XII. VISUAL REPLACEMENT PROJECTS

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A. ACOUSTIC OBSTACLE DETECTION

In the Quarterly Progress Report of April 15, 1954, we described a high-frequency sound pulse projector incorporating automatic scanning. The results obtained with this device were of sufficient interest to warrant the construction of a second model incorporating several improvements. Figure XII-1 is a photograph of the new projector; its circuit is shown schematically in Fig. XII-2. This model, considerably reduced in size, is about 8 1/2 inches long and 3 5/8 inches in diameter. It weighs slightly less than 2 pounds. As in the earlier model, scanning is accomplished by means of a deflecting ellipse, but the motion of the ellipse in the new model takes the form of an angular oscillation rather than a rotation. This motion is achieved with a Scotch crosshead which is driven by the motor near the bottom of the device. The crosshead carries a toothed rack which engages a small spur gear on the shaft of the ellipse. This scanning arrangement is considerably superior to that previously used, since the latter allowed
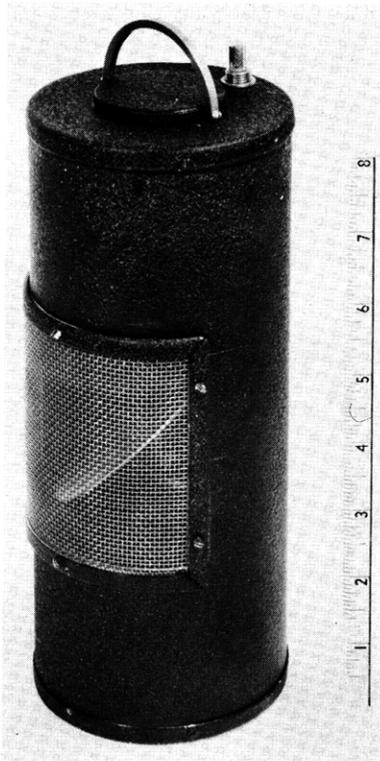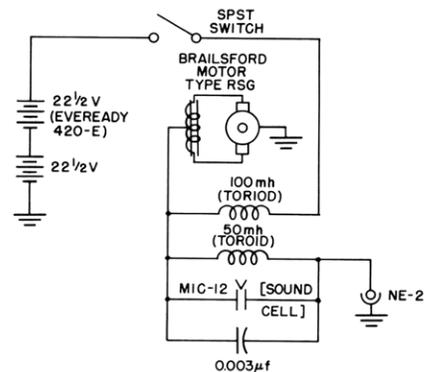

Fig. XII-1
Sound pulse projector.

Fig. XII-2
Sound pulse projector schematic.

the sound beam to emerge from the projector for only about half of each scanning cycle. With the oscillating system, the beam is available for obstacle detection at all times. The angular oscillation of the scanning ellipse is almost strictly sinusoidal, having an angular amplitude of 60° and a period of about 1.0 sec. The reduced dimensions of the new model result in one disadvantage, however; the sound beam is more divergent. The motor in the new projector is of the same general type as that used in the older model, but it was made specially for us by the H. D. Brailsford Company, of Rye, New York.

The operation of the electrical circuit is as follows. The inductive "kicks" appearing across the 0.1-henry coil at each break of the motor contacts produce shock excitations of the tuned circuit associated with the crystal transducer through the type NE-2 neon lamp. The neon lamp functions as a switch that disconnects the tuned circuit from the exciting coil during the second half-cycle of oscillation after the arrival of an exciting pulse, so that the tuned circuit is then left free to ring until the next exciting pulse arrives. This scheme has given much more satisfactory sound pulses than were previously obtained. The resonant frequency of the tuned circuit and transducer is 9.0 kc/sec, and its Q is of the order of 10. The amplitude of the sound pulses produced by the new projector has not been measured, but it is apparently greater than that obtained with the old model (104 db above a sound pressure of 0.0002 dyne/cm^2 at distance of 18 inches from the projector).

We have described this projector in considerable detail because it appears to represent a fairly close approach to what can be ideally expected from this type of obstacle detector. Numerous tests conducted with it during the past few months apparently lead to the conclusion that it cannot be expected to serve as a genuinely useful travel aid to the blind except under highly specialized conditions. All obstacles with rough or irregular surfaces yield clearly audible sound reflections at distances up to 15 or 20 ft, but obstacles such as small, smooth, round pipes or columns, as well as smooth walls on which the sound beam is incident obliquely, do not yield reliably detectable sound reflections. A further increase of perhaps 10-15 db in sound intensity might partially eliminate these difficulties, but then the intensity would be so great as to render the user of the instrument unduly conspicuous. We plan to attempt this, however, if and when a more rugged, but sufficiently small, transducer can be found or developed.

The suggestion has been made that a similarly constructed ultrasonic projector together with a pair of ultrasonic receivers (to provide binaural localization) might provide an improved obstacle detection system. The highly satisfactory scanning mechanism developed for the present model, together with its reasonably low total power consumption (about 150 mw), definitely warrants further work along one of the two lines just mentioned.

B. NEW STEP-DOWN DETECTOR

Some months ago it was concluded that a complete redesign of the step-down detector was needed if reliable results were ever to be obtained. The first step, a redesign of the optical system, was carried through, but a delay of several months followed because of difficulties encountered in obtaining the necessary components. The new receiver and light source have now been completed and will be described briefly.

The principal objectives underlying the new design have been: to achieve a considerable improvement in signal-to-noise ratio, and to reduce substantially the blocking effects caused by sunlight-to-shadow transitions, as discussed in the Quarterly Progress Report of January 15, 1954. In designing the optical system, three steps have been taken to further these objectives: (a) Much faster optics have been used in the receiver, permitting a considerable reduction in photocell area; (b) The vibration frequency of the light source has been increased from 30 cps to 160 cps; (c) By use of a specially designed lamp for the source, together with a Schmidt optical system, the beam from the source has been shaped to coincide closely with the receiver image space in the region where the latter "looks at" the terrain.

The optical element in the receiver is a parabolic mirror on a lightweight plastic base, which was generously donated to us by the Polaroid Corporation of Cambridge, Massachusetts. This mirror has a focal length of 1.06 inches and a circle of confusion less than 0.25 mm. The receiver aperture is 2.45 inches, thus giving a speed of F-0.43. The PbS photocell, produced for us by Photoswitch Corporation, is of the evaporated type, enclosed in an evacuated bulb, and the dimensions of its active area are 0.005 by 0.050 inch. This is about 1/15 the area of our previous cells, and hence, for the same amount of incident light energy, it should provide an improvement in signal-to-noise ratio (assuming same signal frequency) of $15^{1/2}$, or 11.8 db.

Since, for a given bandwidth, the noise power from a PbS cell varies inversely with frequency, the increase of 5.3-fold in source vibration frequency should provide an additional improvement of 7.25 db. Thus we may reasonably expect a total improvement in signal-to-noise ratio of about 19 db from the two factors so far considered. Measurements made by the Photoswitch Corporation on the new cells quantitatively confirm this improvement.

The increased source frequency, combined with the use of a more sharply tuned amplifier, must certainly provide some relief from the blocking effects produced by light-to-shadow transitions. For a walking speed of 5 ft/sec and for a receiver image space extending along the surface of the terrain a distance of 1.5 inches in the direction of motion of the detector, the rise times of the pulses produced by light-to-shadow transitions will be of the order of 1.5/60 = 25 msec, so that most of the energy in these pulses will be at frequencies below 320 cps, that is, twice the vibration frequency of the

source. The use of a Polaroid type XRX-40 infrared filter in front of the receiver (short wavelength cutoff 8600 angstroms) further serves to minimize the influence of sunlight.

The greatly improved light concentration from the source should result in a further improvement in signal-to-noise ratio, although this improvement has been sacrificed to some extent by the use of a lower power lamp in the source. The lamp now used was developed especially for us by the lamp division of the General Electric Company, and we are greatly indebted to Clifton Found, of that organization, for contributing several of these lamps. The tungsten filament in the new lamp is in the form of a helix only 0.005 inch in diameter and approximately 0.05 inch long. It is designed to operate at a nominal temperature of 2400°K with an applied voltage of 1.5 volts and a current of 0.25 amp. These lamps have also proved capable of withstanding the vibrational accelerations of the order of 250g to which they are subjected when the source is in operation.

The receiver is housed in a cylindrical bakelite case 2.75 inches in diameter and 2.25 inches long; its total weight is 3.5 oz. The photocell mounting embodies provisions for accurately centering the cell with respect to the axis of the mirror, and a special optical alignment tool has been developed for this purpose.

A photograph of the source assembly is shown in Fig. XII-3. As may be seen, the frame consists of a bakelite box with aluminum corner supports to provide added rigidity. Note that the aluminum ring which holds the Schmidt corrector plate fits snugly into the front end of the box to afford still more r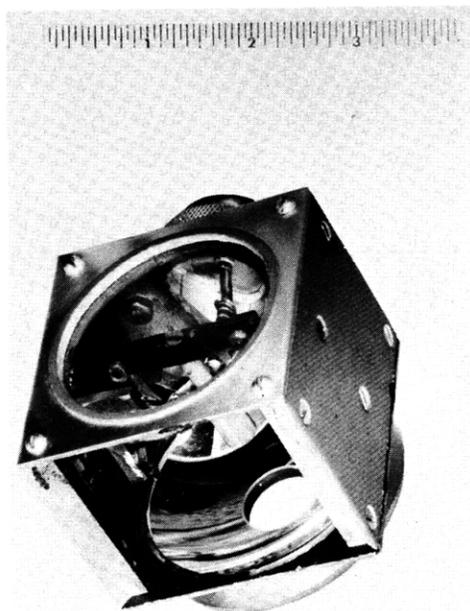igidity in the neighborhood of the supports for the vibrating element. This element is tuned to mechanical resonance at a frequency of 160 cps and is driven from a small, balanced armature type of headphone unit mounted in the collet assembly on top of the box. The system operates in the manner of an ordinary buzzer, utilizing a make-and-break contact arrangement and a small transformer powered from the same 1.5 volt source which furnishes power for the lamp. The position of the lamp, at the end of the vibrating element toward the mirror, is accurately determined to insure that the filament moves in an arc lying on the focal surface of the Schmidt system. We wish to express our sincere thanks to Harrison J. Merrill, of the Evans Signal Laboratory, Fort Monmouth, New Jersey, for providing us with the optical components for the Schmidt system.

Fig. XII-3

Step-down detector light source.

Considerable development work has been

required to obtain a vibratory system with sufficient rigidity and a sufficiently large mechanical Q to give a vibration amplitude of 4-5° at 160 cps with a power input of not more than 100 mw. These conditions have now been achieved satisfactorily.

As this is written, the complete assembly for the source and receiver has not been finished; we have therefore not had an opportunity to make measurements of the system performance.