CAMBRIDGE TEMPERATURE MEASURING INSTRUMENTS

Booklet No. 1.

CAMBRIDGE TEMPERATURE MEASURING INSTRUMENTS

~~THE~~ CAMBRIDGE ~~AND PAUL~~ INSTRUMENT CO. LTD.

Head Office and Showrooms:

45, GROSVENOR PLACE, LONDON, S.W.1

Telegrams: "Unipivot, Sowest, London."   Telephone: Victoria 7640 (3 lines).

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INTRODUCTION

WE are constantly reminded of the fact that a general catalogue dealing with Cambridge Instruments would be of service to our customers. The field covered by these instruments is so large and varied that a full descriptive list, arranged on the lines of our standard catalogues, would be too bulky in character to be of much service save as a book of reference. It is, therefore, with the object of providing the desired information in a concise, portable form that we are issuing a series of small lists, each covering a distinct group of our instruments. The present booklet, which is the first of the series, deals with instruments for the measurement of temperature, the complete series consisting of :—

I.—Temperature Measuring Instruments.

II.—Engineering Instruments.

III.—Electrical Instruments for D. C. Measurements.

IV.—Electrical Instruments for A. C. Measurements.

V.—Physical, Physiological and Medical Instruments.

VI.—Special Instruments.

The range of instruments which we make in connection with the measurement of temperature is so complete that in a booklet of this size it is not possible to give more than brief notes regarding the construction and capabilities of each instrument. In connection with each description, however, reference is made to the more detailed technical catalogue which deals with the same subject, and it is hoped that readers will apply for such catalogues when they require further information. It will be noticed that for any particular range of temperature a number of alternative types of measuring instruments can be used, and, in order to assist in the decision as to which should be employed for a particular purpose, a brief note on the advantages of each

INTRODUCTION—*continued.*

instrument is embodied in the description. It is, however, impossible to make a definite statement to which is the best type of instrument for any particular purpose, as the decision depends on so many factors, such as the temperature range, the number of measurements to be made, and whether the readings are to be taken at one central position or at a number of points. The question as to whether continuous records of the temperature are required has also to be considered. Those of our customers who are undecided as to the best instrument for their purpose are urged to avail themselves of our experience in the practical solution of temperature-measuring problems.

It is frequently desirable not only to measure the temperature of a furnace, etc., but to control the temperature automatically so that it is kept within certain predetermined limits. The apparatus described on pages 58 to 68 is now being widely used in this connection. It can be employed to control temperatures from the lowest measurable by a resistance thermometer, to the highest that can be determined by a Féry radiation pyrometer ; it can also be used to operate alarms or coloured lights. In addition to being sensitive, accurate, and quick in action it is so robust in construction as to give continuous satisfactory service under the most rigorous conditions.

When a number of thermo-electric pyrometers are installed in a works it is advisable that the accuracy of the thermo-couples should be checked from time to time. This is imperative where extreme accuracy is required. It is desirable, therefore, to have some simple form of potentiometer whereby these tests can be quickly and accurately made. A section of this catalogue is devoted to descriptions of potentiometers, which, owing to their construction, ease of manipulation, and accuracy, form a useful accessory to temperature-measuring outfits in the laboratory and workshop. The complete range of our potentiometers is described in Booklet III. of this series.

GLASS THERMOMETERS

Straight Pattern

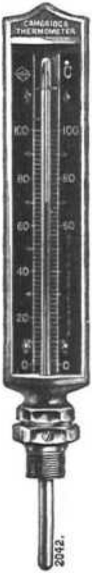

Fig. 1.

MERCURY-IN-GLASS Thermometers are the simplest instruments for measuring temperature, and on this account, and also on account of their cheapness, they are largely used. Of necessity they are less robust than either the electrical or the mechanical type, and are harder to read when the positions where they are inserted are difficult of access, but, provided that the thermometers are efficiently protected, there are many applications where they give satisfactory service. Careful attention has been given to every detail in the construction of Cambridge Glass Thermometers, which are well known for the manner in which they are protected against accidental damage, for their clear scales, accuracy and finish. The V-shaped scale cases are 12 inches, 9 inches or 7 inches in length, depending upon the purpose for which the thermometer is required; the figuring is white on a black background. The thermometer tubes and bulbs are made of selected hard glass, and are thoroughly annealed and aged to ensure constancy; the tubes are lens-fronted to facilitate the reading of the mercury column. The thermometers are supplied in various patterns. Figs. 1 and 2 show the standard thermometers for measuring condenser, feed-water, economiser and superheated steam temperatures. The scale case is 9 inches long. The bulb fits into a detachable socket which

GLASS THERMOMETERS

Angle Pattern

is screwed in position at the point at which the temperature is to be read, so that the thermometer itself can be removed from the socket at any time for examination, without shutting down the plant. In the standard instruments the sockets are screwed $\frac{3}{4}$-inch gas thread, but they can be screwed 1-inch or $\frac{1}{2}$-inch gas thread if desired. Sometimes it is convenient to use the right-angle pattern, shown in Fig. 2, rather than the straight pattern shown in Fig. 1. The standard ranges for both patterns are :—

Fig. 2.

30° to 160°F., or 0° to 70°C.
Suitable for condensers.

40° to 240°F., or 5° to 115°C.
Suitable for boiler feed-water.

50° to 300°F., or 0° to 150°C.
50° to 400°F., or 0° to 200°C. } Suitable for economisers.

200° to 750°F., or 100° to 400°C.
200° to 1000°F., or 100° to 540°C. } Suitable for superheaters, etc.,

but the thermometers can be calibrated to cover any range of temperature up to 1000° F. (or 540° C.). Numbers of these thermometers have been supplied for use in the boiler house and engine room, and for temperatures on board ship.

Further particulars are given in List No. 114.

GLASS THERMOMETERS

Long Stem and Stem-Divided Patterns

Fig. 3.

Fig. 4.

CAMBRIDGE long stem glass thermometers are used in many processes, such as varnish-making, oil-boiling and gum-melting; jam-making, sugar-boiling and baking; and measurement of flue gas and molten metal temperatures.

Various patterns are made to suit the various applications, but in every pattern the glass tube is protected by inner and outer metal tubes with asbestos packing. Fig. 4 shows the standard flue gas thermometer; the stem lengths are 36 inches and 48 inches. A right angle stem can be fitted instead of the straight stem. Fig. 3 illustrates the standard molten metal thermometer; the stem is 18 inches long. In both patterns the scale case is 12 inches long and the standard ranges are 200° – 750° F. (100° – 400° C.), and 200° – 1000° F. (100° – 540° C.). Figs. 5 and 6 show standard stem-divided thermometers, the pattern in Fig. 6 being provided with a steel case in which the glass tube is firmly fitted. These thermometers are made in many ranges up to 1000° F. (540° C.). The standard lengths are 8, 12, 14, and 16 inches.

Fig.5.

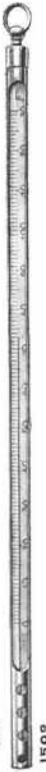

Fig.6.

Further particulars are given in List No. 114.

GLASS THERMOMETERS

For Refrigerating Plant

Fig. 7.

THE standard thermometer for taking temperatures in brine pipes, etc., of refrigerating plant is illustrated in Fig. 7; it is similar in construction to those already described. When the thermometer is permanently installed in any apparatus in which a temperature of less than 32° F. is maintained, it is provided with a heat-insulating device to keep the scale from being covered with frost. This device, indicated by an arrow in Fig. 7, not only serves to keep the scale clear, but also increases the accuracy of the instrument by preventing the warmer temperature of the scale case from affecting the temperature of the bulb. Insulated thermometers are furnished with an extension neck on the bulb socket, which allows for $1\frac{3}{4}$ inches thickness of lagging. Standard thermometers are screwed $\frac{3}{4}$-inch gas thread. The scale case is 7 inches long; the standard range is from −20° to +100° F. (from −30° to +40° C.). For ammonia work, the stem is lead-covered.

Fig. 8.

The thermometer illustrated in Fig. 8 is particularly useful in cold chambers where the temperature must be carefully watched. The scale case is so designed that when the thermometer is fixed on a wall there is ample space between the wall and the bulb for air to circulate freely round the bulb. The scale case is 12 inches long; the standard ranges are from −20° to +70° F. (from −30° to +20° C.) and from −20° to +120° F. (from −30° to +50° C.). The instruments are accurate, sensitive, durable, and easy to read.

Further particulars are given in List No. 114.

DIAL THERMOMETERS

2-inch Dial Patterns

Fig. 9.

SOMETIMES thermometers have to be inserted in positions where they are difficult to read, or it is essential that they should be fitted with alarm attachments which will ring a bell, light a lamp, or operate a switch when a certain temperature is reached. For such applications Cambridge Dial Thermometers should be employed rather than the Glass Thermometers previously described. These are simple, inexpensive, robust instruments designed for quantity production and made in certain standard types and ranges. The standard pattern for taking air temperatures is shown in Fig. 9. Inside the case of the instrument is a Bourdon gauge tube filled with a volatile liquid. Changes in the temperature of the instrument give rise to changes in the volume of the liquid, and the consequent movements of the Bourdon tube are communicated to a pointer which moves over a calibrated scale approximately 3½ inches (90 mm.) long. The instrument illustrated is fitted with an electric alarm attachment which can be arranged to give warning when the temperature reaches a certain predetermined figure; instruments so fitted are suitable for use as fire alarms.

Further particulars are given in List No. 112.

DIAL THERMOMETERS

2-inch Dial Patterns

Fig. 10.

THE Dial Thermometer in Fig. 10 is constructed on the same principle as the instrument illustrated on the preceding page, but a length of flexible tubing is introduced between the bulb and the dial, enabling the latter to be fixed in a convenient position some distance from where the temperature is being measured. The bulb and tubing are usually of nickel-plated copper, the bulb connection being screwed ½-inch gas thread. The fact that the steadiness of the pointer is not liable to be affected by vibration renders these instruments suitable for measuring the temperatures of oil engines on yachts and other small vessels. They are largely employed as radiator thermometers on motor cars and aeroplanes. They are also adapted for taking bearing temperatures; for this application it is sometimes desirable to fit them with electric alarm attachments which are arranged to ring a bell or light a lamp giving warning when the temperature reaches a certain predetermined value. The standard ranges for the patterns in Figs. 9 and 10 are 30°–100° C. and 90°–200° F.

Further particulars are given in List No. 112.

DIAL THERMOMETERS
4-inch Dial Patterns

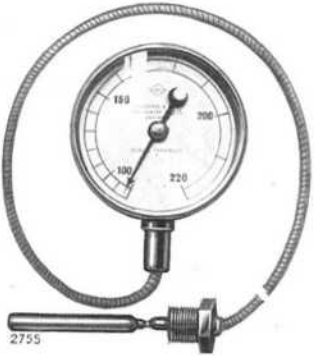

Fig. 11.

THE thermometer in Fig. 11 is constructed on similar principles to those described on pages 10 and 11, but has a larger dial, the scale being 9 inches (230 mm.) long. The instrument is fitted with a length of flexible tubing and a screwed connection (½-inch gas thread), enabling the bulb to be fixed directly in position. Standard instruments are fitted with either 6 or 20 feet of flexible tubing. A bracket enables the dial to be fitted to a wall or other support. The standard ranges are 90°–220° F. and 200°–400° F., or equivalent Centigrade ranges. When it is not desired to take readings some distance away from where the temperature is being measured, the flexible tubing is omitted and the dial mounted so that the distance between the bottom of the dial and the underside of the screwed flange is either 4 or 6 inches. The standard ranges for this pattern are 30°–120° F., 90°–220° F., and 200°–400° F., or corresponding Centigrade ranges.

Further particulars are given in List No. 112.

DIAL THERMOMETERS

4-inch Dial Patterns

Fig. 12.

IN the thermometer in Fig. 12, the bulb and tubing are enclosed in a metal stem provided with an adjustable flange to regulate the depth of immersion. In standard instruments the stem is 4 feet long. The thermometers are suitable for taking temperatures of liquids in tanks, baths, or other vessels, for ovens or stoves, and for transformer temperatures. If the stem is to be exposed to corrosive fumes, it is suitably protected by being coated with lead, tin, copper, brass, or other metal. For some applications the stem is nickel plated. It is sometimes convenient to have a length of tubing inserted between the dial and the rigid stem, enabling the former to be erected at some distance from the position where the temperature is being determined. 10 feet is the usual length of tubing fitted, but other lengths can be supplied to order. The standard ranges are 90°–220° F. and 200°–400° F., or corresponding Centigrade ranges.

Further particulars are given in List No. 112.

INDEX THERMOMETERS

8-inch Dial Patterns

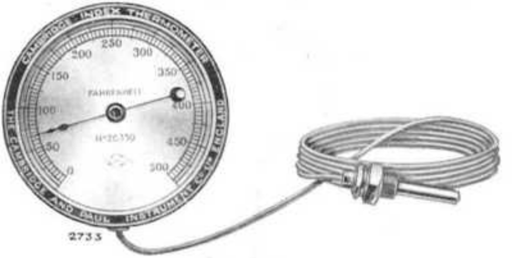

Fig. 13.

CAMBRIDGE Index Thermometers can be used to measure temperature from –40° to +1000° F. (–40° to +540° C.). The instruments can usually be calibrated to cover only the working range of temperatures, thereby ensuring the most open scale possible. This feature, taken in conjunction with their robust construction and permanent accuracy, renders them suitable for many applications. The bulb of the instrument, which is exposed to the temperature to be measured, is connected by a length of capillary tubing to a form of Bourdon gauge tube, the system being filled with mercury. Changes in the temperature of the bulb give rise to corresponding changes in pressure throughout the system, causing movements in the Bourdon tube which are magnified, and indicated by a pointer moving over a graduated scale. Any length up to 50 feet of capillary tubing can be supplied. The thermometer in Fig. 13 is fitted with a screwed connection ($\frac{3}{4}$-inch or 1-inch gas thread) by means of which the bulb can be fixed directly in position. This connection is suitable for temperatures in pipes, tanks, vats, or other vessels under pressure or suction.

Further particulars are given in List No. 112.

INDEX THERMOMETERS

13-inch Dial Patterns

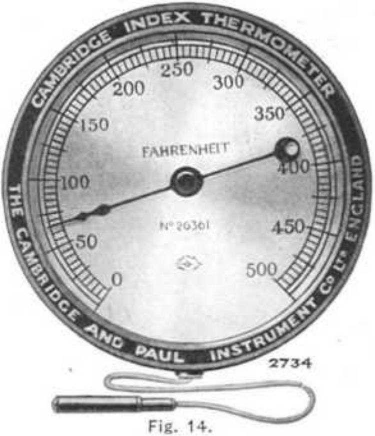

Fig. 14.

THE large dial pattern Index Thermometer is shown in Fig. 14. This illustration and that of the 8-inch dial pattern in Fig. 13 are reproduced to scale. It will be noticed that with the larger dial a greatly increased scale length is obtained, with consequent advantages of openness of scale and ease of reading. A large dial can be fitted to any Cambridge Index Thermometer; conversely, the instrument in Fig. 14 can be supplied with an 8-inch dial. This instrument is fitted with a length of capillary tubing and a plain bulb connection, suitable for insertion in existing pockets, for atmospheric temperatures and for temperatures of liquids in open tanks. The steel bulb is suitably protected when it is likely to be exposed to acids, corrosive fumes, etc. Many hundreds of such thermometers have been installed in refrigerating chambers, cold rooms and handling rooms in margarine works, yeast rooms in breweries, tinning baths in wire works, etc.

Further particulars are given in List No. 112.

INDEX THERMOMETERS

Straight Stem Patterns

Fig. 15.

Fig. 16.

IN the instruments shown in Figs. 15 and 16 the capillary tubing is covered by a rigid stem of any convenient length. Sometimes the stem and bulb are protected against corrosion by a coating of lead or other material. Fig. 15 shows a thermometer for flue gas temperatures. A length of capillary tubing may be inserted between the instrument and the rigid stem, which is fitted with an adjustable stop-flange for regulating the depth of immersion. Some applications are mentioned on page 22. The thermometer in Fig. 16 can be screwed directly into position. This instrument is fitted with an electric alarm attachment, by means of which a bell is rung if the temperature exceeds, or falls below, a certain predetermined value. This attachment, or a double alarm attachment arranged to give warning at both minimum and maximum temperatures, can be fitted to any Index Thermometer.

Further particulars are given in List No. 112.

INDEX THERMOMETERS

Angle Stem Patterns

THE illustrations, Figs. 17 and 18, show angle pattern thermometers which have been found of considerable service in industrial practice. Fig. 17 shows a thermometer suitable for temperatures in ovens, tanks, or other vessels when it is convenient to insert the stem of the instrument horizontally. The instrument illustrated in Fig. 18

Fig. 18.

Fig. 17.

is fitted with a screwed connection (¾-inch or 1-inch gas thread) for fixing directly in position. It is suitable for positions under pressure. Other patterns can be supplied for inaccessible positions, having the stems at suitable angles to enable the dials to be easily read. Any of the thermometers described on pages 16 and 17 can be fitted with a 13-inch dial as illustrated in Fig. 14, instead of with the 8-inch dial shown.

We shall be pleased to furnish details of types of instruments with rigid connections which we have supplied for special applications, or if prospective customers send a few details of their requirements we will submit particulars of a thermometer stem best suited to their conditions.

Further particulars are given in List No. 112.

INDEX THERMOMETERS
Locomotive Pattern

Fig. 19.

THE use of superheaters on locomotives necessitates the adoption of a reliable and accurate means of indicating to the engine-driver the temperature of the steam entering the engine cylinder. The temperature-measuring instruments used for this purpose must be capable of withstanding vibrations and other severe conditions of locomotive use. The Cambridge Index Thermometers previously described meet these requirements. The standard locomotive pattern is illustrated in Fig. 19. It is provided with a length of capillary tubing protected by asbestos, and a screwed bulb connection of suitable form for fixing into the superheater. Standard instruments are fitted with 25 feet of capillary tubing. The standard range is 200°–750° F. (100°–400° C.), but other ranges can be supplied. Numbers of these instruments are in use on the leading railways.

Further particulars are given in List No. 193.

THERMOGRAPHS
Self-Contained Pattern

Fig. 20.

A CAMBRIDGE Thermograph is similar in construction to an Index Thermometer (see page 14), but the dial and pointer are replaced by a circular chart, rotated by clockwork, on which a pen traces a continuous record of the temperature measured. The charts are 9½ inches in diameter. They rotate once in 24 hours or in 7 days; other speeds can be fitted when desired. To facilitate the changing of the chart a pen-lifting device holds the pen clear as soon as the door of the case is opened. The instruments can be used for all temperatures between –40° and +1000° F. (–40° and +540° C.), and charts for a large number of standard ranges are kept in stock; charts for other ranges can be supplied to order. In the thermograph in Fig. 20, a plain bulb projects a few inches from the underside of the case. This pattern is suitable for recording atmospheric and indoor temperatures.

Further particulars are given in List No. 112.

THERMOGRAPHS

With Capillary and Plain Bulb Connection

Fig. 21.

WHEN it is desired to erect a thermograph at some distance from the point where the temperature is being measured, any length up to 50 feet of capillary tubing is inserted between the bulb and the instrument (see Fig. 21). An instrument of this type is suitable for recording the temperatures in hop drying, malting kilns, fermenting tanks and yeast rooms in breweries; in core drying stoves; in brine tanks and cold rooms in refrigerating plant; in liquids in vats in chemical works, and in drying chambers where it is desirable to have the recording instrument mounted outside the room, the temperature of which is being measured. The bulb can be suitably protected from fumes, acids, etc., by being coated with lead, tin, copper, brass, or other metal. If the instrument is to be exposed to moisture or corrosive fumes, the recording movement should be mounted in the totally-enclosed case illustrated in Fig. 22, rather than that in Fig. 21.

Further particulars are given in List No. 112.

THERMOGRAPHS

Totally-Enclosed Pattern

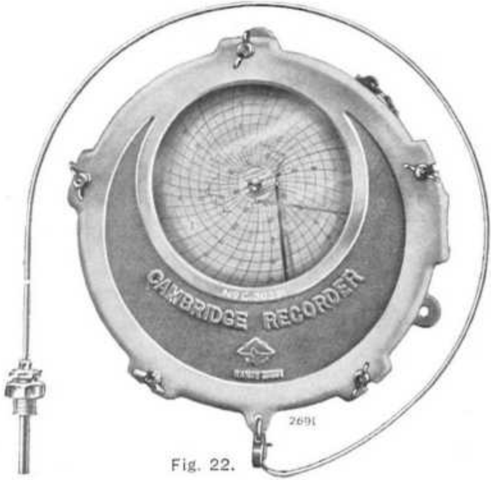

Fig. 22.

IN the thermograph shown in Fig. 22 the recording movement and chart are enclosed in a substantial watertight and fume-proof metal case. This pattern is particularly suitable for use on board ship, and for applications on land where the conditions are unfavourable. A number have been supplied to record the temperature of milk pasteurisers, the robust case preventing the moisture arising from the pasteurising operation from reaching the recording mechanism; for this application the cases can be finished in white enamel. The instrument illustrated is fitted with capillary tubing and a screwed bulb connection, suitable for fixing into pipes and other vessels under pressure or suction. The screwed bulb can be replaced by a plain bulb connection, or by a rigid stem bulb connection (see Figs. 21 and 23).

Further particulars are given in List No. 112.

THERMOGRAPHS

With Capillary and Rigid Stem

Fig. 23.

THE instrument shown in Fig. 23 is fitted with a length of capillary tubing and a rigid stem bulb connection; the latter, which may be of any convenient length, is provided with an adjustable stop-flange. Applications of this type of thermometer include recording the temperature of flue gases in boiler plant; core-drying ovens in foundries; acid-pickling tanks in tin-plate works; hot liquor tanks, mash tuns, and fermenting vats in breweries; liquids in vats in chemical works; ammonia, benzol, tar and glycerine stills; and those temperatures in tempering and annealing processes which come within the range of the instrument. When the stem is likely to be damaged by fumes, acids, etc., it may be suitably protected in the manner already described on page 16. If the thermograph is to be exposed to moisture or corrosive fumes, the recording movement should be mounted in the totally-enclosed case illustrated in Fig. 22.

Further particulars are given in List No. 112.

THERMOGRAPHS

Double Recorders

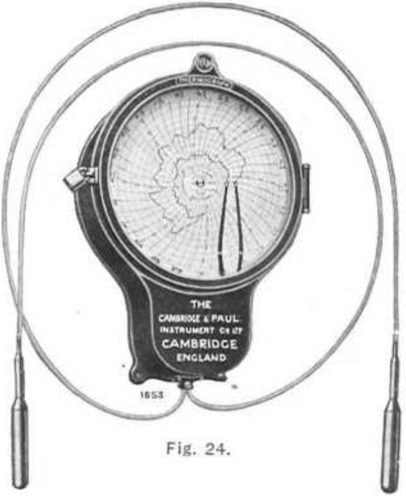

Fig. 24.

WHEN simultaneous records of two different temperatures are desired, the Double Recorder, shown in Fig. 24, should be used. In this instrument two independent systems are mounted in one case and register on one chart. The recorder illustrated is fitted with capillary tubing and plain bulb connections, but these may be replaced by screwed bulb connections, as Fig. 22, or rigid stem bulb connections, as Fig. 23. These instruments are suitable for recording the inlet and outlet gas, feed water or oil temperatures in power plant. They are largely used on wheat conditioners, grain dryers, etc. When the instrument is to be exposed to excessive moisture or corrosive fumes, the totally-enclosed case illustrated in Fig. 22 should replace that in Fig. 24.

Further particulars are given in List No. 112.

DISTANCE THERMOMETERS

Indicators

Fig. 25.
12 × 11 × 8 inches.

CAMBRIDGE Electrical Distance Thermometers possess the advantage that the temperatures at a large number of scattered points may be read on one indicator with an accuracy which is independent of the distance separating the points and the indicator. Recorders giving permanent records are also supplied. Frequently it is desirable to have an indicator for use of those operating the plant while the recorder is placed in the manager's office. In addition to being employed in connection with many industrial processes, these thermometers are now generally recommended by firms supplying power plant equipment, and are included in the standard specifications of leading consulting engineers. They are particularly suitable for use on board ship. The principle on which the measurements are made depends on the variation with temperature of the electrical resistance of a platinum wire. The thermometer element comprises a coil of platinum wire suitably encased and provided with terminals. The resistance of the element at different temperatures is measured on a galvanometer which embodies a modification of the Wheatstone Bridge. This variable resistance is compared with other resistances which do

Indicators

not change with temperature, their value being so adjusted that the Bridge is balanced at the commencing temperature of the range of the galvanometer. Any increase in the temperature of the element then causes the galvanometer pointer to move over a suitably calibrated scale. The instrument can be used for all temperatures from –330° to +1000° F. (–200° to +540° C.), and indicators and recorders can be calibrated to cover just the working range, thus giving the most open scale possible.

Fig. 26.
$26\frac{1}{2} \times 14\frac{1}{4} \times 9\frac{3}{4}$ inches.

The standard indicator for land installations is shown in Fig. 25, while the marine pattern is illustrated in Fig. 26. Both instruments are robust in construction, all sensitive parts being protected from dust, moisture, or fumes by a substantial watertight metal case. A multi-way switch enables any thermometer to be put in circuit. The indicator in Fig. 25 is made for 6, 12, and 18 points; while that in Fig. 26 is made for 12, 18, 24, 36, 48, and 72 points. The push-button switch shown below the handle in Fig. 25 is fitted when the indicator is used in conjunction with a recorder.

Further particulars are given in List No. 195.

DISTANCE THERMOMETERS

Portable Indicator

Fig. 27.
$8\frac{1}{4} \times 4\frac{3}{8} \times 8\frac{3}{4}$ inches.
Weight 8 lbs.

A PORTABLE indicator, which is particularly useful to consulting engineers and inspectors for checking purposes and for use when occasional tests are required, is illustrated in Fig. 27. The indicator is entirely self-contained, and is provided with an unspillable accumulator. To take a reading, it is only necessary to connect the indicator to the ends of the leads from the thermometer under test. For measuring the temperature of gas in airships, outfits are supplied consisting of an indicator, similar to that illustrated in Fig. 27, connected by a length of leads to a straight thermometer bulb with a perforated metal sheath which allows free access of the gas to the platinum bulb.

In addition to the indicators previously described, instruments can be provided for indicating the difference between the temperatures of two thermometers, as well as their actual temperatures.

Further particulars are given in List No. 195.

DISTANCE THERMOMETERS

Recorders

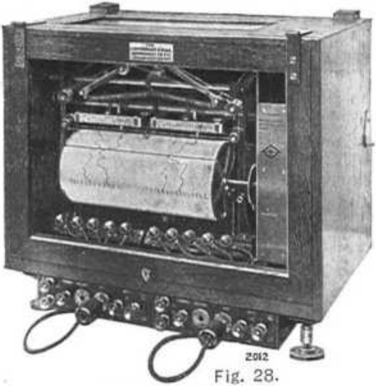

Fig. 28.

18 × 15½ × 11¼ inches.

WHEN a continuous record of temperature is required, a clock-driven thread recorder is supplied. In this instrument, the pointer of a moving coil galvanometer is automatically depressed at frequent intervals on to an inked thread, which it forces down on a chart, rotated once in 25 hours. A continuous record is thus obtained in the form of closely spaced dots, pen friction being entirely avoided. The recorder in Fig. 28 is fitted with two independent galvanometers which record side by side on a chart, each record space being 3¾ inches (95 mm.) wide. Each galvanometer is fitted with a double thread frame, enabling two differently coloured threads to be brought in turn under the galvanometer pointer, the thermometer connections being automatically changed when the thread is changed. Four records are thus obtained on one chart. Similarly, by using one galvanometer, as in Fig. 47, page 40, one record or two simultaneous records can be obtained on a chart half the width of that illustrated above.

Further particulars are given in List No. **195.**

DISTANCE THERMOMETERS

Thermometers

Fig. 29.

Fig. 30.

THE resistance thermometer elements used with the indicators and recorders already described are protected in various ways, depending upon the conditions of use, but they are alike in all essentials and are interchangeable. Fig. 29 shows a thermometer for indoor air temperatures; protection is afforded by a perforated metal sheath allowing free passage of the air. The thermometer in Fig. 30 is designed for air temperatures in ships and in land installations where much moisture is present. A wet bulb thermometer, as in Fig. 31, is supplied for atmospheric temperatures. Fig. 34 shows a thermometer for flue gas temperatures with protecting tube and adjustable flange, while in Fig. 33 is illustrated a thermometer with protecting tube and screwed collar, for positions under pressure, such as steam, water, or bearing temperatures. When thermometers are used in damp situations the terminals should be protected by a watertight head, as in Fig. 32. The metal of which the protecting tube is made depends on the surrounding conditions; in thermometers for flue gas or steam temperatures the protecting tubes are of steel, while

Fig. 31.

Thermometers

copper tubes are usually supplied for water and oil temperatures. Special sheaths can be fitted if required. For example, on sulphuric acid plants, lead-covered steel tubes with outer silica protecting sheaths are recommended. In the standard thermometer for coal-bunker temperatures, the platinum coil is enclosed in a brass tube, to one end of which leads are permanently attached. In fixing the thermometers in position, it is important to ensure that the whole length of the bulb is exposed to the temperature which it is desired to measure, and special means have to be adopted to ensure this when the thermometers have to be mounted in cramped positions. Ordinary lead-covered cable is generally employed for connecting leads; sometimes, however, the leads should be enclosed for protection in steel conduit.

Fig. 33.

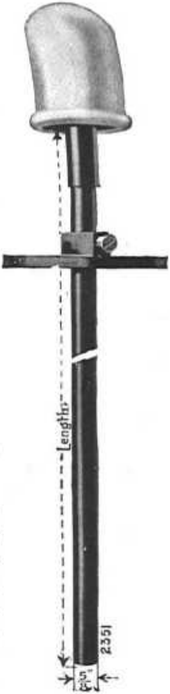

Fig. 34.

Fig. 32.

Further particulars are given in List No. 195.

RESISTANCE PYROMETERS

Whipple Indicator

Fig. 35.

12 × 9½ × 8 inches. Weight 20 lbs.

THE instrument illustrated in Fig. 35 is a form of Wheatstone Bridge designed for use with platinum resistance thermometers. The Bridge is balanced by turning a handle, and the instrument is calibrated to give direct readings of temperature. It is entirely self-contained, and, as a pivoted coil galvanometer is used, levelling is unnecessary. The scale is divided every 1° C. from −10° to +1200° C., each degree averaging about ⅕ inch (4.5 mm.) in length ; it is, therefore, very easily read. If desired, the scale can alternatively be calibrated from 0° – 2000° F. The accuracy of the instrument can be checked at any time, and, since a null method is employed, it is not affected by changes in the galvanometer sensitivity. On account of its accuracy this instrument is valuable as a standard pyrometer against which other instruments can be checked.

Further particulars are given in List No. 196.

RESISTANCE PYROMETERS

Callendar Recorder

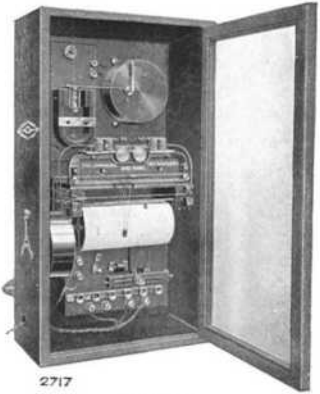

Fig. 36.
29 × 16 × 8¼ inches.

IN the instrument illustrated in Fig. 36 a Wheatstone Bridge is balanced automatically by a recording mechanism. In conjunction with a resistance thermometer, it forms the most accurate instrument for recording temperatures up to 1200° C. In the standard charts, the scale occupies a width of 7.9 inches (200 mm.); the range can be adjusted to practically any value required, so that an open scale covering only the working range of temperatures may be secured. The drum of the recorder rotates once in 25 hours, giving a time scale of half an inch (12.5 mm.) per hour, or, by means of a simple change-speed gear, it may be made to rotate once in two hours five minutes. A continuous paper movement may be fitted if preferred, enabling records extending over a week to be obtained.

Further particulars are given in List No. 196.

RESISTANCE PYROMETERS

Thermometers

Fig. 37.

THE Resistance Thermometers used with the Whipple Indicator and the Callendar Recorder are made in various patterns, some of which are illustrated in Figs. 37 to 40. Each thermometer consists of a suitably protected coil of fine platinum wire, the resistance of which varies with the temperature. Fig. 37 illustrates a commercial pattern thermometer in which the bulb is protected by a porcelain or quartz tube with an outer removable open-ended steel sheath and flange, the terminals being enclosed in an aluminium head with sliding cover. The suspension device shown is usually fitted when taking the temperature of a salt bath, etc. Fig. 38 shows a commercial pattern thermometer for portable use, having a protecting tube of porcelain or steel with adjustable stop flange. In the standard laboratory pattern thermometer, shown in Fig. 39, the

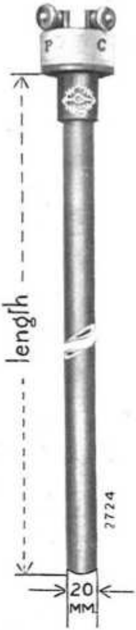

Fig. 38.

Thermometers

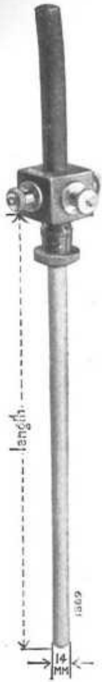

Fig. 39.

coil is protected by a single tube of porcelain or quartz, and the head is so constructed that new tubes can be readily fitted. In Fig. 40 is illustrated a thermometer for blast furnace use.

The thermometers are connected to the recorder or indicator by four-way copper leads, in such a way that alterations in resistance due to changes in temperature or length of leads are automatically eliminated. The temperatures at a number of different points can be measured on one indicator, or on one recorder, by adding to the outfit a suitable switch-board, any one thermometer being brought in circuit by means of a movable plug switch.

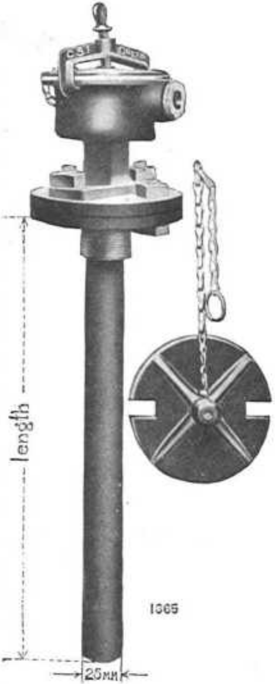

Fig. 40.

Further particulars are given in List No. 196.

THERMO-ELECTRIC PYROMETERS

Portable Indicator

Fig. 41.

8 × 8 × 4¾ inches. Weight 10½ lbs.

CAMBRIDGE Thermo-Electric Pyrometers are the type most generally used for measurements of high temperatures in industry. Single or multi-point indicating, recording, or combined indicating and recording outfits can be supplied. The principle of operation depends upon the fact that if two wires of dissimilar metals are joined together at their ends to form a closed circuit, and one junction is heated, an electromotive force is set up, the magnitude of which depends upon the difference between the temperatures of the hot and cold junctions. If the temperature of the cold junction is fixed and the electromotive force is measured on a millivoltmeter, the temperature of the hot junction can be deduced. In practice, a thermo-couple, comprising one junction of the two dissimilar wires, is exposed to the temperature to be measured, the other ends of the wires being connected to a millivoltmeter graduated to read directly in degrees of temperature; various means are adopted for maintaining the cold junction temperature constant (see pages 48 and 49). All indicators, except that in Fig. 44, can be fitted with a set-up scale, enabling the

Wall Pattern Indicator

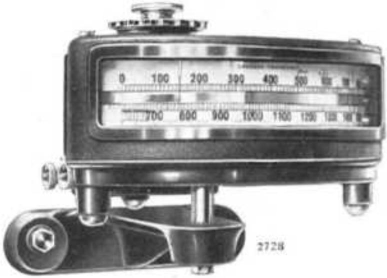

Fig. 42.

8 × 8 × 6 inches.

scale reading to start at any value up to half the full scale reading, thus obtaining a more open scale.

The standard portable and wall pattern indicators are illustrated in Figs. 41 and 42 respectively. In each instrument the moving system is double pivoted and is dead beat in action, no levelling being necessary. The scale, which is about 7 inches long, is easily read. The standard ranges are 0°–300° C., 0°–600° C., 0°–800° C., 0°–1000° C., 0°–1100° C., 0°–1200° C., and 0°–1400° C. Scales can be provided for other ranges, or in degrees Fahrenheit. Two scales can be fitted if desired. All indicators are fitted with a zero adjustment whereby the pointer is set to the cold junction temperature before readings are taken. The portable instrument, Fig. 41, is enclosed in a metal case provided with a handle. The wall pattern indicator shown in Fig. 42 is mounted on a wall bracket in such a way that it can be swivelled round to face the operator. A magnifying device can be fitted to enable readings to be taken easily and accurately at a distance.

Further particulars are given in List No. 194.

THERMO-ELECTRIC PYROMETERS

Totally-Suspended Indicators

1753 Fig. 43.

8 × 8 × 11 inches.

WHEN greater sensitivity is required than can be obtained with a pivoted instrument, an indicator in which the moving system is suspended can be supplied in either wall or portable pattern, the former being illustrated in Fig. 43. These instruments are similar in general construction and finish to the indicators described on pages 34 and 35, but are considerably more sensitive. They are therefore recommended for use when small electromotive forces are to be measured. The coil suspension is of considerable length, and is made of a strong material having good zero-keeping qualities. A device is fitted for clamping the coil when the indicator is moved. Careful levelling is necessary, and provision is made whereby this can be easily performed. The scale length and the standard ranges are the same as for the double pivoted instruments previously described.

Further particulars are given in List No. 194.

THERMO-ELECTRIC PYROMETERS

Small Pattern Indicator

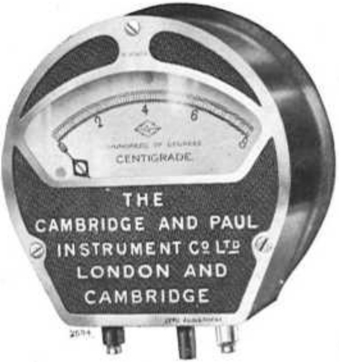

Fig. 44.
7 × 6½ × 3¼ inches.

IN cases where close temperature readings are not required, the small pattern indicator, shown in Fig. 44, may sometimes be used in place of the indicators described in pages 35 or 36. This is a simple and inexpensive instrument which is less sensitive than the standard patterns, and which is, therefore, only suitable for use with the base metal thermo-couples described on page 44. The moving system is of the double pivoted type. The instrument is made in a wall pattern only, and is mounted on the wall or other support by means of screws passing through recesses in the back of the indicator case. A large window in the front of the case gives a clear view of the scale and pointer. The scale is 4½ inches long, and can be read from a distance. The standard ranges are 0°–600° C., 0°–800° C., 0°–1000° C., and 0°–1200° C., but when desired the scales can be calibrated in other ranges, or in degrees Fahrenheit.

Further particulars are given in List No. 194.

THERMO-ELECTRIC PYROMETERS

Multipoint Permanent Indicators

2741

Fig. 45.

12 × 11 × 8 inches.

THE indicator in Fig. 45 is used when the temperatures at a number of points are required. The moving system is enclosed in a robust fume and moisture-proof metal case, similar to that shown on page 24. The indicator, which may have either a pivoted or a totally-suspended movement, is mounted in the upper part of the case; the multi-way switch and terminals are in the lower compartment. A hinged front renders the terminals accessible when the indicator is installed, and enables them to be inspected at any time, should this prove necessary. The switch is operated by an external handle, which may be made removable if desired. Multipoint indicators are supplied for 6, 12, 18, or 24 points. Fig. 45 shows a 6-point indicator with pivoted movement. An 18-point indicator is illustrated in Fig. 60, on page 50. The push-button switch shown below the handle is fitted when the indicator is to be used in conjunction with a recorder.

Further particulars are given in List No. 194.

THERMO-ELECTRIC PYROMETERS

Multipoint Portable Indicator

Fig. 46.
13 × 7 × 5½ inches. Weight 14 lbs.

A PORTABLE multipoint indicator suitable for making occasional tests at various points, and for checking the instruments permanently installed, is illustrated in Fig. 46. The indicator, which is a pivoted moving coil galvanometer, is mounted, together with a multi-way switch, in a compact travelling case. Terminals are provided which enable connection to be made to six (or less) thermo-couples, for which a separate portable case is provided. By adjusting the switch the temperature corresponding to any thermo-couple is read on the indicator scale. With an outfit of this kind the temperatures in the flues of a bank of boilers can be quickly and accurately taken. For this application the scale is usually calibrated from 0°–1000° F., but other ranges can be supplied. Sometimes a double scale is fitted. The type of thermo-couple used depends on the range of temperature to be measured. Standard thermo-couples are described on pages 42 to 47.

Further particulars are given in List No. 906.

THERMO-ELECTRIC PYROMETERS

Recorders

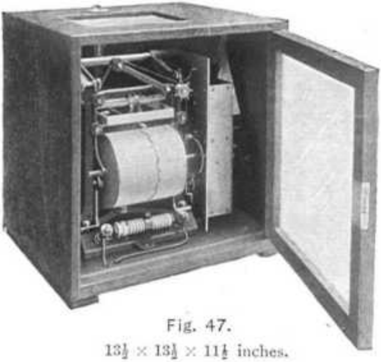

Fig. 47.
$13\frac{1}{2} \times 13\frac{1}{2} \times 11\frac{1}{2}$ inches.

WHEN continuous records of temperature are required, thread recorders, similar to those described on page 27, are employed; one, two, or four records can be obtained on one chart. Single-point and four-point recorders are shown in Figs. 47 and 28. The record for the past few hours is always visible, and an engraved scale is fixed over the pointer, so that the actual temperature at any moment can be read. The charts run for 25 hours, and the record space is 80 mm. wide. When specially ordered, charts can be supplied with a record space of 95 mm. The recorder may be adapted for practically any range, but the standard ranges are as follows: 0°–300° C., 0°–600° C., 0°–800° C., 0°–1000° C., 0°–1100° C., 0°–1200° C., 0°–1400° C., and 300° C. across chart, the latter range being for use with a scale control board (see page 41).

When occasional records are required from a large number of points, but all need not be connected to the recorder simultaneously, a plug selector switchboard, as mentioned on page 33, can be used.

Further particulars are given in List No. 194.

THERMO-ELECTRIC PYROMETERS

Scale Control Boards

Fig. 48.

$7\frac{1}{2} \times 6\frac{1}{2} \times 4\frac{1}{2}$ inches.

THE scale control board, illustrated in Fig. 48, is an electrical device which secures a more open scale on thread recorders, and at the same time gives greater accuracy in the records, since errors due to changes in resistance of the thermo-couple and the leads are practically eliminated. The scale control board is so arranged that a small amount of the electromotive force from a 2-volt accumulator is connected in opposition to the electromotive force produced by the thermo-couple, rendering it impossible for the recorder to start recording the temperatures until the electromotive force produced by the thermo-couple is greater than that opposing it. Temperatures are therefore only recorded when they exceed a certain predetermined value, thus enabling a recorder of greater sensitivity to be employed. Provision is made for altering the range. A " test " position for the switch enables the scale control board to be rapidly standardised. Standard control boards are made to give any desired range to 300° C. across the chart when used with platinum, platinum-rhodium thermo-couples.

Further particulars are given in List No. 194.

THERMO-ELECTRIC PYROMETERS

Rare Metal Thermo-Couples

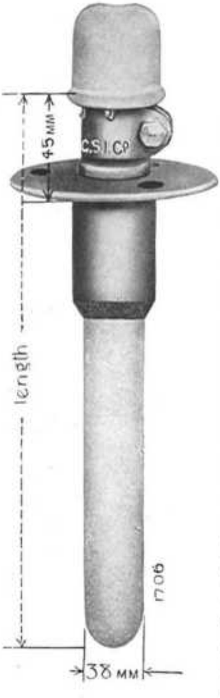

Fig. 49.

RARE metal thermo-couples supplied with Cambridge Pyrometers consist of platinum, platinum-rhodium wires, and are suitable for taking occasional temperatures up to 1400° C., or for average working temperatures up to 1250° C. The thermo-couples generally supplied for industrial processes are shown in Figs. 49 and 52. The wires are protected by a quartz or porcelain tube, which is inserted in a socket supporting the porcelain head on which the terminals are mounted. The terminals are protected by an aluminium cover, and a sheath of steel or fireclay is fitted over the protecting tube. The thermo-couple illustrated in Fig. 52 has an outer sheath of steel, which is left open at the lower end to ensure a rapid response to changes in temperature. In the thermo-couple in Fig. 49 the outer sheath is of fire-clay and is cemented into a flanged socket

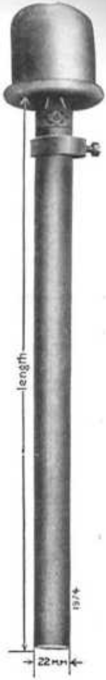

Fig. 50.

Rare Metal Thermo-Couples

which can be built into the brick-work or bolted to the furnace, the thermo-couple being afterwards inserted and fixed into the socket. This arrangement is suitable for oxidising atmospheres, for temperatures above 1000° C., or where the thermo-couple is likely to be touched by flames. Where desired nichrome sheaths can be supplied. The standard lengths are 12, 18, 24, 30, 36, 42, 48, 54, 60 and 66 inches.

The standard thermo-couple for use in small muffle furnaces is illustrated in Fig. 50. It is fitted with a silica tube and an open-ended renewable steel sheath. The standard length is 12 inches. Fig. 51 shows a standard thermo-couple for laboratory use, having the wires protected by a single tube of porcelain or quartz; the head is so constructed that new tubes can be readily fitted. The standard length is 12 inches.

Platinum-iridium thermo-couples are also supplied for certain applications.

Fig. 51.

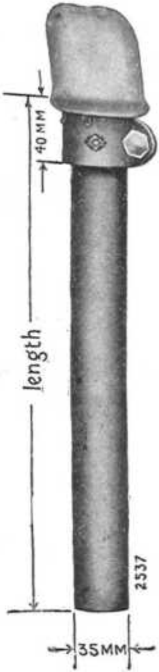

Fig. 52.

Further particulars in List No. 194.

THERMO-ELECTRIC PYROMETERS

Base Metal Thermo-Couples

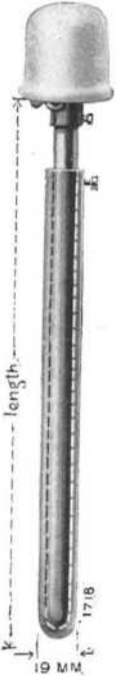

Fig. 53.

Fig. 54.

BASE metal thermo-couples are of two kinds, namely, those consisting of Titan alloy wires (for occasional temperatures up to 1200° C., or for average working temperatures up to 1100° C.), and those consisting of iron-constantan wires (for temperatures up to 800° C.). Titan thermo-couples for commercial use are protected in an exactly similar manner to the rare metal thermo-couples described on pages 42 and 43, and have the same standard lengths. An iron-constantan thermo-couple having a plain stem is shown in Fig. 53. The wires are protected by a steel tube and an outer removable steel sheath. When the thermo-couple is used for temperatures below 600° C. the outer sheath is not usually fitted. The standard lengths are 12, 24, and 36 inches. Fig. 54 shows a screwed pattern thermo-couple ($\frac{3}{4}$-inch gas thread), for positions under pressure. When a thermo-couple is used in damp situations a water-tight head, similar to that illustrated in Fig. 32 on page 29, may be fitted.

Further particulars are given in List No. 194.

THERMO-ELECTRIC PYROMETERS

Blast Furnace Thermo-Couples

THE standard outfit for measuring the temperatures in hot air mains and the temperature of the outgoing gases in blast furnaces, comprises a totally-enclosed indicator, as described on page 38, connected to thermo-couples of the type illustrated in Fig. 55. If the average working temperature is in the neighbourhood of 1000° C. Titan base metal thermo-couples are most suitable, but for higher temperatures rare metal thermo-couples of platinum, platinum-rhodium should be adopted. In each case the wires are protected by a quartz tube and a removable steel sheath which fits into a flanged socket; the socket is threaded 1½-inch gas thread for screwing into the main. The thermo-couple has an enclosed head, the collar being provided with a cap which can be quickly removed for making or inspecting connections. The standard lengths are 12 and 18 inches, but greater lengths can be supplied.

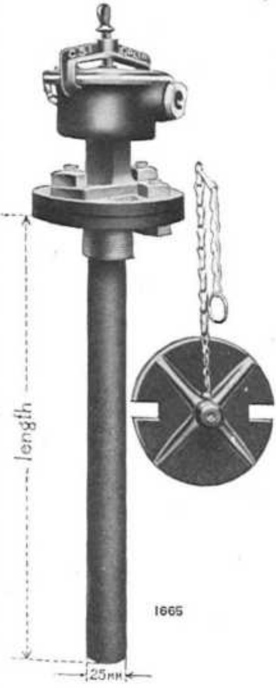

Fig. 55.

Further particulars are given in List No. 194.

THERMO-ELECTRIC PYROMETERS

For Molten Metal Temperatures

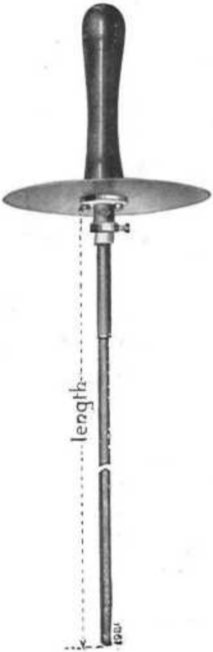

Fig. 56.

THERMO-ELECTRIC pyrometers can be used for taking the temperatures of molten metals which come within their range. For temperatures up to 800° C. an iron-constantan thermo-couple of the form shown in Fig. 56 is used, in which the wires are protected by a covering of woven asbestos, the hot junction being exposed to ensure quick action. For temperatures up to 1200° C. a base metal thermo-couple is used, having the elements protected by a coating of special mixture which is very easily and quickly renewable. For still higher temperatures up to 1400° C. a platinum, platinum-rhodium thermo-couple may be employed, having the wires protected by a quartz tube and outer steel sheath, the end of which is made of nichrome or plumbago. Each pattern of thermo-couple is provided with a shield to protect the hand from radiated heat. The standard length is 48 inches, but other lengths can be supplied. The indicator may be of either the portable or wall pattern, illustrated on pages 34 and 35, calibrated to correspond with the temperatures to be measured. If desired a double scale can be provided, and the indicator connected to any two of the above thermo-couples, thus enabling a large range of temperatures to be covered. For temperatures above 1400° C., and sometimes for lower temperatures, the Cambridge Optical Pyrometer, described on pages 54 and 55, is recommended.

Further particulars are given in List No. 194.

THERMO-ELECTRIC PYROMETERS

For Contact Temperatures

Fig. 57.

$5\frac{3}{4} \times 3\frac{5}{8} \times 3\frac{3}{8}$ inches. Weight 1 lb.

THE standard outfit for contact temperatures comprises a wall pattern indicator, as described on page 35, connected by leads to a thermo-couple of the form shown in Fig. 57. This thermo-couple is designed for taking temperatures of heated metal surfaces up to 400° F. (200° C.) by actual contact under working conditions. It is particularly useful in securing even heating of calendering boles used in cloth finishing processes, rollers of paper-making machines, platens of vulcanising presses, and other similar appliances. In use, the thermo-couple is allowed to rest lightly upon the surface, the temperature of which is required. This temperature is taken up instantly and accurately, and every variation is clearly and immediately shown on the indicator. The design of the thermo-couple ensures that it cannot damage the surface under test. It is guaranteed to have a long life under ordinary works conditions. Other types of contact thermo-couples can be supplied for special applications.

Further particulars are given in List No. 194.

THERMO-ELECTRIC PYROMETERS

Cold Junction Control

Fig. 58.
13 × 6 × 4½ inches.

SINCE the electromotive force generated by a thermo-couple depends on the difference in temperature between the hot and cold junctions, the cold junction temperature should be kept constant. By using compensating leads formed of alloys having similar thermo-electric constants to the thermo-couple, the cold junction can be transferred from the head of the thermo-couple to a position where the temperature is lower, steadier, and better known. When the leads are short, the cold junction can be taken in this way to the indicator (or recorder), where its temperature is measured by a thermometer, an adjustment enabling correction to be made for changes in its temperature. This method is not suitable when the temperature at the indicator varies appreciably, as the pointer has to be reset whenever the temperature changes. When the distance to the indicator is considerable, a short length of compensating leads run to a junction box, placed where the temperature is low and constant, from which copper leads run to the indicator. When it is not possible to erect either the indicator or the

Cold Junction Control

junction box in a suitable position, or where greater accuracy is required, other methods must be adopted. The temperature of the cold junction can be simply and automatically controlled by immersing it in a vacuum flask filled with oil (see Fig. 58). It is found that the temperature inside this flask will not vary more than two or three degrees, although the temperature of the surrounding air may vary by 20 or even 30 degrees. An alternative method is to bury the junction several feet in the soil. The temperature can thus be maintained within about 3° C. throughout the year. The most accurate way of controlling the cold junction temperature is to place the junction in an electrically controlled thermostat, as illustrated in Fig. 59, to which any number up to six thermocouples can be connected. By adopting this method the temperature can be automatically controlled to within about 0.5° C. For this reason consulting engineers are including the electric thermostat in their standard specifications.

Fig. 59.
16 × 14½ × 14½ inches.

Further particulars are given in List No. 194.

STATOR TEMPERATURE OUTFITS

Fig. 60.
12 × 11 × 8 inches.

THE modern demand for high power alternators giving a maximum output necessitates close observation of the temperatures of the machines to prevent insulation trouble. In the Cambridge Outfits these temperatures are determined by the thermo-electric method. The thermocouples, which consist of wires or strips of copper and constantan, suitably insulated, are built into the windings when the machine is constructed. They are connected to a totally-enclosed connector and fuse box mounted on the side of the machine, from which connection is made to a multipoint indicator (Fig. 60), as described on page 38. The standard range is 0°–200° C. As the temperatures measured are low, the cold junction temperature must be kept very constant. This is effected by the use of an electric thermostat, as described on page 49. These outfits are also used to measure the temperatures of transformer windings.

Further particulars are given in List No. **906.**

ROTOR TEMPERATURE OUTFITS

Fig. 61.
$8\frac{3}{4} \times 8\frac{1}{4} \times 5\frac{7}{8}$ inches.

THE indicator shown in Fig. 61 has been designed to ascertain the average temperature of the rotor windings on an alternator. These machines are now run at temperatures which closely approach the danger point for the insulation, and the accurate determination of the temperature is therefore of great importance. Owing to the high speed of rotation, the temperature cannot be measured directly, but it is determined by comparing the resistance of the windings, which increases as the temperature rises, with that of a standard shunt. The indicator is calibrated to read directly in degrees of temperature, the standard range being 0°–150° C. An important feature is the entire absence of thin leading-in strips, with consequent immunity from damage due to overload. This indicator can also be used to measure the temperature of the windings in the exciter field.

When stator and rotor indicators are to be installed side by side, the rotor indicator mechanism can be enclosed in a case similar to Fig. 60.

Further particulars are given in List No. 906.

FÉRY RADIATION PYROMETERS

2725

Fig. 62.

FOR continuous temperatures above 1250° C. it is necessary to employ an instrument which depends for its operation upon the heat radiated from the hot body. The Féry Radiation Pyrometer, which is of this type, is suitable for measuring temperatures of hot furnaces, rolling mills, brick kilns, pottery kilns, glass furnaces, pouring temperatures of molten metals, etc. In this apparatus a telescope, shown in Fig. 63, is focussed on the hot body, the heat rays being received on a concave mirror, and brought to focus on a small thermo-couple. The electromotive force thus produced is measured on an indicating or recording galvanometer, calibrated to give direct readings in temperature. A portable indicating outfit, illustrated in Fig. 62, comprises a telescope, as Fig. 63, mounted upon a wooden tripod stand, and connected by a short length of leads to a portable indicator, similar to that described on page 34. For permanent installations it is convenient to use a wall pattern indicator, similar to Fig. 42,

FÉRY RADIATION PYROMETERS

Fig. 63.

$8\frac{3}{4} \times 7\frac{1}{4} \times 5\frac{3}{8}$ inches.

or a totally-enclosed indicator, similar to Fig. 45; the latter pattern enables a number of telescopes to be connected to a single indicator. Recording, or combined indicating and recording outfits, for one or a number of points can be supplied. The standard ranges for portable outfits are 500°–1100° C., 600°–1400° C., and 800°–1700° C., while the standard ranges for permanent indicating and for recording outfits are 600°–1200° C., 700°–1400° C., and 900°–1700° C. Other ranges, from 500° C. upwards, can be supplied. When it is desired to cover a wide range of temperatures, an indicator can be provided with a second scale calibrated for use with one of the thermo-couples described on pages 42 to 44. With this arrangement, the lower temperature readings are obtained by means of the thermo-couple, and the higher temperatures are measured by a Féry telescope.

Further particulars are given in List No. 190.

Fig. 64.

THIS pyrometer determines temperature by means of the radiation emitted by a hot body, but unlike the Féry instrument, it employs radiation of a single wave-length instead of the total radiation emitted. It is a practical, convenient, and accurate instrument which can be successfully used by unskilled workmen. Owing to the rapidity with which readings can be taken and the ease of sighting upon small objects, the instrument is particularly suitable for the measurement of high temperatures in many industrial processes. Fig. 64 shows the pyrometer on an adjustable tripod stand, connected by leads to a battery case, which also contains an ammeter and a regulating resistance. A spare electric lamp and a standard lamp are also provided. The pyrometer itself is illustrated in Fig. 65. Light from the hot body enters the instrument through one aperture, while through another aperture enters light from the electric lamp. The two beams pass through an optical system whereby they are polarised in different planes, and rendered monochromatic ; they then pass through a nicol prism into the eyepiece. The field seen by the observer is divided into two semicircles, illuminated by rays from the hot body and the electric lamp respectively. The

Fig. 65.
10 × 7½ × 7½ inches.

eyepiece, to which is attached the scale pointer, is rotated until the two semicircles are equally illuminated, and the temperature is then read directly on the scale, which is engraved on a large circular plate forming a convenient handshield. Since both semicircles are of the same colour, the observations can be made with great precision. The accuracy of the instrument depends upon the constancy of the light from the electric lamp. Any fluctuations due to voltage variations can be corrected by means of the ammeter and regulating resistance. Further, ageing of the lamp can be compensated by checking it against the standard amyl-acetate lamp, and altering the resistance accordingly. The pyrometer can be supplied fitted with one or more temperature scales, double scale instruments being provided with an observing screen, which is moved in front of the objective when using a higher range. The standard ranges for single scale instruments are 700°–1400° C. and 900°–2000° C., and for double scale instruments 700°–1400° C. and 900°–2000° C., 700°–1400° C. and 1200°–2500° C., and 900°–2000° C. and 1400°–4000° C. Other ranges can be supplied if desired.

A National Physical Laboratory Certificate of accuracy is furnished with each instrument.

Further particulars are given in List No. 190.

CAMBRIDGE DISAPPEARING FILAMENT PYROMETERS

Fig. 66.

THE pyrometer shown in Fig. 67 is a simple and inexpensive instrument for use where the high accuracy of the Cambridge Optical Pyrometer is not required. It is capable of measuring temperatures up to 2100° C., and is entirely self-contained. The instrument is shown in use in Fig. 66. It consists of an electric lamp connected in series with a small ammeter and a rheostat. Current is supplied by a 2-volt accumulator. The observer looks through the lamp at the hot body and adjusts the electric current by means of the rheostat until the tip of the filament is of the same brightness as the hot body, when it merges into the background and cannot be distinguished. The temperature is then read on the ammeter scale, which is directly calibrated in degrees Centigrade or Fahrenheit. If too much current is passing through the lamp filament, the filament appears as a bright line on a darker background, and if the current is insufficient, the filament appears as a dark line on a light background. The eyepiece is provided with an eyeguard to exclude extraneous light, and can be focussed on to the lamp filament. The objective also can be adjusted to bring the hot body into exact focus. Immediately behind

CAMBRIDGE DISAPPEARING FILAMENT PYROMETERS

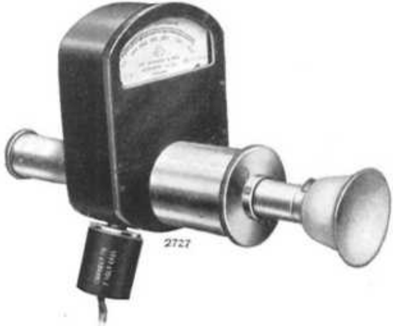

Fig. 67.
$10\frac{3}{4} \times 5\frac{1}{4} \times 3\frac{7}{8}$ inches.

the eyeguard fixed to the eyepiece is a rotatable holder, containing two diaphragms; one is a plain aperture for viewing the filament against the hot body at the lower temperatures, the second is provided with a monochromatic glass for reducing the glare when measuring temperatures near the top of the scale. The introduction of this glass does not affect the scale or accuracy of the instrument. Under actual conditions, the lamps used in these pyrometers are never raised to their maximum brilliancy. Before leaving the works, they are carefully aged so that their brilliancy remains constant indefinitely. It is, therefore, not necessary to provide means for checking and regulating the constancy of the lamp. For temperatures between 700° C. and 1400° C., a single scale instrument, range 700°–1400° C., is used. For temperatures up to 2100° C., an instrument with two scales, ranges 700°–1300° C., and 1000°–2100° C., is supplied. Instruments calibrated for other ranges can be supplied to order.

Further particulars are given in List No. 190.

AUTOMATIC TEMPERATURE CONTROL (Patented)

Fig. 68.

IN many industrial processes the temperature must be kept within narrow limits if satisfactory results are to be obtained. This may be done by regulating the supply of heat by hand so as to keep as constant as possible the reading of a thermometer or pyrometer placed in the furnace, oven, or other form of heated vessel, but this method is not infallible. A sudden change in the conditions, or temporary inattention on the part of the workman in charge, may result in considerable variations of temperature and consequent serious loss. Some form of automatic control is therefore essential if economy and efficiency are to be secured. The apparatus described in this and succeeding pages is being widely used in this connection. Various outfits are made; the decision as to which should be employed depends on the problem under consideration. Each outfit comprises a sensitive element connected to an indicator which is fitted with a device whereby the supply of heat is automatically reduced as soon as the temperature of the furnace exceeds a definite value, and increased when it falls below that value. In gas-fired furnaces, and in processes in which the heat is supplied by steam or water, the device on the indicator operates a valve, either directly or by means of an electric relay, while in electric furnaces it operates a relay which controls the main circuit. When permanent records are required a recorder is used instead of, or in addition to, an indicator.

Further particulars are given in List No. **150.**

AUTOMATIC TEMPERATURE CONTROL (Patented)

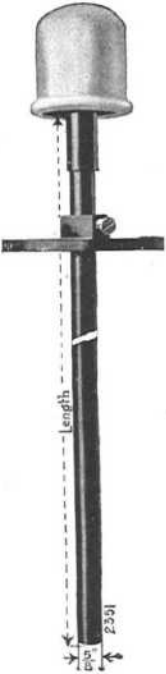

Fig. 69.

Sensitive Elements

FOR temperatures not exceeding 1000° F. (540° C.), an Index Thermometer (see page 14) usually serves as the indicator, and the bulb of the instrument is the sensitive element. Alternatively a wall-pattern millivoltmeter, as in Fig. 72, is used in conjunction with any of the resistance thermometers described on pages 28 and 29. The thermometer as in Fig. 68 should be employed when controlling air temperatures in cold rooms, refrigerator holds, etc., while the straight pattern in Fig. 69 is suitable for furnace temperatures. For temperatures between 540° C. and 1400° C., thermo-couples are generally used. Fig. 70 shows a base metal thermo-couple for temperatures to 1200° C.; other types are illustrated on pages 42 to 46. For higher temperatures the total radiation of the hot body is measured by means of a Féry telescope as in Fig. 63; for some applications the telescope is replaced by a thermo-pile.

Further particulars are given in List No. 150.

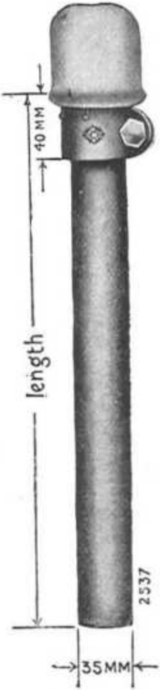

Fig. 70.

AUTOMATIC TEMPERATURE CONTROL (Patented)

Indicators for Temperatures to 1000° F. (540° C.)

Fig. 71. 2706

THE indicator in Fig. 71 is a standard Index Thermometer, as described on page 14. It is fitted with an adjustable contact, which is set to the temperature at which the furnace is to be controlled. When the thermometer pointer reaches the contact an electrical circuit is closed, thereby energising mechanism which controls the supply of heat to the furnace. In gas-fired furnaces, closing the circuit either energises an electric gas valve, as shown in Fig. 75, or operates a ball relay, as in Fig. 73, which in turn energises a ball valve of somewhat different construction (see page 64). In electric furnaces closing the circuit operates a ball relay which controls the main circuit. As soon as the temperature falls the thermometer pointer leaves the contact and the process is reversed. When a permanent record, in addition to the control, is required a Thermograph can be used instead of an Index Thermometer. Either instrument can be fitted with any of the standard bulb connections shown on pages 14 to 23.

Further particulars are given in List No. 150.

AUTOMATIC TEMPERATURE CONTROL (Patented).

Indicators for Temperatures to 2552° F. (1400° C.)

Fig. 72.

9½ × 8½ × 6 inches.

THE indicator in Fig. 72 is a high resistance moving coil galvanometer fitted with a calibrated temperature scale. It is connected by leads to a sensitive element which may be a resistance thermometer, thermo-couple, Féry telescope or thermo-pile. Near the end of the pointer is attached a light thermo-couple which is electrically connected to a moving coil relay. A small electrically heated coil is set to the point on the scale at which it is desired to control the temperature. When this temperature is reached the thermo-couple on the pointer is brought opposite to the coil and becomes suddenly heated, the electromotive force thus set up energising the relay and so completing an electrical circuit which operates mechanism controlling the supply of heat. As soon as the temperature falls the thermo-couple leaves the coil and the process is reversed. The coil can be set to any point on the indicator scale. The accuracy of control depends on the openness of the scale and the sensitivity of the element. With a suitable combination of indicator and element an accuracy of 0.3% can be guaranteed for temperatures not exceeding 800° C.

Further particulars are given in List No. 150.

AUTOMATIC TEMPERATURE CONTROL (Patented)

Ball Relay

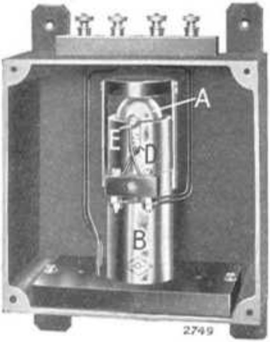

Fig. 73.
9 × 6¼ × 3½ inches.

THE Ball Relay, which is used in conjunction with the indicators in Figs. 71 and 72, is somewhat similar to that designed by Dr. Guy Barr, of the National Physical Laboratory. In Fig. 73 the relay is shown with cover removed. A glass sphere A, into which two platinum wire electrodes (D, E) are sealed, rests on a bell-shaped magnet B, consisting of a hollow steel cylinder, the vertical core of which is wound with a coil. Electrode D is covered with mercury; electrode E is normally above the level of the mercury. On the mercury floats a hollow steel sphere. When the magnet is energised this sphere is pulled downwards and the mercury squeezed out laterally, thereby closing the previously open circuit between the two electrodes. Closing the circuit either operates a valve, or energises a circuit breaker in the main circuit. The relay can be operated either by the current from a 4-volt accumulator or by a direct current supply.

Further particulars are given in List No. 150.

AUTOMATIC TEMPERATURE CONTROL (Patented)

3-Contact Relay

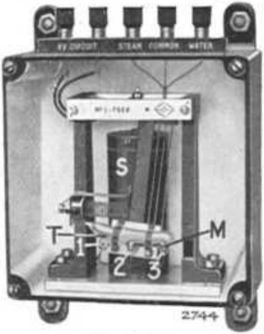

Fig. 74.
$8\frac{3}{4} \times 6\frac{1}{8} \times 3$ inches.

SOMETIMES very quick control of a temperature is required; for example, in certain steam-heated rubber processes it is necessary to turn on cold water at the same time as steam is shut off. The 3-Contact Relay, Fig. 74, is then usually employed. Three platinum wires are sealed into a glass tube T containing mercury M. Normally the position of the tube is such that electrodes 2 and 3 are covered by the mercury, thus completing a circuit which closes a water valve. As soon as the temperature rises to a certain figure, the solenoid S is energised, causing the tube T to be tilted. This makes the mercury flow to the other end of the tube, thereby breaking circuit 2, 3, thus opening the water valve, and making circuit 1, 2, which in turn closes the steam valve. As soon as the temperature drops the solenoid ceases to be energised, circuit 1, 2 is broken, and circuit 2, 3 is made. The relay can be operated either by the current from a 4-volt accumulator or by a direct current supply.

Further particulars are given in List No. 150.

AUTOMATIC TEMPERATURE CONTROL (Patented)

Valves for Low Pressure Work

Fig. 75.
$10\frac{1}{2} \times 9 \times 5$ inches.

FIG. 75 shows a Balanced Valve for use with gas or air when the flow passes through a 2-inch pipe. The valve is by-passed by a cock so that the amount of gas or air which it regulates can be adjusted to any proportion of the total. The gas enters a chamber with circular outlets, top and bottom, to the main chamber. Above the outlets are discs mounted on a spindle suspended from one end of a horizontal bar. This bar is pivoted near its middle and carries at its other end a soft iron armature which is just below the pole pieces of an electro-magnet. Normally the weight of the discs and spindle is balanced by a spring, and the valve is open. When the electro-magnet is energised it attracts the armature and the discs are forced downwards on to their seatings, so closing both apertures. For pipes up to 1 inch in diameter a simple Ball Valve is inserted directly into the pipe line. About 2 watts is required to close the valve against a pressure of 10 lbs. per square inch. This valve can also be used for low pressure work with liquids or steam.

Further particulars are given in List No. 150.

AUTOMATIC TEMPERATURE CONTROL (Patented)

Valves for High Pressure Work

IN applications where the pressure is more than 10 lbs. per square inch and the flow passes through a 1-inch pipe a Balanced Valve is employed. This valve is operated by means of an iron core moving inside a solenoid. When the solenoid is energised the valve is closed. It will control a flow at a pressure of 40 lbs. per square inch with an energy consumption of **36** watts. For higher pressures where screwed valves must be used the mechanism shown

Fig. 76.

$10\frac{3}{4} \times 10\frac{1}{8} \times 9$ inches.

(with cover removed) in Fig. 76 is utilised. The shaft A is connected to the spindle of the valve (not shown in the illustration, but mounted behind the control gear). Two phosphor bronze band brakes, working in connection with solenoids D and D_1 respectively, are wrapped round a steel disc B, fixed to the shaft. These brakes are attached at H and H_1 to the arm G, and to the solenoid cores. When D is energised, the arm G is drawn downwards, the band C attached at H tightened, and the valve slightly closed. At the end of the stroke the electrical circuit is broken at the contact E and the arm restored to its neutral position by the spring F. This operation is continued until the valve is closed sufficiently to maintain the desired temperature. The same operation is performed by D_1 when the valve is to be opened. A safety contact prevents the valve being jammed in the fully opened or fully closed position.

Further particulars are given in List No. 150.

AUTOMATIC TEMPERATURE CONTROL (Patented)

Complete Outfits

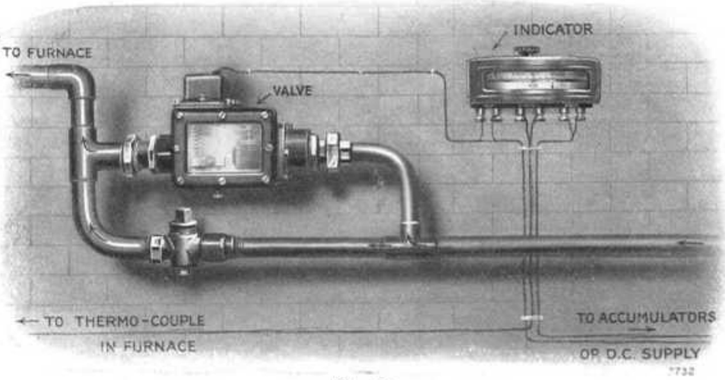

Fig. 77.

AS already indicated in connection with the descriptions of the various units employed, a number of different outfits for automatic temperature control can be supplied. In this booklet it is not possible to describe all these outfits in detail. As an example, however, a standard outfit for controlling the temperature of gas-fired furnaces is illustrated above. It consists of an indicator, as in Fig. 72, connected by a length of leads to a thermo-couple which is so placed in the furnace that it gives a true indication of the furnace conditions. The type of thermo-couple employed depends on the temperature of the furnace. The moving coil relay, which is contained in the indicator case, is connected to a balanced valve, as illustrated in Fig. 75. For pipes up to 1 inch in diameter, this valve is replaced by a ball valve operated by a ball relay (Fig. 73). With either outfit it is possible to control the temperature to within 1 per cent. of the indicator range.

Further particulars are given in List No. **150.**

AUTOMATIC TEMPERATURE CONTROL (Patented)

Outfit for Liquids in Steam-Heated Tanks

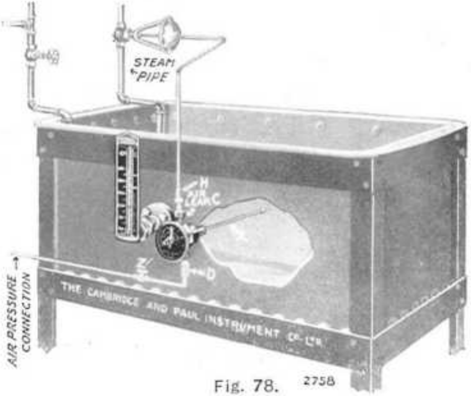

Fig. 78. 2758

THE outfit for controlling the temperatures of liquids in tanks operates on a different principle from those described in pages 58 to 65. One arrangement of the apparatus is shown in Fig. 78. A valve in the steam supply is fitted with a diaphragm chamber, and is so arranged that when suitable water or air pressure is applied to the diaphragm the valve closes and the steam supply is cut off. The water or air pressure is applied through a thermostât comprising a valve, the opening of which is governed by the expansion of a brass tube immersed in the tank under temperature control. When the temperature of the tank rises, the thermostat valve opens and allows a larger supply of water to pass through to the diaphragm, thus closing the steam valve. Conversely, when the temperature falls, the water supply is reduced, and the steam valve opens. A strainer is fitted in the water supply pipe to prevent dirt from being carried into the regulating thermostat.

Further particulars are given in List No. 150.

THERMO-COUPLE POTENTIOMETERS

Workshop Pattern

Fig. 81. $12 \times 9\frac{1}{2} \times 8$ inches.

THE Cambridge Workshop Potentiometer has been primarily designed to measure the electromotive force given by thermo-couples, and forms a useful standard for pyrometer users ; it can check any thermo-couple of which the constants are known. The instrument also affords a ready means of standardising the direct-reading galvanometers, recording or otherwise, used in a works. In the potentiometric method of measuring temperature, the resistance of the leads connecting the thermo-couple to the instrument may be neglected. The method being a null one, the readings are independent of changes in the sensitivity of the galvanometer. The potentiometer is compact, portable and easily operated. Each instrument has two ranges :—

0–18 millivolts, for rare-metal thermo-couples (reading to 0.01 millivolts).

0–90 millivolts, for base-metal thermo-couples (reading to 0.05 millivolts).

Further particulars are given in List No. 191.

THERMO-COUPLE POTENTIOMETERS

Laboratory Pattern

Fig. 82.
17½ × 14½ × 6½ inches.

THE potentiometer illustrated in Fig. 82 is a laboratory instrument designed for measuring the electromotive force derived from any thermo-couple. To avoid inaccuracies due to the accumulation of dust and dirt on the contacts, and also to minimise local heating effects, the coils, slide wires and contacts are mounted inside the instrument case. The two slide wires are arranged in circular form so that the contacts can easily be manipulated by turning external handles. Terminals are provided for connecting to a Weston normal cell, 2-volt accumulator, reflecting galvanometer, and the thermo-couple under test. The instrument has three ranges, 0–30 millivolts, 30–60 millivolts, and 60–90 millivolts, the change of range being effected by plug switches. Readings can be obtained directly to 0.00001 volt, and, by estimation, to a quarter of that value.

Further particulars are given in List No. 191.