List No. 36.

THE FÉRY RADIATION PYROMETER

SOLE AGENTS

For the United Kingdom, British Colonies, United States of America, Norway and Sweden
(Agents also for the sale of these Instruments in Russia),

THE CAMBRIDGE

SCIENTIFIC INSTRUMENT COMPANY, LTD.,

CAMBRIDGE, ENGLAND.

AGENTS
ARTHUR H. THOMAS COMPANY
S. W. COR. WALNUT AND TWELFTH STREETS
PHILADELPHIA.

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1905

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DIRECTIONS FOR FILLING ORDERS, ETC.

Do not hesitate to inform us fully of your requirements. We may be able to help you.

Foreign orders must be accompanied by either a remittance or instructions for payment in London, on delivery of bills of lading, &c.

Cheques to be drawn payable to "The Cambridge Scientific Instrument Co., Limited," and crossed "London and County Bank, Cambridge."

The greatest care is exercised in packing, but we cannot hold ourselves responsible for breakages in transit. In the event of any damage occurring, application should at once be made to the railway company or carrier.

The full invoice price is allowed for returned packing cases, when actually received, in good condition, carriage paid, within fourteen days from delivery.

Designs, materials and prices are subject to alteration without notice.

Trunk Line Telephone: "Cambridge, No. 6."

A B C Code, 5th Edition, used.

Telegraphic and Cable Address: "Instrument, Cambridge."

All Correspondence should be addressed

The Instrument Company,
Cambridge,
England.

Note. The Works of the Company are in Carlyle Road, Chesterton Road, just opposite Jesus Lock.

October 1905.

ACCURACY - PERMANENCE - CONVENIENCE - ECONOMY

THE FÉRY RADIATION PYROMETER

(Patented in the majority of European Countries, United States of America, etc.)
Standardized by the Conservatoire National des Arts et Métiers, Paris.

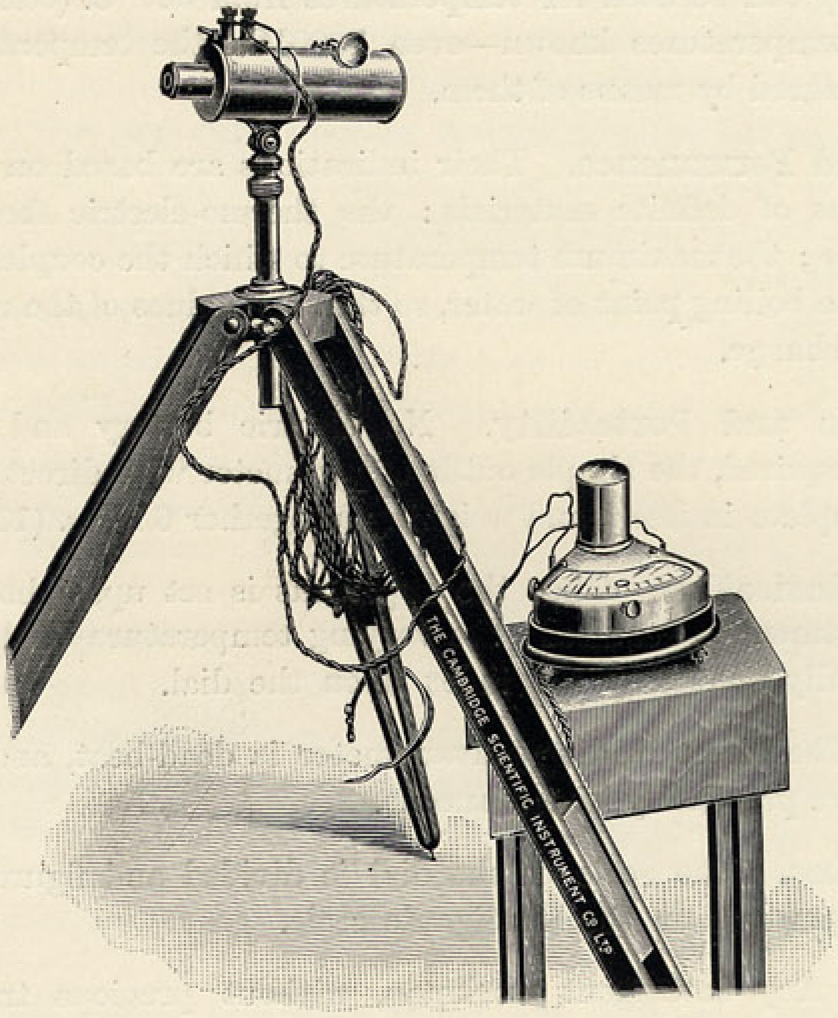

Fig. 1.

SOLE AGENTS

For the United Kingdom, British Colonies, United States of America, Norway and Sweden

(Agents also for the sale of these Instruments in Russia),

THE CAMBRIDGE SCIENTIFIC INSTRUMENT COMPANY, LTD., CAMBRIDGE, ENGLAND.

Advantages of the Féry Radiation Pyrometer.

Range. They can be used for temperatures from 500° C. (*below* a red heat) up to the highest temperatures known—even 7800° C., the temperature of the sun, having been measured by means of them.

Accuracy and Permanence. Their indications are based on well ascertained specific properties of definite materials: the thermo-electric forces of a copper-constantan couple; the maximum temperature to which the couple is exposed being approximately the boiling point of water, so that the values of the readings obtained are not liable to change.

Completeness and Portability. No electric battery and no standard of luminosity are required, the simple outfit of pyrometer with direct reading galvanometer being complete in itself, and weighing altogether 6 kilos. (13 lbs.).

Automatic Indication. Once the apparatus is set up, sighted and focussed, no further adjustment is required; the varying temperature of the body observed being automatically shown by the index upon the dial.

Rapidity. The direct reading galvanometer is dead-beat, and the indications of temperature are practically instantaneous.

Direct reading. The scale of the dial is divided and figured to give direct readings of temperature on the Centigrade scale.

Simplicity. Any intelligent workman, without previous training can read temperatures from the dial.

Freedom from Personal Error. The readings are in no way dependent upon the colour-perception or other individual peculiarity of the observer.

Independence of Lighting. These instruments are not perceptibly affected by extraneous light falling upon the body observed.

Flexibility. A hot or molten mass can readily be followed about as it is moved, and its temperature ascertained from moment to moment.

RADIATION PYROMETERS.

In all pyrometers other than radiation pyrometers, there is some part—the sensitive or receptive part—which is made to acquire a temperature identical with the temperature to be measured. In the measurement of furnace-temperatures, for example, radiation pyrometers are the only pyrometers which are entirely outside the furnace. Our long experience as makers of electrical resistance thermometers and thermo-electric couples for temperature measurement over a wide range and under the most varied conditions, has shown conclusively the accuracy and value of such instruments and the economies to be effected by their use; at the same time the great practical difficulties to be encountered in many cases have convinced us of the need for a convenient and reliable form of radiation pyrometer. As is well known, it is difficult to construct anything of solid material which can be maintained for prolonged periods at a high temperature without suffering some permanent or sub-permanent change in its physical properties, and as we ascend higher in the temperature scale, the difficulties increase in a quite disproportionate degree.

A further aggravation of the trouble is to be found in the chemical activities of furnace products and furnace gases, which in some cases render difficult the adequate protection of the resistance-wire or thermo-couple.

With the radiation pyrometers invented by M. Féry, Professor of Physics at the École de Physique et de Chimie, Paris, these difficulties are not encountered, the instruments being of course placed at some distance from the furnace, while no part of them is raised above the air temperature by more than 80 Centigrade degrees.

The radiation which emanates from a hot body, or which passes out through an observation hole in the wall of a furnace, falls upon a concave mirror and is thus brought to a focus. In this focus is a thermo-electric couple, whose temperature is raised by the radiation falling upon it: the hotter the furnace, the greater the rise of temperature of the couple.

The arrangement of the instruments is such that they are uninfluenced, within wide limits, by the size of the hot body or observation hole on the one hand, or on the other hand by the distance which separates them from the hot body or furnace*.

* No account is here taken of atmospheric absorption of radiant energy, which up to any practical working distance is quite inappreciable.

PYROMETER

For temperatures from **700° C.** to **any higher limit.**

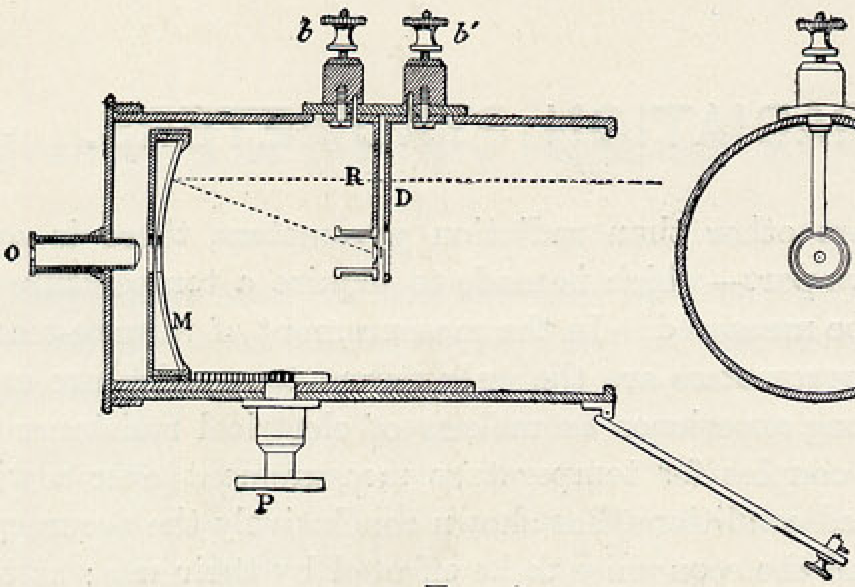

Fig. 2.

The complete outfit consists of telescope and galvanometer; fixed within the telescope, at a point upon its optic axis, is the junction of a copper-constantan thermo-couple arranged in the form of a cross. The two wires are attached to two brass strips *D* and *R* which are attached to the terminals *bb′*, Fig. 2. The terminals are connected by leads to the galvanometer as shown in Fig. 1. To use this apparatus for measuring the temperature of a furnace, an observation hole in the wall of the furnace is sighted through the eyepiece *O*, the image of this hole being brought into coincidence with the thermo-junction. **It is essential that the image of the observation hole should slightly overlap the junction which appears to the eye as a black disc in the centre of the field of view.** The readings of the instrument are then independent of the size of the observation hole. The image of the hole is reflected to the eyepiece *O* by two mirrors placed close to the couple. These mirrors serve for the adjustment of focus; they are so arranged that the image of the hole appears to be split into two parts, which only coincide when the focussing is correct. The image thus formed upon the junction produces a rise of temperature which is shown experimentally to be proportional to the amount of radiant energy which enters the telescope. The junction acquires exactly, and with great rapidity, the temperature of the image, but in no case does its temperature rise by more than 80 Centigrade degrees above the atmospheric temperature. The electro-motive force which is thus generated is measured by a highly sensitive galvanometer whose scale is divided and figured so as to read temperatures directly.

An adjustable diaphragm (not shown in Fig. 2) is fitted in front of the telescope in order that the amount of radiation falling on the thermo-couple may be varied. When measuring high temperatures the diaphragm is partially closed and the temperatures read directly on the second scale of the galvanometer. The two temperature scales ordinarily divided on the galvanometer are approximately 700° to 1300° C. and 1000° to 2000° C.

Price of the Pyrometer **£15 15 0** ($76.70)

For Price of Complete Outfit see p. 10.

MEYLAN-D'ARSONVAL GALVANOMETER.

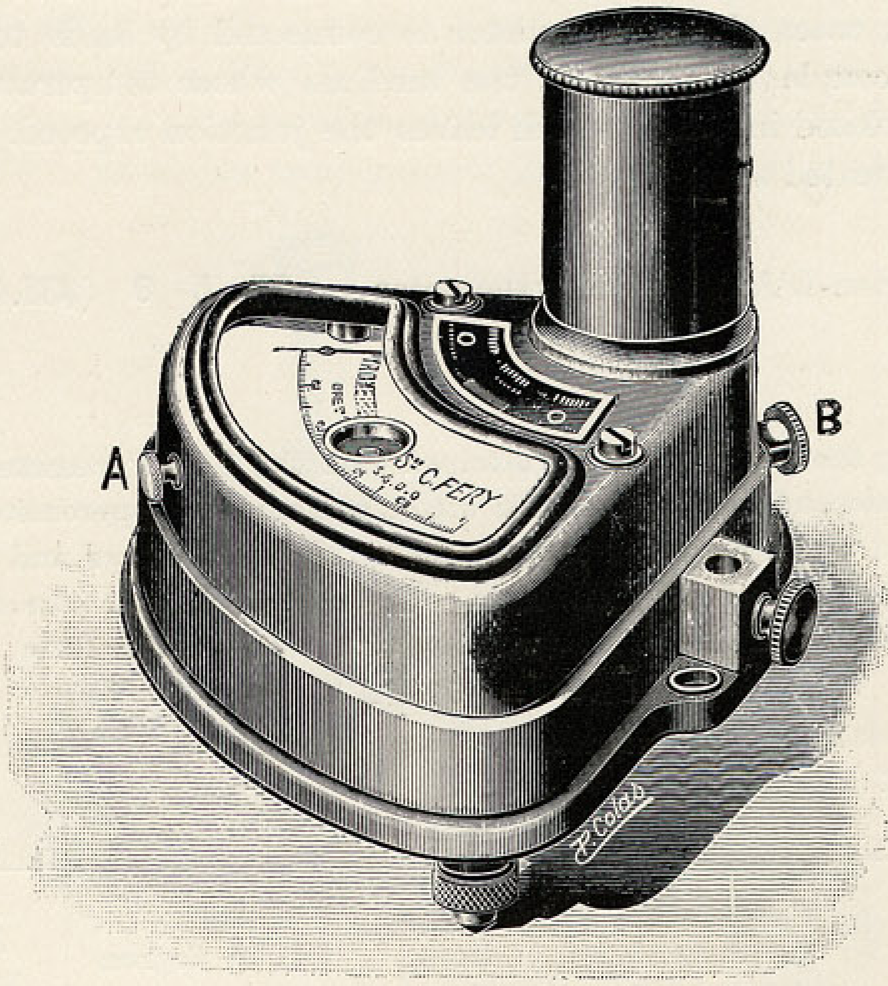

Fig. 3.

The thermo-electro-motive force due to the heating of the couple is measured by a very sensitive galvanometer, divided both in millivolts and on the Centigrade scale. This galvanometer, notwithstanding its sensitiveness, is of substantial construction ; it comprises a moving coil, provided with a needle and carried by a torsion strip, which is attached to a spring support, so as to minimise the effect of vibration and shocks. The movement of the coil takes place within a single air-gap between the poles of a strong permanent magnet. These galvanometers are invariable in their indications and unaffected by all external influences. They are provided with levelling screws and a sensitive circular spirit level. By turning the milled head *B*, Fig. 3, the moving coil can be freed when a reading is to be taken, or clamped to facilitate the removal of the instrument. Another milled head *A* enables the divided scale to be unclamped, adjusted in position to a small extent, and reclamped, so that the reading is zero when no current is flowing. The instrument has a resistance of about 10 ohms and is connected by leads about 10 metres (33 ft.) long to the terminals of the pyrometer. The graduation of the galvanometer scale is based upon Stefan's Law which expresses the relation between the temperature of a body and the amount of radiant energy which it emits. The law is as follows : "The radiant energy emitted by a furnace or a black body is proportional to the fourth power of the absolute temperature of the body." This law is a mathematical deduction from the Electro-magnetic Theory of Light*.

This galvanometer can also be made and calibrated so as to measure directly low temperatures, the temperature of liquefaction of gases, liquid air and liquid carbonic acid, or for the measurement of moderate temperatures between 0° and 600° C. In such cases the galvanometer is connected by leads to a copper constantan thermo-couple immersed in the medium whose temperature is required. The couple is enclosed in a tube which leaves the junction exposed. These couples should never be heated above 700° C.

		Code Word.
Price of the Meylan-D'Arsonval Galvanometer	£7 5 0 ($35.40)	*Headless*

* As indicating the precision to be attained with the Féry Pyrometer, over the range of temperatures independently controllable with a thermo-couple-pyrometer, we may quote some data obtained by M. Féry and reproduced by Messrs Waidner and Burgess in Bulletin No. 2, of the Bureau of Standards, Washington, U.S.A. In the investigation referred to, the Stefan-Boltzmann Law was assumed to hold in the form

$$CE = d = 7 \cdot 66\, T^4 X 10^{-12}$$

where E is the total energy of radiation, d the galvanometer deflection, T the absolute temperature, and C a constant.

d	Temperature from thermo-couple	Temperature from Stefan's Law	Δ in degrees	Error in percentage
11·0	844°	860°	+16°	1·85
14·0	914°	925°	+11°	·84
17·7	990°	990°	0°	·0
21·5	1054°	1060°	+ 6°	·60
26·0	1120°	1120°	0°	·0
32·2	1192°	1190°	− 2°	·17
38·7	1260°	1250°	−10°	·80
45·7	1328°	1320°	− 8°	·60
52·5	1385°	1380°	− 5°	·36
62·2	1458°	1450°	− 8°	·50

These figures show how far the assumptions made may be considered accurate; the *consistency* of the temperature-scale realizable with a Féry pyrometer is of a high order.

REFLECTING D'ARSONVAL GALVANOMETERS.

These instruments are made by us primarily for laboratory work, and are used with a lamp and scale or telescope and scale. In conjunction with a Féry pyrometer they serve for the finer discrimination of temperatures. The figure of merit of these galvanometers, with a suspended coil of 25 ohms resistance, is 15 millimetres deflection per microvolt, at a scale distance of one metre; such an instrument used in conjunction with a Féry pyrometer will show a scale-reading difference of about 20 millimetres for a temperature difference of 1 degree in the neighbourhood of 800° and 900° C. At higher temperatures the sensitiveness is of course higher.

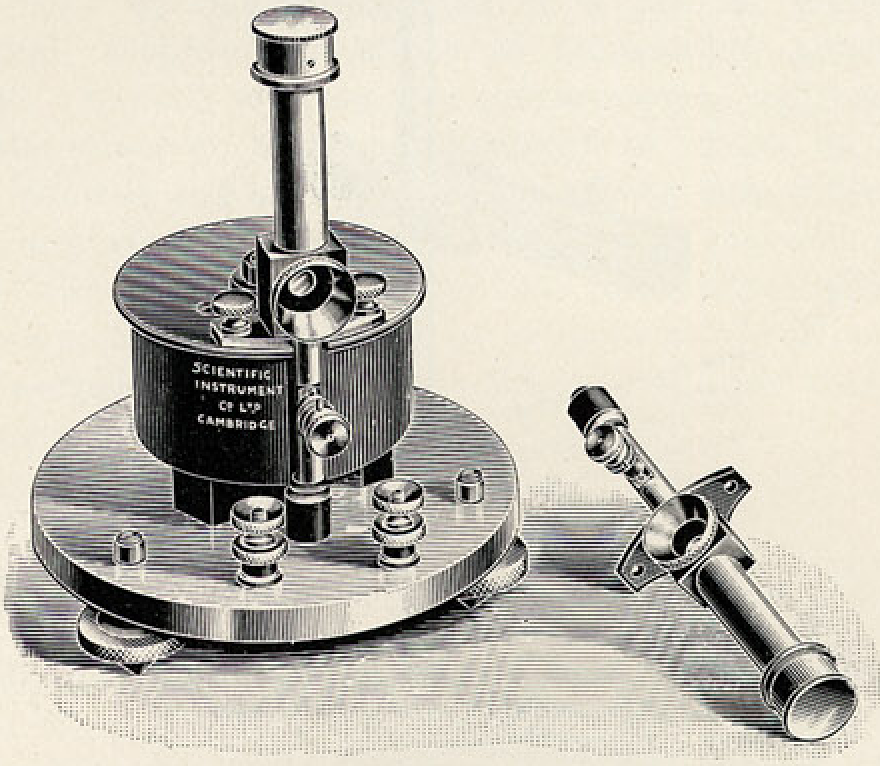

FIG. 4.

Price of reflecting d'Arsonval galvanometer complete, with one suspended coil :

	£.	s.	d.	$	Code Word.
Without tangent head (Fig. 4)	6	0	0	29.30	*Cokernut*
With tangent head	7	0	0	34.10	*Colander*
Telescope and Scale (Fig. 5) with Iron stand	3	17	6	19.00	*Haughty*
" " " with Brass stand	4	2	6	20.10	*Hauteur*
Lamp and Transparent Scale fitted with Nernst lamp	2	5	0	11.00	*Headpiece*

These are fitted with 100 Volt lamps unless otherwise ordered.

GENERAL CONSIDERATIONS.

A few words should now be said regarding different qualities of radiating surfaces as affecting the readings of the Féry pyrometers. The Law of Stefan already referred to is strictly true only of "perfectly black" bodies; bodies, that is, which absorb all the radiation falling upon them, and are destitute of reflecting power. Some bodies conform so nearly to this definition that no appreciable error is introduced by treating them as perfectly black, and by taking their true temperatures to be given by the readings of a Féry pyrometer, sighted and focussed upon them. Such substances are coal, carbon, and those metals which, on being heated, become coated with a black oxide: for example, iron and copper.

But a far larger class of *effectively black* bodies is furnished by enclosed furnaces, muffles, combustion chambers and the like. When the interior of such a furnace or chamber is at nearly the same temperature throughout, and when the observation hole is only of moderate dimensions compared with the distance behind it of the nearest furnace wall or solid body, the radiation issuing through the hole is independent of the quality of the radiating surfaces, and is the same as if those surfaces were perfectly black.

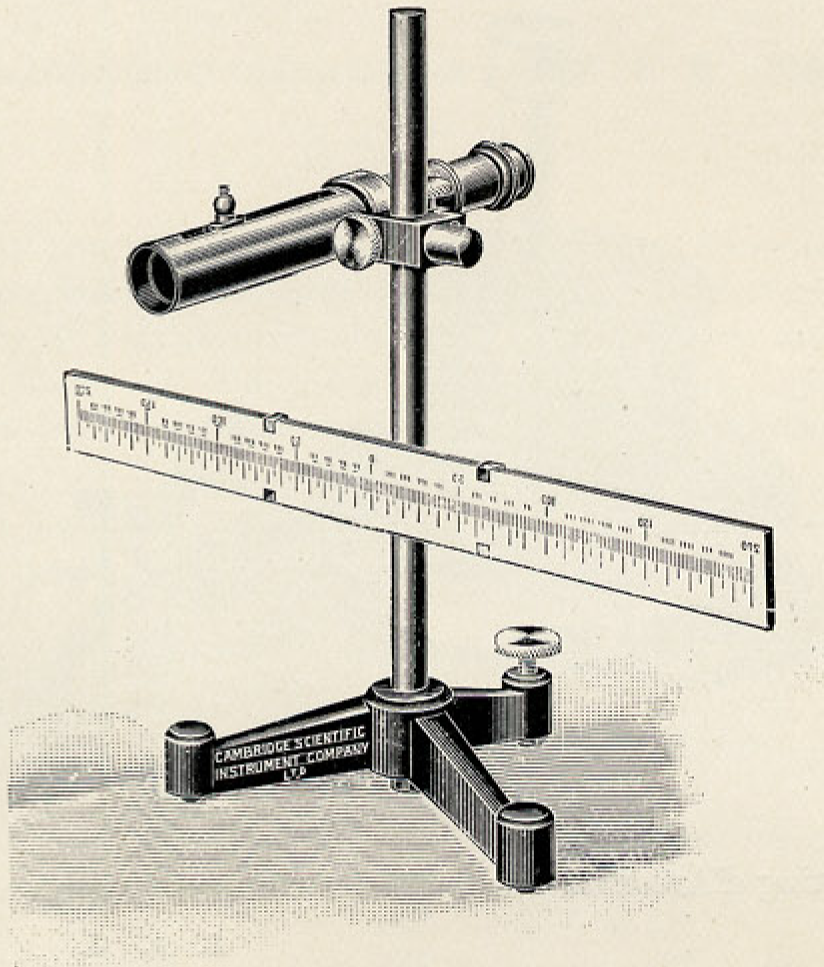

Fig. 5.

Flames interposed between the observation hole and the solids behind, provided they are at the same temperature as the furnace, will not alter the case in the least. But even when their temperature differs from that of the furnace, such flames are too transparent to absorb or emit any perceptible radiation, so that in practice no error arises from this cause. When the pyrometer is sighted upon a body which is neither black nor the effectively black interior of a furnace, the temperature directly read off from the scale of the galvanometer will be *lower* than the true temperature of the body. This uncorrected reading is called the *black-body temperature* of the body observed, and the greater the reflecting power of the body, the more widely does the black-body temperature differ from the true temperature*.

* Transparency of the observed body would further tend to increase the discrepancy, but in any practical case the thickness of the body in the line of sight would be sufficient to ensure opacity, so that the error thus arising would not be perceptible.

The question arises: How are black-body temperatures to be dealt with in practice? If a knowledge of true temperatures is essential, it will be necessary to apply corrections, based on independent investigation; the data being in some cases already available. On the other hand, *for any given substance with its surface in a specified condition, the black-body temperature serves just as certainly and definitely as the true temperature to define the thermal state.* It is precisely this certainty and definiteness which is of paramount importance in industrial operations, and in a very large number of cases black-body temperatures will be found the most convenient for specifying the thermal conditions under which a process is to be carried out.

Amongst radiation-pyrometers M. Féry's instruments are unique in showing temperatures directly **by the indications of a pointer which moves over a graduated dial,** following variations of temperature **automatically and instantaneously.** Beyond levelling the galvanometer, sighting and focussing the telescope, the observer has no adjustment to make, no special skill in observing being required, and no personal error arising from differences in colour-vision. Nor is any absolute standard of luminosity required as an auxiliary apparatus. It is also important to notice that the readings given by the Féry pyrometers are not appreciably influenced by extraneous light falling upon the body examined; the observed temperature will be the same whether the body in question is in a dark room or in daylight.

APPLICATIONS.

It will readily be seen that the Féry pyrometers can be applied to the measurement of temperatures from 500° C. up to any higher limit, the only restriction being that the body observed (or, in a furnace, the observation hole) must not be too minute.

More especially these pyrometers are valuable where the high temperature of a furnace, or the nature of the furnace gases or furnace products is destructive to ordinary pyrometers. Blast furnaces, open-hearth steel furnaces, glass-melting furnaces, brick-kilns and porcelain kilns may be mentioned as examples. In electric-arc furnaces it would evidently be hopeless to attempt a temperature-measurement by means of any pyrometer not based on the effects of radiation.

By means of his pyrometer, M. Féry finds the temperature of the electric-arc to be 3760° C.*

Again the Féry pyrometers can be rapidly sighted upon a mass of hot iron or steel that may be anywhere within convenient range, the galvanometer reading showing immediately whether the temperature is correct for forging; and in the same way a crucible full of metal ready for pouring can be observed, so as to ensure casting at the most suitable temperature, or any other product taken from a furnace can be readily examined before being further treated.

* *Comptes Rendus.*

INSTRUCTIONS FOR THE USE OF THE FÉRY PYROMETERS.

Connect the galvanometer to the pyrometer by means of the leads, taking care that the terminals of the same sign are connected together. Level the galvanometer by means of the screw feet, so that the bubble of the spirit level is central. Turn the milled head *B*, Fig. 3, so that the moving coil is unclamped; if necessary adjust the reading to zero by means of the milled head *A*; when the galvanometer has to be moved, turn the milled head *B* so as to clamp the moving coil.

Move the mirror in or out as required by means of the milled head *P*, Fig. 2. The upper and lower halves of the image of the observation hole will only blend to form a single circular image when the focus is correct; when the instrument is out of focus, the two parts of the image will appear out of centre with one another.

PRICES.

	£.	s.	d.	$	Code Word.
Pyrometer with adjustable diaphragm ...	15	15	0	76.70	*Hector*
Meylan-d'Arsonval galvanometer (direct reading on Centigrade scale)	7	5	0	35.40	*Headless*

Unless otherwise ordered, the galvanometer will be furnished with two direct reading temperature scales; one from 700° to 1300° C., the other from 1000° to 2000° C.

	£.	s.	d.	$	
Reflecting d'Arsonval galvanometer					
without torsion-head	6	0	0	29.30	*Cokernut*
with torsion-head	7	0	0	34.10	*Colander*
Tripod stand for pyrometer	1	2	6	5.50	*Headship*
Leads (33 feet long)		8	0	2.00	*Headgear*
Travelling box for pyrometer and galvanometer	1	12	6	8.00	*Headman*

Complete Outfit, for Industrial Use.

(**Temperature-range 700° to 1300° C.** and **1000°** to **2000° C., unless otherwise ordered.**)

	£.	s.	d.	$	
Pyrometer and Galvanometer, *with certificate* of the Conservatoire National des Arts et Métiers, Paris, leads 33 feet long in case complete and tripod stand for pyrometer	26	3	0	127.50	*Hectic*

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