

F. W. LYLE.  
ELECTRIC REGULATOR.  
APPLICATION FILED SEPT. 18, 1912.

1,094,733.

Patented Apr. 28, 1914.

Fig. 1.

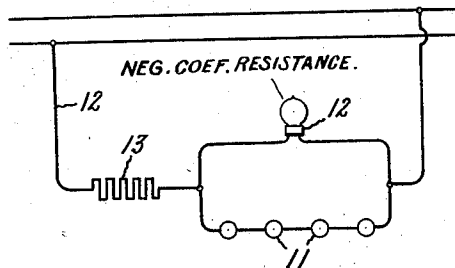
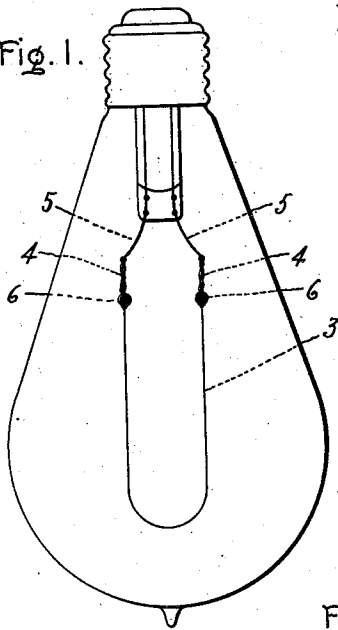


Fig. 5.

Fig. 6.

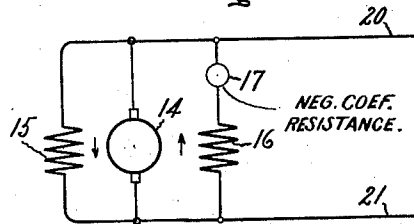


Fig. 3.

Fig. 4.



Fig. 2.

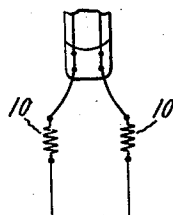
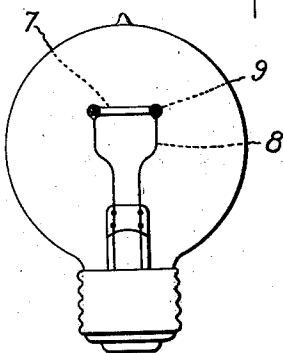


Fig. 7.

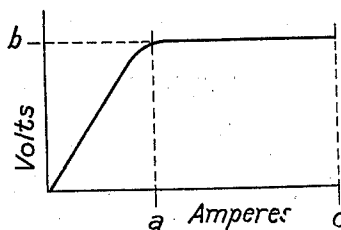


Fig. 8.

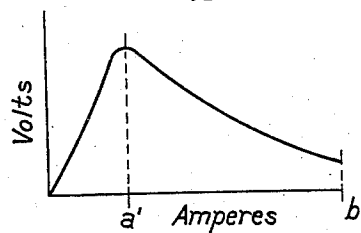
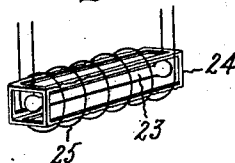


Fig. 9.



WITNESSES:

J. Ellis Glen  
Anthony Marx

INVENTOR:

FRED W. LYLE,

BY Albert S. Davis  
HIS ATTORNEY.

# UNITED STATES PATENT OFFICE.

FRED W. LYLE, OF LYNN, MASSACHUSETTS, ASSIGNOR TO GENERAL ELECTRIC COMPANY, A CORPORATION OF NEW YORK.

## ELECTRIC REGULATOR.

1,094,733.

Specification of Letters Patent.

Patented Apr. 28, 1914.

Application filed September 18, 1912. Serial No. 720,998.

*To all whom it may concern:*

Be it known that I, FRED W. LYLE, a citizen of the United States, residing at Lynn, county of Essex, State of Massachusetts, have invented certain new and useful Improvements in Electric Regulators, of which the following is a specification.

The present invention relates to the regulation of electrical line conditions, for example, the maintenance of steady voltage, and it comprises particularly a regulator having a marked negative temperature resistance coefficient, which responds very quickly to counteract voltage or current changes as the case may be.

The device contains a solid resistor, preferably of filamentary form, having as an essential constituent a material, such as boron having a high negative temperature resistance coefficient. This material is preferably associated with another material of relatively high conductivity and moderate temperature resistance coefficient, such as carbon or tungsten. The resistor is mounted in an envelop which may be evacuated, but preferably contains a gas having a high heat conductivity.

The novel features of my invention will be pointed out with greater particularity in the claims.

In the accompanying drawings, Figures 1 and 2 illustrate the resistor mounted in a bulb so as to be conveniently inserted in a circuit; Fig. 3 illustrates a modified form of connection to the leading-in conductor; Fig. 4 is an enlarged cross section of a preferred form of the composite resistor; Figs. 5 and 6 are diagrams of circuit connections illustrating the application of my regulator for the purpose of maintaining constant voltage upon a load; Figs. 7 and 8 are curves illustrating the volt-ampere characteristic of two modifications of regulators, and Fig. 9 is a modified form of regulator shown without its inclosing globe.

Elemental boron has an enormous negative temperature resistance coefficient; that is, with increasing temperature the resistance decreases very rapidly. I have found that by combining a substance having such a characteristic with the heater and in some cases with an ordinary resistance connected in series with it and by properly proportioning the heater and resistance, it is pos-

sible to produce a unit which has a constant voltage over a very wide range of current. The heater may, by making it of proper dimensions, conveniently be connected in shunt with the boron and should preferably be in good thermal relation to it. The portions of the heater and resistance can be calculated if so desired with considerable precision, but are also readily determined by a few simple trials. In the filament form of regulator, the "base filament" on which the boron is deposited conveniently performs the function of a heater.

In the preferred form of my invention, I coat a thin filament of carbon, tungsten, tantalum or other suitable refractory material with boron by treating the filament at an elevated temperature with a mixture of boron chlorid and hydrogen as described in patent to Ezechiel Weintraub, No. 1,019,569 of March 5, 1912. The thickness of the boron coating as compared with the diameter of the core will vary with the desired characteristics of the regulator. By this means, as shown in cross-section in Fig. 4, there is secured a composite filamentary resistor in which the boron shell 1 is electrically in parallel with the core 2, which we assume to consist of carbon. The filamentary character of the resistor permits very rapid temperature changes, and thus enables it to respond very quickly to counteract a change of voltage or current when used for regulating purposes. At low voltages the current will be carried very largely by the carbon core and at higher voltages the boron shell, heated by the core, will begin to carry a rapidly increasing part of the current. By this means a conductor may be built up which for current exceeding a value  $a$ , Fig. 7, will have a substantially constant voltage drop  $b$  across its terminals for relatively wide variations of currents, as is apparent from the curve. The voltage drop in the resistor is substantially constant even though the current varies between the limits  $a$  and  $c$ . If desired, the resistor by proper proportioning may be given a drooping characteristic so that an increase of current is accompanied by a decrease of voltage drop as illustrated in Fig. 8. In this instance the thickness of the boron coating is relatively greater.

A resistor having a slight drooping

characteristic may be compensated if desired to have a constant voltage drop, as shown in Fig. 7, over a range of current variation, by connecting it in series with a proper amount of ordinary positive temperature-resistance coefficient resistance.

The resistor is mounted in a bulb, or other container, which is either evacuated or better still, filled with a gas, such as hydrogen, of high heat conductivity. Fig. 1 shows how a resistor 3 of filamentary form is attached by a flexible connection consisting of fine stranded conductors 4 consisting, for example, of copper, to the usual leading-in conductors 5. The filament 3 is connected to the strands 4 by a high resistance paste 6, which preferably consists of a compound of boron and some other refractory conducting material, such as tungsten, carbon or the like. It is preferable to use a high resistance paste instead of the common carbon paste because of the high resistance of the filaments. When a low resistance paste is used, the filament is locally heated at the junction of the paste resulting in a short life. When using paste having approximately the resistance of the filament, a better distribution of the current at the junction is secured. A suitable paste may be made by fusing a mixture consisting of about 70 parts boron and 10 parts tungsten in hydrogen in the electric arc. The resulting melted mass is ground fine and mixed to the consistency of thick cream with pitch or caramel syrup. The paste consisting largely of boron also possesses the advantage of having a coefficient of expansion approaching that of the boron filament which is very effective in maintaining good electrical contact between the filament and the paste and preventing the paste from cracking off when subjected to temperature changes.

Fig. 2 illustrates a boron resistor in which the flexible connection 4 is dispensed with, the short resistor 7 being connected directly to the wires 8 by high resistance paste 9. In this case the short length and increased diameter of the regulator makes the flexible connection unnecessary.

Fig. 3 illustrates an alternative connection consisting of a resilient spiral of coiled molybdenum, or tungsten wire 10.

A boron regulator as above described may be used to maintain constant voltage across a load, such as lamps 11 subject to variations of voltage, as on a street car line. In series with the boron regulator 12 is a resistor 13 having a positive temperature coefficient, for example, a resistor of tungsten operating in hydrogen. When the supply voltage varies a greater or smaller part of the current is carried by the regulator, the voltage across its terminals remaining substantially constant as already explained in connection with Fig. 7. The excess voltage is consumed

by the resistance 13. Claims for this combination are made in my copending application, Serial No. 720,997, filed concurrently herewith.

Fig. 6 illustrates another application of my regulator for the maintenance of substantially constant voltage across the terminals of a generator which is operated at variable speed, as in an automobile. In this case, the generator 14 is provided with differential or opposing shunt fields 15 and 16. In series with field 16 is a negative resistance coefficient regulator 17. In this case, the regulator should be designed to have a volt-ampere curve, such as shown in Fig. 8. When a boron filament has such a characteristic, it is possible to connect in series with it a resistance of such value that the voltage across the two, filament and resistance, will be constant over the range of current  $a'$ ,  $b'$ , Fig. 8. The resistance of field 16 is made of this proper value. When the generator speeds up and thus tends to raise its voltage, the resistance of the regulator will decrease causing the field 16 to take more current and by its demagnetizing effect lower the excitation of the generator. In this manner substantially constant voltage is maintained. For example, I have been able to operate a generator varying in speed from 1200 to 3200 revolutions per minute, or 230%, with a voltage variation of only a few per cent. Claims on this system are made in my copending application, Serial No. 720,996, filed concurrently herewith.

In some cases the negative resistor and heater may be out of direct contact with each other, as shown in Fig. 9. The resistor 23 is supported within a fused silica frame 24, about which is wound heater wire 25.

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

1. An electric regulator, comprising the combination of a boron resistor of filamentary dimensions, current connections therefor, and a heater electrically in parallel and in heat conveying relation therewith.

2. An electric regulator, comprising a sealed container and a composite conductor mounted therein, comprising two elements in electrical parallel and heat conveying relation, one of said elements consisting of a refractory material of relatively high conductivity and the other of a refractory material of high resistance and high negative temperature resistance coefficient.

3. An electric regulator, comprising a sealed container filled with hydrogen and a composite conductor mounted therein, said conductor consisting of a core of refractory material of relatively high conductivity and moderate temperature resistance coefficient, and a coating of low conductivity and having a high negative temperature resistance coefficient.

4. An electrical regulator, comprising the combination of a filamentary boron resistor, and a resistor which exhibits an increasing voltage drop with increasing current in intimate heat conducting relation thereto and electrically in parallel therewith.

5. A regulator for electric circuits comprising a container, a composite conductor mounted therein, and current connections therefor, said conductor being composed of two refractory materials, one of which is of comparatively high electrical conductivity and has a moderate temperature coefficient and the other having a relatively low electrical conductivity and a high negative temperature resistance coefficient, said materials being proportioned so that for an increase in current flow the voltage drop in the regulator will not increase.

6. A regulator for electric circuits comprising a sealed envelop and a filamentary composite conductor therein having a carbon core and a surrounding shell consisting largely of boron, the core and shell being proportioned so that for an increase in cur-

rent flow through the resistor the voltage drop therein will not increase.

7. A regulator for electrical circuits comprising a sealed envelop and a conductor of filamentary dimensions mounted therein and suitable current connections therefor, said conductor consisting of two elements electrically in parallel and in intimate heat conveying relation, one of said elements consisting largely of boron and the other element consisting largely of a refractory material of relatively high conductivity and moderate temperature resistance coefficient, said elements being proportioned to give the conductor a decreasing voltage drop when the current flowing through the regulator increases beyond a predetermined limit.

In witness whereof, I have hereunto set my hand this twelfth day of September, 1912.

FRED W. LYLE.

Witnesses:

JOHN A. McMANUS, Jr.,

FRANK H. JOHNSON.