The Permeability of Glass and Fused Quartz to Ether, Alcohol, and Water at High Pressure

By THOS. C. POULTER AND ROBERT O. WILSON
Department of Physics, Iowa Wesleyan College

(Received April 16, 1932)

The permeability of glass and fused quartz to water, alcohol and ether and its relation to pressure windows has been studied. These liquids are shown to penetrate to considerable depths if the pressure is maintained for as long as fifteen minutes, in which case the pieces of glass or quartz are shattered if the pressure is rapidly released. However, if the pressure is released over a period of several days little or no breakage occurs. It is, therefore, likely that much of the difference in the behavior of pressure windows as different liquids are used in contact with the windows is due to their ability to penetrate the glass or quartz.

INTRODUCTION

DURING the past several years the writer has been engaged in experiments involving very high pressures. This work has been described in a number of papers.[1–8]

Pressures up to 30,000 atmospheres were employed in cylinders with glass or quartz windows. In the course of these investigations it became necessary to study the properties of glass and quartz when in a liquid at high pressures.

The difference in the behavior of different liquids on pressure windows has suggested that in some cases the liquid was penetrating the glass or quartz of the window. P. W. Bridgman[9] found that hydrogen at 9000 atmospheres would penetrate the walls of a steel container and that cylinders containing hydrogen under high pressure would be frequently broken at less than half the pressure they had previously withstood. This has been encountered many times by the authors. Bridgman also found that if mercury were allowed to come in contact with the inner surface of the cylinder at very high pressure the cylinder wall would be weakened. Pressure windows will withstand several times as much pressure if oil or glycerine is used to transmit the pressure as they will if water, alcohol or ether, is employed. Windows surrounded by water, alcohol, or ether would frequently break on lowering the pressure even though they had previously withstood much

[1] Thos. C. Poulter and Robert Wilson, Iowa Acad. of Sci. **36,** 295–6 (1929).
[2] Thos. C. Poulter, Phys. Rev. **35,** 295 (1930).
[3] Thos. C. Poulter and Robert Wilson, Iowa Acad. of Sci. **37,** 299–302 (1930).
[4] Thos. C. Poulter and Harold C. McComb, Iowa Acad. of Sci. **37,** 311–312 (1930).
[5] Thos. C. Poulter and Carl A. Benz, Phys. Rev. **40,** 872 (1932).
[6] Thos. C. Poulter, Phys. Rev. **40,** 860 (1932).
[7] Thos. C. Poulter and Glen E. Frazer, paper in preparation.
[8] Thos. C. Poulter and Carter Ritchey, Phys. Rev. **39,** 816 (1932).
[9] P. W. Bridgman, Rec. trav. chim. **42,** 568–71 (1923); Proc. of Am. Acad. Arts Sci. **59,** No. 8, 177–221 (1924).

greater pressures. This investigation was undertaken in order to determine the nature of this difference in behavior.

Apparatus and Procedure

The pressure equipment used in this work is the vertical type cylinder used in other investigations by the author. This cylinder has an inside diameter of 1.6 cm and a capacity of about 17 cm^3. The pressure was produced and measured as in previous work.

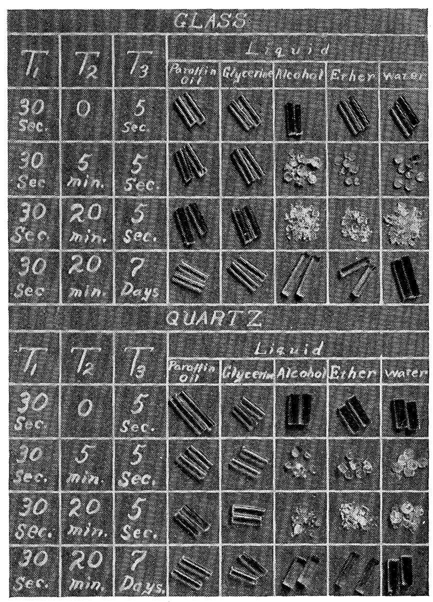

Fig. 1. Type of fractures occurring under various conditions: T_1, time required to develop the pressure, T_2, time the pressure was maintained, T_3, time consumed in reducing the pressure to atmospheric.

The samples to be tested were pieces of glass or quartz rod 3 to 4 mm in diameter and about 15 mm long. These pieces were placed in a piece of rubber tubing 5 cm long and 6 mm inside diameter. This tube was filled with the desired liquid and stoppered at both ends. It was then placed in the pressure cylinder and the pressure applied.

The manner in which the pressure is built up seems to have nothing to do with the behavior of the glass or quartz and the breakage usually occurs as the pressure is released. Little difference was noticed in the behavior of glass and quartz except that the quartz does not break with as regular a surface as does the glass. Oil and glycerine produce no fracturing of the glass of quartz. In the case of water, alcohol, and ether the following results were obtained. If the pressure was built up to any value above 15,000 atmospheres and immediately dropped to zero, the pieces would usually not be broken; occasionally they would be broken into two or three pieces. If the pressure was built up above 15,000 atmospheres and held there for five minutes and then released, the rod would be broken in rather regular plates, the fractures running perpendicular to the length of the piece. The plates thus produced would be from one half to two or three millimeters in thickness. If the pressure was built up and allowed to stand for fifteen minutes or longer and then released rapidly the fractures would be irregular and the pieces usually much smaller. If the pressures were built up and released very slowly over a period of five to ten days very few if any fractures would occur. However, if the pieces of glass or quartz were surrounded with oil or glycerine and all of the above procedure carried out it is very unusual for any fracture to occur. The results of these experiments are shown in Fig. 1.

A glass disk such as those used for pressure windows is mounted in the center of a rubber tube with oil on one side and water, alcohol or ether on the other side and the two ends of the tube stoppered. This assembly is then placed in a pressure cylinder and surrounded with oil. If a pressure of 20,000

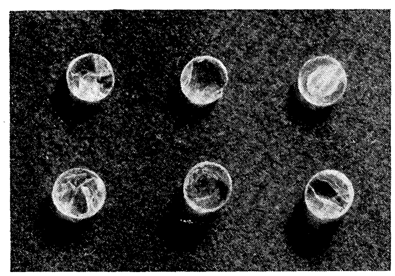

Fig. 2. Showing the fracture of the surface of glass and quartz in contact with water, alcohol or ether. Pieces are layed with fractured side down for photographing. The upper three are quartz and the lower three are glass.

atmospheres is developed and maintained for from 5 to 10 minutes and then rapidly released the side of the glass in contact with the water will be shattered while that in contact with the oil will remain intact. Fig. 2 shows such a group of fractured pieces.

Discussion of Results

The difference in the behavior of glass or quartz when surrounded by different liquids cannot be explained on the basis of temperature changes accompanying the rapid pressure changes, although these are large, sometimes amounting to as much as 100°C. If it were a temperature change the glass only would be effected, whereas the quartz is just as susceptible to the fracturing as the glass. Neither can it be explained on the basis of a differential compressibility of the solid modification of the water and the glass or quartz for no solid modification is known for alcohol or ether at these pressures and temperatures.

The fact that in cases where the glass has water on one side and oil on the other, only that side in contact with the water is shattered eliminates the possibility of the fracturing being due to a compressibility hysteresis effect due to the glass or quartz being under extreme pressure. This is further shown by the fact that glass or quartz pressure windows four millimeters thick and twelve millimeters in diameter can be bent to a radius of curvature of eleven centimeters and return without fracturing. In the case of glass this has been done as many as ten times with a single window and with quartz it has been done as many as four times.

The most probable explanation of the fracturing of these materials after having been subjected to pressure while surrounded by water, alcohol, or ether is that the liquids while compressed actually penetrate the glass or quartz. Then as the pressure is released the cohesive force of the glass or quartz is not great enough to retain the liquids under this compressed condition. This explanation of the fracturing is in agreement with all the facts at hand:

(a) Little or no breakage occurs if insufficient time is allowed for the liquid to penetrate.

(b) Breakage occurs as the pressure is released rather than when it is being built up or retained at a high pressure.

(c) Little or no breakage occurs if the pressure is allowed to drop slowly enough to permit the gradual escape of the liquid.

(d) No breakage occurs if liquids of relatively large molecules and high viscosity are used such as oil or glycerine.

(e) The fracturing is determined by the type of liquid and not by the pressure alone, as is shown when different liquids are on opposite sides of the same piece of glass or quartz. In this case the pressures are necessarily equal.

The authors wish to express their appreciation for the assistance in the form of a grant from the Rumford Fund of the American Academy of Arts and Science.

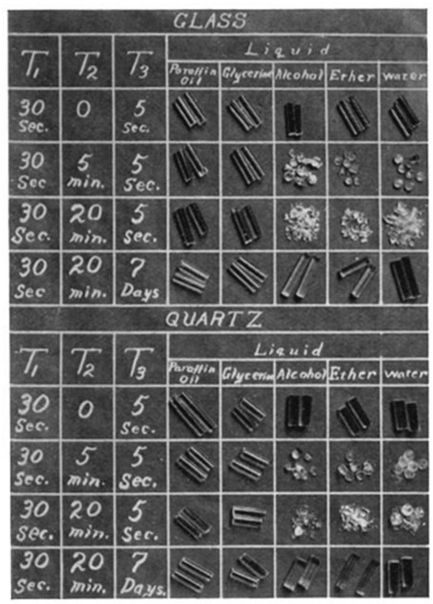

Fig. 1. Type of fractures occurring under various conditions: T_1, time required to develop the pressure, T_2, time the pressure was maintained, T_3, time consumed in reducing the pressure to atmospheric.

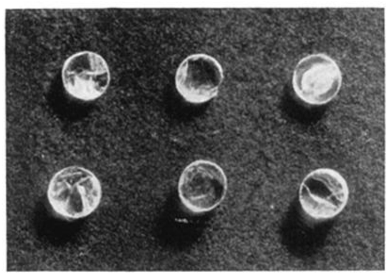

Fig. 2. Showing the fracture of the surface of glass and quartz in contact with water, alcohol or ether. Pieces are layed with fractured side down for photographing. The upper three are quartz and the lower three are glass.