MEASUREMENT OF PRESSURES UP TO 100 kbar BY THE FREE-PISTON METHOD

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Corresponding Member of the Academy of Sciences of the USSR L. F. Vereshchagin, E. V. Zubova,
I. P. Buimova, K. P. Burdina

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Until now there has been no instrument permitting direct measurement of high pressures in the range up to 60 kbar. There exist a number of relative manometers, such as the manganin manometer (in which pressure is measured from the change in the electrical resistance of a metal wire); however, of exceptional importance is the direct determination of the force with which an unsealed piston of strictly defined diameter is forced out of a high-pressure vessel—the so-called free-piston type manometer. Such a manometer consists of a piston on which the pressure being measured acts; by balancing this pressure with a known load and knowing the piston area, one can determine the pressure.

P. W. Bridgman ([1]) designed a free-piston type manometer for pressures up to 13 kbar; L. F. Vereshchagin and B. S. Aleksandrov ([2]) produced a free-piston type manometer for pressures up to 10 kbar; M. K. Zhokhovskii ([3]) built a manometer measuring pressures up to 14 kbar; and Yu. S. Konyaev ([4]) designed a manometer for 25 kbar. The instrument designed by Kennedy and La Mori ([5]) is the greatest achievement in this field, but even with it pressures were measured only up to 40 kbar at room temperature. Kennedy and La Mori measured pressures at the points of polymorphic transformations for Bi_{I-II}, Bi_{II-III}, and Tl_{II-III}, and established the following pressure values:

Polymorphic transition	Bi_{I-II}	Bi_{II-III}	Tl_{II-III}
Pressure in kbar	25.4 ± 0.1	26.9 ± 0.2	36.7 ± 0.1

Thus, the pressure values determined experimentally by the free-piston method did not exceed 36.7 kbar. At present, however, the working range of pressures used in industrial and laboratory research is on the order of 100 kbar and higher. Various extrapolations in this pressure region are inaccurate. It is therefore very important to continue the work begun by Kennedy and La Mori in determining

Fig. 1. Diagram of the piston manometer

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Fig. 2. Graph of the dependence of the indicator readings on the applied force

Figure 2: Fig. 2. Graph of the dependence of the indicator readings on the applied force

the pressure values of the points of polymorphic transformations of a number of metals lying at higher pressures than Bi_{I-II} and Tl_{II-III}, so that these points may in the future be regarded as reference points, along with the previously determined Bi and Tl points in the work of Kennedy and La Mori. For this purpose the authors built a free-piston type manometer operating satisfactorily in the pressure range up to 100 kbar.

Figure 1 presents a diagram of a piston manometer measuring pressure in high-pressure chambers of any type. The pressure in the working medium is measured directly from the force acting on piston A, made of a strong material and fitted into a hole in one of the punches. Between piston A and the hole in the punch there is a small clearance B, providing sufficiently free movement of the piston in the channel and at the same time preventing the compressed working medium from flowing into it. The magnitude of the force acting from the side of the pressure being measured on piston A is determined, after subtracting the friction forces arising on the lateral surface of piston A, by means of a spring-type

of a DS-3 dynamometer **B**. The measured pressure is determined from the formula $P = F/S$, where F is the reading taken from the dynamometer, and S is the effective cross-sectional area of the piston in its lower conical part under load (see Fig. 2).

However, owing to the existence of frictional forces, F is always less than the true force acting on piston **A**. Since an exact allowance for the frictional forces is not possible, it remains to try to reduce them to a minimum.

In our design, the frictional forces have been reduced to insignificant values thanks to the special configuration of piston **A**, its rotation about its own axis, and the use of a special lubricant.

Fig. 1. Diagram of the piston manometer

Fig. 2. Graph of the dependence of the indicator readings on the applied force

The conical piston **A** has, at its upper and lower ends, strictly coaxial cylindrical sections. The length of the lower cylindrical section is chosen to be minimal, but sufficient to prevent leakage from the high-pressure chamber. The upper cylindrical section, carefully fitted to the opening in the punch, ensures the stability of the piston during operation. The configuration used for piston **A**—the main part of the manometer—together with the special lubricant introduced into gap , provides minimal friction and effective support for the heavily loaded cylindrical part of the piston. Minimal friction and effective support make it possible to carry out an accurate measurement of pressure whose magnitude considerably exceeds the strength limit of the material at atmospheric pressure.

Using this piston manometer, pressures up to 100 kbar were measured. In addition to the direct measurement of pressure by the rotating piston, in each experiment the pressure was also measured from the jump in electrical resistance at the moment of a polymorphic transformation in a number of metals. As a result of our experiments, it was established that, for already known polymorphic transformations, our data are in good agreement with the data of Kennedy and La Mori.

Polymorphic transition	Bi I–II	Bi II–III	Tl II–III	Ba II–III	Bi VI–VIII
Pressure in kbar	25.4	26.9	36.9	58.5	89.3

In our experiments, new determinations were made of the pressure values of the polymorphic transformations Ba II–III and Bi VI–VIII (see the diagram of Bundy [(6)]), as well as of S. S. Sekoyan, G. Kh. Panova, and L. F. Vereshcha-

···gin (7)), which, as is evident from the data given above, occur at $P = 58.5$ kbar and $P = 89.3$ kbar, respectively, with an accuracy of $\sim 1\%$, which in the pressure range up to 100 kbar may be regarded as satisfactory accuracy.

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Institute of High Pressures
Academy of Sciences of the USSR

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