Universidad del País Vasco
Euskal Herriko Unibertsitatea

# FLUID FACILITIES AND MACHINERY

## GUIDE TO LABORATORY PRACTICALS

University of the Basque Country (UPV/EHU)

Energy Engineering Department

## THEME 1: PUMPS 1: CONNECTIONS

# 1. REQUIRED BACKGROUND KNOWLEDGE

Fluid Mechanics.

Hydraulic Machinery. Turbomachinery. Pumps.

# 2. PRE-LABORATORY

Detailed reading of the description of the practical for its completion within 1 [h]. See Video of P1.

# 3. OBJECTIVES

To calculate and to demonstrate the operation of the pumps: i) individually; ii) in series; and, iii) in parallel:

- Visual observation of the operation of one pump.
- Experimental determination of the characteristic curves of pump-performance in each case.
- Comprehension and comparison of the ***H-Q*** characteristic curves obtained in the laboratory.

# 4. THEORETICAL FOUNDATION

The most frequent characteristic curve of a hydraulic pump is the ***driving curve***, which at a given rotation speed relates the height, $H$, to the flow rate, $Q$, that is supplied. In this way, the pump's operating points will be determined by the curve formed between the manometric height and the flow rate, $H(Q) = A + B \cdot Q + C \cdot Q^2$. The real curve is defined as a parabolic function instead of a linear (theoretical curve), due to energy losses and the existence of a finite number of vanes in the impeller, as may be observed in Figure 1:

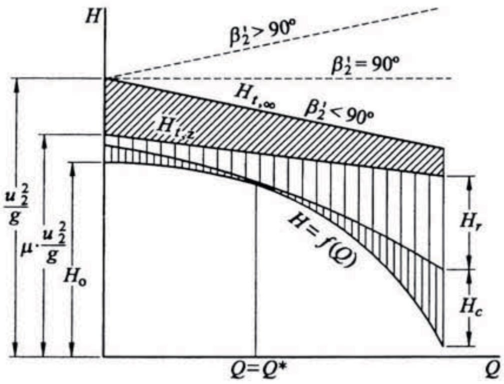


**Figure 1:** *H-Q theoretical and real curves.* $H_{t,\infty}$ *denotes an infinite number, ∞, of vanes;* $H_{t,z}$ *denotes a finite number, z, of vanes;* $H_r$ *denotes friction losses; and,* $H_c$ *denotes impact losses.*

The mathematical expression cannot in each specific case be obtained by means of a purely theoretical analysis. In general, the curve that is experimentally determined on a test bench will be the one that appears in the product specifications of the pump manufacturer.

When designing important facilities, there is the possibility of connecting pumps either in series or in parallel, depending on the fluid movement that is under demand. When connecting ***n*** different pumps in parallel, the total flow, ***Q***, that is under demand will be the sum of the flows that pass through each pump. Therefore, this type of connection is used when high flow rates of a liquid have to be pumped. Assuming two different pumps, B.1 and B.2, each with its corresponding characteristic curve:

B.1: $H_1 = A_1 + B_1 \cdot Q_1 + C_1 \cdot Q_1^2$

B.2: $H_2 = A_2 + B_2 \cdot Q_2 + C_2 \cdot Q_2^2$

These curves can then be expressed as follows:

$$Q_1 = f_1 (H_{//})$$

$$Q_2 = f_2 (H_{//})$$

Therefore, the ***H-Q*** curve of the parallel connection will be as follows:

$$Q_{//} = Q_1 + Q_2 = f_1(H) + f_2(H)$$

When the pumps are coupled in a series connection, the flow (which is held constant) will undergo successive rises or increases in pressure. Series connection is therefore interesting when high pressure increases are required and when there is a limitation on the diameter of the pumps, as can happen in deep wells. The characteristic curve of a series connection of the two pumps, B.1 and B.2, can be expressed as:

$$H_s = H_1 + H_2 = (A_1 + A_2) + (B_1 + B_2) \cdot Q_s + (C_1 + C_2) \cdot Q_s^{\,2}$$

## 5. DESCRIPTION OF EQUIPMENT AND FACILITY

The Fluid Mechanics laboratory is equipped with a hydraulic bench that has two pumps installed. This bench contains the following basic elements (Figure 2):

1: Two pumps (***N*** ~ 2900 [r.p.m.]) brand PEDROLLO SPA (B.1 and B.2).

2: Two manometers each connected to the output of pumps B.1 and B.2.

3: Two vacuum gauge-manometers each connected to a suction pipe of the pumps.

4: Two wattmeters that measure the power consumed by the motors driving impellers 1 and 2.

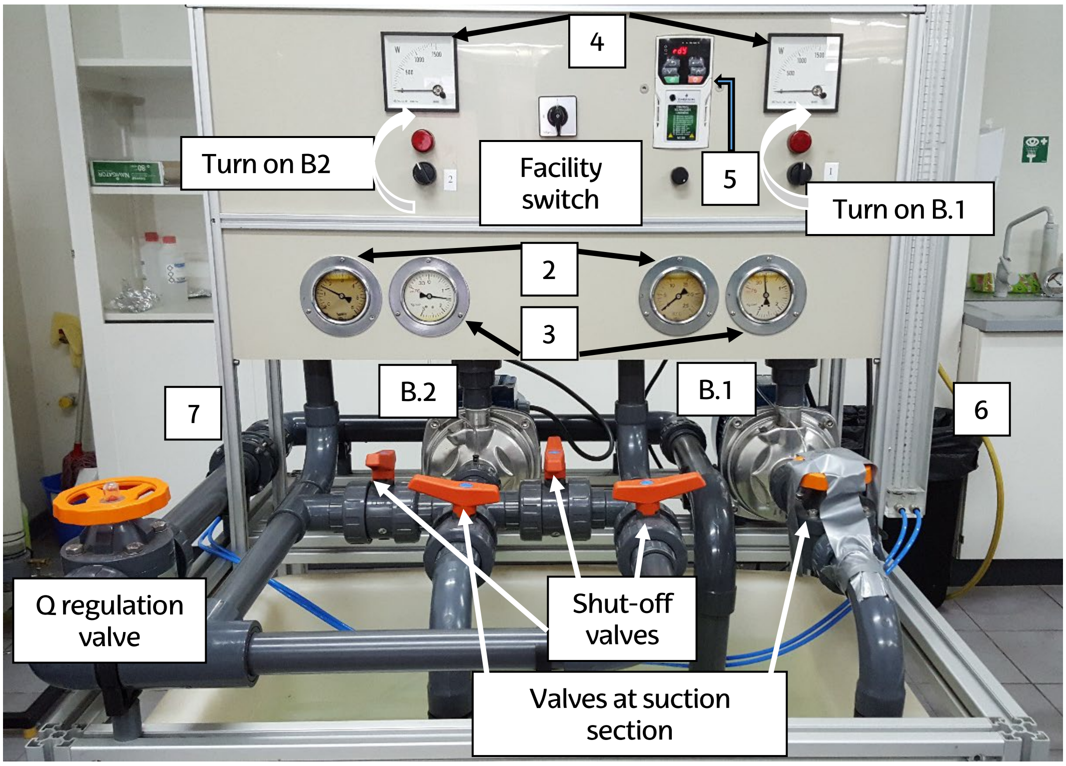


**Figure 2:** *Hydraulic bench and main elements.*


**Figure 3:** *Frequency controller (5).*

In addition, pump B.1 is equipped with a frequency controller (5) that modulates the electricity supply, thereby controlling the rotation speed of the pump. The controller consists of a screen where the working frequency is displayed, and a regulation wheel that modifies the frequency with which pump B.1 is fed (Figure 3). However, the frequency will be held constant in this practical, so there will be no need to modify the frequency controller. Pump B.2 has no frequency controller.

On its right side, the hydraulic bench has an orifice plate (7) to measure flow rates (Figure 2). The drop in pressure, due to the narrower orifice, is measured as a difference of a piezometric head (in [mm W.C.]) through two graduated columns. The passing flow, in [$m^3$/h], may be calculated as follows:

$$Q = 0{,}568\sqrt{(h_2 - h_1)}$$


**Figure 4:** *Graduated columns (6) connected to an orifice plate.*

Finally, the hydraulic bench and its network of pipes and connection valves positioned over a water tank, can be adjusted, so that practicals with different set ups may be performed (Figure 5).

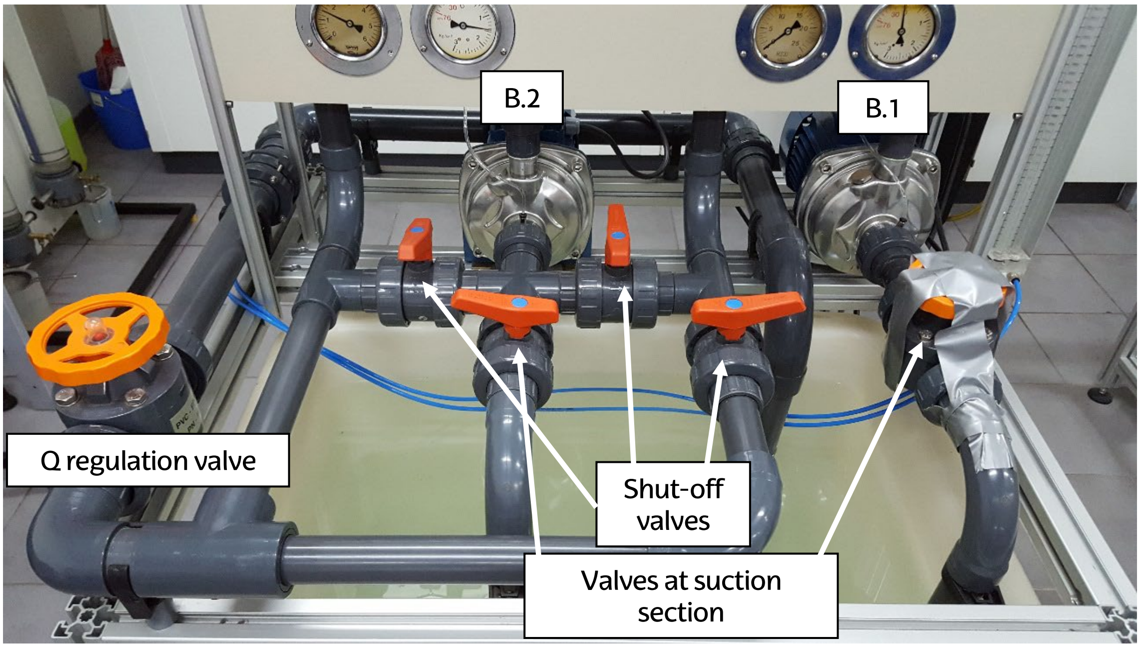


**Figure 5:** *Pipes, valves, regulation valves, and water tank.*