Feb. 1, 1955 J. KURSHAN 2,701,289

BALLAST TUBE

Filed April 28, 1951

Fig_1

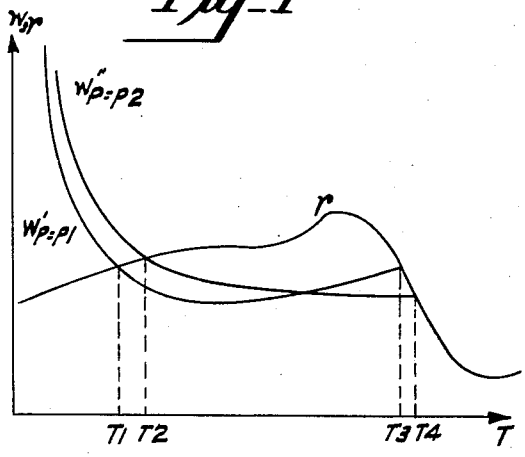
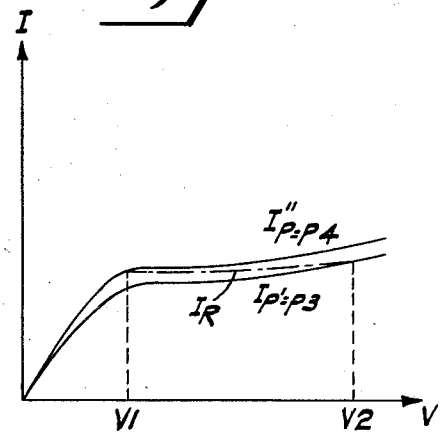


Fig_2



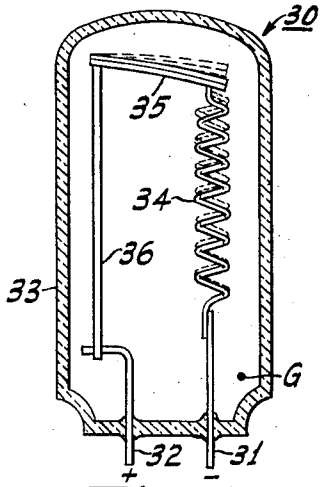


Fig_3

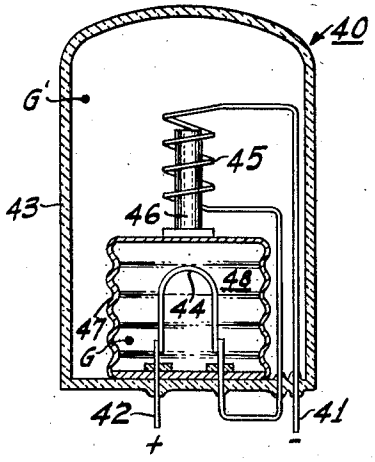


Fig_4

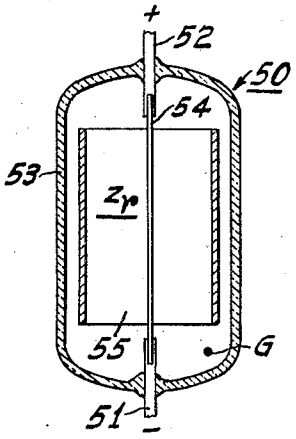


Fig_5

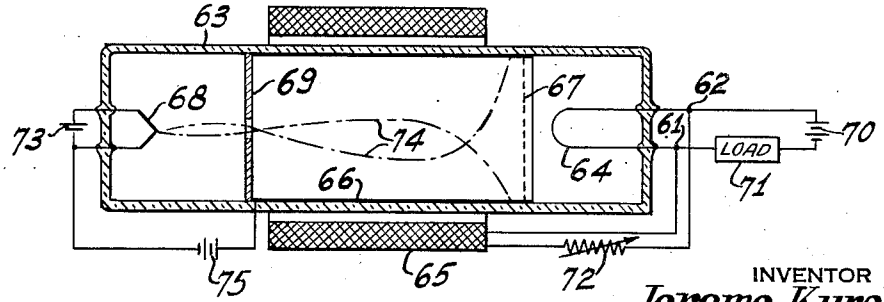


Fig_6

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BALLAST TUBE

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2 Claims. (Cl. 201—63)

The present invention relates to current-regulating devices, more particularly to devices of the type known as ballast tubes wherein an element of suitable resistance material (usually iron), suspended in an atmosphere of rarified gas (e. g. hydrogen or helium), serves to keep a current flowing through it at a substantially constant value over an extended range of voltages.

The regulatory effect of such tubes is due to the fact that a rise in applied voltage increases the dissipation of electric energy and, hence, the generation of heat in the element, the temperature coefficient of resistance of the element being positive and such as to cause its resistance to rise substantially in proportion to the voltage. Since, however, the change in the temperature of the resistance element is dependent not only upon the heat generated therein but also upon the heat carried off by radiation, convection and thermal conduction, the magnitude of the current drawn by the tube is not only a function of the applied voltage but also of the thermal coupling between the resistance element and the surrounding atmosphere.

Since the thermal coupling is, inter alia, determined by the pressure obtaining within the tube, it might be expected that variations in pressure would affect its current versus voltage characteristic; this is in fact borne out by experiments. There exists, however, no simple relation between pressure and thermal coupling; thus while the logarithmic temperature derivative of heat dissipation will generally increase with rising pressures, yet for very low pressures there exsts an anomalous region where the reverse is true. For a given pressure one can find, nevertheless, a predetermined voltage range within which ballast action, i. e. stabilization of the current, will occur.

The general object of the present invention is to provide a method of and means for extending the voltage range throughout which a substantially constant output current is obtainable, or, conversely, for reducing current variations within a given voltage range, as compared with conventional ballast tubes.

According to the invention I accomplish the above object by varying the thermal coupling between the resistance element of a tube and the tube's gaseous filling under the control of the voltage applied. Means for varying this coupling may comprise a current-responsive device connected in series or in shunt with the resistance element and adapted to vary, for example, the pressure inside the tube or the volume effectively occupied by the element, the latter expedient affecting directly the rate of heat transfer between the element and the coolant atmosphere in which it is immersed. Where a pressure control means is provided, the same may operate either to raise or to lower the gas pressure with rising voltages, depending upon the pressure range for which the tube is designed.

The invention will be described in detail with reference to the accompanying drawing in which:

Figure 1 is a graph illustrating the behavior of a ballast tube at different temperatures and pressures;

Figure 2 is a graph illustrating the stabilizing effect of a ballast tube for two different pressures in a different pressure range from Figure 1;

Figures 3, 4, 5 and 6 show, somewhat schematically, axial sections through different ballast tubes representing various embodiments of the invention.

Referring first to Figure 1, there is shown a diagram in which the abscissae represent the absolute temperature T in degrees K and the ordinates are either $w=d\ (\log W)/d(\log T)$ or $r=d\ (\log R)/d(\log T)$, R being the resistance of an iron wire in a ballast tube and W being the thermal energy dissipated into the surrounding atmosphere. It will be noted that there is only one curve for r whereas w assumes different values for different pressures P. By way of illustration it may be mentioned that the two curves $w'(P=P1)$ and $w''(P=P2)$ may be for pressures of 1 mm. Hg (P1) and 10 mm. Hg (P2), respectively.

It can be shown that ballast action will occur as long as $r>w$. For a pressure P1 the curves w' and r intersect a first time at a relatively low temperature T1 and a second time at a higher temperature T3; for a pressure P2 the curves w'' and r intersect at a temperature $T2>T1$ and again at a temperature $T4>T3$. It follows that for $P=P1$ ballast action will be obtainable at temperatures ranging from T1 to T3 whereas for $P=P2$ the range will extend from T2 to T4. If the pressure is changed from P1 to P2 as the voltage increases, the operating range can be extended from a starting voltage corresponding to a temperature T1 to a limiting voltage corresponding to a temperature T4, this range being evidently greater than that obtainable if the pressure is maintained at P1, P2 or some intermediate constant value.

In Figure 2, the abscissae represent the applied voltage V while the ordinates show the current I drawn by the tube. Between voltages V1 and V2 the current rises gradually along curve 1' if the pressure is maintained at a value $P=P3$, and along a similar curve 1'', corresponding to higher values, if the pressure is at $P=P4$; it is assumed that both values P3 and P4 are substantially higher than the value P2 of Figure 1, thus greater than 10 mm. Hg, and that $P4>P3$. It will be seen that the current may be maintained at a substantially constant value I_R if the pressure is gradually changed from P4 to P3 as the voltage rises from V1 to V2.

An arrangement embodying the invention is shown in Figure 3; the ballast tube **30** includes input terminals **31**, **32**, an envelope **33** enclosing a rarified gas G such as, for example, hydrogen or helium, and a resistance element in the form of a coiled wire **34**, e. g., of iron, surrounded by the rarified gas and connected to terminal **31**. The tube also includes means for varying the thermal coupling between the wire coil **34** and the gaseous atmosphere, in the form of a bimetallic strip **35** having one end rigidly supported by a conductive rod **36** which in turn is connected to terminal **32**, the coil **34** being anchored to the other, free end of strip **35**.

When a voltage, e. g., as indicated in the drawing, is applied to the terminals **31**, **32**, current will flow in a series circuit consisting of rod **36**, strip **35** and element **34**, the latter being initially contracted as shown in full lines. In this condition of the coil there is less thermal coupling between it and the surrounding atmosphere than for more extended conditions, therefore the wire **34** heats up relatively rapidly to reach at low voltage the point at which ballast action starts. From this point on, the current will increase at a slow rate which, however, will be sufficient to cause a gradual deformation of the bimetallic strip **35** into the position shown dot-dash lines, this resulting in a corresponding expansion of the coil **34**. Owing to this expansion the coupling between coil **34** and the atmosphere increases, more heat is dissipated and the temperature of the wire rises slowly toward a point at which the current departs from its substantially constant value. It will thus be seen that this arrangement affords current stabilization over an increased range of input voltages.

While the element **34** has been described above as an iron wire, greater elasticity of the coil may be obtained through the use of a more resilient material as a core supporting the iron in the form of a coating thereon. A suitable material for this purpose is tungsten; since this, however, is a conductor, an insulating layer (e. g. of aluminum oxide) must be interposed between the core and the iron. It may also be mentioned that where it is possible to use the tube **30** exclusively in the vertical position illustrated, the resiliency of the wire **34** will be

of less importance inasmuch as the turns of the coil **34** will tend to contract under their own weight; they may, of course, be additionally loaded to increase this tendency.

In the modification of Fig. 4 there is shown a tube **40** comprising terminals **41**, **42**, envelope **43** and resistance element **44**, the latter being in the form of a simple wire loop having one leg connected to terminal **42**. Connected in series between the other leg of wire **44** and terminal **41** is a solenoid coil **45** controlling a plunger **46** which in turn operates a bellows **47** enclosing the loop **44**. The interior **48** of the bellows **47** contains a rarefied gas G while the rest of the tube may include a similar or different gas G′ preferably under approximately the same pressure, a slight but variable pressure differential between the chamber **48** and its surroundings being brought about by expansion or contraction of the bellows under the control of solenoid **45**, **46**.

Depending on whether the device operates in a pressure range as indicated in Figure 1 or as indicated in Figure 2, the solenoid may be arranged either to compact or to expand the bellows **47** as the current through the wire **44** and, with it, through the coil **45** increases. It is, of course, again understood that a relatively small increment of current should suffice to bring about the desired control action, the initial pressure inside chamber **48** being for this purpose so selected as to vary critically from, say, P4 to P3 (Fig. 2) as the input voltage rises from V1 to V2.

In Figure 5 use is made of the thermal characteristics of a reversible adsorbent for gas, such as zirconium, to achieve the desired change in pressure. This material has the property of absorbing hydrogen gas at relatively low temperatures and to release it when heated to higher temperatures. In Figure 5 the tube **50** comprises terminals **51**, **52**, an envelope **53**, a resistance wire **54** extending between the terminals, and a control member **55** of zirconium exposed to thermal radiation from wire **54**; the member **55** may be in the form of a tube spacedly surrounding the wire. When the wire **54** is traversed by current, and the initial pressure has a value of, say, P1 (Fig. 1), then ballast action will start when the wire reaches a temperature T1. Somewhere between this temperature and a temperature T3, at which ballast action would normally end as shown in Figure 1, the zirconium member **55** is heated sufficiently to release some gas which will increase the pressure to a value P2, thereby extending the range of current stabilization to a point corresponding to a temperature T4. It should be noted that even with an almost constant current I the rise in voltage V may suffice to create enough additional heat to bring about this change in gas pressure.

In the arrangement of Figure 6 the ballast tube is associated with an ionic pump of the type disclosed in U. S. Patent No. 2,282,401, issued May 12, 1942. Across the input terminals of the tube **60**, indicated diagrammatically at **61** and **62**, is connected the resistance element **64** and in shunt therewith a magnet coil **65** surrounding the central portion of the tube envelope **63** which is internally lined with an anodic coating **66**. This central portion is shielded from the right-hand end of the tube, containing the resistance wire **64**, by a metal screen **67** and from the left-hand end of the tube, enclosing a cathode **68**, by an apertured plate **69**. The input voltage is applied to the terminals **61**, **62** from a source **70** in series with a load **71**, the magnet coil **65** being, if desired, in series with a resistor **72** designed to limit and/or adjust the current drawn by this coil. Operating voltages for the cathode **68** and the anode **66** are derived from batteries **73** and **75** respectively.

In operation, electrons emitted by the cathode **68** are drawn toward the anode coating **66** and ionize the gas within the envelope **63**, the paths of the electrons being indicated at **74**. Ions produced by collision of gas molecules with the electrons are attracted by the cathode **68** and pass through the aperture of plate **69**, thereby lowering the gas pressure inside the part of the tube to the right of that plate. Thus the pressure around the wire **64** will assume a value such that the pumping action due to the leftward electron injection movement of positive ions is just balanced by diffusion of neutral atoms in the opposite direction. Since, however, the magnetic field produced by the coil **64** will tend to lengthen the electron paths (as more fully set out in the patent referred to), the number of collisions will be increased and the pressure level around wire **64** will be reduced as the voltage across terminals **61**, **62** rises, hence stabilizing action as described in connection with Figure 2 will again occur. Since the control current (through magnet coil **65**) is here independent of the current through the resistance element, the latter may, in fact, be made to decrease with increasing voltages to compensate for the rise in the current drawn by the circuits **65**, **72** whereby the total current through the load **71** may be held constant. It will, of course, be understood that a similar shunt arrangement may be substituted for the series arrangements shown in Figures 3 and 4.

The various embodiments described above and shown in the drawing have been given merely for purposes of illustration and not as a limitation upon the scope of the invention which, on the contrary, is capable of numerous adaptations and modifications within the scope of the appended claims.

What is claimed is:

1. A ballast tube comprising an envelope, a gas in said envelope, input terminals, a resistance element in said gas connected between said input terminals, pressure regulating means adapted to vary the pressure of said gas, and electric control means for said pressure regulating means, said control means being connected between said input terminals and in series with said resistance element for actuation by a voltage applied thereto.

2. A ballast tube comprising an envelope, a gas in said envelope, input terminals, an expandible resistance element in said gas connected between said input terminals, and a bimetallic strip mechanically secured to said element for varying the expansion of said resistance element, said bimetallic strip being connected between said input terminals and electrically in series with said element for actuation by a voltage applied thereto.

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