No. 720,095. PATENTED FEB. 10, 1903.

W. S. ANDREWS.

# AUTOMATIC REGULATOR FOR X-RAY TUBES.

APPLICATION FILED JUNE 5, 1897.

NO MODEL.

FIG. 1.

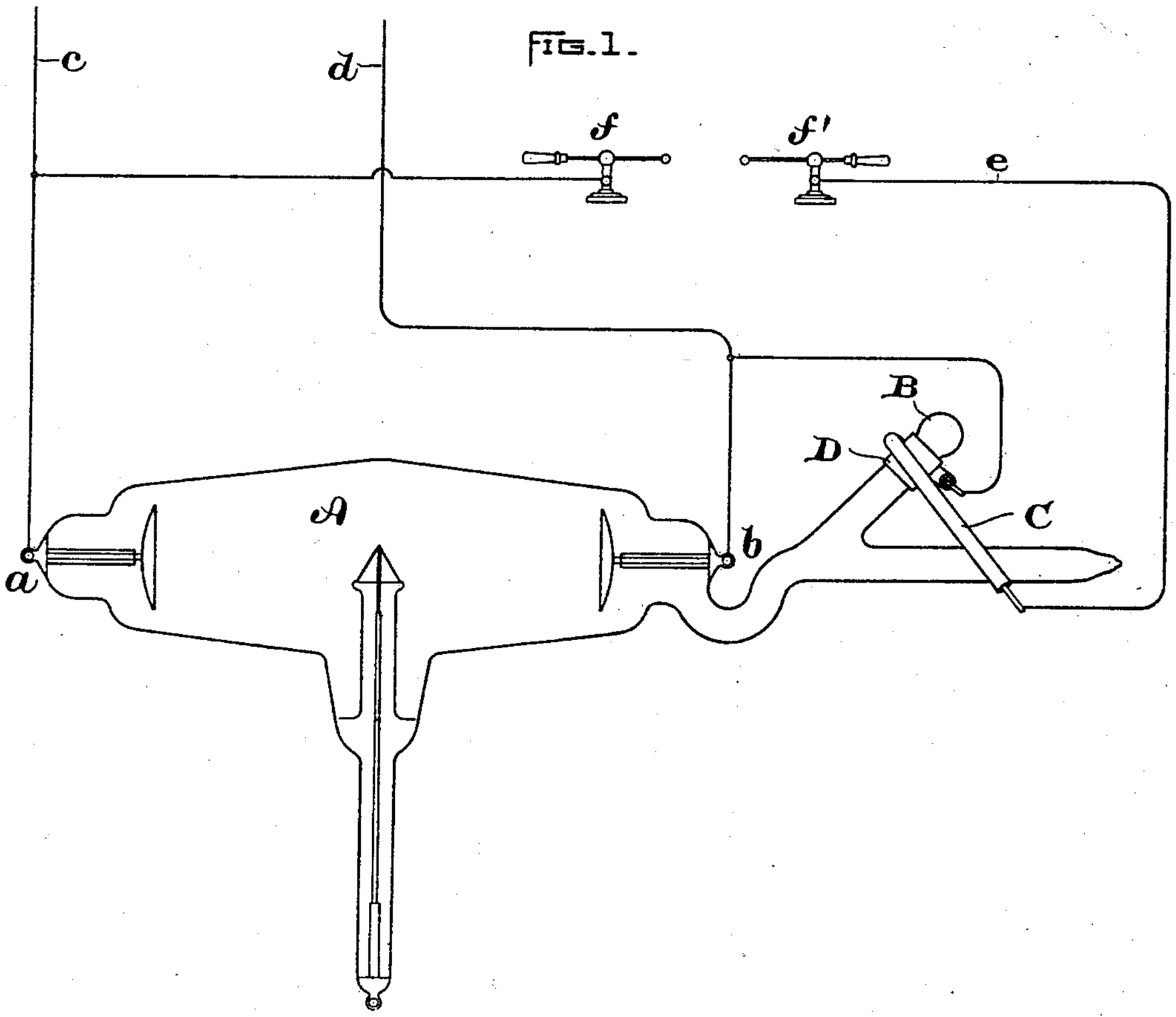
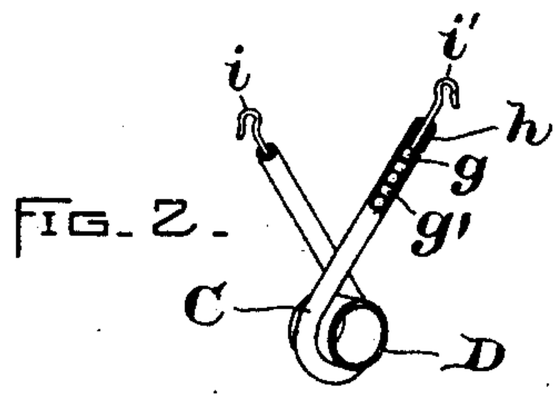



FIG. 2.




WITNESSES.

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# UNITED STATES PATENT OFFICE.

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## AUTOMATIC REGULATOR FOR X-RAY TUBES.

SPECIFICATION forming part of Letters Patent No. 720,095, dated February 10, 1903.

Application filed June 5, 1897. Serial No. 639,510. (No model.)

*To all whom it may concern:*

Be it known that I, WILLIAM S. ANDREWS, a citizen of the United States, residing at Schenectady, county of Schenectady, State of New York, have invented certain new and useful Improvements in Automatic Regulators for X-Ray Tubes, of which the following is a specification.

My invention relates to X-ray tubes; and its object is to provide an arrangement at once simple, durable, and efficient for preserving automatically the vacuum at a practically constant degree of exhaustion, and thereby prolonging the life of the tube.

It is well known that by long-continued use the vacuum in an X-ray tube will become higher and higher, so that eventually the tube becomes no longer serviceable, by reason of the increased resistance to the passage of the current. To obviate this defect, certain tubes known in the market as "Thomson adjustable vacuum-tubes" have been invented, which have a glass bulb containing a chemical substance which will liberate a vapor upon the application of heat. When the vacuum in one of these adjustable tubes becomes too high for the current to pass, the bulb is heated and a vapor liberated which lowers the vacuum and makes the tube temporarily active. Great care has to be used in this operation, however, for if the heat is too great or is applied for too long a time too much vapor will be liberated. The vacuum will then become too low for the generation of X-rays, and the tube will have to be cooled sufficiently to condense the excess of vapor. If the heating process is performed carefully, so that the proper degree of vacuum is produced, the tube will then operate well for a few minutes until the vapor condenses by cooling of the bulb, when the vacuum will rise and the heating process must be repeated. With the Thomson tube the heating has been accomplished ordinarily by a lamp or flame placed under the bulb.

From the foregoing explanation it will be seen that a simple and effective automatic arrangement for regulating the heat applied to the chemical bulb and preserving the vacuum constantly at just the proper degree is highly desirable for a variety of reasons. Such a simple and cheap device is provided by my invention. It is so made that it can be easily attached to any Thomson adjustable tube and removed therefrom, so that the temperature-regulator is an entirely distinct piece of apparatus from the tube, and its life is not at all limited to the life of any given tube. I have demonstrated its practical usefulness by a careful series of experiments and find that it will regulate the vacuum with great accuracy and that its operation is entirely automatic.

In the accompanying drawings, Figure 1 shows in diagram how my invention is applied to an X-ray tube, and Fig. 2 is a detail view of a preferred form of resistance or electric heating device.

The drawings show a Thomson adjustable vacuum-tube A, having its electrodes *a b* connected to the opposite leads of the external circuit *c d* in the way usually employed in operating these tubes from an alterating-current circuit.

B is the chemical-tube connected to the vacuum-tube in the ordinary way and containing the chemical substance from which vapor is liberated to maintain the vacuum at the proper degree of exhaustion. I connect a shunt-circuit *e* around the terminals of the tube, and in the shunt-circuit I include a spark-gap having terminals *f f'*, which are adjustable, so as to vary the length of the spark-gap, and consequently the resistance of the shunt-circuit. In series in the shunt-circuit I also include a small resistance or electric heating device C, so located that the heat developed therein regulates the liberation of the vapor from the chemical-bulb. Many kinds of resistance material may be used. I have employed with successful results a liquid resistance, consisting of a saline or acid solution of the proper strength, a solid or semisolid resistance consisting of preparations of graphite and various metallic oxids or of metallic oxids alone; but I have found most successful and prefer an interrupted conductor forming a succession of small air-gaps across which the current passes, producing sparks and consequent heat. The interrupted conductor may

consist of common shot or other comparatively small metal pieces insulated from one another, as by glass beads arranged between the metal balls. This is the construction shown in Fig. 2, where *g* indicates shot or balls, and *g'* the insulating-beads. These are placed in an insulating-tube *h*, made of glass, porcelain, or similar material, and metallic terminals *i i'* are provided at the ends of the tube. I have shown the resistance bent so as to form a loop or eye at one end, and in this eye I place a copper thimble D. This thimble is then slipped over the chemical-bulb, as in Fig. 1, and the circuit connections made, when the apparatus is ready for use. The copper thimble equalizes the heat developed in the resistance.

When the apparatus described is in use, the spark-gap will be adjusted to suit the power of the apparatus and the degree of vacuum required.

When the current is turned on, the operation will be as follows: Assuming that the vacuum in the tube is too high, so that it offers too great a resistance to the current, the resistance of the shunt-circuit will be so adjusted that a certain amount of current will pass through the resistance and spark-gap in series with it. Heat will be generated in the resistance, thereby heating the chemical-bulb and liberating a vapor which will lower the vacuum in the tube and decrease its resistance. The X-ray tube will then begin to fluoresce and grow brighter and brighter until normal fluorescence is reached. At this stage the flow of current across the shunt-circuit will substantially cease, provided the adjustments have been properly made, since the tube now offers an easier path. Sufficient current will, however, continue to pass at intervals through the spark-gap to keep the chemical-bulb at a certain temperature, dependent upon the distance between the terminals of the spark-gap and the working potential. When the vacuum tends to rise by cooling of the tube and the resistance increases, more current then flows through the shunt-circuit, restoring the normal resistance of the two paths and maintaining proper vacuum. By regulating the length of the spark-gap any desired degree of vacuum may be produced and maintained in the tube.

Since the electric heating device is a distinct piece of apparatus from the vacuum-tube, the two articles can be separately manufactured in ways most appropriate to each. The expense of the X-ray tube is not increased, as it would be were regulating devices incorporated in and made a permanent part of it, and, furthermore, the life of the regulating apparatus is in no wise limited by the life of the tube. The resistances may simply be kept in stock and applied to the tubes as occasion may require.

On account of the difficulty hitherto experienced in properly regulating the application of heat to a chemical-bulb it is now generally conceded that the X-ray tube has outlived its useful existence when it becomes necessary to apply heat to lower the vacuum. By the addition of this simple automatic device I have found that the tubes will give uniformly good service for a practically indefinite length of time.

What I claim as new, and desire to secure by Letters Patent of the United States, is—

1. An electric heater for vacuum-tubes comprising a number of conductors in series insulated from each other and supported by insulating material.

2. The combination of an adjustable vacuum-tube having a chemical-bulb, with an electric heating device, suitable for high potentials, connected in a shunt-circuit around the tube, and consisting of a number of conductors supported by insulating material in series-circuit relation, and insulated from one another by short air-gaps, said heating device serving to heat the chemical-bulb, as set forth.

3. The combination with an adjustable vacuum-tube having a chemical-bulb, of an electric heating device, and an adjustable spark-gap, in a shunt-circuit across the terminals of the tube, said electric heating device being external to the tube and consisting of a number of conductors supported by insulating material in series-circuit relation and insulated from one another by short air-gaps, as set forth.

4. An electric heating device suitable for high potentials, consisting of a series of electrically-disconnected balls or pieces supported by insulating material in a series-interrupted circuit having a number of short air-gaps, substantially as set forth.

5. The combination with a vacuum-tube, of an electric heating device in a shunt-circuit around the tube, comprising a tube of glass, porcelain or similar material, and a series of metal balls or pieces separated by insulation and forming a succession of short spark-gaps, as set forth.

6. The combination with the chemical-bulb of a vacuum-tube, of an electric heating device made of a number of conductors supported by insulating material in series-circuit relation, insulated by short air-gaps, and of such form that the heating device can be readily applied to the bulb and removed therefrom, as described.

7. The combination with the chemical-bulb of a vacuum-tube, of an electric heating device for heating the bulb, consisting of a number of conductors supported by insulating material in series-circuit relation, insulated from one another by short air-gaps, thereby forming a heating device suitable for high potentials around which there is a very large resistance-drop, as set forth.

8. An electric heater for vacuum-tubes com-

prising a number of conductors, including air-gaps in series, and supported by insulating material.

9. An electric heater for vacuum-tubes comprising a number of conductors in series insulated from each other and supported by an electrical insulator adapted to transmit heat to the tube.

10. In an electric heater, the combination with an insulating-support adapted to be placed in heat-transferring relation to a vacuum-tube, a series of conductors held by said support and insulated from each other, and suitable terminals secured to said support.

11. The combination with a vacuum-tube, of a gas-yielding substance therein, a shunt-circuit about said tube, and a high-potential resistance-heater separate from said tube, included in said shunt-circuit and located in coöperative relation to said gas-yielding substance.

12. The combination with a vacuum-tube, of a gas-yielding substance therein, a shunt-circuit about said tube, a spark-gap in said shunt-circuit and in heat-transferring relation to said gas-yielding substance, and an inclosure for said spark-gap separate from said vacuum-tube.

13. The combination with a vacuum-tube, of a shunt-circuit about said tube for varying the pressure in the tube, a spark-gap in said shunt-circuit, and an inclosure for said spark-gap formed separate from said vacuum-tube and arranged to maintain the spark-gap at substantially atmospheric pressure but out of free and unrestrained contact with the atmosphere.

14. An electrical heater for use on circuits of high potential, consisting of an insulating-support containing a number of conducting-bodies separated from each other by non-conducting material, such that the current will be obliged to pass through a number of short air-gaps in series.

In witness whereof I have hereunto set my hand this 26th day of May, 1897.

WILLIAM S. ANDREWS.

Witnesses:

T. J. JOHNSTON,

A. F. MACDONALD.