# FLUID FACILITIES AND MACHINERY

## GUIDE TO LABORATORY PRACTICALS

University of the Basque Country (UPV/EHU)

Energy Engineering Department

## THEME 6: PROPELLER TURBINE

## 1. REQUIRED BACKGROUND

Fluid Mechanics.

Hydraulic Machinery. Turbomachinery. Turbines.

## 2. PRE-LABORATORY

Detailed reading of the description of the practical for its completion within 1 [h]. See Video of P6.

## 3. OBJECTIVES

To calculate and to demonstrate the operation of the propeller reaction turbine.

- Visual analysis of the operation of the propeller reaction turbine.
- Reading to gain an understanding of the parameters to take into account when selecting, designing, and optimizing the operation of the propeller reaction turbine.
- Determination of the characteristic curves of the turbine at different opening levels of the wicket gates with constant $H$ and $Q$ values.

## 4. THEORETICAL FOUNDATION

The propeller turbine is a reaction turbine. In the same way as with the Francis turbine, its basic components are: i) the wicket gates (system composed of a crown of hydrodynamically shaped vanes that guides the water and regulates the flow rate, although these vanes are not adjustable; ii) the runner coupled to the turbine shaft that causes rotary movement as the water passes over the blades; and, iii) a draft tube at the outlet of the runner, to optimize the efficiency of the turbine.

The wicket gates are of a larger diameter than the runner, so that the movement of the water is centripetal in relation to the shaft. The propeller turbine of the Fluid Mechanics laboratory also has a flow rectifier located after the runner, in order to transform the rotational movement of the streamlines into linear paths, which minimizes energy loss due to turbulence. The end of this turbine is defined by the draft tube that flows into the water tank from which the turbine itself is supplied. The elevation difference between the inlet of the turbine (crown of vanes) and its outlet (draft tube) is 0,72 [m].

When operating with a propeller turbine, the different points of operation can be experimentally obtained working at constant flow rate and head. Then, these points are fitted to a curve by using the least squared adjustment or a similar one.

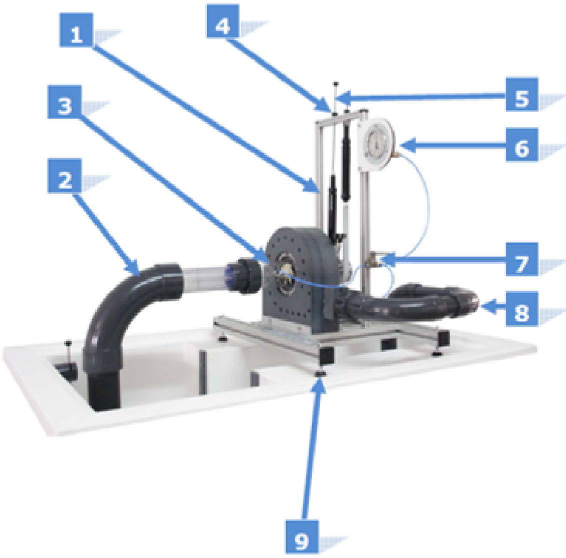
These are the characteristic parameters that define the operation of a single turbine:

- Flow rate ($Q$)
- Net head ($H_n$)
- Hydraulic power ($P_h$)
- Mechanical torque ($C_m$)
- Mechanical power ($P_m$)
- Efficiency ($\eta$)

## 5. DESCRIPTION OF EQUIPMENT AND FACILITY

The Fluid Mechanics laboratory is equipped with a propeller turbine mounted on a multifunctional Armfield hydraulic bench (Figure 26).

Water is pumped from a tank in the lower part of the hydraulic bench by two pumps connected in parallel to the propeller turbine. The discharge flow can be regulated by means of a flow regulation valve and can be determined by a direct reading from an electronic gauge located at the inflow pipe of the turbine (in [L/min]). Once the water enters the turbine, its pressure can be measured by either a Bourdon type manometer at the inlet of the turbine or by a water column, when the pressure at the inlet is low. Once the water exits the draft tube, it returns to the tank of the hydraulic bench in a closed circuit. The main components of the turbine are shown in Figure 26.




1. Dynamometer
2. Water outflow
3. Outflow tube
4. Knurled nut
5. Braking rod
6. Vacuum gauge-manometer
7. Pressure selection valve
8. Water supply tube
9. Adjustable feet

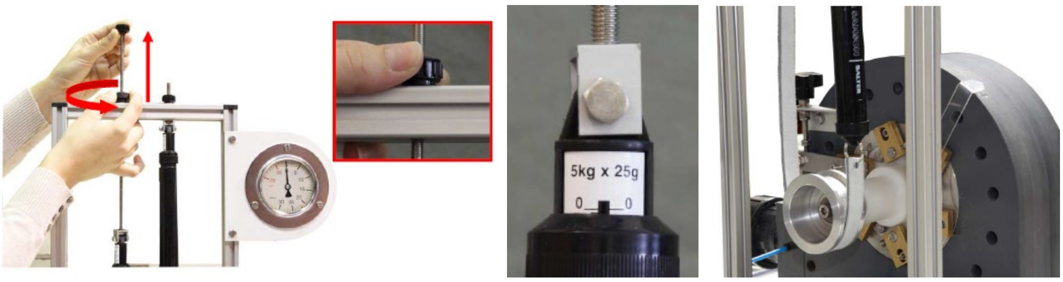
**Figure 26**: *Main components of the propeller turbine.*

Before starting to work with the turbine, it is necessary to check the adjustable feet of the apparatus so that it is level (Figure 27).

The hydraulic bench has two pumps and it is very important that they are properly activated in the right order (Figure 27); the upper switch must be activated first of all (no effect will be apparent until the lower switch is activated) and then, the lower switch (which activates the whole system). Once the pumps of the hydraulic bench are functioning, the regulation valve should be gradually opened, and the turbine will start rotating.


**Figure 27**: *Levelling system of the turbine and switches for the activation of the pumps*.

By using the friction brake, the load of the turbine can be regulated and it can even be completely stopped. Calculation of the applied torque when doing so can be done by reading the dynamometer measurement of applied force. To perform this task properly, the hydraulic brakes of the dynamometers should be loosened until they reach a value of zero, <u>when the turbine is not in operation</u> (the knurled nut of each dynamometer is used to make this adjustment). Once in operation, tightening the upper knurled nuts will brake the turbine until the desired rotation speed is reached. At that point, the force that is applied will be equal to the difference between the readings of the two dynamometers.




(A) (B) (C)

**Figure 28**: *A: Dynamometer and detail of the knurled nut. B: Detail of dynamometer measurement. C: Turbine Brake*.

This turbine also offers the possibility of modifying the direction of the guide vanes, so that the flow rate that enters can be regulated with the manual system of the turbine (see Figure 29). These vanes can be gradually opened or closed, by means of the knob shown in the first image of Figure 29. The indicator shown in the middle image points to the opening level. The opening or closing of the vanes can also been visually observed within the turbine itself.

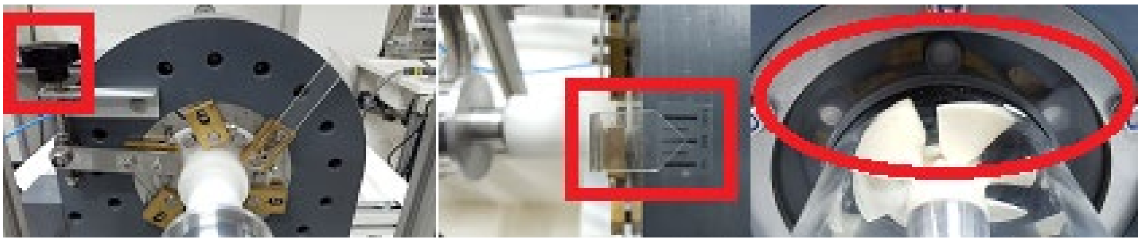
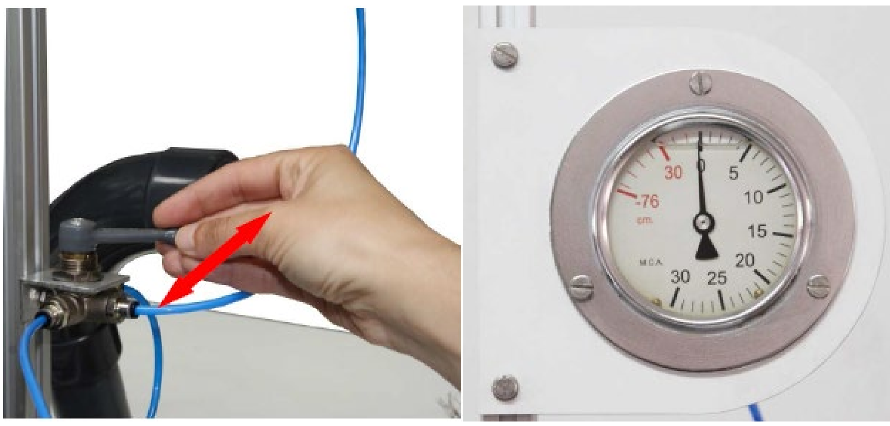


**Figure 29**: *Regulation of the turbine guide vanes.*

Pressure measurements may be performed at two points: at the inlet and at the outlet of the turbine. Depending on the pressure to be measured, the valve handle must be turned to the right (pressure intake at the inlet of the turbine) or to the left (pressure intake downstream of the runner). Special care needs to be taken with the units that are specified in the Bourdon vacuum meter-manometer, insofar as the pressure measurement can be negative in [cm Hg.C.] or positive in [m W.C.]




**(A)** **(B)**

**Figure 30**: *(A) Selecting the pressure intake; and, (B) detail of the Bourdon vacuum meter-manometer.*

Next, the main features of some of the components of the facility will be described:

Diameters:

- Feeding pipe: $\emptyset_{external}$ = 50 [mm], $\emptyset_{internal}$ = 45 [mm]
- Discharge pipe: $\emptyset_{external}$ = 70 [mm], $\emptyset_{internal}$ = 59 [mm]

Vacuum meter-manometer:

- Bourdon type with glycerine, from −76 [cm Hg.C.] to 25 [m W.C.].

Dynamometer:

- 2 x dynamometer, 5 [kg] x 25 [g]

Characteristics of the turbine:

- Type: propeller
- Number of runner blades: 6
- Runner:
  - Average angle (inlet/outlet): 41[º]/26[º]
  - Guide vanes: 6 (adjustable from 0 [%] to 100 [%])
  - Approximate maximum power in the shaft: 30 [W]