	Nickel, 25 per cent.		Nickel, 22 per cent.	
	Density.	Temp.	Density.	Temp.
After heating, non-magnetisable......	8·15	15·1	8·13	16·5
After cooling, magnetisable..........	7·99	14·5	7·96	15·6
After heating again, non-magnetisable	8·15	18·0	8·12	18·2
After cooling again, magnetisable	7·97	22·0	7·95	21·8

The rings were each time cooled to from −100° C. to −110° C. by carbonic acid and ether *in vacuo*.

IV. "An Apparatus for testing the Sensitiveness of Safety-lamps." By Frank Clowes, D.Sc., Lond., Professor of Chemistry, University College, Nottingham. Communicated by Professor Armstrong, F.R.S. Received June 4, 1891.

It is generally acknowledged that the Davy safety-lamp cannot with certainty detect less than 3 per cent. of firedamp in the air of the mine. Gas-indicators of much greater sensitiveness have been invented; amongt these the electrical apparatus of Liveing and the spirit safety-lamp of Pieler take first rank. The objection to these special forms is, however, a serious one. They do not serve for illuminating purposes, and therefore it becomes necessary to carry an ordinary safety-lamp, together with the testing apparatus. Many attempts have been made to obviate this inconvenience by producing a safety-lamp which shall serve the double purpose of illumination and of detecting minute percentages of firedamp. The discovery of such a lamp would be of great value to the miner, in view of the fact that very low percentages of firedamp have been proved to be dangerous in the presence of coal-dust.

The following apparatus has been devised to render easy the process of testing the sensitiveness of different forms of safety-lamps when used for detecting firedamp. To enable satisfactory tests to be made in the laboratory, it was necessary to insure (1) the easy and rapid production of mixtures of firedamp and air in known proportions; (2) to insure economy of the artificially prepared methane, which represented firedamp; and (3) to examine the flame of the lamp under conditions as satisfactory as those existing in the mine.

A wooden cubical box of about 100 litres capacity was constructed so as to be as nearly gas-tight as possible. It was then made absolutely gas-tight by painting it over with melted paraffin wax, which was afterwards caused to penetrate more perfectly by passing an ordinary hot flat-iron over the surface. This testing chamber was furnished with a small inlet tube at the top, and with a similar outlet

Fig. 1.

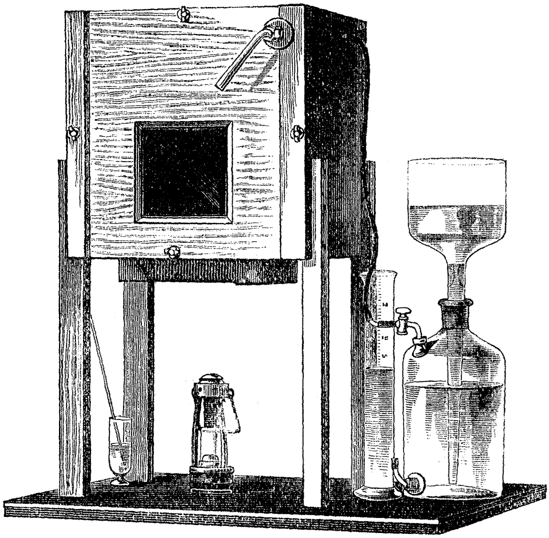
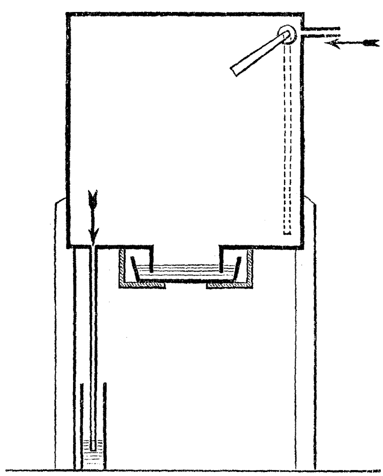


Fig. 2.



tube below. It had a plate-glass window in front for observing the lamp in the interior, and a flanged opening below for introducing the safety-lamp. This opening was closed by a water-seal consisting of a small zinc tray supported by buttons, and containing about 2 inches depth of water, into which the flange dipped. A mixer was arranged, which consisted of a light flat board, nearly equal in dimensions to the

section of the chamber, and suspended by an axis from the upper corner of the chamber. The mixer was moved rapidly backwards and forwards from the side to the top of the interior of the chamber, by grasping a handle projecting through the front of the chamber.

When a mixture of air with a certain definite percentage of fire-damp was required, the methane, prepared and purified by ordinary chemical methods, was introduced into the chamber in the requisite quantity by the top inlet. It displaced an equal volume of air, which escaped through the lower outlet, the exit end of which was sealed by being immersed just beneath a water surface. A vigorous use of the mixer secured a uniform mixture of gas and air throughout the interior of the chamber in the course of a few seconds. The lamp was then introduced into the chamber, and placed in position behind the glass window. The simplicity of arrangement of the water-seal rendered the necessary opening of the chamber very brief, and the introduction and removal of the lamp many times in succession was not found to produce any appreciable effect upon the composition of the atmosphere inside the chamber. The appearance and dimensions of the "cap" over the flame were noted as soon as the cap underwent no further change. A lamp was left burning in the chamber for a considerable length of time, and its indications underwent no change, owing to the large capacity of the chamber and the very limited amount of air required to support the combustion of the small flame always used in gas-testing. The whole interior of the chamber and mixer were painted dead-black, so as to render visible pale and small caps against a black ground.

The methane was introduced from an ordinary gas-holder. A volume of water, equal to that of the methane to be displaced, was poured into the top of the gas-holder. The gas-tap of the holder was then momentarily opened, so as to produce equilibrium of pressure between the methane and the atmosphere. The gas-tap having then been placed in connexion with the upper inlet of the chamber, the water-tap was opened, and the measured volume of water was allowed to flow down and drive the methane into the chamber. As soon as bubbles of air ceased to appear through the water at the outlet, the chamber was closed; the mixer was then vigorously worked for a few seconds, and the mixture of gas and air was ready for the introduction of the lamp. Before introducing the methane for a fresh mixture, the atmosphere of the chamber was replaced by fresh air by removing the water-tray from beneath the opening at the bottom of the chamber, and blowing in a powerful stream of air from a bellows to the top of the chamber.

The chamber was supported on legs, which were arranged so as to place it at a convenient height for observations through the window, and also for the introduction and removal of the safety-lamp.

The accuracy of this method was tested by introducing the Pieler lamp into the chamber, which was charged successively with a series of mixtures containing proportions of methane varying from 0·5 to 4 per cent. The height and appearance of the cap over the flame absolutely corresponded with a series of standard tests already published, and made by a different method, in which firedamp was used instead of methane.

The observations were usually made in a darkened room, but the flame-caps were easily seen in a lighted room, provided direct light falling on the eye or chamber was avoided.

The capacity of the chamber was 95,220 c.c.; accordingly the following volumes of methane were introduced: for $\frac{1}{2}$ per cent. mixture 476 c.c., for 1 per cent. 952 c.c., for 2 per cent. 1904 c.c., for 3 per cent. 2856 c.c., for 4 per cent. 3808 c.c., and for 5 per cent. 4760 c.c. It will be seen that a series of tests, in which the above-mentioned percentage mixtures were employed, involves an expenditure of only 15 litres of methane, a quantity far smaller than that required by any other method of testing as yet described.

Of many forms of safety-lamp tested in the above apparatus, the one which most satisfactorily fulfilled the two purposes of efficient illumination and delicacy in gas-testing was Ashworth's improved Hepplewhite-Gray lamp. This lamp is of special construction, burns benzoline from a sponge reservoir, and its flame is surrounded with a glass cylinder, which is ground rough at the hinder part; this latter device prevents the numerous reflected images of the flame, and the generally diffused reflections which are seen from a smooth glass surface, and which render the observation of a small pale flame-cap very difficult, if not impossible.

The wick of this lamp, when at a normal height, furnishes a flame of great illuminating power. When lowered by a fine screw adjustment the flame becomes blue and non-luminous, and does not interfere therefore with the easy observation of a pale cap. The following heights of flame-cap were observed, which fully bear out the unusual sensitiveness of this flame. With 0·5 per cent. of methane 7 mm.; with 1 per cent. 10 mm.; with 2 per cent. 14 mm.; with 3 per cent. 20 mm.; with 4 per cent. 25 mm.; and with 5 per cent. 30 mm. The cap, which with the lower proportions was somewhat ill-defined, became remarkably sharp and definite when 3 per cent. and upwards of methane was present. But even the lowest percentage gave a cap easily seen by an inexperienced observer.

It appears from the above record of tests that the problem of producing a lamp which shall serve both for efficient illuminating and for delicate gas-testing purposes has been solved. The solution is in some measure due to the substitution of benzoline for oil, since the

flame of an oil-flame cannot be altogether deprived of its yellow luminous tip, without serious risk of total extinction; and this faint luminosity is sufficient to prevent pale caps from being seen.

From further experiments made in the above testing chamber with flames produced by alcohol and by hydrogen, it was found to be true in practice, as might be inferred from theory, that, if the flame was pale and practically non-luminous, the size and definition of the flame-cap was augmented by increasing either the size or the temperature of the flame. It is quite possible by attending to these conditions to obtain a flame which, although it is very sensitive for low percentages of gas, becomes unsuitable for the measurement of any proportion of gas exceeding 3 per cent. This must, for the general purposes of the miner, be looked upon as a defect; but it is not a fault of the lamp already referred to. It is of interest to note that with the Pieler spirit-lamp a flame-cap an inch in height was seen in air containing only 0·5 per cent. of methane.

V. "On the Forces, Stresses, and Fluxes of Energy in the Electromagnetic Field." By OLIVER HEAVISIDE, F.R.S. Received June 9, 1891.

(Abstract.)

The abstract nature of this paper renders its adequate abstraction difficult. The principle of conservation of energy, when applied to a theory such as Maxwell's, which postulates the definite localisation of energy, takes a more special form, viz., that of the continuity of energy. Its general nature is discussed. The relativity of motion forbids us to go so far as to assume the objectivity of energy, and to identify energy, like matter; hence the expression of the principle is less precise than that of the continuity of matter (as in hydrodynamics), for all we can say in general is that the convergence of the flux of energy equals the rate of increase of the density of the energy; the flux of the energy being made up partly of the mere convection of energy by motion of the matter (or other medium) with which it is associated localisably, and partly of energy which is transferred through the medium in other ways, as by the activity of a stress, for example, not obviously (if at all) representable as the convection of energy. Gravitational energy is the chief difficulty in the way of the carrying out of the principle. It must come from the ether (for where else can it come from?), when it goes to matter; but we are entirely ignorant of the manner of its distribution and transference. But, whenever energy can be localised, the principle of continuity of energy is (in spite of certain drawbacks connected with the circuital flow of energy) a valuable principle which should be utilised to the

FIG. 1.

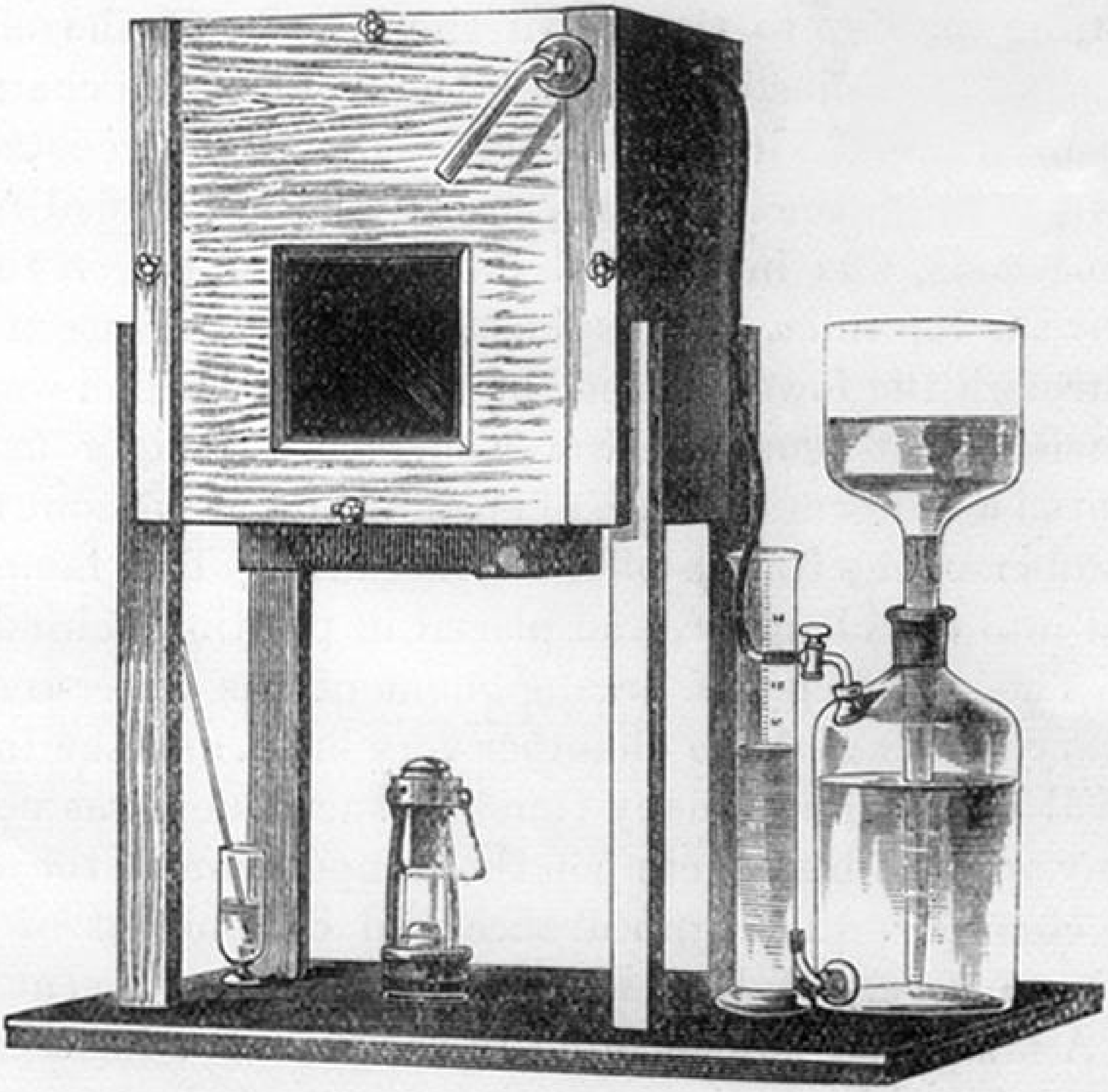


FIG. 2.