The GENERAL RADIO EXPERIMENTER

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ELECTRICAL COMMUNICATIONS TECHNIQUE AND ITS APPLICATIONS IN ALLIED FIELDS

A NEW PRECISION CONDENSER

WORM-DRIVE air condensers have for many years been widely used as continuously-adjustable standards of capacitance. It has long been recognized that these condensers are subject to small variations from their desired characteristics caused by such factors as temperature, aging, worm eccentricity, backlash, and strains in the frame and plates, but, as a rule, the resultant errors have been negligible in all but the most precise measurements. In the TYPE 222 Precision Condenser these small variations were known and allowance could be made for them when necessary.

The availability of new materials and methods of construction, however, have made it possible to replace this condenser with one of completely new design, the TYPE 722 Precision Condenser, in which these factors are markedly reduced. The panel of the condenser assembly is shown in Figure 2 and the constructional details in Figure 1.

> **NEW PRICE FOR TYPE 631-A STROBOTAC**
>
> **Effective February 1, 1936, the price of the Type 631-A Strobotac will be $95.00, net, F.O.B. Cambridge.**

In designing the new condenser, the chief requirement has been stability of capacitance. Consequently both the material used and the mechanical arrangement have been selected with this end in view.

The whole condenser assembly is mounted in a cast frame which gives the assembly a degree of rigidity not otherwise possible. This frame, the stator rods and spacers, and the rotor shaft are made of an alloy of aluminum and copper, which combines the mechanical strength of brass with the weight and temperature coefficient of aluminum. Since the condenser plates are of aluminum, all parts have the same temperature coefficient of linear expansion, resulting in a low temperature coefficient of capacitance (0.002% per degree Centigrade).

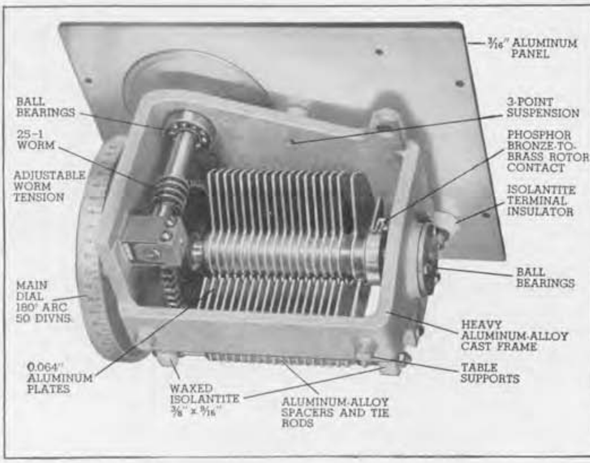


FIGURE 1. View of TYPE 722-H Precision Condenser with cabinet removed showing constructional details

Increased stability is also obtained by the use of plates 1/16-inch thick, which reduces materially the sagging which might normally occur with age, and, since the rotor shaft is horizontal, no constant stress exists which would cause the plates to bend in a direction parallel to the shaft.

The ball bearings used on both ends of the rotor shaft are conducive to both stability and smoothness of rotation.

Connection to the rotor is made, not through the bearing, but by means of a phosphor bronze brush running on a brass drum, which assures positive contact.

Since it is difficult to mount a worm gear on a shaft without some slight eccentricity, the worm in the TYPE 722 Precision Condenser is cut directly on the shaft. The dial end of the worm shaft runs in ball bearings; the other end is supported by an adjustable spring mounting.

This arrangement of bearings and drive mechanism results in a backlash of less than ½ worm division and a low worm correction. Since the capacitance per worm division for the new condenser is less than half that for the TYPE 222, the backlash in terms of capacitance has been considerably reduced.

It will be seen from Figure 1 that the usual dial arrangement is reversed, and that the drum dial is on the rotor shaft and the disk dial on the worm shaft. Because of this, both dials are read from a single window in the panel, and the condenser is driven from the panel without the use of bevel gears and their resultant backlash.

FIGURE 2. Panel view of TYPE 722-H Precision Condenser

The worm drives a 50-tooth gear, so that 25 revolutions of the worm rotate the main shaft through 180 degrees. One-half revolution (100 divisions) of the worm advances the main scale one division. Since the main scale carries 50 divisions, the 180-degree rotation is divided into 5000 worm divisions, each half of the worm dial being engraved 0 to 100.

The capacitance per worm division on the 1400-$\mu\mu$f model is approximately 0.28 $\mu\mu$f and on the 500-$\mu\mu$f model is 0.11 $\mu\mu$f. Since the scale can be set to about 1/5th of a worm division, the precision of setting for these two models is 0.06 $\mu\mu$f and 0.02 $\mu\mu$f respectively.

The over-all characteristics of the TYPE 722 Precision Condenser are similar to those of the older TYPE 222. The figure of merit, $R\omega C^2$, is 0.04×10^{-12} (or less) at 1 kc.

Isolantite is used for the insulating supports and, since a smaller amount of this solid dielectric is used, the figure of merit is lower than on the TYPE 222. As in other condensers, this factor is a function of temperature, humidity, and frequency, but is constant with scale reading over the usable range of the condenser.

The surface leakage is reduced to about one-third of the old value.

At 1 Mc the inductance is 0.06 μh and the metallic resistance is 0.024 Ω. The effect of these residual impedances at radio frequencies was discussed in a recent issue of the *Experimenter*.*

Two mounted models are available at present: TYPE 722-H, with a maximum capacitance of 1400 $\mu\mu$f, and TYPE 722-F, with a maximum capacitance of 500 $\mu\mu$f. These are supplied with a white wood shipping case.

Both sizes are also available unmounted. The casting is provided with three tapped holes for mounting. Since only a single panel window is necessary in order to read both dials, the ease of mounting is considerably improved. A template is provided for drilling the mounting holes.

Prices include a capacitance calibration table giving the capacitance at 26 points to 1 $\mu\mu$f or 0.1%, whichever is the larger. A worm correction calibration can be supplied accurate to 0.1 $\mu\mu$f or 0.1%, whichever is the larger.

TYPE 722 Precision Condensers will be supplied in the future on all orders calling for TYPE 222 Precision Condensers.

*Residual Impedances in the Precision Condenser, General Radio *Experimenter*, X, 5, October, 1935.

SPECIFICATIONS

Dimensions: (Mounted models) Panel, 8 x 9⅛ inches; depth, 8⅛ inches. (Unmounted models) Panel, 7¾ (length) x 6⅜ (width) x 7 (depth) inches.

Weight: 11⅛ pounds; 20¼ pounds with shipping case.

Type		*Capacitance*	*Code Word*	*Price*
722-HM	Cabinet Model . . .	1400 $\mu\mu$f	CUBBY	$90.00
722-HU*	Unmounted	1400 $\mu\mu$f	CUBBYPANEL	70.00
722-FM	Cabinet Model . . .	500 $\mu\mu$f	CUBIT	85.00
722-FU*	Unmounted	500 $\mu\mu$f	CUBITPANEL	65.00
Worm Correction Calibration Data			WORMY	35.00

*No calibration is supplied with unmounted models.

HIGH-SPEED MOTION PICTURES

There is a close analogy between the study of steady state conditions with the stroboscope in mechanical engineering and the oscillograph (or, more exactly perhaps, the oscilloscope), in electrical engineering. The equipment described here extends this technique to include the analysis of mechanical transients in the same way that the camera-oscillograph combination or the recording oscillograph provides a record of transient phenomena in electrical circuits.

THE study of repetitive motion in machinery at high speeds has been greatly simplified by the development of the stroboscope. There exists, however, a considerable demand for both apparatus and technique for studying mechanical transients and non-uniform motion.

For those applications where it is desirable to study a whole sequence of operations, the problem is best solved by photographing the motion and reprojecting it. Such a cycle does not have to be repeated and a single transient can be observed. When investigating cyclic motion, high-speed motion pictures provide a permanent record of the phenomenon, which may be examined later, whether or not the mechanism is still available.

Slow-motion pictures are, of course, no novelty and high-speed stroboscopic pictures are simply a further development of this familiar device. The value of all high-speed cinema work lies in projection at slow speeds. Slow-motion phenomena as seen in the motion-picture theater are obtained by photographing at speeds between 50 and 120 frames per second and projecting the film at the ordinary projection speed of approximately 16 frames per second. There is, however, an upper limit of practicability to slow-motion picture cameras using mechanical shutters. At picture speeds of several thousand per second, shutters would be required to operate at extremely high speeds, and the mechanics of such systems are complicated, unreliable, and expensive. The possibilities of speeding up a standard camera are further limited because of the mechanical problem of starting and stopping the film at high speeds.

The stroboscope presents an ideal solution for this problem. All of the complicated camera mechanism is eliminated and a simple, continuous-film

FIGURE 1. TYPE 621-H Stroboscope and TYPE 651-A Camera set up to photograph a machine for stitching leather

FIGURE 2. Control unit of the TYPE 621-H Edgerton Power Stroboscope showing the mercury lamps. The complete stroboscope consists of this unit and a 10-kw motor generator

camera is used. The exposure is obtained by illuminating the object intermittently with light flashes of such brief duration compared even to the highest film speeds that no provision for synchronization of the image is necessary — that is, the image can be impressed directly on the rapidly moving film without blurring.

The ability of high-speed pictures to "stop" motion is derived from a very brief flash of light. In the Edgerton equipment this lasts from five to ten one-millionths of a second. A corollary requirement is a high intensity of illumination in order that the film may be properly exposed during this brief period.

A high-speed photographic system falls into two portions, the light source and the camera. As developed by Professor Edgerton and manufactured by the General Radio Company, the light source has been an outgrowth of the smaller visual types of stroboscopes.

As in the latter instruments, a condenser bank is discharged through a mercury tube. In order to assure regular discharges which can be accurately controlled, a reliable control system had to be worked out. This makes use of a thyratron tube and a mechanical contactor. The contactor, which is connected into the grid circuit of the thyratron, controlling the flashing cycle of the condenser bank, is driven on the camera shaft and assures accurate framing of the pictures for reprojection.

Power for charging the condensers can be provided from any suitable source of high-voltage direct current which is capable of withstanding instantaneous short circuits. A high-voltage motor-generator set has been

FIGURE 3. External view of TYPE 651-A Camera showing the commutator and drive motors

FIGURE 4. Interior view of TYPE 651-A Camera showing the film reels and sprocket

adopted as the most suitable equipment available for this purpose.

The power requirements are directly proportional to the flashing frequency. One thousand flashes per second require one thousand times as much energy as one flash per second and consequently a power supply of one thousand times as great a capacity.

The camera is reduced to a means for carrying the film past an aperture of proper dimensions at the desired speed. The structure of the camera is shown in Figure 4. The moving parts consist of the sprocket and two spools which are shown, the drive motors, and the commutator which controls the stroboscopic flash rate and serves to space the frames on the film properly for projection.

The principal problem in the design of the drive sprocket and reels was the elimination of inertia and the reduction of friction, since there is some fire hazard involved in passing film through the camera at very high speeds. The matter of inertia is of great importance because of the necessity of bringing the camera quickly to speed.

The film is held against the sprocket by an aluminum roller and a metal plow is provided under the sprocket to prevent the film being carried around by the sprocket teeth and breaking. The plow does not touch the film in normal operation, but will immediately correct any tendency to stick. The plow also prevents the film winding around the sprocket in case of breakage.

No mechanical connection is provided between the driving sprocket and the take-up reel. The take-up reel is driven by a series motor of sufficient torque to keep the film taut, but not to break it. The difference in speed required by the changing diameter of the reel as the film is taken up is thus automatically cared for by the slowing down of the motor. Extremely high acceleration rates can be provided for since it is possible to operate the motors at over-voltage. The time required to run 100 feet of film through the camera is only a second or two, and no damage results to the motors from such momentary overloading. The acceleration under these conditions is remarkably rapid. Full and constant speed is reached within less than 10 feet of the film length.

Standard lens equipment is used. Focusing is facilitated by a pair of openings spaced diametrically in the sprocket and an eyepiece in the back of the camera.

It will be observed that distortion in

the image will result in consequence of the curvature of the sprocket. This distortion can be minimized by the use of a sufficiently large sprocket diameter. In the camera described, the sprocket diameter is $4\frac{3}{4}$ inches, carrying twenty standard 35-millimeter frames on its periphery. The center of the picture is approximately 0.03-inch closer to the lens plane than the extreme upper and lower edges of the frame. This difference does not cause serious distortion or lack of focus with the subjects and lens systems normally used. When using 16-millimeter film the distortion is, of course, proportionately reduced.

Since the film moves through the camera continuously without shutters, the distribution of exposures on the film is determined by the rate of flash of the stroboscope light in relation to the film speed. If the film is to be projected, the images must be spaced properly along the film. In order to accomplish this a commutator is mounted on the sprocket shaft to provide electrical impulses setting off the stroboscopic flash at intervals of one frame on the film. A film thus exposed can be projected in standard projection equipment. The commutator presents a rather serious mechanical problem because the segments must be located with extreme precision. The film speed is so great that a minute irregularity in the spacing of the commutator segments will result in serious flicker.

The equipment illustrated in Figure 1, which has been found suitable to several typical industrial problems, is capable of taking pictures up to about fifteen hundred per second and will illuminate an area about one foot square to a sufficiently high intensity to take satisfactory photographs on high-speed film with an f/1.5 lens. The *maximum* speed is in the vicinity of two thousand per second. Pictures have been taken experimentally with similar apparatus with speeds as high as five thousand per second, but development of such equipment has not as yet reached a stage where it can be made commercially available.

Figures 5 and 6 illustrate an excellent example of the use of this equipment in the mechanical field. In redesigning an automatic tapping machine, it was desirable to know the speed-time characteristic throughout the cycle of operation.

The machine was fitted with a drum and cross hairs as shown in Figure 5, and high-speed pictures were taken of a

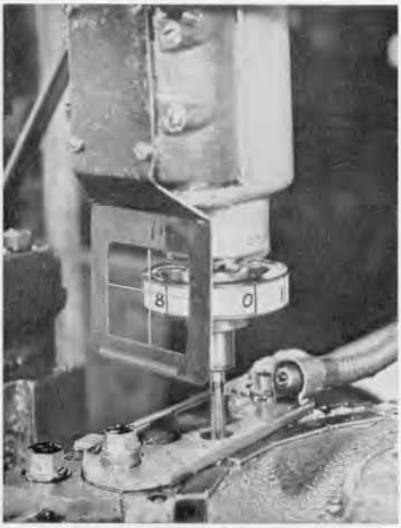
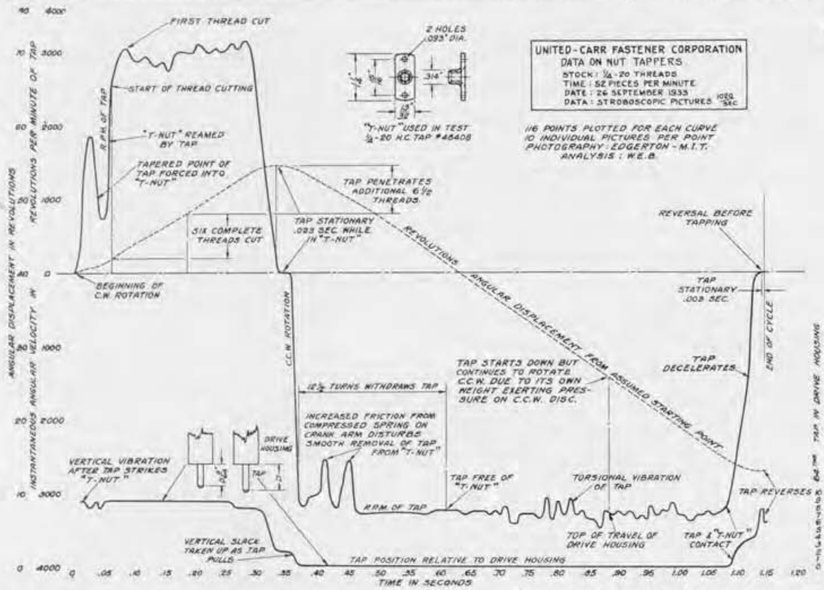


FIGURE 5. Photograph of the automatic tapping machine from which the data of Figure 6 was obtained. The drum, numbered in sections, and the cross hairs were attached in order that the pictures might be accurately analyzed. This arrangement makes it possible to measure the angular displacement accurately for each frame of the motion picture film



Courtesy of United-Carr Fastener Corporation

FIGURE 6. Plot showing angular displacement and instantaneous velocity of the automatic tapping machine over a period of one complete operation. From this data it was possible to redesign the machine to eliminate the irregularities shown in the plot

single cycle of operation at rated speed. In this case, it was not necessary to project the film. Examination of it yielded data for the plot of Figure 6, which shows clearly each irregularity of operation and the exact time at which it occurs in the cycle of operation. Compensation by means of cams could then be provided to give smoother operation. — CHARLES T. BURKE

The TYPE 621-H Edgerton Power Stroboscope is composed of the following units:

Control Unit	$1950.00
10-KW Motor Generator Set, mounted on truck and including switch	600.00
2 Single-Tube Reflecting Lamp Units	400.00
Total	$2950.00

This equipment is rated at 10 KW and gives a maximum flashing speed of 2000 per second. The motor is wound for 230-volt, 60-cycle, 3-phase service.

The complete 35-millimeter camera recommended for use with the TYPE 621-H Edgerton Power Stroboscope consists of:

Type 651-A Camera	$360.00
Motor, Base, and Switches	70.00
Commutator and Brush	65.00
Hugo Meyer f/1.5 2-inch Lens	115.00
Total	$610.00

The tripod shown in Figure 1 is not included.

If a 16-millimeter outfit is desired, the price is $635.00. The price with interchangeable parts for both 35-millimeter and 16-millimeter use is $775.00.

The above equipment is not carried in stock but can be built to order. Delivery at the present time can be made in about ten weeks from date of order.

GENERAL RADIO COMPANY

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