

pressures. This resistance also may be varied as desired by altering the thickness of the walls of the enclosing tube, and the pressure under which the rock is being deformed can be accurately measured, seeing that the whole vertical pressure is brought to bear directly upon the specimen. The deformation may, furthermore, be carried on at temperatures approaching even to incipient redness and, if required, in the presence of water or steam.

The material employed in the construction of the enclosing tubes in our earlier experiments was wrought iron or a mild carbon steel, but in all later work a steel containing 4.10 to 5.18 per cent of nickel was employed. This steel has a considerably higher elastic limit than ordinary carbon steel, and our thanks are due to the Bethlehem Steel Company for several consignments of this steel which have been used in the investigation. For the construction of the pistons the chromium tungsten "Novo" steel was employed. This steel when heated to whiteness and plunged into fish oil develops extraordinary strength, a specimen having the dimensions of one of the pistons—namely .815 inch in diameter and 1.56 inch long—when tested in compression having sustained a load of 215,000 lbs., equivalent to 411,880 pounds per square inch, with practically no alteration of shape. The pistons of this steel may, furthermore, be used under the great pressures employed at temperatures as high as 600° C.

In order that the conditions of differential pressure may be satisfactorily developed, it is necessary to make that portion of the enclosing nickel-steel tube immediately surrounding the central portion of the rock column thinner than it is elsewhere, while leaving the portions of the tube about the ends of the column thicker. This concentrates the flow or deformation of the rock, giving a symmetrical bulge developed within the column and between its extreme ends, and prevents the enclosing tube from opening up under the pressure and permitting the rock to force itself up between the pistons and the ends of the steel tube. As the result of a long series of experiments, too numerous to detail here, it was found that a tube of the dimensions shown in the accompanying drawing (fig. 2) was the most suitable, the thickness of the wall immediately around the central part of the specimen being increased from 25 millimeters to a centimeter according to the amount of lateral pressure or resistance which it is desired to develop, all the other dimensions of the tube remaining the same. The pistons at either end were inserted into heavy steel castings by which the load was transmitted from the press.

The rock columns upon which the experiments were carried out were in most cases about 2<sup>cm</sup> (.814 inch) in diameter and

about 4<sup>cm</sup> (1.56 inch) long. In the earlier experiments the rock was first ground into rough columns 6<sup>cm</sup> long and 2.5<sup>cm</sup> in diameter on a rubbing bed. Subsequently a small diamond drill was installed having a hollow bit, which proved an excellent device for readily securing a rough column of any rock which it was desired to use for experimental work. This was then cut into lengths and turned into columns of the required size in a lathe. The final very accurate shaping of the columns was given to them by grinding with an emery or corundum wheel while in the lathe. In this way the little columns were turned to the desired shape with extreme accuracy. They were not as a general rule made exactly cylindrical in shape, but in order to secure a very accurate fit were usually made slightly conical with a taper of 1/1000 of an inch in their length.

In the same way the steel tube was first turned in a lathe in the usual manner, the inner surface was then ground to secure greater accuracy of shape, and the tube was finally finished by the employment of a reamer. In this way a taper identical with that given to the column was secured, the column, however, being slightly larger than that portion of the tube which was to enclose it. The tube was then heated by placing a red hot iron ring about it and when thus expanded the rock was gently shoved into it to the required position, and the tube being allowed to cool, a mechanically perfect fit of the tube to the column was secured.

When it is desired to carry out the deformation at temperatures above that of the laboratory and up to 600° C. or more,

FIG. 2.

