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भारतीय मानक मसौदा

जल विद्युत गृहों के टर्बाइनों का चयन, प्रारम्भिक आयाम और विन्यास — दिशानिर्देश

भाग-1 मध्यम और वृहत् विद्युत गृह

Draft Indian Standard

SELECTION OF TURBINES, PRELIMINARY DIMENSIONING AND LAYOUT OF HYDRO-ELECTRIC POWER HOUSES — GUIDELINES

PART 1 MEDIUM AND LARGE POWER HOUSES

(*First Revision of* IS 12800 (Part 1))

Hydroelectric Power House Structures Sectional Committee, 15	Last date for Comments: **25 June 2025**

FOREWORD
(*Formal clauses of the foreword will be added later*)

So far as to generate electrical energy from hydroelectric power houses, selection of turbines, preliminary dimensioning and layout is necessary. In designing of such power houses, requirements will be different in large, medium and micro (small) power houses. Requirements are, therefore, laid down separately for large and medium power houses and small power houses. This standard is, therefore, formulated into three parts - Part 1 covering medium and large power houses, Part 2 covering storage power houses and Part 3 mini and micro power houses.

Guidelines covered in this standard are applicable after fixing the data with regard to the capacity, type, number of units and discharges. Departure from the guidelines may be necessary to meet such special requirements and condition of individual site based on judgment and experience.

This standard was first published in 1993. This revision of the standard has been brought out based on wide field experience and international practices, also updating the references. In this revision, the major changes that have been made are as follows:

a) The definition and formula of specific speed has been updated;
b) Maximum tail water level has been defined;

c) Sketches of relationship between specific speed and rated head for Francis and Kaplan turbines have been updated;

d) For the calculation of suction head, the temperature condition has been updated;

e) Mathematical equations for various parameters have been given along with their sketches;

f) Addition of a minimum margin for deeper setting of turbine from calculated values has been specified;

g) Provision for calculation of length of stator frame has been updated; and

h) Formula for calculation of weight of generator rotor has been added and the old sketch meant for its calculation has been deleted.

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2: 2022 'Rules for rounding off numerical values (*second revision*). The number of significant places retained in the rounded-off value shall be the same as that of the specified value in this standard.

Draft Indian Standard

SELECTION OF TURBINES, PRELIMINARY DIMENSIONING AND LAYOUT OF HYDRO-ELECTRIC POWER HOUSE — GUIDELINES

PART 1 MEDIUM AND LARGE POWER HOUSES

(*First Revision of* IS 12800 Part 1)

Hydroelectric Power House Structures Sectional Committee, 15

Last date for Comments: **25 June 2025**

1 SCOPE

This standard (Part 1) lays down guidelines for preliminary dimensioning for hydroelectric power houses with reaction turbines having vertical shaft arrangement.

NOTE — These guidelines will generally apply to vertical shaft unit capacities from 5 MW to 500 MW.

2 REFERENCES

The standards listed below Annex B contain provisions, which through reference in this text constitute provisions of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards.

3 TERMINOLOGY

For this standard, the definitions given in IS 4410 (Part 10), IS 7418 and the following shall apply.

3.1 Specific Speed (n_s)

It is the speed in r.p.m. at which a turbine of homologous design would operate if the runner were reduced to a size which would develop one kilo watt under one metre head. It is given by:

$$n_s = \frac{n\,.\sqrt{P}}{H^{5/4}}$$

where

n_s = specific speed of turbine;
n = rated speed of turbine in revolutions/ minute;
P = rated turbine output in kW; and
H = rated head in metres.

3.2 Minimum Tail Water Level

It is the water level in the tail race at the exit end of the draft tube corresponding to a discharge required to run one machine at no load.

3.3 Maximum Tail Water Level

It is the water level in the tail race at the exit end of the draft tube corresponding to the maximum discharge through all the machines.

4 MAIN PARAMETERS OF TURBINE

4.1 Type of Turbine

The selection of type of turbine shall be made in accordance with IS 12837.

4.2 Speed

4.2.1 Rated head and rated output per machine being known, suitable speeds from economic considerations may be decided in consultation with the manufacturer.

4.2.2 Alternatively, speed can be determined by the following steps.

4.2.2.1 Determine trial specific speed by Fig. 1A or Fig. 1B corresponding to available rated head of site.

4.2.2.2 After ascertaining trial specific speed as mentioned in the foregoing para, trial synchronous speed/rotational speed n' can be computed from the following formula:

$$n' = \frac{n'_{\mathrm{s}} \, . \, H^{5/4}}{\sqrt{P}}$$

where

n'_{s} = trial specific speed.

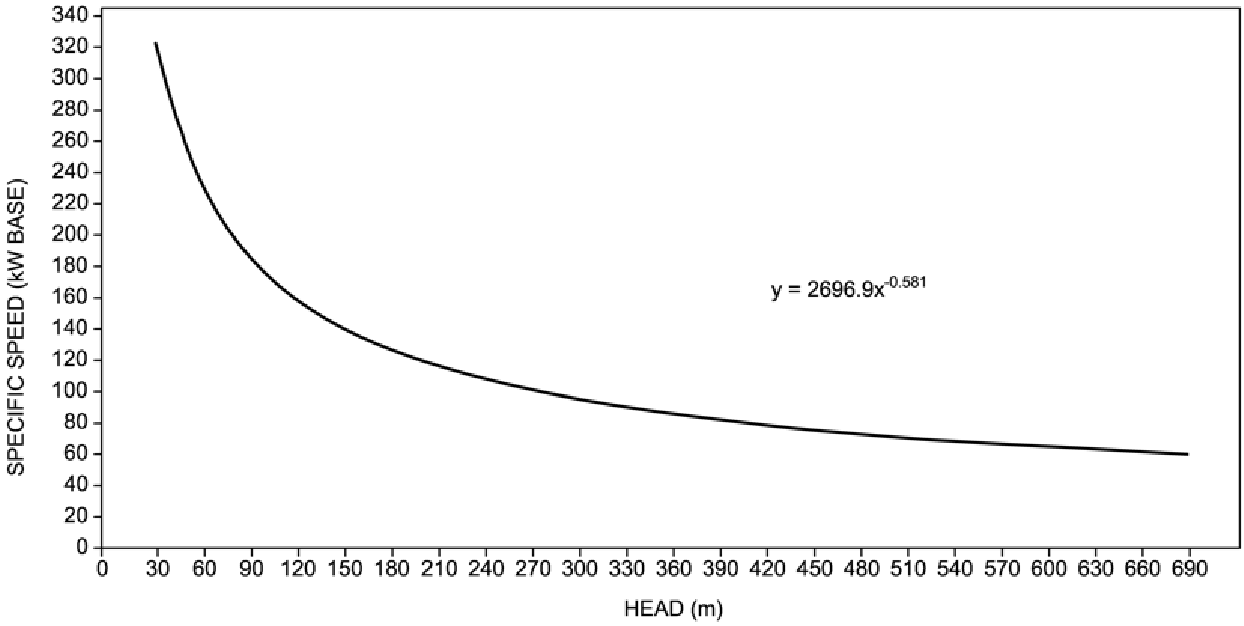


FIG. 1A RELATIONSHIP BETWEEN SPECIFIC SPEED AND RATED HEAD FOR FRANCIS TURBINE

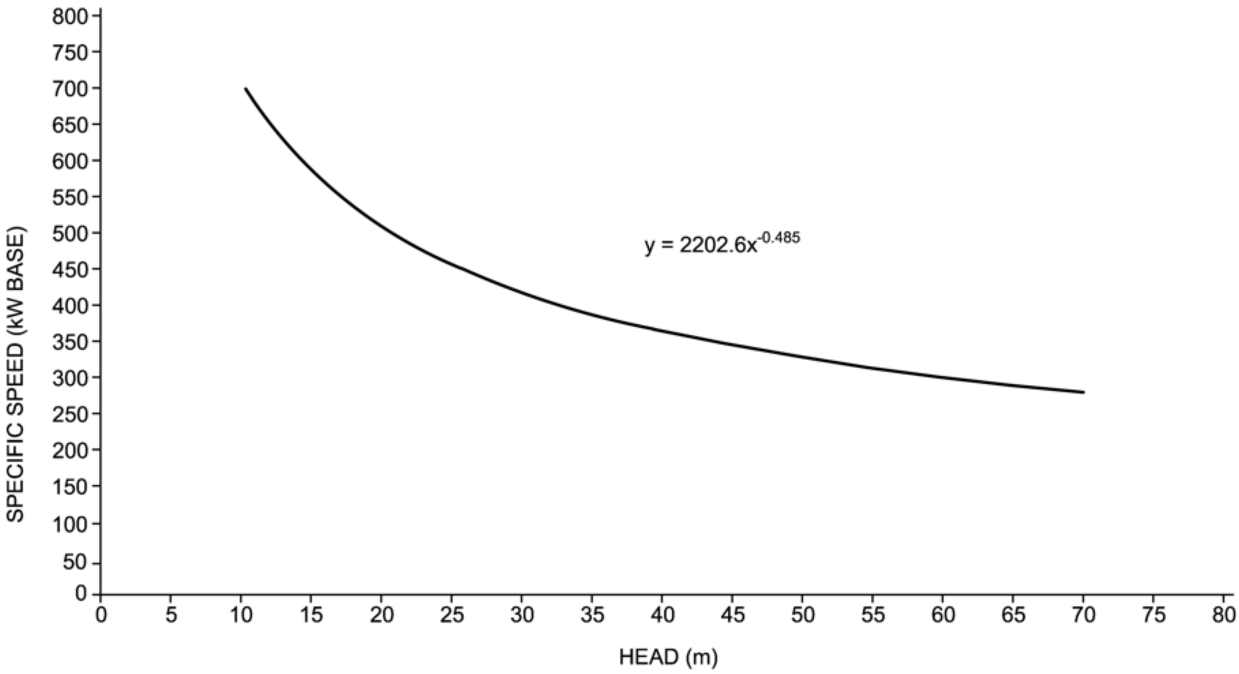


FIG. 1B RELATIONSHIP BETWEEN SPECIFIC SPEED AND RATED HEAD FOR KAPLAN TURBINE

4.2.2.3 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 = $\frac{60 \times f}{p}$

where

f = frequency in cycles per second (in Indian Power systems, frequency = 50 cycles per second); and

p = number of pairs of poles.

The selection of rated speed by the above formula is subject to the following considerations:

a) An even number of pairs of poles shall be preferred for the generator, through standard generators with odd number of pairs of poles are also available; and
b) If the head is expected to vary less than 10 percent from the design head, the nearest greater speed shall be chosen. A head varying in excess of 10 percent from the design head suggests the nearest lower speed.

4.2.3 After determining the rated speed as mentioned above, the specific speed can be determined by the formula given in **3.1.**

4.2.4 If on account of heavy silt abrasion is apprehended then a lower value may be adopted.

4.3 Turbine Setting

4.3.1 In reaction turbines, the setting of turbine with respect of minimum tail water level shall be fixed from the consideration of cavitation. The suction height of distributor centre line with respect to the minimum tail water level can be determined from the following formula:

$$H_s \leq H_b - \sigma H - H_v$$

where

H_s = Suction head in metres;
H_b = Barometric pressure in metres of water column;
H = Maximum Head;
H_v = vapour pressure; and
(In the absence of specific data the value of $H_b - H_v$ can be determined from Fig. 2 for a given altitude above mean sea level and for a given temperature which is generally taken as 20ºC.)
σ = Thoma's cavitation coefficient, which can be obtained from Fig. 3A and Fig. 3B.

The positive value of H_s indicates that the centre line of the distributor may be placed up to H_s metres above the minimum tail water level. The negative value of H_s indicates that the centre line of the distributor is to be placed at an elevation of at least H_s metres below minimum tail water level.

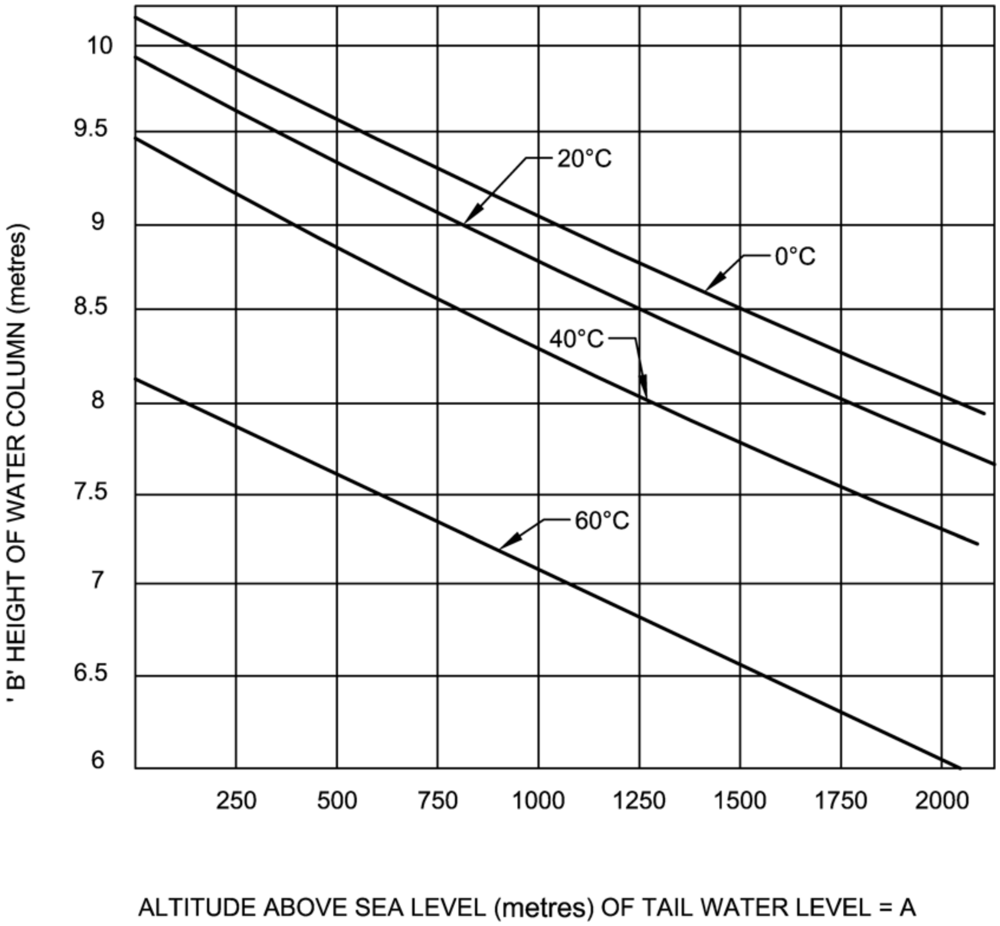
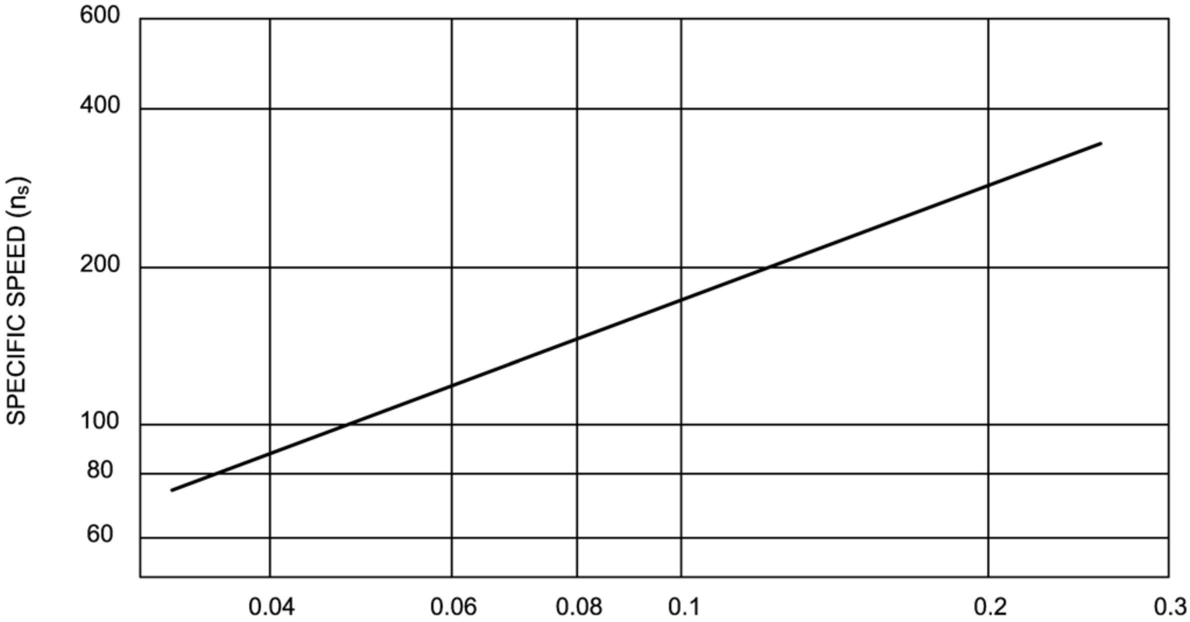


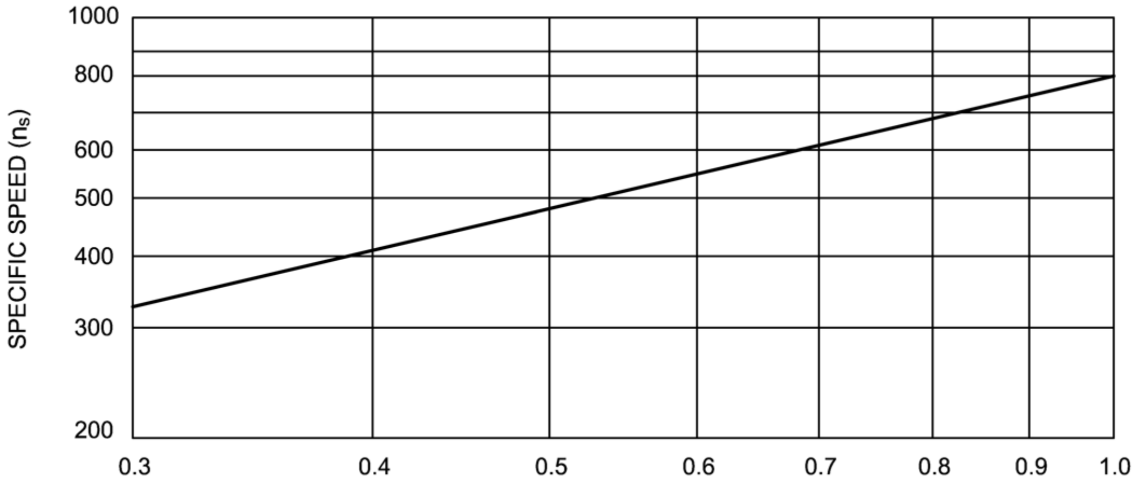
FIG. 2 HEIGHT OF BAROMETRIC WATER COLUMN AT DIFFERENT TEMPERATURES OF WATER AND ALTITUDES ABOVE SEA LEVEL

B = (-0.001063*A) +10.1457 (for 0^0C)
B = (-0.0011*A) + 9.925 (for 20^0C)
B = (-0.00112*A) + 9.43 (for 40^0C)
B = (-0.001033*A) + 8.1083 (for 60^0C)



THOMA'S COEFFICIENT, $\sigma = 7.54 \times 10^{-5} \times {n_s}^{1.41}$

FIG. 3A THOMA'S COEFFICIENT AT DIFFERENT SPECIFIC SPEED FOR FRANCIS TURBINE



THOMA'S COEFFICIENT, $\sigma = 6.40 \times 10^{-5} \times {n_s}^{1.45}$

FIG. 3B THOMA'S COEFFICIENT FOR DIFFERENT SPECIFIC SPEED FOR KAPLAN TURBINES

4.3.2 In case the turbine setting, to have a cavitation free runner at a given specific speed, is found to be very low resulting in uneconomical construction of power house, the specific speed may be reduced by decreasing the speed of rotation.

4.3.3 A minimum margin of 0.5 m for deeper setting of Turbine from calculated value (as per clause no. 4.3.1) shall be added.

4.4 Runner

4.4.1 The runner discharge diameter D_3 for Francis turbine and runner diameter D_R for Kaplan turbine (shown in Fig. 4) are both determined by the peripheral velocity coefficient K_u which is defined as:

$$K_\mathrm{u} = \frac{\pi\, D\, n_\mathrm{s}}{60\sqrt{2\,\mathrm{g}H}}$$

Where D is D_3 in case of Francis turbine and D_R in case of Kaplan turbine.

The relationship between specific speed (n_s) of machine and peripheral velocity coefficient (K_u) is shown in Fig. 4 for Kaplan turbines and in Fig. 5 for Francis turbines.

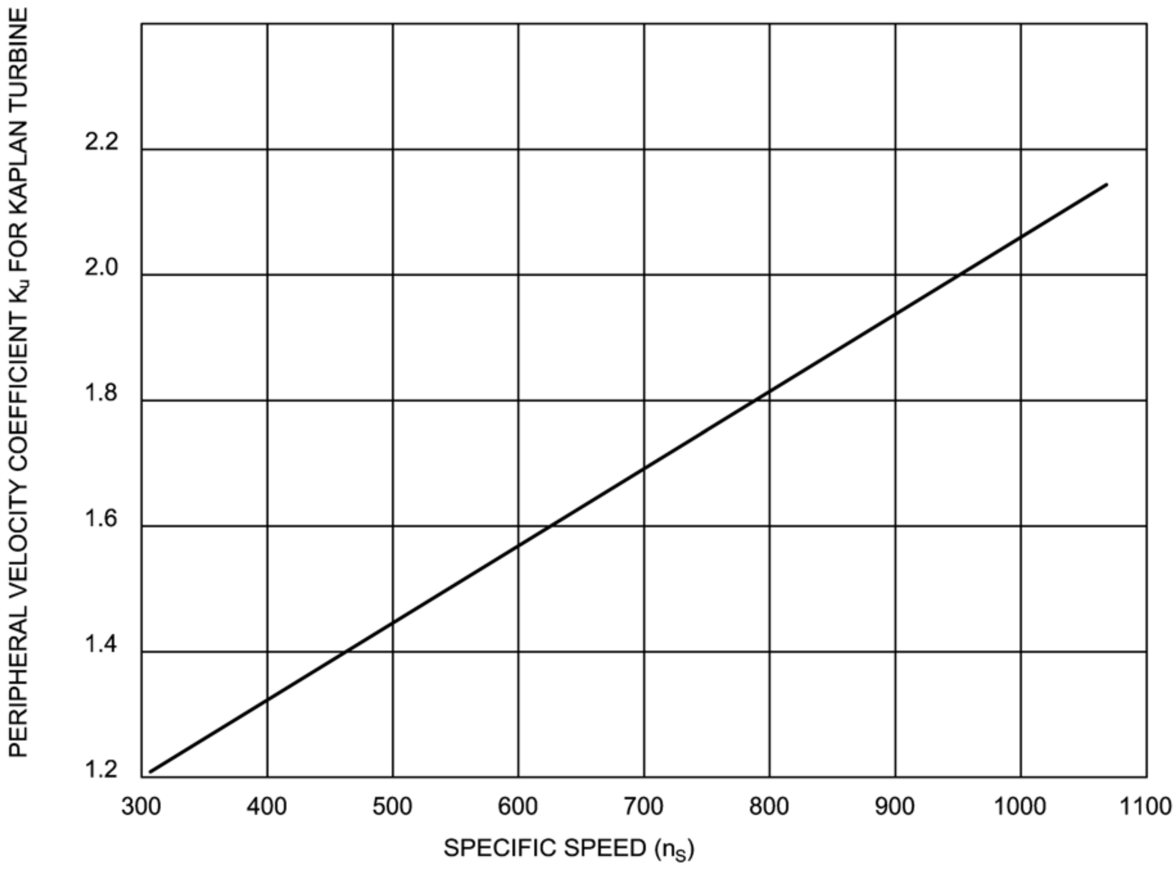


FIG. 4 RELATIONSHIP BETWEEN SPECIFIC SPEED (n_s) AND PERIPHERAL VELOCITY COEFFICIENT Ku FOR KAPLAN TURBINE

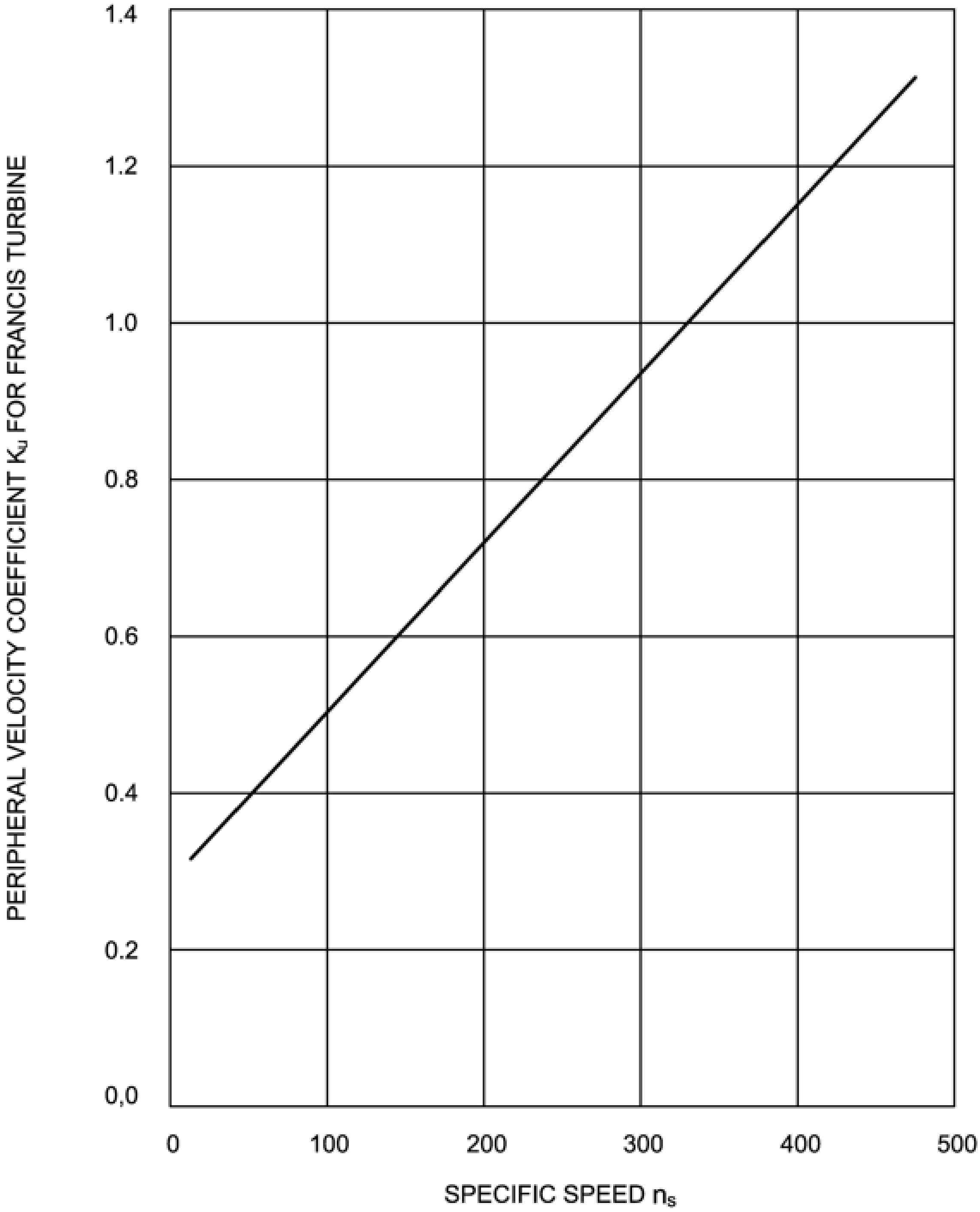
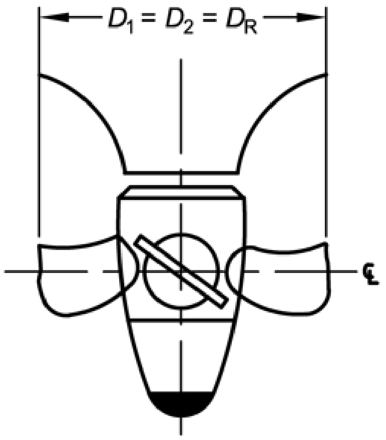


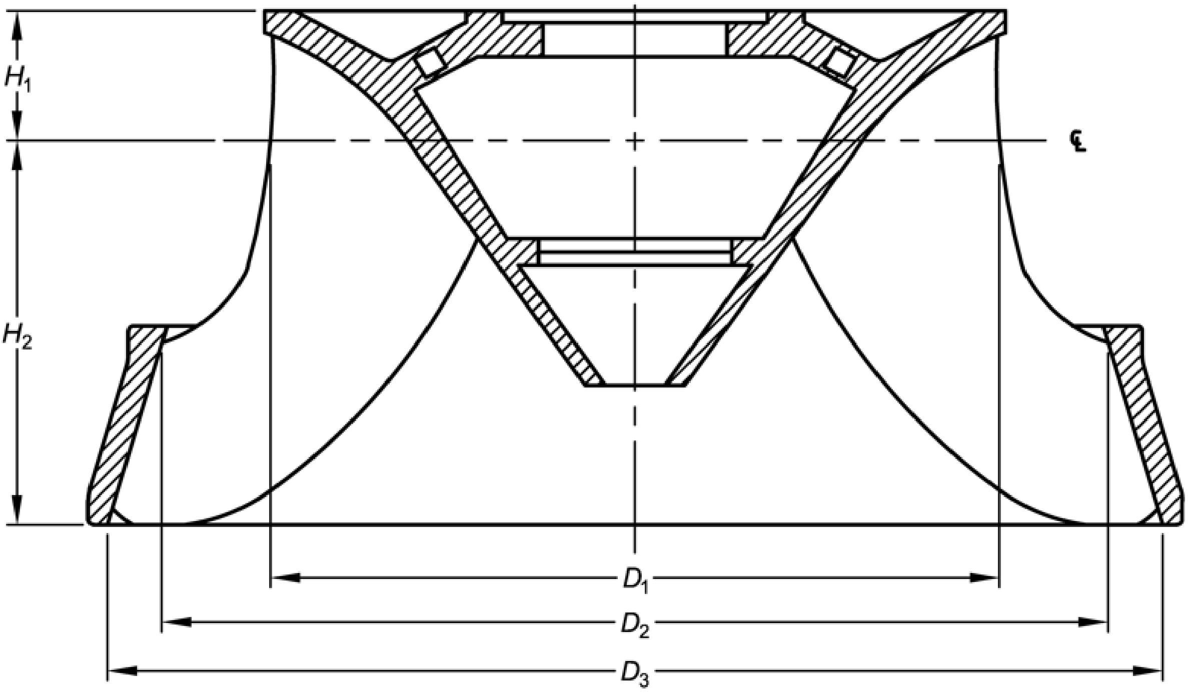
FIG. 5 RELATIONSHIP BETWEEN SPECIFIC SPEED (n_s) AND PERIPHERAL VELOCITY COEFFICIENT K_u FOR FRANCIS TURBINE

$$k_u = (0.002 \times n_s) + 0.3$$

4.4.2 The other runner dimensions of Francis turbine indicated in Fig. 6 may be obtained with respect to the diameter D_3 and specific speed n_s from the curves shown in Fig. 7.



KAPLAN TURBINE



FRANCIS TURBINE

FIG. 6 TYPICAL SHAPES OF REACTION TURBINE RUNNERS

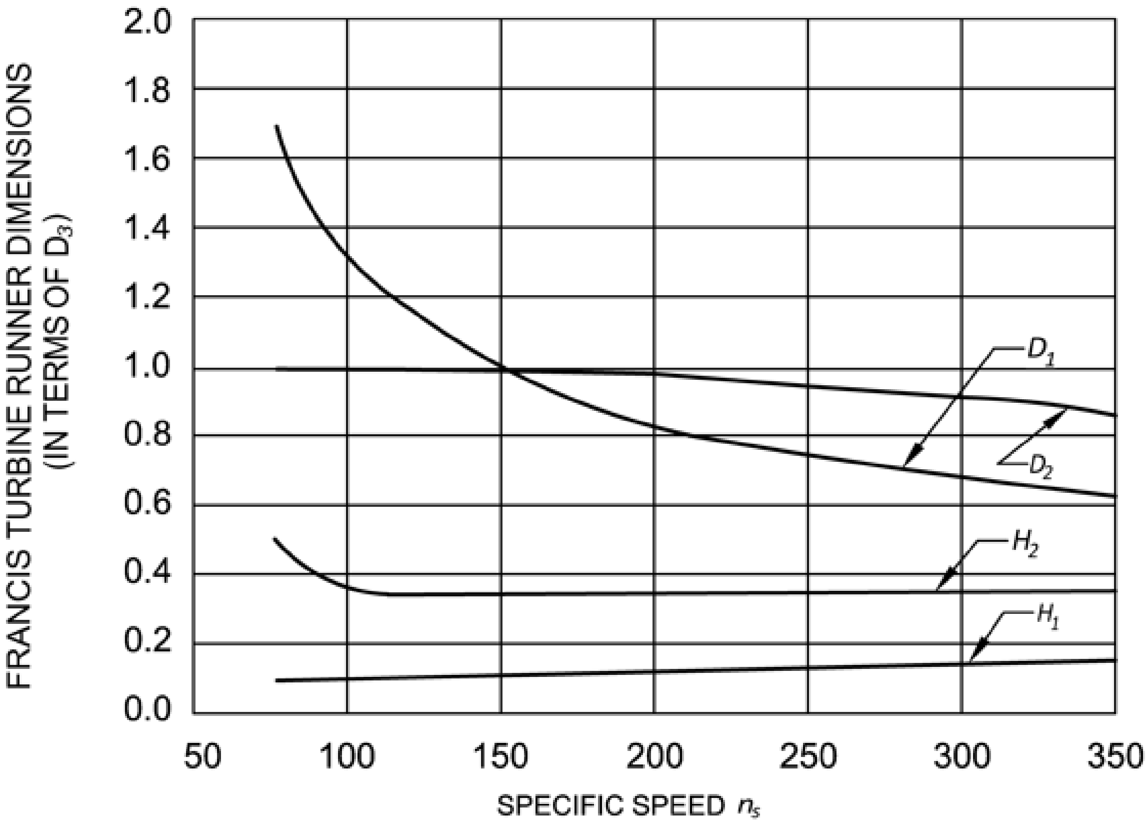


FIG. 7 RUNNER DIMENSIONS WITH RESPECT TO THE DIAMETER D_3 AND SPECIFIC SPEED FOR FRANCIS TURBINE

4.5 Spiral Casing

4.5.1 *Metallic Spiral Casing*

Metallic spiral casing shall be used for gross heads generally above 30 metres. The major dimensions of the spiral casing indicated in Fig. 8 may be obtained as a function of n_s, referred to runner diameter D_3 or D_R from the curves shown in Fig. 9 and 10.

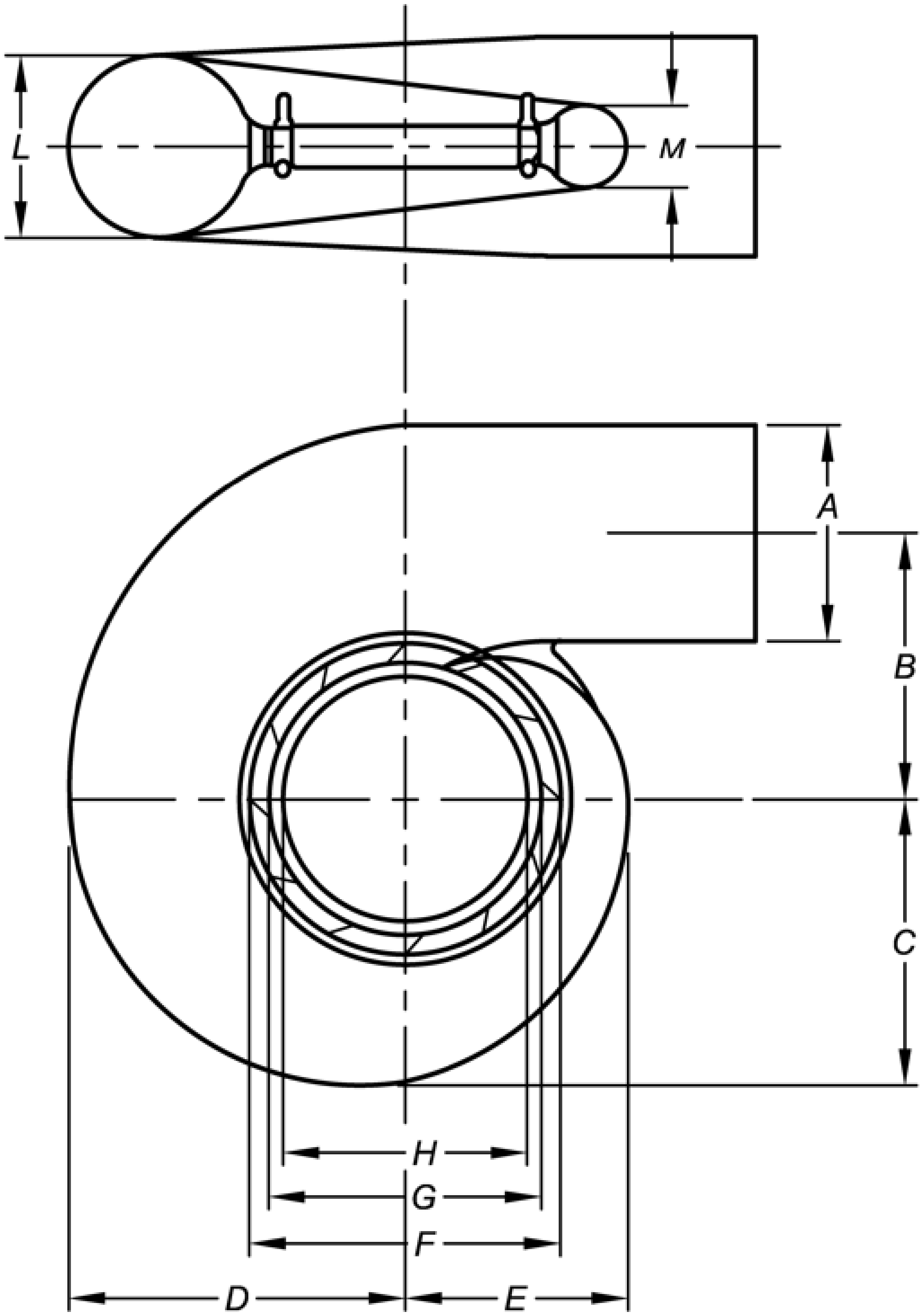
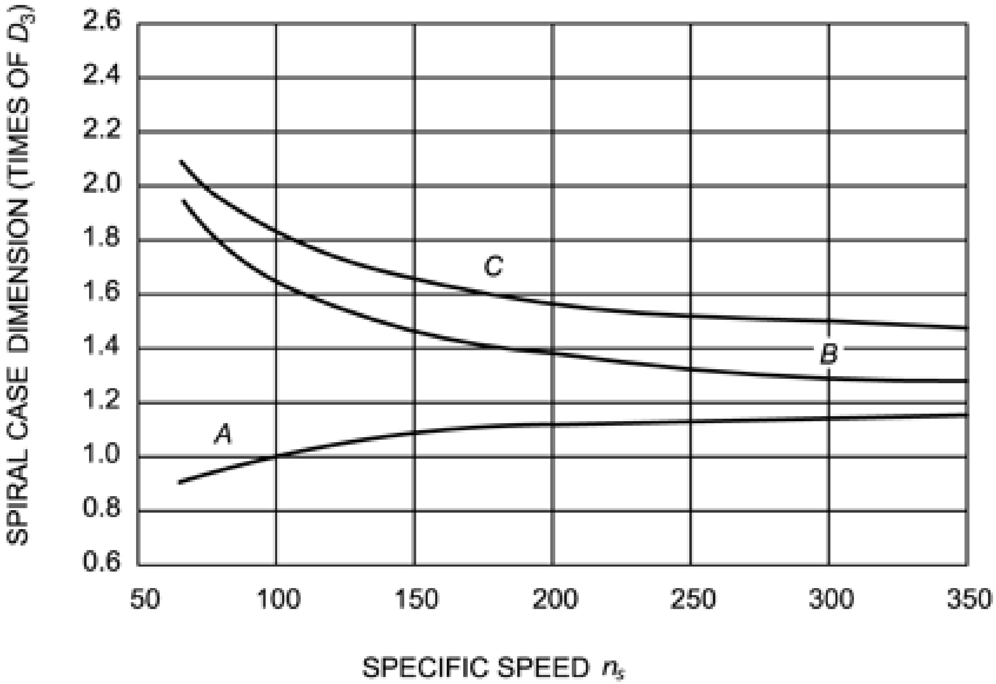


FIG. 8 MAJOR DIMENSIONS OF THE SPIRAL CASING



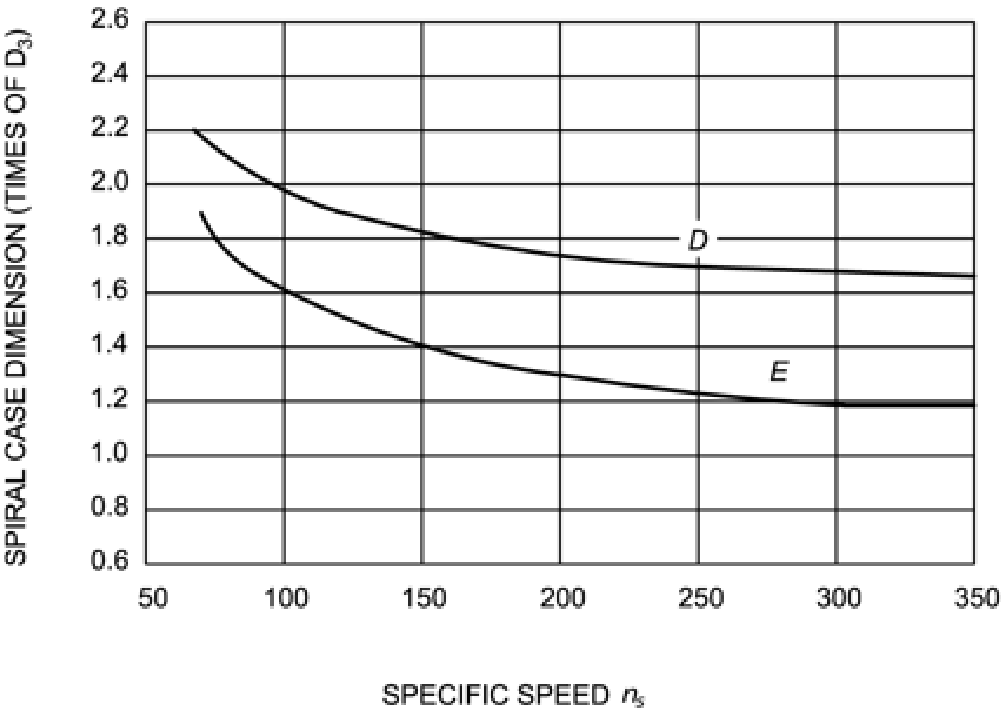


FIG. 9 SPIRAL CASING DIMENSIONS WITH RESPECT TO RUNNER DIAMETER D_3 OR D_R AND SPECIFIC SPEED n_s

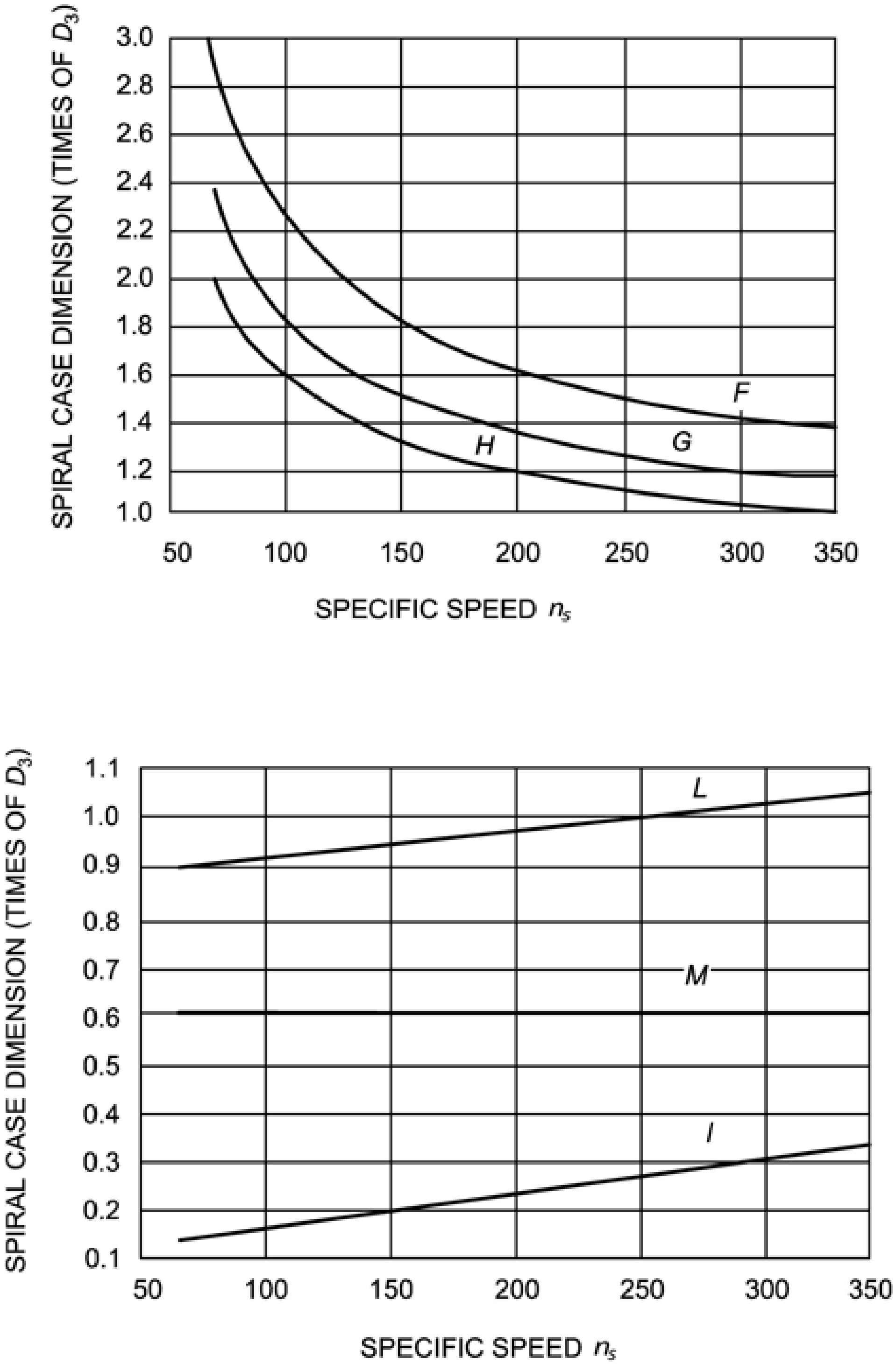


FIG. 10 SPIRAL CASING DIMENSIONS WITH RESPECT TO RUNNER DIAMETER D_3 OR D_R AND SPECIFIC SPEED n_s

4.5.2 *Concrete Spiral Casing*

Concrete spiral casing shall be designed in accordance with IS 7418. The radius R of the inlet portion and the width B of the open portion of the casing, indicated in Fig. 11 can
be determined by the following formula:

$$R = 1.6\, D_{1,} \text{ and}$$
$$B = R + KD_{1.}$$

where

$K = 0.95$ for $\emptyset = 180°$ to $200°$; and
$K = 1.1$ for $\emptyset = 200°$ to $225°$.

The equation of semispiral is given below:

$$P = K_1 - K_2 - \theta^2$$

Where

P = radius of curvature of the semispiral at an angle θ in radians; and

$K_{1,} K_2$ = constants.

The values of constants K_1 and K_2 can be evaluated by the following conditions:

$$P = R \text{ at } \theta = 0°, and$$

$P = 0.5 \times$ stayvane outside diameter at $\theta = \phi$.

Stay vane outside diameter is 'F' as determined from Fig. 10.

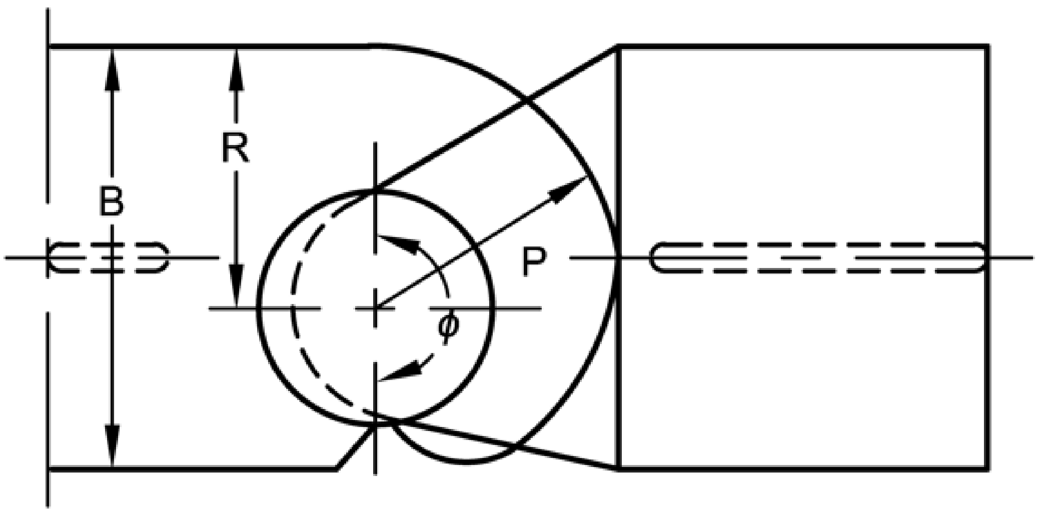


FIG. 11 CONCRETE SPIRAL CASING

4.6 Draft Tube

Major dimensions of the draft tube are given in Fig. 12 and shall be determined considering outlet D of the runner.

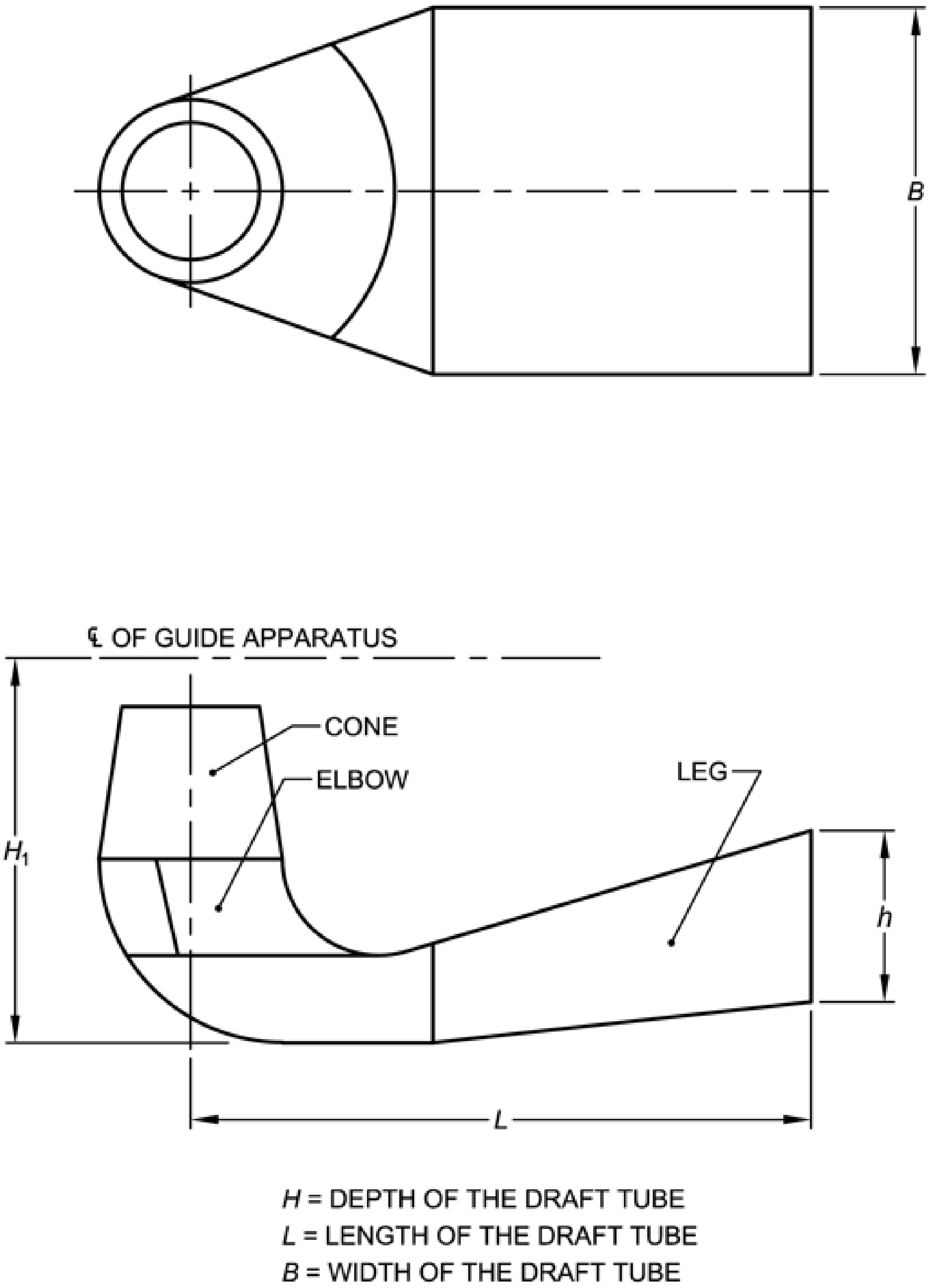


FIG. 12 MAJOR DIMENSIONS OF DRAFT TUBE

5 MAIN PARAMETERS OF HYDRO-GENERATORS

5.1 Air Gap Diameter (D_g)

The air gap diameter (*see* Fig. 13 and 14) can be determined from the following criteria:

a) The air gap diameter D_g shall be large enough to allow the turbine runner top cover to pass through the stator bore. This condition is likely to be limiting only with large Kaplan turbines of low speed where a clearance of at least 5 cm shall be allowed.

b) 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. Assuming the runaway ratio to be 1.85 to 2.3 for Francis turbine and 2.3 to 3.2 for Kaplan turbine (higher speed ratio for lower head) the value of maximum peripheral rotor velocity V_r at rated speed can be read from Fig. 15.

This curve relates to sheet steels 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 metres can be obtained from the following formula:

$$D_g = \frac{60}{\pi} \times \frac{V_r}{n}$$

where

V_r = maximum peripheral velocity in metres/sec; and

n = rated speed of machine in r.p.m.

5.2 Outer Core Diameter (D_o)

Outer core diameter D_o of the stator (*see* Fig. 13 and 14) can be determined by the following formula:

$$D_o = D_g \left(1 + \frac{\pi}{2\,p}\right) \text{ metres}$$

where

p = number of pairs of poles.

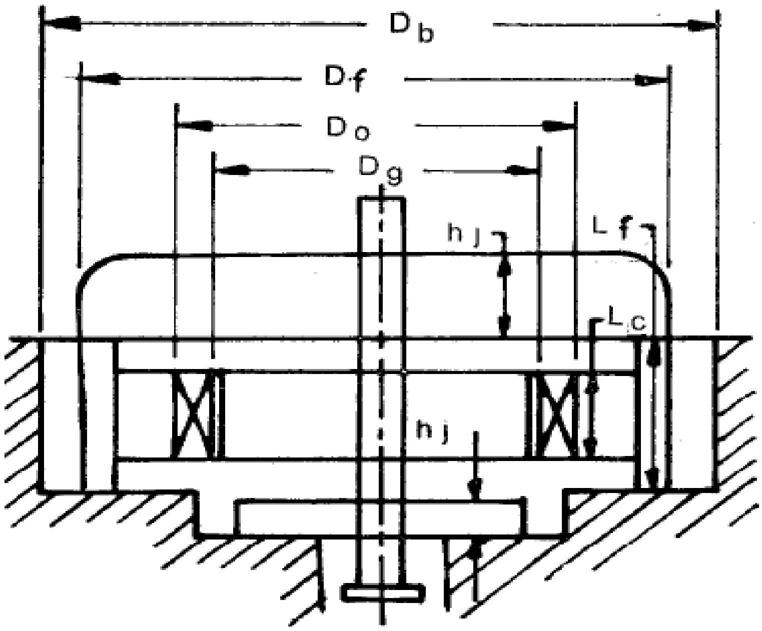


FIG. 13 SUSPENDED TYPE CONSTRUCTION

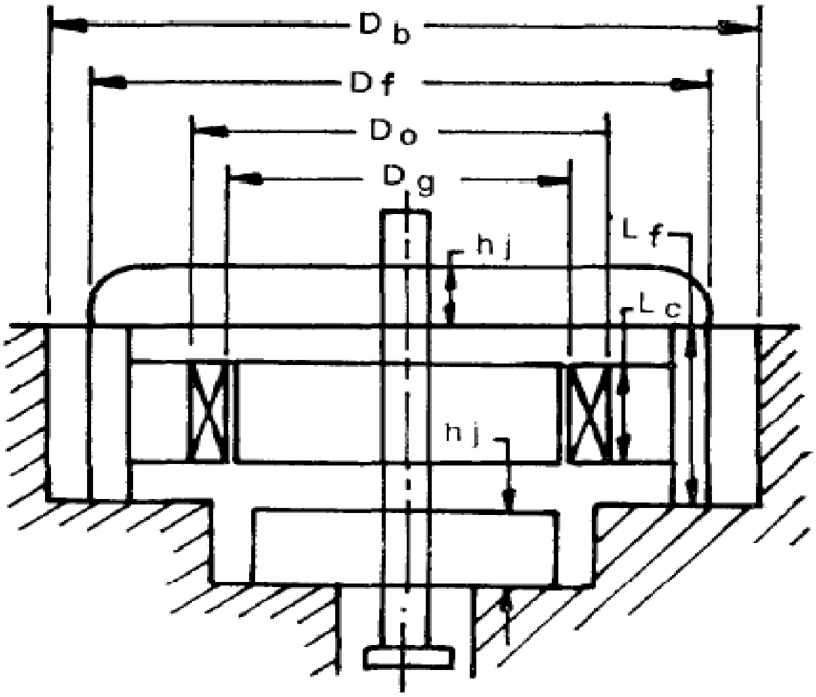


FIG. 14 UMBRELLA/SEMI-UMBRELLA TYPE CONSTRUCTION

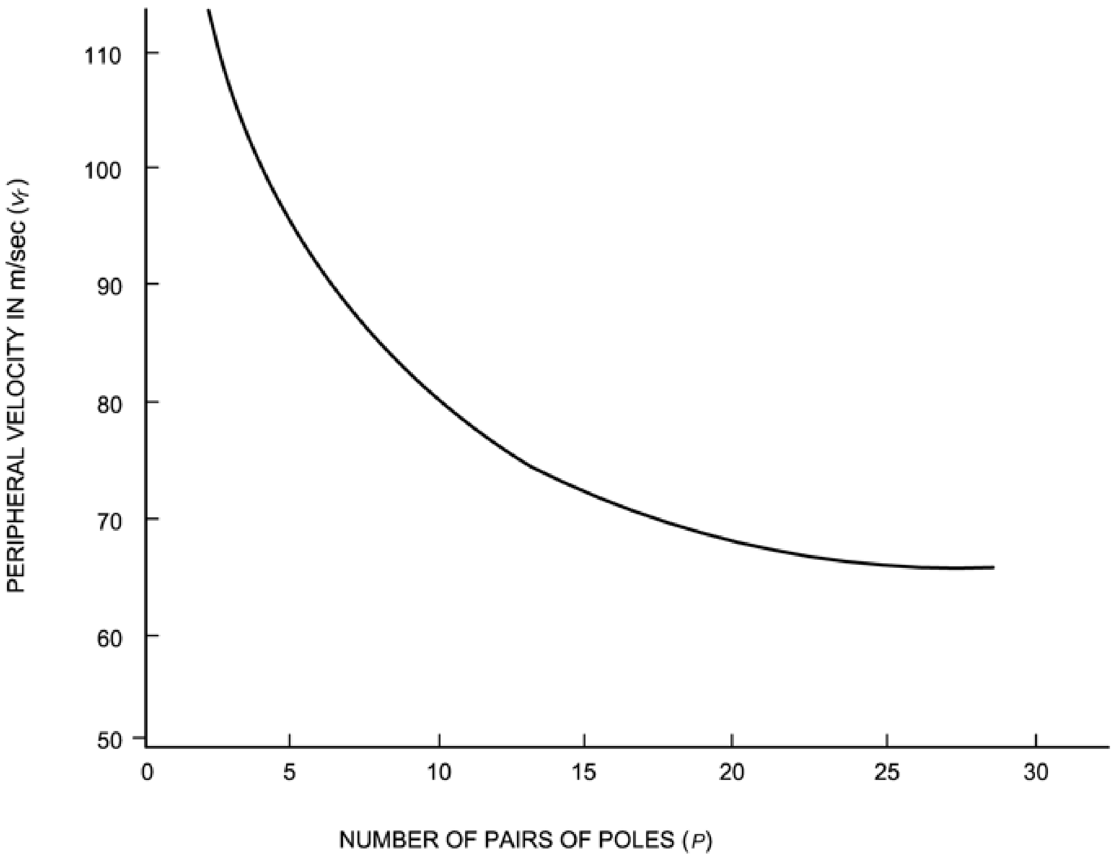


FIG. 15 MAXIMUM PERIPHERAL ROTOR VELOCITY V_r AT RATED SPEED

$$V_r = 0.0002P^4 - 0.0193P^3 + 0.6134P^2 - 9.6384P + 131.79$$

5.3 Stator Frame Diameter (D_f)

Stator frame diameter D_f (*see* Fig. 13 and 14) (across flat dimension in case of polygonal shape) can be determined by adding 1.2 metres to the outer core diameter, D_o i.e.

$$D_\mathrm{f} = (D_\mathrm{o} + 1.2) \text{ metres.}$$

5.4 Inner Diameter of Generator Barrel (D_b)

Inner diameter (D_b) of generator barrel (*see* Fig. 13 and 14 - Inner dimensions across flat faces in case of polygonal shaped barrel) can be determined as follows:

Umbrella type:

$$D_\mathrm{b} = (D_\mathrm{f} + 2.3 \text{ to } 2.8) \text{ metres}$$

$$= (D_\mathrm{o} + 3.5 \text{ to } 4.0) \text{ metres}$$

Suspended type:

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

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

5.5 Core Length of Stator L_c

Core length of stator L_c (*see* Fig. 13 and 14) can be determined by the following formula:

$$L_c = \frac{W}{K_o \; D_g^2 n}$$

where

W = Rated KVA of machine; and
K_o = Output coefficient to be determined from Fig. 16.

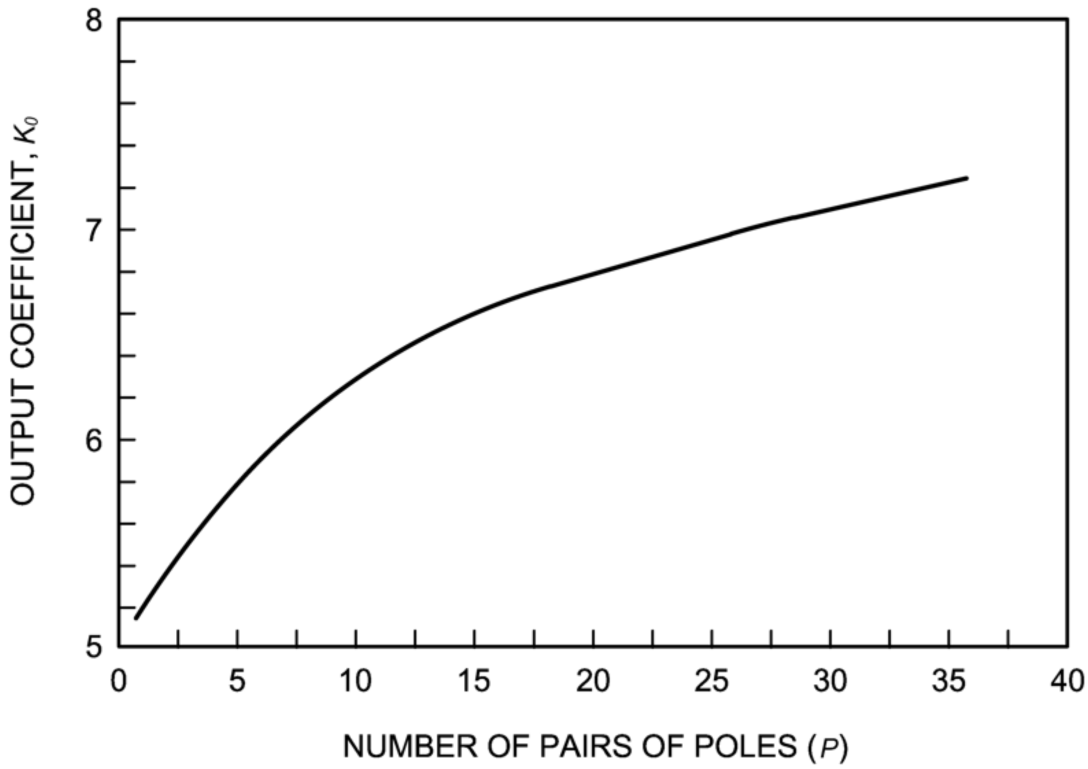


FIG. 16 DETERMINATION OF OUTPUT COEFFICIENT

K_o = – 000002228729P^4 + 0.0002P^3 – 0.0093P^2 + 0.2013P + 5.0066

5.6 Length of Stator Frame (L_f)

Length of stator frame L_f (*see* Fig. 13 and 14) can be determined by adding 0.9 to 1.2 metres to the length of stator core i.e.

$$L_f = (L_c + 0.9\ to\ 1.2)\ \text{metres.}$$

5.7 Height of Load Bearing Bracket (h_j)

Height of load bearing bracket H_j (*see* Fig. 13 and 14) can be determined by the following formula:

$h_j = K\sqrt{D_f}$ for suspended type construction; and

$h_j = K\sqrt{D_g}$ for umbrella type construction.

Where

K = 0.65 for load of less than 50 tonnes per arm of the bracket; and

K = 0.75 for load above 50 tonnes per arm of the bracket

Load per arm of the bracket shall be determined as given in the following clauses.

5.8 Number of Arms of Brackets

The number of the arms of the bracket are 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 rotating parts. Generally, 4 to 8 arms of the bracket are taken.

5.9 Axial Hydraulic Thrust

Axial hydraulic thrust P_H on the turbine runner may be determined by the following formula:

$P_H = K\ D_1^2\ H_{max}$ in tonnes.

Where

K = a constant to be determined from Fig. 17A and Fig. 17B;

D_1 = Inlet diameter of runner in metres; and

H_{max} = maximum head in metres.

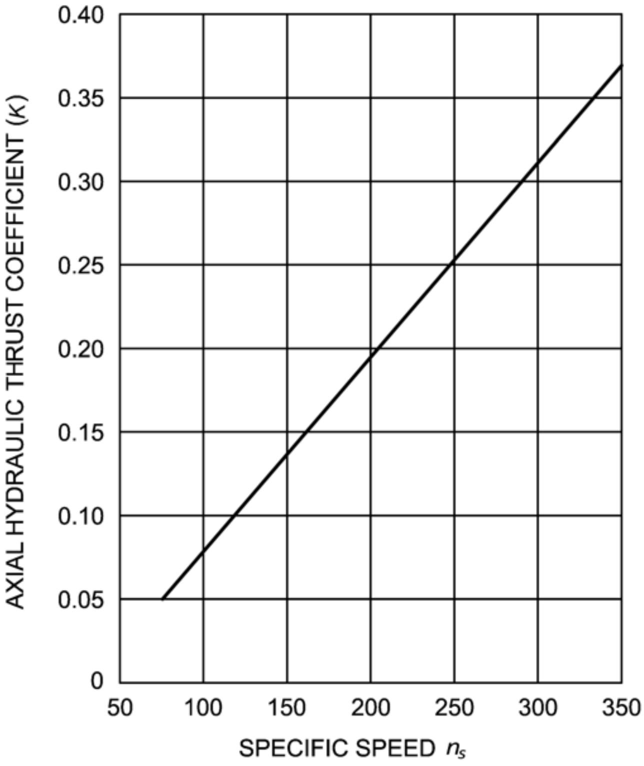


FIG. 17A DETERMINATION OF AXIAL HYDRAULIC THRUST COEFFICIENT FOR FRANCIS TURBINE

$$K = (0.001143 \times n_s) - 0.03001$$

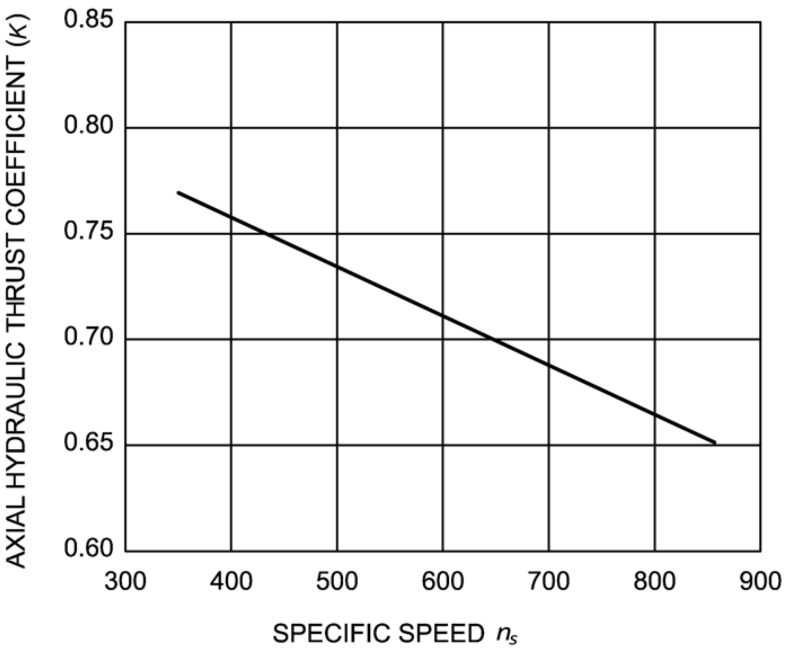


FIG. 17B DETERMINATION OF AXIAL HYDRAULIC THRUST COEFFICIENT FOR KAPLAN TURBINE

5.10 Weight of Generator Rotor

Weight W_{R} of generator rotor may be determined as per equation given below:

$$W_R = 50 \times (\frac{MVA\ of\ Generator}{n^{0.5}})^{0.74}$$

5.11 Weight of Turbine Runner

Weight of turbine runner can be determined from Fig. 18A and 18B.

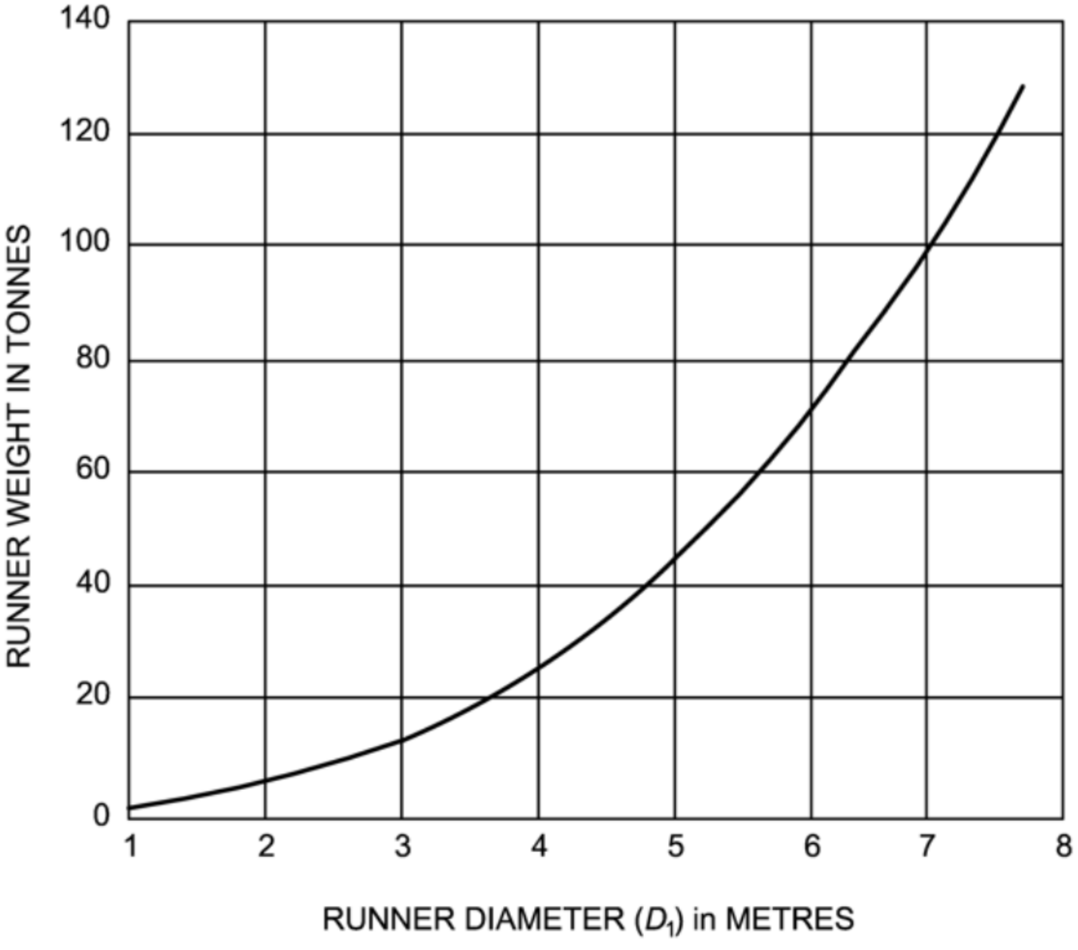


FIG. 18A RELATIONSHIP BETWEEN RUNNER WEIGHT AND RUNNER DIAMETER FOR FRANCIS TURBINE

Runner Weight = $2.8636D_3^2 - 6.94D_3 + 7.4821$

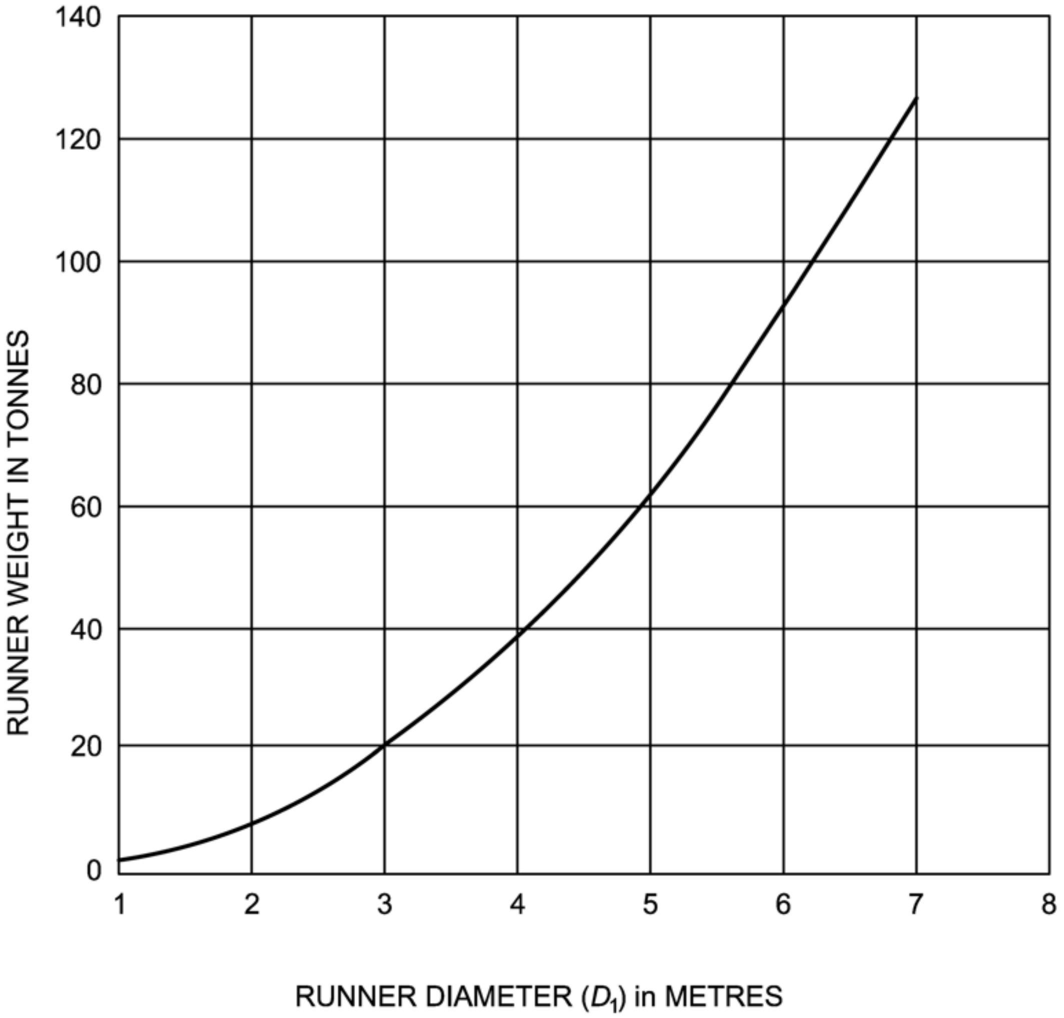


FIG. 18B RELATIONSHIP BETWEEN RUNNER WEIGHT AND RUNNER DIAMETER FOR KAPLAN TURBINE

5.12 Weight of machine rotating parts comprises the weights of rotor and runner. Total axial load for use in the determination of height and number of load bearing brackets shall comprise the hydraulic thrust and the weights of rotor and runner.

6 OVERALL DIMENSIONS OF POWER HOUSE

6.1 The overall dimensions of power house mainly depend upon the following:

a) Overall dimensions of the turbine, draft tube and scroll-case;
b) Overall dimensions of the generator;
c) Number of units in the power house; and
d) Size of the erection bay.

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

6.2 Length of Power House

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

6.2.1 *Unit spacing*

For determining the distance between the centre lines of the successive units, a plan showing the overall dimensions of the spiral casing, the draft-tube and the hydro-generator shall be drawn with respect to the vertical axis of the machine. For determining the outer dimensions of the generator barrel the inner diameter of the generator barrel may be increased by 0.5 to 15 m depending upon the size of the machine. A clearance of 1.5 to 2.0 m shall be added on either side of the extremities of the above drawn figures to determine the unit spacing. These clearances shall be such that a concrete thickness on either side of scroll case shall be at least 2.0 to 2.5 m in case of concrete scroll cases and 1.0 to 1.5 m in case of fully-embedded steel scroll cases.

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

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

$$L = N_{\mathrm{o}} \times (unit\ spacing) + L_{\mathrm{s}} + K$$

where

N_{o} = Number of units,

L_{s} = Length of 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 metres.

NOTE — Due to special topographical tail water conditions it may become necessary to provide additional unloading bay at different levels.

NOTE — In case, runner removal hatch is provided between the Units then the Unit Spacing shall be increased correspondingly.

6.3 Width of Power House Super structure

For determining the width of the power house superstructure, the overall dimensions of the spiral casing and the hydrogenerator may be drawn with respect to the vertical axis of the machine. Superstructure columns shall be clear of the downstream extremities of the above drawn figure by about 2.0 to 2.5 metres.

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

a) A clearance of about 1.5 to 2.0 m for concrete the upstream of scroll case;

b) A gallery of 1.5 to 2.0 m width for approaching the draft tube manhole;

c) In case the main inlet valve is also accommodated in the power house, a valve pit of appropriate size shall have to be provided as per IS 7326 (Part 1) and IS 7332 (Part 1).

d) A clearance of about 1.5 to 2.0 metres for pressure relief valve in the scroll case, if required; and

e) The spaces as indicated against item (a) to (d) are supposed to be sufficient for accommodating the auxiliary equipment also but may have to be reviewed considering the layout of essential equipment and operational requirements.

6.3.1 The inlet valve gallery, if provided, can be utilized for approaching the draft-tube man-hole also and hence no separate gallery is needed for this purpose.

6.3.2 The criteria laid down in **6.3** gives the internal width of the Power House (excluding column width).

6.4 Height of Power House

6.4.1 The height of power house from the bottom of the draft-tube to the centre line of the spiral casing H_1 (*see* Fig. 19), can be determined in accordance with IS 5496. The thickness of the concrete below the lowest point of draft-tube may be taken from 1.0 to 2.0 m depending upon the type of foundation strata, backfill conditions and size of the power house.

6.4.2 The height of power house from the centre line of the spiral-casing up to the top of the generator H_2 (*see* Fig. 19) can be determined, as follows:

$$H_2 = L_\mathrm{f} + h_\mathrm{j} + K$$

L_f and h_j have been defined in **5.6** and **5.7.1** respectively. The value of K may be taken as 5.5 to 7.0 depending upon the size of the machine.

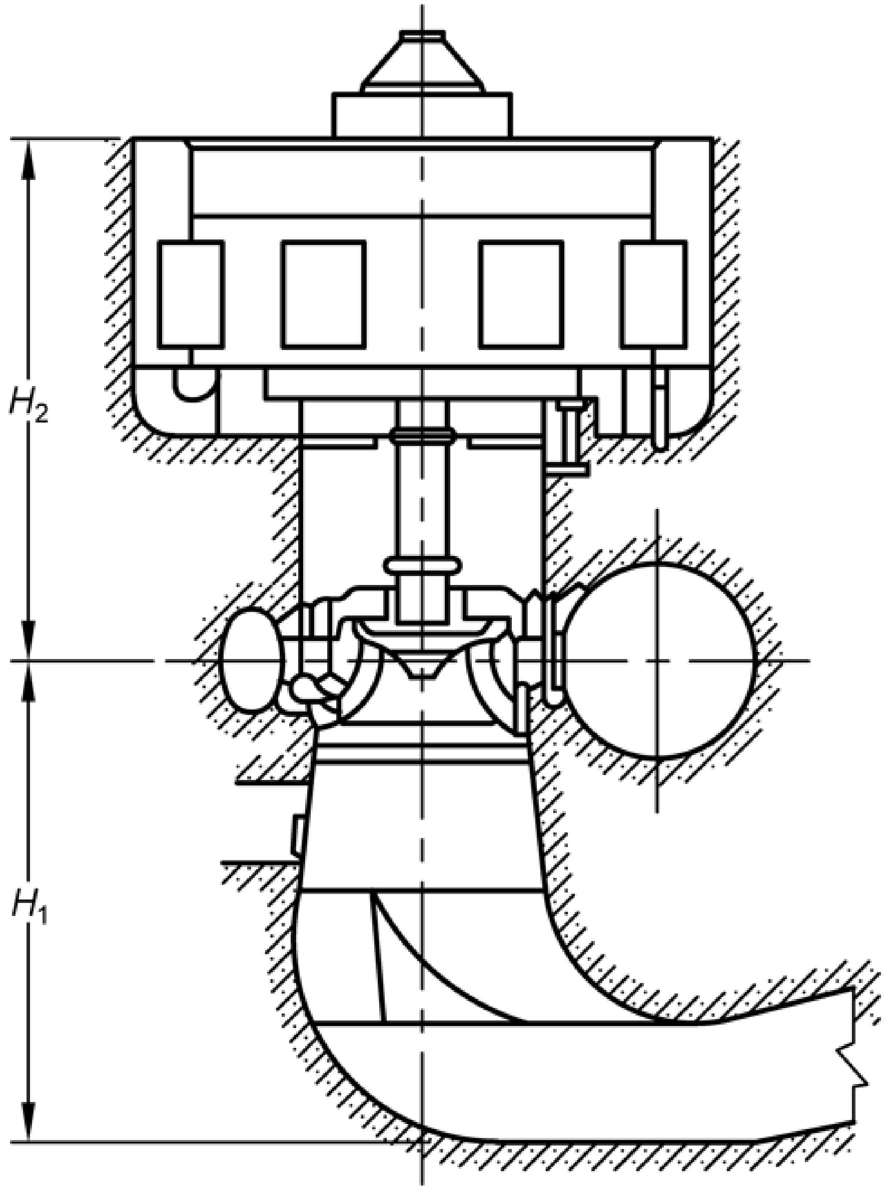


FIG. 19 CROSS SECTION THROUGH GENERATING UNIT

6.4.3 The 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 shall depend upon the height of the service bay floor from where the equipment is to be handled.

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

a) Hauling moving major items of equipment viz. turbine runners assembly, rotor assembly and even entire generator stator;

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

c) Clearance required for untaking of transformers; and

d) Unloading of largest package from the trailors. A height of 7 to 8.5 metres tween the top erection bay floor and highest hook level may be sufficient.

6.4.3.2 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 E.O.T. crane. Keeping a clearance of 0.3 metre between the highest part of the gantry crane and the ceiling of the power house. A typical example for calculating the overall dimensions of the power house is given in Annex A.

ANNEX A

(*Clause* 6.4.3.2)

TYPICAL EXAMPLE FOR CALCULATING THE OVERALL DIMENSIONS OF POWER HOUSE

A-1 DATA

Type of Machine	Francis Turbine
Total Number of Machine	4
Unit Capacity	100 MW
Generator Efficiency	98.5 Percent
Maximum Head	105 m
Rated Head	100 m
Minimum Head	92 m
Barometric Pressure of Power House site	10 m
Vapour Pressure at Power House site	0.4 m
Power Factor	0.85

A-2 SYNCHRONOUS SPEED

From Fig. 1A, specific speed of machine may be taken as 185.72.

Synchronous speed of machine

$$= \frac{n_s \,.\, H^{5/4}}{\sqrt{P}}$$ [*see* IS 12800 (Part 2)]

where

$n_s =$ 185.72 r.p.m.;

$H =$ 100 m; and

$P =$ (100 $\times$ 1000)/0.985 kW

$\therefore$ Trial synchronous speed machine

$$= \frac{185.72 \times 100^{5/4}}{\sqrt{101522.84}}$$

$$= 184.32\ r.p.m.$$

Synchronous speed for 14 pairs of poles

$$= \frac{60 \times 50}{16} = 187.5\ r.p.m.$$

Synchronous speed for 16 pairs of poles

$$= \frac{60 \times 50}{18} = 166.67\ r.p.m.$$

As the head variation from the rated head is less than 10 percent synchronous speed i.e. a synchronous speed of 187.5 r.p.m. is being adopted.

Corrected specific speed

$$= \frac{187.5\sqrt{101522.84}}{100^{5/4}} = 188.922$$

A-3 TURBINE SETTING

$$H_\mathrm{s} \leq H_\mathrm{b} - \sigma H - H_\mathrm{v}$$

where

H_b = 10 m;

H_v = 0.4 m;

H = 105 m; and

σ = from Fig. 3 corresponding a specific speed of 188.922 = 0.12216

$$H_s \leq 10 - 0.12216 \times 105 - 0.4 \text{ m}$$

$$\leq -3.227 \text{ m.}$$

With a further margin of 0.5 metre, the centre line of the distributor shall be set 3.227 + 0.5 = 3.727 metres below minimum tailrace level as defined in **4.3.3**.

A-4 SIZE OF RUNNER

Discharge diameter, $D_3 = \frac{60\ (2\ gH)^{0.5} K_u}{\pi\ n}$ [*see* IS 12800 (Part 2)].

where

H = 105 m;

n = 187.5; and

K_u = from Fig. 6 corresponding to a specific speed of 188.922 = 0.677

$$D_3 \frac{60\ (2\ \times 9.81 \times 105)^{0.5}\ \times 0.677}{3.14 \times 187.5}$$

$= 3.13\ m$, Say 3.2 metres.

D_1 = 0.85 D_3 from Fig. 7

D_1 = 0.85*3.2 = 2.72

A-5 DIMENSIONS OF SPIRAL CASE

As the gross head above the turbine is more than 30 metres, metallic spiral casing shall be used. The main dimensions of the spiral casing as determined in accordance with Fig. 8, 9 and 10 work out to be as shown below:

$$A = 1.1 \times 3.2 = 3.52 \text{ m}$$

$$B = 1.4 \times 3.2 = 4.48 \text{ m}$$

$$C = 1.58 \times 3.2 = 5.056 \text{ m}$$

$$D = 1.75 \times 3.2 = 5.60 \text{ m}$$

$$E = 1.31 \times 3.2 = 4.192 \text{ m}$$

$$F = 1.67 \times 3.2 = 5.344 \text{ m}$$

$$G = 1.39 \times 3.2 = 4.448 \text{ m}$$

$$H = 1.21 \times 3.2 = 3.872 \text{ m}$$

$$I = 0.23 \times 3.2 = 0.736 \text{ m}$$

$$L = 0.975 \times 3.2 = 3.12 \text{ m}$$

$$M = 0.61 \times 3.2 = 1.952 \text{ m}$$

A-6 SIZE OF DRAFT-TUBE

The various dimensions of the draft-tube shown in Fig. 12 as determined in accordance with IS 5496 shall be as below:

Height of draft-tube at exit end $h\ = 0.94\ D_3\ to\ 1.32\ D_3$

As the specific speed of the turbine is on the lower side, 'h' will be on the higher side.

Taking $h\ = 1.25\ D_{3,}\ h\ = 1.25 \times 3.2 = 4.0 \text{ m}$

Depth of draft tube 'H_1' for Francis Turbine $= 2.5$ to $3.0\ D_3$

Taking $H_1 = 2.75\ D_{3,}\ H_1 = 8.8$ m.

Length of draft-tube L = 4 to 5 D_3

Taking $L = 4.5\ D_{3,}\ L = 4.5\ \times 3.2 = 14.4$ m.

Clear width 'B' of the draft-tube at exit end $= 2.6$ to $3.3\ D_{3.}$

Taking $B = 3\ D_{3,}\ B = 3 \times 3.2 = 9.6\ m$.

Since the clear width of the draft-tube is excessive a pier of 1.5 metres width shall be introduced in the centre of the draft-tube. The total width of the draft-tube will, thus, be 11.1 m.

Since, power in $k\ W\ = 9.8\ \times Q \times H \times\ \eta$

where

$Q =$ discharge in cumecs;

$H =$ rated head in metres; and

$\eta\ =$ turbine efficiency of machine.

Assuming efficiency of machine to be 0.92,

$$Q = \frac{101522.84}{9.81 \times 100 \times 0.92} = 112.488 \text{ cumecs}$$

Velocity at the exit end of draft-tube,

$$V_{\mathrm{e}} = \frac{112.488}{4.0 \times 9.6} = 2.929 \text{ m/sec.}$$

In accordance with **3.5.1** of IS 5496, minimum submergence at the outlet end of draft-tube shall be greater than 0.3 metre, or

$$\frac{V_{\mathrm{e}}^2}{2\ \mathrm{g}}\ i.e. \frac{(2.929)^2}{2 \times 9.81}\ 0.437 \text{ m, Say } 0.437\ m.$$

Keeping bed slope 1 vertical to 10 horizontal at the bottom of the draft-tube, the exit end of draft-tube will be 1.44 metres above the bottom or draft-tube.

Top of exit end of draft-tube will be 1.44 + 4.0 = 5.44 m above the bottom of the draft-tube.

Since height of draft-tube below centre line of guide apparatus is 8.8 metres and the centre line of guide apparatus itself is 1.925 metres below minimum tail water level, the top of the exit end of draft-tube will be (1.925 + 8.8 – 5.44) = 5.285 metres below minimum tail water level, which is in order.

A-7 GENERATOR PARAMETERS

A-7.1 Air Gap Diameter 'D_g'

Total number of pair of poles = 18

Rated kVA of generator = 100 000/0.85

= 117647.05

From Fig. 15 or using equation

$V_r = 0.0002x^4 - 0.0193x^3 + 0.6134x^2 - 9.6384x + 131.79$

x = no of pole pairs

V_r = 71.270

$$Dg = \frac{60 \times V_r}{\pi \times \mathrm{n}}$$

$$Dg = 7.26 \text{ m}$$

A-7.2 Outer core diameter D_o

$$= D_g\left(1 + \frac{\pi}{2p}\right) \text{ metres}$$

$$= 7.26\left(1 + \frac{3.14}{2 \times 16}\right) = 7.97 \text{ m, Say } 8.0 \text{ metres.}$$

A-7.3 Stator frame diameter D_f

$$= D_0 + 1.2 \text{ metres}$$

$$= 8.0 + 1.2 = 9.2 \text{ m.}$$

A-7.4 Inner diameter of generator barrel D_b

$$= D_f + 2.3 \; to \; 2.8 \text{ m}$$

$$= 9.2 + 2.5 = 11.7 \text{ m.}$$

Outer diameter of generator barrel = 11.7+1.5 = 13.2 m

A-7.5 Core length of stator $L_e = \frac{W}{K_o D_g^2 n}$

where

$W = 117647.05$ kVA;

$K_{\mathrm{o}} = 6.94$ (from Fig. 16) or using equation;

$K_{\mathrm{o}} =$ - 000002228729P^4 + 0.0002P^3 - 0.0093P^2 + 0.2013P + 5.0066;

$D_{\mathrm{g}} = 7.26$ metre; and

$n = 187.5$ r.p.m.

$$L_0 = \frac{117647.05}{6.94 \times (7.26)^2 \times 187.5} = 1.72 \text{ m, Say } 1.7 \text{ m.}$$

A-7.6 Length of stator frame L_{f}

$$= L_{\mathrm{o}} + 0.9\ to\ 1.2 \text{ m}$$

$$= 1.7 + 1.2 = 2.9 \text{ m}$$

A-7.7 Axial hydraulic thrust $P_{\mathrm{H}} = KD_3^2\ H_{Max}$ in tonnes,

where

$K = 0.185$ from Fig. 17;

$D_1 = 2.72$ m; and

$H_{\mathrm{max}} =$ 105 m.

$P_H = 0.185 \times 2.72\ X\ 2.72 \times 105 = 143.71$ tonnes.

A-7.8 Weight of generator rotor $W_R = 245.57$

A-7.9 Weight of turbine runner = 14.60 tonnes (from Fig. 18).

A-7.10 Height of load bearing bracket h_{j} = Total weight of rotating parts + axial thrust = 245.57 + 14.60 + 143.71 = 403.88 tonnes.

Let there be 4 arms in the bearing bracket,

Load on each arm = $\frac{403.88}{4} = 100.97$ Say 101 tonnes.

Height of load bearing bracket $h_{\mathrm{j}} = K\sqrt{D_{\mathrm{f}}}$ for suspended type construction, and

$= \sqrt{K\ D_{\mathrm{g},}}$ for umbrella type construction

where

$K = 0.75$ (*see* **5.7.1**);

$h_j = 0.75\sqrt{9.2} = 2.27$ for suspended type construction; and

$= 0.75\sqrt{7.26} = 2.02$ for umbrella type construction.

A-8 OVERALL DIMENSIONS OF POWER STATION

A-8.1 From Fig. 21 drawn in accordance with **6.2.1** the extremities of scroll case/draft tube/generator are as below. Adding 1.5 to 2 metres to these dimensions, the size of the unit bay in longitudinal direction or unit spacing work out to be 20.2 metres.

Spiral casing = C+B+A/2

= 5.056+4.48+3.52/2

= 11.296

Outer Diameter of Generator Barrel = 13.2

Width of the draft tube = 11.1

Largest of above = 13.2

Unit spacing = 13.2+2*1.5+2*2 + (placement of pumps, MIV hatch, runner removal hatch etc, if any)

= 20.2 m, Say 21 m

Length of erection bay = $0.7\ to\ 1.5$ times the unit bay size $= 1 \times 21 = 21$ m.

Space required for the E.O.T. crane to handle the last unit will depend upon the number and size of the crane. For preliminary purpose assuming it to be 3 to 5 metres (4 metres in the present case).

Total length of power station $= 4 \times 21 + 21 + 4 = 109$ m.

From Fig. 21 and 22 and clause 6.3, the distance of the inner face of downstream columns from the longitudinal centre line of machine works out to be 6.6 + (1.5 to 2.0, Say 2.0) = 8.6 m.

Distance of the inner face of upstream columns from the longitudinal centre line of machine = 6.6 (extremity of draft-tube/scroll-case/ generator barrel) + 4.00 (For accommodating control valve; the same space can also be used for approaching draft-tube) = 10.6 m.

A-8.2 Total height of machine (*see* Fig. 19)

$$= H_1 + H_2$$

From the size of draft-tube as already calculated in A-6, $H_1 = 8.8\ m$.

$H_2 = L_f + h_j + K$ (*see* **6.4.2**).

As already calculated, $L_f = 2.9$ metres and $h_j = 2.27$ (For suspended type machine).

$$K = 5.5 \text{ } to \text{ } 7.0, \text{Say } 6.0 \text{ m.}$$

$$H_2 = 2.9 + 2.27 + 6 = 11.18 \text{ m.}$$

Total height of machine $8.8 + 11.18 = 19.98$ m.

A-8.3 Total height of machine hall will depend upon type of foundation, height of E.O.T. crane, size of assemblies, type of roof and can be determined accordingly.

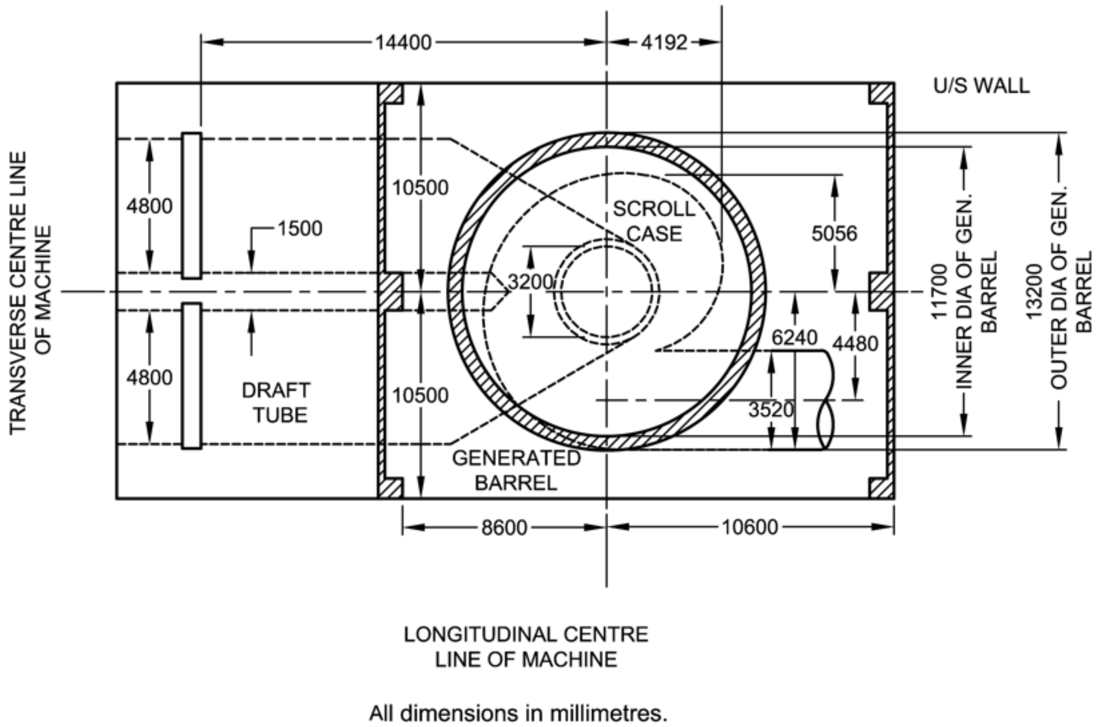
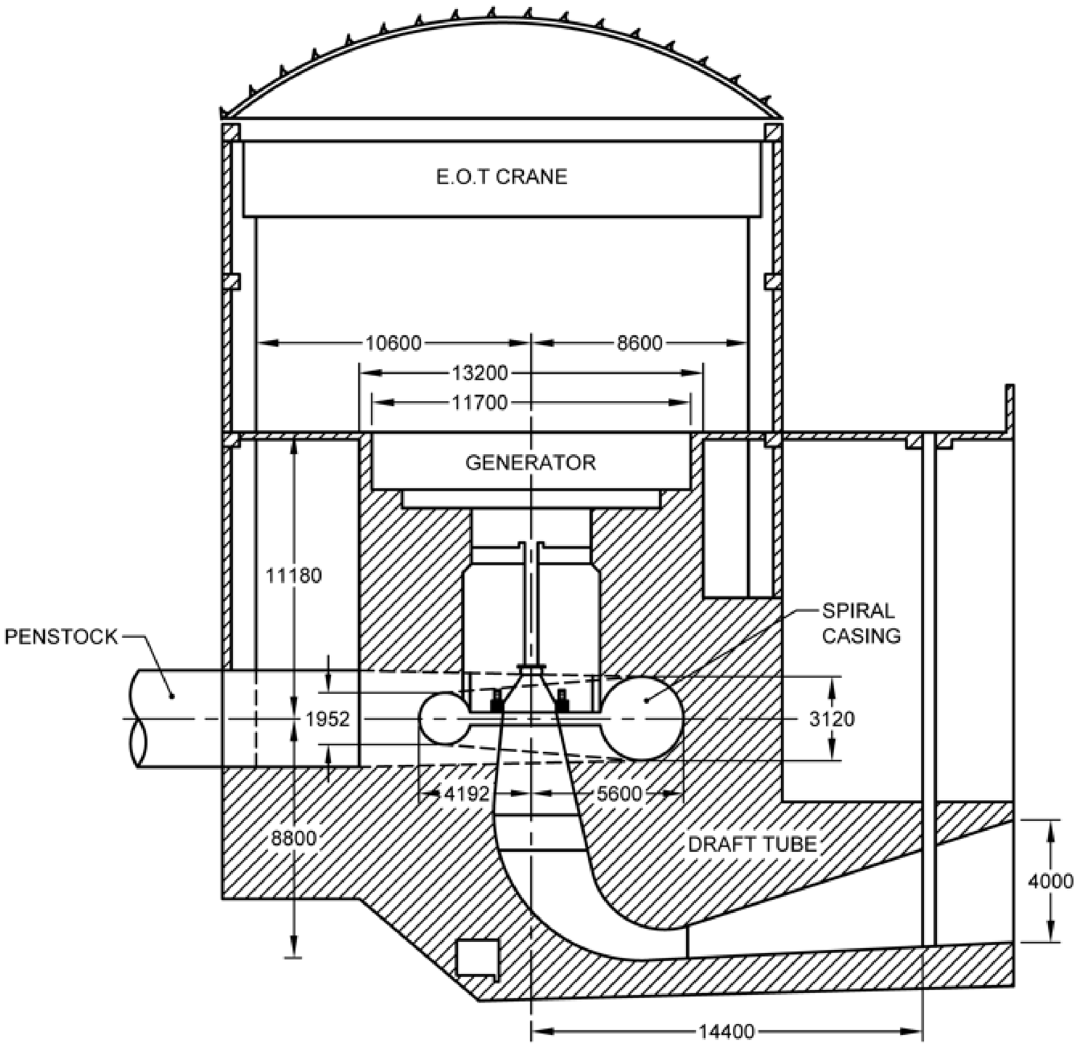


FIG. 20 PLAN SHOWING MAIN DIMENSIONS OF UNIT BAY



All dimensions in millimetres.

FIG. 21 CROSS SECTION OF POWER HOUSE

ANNEX B

(*Foreword*)

LIST OF REFERRED STANDARDS

IS No.	*Title*
IS 4410 (Part 10) : 1988	Glossary of terms relating to river valley projects: Part 10 hydro - Electric power station including water conductor system (*first revision*)
IS 5496 : 1993	Guide for preliminary dimensioning and layout of elbow type draft tubes for surface hydroelectric power stations (*first revision*)
IS 7418 : 1991	Criteria for design of spiral casing (Concrete and Steel) (*first revision*)
IS 7326 (Part 1) : 1992	Penstock and turbine inlet butterfly valves for hydropower stations and systems: Part 1 criteria for structural and hydraulic design (*first revision*)
IS 12837 : 1989	Hydraulic turbines for medium and large power houses - Guidelines for selection
IS 7332 (Part 1) : 1991	Spherical valves for hydropower stations and systems: Part 1 criteria for structural and hydraulic design (*first revision*)
IS 12800 (Part 2) : 1989	Guidelines for selection of turbines, preliminary dimensioning and layout of surface hydro-electric power houses: Part 2 pumped storage power house