IS 12837 (1989): Hydraulic Turbines for Medium and Large Power Houses - Guidelines for Selection [WRD 15: Hydroelectric Power House Structures]

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IS 12837 : 1989
(Reaffirmed 2000)

Indian Standard

HYDRAULIC TURBINES FOR MEDIUM AND LARGE POWER HOUSES — GUIDELINES FOR SELECTION

भारतीय मानक

मध्यम और बड़े बिजलीघरों के लिए द्रवचालित टर्बाइनों के चयन – मार्गदर्शी सिद्धान्त

UDC 621·224 : 621·311·21

BUREAU OF INDIAN STANDARDS
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NEW DELHI 110002

July 1990

Price Group 2

Hydroelectric Power House Structures Sectional Committee, RVD 15

FOREWORD

This Indian Standard was adopted by the Bureau of Indian Standards on 20 October 1989, after the draft finalized by the Hydroelectric Power House Structures Sectional Committee.

Water turbine is basically a machine to convert hydraulic energy into mechanical energy. The type of water turbines influences the layout of power stations and other civil engineering structures. The different types of turbines are suitable for specific parameters of a hydro-development like head and discharge, etc, and these turbines have different identifying characteristics like specific speed, runaway speed and efficiencies, etc, which are dealt in the standard.

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 : 1960 'Rules for rounding off numerical values (*revised*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

Indian Standard

HYDRAULIC TURBINES FOR MEDIUM AND LARGE POWER HOUSES — GUIDELINES FOR SELECTION

1 SCOPE

1.1 This standard covers guidelines for selection of types of hydraulic turbines for medium and large power houses.

2 REFERENCES

2.1 The following Indian Standard is a necessary adjunct to this standard:

IS 4410 (Part 10) : 1987	Glossary of terms relating to river valley projects: Part 10 Hydroelectric power station including water conductor system (*first revision*)

3 TERMINOLOGY

3.0 For the purpose of this standard the definitions given in IS 4410 (Part 10) : 1987 and the following shall apply.

3.1 Maximum Net Head

Maximum effective head available for power generation which is maximum gross head less all the losses in the water conductor system including penstock.

3.2 Minimum Net Head

The net head resulting from the differences in elevation between the minimum head water level and the tail race level minus losses with all turbines operating head full gate opening.

3.3 Over Load

Additional turbine output in percentage over the rated output of the machine at a head to be specified.

3.4 Part Load

Fraction of rated output for which machine is designed to operate continuously with safety.

3.5 Rated Output

Maximum guaranteed turbine output at rate head.

3.6 Rated Speed

Speed corresponding to synchronous speed of the generator connected to the turbine.

3.7 Submergence

Difference in elevation of minimum tail water level above distributor centre line or runner centre line.

4 TYPES OF HYDRAULIC TURBINES

4.1 Following are the types of hydraulic turbines used for medium and large power houses:

a) *Impulse Turbines*

A turbine in which all the potential energy of water is converted to kinetic energy before it acts on the runner.

b) *Reaction Turbine*

Under this type, the following turbines are described below:

1) *Francis turbine*

It has fixed blades runner, where the water under pressure enters the runner through guide vanes in radial direction and leaves the runner practically in axial direction.

2) *Kaplan turbine*

It has movable blades where flow direction is axial and remains unchanged.

3) It is a Kaplan type of turbine with fixed runner blades.

4) *Bulb turbine*

Kaplan turbine with horizontal arrangement and having generator located inside bulb over which water flows while approaching to runner.

c) *Deriaz Turbine*

It is a diagonal type of Kaplan turbine with runner blade axis at an angle of less than 90° to the shaft axis.

5 CRITERIA FOR SELECTION OF HYDRAULIC TURBINE

5.1 Type of turbine is selected from techno economic considerations of the generating equipment power house cost and relative benefits of power generation. The factors given in Table 1 determine the type of turbine to be used depending upon the site conditions.

Table 1 Criteria for Selection of Hydraulic Turbine

(*Clause* 5.1)

Type of Machine	Head Variation Percent of Rated Head	Load Variation Percent of Rated Output	Specific Speed (m-mhp)	Peak Efficiency in Percent
Pelton	120 to 80	50 to 100	15 to 065	90
Francis	125 to 65	50 to 100	60 to 400	93
Deriaz	125 to 65	50 to 100	200 to 400	92
Kaplan	125 to 65	40 to 100	300 to 800	92
Propeller	110 to 90	90 to 100	300 to 800	92
Bulb	125 to 65	40 to 100	600 to 1 200	92

NOTES

1 Performance of turbine is ideal, at design head. Fall of efficiency in case of Pelton, Kaplan and Bulb is much less in comparison to Francis and Propeller types. Therefore in overlapping head ranges selection of type of turbine is affected by head variation existing at site.

2 Turbine efficiency varies with load. Fall of efficiency at part load for Francis and Propeller is much steeper in comparison to that for Kaplan and Pelton turbines, therefore, necessity of operating turbines at part loads for longer time influences choice of turbines in the overlapping head ranges. Thus in the head ranges where both Kaplan and Francis are suitable. in case of requirement of large head and load variation, Kaplan turbine in superior to Francis turbine from considerations of higher power generation on account of better overall efficiency. Similarly, in the overlapping head ranges where both Francis and Pelton could be used, Pelton has advantages over Francis in overall performance level when variation of load and head is higher.

3 Highest specific speed of turbine resulting in higher speed of rotation for generator with consequent reduction in cost of generator. This criteria is very important for selecting type of turbine from cost consideration in the overlapping head ranges (*see* Fig. 1).

5.2 Head

Maximum net head acting on the turbine is one of the most important criteria dictating type of turbine to be used for the power station under consideration. In general, Pelton turbines are recommended for high heads, Francis for medium heads, Kaplan and Deriaz for low heads and bulb for very low heads. The above criteria of selection is on account of turbine constructional features, requirement of strength and from all cost considerations. Normal range of maximum net head for each of the turbines generally adopted is given below:

Type of Turbine	*Range of Maximum Net Heads*
Pelton	Above 300 m
Francis	30 to 400 m (sometimes even up to 500 to 600 m)
Kaplan	10 to 60 m
Bulb	3 to 20 m
Deriaz	50 to 150 m

In the overlapping head ranges more detailed analysis shall be carried out to optimise cost for selecting the exact type of turbine.

5.3 Minimum load up to which turbine may be continuously operated without undue cavitation and vibration is dictated by type of turbine. Normal range for continuous operation for various types of turbines from this criteria is given below:

Type of Turbine	*Minimum Output for Continuous Operation (Percent)*
Pelton	30-50
Francis	50
Kaplan/Bulb	30-40
Propeller	85
Deriaz	40

5.4 Turbine Setting and Excavation Requirement

Setting of reaction turbine with reference to minimum tail water level is dictated by requirement from cavitational considerations. Further in view of bent draft tube, excavation up to bottommost point of knee that is much deeper than runner centre line is required. In general cavitation coefficient for Francis turbines is much less than that for Kaplan turbines necessitating relatively lesser submergence and exacavation for Francis turbine. Pelton turbine shall be installed above maximum tail water level, thus requiring minimum excavation cost.

5.5 Transport Consideration

In case of large unit rating machines, this criteria plays important role in selecting type of turbine. Normally runner is one of the costliest and most critical part which shall be handled in one piece from consideration of cost, reliability and reduced site work. Transport requirement of large Kaplan size runner is much less on account of possibility of removing runner blades easily as they are fixed by bolts and keys. In case of Francis turbines, necessity of limiting runner size during transport, requires manufacture of runner in two pieces increasing cost of the turbine by about 10 percent. Pelton turbine runner as a rule shall be transported in one piece.

5.6 Pressure Rise and Speed Rise Consideration

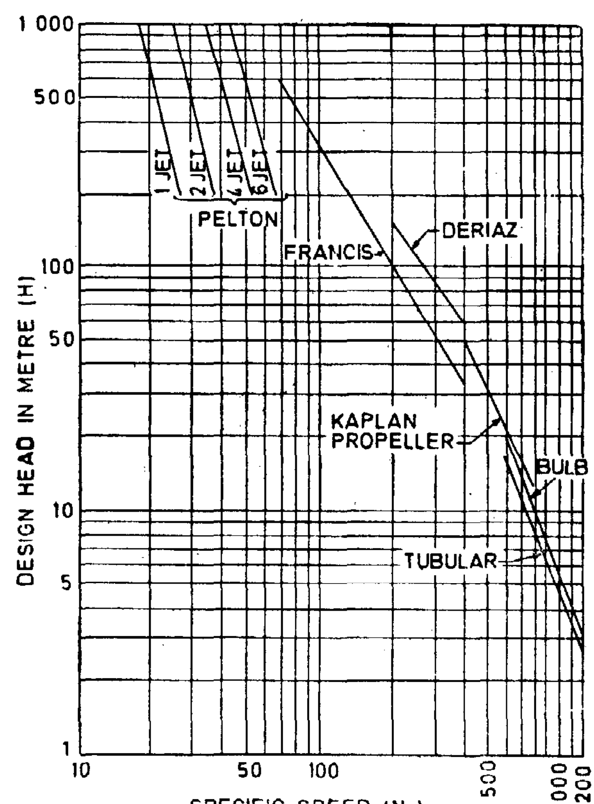
This criteria is more important in high head machines as higher pressure rise affects the cost of penstock substantially. Necessity of limiting pressure rise is accomplished by use of pressure relief valve in case of Kaplan and Francis turbine with relatively, long water conductor system resulting in increased cost of equipment and power house. Pelton turbine as a rule does not require this device on account of availability of design feature of deflector. Pressure rise and speed rise can therefore be limited to very economical level in case of Pelton turbine, without increase cost of turbine. Permissible pressure rise and speed rise for various turbines are given below:

Type of Turbine	*Pressure Rise* (*Percent*)	*Speed Rise* (*Percent*)
Pelton	15 to 30	20 to 45
Francis	30 to 35	35 to 55
Kaplan/Bulb and Propeller	30 to 50	30 to 65
Deriaz	20 to 45	35 to 65

5.7 Maintenance Consideration

In hydraulic turbines guide vanes/nozzles and runner blades are most critical components which get damaged by cavitation and silt and have to be repaired regularly. Large Kaplan turbines may be designed to enable replacement of all the runner blades without dismantling generator and top covers. Francis turbine may be designed to have a feature of removing and replacing the runner including other under water parts without dismantling generator. For large size Francis runners usually *in situ* repair is recommended. Cavitation and erosion damage for Kaplan and Francis turbines are relatively much serious in comparison to Pelton turbines. Pelton turbines have an advantage of replacing spear and nozzle quickly which is normally not possible in case of guide vanes of Kaplan and Francis turbines.

5.7.1 Choice of turbine is normally dictated by rated head consideration. In case of overlapping heads where two types of turbines could be considered suitable more detailed analysis need to be carried out when a number of factors are favouring different types of turbines.



$$N_s = \frac{RPM\sqrt{MHP}}{(HEAD)^{5/4}}$$

FIG. 1 RELATIONSHIP BETWEEN HEAD AND SPECIFIC SPEED

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Doc : No. RVD 15 (4005)

Amendments Issued Since Publication

Amend No.	Date of Issue	Text Affected

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Printed at Printwell Printers, Delhi, India