Light Rays Can Be Tools

A. R. Fultz

Eastman Kodak Company
Rochester, New York

The supreme precision of a beam of light is an old story. It is straight—regardless of the distance it travels. It exerts no pressure on the objects it falls upon. It does not wear. And it is exact, furnishing the universal standard for all measurement.

But if these properties of light are themselves an old story, their applications in industry constitute a new one. For not until light has been harnessed by optics are these properties useful as a means of gaging in the shop or plant. Yet once harnessed, light rays can be tools—can, for example, measure a rise of 0.002 in. in a distance of 30 yd, measure the angle between two related surfaces to an accuracy of less than one sec of arc, or magnify an object to a degree where one operator can check 18 separate dimensions to tolerances of 0.0005 in. at a rate of 280 parts an hour—an operation that formerly required 9 operators and 16 mechanical gages.

Each of these applications applies familiar principles of light. In one case a beam of light is used as a perfectly straight line of reference. In another, this beam is put to work by applying the simple geometric principle that the angle of reflection equals the angle of incidence. In the third, advantage is taken of the ability of optics to change scale. Which property is pertinent depends on the product in manufacture, how it is made, how it is inspected, and how it is used.

This does not mean, however, that a large research program in optics is a prerequisite of using light as an industrial tool. Certain basic optical designs are applicable to the majority of industrial uses because of their universality and their versatility. These fall into three major classifications: (a) Autocollimation—in which a beam of light is reflected back on itself from a reference surface on the work, for checking the angle between two planes, however far separated, to any desired accuracy. (b) Telescopic alignment—employing such devices as double-ended telescopes and divided-aperture objectives, for establishing by absolute methods a line of sight in fixed relation to a plane and then measuring displacements of distant targets from it. (c) Projection of silhouettes and illuminated surfaces to a screen, where they can be measured and examined at any magnification —by eye, photocell, or by photography.

Instruments falling under the classification of autocollimation are for the measurement of angle. Everyone knows that to see his image in a mirror he must stand directly in front of the mirror, and this principle is the basic premise of the autocollimator. Yet these instruments are capable of working to angular tolerances of less than one sec of arc: i.e., to an angle equivalent to a rise of 0.001 in. in a distance of 17 ft.

Fig. 1 is a cross-sectional view of an autocollimator and target mirror mount used to check flange faces on

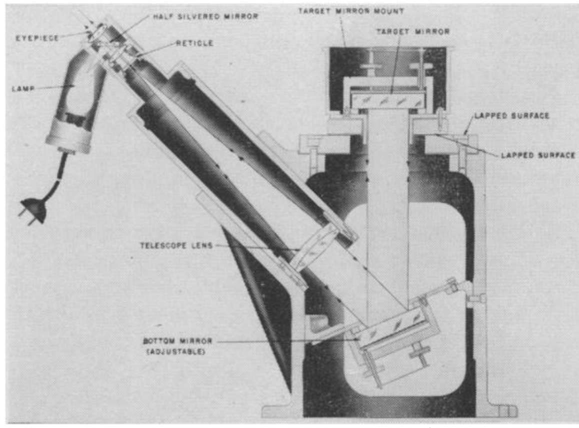

FIG. 1.

the ends of a tube for parallelism. The instrument is self-checking, since the reticle image will coincide exactly with the reticle itself when the surface of the mount is placed directly on the surface of the instrument. Once the instrument has been zeroed in this way, the tube may be placed on the surface of the instrument and the target mount placed on the opposite end of the tube. Any deviation from parallelism in the flange faces will be manifested by the amount the reticle image is offset from the reticle.

Modifications of this instrument may be used for checking many other types of angular measurement, or its principles may be employed in special instruments for complex tasks by combining autocollimation with other optical devices, such as telescopic aligners.

The telescopic aligner, shown schematically in Fig. 2,

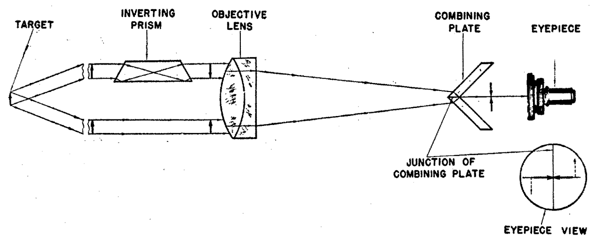

FIG. 2.

establishes by absolute methods a line of sight in relation to a plane and will measure displacements from this line to ten-thousandths of an inch. The target itself may be regarded as an illuminated vertical arrow which is viewed under two different conditions, as an erect and as an inverted image. The objective lens directs these images to a common focal point and when the target is on the level of the lens axis, the images coincide. Conversely, when the target is displaced from the lens axis, the images move in opposite directions. Thus the target may be used to establish a position along a line with complete accuracy and regardless of distance.

The repetitive accuracy of measurement is remarkable. Readings can be repeated to a tolerance of ± 0.0003 in. with the target at a distance of 20 ft from the aligner.

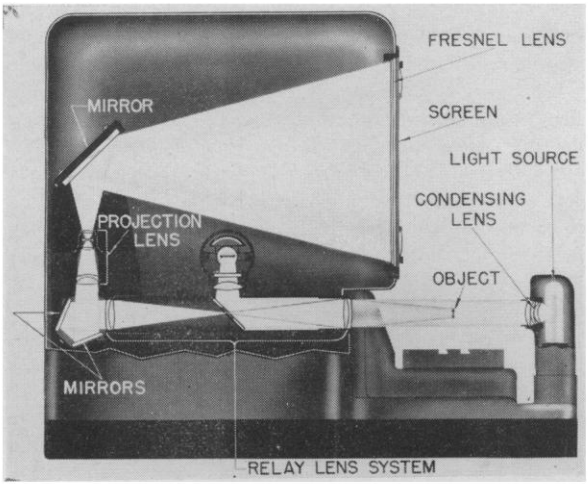

FIG. 3.

With the target at a distance of 100 ft, measurements can be made with a tolerance of ± 0.003 in.

While this instrument was designed primarily for aligning planer beds, it can undoubtedly be applied to the solution of other problems involving heavy machine tools and other massive equipment.

The third major classification of optical instruments, that of contour projection, introduces the only use of optics for gaging mechanical components that has been employed to any extent in industrial inspection. However, the practically limitless applications of this tool to inspection problems have not been generally realized.

All contour projectors work on the same basic principle and are made up of a light source, object, lens, and

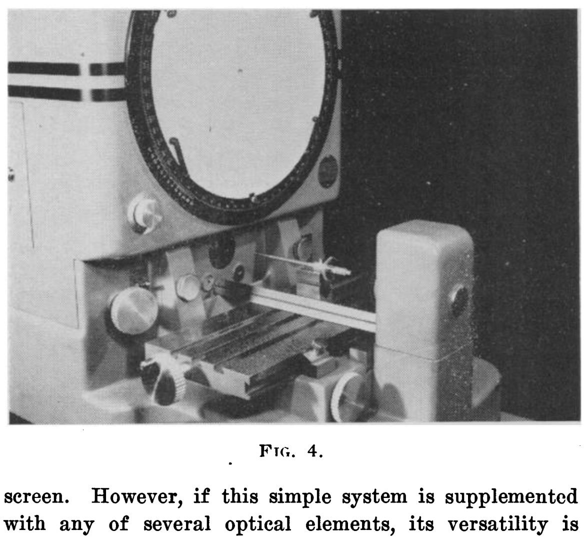

FIG. 4.

screen. However, if this simple system is supplemented with any of several optical elements, its versatility is greatly increased. The first of these elements is a relay lens (Fig. 3) and the second a Fresnel lens, mounted behind the screen.

This Fresnel lens provides increased screen brightness by concentrating the cone of light coming from the screen into a cylindrical beam directed at the operator. This permits the use of the projector in lighted rooms without hoods or curtains and, with the relay lens, helps to provide surface projection of brilliance hitherto customary only in shadow projection.

There are many instances in which a work piece may be recessed or obstructed, or measurement of surface details must be made. In such cases the surfaces themselves can be projected as a bright image in contrast with the more familiar contour, or shadow, image. Here the relay lens affords a unique opportunity for obtaining maximum illumination. An elliptical mirror may be inserted in the relay lens system (Fig. 3) and light from a 1000-w lamp directed through the front lens to the object. The object reflects the light back in turn, but the reflected image converges and a hole in the mirror permits the image to pass through and be directed onto the screen.

So successful is this system that it is possible actually to project the surface of black Bakelite molded parts.

The relay lens also serves two other functions of major importance, both of which increase the scope and versatility of contour projection. It permits an 8-in. clearance between the work piece (Fig. 4) and the first lens of the system, at all magnifications, providing ample space for awkward parts or for efficient staging fixtures. It also transfers an image at 1: 1 magnification to the rear of the instrument, where projection lenses of any desired magnification may be mounted.

Here again, the versatility of the science of optics is illustrated, incorporating in a single system elements which can do, not one, but a variety of tasks, with the inherent advantage of a precise, pressureless, and predictable gaging element.

The Differential Transformer as Applied to Instrumentation

W. D. Macgeorge

Automatic Temperature Control Company, Philadelphia

The measurement of substantially straight line motions is an important factor in the science of instrumentation: for example, the measurement of the displacement of a bellows or a diaphragm, the motion of a float, the tip travel of a Bourdon tube, and the tilt of a weigh beam. Various means have been devised for converting these displacements into signals suitable for electrical transmission, but only in recent years has the differential transformer been used to any extent in this field.

It is the purpose of this paper to treat with only two general phases of this topic: (1) the basic design of differential transformers: and, (2) the circuits which permit their application to the measurement of instrumentation variables such as pressure, flow, and force.

A differential transformer consists essentially of a primary coil, two secondary coils, and an armature of magnetic material. The primary coil is energized from a suitable source of alternating current, the two secondary coils are connected so that their output voltages are 180° out of phase and the armature is located so that it can alter