physics without sight

By C. M. Witcher

AS RECENTLY as ten years ago blind students in colleges and universities of New York City were excluded from natural science courses because of the belief that they would not be able to handle the laboratory work. The writer has personally known of many similar occurrences in other places and of even more recent origin. The notion that blindness necessarily bars an individual from any discipline involving laboratory work is, for the most part, a pure fallacy, and this is certainly the case in the domain of physics. During the past few years enormous strides have been taken toward making practically all physical data directly available to the blind, and it now seems highly appropriate that these advances should be made a matter of record, readily available to all who might be concerned.

The basic observations in physics are all (ideally at least) reducible to the task of determining the positions of pointers on scales. Because of the fact that optical pointer readings produce a minimum disturbance of the system under observation, light has long served as the basic tool for conveying information from the observed system to the observer. Informationally, every physical observation is an extremely simple task. The degree of refinement of an observation determines, of course, the amount of information associated with it. For example, an observation in which accuracy to 1.0 percent is desired will involve just about 6.6 bits of information.

To make physical data available to the blind, the basic problem is that of transforming the information so that it will be available to sensory channels other than that of sight. In cases in which the observed system is not easily disturbed, the procedure will invariably consist of supplementing the existing visual scale and pointer with a corresponding set of tactually observable elements. In more delicate cases, methods that convert optical observations into tactile and/or audible data have to be used. A very simple scheme for doing this is now available, as will be seen presently. Let us look first at a few examples of what has been achieved and what may be expected in the near future.

So far as the writer is aware, the first modern attempt to adapt measuring instruments for the blind in this country was that of P. C. Mitchell, of the New York Institute for the Blind, in 1935. He attached very crude raised scales to a micrometer and a simple spring balance to make them tactually readable. About two years later the writer, then at Columbia University, developed, with the help of James Wood of the physics shop, another crude adaptation of a micrometer and a vernier depth gage readable to sixty-fourths of an inch. At the same time a circular slide rule suitable for tactile reading was developed for the writer's use by Lucy J. Hayner of the Columbia physics department. This was a really beautiful instrument (its construction required more than 100 hours) that permitted accuracy of reading somewhat better than that obtainable with a conventional 12-inch straight slide rule.

The first systematic attack on the general problem of adaptation of instruments for the blind began in the technical research department of the American Foundation for the Blind, New York City, in 1946. This department, under the joint direction of C. G. Ritter and the writer, had as its aim the development and standardization of methods for the adaptation and/or production of a large variety of items that would serve to remove the limitations of blindness in the performance of numerous specific tasks. As its first two projects the department undertook the development of (a) an accurate, inexpensive, and durable circular slide rule for use by the blind and (b) a set of tactile scales and indices that could readily be attached to a conventional micrometer. The final form of the slide rule consisted of a vinylite disk 12 inches in diameter with two raised scales (one on each side) near its periphery. One scale is linear and the other logarithmic, the points of division being the same as those on a conventional 10-inch straight slide rule. The indices are three vinylite pointers. It was found that the simplest way to produce these slide rule disks was by a process of pressing, precisely like that used for the manufacture of phonograph records. The micrometer attachments permit direct readings to 0.001 inch and interpolation to about 0.0002 inch.

The completion of these projects required a rather careful study of the optimum design characteristics of tactile scales and indices, and the results have now been applied to innumerable other items—clocks, thermometers, scales for weighing, and even anaeroid sphygmomanometers.

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Micrometer adapted for touch reading. This standard 0–1 inch micrometer has been converted for touch reading by the addition of (1) a collar with raised graduations, (2) a sliding bracket which carries the index for the collar and the straight strip with raised markings, and (3) a vernier index clamp for reading the straight scale. The straight scale and index permit readings to the nearest 0.025 inch, and the scale on the collar can be read directly in thousandths of an inch. Interpolation to 0.0002 inch is readily accomplished.

Other devices for length measurement now adapted for touch reading include metric tapes readable to 1.0 mm and depth gages up to 1 ft in length, readable to better than sixty-fourths of an inch. The gages were developed by F. M. Sigafoos of the Pennsylvania School for the Blind.

The technical research department adapted literally thousands of clocks and timers, the most accurate being an electric stop clock with which intervals up to 12 min in length could be measured to a precision of ±0.25 sec.

Although the department adapted many devices for weighing, the most important fact for the present discussion is that the blind can learn to make weighings accurate to ±0.1 gm with an ordinary laboratory beam balance, with no adaptation of the instrument. For more accurate weighing, where optical observations are necessary, the blind must use the so-called "line and pointer locator" described below.

Numerous bimetallic element thermometers of the dial type, for both Fahrenheit and centigrade temperature measurements, were adapted. However, the precision thus far attained is not too satisfactory. The best precision at present is that provided in a 25–125°F Weston photographic thermometer, which is readable tactually to slightly better than ±1°.

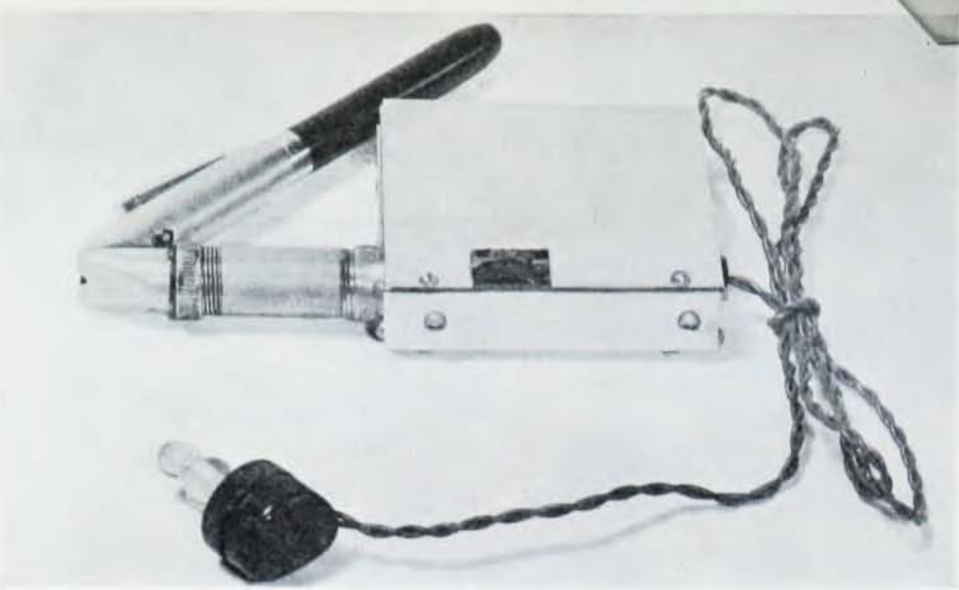
FROM all of these examples, then, it would seem that the blind experimenter is not very far behind his sighted companions with regard to the measurements of length, mass, time, and temperature. In the field of electrical measurements the situation for the blind is even better, as we shall now see.

The first adaptation of electrical measuring equipment was apparently that developed by the British National Institute for the Blind in the early 30's. They adapted a very rugged commercial ammeter by removing the glass over the dial, attaching a raised scale, and providing an arrangement by which the pointer could be clamped while a touch reading was being made. An improved version of this scheme was developed and used by T. A. Benham during the last war while he was employed by the Radio Corporation of America. Professor Benham also devised apparatus for the rapid and accurate detection of maxima and minima of voltage and current by the use of a saturable reactor as the inductance in an audio oscillator.

About 1942 the writer began applying the basic circuits of the Wheatstone bridge and the potentiometer to the measurement of various electrical quantities by tactile and auditory means. The variable element in this type of measuring apparatus was an accurately linear potentiometer provided with a raised scale and index. Over the next three years this work led to the development of a rather complete multimeter capable of measuring direct and alternating currents and voltages, resistance, and even inductance and capacitance when an audio oscillator and suitable standards were available. The accuracy of this instrument was about ±1.4 percent. A production model was made generally available to the blind by the technical research department of the American Foundation for the Blind in 1947.

When this simple idea became generally known, blind radio amateurs and electronics enthusiasts throughout the country rapidly began putting it to use in creating a vast variety of test equipment. Some of this equipment utilized vacuum tubes to obtain sensitivities entirely comparable with that of the best commercial apparatus. By now it is quite probable that no type of electrical measurement other than oscilloscopic observations remains inaccessible to the blind, and considerable thought is now being given to the problem of finding some way to make these observations available. Here, obviously, the informational character of the problem is much more complex than that of simple pointer reading situations.

As early as 1945 several people began wondering if there might not be an even simpler way to handle electrical measurements, namely, by constructing some form of optical probe that would detect the position of the pointer on a conventional meter. The meter face could then be fitted with a very simple raised scale punched on a piece of transparent plastic to facilitate tactual reading. It was soon found that the so-called "type C reading aid" developed by the Haskins Laboratories of New York City and the Radio Corporation of America served fairly well as a probe. However, these devices were quite costly, and not more than a dozen of them existed. Capacity probes (utilizing the change in capacity between meter pointer and probe end) were tried, also with partial success. It has only been in the past year that a simple and effective, and quite inexpensive, probe has been developed at the Re-



Line and pointer locator. Light from the small pen-light emerges from the opening in the end of the V-shaped tube and will be reflected back into the other arm of the tube by any object in front of the opening. The amount of light reflected back determines the pitch of a tone heard in the small ear phone, thus permitting the audible detection of printed lines, edges, meter pointers, etc.

search Laboratory of Electronics, Massachusetts Institute of Technology.* This probe makes use of a type Ne_2 neon glow lamp connected as a relaxation oscillator, this oscillator having as its resistance element a small lead sulphide photocell. Even a relatively small change of light intensity on the cell produces a noticeable change in the oscillator frequency. A small pen light serves as light source, or an ac operated bulb can be used. Light from the source, after being reflected from the dial or the pointer of a meter, is focused on the photocell. This simple arrangement produces a very definite change in the oscillator frequency when the light beam passes over the pointer. When this probe was developed, another object that we had in view was to make possible the detection of an ink line on paper. If the line was quite narrow, the frequency change caused by passing over it was extremely small. Accordingly, we added a second Ne_2 oscillator whose frequency could be varied by adjusting the potentiometer which served as resistance element. By tuning to zero beat with the photocell oscillator, a very small change in the frequency of the latter was made easily detectable. The probe in its present form operates for about 500 hours on three small hearing-aid B-batteries and costs only a few dollars to produce.

Naturally, this sort of optical probe has numerous applications other than the location of pointers on electrical meters. Its use enables anyone without sight to observe such things as heights of liquids in vessels, the swings of an analytical balance, and even positions of optical images. (For this last application the light source in the probe would, of course, not be used.) Complete design information on the line and pointer locator has been furnished to the American Foundation for the Blind, and it may be hoped that they will eventually make the device generally available to the blind.

The line and pointer locator may properly be called a multipurpose aid. A recital of this kind would surely be incomplete without a few words about a second multipurpose aid developed in 1949 by H. P. Sewell, of New York, working with the American Foundation's technical research department. This is a simple device that makes possible the production of raised line drawings on the top surface of the drawing medium, thus affording the blind a complete tactile feedback in this area. Many schemes for producing raised drawings have been previously used, but in all of them the raised lines appeared on the under side of the paper, thus being unavailable for tactile examination until the paper was turned over. In Sewell's "embossing set", the drawing medium is a special type of cellophane that rests on a gum rubber sheet 1/16 inch thick. Drawing is done with an ordinary ball-point pen that may or may not contain ink. The raised lines that appear are actually a succession of "gathers" in the cellophane that are created by the stretching of the material in the direction of motion of the pen. This scheme has provided a completely satisfactory means for enabling the blind to draw geometrical figures, plot graphs, produce electronic schematics, and the like. The instantaneous tactile feedback that it provides makes it ideal for teaching handwriting to blind children.

LOOKING back at what has already been accomplished and the possibilities for the future that can be inferred, it would now seem fairly safe to say that there is no ultimate limit to the adaptability of physical measuring devices for use by the blind. During the second world war the writer, by using only a few simple principles of adaptation, converted a complete microwave measurements bench so that all measurements could be made by tactile and auditory means. About the same time, T. A. Benham adapted the necessary equipment to permit him to make several types of measurements on crystals as a part of his work at the Radio Corporation of America.

The fact is that so many similar examples are now at hand that they have almost become commonplace to those familiar with the field, so that emphasis in technical research for the blind has now turned to problems of a much higher order of complexity—such problems as the creation of means to enable the blind to read printed material and to get about safely and independently.

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