed. They may be arranged together on one side of the generator and each of them having its own bearing or one on each of the projecting end of the shaft. The latter arrangement is known as *double-overhung* unit.

(c) *Arrangement of turbine shaft*: As already explained Pelton turbines are usually installed with horizontal shaft and equipped with only one nozzle. The numbers may be one or two keyed to the horizontal shaft. Two runners are used to obtain higher speed and more power.In case the number of jets is two, horizontal shaft arrangement may be employed.For four jets and six jets vertical shaft arrangement is used.

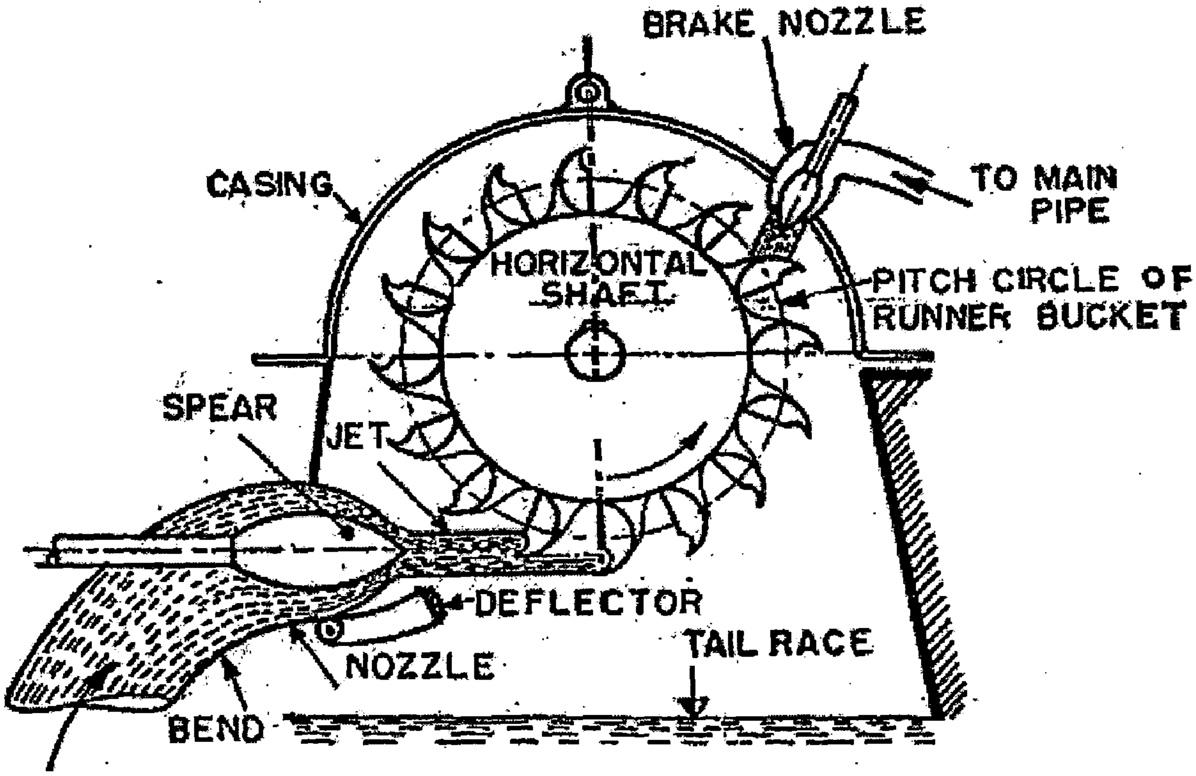

Fig. 2.2(a); Single jet, horizontal Pelton turbine [7]

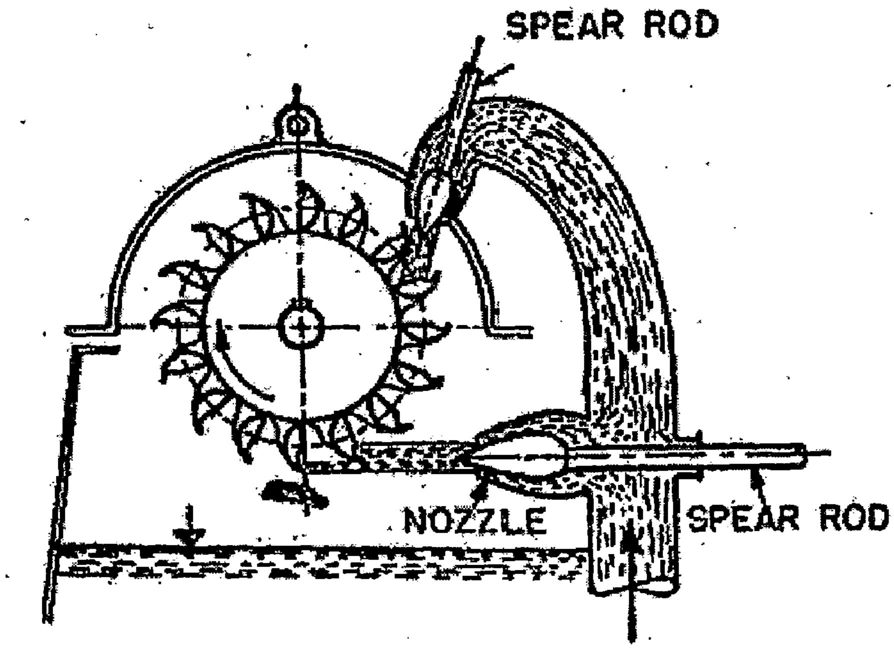

Fig..2(b)Double jet; horizontal shaft Pelton turbine,[7]

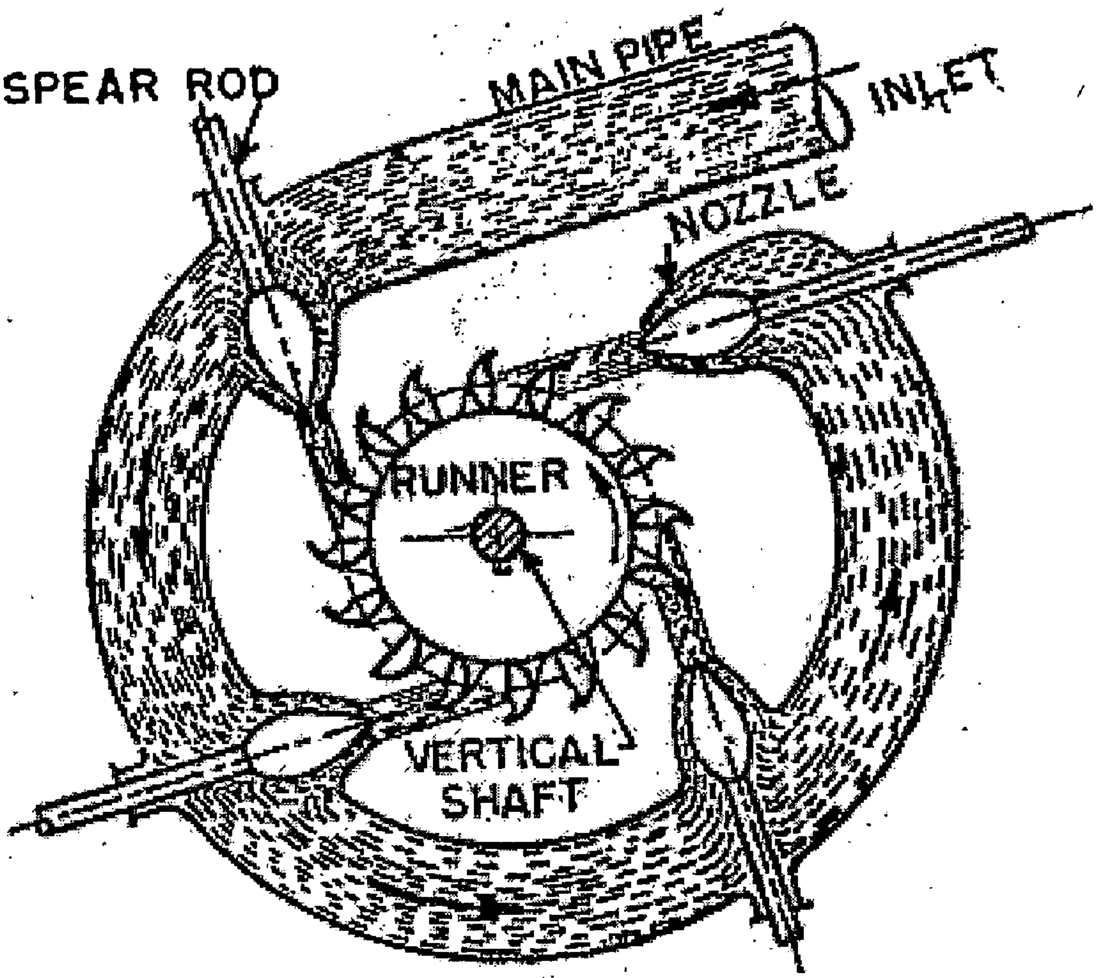

Fig. 2.2(c), Four jet vertical shaft pelton turbine, [7]

PELTON TURBINE: MAIN COMPONENTS AND THEIR FUNCTION

2.1 MAIN COMPONENTS OF PELTON TURBINE:

The main components of Pelton turbine are

(a) Buckets and runners

(b) Casing and guide mechanism

(c) Hydraulic braking system

2.1.1 Buckets and Runners:

Each bucket is divided vertically into two parts by a splitter, which is a sharp edge at the center, giving the shape of double hemispherical cup. The splitter helps the jet to be divided, without shock, into two parts moving sideways in opposite directions.

The rear of the bucket should be shaped so as not to interfere with the passage of the water to the buckets proceeding in order of rotation. The jet should be deflected backwards when leaving the buckets as shown in the figure 2.1, (reference-7), the angle of deflection being about 160 degrees. The form the most important part of the turbine and should be designed to withstand the full force of the jet when the turbine is shut off. It is important to select a suitable material for the buckets, so that they should not crack under the considerable force of the jet. Cast iron is used for the low heads but for higher heads bronze or stainless steel is used. The buckets should be properly polished in order to avoid undue stresses under the section of the jet, which may lead to cracking at sections, which are incorrectly shaped.

The buckets are bolted on to circumference of a round disk forming the runner of the Pelton turbine as shown in the figure 2.1. The buckets and the disc can be cast as a single unit now a day, which will be more economical. Many turbine manufacturers believe that all the buckets wear equally in a given time, but it is found in practice that the buckets may break down one at a time. It is easy to replace a broken bucket unless the runner is cast as a single unit. The runner is made of cast iron, Cast Steel or Stainless Steel. Cast iron is used to reduce cost in turbines designed for low heads.

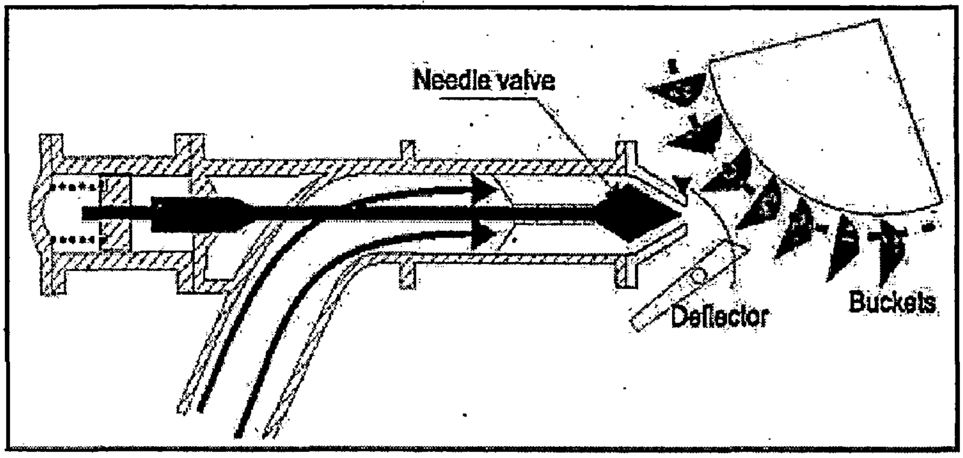

Fig.2.1 Deflector and buckets of Pelton turbine *(internet, energy saving)*

2.1.2 Casing and Guide Mechanism:

As already mentioned above the casing of Pelton turbine has no hydraulic function to perform. It is necessary only to prevent splashing and to lead the water to tail race, and also as a safeguard against accidents.

The casing is cast or fabricated. It has to take a force of the jet projecting beyond the runner in the event of overspread. In horizontal shaft units, the casing is split into bed plate and cover so that the runner can be lowered into place or lifted out by a crane. The lowest part of the bedplate is embedded and anchored in the lower house floor. The escape of water along the shaft is prevented by a seal. Baffles are arranged to reduce to reduce the windage loss or to protect the runner and jet from interferenceby splash.

This mechanism controls the quantity of water passing through the nozzle and striking the buckets, thus meeting the variable demand for power. It maintains the speed of the wheel constant even when the head varies. The mechanism essential consists of a spear fixed to the end of the shaft, which is operated by governor. When the speed of the

1.6 ORGANIZATION OF THE DISSERTATION:

Chapter-1 presents the introduction of hydraulic turbines, classifications, scope of the study and methodology.

Chapter-2 deals with the main components of the Pelton turbine and their use.

Chapter-3 presents the procedure for dimensioning of hydropower stations with Pelton turbine.

Chapter-4 emphasizes the selection of turbine to be made in the overlapping head ranges of Pelton and Francis turbine.

Chapter-5 deals with computation of main dimensions of power stations in India with Pelton turbine using the enumerated procedure in chapter 3.

Chapter-6 presents the valuable conclusions made during the study.

PROCEDURE FOR DIMENSIONING OF HYDROPOWER STATIONS WITH PELTON TURBINE

3.1 INTRODUCTION:

The dimensioning of hydropower station with Pelton turbines is based quite on the derived equations than on the experience curves, as is generally the case for Francis and Kaplan Turbines. For the preliminary dimensioning of Pelton turbines the relationship developed by F. de Sievro and A. Lugaresi [5] with extensive statistical investigation of 90 Pelton turbines has been considered. To find the dimensions of main parameters of Generator the guidelines available for preliminary dimensioning for surface hydroelectric power house with reaction turbines has been considered namely IS 12800 (Part I) [6]. Thus the relationship from De Sievro and IS 12800 both is used to find the complete preliminary dimensioning of hydropower station with Pelton turbines. The different steps follow as below.

Emphasis is given to multi-jet, vertical-type Pelton turbines because of there prevalence in high capacity applications; horizontal machines are considered only for specific speed and main wheel dimensions. The power house and generator dimensions are considered for surface type power house and vertical-type arrangements.

MAIN PARAMETERS OF PELTON TURBINE:

3.2 *DETERMINATION OF SPECIFIC SPEED:*

3.2.1 After fixing the design head and deciding the type of turbine and capacity of the unit, suitable specific speed has to be determined upon which all other parameters, such as diameters of the runner, setting of the machine, actual synchronous speed and pair of poles in the rotor, depends.

Here, trial specific speed per jet, $N_{sj} = 85.49\ H^{-0.243}$

$$N_s = N\, P_t^{0.5}\, H^{-1.25}$$

Where, P_t = rated capacity of the turbine.

P_t can be calculated by dividing the rated generator output by efficiency of generator and turbine.

The Pelton impulse turbine differs considerably from the Francis and Kaplan reaction turbines, being a partial – admission machine in which the hydraulic energy is transmitted to the wheel by a discrete number of nozzles independent from each other. Consequently the main hydro dynamic characteristics of the turbine has to be referred to one jet only. The specific speed N_{sj} relevant to one jet is then introduced.

$$N_{sj} = N\,(P_t/i)^{0.5}\,H^{-1.25}$$

3.2.2 after ascertaining the value of trial specific speed per jet N_{sj}, the trial synchronous speed / rotational speed can be computed from the formula in equation (2).

3.2.3 the rotational / synchronous / rated speed of the turbine in revolutions per minute is determined from the following formula:

Rated speed in r.p.m, $N = 60*f / p$.

Where, f = frequency in cycles per second (in Indian power system, frequencyis 50 cycles per second), and

p = number of pair of poles.

The rated speed of the turbine thus calculated has to coincide with one of the nearest synchronous speed. The selection of rated speed by the above formula is subject to the following considerations:

(a) An even number of pairs of poles should be preferred for the generator, though standard generators with odd number of pairs of poles are also available; and
(b) If the rated head is expected to vary less than 10 % from designed head, the next greater speed should be chosen. A head varying in excess of 10 % from the designed head suggests the next lower speed.

3.2.4 after determining the actual rated speed from above, the actual specific speed per jet N_{sj} is determined from equation (2).

3.2.5 The turbine specific speed N_s can be calculated from the following formula:

$$N_s = N_{sj} * (\text{no.of jets})^{0.5}$$

To select the most suitable specific speed per jet, it has to be calculated for the different number of nozzles, (1- 6), generally 2,4,6 and the closest one to the trial specific speed should be chosen.

3.3 *WHEEL DIMENSIONS:*

3.3.1The main dimensions of runner as shown in the figure 3.1 are determined by the peripheral velocity coefficient k_u, which can be determined by the following relationship:

$$K_u = 0.5445 - 0.0039Nsj$$

Once the value of ku and frequency of rotation N are established, it is possible to calculate the value of D2 from the following equation:

$$K_u = \pi D_2 N / [60*\sqrt{(2gH)}]$$

Or $$D_2 = k_u*[60*\sqrt{(2gH)}] / \pi N$$

$$= 84.5*K_u*\sqrt{(H)}] / N$$

Another highly characteristic constant is commonly used for Pelton turbines that are the ratio D_j / D_2 of the jet diameter to the wheel pitch diameter. It has been seen that this constant virtually determines the main geometrical characteristics of the machine. D_j / D_2 strictly related to the specific speed per jet, Nsj. This can be easily demonstrated by introducing the following relationship.

$$D_j / D_2 = Nsj / (250.74 - 1.796 N_{sj})$$

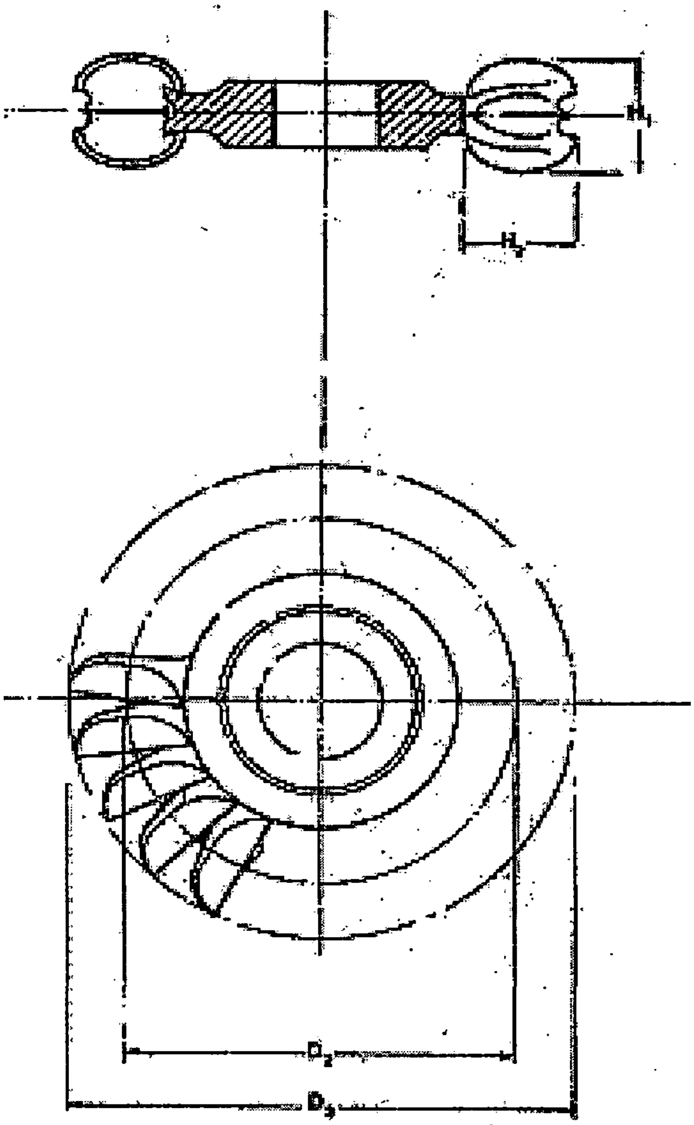

Fig. 3.1 Wheel dimensions [5]

The outer wheel diameter D_3, referred to the diameter D_2 as shown in the figure 3.1, is given as function of Ns by the following interpolating function:

$$D_3/D_2 = 1.028+0.0137\ N_{sj}$$

The width and the length of the wheel bucket, as in the figure, are given as functions of D_j by the following relationship:

$$H_1 = 3.20*D_j^{0.96}$$

$$H_2 = 3.23*D_j^{1.02}$$

3.4 *THE ELEVATION OF THE TURBINE ABOVE THE TAILRACE WATER LEVEL, H_S, (TURBINE SETTING)*

3.4.1 It is determined by the necessity to avoid any interference between the wheel and agitated water surface within the turbine casing, during both steady state operation and during transients. The parameter Hs is then introduced, being the distance between the wheel centerline and maximum water level within the casing in steady conditions.

According to the literature, the value of Hs depends basically on the total turbine discharge Q, and increases with it. On the other hand the data examined show that for a given discharge Q, the value of this increases with the net head H of the machine. Probably this phenomenon can be ascribed to the ventilation effect, which is stronger for high head turbines because of their higher frequency of rotation, other conditions being equal. Considering the preceding, the best correlation from the examined data has been found by the following relationship:

$$H_s = 1.87 + 2.24(Q/N_{sj})$$

Also the capacity equation is:

$$Pt = 9.81*\eta*H*Q$$

Where, η = the overall efficiency of generator and turbine.

Q = turbine discharge.

3.5 *CASING DIMENSIONS:*

The dimensions of the Pelton turbine casing as shown in the figure 3.2 depend essential on the outer diameter D_3 of the wheel. The casing dimensions considered are indicated in Figures below.

3.5.1 *Casing Diameter L:*

The most expressive of them is the diameter L which gives the plan size of the casing; for prismatic casings this value has been assumed equal to the average diameter of the circles inscribed and circumscribed on the casing, as indicated in figure below.

The relationship for the diameter L is given by:

$$L = 0.78 + 2.06D_3$$

3.5.2 *Distance G Between the Wheel Centerline and the Top of the Casing:*

The distance G between the wheel centerline and the top of the casing is given in figure and the relationship is given by:

$$G = 0.196 + 0.376\ D_3$$

3.5.3 *The Other Dimensions F, H, I are Expressed Respectively by the Following Equations:*

$$F = 1.09 + 0.71L$$

$$H = 0.62 + 0.513L$$

$$I = 1.28 + 0.37L$$

Power plants fitted with long discharge channel or characterized by the wide variations of the tail race level will require deeper setting of the casing bottom or higher values of the channel width, to achieve the required Hs and the wheel aeration even during load transients with high tailrace water levels.

3.6 *SPIRAL CASE SIZE:*

3.6.1 The water velocity at the spiral case inlet depends upon the square of the design head according to the interpolating function:

$$v = 0.82 + 0.358\ .\ H_n$$

The head losses of the spiral case calculated according to the equation (15) and referred to the rated head, increase approximately with the cubic root of H_n. For high head plants the influence of the spiral case head losses becomes negligible in comparison with the head losses of the whole hydraulic system; this allows an increase in v and consequently a reduction in the spiral inlet diameter without compromising the overall system efficiency.

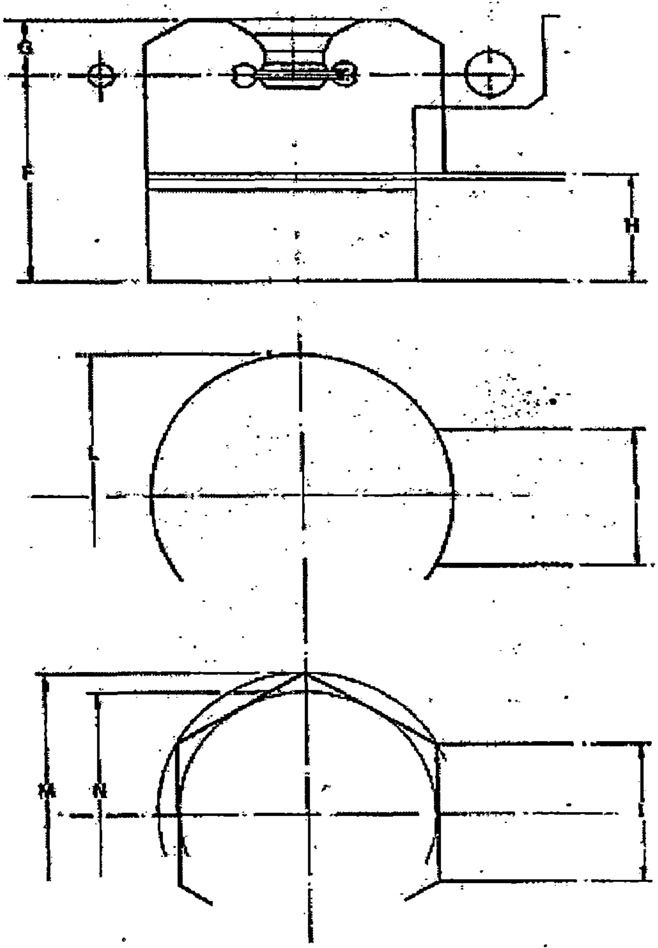

Figure 3.2, Casing dimensions [5]

3.6.2 The main dimensions of the spiral case are as shown in the figure 3.3, which refers to the four nozzle turbine. The dimensions C and D for two and three nozzle machine will deviate from the values indicated in the diagrams according to the actual arrangement of the nozzles within the turbine casing.

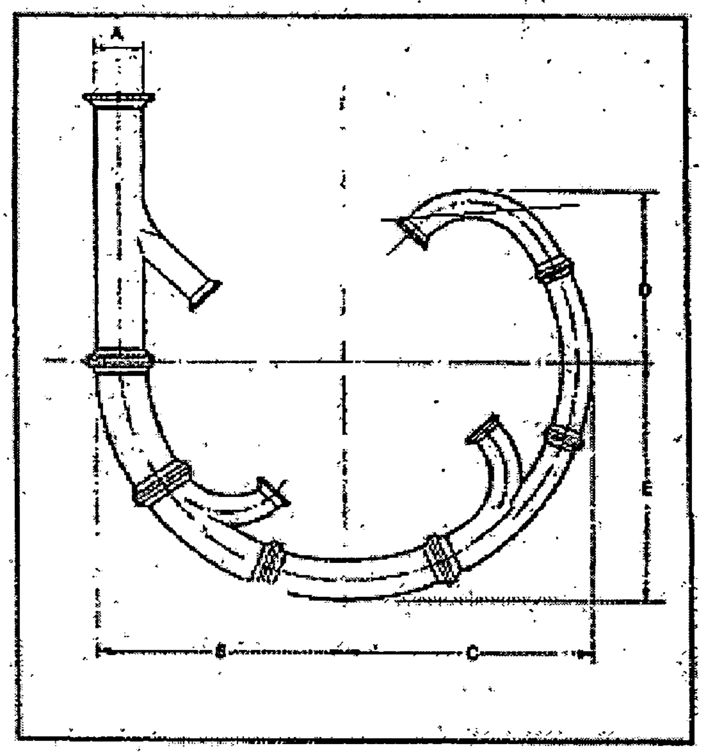

Fig. 3.3, Distributor dimensions [5]

The relationships are as follows:

B = 0.595 +0.694L

C = 0.362 + 0.68L

D = -0.219 +0.70L

E = 0.430 + 0.70L

If the number of nozzles is four, five or six it does not have an appreciable influence on the overall dimensions of the spiral case.

3.7 MAIN PARAMETERS OF HYDRO-GENERATORS:

3.7.1 *Air Gap Diameter (D_g):*

The calculations pertaining to the main parameters of the hydro generator as described below are based on IS 12800 (Part I) [6].

The air gap diameter D_g as shown in the figure 3.6 should large enough to allow the turbine runner top cover to pass through the stator bore. The maximum value of air gap diameter D_g is governed by the maximum permissible stresses in the rotor parts and rim and these are directly linked with the peripheral velocity on runaway speed. The value of maximum peripheral rotor velocity V_r at rated speed can be read from figure. This curve relates to sheet steel having a yield point of 525 N/mm^2. For better quality steels peripheral velocity be increased in direct ratio of yield strength. The peripheral velocity thus settled, the value of D_g in meters can be obtained from the following formula:

$$D_g = 60 * V_r / \pi * N$$

Where,

V_r = maximum peripheral velocity in meters/sec, and

N = rated speed of the machine in r.p.m.

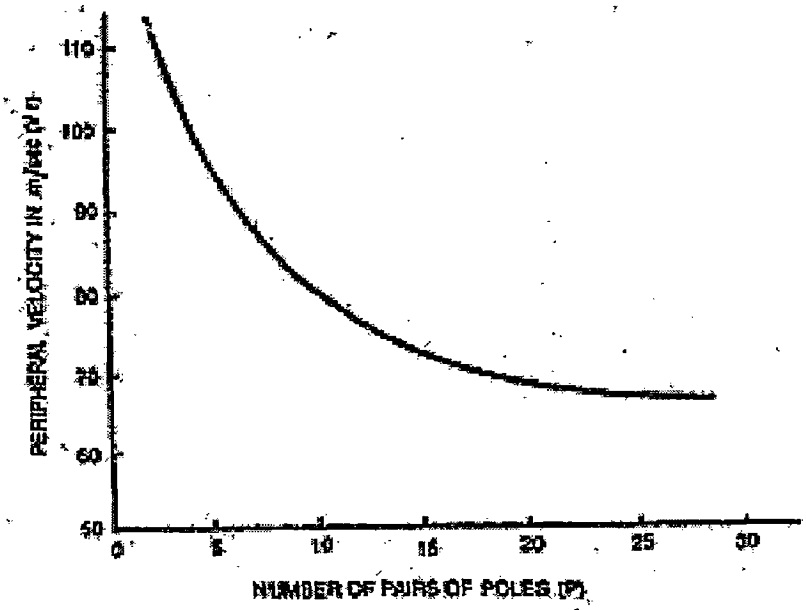

Fig. 3.4, Maximum peripheral rotor velocity V_r at rated speed *[6])*

3.7.2 *Outer Core Diameter:*

The outer core diameter of the stator core as in the figure 3.6 can be determined by the following formula:

$$D_o = D_g (1 + \pi/2p$$

Where,

P = number of pair of poles.

3.7.3 *Stator Frame Diameter:*

The stator frame diameter D_f as shown in the figure 3.6 can be determined by adding 1.2 meters to the outer core diameter, D_o i. e.

$$D_f = (D_o + 1.2)$$

3.7.4 *Inner Diameter of Generator Barrel (D_b):*

Inner diameter (D_b) of generator barrel as shown in the figure 3.6 can be determine by adding 1.6 to 2.0 to the stator frame diameter:

$$D_b = (D_f + 1.6 \text{ to } 2.0) \text{ meters}$$

$$= (D_o + 2.8 \text{ to } 3.2)$$

3.7.5 *Core Length of Stator (L_c):*

The core length of stator frame L_c as shown in the figure 3.6 can be determined by the following formula:

$$L_c = W / (K_o * D_g^2 * N) \text{ meters}$$

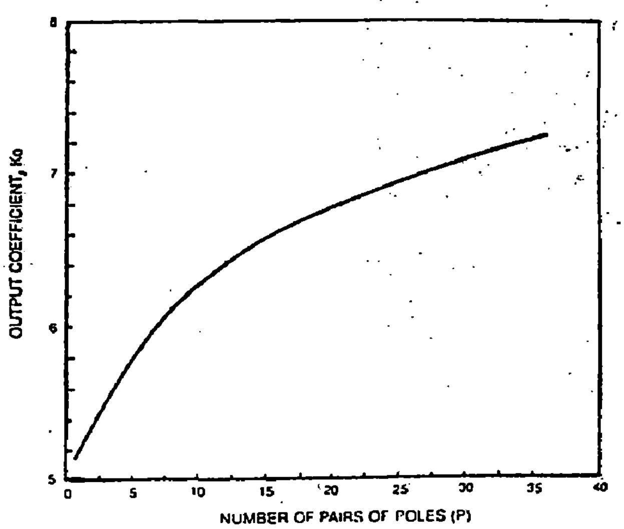

Fig 3.5 Determination of output coefficient [6]

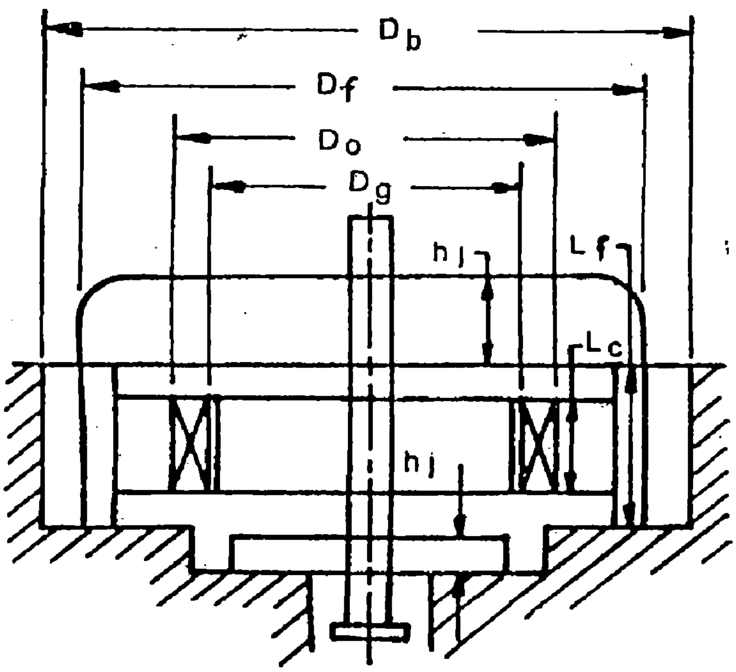

Fig. 3.6 Parameters of generator suspended type construction. [6]

3.7.6 *Length of Stator Frame (L_f):*

Length of the stator frame L_f as shown in the figure 3.6 can be determined by adding 1.5 to 1.6 meters to the length of the stator core i. e.

$$L_f = (L_c + 1.5 \text{ to } 1.6) \text{ meters}$$

3.7.7 *Height of the Load Bearing Bracket (h_f):*

Height of the load bearing bracket h_f as shown in the figure 3.6 can be determined by the following formula:

$h_f = K \sqrt{(D_f)}$ for suspended type of construction.

Where,

K = 0.65 for load less than 50 tons per arm of the bracket,

K = 0.75 for load of 50 to 100 tons per arm of the bracket,

K = 0.85 for load of 100 tons and above per.arm of the bracket.

The number of arms of the bracket is to be decided on the basis of the total load on the thrust bearing that is maximum hydraulic thrust of the turbine runner and weight of the rotating parts. Generally 4 to 8 arms of the bracket are taken.

3.7.8 *Weight of the Generator Rotor:*

The weight of the generator rotor in relation with air gap diameter Dg and active core length L_c as shown in the figure 3.7and 3.8 can be determined from figure below.

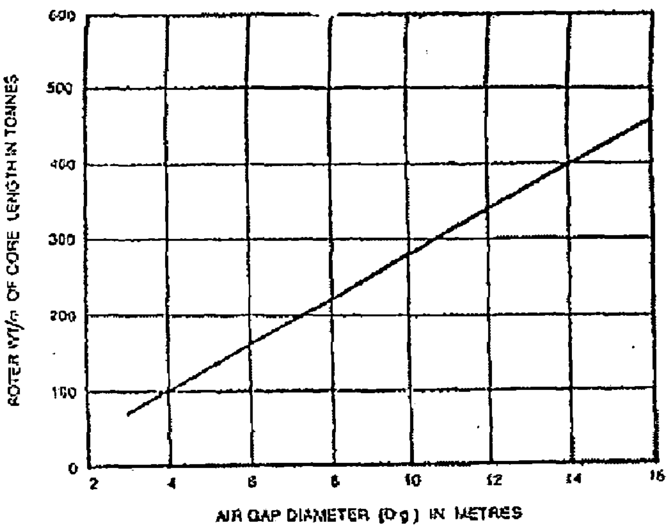

Fig.3.7, Wt. of gen rotor in relation with air gap dia Dg and active core length Lc [6]

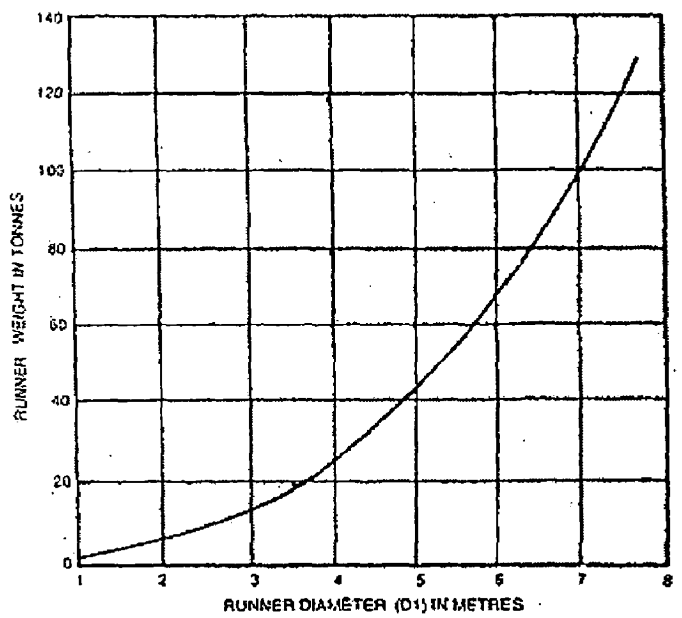

Fig. 3.8 Relation between runner wt and runner dia for Francis turbine [6]

3.8 *OVERALL DIMENSIONS OF POWER HOUSE:*

3.8.1 *The Overall Dimensions of Power House Mainly Depend Upon the Following:*

(a) Overall dimensions of the turbine;

(b) Overall dimensions of the generator;

(c) Number of units in the power house; and

(d) Size of the erection bay.

Note: Provision for the inlet valve , erection of rotor and untanking of transformers should be made in such a way that the space required is minimum without impairing the operational and maintenance requirements.

3.8.2 *Length of the Power House:*

It depends upon the unit spacing, length of the erection bay and the length required for the E. O. T. crane to handle the last unit.

3.8.2.1 *Unit spacing:*

For determining the distance between the center lines of the successive units, a plan showing the overall dimensions of the turbine and the hydro-generators should be drawn with respect to the vertical axis of the machine. For determining the outer dimensions of the generator barrel, the inner diameter of generator barrel may be increased by 0.5 to 1.5 m depending upon the size of the machine. A clearance of 1.5 to 2.0 m should be added on either side of the extremities of the above drawn figures to determine the unit spacing.

3.8.2.2 *Length of the erection bay:*

The length of the erection bay may be taken as 1.0 to 1.5 times the unit bay size as per erection requirements.

The total length L of the power house can then be determined as follows:

$$L = N_o * (\text{ unit spacing }) + L_s + K$$

Where,

N_o = number of units,

L_s = length of the erection bay, and

K = length required for the E. O. T. crane to handle the last unit. Depending upon the number and size of the e. O. T. crane, this length is usually 3.0 to 5.0 meters.

3.8.3 *Width of the Power House:*

For determining the width of the power house, a plan showing the overall dimensions of the turbine and the hydro-generators may be drawn with respect to the vertical axis of the machine. Superstructure columns should be clear of the downstream extremities of the above drawn figure by about 2.0 to 2.5 meters.

On the upstream side provision should be made for the following:

(a) A clearance of about 1.5 to 2.0 meters for concrete the upstream of distributor;

(b) In case the main inlet valve is also accommodated in the powerhouse, a valve pit of appropriate size should have to be provided.

The criteria laid down gives the internal width of the power house (excluding the column width)

3.8.4 *Height of the Power House:*

The height of power house can be calculated by considering the, height of the wheel centerline from the bottom of the tail race channel H_1 and the height of the power house from the wheel centerline to the top of the generator H_2.

Where,

$$H_2 = L_f + h_f + K$$

L_f and h_f have been defined in 2.6.6 and 2.6.7 respectively.

3.8.4.1The height of the machine hall above the top bracket of the generator depends upon the E. O. T. crane hook level and the corresponding E. O. T. crane rail level and the clearance required between the ceiling and the top of the crane. Further the height should depend upon the height of the service bay floor from where the equipment is to be handled.

3.8.4.2 The E. O. T. crane hook level and the corresponding crane rail level are determined by providing adequate clearances for the following cases:

(a) Hauling moving major items of the equipment viz. turbine runner assembly and even entire generator stator.

(b) Hauling the main transformer with bushing into the erection bay under the E. O. T. crane girder.

(c) Clearances required for the untanking of transformers.

(d) Unloading of largest package from the tailors. A height of 6 to 8.5 meters between the top erection bay floor and highest hook level may be sufficient.

3.8.4.3 The height of the power house ceiling above the highest level of the E. O. T. crane hook may generally vary from 4 to 6.5 m depending upon the width of the power house superstructure and capacity of the E. O. T. crane. Keeping a clearance of 0.3 m between the highest part of the gantry crane and ceiling of the power house.

Note: The different allowances for the height determination can be considered as below:

(a) For the exciter about 2 m. on top of the generator.

(b) 1.5 m. between the lowest portion of the crane and handling parts.

(c) Depth of the crane beam about 2.0 m.

(d) A space of 2.50 m. height above the top of the crane so that a trolley can move on it and accommodate a persons height during operation and maintenance.

SELECTION OF TURBINE IN THE OVERLAPPING HEAD RANGE OF PELTON AND FRANCIS TURBINES

4.1 INTRODUCTION:

For the selection of turbine in the overlapping range of Pelton and Francis turbines, between the head range of 200m and 800m, comparison of different parameters of both the turbines like Turbine dimensions, Generator dimensions and Unit bay dimensions are considered. After comparing the different components in terms of size, comparison in terms of cost has to be made to make the selection among two in terms of economy.

While finding out different parameters, selection of speed for Pelton turbines has to be considered because of possibility of choosing the number of jets. Where as in contest to Francis turbines choice of speed does not vary.

4.2 SELECTION OF SPEED FOR PELTON TURBINES:

For a given head and discharge conditions, Pelton turbines could have a wide range of speed depending upon the number of jets, but it is required to adopt the speed which yields the maximum efficiency.

It is not out of place to mention that, if speed of the turbine is made higher, then the specific speed of the turbine will increase. When specific speed increases the size of the turbine will become smaller and hence it would be less costly. On the other hand, the jet diameter, will decrease, which will raise the jet ratio and enhance the turbine efficiency. The disadvantage of having higher specific speed is that, it necessitates multi-jets because of which the governing becomes complicated and more expensive. Again, the speed of directly coupled generator will increase when the speed of the turbine is made higher, which necessitates to provide smaller number of pair of poles and hence the generator will also be less costly. Also, the material employed for high specific speed machines (turbines and generator) will be costly, as high specific speed causes large stress in the revolving parts. All the above enumerated advantages and disadvantages should be considered and a balance has to be made for the conflicting interests in the selection of proper speed.

However, the selection of specific speed and hence rated speed of the Pelton turbine for determining the different parameters of turbine for comparison purpose, a trial specific speed is calculated by using the relationship developed by De Sievro [5] at the beginning and then actual specific speed for the corresponding number of jets is taken. Specific speeds for the four jet and six jets are calculated as per recent trends and the closer one to the trial specific speed is taken. However for the turbines above 40MW the number of jets considered as six and on this basis all the parameters is determined.

Emphasis is given to multi-jet, vertical-type Pelton turbines because of there prevalence in high capacity application. The power house and generator dimensions are considered for surface type power house and vertical-type arrangements.

4.3 CHOICE OF TURBINE TYPE:

The choice between Francis and Pelton turbines is governed by the well-known general principle, according to which the former type is expediently relied upon to utilize heads in the lower range of high heads, whereas the latter is installed under very high heads. Of course, the first problem to be answered in this context is to determine a limit head, which could be considered as the boundary separating the range of application of these types [10]. Reference is made to highly interesting trend of development in the course of which Francis turbines have been applied to utilize increasing heads and have replaced the Pelton wheel in the head range between 200 to 600 meters.

For the proper selection of the turbines between Francis and Pelton, a comparison of advantages and disadvantages of two machines of the same capacity and head has to be made and analyzed to reach on a conclusion.

4.3.1 Efficiency:

The comparison of efficiency curves of Pelton and Francis turbines as shown in the fig. 4.1 and 4.2 shows that the efficiency curves of Pelton wheels are considerably flatter than those of Francis turbines [10]. This accounts for the fact that the former operate more efficiently under fluctuating discharge or load conditions. On the other hand, a comparison of two machines of approximately the same power capacity and operating in the high-efficiency range may show the efficiency of Francis turbine to be superior to that of the Pelton turbine by about 1 to 2 percent.

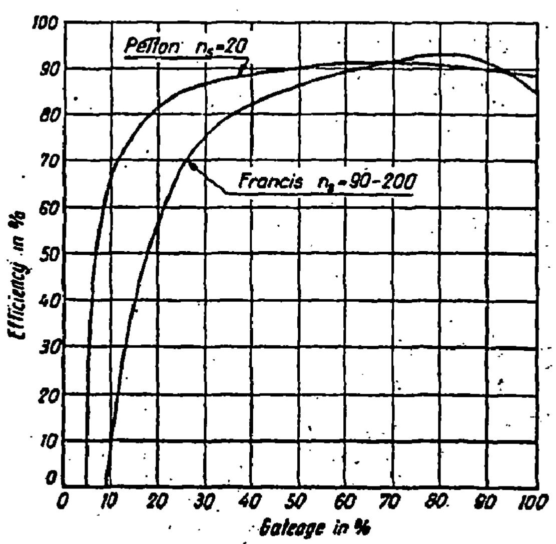

Fig.4.1 Informative efficiency curves of turbine types of high head developments plotted against Wheel discharge [10].

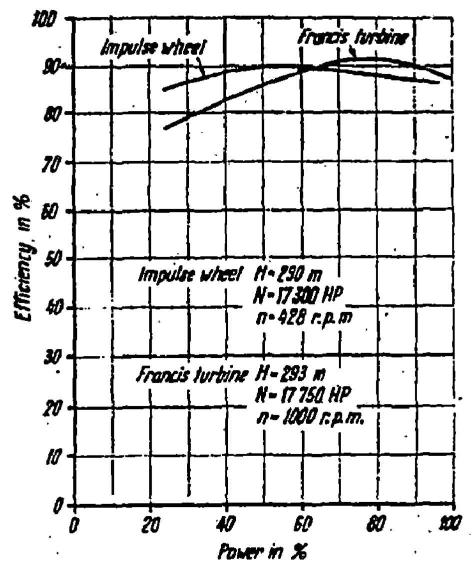

Fig.4.2 Efficiency plotted versus power, Comparison of a Pelton and Francis turbine of identical Power, designed for identical head.[10]

4.3.2 Cost:

As far as the investment costs are concerned, Francis turbines offer, in general, numerous advantages. Because of their higher speed, both dimensions and weight and consequently also their costs are lower than those of a Pelton turbine. Higher speeds favorably influences the cost of generator as well, although up to a certain limit only. Costs of generators built for speeds in the 1000 r. p. m. range tends to rise sharply [10].

Owing to the smaller dimensions less space is required for Francis turbines than for Pelton wheels, especially for those of the multijet type. For this reason foundations of smaller horizontal dimensions and a machine hall of reduced floor area must be provided. The smaller width of the machine hall calls for an overhead crane of smaller span and less weight.

These advantages are, however, partly or entirely offset by the costs of rock or earth excavation for the deeper foundations of the Francis turbine, required in order to reduce the draft head or to provide the counterpressure in case of very high heads. However, at underground installation this advantage of Pelton wheels loses its significances and, at the same time, the smaller space required for Francis units becomes of major importance.

4.3.3 Water Conveyance:

Water can be supplied to Francis turbines in a simpler and more economical manner than to multijet Pelton units [10].

4.3.4 Head Utilization:

Francis turbine utilizes the entire head down to tailwater level, whereas the setting height of the Pelton wheel, i. e. 0.60 to 3.00 metres, is lost. This loss is, of course, negligible in case of very high heads. If, however, the tailwater level is subject to wide-range variations, this loss become appreciable, since the runner must be set high to avoid submergence under all conditions [10].

4.3.5 Wear and Abrasion:

As indicated by experience, Pelton wheels appear to be more susceptible to wear and abrasion than Francis turbines. Parts most exposed to effects of flowing water in a Francis turbine are: the upper and lower ring of the wicket gate, the guide vanes, the sealing rings of the runner and the runner vanes themselves. Parts most subject to wear in a Pelton turbine are: the mouth ring of the nozzle, the needle (spear) tip and the runner buckets. Erosion is most pronounced and rapid if the water carries sand in suspension, and depends, to a considerable extent, on the character of the sand; sharp-edged particles cause deep pitting of the affected surfaces.

The more rapid wear of Pelton buckets is due to the relative flow velocity, which is higher than in the passage between the vanes of Francis runner. Practical experience shows the detrimental effect of wear on efficiency to be less pronounced in case of Francis turbines; guide vanes and runner vanes wear more uniformly. On the other hand, a slight wear of the nozzle and the needle of Pelton turbines may markedly disturb the uniformity of the jet, which entails unfavorable hydraulic conditions as well as increased wear of bucket. Both effects lead eventually to a deterioration of efficiency. Buckets of Pelton turbines wear more rapidly if several jets are applied per wheel [10].

5.3.6 Repair and Replacement of Worn Parts:

The Pelton wheels have significant advantages over the other type. It is exactly the most susceptible parts, i.e. the nozzle and the spear tip that can be dismounted and replaced with spare parts in a very short time. Slightly pitted parts of the bucket can be repaired by grinding, or by welding without the necessity of replacing the buckets. On the other hand, in case of more serious damage the entire runner of the Pelton turbine must be disassembled and replaced with a spare runner. The operation can be carried out even at the largest within a period of 36 hours. Repair and replacement of damaged parts of Francis turbines are a more lengthy operation.

Summing up the foregoing, parts of the Pelton wheel have a shorter useful life, the exposed parts require a more frequent replacement, but this can be done in a shorter time. The situation with Francis wheels is reversed; a replacement is less frequently necessary, but the operation involved is more complicated and time-consuming. It should be added that spare parts for Francis turbines are more expensive than those for Pelton wheels [10].

For the selection of the turbines in the overlapping ranges of Pelton and Francis turbines an analysis for the same power output of 20,40,60,80,100 and 250MW and head ranges of 200,300,400,500,600,700 and 800metres has been carried out considering the recent trend of use these turbines. For the comparison of Pelton and Francis turbines, curves of floor area, runner diameter, turbine setting, scroll case diameter are plotted against the head in figure 4.3 to figure 4.26 for the different capacities of 20,40,60,80,100 and 250MW.

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Table 4.1

For 200 m head and different capacities (Pelton).

Here Pt is in kw

Considering the efficiency of turbine 90% and Generator 96%.

20 MW	40 MW	60 MW	80 MW	100 MW	250 MW
Trail N_{sj} = 85.49/$(H)^{243}$	Trail N_{sj} = 85.49/$(H)^{243}$	Trail N_{sj} = 85.49/$(H)^{243}$	Trail N_{sj} = 85.49/$(H)^{243}$	Trail N_{sj} = 85.49/$(H)^{243}$	Trail N_{sj} = 85.49/$(H)^{243}$
$(H)^{243}$ = 3.62	$(H)^{243}$ = 3.62	$(H)^{243}$ = 3.62	$(H)^{243}$ = 3.62	$(H)^{243}$ = 3.62	$(H)^{243}$ = 3.62
$(H)^{1.25}$ = 752.1	$(H)^{1.25}$ = 752.1	$(H)^{1.25}$ = 752.12	$(H)^{1.25}$ = 752.1	$(H)^{1.25}$ = 752.1	$(H)^{1.25}$ = 752.1
$(P)^{0.5}$ = 152.15	$(P)^{0.5}$ = 215.17	$(P)^{0.5}$ = 263.5	$(P)^{0.5}$ = 304.3	$(P)^{0.5}$ = 340.2	$(P)^{0.5}$ = 537.9
For 6 jets $(P/j)^{0.5}$ = 62.11	For 6 jets $(P/j)^{0.5}$ = 87.84	For 6 jets $(P/j)^{0.5}$ = 107.58	For 6 jets $(P/j)^{0.5}$ = 124.2	For 6 jets $(P/j)^{0.5}$ = 138.9	For 6 jets $(P/j)^{0.5}$ = 219.6
For 4 jets $(P/j)^{0.5}$ = 76.07	For 4 jets $(P/j)^{0.5}$ = 107.6	For 4 jets $(P/j)^{0.5}$ = 131.76	For 4 jets $(P/j)^{0.5}$ = 152.15	For 4 jets $(P/j)^{0.5}$ = 170.1	For 4 jets $(P/j)^{0.5}$ = 269.0
Trial, N_{sj} = 23.59	Trial, N_{sj} = 23.59	Trial, N_{sj} = 23.59	Trial, N_{sj} = 23.59	Trial, N_{sj} = 23.59	Trial, N_{sj} = 23.59
Also, N_{sj} = $N(P/j)^{0.5}/H^{1.25}$	Also, N_{sj} = $N(P/j)^{0.5}/H^{1.25}$	Also, N_{sj} = $N(P/j)^{0.5}/H^{1.25}$	Also, N_{sj} = $N(P/j)^{0.5}/H^{1.25}$	Also, N_{sj} = $N(P/j)^{0.5}/H^{1.25}$	Also, N_{sj} = $N(P/j)^{0.5}/H^{1.25}$
for 6 jets	for 6 jets	for 6 jets	for 6 jets	for 6 jets	for 6 jets
Trial, N = 285.7	Trial, N = 202.0	Trial, N = 164.9	Trial, N = 142.8	Trial, N = 127.8	Trial, N = 80.80
poles, p= 21.00	poles, p= 29.70	poles, p= 36.38	poles, p= 42.01	poles, p= 46.96	poles, p= 74.26
Taking,P= 22	Taking,P 30	Taking,P= 38	Taking,P= 44	Taking,P= 48	Taking,P 74
Actual,N= 272.7	Actual,N= 200	Actual,N= 157.9	Actual,N= 136.3636	Actual,N= 125	Actual,N= 81.08
Actual,Nsj= 22.52	Actual,Nsj= 23.36	Actual,Nsj= 22.59	Actual,Nsj= 22.52	Actual,Nsj= 23.08	Actual,Nsj= 23.67
for 4jets	for 4jets	for 4jets	for 4jets	for 4jets	for 4jets
Trial, N = 233.3	Trial, N = 164.9	Trial, N = 134.7	Trial, N = 116.63	Trial, N = 104.31	Trial, N = 65.97
poles, p= 25.72	poles, p= 36.38	poles, p= 44.55	poles, p= 51.45	poles, p= 57.52	poles, p= 90.95
Taking,P= 26	Taking,P= 38	Taking,P= 46	Taking,P= 52	Taking,P= 58	Taking,P= 92
Actual,N= 230.77	Actual,N= 157.89	Actual,N= 130.43	Actual,N= 115.38	Actual,N= 103.45	Actual,N= 65.22
Actual,Nsj= 23.34	Actual,Nsj= 22.59	Actual,Nsj= 22.85	Actual,Nsj= 23.34	Actual,Nsj= 23.40	Actual,Nsj= 23.32
Main parameters of Turbine	***Main parameters of Turbine***	***Main parameters of Turbine***	***Main parameters of Turbine***	***Main parameters of Turbine***	***Main parameters of Turbine***
Taking 4 Jets	**Taking 6 Jets**	**Taking 6 Jets**	**Taking 6 Jets**	**Taking 6 Jets**	**Taking 6 Jets**
N_{sj} = 23.34	N_{sj} = 23.36	N_{sj} = 22.59	N_{sj} = 22.52	N_{sj} = 23.08	N_{sj} = 23.67
N = 230.77	N = 200	N = 157.89	N = 136.36	N = 127.76	N = 81.08
Ns = 46.68	Ns = 57.22	Ns = 55.33	Ns = 55.16	Ns = 56.53	Ns = 57.98
Ku = 0.4535	Ku = 0.4534	Ku = 0.4564	Ku = 0.4567	Ku = 0.4545	Ku = 0.4522
D2 = 2.35	D2 = 2.71	D2 = 3.45	D2 = 4.00	D2 = 4.25	D2 = 6.66
Dj/D2 = 0.1118	Dj/D2 = 0.1119	Dj/D2 = 0.1075	Dj/D2 = 0.1071	Dj/D2 = 0.1103	Dj/D2 = 0.1137
Dj = 0.26	Dj = 0.30	Dj = 0.37	Dj = 0.43	Dj = 0.47	Dj = 0.76
Q = 11.80	Q = 23.60	Q = 35.39	Q = 47.19	Q = 58.99	Q = 147.48
Hs = 1.98	Hs = 2.13	Hs = 2.37	Hs = 2.65	Hs = 2.90	Hs = 5.94
D3 = 3.16	D3 = 3.65	D3 = 4.62	D3 = 5.35	D3 = 5.71	D3 = 9.01
Casing L = 7.30	Casing L = 8.30	Casing, L = 10.30	Casing, L = 11.80	Casing, L = 12.55	Casing, L = 19.35
G = 1.39	G = 1.57	G = 1.93	G = 2.21	G = 2.34	G = 3.58
F = 6.27	F = 6.99	F = 8.40	F = 9.47	F = 10.00	F = 14.83
H = 4.36	H = 4.88	H = 5.90	H = 6.67	H = 7.06	H = 10.54

I = 3.98	I = 4.35	I = 5.09	I = 5.65	I = 5.92	I = 8.44
Spiral ,B = 5.66	Spiral , B = 6.36	Spiral , B = 7.74	Spiral, B = 8.78	Spiral, B = 9.31	Spiral, B = 14.02
case C = 5.33	case C = 6.01	case C = 7.36	case C = 8.39	case C = 8.90	case C = 13.52
D = 4.89	D = 5.59	D = 6.99	D = 8.04	D = 8.57	D = 13.32
E = 5.54	E = 6.24	E = 7.64	E = 8.69	E = 9.22	E = 13.97
D+E = 10.43	D+E = 11.84	D+E = 14.6	D+E = 16.7	D+E = 17.8	D+E = 27.3
B+C = 10.99	B+C = 12.4	B+C = 15.11	B+C = 17.17	B+C = 18.2	B+C = 27.5
Main parameters of Gen.	***Main parameters of Gen.***	***Main parameters of Gen.***	***Main parameters of Gen.***	***Main parameters of Gen.***	***Main parameters of Gen.***
Air gap dia D_g = 6.12	D_g = 6.88	D_g = 8.29	D_g = 9.38	D_g = 9.72	D_g = 15.08
Out st core dia.D_o = 6.86	D_o = 7.60	D_o = 8.97	D_o = 10.05	D_o = 10.35	D_o = 15.72
St rame dia D_f = 8.06	D_f = 8.80	D_f = 10.17	D_f = 11.25	D_f = 11.55	D_f = 16.92
Inn dia Gen.Bar D_b = 9.86	D_b = 10.60	D_b = 11.97	D_b = 13.05	D_b = 13.35	D_b = 18.72
Core leng of st L_c = 0.3981	L_c = 0.707	L_c = 0.9179	L_c = 1.09	L_c = 1.34	L_c = 2.07
length of st.fr L_f = 1.95	L_f = 2.26	L_f = 2.47	L_f = 2.64	L_f = 2.89	L_f = 3.62
Outer bar dia.D = 10.86	D = 11.60	D = 12.97	D = 14.05	D = 14.35	D = 19.72
Wt of Gen.Rot Wr = 65.68	Wr = 134.31	Wr = 211.12	Wr = 272.2	Wr = 369.80	Wr = 888.0
Wt of Tur.Runner = 17.00	Wtr = 18.00	Wtr = 36.00	Wtr = 50.00	Wtr = 57.00	Wtr = 140.0
Wt of rot.parts = 82.68	Wtr = 152.31	Wtr = 247.12	Wtr = 322.2	Wtr = 426.8	Wtr = 1028
Ht load bear Bra.= 1.85	Ht = 1.93	Ht = 2.07	Ht = 2.52	Ht = 2.55	Ht = 3.08
H1 = 6.27	H1 = 6.99	H1 = 8.40	H1 = 9.47	H1 = 10.00	H1 = 14.83
H2 = 9.79	H2 = 10.18	H2 = 10.54	H2 = 11.15	H2 = 11.44	H2 = 12.70
Unit bay Dimensions	***Unit bay Dimensions***	***Unit bay Dimensions***	***Unit bay Dimensions***	***Unit bay Dimensions***	***Unit bay Dimensions***
Length Unit bay = 13.99	Length Unit bay = 15.37	Length Unit bay = 18.11	Length Unit bay = 20.17	Length Unit bay = 21.20	Length Unit bay = 30.54
Width Unit bay = 15.99	Width Unit bay = 17.37	Width Unit bay = 20.11	Width Unit bay = 22.17	Width Unit bay = 23.20	Width Unit bay = 32.54
Height unit bay = 25.57	Height unit bay = 26.67	Height unit bay = 28.44	Height unit bay = 30.12	Height unit bay = 30.95	Height unit bay = 37.03

Table 4.2

For 300 m head and different capacities (Pelton).

Here Pt is in kw

Considering the efficiency of turbine 90% and Generator 96%.

20 MW	40 MW	60 MW	80 MW	100 MW	250 MW
Trail N_{sj} = 85.49/$(H)^{243}$	Trail N_{sj} = 85.49/$(H)^{243}$	Trail N_{sj} = 85.49/$(H)^{243}$	Trail N_{sj} = 85.49/$(H)^{243}$	Trail N_{sj} = 85.49/$(H)^{243}$	Trail N_{sj} = 85.49/$(H)^{243}$
$(H)^{243}$= 4.00	$(H)^{243}$= 4.00	$(H)^{243}$= 4.00	$(H)^{243}$= 4.00	$(H)^{243}$= 4.00	$(H)^{243}$= 4.00
$(H)^{1.25}$= 1248.54	$(H)^{1.25}$= 1248.54	$(H)^{1.25}$= 1248.54	$(H)^{1.25}$= 1248.54	$(H)^{1.25}$= 1248.54	$(H)^{1.25}$= 1248.54
$(P)^{0.5}$= 152.15	$(P)^{0.5}$= 215.17	$(P)^{0.5}$= 263.52	$(P)^{0.5}$= 304.29	$(P)^{0.5}$= 340.21	$(P)^{0.5}$= 537.91
For 6 jets $(P/j)^{0.5}$= 62.11	For 6 jets $(P/j)^{0.5}$= 87.84	For 6 jets $(P/j)^{0.5}$= 107.58	For 6 jets $(P/j)^{0.5}$= 124.23	For 6 jets $(P/j)^{0.5}$= 138.89	For 6 jets $(P/j)^{0.5}$= 219.60
For 4 jets $(P/j)^{0.5}$= 76.07	For 4 jets $(P/j)^{0.5}$= 107.58	For 4 jets $(P/j)^{0.5}$= 131.76	For 4 jets $(P/j)^{0.5}$= 152.15	For 4 jets $(P/j)^{0.5}$= 170.10	For 4 jets $(P/j)^{0.5}$= 268.96
Trial, N_{sj} = 21.38	Trial, N_{sj} = 21.38	Trial, N_{sj} = 21.38	Trial, N_{sj} = 21.38	Trial, N_{sj} = 21.38	Trial, N_{sj} = 21.38
Also, N_{sj} = $N(P/j)^{0.5}/H^{1.25}$	Also, N_{sj} = $N(P/j)^{0.5}/H^{1.25}$	Also, N_{sj} = $N(P/j)^{0.5}/H^{1.25}$	Also, N_{sj} = $N(P/j)^{0.5}/H^{1.25}$	Also, N_{sj} = $N(P/j)^{0.5}/H^{1.25}$	Also, N_{sj} = $N(P/j)^{0.5}/H^{1.25}$
for 6 jets	for 6 jets	for 6 jets	for 6 jets	for 6 jets	for 6 jets
Trial, N = 429.73	Trial, N = 303.86	Trial, N = 248.10	Trial, N = 214.86	Trial, N = 192.18	Trial, N = 121.55
poles, p= 13.96	poles, p= 19.75	poles, p= 24.18	poles, p= 27.92	poles, p= 31.22	poles, p= 49.36
Taking,P= 14	Taking,P= 20	Taking,P= 26	Taking,P= 28	Taking,P= 32	Taking,P= 50
Actual,N= 428.57	Actual,N= 300	Actual,N= 230.77	Actual,N= 214.29	Actual,N= 187.5	Actual,N= 120
Actual,Nsj= 21.32	Actual,Nsj= 21.11	Actual,Nsj= 19.88	Actual,Nsj= 21.32	Actual,Nsj= 20.86	Actual,Nsj= 21.11
for 4jets	for 4jets	for 4jets	for 4jets	for 4jets	for 4jets
Trial, N = 350.87	Trial, N = 248.10	Trial, N = 202.58	Trial, N = 175.44	Trial, N = 156.91	Trial, N = 99.24
poles, p= 17.10	poles, p= 24.18	poles, p= 29.62	poles, p= 34.20	poles, p= 38.24	poles, p= 60.46
Taking,P= 18	Taking,P= 26	Taking,P= 30	Taking,P= 36	Taking,P= 40	Taking,P= 62
Actual,N= 333.33	Actual,N= 230.77	Actual,N= 200.00	Actual,N= 166.67	Actual,N= 150	Actual,N= 96.77
Actual,Nsj= 20.31	Actual,Nsj= 19.88	Actual,Nsj= 21.11	Actual,Nsj= 20.31	Actual,Nsj= 20.44	Actual,Nsj= 20.85
Main parameters of Turbine	***Main parameters of Turbine***	***Main parameters of Turbine***	***Main parameters of Turbine***	***Main parameters of Turbine***	***Main parameters of Turbine***
Taking 6 Jets	**Taking 6 Jets**	**Taking 6 Jets**	**Taking 6 Jets**	**Taking 6 Jets**	**Taking 6 Jets**
N_{sj} = 21.32	N_{sj} = 21.11	N_{sj} = 19.88	N_{sj} = 21.32	N_{sj} = 20.86	N_{sj} = 21.11
N = 428.57	N = 300	N = 230.77	N = 214.29	N = 187.5	N = 120
Ns = 52.22	Ns = 51.71	Ns = 48.70	Ns = 52.22	Ns = 51.10	Ns = 51.71
Ku = 0.4614	Ku = 0.4622	Ku = 0.4670	Ku = 0.4614	Ku = 0.4631	Ku = 0.4622
D2 = 1.58	D2 = 2.25	D2 = 2.96	D2 = 3.15	D2 = 3.62	D2 = 5.64
Dj/D2 = 0.1004	Dj/D2 = 0.0992	Dj/D2 = 0.0924	Dj/D2 = 0.1004	Dj/D2 = 0.0978	Dj/D2 = 0.0992
Dj = 0.16	Dj = 0.22	Dj = 0.27	Dj = 0.32	Dj = 0.35	Dj = 0.56
Q = 7.87	Q = 15.73	Q = 23.60	Q = 31.46	Q = 39.33	Q = 98.32
Hs = 1.91	Hs = 1.99	Hs = 2.10	Hs = 2.20	Hs = 2.34	Hs = 3.71
D3 = 2.08	D3 = 2.97	D3 = 3.85	D3 = 4.16	D3 = 4.75	D3 = 7.42
Casing L = 5.06	Casing L = 6.90	Casing, L = 8.71	Casing, L = 9.35	Casing, L = 10.56	Casing, L = 16.08
G = 0.98	G = 1.31	G = 1.64	G = 1.76	G = 1.98	G = 2.99
F = 4.69	F = 5.99	F = 7.28	F = 7.73	F = 8.59	F = 12.50
H = 3.22	H = 4.16	H = 5.09	H = 5.42	H = 6.04	H = 8.87

I = 3.15	I = 3.83	I = 4.50	I = 4.74	I = 5.19	I = 7.23
Spiral B = 4.11	Spiral , B = 5.38	Spiral , B = 6.64	Spiral, B = 7.08	Spiral, B = 7.93	Spiral, B = 11.75
case ,C = 3.81	case, C = 5.05	case C = 6.29	case C = 6.72	case C = 7.55	case C = 11.29
D = 3.33	D = 4.61	D = 5.88	D = 6.33	D = 7.18	D = 11.03
E = 3.98	E = 5.26	E = 6.53	E = 6.97	E = 7.82	E = 11.68
D+E = 7.30	D+E = 9.87	D+E = 12.41	D+E = 13.30	D+E = 15.00	D+E = 22.72
B+C = 7.92	B+C = 10.44	B+C = 12.93	B+C = 13.80	B+C = 15.47	B+C = 23.04
Main parameters of Gen.	*Main parameters of Gen.*	*Main parameters of Gen.*	*Main parameters of Gen.*	*Main parameters of Gen.*	*Main parameters of Gen.*
Air gap dia D_g = 3.97	D_g = 5.19	D_g = 6.12	D_g = 6.55	D_g = 7.38	D_g = 10.50
Out st core dia.D_o = 4.86	D_o = 6.00	D_o = 6.86	D_o = 7.29	D_o = 8.11	D_o = 11.16
St rame dia D_f = 6.06	D_f = 7.20	D_f = 8.06	D_f = 8.49	D_f = 9.31	D_f = 12.36
Inn dia Gen.Bar D_b = 7.86	D_b = 9.00	D_b = 9.86	D_b = 10.29	D_b = 11.11	D_b = 14.16
Core leng of st,L_c = 0.5494	L_c = 0.8819	L_c = 1.19	L_c = 1.48	L_c = 1.65	L_c = 3.04
length of st.fr L_f = 2.10	L_f = 2.43	L_f = 2.74	L_f = 3.03	L_f = 3.20	L_f = 4.59
Outer bar dia.D = 8.86	D = 10.00	D = 10.86	D = 11.29	D = 12.11	D = 15.16
Wt of Gen.Rot Wr = 54.94	Wr = 119.06	Wr = 208.98	Wr = 265.65	Wr = 345.75	Wr = 912.14
Wt f Tur.Runner = 7.00	Wtr = 13.00	Wtr = 22.00	Wtr = 29.00	Wtr = 38.00	Wtr = 150.00
Wt of rot.parts = 61.94	Wtr = 132.06	Wtr = 230.98	Wtr = 294.65	Wtr = 383.75	Wtr = 1062.14
Ht load bear Bra.= 1.60	Ht = 1.74	Ht = 1.85	Ht = 1.89	Ht = 2.29	Ht = 2.99
H1 = 4.69	H1 = 5.99	H1 = 7.28	H1 = 7.73	H1 = 8.59	H1 = 12.50
H2 = 9.70	H2 = 10.18	H2 = 10.59	H2 = 10.92	H2 = 11.48	H2 = 13.58
Unit bay Dimensions	***Unit bay Dimensions***	***Unit bay Dimensions***	***Unit bay Dimensions***	***Unit bay Dimensions***	***Unit bay Dimensions***
Length Unit bay = 11.86	Length Unit bay = 13.44	Length Unit bay = 15.93	Length Unit bay = 16.80	Length Unit bay = 18.47	Length Unit bay = 26.04
Width Unit bay = 13.86	Width Unit bay = 15.44	Width Unit bay = 17.93	Width Unit bay = 18.80	Width Unit bay = 20.47	Width Unit bay = 28.04
Height unit bay = 23.88	Height unit bay = 25.66	Height unit bay = 27.37	Height unit bay = 28.15	Height unit bay = 29.58	Height unit bay = 35.58

For 400 m head and different capacities (Pelton).

Here Pt is in kw

Considering the efficiency of turbine 90% and Generator 96%.

	20 MW	40 MW	60 MW	80 MW	100 MW	250 MW
Trail N_{sj} =	$85.49/(H)^{.243}$	$85.49/(H)^{.243}$	$85.49/(H)^{.243}$	$85.49/(H)^{.243}$	$85.49/(H)^{.243}$	$85.49/(H)^{.243}$
$(H)^{.243}$ =	4.29	4.29	4.29	4.29	4.29	4.29
$(H)^{1.25}$ =	1788.9	1788.9	1789	1789	1788.85	1788.85
$(P)^{0.5}$ =	152.15	215.17	263.5	304.3	340.21	537.91
For 6 jets $(P/j)^{0.5}$ =	62.11	87.84	107.6	124.2	138.89	219.60
For 4 jets $(P/j)^{0.5}$ =	76.07	107.58	131.76	152.15	170.10	268.96
Trial, N_{sj} =	19.93	19.93	19.93	19.93	19.93	19.93
Also, N_{sj} =	$N(P/j)^{0.5}/H^{1.25}$	$N(P/j)^{0.5}/H^{1.25}$	$N(P/j)^{0.5}/H^{1.25}$	$N(P/j)^{0.5}/H^{1.25}$	$N(P/j)^{0.5}/H^{1.25}$	$N(P/j)^{0.5}/H^{1.25}$
for 6 jets						
Trial, N =	574.13	405.97	331.47	287.06	256.76	162.39
poles, p=	10.45	14.78	18.10	20.90	23.37	36.95
Taking,P=	12	16	20	22	24	38
Actual,N=	500	375	300	272.73	250	157.89
Actual,Nsj=	17.36	18.41	18.04	18.94	19.41	19.38
for 4jets						
Trial, N =	468.77	331.47	270.65	234.39	209.64	132.59
poles, p=	12.80	18.10	22.17	25.60	28.62	45.25
Taking,P=	14	20	24	26	30	46
Actual,N=	428.57	300.00	250.00	230.77	200	130.43
Actual,Nsj=	18.23	18.04	18.41	19.63	19.02	19.61
Main parameters of Turbine	***Main parameters of Turbine***	***Main parameters of Turbine***	***Main parameters of Turbine***	***Main parameters of Turbine***	***Main parameters of Turbine***	***Main parameters of Turbine***
	Taking 4 Jets	**Taking 6 Jets**	**Taking 6 Jets**	**Taking 6 Jets**	**Taking 6 Jets**	**Taking 6 Jets**
N_{sj} =	18.23	18.41	18.04	18.94	19.41	19.38
N =	428.57	375	300	272.73	250	157.89
Ns =	44.65	45.10	44.19	46.39	47.54	47.47
Ku =	0.4734	0.4727	0.4741	0.4706	0.4688	0.4689
D2 =	1.87	2.13	2.67	2.92	3.17	5.02
Dj/D2 =	0.0836	0.0846	0.0826	0.0874	0.0899	0.0897
Dj =	0.16	0.18	0.22	0.25	0.28	0.45
Q =	5.90	11.80	17.70	23.60	29.50	73.74
Hs =	1.90	1.94	2.00	2.06	2.13	2.92
D3 =	2.39	2.73	3.41	3.75	4.10	6.49
Casing, L =	5.69	6.40	7.80	8.51	9.23	14.15
G =	1.09	1.22	1.48	1.61	1.74	2.64
F =	5.13	5.63	6.63	7.14	7.64	11.14
H =	3.54	3.90	4.62	4.99	5.35	7.88

I = 3.39	I = 3.65	I = 4.16	I = 4.43	I = 4.69	I = 6.52
Spiral ,B = 4.55	Spiral , B = 5.04	Spiral , B = 6.01	Spiral, B = 6.50	Spiral, B = 7.00	Spiral, B = 10.42
case , C = 4.23	case, C = 4.71	case C = 5.66	case C = 6.15	case C = 6.64	case C = 9.99
D = 3.77	D = 4.26	D = 5.24	D = 5.74	D = 6.24	D = 9.69
E = 4.42	E = 4.91	E = 5.89	E = 6.39	E = 6.89	E = 10.34
D+E = 8.18	D+E = 9.17	D+E = 11.13	D+E = 12.13	D+E = 13.13	D+E = 20.03
B+C = 8.78	B+C = 9.75	B+C = 11.67	B+C = 12.66	B+C = 13.64	B+C = 20.40
Main parameters of Genrator	*Main parameters of Genrator*	*Main parameters of Genrator*	*Main parameters of Genrator*	*Main parameters of Genrator*	*Main parameters of Genrator*
Air gap dia D_g = 3.97	D_g = 4.33	D_g = 5.19	D_g = 5.46	D_g = 5.84	D_g = 8.29
Out st core dia.D_o = 4.86	D_o = 5.18	D_o = 6.00	D_o = 6.24	D_o = 6.61	D_o = 8.97
St rame dia D_f = 6.06	D_f = 6.38	D_f = 7.20	D_f = 7.44	D_f = 7.81	D_f = 10.17
Inn dia Gen.Bar D_b = 7.86	D_b = 8.18	D_b = 9.00	D_b = 9.24	D_b = 9.61	D_b = 11.97
Core leng of st,L_c = 0.549	L_c = 1.028	L_c = 1.323	L_c = 1.72	L_c = 2.03	L_c = 3.82
length of st.fr L_f = 2.10	L_f = 2.58	L_f = 2.87	L_f = 3.27	L_f = 3.58	L_f = 5.37
Outer bar dia.D = 8.86	D = 9.18	D = 10.00	D = 10.24	D = 10.61	D = 12.97
Wt of Gen.Rot Wr = 54.94	Wr = 123.4	Wr = 224.9	Wr = 258.05	Wr = 304.99	Wr = 841.43
Wt f Tur.Runner = 9.00	Wtr = 11.00	Wtr = 18.00	Wtr = 22.00	Wtr = 24.00	Wtr = 76.00
Wt of rot.parts = 63.94	Wtr = 134.4	Wtr = 242.9	Wtr = 280.05	Wtr = 328.99	Wtr = 917.4
Ht load bear Bra.= 1.60	Ht = 1.64	Ht = 1.74	Ht = 1.77	Ht = 2.10	Ht = 2.71
H1 = 5.13	H1 = 5.63	H1 = 6.63	H1 = 7.14	H1 = 7.64	H1 = 11.14
H2 = 9.70	H2 = 10.22	H2 = 10.62	H2 = 11.04	H2 = 11.68	H2 = 14.09
Unit bay Dimensions	*Unit bay Dimensions*	*Unit bay Dimensions*	*Unit bay Dimensions*	*Unit bay Dimensions*	*Unit bay Dimensions*
Length Unit bay = 11.86	Length Unit bay = 12.75	Length Unit bay = 14.67	Length Unit bay = 15.66	Length Unit bay = 16.64	Length Unit bay = 23.40
Width Unit bay = 13.86	Width Unit bay = 14.75	Width Unit bay = 16.67	Width Unit bay = 17.66	Width Unit bay = 18.64	Width Unit bay = 25.40
Height unit bay = 24.33	Height unit bay = 25.35	Height unit bay = 26.74	Height unit bay = 27.68	Height unit bay = 28.82	Height unit bay = 34.72

Table 4.4

For 500 m head and different capacities (pelton).

Here Pt is in kw

Considering the efficiency of turbine 90% and Generator 96%.

20 MW	40 MW	60 MW	80 MW	100 MW	250 MW
Trail N_{sj} = 85.49/$(H)^{243}$	Trail N_{sj} = 85.49/$(H)^{243}$	Trail N_{sj} = 85.49/$(H)^{243}$	Trail N_{sj} = 85.49/$(H)^{243}$	Trail N_{sj} = 85.49/$(H)^{243}$	Trail N_{sj} = 85.49/$(H)^{243}$
$(H)^{243}$= 4.53	$(H)^{243}$= 4.53	$(H)^{243}$= 4.53	$(H)^{243}$= 4.53	$(H)^{243}$= 4.53	$(H)^{243}$= 4.53
$(H)^{1.25}$= 2364	$(H)^{1.25}$= 2364.4	$(H)^{1.25}$= 2364	$(H)^{1.25}$= 2364	$(H)^{1.25}$= 2364.4	$(H)^{1.25}$= 2364.4
$(P)^{0.5}$= 152.15	$(P)^{0.5}$= 215.17	$(P)^{0.5}$= 263.5	$(P)^{0.5}$= 304.3	$(P)^{0.5}$= 340.21	$(P)^{0.5}$= 537.91
For 6 jets $(P/j)^{0.5}$= 62.11	For 6 jets $(P/j)^{0.5}$= 87.84	For 6 jets $(P/j)^{0.5}$= 107.58	For 6 jets $(P/j)^{0.5}$= 124.23	For 6 jets $(P/j)^{0.5}$= 138.89	For 6 jets $(P/j)^{0.6}$= 219.60
For 4 jets $(P/j)^{0.5}$= 76.07	For 4 jets $(P/j)^{0.5}$= 107.58	For 4 jets $(P/j)^{0.5}$= 131.76	For 4 jets $(P/j)^{0.5}$= 152.15	For 4 jets $(P/j)^{0.5}$= 170.10	For 4 jets $(P/j)^{0.5}$= 268.96
Trial, N_{sj} = 18.88	Trial, N_{sj} = 18.88	Trial, N_{sj} = 18.88	Trial, N_{sj} = 18.88	Trial, N_{sj} = 18.88	Trial, N_{sj} = 18.88
Also, N_{sj} = $N(P/j)^{0.5}/H^{1.25}$	Also, N_{sj} = $N(P/j)^{0.5}/H^{1.25}$	Also, N_{sj} = $N(P/j)^{0.5}/H^{1.25}$	Also, N_{sj} = $N(P/j)^{0.5}/H^{1.25}$	Also, N_{sj} = $N(P/j)^{0.5}/H^{1.25}$	Also, N_{sj} = $N(P/j)^{0.5}/H^{1.25}$
for 6 jets	for 6 jets	for 6 jets	for 6 jets	for 6 jets	for 6 jets
Trial, N = 718.78	Trial, N = 508.25	Trial, N = 414.99	Trial, N = 359.39	Trial, N = 321.45	Trial, N = 203.30
poles, p= 8.35	poles, p= 11.81	poles, p= 14.46	poles, p= 16.69	poles, p= 18.67	poles, p= 29.51
Taking,P= 10	Taking,P= 12	Taking,P= 16	Taking,P= 18	Taking,P= 20	Taking,P 30
Actual,N= 600	Actual,N= 500	Actual,N= 375	Actual,N= 333.33	Actual,N= 300	Actual,N= 200
Actual,Nsj= 15.76	Actual,Nsj= 18.58	Actual,Nsj= 17.06	Actual,Nsj= 17.51	Actual,Nsj= 17.62	Actual,Nsj= 18.58
for 4jets	for 4jets	for 4jets	for 4jets	for 4jets	for 4jets
Trial, N = 586.88	Trial, N = 414.99	Trial, N = 338.8	Trial, N = 293.44	Trial, N = 262.46	Trial, N = 165.99
poles, p= 10.22	poles, p= 14.46	poles, p= 17.71	poles, p= 20.45	poles, p= 22.86	poles, p= 36.15
Taking,P= 12	Taking,P= 16	Taking,P= 18	Taking,P= 22	Taking,P= 24	Taking,P= 38
Actual,N= 500.00	Actual,N= 375.00	Actual,N= 333.3	Actual,N= 272.73	Actual,N= 250	Actual,N= 157.89
Actual,Nsj= 16.09	Actual,Nsj= 17.06	Actual,Nsj= 18.58	Actual,Nsj= 17.55	Actual,Nsj= 17.99	Actual,Nsj= 17.96
Main parameters of Turbine	***Main parameters of Turbine***	***Main parameters of Turbine***	***Main parameters of Turbine***	***Main parameters of Turbine***	***Main parameters of Turbine***
Taking 4 Jets	**Taking 6 Jets**	**Taking 6 Jets**	**Taking 6 Jets**	**Taking 6 Jets**	**Taking 6 Jets**
N_{sj} = 16.09	N_{sj} = 18.58	N_{sj} = 17.06	N_{sj} = 17.51	N_{sj} = 17.62	N_{sj} = 18.58
N = 500	N = 500	N = 375	N = 333.33	N = 300	N = 200
Ns = 39.41	Ns = 45.51	Ns = 41.79	Ns = 42.89	Ns = 43.16	Ns = 45.51
Ku = 0.4817	Ku = 0.4720	Ku = 0.4780	Ku = 0.4762	Ku = 0.4758	Ku = 0.4720
D2 = 1.82	D2 = 1.78	D2 = 2.41	D2 = 2.70	D2 = 3.00	D2 = 4.46
Dj/D2 = 0.0725	Dj/D2 = 0.0855	Dj/D2 = 0.0775	Dj/D2 = 0.0798	Dj/D2 = 0.0804	Dj/D2 = 0.0855
Dj = 0.13	Dj = 0.15	Dj = 0.19	Dj = 0.22	Dj = 0.24	Dj = 0.38
Q = 4.72	Q = 9.44	Q = 14.16	Q = 18.88	Q = 23.60	Q = 58.99
Hs = 1.89	Hs = 1.91	Hs = 1.95	Hs = 2.00	Hs = 2.05	Hs = 2.53
D3 = 2.27	D3 = 2.29	D3 = 3.04	D3 = 3.42	D3 = 3.80	D3 = 5.72
Casing L = 5.46	Casing L = 5.49	Casing, L = 7.04	Casing, L = 7.83	Casing, L = 8.62	Casing, L = 12.56
G = 1.05	G = 1.06	G = 1.34	G = 1.48	G = 1.63	G = 2.35
F = 4.97	F = 4.99	F = 6.09	F = 6.65	F = 7.21	F = 10.01
H = 3.42	H = 3.44	H = 4.23	H = 4.64	H = 5.04	H = 7.06

I = 3.30	I = 3.31	I = 3.88	I = 4.18	I = 4.47	I = 5.93
Spiral ,B = 4.39	Spiral , B = 4.41	Spiral , B = 5.48	Spiral, B = 6.03	Spiral, B = 6.57	Spiral, B = 9.31
case , C = 4.08	case, C = 4.10	case C = 5.15	case C = 5.69	case C = 6.22	case C = 8.90
D = 3.60	D = 3.63	D = 4.71	D = 5.26	D = 5.81	D = 8.57
E = 4.25	E = 4.28	E = 5.36	E = 5.91	E = 6.46	E = 9.22
D+E = 7.86	D+E = 7.90	D+E = 10.07	D+E = 11.17	D+E = 12.27	D+E = 17.80
B+C = 8.46	B+C = 8.50	B+C = 10.63	B+C = 11.72	B+C = 12.80	B+C = 18.22
Main parameters of Generator	*Main parameters of Gen.*	*Main parameters of Gen.*	*Main parameters of Gen.*	*Main parameters of Gen.*	*Main parameters of Gen.*
Air gap dia D_g = 3.55	D_g = 3.55	D_g = 4.38	D_g = 4.73	D_g = 5.19	D_g = 6.92
Out st core dia.D_o = 4.48	D_o = 4.48	D_o = 5.24	D_o = 5.55	D_o = 6.00	D_o = 7.65
St rame dia D_f = 5.68	D_f = 5.68	D_f = 6.44	D_f = 6.75	D_f = 7.20	D_f = 8.85
Inn dia Gen.Bar D_b = 7.48	D_b = 7.48	D_b = 8.24	D_b = 8.55	D_b = 9.00	D_b = 10.65
Core leng of st,L_c = 0.597	L_c = 1.19	L_c = 1.52	L_c = 1.92	L_c = 2.20	L_c = 4.64
length of st.fr L_f = 2.15	L_f = 2.74	L_f = 3.07	L_f = 3.47	L_f = 3.75	L_f = 6.19
Outer bar dia.D = 8.48	D = 8.48	D = 9.24	D = 9.55	D = 10.00	D = 11.65
Wt of Gen.Rot Wr = 53.73	Wr = 107.5	Wr = 182.3	Wr = 231.0	Wr = 308.7	Wr = 835.9
Wt f Tur.Runner = 9.00	Wtr = 9.50	Wtr = 16.00	Wtr = 18.00	Wtr = 22.00	Wtr = 56.00
Wt of rot.parts = 62.73	Wtr = 116.95	Wtr = 198.3	Wtr = 249.0	Wtr = 330.7	Wtr = 891.9
Ht load bear Bra.= 1.55	Ht = 1.55	Ht = 1.65	Ht = 1.69	Ht = 2.01	Ht = 2.53
H1 = 4.97	H1 = 4.99	H1 = 6.09	H1 = 6.65	H1 = 7.21	H1 = 10.01
H2 = 9.70	H2 = 10.29	H2 = 10.72	H2 = 11.16	H2 = 11.77	H2 = 14.72
Unit bay Dimensions	*Unit bay Dimensions*	*Unit bay Dimensions*	*Unit bay Dimensions*	*Unit bay Dimensions*	*Unit bay Dimensions*
Length Unit bay = 11.48	Length Unit bay = 11.50	Length Unit bay = 13.63	Length Unit bay = 14.72	Length Unit bay = 15.80	Length Unit bay = 21.22
Width Unit bay = 13.48	Width Unit bay = 13.50	Width Unit bay = 15.63	Width Unit bay = 16.72	Width Unit bay = 17.80	Width Unit bay = 23.22
Height unit bay = 24.16	Height unit bay = 24.78	Height unit bay = 26.31	Height unit bay = 27.31	Height unit bay = 28.48	Height unit bay = 34.23

Table 4.5

For 600 m head and different capacities (Pelton).

Here Pt is in kw

Considering the efficiency of turbine 90% and Generator 96%.

20 MW	40 MW	60 MW	80 MW	100 MW	250 MW
Trail N_{sj} = $85.49/(H)^{243}$	Trail N_{sj} = $85.49/(H)^{243}$	Trail N_{sj} = $85.49/(H)^{243}$	Trail N_{sj} = $85.49/(H)^{243}$	Trail N_{sj} = $85.49/(H)^{243}$	Trail N_{sj} = $85.49/(H)^{243}$
$(H)^{243}$ = 4.73	$(H)^{243}$ = 4.73	$(H)^{243}$ = 4.73	$(H)^{243}$ = 4.73	$(H)^{243}$ = 4.73	$(H)^{243}$ = 4.73
$(H)^{1.25}$ = 2970	$(H)^{1.25}$ = 2970	$(H)^{1.25}$ = 2970	$(H)^{1.25}$ = 2969.5	$(H)^{1.25}$ = 2969.5	$(H)^{1.25}$ = 2969.5
$(P)^{0.5}$ = 152.15	$(P)^{0.5}$ = 215.17	$(P)^{0.5}$ = 263.5	$(P)^{0.5}$ = 304.29	$(P)^{0.5}$ = 340.21	$(P)^{0.5}$ = 537.91
For 6 jets $(P/j)^{0.5}$ = 62.11	For 6 jets $(P/j)^{0.5}$ = 87.84	For 6 jets $(P/j)^{0.5}$ = 107.58	For 6 jets $(P/j)^{0.5}$ = 124.23	For 6 jets $(P/j)^{0.5}$ = 138.89	For 6 jets $(P/j)^{0.5}$ = 219.60
For 4 jets $(P/j)^{0.5}$ = 76.07	For 4 jets $(P/j)^{0.5}$ = 107.58	For 4 jets $(P/j)^{0.5}$ = 131.76	For 4 jets $(P/j)^{0.5}$ = 152.15	For 4 jets $(P/j)^{0.5}$ = 170.10	For 4 jets $(P/j)^{0.5}$ = 268.96
Trial, N_{sj} = 18.06	Trial, N_{sj} = 18.06	Trial, N_{sj} = 18.06	Trial, N_{sj} = 18.06	Trial, N_{sj} = 18.06	Trial, N_{sj} = 18.06
Also, N_{sj} = $N(P/j)^{0.5}/H^{1.25}$	Also, N_{sj} = $N(P/j)^{0.5}/H^{1.25}$	Also, N_{sj} = $N(P/j)^{0.5}/H^{1.25}$	Also, N_{sj} = $N(P/j)^{0.5}/H^{1.25}$	Also, N_{sj} = $N(P/j)^{0.5}/H^{1.25}$	Also, N_{sj} = $N(P/j)^{0.5}/H^{1.25}$
for 6 jets	for 6 jets	for 6 jets	for 6 jets	for 6 jets	for 6 jets
Trial, N = 863.64	Trial, N = 610.68	Trial, N = 498.62	Trial, N = 431.82	Trial, N = 386.23	Trial, N = 244.27
poles, p= 6.95	poles, p= 9.83	poles, p= 12.03	poles, p= 13.89	poles, p= 15.53	poles, p= 24.56
Taking,P= 8	Taking,P= 10	Taking,P= 12	Taking,P= 14	Taking,P= 16	Taking,P 26
Actual,N= 750	Actual,N= 600	Actual,N= 500.00	Actual,N= 428.57	Actual,N= 375	Actual,N= 230.77
Actual,Nsj= 15.69	Actual,Nsj= 17.75	Actual,Nsj= 18.11	Actual,Nsj= 17.93	Actual,Nsj= 17.54	Actual,Nsj= 17.07
for 4jets	for 4jets	for 4jets	for 4jets	for 4jets	for 4jets
Trial, N = 705.16	Trial, N = 498.62	Trial, N = 407.12	Trial, N = 352.58	Trial, N = 315.36	Trial, N = 199.45
poles, p= 8.51	poles, p= 12.03	poles, p= 14.74	poles, p= 17.02	poles, p= 19.03	poles, p= 30.08
Taking,P= 10	Taking,P= 14	Taking,P= 16	Taking,P= 18	Taking,P= 20	Taking,P= 32
Actual,N= 600.00	Actual,N= 428.57	Actual,N= 375.00	Actual,N= 333.33	Actual,N= 300	Actual,N= 187.5
Actual,Nsj= 15.37	Actual,Nsj= 15.53	Actual,Nsj= 16.64	Actual,Nsj= 17.08	Actual,Nsj= 17.18	Actual,Nsj= 16.98
Main parameters of Turbine	***Main parameters of Turbine***	***Main parameters of Turbine***	***Main parameters of Turbine***	***Main parameters of Turbine***	***Main parameters of Turbine***
Taking 6 Jets	**Taking 6 Jets**	**Taking 6 Jets**	**Taking 6 Jets**	**Taking 6 Jets**	**Taking 6 Jets**
N_{sj} = 15.69	N_{sj} = 17.75	N_{sj} = 18.11	N_{sj} = 17.93	N_{sj} = 17.54	N_{sj} = 17.07
N = 750	N = 600	N = 500	N = 428.57	N = 375	N = 230.77
Ns = 38.43	Ns = 43.48	Ns = 44.36	Ns = 43.92	Ns = 42.96	Ns = 41.81
Ku = 0.4833	Ku = 0.4753	Ku = 0.4739	Ku = 0.4746	Ku = 0.4761	Ku = 0.4779
D2 = 1.33	D2 = 1.64	D2 = 1.96	D2 = 2.29	D2 = 2.63	D2 = 4.29
Dj/D2 = 0.0705	Dj/D2 = 0.0811	Dj/D2 = 0.0830	Dj/D2 = 0.0820	Dj/D2 = 0.0800	Dj/D2 = 0.0776
Dj = 0.09	Dj = 0.13	Dj = 0.16	Dj = 0.19	Dj = 0.21	Dj = 0.33
Q = 3.93	Q = 7.87	Q = 11.80	Q = 15.73	Q = 19.66	Q = 49.16
Hs = 1.88	Hs = 1.90	Hs = 1.92	Hs = 1.95	Hs = 1.99	Hs = 2.35
D3 = 1.66	D3 = 2.08	D3 = 2.50	D3 = 2.92	D3 = 3.33	D3 = 5.41
Casing L = 4.20	Casing L = 5.07	Casing, L = 5.94	Casing, L = 6.79	Casing, L = 7.65	Casing, L = 11.92
G = 0.82	G = 0.98	G = 1.14	G = 1.29	G = 1.45	G = 2.23
F = 4.07	F = 4.69	F = 5.31	F = 5.91	F = 6.52	F = 9.56
H = 2.77	H = 3.22	H = 3.67	H = 4.11	H = 4.54	H = 6.74

I = 2.83	I = 3.16	I = 3.48	I = 3.79	I = 4.11	I = 5.69
Spiral ,B = 3.51	Spiral , B = 4.12	Spiral , B = 4.72	Spiral, B = 5.31	Spiral, B = 5.90	Spiral, B = 8.87
case , C = 3.21	case, C = 3.81	case C = 4.40	case C = 4.98	case C = 5.56	case C = 8.47
D = 2.72	D = 3.33	D = 3.94	D = 4.54	D = 5.13	D = 8.13
E = 3.37	E = 3.98	E = 4.59	E = 5.19	E = 5.78	E = 8.78
D+E = 6.08	D+E = 7.31	D+E = 8.52	D+E = 9.72	D+E = 10.91	D+E = 16.90
B+C = 6.72	B+C = 7.93	B+C = 9.11	B+C = 10.29	B+C = 11.46	B+C = 17.34
Main parameters of Generator	*Main parameters of Generator*	*Main parameters of Generator*	*Main parameters of Generator*	*Main parameters of Generator*	*Main parameters of Generator*
Air gap dia D_g = 2.55	D_g = 3.07	D_g = 3.44	D_g = 3.97	D_g = 4.38	D_g = 6.12
Out st core dia.D_o = 3.55	D_o = 4.04	D_o = 4.34	D_o = 4.86	D_o = 5.24	D_o = 6.86
St rame dia D_f = 4.75	D_f = 5.24	D_f = 5.54	D_f = 6.06	D_f = 6.44	D_f = 8.06
Inn dia Gen.Bar D_b = 6.55	D_b = 7.04	D_b = 7.34	D_b = 7.86	D_b = 8.24	D_b = 9.86
Core leng of st,L_c = 0.8016	L_c = 1.35	L_c = 1.91	L_c = 2.20	L_c = 2.53	L_c = 4.98
length of st.fr L_f = 2.35	L_f = 2.90	L_f = 3.46	L_f = 3.75	L_f = 4.08	L_f = 6.53
Outer bar dia.D = 7.55	D = 8.04	D = 8.34	D = 8.86	D = 9.24	D = 10.86
Wt of Gen.Rot Wr = 56.11	Wr = 108.29	Wr = 162.5	Wr = 197.8	Wr = 278.5	Wr = 845.87
Wt f Tur.Runner = 5.00	Wtr = 8.00	Wtr = 10.00	Wtr = 13.00	Wtr = 17.00	Wtr = 42.00
Wt of rot.parts = 61.11	Wtr = 116.29	Wtr = 172.5	Wtr = 210.8	Wtr = 295.5	Wtr = 887.9
Ht load bear Bra.= 1.42	Ht = 1.49	Ht = 1.53	Ht = 1.60	Ht = 1.65	Ht = 2.41
H1 = 4.07	H1 = 4.69	H1 = 5.31	H1 = 5.91	H1 = 6.52	H1 = 9.56
H2 = 9.77	H2 = 10.39	H2 = 10.99	H2 = 11.35	H2 = 11.73	H2 = 14.94
Unit bay Dimensions	*Unit bay Dimensions*	*Unit bay Dimensions*	*Unit bay Dimensions*	*Unit bay Dimensions*	*Unit bay Dimensions*
Length Unit bay = 10.55	Length Unit bay = 11.04	Length Unit bay = 12.11	Length Unit bay = 13.29	Length Unit bay = 14.46	Length Unit bay = 20.34
Width Unit bay = 12.55	Width Unit bay = 13.04	Width Unit bay = 14.11	Width Unit bay = 15.29	Width Unit bay = 16.46	Width Unit bay = 22.34
Height unit bay = 23.34	Height unit bay = 24.58	Height unit bay = 25.80	Height unit bay = 26.76	Height unit bay = 27.75	Height unit bay = 33.99

Table 4.6

For 700 m head and different capacities (Pelton).

Here Pt is in kw

Considering the efficiency of turbine 90% and Generator 96%.

20 MW	40 MW	60 MW	80 MW	100 MW	250 MW
Trail N_{sj} = $85.49/(H)^{243}$	Trail N_{sj} = $85.49/(H)^{243}$	Trail N_{sj} = $85.49/(H)^{243}$	Trail N_{sj} = $85.49/(H)^{243}$	Trail N_{sj} = $85.49/(H)^{243}$	Trail N_{sj} = $85.49/(H)^{243}$
$(H)^{243}$= 4.91	$(H)^{243}$= 4.91	$(H)^{243}$= 4.91	$(H)^{243}$= 4.91	$(H)^{243}$= 4.91	$(H)^{243}$= 4.91
$(H)^{1.25}$= 3600.6	$(H)^{1.25}$= 3601	$(H)^{1.25}$= 3601	$(H)^{1.25}$= 3601	$(H)^{1.25}$= 3601	$(H)^{1.25}$= 3601
$(P)^{0.5}$= 152.15	$(P)^{0.5}$= 215.17	$(P)^{0.5}$= 263.5	$(P)^{0.5}$= 304.3	$(P)^{0.5}$= 340.2	$(P)^{0.5}$= 537.91
For 6 jets $(P/j)^{0.5}$= 62,11	For 6 jets $(P/j)^{0.5}$= 87.84	For 6 jets $(P/j)^{0.5}$= 107.6	For 6 jets $(P/j)^{0.5}$= 124.23	For 6 jets $(P/j)^{0.5}$= 138.9	For 6 jets $(P/j)^{0.5}$= 219.60
For 4 jets $(P/j)^{0.5}$= 76.07	For 4 jets $(P/j)^{0.5}$= 107.58	For 4 jets $(P/j)^{0.5}$= 131.76	For 4 jets $(P/j)^{0.5}$= 152.15	For 4 jets $(P/j)^{0.5}$= 170.10	For 4 jets $(P/j)^{0.5}$= 269.0
Trial, N_{sj} = 17.40	Trial, N_{sj} = 17.40	Trial, N_{sj} = 17.40	Trial, N_{sj} = 17.40	Trial, N_{sj} = 17.40	Trial, N_{sj} = 17.40
Also, N_{sj} = $N(P/j)^{0.5}/H^{1.25}$	Also, N_{sj} = $N(P/j)^{0.5}/H^{1.25}$	Also, N_{sj} = $N(P/j)^{0.5}/H^{1.25}$	Also, N_{sj} = $N(P/j)^{0.5}/H^{1.25}$	Also, N_{sj} = $N(P/j)^{0.5}/H^{1.25}$	Also, N_{sj} = $N(P/j)^{0.5}/H^{1.25}$
for 6 jets	for 6 jets	for 6 jets	for 6 jets	for 6 jets	for 6 jets
Trial, N = 1008.66	Trial, N = 713.23	Trial, N = 582.35	Trial, N = 504.33	Trial, N = 451.09	Trial, N = 285.29
poles, p= 5.95	poles, p= 8.41	poles, p= 10.30	poles, p= 11.90	poles, p= 13.30	poles, p= 21.03
Taking,P= 6	Taking,P= 10	Taking,P= 10	Taking,P= 12	Taking,P= 14	Taking,P= 22
Actual,N= 1000	Actual,N= 600	Actual,N= 600.00	Actual,N= 500.00	Actual,N= 428.57	Actual,N= 272.73
Actual,Nsj= 17.25	Actual,Nsj= 14.64	Actual,Nsj= 17.93	Actual,Nsj= 17.25	Actual,Nsj= 16.53	Actual,Nsj= 16.63
for 4jets	for 4jets	for 4jets	for 4jets	for 4jets	for 4jets
Trial, N = 823.57	Trial, N = 582.35	Trial, N = 475.49	Trial, N = 411.79	Trial, N = 368.31	Trial, N = 232.94
poles, p= 7.29	poles, p= 10.30	poles, p= 12.62	poles, p= 14.57	poles, p= 16.29	poles, p= 25.76
Taking,P= 8	Taking,P= 12	Taking,P= 14	Taking,P= 16	Taking,P= 18	Taking,P= 26
Actual,N= 750.00	Actual,N= 500.00	Actual,N= 428.57	Actual,N= 375.00	Actual,N= 333.33	Actual,N= 230.769
Actual,Nsj= 15.85	Actual,Nsj= 14.94	Actual,Nsj= 15.68	Actual,Nsj= 15.85	Actual,Nsj= 15.75	Actual,Nsj= 17.24
Main parameters of Turbine	***Main parameters of Turbine***	***Main parameters of Turbine***	***Main parameters of Turbine***	***Main parameters of Turbine***	***Main parameters of Turbine***
Taking 6 Jets	Taking 6 Jets	Taking 6 Jets	Taking 6 Jets	Taking 6 Jets	Taking 6 Jets
N_{sj} = 17.25	N_{sj} = 14.64	N_{sj} = 17.93	N_{sj} = 17.25	N_{sj} = 16.53	N_{sj} = 16.63
N = 1000	N = 600	N = 600	N = 500	N = 428.57	N = 272.73
Ns = 42.25	Ns = 35.86	Ns = 43.92	Ns = 42.25	Ns = 40.49	Ns = 40.74
Ku = 0.4772	Ku = 0.4874	Ku = 0.4746	Ku = 0.4772	Ku = 0.4800	Ku = 0.4796
D2 = 1.07	D2 = 1.82	D2 = 1.77	D2 = 2.13	D2 = 2.50	D2 = 3.93
Dj/D2 = 0.0785	Dj/D2 = 0.0652	Dj/D2 = 0.0820	Dj/D2 = 0.0785	Dj/D2 = 0.0748	Dj/D2 = 0.0753
Dj = 0.08	Dj = 0.12	Dj = 0.15	Dj = 0.17	Dj = 0.19	Dj = 0.30
Q = 3.37	Q = 6.74	Q = 10.11	Q = 13.48	Q = 16.85	Q = 42.14
Hs = 1.88	Hs = 1.90	Hs = 1.91	Hs = 1.93	Hs = 1.96	Hs = 2.22
D3 = 1.35	D3 = 1.98	D3 = 2.25	D3 = 2.70	D3 = 3.14	D3 = 4.94
Casing L = 3.56	Casing L = 4.86	Casing, L = 5.42	Casing, L = 6.34	Casing, L = 7.25	Casing, L = 10.95
G = 0.70	G = 0.94	G = 1.04	G = 1.21	G = 1.38	G = 2.05
F = 3.62	F = 4.54	F = 4.94	F = 5.59	F = 6.24	F = 8.87
H = 2.45	H = 3.11	H = 3.40	H = 3.87	H = 4.34	H = 6.24

l = 2.60	l = 3.08	l = 3.29	l = 3.62	l = 3.96	l = 5.33
Spiral ,B = 3.06	Spiral , B = 3.97	Spiral , B = 4.36	Spiral, B = 4.99	Spiral, B = 5.63	Spiral, B = 8.20
case , C = 2.78	case, C = 3.67	case C = 4.05	case C = 4.67	case C = 5.29	case C = 7.81
D = 2.27	D = 3.18	D = 3.57	D = 4.22	D = 4.86	D = 7.45
E = 2.92	E = 3.83	E = 4.22	E = 4.87	E = 5.51	E = 8.10
D+E = 5.19	D+E = 7.01	D+E = 7.80	D+E = 9.08	D+E = 10.36	D+E = 15.54
B+C = 5.85	B+C = 7.63	B+C = 8.40	B+C = 9.66	B+C = 10.92	B+C = 16.00
Main parameters of Generator	*Main parameters of Generator*	*Main parameters of Generator*	*Main parameters of Generator*	*Main parameters of Generator*	*Main parameters of Generator*
Air gap dia D_g = 2.01	D_g = 2.96	D_g = 3.09	D_g = 3.44	D_g = 3.97	D_g = 5.46
Out st core dia.D_o = 3.06	D_o = 3.89	D_o = 4.06	D_o = 4.34	D_o = 4.86	D_o = 6.24
St rame dia D_f = 4.26	D_f = 5.09	D_f = 5.26	D_f = 5.54	D_f = 6.06	D_f = 7.44
Inn dia Gen.Bar D_b = 6.06	D_b = 6.89	D_b = 7.06	D_b = 7.34	D_b = 7.86	D_b = 9.24
Core leng of st,L_c = 1.005	L_c = 1.46	L_c = 1.98	L_c = 2.55	L_c = 2.75	L_c = 5.38
length of st.fr L_f = 2.55	L_f = 3.01	L_f = 3.53	L_f = 4.10	L_f = 4.30	L_f = 6.93
Outer bar dia.D = 7.06	D = 7.89	D = 8.06	D = 8.34	D = 8.86	D = 10.24
Wt of Gen.Rot Wr = 40.19	Wr = 102.0	Wr = 167.9	Wr = 216.7	Wr = 274.7	Wr = 752.7
Wt f Tur.Runner = 4.00	Wtr = 8.00	Wtr = 10.00	Wtr = 12.00	Wtr = 15.00	Wtr = 40.00
Wt of rot.parts = 44.19	Wtr = 110.0	Wtr = 177.9	Wtr = 228.7	Wtr = 289.7	Wtr = 792.7
Ht load bear Bra.= 1.34	Ht = 1.47	Ht = 1.49	Ht = 1.53	Ht = 1.60	Ht = 2.32
H1 = 3.62	H1 = 4.54	H1 = 4.94	H1 = 5.59	H1 = 6.24	H1 = 8.87
H2 = 9.90	H2 = 10.47	H2 = 11.02	H2 = 11.63	H2 = 11.90	H2 = 15.24
Unit bay Dimensions	*Unit bay Dimensions*	*Unit bay Dimensions*	*Unit bay Dimensions*	*Unit bay Dimensions*	*Unit bay Dimensions*
Length Unit bay = 10.06	Length Unit bay = 9.97	Length Unit bay = 11.40	Length Unit bay = 12.66	Length Unit bay = 13.92	Length Unit bay = 19.00
Width Unit bay = 12.06	Width Unit bay = 11.97	Width Unit bay = 13.40	Width Unit bay = 14.66	Width Unit bay = 15.92	Width Unit bay = 21.00
Height unit bay = 23.01	Height unit bay = 24.51	Height unit bay = 25.45	Height unit bay = 26.72	Height unit bay = 27.63	Height unit bay = 33.61

Table 4.7

For 800 m head and different capacities (Pelton).

Here Pt is in kw

Considering the efficiency of turbine 90% and Generator 96%.

20 MW	40 MW	60 MW	80 MW	100 MW	250 MW
Trail N_{sj} = 85.49/$(H)^{243}$	Trail N_{sj} = 85.49/$(H)^{243}$	Trail N_{sj} = 85.49/$(H)^{243}$	Trail N_{sj} = 85.49/$(H)^{243}$	Trail N_{sj} = 85.49/$(H)^{243}$	Trail N_{sj} = 85.49/$(H)^{243}$
$(H)^{243}$ = 5.08	$(H)^{243}$ = 5.08	$(H)^{243}$ = 5.08	$(H)^{243}$ = 5.08	$(H)^{243}$ = 5.08	$(H)^{243}$ = 5.08
$(H)^{1.25}$ = 4254.6	$(H)^{1.25}$ = 4255	$(H)^{1.25}$ = 4255	$(H)^{1.25}$ = 4255	$(H)^{1.25}$ = 4255	$(H)^{1.25}$ = 4255
$(P)^{0.5}$ = 152.15	$(P)^{0.5}$ = 215.17	$(P)^{0.5}$ = 263.5	$(P)^{0.5}$ = 304.3	$(P)^{0.5}$ = 340.2	$(P)^{0.5}$ = 537.91
For 6 jets $(P/j)^{0.5}$ = 62.11	For 6 jets $(P/j)^{0.5}$ = 87.84	For 6 jets $(P/j)^{0.5}$ = 107.6	For 6 jets $(P/j)^{0.5}$ = 124.23	For 6 jets $(P/j)^{0.5}$ = 138.9	For 6 jets $(P/j)^{0.5}$ = 219.60
For 4 jets $(P/j)^{0.5}$ = 76.07	For 4 jets $(P/j)^{0.5}$ = 107.58	For 4 jets $(P/j)^{0.5}$ = 131.76	For 4 jets $(P/j)^{0.5}$ = 152.15	For 4 jets $(P/j)^{0.5}$ = 170.10	For 4 jets $(P/j)^{0.5}$ = 269.0
Trial, N_{sj} = 16.84	Trial, N_{sj} = 16.84	Trial, N_{sj} = 16.84	Trial, N_{sj} = 16.84	Trial, N_{sj} = 16.84	Trial, N_{sj} = 16.84
Also, N_{sj} = $N(P/j)^{0.5}/H^{1.25}$	Also, N_{sj} = $N(P/j)^{0.5}/H^{1.25}$	Also, N_{sj} = $N(P/j)^{0.5}/H^{1.25}$	Also, N_{sj} = $N(P/j)^{0.5}/H^{1.25}$	Also, N_{sj} = $N(P/j)^{0.5}/H^{1.25}$	Also, N_{sj} = $N(P/j)^{0.5}/H^{1.25}$
for 6 jets	for 6 jets	for 6 jets	for 6 jets	for 6 jets	for 6 jets
Trial, N = 1153.84	Trial, N = 815.89	Trial, N = 666.17	Trial, N = 576.92	Trial, N = 516.01	Trial, N = 326.35
poles, p= 5.20	poles, p= 7.35	poles, p= 9.01	poles, p= 10.40	poles, p= 11.63	poles, p= 18.38
Taking,P= 6	Taking,P= 8	Taking,P= 10	Taking,P= 10	Taking,P= 12	Taking,P= 20
Actual,N= 1000	Actual,N= 750	Actual,N= 600.00	Actual,N= 600.00	Actual,N= 500.00	Actual,N= 300.00
Actual,Nsj= 14.60	Actual,Nsj= 15.48	Actual,Nsj= 15.17	Actual,Nsj= 17.52	Actual,Nsj= 16.32	Actual,Nsj= 15.48
for 4jets	for 4jets	for 4jets	for 4jets	for 4jets	for 4jets
Trial, N = 942.10	Trial, N = 666.17	Trial, N = 543.92	Trial, N = 471.05	Trial, N = 421.32	Trial, N = 266.47
poles, p= 6.37	poles, p= 9.01	poles, p= 11.03	poles, p= 12.74	poles, p= 14.24	poles, p= 22.52
Taking,P= 8	Taking,P= 10	Taking,P= 12	Taking,P= 14	Taking,P= 16	Taking,P= 24
Actual,N= 750.00	Actual,N= 600.00	Actual,N= 500.00	Actual,N= 428.57	Actual,N= 375.00	Actual,N= 250
Actual,Nsj= 13.41	Actual,Nsj= 15.17	Actual,Nsj= 15.48	Actual,Nsj= 15.33	Actual,Nsj= 14.99	Actual,Nsj= 15.80
Main parameters of Turbine	***Main parameters of Turbine***	***Main parameters of Turbine***	***Main parameters of Turbine***	***Main parameters of Turbine***	***Main parameters of Turbine***
Taking 6 Jets	Taking 6 Jets	Taking 6 Jets	Taking 6 Jets	Taking 6 Jets	Taking 6 Jets
N_{sj} = 14.60	N_{sj} = 15.48	N_{sj} = 15.17	N_{sj} = 17.52	N_{sj} = 16.32	N_{sj} = 15.48
N = 1000	N = 750	N = 600	N = 600	N = 500	N = 300
Ns = 35.76	Ns = 37.92	Ns = 37.16	Ns = 42.92	Ns = 39.98	Ns = 37.92
Ku = 0.4876	Ku = 0.4841	Ku = 0.4853	Ku = 0.4762	Ku = 0.4809	Ku = 0.4841
D2 = 1.17	D2 = 1.54	D2 = 1.93	D2 = 1.90	D2 = 2.30	D2 = 3.86
Dj/D2 = 0.0650	Dj/D2 = 0.0694	Dj/D2 = 0.0679	Dj/D2 = 0.0799	Dj/D2 = 0.0737	Dj/D2 = 0.0694
Dj = 0.08	Dj = 0.11	Dj = 0.13	Dj = 0.15	Dj = 0.17	Dj = 0.27
Q = 2.95	Q = 5.90	Q = 8.85	Q = 11.80	Q = 14.75	Q = 36.87
Hs = 1.88	Hs = 1.89	Hs = 1.90	Hs = 1.91	Hs = 1.94	Hs = 2.15
D3 = 1.29	D3 = 1.91	D3 = 2.19	D3 = 2.41	D3 = 2.88	D3 = 4.78
Casing L = 3.44	Casing L = 4.72	Casing, L = 5.29	Casing, L = 5.73	Casing, L = 6.71	Casing, L = 10.63
G = 0.68	G = 0.92	G = 1.02	G = 1.10	G = 1.28	G = 1.99
F = 3.53	F = 4.44	F = 4.85	F = 5.16	F = 5.85	F = 8.64
H = 2.38	H = 3.04	H = 3.33	H = 3.56	H = 4.06	H = 6.07

l = 2.55	l = 3.03	l = 3.24	l = 3.40	l = 3.76	l = 5.21
Spiral ,B = 2.98	Spiral , B = 3.87	Spiral , B = 4.27	Spiral, B = 4.57	Spiral, B = 5.25	Spiral, B = 7.97
case , C = 2.70	case, C = 3.57	case C = 3.96	case C = 4.26	case C = 4.92	case C = 7.59
D = 2.19	D = 3.09	D = 3.48	D = 3.80	D = 4.48	D = 7.22
E = 2.84	E = 3.73	E = 4.13	E = 4.44	E = 5.12	E = 7.87
D+E = 5.02	D+E = 6.82	D+E = 7.62	D+E = 8.24	D+E = 9.60	D+E = 15.10
B+C = 5.68	B+C = 7.44	B+C = 8.23	B+C = 8.84	B+C = 10.17	B+C = 15.57
Main parameters of Generator	*Main parameters of Generator*	*Main parameters of Generator*	*Main parameters of Generator*	*Main parameters of Generator*	*Main parameters of Generator*
Air gap dia D_g = 2.01	D_g = 2.55	D_g = 3.07	D_g = 3.09	D_g = 3.55	D_g = 5.19
Out st core dia.D_o = 3.06	D_o = 3.55	D_o = 4.04	D_o = 4.06	D_o = 4.48	D_o = 6.00
St rame dia D_f = 4.26	D_f = 4.75	D_f = 5.24	D_f = 5.26	D_f = 5.68	D_f = 7.20
Inn dia Gen.Bar D_b = 6.06	D_b = 6.55	D_b = 7.04	D_b = 7.06	D_b = 7.48	D_b = 9.00
Core leng of st,L_c = 1.005	L_c = 1.60	L_c = 2.03	L_c = 2.68	L_c = 2.98	L_c = 5.51
length of st.fr L_f = 2.55	L_f = 3.15	L_f = 3.58	L_f = 4.23	L_f = 4.53	L_f = 7.06
Outer bar dia.D = 7.06	D = 7.55	D = 8.04	D = 8.06	D = 8.48	D = 10.00
Wt of Gen.Rot Wr = 40.19	Wr = 96.2	Wr = 142.1	Wr = 187.6	Wr = 253.7	Wr = 771.7
Wt f Tur.Runner = 4.00	Wtr = 5.00	Wtr = 10.00	Wtr = 12.00	Wtr = 15.00	Wtr = 38.00
Wt of rot.parts = 44.19	Wtr = 101.2	Wtr = 152.1	Wtr = 199.6	Wtr = 268.7	Wtr = 809.7
Ht load bear Bra.= 1.34	Ht = 1.42	Ht = 1.49	Ht = 1.49	Ht = 1.55	Ht = 2.28
H1 = 3.53	H1 = 4.44	H1 = 4.85	H1 = 5.16	H1 = 5.85	H1 = 8.64
H2 = 9.90	H2 = 10.57	H2 = 11.07	H2 = 11.72	H2 = 12.08	H2 = 15.34
Unit bay Dimensions	*Unit bay Dimensions*	*Unit bay Dimensions*	*Unit bay Dimensions*	*Unit bay Dimensions*	*Unit bay Dimensions*
Length Unit bay = 10.06	Length Unit bay = 9.71	Length Unit bay = 11.15	Length Unit bay = 11.64	Length Unit bay = 13.17	Length Unit bay = 18.57
Width Unit bay = 12.06	Width Unit bay = 11.71	Width Unit bay = 13.15	Width Unit bay = 13.84	Width Unit bay = 15.17	Width Unit bay = 20.57
Height unit bay = 22.93	Height unit bay = 24.51	Height unit bay = 25.41	Height unit bay = 26.38	Height unit bay = 27.44	Height unit bay = 33.48

Table 4.8

For 200 m head and different capacities.(Francis)

Here Pt is in kw

Considering the efficiency of turbine 90% and Generator 96%.

20 MW	40 MW	60 MW	80 MW	100 MW	250 MW
Trail $N_s = 3470/(H)^{.625}$	Trail $N_s = 3470/(H)^{.625}$	Trail $N_s = 3470/(H)^{.625}$	Trail $N_s = 3470/(H)^{.625}$	Trail $N_s = 3470/(H)^{.625}$	Trail $N_s = 3470/(H)^{.625}$
$(H)^{.625} = 27.42$	$(H)^{.625} = 27.42$	$(H)^{.625} = 27.42$	$(H)^{.625} = 27.42$	$(H)^{.625} = 27.42$	$(H)^{.625} = 27.42$
$(H)^{1.25} = 752.1$	$(H)^{1.25} = 752.1$	$(H)^{1.25} = 752.1$	$(H)^{1.25} = 752.12$	$(H)^{1.25} = 752.1$	$(H)^{1.25} = 752.1$
$(P)^{0.5} = 152.15$	$(P)^{0.5} = 215.17$	$(P)^{0.5} = 263.5$	$(P)^{0.5} = 304.3$	$(P)^{0.5} = 340.2$	$(P)^{0.5} = 537.9$
Trial, N_s = 126.53	Trial, N_s = 126.53	Trial, N_s = 126.53	Trial, N_s = 126.53	Trial, N_s = 126.53	Trial, N_s = 126.53
Also, $N_s = (N*P^{0.9})/H^{1.25}$	Also, $N_s = (N*P^{0.9})/H^{1.25}$	Also, $N_s = (N*P^{0.9})/H^{1.25}$	Also, $N_s = (N*P^{0.9})/H^{1.25}$	Also, $N_s = (N*P^{0.9})/H^{1.25}$	Also, $N_s = (N*P^{0.9})/H^{1.25}$
Trial, N = 625.48	Trial, N = 442.28	Trial, N = 361.12	Trial, N = 312.74	Trial, N = 279.72	Trial, N = 176.91
poles, p= 9.59	poles, p= 13.57	poles, p= 16.61	poles, p= 19.19	poles, p= 21.45	poles, p= 33.91
Taking,P= 10	Taking,P= 14	Taking,P= 18	Taking,P= 20	Taking,P= 22	Taking,P= 34
Actual,N= 600	Actual,N= 428.57	Actual,N= 333.33	Actual,N= 300	Actual,N= 272.73	Actual,N= 176.47
Actual,Ns= 121.37	Actual,Ns= 122.61	Actual,Ns= 116.79	Actual,Ns= 121.37	Actual,Ns= 123.36	Actual,Ns= 126.21
Main parameters of Turbine	***Main parameters of Turbine***	***Main parameters of Turbine***	***Main parameters of Turbine***	***Main parameters of Turbine***	***Main parameters of Turbine***
N_s = 121.37	N_s = 122.61	N_s = 116.79	N_s = 121.37	N_s = 123.36	N_s = 126.21
N = 600	N = 428.57	N = 333.33	N = 300	N = 272.73	N = 176.47
Ku (. 3) = 0.6134	Ku (. 3) = 0.6165	Ku (. 3) = 0.6020	Ku (. 3) = 0.6134	Ku (. 3) = 0.6184	Ku (. 3) = 0.6255
D3 = 2.12	D3 = 1.72	D3 = 2.16	D3 = 2.44	D3 = 2.71	D3 = 4.24
D1/D3 = 1.1786	D1/D3 = 1.1707	D1/D3 = 1.2091	D1/D3 = 1.1786	D1/D3 = 1.1661	D1/D3 = 1.1488
D1 = 2.49	D1 = 2.01	D1 = 2.61	D1 = 2.88	D1 = 3.16	D1 = 4.87
D2/D3 = 0.99	D2/D3 = 0.99	D2/D3 = 1.00	D2/D3 = 0.99	D2/D3 = 0.99	D2/D3 = 0.99
D2 = 2.10	D2 = 1.71	D2 = 2.15	D2 = 2.43	D2 = 2.69	D2 = 4.20
Q = 11.80	Q = 23.60	Q = 35.39	Q = 47.19	Q = 58.99	Q = 147.48
Spiral A = 2.20	Spiral A = 1.79	Spiral A = 2.23	Spiral A = 2.54	Spiral A = 2.82	Spiral A = 4.43
csing B = 3.29	csing B = 2.66	csing B = 3.39	csing B = 3.79	csing B = 4.19	csing B = 6.50
C = 3.65	C = 2.96	C = 3.76	C = 4.22	C = 4.66	C = 7.24
D = 4.03	D = 3.26	D = 4.14	D = 4.65	D = 5.14	D = 7.99
E = 3.18	E = 2.58	E = 3.29	E = 3.68	E = 4.05	E = 6.29
F = 4.41	F = 3.56	F = 4.59	F = 5.09	F = 5.60	F = 8.65
G = 3.57	G = 2.88	G = 3.70	G = 4.12	G = 4.53	G = 7.01
H = 3.10	H = 2.50	H = 3.22	H = 3.58	H = 3.94	H = 6.09
I = 0.38	I = 0.31	I = 0.38	I = 0.44	I = 0.49	I = 0.77
L = 1.99	L = 1.62	L = 2.02	L = 2.30	L = 2.55	L = 3.99
M = 1.27	M = 1.03	M = 1.30	M = 1.47	M = 1.63	M = 2.55
N = 6.81	N = 5.50	N = 7.08	N = 7.86	N = 8.64	N = 13.35
S = 12.19	S = 9.86	S = 12.65	S = 14.08	S = 15.50	S = 24.00
O = 4.21	O = 3.40	O = 4.39	O = 4.86	O = 5.34	O = 8.24
P = 2.76	P = 2.24	P = 2.82	P = 3.18	P = 3.52	P = 5.50
Q = 1.62	Q = 1.31	Q = 1.67	Q = 1.87	Q = 2.07	Q = 3.22
R = 3.39	R = 2.75	R = 3.45	R = 3.91	R = 4.34	R = 6.78
T = 3.22	T = 2.62	T = 3.29	T = 3.72	T = 4.13	T = 6.46

U = 0.90	U = 0.73	U = 0.92	U = 1.04	U = 1.15	U = 1.79
V = 3.26	V = 2.64	V = 3.37	V = 3.77	V = 4.16	V = 6.46
Z = 6.15	Z = 5.00	Z = 6.30	Z = 7.11	Z = 7.87	Z = 12.27
Width (2V+U) = 7.43	Width (2V+U) = 6.02	Width (2V+U) = 7.66	Width (2V+U) = 8.58	Width (2V+U) = 9.47	Width (2V+U) = 14.71
o = 0.07	o = 0.07	o = 0.06	o = 0.07	o = 0.07	o = 0.07
Hs = -3.66	Hs = -3.85	Hs = -2.97	Hs = -3.66	Hs = -3.97	Hs = -4.41
B+C+A/2 = 8.04	B+C+A/2 = 6.52	B+C+A/2 = 8.26	B+C+A/2 = 9.28	B+C+A/2 = 10.26	B+C+A/2 = 15.96
D+E = 7.21	D+E = 5.84	D+E = 7.43	D+E = 8.32	D+E = 9.19	D+E = 14.28
Main parameters of Generator	*Main parameters of Generator*	*Main parameters of Generator*	*Main parameters of Generator*	*Main parameters of Generator*	*Main parameters of Generator*
Air gap dia D_g= 3.07	D_g= 3.97	D_g= 4.73	D_g= 5.19	D_g= 5.46	D_g= 7.68
Out st core dia D_o= 4.04	D_o= 4.86	D_o= 5.55	D_o= 6.00	D_o= 6.24	D_o= 8.39
St.frame dia D_f = 5.24	D_f = 6.06	D_f = 6.75	D_f = 7.20	D_f = 7.44	D_f = 9.59
In dia Gen Bar D_b= 7.04	D_b= 7.86	D_b= 8.55	D_b= 9.00	D_b= 9.24	D_b= 11.39
Core leng of st L_c= 0.68	L_c= 1.10	L_c= 1.44	L_c= 1.76	L_c= 2.15	L_c= 3.98
Length of st fr L_f = 2.23	L_f = 2.65	L_f = 2.99	L_f = 3.31	L_f = 3.70	L_f = 5.53
Out bar diaD_{ob} = 8.04	D_{ob} = 8.86	D_{ob} = 9.55	D_{ob} = 10.00	D_{ob} = 10.24	D_{ob} = 12.39
Wt of Gen Rot Wr = 50.76	Wr = 107.7	Wr = 166.0	Wr = 238.1	Wr = 322.6	Wr = 795.8
Wt of Tu.Run = 10.00	Wtr = 7.00	Wtr = 10.00	Wtr = 16.00	Wtr = 18.00	Wtr = 38.00
Axial hyd Thr P_H = 69.83	P_H = 56.73	P_H = 71.22	P_H = 80.64	P_H = 89.42	P_H = 139.78
Wt. Of rot.parts = 130.6	Wtrp = 171.41	Wtrp = 247.2	Wtrp = 334.8	Wtrp = 430.0	Wtrp = 973.6
Ht of load br Bra= 1.49	Ht = 1.60	Ht = 1.69	Ht = 2.01	Ht = 2.05	Ht = 2.63
Dep of dra tube H = 5.82	H = 4.73	H = 5.93	H = 6.72	H = 7.45	H = 11.65
H_2= 9.71	H_2= 10.25	H_2= 10.68	H_2= 11.33	H_2= 11.75	H_2= 14.16
Unit bay Dimensions	***Unit bay Dimensions***	***Unit bay Dimensions***	***Unit bay Dimensions***	***Unit bay Dimensions***	***Unit bay Dimensions***
Length Unit bay = 11.04	Length Unit bay = 11.86	Length Unit bay = 12.55	Length Unit bay = 13.00	Length Unit bay = 13.26	Length Unit bay = 18.96
Width Unit bay = 13.04	Width Unit bay = 13.86	Width Unit bay = 14.55	Width Unit bay = 15.00	Width Unit bay = 15.26	Width Unit bay = 20.96
Height unit bay = 25.03	Height unit bay = 24.5	Height unit bay = 26.12	Height unit bay = 27.55	Height unit bay = 28.70	Height unit bay = 35.31

Table 4.9

For 300 m head and different capacities.(Francis)

Here Pt is in kw

Considering the efficiency of turbine 90% and Generator 96%.

	20 MW	40 MW	60 MW	80 MW	100 MW	250 MW
Trail N_s =	$3470/(H)^{.625}$	$3470/(H)^{.625}$	$3470/(H)^{.625}$	$3470/(H)^{.625}$	$3470/(H)^{.625}$	$3470/(H)^{.625}$
$(H)^{.625}$ =	35.33	35.33	35.33	35.33	35.33	35.33
$(H)^{1.25}$ =	1248.5	1249	1248.5	1248.5	1248.5	1249
$(P)^{0.5}$ =	152.15	215.17	263.52	304.3	340.21	537.9
Trial, N_s =	98.20	98.20	98.20	98.20	98.20	98.20
Also, N_s =	$(N{*}P^{0.5})/H^{1.25}$	$(N{*}P^{0.5})/H^{1.25}$	$(N{*}P^{0.5})/H^{1.25}$	$(N{*}P^{0.5})/H^{1.25}$	$(N{*}P^{0.5})/H^{1.25}$	$(N{*}P^{0.5})/H^{1.25}$
Trial, N =	805.88	569.85	465.28	402.94	360.40	227.94
poles, p=	7.45	10.53	12.90	14.89	16.65	26.32
Taking,P=	8	12	14	16	18	28
Actual,N=	750	500	428.57	375	333.33	214.29
Actual,Ns=	91.39	86.17	90.46	91.39	90.83	92.32
Main parameters of Turbine	***Main parameters of Turbine***	***Main parameters of Turbine***	***Main parameters of Turbine***	***Main parameters of Turbine***	***Main parameters of Turbine***	***Main parameters of Turbine***
N_s =	91.39	86.17	90.46	91.39	90.83	92.32
N =	750	500	428.57	375	333.33	214.29
Ku (. 3) =	0.5385	0.5254	0.5362	0.5385	0.5371	0.5408
D3 =	1.05	1.54	1.83	2.10	2.36	3.69
D1/D3 =	1.4340	1.4967	1.4447	1.4340	1.4404	1.4236
D1 =	1.51	2.30	2.65	3.01	3.40	5.26
D2/D3 =	1.01	1.01	1.01	1.01	1.01	1.00
D2 =	1.06	1.55	1.84	2.11	2.37	3.71
Q =	7.87	15.73	23.60	31.46	39.33	98.32
Spiral A =	1.04	1.50	1.80	2.07	2.32	3.65
csing B =	1.79	2.67	3.13	3.58	4.02	6.26
C =	1.95	2.91	3.41	3.91	4.39	6.85
D =	2.14	3.18	3.73	4.27	4.80	7.49
E =	1.76	2.64	3.08	3.52	3.96	6.16
F =	2.56	3.88	4.49	5.12	5.77	8.95
G =	2.04	3.09	3.58	4.09	4.60	7.15
H =	1.77	2.67	3.10	3.54	3.99	6.19
I =	0.17	0.24	0.29	0.34	0.38	0.59
L =	0.97	1.42	1.69	1.94	2.18	3.42
M =	0.63	0.92	1.10	1.26	1.42	2.22
N =	3.96	6.00	6.94	7.92	8.91	13.83
S =	7.08	10.81	12.42	14.16	15.95	24.71
O =	2.49	3.79	4.37	4.98	5.61	8.69
P =	1.39	2.03	2.42	2.77	3.11	4.87
Q =	0.87	1.30	1.52	1.74	1.95	3.05
R =	1.68	2.46	2.93	3.36	3.77	5.91
T =	1.59	2.33	2.76	3.19	3.58	5.61

U = 0.47	U = 0.69	U = 0.82	U = 0.94	U = 1.05	U = 1.65
V = 1.77	V = 2.65	V = 3.10	V = 3.55	V = 3.99	V = 6.21
Z = 3.15	Z = 4.65	Z = 5.50	Z = 6.30	Z = 7.08	Z = 11.07
Width (2V+U) = 4.02	Width (2V+U) = 5.99	Width (2V+U) = 7.02	Width (2V+U) = 8.03	Width (2V+U) = 9.03	Width (2V+U) = 14.07
o = 0.04	o = 0.04	o = 0.04	o = 0.04	o = 0.04	o = 0.04
Hs = -3.74	Hs = -2.69	Hs = -3.55	Hs = -3.74	Hs = -3.62	Hs = -3.93
B+C+A/2 = 4.26	B+C+A/2 = 6.33	B+C+A/2 = 7.44	B+C+A/2 = 8.52	B+C+A/2 = 9.57	B+C+A/2 = 14.93
D+E = 3.90	D+E = 5.82	D+E = 6.82	D+E = 7.80	D+E = 8.77	D+E = 13.66
Main parameters of Generator	*Main parameters of Generator*	*Main parameters of Generator*	*Main parameters of Generator*	*Main parameters of Generator*	*Main parameters of Generator*
Air gap dia D_g= 2.55	D_g= 3.55	D_g= 3.97	D_g= 4.38	D_g= 4.73	D_g= 6.55
Out st core dia D_o= 3.55	D_o= 4.48	D_o= 4.86	D_o= 5.24	D_o= 5.55	D_o= 7.29
St.frame dia D_f = 4.75	D_f = 5.68	D_f = 6.06	D_f = 6.44	D_f = 6.75	D_f = 8.49
In dia Gen Bar D_b= 6.55	D_b= 7.48	D_b= 7.86	D_b= 8.24	D_b= 8.55	D_b= 10.29
Core leng of st L_c= 0.80	L_c= 1.19	L_c= 1.65	L_c= 2.01	L_c= 2.41	L_c= 4.61
Length of st fr L_f = 2.35	L_f = 2.74	L_f = 3.20	L_f = 3.56	L_f = 3.96	L_f = 6.16
Out bar diaD_{ob} = 7.55	D_{ob} = 8.48	D_{ob} = 8.86	D_{ob} = 9.24	D_{ob} = 9.55	D_{ob} = 11.29
Wt of Gen Rot Wr = 48.10	Wr = 107.5	Wr = 161.5	Wr = 231.0	Wr = 276.7	Wr = 761.0
Wt of Tu.Run = 1.25	Wtr = 9.00	Wtr = 10.00	Wtr = 17.50	Wtr = 19.00	Wtr = 45.00
Axial hyd Thr P_H = 25.22	P_H = 34.61	P_H = 43.94	P_H = 50.44	P_H = 56.60	P_H = 88.65
Wt. Of rot.parts = 74.57	Wtrp = 151.1	Wtrp = 215.5	Wtrp = 299.0	Wtrp = 352.3	Wtrp = 894.6
Ht of load br Bra= 1.42	Ht = 1.55	Ht = 1.60	Ht = 1.65	Ht = 1.69	Ht = 2.48
Dep of dra tube H = 2.89	H = 4.23	H = 5.04	H = 5.78	H = 6.49	H = 10.16
H_2 = 9.77	H_2 = 10.29	H_2 = 10.80	H_2 = 11.21	H_2 = 11.65	H_2 = 14.64
Unit bay Dimensions	***Unit bay Dimensions***	***Unit bay Dimensions***	***Unit bay Dimensions***	***Unit bay Dimensions***	***Unit bay Dimensions***
Length Unit bay = 10.55	Length Unit bay = 11.48	Length Unit bay = 11.86	Length Unit bay = 12.24	Length Unit bay = 12.57	Length Unit bay = 17.93
Width Unit bay = 12.55	Width Unit bay = 13.48	Width Unit bay = 13.86	Width Unit bay = 14.24	Width Unit bay = 14.57	Width Unit bay = 19.93
Height unit bay = 22.16	Height unit bay = 24.02	Height unit bay = 25.33	Height unit bay = 26.49	Height unit bay = 27.63	Height unit bay = 34.30

Table 4.10

For 400 m head and different capacities.(Francis)

Here Pt is in kw

Considering the efficiency of turbine 90% and Generator 96%.

20 MW	40 MW	60 MW	80 MW	100 MW	250 MW
Trail N_s = $3470/(H)^{.625}$	Trail N_s = $3470/(H)^{.625}$	Trail N_s = $3470/(H)^{.625}$	Trail N_s = $3470/(H)^{.625}$	Trail N_s = $3470/(H)^{.625}$	Trail N_s = $3470/(H)^{.625}$
$(H)^{.625}$ = 42.29	$(H)^{.625}$ = 42.29	$(H)^{.625}$ = 42.29	$(H)^{.625}$ = 42.29	$(H)^{.625}$ = 42.29	$(H)^{.625}$ = 42.29
$(H)^{1.25}$ = 1788.85	$(H)^{1.25}$ = 1788.85	$(H)^{1.25}$ = 1788.85	$(H)^{1.25}$ = 1788.85	$(H)^{1.25}$ = 1788.85	$(H)^{1.25}$ = 1788.85
$(P)^{0.5}$ = 152.15	$(P)^{0.5}$ = 215.17	$(P)^{0.5}$ = 263.52	$(P)^{0.5}$ = 304.29	$(P)^{0.5}$ = 340.21	$(P)^{0.5}$ = 537.91
Trial, N_s = 82.04	Trial, N_s = 82.04	Trial, N_s = 82.04	Trial, N_s = 82.04	Trial, N_s = 82.04	Trial, N_s = 82.04
Also, N_s = $(N*P^{0.9}/H^{1.25}$	Also, N_s = $(N*P^{0.9}/H^{1.25}$	Also, N_s = $(N*P^{0.9}/H^{1.25}$	Also, N_s = $(N*P^{0.9}/H^{1.25}$	Also, N_s = $(N*P^{0.9}/H^{1.25}$	Also, N_s = $(N*P^{0.9}/H^{1.25}$
Trial, N = 964.63	Trial, N = 682.09	Trial, N = 556.93	Trial, N = 482.31	Trial, N = 431.39	Trial, N = 272.84
poles, p= 6.22	poles, p= 8.80	poles, p= 10.77	poles, p= 12.44	poles, p= 13.91	poles, p= 21.99
Taking,P= 8	Taking,P= 10	Taking,P= 12	Taking,P= 14	Taking,P= 14	Taking,P= 22
Actual,N= 750	Actual,N= 600	Actual,N= 500	Actual,N= 428.57	Actual,N= 428.57	Actual,N= 272.73
Actual,Ns= 63.79	Actual,Ns= 72.17	Actual,Ns= 73.66	Actual,Ns= 72.90	Actual,Ns= 81.51	Actual,Ns= 82.01
Main parameters of Turbine	***Main parameters of Turbine***	***Main parameters of Turbine***	***Main parameters of Turbine***	***Main parameters of Turbine***	***Main parameters of Turbine***
N_s = 63.79	N_s = 72.71	N_s = 73.66	N_s = 72.9	N_s = 81.51	N_s = 82.01
N = 750	N = 600	N = 500	N = 428.57	N = 428.57	N = 272.73
Ku (. 3) = 0.4695	Ku (. 3) = 0.4918	Ku (. 3) = 0.4942	Ku (. 3) = 0.4923	Ku (. 3) = 0.5138	Ku (. 3) = 0.5150
D3 = 1.06	D3 = 1.39	D3 = 1.67	D3 = 1.94	D3 = 2.03	D3 = 3.19
D1/D3 = 1.8814	D1/D3 = 1.6997	D1/D3 = 1.6829	D1/D3 = 1.6963	D1/D3 = 1.5594	D1/D3 = 1.5523
D1 = 1.99	D1 = 2.35	D1 = 2.81	D1 = 3.29	D1 = 3.16	D1 = 4.95
D2/D3 = 1.02	D2/D3 = 1.01	D2/D3 = 1.01	D2/D3 = 1.01	D2/D3 = 1.01	D2/D3 = 1.01
D2 = 1.07	D2 = 1.40	D2 = 1.69	D2 = 1.97	D2 = 2.04	D2 = 3.22
Q = 5.90	Q = 11.80	Q = 17.70	Q = 23.60	Q = 29.50	Q = 73.74
Spiral A = 0.95	Spiral A = 1.29	Spiral A = 1.56	Spiral A = 1.81	Spiral A = 1.95	Spiral A = 3.07
csing B = 2.08	csing B = 2.57	csing B = 3.08	csing B = 3.60	csing B = 3.59	csing B = 5.65
C = 2.21	C = 2.77	C = 3.32	C = 3.87	C = 3.90	C = 6.13
D = 2.40	D = 3.01	D = 3.61	D = 4.21	D = 4.25	D = 6.69
E = 2.09	E = 2.57	E = 3.08	E = 3.60	E = 3.57	E = 5.60
F = 3.24	F = 3.89	F = 4.65	F = 5.44	F = 5.29	F = 8.30
G = 2.54	G = 3.07	G = 3.67	G = 4.30	G = 4.20	G = 6.60
H = 2.19	H = 2.65	H = 3.17	H = 3.71	H = 3.63	H = 5.70
I = 0.15	I = 0.20	I = 0.25	I = 0.29	I = 0.31	I = 0.49
L = 0.96	L = 1.27	L = 1.53	L = 1.78	L = 1.86	L = 2.94
M = 0.64	M = 0.83	M = 1.00	M = 1.17	M = 1.22	M = 1.92
N = 5.00	N = 6.01	N = 7.19	N = 8.41	N = 8.18	N = 12.83
S = 10.12	S = 11.32	S = 13.47	S = 15.82	S = 14.88	S = 23.32
O = 3.21	O = 3.83	O = 4.58	O = 5.36	O = 5.18	O = 8.12
P = 1.41	P = 1.84	P = 2.22	P = 2.58	P = 2.68	P = 4.23
Q = 0.99	Q = 1.23	Q = 1.48	Q = 1.73	Q = 1.74	Q = 2.73
R = 1.69	R = 2.22	R = 2.67	R = 3.11	R = 3.24	R = 5.11
T = 1.60	T = 2.10	T = 2.53	T = 2.94	T = 3.07	T = 4.84

U = 0.49	U = 0.64	U = 0.77	U = 0.89	U = 0.92	U = 1.44
V = 2.05	V = 2.55	V = 3.05	V = 3.57	V = 3.56	V = 5.60
Z = 3.34	Z = 4.29	Z = 5.16	Z = 6.01	Z = 6.17	Z = 9.71
Width (2V+U) = 4.60	Width (2V+U) = 5.73	Width (2V+U) = 6.88	Width (2V+U) = 8.02	Width (2V+U) = 8.04	Width (2V+U) = 12.64
o = 0.03	o = 0.03	o = 0.03	o = 0.03	o = 0.04	o = 0.04
Hs = -1.14	Hs = -3.29	Hs = -3.52	Hs = -3.33	Hs = -5.51	Hs = -5.64
B+C+A/2 = 4.76	B+C+A/2 = 5.98	B+C+A/2 = 7.19	B+C+A/2 = 8.38	B+C+A/2 = 8.47	B+C+A/2 = 13.31
D+E = 4.49	D+E = 5.58	D+E = 6.69	D+E = 7.81	D+E = 7.82	D+E = 12.29
Main parameters of Generator	*Main parameters of Generator*	*Main parameters of Generator*	*Main parameters of Generator*	*Main parameters of Generator*	*Main parameters of Generator*
Air gap dia D_g= 2.55	D_g= 3.07	D_g= 3.55	D_g= 3.97	D_g= 3.97	D_g= 5.46
Out st core dia D_o= 3.55	D_o= 4.04	D_o= 4.48	D_o= 4.86	D_o= 4.86	D_o= 6.24
St.frame dia D_f = 4.75	D_f = 5.24	D_f = 5.68	D_f = 6.06	D_f = 6.06	D_f = 7.44
In dia Gen Bar D_b= 6.55	D_b= 7.04	D_b= 7.48	D_b= 7.86	D_b= 7.86	D_b= 9.24
Core leng of st L_c= 0.80	L_c= 1.35	L_c= 1.79	L_c= 2.20	L_c= 2.75	L_c= 5.38
Length of st fr L_f = 2.35	L_f = 2.90	L_f = 3.34	L_f = 3.75	L_f = 4.30	L_f = 6.93
Out bar diaD_{ob} = 7.55	D_{ob} = 8.04	D_{ob} = 8.48	D_{ob} = 8.86	D_{ob} = 8.86	D_{ob} = 10.24
Wt of Gen Rot Wr = 48.10	Wr = 101.52	Wr = 161.18	Wr = 215.36	Wr = 269.20	Wr = 779.53
Wt of Tu.Run = 1.75	Wtr = 9.00	Wtr = 16.00	Wtr = 18.00	Wtr = 18.00	Wtr = 40.00
Axial hyd Thr P_H = 14.81	P_H = 30.5	P_H = 36.74	P_H = 42.70	P_H = 48.62	P_H = 76.59
Wt. Of rot.parts = 64.66	Wtrp = 141.0	Wtrp = 213.9	Wtrp = 276.06	Wtrp = 335.82	Wtrp = 896.13
Ht of load br Bra= 1.42	Ht = 1.49	Ht = 1.55	Ht = 1.60	Ht = 1.60	Ht = 2.32
Dep of dra tube H = 2.91	H = 3.81	H = 4.59	H = 5.34	H = 5.57	H = 8.78
H_2 = 9.77	H_2 = 10.39	H_2 = 10.89	H_2 = 11.35	H_2 = 11.90	H_2 = 15.24
Unit bay Dimensions	***Unit bay Dimensions***	***Unit bay Dimensions***	***Unit bay Dimensions***	***Unit bay Dimensions***	***Unit bay Dimensions***
Length Unit bay = 10.55	Length Unit bay = 11.04	Length Unit bay = 11.48	Length Unit bay = 11.86	Length Unit bay = 11.86	Length Unit bay = 16.31
Width Unit bay = 12.55	Width Unit bay = 13.04	Width Unit bay = 13.48	Width Unit bay = 13.86	Width Unit bay = 13.86	Width Unit bay = 18.31
Height unit bay = 22.18	Height unit bay = 23.7	Height unit bay = 24.98	Height unit bay = 26.19	Height unit bay = 26.97	Height unit bay = 33.52

Table 4.11

For 500 m head and different capacities.(Francis)

Here Pt is in kw

Considering the efficiency of turbine 90% and Generator 96%.

	20 MW	40 MW	60 MW	80 MW	100 MW	250 MW
Trail $N_s = 3470/(H)^{.625}$						
$(H)^{.625}$ =	48.62	48.62	48.62	48.62	48.62	48.62
$(H)^{1.25}$ =	2364.35	2364.35	2364.35	2364.35	2364.35	2364.35
$(P)^{0.5}$ =	152.15	215.17	263.52	304.29	340.21	537.91
Trial, N_s =	71.36	71.36	71.36	71.36	71.36	71.36
Also, $N_s = (N*P^{0.5})/H^{1.25}$						
Trial, N =	1108.99	784.17	640.28	554.49	495.96	313.67
poles, p=	5.41	7.65	9.37	10.82	12.10	19.13
Taking,P=	6	8	10	12	14	20
Actual,N=	1000	750	600	500	428.57	300.00
Actual,Ns=	64.35	68.25	66.87	64.35	61.67	68.25
Main parameters of Turbine						
N_s =	64.35	68.25	66.87	64.35	61.67	68.25
N =	1000	750	600	500	428.57	300
Ku (. 3) =	0.4709	0.4806	0.4772	0.4709	0.4642	0.4806
D3 =	0.89	1.21	1.50	1.78	2.05	3.03
D1/D3 =	1.8685	1.7846	1.8132	1.8685	1.9323	1.7846
D1 =	1.66	2.16	2.72	3.32	3.95	5.40
D2/D3 =	1.02	1.01	1.01	1.02	1.02	1.01
D2 =	0.90	1.23	1.52	1.81	2.08	3.07
Q =	4.72	9.44	14.16	18.88	23.60	58.99
Spiral A =	0.80	1.11	1.36	1.59	1.81	2.76
csing B =	1.74	2.31	2.89	3.48	4.07	5.77
C =	1.86	2.47	3.09	3.71	4.34	6.18
D =	2.01	2.68	3.35	4.02	4.69	6.71
E =	1.75	2.31	2.90	3.50	4.12	5.79
F =	2.71	3.54	4.46	5.41	6.41	8.86
G =	2.13	2.79	3.51	4.25	5.02	6.97
H =	1.83	2.41	3.02	3.67	4.33	6.02
I =	0.13	0.17	0.22	0.25	0.29	0.44
L =	0.81	1.11	1.37	1.62	1.86	2.77
M =	0.53	0.73	0.90	1.07	1.23	1.82
N =	4.18	5.48	6.89	8.37	9.90	13.69
S =	8.41	10.62	13.51	16.82	20.56	26.55
O =	2.68	3.50	4.41	5.37	6.37	8.75
P =	1.19	1.61	2.00	2.37	2.73	4.03
Q =	0.83	1.10	1.38	1.66	1.94	2.76
R =	1.42	1.94	2.40	2.85	3.27	4.84
T =	1.35	1.83	2.27	2.69	3.09	4.58

U = 0.41	U = 0.56	U = 0.70	U = 0.83	U = 0.96	U = 1.40
V = 1.72	V = 2.28	V = 2.86	V = 3.44	V = 4.03	V = 5.71
Z = 2.81	Z = 3.78	Z = 4.71	Z = 5.61	Z = 6.50	Z = 9.46
Width (2V+U) = 3.86	Width (2V+U) = 5.13	Width (2V+U) = 6.42	Width (2V+U) = 7.71	Width (2V+U) = 9.02	Width (2V+U) = 12.82
o = 0.03	o = 0.03	o = 0.03	o = 0.03	o = 0.03	o = 0.03
Hs = -3.95	Hs = -5.11	Hs = -4.70	Hs = -3.95	Hs = -3.17	Hs = -5.11
B+C+A/2 = 3.99	B+C+A/2 = 5.33	B+C+A/2 = 6.66	B+C+A/2 = 7.99	B+C+A/2 = 9.31	B+C+A/2 = 13.33
D+E = 3.76	D+E = 5.00	D+E = 6.25	D+E = 7.52	D+E = 8.81	D+E = 12.49
Main parameters of Generator	***Main parameters of Generator***	***Main parameters of Generator***	***Main parameters of Generator***	***Main parameters of Generator***	***Main parameters of Generator***
Air gap dia D_g= 2.06	D_g= 2.55	D_g= 3.07	D_g= 3.55	D_g= 3.97	D_g= 5.19
Out st core dia D_o= 3.14	D_o= 3.55	D_o= 4.04	D_o= 4.48	D_o= 4.86	D_o= 6.00
St.frame dia D_f = 4.34	D_f = 4.75	D_f = 5.24	D_f = 5.68	D_f = 6.06	D_f = 7.20
In dia Gen Bar D_b= 6.14	D_b= 6.55	D_b= 7.04	D_b= 7.48	D_b= 7.86	D_b= 9.00
Core leng of st L_c= 0.95	L_c= 1.60	L_c= 2.03	L_c= 2.39	L_c= 2.75	L_c= 5.51
Length of st fr L_f = 2.50	L_f = 3.15	L_f = 3.58	L_f = 3.94	L_f = 4.30	L_f = 7.06
Out bar diaD_{ob} = 7.14	D_{ob} = 7.55	D_{ob} = 8.04	D_{ob} = 8.48	D_{ob} = 8.86	D_{ob} = 10.00
Wt of Gen Rot Wr = 42.74	Wr = 96.20	Wr = 152.28	Wr = 214.90	Wr = 269.20	Wr = 771.70
Wt of Tu.Run = 7.00	Wtr = 8.00	Wtr = 14.00	Wtr = 18.00	Wtr = 24.00	Wtr = 50.00
Axial hyd Thr P_H = 15.57	P_H = 21.19	P_H = 26.30	P_H = 31.14	P_H = 33.77	P_H = 49.95
Wt. Of rot.parts = 65.31	Wtrp = 125.39	Wtrp = 192.58	Wtrp = 264.04	Wtrp = 326.97	Wtrp = 871.64
Ht of load br Bra= 1.35	Ht = 1.42	Ht = 1.49	Ht = 1.55	Ht = 1.60	Ht = 2.28
Dep of dra tube H = 2.45	H = 3.33	H = 4.13	H = 4.89	H = 5.63	H = 8.32
H_2 = 9.85	H_2 = 10.57	H_2 = 11.07	H_2 = 11.49	H_2 = 11.90	H_2 = 15.34
Unit bay Dimensions	***Unit bay Dimensions***	***Unit bay Dimensions***	***Unit bay Dimensions***	***Unit bay Dimensions***	***Unit bay Dimensions***
Length Unit bay = 10.14	Length Unit bay = 10.55	Length Unit bay = 11.04	Length Unit bay = 11.48	Length Unit bay = 12.31	Length Unit bay = 16.33
Width Unit bay = 12.14	Width Unit bay = 12.55	Width Unit bay = 13.04	Width Unit bay = 13.48	Width Unit bay = 14.31	Width Unit bay = 18.33
Height unit bay = 21.80	Height unit bay = 23.40	Height unit bay = 24.70	Height unit bay = 25.88	Height unit bay = 27.02	Height unit bay = 33.17

Table 4.12

FOR 600 m head and different capacities.(Francis)

Here Pt is in kw

Considering the efficiency of turbine 90% and Generator 96%.

	20 MW	40 MW	60 MW	80 MW	100 MW	250 MW
Trail N_s = 3470/(H)$^{.625}$						
(H)$^{.625}$ =	54.49	54.49	54.49	54.49	54.49	54.49
(H)$^{1.25}$ =	2969.54	2969.54	2969.54	2969.54	2969.54	2969.54
(P)$^{0.5}$ =	152.15	215.17	263.52	304.29	340.21	537.91
Trial, N_s =	63.68	63.68	63.68	63.68	63.68	63.68
Also, N_s =	$(N*P^{0.5})/H^{1.25}$	$(N*P^{0.9})/H^{1.25}$	$(N*P^{0.9})/H^{1.25}$	$(N*P^{0.9})/H^{1.25}$	$(N*P^{0.9})/H^{1.25}$	$(N*P^{0.9})/H^{1.25}$
Trial, N =	1242.84	878.82	717.56	621.42	555.82	351.53
poles, p=	4.83	6.83	8.36	9.66	10.79	17.07
Taking,P=	6	8	10	10	12	18
Actual,N=	1000	750	600	600	500	333.33
Actual,Ns=	51.24	54.34	53.25	61.48	57.28	60.38
Main parameters of Turbine						
N_s =	51.24	54.34	53.25	61.48	57.28	60.38
N =	1000	750	600	600	500	333.33
Ku (. 3) =	0.44	0.45	0.44	0.46	0.45	0.46
D3 =	0.91	1.23	1.53	1.60	1.88	2.86
D1/D3 =	2.2443	2.1391	2.17	1.9371	2.05	1.97
D1 =	2.04	2.63	3.32	3.10	3.85	5.62
D2/D3 =	1.02	1.02	1.02	1.02	1.02	1.02
D2 =	0.93	1.25	1.56	1.63	1.91	2.91
Q =	3.93	7.87	11.80	15.73	19.66	49.16
Spiral A =	0.74	1.03	1.27	1.41	1.61	2.51
csing B =	1.97	2.60	3.26	3.19	3.86	5.75
C =	2.07	2.74	3.43	3.39	4.09	6.11
D =	2.22	2.95	3.69	3.67	4.41	6.61
E =	2.01	2.65	3.32	3.22	3.92	5.82
F =	3.23	4.21	5.30	5.02	6.18	9.09
G =	2.51	3.28	4.13	3.93	4.83	7.12
H =	2.16	2.82	3.55	3.39	4.16	6.14
I =	0.12	0.17	0.21	0.22	0.26	0.40
L =	0.82	1.12	1.39	1.46	1.70	2.60
M =	0.54	0.74	0.92	0.96	1.13	1.72
Dragt tube dim. N =	5.00	6.50	8.20	7.76	9.55	14.05
S =	13.16	15.53	20.19	16.15	21.32	29.72
O =	3.24	4.21	5.31	4.99	6.17	9.05
P =	1.22	1.65	2.05	2.14	2.51	3.82
Q =	0.93	1.23	1.54	1.52	1.83	2.73
R =	1.45	1.97	2.45	2.56	3.00	4.58
T =	1.37	1.86	2.31	2.42	2.83	4.33

U = 0.43	U = 0.58	U = 0.72	U = 0.75	U = 0.88	U = 1.34
V = 1.95	V = 2.57	V = 3.22	V = 3.16	V = 3.82	V = 5.69
Z = 2.98	Z = 4.00	Z = 4.99	Z = 5.09	Z = 6.04	Z = 9.13
Width (2V+U) = 4.33	Width (2V+U) = 5.72	Width (2V+U) = 7.17	Width (2V+U) = 7.06	Width (2V+U) = 8.53	Width (2V+U) = 12.73
o = 0.02	o = 0.02	o = 0.02	o = 0.03	o = 0.02	o = 0.02
Hs = -2.22	Hs = -3.22	Hs = -2.87	Hs = -5.63	Hs = -4.20	Hs = -5.25
B+C+A/2 = 4.41	B+C+A/2 = 5.85	B+C+A/2 = 7.33	B+C+A/2 = 7.29	B+C+A/2 = 8.76	B+C+A/2 = 13.12
D+E = 4.24	D+E = 5.60	D+E = 7.02	D+E = 6.89	D+E = 8.33	D+E = 12.43
Main parameters of Generator	*Main parameters of Generator*	*Main parameters of Generator*	*Main parameters of Generator*	*Main parameters of Generator*	*Main parameters of Generator*
Air gap dia D_g = 2.06	D_g = 2.55	D_g = 3.07	D_g = 3.07	D_g = 3.55	D_g = 4.73
Out st core dia D_o = 3.14	D_o = 3.55	D_o = 4.04	D_o = 4.04	D_o = 4.48	D_o = 5.55
St.frame dia D_f = 4.34	D_f = 4.75	D_f = 5.24	D_f = 5.24	D_f = 5.68	D_f = 6.75
In dia Gen Bar D_b = 6.14	D_b = 6.55	D_b = 7.04	D_b = 7.04	D_b = 7.48	D_b = 8.55
Core leng of st L_c = 0.95	L_c = 1.60	L_c = 2.03	L_c = 2.71	L_c = 2.98	L_c = 6.02
Length of st fr L_f = 2.50	L_f = 3.15	L_f = 3.58	L_f = 4.26	L_f = 4.53	L_f = 7.57
Out bar diaD_{ob} = 7.14	D_{ob} = 7.55	D_{ob} = 8.04	D_{ob} = 8.04	D_{ob} = 8.48	D_{ob} = 9.55
Wt of Gen Rot Wr = 42.74	Wr = 96.20	Wr = 152.28	Wr = 203.04	Wr = 268.6	Wr = 721.86
Wt of Tu.Run = 7.00	Wtr = 13.00	Wtr = 18.00	Wtr = 17.50	Wtr = 23.00	Wtr = 54.00
Axial hyd Thr P_H = 13.60	P_H = 22.15	P_H = 27.52	P_H = 33.59	P_H = 39.40	P_H = 60.11
Wt. Of rot.parts = 63.34	Wtrp = 131.34	Wtrp = 197.79	Wtrp = 254.13	Wtrp = 331.03	Wtrp = 836.0
Ht of load br Bra= 1.35	Ht = 1.42	Ht = 1.49	Ht = 1.49	Ht = 1.55	Ht = 2.21
Dep of dra tube H = 2.49	H = 3.38	H = 4.20	H = 4.40	H = 5.16	H = 7.87
H_2 = 9.85	H_2 = 10.57	H_2 = 11.07	H_2 = 11.74	H_2 = 12.08	H_2 = 15.77
Unit bay Dimensions	*Unit bay Dimensions*	*Unit bay Dimensions*	*Unit bay Dimensions*	*Unit bay Dimensions*	*Unit bay Dimensions*
Length Unit bay = 10.14	Length Unit bay = 10.55	Length Unit bay = 11.04	Length Unit bay = 11.04	Length Unit bay = 11.76	Length Unit bay = 16.12
Width Unit bay = 12.14	Width Unit bay = 12.55	Width Unit bay = 13.04	Width Unit bay = 13.04	Width Unit bay = 13.76	Width Unit bay = 18.12
Height unit bay = 21.85	Height unit bay = 23.45	Height unit bay = 24.77	Height unit bay = 25.64	Height unit bay = 26.74	Height unit bay = 33.15

Table 4.13

For 700 m head and different capacities.(Francis)

Here Pt is in kw

Considering the efficiency of turbine 90% and Generator 96%.

20 MW	40 MW	60 MW	80 MW	100 MW	250 MW
Trail $N_s = 3470/(H)^{.625}$	Trail $N_s = 3470/(H)^{.625}$	Trail $N_s = 3470/(H)^{.625}$	Trail $N_s = 3470/(H)^{.625}$	Trail $N_s = 3470/(H)^{.625}$	Trail $N_s = 3470/(H)^{.625}$
$(H)^{.625} = 60.00$	$(H)^{.625} = 60.00$	$(H)^{.625} = 60.00$	$(H)^{.625} = 60.00$	$(H)^{.625} = 60.00$	$(H)^{.625} = 60.00$
$(H)^{1.25} = 3600.6$	$(H)^{1.25} = 3600.6$	$(H)^{1.25} = 3600.6$	$(H)^{1.25} = 3601$	$(H)^{1.25} = 3600.6$	$(H)^{1.25} = 3601$
$(P)^{0.5} = 152.15$	$(P)^{0.5} = 215.17$	$(P)^{0.5} = 263.52$	$(P)^{0.5} = 304.3$	$(P)^{0.5} = 340.2$	$(P)^{0.5} = 537.9$
Trial, N_s = 57.83	Trial, N_s = 57.83	Trial, N_s = 57.83	Trial, N_s = 57.83	Trial, N_s = 57.83	Trial, N_s = 57.83
Also, $N_s = (N{*}P^{0.5})/H^{1.25}$	Also, $N_s = (N{*}P^{0.5})/H^{1.25}$	Also, $N_s = (N{*}P^{0.5})/H^{1.25}$	Also, $N_s = (N{*}P^{0.5})/H^{1.25}$	Also, $N_s = (N{*}P^{0.5})/H^{1.25}$	Also, $N_s = (N{*}P^{0.5})/H^{1.25}$
Trial, N = 1368.54	Trial, N = 967.70	Trial, N = 790.13	Trial, N = 684.27	Trial, N = 612.03	Trial, N = 387.08
poles, p= 4.38	poles, p= 6.20	poles, p= 7.59	poles, p= 8.77	poles, p= 9.80	poles, p= 15.50
Taking,P= 6	Taking,P= 8	Taking,P= 10	Taking,P= 10	Taking,P= 12	Taking,P= 18
Actual,N= 1000	Actual,N= 750	Actual,N= 600	Actual,N= 600	Actual,N= 500	Actual,N= 333.33
Actual,Ns= 42.26	Actual,Ns= 44.82	Actual,Ns= 43.91	Actual,Ns= 50.71	Actual,Ns= 47.24	Actual,Ns= 49.80
Main parameters of Turbine	***Main parameters of Turbine***	***Main parameters of Turbine***	***Main parameters of Turbine***	***Main parameters of Turbine***	***Main parameters of Turbine***
N_s = 42.26	N_s = 44.82	N_s = 43.91	N_s = 50.71	N_s = 47.24	N_s = 49.8
N = 1000	N = 750	N = 600	N = 600	N = 500	N = 333.33
Ku (. 3) = 0.42	Ku (. 3) = 0.42	Ku (. 3) = 0.42	Ku (. 3) = 0.44	Ku (. 3) = 0.43	Ku (. 3) = 0.43
D3 = 0.93	D3 = 1.26	D3 = 1.56	D3 = 1.63	D3 = 1.91	D3 = 3.31
D1/D3 = 2.6362	D1/D3 = 2.5084	D1/D3 = 2.55	D1/D3 = 2.2635	D1/D3 = 2.40	D1/D3 = 2.30
D1 = 2.45	D1 = 3.16	D1 = 3.99	D1 = 3.68	D1 = 4.59	D1 = 7.61
D2/D3 = 1.02	D2/D3 = 1.02	D2/D3 = 1.02	D2/D3 = 1.02	D2/D3 = 1.02	D2/D3 = 1.02
D2 = 0.95	D2 = 1.29	D2 = 1.60	D2 = 1.66	D2 = 1.96	D2 = 3.38
Q = 3.37	Q = 6.74	Q = 8.85	Q = 13.48	Q = 16.85	Q = 36.87
Spiral A = 0.68	Spiral A = 0.96	Spiral A = 1.18	Spiral A = 1.33	Spiral A = 1.50	Spiral A = 2.67
csing B = 2.23	csing B = 2.93	csing B = 3.68	csing B = 3.55	csing B = 4.33	csing B = 7.29
C = 2.31	C = 3.04	C = 3.82	C = 3.73	C = 4.52	C = 7.64
D = 2.47	D = 3.26	D = 4.08	D = 4.01	D = 4.85	D = 8.21
E = 2.31	E = 3.02	E = 3.80	E = 3.64	E = 4.45	E = 7.47
F = 3.82	F = 4.95	F = 6.24	F = 5.84	F = 7.24	F = 12.04
G = 2.95	G = 3.83	G = 4.83	G = 4.55	G = 5.61	G = 9.36
H = 2.53	H = 3.29	H = 4.15	H = 3.91	H = 4.82	H = 8.05
I = 0.12	I = 0.16	I = 0.20	I = 0.22	I = 0.25	I = 0.44
L = 0.84	L = 1.13	L = 1.41	L = 1.47	L = 1.73	L = 2.99
M = 0.56	M = 0.76	M = 0.94	M = 0.98	M = 1.15	M = 1.99
Dragt tube dim. N = 5.91	Dragt tube dim. N = 7.65	Dragt tube dim. N = 9.66	Dragt tube dim. N = 9.04	Dragt tube dim. N = 11.19	Dragt tube dim. N = 18.62
S = 30.56	S = 29.29	S = 40.46	S = 24.29	S = 35.74	S = 52.00
O = 3.87	O = 4.99	O = 6.31	O = 5.87	O = 7.29	O = 12.10
P = 1.25	P = 1.69	P = 2.10	P = 2.18	P = 2.57	P = 4.44
Q = 1.04	Q = 1.36	Q = 1.71	Q = 1.67	Q = 2.03	Q = 3.42
R = 1.49	R = 2.01	R = 2.50	R = 2.60	R = 3.06	R = 5.30
T = 1.40	T = 1.90	T = 2.36	T = 2.46	T = 2.89	T = 5.00

U = 0.45	U = 0.60	U = 0.75	U = 0.77	U = 0.91	U = 1.57
V = 2.20	V = 2.89	V = 3.63	V = 3.51	V = 4.28	V = 7.21
Z = 3.19	Z = 4.26	Z = 5.32	Z = 5.37	Z = 6.40	Z = 10.95
Width (2V+U) = 4.85	Width (2V+U) = 6.38	Width (2V+U) = 8.02	Width (2V+U) = 7.80	Width (2V+U) = 9.48	Width (2V+U) = 15.99
o = 0.01	o = 0.02	o = 0.02	o = 0.02	o = 0.02	o = 0.02
Hs = -0.93	Hs = -1.82	Hs = -1.50	Hs = -3.96	Hs = -2.69	Hs = -3.62
B+C+A/2 = 4.88	B+C+A/2 = 6.45	B+C+A/2 = 8.09	B+C+A/2 = 7.95	B+C+A/2 = 9.61	B+C+A/2 = 16.27
D+E = 4.78	D+E = 6.28	D+E = 7.88	D+E = 7.64	D+E = 9.30	D+E = 15.68
Main parameters of Generator	***Main parameters of Generator***	***Main parameters of Generator***	***Main parameters of Generator***	***Main parameters of Generator***	***Main parameters of Generator***
Air gap dia D_g = 2.14	D_g = 2.55	D_g = 3.09	D_g = 3.07	D_g = 3.55	D_g = 4.73
Out st core dia D_o = 3.26	D_o = 3.55	D_o = 4.06	D_o = 4.04	D_o = 4.48	D_o = 5.55
St.frame dia D_f = 4.46	D_f = 4.75	D_f = 5.26	D_f = 5.24	D_f = 5.68	D_f = 6.75
In dia Gen Bar D_b = 6.26	D_b = 6.55	D_b = 7.06	D_b = 7.04	D_b = 7.48	D_b = 8.55
Core leng of st L_c = 0.87	L_c = 1.60	L_c = 2.01	L_c = 2.71	L_c = 2.98	L_c = 6.02
Length of st fr L_f = 2.42	L_f = 3.15	L_f = 3.56	L_f = 4.26	L_f = 4.53	L_f = 7.57
Out bar dia D_{ob} = 7.26	D_{ob} = 7.55	D_{ob} = 8.06	D_{ob} = 8.04	D_{ob} = 8.48	D_{ob} = 9.55
Wt of Gen Rot Wr = 39.03	Wr = 96.20	Wr = 150.71	Wr = 175.97	Wr = 194.01	Wr = 721.86
Wt of Tu.Run = 7.00	Wtr = 15.00	Wtr = 22.00	Wtr = 19.00	Wtr = 36.00	Wtr = 80.00
Axial hyd Thr P_H = 16.26	P_H = 26.42	P_H = 32.85	P_H = 39.87	P_H = 46.90	P_H = 81.10
Wt. Of rot.parts = 62.29	Wtrp = 137.62	Wtrp = 205.56	Wtrp = 234.84	Wtrp = 276.91	Wtrp = 882.95
Ht of load br Bra = 1.37	Ht = 1.42	Ht = 1.49	Ht = 1.49	Ht = 1.79	Ht = 2.21
Dep of dra tube H = 2.56	H = 3.46	H = 4.30	H = 4.48	H = 5.26	H = 9.10
H_2 = 9.79	H_2 = 10.57	H_2 = 11.05	H_2 = 11.74	H_2 = 12.32	H_2 = 15.77
Unit bay Dimensions	***Unit bay Dimensions***	***Unit bay Dimensions***	***Unit bay Dimensions***	***Unit bay Dimensions***	***Unit bay Dimensions***
Length Unit bay = 10.26	Length Unit bay = 10.55	Length Unit bay = 11.09	Length Unit bay = 11.04	Length Unit bay = 12.61	Length Unit bay = 19.27
Width Unit bay = 12.26	Width Unit bay = 12.55	Width Unit bay = 13.09	Width Unit bay = 13.04	Width Unit bay = 14.61	Width Unit bay = 21.27
Height unit bay = 21.85	Height unit bay = 23.53	Height unit bay = 24.85	Height unit bay = 25.72	Height unit bay = 27.09	Height unit bay = 34.38

Table 4.14

For 800 m head and different capacities.(Francis)

Here Pt is in kw

Considering the efficiency of turbine 90% and Generator 96%.

	20 MW	40 MW	60 MW	80 MW	100 MW	250 MW
Trail N_s =	$3470/(H)^{.625}$	$3470/(H)^{.625}$	$3470/(H)^{.625}$	$3470/(H)^{.625}$	$3470/(H)^{.625}$	$3470/(H)^{.625}$
$(H)^{.625}$ =	65.23	65.23	65.23	65.23	65.23	65.23
$(H)^{1.25}$ =	4254.6	4254.6	4254.6	4255	4254.6	4255
$(P)^{0.5}$ =	152.15	215.17	263.52	304.3	340.2	537.9
Trial, N_s =	53.20	53.20	53.20	53.20	53.20	53.20
Also, N_s =	$(N*P^{0.5})/H^{1.25}$	$(N*P^{0.5})/H^{1.25}$	$(N*P^{0.5})/H^{1.25}$	$(N*P^{0.5})/H^{1.25}$	$(N*P^{0.5})/H^{1.25}$	$(N*P^{0.5})/H^{1.25}$
Trial, N =	1487.66	1051.93	858.90	743.83	665.30	420.77
poles, p=	4.03	5.70	6.99	8.07	9.02	14.26
Taking,P=	6	8	10	10	12	16
Actual,N=	1000	750	600	600	500	375.00
Actual,Ns=	35.76	37.93	37.16	42.91	39.98	47.41
Main parameters of Turbine						
N_s =	35.76	37.93	37.16	42.91	39.98	47.41
N =	1000	750	600	600	500	375
Ku (. 3) =	0.40	0.40	0.40	0.42	0.41	0.43
D3 =	0.95	1.29	1.60	1.66	1.96	3.31
D1/D3 =	3.0426	2.8914	2.94	2.6023	2.76	2.39
D1 =	2.90	3.73	4.72	4.33	5.42	7.92
D2/D3 =	1.03	1.03	1.03	1.02	1.03	1.02
D2 =	0.98	1.32	1.65	1.70	2.01	3.38
Q =	2.95	5.90	8.85	11.80	14.75	36.87
Spiral A =	0.62	0.88	1.08	1.24	1.39	2.61
csing B =	2.52	3.29	4.14	3.96	4.85	7.48
C =	2.57	3.38	4.25	4.10	5.00	7.81
D =	2.73	3.59	4.51	4.38	5.33	8.37
E =	2.63	3.43	4.32	4.09	5.04	7.68
F =	4.46	5.78	7.28	6.78	8.40	12.48
G =	3.43	4.43	5.60	5.22	6.47	9.68
H =	2.94	3.80	4.80	4.48	5.55	8.32
I =	0.12	0.16	0.20	0.21	0.25	0.43
L =	0.86	1.16	1.44	1.50	1.76	2.99
M =	0.57	0.77	0.96	1.00	1.18	1.99
Dragt tube dim. N =	6.90	8.91	11.26	10.44	12.99	19.31
S =	-100.40	241.64	5963.8	49.27	109.57	61.00
O =	4.55	5.86	7.41	6.83	8.52	12.57
P =	1.29	1.74	2.17	2.24	2.64	4.45
Q =	1.16	1.52	1.91	1.84	2.24	3.50
R =	1.53	2.06	2.57	2.66	3.14	5.30
T =	1.44	1.94	2.42	2.51	2.95	4.99

U = 0.46	U = 0.62	U = 0.78	U = 0.80	U = 0.94	U = 1.58
V = 2.48	V = 3.25	V = 4.08	V = 3.91	V = 4.79	V = 7.39
Z = 3.41	Z = 4.54	Z = 5.68	Z = 5.68	Z = 6.81	Z = 11.07
Width (2V+U) = 5.43	Width (2V+U) = 7.11	Width (2V+U) = 8.95	Width (2V+U) = 8.61	Width (2V+U) = 10.52	Width (2V+U) = 16.36
o = 0.01	o = 0.01	o = 0.01	o = 0.02	o = 0.01	o = 0.02
Hs = 0.08	Hs = -0.73	Hs = -0.44	Hs = -2.66	Hs = -1.51	Hs = -4.49
B+C+A/2 = 5.40	B+C+A/2 = 7.11	B+C+A/2 = 8.93	B+C+A/2 = 8.68	B+C+A/2 = 10.55	B+C+A/2 = 16.59
D+E = 5.37	D+E = 7.02	D+E = 8.83	D+E = 8.48	D+E = 10.37	D+E = 16.06
Main parameters of Generator	***Main parameters of Generator***	***Main parameters of Generator***	***Main parameters of Generator***	***Main parameters of Generator***	***Main parameters of Generator***
Air gap dia D_g = 2.14	D_g = 2.60	D_g = 3.09	D_g = 3.09	D_g = 3.44	D_g = 4.38
Out st core dia D_o = 3.26	D_o = 3.62	D_o = 4.06	D_o = 4.06	D_o = 4.34	D_o = 5.24
St.frame dia D_f = 4.46	D_f = 4.82	D_f = 5.26	D_f = 5.26	D_f = 5.54	D_f = 6.44
In dia Gen Bar D_b = 6.26	D_b = 6.62	D_b = 7.06	D_b = 7.06	D_b = 7.34	D_b = 8.24
Core leng of st L_c = 0.88	L_c = 1.57	L_c = 2.08	L_c = 2.78	L_c = 3.19	L_c = 6.33
Length of st fr L_f = 2.43	L_f = 3.12	L_f = 3.63	L_f = 4.33	L_f = 4.74	L_f = 7.88
Out bar dia D_{ob} = 7.26	D_{ob} = 7.62	D_{ob} = 8.06	D_{ob} = 8.06	D_{ob} = 8.34	D_{ob} = 9.24
Wt of Gen Rot Wr = 39.74	Wr = 78.43	Wr = 145.69	Wr = 194.25	Wr = 254.96	Wr = 759.6
Wt of Tu.Run = 16.00	Wtr = 20.00	Wtr = 36.00	Wtr = 34.00	Wtr = 50.00	Wtr = 130.00
Axial hyd Thr P_H = 19.09	P_H = 30.96	P_H = 38.52	P_H = 46.54	P_H = 54.87	P_H = 92.68
Wt. Of rot.parts = 74.83	Wtrp = 129.39	Wtrp = 220.21	Wtrp = 274.79	Wtrp = 359.83	Wtrp = 982.3
Ht of load br Bra = 1.37	Ht = 1.43	Ht = 1.49	Ht = 1.49	Ht = 1.76	Ht = 2.16
Dep of dra tube H = 2.63	H = 3.55	H = 4.41	H = 4.57	H = 5.39	H = 9.10
H_2 = 9.81	H_2 = 10.55	H_2 = 11.12	H_2 = 11.82	H_2 = 12.50	H_2 = 16.04
Unit bay Dimensions	***Unit bay Dimensions***	***Unit bay Dimensions***	***Unit bay Dimensions***	***Unit bay Dimensions***	***Unit bay Dimensions***
Length Unit bay = 10.26	Length Unit bay = 10.62	Length Unit bay = 11.93	Length Unit bay = 11.68	Length Unit bay = 13.55	Length Unit bay = 19.59
Width Unit bay = 12.26	Width Unit bay = 12.62	Width Unit bay = 13.93	Width Unit bay = 13.68	Width Unit bay = 15.55	Width Unit bay = 21.59
Height unit bay = 21.93	Height unit bay = 23.59	Height unit bay = 25.04	Height unit bay = 25.89	Height unit bay = 27.39	Height unit bay = 34.64

Table 4.15

Summary of main dimensions of power stations with Pelton & Francis turbines

20 MW																
Head (m)	Unit bay length		Unit bay width		Unit bay height		floor area(m^2)		Runner dia (m)		Turbine Setting (m)		Scroll case dia (m)	
	Pelton	Francis	Pelton	Francis	Pelton	Francis	Pelton	Francis	Pelton	Francis	Pelton	Francis	Pelton	Francis
200	13.99	11.04	15.99	13.04	25.99	25.03	223.70	143.96	3.16	2.12	1.98	-3.66	10.99	8.04
300	11.86	10.55	13.86	12.55	23.88	22.16	164.38	132.40	2.08	1.05	1.91	-3.74	7.92	4.26
400	11.86	10.55	13.86	12.55	24.33	22.18	164.38	132.40	2.39	1.06	1.90	-1.14	8.78	4.76
500	11.48	10.14	13.48	12.14	24.16	21.8	154.75	123.10	2.27	0.89	1.89	-3.95	8.46	3.99
600	10.55	10.14	12.55	12.14	23.34	21.85	132.40	123.10	1.66	0.91	1.88	-2.22	6.72	4.41
700	10.06	10.26	12.06	12.26	23.01	21.85	121.32	125.79	1.35	0.93	1.88	-0.93	5.85	4.88
800	10.06	10.26	12.06	12.26	22.00	21.91	121.32	125.79	1.29	0.95	1.88	0.08	5.68	5.40

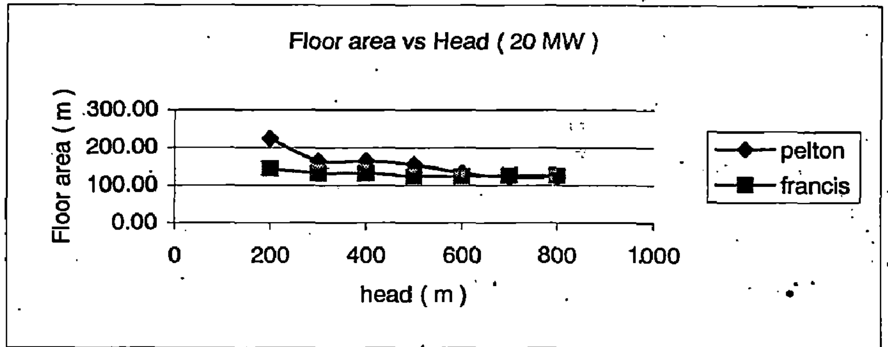

Figure 4.3 Relation between floor area and head.

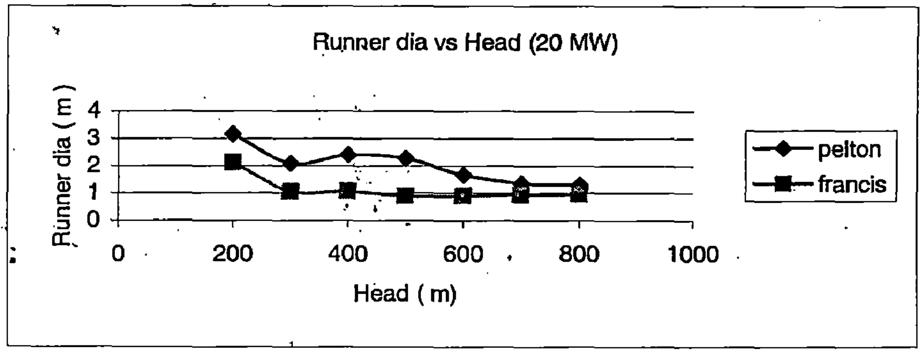

Figure 4.4 Relation between runner dia and head.

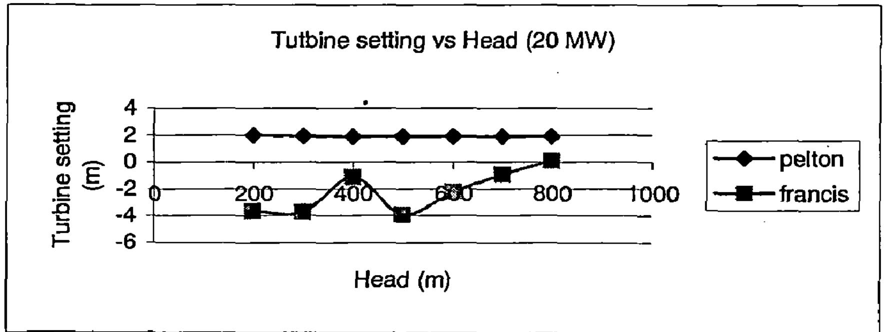

Figure 4.5 Relation between turbine setting and head.

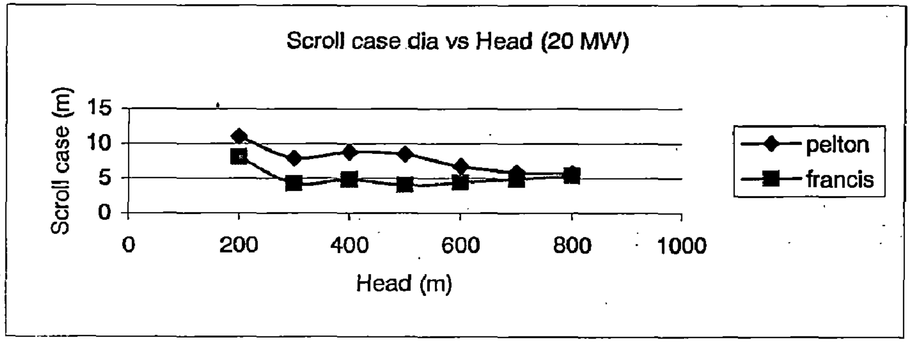

Figure 4.6Relation between scroll case dia and head.

Table 16

Summary of main dimensions of power stations with Pelton & Francis turbines

40 MW																
Head (m)	Unit bay length		Unit bay width		Unit bay height		floor area(m^2)		Runner dia (m)		Turbine Setting (m)		Scroll case dia (m)	
	Pelton	Francis	Pelton	Francis	Pelton	Francis	Pelton	Francis	Pelton	Francis	Pelton	Francis	Pelton	Francis
200	15.37	11.86	17.37	13.86	26.67	24.48	266.98	164.3796	3.65	1.72	2.13	-3.85	12.37	6.52
300	13.44	11.48	15.44	13.48	25.66	24.02	207.51	154.7504	2.97	1.54	1.99	-2.69	10.44	6.33
400	12.75	11.04	14.75	13.04	25.35	23.70	188.06	143.9616	2.73	1.39	1.94	-3.29	9.75	5.98
500	11.50	10.55	13.50	12.55	24.78	23.4	155.25	132.4025	2.29	1.21	1.91	-5.11	8.50	5.33
600	10.04	10.55	12.04	12.55	24.58	23.45	120.88	132.4025	2.08	1.23	1.90	-3.22	7.93	5.85
700	9.97	10.55	11.97	12.55	24.43	23.53	119.34	132.4025	1.98	1.26	1.90	-1.82	7.89	6.42
800	9.71	10.62	11.71	12.62	24.51	23.51	113.70	134.0244	1.91	1.29	1.89	-0.73	7.55	7.11

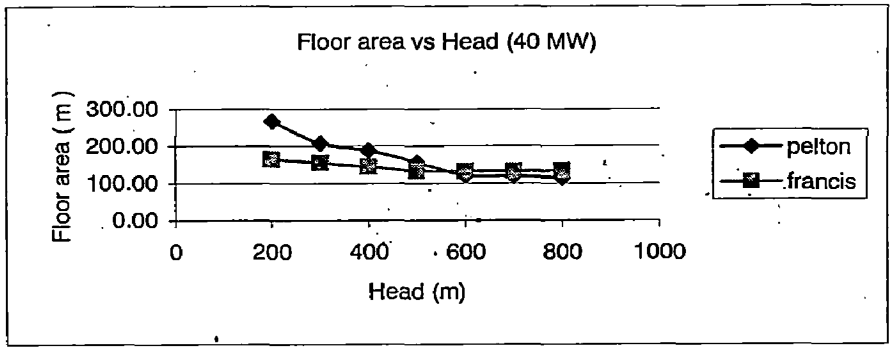

Figure 4.7Relation between floor area and head.

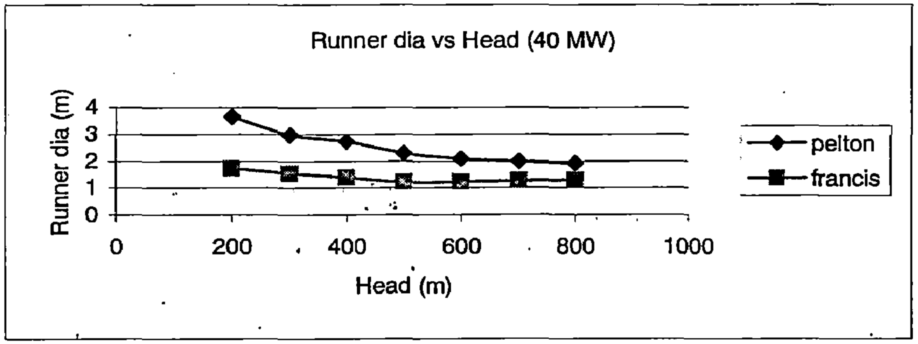

Figure 4.8 Relation between runner dia and head.

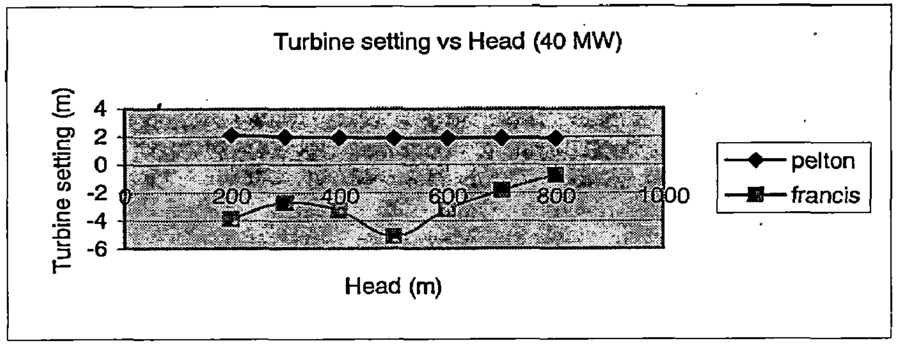

Figure 4.9 Relation between turbine setting and head.

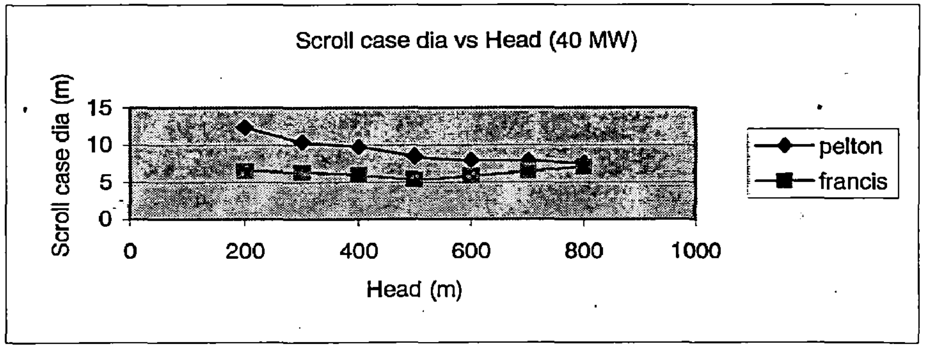

Figure 4.10 Relation between scroll case dia and head.

Table 4.17
Summary of main dimensions of power stations with Pelton & Francis turbines.

60 MW															
Head (m)	Unit bay length		Unit bay width		Unit bay height		floor area(m^2)		Runner dia (m)		Turbine Setting (m)		Scroll case dia (m)	
	Pelton	Francis	Pelton	Francis	Pelton	Francis	Pelton	Francis	Pelton	Francis	Pelton	Francis	Pelton	Francis
200	18.11	12.55	20.11	14.55	28.44	26.12	364.19	182.6025	5.6	2.16	2.37	-2.97	15.11	7.43
300	15.93	11.86	17.93	13.86	27.37	25.33	285.62	164.3796	4.45	1.83	2.1	-3.55	12.93	7.44
400	14.67	11.48	16.67	13.48	26.74	24.98	244.55	154.7504	4.09	1.67	2	-3.52	11.67	7.19
500	13.63	11.04	15.63	13.04	26.31	24.7	213.04	143.9616	3.43	1.50	1.95	-4.70	10.63	6.66
600	12.11	11.04	14.11	13.04	25.70	24.77	170.87	143.9616	2.50	1.53	1.92	-2.87	9.11	7.33
700	11.40	11.09	13.40	13.09	25.95	24.85	152.76	145.1681	2.25	1.56	1.91	-1.50	8.40	8.09
800	11.15	11.93	13.15	13.93	25.71	25.04	146.62	166.1849	2.19	1.60	1.90	-0.44	8.23	8.93

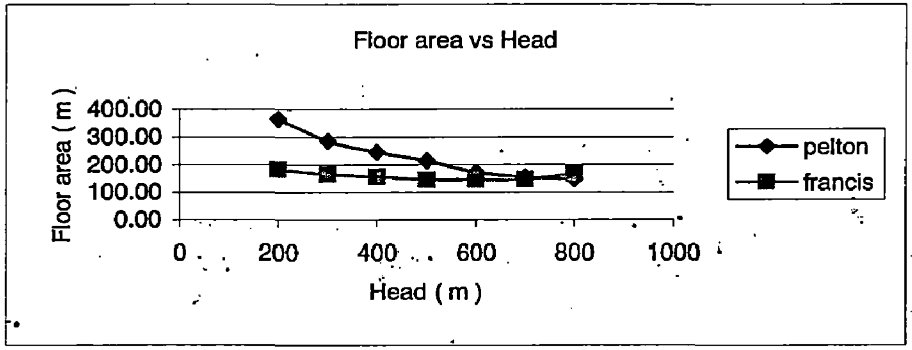

Figure 4.11 Relation between floor area and head.

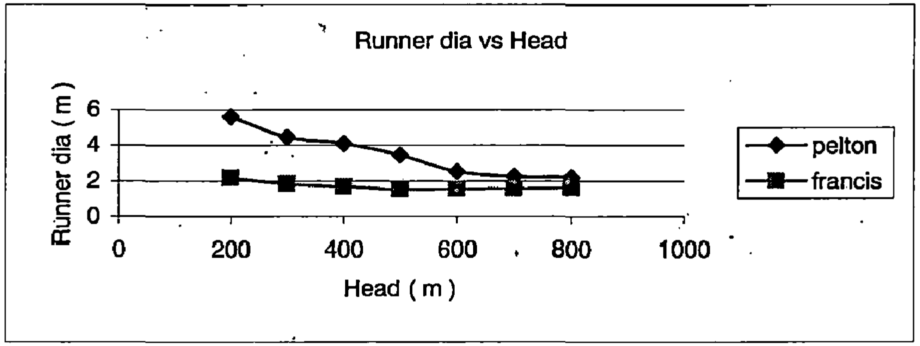

Figure 4.12Relation between runner dia and head.

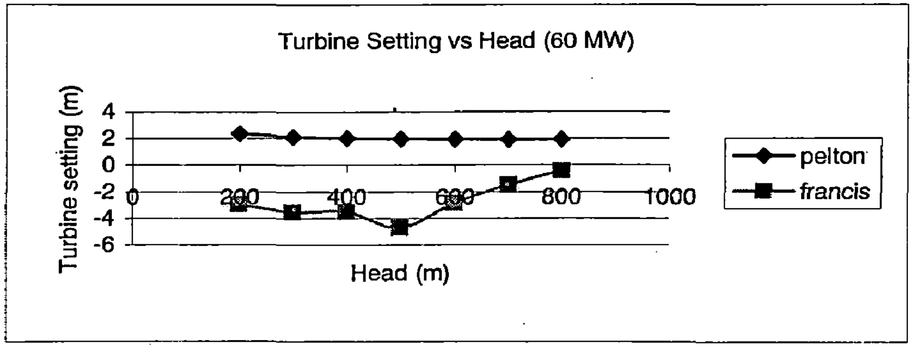

Figure 4.13 Relation between turbine setting and head.

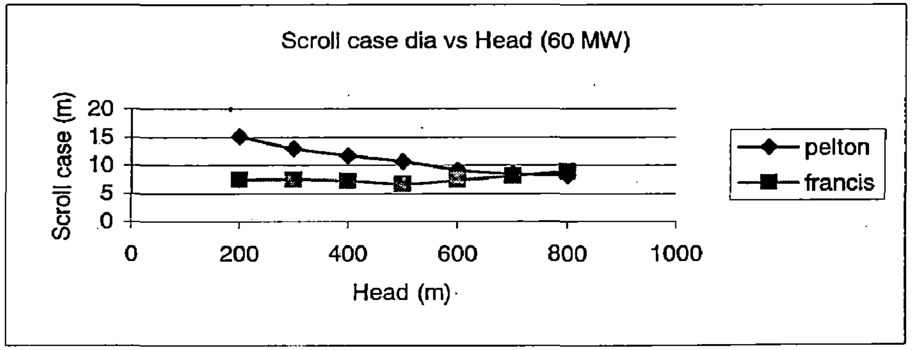

Figure 4.14 Relation between scroll case dia and head.

Table 18
Summary of main dimensions of power stations with Pelton & Francis turbines

80 MW														
Head (m)	Unit bay length		Unit bay width		Unit bay height		floor area(m^2)		Runner dia (m)		Turbine Setting (m)		Scroll case dia (m)	
	Pelton	Francis	Pelton	Francis	Pelton	Francis	Pelton	Francis	Pelton	Francis	Pelton	Francis	Pelton	Francis
200	20.17	13.00	22.17	15.00	30.12	27.55	447.17	195.00	5.35	2.44	2.65	-3.66	17.17	9.28
300	16.80	12.24	18.80	14.24	28.15	26.49	315.84	174.30	4.16	2.10	2.20	-3.74	13.80	8.52
400	15.66	11.86	17.66	13.86	27.68	26.19	276.56	164.38	3.75	1.94	2.06	-3.33	12.66	8.38
500	14.72	11.48	16.72	13.48	27.31	25.88	246.12	154.75	3.42	1.78	2.00	-3.95	11.72	7.99
600	13.29	11.04	15.29	13.04	26.76	25.64	203.20	143.96	2.92	1.6	1.95	-5.63	10.29	7.29
700	12.66	11.04	14.66	13.04	26.58	25.72	185.60	143.96	2.70	1.63	1.93	-3.96	9.66	7.95
800	11.84	11.68	13.84	13.68	26.38	25.89	163.87	159.78	2.41	1.66	1.91	-2.66	8.84	8.68

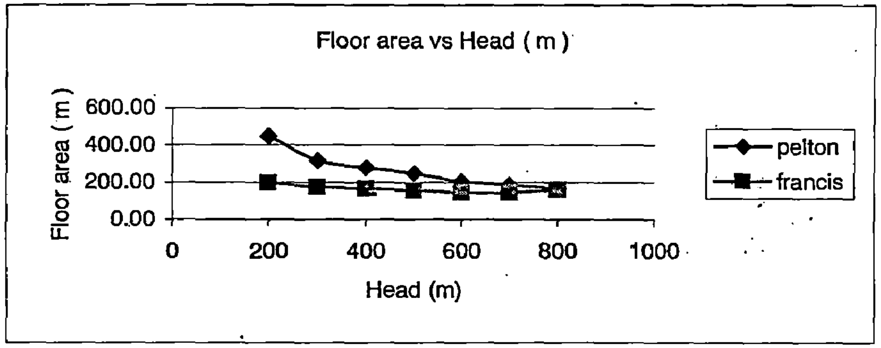

Figure 4.15 Relation between floor area and head.

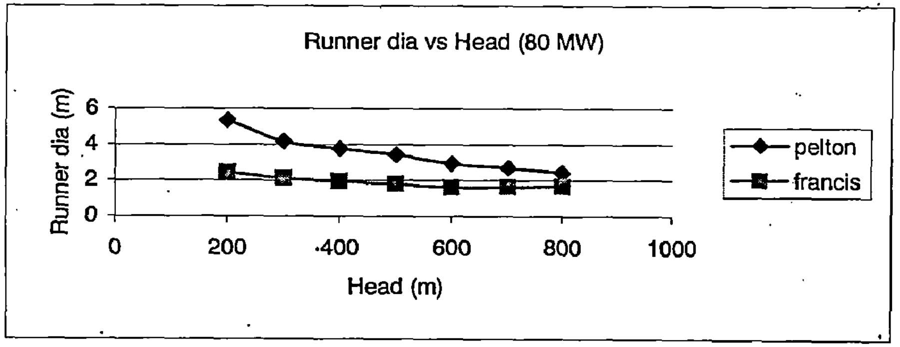

Figure 4.16 Relation between runner dia and head.

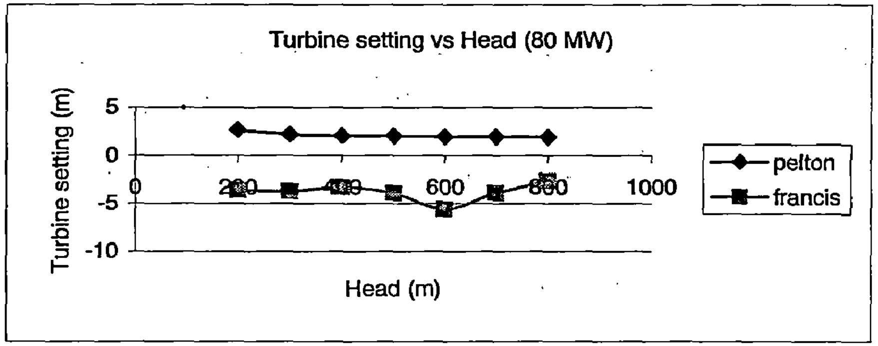

Figure 4.17 Relation between turbine setting and head.

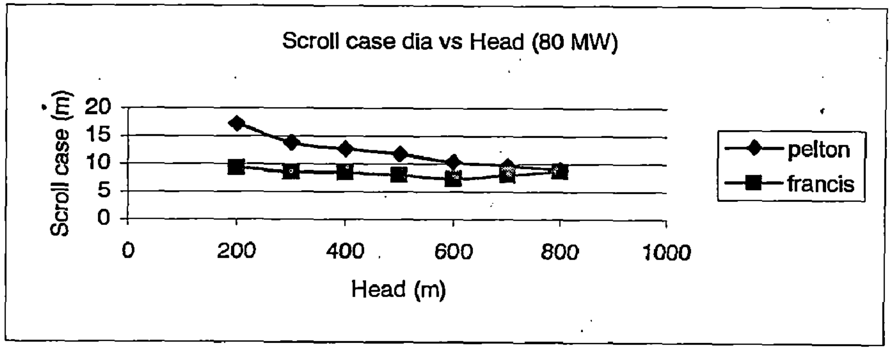

Figure 4.18 Relation between scroll case dia and head.

Table 4.19

Summary of main dimensions of power stations with Pelton & Francis turbines

100 MW																
Head (m)	Unit bay length		Unit bay width		Unit bay height		floor area(m^2)		Runner dia (m)		Turbine Setting (m)		Scroll case dia (m)	
	Pelton	Francis	Pelton	Francis	Pelton	Francis	Pelton	Francis	Pelton	Francis	Pelton	Francis	Pelton	Francis
200	21.2	13.26	23.2	15.26	30.95	28.7	491.84	202.3476	7.06	2.44	2.9	-3.97	18.2	10.26
300	18.47	12.57	20.47	14.57	29.58	27.63	378.08	183.1449	4.75	2.36	2.34	-3.62	15.47	9.57
400	16.64	11.86	18.64	13.86	28.82	26.97	310.17	164.3796	4.10	1.94	2.13	-5.51	13.64	8.47
500	15.8	12.31	17.8	14.31	28.48	27.02	281.24	176.1561	3.80	2.05	2.05	-3.17	12.8	9.31
600	14.46	11.76	16.46	13.76	27.75	26.74	238.01	161.8176	3.33	1.88	1.99	-4.2	11.46	8.76
700	13.92	12.61	15.92	14.61	27.63	26.55	221.61	184.2321	3.14	1.91	1.97	-2.69	10.92	9.61
800	13.17	13.55	15.17	15.55	27.44	27.39	199.79	210.7025	2.98	1.96	1.94	-1.51	10.17	10.55

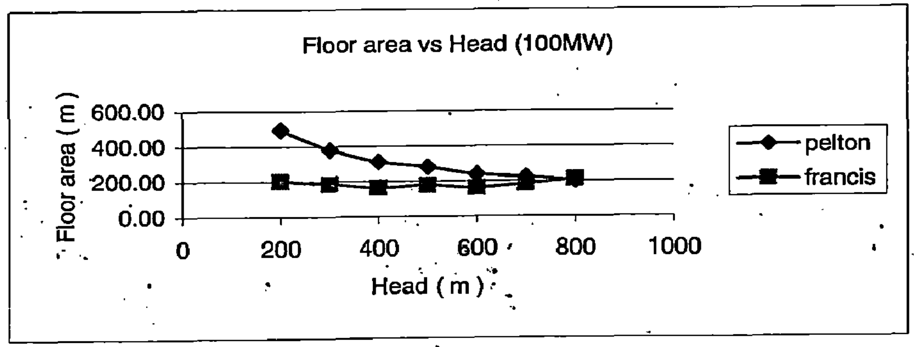

Figure 4.19 Relation between floor area and head.

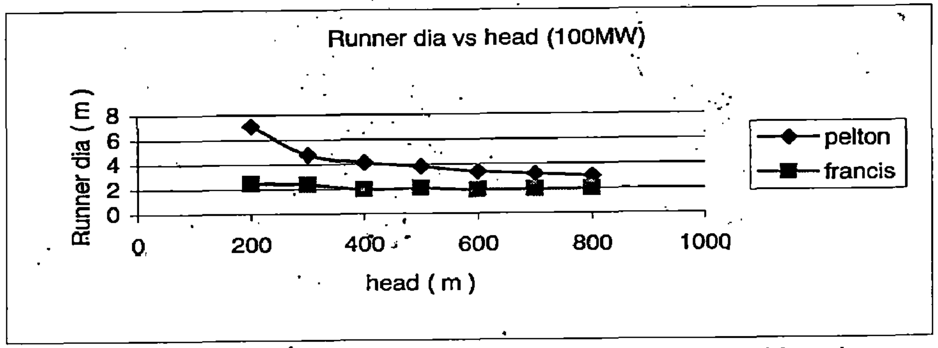

Figure 4.20 Relation between runner dia and head.

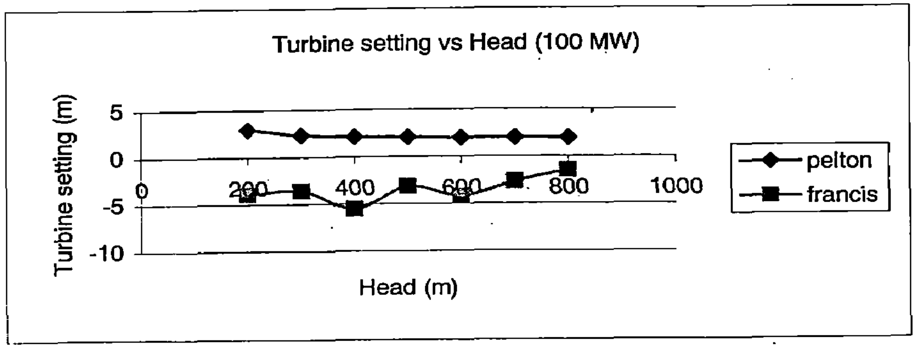

Figure 4.21 Relation between turbine setting and head.

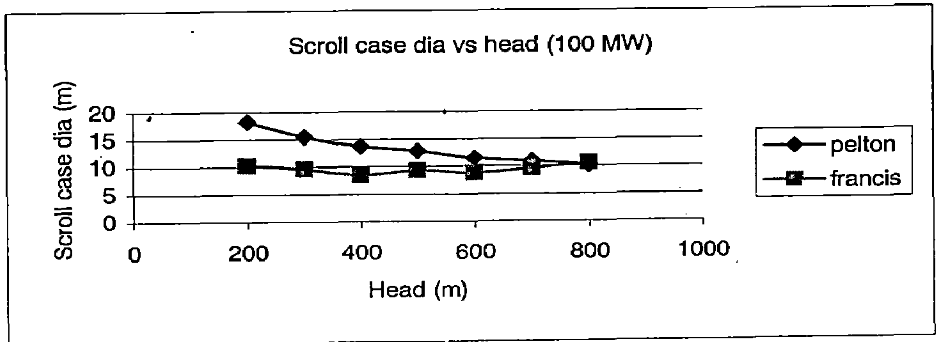

Figure 4.22 Relation scroll case dia setting and head.

Table 20

Summary of main dimensions of power stations with Pelton & Francis turbines

250 MW															
Head (m)	Unit bay length		Unit bay width		Unit bay height		floor area(m^2)		Runner dia (m)		Turbine Setting (m)		Scroll case dia (m)	
	Pelton	Francis	Pelton	Francis	Pelton	Francis	Pelton	Francis	Pelton	Francis	Pelton	Francis	Pelton	Francis
200	30.54	18.96	32.54	20.96	37.03	35.31	993.77	397.4016	9.01	4.24	5.94	-4.41	27.54	15.96
300	26.04	17.93	28.04	19.93	35.58	34.30	730.16	357.3449	7.42	3.69	3.71	-3.93	23.04	14.93
400	23.4	16.31	25.4	18.31	34.72	33.52	594.36	298.6361	6.49	3.19	2.92	-5.64	20.4	13.31
500	21.22	16.33	23.22	18.33	34.23	33.17	492.73	299.3289	5.72	3.03	2.53	-5.11	18.22	13.33
600	20.34	16.12	22.34	18.12	33.99	33.15	454.40	292.0944	5.41	2.86	2.35	-5.25	17.34	13.12
700	19.00	17.33	21.00	19.33	33.61	33.29	399.00	334.9889	4.94	3.31	2.22	-3.62	16.00	16.27
800	18.57	19.59	20.57	21.59	33.48	34.64	381.98	422.9481	1.78	3.31	2.15	-4.49	15.57	16.59

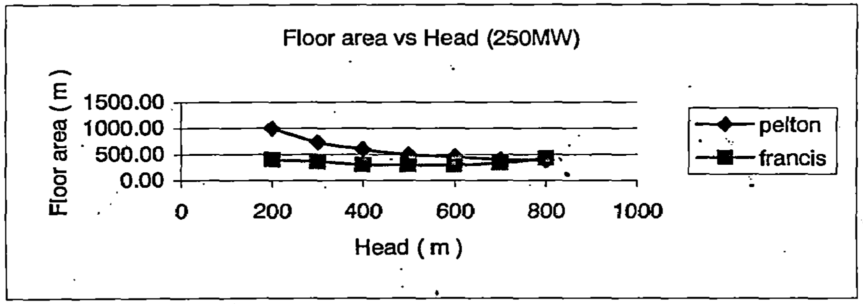

Figure 4.23 Relation between floor area and head.

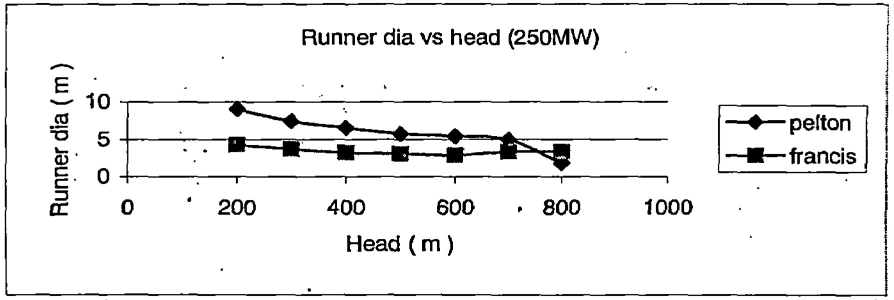

Figure 4.24 Relation between runner dia and head.

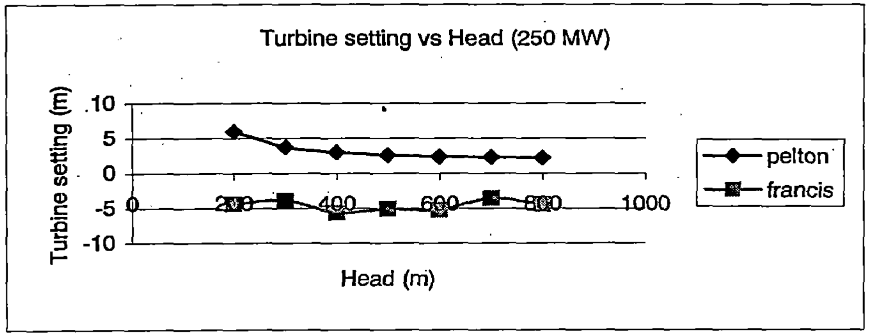

Figure 4.25 Relation between turbine setting and head.

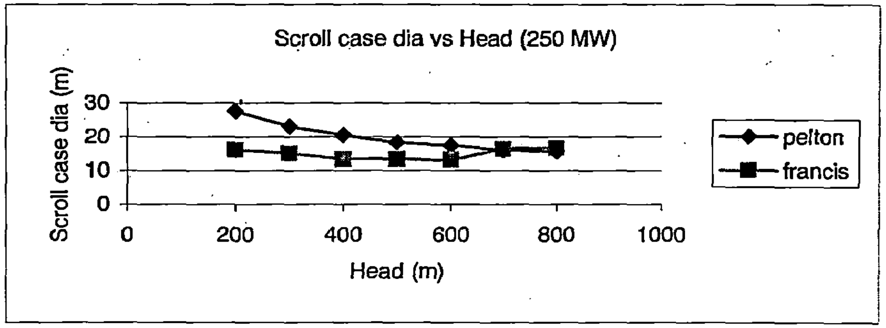

Figure 4.26 Relation between Sroll case dia and head.

MAIN DIMENSIONS OF POWER STATIONS IN INDIA WITH PELTON TURBINE

5.1 INTRODUCTION:

The turbine dimensions of a number of existing power stations with Pelton turbines having surface and underground type power house, vertical and horizontal type of turbine, in India have been calculated using the statistical relationship developed by De-sievro [5] and the generator and power house dimensions by using IS 12800. While comparing the calculated dimensions with actual ones following points are concluded.

The length of the power house is determined by the number of units and the spacing of the unit axes. The width of the power house will be governed by the width of the structures and equipment to be accommodated side by side in the direction of flow, increased by the required operating clearances or by the length of the water passage ways, necessary to ensure favorable hydraulic condition.

For the calculation purpose dimensions of suspended type arrangement is taken into account as nothing mentioned in the data available. However vertical umbrella type design can also be done as mentioned in the chapter - 3.

Main dimensions of all the power stations have been calculated applying relationships enumerated in chapter 3 and is presented in table 5.1 to 5.10 for twenty power houses (each table contains data for two power houses). The main dimensions of Generator and power house have been calculated by considering the vertical type of arrangements only as the actual power house layout and cross section are not a available. However, the unit bay dimensions have been calculated as per the general trend for the suspended type of turbine generator arrangement.

Summary of comparison between various computed and actual parameters are presented in table 5.11, where in only those parameters have included which have found to correspond with the computed parameters. It has not been possible to compare all the parameter because of lack clarity in the actual data as available.

Table 5.1

Bassi Hydro Power Station Himanchal Pradesh Capacity 60 MW Surface power house,vertical type	Sanjay Bhaba Hydro Power Station Himanchal Pradesh Capacity 120 MW Underground power house,vertical type
15 MW unit and 345m head	40 MW unit and 887m head
Trail $N_{sj} = 85.49/(H)^{.243}$	Trail $N_{sj} = 85.49/(H)^{.243}$
$(H)^{.243} = 4.14$	$(H)^{.243} = 5.20$
$(H)^{1.25} = 1487$	$(H)^{1.25} = 4841$
$(P)^{0.5} = 135.8$	$(P)^{0.5} = 213.8$
For 6 jets $(P/j)^{0.5} = 55.43$	For 6 jets $(P/j)^{0.5} = 87.28$
For 4 jets $(P/j)^{0.5} = 67.88$	For 4 jets $(P/j)^{0.5} = 106.9$
Trial, $N_{sj} = 20.66$	Trial, $N_{sj} = 16.43$
Also, $N_{sj} = N(P/j)^{0.5}/H^{1.25}$	Also, $N_{sj} = N(P/j)^{0.5}/H^{1.25}$
for 6 jets	for 6 jets
Trial, N = 554.36	Trial, N = 911.08
poles, p= 10.82	poles, p= 6.59
Taking,P= 12	Taking,P= 8
Actual,N= 500.00	Actual,N= 750.00
Actual,Nsj= 18.64	Actual,Nsj= 13.52
for 4jets	for 4jets
Trial, N = 452.63	Trial, N = 743.90
poles, p= 13.26	poles, p= 8.07
Taking,P= 14	Taking,P= 12
Actual,N= 428.57	Actual,N= 500.00
Actual,Nsj= 19.57	Actual,Nsj= 11.04
Main parameters of Turbine	*Main parameters of Turbine*
Taking 6 Jets	Taking 4 Jets
$N_{sj} = 18.64$	$N_{sj} = 11.04$
N = 500	N = 500
Ns = 45.66	Ns = 22.08
Ku = 0.4718	Ku = 0.5014
D2 = 1.48	D2 = 2.52
Dj/D2 = 0.0858	Dj/D2 = 0.0478
Dj = 0.13	Dj = 0.12
Q = 11.80	Q = 5.25
Hs = 2.45	Hs = 2.40
D3 = 1.901	D3 = 2.976
Casing L = 4.70	Casing L = 6.91
G = 0.91	G = 1.32
F = 4.42	F = 6.00
H = 3.03	H = 4.17
I = 3.02	I = 3.84
Spiral ,B = 3.85	Spiral ,B = 5.39
case C = 3.55	case C = 5.06
D = 3.07	D = 4.62
E = 3.72	E = 5.27
D+E = 6.78	D+E = 9.89
B+C = 7.41	B+C = 10.45

Main parameters of Gen.	*Main parameters of Gen.*
Air gap dia D_g = 3.55	Air gap dia D_g = 3.55
Out st core dia.D_o = 4.48	Out st core dia.D_o = 4.95
St frame dia D_f = 5.68	St frame dia D_f = 6.15
Inn dia Gen.Bar D_b = 7.48	Inn dia Gen.Bar D_b = 7.95
Core leng of st L_c = 0.4477	Core leng of st L_c = 1.1939
length of st.fr L_f = 2.00	length of st.fr L_f = 2.74
Outer bar dia.D = 8.48	Outer bar dia.D = 8.95
Wt of Gen.Rot Wr = 38.06	Wt of Gen.Rot Wr = 101.48
Wt of Tur.Runner = 5.00	Wt of Tur.Runner = 14.00
Wt of rot.parts = 43.06	Wt of rot.parts = 115.48
Ht load bear Bra.= 1.55	Ht load bear Bra.= 1.61
H1 = 4.42	H1 = 6.00
H2 = 9.55	H2 = 10.36
Unit bay Dimensions	*Unit bay Dimensions*
Length Unit bay = 10.41	Length Unit bay = 13.45
Width Unit bay = 11.78	Width Unit bay = 14.89
Height unit bay = 23.47	Height unit bay = 25.85
Length of the power house for four units 56.04	Length of the power house for four units 57.81

Table 5.2

Ghanvi Hydro Power Station Himanchal Pradesh Capacity 22.5 MW Underground power house,vertical type	Baspa II Hydro Power Station Himanchal Pradesh Capacity 300 MW Underground power house,vertical type
11.25 MW unit and 380m head	100MW unit and 702m head
Trail N_{sj} = 85.49/(H)$^{.243}$	Trail N_{sj} = 85.49/(H)$^{.243}$
(H)$^{.243}$= 4.24	(H)$^{.243}$= 4.92
(H)$^{1.25}$= 1677.8	(H)$^{1.25}$= 3613
(P)$^{0.5}$= 114.48	(P)$^{0.5}$= 331.6
For 6 jets (P/j)$^{0.5}$= 46.74	For 6 jets (P/j)$^{0.5}$= 135.4
For 4 jets (P/j)$^{0.5}$= 57.24	For 4 jets (P/j)$^{0.5}$= 165.8
Trial, N_{sj} = 20.18	Trial, N_{sj} = 17.39
Also, N_{sj} = N(P/j)$^{0.5}$/H$^{1.25}$	Also, N_{sj} = N(P/j)$^{0.5}$/H$^{1.25}$
for 6 jets	*for 6 jets*
Trial, N = 724.62	Trial, N = 464.14
poles, p= 8.28	poles, p= 12.93
Taking,P= 10	Taking,P= 16
Actual,N= 600.00	Actual,N= 375.00
Actual,Nsj= 16.71	Actual,Nsj= 14.05
for 4jets	for 4jets
Trial, N = 591.65	Trial, N = 378.97
poles, p= 10.14	poles, p= 15.83
Taking,P= 12	Taking,P= 16
Actual,N= 500.00	Actual,N= 375.00
Actual,Nsj= 17.06	Actual,Nsj= 17.21
Main parameters of Turbine	*Main parameters of Turbine*
Taking 6 Jets	Taking 6 Jets
N_{sj} = 16.71	N_{sj} = 14.05
N = 600	N = 375
Ns = 40.93	Ns = 34.42
Ku = 0.4793	Ku = 0.4897
D2 = 1.32	D2 = 2.92
Dj/D2 = 0.0757	Dj/D2 = 0.0623
Dj = 0.10	Dj = 0.18
Q = 3.45	Q = 15.97
Hs = 2.06	Hs = 2.91
D3 = 1.654	D3 = 3.568
Casing L = 4.19	Casing L = 8.13
G = 0.82	G = 1.54
F = 4.06	F = 6.86
H = 2.77	H = 4.79
I = 2.83	I = 4.29
Spiral ,B = 3.50	Spiral ,B = 6.24
case C = 3.21	case C = 5.89
D = 2.71	D = 5.47
E = 3.36	E = 6.12
D+E = 6.07	D+E = 11.59
B+C = 6.71	B+C = 12.13

Main parameters of Gen.	*Main parameters of Gen.*
Air gap dia D_g = 3.07	Air gap dia D_g = 4.38
Out st core dia.D_o = 4.04	Out st core dia.D_o = 5.24
St frame dia D_f = 5.24	St frame dia D_f = 6.44
Inn dia Gen.Bar D_b = 7.04	Inn dia Gen.Bar D_b = 8.24
Core leng of st L_c = 0.3807	Core leng of st L_c = 2.5320
length of st.fr L_f = 1.93	length of st.fr L_f = 4.08
Outer bar dia.D = 8.04	Outer bar dia.D = 9.24
Wt of Gen.Rot Wr = 30.46	Wt of Gen.Rot Wr = 291.18
Wt of Tur.Runner = 5.00	Wt of Tur.Runner = 20.00
Wt of rot.parts = 35.46	Wt of rot.parts = 311.18
Ht load bear Bra.= 1.49	Ht load bear Bra.= 1.90
H1 = 4.06	H1 = 6.86
H2 = 9.42	H2 = 11.99
Unit bay Dimensions	*Unit bay Dimensions*
Length Unit bay = 9.71	Length Unit bay = 15.13
Width Unit bay = 11.07	Width Unit bay = 16.59
Height unit bay = 22.98	Height unit bay = 28.35
Length of the power house for four units 33.13	Length of the power house for three units 64.51

Table 5.3

Bhira Hydro Power Station Maharastra Capacity 150 MW Suraface power house,horizontal type	Koyna I Hydro Power Station Maharastra Capacity 260 MW Underground power house,vertical type
25MW unit and 460m head	75MW unit and 488m head
Trail N_{sj} = 85.49/(H)$^{.243}$	Trail N_{sj} = 85.49/(H)$^{.243}$
(H)$^{.243}$= 4.44	(H)$^{.243}$= 4.50
(H)$^{1.25}$= 2130	(H)$^{1.25}$= 2294
(P)$^{0.5}$= 182.9	(P)$^{0.5}$= 292
For 6 jets (P/j)$^{0.5}$= 74.69	For 6 jets (P/j)$^{0.5}$= 119
For 4 jets (P/j)$^{0.5}$= 91.47	For 4 jets (P/j)$^{0.5}$= 146
Trial, N_{sj} = 19.27	Trial, N_{sj} = 18.99
Also, N_{sj} = N(P/j)$^{0.5}$/H$^{1.25}$	Also, N_{sj} = N(P/j)$^{0.5}$/H$^{1.25}$
for 6 jets	for 6 jets
Trial, N = 549.64	Trial, N = 365.96
poles, p= 10.92	poles, p= 16.40
Taking,P= 12	Taking,P= 16
Actual,N= 500.00	Actual,N= 375.00
Actual,Nsj= 17.53	Actual,Nsj= 19.46
for 4jets	for 4jets
Trial, N = 448.78	Trial, N = 298.80
poles, p= 13.37	poles, p= 20.08
Taking,P= 16	Taking,P= 22
Actual,N= 375.00	Actual,N= 272.73
Actual,Nsj= 16.10	Actual,Nsj= 17.34
Main parameters of Turbine	*Main parameters of Turbine*
Taking 4 Jets	Taking 6 Jets
N_{sj} = 16.1	N_{sj} = 19.46
N = 375	N = 375
Ns = 32.20	Ns = 47.67
Ku = 0.4817	Ku = 0.4686
D2 = 2.33	D2 = 2.33
Dj/D2 = 0.0726	Dj/D2 = 0.0902
Dj = 0.17	Dj = 0.21
Q = 7.11	Q = 17.76
Hs = 2.36	Hs = 2.70
D3 = 2.907	D3 = 3.020
Casing L = 6.77	Casing L = 7.00
G = 1.29	G = 1.33
F = 5.90	F = 6.06
H = 4.09	H = 4.21
I = 3.78	I = 3.87
Spiral ,B = 5.29	Spiral ,B = 5.45
case C = 4.96	case C = 5.12
D = 4.52	D = 4.68
E = 5.17	E = 5.33
D+E = 9.69	D+E = 10.01
B+C = 10.26	B+C = 10.58

Main parameters of Gen.	*Main parameters of Gen.*
Air gap dia D_g = 4.38	Air gap dia D_g = 4.38
Out st core dia.D_o = 5.24	Out st core dia.D_o = 5.24
St frame dia D_f = 6.44	St frame dia D_f = 6.44
Inn dia Gen.Bar D_b = 8.24	Inn dia Gen.Bar D_b = 8.24
Core leng of st L_c = 0.6330	Core leng of st L_c = 1.8990
length of st.fr L_f = 2.18	length of st.fr L_f = 3.45
Outer bar dia.D = 9.24	Outer bar dia.D = 9.24
Wt of Gen.Rot Wr = 69.63	Wt of Gen.Rot Wr = 208.89
Wt of Tur.Runner = 14.00	Wt of Tur.Runner = 15.00
Wt of rot.parts = 83.63	Wt of rot.parts = 223.89
Ht load bear Bra.= 1.65	Ht load bear Bra.= 1.65
H1 = 5.90	H1 = 6.06
H2 = 9.83	H2 = 11.10
Unit bay Dimensions	*Unit bay Dimensions*
Length Unit bay = 13.26	Length Unit bay = 13.58
Width Unit bay = 14.69	Width Unit bay = 15.01
Height unit bay = 25.23	Height unit bay = 26.66
Length of the power house for six units 96.79	Length of the power house for four units 71.88

Table 5.4

Koyna II Hydro Power Station Maharastra Capacity 300 MW Underground power house,vertical type	Mahatma Gandhi Power Station Karnataka Capacity 120 MW Surface power house,horizontal type
65MW unit and 484.5m head	12MW unit and 356.31m head
Trail N_{sj} = 85.49/$(H)^{.243}$	Trail N_{sj} = 85.49/$(H)^{.243}$
$(H)^{.243}$= 4.49	$(H)^{.243}$= 4.17
$(H)^{1.25}$= 2273	$(H)^{1.25}$= 1548
$(P)^{0.5}$= 271	$(P)^{0.5}$= 125
For 6 jets $(P/j)^{0.5}$= 111	For 6 jets $(P/j)^{0.5}$= 51.03
For 4 jets $(P/j)^{0.5}$= 136	For 4 jets $(P/j)^{0.5}$= 62.50
Trial, N_{sj} = 19.03	Trial, N_{sj} = 20.50
Also, N_{sj} = $N(P/j)^{0.5}/H^{1.25}$	Also, N_{sj} = $N(P/j)^{0.5}/H^{1.25}$
for 6 jets	for 6 jets
Trial, N = 390.26	Trial, N = 621.97
poles, p= 15.37	poles, p= 9.65
Taking,P= 16	Taking,P= 10
Actual,N= 375.00	Actual,N= 600.00
Actual,Nsj= 18.28	Actual,Nsj= 19.78
for 4jets	for 4jets
Trial, N = 318.65	Trial, N = 507.84
poles, p= 18.83	poles, p= 11.81
Taking,P= 20	Taking,P= 14
Actual,N= 300.00	Actual,N= 428.57
Actual,Nsj= 17.91	Actual,Nsj= 17.30
Main parameters of Turbine	*Main parameters of Turbine*
Taking 4 Jets	Taking 4 Jets
N_{sj} = 17.91	N_{sj} = 17.3
N = 300	N = 428.57
Ns = 35.82	Ns = 34.60
Ku = 0.4747	Ku = 0.4770
D2 = 2.94	D2 = 1.78
Dj/D2 = 0.0819	Dj/D2 = 0.0788
Dj = 0.24	Dj = 0.14
Q = 15.51	Q = 4.47
Hs = 2.84	Hs = 2.16
D3 = 3.747	D3 = 2.246
Casing L = 8.50	Casing L = 5.41
G = 1.60	G = 1.04
F = 7.12	F = 4.93
H = 4.98	H = 3.39
I = 4.42	I = 3.28
Spiral ,B = 6.49	Spiral ,B = 4.35
case C = 6.14	case C = 4.04
D = 5.73	D = 3.57
E = 6.38	E = 4.21
D+E = 12.11	D+E = 7.78
B+C = 12.64	B+C = 8.39

Main parameters of Gen.	Main parameters of Gen.
Air gap dia D_g = 5.19	Air gap dia D_g = 3.97
Out st core dia.D_o = 6.00	Out st core dia.D_o = 4.86
St frame dia D_f = 7.20	St frame dia D_f = 6.06
Inn dia Gen.Bar D_b = 9.00	Inn dia Gen.Bar D_b = 7.86
Core leng of st L_c = 1.4331	Core leng of st L_c = 0.3296
length of st.fr L_f = 2.98	length of st.fr L_f = 1.88
Outer bar dia.D = 10.00	Outer bar dia.D = 8.86
Wt of Gen.Rot Wr = 171.98	Wt of Gen.Rot Wr = 32.30
Wt of Tur.Runner = 20.00	Wt of Tur.Runner = 7.00
Wt of rot.parts = 191.98	Wt of rot.parts = 39.30
Ht load bear Bra.= 1.74	Ht load bear Bra.= 1.60
H1 = 7.12	H1 = 4.93
H2 = 10.73	H2 = 9.48
Unit bay Dimensions	*Unit bay Dimensions*
Length Unit bay = 15.64	Length Unit bay = 11.39
Width Unit bay = 17.11	Width Unit bay = 12.78
Height unit bay = 27.35	Height unit bay = 23.91
Length of the power house for four units 82.18	Length of the power house for four units 60.93

Table 5.3

Varahi Hydro Power Station Karnataka Capacity 230 MW Underground power house,vertical type	Pykara Singara Hydro Power Station Tamilnadu Capacity 70 MW Surface power house,horizontal type
115MW unit and 463.28m head	14MW unit and 868m head
Trail $N_{sj} = 85.49/(H)^{.243}$	Trail $N_{sj} = 85.49/(H)^{.243}$
$(H)^{.243}$= 4.44	$(H)^{.243}$= 5.18
$(H)^{1.25}$= 2149	$(H)^{1.25}$= 4711
$(P)^{0.5}$= 361.1	$(P)^{0.5}$= 128.7
For 6 jets $(P/j)^{0.5}$= 147.4	For 2 jets $(P/j)^{0.5}$= 91.03
For 4 jets $(P/j)^{0.5}$= 180.5	For 4 jets $(P/j)^{0.5}$= 64.37
Trial, N_{sj} = 19.24	Trial, N_{sj} = 16.51
Also, $N_{sj} = N(P/j)^{0.5}/H^{1.25}$	Also, $N_{sj} = N(P/j)^{0.5}/H^{1.25}$
for 6 jets	for 2 jets
Trial, N = 280.47	Trial, N = 854.74
poles, p= 21.39	poles, p= 7.02
Taking,P= 24	Taking,P= 10
Actual,N= 250.00	Actual,N= 600.00
Actual,Nsj= 17.15	Actual,Nsj= 11.59
for 4jets	for 4jets
Trial, N = 229.00	Trial, N = 1208.78
poles, p= 26.20	poles, p= 4.96
Taking,P= 26	Taking,P= 6
Actual,N= 230.77	Actual,N= 1000.00
Actual,Nsj= 19.38	Actual,Nsj= 13.66
Main parameters of Turbine	*Main parameters of Turbine*
Taking 6 Jets	Taking 2 Jets
N_{sj} = 17.15	N_{sj} = 11.59
N = 250	N = 600
Ns = 42.01	Ns = 28.39
Ku = 0.4776	Ku = 0.4993
D2 = 3.47	D2 = 2.07
Dj/D2 = 0.0780	Dj/D2 = 0.0504
Dj = 0.27	Dj = 0.10
Q = 28.69	Q = 1.95
Hs = 3.40	Hs = 2.02
D3 = 4.388	D3 = 2.459
Casing L = 9.82	Casing L = 5.84
G = 1.85	G = 1.12
F = 8.06	F = 5.24
H = 5.66	H = 3.62
I = 4.91	I = 3.44
Spiral ,B = 7.41	Spiral ,B = 4.65
case C = 7.04	case C = 4.34
D = 6.66	D = 3.87
E = 7.30	E = 4.52
D+E = 13.96	D+E = 8.39
B+C = 14.45	B+C = 8.99

Main parameters of Gen.	*Main parameters of Gen.*
Air gap dia D_g = 5.84	Air gap dia D_g = 3.07
Out st core dia.D_o = 6.61	Out st core dia.D_o = 4.04
St frame dia D_f = 7.81	St frame dia D_f = 5.24
Inn dia Gen.Bar D_b = 9.61	Inn dia Gen.Bar D_b = 7.04
Core leng of st L_c = 2.3383	Core leng of st L_c = 0.4738
length of st.fr L_f = 3.89	length of st.fr L_f = 2.02
Outer bar dia.D = 10.61	Outer bar dia.D = 8.04
Wt of Gen.Rot Wr = 362.43	Wt of Gen.Rot Wr = 33.16
Wt of Tur.Runner = 30.00	Wt of Tur.Runner = 10.00
Wt of rot.parts = 392.43	Wt of rot.parts = 43.16
Ht load bear Bra.= 2.10	Ht load bear Bra.= 1.49
H1 = 8.06	H1 = 5.24
H2 = 11.98	H2 = 9.51
Unit bay Dimensions	*Unit bay Dimensions*
Length Unit bay = 17.45	Length Unit bay = 11.99
Width Unit bay = 18.96	Width Unit bay = 13.39
Height unit bay = 29.55	Height unit bay = 24.25
Length of the power house for ten units 56.35	Length of the power house for seven units 99.90

Table 5.6

Moyar Hydro Power Station Tamilnadu Capacity 36 MW Surface power house,vertical type	Kundah I Hydro Power Station Tamilnadu Capacity 60 MW Surface power house,vertical type
12MW unit and 371.64m head	20MW unit and 344m head
Trail $N_{sj} = 85.49/(H)^{.243}$	Trail $N_{sj} = 85.49/(H)^{.243}$
$(H)^{.243} = 4.21$	$(H)^{.243} = 4.13$
$(H)^{1.25} = 1632$	$(H)^{1.25} = 1481$
$(P)^{0.5} = 119.2$	$(P)^{0.5} = 152.2$
For 6 jets $(P/j)^{0.5} = 48.66$	For 6 jets $(P/j)^{0.5} = 62.14$
For 4 jets $(P/j)^{0.5} = 59.59$	For 4 jets $(P/j)^{0.5} = 76.10$
Trial, $N_{sj} = 20.29$	Trial, $N_{sj} = 20.68$
Also, $N_{sj} = N(P/j)^{0.5}/H^{1.25}$	Also, $N_{sj} = N(P/j)^{0.5}/H^{1.25}$
for 2 jets	for 6 jets
Trial, N = 680.60	Trial, N = 493.03
poles, p= 8.82	poles, p= 12.17
Taking,P= 10	Taking,P= 14
Actual,N= 600.00	Actual,N= 428.57
Actual,Nsj= 17.89	Actual,Nsj= 17.98
for 4jets	for 4jets
Trial, N = 555.71	Trial, N = 402.56
poles, p= 10.80	poles, p= 14.90
Taking,P= 14	Taking,P= 16
Actual,N= 428.57	Actual,N= 375.00
Actual,Nsj= 15.65	Actual,Nsj= 19.26
Main parameters of Turbine	*Main parameters of Turbine*
Taking 4 Jets	Taking 6 Jets
$N_{sj} = 15.65$	$N_{sj} = 17.98$
N = 428.57	N = 428.57
Ns = 31.30	Ns = 44.04
Ku = 0.4835	Ku = 0.4744
D2 = 1.84	D2 = 1.73
Dj/D2 = 0.0703	Dj/D2 = 0.0823
Dj = 0.13	Dj = 0.14
Q = 3.90	Q = 6.87
Hs = 2.15	Hs = 2.22
D3 = 2.283	D3 = 2.211
Casing L = 5.48	Casing L = 5.33
G = 1.05	G = 1.03
F = 4.98	F = 4.88
H = 3.43	H = 3.36
I = 3.31	I = 3.25
Spiral ,B = 4.40	Spiral ,B = 4.30
case C = 4.09	case C = 3.99
D = 3.62	D = 3.51
E = 4.27	E = 4.16
D+E = 7.89	D+E = 7.68
B+C = 8.49	B+C = 8.29

Main parameters of Gen.	*Main parameters of Gen.*
Air gap dia D_g = 3.97	Air gap dia D_g = 3.97
Out st core dia.D_o = 4.86	Out st core dia.D_o = 4.86
St frame dia D_f = 6.06	St frame dia D_f = 6.06
Inn dia Gen.Bar D_b = 7.86	Inn dia Gen.Bar D_b = 7.86
Core leng of st L_c = 0.3296	Core leng of st L_c = 0.5494
length of st.fr L_f = 1.88	length of st.fr L_f = 2.10
Outer bar dia.D = 8.86	Outer bar dia.D = 8.86
Wt of Gen.Rot Wr = 32.30	Wt of Gen.Rot Wr = 53.84
Wt of Tur.Runner = 8.00	Wt of Tur.Runner = 8.00
Wt of rot.parts = 40.30	Wt of rot.parts = 61.84
Ht load bear Bra.= 1.60	Ht load bear Bra.= 1.60
H1 = 4.98	H1 = 4.88
H2 = 9.48	H2 = 9.70
Unit bay Dimensions	*Unit bay Dimensions*
Length Unit bay = 11.49	Length Unit bay = 11.29
Width Unit bay = 12.89	Width Unit bay = 12.68
Height unit bay = 23.96	Height unit bay = 24.08
Length of the power house for three units 49.96	Length of the power house for three units 49.14

Table 5.7

Kundah II Hydro Power Station Tamilnadu Capacity 175 MW Surface power house,vertical type	Kundah III Hydro Power Station Tamilnadu Capacity 180 MW Surface power house,vertical type
35MW unit and 713.41m head	60MW unit and 713.23m head
Trail N_{sj} = 85.49/(H)$^{.243}$	Trail N_{sj} = 85.49/(H)$^{.243}$
(H)$^{.243}$= 4.94	(H)$^{.243}$= 4.94
(H)$^{1.25}$= 3687	(H)$^{1.25}$= 3686
(P)$^{0.5}$= 201.4	(P)$^{0.5}$= 260.8
For 6 jets (P/j)$^{0.5}$= 82.20	For 6 jets (P/j)$^{0.5}$= 106.5
For 4 jets (P/j)$^{0.5}$= 100.7	For 4 jets (P/j)$^{0.5}$= 130.4
Trial, N_{sj} = 17.32	Trial, N_{sj} = 17.32
Also, N_{sj} = N(P/j)$^{0.5}$/H$^{1.25}$	Also, N_{sj} = N(P/j)$^{0.5}$/H$^{1.25}$
for 6 jets	for 6 jets
Trial, N = 776.87	Trial, N = 599.59
poles, p= 7.72	poles, p= 10.01
Taking,P= 14	Taking,P= 12
Actual,N= 428.57	Actual,N= 500.00
Actual,Nsj= 9.55	Actual,Nsj= 14.44
for 4jets	for 4jets
Trial, N = 634.31	Trial, N = 489.56
poles, p= 9.46	poles, p= 12.26
Taking,P= 14	Taking,P= 14
Actual,N= 428.57	Actual,N= 428.57
Actual,Nsj= 11.70	Actual,Nsj= 15.16
Main parameters of Turbine	*Main parameters of Turbine*
Taking 6 Jets	Taking 4 Jets
N_{sj} = 9.55	N_{sj} = 15.16
N = 428.57	N = 428.57
Ns = 23.39	Ns = 30.32
Ku = 0.5073	Ku = 0.4854
D2 = 2.67	D2 = 2.56
Dj/D2 = 0.0409	Dj/D2 = 0.0678
Dj = 0.11	Dj = 0.17
Q = 3.31	Q = 9.72
Hs = 2.19	Hs = 2.59
D3 = 3.096	D3 = 3.158
Casing L = 7.16	Casing L = 7.29
G = 1.36	G = 1.38
F = 6.17	F = 6.26
H = 4.29	H = 4.36
I = 3.93	I = 3.98
Spiral ,B = 5.56	Spiral ,B = 5.65
case C = 5.23	case C = 5.32
D = 4.79	D = 4.88
E = 5.44	E = 5.53
D+E = 10.23	D+E = 10.41
B+C = 10.79	B+C = 10.97

Main parameters of Gen.	Main parameters of Gen.
Air gap dia D_g = 3.97	Air gap dia D_g = 3.97
Out st core dia.D_o = 4.86	Out st core dia.D_o = 4.86
St frame dia D_f = 6.06	St frame dia D_f = 6.06
Inn dia Gen.Bar D_b = 7.86	Inn dia Gen.Bar D_b = 7.86
Core leng of st L_c = 0.5494	Core leng of st L_c = 1.6482
length of st.fr L_f = 2.10	length of st.fr L_f = 3.20
Outer bar dia.D = 8.86	Outer bar dia.D = 8.86
Wt of Gen.Rot Wr = 53.84	Wt of Gen.Rot Wr = 161.52
Wt of Tur.Runner = 8.00	Wt of Tur.Runner = 17.00
Wt of rot.parts = 61.84	Wt of rot.parts = 178.52
Ht load bear Bra.= 1.60	Ht load bear Bra.= 1.60
H1 = 6.17	H1 = 6.26
H2 = 9.70	H2 = 10.80
Unit bay Dimensions	*Unit bay Dimensions*
Length Unit bay = 13.79	Length Unit bay = 13.97
Width Unit bay = 15.23	Width Unit bay = 15.41
Height unit bay = 25.37	Height unit bay = 26.56
Length of the power house for three units 59.16	Length of the power house for three units 59.87

Table 5.8

Kodyar I Hydro Power Station, Tamilnadu Capacity 60 MW Surface power house, vertical type	Suruliyar Hydro Power Station Tamilnadu Capacity 35 MW Surface power house, horizontal type
60MW unit and 948m head	35MW unit and 979m head
Trail $N_{sj} = 85.49/(H)^{.243}$ $(H)^{.243} = 5.29$ $(H)^{1.25} = 5260$ $(P)^{0.5} = 257.6$ For 6 jets $(P/j)^{0.5} = 105.1$ For 4 jets $(P/j)^{0.5} = 128.8$ Trial, N_{sj} = 16.16 Also, $N_{sj} = N(P/j)^{0.5}/H^{1.25}$ for 6 jets Trial, N = 808.68 poles, p= 7.42 Taking,P= 8 Actual,N= 750.00 Actual,Nsj= 14.99 for 4jets Trial, N = 660.28 poles, p= 9.09 Taking,P= 12 Actual,N= 500.00 Actual,Nsj= 12.24	Trail $N_{sj} = 85.49/(H)^{.243}$ $(H)^{.243} = 5.33$ $(H)^{1.25} = 5476$ $(P)^{0.5} = 209.0$ For 6 jets $(P/j)^{0.5} = 85.34$ For 4 jets $(P/j)^{0.5} = 104.5$ Trial, N_{sj} = 16.04 Also, $N_{sj} = N(P/j)^{0.5}/H^{1.25}$ for 6 jets Trial, N = 1029.18 poles, p= 5.83 Taking,P= 6 Actual,N= 1000.00 Actual,Nsj= 15.58 for 4jets Trial, N = 840.32 poles, p= 7.14 Taking,P= 10 Actual,N= 600.00 Actual,Nsj= 11.45
Main parameters of Turbine Taking 4 Jets N_{sj} = 12.24 N = 500 Ns = 24.48 Ku = 0.4968 D2 = 2.58 Dj/D2 = 0.0535 Dj = 0.14 Q = 7.13 Hs = 2.52 D3 = 3.091 Casing L = 7.15 G = 1.36 F = 6.16 H = 4.29 I = 3.92 Spiral ,B = 5.55 case C = 5.22 D = 4.78 E = 5.43 D+E = 10.22 B+C = 10.78	*Main parameters of Turbine* Taking 4 Jets N_{sj} = 11.45 N = 600 Ns = 22.90 Ku = 0.4998 D2 = 2.20 Dj/D2 = 0.0497 Dj = 0.11 Q = 4.55 Hs = 2.32 D3 = 2.610 Casing L = 6.16 G = 1.18 F = 5.46 H = 3.78 I = 3.56 Spiral ,B = 4.87 case C = 4.55 D = 4.09 E = 4.74 D+E = 8.83 B+C = 9.42

Main parameters of Gen.	Main parameters of Gen.
Air gap dia D_g = 3.55	Air gap dia D_g = 3.18
Out st core dia.D_o = 4.95	Out st core dia.D_o = 4.18
St frame dia D_f = 6.15	St frame dia D_f = 5.38
Inn dia Gen.Bar D_b = 7.95	Inn dia Gen.Bar D_b = 7.18
Core leng of st L_c = 1.7909	Core leng of st L_c = 1.1223
length of st.fr L_f = 3.34	length of st.fr L_f = 2.67
Outer bar dia.D = 8.95	Outer bar dia.D = 8.18
Wt of Gen.Rot Wr = 152.22	Wt of Gen.Rot Wr = 67.34
Wt of Tur.Runner = 14.00	Wt of Tur.Runner = 6.00
Wt of rot.parts = 166.22	Wt of rot.parts = 73.34
Ht load bear Bra.= 1.61	Ht load bear Bra.= 1.51
H1 = 6.16	H1 = 5.46
H2 = 10.95	H2 = 10.18
Unit bay Dimensions	*Unit bay Dimensions*
Length Unit bay = 13.78	Length Unit bay = 12.42
Width Unit bay = 15.22	Width Unit bay = 13.83
Height unit bay = 26.62	Height unit bay = 25.14
Length of the power house for three units 31.55	Length of the power house for one units 28.83

Table 5.9

Sabarigiri Hydro Power Station Kerala Capacity 300 MW Surface power house,vertical type	Kuttiyadi Hydro Power Station Kerala Capacity 75 MW Surface power house,horizontal type
60MW unit and 715m head	25MW unit and 643m head
Trail $N_{sj} = 85.49/(H)^{.243}$	Trail $N_{sj} = 85.49/(H)^{.243}$
$(H)^{.243}$= 4.94	$(H)^{.243}$= 4.81
$(H)^{1.25}$= 3697.3	$(H)^{1.25}$= 3238
$(P)^{0.5}$= 260.24	$(P)^{0.5}$= 169.3
For 6 jets $(P/j)^{0.5}$= 106.24	For 6 jets $(P/j)^{0.5}$= 69.12
For 4 jets $(P/j)^{0.5}$= 130.12	For 4 jets $(P/j)^{0.5}$= 84.66
Trial, N_{sj} = 17.31	Trial, N_{sj} = 17.76
Also, $N_{sj} = N(P/j)^{0.5}/H^{1.25}$	Also, $N_{sj} = N(P/j)^{0.5}/H^{1.25}$
for 6 jets	for 6 jets
Trial, N = 602.42	Trial, N = 832.06
poles, p= 9.96	poles, p= 7.21
Taking,P= 10	Taking,P= 8
Actual,N= 600.00	Actual,N= 750.00
Actual,Nsj= 17.24	Actual,Nsj= 16.01
for 4jets	for 4jets
Trial, N = 491.87	Trial, N = 679.37
poles, p= 12.20	poles, p= 8.83
Taking,P= 12	Taking,P= 10
Actual,N= 500.00	Actual,N= 600.00
Actual,Nsj= 17.60	Actual,Nsj= 15.69
Main parameters of Turbine	*Main parameters of Turbine*
Taking 4 Jets	Taking 6 Jets
N_{sj} = 17.6	N_{sj} = 16.01
N = 500	N = 750
Ns = 35.20	Ns = 39.22
Ku = 0.4759	Ku = 0.4821
D2 = 2.15	D2 = 1.38
Dj/D2 = 0.0803	Dj/D2 = 0.0721
Dj = 0.17	Dj = 0.10
Q = 9.66	Q = 4.54
Hs = 2.48	Hs = 2.13
D3 = 2.729	D3 = 1.718
Casing L = 6.40	Casing L = 4.32
G = 1.22	G = 0.84
F = 5.64	F = 4.16
H = 3.90	H = 2.84
I = 3.65	I = 2.88
Spiral ,B = 5.04	Spiral ,B = 3.59
case C = 4.72	case C = 3.30
D = 4.26	D = 2.80
E = 4.91	E = 3.45
D+E = 9.17	D+E = 6.26
B+C = 9.75	B+C = 6.89

Main parameters of Gen.	*Main parameters of Gen.*
Air gap dia D_g = 3.55	Air gap dia D_g = 2.46
Out st core dia.D_o = 4.48	Out st core dia.D_o = 3.23
St frame dia D_f = 5.68	St frame dia D_f = 4.43
Inn dia Gen.Bar D_b = 7.48	Inn dia Gen.Bar D_b = 6.23
Core leng of st L_c = 1.7909	Core leng of st L_c = 1.0575
length of st.fr L_f = 3.34	length of st.fr L_f = 2.61
Outer bar dia.D = 8.48	Outer bar dia.D = 7.23
Wt of Gen.Rot Wr = 152.22	Wt of Gen.Rot Wr = 84.60
Wt of Tur.Runner = 11.00	Wt of Tur.Runner = 6.00
Wt of rot.parts = 163.22	Wt of rot.parts = 90.60
Ht load bear Bra.= 1.55	Ht load bear Bra.= 1.37
H1 = 5.64	H1 = 4.16
H2 = 10.89	H2 = 9.98
Unit bay Dimensions	*Unit bay Dimensions*
Length Unit bay = 12.75	Length Unit bay = 9.89
Width Unit bay = 14.17	Width Unit bay = 11.26
Height unit bay = 26.03	Height unit bay = 23.63
Length of the power house for six units 93.27	Length of the power house for three units 43.56

Table 5.10

Rammam II Hydro Power Station West Bengal Capacity 51 MW Surface power house,horozontal type	Shanan Hydro Power Station Himanchal Capacity 110 MW Surface power house,horozontal type
12.75MW unit and 500m head	15MW unit and 488m head
Trail N_{sj} = 85.49/$(H)^{.243}$ $(H)^{.243}$= 4.53 $(H)^{1.25}$= 2364 $(P)^{0.5}$= 122.9 For 6 jets $(P/j)^{0.5}$= 50.15 For 4 jets $(P/j)^{0.5}$= 61.43 Trial, N_{sj} = 18.88 Also, N_{sj} = $N(P/j)^{0.5}/H^{1.25}$ for 6 jets Trial, N = 890.18 poles, p= 6.74 Taking,P= 8 Actual,N= 750.00 Actual,Nsj= 15.91 for 4jets Trial, N = 726.83 poles, p= 8.26 Taking,P= 10 Actual,N= 600.00 Actual,Nsj= 15.59	Trail N_{sj} = 85.49/$(H)^{.243}$ $(H)^{.243}$= 4.50 $(H)^{1.25}$= 2294 $(P)^{0.5}$= 130.9 For 2 jets $(P/j)^{0.5}$= 92.59 For 4 jets $(P/j)^{0.5}$= 65.47 Trial, N_{sj} = 18.99 Also, N_{sj} = $N(P/j)^{0.5}/H^{1.25}$ for 2 jets Trial, N = 470.56 poles, p= 12.75 Taking,P= 14 Actual,N= 428.57 Actual,Nsj= 17.30 for 4jets Trial, N = 665.47 poles, p= 9.02 Taking,P= 10 Actual,N= 600.00 Actual,Nsj= 17.13
Main parameters of Turbine Taking 4 Jets N_{sj} = 15.59 N = 600 Ns = 31.18 Ku = 0.4837 D2 = 1.52 Dj/D2 = 0.0700 Dj = 0.11 Q = 3.08 Hs = 2.09 D3 = 1.891 Casing L = 4.68 G = 0.91 F = 4.41 H = 3.02 I = 3.01 Spiral ,B = 3.84 case C = 3.54 D = 3.05 E = 3.70 D+E = 6.76 B+C = 7.38	*Main parameters of Turbine* Taking 2 Jets N_{sj} = 17.3 N = 428.57 Ns = 24.47 Ku = 0.4770 D2 = 2.08 Dj/D2 = 0.0788 Dj = 0.16 Q = 3.58 Hs = 2.20 D3 = 2.628 Casing L = 6.19 G = 1.18 F = 5.49 H = 3.80 I = 3.57 Spiral ,B = 4.89 case C = 4.57 D = 4.12 E = 4.77 D+E = 8.88 B+C = 9.47

Main parameters of Gen. Air gap dia D_g = 3.07 Out st core dia.D_o = 4.04 St frame dia D_f = 5.24 Inn dia Gen.Bar D_b = 7.04 Core leng of st L_c = 0.4315 length of st.fr L_f = 1.98 Outer bar dia.D = 8.04 Wt of Gen.Rot Wr = 34.52 Wt of Tur.Runner = 5.00 Wt of rot.parts = 39.52 Ht load bear Bra.= 1.49 H1 = 4.41 H2 = 9.47	*Main parameters of Gen.* Air gap dia D_g = 3.97 Out st core dia.D_o = 4.86 St frame dia D_f = 6.06 Inn dia Gen.Bar D_b = 7.86 Core leng of st L_c = 0.4120 length of st.fr L_f = 1.96 Outer bar dia.D = 8.86 Wt of Gen.Rot Wr = 41.20 Wt of Tur.Runner = 10.00 Wt of rot.parts = 51.20 Ht load bear Bra.= 1.60 H1 = 5.49 H2 = 9.56
Unit bay Dimensions Length Unit bay = 10.38 Width Unit bay = 11.76 Height unit bay = 23.38 Length of the power house for four units 55.91	*Unit bay Dimensions* Length Unit bay = 12.47 Width Unit bay = 13.88 Height unit bay = 24.55 Length of the power house for four units 66.34

Table 5.11

Comparison of dimensions of power stations in India between actual and computed data.

S. No.	Name of Power Station	Unit Cap. (MW)	No.of units	Run dia.(m)		No. of noz.	RPM		specific speed		specific speed per jet	Head (m)	Turbine type	Type of PH	Remarks
				actual	calcul.		actual	calcul	actual (rpm)	calcul. (rpm)					
1	Bassi (60 MW), Himachal	15	4	1.906	1.901	6	500	500	NA	45.66	18.64	345	Vert, Pel.	Surface	
2	Sanjay Bhabha (120 MW), Himachal	40	3	2.957	2.976	4	500	500	NA	22.08	11.04	887	Vert, Pel.	Undergr.	
3	Ghanvi (22.5 MW), Himachal	11.25	2	1.722	1.654	6	600	600	39.41	40.93	16.71	380	Vert, Pel.	Undergr.	
4	Baspa II (300 MW), Himachal	100	3	3.58	3.568	6	375	375	33.3	34.42	14.05	702	Vert, Pel.	Undergr.	
5	Bhira (150 MW), Maharastra	25	6	2.905	2.907	4	375	375	NA	32.2	16.1	460	Horiz,Pel.	Surface	
6	Koyna I (260 MW) ,Maharastra	65	4	3.621	3.747	6	375	375	NA	47.67	19.46	485	Vert, Pel.	Undergr.	
7	Koyna II (300 MW) ,Maharastra	75	4	3.02	3.02	4	300	300	NA	35.82	17.91	488	Vert, Pel.	Undergr.	
8	Mahatma Gandhi (120 MW),Karnataka	12	4	2.134	2.246	4	428.6	428.6	NA	34.6	17.3	356	Horiz,Pel.	Surface	
9	Varahi (230 MW),Karnataka	115	2	4.5	4.388	6	250	250	NA	42.01	17.15	463	Vert, Pel.	Undergr.	
10	Pykara Singara (70 MW),Tamilnadu	14	2	2.368	2.459	2	600	600	NA	28.39	11.59	868	Horiz,Pel.	Surface	
11	Moyar (36 MW),Tamilnadu	12	3	2.23	2.283	4	428.6	428.6	NA	31.3	15.65	372	Vert, Pel.	Surface	
12	Kundah I (60 MW),Tamilnadu	20	3	2.161	2.211	6	428.6	428.6	NA	44.04	17.98	344	Vert, Pel.	Surface	
13	Kundah II (175 MW),Tamilnadu	35	5	3.033	3.096	6	428.6	428.6	NA	23.39	9.55	714	Vert, Pel.	Surface	
14	Kundah III(180 MW),Tamilnadu	60	3	2.957	3.158	4	333.3	428.6	NA	30.32	15.16	714	Vert, Pel.	Surface	
15	Kodyar I (60 MW),Tamilnadu	60	1	3.1	3.091	4	500	500	NA	24.48	12.24	948	Vert, Pel.	Surface	
16	Suruliyar (35 MW), Tamilnadu	35	1	2.63	2.61	4	600	600	NA	22.9	11.45	979	Horiz,Pel.	Surface	
17	Sabarigiri (300 MW), Kerala	50	6	2.59	2.72	4	500	500	NA	35.2	17.6	715	Vert, Pel.	Surface	
18	Kuttiyadi (75 MW), Kerala	25	3	1.703	1.718	6	600	750	NA	39.22	16.01	643	Vert, Pel.	Surface	
19	Rammam II (51 MW), West Bengal	12.75	4	1.988	1.891	4	600	600	23.96	31.18	15.59	500	Horiz,Pel.	Surface	
20	Shanan (110 MW), Himachal	15	4	2.55	2.628	2	428.6	428.6	NA	24.47	17.3	488	Horiz,Pel.	Surface	

CONCLUSION AND RECOMMENDATIONS

Critical analysis of some of the hydro power stations as mentioned in the foregoing chapters, yield the following conclusions:

(6.1) The turbine dimensions of a number of existing power stations with Pelton turbines having surface and underground type power house, vertical and horizontal type of turbine, in India have been computed and compared with the actual data available. While comparing the computed dimensions with actual data following points are concluded.

(a) The computed and actual runner diameter of turbines are very closely matching both for the vertical and horizontal types. *So the enumerated relationships in chapter 3 are very useful for preliminary dimensioning of Pelton turbines.*

(b) It has been observed that, the recent trend is to have higher specific speed day by day to have smaller electro-mechanical equipments, higher efficiency and overall economy of the power house. *The specific speed has to be chosen carefully keeping in view the current overall picture and the international practice.*

(6.2) Selection of turbine in the overlapping ranges of Pelton and Francis turbines can be made through the comparison of installations of electric power stations with the different capacities and head. For this purpose, a head range of 200 to 800 metres has been chosen for both the type of machines with the same capacities 20 to 250 MW to find out the main dimensions according to the relationships enumerated in chapter 3.

Taking into account the fact that turbines were sized according to the statistical data and not on the basis of actual model test results, some interesting conclusions can be drawn:

- the setting of the Francis turbine is much deeper than the Pelton turbine between the head range of 200 to 600 metres which requires greater excavations for outdoor power plants with the Francis turbine,
- the floor area of unit bay for Pelton turbine is more than the Francis turbine between the head range of 200 to 600 metres, leading to wider and larger power houses for the power plants with Pelton turbine,

- the runner diameter of the Pelton turbines are larger than Francis turbines between the head range of 200 to 600 metres leading to the larger size of the machine for the power plants with Pelton turbine ,
- the distributor of the Pelton turbines are larger in size than the scroll case of Francis turbines between the head ranges of 200 to 600 metres, leading to the wider and larger power houses for the power plants with Pelton turbine; and,
- the cost of generator is lower for Francis, because of its higher speed of rotation.

The actual choice depends upon several other technical and economical considerations, among which the worth mentioning are:

- the variation in net head variations to which Pelton is more sensitive,
- the output variations that are accepted with higher efficiencies by Pelton turbine,
- the absence of hydraulic thrust in Pelton turbines,
- higher reliability of Pelton turbines due to simpler design,
- the inherent advantages of Pelton machines in presence of high solid water content because of their easier and less expensive maintenance.

It has to be pointed out that the need to install Pelton wheels above the maximum tail water level does not allow the available head to be fully utilized. This disadvantage becomes evident at low heads.

Evaluating all the relative merits and disadvantages of Pelton and Francis turbines within the head range of 200 to 800 metres, it is seen that between the head range of 200 to 600 metres and under circumstances where both types can be considered for installation, the application of a Francis turbine is usually preferred. Beyond the head ranges of 600 metres, use of Pelton turbine is preferable.

(6.3) For the determination of unit bay size, in the case of Pelton turbine installations, the distributor dimensions govern for the units of capacity 40 to 250 MW. For lower outputs generator barrel dimension governs the unit bay size.

Whereas, in case of Francis turbines, spiral case dimensions governs for determining the unit bay size for the units of capacity 20 to 80 MW. For higher generator outputs the generator barrel dimensions governs the unit bay size.

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