THE PRESSURE-VOLUME RELATION OF THE TOY BALLOON

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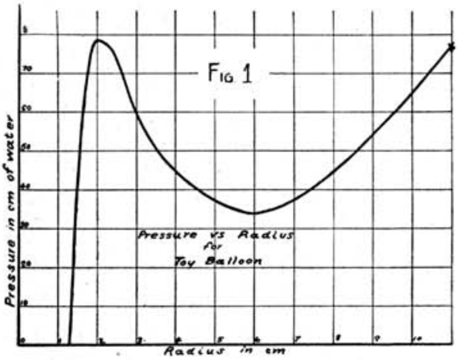
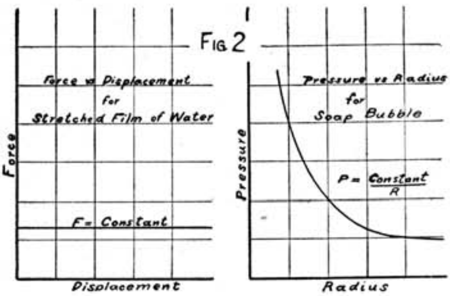
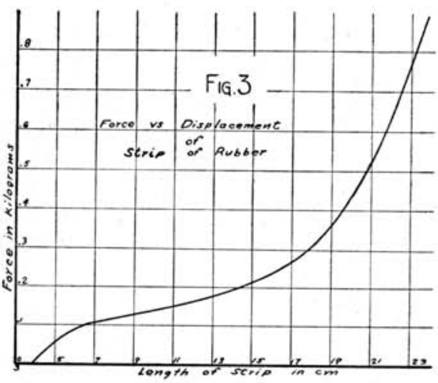
The peculiar elastic properties of rubber are reflected in the pressure-volume relation of the toy balloon. Fig. 1 shows how the pressure of a balloon varies with its radius when it is blown up. There is first a steep rise of pressure which reaches a maximum. As more gas is then forced into the balloon, the pressure drops, reaches a minimum, and then rises again until the balloon finally bursts.



The balloon was inflated with dry air and its pressure measured by a water manometer. A number of spherical balloons were tried and all showed the same sort of relation as indicated by fig. 1.



It is interesting to compare the pressure-volume relation of the rubber balloon with that of the soap bubble. Figure 2 shows the force-displacement graph typical of a soap bubble film. In this simple case the surface tension force does not vary with displacement. By virtue of the geometry of a sphere, this relation is reflected in a spherical bubble as an inverse proportionality between the pressure and the radius of the bubble. As is generally known, the larger a soap bubble is, the smaller is the pressure it exerts. When two soap bubbles of unequal size are connected the smaller loses its gas to the larger.



With two balloons of unequal size, the situation is more complex. From an inspection of the pressure-radius graph it is apparent that the direction of flow of gas between the two balloons may be from smaller to larger or vice-versa. Furthermore, equilibrium of pressure may exist between two balloons of different size.

It is interesting also to correlate the force-displacement graph, fig. 3, with the pressure-radius graph, fig. 1. The relation between pressure and radius may be written in the general form $p = Kr^n$. If the stretching force per cm is independent of displacement, $n = -1$, as in the case of the soap bubble. In the case of the balloon three different ranges in the pressure-radius graph may easily be distinguished. During the initial pressure rise n is positive, but probably a little less than 1. During the succeeding pressure drop n is negative. During the final pressure rise n is positive again and larger than 1. Three different ranges may correspondingly be detected in the force-displacement graph. Further analysis of the interrelations of the two graphs is in process.