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In This Issue

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A PHOTOELECTRIC LIGHT RECORDER

THE LIGHT recorder described below was designed to enable manufacturers and purchasers of railroad or truck fusees, the sticks of colored fire used for emergency signalling, to manufacture and test them in accordance with the specifications drawn up by the Bureau of Explosives, Association of American Railroads. A typical specification states that the light emitted from the fusee shall be at least 70 candlepower and shall not be less than 50 candlepower for more than 25 consecutive seconds. Other specifications cover fusees up to much higher candlepower values. The total time of burning is also specified. By means of the Light Recorder a graph can be easily obtained which will show the time of burning and the instantaneous illumination at every instant during the test. Figure 1 is a reduced copy of an actual record made on a 10-minute type of red fusee and this record will be discussed later.

Light Recorder

The Light Recorder consists of two basic units, the Recorder shown in Figure 2 and the Photoelectric Cell Assembly shown in Figure 3, so arranged and calibrated that full chart deflection can be obtained with either 20, 40 or 80 foot candles of illumination. The selection of the desired range is accomplished by means of a selector switch on the box containing the photoelectric cell and its attenuating circuit. Although a red fusee is referred to above, other colored fusees, such as yellow and green, are also manufactured and tested. The recorder will record illumination in terms of what the eye actually sees or, more technically, it is designed to respond to the various colors in accordance with the Luminosity Curve adopted by the International Commission on Illumination. The fact that these fusees do not burn uniformly, but rather sputter and change their instantaneous candlepower very rapidly, makes the use of an indicating meter impractical, as the testing personnel could not possibly read and record the values fast enough to prepare a satisfactory graph. The recorder is so designed that the chart travel and the dynamics of the recording system are capable of following each and every change in illumination, and recording it so that the whole job is completed at the time the fusee burns out.

Recorder

The recorder is the Tagliabue *CELECTRAY manufactured by the Weston Electrical Instrument Corp. in its Newark plant. Thousands of these recorders are in use in the various industries; hence the design has stood the test of field use for many years. The recorder is a photo-mechanical type in which a mirror type of galvanometer reflects light on and off a phototube. Depending upon the direction of the light with respect to the phototube, relays are operated which control the direction of rotation of the motor which balances the potentiometric circuit and determines the position of the recorder indicator and pen. A more detailed description of the Tagliabue *CELECTRAY is covered in available literature.

The recorder characteristics for this specific application are as follows:

1. The effective chart width is 10 inches. It has 200 divisions which

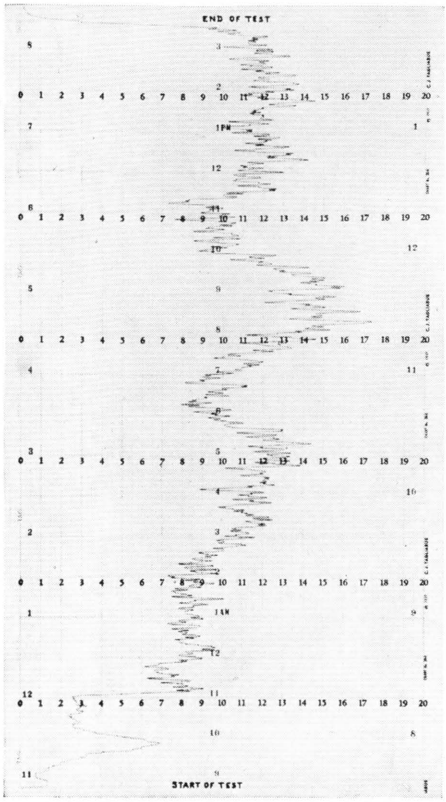

Figure 1—A reduced copy of an actual record made on a ten-minute type of red fusee.

are figured from 0 to 20 as shown in Figure 1. Since the actual illumination ranges are 20, 40 and 80 foot candles, the multiplying factors for the chart are 1, 2, and 4 in order to convert the chart values to actual foot candles. The chart travels at the rate of two inches per minute and as each horizontal line is spaced one inch, these horizontal divisions are equal to 30 seconds.

Note: The time values shown on these horizontal lines should be ignored, as a standard chart is used for commercial reasons.

2. The pen will traverse the chart in approximately 10 seconds. By means of a special circuit arrangement, the recorder pen follows the sputtering of the fusee without any tendency to overshoot or hunt, a condition often found on so-called faster recorders.

3. The recorder is calibrated in terms of the illumination on the photoelectric cell, the actual ranges being 0 to 20, 0 to 40, and 0 to 80 foot candles. Specifications on the fusees specify values in candlepower, but in order to make the recorder more versatile the foot candle calibration was decided upon. From the inverse square law of illumination, the candlepower of a light source is equal to the foot candles multiplied by the square of the distance in feet. If the distance between the fusee and the photocell is set at a distance of the square root of 10 (3.16) feet, then the candlepower ranges of the recorder are 200, 400 and 800; hence the chart readings must be multiplied by 10, 20 or 40 to obtain candlepower. If larger light sources are to be tested, the distance can be increased and, therefore, the candlepower range increased ad infinitum.

Photoelectric Cell Assembly

The Photoelectric Cell Assembly consists of a photoelectric cell, a correction filter, an attenuating circuit and a three-point selector switch all mounted in a bakelite case as shown in Figure 3.

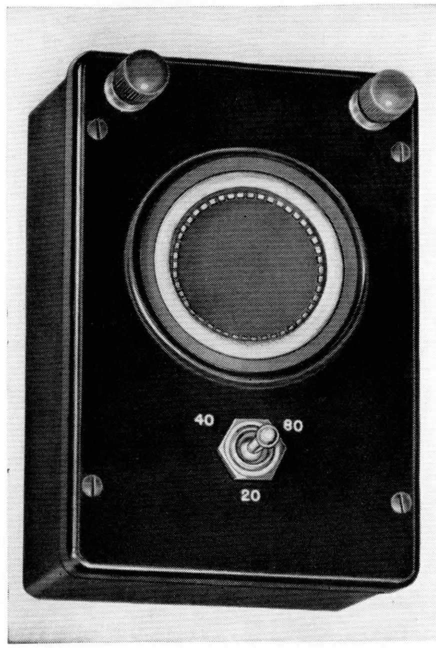

Figure 3—The Photoelectric Cell Assembly.

The photoelectric cell is a barrier-layer (dry disc) type, as manufactured by the Weston Electrical Instrument Corp. for over 15 years and marketed under the trade name of the *PHOTRONIC Photoelectric Cell. In order that the cell shall respond to the various colored fusees in the same manner as the average human eye, a *VISCOR or visual correction filter is mounted over the cell. By means of the attenuating resistors and the selector switch, any one of the three recorder ranges may be quickly and easily selected.

Discussion of Chart Record

Reverting to Figure 1, this graphically shows the characteristics of a 10-minute red fusee. At the start of the test it will be seen that the fusee required about 0.9 of a division of chart travel, or 27 seconds, before it reached the minimum specified value of five foot candles or 50 candlepower. It then increased to 69 candlepower and quickly dropped to 23.5 candlepower and remained below 50 candlepower for about 1.1 divisions of chart travel, or 33 seconds, before it became relatively stable. During the next 8.3 minutes it remained between 61.5 and 173.5 candlepower and then burned out

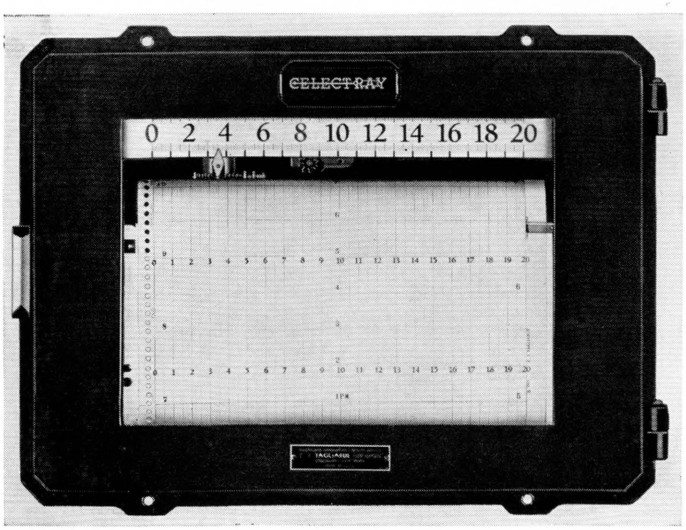

Figure 2—The TAG CELECTRAY Recorder illustrated here is a photomechanical type in which a mirror type of galvanometer reflects light on and off a phototube.

* *Registered Trade-Marks.*

after a total burning time of 9.5 minutes. An analysis of this record would justify rejection of the fusee because of the characteristics at the start of the test and the short burning time, and yet the manufacturer greatly exceeded the specification of 70 candlepower by about 50% during 80% of the burning time, and was as high as 2.5 times the specified candlepower at one time. Actually the manufacturer could, if he had possessed the proper data, as shown on the chart, reduce his costs and at the same time build a fusee which would pass the specifications. It is a perfect example of the statement credited to an old philosopher, "To measure is to economize."

General

Although the above refers specifically to a light recorder for the testing of fusees, the recorder can be used for many other applications. By means of special mounting fixtures, special filters, etc., light recorders of practically any desired range or ranges can be supplied.

E. N.—No. 74 —*A. T. Williams*

THERMAL PROBLEMS RELATING TO MEASURING AND CONTROL DEVICES—PART VII. DISTRIBUTION OF TEMPERATURE ALONG UNIFORMLY HEATED CONDUCTORS

Distribution of temperature along a conductor connected between heat absorbing terminals at any time after the initial application of current through it, or radiant energy upon it, uniformly distributed over its surface and absorbed by it.

Introduction

IN A PREVIOUS paper(1) by the author, a study was made of the steady state temperature distribution of temperature along a conductor heated by current or by radiant energy applied to its surface.

This part of the present series will consider the transient temperature conditions, and determine the distribution of temperature along the conductor at any time after the initial application of the heating means. Two conditions of cooling will be studied: (1) when the heat generated is dissipated both by conduction through the conductor to the terminals, and by convection from the surface to the surrounding medium, and (2) when the conductor is so short thermally, that it may be assumed that all of the heat generated, not absorbed by the material, is conducted to the terminals.

This analysis may be applied to the permissible duration of overloads in shunts; to fuses; to time constants and response time of thermocouple ammeters; radiation thermopiles; and other conductors.

21. GENERAL CONDUCTOR.

The general conductor is a conductor in which the Heat is Dissipated Both by Conduction to the Terminals, and by Convection from the Surface to the Surrounding Medium.

Figure 17 illustrates a conductor of uniform cross-section connected between heat absorbing terminals T_1 and T_2, both of which are assumed to be at the same temperature as the surrounding medium.

Let heat be suddenly applied uniformly to the conductor, as for example, by an electric current through it, or radiant flux on its surface and continued at a constant rate. Let the dotted curve show the temperature distribution at any time, and the full curve the final temperature distribution after a relatively long time.

List of Principal Symbols Used

A = area of cross-section of conductor; cm².
α = diffusivity of conductor material $= k/(sm)$.
β = thermal length of conductor $= L\sqrt{h/(Ak)}$; hyperbolic radians.
h = rate of heat convection from conductor per unit length; watts per cm. per deg. C.
k = thermal conductivity of conductor; watts, cm. deg. C.
L = length of conductor; cm.
m = density of conductor material; grams per cm³.
ρ = electrical resistivity of conductor material; ohms-cm³.
s = heat capacity of conductor per gram per degree; joules/gm. deg. C.
t = time from initial application of heat; seconds.
t_o = time constant of conductor; seconds.
θ = temperature elevation of conductor at any time after initial application of heat, and at any part of the conductor.
$\theta_c = V^2/(8k\rho)$ = maximum temperature elevation at the mid-point of a conductor in which all heat is conducted to the terminals.
u = hyberbolic angle per cm. length of conductor $= \sqrt{h/(Ak)} = \beta/L$.
V = difference of potential between terminals; volts.
w = rate at which heat is added per unit length of conductor; watts/cm.
x = distance from terminal T_1 to any section of conductor; cm.

General Heating Means: As the most general means of heating, let us consider that heat is added to the conductor uniformly at a rate of w watts per cm. length, as for example, by an electric current, as in shunts, fuses and other conductors, or by radiant energy received upon the surface and absorbed by it, as in thermopile radiation meters and bolometers.

As will be shown later, the temperature elevation θ of the conductor at any distance x from the terminal

T_1, and at any time t after the initial application of the heat is

$$\theta=\frac{wL^2}{\beta^2Ak}\left(1-\frac{\sinh\,(1-x/L)\beta+\sinh\,x\beta/L}{\sinh\,\beta}\right)$$

$$-\frac{4wL^2}{Ak}\left[\frac{\epsilon^{-\frac{\alpha(\pi^2+\beta^2)t}{L^2}}}{\pi(\pi^2+\beta^2)}\sin\frac{\pi x}{L}+\frac{\epsilon^{-\frac{\alpha(3^2\pi^2+\beta^2)t}{L^2}}}{3\pi(3^2\pi^2+\beta^2)}\sin\frac{3\pi x}{L}+\ldots\right] \quad (111)$$

For the meaning of the symbols, see List of Symbols.

Conductor Heated by Electric Current: Where the heat is produced in the conductor by an electric current which develops a difference of potential of V volts between terminals, and the heat is dissipated both by conduction and convection, the temperature elevation at any distance x from the terminal T_1 and at any time t, as deduced from Equation (111), is

$$\theta_{xt}=\frac{V^2}{\beta^2k\rho}\left(1-\frac{\sinh\,(1-x/L)\beta+\sinh\,x\beta/L}{\sinh\,\beta}\right)$$

$$-\frac{4V^2}{k\rho}\left[\frac{\epsilon^{-\frac{\alpha(\pi^2+\beta^2)t}{L^2}}}{\pi(\pi^2+\beta^2)}\sin\frac{\pi x}{L}+\frac{\epsilon^{-\frac{\alpha(3^2\pi^2+\beta^2)t}{L^2}}}{3\pi(3^2\pi^2+\beta^2)}\sin\frac{3\pi x}{L}+\ldots\right] \quad (112)$$

Time Constants: The reciprocals of the coefficients of t in Equations (111) and (112) have the dimensions of time, and are functions of constants and system parameters, and, therefore, may be considered as time constants. It is thus evident that there is no one definite time constant that applies to this case as was found previously for simple bodies. However, in many practical cases the second and succeeding terms in the series in Equations (111) and (112) are small relative to the first term, so that the time constant in the first term is the principal time constant and for most practical purpose may be considered as controlling. The principal time constant then is

$$t_o=\frac{L^2}{\alpha(\pi^2+\beta^2)};\ seconds \quad (113)$$

This equation may be written

$$t_o=\frac{1}{\frac{\alpha\pi^2}{L^2}+\frac{\alpha\beta^2}{L^2}};\ seconds \quad (114)$$

It is interesting to note that in this equation, $L^2/(\alpha\pi^2)$ is the time constant which would result if all the heat not absorbed were dissipated by conduction to the terminals, and none by convection from the surface; and $L^2/(\alpha\beta^2)$ is the time constant for the condition that all heat not absorbed is dissipated by convection to the surrounding medium. This shows that the time constants are combined in the same manner as parallel resistors and other similar quantities. From these equations, the time constant of the conductor, and from it the response time, may be computed directly from known or readily determined parameters, as will be shown in examples later.

Final Temperature Distribution: The temperature elevation at any point reaches its final maximum value when $t=\infty$. When this is substituted in Equation (111), we obtain the temperature elevation at any part of the conductor for the general case where heat is added at the rate of w watts per cm. length,

$$\theta\Big]_{t=\infty}=\frac{wL^2}{\beta^2Ak}\left(1-\frac{\sinh\,(1-x/L)\beta+\sinh\,x\beta/L}{\sinh\,\beta}\right) \quad (115)$$

and for the case where an electric current produces a difference of potential of V volts between terminals.

$$\theta\Big]_{t=\infty}=\frac{V^2}{\beta^2k\rho}\left(1-\frac{\sinh\,(1-x/L)\beta+\sinh\,x\beta/L}{\sinh\,\beta}\right) \quad (116)$$

These equations are the same as found in the reference paper(1) for steady state conditions.

Temperature Elevation of the Conductor Midway Between Terminals at Any Time: The temperature elevation at any time t, of the mid-point on the conductor, may be determined by substituting $x=L/2$ in Equation (112) and we find for the case where the conductor is heated by an electric current, the temperature elevation at any time at the mid-point is

$$\theta_{ct}=\frac{V^2}{\beta^2k\rho}\left(1-\frac{1}{\cosh\,\beta/2}\right)-\frac{4V^2}{k\rho}\left[\frac{\epsilon^{-\frac{\alpha(\pi^2+\beta^2)t}{L^2}}}{\pi(\pi^2+\beta^2)}-\frac{\epsilon^{-\frac{\alpha(3^2\pi^2+\beta^2)t}{L^2}}}{3\pi(3^2\pi^2+\beta^2)}+\ldots\right] \quad (117)$$

A similar equation, with coefficients given in Equation (111), gives the temperature at the mid-point of the conductor at any time, when heat is added at the rate of w watts per cm. length.

The maximum temperature elevation, θ_m, at the mid-point of the conductor is reached when $t=\infty$. Placing this value for t in Equation (117) we have

$$\theta_m=\frac{V^2}{\beta^2k\rho}\left(1-\frac{1}{\cosh\,\beta/2}\right) \quad (118)$$

It is convenient to express the temperature elevation, θ_{ct}, at any time at the mid-point of the conductor, in

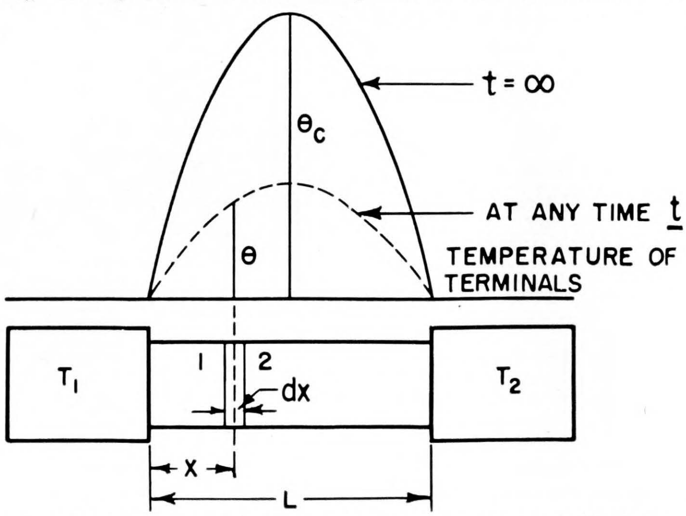

Figure 17—Temperature-time distribution diagram for a conductor connected between heat absorbing terminals, heated uniformly at a constant rate and, in general, cooled by conduction to the terminals, and by convection to the surrounding medium.

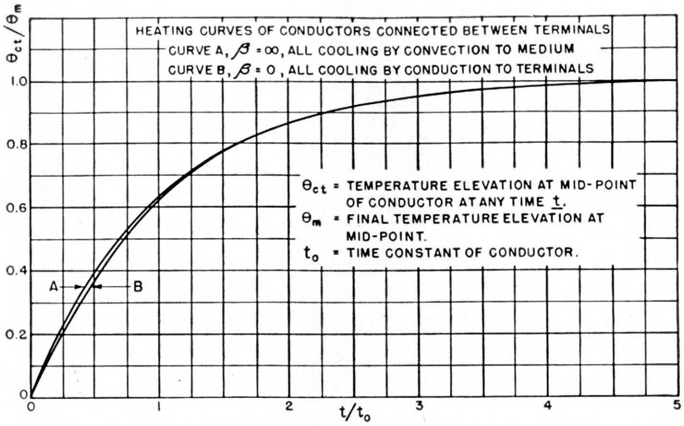

Figure 18—Temperature-time heating curves for the mid-point of the heated general conductor, as illustrated and described in Figure 17, for various values of thermal length, β. To make the curves universally applicable, temperatures are given relative to the maximum temperature θ_m, and time, relative to the time constant, t_o. *Note:* The curves for $\beta = 8$, and $\beta = 0$ are so nearly alike that they are difficult to separate in drawing.

terms of the maximum temperature elevation at that point. This is obtained by dividing Equation (117) by (118) and we have

$$\frac{\theta_{ct}}{\theta_m} = 1 - \frac{4\beta^2}{\pi\left(1 - \frac{1}{\cosh \beta/2}\right)} \left[\frac{\epsilon^{-\frac{\alpha(\pi^2+\beta^2)t}{L^2}}}{\pi^2+\beta^2} - \frac{\epsilon^{-\frac{\alpha(3^2\pi^2+\beta^2)t}{L^2}}}{3(3^2\pi^2+\beta^2)} + \ldots \right] \quad (119)$$

Equation (119) may be written in terms of the time constant $t_o = L^2/[\alpha(\pi^2+\beta^2)]$ as follows:

$$\frac{\theta_{ct}}{\theta_m} = 1 - \frac{4\beta^2}{\pi\left(1 - \frac{1}{\cosh \beta/2}\right)} \left[\frac{\epsilon^{-\frac{t}{t_o}}}{(\pi^2+\beta^2)} - \frac{\epsilon^{-\left(\frac{3^2\pi^2+\beta^2}{\pi^2+\beta^2}\right)\frac{t}{t_o}}}{3(3^2\pi^2+\beta^2)} + \ldots \right] \quad (120)$$

by which the increase in temperature at the mid-point, relative to the maximum temperature, may be computed for any time in terms of the principal time constant. Figure 18 shows curves computed by this equation for a very short thermal length, $\beta = 0$; for a very long thermal length, $\beta = \infty$, and for $\beta = 8$ hyp. radians which departs slightly more from the simple exponential heating curve than that for $\beta = 0$.

Temperature Elevation at the Mid-Point of the Conductor Reached in a Time Equal to the Time Constant: The temperature elevation at the mid-point of the conductor which results in a time equal to the time constant t_o may be computed by substituting $t/t_o = 1$ in Equation (120).

Figure 19, Curve A, illustrates this proportional temperature elevation during a time $t = t_o$, for various values of β, as computed from Equation (120).

It will be observed at $\beta = 0$, which is the condition where all of the heat produced not absorbed, is conducted to the terminals and none lost by convection, that is, the thermal length of the conductor is very short, the temperature increases to 62.03 per cent of the final and maximum value in a time $t = t_o = L^2/(\alpha\pi^2)$. This temperature increase differs from the value of 63.21 per cent found previously for simple bodies. The latter figure is often used erroneously as the criterion of time constants in general.

At the other extreme where the conductor is so long thermally, that is, where the convection losses are so large relatively that the temperature at the mid-point is practically unaffected by the terminal cooling, then in a time equal to its time constant, which under this condition is $t_o = L^2/(\alpha\beta^2)$, the temperature increases to 63.21 per cent of its final value. This is the same value as found previously for simple bodies.

Between the two extremes referred to, the relative temperature increase during a time $t = t_o$ dips to 60.08 per cent for a thermal length of conductor $\beta = 8$ hyperbolic radians.

Response Time: In thermal instruments, such as thermoammeters, thermovoltmeters, radiation measuring devices and so forth, it is desirable to know the time required for the temperature to reach sufficiently close to its final value to enable a reading to be taken. This is known as the response time, which is often defined as the time required for any changing quantity to reach 99 per cent of its final value.

To compute the response time of a conductor being heated, Equation (120) may be used in which 0.99 is substituted for θ_{ct}/θ_m, from which the relative time t/t_o can be found for any value of β. For values of β less than 5, only the first term of the series need be used, as the following terms become relatively negligible. In Figure 19, curve B gives the relative response time, as defined, for conductors of various thermal lengths, β.

Examples of the Use of the Equations:

Example 1: As a practical example, let us consider a shunt consisting of a single sheet of manganin, 4 inches long, 1 inch wide and 0.040 inch thick, connected between terminals. Sufficient current is passed through

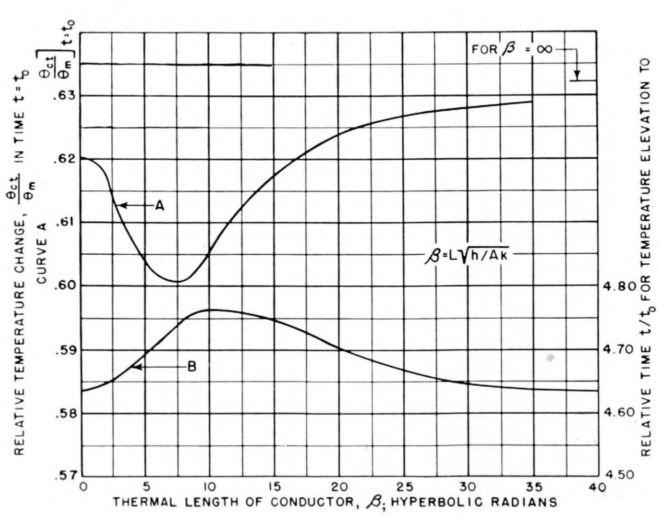

Figure 19—Temperature-time relations in a heated general conductor, as illustrated in Figure 17. *Curve A* shows the increase in temperature, θ_{ct}, at the mid-point, relative to the maximum temperature, θ_m, which takes place in a time equal to the time constant t_o. *Curve B* shows the time, relative to the time constant t_o, required for the temperature increase to reach 99 per cent of its final value θ_m, both for various values of thermal length, β.

it to produce a difference of potential between terminals of 100 millivolts.

The following are the physical constants involved for manganin. Thermal conductivity $k=0.26$ *watt—cm.—deg. C.* Electrical resistivity $\rho=40\times10^{-6}$ *ohm-cm. cube.* Heat capacity per gram per degree, $s=0.42$ *joule/gm./deg. C.* Density, $m=8.5$ *grams per cu. cm.* Length of conductor $L=4$ in. $=10.16$ *cm.* Area of cross-section $A=0.258\ cm^2$. Rate of convection from surface in still air as previously given [2], is 0.00892 watt per sq. inch per deg. C. Rate of convection per cm. length of conductor, $h=0.00703$ *watt/cm.* Then the thermal length of the conductor is

$$\beta=L\sqrt{\frac{h}{Ak}}=10.16\sqrt{\frac{0.00703}{0.258\times0.26}}=3.29\ \text{hyperbolic radians.}$$

The diffusivity, $\alpha=\frac{k}{sm}=\frac{0.26}{0.42\times8.5}=0.0728.$

Then from Equation (118), the final and maximum temperature at the mid-point of the conductor is

$$\theta_m=\frac{(0.1)^2}{(3.29)^2\times0.26\times40\times10^{-6}}\left(1-\frac{1}{\cosh 1.645}\right)$$

or $\theta_m=55.7$ *deg. C.* above ambient.

The *time constant* from Equation (113) is

$$t_o=\frac{(10.16)^2}{0.0728[\pi^2+(3.29)^2]}=68.5\ \text{seconds.}$$

The temperature increase which takes place in a time equal to the time constant is found by substituting $\beta=3.29$ in Equation (120), and is also given by the curve in Figure 19, which we find to be 61.03 per cent.

The response time, as defined previously, may be computed by Equation (120) by making $\theta_{ct}/\theta_m=0.99$, and substituting the value of $\beta=3.29$, using the first term only of the series.

Then we have

$$0.99=1-\frac{4\times(3.29)^2}{\left(1-\frac{1}{\cosh 1.645}\right)}\times\frac{\epsilon^{t/t_o}}{(\pi^2+(3.29)^2)}$$

From which, $\epsilon^{t/t_o}=0.00945$ and $t/t_o=4.66$ as shown also in curve B of Figure 19. Then the response time $t_r=4.66\times68.5=319$ *seconds.*

Example 2: At the other extreme we may consider the small conductor used as the heating element in thermo-ammeters for measuring currents at radio frequencies.

By the same procedure as given in Example 1, it is found that the time constant is about 0.2 second, and the response time about 0.95 second.

Devices for Measurement of Radiant Flux: Since Equation (120) is independent of the means used for heating a conductor, provided that the heat generated is uniformly distributed over it, the time constant and the relative transient conditions are computed exactly as those just given for the electrically heated conductor. The final temperature at the mid-point, however, may be computed by Equation (115) by substituting the values of the radiant flux, w watts per unit area, and $x=L/2$, as in Equation (118).

References:

(1) *W. N. Goodwin, Jr.*, The Compensated Thermocouple Ammeter, Trans. A.I.E.E., Vol. 55, Page 23, 1936.

(2) *W. N. Goodwin, Jr.*, Thermal Problems, Part III, WESTON ENGINEERING NOTES, Vol. 3, No. 4, Page 8, Aug., 1948.

E. N.—No. 75 —*W. N. Goodwin, Jr.*

Part VII will be continued in a future issue of ENGINEERING NOTES. *It will consider the special case in which all the heat generated, not absorbed, is conducted to the terminals; and also the derivation of the fundamental equations.*

TACHOMETERS FOR HAZARDOUS LOCATIONS

IT IS frequently necessary to mount tachometer generators and indicators in locations which impose more or less severe operational conditions, such as mechanical abuse, water spray, or even in explosive atmospheres. To cope with such conditions, it is usually necessary to house the equipment in accordance with the condition.

The Weston Type C generator housing, which has been available for many years, serves adequately under conditions of mechanical abuse, and since it is gasket sealed it will operate in wet locations, such as are found in paper mills and in chemical plants where cleaning up by a hose is frequent. Tachometer generators in the Type C housing have also been found satisfactory for mounting on diesel engines where considerable vibration exists. The indicating instrument itself presents a somewhat different problem and, of course, if it is mounted remotely from the tachometer generator it may be of conventional type, or with a special high torque mechanism to take care of vibration. Waterproof indicating instruments are also available where required.

Service in an explosive atmos-

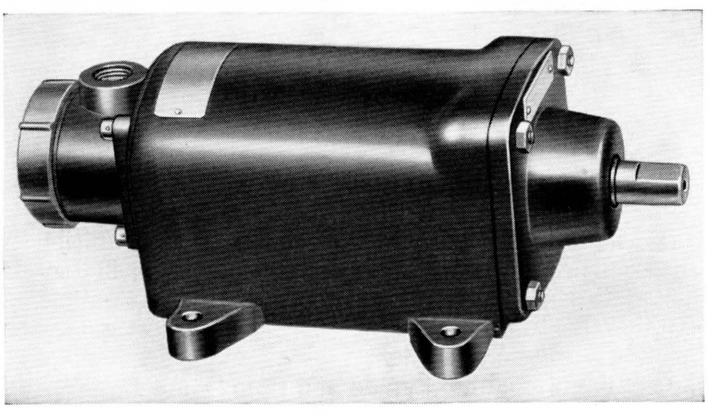

Figure 1—The new explosion-proof Weston Tachometer Generator.

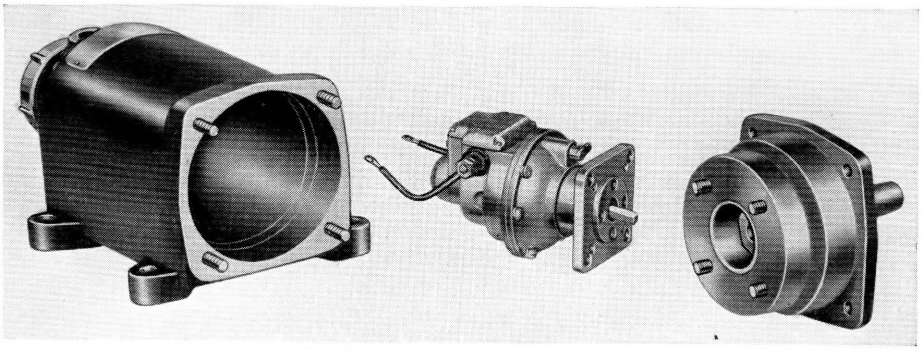

Figure 2—An internal view of the explosion-proof tachometer generator, showing the driving end and generator removed.

phere presents further hazards and it is necessary in such applications that the electrical equipment meet the standards of performance set by the Underwriters' Laboratories Inc. for such locations. This group has taken cognizance of the hazards of electrical equipment in explosive atmospheres and has broken down the requirements into Class 1, where the vapors are explosive, and Class 2, where the explosive material consists of dusts of various kinds.

These classes are further subdivided, and perhaps the one of greatest industrial importance is Class 1, Group D, covering atmospheres containing either natural gas or the vapors from lacquer solvents, acetone, alcohols and petroleum derivatives, such as gasoline. Also of interest industrially are Groups F and G under Class 2, covering carbon black, coal or coke dust and grain dust.

In the first instance, protection against the vapors from volatile liquids requires that even if the vapors enter the device and an explosion occurs inside the device, no flame can emerge. Essentially, the requirements include a long flame path between contiguous metal surfaces, no gaskets being allowed, as well as an actual test of the device wherein specific gas mixtures inside the device are exploded by a spark plug.

With regard to the Class 2 requirements, it is essential that the dust in question be prevented from entering the device at least to the extent which could cause any damage to such internal parts as the bearings, causing them to overheat and possibly ignite the dust outside the device. It must also be of such design that the device can be completely blanketed with the dust in question without overheating to the point where the outside dust might become ignited.

It might be pointed out that explosion-proof housings for several types of indicating instruments are currently available so that the problem is confined to the tachometer generator proper. Since a rotating shaft is present and some servicing is required, it is not possible to seal the generator as simply as the instrument and a special design is required.

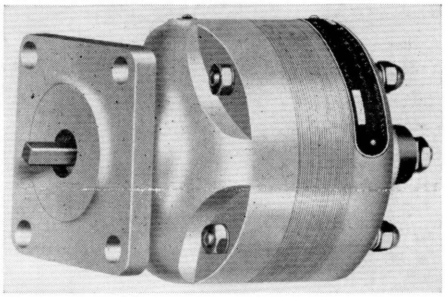

Figure 3—The Weston Model 758 a-c generator, shown above, can also be used in place of the d-c generator, shown in Figure 2.

In somewhat greater detail, where parts of the case or housing join, no gaskets are permitted since they might be accidentally omitted in a servicing operation, thereby losing protection. Joints must be metal-to-metal of definite width and clearance. Where a revolving shaft protrudes through the housing, the bearing assembly must include metal-to-metal paths of definite length related to the maximum clearance between the parts; to take care of the requirement for preventing dust entrance, a suitable restriction must also be included. Fortunately the power dissipation is so small that the temperature rise even under a blanket of dust is well within the requirements.

The new explosion-proof Weston tachometer generator designed to conform with all of these requirements is shown in Figure 1. It is listed by the Underwriters' Laboratories Inc. as satisfactory for use in explosive atmospheres, Class 1, Group D and Class 2, Groups F and G as described above.

Figure 2 shows the driving end removed and the long cylindrical restricted flame path will be noted. The generator is mounted to the outboard bearing housing and coupled to the outboard shaft by a flexible coupling assuring self-alignment. The unit may be readily removed from the housing for servicing.

The Model 750 d-c generator shown has the same electrical characteristics as the older Model 44, namely: 20-ohms resistance and a generated voltage of 6 volts per thousand rpm. Alternatively, a Model 758 a-c generator shown in Figure 3 can be furnished, which is an 8-pole generator having a resistance of 100 ohms, and it generates 10 volts at

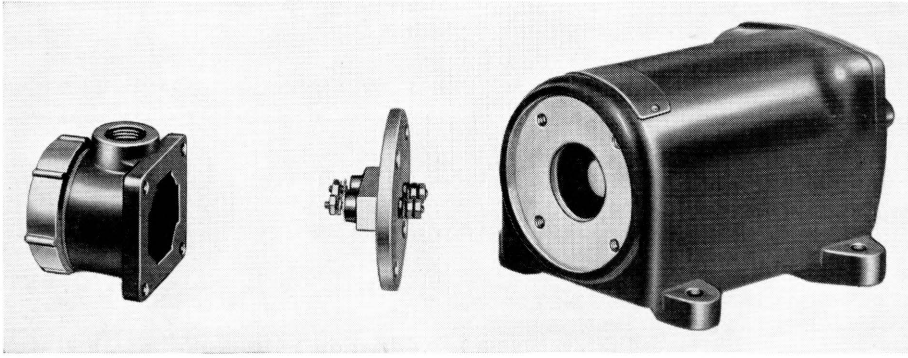

Figure 4—An internal view of the connection end of the explosion-proof tachometer generator, showing the special binding post assembly and housing removed.

thousand rpm. Having no brushes, the a-c generator is somewhat simpler than the direct current machine and requires less service; by the same token, it must be used with a rectifier or other high sensitivity a-c instrument, the accuracy of which is slightly less than that of the straight d-c combination. The characteristics of these generators are described in WESTON ENGINEERING NOTES, Vol. 4, No. 2, April 1949.

Figure 4 shows the connection end of the housing removed with the long flame path joints and the special binding post assembly visible. The terminal box itself is arranged so that conduit, with ½″ pipe thread, may be oriented in any of four directions. The terminal housing is closed by a screw cap which may be removed to connect the line wires to the binding posts. Even if the screw cap is removed the generator is adequately protected but, of course, the cap should be turned up tight to protect the conduit and wiring.

These explosion-proof generators carry the Underwriters' Laboratories Inc. label and are suitable for use in oil refineries or wherever explosive petroleum gasses may permeate the surroundings. They are also suitable for speed indications in grain elevators, flour mills, and plants making starch and other explosive powders. Occasionally they find service as part of coal mining equipment.

E. N.—No. 76 *—A. H. Wolferz*

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WESTON representatives are well qualified as consultants on instrumentation problems and are listed below for the convenience of those readers who may desire information on Weston or Tagliabue instruments, beyond that provided in articles appearing in WESTON ENGINEERING NOTES.

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