DESCRIPTION OF APPARATUS

The apparatus is shown in plate 1, and schematically in figure 1. A Blackhawk 20-ton ram pushes the pistons together in a homemade press. The ram is activated by a hand pump through a manifold valve which allows operation of five presses simultaneously. Each ram is fitted with a U. S. Gauge Company 10,000 lbs/in^2 gauge. A 700 bar Heise gauge is connected to the manifold valve and is used to check these gauges. Rudimentary measures are taken to provide coaxial alignment of the pistons. Alignment has not been found to be critical, fortunately, since thermal distortions make exact alignment very difficult.

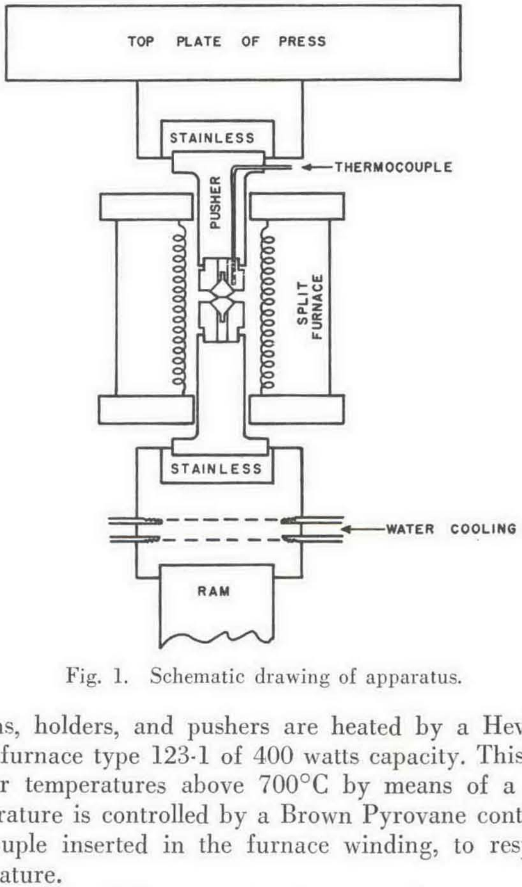
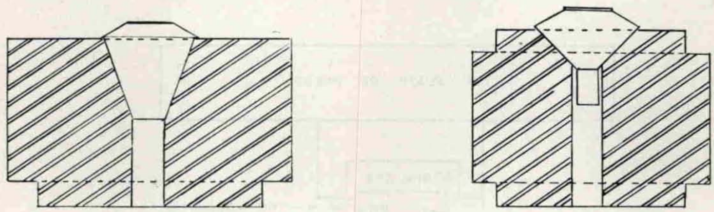


Fig. 1. Schematic drawing of apparatus.

The pistons, holders, and pushers are heated by a Hevi duty Electric Company split furnace type 123-1 of 400 watts capacity. This furnace is run over-voltage for temperatures above 700°C by means of a variable transformer. Temperature is controlled by a Brown Pyrovane controller, operated by a thermocouple inserted in the furnace winding, to respond to heater element temperature.

Materials with the highest compressive strength are most desirable for the pistons. Such materials are brittle and must be subjected to confining pressure to prevent brittle fracture. This confining pressure is provided by making the pistons conical as shown in figure 2. Two cone angles have been used: 20°, and 45° half-angle. Neglecting friction, the normal stress on the cone surface is given by the force divided by the area of the cone surface projected on a plane normal to the force. For .250″ diameter piston faces in the designs illustrated, the normal stress is 29 percent of the sample pressure in both cases. The radial stress, normal to the applied force, is 27 percent and 20 percent of the sample pressure for the 20° and 45° cones, respectively. Higher confining pressures are desirable to achieve the highest sample pressures but have so far not been attained, due to insufficient strength in the material of the holders. Lubrication on the cone surface is provided by a thin copper foil, which has small strength at elevated temperatures. Even at 1000°C, this foil does not entirely squeeze out.



A B

Fig. 2. Pistons and holders: A. 20° cone, used only for cemented carbides. B. 45° cone in configuration used for high speed and stellite pistons. When using this cone angle for carbides, the upper and lower cylindrical sections are omitted, and the acute angle between the two cones is flush with the top of the holder. In both cases, .003″ copper sheet was placed between the pistons and holders to serve as lubricant.

The highest pressures have been attained with cemented carbide pistons in the 20° cone shape (fig. 3). Kennametal grade K-6 was used to 800°C, where oxidation became excessive. Kentanium K-161B was used from 800°C to 1000°C. In these experiments, Carpenter 883 steel was used for holders to 500°C, and Inconel X from 500° to 1000°C. Due to the decrease of strength of the Inconel at high temperatures, the area of the piston face had to be diminished with successively higher pressures to prevent excessive deformation of the Inconel. At 1000°C, the diameter of the piston face was 0.10″ for sample pressures of 21 kb. The normal stress on the cone face was only 4 percent of the sample pressure, or about 0.8 kb. With Stellite 98M2 holders, it is anticipated that .250″ diameter piston faces could be used to 1000°C and that the sample pressures attained would be somewhat higher than those shown in figure 3, due to the beneficial effect of larger confining pressure.

Stellite 98M2 has been used in pistons with 45° cone (fig. 2). The pressures attained with these pistons is about 60 percent of that attained with the carbide pistons (fig. 3). The stellite 98M2 pistons have the advantage, however, of being less brittle than the carbide pistons and hence less subject to cracking.

All types of pistons, but most particularly cemented carbide, develop fractures long before their useful life is over. These fractures are typically of two types: (1) radial fractures extending up to but not entering the flat face; (2) spalling fractures roughly parallel to the upper, unsupported conical surface. In the case of carbide pistons, the former type of fractures almost