

RECAPITULATION OF DRAFT TUBES

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ABSTRACT

Draft tube is an important part of reaction turbine which is used to convert kinetic head available at exit of runner into pressure head, thereby, increasing the overall output. Turbines need to have a minimum amount of water to propel them in order to produce enough energy. Without these tubes, the pressure could drop because of lack of water, and in turn, the entire turbine could fail to work and power could be lost.

In this study, we have discussed different types of draft tubes with detailed study of the problems which are encountered in the reaction turbines. Few researches that were carried out earlier have been discussed. The basic design parameters which govern the working of draft tube have been discussed along with the effects of cavitation.

Keywords: Cavitation Effects, Classification, Draft Tubes, Efficiency, Reaction Turbines

I. INTRODUCTION

Draft tube used in reaction turbine for 2 main purposes i.e. to convert the excess velocity head available at the exit of the runner into pressure head and positioning the turbine at an convenient location (for repair and maintenance). The turbine has "tail race," which is the lowest portion of a dam or construction project where water pools. The draft tube connects the turbine to this tail race, permitting the turbine to be outside of the water but still have access to the water. A draft tube can be relatively simple to construct, but it must be strong and tough enough to withstand the elements and the work of the turbines. It can be either straight or curved, depending on the general construction of the turbine. With this part, it is possible to maintain the important column of water that keeps the turbine running. The right water level can be maintained despite any potential lack within the amount of material that flows into the machine. In this matter, the tube can help keep the inflow of water into the turbine regular, even if water levels drop, so that the turbine can run properly with the correct amount of pressure maintained.

II. CONSTRUCTIONAL DETAILS AND TYPES OF DRAFT TUBE

The water (hydraulic energy) imparts its energy to the vanes and runner, thereby reducing its pressure less than that of atmospheric pressure (vacuum pressure). As the water flows from higher pressure to lower pressure, it cannot come out of the turbine and hence a divergent tube is connected to the end of the turbine. Draft tube is a divergent tube one end of which is connected to the outlet of the turbine and other end is immersed well below the tailrace [1]. The major function of the draft tube is to increase the pressure from the inlet to outlet of the draft tube as it flows through it and hence increase it more than atmospheric pressure. The other function is to safely discharge the water that has worked on the turbine to tailrace. Depending on the shape and alignment, draft tubes are classified as [2]:

2.1 Vertical Divergent Draft Tube or Conical Draft Tube

This type of draft tube consists of a conical diffuser with half angle generally less than equal to 10° to prevent flow separation. This draft tube has the shape of a frustum of a cone. This is generally provided for low specific speed. For greater values of the cone angle, it is seen that the flowing body of water may not touch the sides of the draft tube (leaving the boundary). This will lead to the eddy formation bringing down the efficiency of the draft tube. Efficiency of this type of draft tube is 90%.

2.2 Moody's Draft Tube or Hydra Cone

This is a bell mouthed draft tube or a conical tube with a solid conical central core. The whirl of discharged water is very much reduced in this arrangement.

2.3 Simple Elbow Type Draft Tube

It consists of an extended elbow type tube. Generally, used when turbine has to be placed close to the tail-race. It helps to cut down the cost of excavation and the exit diameter should be as large as possible to recover kinetic energy at the outlet of runner. Efficiency of this kind of draft tube is less almost 60%

2.4 Elbow with Varying Cross Section

It is similar to the Bent Draft tube except the bent part is of varying cross section with rectangular outlet. This draft tube manages to discharge the water horizontally to the tail race. The horizontal portion of draft tube is generally inclined upwards to prevent entry of air from the exit end and it is an improvement of the simple elbow draft tube. In all the types mentioned above, the outlet of the draft tube should be situated below the tail water level (as shown in Figure 1)

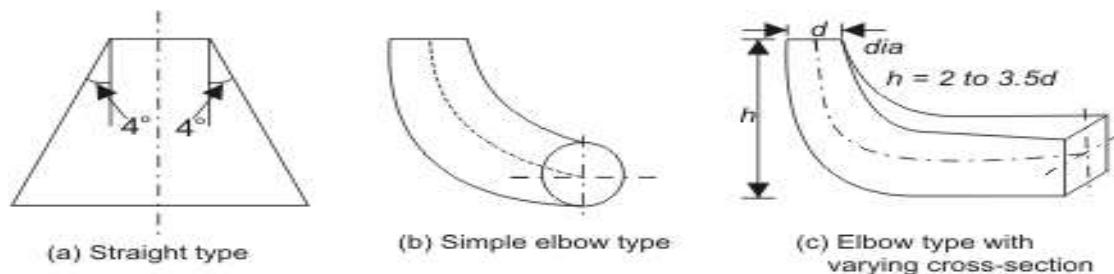


Figure 1: Different Types of Draft Tubes [3]

III. FIELD EXPERIENCES

A number of authors have reported case studies of field experiences with draft tube surging problems. Fluctuation of penstock pressure is one of the more common problems.

Guarga, Hiriart, and Torres [4] reported that at the La Angostura power plant in south-eastern Mexico, pressure fluctuations in the penstocks induced by draft tube surging were as high as 60.5 m peak-to-peak compared with a total head of 104 m. This problem was solved using a very small flow of air injected into the draft tube through the runner cone. The maximum penstock pressure fluctuation was reduced to 7.7 m.

Falvey [5] described a problem with the USBR's Fremont Canyon Power Plant. Vibrations and noise due to surging were so severe that operation was prohibited in the surging zone. A variety of air admission schemes and structural changes to the draft tube were attempted, with unsatisfactory results. Finally, it was found that the exit area of the runner was significantly smaller than most runners of similar specific speed. The trailing edge of

each runner blade was trimmed to increase the exit area. This produced an increase in maximum power output and reduced the size and severity of the surge region considerably.

Grein [6] summarized field methods used in attempts to reduce or eliminate surging and its effects. Among the methods most commonly used are air injection in the runner and draft tube area, structural modifications to the draft tube, and occasionally modifications to the runner. Each of these usually introduces some loss of efficiency. The variations on these approaches seen in the field are nearly as numerous as the number of field problems, as each situation is unique.

Common structural modifications to the draft tube are discussed by Falvey and Grein [7]. The most common structural modification is the addition of a flow straightener in the draft tube that serves to break up the vortex. Typical devices include fins attached to the draft tube wall, or concentric cylinders mounted in the draft tube. Fins have proven to be effective in many cases, but they introduce significant efficiency loss and are also subject to cavitation erosion and structural vibrations. Concentric cylinders do not normally reduce efficiency significantly. However, structural problems with mounting the cylinders in the draft tube are significant. Cavitation erosion and vibration are also serious problems. One advantage of concentric cylinders is that the supporting struts can also serve as air injection locations. This may help reduce the surge further and prevent cavitation damage to the struts.

Kito [8] described a Japanese power plant with severe vibrations of the penstock caused by draft tube surging. Attempts to control the surge itself caused large reductions in output power. The problem was finally solved by adding stiffener rings to the penstock walls and allowing surging to continue. This plant was especially susceptible to draft tube surging because it was not only required to operate under varying head and load conditions, but also at two different speeds corresponding to 50 Hz and 60 Hz power output.

Another type of modification is an extension to the runner cone, sometimes called a snorkel. These devices may be attached to the runner, or fixed within the draft tube so that they sit just beneath the runner cone. Some authors suggest that these devices break up the surge by filling a portion of the reverse flow region. Air injection can also be combined with these structures. When attached to the draft tube the disadvantages are similar to those for concentric cylinders. If attached to the runner, these devices may cause excessive runout of the shaft due to lateral forces arising from pressure pulsations in the draft tube. Nishi et al. [9] conducted a model study in which the presence of a cavitating vortex core produced large synchronous pressure pulsations.

IV. PRINCIPLE AND CAVITATION EFFECT ON DRAFT TUBE

The principle of a draft tube can be outlined by aid of Bernoulli's equation between section 2-2 and 3-3 (inlet and outlet, respectively)

$$z_2 + \frac{p_2}{\rho g} + \frac{V_2^2}{2g} = z_3 + \frac{p_3}{\rho g} + \frac{V_3^2}{2g}, \quad (1)$$

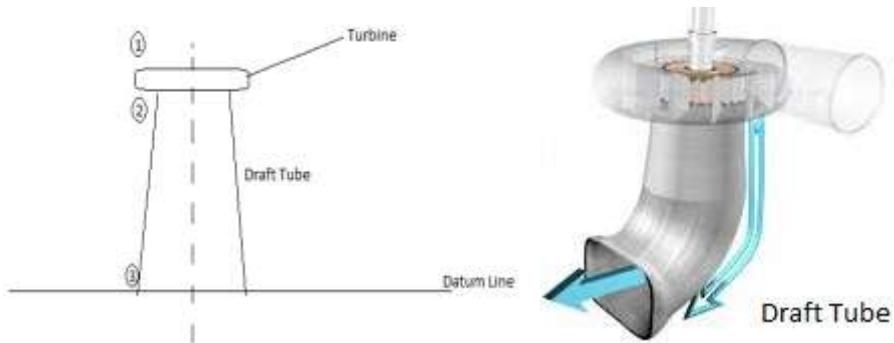


Figure 2: Schematic View of Draft Tube

Here p is the absolute pressure, z the height, V the mean velocity. The absolute pressure p at section 3 is atmospheric pressure or more in case of submergence. Let H_s be the height of the draft tube. Hence, Pressure head₂ = P_{atm} head – difference in velocity head - H_s . Hence, the pressure head at section 2 is less than atmospheric pressure thereby increasing the total power output.

One of the most remarkable feature of draft tube is that it enables us to use pressure head below the atmospheric pressure (suction or vacuum) for power production. However, there is a limit upto which we can recuperate the negative pressure head i.e. vapour pressure. If the pressure at any point in the draft tube reaches below the vapour pressure at a particular temperature, bubble formation takes place. The phenomenon of bubble formation leads to an important phenomenon called Cavitation. Cavitations occur when the local absolute pressure falls below the saturated vapor pressure of the water for the water temperature. The height of draft tube is an important parameter for avoiding cavitation. Applying Bernoulli's equation between outlet of the runner and discharge point of the draft tube neglecting any head loosed in draft tube)

$$z_2 + \frac{p_2}{\rho g} + \frac{V_2^2}{2g} = z_3 + \frac{p_3}{\rho g} + \frac{V_3^2}{2g}, \quad (2)$$

$z_2 = z$ (Height of draft tube)

z_3 = height of tail race which is referenced as datum line (=0)

p_2 = pressure at the outlet of the runner

p_3 = gauge pressure

$$\frac{p_2}{\rho g} = - \left[z + \frac{V_2^2 - V_3^2}{2g} \right] \quad (3)$$

Since draft tube is a diffuser V_3 is always less than V_2 which implies p_2 is always negative thus height of the draft tube is an important parameter to avoid cavitation.

V. CONCLUSION

Draft tubes have to be installed underneath a dam, plane, or other machinery that is controlled by the work of the turbine. They must be strong enough to withstand the pressure placed on them. If they are installed or repaired after the turbine is already functioning, sometimes they must be placed while other parts are working as well — sometimes even while air, gas or water is already flowing through the turbine. They have to be put into place in the turbine through careful movement along the edge of the equipment as a result. the decrease in kinetic energy of the fluid in the draft tube. The value of this minimum pressure should never fall below the vapour

pressure of the liquid at its operating temperature to avoid the problem of cavitations. Therefore, we find that the incorporation of a draft tube allows the turbine runner to be set above the tail race without any drop of available head by maintaining a vacuum pressure at the outlet of the runner.

REFERENCES

- [1] 6th International Conference on Pumps and Fans with Compressors and Wind Turbines IOP Publishing IOP Conf. Series: Materials Science and Engineering 52 (2013) 052034 doi:10.1088/1757-899X/52/5/052034
- [2] ASME, The Guide to Hydropower Mechanical Design, HCI Publications, Kansas City, 1996
- [3] Bhan, S., J. B. Codrington, and H. Mielke, "Reduction of Francis Turbine Draft Tube Surges," Proceedings, Fifth International Symposium on Hydro Power Fluid Machinery, Chicago, Illinois, 1988, pp. 95-102.
- [4] Guarga, R., G. Hiriart, and J. J. Torres, "Oscillatory Problems at Mexico's La Angostura Plant," Water Power & Dam Construction, Oct. 1983, pp. 33-36
- [5] Falvey, H. T., "The Anatomy of a Steady Oscillatory Flow Problem," Proceedings, Fourth Meeting of the IAHR/AIRH Work Group on the Behaviour of Hydraulic Machinery under Steady Oscillatory Conditions, Fort Collins, Colorado, Aug. 1989
- [6] Grein, H., "Vibration Phenomena in Francis Turbines: Their Causes and Prevention," Proceedings, 10th Symposium of the International Association for Hydraulic Research Section for Hydraulic Machinery Equipment and Cavitation, Tokyo, Japan, 1980
- [7] Falvey, H. T., "Draft Tube Surges - A Review of Present Knowledge and an Annotated Bibliography," Report No. REC-ERC-71-42, U. S. Bureau of Reclamation, Dec. 1971
- [8] Kito, F., 'The Vibration of Penstocks,' *Water Power*, Vol. 11, Oct. 1959, pp. 379-392.
- [9] Nishi, M., Matsunaga, S., Kubota, T., and Senoo, Y., 1984, "Surging Characteristics of Conical and Elbow-Type Draft Tubes," in Proceedings of the 12th IAHR Symposium, pp. 272-283.