The value, ρ_m, depends upon the way in which the values for the loading weights are reported. When they are reported as true mass, the actual value for the density of the weights should be used. If, however, the apparent mass is given, as determined by comparison with brass standards in air having a density of 0.0012 g/cm^3, the density of the weights should be assumed to have the same density as the brass standards (8.4 g/cm^3). Apparent mass values are usually used when reporting loading weight values.

By substituting eq (9) in eq (6) we obtain the following expression for F_e,

$$F_e=\left[M_m\left(1-\frac{\rho_a}{\rho_m}\right)+M_f\left(1-\frac{\rho_a}{\rho_f}\right)\right]kg_L+\gamma C. \tag{10}$$

Piston gages operating with the piston assembly partially submerged in a liquid are subjected to a force resulting from the surface tension of the liquid acting on the periphery of the piston where it emerges from the surface of the liquid. This force, γC, is added to the force due to the load on the piston.

3.3. Fluid Head

The fluid head pressure, H_{fp}, eq (3) and (4), exerted by the column of pressure fluid between the reference level of the piston gage and the reference level of the pressure system to be measured, may be calculated as follows:

$$H_{fp}=-\rho_{fp}h_{fp}kg_L \tag{11}$$

where ρ_{fp} = the density of the pressure fluid at pressure P,

h_{fp} = the height of the column of fluid of density ρ_{fp}, measured from the reference level of the piston gage. Measurements up from the reference level are positive and down from the reference level are negative.

3.4. Air Head

The air head pressure, H_a, eq (4), exerted by the column of air between the reference level of the piston gage and the reference level of the pressure system to be measured, may be calculated as follows:

$$H_a=-\rho_a h_a kg_L \tag{12}$$

where ρ_a = the density of the air at the ambient atmospheric pressure, and temperature,

h_a = the height of the air column measured from the reference level of the piston gage. Measurements above the reference level have a positive sign and those below have a negative sign.

3.5. Fluid Buoyancy

In certain instances, the pressure fluid in which the piston is immersed contributes to the load on the piston. This effect may be accounted for in two ways. One method is to compute the mass of the fluid, M_f, contributing to the load on the piston and include it in the calculation of the force as shown in eq (6). The other method is to shift the reference level (the level at which the piston gage pressure, p_p, is measured) from the lower end of the piston by an amount equal to the height of a column of oil that will compensate for the mass of the fluid acting on the piston.

In order to determine the contribution of the pressure fluid to the load on the piston, first consider the case of a piston of uniform cross section exactly fitting the cylinder (fig. 1). If the pressure is measured at the level of the lower end of the piston (level R), the fluid exerts no vertical forces other than that against the area of the end of the piston. In this case, therefore, there is no buoyancy correction to be applied.

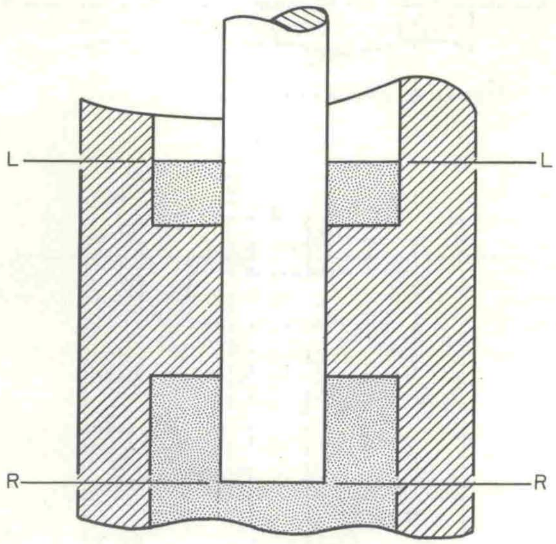

FIGURE 1. *Piston of uniform cross section*

Next consider a piston with grooves or holes machined in it as shown in figure 2. The weight of the fluid contained in the grooves and holes, is part of the load on the piston. That is to say that all of the material included within a cylinder having a cross section equal to the effective area of the piston is included in the load on the piston.

In practice, the effective area of a piston is very nearly equal to the mean of the areas of the piston and the cylinder as shown in figure 3 by the dotted lines C and C′. Any metal extending beyond those bounds displaces a volume of fluid the mass of which must be subtracted from the load on the piston and any fluid within those bounds must be added to the load on the piston.

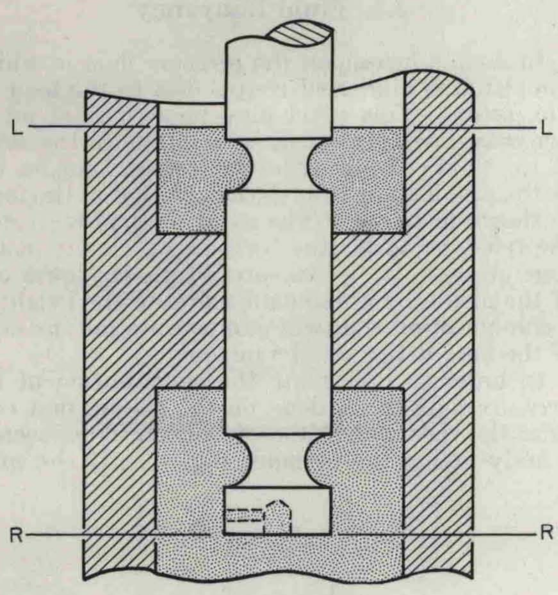

FIGURE 2. *Piston of irregular cross section.*

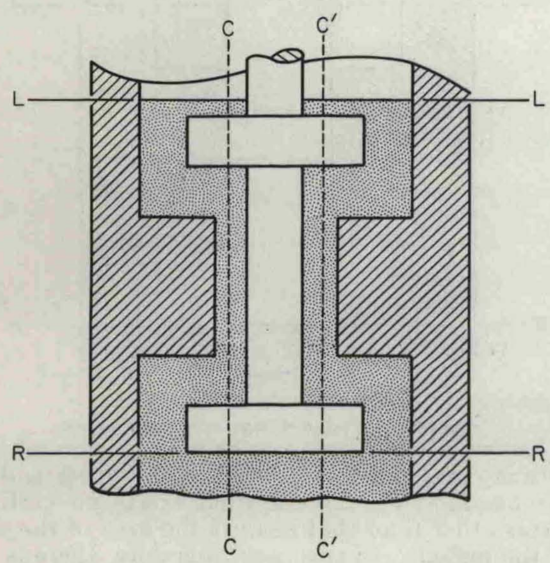

FIGURE 3. *Piston of irregular cross section.*

From these examples we see that the fluid buoyancy correction can be either positive or negative. It can be calculated from the following equation:

$$M_f=(A_e y_f-V_s)\,\rho_f \tag{13}$$

where A_e=the effective area of the piston as before,
y_f=the length of the submerged part of the piston,
V_s=the volume of the submerged part of the piston.

To determine the pressure equivalent, p_f, of the fluid, M_f, the following equation may be used:

$$p_f=\frac{M_f}{A_e}\left(1-\frac{\rho_a}{\rho_f}\right)kg_L \tag{14}$$

Shifting the reference level of the piston gage by an amount, Δh, effectively consists of adding the pressure exerted by a column of fluid of height, Δh, and density, ρ_{fp}, and subtracting the pressure exerted by a column of air of height, Δh, and density, ρ_a. The resulting pressure change,

$$\Delta p=\rho_{fp}\Delta hkg_L-\rho_a\Delta hkg_L. \tag{15}$$

By shifting the reference level an amount sufficient to make the resulting fluid head compensate for the pressure equivalent of the fluid buoyancy [3, 4] $\Delta p=p_f$ we obtain (from eqs 13, 14, and 15),

$$\Delta h=\frac{(A_e y_f-V_s)}{A_e}\frac{(\rho_f-\rho_a)}{(\rho_{fp}-\rho_a)}, \tag{16}$$

When the buoyancy correction is determined as shown in eq (13) the density of the fluid, ρ_f, is included. For the portion of the piston between the cylinder and the surface of the fluid (level L) the value of ρ_f will be the density of the fluid at atmospheric pressure, ρ_{fa}, but for the portion of the piston below the cylinder the value of ρ_f will be the density of the fluid, ρ_{fp}, at pressure, P, and may not be easily determined.

On the other hand, when the buoyancy correction for the lower end of the piston is applied by shifting the reference level, ρ_f in eq (16) is equal to ρ_{fp}, and the ratio $\frac{(\rho_f-\rho_a)}{(\rho_{fp}-\rho_a)}$ is equal to 1, so that the value for ρ_{fp} need not be known.

3.6. Mass of Fluid

By applying the buoyancy correction for the upper portion of the piston as a load correction, eq (13) becomes

$$M_{fa}=(A_e y_{fa}-V_{fa})\,\rho_{fa} \tag{17}$$

where y_{fa}=the length of the submerged part of the piston above the cylinder,
V_{fa}=the volume of the submerged part of the piston above the cylinder,

and eq (10) becomes

$$F_e=M_m\left[\left(1-\frac{\rho_a}{\rho_m}\right)+M_{fa}\left(1-\frac{\rho_a}{\rho_{fa}}\right)\right]kg_L+\gamma C. \tag{18}$$