Proceedings of the Iowa Academy of Science

Volume 37 | Annual Issue Article 72

1930

Some Recent Developments in High Pressure Windows

Robert Wilson
Iowa Wesleyan College

Thos. C. Poulter
Iowa Wesleyan College

SOME RECENT DEVELOPMENTS IN HIGH PRESSURE WINDOWS

ROBERT WILSON AND THOS. C. POULTER

The field of optical studies at high pressures has been limited to a range of a few thousand atmospheres not because glass would not withstand a higher pressure but because the proper window support had not been used in order to utilize the maximum strength of the glass.

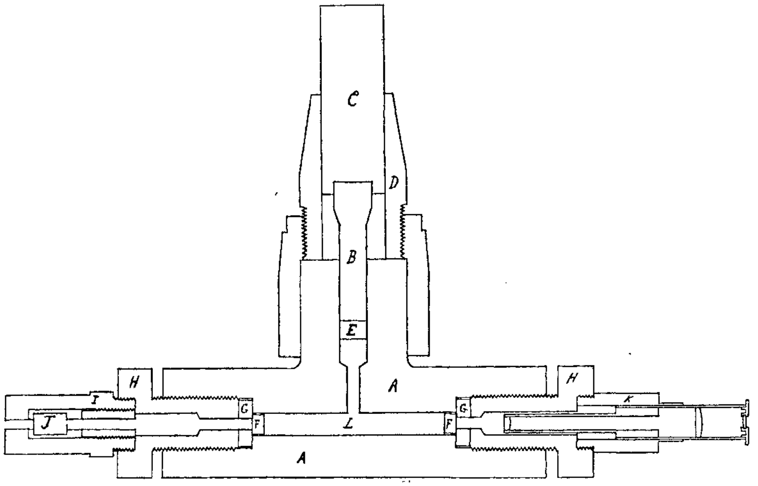
E. H. Amagat[1-2] reported a window mounting consisting of a piece of glass in the form of a truncated cone and mounted in the side of the pressure cylinder with the small end of the cone in the direction of the observer.

Numerous other investigators[3-4] have used various modifications of Amagats window mounting with varying degrees of success. In all window mountings previously employed some kind of a gasket material was used between the glass and its steel support. For this purpose ivory, fiber, lead, silverchloride, rubber, paper, various cements, and combinations of these were used.

As the pressure is built up in the cylinder the gasket tends to flow. The pressure in the cylinder prevents the gasket material from flowing into the cylinder whereas it is free to flow into the opening over which the window is placed. An unequal distribution of pressure is thereby produced on the glass. Aside from this unequal pressure the window is being supported by a moving surface which tends to rupture the surface of the glass. With the conical windows it is obvious that the maximum pressure cannot be obtained due to the wedging effect of the glass. For the minimum of strain to the glass it must be so mounted that its supporting surface be perpendicular to the resultant force exerted upon it by the liquid in the cylinder. It is also necessary that the liquid have free access to the edges of the glass so as to make the total force on the glass as nearly a compressional force as possible.

1 Compt. Rend. CV 1887, p. 165.
2 Notice sur les Travaux Scientifiques de M. E. H. Amagat Paris, 1896.
3 Dr. Walter Wahl Philosophical transactions of the Royal Society A, Vol. 212, 1913 p. 117.
4 Frances G. Wick and P. W. Bridgman, Proceedings of the American Academy of Arts and Sciences, Vol. 58, No. 16, p. 557, 1923.

To meet these requirements the following window support was constructed:



The window F is a piece of glass approximately 11 mm. in diameter and from 2 to 10 mm. in thickness cut from plate glass. This glass window is placed directly in contact with the flat polished surface of the hardened steel[5] window support G. The surface of the window support is ground to an accuracy of 1×10^{-4} cm. which is measured by counting the interference fringes when the window is placed in contact with the polished surface of the steel. The window support makes a tight joint with the end of the cylinder and is held in place by means of a plug H screwed in tightly against it. A case I carrying a safety window mounted in fiber is screwed into the end of the plug H in order to catch flying pieces in case the pressure window breaks or develops a leak. If the proper liquid is used to transmit the pressure to the glass or quartz windows they will withstand a surprising pressure of 30,000 atmospheres. For this purpose a light colorless paraffin oil (binoil or Merusol) has been found most satisfactory. However if the liquid in contact with the window is water, Ethyl alcohol, or Ether, it is with difficulty that pressures of more than 6,000 to 8,000 atmospheres are reached.

In order to show that the windows are actually withstanding a pressure of 30,000 atmospheres and that a large pressure gradient does not exist between the piston and the window a window was mounted in the bottom of a vertical cylinder. The cylinder

5 The window supports are made of Rex AAA High speed steel heat treated to maximum hardness. This steel is manufactured by the Crucible Steel Co. of America.

had an inside diameter of 1.6 cm. and the window was only 2 cm. below the end of the piston. In this case a pressure of 30,000 atmospheres was built up before the cracks developed in the glass. Even if the oil did solidify in this case it would not have prevented the pressure from being transmitted to the window. On the other hand, if the paraffin oil is used to transmit the pressure and water, alcohol, or ether comes in contact with the glass it will usually be cracked at pressures below 8,000 atmospheres.

In many cases the window does not blow out completely but will still hold the pressure even after it is considerably cracked.

In cases of this kind where the windows have been removed there are two general types of fractures. The concentric shell fracture produced by windows being mounted against a gasket and the pressure transmitted by any liquid on the window mounted without a gasket and the pressure being transmitted by water, alcohol, or ether. In this type of fracture the edges of some of the concentric shells usually extend to the outside diameter of the window.

The other type of fracture is that in which the surface of the glass over the opening in the window support is chipped off and very few if any cracks are produced in the remainder of the window. This type of fracture is produced by transmitting the pressure with oil or some other liquid composed of large molecules such as glycerine.

A series of tests were run in which a piece of 4 mm. glass 15 mm. long was placed in a rubber capsule of 2 mm. wall thickness. This capsule was filled with water, alcohol, ether, glycerine, or oil, and placed in the pressure cylinder and surrounded with oil. A pressure of about 21,000 atmospheres was then applied and allowed to stand for 5 minutes, and then released. Similar tests were run using quartz instead of glass. In all cases where the material surrounding the glass or quartz was water, alcohol, or ether, the pieces of glass or quartz were shattered, when the pressure was released. And in no case where oil or glycerin was used had any breakage occurred.

It will be noticed that in all cases where water, alcohol, or ether were used in contact with the glass or quartz fractures occurred, but in no case where paraffin oil or glycerine was used was the glass or quartz fractured. Three possible explanations present themselves. One of these being the large temperature change as the liquid is compressed or allowed to expand. This is quite apparent in the case of water, since in most cases where water has been under a pressure of more than 10,000 atmospheres for a time and then released, the water is usually frozen solid, particularly if the pressure has been allowed to drop rapidly. However, if this were the main cause of the breakage, one would expect only the glass to be broken and not the quartz, since the thermal expansion of quartz is very low. Furthermore, oil shows a large temperature change and produces no fractures.

Another possibility, particularly in the case of water, is the differential compressibility of the solid modification and the glass, but no solid modification is known for alcohol and ether at these pressures.

Another possible explanation is that those liquids composed of smaller molecules penetrate the glass and then when the pressure is released the cohesive force of the glass is not great enough to retain these molecules under their compressed condition. This explanation is made even more possible by the fact that breakage usually occurs as the pressure is released, rather than as it is being built up or retained, at a high pressure.

Now in the case of water, alcohol or ether being used in contact with a pressure window the very slight leakage which occurs between the glass and the steel support produces the same effect as though the window were mounted on a gasket, namely, that it is being supported by a moving surface.

In the case of the liquids composed of larger molecules such as glycerine or paraffin oil there is not room for such leakage to occur and as a result the window is being supported on a stationary surface.

Summary

1. Some light is thrown on the reason for the difference in behavior of high pressure windows as different liquids are used to transmit the pressure.
2. Quartz windows are tested out for high pressure work and found to withstand about the same pressures as glass (namely 30,000 atmospheres.).

Iowa Wesleyan College,
Mt. Pleasant, Iowa.