No. 724,229. PATENTED MAR. 31, 1903.

J. J. WOOD.

ELECTRIC ARC LAMP.

APPLICATION FILED APR. 23, 1902.

NO MODEL. 2 SHEETS—SHEET 1.

FIG. 1.

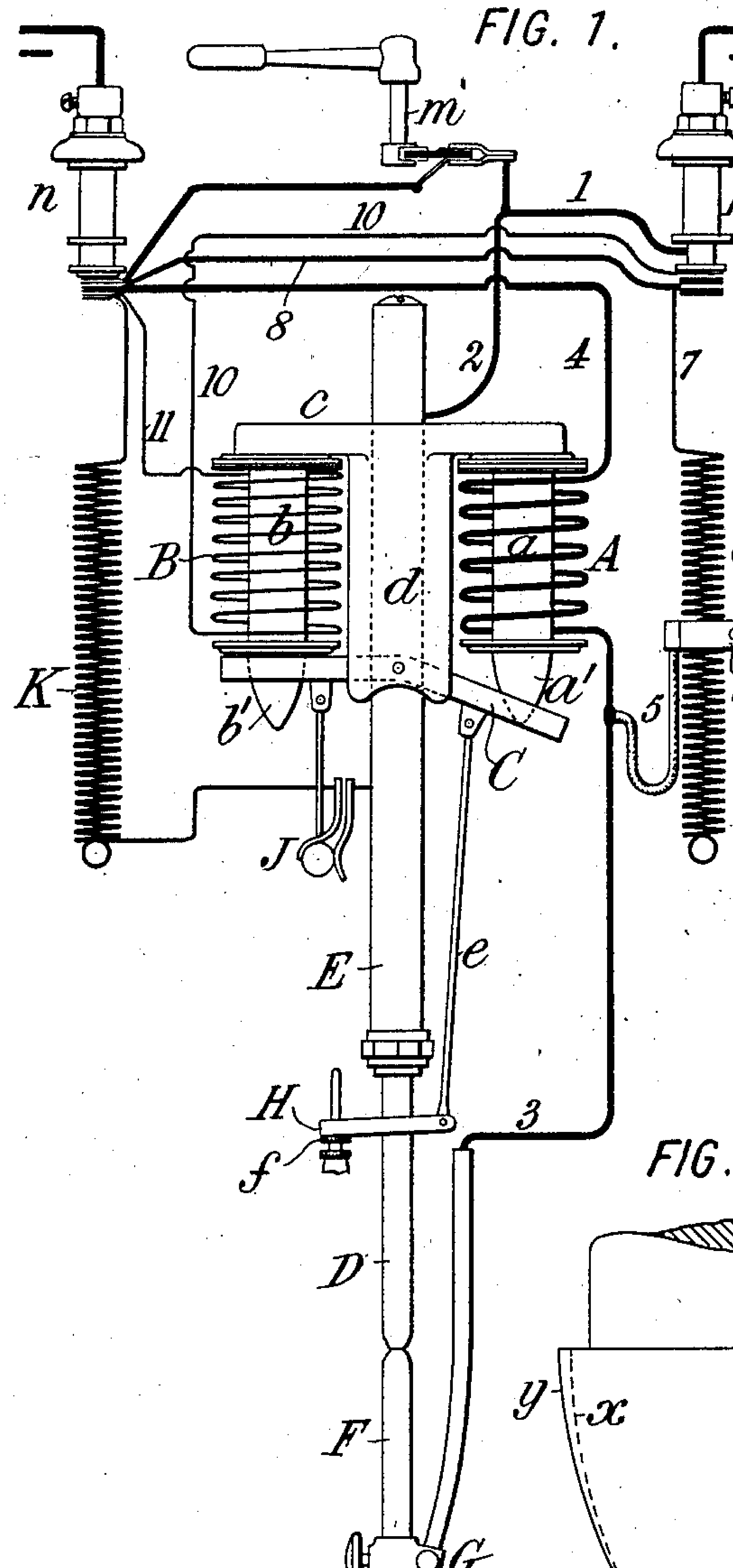


FIG. 2.

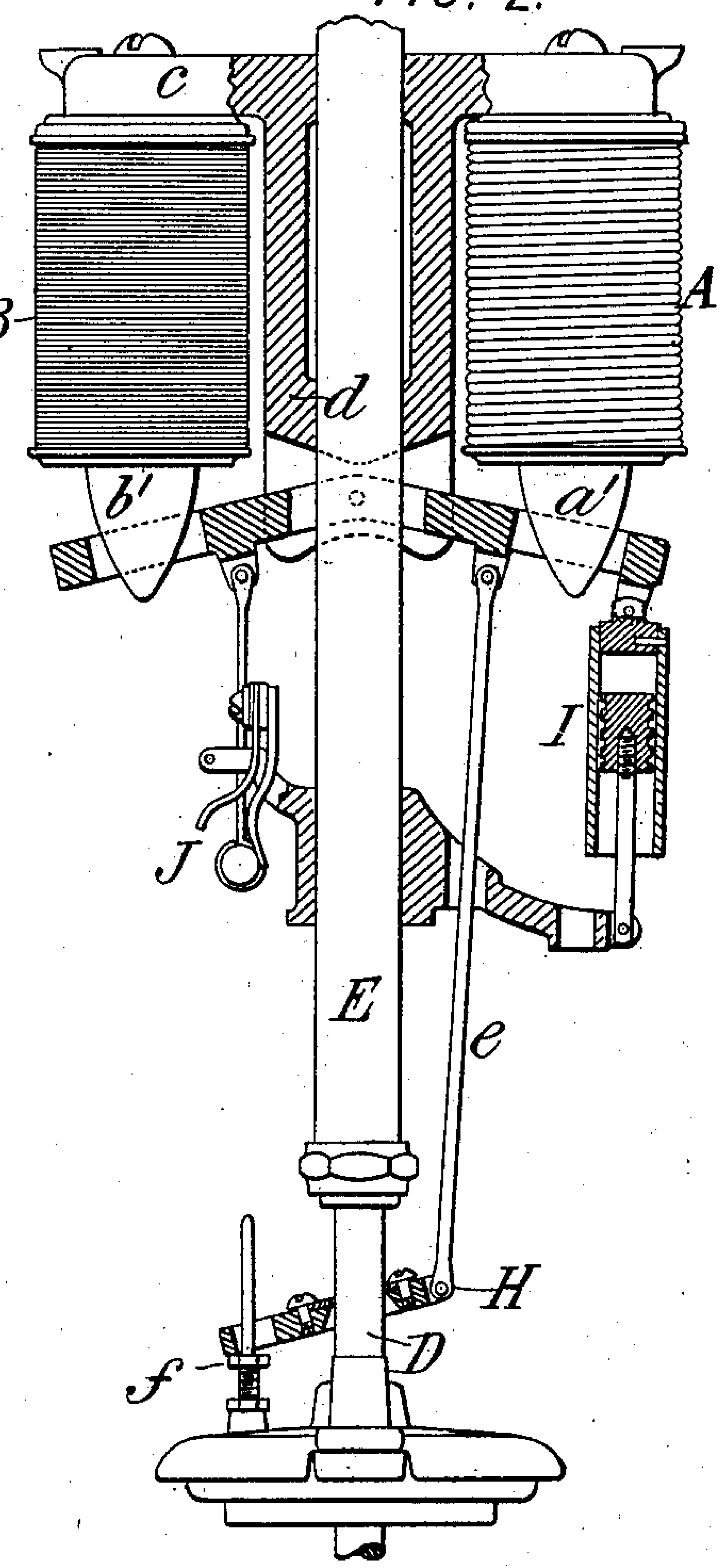


FIG. 5.

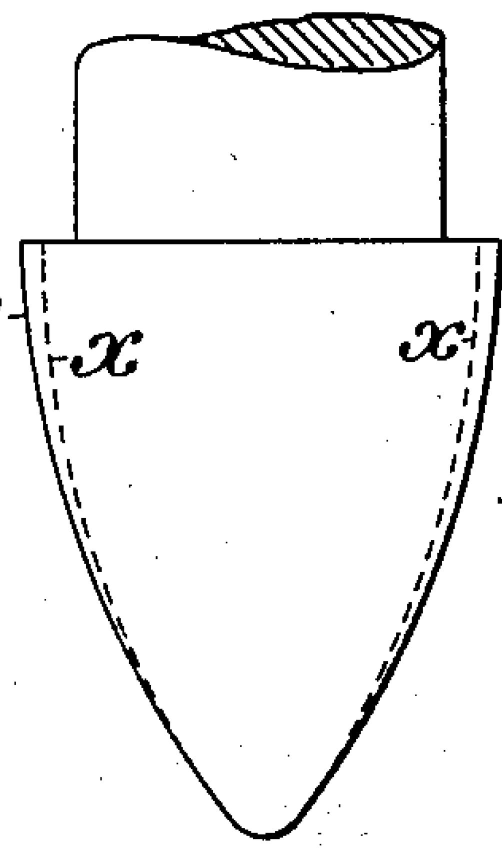


FIG. 3.

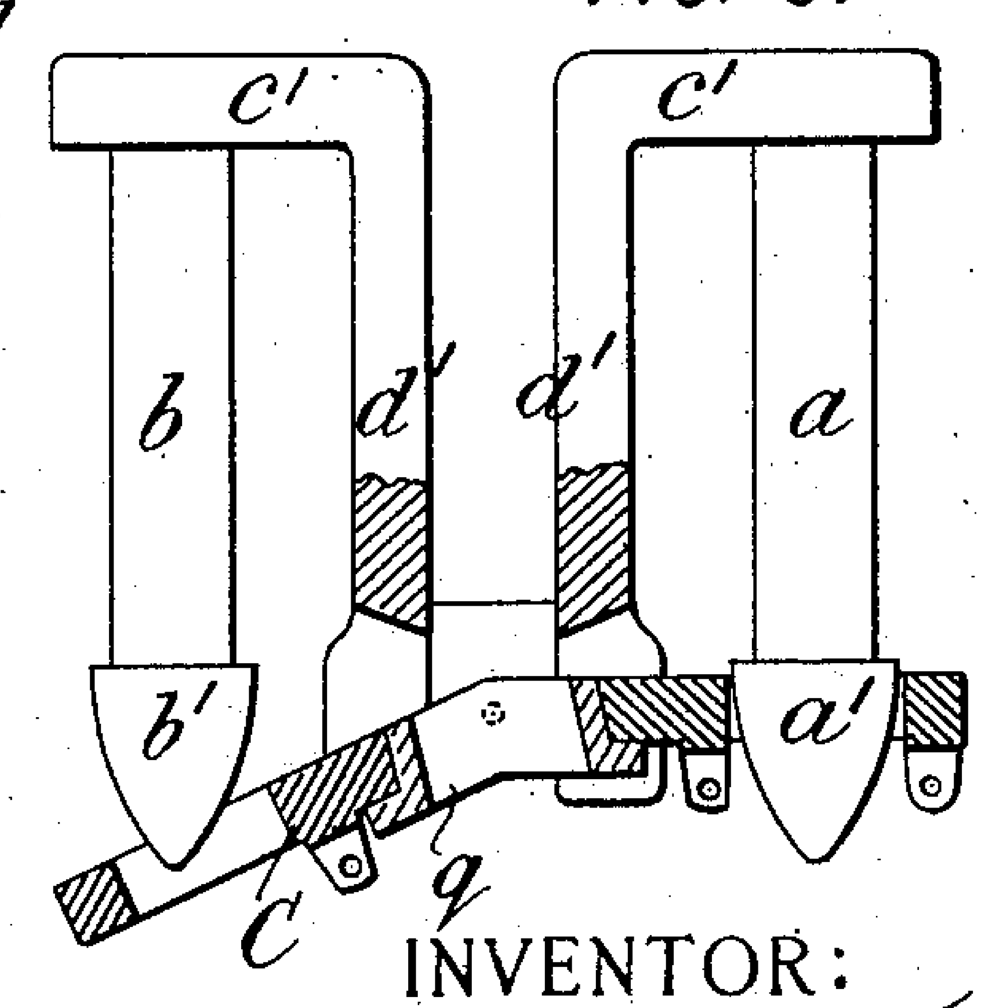
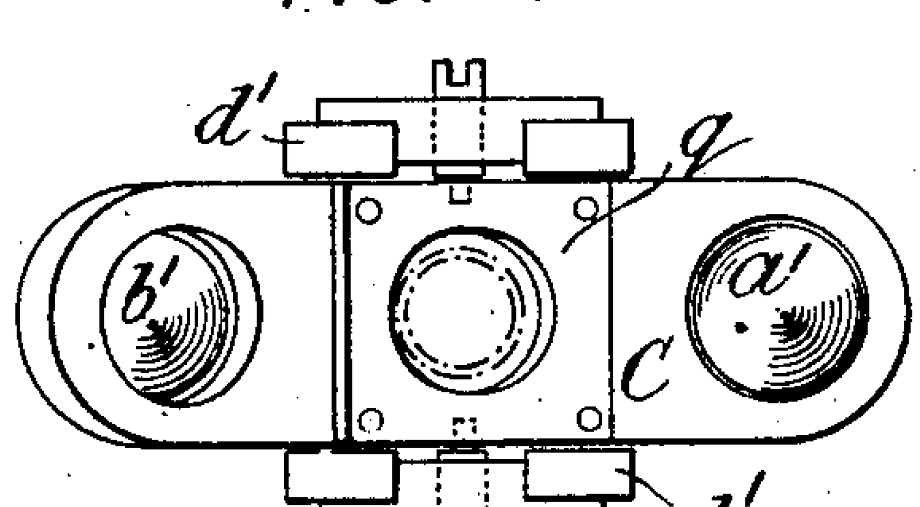


FIG. 4.



WITNESSES:

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Thomas F. Wallace

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ELECTRIC ARC LAMP.

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NO MODEL. 2 SHEETS—SHEET 2.

FIG. 6.

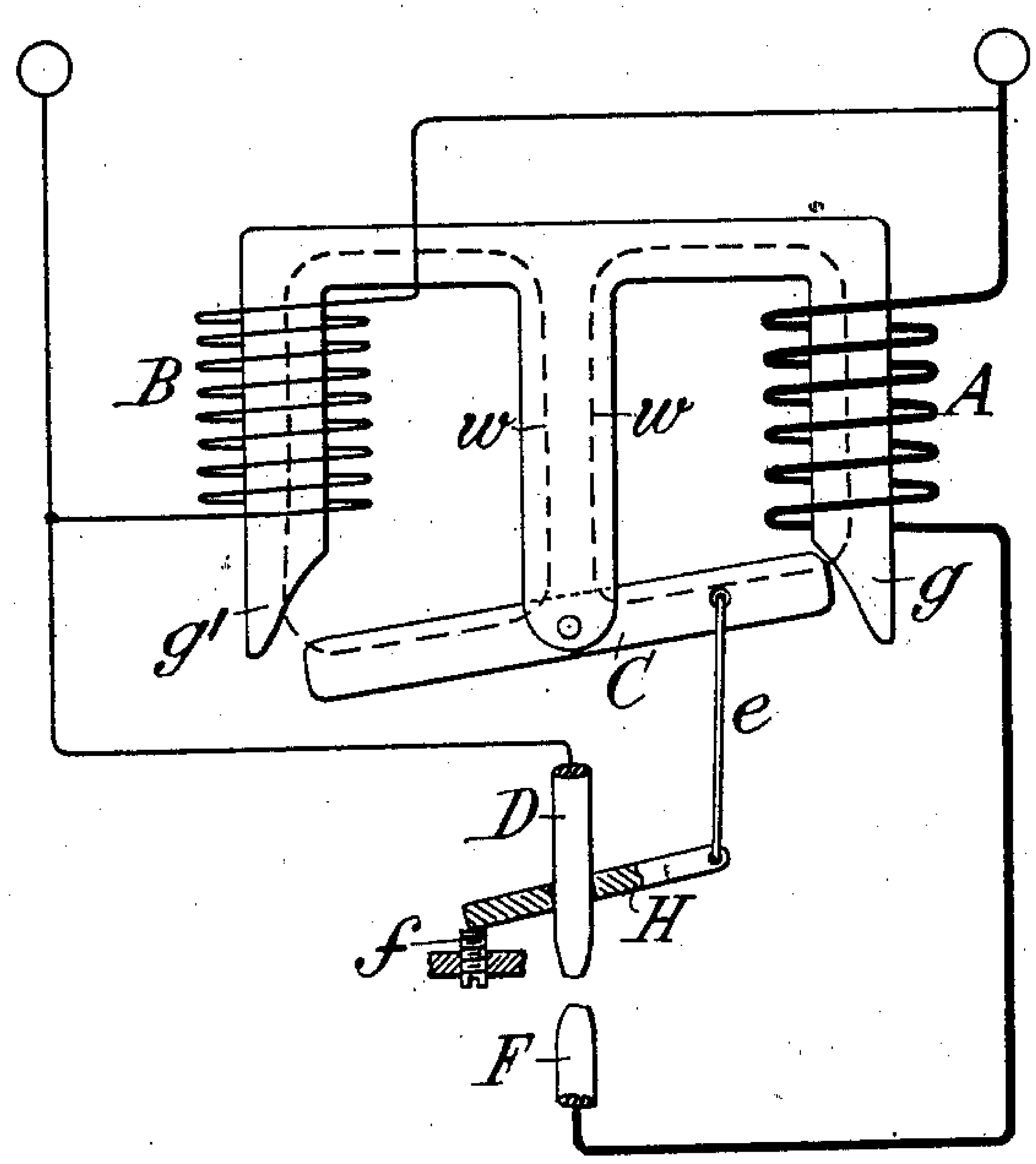


FIG. 7.

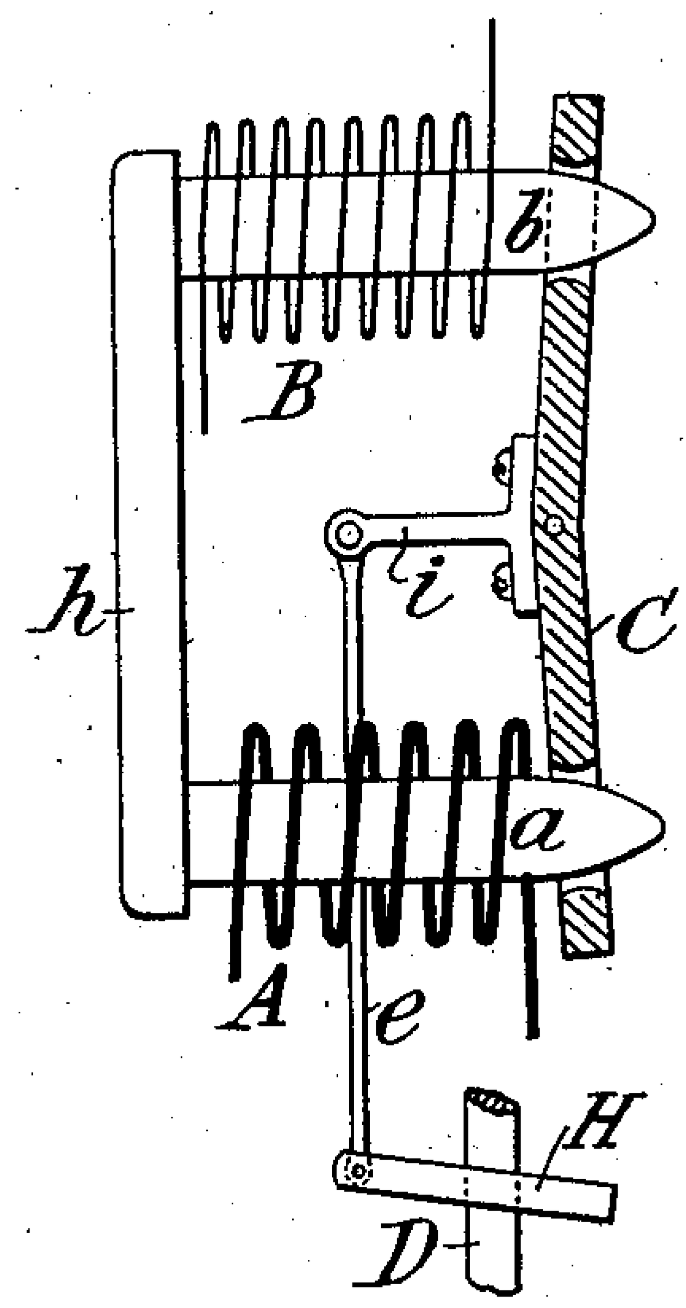


FIG. 8.

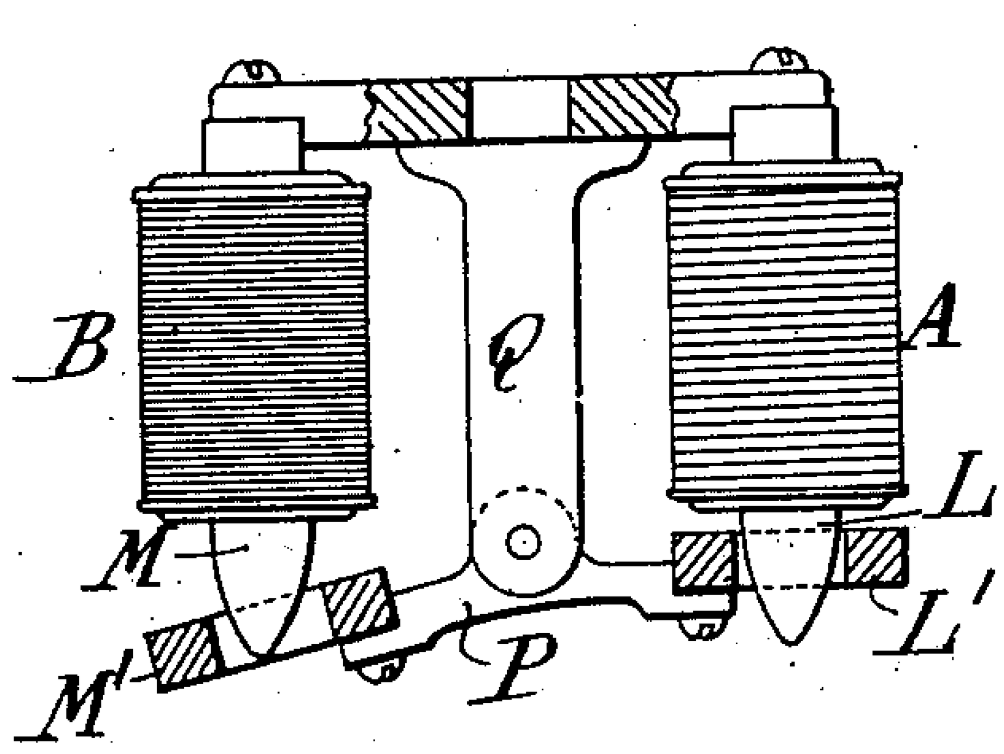
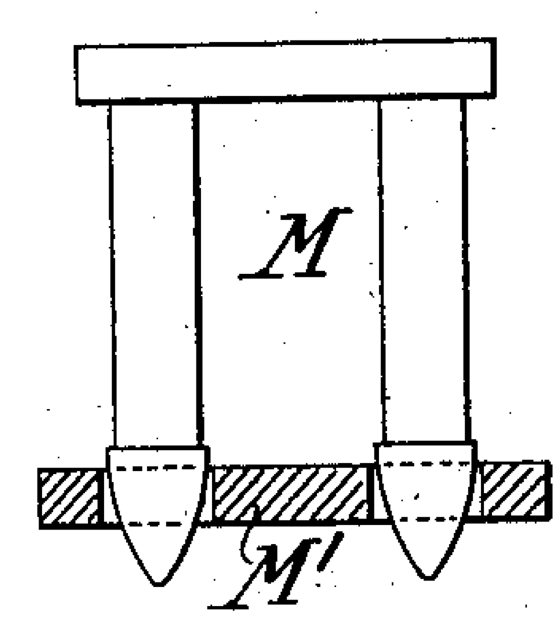


FIG. 9.



WITNESSES:

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UNITED STATES PATENT OFFICE.

JAMES J. WOOD, OF FORT WAYNE, INDIANA.

ELECTRIC-ARC LAMP.

SPECIFICATION forming part of Letters Patent No. 724,229, dated March 31, 1903.

Application filed April 23, 1902. Serial No. 104,325. (No model.)

To all whom it may concern:

Be it known that I, JAMES J. WOOD, a citizen of the United States, residing at Fort Wayne, in the county of Allen and State of Indiana, have invented certain new and useful Improvements in Arc-Lamps, of which the following is a specification.

This invention relates to means for compensating for the effect of changes of temperature upon the operation of arc-lamps, being peculiarly adapted to carbon-feed long-burning or inclosed-arc lamps in which the arc is close to the mechanism-case, so that it has a considerable heating effect upon the magnets.

In arc-lamps the feeding of which is controlled wholly or in great part by the excitation of a shunt-coil it is well known that the feeding-voltage varies with variations in temperature of this coil. The separating or "pick-up" voltage, or voltage at which the arc is sprung, also varies with changes in temperature, affecting the starting-magnet whenever the coil of this magnet is wholly or partly short-circuited by a resistance. Thus in differential lamps or those controlled by the mutual reaction of series and shunt coils, acting either on a common magnetic circuit or on separate circuits, so that the moving part of the magnetic system responds to the mean of the magnetizing effect of the two coils, the lamp when first started and while cold separates its carbons at a voltage lower than that under which the lamp is designed to operate normally and feeds at a somewhat-higher voltage so long as the lamp continues cool, while when it becomes heated the feeding-voltage is raised by the increased resistance of the shunt-coil due to its higher temperature, which weakens it, while the separating-voltage is not affected nearly so much, though the higher resistance of the series coil under its increased temperature causes an increased proportion of the current to be diverted through the shunt around this coil, so that the effect of increased temperature is to weaken the magnetizing effect of both shunt and series coils, so that a higher voltage is required to energize them to the requisite extent. For example, it is a common experience for a lamp designed normally to work at, say, seventy-four volts and to pick up when cold at about seventy to seventy-two volts to feed at about the normal voltage only when cold, (a condition, however, which exists only in lamps hung outdoors in very cold weather,) while with the heating of the lamp, which commonly occurs, the voltage rises often to eighty or sometimes even to ninety volts. This increased voltage is of course accompanied by an arc of abnormal length and is of course a waste of energy, which is not even compensated for by the increase of light. Many attempts have been made to provide means for overcoming this difficulty. Apparently a lamp designed to be used where it is subject to a high temperature might be made to pick up at a voltage so far below the normal that when the lamp is heated to that temperature under which it would normally operate its voltage would have risen to the normal; but this would afford no satisfactory solution of the problem, since the lamp after starting must burn for a long time before its carbons can waste away sufficiently to produce an arc of proper length, and during this period of perhaps an hour or more the light given out by the lamp would be insufficient or unsatisfactory; further, each lamp would have to be designed for its own special temperature condition, which would be practically inconvenient, and as the temperature inevitably varies within considerable limits the lamp would oftener be operating under a different temperature from that for which it was designed than under its normal temperature. The only measurably successful efforts to solve this problem of temperature compensation have been those which apply some thermostatic device essentially extraneous to the feeding mechanism proper of the lamp, which device, responding to changes in temperature, in turn influences the feeding mechanism in such direction as to effect at least an approximate compensation for the temperature changes. Since the effect of a rise of temperature is to weaken the shunt-magnet, such thermostatic regulator must be so applied as to correspondingly strengthen the magnet. This is effected in various ways, as by diminishing the resistance of the shunt-circuit or by increasing the conductivity of the magnetic circuit. Thus this thermostatic device has been applied to partially close or bridge the air-gap of the magnet with the rise of temperature. Such thermostatic regulators, however, while measurably effective, are objectionable by reason of their complication, their expense, the delicate adjustment they require, and their liability to get out of order.

My invention aims to solve the problem of temperature compensation by means wholly within the feeding or controlling magnet or magnets of the lamp and without recourse to any extraneous device whatever and without adding anything to the cost of the lamp. This I accomplish through the medium of a method or principle which I have discovered and applied, whereby by merely suitably proportioning the magnetic elements of the feeding mechanism I accomplish the requisite compensation to such effect that the lamp after being warmed to the minimum amount which necessarily accompanies its operation will both separate and feed at a voltage which remains constant notwithstanding any subsequent increase of temperature, while when the lamp is cold it separates its carbons at a voltage somewhat less than the normal feeding-voltage, and when forced to feed by hand feeds at a voltage much lower than its pick-up voltage. These results I attain by so proportioning the magnetic elements that with a given current in the series coil the lifting action of the magnet is strengthened, while with a given current in the shunt-coil the action of the magnet in the feeding position is strengthened. This is preferably done by so mutually shaping the portions of the magnet at or adjacent to the air gap or gaps that when the movable part approaches the fixed part of the magnetic circuit the air-gap shall be diminished in such ratio that it will strengthen the magnet to an extent substantially equal to that to which it is weakened by the increased resistance due to a higher temperature.

I will proceed to describe my invention in its preferred embodiment and in certain modifications with reference to the accompanying drawings, wherein—

Figure 1 is a circuit diagram illustrating so much of the mechanism of one form of lamp to which my invention is applied as to enable the same to be understood. Fig. 2 is a sectional elevation, on a larger scale, of the regulating-magnet and feeding mechanism. Fig. 3 is a sectional elevation of a slightly-modified magnet, the coils being omitted. Fig. 4 is an inverted plan of the magnet shown in Fig. 3. Fig. 5 is an elevation, on a larger scale, of the pole-piece of either of the magnets shown in the preceding figures. Fig. 6 is a diagrammatic view, the circuits being simplified with respect to Fig. 1 and showing a different construction of magnet. Fig. 7 is a sectional side elevation showing another form of magnet. Fig. 8 is a sectional side elevation illustrating a double horseshoe-magnet. Fig. 9 shows a core of one horseshoe-magnet of Fig. 8 and the armature thereof in section.

Referring to Figs. 1 and 2, let A designate the series coil and B the shunt-coil, the magnet in this instance having cores *a* and *b*, Fig. 1, encircled by the respective coils and united by a yoke *c*, from the middle of which a leg *d* projects between the cores and has pivoted to it the armature C, the opposite arms of which approach the pole-pieces *a'* and *b'* of the respective cores, so that two magnetic circuits are formed, the circuit of the series magnet being through the core *a*, the yoke, the leg *d*, and the corresponding arm of the armature, while that of the shunt-magnet is through the core *b*, the yoke, the leg *d*, and the opposite arm of the armature. In the slightly-modified magnet shown in Fig. 3 the two magnetic circuits are more distinctly seen, since instead of the one leg *d* each magnet-core has its corresponding yoke *c'* and connecting-leg *d'*, with its independent armature. The two armatures are joined by non-magnetic metal *q*. In the magnets shown the pole-pieces are conoidal and project into holes in the opposite arms of the armature.

In the lamp shown the upper carbon D slides up in a fixed tube E, while the negative carbon F is held in a clamp G. A feeding-clutch H of any ordinary kind engages the upper carbon D and is connected by a link *e* with the armature, while an adjustable stop or abutment *f* serves for tripping it at the feeding-point in the manner well known. A dash-pot I is provided for moderating the movements of the armature, and a cut-out J is shown for short-circuiting the lamp through a relighting resistance K upon an abnormal attraction of the shunt-magnet. The positive and negative binding-posts are lettered *p* and *n*, respectively.

m is the starting-switch. A main or series circuit passes from post *p* by the wires 1 and 2 to tube E, thence through the carbons D F by wire 3 to the series coil A, thence by wire 4 to the negative binding-post *n*. The series coil A is short-circuited by a shunt comprising wire 5, resistance 6, and wires 7 8, leading to the negative post. The shunt resistance 6 is used in the ordinary way to vary the strength of the series coil A by setting a clamp 9 to include more or fewer turns of the resistance-coil. The coil 6 is commonly made of a metal the resistance of which does not increase to any material extent when heated. The shunt-coil B is connected, as shown, in a shunt 10 11 between the binding-posts. The features thus described form no part of my present invention.

An inclosed-arc direct-current lamp of the construction just described with its electrical and mechanical elements carefully proportioned to give the best results according to the best methods and rules known in the art prior to my invention gave the following results: Started cold, it would separate or pick up at about seventy-two volts. During the first hour or so of burning, as the carbons were gradually consumed, the voltage gradually increased, so that the voltage would rise to an extent varying with the temperature of the air surrounding the lamp until the feeding-point was reached. With the lamp hung outdoors in cold weather the feeding-point would vary from seventy-four volts to about eighty volts, being lower in cold weather or with a high wind and higher in mild weather or with no wind. Hung indoors, the feeding-point would rise to a proportionally higher voltage, depending upon the temperature to which the lamp was subjected. Hung near the ceiling of a warm room, the lamp would gradually increase in temperature and the voltage would correspondingly rise, so that the lamp would feed at voltages varying from about eighty to ninety volts. The pick-up voltage, or voltage at which the lamp would relight in case it were turned off and then on again or in case of an interruption of current, would be considerably higher than the original pick-up voltage of about seventy-two volts, although lower than the increased feeding voltage—that is to say, the lamp would pick up at voltages varying from about seventy-six to about eighty volts, according to the temperature. By reason of this varying operation the lamp, although in every other respect wholly abreast of or in advance of the best practice in the art, was wasteful of energy and with a great number in circuit would overload the generator unless used for burning outdoors in cold or windy weather and was but imperfectly fitted for that use. To make it a satisfactory lamp, it became necessary to find some means for correcting this defect. Prior to my present invention the only means that could be applied for this purpose would be to add to the lamp a thermostatic compensator or compensating winding with its inevitable complication, unreliability, and increased expense.

The causes of the variations of voltage under different temperatures just stated are not obscure. When the lamp is cold and the current first turned on, the series coil A receives its maximum current, (determined by the adjustment of the resistance 6,) since this coil at this time presents its minimum resistance, and there exists at first practically no impressed electromotive force to divert any appreciable portion of the current through the shunt-coil B. Consequently the lamp picks up at its lowest voltage. As the arc is sprung its resistance is introduced in the series circuit, whereby is generated a corresponding impressed electromotive force between the lamp-terminals, whereby a corresponding current is diverted through the shunt-coil B; but at first this current is insufficient to so far excite this coil as to set up sufficient counter attraction upon the armature to resist effectively the pull of the series coil. Hence the latter draws the arc to its full initial length. As the lamp burns the carbons gradually waste away, thereby lengthening the arc and increasing its resistance, and hence increasing the impressed electromotive force across it and augmenting the current in the shunt-coil, so that this coil gradually exerts a greater magnetic effect which eventually preponderates over that of the series coil, and the armature is drawn toward the shunt side, thereby gradually lowering the clutch until it rests on its stop *f*, whereupon the next movement due to further augmentation of the excitation of the shunt-coil results in the feeding movement. If no increase in temperature had occurred, the feeding voltage would normally considerably exceed the pick-up voltage; but during this time the heating effect from the arc and the resistance of the respective coils has raised the temperature and increased the resistance of both the series and shunt coils. This effect upon the shunt-coil is to require a higher impressed electromotive force to divert through it the quantity of current required to energize it to the feeding-point, so that the arc must burn correspondingly longer and raise the lamp to a higher voltage before the feeding can occur. The effect of the increased temperature of the series coil is by increasing its resistance to divert an increased proportion of current through the resistance-coil 6, the resistance of which is not materially increased with a rising temperature. This weakens the series magnet, but to a much less extent than is the case with the shunt-magnet, so that it but very slightly compensates for the increased voltage required for exciting the shunt coil or magnet to the feeding-point. In case the lamp has to relight itself while hot the series or arc-drawing magnet, not having weakened in the same proportion as the shunt-magnet, is capable of lifting the carbon higher. Hence the pick-up voltage is higher when the lamp is hot than it was originally, when the lamp was cold.

The foregoing statements concerning the operation of a lamp which does not embody my invention will enable the application and effect of my invention to be understood.

My invention is based upon a discovery which I have made that by suitably proportioning the magnetic elements of the lamp-regulating mechanism these may be made to automatically compensate for changes in temperature. To the extent that the magnetizing effect of the shunt-coil is weakened by the increased resistance due to a high temperature, I so reproportion it that when its armature or movable member is attracted to or beyond the feeding position the air-gap is so reduced as to increase the magnetic conductivity, and thereby strengthen the magnet enough to compensate for the weakened magnetizing effect of its coil. With a series coil I apply the same principle to such effect that in the lifting or picking up position the magnet is strengthened by reason of the diminution of the air-gap. In practice I so strengthen the series or lifting magnet in this way as to cause it to separate to a higher voltage than heretofore, but lower than the normal voltage, and I so strengthen the shunt or feeding magnet as to cause it when forced to feed when cold to feed at a voltage lower than the separating voltage. The result is that when the series and shunt coils have become heated to a normal or practically minimum extent their increased resistance so weakens the respective magnets that the feeding voltage is brought to the designed or predetermined normal, while the pick-up voltage is preferably raised to or nearly to the same normal voltage. It results from my invention that the lamp when started cold picks up at a voltage but slightly below the normal and not enough below to materially impair the light, that in normal operation the voltage gradually increases as the arc burns longer, during which time the coils are heating, so that after burning for perhaps an hour or so the voltage has been gradually increased to the normal, after which this normal voltage is maintained almost absolutely constant, since the lamp is designed to feed at such normal voltage, while if the current is discontinued and then reëstablished the lamp relights itself or again picks up at or close to the normal voltage; but if before the coils are heated the lamp should be forced to feed it would feed at a voltage lower than the pick-up voltage, this being a new and anomalous feature in arc-lamp construction. It is an important advantage of my invention that the lamp after attaining the minimum normal temperature, whereby it is raised to the normal voltage, automatically compensates for any increased temperature to such effect that however the temperature of the coils may be increased the voltage does not proportionately increase, but remains normal. It results from these properties that a lamp embodying my invention may be used either outdoors or indoors and in any condition of weather and in either a cool or a hot room with equal effect.

In applying my invention to the type of lamp thus far described the only thing necessary is to so alter the shape of the polepieces a' b' as to diminish the air-gap between the fixed and movable parts of the magnetic circuit in the requisite proportion. To make this clear, I will refer to Fig. 5, which shows either one of the pole-pieces enlarged. The pole-piece is conoidal and has generally the shape heretofore found most effective in lamps of this type. Its shape is not changed by my invention except to the extent that its base or upper part is widened. The dotted lines x show the shape heretofore used, while the full lines y show the new shape, which carries into effect the principle of my invention. I am unable to give any absolute rule for determining the extent to which the base portion of the pole-piece is enlarged, since it must in each type or design of lamp be determined by experiment. It is only necessary to gradually enlarge the pole-piece at its base, the increased diameter tapering toward its apex, so as to preserve substantially the former shape, and to try successive enlargements until that which best carries into effect the new mode of operation material to my invention is found. I have found that with a pole-piece of proper shape one and seven thirty-seconds inches long and previously fifty-three sixty-fourths of an inch in diameter at the base, an increase of the base diameter to seven-eighths of an inch is sufficient, without making any other change whatever, to introduce the principle of my present invention into a lamp of the construction shown in Figs. 1 and 2 and having previously the defective mode of operation hereinabove explained. The precise variation in proportions, however, would probably be different for each different type of lamp or each different proportion of the series and shunt coils. It may also be varied by differences in the metals or alloys of which these coils are wound and in the metal of the shunt resistance 6.

It is understood that the enlargement of the conoidal pole-piece has the effect of diminishing the air-gap when the armature is attracted to the farthest extent onto the pole-piece, while when the armature is most fully retracted, as shown at the left in Fig. 3, the air-gap remains substantially as heretofore, the air-gap varying between these extremes in regular ratio according as the armature approaches or recedes. The novel and distinct feature of my invention resides in this, that as the armature is attracted the air-gap is diminished in a more rapid ratio than heretofore and in a ratio so exactly proportioned that as the magnetic effect is weakened by the increased resistance of the coil due to heat the magnet is correspondingly strengthened by the diminution of the air-gap when approaching the critical position—that is, the lifted position of the series magnet or the feeding position of the shunt-magnet. The variation of the air-gap is of course merely a means for varying the resistance of the magnetic circuit, or, in other words, for varying the effective magnetization, and it would be within my invention to accomplish these variations in the required ratio by other means than the variation of the air-gap alone.

With the lamp already described with reference to Figs. 1 and 2 and altered only by the enlargement of its pole-pieces in the manner indicated in Fig. 5 the lamp has been found to operate at the following voltages: When started cold, it picks up at about sixty-eight. If forced to feed when cold, it feeds at from sixty to sixty-two volts. In operating normally, however, after starting the voltage gradually rises to the normal—say seventy-four volts—the rate of rise being proportional to the lengthening of the arc by burning away and to the rise of temperature of the coils. Thereafter the voltage remains at substantially seventy-four, the extreme fluctuation from this with varying temperatures being within four volts. If after the lamp is heated it is extinguished and relighted, it picks up at seventy-four volts.

Thus the lamp embodying my invention, when cold, picks up at a higher voltage than heretofore, because by diminishing the air-gap on the series side as the series magnet attracts the armature this magnet is strengthened more rapidly than heretofore, while by the same movement the widening of the air-gap on the shunt side more rapidly weakens the opposing force of the shunt-magnet. Hence the series magnet is able to separate the carbons farther. Immediately after lighting the armature, being attracted close to the pole of the series magnet, is held there more strongly than heretofore, so that the current diverted at normal voltage through the shunt-magnet is ineffective to draw off the armature. If, however, the armature were partially drawn off—say to the position shown in Fig. 2—the increase in the air-gap on the series side and the diminution of that on the shunt side would enable the shunt-coil to attract the armature to it under an impressed electromotive force lower than heretofore and also even lower than the pick-up voltage. Hence the lamp, if forced to feed when cold, feeds at a lower voltage than that at which it lights. When both coils are normally warmed, the conditions are so readjusted that the shunt-magnet receives a lower proportion of current by reason of its increased resistance than at starting, so that the feeding voltage is raised; but by the varying of the air-gap the shunt-magnet is strengthened on approaching the feeding-point, so that the feeding voltage is not raised nearly so high as would otherwise occur and actually rises to a voltage only slightly higher than the original pick-up voltage or, in the example given, to seventy-four volts. At this voltage the weakened effect of the coil is just compensated for by the increased effect of the magnetic circuit due to diminishing the air-gap. Hence the lamp feeds at this voltage. The automatic temperature compensation occurring beyond the temperature at which the normal voltage is first reached is due to the fact that both the shunt and series coils are heated alike, so that each neutralizes the other, the coil A (commonly called the "series" coil) being in fact a shunt-coil by reason of the short-circuiting resistance 6. Hence the coil A as it heats increases its resistance and diverts a greater proportion of current through the shunt, just as the coil B by heating increases its resistance and receives a lower current for a given impressed electromotive force. These two effects are in practice almost exactly proportioned to one another when the adjustable resistance 6 is graduated in the usual manner to give the lifting-magnet the proper strength.

My invention is not limited to the precise type of differential lamp described with reference to Figs. 1 and 2. To illustrate some examples of other types of lamp to which my invention is applicable, I will refer to Figs. 6 to 9 of the drawings. In Fig. 6 the differential magnet is of the consequent-pole type, in this respect resembling that shown in Figs. 1 and 2, but differing therefrom in that the armature, instead of being perforated and receiving tapering pole-pieces of the magnet, has its end portions approaching suitably-shaped pole-pieces of the fixed part of the magnet. In any magnet of this type there are two magnetic circuits formed, as indicated by the lines *w w*.

In carrying my invention into effect it is only necessary to correctly shape the polar faces *g g'* of the magnet-cores with reference to the shape of the ends of the armature, so that the air-gaps will diminish in the proper proportion as each arm of the armature is attracted toward its corresponding pole. I have shown a conventional clutch H, connected by a link *e* to the armature and having an adjustable stop *f*.

In Fig. 7 another type of differential magnet is shown, the series coil A and shunt-coil B being wound on cores *a b*, connected by a single yoke *h* and attracting opposite arms of the armature C, which latter is constructed similarly to that shown in Figs. 1 and 2 and has an arm *i*, connected by the link *e* to the clutch H. This form of differential magnet has no consequent pole, and the coils A B are wound in opposition to one another.

In the magnet shown in Fig. 8 the coils A B are wound to inclose distinct magnets, each having its core of the shape shown in Fig. 9, to form a horseshoe-magnet, and each having its separate armature. The series coil A excites a lifting-magnet L and the coil B a feeding-magnet M. Fig. 9 may be taken as showing the core of either of these magnets with the coil removed. The magnet L has an armature L', and the magnet M an armature M', these armatures being mounted on opposite arms of an armature-lever P, which is pivoted to a supporting-frame Q, preferably non-magnetic, and which supports the respective magnet-cores. The position of the lever P corresponds to the differential attractions of the respective magnets L M as excited by their coils A B, in the well-known manner.

It is to be understood that Figs. 6, 7, 8, and 9 are not intended to illustrate the exact proportions required by my invention, it being necessary, as before stated, to determine these proportions in each case by practical experiment.

It will be understood that my invention provides both a new system or method of temperature compensation in arc-lamps and a new lamp constituting an embodiment of this system and operating to carry into effect such method.

What I claim is—

1. An arc-lamp having its feed-controlling magnetic element proportioned substantially as described to render the lamp self-compensating for temperature changes.

2. An arc-lamp the feed-controlling magnet of which is proportioned to feed when cold at a voltage lower than the separating voltage.

3. An arc-lamp the feed-controlling magnet of which is proportioned to feed when cold at a voltage lower than the separating voltage, and when hot to feed at approximately the same as the separating voltage.

4. An arc-lamp having its feed-controlling magnetic element proportioned substantially as described to cause the lamp to separate its carbons at a voltage lower than the normal feeding voltage, and to feed when cold at a voltage lower than the separating voltage.

5. An arc-lamp having its feed-controlling magnetic element proportioned substantially as described to feed at the normal voltage when heated to the minimum temperature of normal use, and to compensate for the effect of higher temperatures by a balance between the diminishing excitation as the coils heat and the increasing magnetic attraction as the movable member of the magnet is attracted to the feeding position.

6. In an arc-lamp a feeding mechanism including a shunt-magnet and its armature, the terminal portions of said parts being shaped to vary the air-gap at such a rate as the armature moves, as to compensate for the weakened excitation due to the increased temperature of the shunt-coil, whereby to preserve a uniform feeding voltage at all temperatures above the minimum temperature of normal arc.

7. An arc-lamp having differential magnets excited by shunt and series coils, with the terminal portions of the magnets shaped to vary the air-gap in such ratio as to compensate for the weakened excitation due to the increased temperature of the shunt-coil, and to preserve a uniform feeding voltage at all temperatures above the minimum temperature of normal use.

8. An arc-lamp having differential magnets excited by a shunt or feeding coil, and a series coil with a resistance in shunt around it substantially unaffected by temperature, the terminal portions of the magnets shaped to vary the air-gap in such ratio as to compensate for the weakened excitation due to the increased temperatures of the respective coils, and to preserve a uniform feeding voltage and a uniform separating voltage at all temperatures above the minimum temperature of normal use.

In witness whereof I have hereunto signed my name in the presence of two subscribing witnesses.

JAMES J. WOOD.

Witnesses:
F. T. HUNTING,
W. L. BLISS.