TABLE OF CONTENTS

7 PRACTICAL EXERCISES MANUAL

7.1 DESCRIPTION

7.1.1 Description of the unit

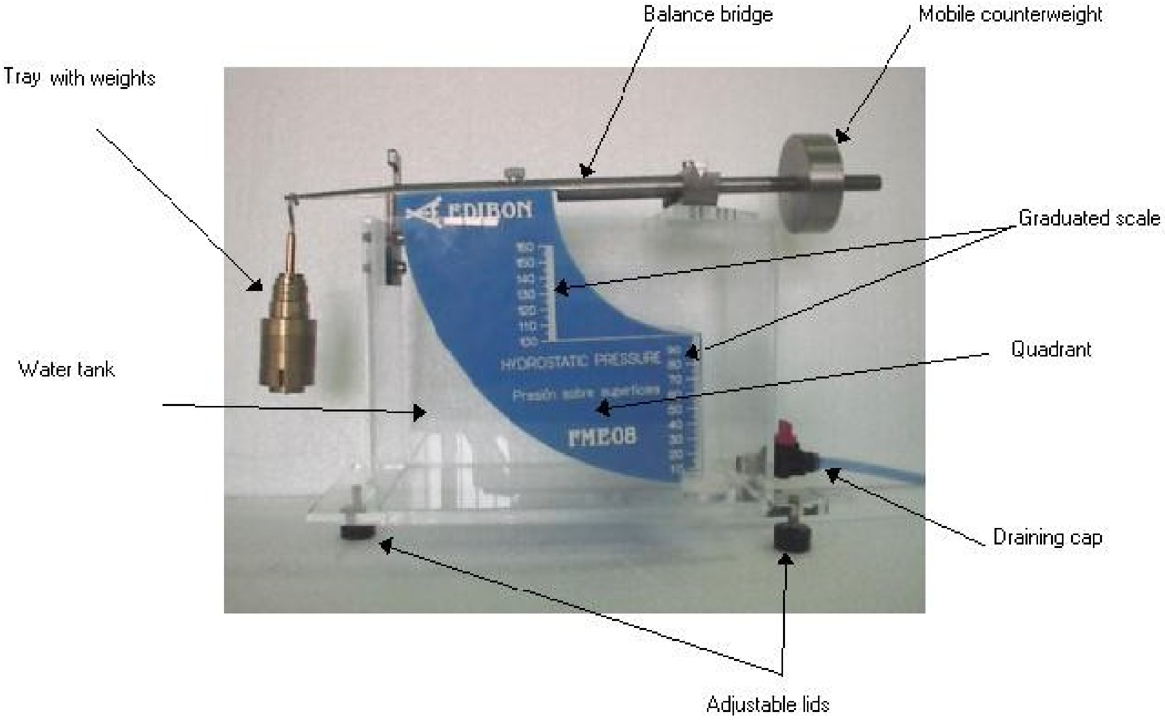

Figure 1. General sight of the unit

The accessory consists of a quadrant (a fourth of a ring) that will float on the fluid. This element is mounted on an arm of a balance that swings around and axle.

When the quadrant is submerged into the water tank, the force that acts against the frontal surface (flat and rectangular) will cause a momentum in relation to the supporting axle.

The balance bridge has a support for weights, where we can place different weights, and a counterweight that can move in the turn direction of the system.

The tank includes adjustable supporting legs that determine its correct levelling with the help of the bubble level, located in one of the legs. It has a draining valve.

The level reached by water inside the tank is indicated in a graduated scale placed inside the ballcock. The dimensions and levels of the equipment will be:

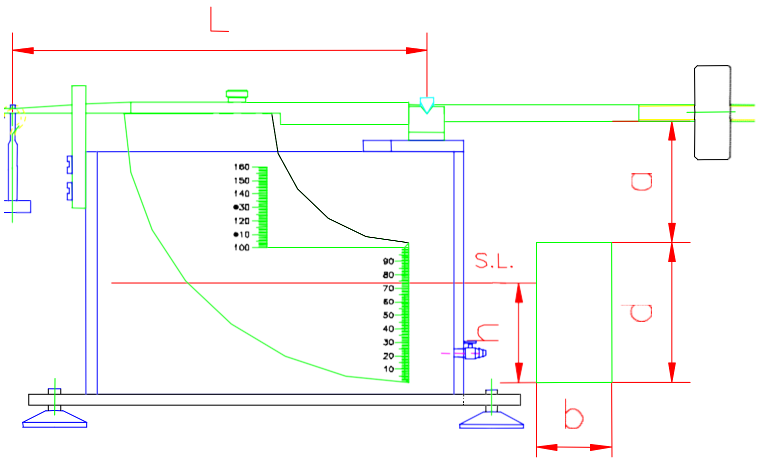

Figure 2. Dimensions of the unit (I)

See ANNEX III for the dimensions of the equipment.

The B level represents the depth of the quadrant.

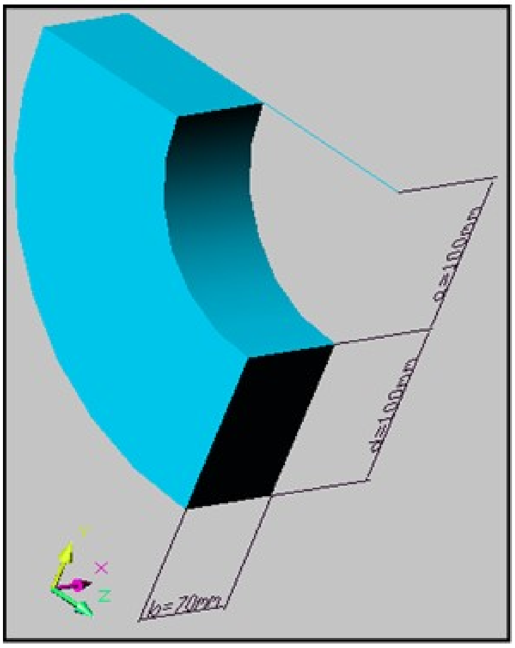

Figure 3. Dimensions of the unit (II)

7.1.2 Practical possibilities

- Experimental determination of the center of pressures on a flat surface, partially submerged into a liquid at rest, and comparison with the theoretical positions.

- Experimental determination of the center of pressures on a flat surface, totally submerged into a liquid at rest, and comparison with the theoretical positions.

- Experimental determination of the resultant force on a flat surface, partially submerged into a liquid at rest, and comparison with the theoretical positions.

- Experimental determination of the resultant force on a flat surface, totally submerged into a liquid at rest, and comparison with the theoretical positions.

- Balance of momentum and calculations of angles, turned in relation with the pressures done on a flat surface.

7.1.3 Specifications

- Tank capacity: 5,5 L

- Distance between the masses in suspension and the supporting point: 285 mm (Length of the revolving arm).

- Section area: 0.007 m^2

- Maximum depth of the submerged quadrant: 160 mm
- Height of the supporting point over the quadrant: 100 mm
- A set of masses of different weights is also supplied.

    4 weights of 100gr

    1 weight of 50gr

    5 weights of 10gr

    1 weight of 5gr

7.1.4 Dimensions and weights

- Estimated dimensions: 500x200x300 mm.
- Estimated volume: 0.04 m^3
- Estimated weight: 5 kg.

7.1.5 Required services

- This unit works as an independent device.

7.2 THEORY

The objective of this equipment is to measure the force made on the surfaces which are in contact with it. In order to do it, we will take a geometry in which the pressure made on its surfaces do not generate momentum in relation to a point (with the exception of one of them, that will be the surface upon which we will carry out the experiment).

Important concepts:

a) Momentum is the product of applying a force at a given distance.

$$M = F * d$$

b) The force produced by the fluid on a solid surface, that is in contact with it, is equal to the product of the pressure made on it with its area, (see **Figure 4**, where A = b* l) .

$$F = P * A$$

c) That force, that acts on each essential area, can be represented by an only resultant force (see F in **Figure 4**) on the complete surface that acts on a point, called pressures center. (In the figure, it coincides with the center of gravity).

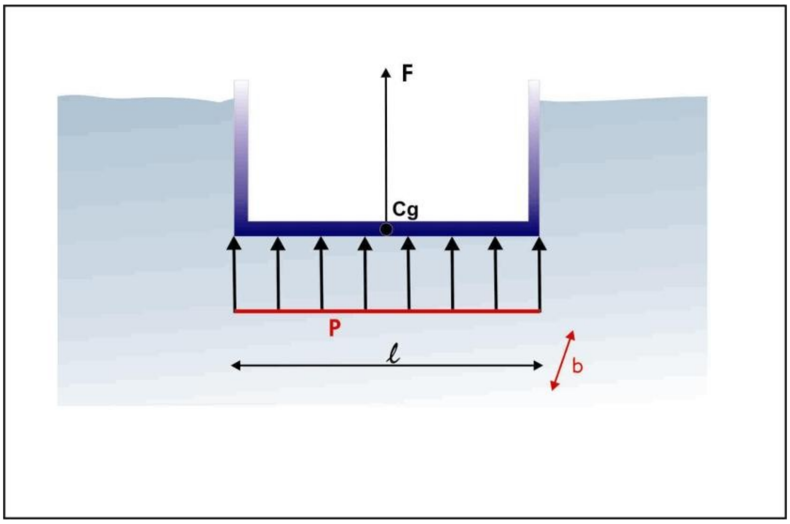

Figure 4

Starting from these fundaments, we will calculate the pressure done by the fluid on the submerged surface, that, as we said, will be equal to an equivalent force applied to a certain point.

- If the solid surface is flat, the resultant force coincides with the total force, because the essential forces are parallel (It is an arithmetic addition of the forces).

- If the surface is not flat, the essential forces are not parallel and they will have opposite components, so the resultant force will be smaller than the total force (it is a vectorial addition of the forces, and there will be components to add up and to subtract).

7.2.1 Determination of the center of pressures

If we have a submerged pressure, the pressure done on it by the fluid is proportional to the depth. In the figure, we see that the pressure “p “ increases as the distance with the surface of the fluid “h” varies. The pressure will vary from the pressure “p1 “ to ” p2”.

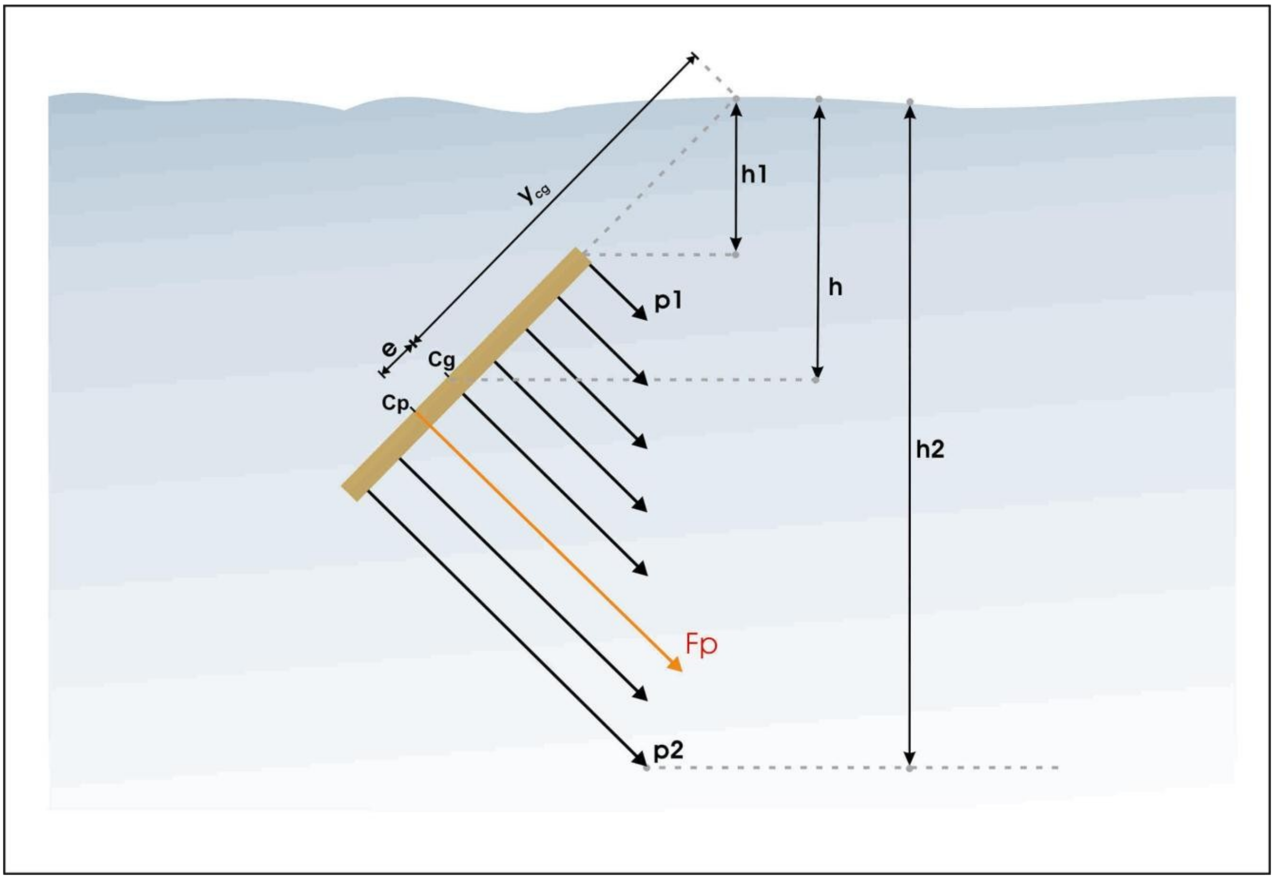

Figure 5

Due to this variation of pressures all along the surface, the Equivalent Force “***Fp*** “ is moved from the Center of Gravity “***Cg*** “ of the surface to the point “***Cp***“, called center of pressures, a given distance “***e***“.

If we take a given surface, we divide the pressures distribution on a rectangular zone of constant pressure”***p1***“ and a triangle with base ”***p2- p1***“ and height ”***l***”. These two distributions of pressures cause two equivalent forces: “***F1***“

and "***F2***".

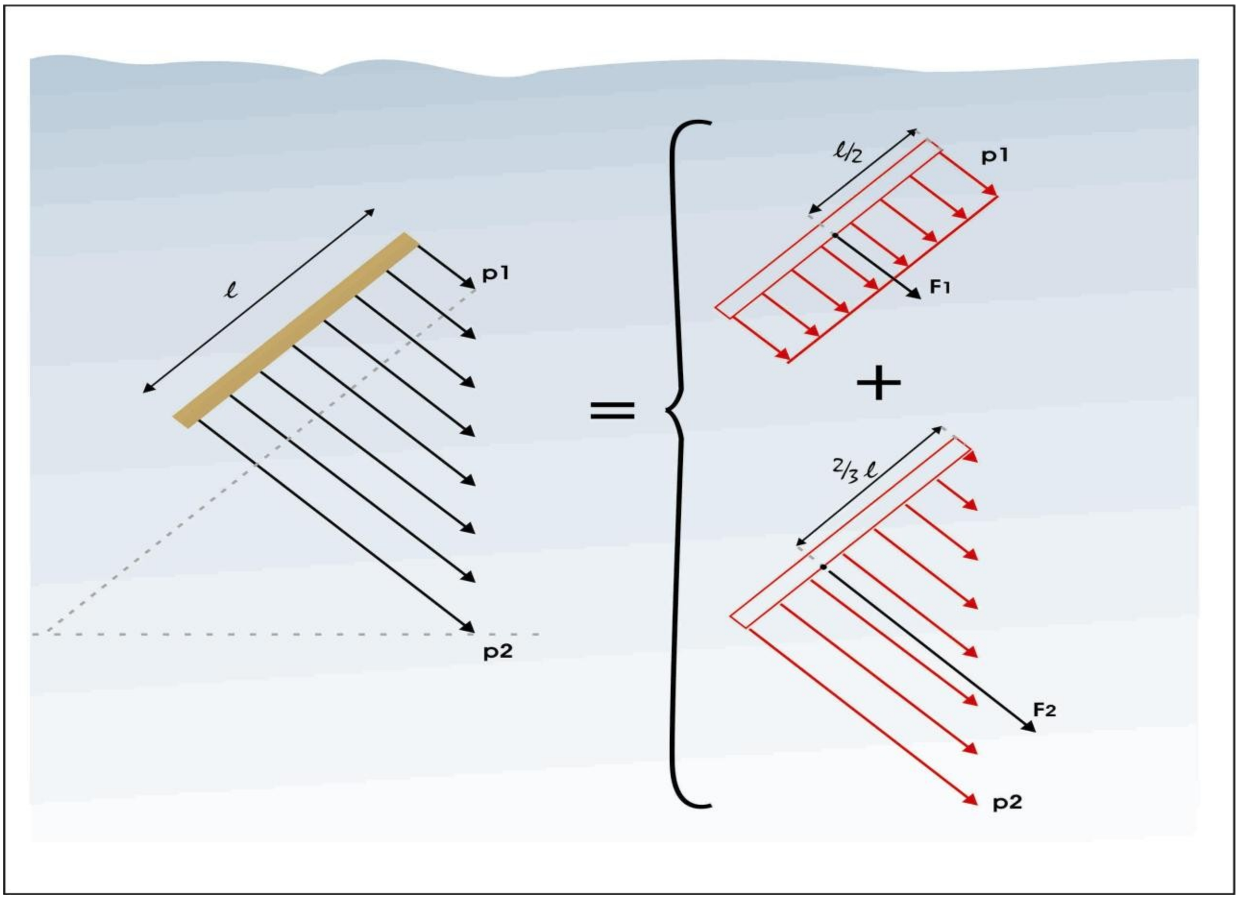

Figure 6

If we calculate the momentum generated in relation with a point "***O***", and taking into account the geometry of pressures distribution, "***F1***" will be applied to "***l/2***", and "***F2***" to "***2*l/3***", both from the closest point to the surface of the fluid.

$$\sum M = 0 \rightarrow Fcp \cdot \left(\frac{l}{2} + e\right) = F1 \cdot \frac{l}{2} + F2 \cdot \frac{2 \cdot l}{3}$$

Equation 1

So, the two forces left applied to the known distances generate the same momentum that a total force (Equivalent Force "Fp ") applied to a given distance (Center of Pressures, "Cp").

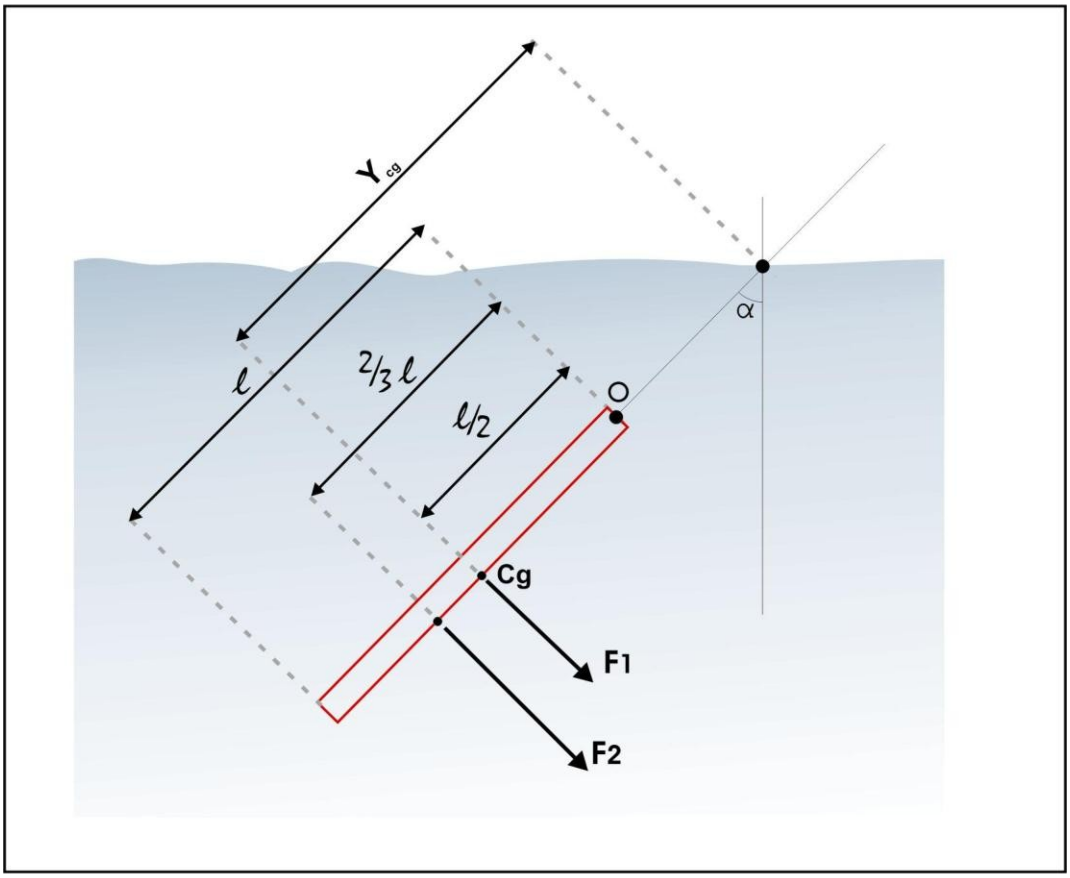

Figure 7

Finding the previous equation, we obtain:

$$e = \frac{l}{6} \cdot \frac{(p2 - p1)}{p2 + p1}$$

Equation 2

Taking into account that the hydrostatic pressure tell us that:

$$p = \rho * g * h$$

Equation 3

and applied to our case:

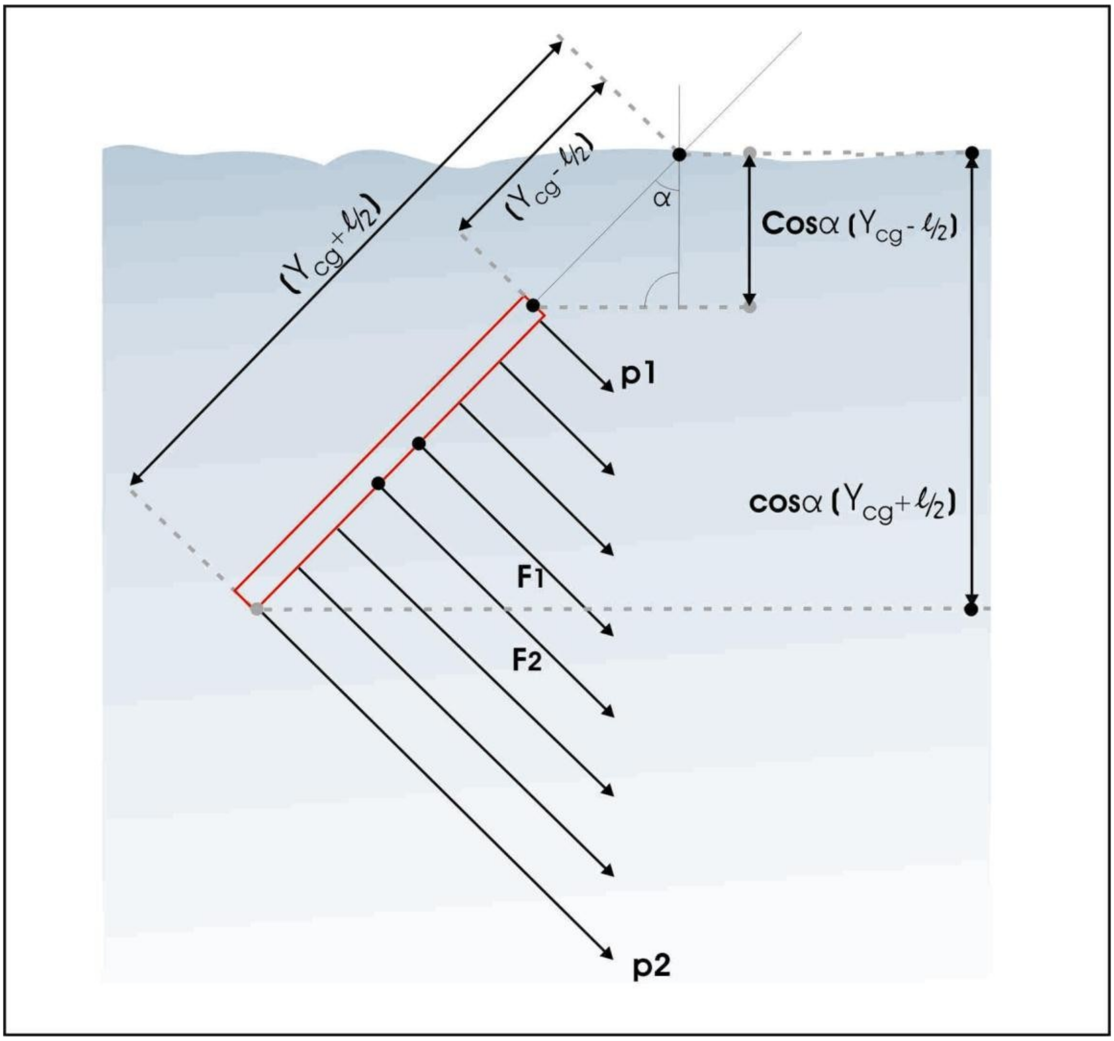

Figure 8

$$p1 = \rho \cdot g \cdot \cos\alpha \cdot \left(y_{cg} - \frac{l}{2}\right)$$

$$p2 = \rho \cdot g \cdot \cos\alpha \cdot \left(y_{cg} + \frac{l}{2}\right)$$

Equation 4

entering in the previous equation:

$$e = \frac{l^2}{12 \cdot y_{cg}}$$

Equation 5

With this equation we will infer the distance between the Center of Pressures and the turning point (point where the equivalent force is applied).

$$Lcp = Lcg + e$$

Equation 6

7.2.2 Determination of the resultant force

The pressure done by a fluid on a submerged surface depends on the density of the fluid and the distance between the solid and the surface of the fluid "***h***".

$$p_{cg} = \rho * g * h_{cg}$$

Equation 7

This pressure will vary with depth (distance from the solid to the surface of the fluid "***h***"), and it will increase as the element submerges more and more. The previous equation can also be expressed as:

$$p_{cg} = \rho * g * \cos\alpha * y_{cg}$$

Equation 8

The resultant force is the multiplication of the pressure of the center of gravity of the working surface with the area of the submerged surface.

$$Fp = Pcg * As$$

Equation 9

7.2.3 Distribution of pressures at FME08

In the **Figure 9**, we can see that the distribution of pressures over surfaces that are not flat does not cause any momentum in relation to the turning axle (because they are in the radial direction to this one, Pr1 and Pr2). The distribution of pressures in the frontal side (side with graduated scale) is equal and with opposite direction to the rear side (opposite side to the graduated scale). In conclusion, the only surfaces that causes a momentum in relation with the turning point "O" will be the flat one (Pp).

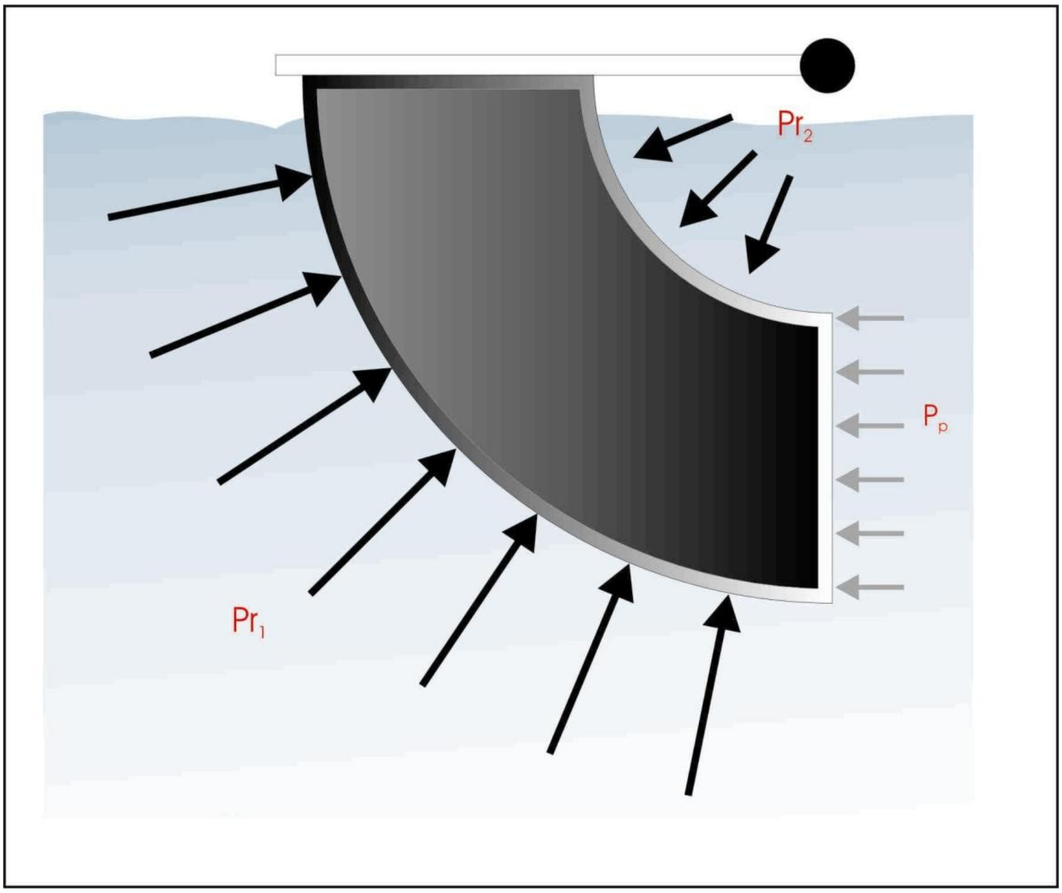

Figure 9

This equipment is based on the equalisation of momentum generated in this side with the ones generated by the crook with weights. If we find it, we will obtain the pressure done by the fluid on the flat surface.

7.2.4 Flat Surface partially submerged

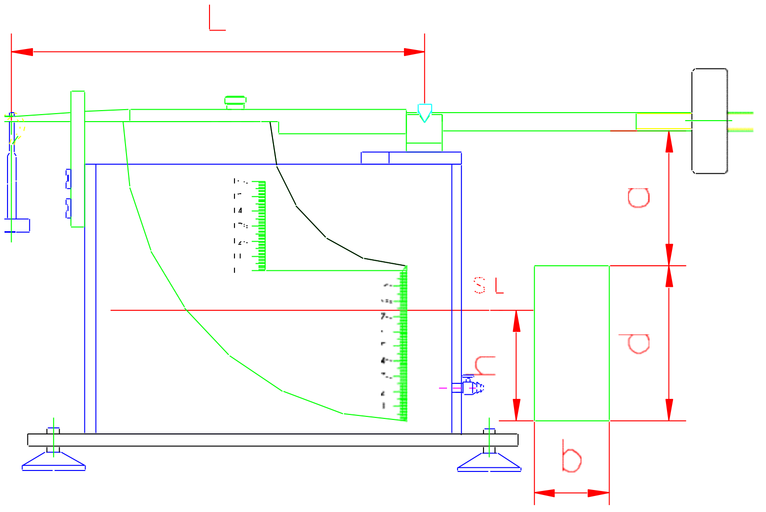

Figure 10. Flat Surface partially submerged

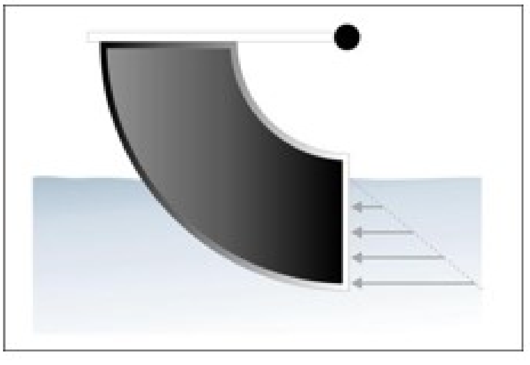

Figure 11. α=90°

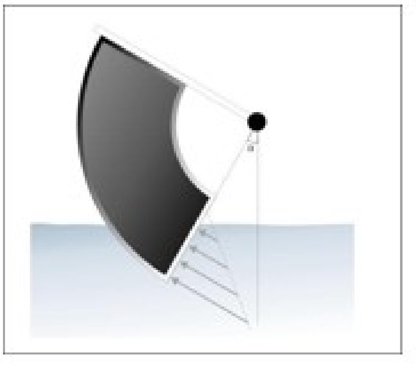

Figure 12. α<>90°

7.2.4.1 Determination of the center of pressures at α=90°, partially submerged

When the ballcock is partially submerged, we have to base on the **Equation 5** and take into account that at this situation "l = h" and "ycg = h/2", so we have to:

$$e = \frac{h^2}{12 \cdot (h/2)} \rightarrow e = \frac{h}{6}$$

Equation 10

Using the **Equation 6**, we find that the center of pressures will at a distance:

$$Lcp = Lp2 - \frac{h}{3}$$

Equation 11

Where Lp2 is the extreme turning radius (distance of the turning point to the most submerged one); in other words, of maximum pressure p2, Lp2 = a+d, and we subtract h/3, because we will have a triangular pressures distribution, instead of trapezoid (because the element is partially submerged).

7.2.4.2 Determination of the resultant force at α=90°, partially submerged

We will base on the **Equation 8** for α = 0, in order to calculate the pressure done on the flat surface of the object.

$$p_{cg} = \rho \cdot g \cdot \frac{h}{2}$$

Equation 12

and the submerged area will be:

$$As = h * b$$

Equation 13

so the Equivalent Force will be:

$$Fcp = \rho \cdot g \cdot \frac{h^2}{2} \cdot b$$

Equation 14

7.2.4.3 Determination of the center of pressures at α<>90°, partially submerged

When the ballcock is partially submerged, we have to base on the **Equation 5** and take into account that in this situation "l = h*cosα" and "ycg = h*cosα /2", and we have to:

$$e = \frac{(h \cdot \cos\alpha)^2}{12 \cdot (h \cdot \cos\alpha/2)} \rightarrow e = \frac{l}{6} = \frac{h \cdot \cos\alpha}{6}$$

Equation 15

For it, using the **Equation 6**, we will see that the center of pressures will be at a distance:

$$L_{cp} = L_{p2} - \frac{l}{3} = L_{p2} - \frac{h \cdot \cos\alpha}{3}$$

Equation 16

Where Lp2 is the extreme turning radius (Distance between the turning point and the most submerged one; in other words, of maximum pressure p2, Lp2 = a+d) and we subtract l/3 because we will have a triangular distribution of pressures, instead of trapezoidal (because the element is partially submerged).

7.2.4.4 Determination of the resultant force at α<>90°, partially submerged

The pressure done on the flat surface of the object will be calculated focusing on the **Equation 8**

$$p_{cg} = \rho \cdot g \cdot \frac{\cos\alpha \cdot l}{2}$$

Equation 17

and the submerged area will be:

$$As = l * b$$

Equation 18

So the Equivalent Force will be:

$$Fcp = \rho \cdot g \cdot \frac{\cos\alpha \cdot l^2}{2} \cdot b$$

Equation 19

7.2.5 Flat surface totally submerged

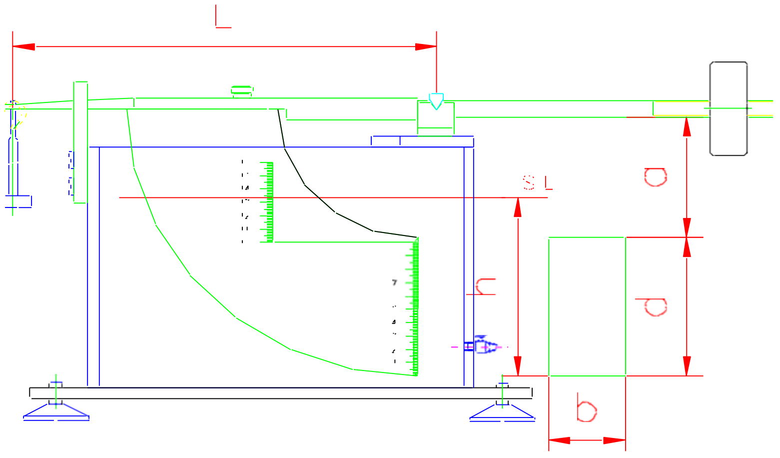

Figure 13. Flat Surface totally submerged

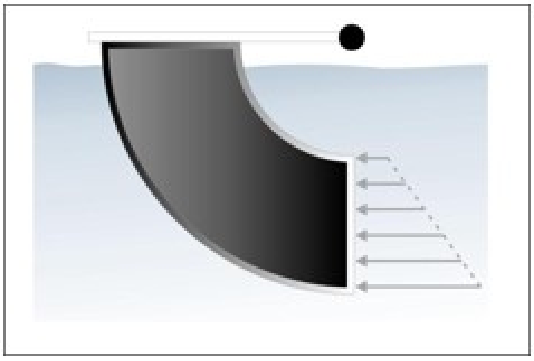

Figure 14. α=90°

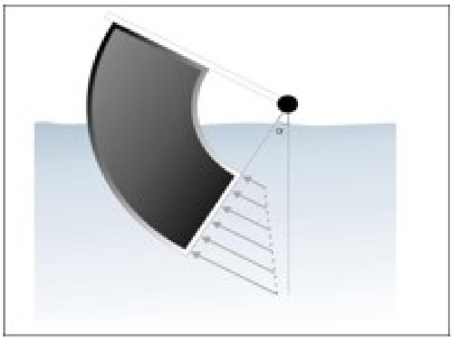

Figure 15. α<>90°

7.2.5.1 Determination of the center of pressures at α=90°, totally submerged

When the ballcock is totally submerged, based on the **Equation 5**. and taking into account that at this situation "l = d" and "ycg = h-d/2", we have to:

$$e = \frac{d^2}{12 \cdot \left(h - \frac{d}{2}\right)}$$

Equation 20

For it, and using the **Equation 6**, we find that the center of pressures will be at a distance:

$$L_{cp} = L_{cg} + \frac{d^2}{12 \cdot \left(h - \frac{d}{2}\right)} \rightarrow L_{cp} = a + \frac{d}{2} + \frac{d^2}{12 \cdot \left(h - \frac{d}{2}\right)}$$

Equation 21

7.2.5.2 Determination of the the resultant force at α = 90°, totally submerged

We will calculate the pressure done on the surface of the object with the **Equation 8** for α = 0. Remember that “l = d” and “ycg = h-d/2”.

$$p_{cg} = \rho \cdot g \cdot \left(h - \frac{d}{2}\right)$$

Equation 22

and the submerged area will be:

$$As = d * b$$

Equation 23

so the Equivalent Force will be:

$$Fcp = \rho \cdot g \cdot \left(h - \frac{d}{2}\right) \cdot d \cdot b$$

Equation 24

7.2.5.3 Determination of the center of pressures at α <> 90°, totally submerged

When the ballcock is totally submerged according to the **Equation 5** and taking into account that at this situation “l = d” and “ycg = h/cosα -d/2”, we have to:

$$e = \frac{d^2}{12 \cdot \left(\frac{h}{\cos \alpha} - \frac{d}{2}\right)}$$

Equation 25

For it, using the **Equation 6**, we find that the center of pressures will be at a distance:

$$L_{cp} = L_{cg} + e \rightarrow L_{cp} = L_{cg} + \frac{d^2}{12 \cdot \left(\frac{h}{\cos \alpha} - \frac{d}{2}\right)}$$

Equation 26

where Lcg = +d/2.

7.2.5.4 Determination of the resultant force at α <>90°, totally submerged

We will calculate the pressure done on the flat surface of the object using the **Equation 8**. Remember that "l = d" and "ycg = h/cosα -d/2".

$$p_{cg} = \rho \cdot g \cdot \left(h - \frac{d \cdot \cos \alpha}{2}\right)$$

Equation 27

and the submerged area will be:

$$As = d * b$$

Equation 28

so the Equivalent Force will be:

$$Fcp = \rho \cdot g \cdot \left(h - \frac{d \cdot \cos \alpha}{2}\right) \cdot d \cdot b$$

Equation 29

7.2.5.5 Balance of momentums

If we make a balance of momentum, taking into account that we have an Equivalent Force produced by the pressure of the Center of Pressures, and a Force produced by the weights (FL), at a distance L...

$$\sum M = 0 \rightarrow Fcp \cdot Lcp = F_L \cdot L$$

Equation 30

we can check the execution of the previous equation.

7.3 LABORATORY PRACTICAL EXERCISES

7.3.1 Practical exercise 1: Determination of the center of pressures with and angle of α=90°, partially submerged

7.3.1.1 Objective

Determination of the position of the Center of Pressures on a flat surface, perpendicular to the surface of the fluid, partially submerged into a liquid at rest.

7.3.1.2 Experimental procedure

1. Level the tank, acting conveniently on the supporting feet, that are adjustable, while checking the "bubble level".

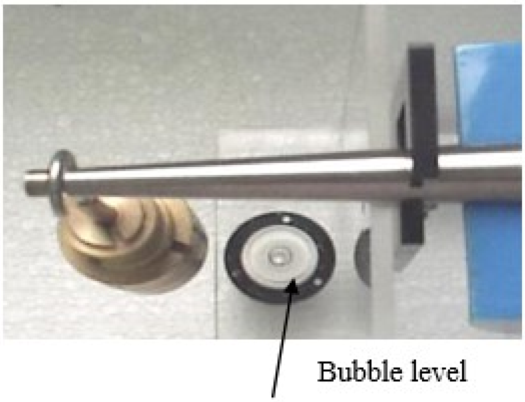

Figure 16

2. Measure and take note of the designed dimensions by a, L, d y b; These latest ones correspond to the flat surface placed at the extreme of the quadrant (**Figure 17**). Do not forget this step in order to get accurate measures.

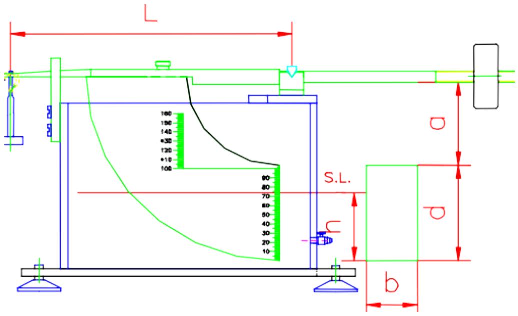

Figure 17

3. With the tank placed on the Hydraulic Bench or on the Hydraulic Group, locate the balance bridge on the support (sharp form, see **Figure 18**). Hang the tray at the end of the arm (see **Figure 19**).

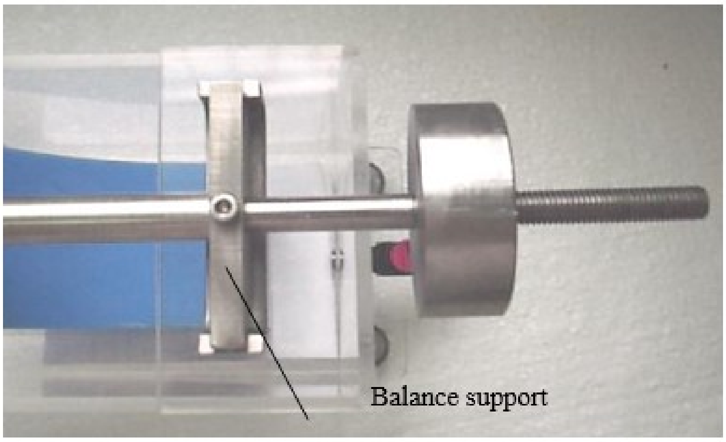

Figure 18

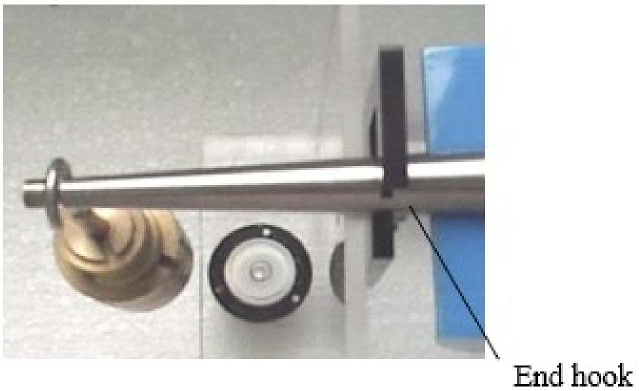

Figure 19

4. Close the draining tap of the bottom of the tank. Move the counterweight of the bridge balance until the flat surface will be perpendicular to the base of the tank (base that we will level previously). With the balance, we will be able to start with the measures totally balanced, so all changes will be done with a difference in the water volume or with a difference of the masses placed on the tray. This step is very important in order to get good measurements (the equipment has several mortises in the "end hook", the central one identifies this balance point).

5. Introduce water into the tank until the free surface of this will be tangent to the lowest edge of the quadrant (until the inferior point of the floating element is reached). The fine adjustment of this level can be managed overfilling the pretended filling and then,draining it slowly through its cap. Maybe you will have to incline a bit the tank to the side of the cap in order to carry out the drainage. If you have to do it, make sure that you place it correctly again after that.

6. Place a calibrated weight on the balance tray and add water slowly until the flat surface will be perpendicular to the base of the tank. In order to carry out this adjustment, we have a white mark that is in the end of the arm (end- hook), besides the tray.

   Take note of the water level, indicated in the quadrant, and of the value of the weight located on the tray (**Table 1**). Note: Make sure if the weights are marked on gr or grf = N). The shading columns in the table correspond to the experimental data obtained, and these will be the ones in which we will focus in this practice.

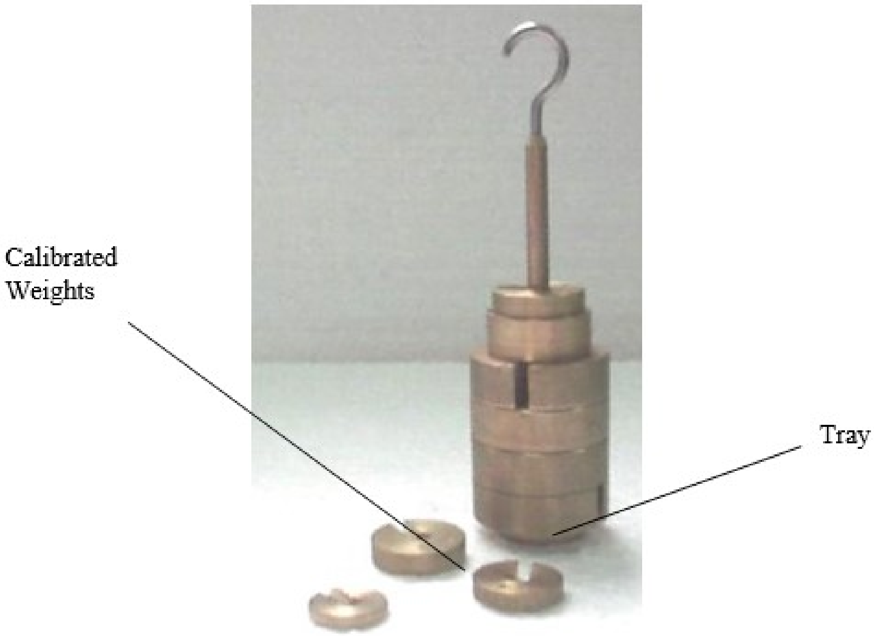

Figure 20

7. Repeat the previous operation several times, increasing steadily the weight of the tray in each one of them until, once the balance bridge will be levelled, the level of the water free surface will touch the upper edge of the rectangular flat surface that the end of the quadrant has (until the flat surface is completely covered).

Figure 21

8. Since now, and on the contrary order as they were placed on the tray, we remove the added weights in each operation, we level the arm (after each removal) using the draining cap, and the weights and water levels (h) are noted on the tray.

7.3.1.3 Worksheet

Student: ________ Year: __________

Table 1

Filling of the tank		Emptying of the tank		Averages		Calculations	
Weights F (g)	Heights h (mm)	Weights F (g)	Heights h (mm)	F_m (kg)	h_m (m)	L_{cp}	F_{cp}

For h < d (Partial immersion)

Q.1. Measure the heights a, b,d and L:

$a = \_\_\_ mm$

$b = \_\_\_ mm$

$d = \_\_\_ mm$

$L = \_\_\_ mm$

Q.2. Average the obtained values and fill in the columns Fm and hm in the **Table 1**. Analyse the obtained deviation, in relation to the first values.

Q.3. Calculate the values of Lcp, taking into account that:

$$Lcp = Lp2 - \frac{h}{3}$$

Where Lp2 is the turning end radius (Lp2 = a+d).

Q.4. Explain the previous peculiarity, starting from the **Equation 5** and **Equation 6**.

Q.5. Analyse and comment the obtained data, and comment possible differences with the wished data.

7.3.2 Practical exercise 2: Determination of the resultant force with and angle of 90°, partially submerged

7.3.2.1 Objective

To determine the equivalent force on a flat surface, perpendicular to the surface of the fluid and partially submerged into a liquid at rest

7.3.2.2 Experimental procedure

The procedure is the same as in practical exercise 1 (we can use the same experimental data as in the previous practical exercise, if we have already done it).

7.3.2.3 Worksheet

Student: ________ Year: __________

Q.1. With the experimental data obtained in Practical exercise 1 and using the following equation:

$$Fcp = \rho \cdot g \cdot \frac{h^2}{2} \cdot b$$

- calculate the values of Fcp and include them in the **Table 1 of the Practical exercise 1.**

Q.2. Explain the previous peculiarity starting from the **Equation 8**

Q.3. Analyse and comment the obtained data and comment possible differences from the wished data.

7.3.3 Practical exercise 3: Determination of the center of pressures, angle <>90°, partially submerged

7.3.3.1 Objective

To determine the position of the center of pressures on a flat surface with an inclination of the angle in relation to the surface of the fluid, partially submerged into a liquid at rest.

7.3.3.2 Experimental procedure

1. To level the tank, acting conveniently on the supporting feet, that are adjustable, while checking the "bubble level".

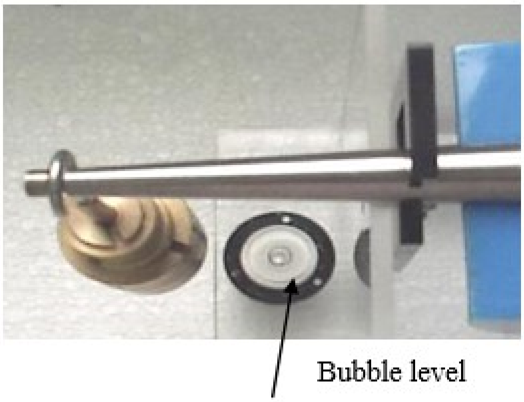

Figure 22

2. Measure and take note of the designed dimensions by a, L, d y b; These correspond to the flat surface placed at the extreme of the quadrant. Do not forget this step in order to get accurate measures.

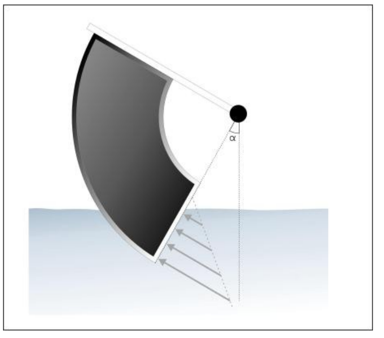

Figure 23

3. With the tank placed on the Hydraulic Bench or on the Hydraulic Group, locate the balance bridge on the support (sharp form, see **Figure 24**). Hang the tray at the end of the arm (see **Figure 25**).

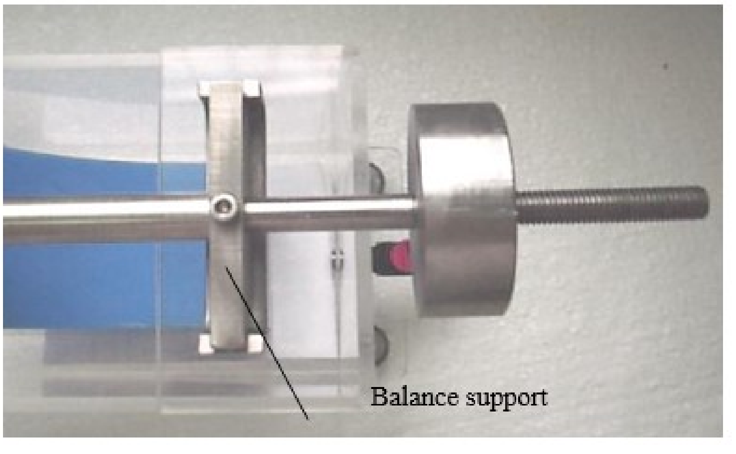

Figure 24

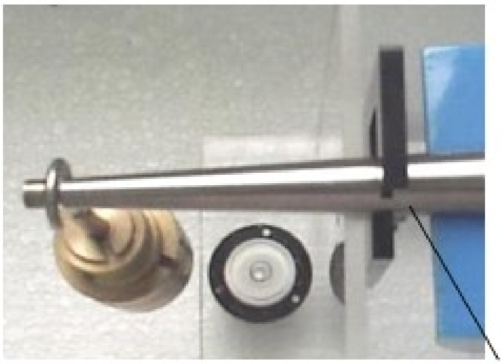

Figure 25

4. Close the draining tap of the bottom of the tank. Move the counterweight of the bridge balance until the flat surface will be perpendicular to the base of the tank (base that we will level previously). With the balance, we will be able to start with the measures totally balanced, so all changes will be done with a difference in the water volume or with a difference of the masses placed on the tray. This step is very important in order to get good measurements (the equipment has several mortises in the “end hook”, the central one identifies this balance point).

5. Introduce water into the tank until the free surface of this will be tangent to the lowest edge of the quadrant (until the inferior point of the floating element is reached). The fine adjustment of this level can be managed overfilling the pretended filling and then,draining it slowly through its cap. Maybe you will have to incline a bit the tank to the side of the cap in order to carry out the drainage. If you have to do it, make sure that you place it correctly again after that.

6. Place a calibrated weight on the tray of the balance and add water slowly until the upper mortise in the “end hook” is reached, just besides the hook that contains the weights.

   Note: Confirm if the weights are marked on gr or grf=N. The shading columns in the table correspond to the experimental data obtained, and these will be the ones in which we will focus in this practice.

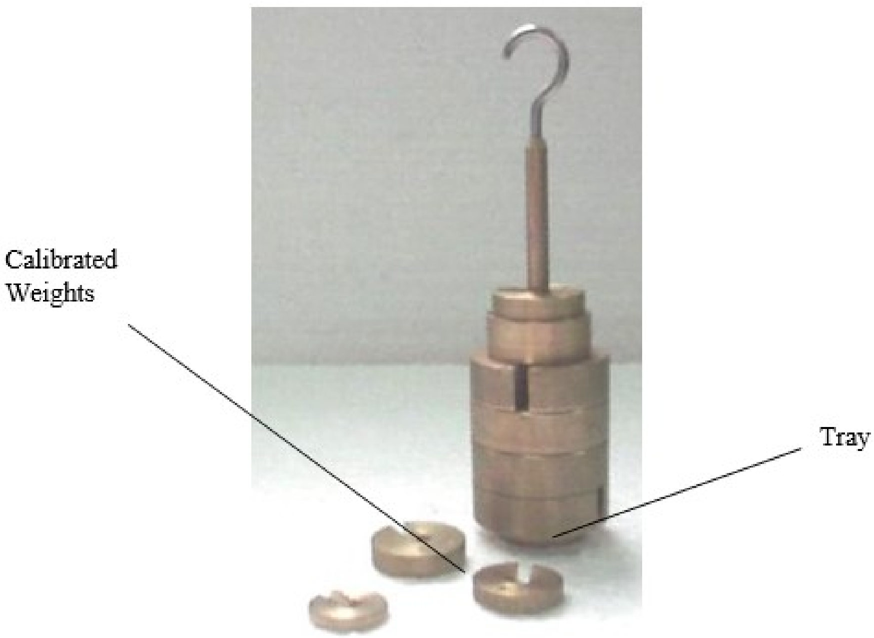

Figure 26

7. Repeat the previous operation several times, increasing the weight of the tray in each one of them until, once the balance bridge will be levelled, the level of the water free surface will touch the upper edge of the rectangular flat surface that the end of the quadrant has (until the flat surface is completely covered).

Figure 27

8. Since now, and on the contrary order as they were placed on the tray, we remove the added weights in each operation, we level the arm (after each removal) using the draining cap, and the weights and water levels (h) are noted on the tray.

9. Repeat the experiments with the lower mark and take note of the results on the table of the worksheet.

7.3.3.3 Worksheet

Student: ________ Year: __________

First angle: α_1

Table 2

Filling of the tank		Emptying of the tank		Averages		Calculations		
Weights F (g)	Heights h (mm)	Weights F (g)	Heights h (mm)	F_m (kg)	h_m (m)	L_{cp}	F_{cp}	α_1

Second angle: α_2

Table 3

Filling of the tank		Emptying of the tank		Averages		Calculations		
Weights F (g)	Heights h (mm)	Weights F (g)	Heights h (mm)	F_m (kg)	h_m (m)	L_{cp}	F_{cp}	α_2

For h < d (Partial immersion)

Q.1. Measure the heights a, b,d and L:

a=___mm

b=___mm

d=___mm

L=___mm

Q.2. Average the obtained values and fill in the columns Fm and hm in the **Table 2**. Analyse the obtained deviation, in relation to the first values.

Q.3. Calculate the values of Lcp, taking into account that:

$$L_{cp} = L_{p2} - \frac{l}{3} = L_{p2} - \frac{h \cdot \cos \alpha}{3}$$

Where Lp2 is the turning end radius (Lp2 = a+d).

Q.4. Explain the previous peculiarity, starting from the **Equation 5** and **Equation 6.**

Q.5. Analyse and comment the obtained data, and comment possible differences with the wished data.

7.3.4 Practical exercise 4: Determination of the equivalent force with and angle <>90°, partially submerged

7.3.4.1 Objective

To determine the equivalent force on a flat surface, with an inclined angle in relation to the surface of the fluid, partially submerged into a liquid rest.

7.3.4.2 Experimental procedure

The procedure is the same as in the Practical exercise 3 (we can use the experimental obtained data in the previous Practical exercise, if we have already done it).

7.3.4.3 Worksheet

Student: ________ Year: __________

Q.1. With the experimental data obtained in Practical exercise 3 and using the following equation:

$$Fcp = \rho \cdot g \cdot \frac{\cos\alpha \cdot l^2}{2} \cdot b$$

- calculate the values of Fcp and include them in the **Table 2 of the Practical exercise 3.**

Q.2. Explain the previous peculiarity starting from the **Equation 8.**

Q.3. Analyse and comment the obtained data and comment possible differences from the wished data.

7.3.5 Practical exercise 5: Determination of the center of pressures with an angle of 90°, totally submerged

7.3.5.1 Objective

To determine the position of the center of pressures on a flat surface, totally submerged into a liquid rest

7.3.5.2 Experimental procedure

1. Level the tank, acting conveniently on the supporting feet, that are adjustable, while checking the "bubble level".

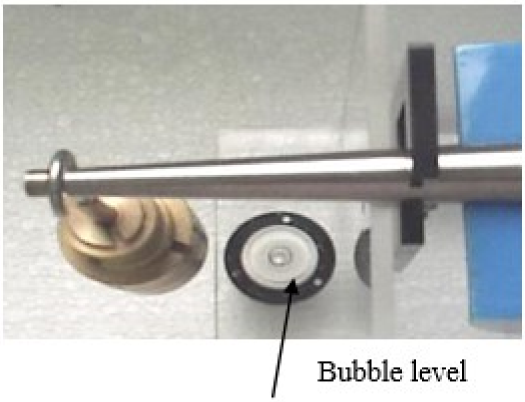

Figure 28

2. Measure and take note of the designed dimensions by a, L, d y b; These latest ones correspond to the flat surface placed at the extreme of the quadrant (**Figure 29**). Do not forget this step in order to get accurate measures.

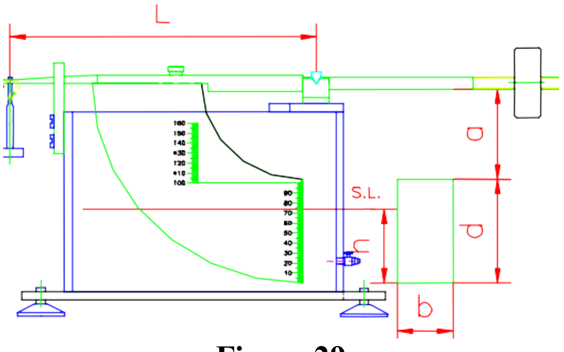

Figure 29

3. With the tank placed on the Hydraulic Bench or on the Hydraulic Group, locate the balance bridge on the support (sharp form, see **Figure 30**). Hang the tray at the end of the arm (see **Figure 31**).

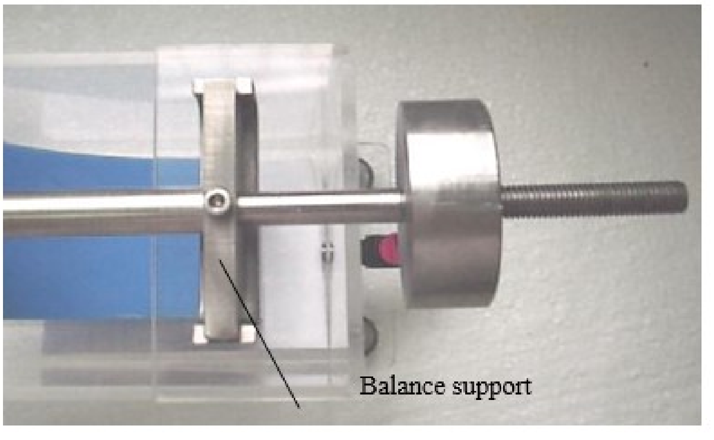

Figure 30

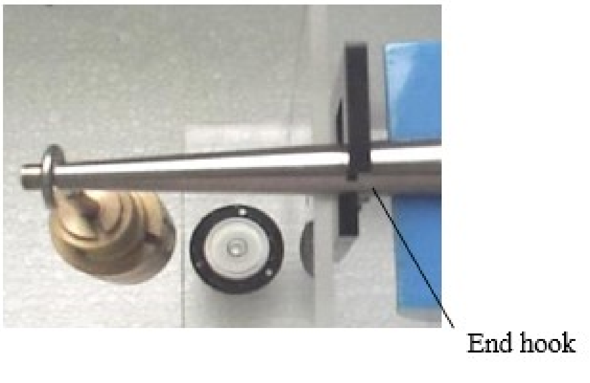

Figure 31

4. Close the draining tap of the bottom of the tank. Move the counterweight of the bridge balance until the flat surface will be perpendicular to the base of the tank (base that we will level previously). With the balance, we will be able to start with the measures totally balanced, so all changes will be done with a difference in the water volume or with a difference of the masses placed on the tray. This step is very important in order to get good measurements (the equipment has several mortises in the “end hook”, the central one identifies this balance point).

5. Introduce water into the tank until the free surface of this will be tangent to the lowest edge of the quadrant (until the inferior point of the floating element is reached). The fine adjustment of this level can be managed overfilling the pretended filling and then,draining it slowly through its cap. Maybe you will have to incline a bit the tank to the side of the cap in order to carry out the drainage. If you have to do it, make sure that you place it correctly again after that.

6. Place a calibrated weight on the balance tray and add water slowly until the flat surface will be perpendicular to the base of the tank. In order to carry out this adjustment, we have a white mark that is in the end of the arm (end- hook), besides the tray.

   Take note of the water level, indicated in the quadrant, and of the value of the weight located on the tray (**Table 4**).

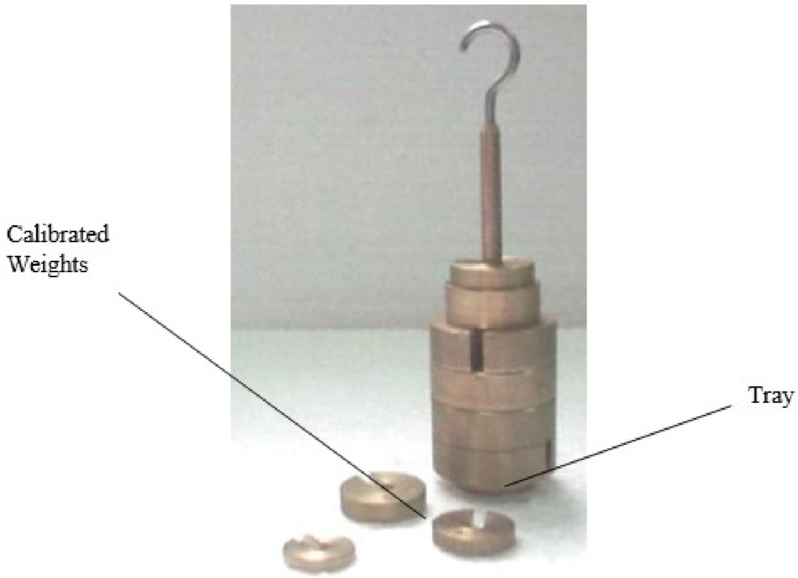

Figure 32

7. Repeat the previous operation several times, increasing steadily the weight of the tray in each one of them until, once the balance bridge will be levelled, the level of the water free surface will touch the upper edge of the rectangular flat surface that the end of the quadrant has.

Figure 33

8. Since now, and on the contrary order as they were placed on the tray, we remove the added weights in each operation, we level the arm (after each removal) using the draining cap, and the weights of the tray and water levels (h) are taken noted.

7.3.5.3 Worksheet

Student: ________ Year: __________

Table 4

Filling of the tank		Emptying of the tank		Averages		Calculations	
Weights F (g)	Heights h (mm)	Weights F (g)	Heights h (mm)	F_m (kg)	h_m (m)	L_{cp}	F_{cp}

For h> d (total immersion)

Q.1. Calculation of the values of h_0, F/h_0 y de l/h_0.

Q.2. Draw, at a convenient scale and with the experimental obtained values, the graphic correspondent to:

$$F/h_0=\xi(l/h_0)$$

The slope of this line should be $\gamma bd^3/12L$, and the ordinate of its intersection with the axle of that $(\gamma bd/L)(a + d/2)$. Starting with this graphic, calculate the exactly value of the center of pressures.

Note: Be careful with the units used.

Q.3. Express the reasons of the possible differences, if there are, between the taken values and the ones that are shown in the previous expressions.

7.3.6 Practical exercise 6: Determination of the resultant force with an angle of 90°, totally submerged

7.3.6.1 Objective

To determine the equivalent force on a flat surface, perpendicular to the surface of the fluid and totally submerged into a liquid at rest.

7.3.6.2 Experimental procedure

The procedure is the same as in practical exercise 5 (we can use the same experimental data as in the previous practical exercise, if we have already done it).

7.3.6.3 Worksheet

Student: ________ Year: __________

The table is the one included in Practical exercise 5.

Q.1. To calculate the values of Fcp.

7.3.7 Practical exercise 7: Determination of the center of pressures, angle<>90°, totally submerged

7.3.7.1 Objective

To determine the position of the center of pressures on a flat surface with an inclination of the angle in relation to the surface of the fluid, totally submerged into a liquid at rest.

7.3.7.2 Experimental procedure

The procedure is the same as in practical exercise 5 and 6 (changing the angle).

7.3.7.3 Worksheet

Student: ________ Year: __________

The table is the one included in Practical exercise 3.

Q.1. To calculate the values of Lcp.

7.3.8 Practical exercise 8: Determination of the resultant force, angle<>90°, totally submerged

7.3.8.1 Objective

To determine the equivalent force on a flat surface, with an inclined angle in relation to the surface of the fluid and totally submerged into a liquid at rest.

7.3.8.2 Experimental procedure

The procedure is the same as in practical exercise 7 (we can use the same experimental data as in the previous practical exercise, if we have already done it).

7.3.8.3 Worksheet

Student: ________ Year: __________

The table is the one included in Practical exercise 3.

Q.1. To calculate the values of Fcp.

7.3.9 Practical exercise 9: Balance of momentum

7.3.9.1 Objective

To check the equation of balance of momentum with the data obtained.

$$\Sigma M = 0 \longrightarrow Fcp * Lcp = F_L * L$$

7.4 ANNEXES

7.4.1 ANNEX I. SYMBOLOGY

GEOMETRIC DIMENSIONS:

a = Inner radius of the element.

b = Depth of the element to study (geometric dimension of the thickness).

d = Height of the section to study (outer diameter- inner diameter).

L = Distance from the weights support to the turning point.

Lp2 = Distance from the turning axle to the most pressure applied point (outer radius of the ring).

ELEMENT SYMBOLOGY:

p = Pressure over the surface of the object.

p1 = Pressure on the closest point to the fluid surface.

p2 = Pressure on the farest point to the fluid surface.

y = Distance to the fluid surface all along the object surface.

ycg = Distance to the fluid surface from the center of gravity all along the object surface.

ycp = Distance to the fluid surface from the center of pressures all along the object surface.

h = Depth.

h1 = Depth from the closest point to the fluid surface.

h2 = Depth from the farest point to the fluid surface.

Fcp = Equivalent force on the center of pressures.

e = Distance from the center of gravity to the center of pressures [m].

l = Submerged length of the surface to study [m].

CONSTANTS OF THE FLUID:

g = Acceleration produced by the gravity force [m/s2].

ρ = Fluid density [g / cm3] (1000Kg/m3=1g/cm3 for water).

7.4.2 ANNEX II. EXAMPLES OF RESULTS

Filling of the tank		Emptying of the tank		Averages		Calculations	
Weights F_1 (g)	Heights H_1 (mm)	Weights F_2 (g)	Heights H_2 (mm)	F_m (kg)	h_m (m)	$h_m/3$	F_m/h_m^2

7.4.3 ANNEX III. ESTIMATED GEOMETRIC DATA OF THE UNIT

-a = 100mm

-b = 70mm

-d =100mm

-L =285mm