APPARATUS FOR INVESTIGATING THE MECHANICAL QUALITIES OF METALS UNDER HIGH HYDROSTATIC PRESSURE *

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Described here is the design of a new apparatus for studying the plastic qualities of metals by elongation tests of specimens under hydrostatic pressure up to 10,000 kg/cm², with automatic recording of a test-diagram.

A very limited number of experimental works have been devoted to the study of the mechanical qualities of metals extended under conditions of high hydrostatic pressure, and this is connected with the serious difficulties which arise in the measurement of the various strength characteristics of metals under pressure.

The first trials in the study of the action of high pressure on the mechanical qualities of various steels were made by P. Bridgman between 1942- 1944, but a description of his apparatus and trial results were not published until 1952 [1].

The apparatus devised by Bridgman permitted the testing of specimens under pressures of up to 30,000 kg/cm², but unfortunately did not succeed in obtaining consistent hydrostatic pressure at the time of the trials.

In 1949 Ratner [2] carried out extension tests on various non-ferrous alloys under external hydrostatic pressure up to 4,000 kg/cm², Ratner's apparatus enabled pressure to be maintained at one level for the whole duration of the tests. Furthermore, the force acting on the test-piece was applied not inside a chamber, as was the case with Bridgman, but from the outside, and this, seemingly, cannot but affect the accuracy of the results of experiments.

In the types of apparatus described above, load was applied by degrees with the idea of making it possible for readings to be taken. Then a strain diagram was built up from experimental points. Naturally, for the widest scope in testing the mechanical qualities of metals under high pressure the apparatus should embody automatic recording of the diagrams of extension. Such as apparatus would first of all reveal certain general laws of behaviour of metals and alloys under load in conditions of high hydrostatic compression: for example, the effect of the rate of deformation of test-pieces etc.

Apparatus intended for work under high pressure must satisfy the following requirements: (1) guarantee the attainment of high hydrostatic pressure; (2) guarantee adequate accuracy in plotting curves with force - strain co-ordinates; (3) make it possible to carry out extension tests of specimens in a chamber not only under pressure, but for comparison, under atmospheric pressure.

The Metals Physics Institute of the Urals branch of the Academy of Sciences of the U.S.S.R. built and prepared an apparatus which permits tests to be made on metals under pressures of up to 10,000 kg/mm². The apparatus consists of a high pressure chamber, a small hydraulic press, a high pressure compressor and electrical gear. Fig. 1 shows a schematic drawing of the general arrangement of the apparatus. The high pressure chamber 6 has the form of a thick-walled steel cylinder with external diameter of 200 mm, and internal diameter of 20 mm and a length of 230 mm. The test-piece under study 8, in diameter 5 mm, is inserted in the channel of the pressure chamber and connected by one end to the fixed obturator 9, and by the other end to the spindle 11, which must move freely in anaxial direction. The spindle protrudes outside the chamber and rests with its end against the piston of the hydraulic press 1. Sealing of the spindle is achieved by using a set of Babbit-metal rings, which can be tightened up as they wear.

The pressure developed by the high-pressure compressor of L.F. Bereshchagin's system is supplied to the chamber through the fixed obturator, which has holes to admit liquid. The operation of the compressor is controlled in such a manner that within the chamber hydrostatic pressure is kept at one level for the duration of the tests. As a pressure-giving medium a mixture of transformer oil and kerosene is used, which has sufficiently good dielectric qualities.

Under the action of pressure the spindle 11 tries to move out of the chamber channel. However, this movement can take place only if the supporting

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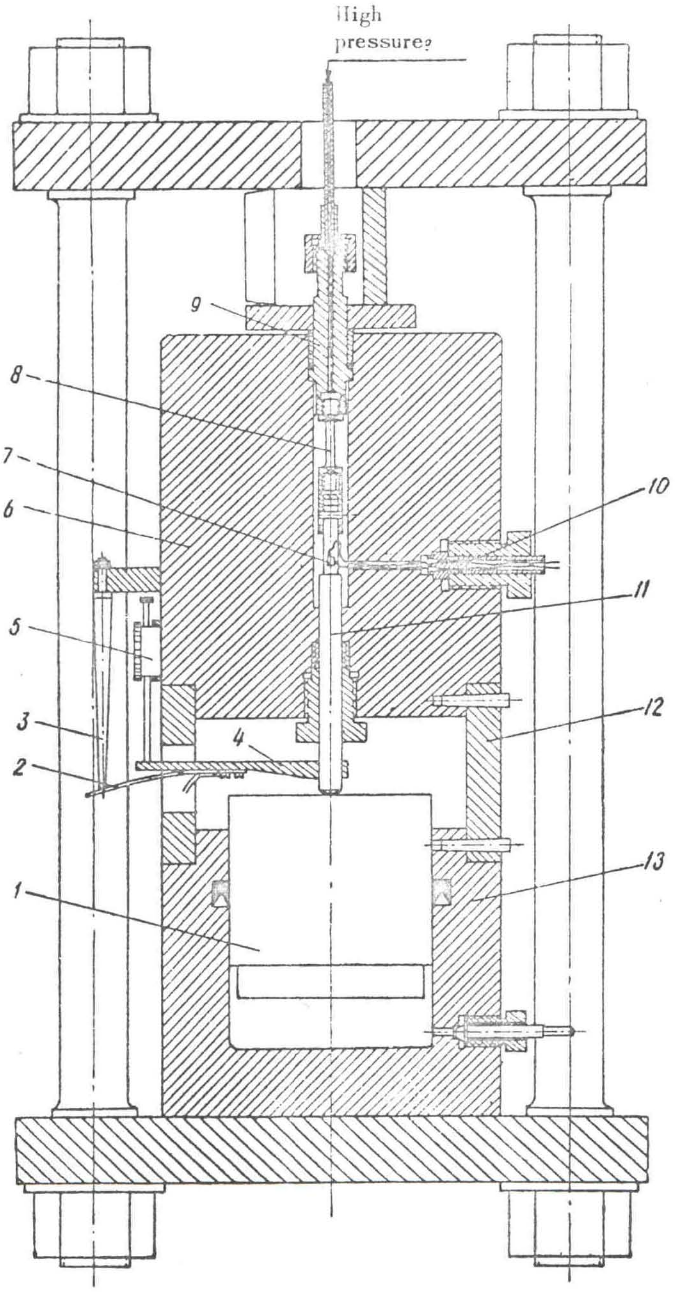

FIG. 1. Schematic diagram of the general arrangement of the apparatus:

1, piston of hydraulic press;
2-5, detail of the device for measuring displacement of spindle;
6, high pressure chamber;
7, contact resistance;
8, test piece;
9, fixed obturator;
10, electric leads;
11, spindle;
12, connecting collar;
13, cylinder of hydraulic press.

pressure of the hydraulic press is removed. Hence the straining of the test-piece is carried out by gradually withdrawing the supporting pressure. Extension tests of specimens at atmospheric pressure are carried out in the same apparatus by means of an additional adaptor.

Automatic recording of the curves of the force-strain co-ordinates, is achieved with an apparatus consisting of wire contact resistances a single-channel electronic amplifier, an oscillograph circuit and other gear, assembled as in the diagram given in Fig. 2.*

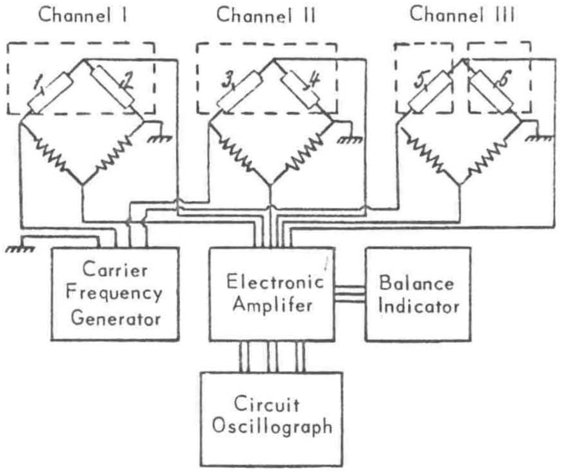

FIG. 2. Electrical circuit diagram of the apparatus.

The first channel of the circuit is designed to measure the deforming force applied to the test-piece. A measuring bridge is connected to the wire resistance contacts. One of the bridge arms consists of a working contact, pressing against the surface of the spindle 11 which transmits the extending force to the test-piece. The elastic strain thus arising in the spindle is received by the working contacts. The strain on the contact produces a change in its resistance and leads to a small current forming on the measuring diagonal. Alternating current of the frequency of sound is fed to the input diagonal of the bridge. The electronic amplifier has two functions: firstly, it supplies the measuring bridge with current at about five volts at a frequency of 5,000 c/s and secondly, amplifies, detects and filters the current led off from the measuring diagonal of the bridge.

To remove the effect of pressure on the neighbouring bridge-arm a compensating contact is included, attached to a disk made of the same material as the spindle. Both contacts are placed within the high pressure container and are connected to the outer part of the system by tapered electric leads. To ensure identical temperature conditions the working and compensating contacts are placed in series. The remaining arms of the bridge circuit were designed with constant resistances each of which is equal to the value of the nominal resistance of the contact.

Calibration of the contacts is done at atmospheric pressure according to the compressive force measured by a control dynamometer.

The second channel of the system is designed to measure the deformation of the test-piece, the degree of deformation of a test-piece was measured by the deflection of a small beam closely connected to the lower end of the moving spindle. To convert the mechanical deformation of the beam to electrical oscillation a special measuring bridge is used, also connected to the wire resistance contacts. The contacts (working and compensating) are attached to the horizontal surface of the beam. Calibration of the beam with its contacts is done by indicator readings with an accuracy of 0.01mm.

The third channel of the system is used to measure the variation in hydrostatic pressure in the chamber by means of a manganin pressure gauge. Further, fluid pressure within the chamber is additionally tested by the readings from a manometer for super-high pressure, rated for pressures up to 16,000 kg/cm².

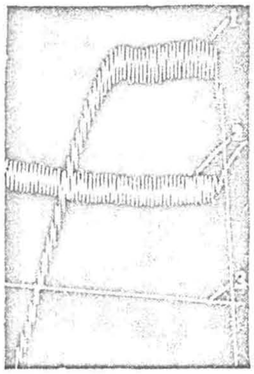

FIG. 3. Oscillogram obtained during the deformation of hardened beryllium bronze under a pressure of 3000 kg/cm²;

From the oscillograms values are determined for force, strain, pressure and the nature of their

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* M.G. Kozhukhov took part in the arrangement and setting up of the electrical circuit.

variation from time to time, also the construction of general curves for the extension of the test pieces, with stress-strain co-ordinates. A typical oscillogram, taken during 20 per cent extension of hardened beryllium bronze under a pressure of 3000 kg/cm² is given in Fig. 3. From the results of the tests the first part of the curve for the extension of beryllium bronze, hardened at 800°C in water, has been constructed (Fig. 4). As is evident from the diagram, hydrostatic pressure markedly increases the limits of flow. Nevertheless, the growth of stress with an increase of strain at a pressure of 3000 kg/cm² proceeds notably more slowly than at atmospheric pressure.

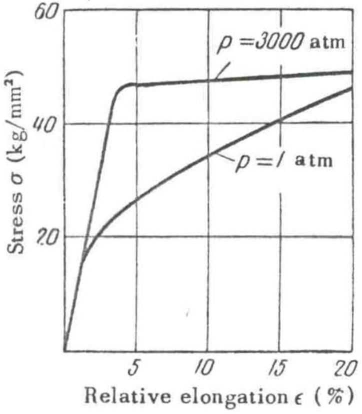

FIG. 4. Relationship of stress to deformation during tension in a test-piece of hardened beryllium bronze under all-round hydrostatic pressure.

We express our thanks to Professor L.F. Bereshchagin for his valuable advice.

REFERENCES

1. P.W. Bridgman, Studies in large plastic flow and fracture, 1952.
2. S.I. Ratner, *Zh. tekh. fiz.* 19, 3, 408 (1949).