That dilatometer is not easy to construct, since the 90° groove in the supports, even though not demanding precision, is obtained by hand-lapping with a very short stroke. The fundamental asymmetry in the "J" dilatometer might also be increased by any temperature inhomogeneity within the high pressure apparatus. Scanning electron microscope examination shows that vacuum-evaporated metal coatings crumple when scratched, tear from pressure welding, and occasionally buckle after high temperature runs due to differential strain between coating and substrate or expansion of gas beneath the coating; such damage may cause nonrandom errors that are difficult to detect or evaluate. The lesser problem of resetting of the devices can be offset by careful experimental procedure. The earlier-mentioned necessity of making two devices of this type, interchanging materials of rod(s) and base, to explore all of *P-T* space is an added difficulty.

Two-Contact ('Gate') Dilatometer (Figure 5)

This dilatometer is formed by clamping rods of the two minerals to be investigated side-by-side to a non-reactive base. Only when both rods are of equal length do the two simultaneously make contact with a spring-loaded, hinged gate. Such contact completes a series electric circuit, and the flow of current indicates presence on a particular isomeke. Electric contact can be broken by *any P-T* change away from the isomeke.

Description. In the "gate" dilatometer, any condition of equidistance $l_x = l_y$ between fiducial ridges F_1 and F_2 in the base B, and the free ends of the rods R_1 and R_2, is indicated by completion of an electrical circuit. When the circuit (Fig. 7) is completed, *i.e.,* when on an isomeke, the electrical path from the voltage source is: strip chart recorder; chromel lead through closure piston to chromel terminal; gold wire

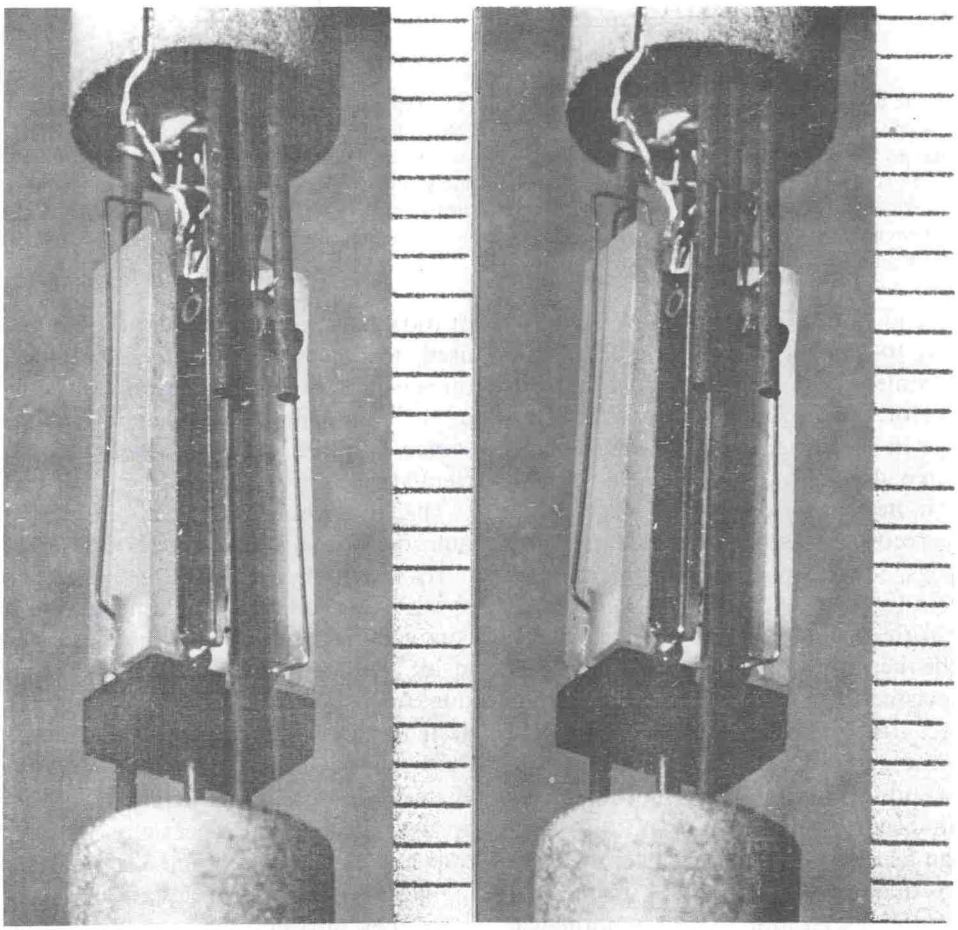

FIG. 5. Stereoscopic photograph of "gate"-type comparison dilatometer. Units on scale are millimeters. See Figure 6 for identification of parts.

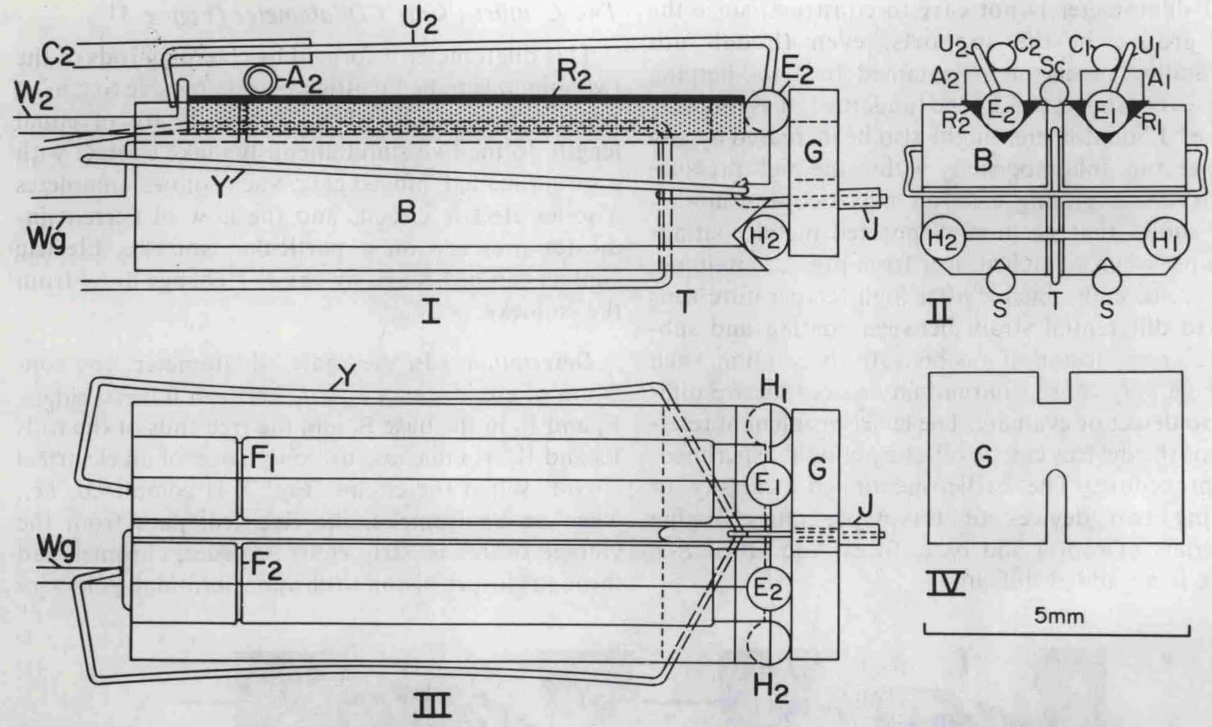

FIG. 6. Scale drawing of "gate" dilatometer. I. Side view, supports (S) removed for clarity. II. View from gate end with gate removed. III. View from top; some components removed for clarity. IV. Gate. Letters designate the following components: A_1, A_2–roller bearings; B–base; C_1, C_2–tungsten wires that clamp rods to fiducial ridge in base; E_1, E_2–electrical contact ball bearings; F_1, F_2–fiducial ridges; G–gate; H_1, H_2–hinge ball bearings; J–connection between gate and gate spring; R_1, R_2–rods of minerals being investigated; S–supports for dilatometer; T–thermocouple; U_1, U_2–spring clamps that keep electrical contact balls, E, in contact with rods, R, and also serve as part of the electric switch circuit; W_2–electrical lead from closure piece to electrical contact ball, E_2 (note: W_1 not shown); W_g–electrical lead, when connected, from gate to ground; Y–gate spring.

W_1 to clamped end of rod R_1; through W-Re alloy spring clamp U_1 to coated 0.7938 mm (0.03125 ± 0.00001 inch) stainless steel ball bearing E_1 that was welded to U_1 before coating; through polished, optically flat, tungsten carbide gate G; and then back to the voltage source along a path on the other side of the device, symmetrically equivalent except for absence of the recorder. The chromel-alumel thermocouple T (Figs. 6, 7) is placed in a longitudinal central groove in the base with the junction located symmetrically in the plane of the rods. The voltage developed by the thermocouple is charted by one pen of a two-channel recorder, and current through the electrical contact circuit is charted by the other pen. Lead W_g from the gate to ground *via* J and the gate spring Y is useful primarily for trouble-shooting malfunctions in electrical contacts.

Certain design features of this dilatometer merit attention. The position at which the gate is loaded by J lies just beneath the intersection of two hypothetical lines connecting the points of contact between E_2 and H_1, and E_1 and H_2. Except for the small deformation of rods, balls, and gate under the slight spring forces used, the method of loading the gate assures that there will be an electrical signal only when the centers of the four balls are coplanar. Under this circumstance, presence on an isomeke is assured, given sufficiently precise shaping of base, balls, and gate.

The five straight lengths of 0.508 mm diam. tungsten wire, S and C, support the dilatometer. Supports S terminate on both ends in segments of fired pyrophyllite rod that simultaneously hold the device, conduct electrical wires to the dilatometer, fill space inside the cylindrical furnace, and center an encapsulating cylinder of stainless steel with internally nested cylinder of gold. The high thermal conductivity of the last reduces thermal gradients in the vicinity of the dilatometer to negligible values. Springs C cause roller bearings A to pin the mineral rods to fiducial ridges F and also hold the dilatometer in place. The roller bearings are an important feature, since they also effectively decouple the dilatometer from flexural motions of the supporting assembly.

The base was machined from annealed, stoichio-