On an Arc-Lamp suitable to be used with the Duboscq Lantern

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e is a micrometer-screw with graduated head, which supports the upper clip on the lower clip. In use the lower clip is first levelled by the screw *d*; then the upper clip is levelled by the micrometer-screw, and a reading taken. The clips being always accurately levelled, in a plane perpendicular to that in which the four points attaching the clips to the test-bar lie, the micrometer-readings are the distances between the middle points of the two parallel clips; and their differences are the mean of the elongations on the two sides of the test-bar, or virtually are readings at the axis of the test-bar. Readings to $\frac{1}{10000}$ th of an inch can be taken.

Roller-and-Mirror Extensometer.—Fig 3 is a diagrammatic sketch of another instrument on the same principle. *a* and *b* are two clips similar to those in fig. 2; the lower clip is supported on the test-bar by a screw *d*; the upper clip is supported on the lower by a stay-bar with knife-edges, *e*. At *r* and *m* are the roller and mirror, the axis of these being at the same distance from the knife-edge of the stay-bar as the set screw of the clip. A touch-piece or finger, *f*, attached to the lower clip presses on the roller. If the bar extends, the roller approaches the lower clip by an equal amount; it turns against the finger *f*; and the amount of rotation is read by a telescope and scale. This instrument will easily read to $\frac{1}{100000}$ th of an inch. The roller being at the centre of the clip, its movement is the mean of the elongations on the two sides of the test-bar.

The author showed a third instrument on the same principle, for obtaining the compression of small blocks of stone.

XXVII. *On an Arc-Lamp suitable to be used with the Duboscq Lantern.* By PROFESSOR SILVANUS P. THOMPSON, D.Sc.*

[Plate III.]

THE lamp devised by Foucault and Duboscq, and supplied for so many years by the famous house of Duboscq, fails to fulfil the electrical requirements of the modern physical laboratory, though it has rendered excellent service in the past. Yet the lantern and optical adjuncts of the standard

* Read March 27, 1886.

pattern of Duboscq are so widely used that it seemed desirable to find some other arc lamp which, while fulfilling the electrical requirements of the case, could be used with the Duboscq lantern.

Before describing the lamp which I have for twelve months employed for this purpose, I propose to state the conditions to be fulfilled, and the reasons why the old Duboscq lamp fails to fulfil them.

The modern physical laboratory is usually supplied with electric energy under one of two alternative conditions, namely either at constant potential or with constant current ; more usually under the former condition. If supplied from a dynamo the dynamo may be either series-wound, shunt-wound, or compound-wound. If supplied from accumulators the accumulators will work at constant potential, and will have a very small internal resistance.

The arc-lamp for laboratory use must be capable of working under the given conditions. No doubt the Duboscq lamp worked fairly when supplied with current from 50 Grove's cells. But in a laboratory where there is another and better and less wasteful source of supply, 50 Grove's cells are not desirable. Though 40 accumulators have an electromotive force almost exactly equal to that of 50 Grove's cells, the Duboscq lamp does not work well with them unless a resistance of several ohms is intercalated in the circuit to represent the internal resistance of the Grove cells ; and even then the Duboscq lamp does not, for certain reasons, work as satisfactorily as the lamp to be described, and its cost is about three times as great.

In every arc-lamp for optical purposes there must be mechanism adapted to perform the four following actions:—

1. To bring the carbons together into initial contact.
2. To part the carbons suddenly, and with certainty, to a short distance—about 3 millimetres—apart. This action is technically called “striking” the arc.
3. To supply carbon as fast as it is consumed, by moving one (or both) of the pencils forward into the arc. This action is called “feeding” the arc.
4. To so move the carbons, or their holders, that the luminous points retain the same position in space at the proper

focus of the optical system. This action is called "focusing" the arc.

It may be remarked, in passing, that the feeding mechanism of many lamps also performs the action, set down as No. 1 of the above, of bringing the carbons into initial contact preparatory to striking the arc.

In many arc-lamps the attempt is made to unite the striking and feeding mechanisms in one ; but in many lamps, and in the one I have to describe, the striking and feeding mechanisms are distinct. The striking mechanism in all the arc-lamps of commerce consists of an electromagnet or solenoid arranged in the main circuit of the lamp, the armature or plunger of the same being mechanically connected with one or both of the carbons, so that when, by the turning on of the current through the touching carbons, there is a great rush of current, the attraction of the electromagnet or solenoid shall instantly part the carbons and strike the arc. In the majority of the commercial arc-lamps it is the upper carbon only that is raised to strike the arc ; in a few other lamps, and in the one I am using, the lower carbon is depressed. In one of the older patterns of the Duboscq lamp the lower carbon was also thus directly acted upon, its holder being attached to the armature of an electromagnet beneath it. The same is true of the Serrin lamp. But in the Duboscq-Foucault lamp the arc is struck in a different way. The two carbon-holders are connected by racks to a clockwork gearing which either parts them or brings them together, the movement being driven by a double train of wheels, either of which can be released in turn. The weight of the upper carbon-holder drives the train that moves the carbons together ; a coiled spring drives the train that parts the carbons. Whether either of the trains, or neither of them, shall be released is determined by the position of a double-toothed detent which, placed between the final spur-wheels of the two trains, locks both of them when in its mean position, but releases one or other when shifted to right or left. The position of this detent is determined by the current through the lamp, it being attached to one end of a three-arm lever, the two other ends of which are respectively attached to the armature of the controlling electromagnet and to an opposing spiral spring.

When the moment of pull of the electromagnet upon its armature is greater than that of the opposing spring, the detent is pulled over one way, releasing the approximating train of wheels while retaining locked the parting train. When the moment of the pull of the opposing spring exceeds that of the electromagnet on its armature, the detent is pulled over the other way, locking the approximating train and releasing the parting train. When the pull of the electromagnet exactly balances that of the opposing spring, both trains are locked. Now when the current is at first turned on, there is a sudden pull upon the armature of the electromagnet; but the carbons are not instantly parted, partly because of the inertia of the train of wheels, and partly because of the backlash of the mechanism. Two or three seconds may elapse before the arc is struck. This delay is serious, either when working with dynamo or with accumulators. If the dynamo is shunt-wound, the shortcircuiting even for this short period demagnetizes the field-magnets. If the dynamo is series-wound or compound-wound, or if accumulators are being used, there is overheating during the period of delay. Supposing, however, the arc to be struck, then the inertia of the train of wheels makes itself evident in another way; for it parts the carbons too far, producing a long arc of considerable resistance; and as the current then drops below its normal value, the armature goes over the other way, and the other train of wheels is momentarily released. This alternation between the two trains, which often lasts for some time, produces a disagreeable instability.

The feeding mechanism of arc-lamps next comes in for consideration. The object of the feeding mechanism is to supply carbon as fast as it is consumed, and so keep the light constant. But the light cannot be kept constant unless the consumption of electric energy in the arc is constant. The electric energy is the product of two factors—the current through the arc, and the difference of potential between the electrodes. Calling the current i and the potential difference e , it is the product ei which is to be kept constant. Now, as remarked at the outset, the very conditions of modern electric supply are that either e or i is maintained constant, the usual arrangement in commercial lighting being i constant for arc-lamps in series,

and e constant for glow-lamps in parallel. One of the two factors being a constant by the conditions of the supply, the other factor must be kept constant by the feeding mechanism. Or, in other words, the variations of the other factor should be made to control the action of the feeding mechanism. The mechanical part of the feed may consist of a train of wheels driven by the weight of the carbon-holder or by a spring, or it may consist of a friction-clutch holding the carbon from sliding forward, or of a worm-gearing or any other; but it must be controlled by an electric mechanism of one of the two following kinds. For keeping i constant, the feeding mechanism must be controlled by an electromagnet (or solenoid) placed in the main circuit, working against an opposing spring or weight. For keeping e constant, the feeding mechanism must be controlled by an electromagnet (or solenoid) placed as a shunt to the arc, and working against an opposing spring or weight. In the latter case, if for any reason the arc grows too long, the potential at the terminals will rise, more current will flow around the shunt, which will then overcome its opposing spring (or weight), and will release the feeding machinery until balance is restored. The use of the shunt, introduced first by Lontin, enables arc-lamps to be connected two or more in series in one circuit. A less perfect solution is the differential principle introduced by Von Hefner Alteneck, where the difference between the attractions of a series and a shunt-solenoid maintains constant, not the product ei , but the difference $e-i$.

The only perfect solution of the problem is a feeding mechanism which, by combining in itself a shunt-coil and a series-coil, shall keep the product ei a constant, however either factor may vary. All the commercial arc-lamps for lighting in series have shunt-circuits to control the feeding mechanism; though often the arrangement takes the form of a shunt-coil wound (differentially) outside the series-coil of the striking mechanism; so that feeding is accomplished by the shunt-coil demagnetizing the striking electromagnet and momentarily un-striking the arc.

Returning to the Duboscq lamp, it may be observed that, as it possesses no shunt-coil, it can only feed by a weakening of the current in the main circuit. Hence it is obvious that a

Dubosq lamp cannot possibly work in a constant-current circuit. Also two Dubosq lamps will not work in series with one another, as their individual feeding is not independent of the other. Neither will two work in parallel with one another; for the weakening of current in one throws more current through the other, and the instability before alluded to—called “hunting” by electric engineers—becomes yet more pronounced.

The lamp that I have adapted to the Dubosq lantern is one known in commerce as the “Belfast” arc-lamp, its principles of construction being due to Mr. F. M. Newton; but I have had the design altered to suit the special work. In this lamp, as previously mentioned, the striking and feeding mechanisms are separate. The arc is struck by means of an electromagnet E of the tubular pattern, having as its armature an iron disk A, which, when no current is passing, is held up by a short spiral spring at about 3 millim. from the end of the electromagnet. The lower carbon-holder is mounted upon this disk, so that the arc is struck by the downward movement of the lower carbon. The feeding mechanism is both simple and effective. The upper carbon-holder is a long straight tube of brass: it passes through a collar in the frame of the lamp, and also through a metal box B above. This metal box contains a piece of curry-comb with the steel bristles of the comb set to point obliquely inwards and downwards. They grip the carbon-holder and allow it to be pushed downwards, but not upwards. The box itself is mounted upon a strong brass lever, L, close to the point of the lever. One end of this lever is drawn downwards by an adjustable spiral spring S, whilst the other carries an iron armature which stands immediately above the poles of an electromagnet, which is wound with fine wire and placed as a shunt to the lamp. Above the lever there is a contact-screw, platinum-tipped, making contact with the lever, exactly as in the ordinary trembling electric bell, and the lever and contact-screw are included in the shunt-circuit. The attraction of the shunt-magnet for its armature is opposed by the pull of the spiral spring. Whenever, by reason of the resistance of the arc, a sufficient current flows through the shunt-circuit, the opposing spring is overcome, and the lever is set into vibration like the lever of an electric

bell, but more rapidly. The vibratory motion is thus communicated to the box containing the steel wire comb, which at once, by an action well known in mechanism, wriggles the carbon-holder downwards by innumerable small successive impulses. So soon as the motion of the carbon has reduced the resistance of the arc, the shunt-current diminishes and the feeding action ceases, to recommence when required. It is found best for lantern-purposes to send the current upwards through the lamp, the lower carbon being the positive one. A thick cored carbon of 13 to 15 millim. diameter is preferred, as it gives a good luminous crater and burns slowly. A 10-millim. copper-plated carbon is used for the upper electrode, and it is adjusted so that its centre falls slightly in front of the centre of the lower carbon, thereby causing the crater to send its light forward.

The lamp as used in commerce has no focusing-arrangement. In adapting it to the Duboscq lantern, the frame was made narrow; so that when the inner chimney of the Duboscq lantern was removed, the lamp could be dropped entire down the outer chimney, a metal sleeve of the same diameter as the inner chimney being added to the lamp as a guide. At the bottom of the lamp a gun-metal tube was added, tapped inside with a screw-thread, into which works a steel screw having a small hand-wheel near its lower end and a pointed pivot at the extremity. The lamp slides down the chimney of the lantern until the pivot touches the base-board. When the arc burns down the lower carbon, so that the luminous crater is no longer in the optical focus, a turn given by hand to the wheel suffices to raise it to the proper position; but the lamp will burn for ten minutes without requiring any readjustment on this account. The lamp shown to the Physical Society was constructed by Mr. E. Rousseau, Instructor in the Physical Workshop of the Finsbury Technical College, assisted by Mr. A. D. Raine, now Demonstrator in the City and Guilds Central Institution.