crease of temperature of about 2° *C.* per minute. This slow increase in temperature and the fact that the specimen was of small dimensions resulted in a very small temperature gradient in the specimen, and the allotropic changes took place in a minimum time. Four clays of approximately the same chemical composition but of different origin were fired for six hours at a temperature of 1350° *C.* The four expansion curves are shown in *Fig. No. 3.* Clay No. 1 gave a straight line up to a temperature of about 850° *C.*, showing that no crystalline silica was present. This clay after firing consists of an aggregate of mullite crystals in a silica glass matrix. In clay No. 2 the presence of quartz is clearly shown by the sudden increase of expansion at 575° *C.* In clay No. 3 the change in expansion coefficient takes place around 130° *C.*, indicating the presence of tridymite. The expansion curve of clay No. 4 shows definitely the presence of both quartz and tridymite. All these conclusions were checked by means of X-ray diffraction spectra, which revealed the presence of the constituents indicated by the expansion curves.

This typical example demonstrates the influence of silica on the average coefficient of expansion of a ceramic body. This average coefficient of expansion is of great practical importance in problems concerned with glazes in porcelain and china ware and also in the making of refractory bricks intended to resist thermal shock.

PROGRESS

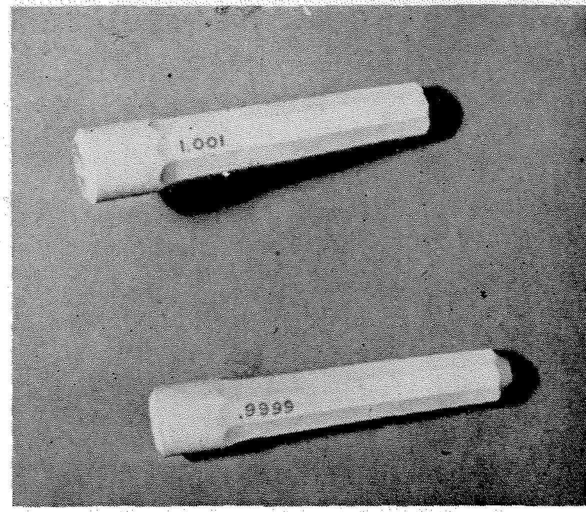
The demands of metallurgy for better refractory materials have been largely responsible for the progress made in the manufacture of refractories. This progress has resulted in a better control of the materials and in the development of new products. Simultaneously, methods have been developed for testing refractory materials under conditions approaching those found in service. Some of these tests, such as the determination of the softening point, the measurement of the load-bearing capacity at high temperature, and the spalling resistance of firebrick, have already been standardized. Other useful measurements, such as the thermal expansion, and the thermal and electrical conductivity, require more elaborate equipment, which is limited to very few laboratories. The resistance of a refractory to erosion and corrosion by a molten slag is of the greatest importance to the metallurgist. Laboratory tests reproducing the service conditions have already demonstrated their value.

Experimental research in ceramics is primarily dependent upon furnaces in which high temperatures can be easily reached with any desired atmosphere. Considerable progress has been made in this direction during the last decade. This achievement, together with the use of the methods of investigation which modern physics has placed at the disposal of the engineer, will greatly contribute to the development of research in the field of ceramics.

CERAMIC GAUGES

By B. W. MORANT

CHANGING conditions of the world have always brought about many new ideas in connection with production and the use of materials. One idea that has turned into a reality is the ceramic type of gauge, the earliest development of which occurred through the use of glass. Chief concern in any volume production program is the life of the tool before it must be taken out of service for replacement or reconditioning. The next concern is how cheaply and how quickly it may be replaced. The ceramic gauge offers a valuable solution for both of these problems as it is very resistant to wear, and is quickly and cheaply produced and replaced.



Ceramic gauge, designed to replace gauges of critical metals.

While there are many reasons for substituting non-critical materials for those in the more critical classifications, it is unnecessary to analyze the ceramic gauge for anything but its own direct merits. At all times the raw material from which it is made is both plentiful and cheap. The product is very hard and of excellent wearing quality. The rough blank is easily produced by pressure with the minimum of equipment. By varying their composition, ceramic gauges may be provided with a wide range of coefficients of expansion. Oxidation of ceramic gauges does not present any problem, and perspiration does not etch their surfaces. Ceramic gauges do not tend to gall when used with copper alloys. Compressive strength of ceramic gauges can be as high as 100,000 pounds per square inch. Tensile strength, however, will vary from 5,000 pounds to 15,000 pounds per square inch. Similarly the impact strength of ceramic materials is low.

At first glance these last factors discourage industry from the general use of ceramic gauges. However, experts with steel gauges agree that after a gauge has been dropped, it should not be relied upon until standardized. The ceramic gauge is never in doubt because it always dismembers itself or else is picked up in an immediately usable condition. The behavior of ceramics is such that an impact which is sufficient to remove a small chip does not affect the balance of the dimensional characteristics, although intraconchoidal fracture may result on the second or third impact. Therefore, in order to prevent or at least minimize breakage from rough handling, the ceramic gauge should have all exposed edges beveled or finished to a radius.

Briefly, the blank for a ceramic gauge of the type so far considered is slip cast, hollow, and with or without integral handle. It is provided with cast-in-center bores at each end to facilitate the finish grinding. The blank is capable of great accuracy as cast and fired, but the usual finish grinding operations are required to meet the tolerances demanded.

In the above comments an attempt has been made to present some of the factors involved in the use of ceramic gauges, both favorable and unfavorable, in order that the reader may draw his own conclusions as to why after more than a year of general consideration and in

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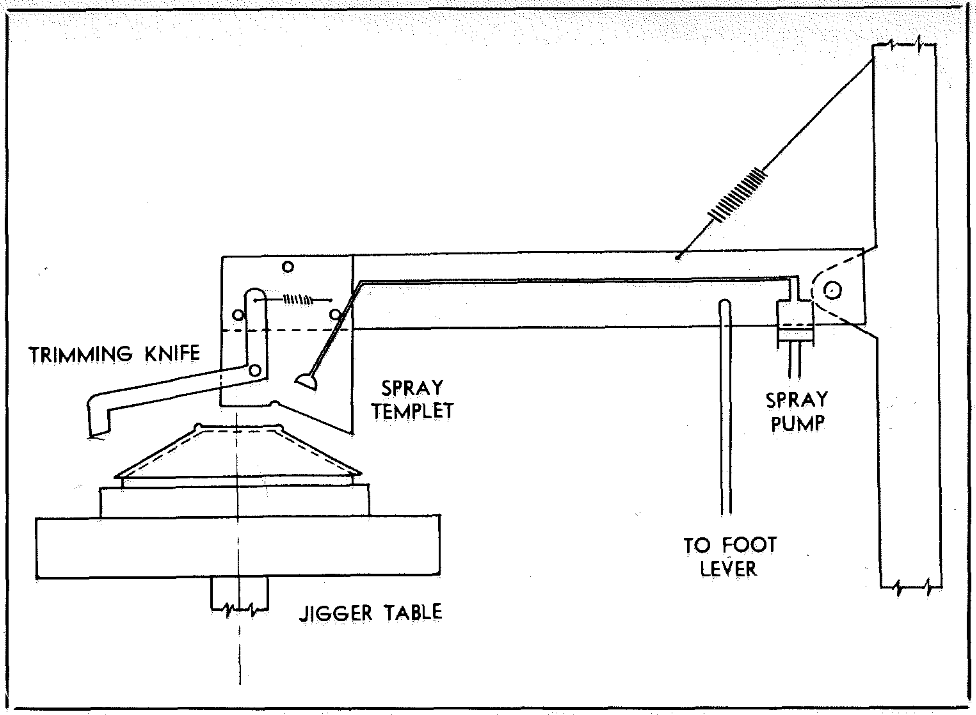

AT RIGHT
Diagram showing proposed jigger arm assembly.

conclusions already determined by the company. Many suggestions needed much practical refinement before they were ready for the test of application.

Several specific contributions can be listed as representative of the important items:

1. In layout, the idea of combining the efficiency of straight product- or line-flow of materials with the cross-cutting flexibility of functional grouping of major units possesses great merit in this case. While the idea is not new, it has had only limited application; this is a case where it would be applicable.

2. Revision of the layouts achieved over 50 per cent saving in transportation distance, with several handlings of materials eliminated, combined, or simplified. Since materials were heavy or fragile, this was an important saving.

3. Suggestions for the improvement of the jiggering operation varied from designs for new dryers with automatic loading and return systems to suggestions for the combination of applying water to the revolving vessel and trimming it with the action of the template arm.

4. Numerous suggestions for improvement of the laborious hand pouring operation in the casting department centered around pumping the slip to the casting stations. Despite protests that "it can't be done," a fine circulating system is now operating in the plant.

The company engineers and operating men have taken a very broad gauge attitude about accepting the suggestions rather than resenting them as criticisms.

From the view of the California Institute, this problem permitted the development of excellent material for teaching and made for good training in practical problems for the students with an interest in production problems.

The fact that the California Institute, without a separate department of industrial engineering, should be called on to participate in this undertaking to the mutual benefit of both parties indicates the need for specialized training, research, and service in production engineering in the growing industrial community of southern California. Neither industry nor the California Institute will ignore the possibilities of further collaboration on production problems.

Ceramic Gauges

(Continued from Page 7)

the face of severe priority restrictions on critical steel tools the metal-working industry is still hesitating to adopt the newer ceramic materials. The ceramic industry should not be expected to be the one to promote the use of ceramic gauges, because the volume of material involved represents an insignificant percentage of its total product. It has, however, carried on research to increase the mechanical shock resistance of its materials and has been able to present finished surfaces which are "nonfreezing," "nongalling," and capable of resisting the abrasion of anodized and other finishes found on the pieces to be gauged. The gauge industry is inherently conservative, but there seems to be much of future interest in the nonmetallic standard of measurement.

APRIL ISSUE COVER

The April issue of *Engineering and Science Monthly* featured an interesting view on the cover and several readers of the magazine have requested identification of the subject matter. The caption to the illustration reads as follows: "*Birth of a Multiple Contact Plug:* The electric circuit comes into its own in the multiple contact plug. These connectors are specially designed to meet specific and often unusual requirements. Engineers of the Cannon Electric Development Company have designed and manufactured connectors carrying well over a hundred circuits."