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Takei et al.

[11] **3,716,751**

[45] **Feb. 13, 1973**

[54] **STARTER DEVICE FOR A DISCHARGE LAMP**

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[21] Appl. No.: **821,611**

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[52] **U.S. Cl.** **315/106,** 315/243

[51] **Int. Cl.** **H05b 41/16**

[58] **Field of Search** ..... 315/100 H, 100 V, 101, 105, 315/106, 107, 98–100, 200, 202, 205, 207, 233, 235, 241, 242, 246, 260, 265; 307/302, 318

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Primary Examiner—Roy Lake

Attorney—Stevens, Davis, Miller & Mosher

[57] **ABSTRACT**

A starter device for a discharge lamp instantaneously lighting a preheating type fluorescent discharge tube where in parallel to the said fluorescent discharge tube is connected a reverse blocking diode thyristor, the breakover voltage being lower than the maximum value of the rated voltage of the power source but higher than the discharge voltage of the said fluorescent discharge tube while the blocking voltage being sufficiently larger than the said breakover voltage.

9 Claims, 20 Drawing Figures

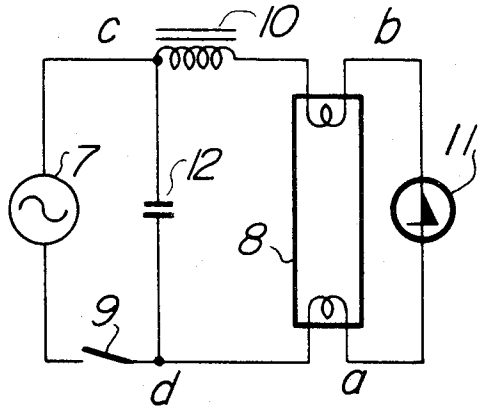


FIG. 1 PRIOR ART

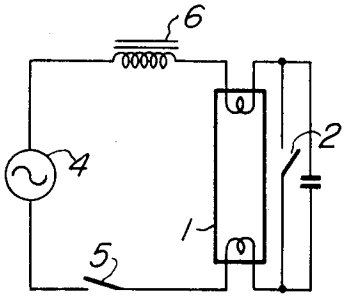


FIG. 2 PRIOR ART

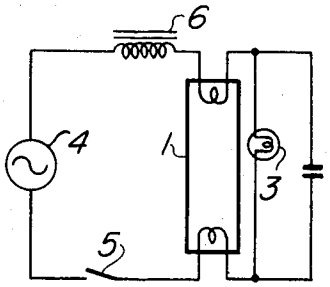


FIG. 3

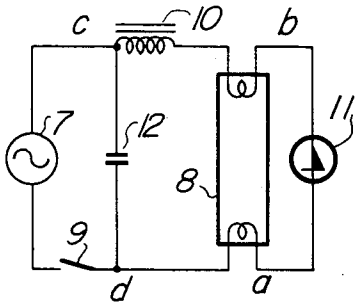


FIG. 4

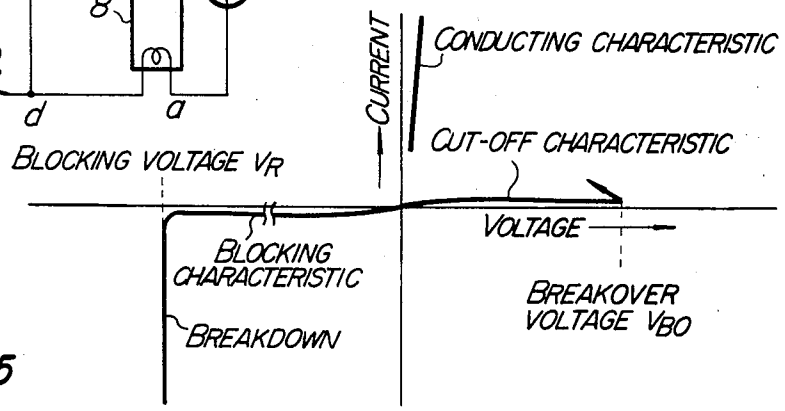


FIG. 5

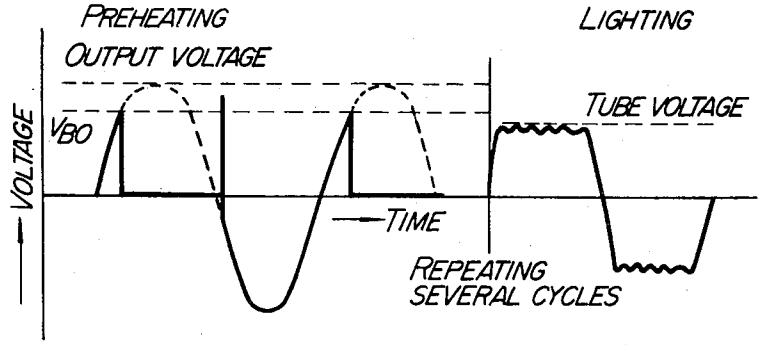


FIG. 6

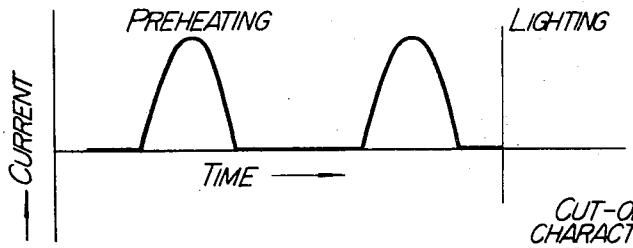


FIG. 7

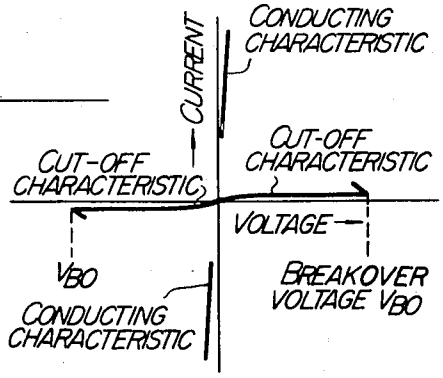


FIG. 9

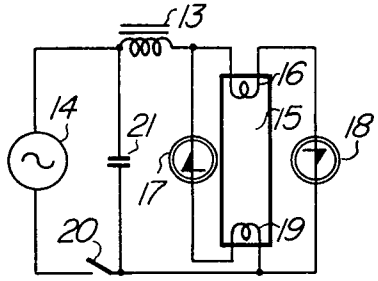


FIG. 8

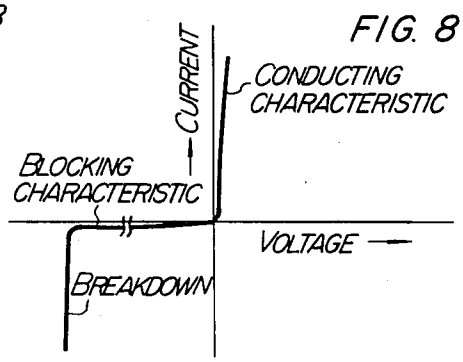


FIG. 10

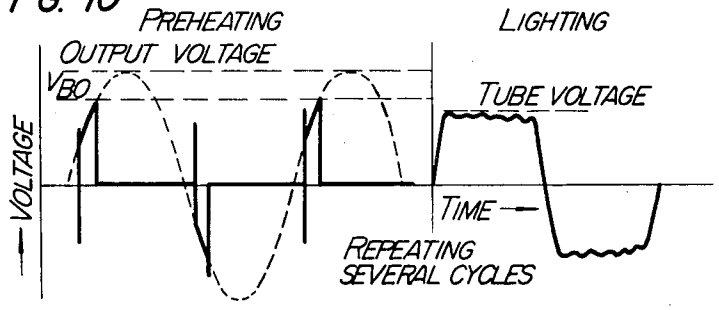


FIG. 11

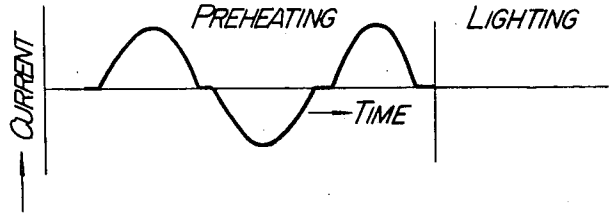


FIG. 12

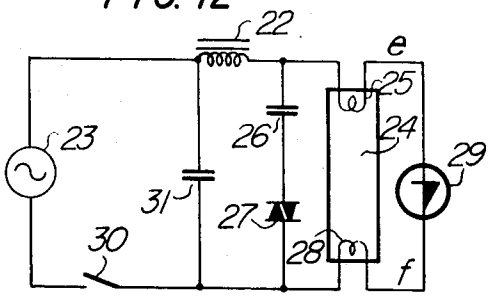


FIG. 13

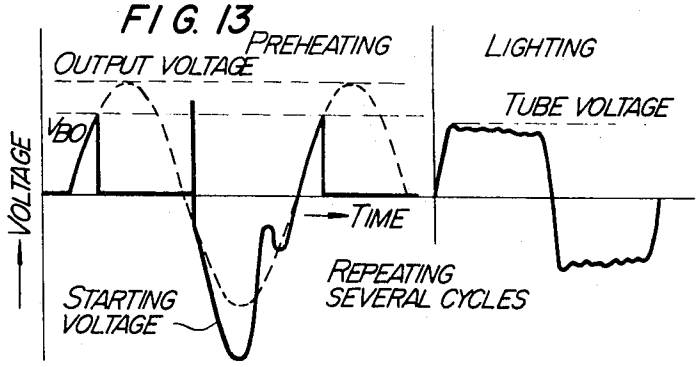


FIG. 14

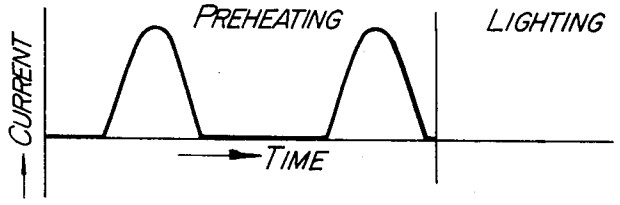


FIG. 15

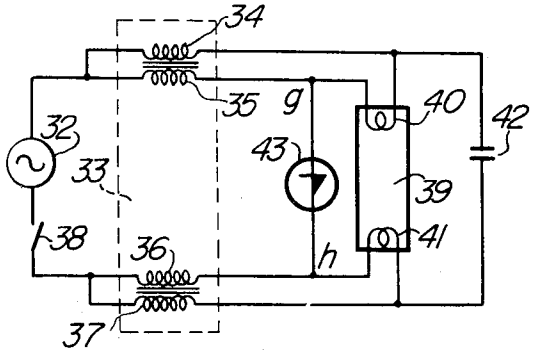


FIG. 16

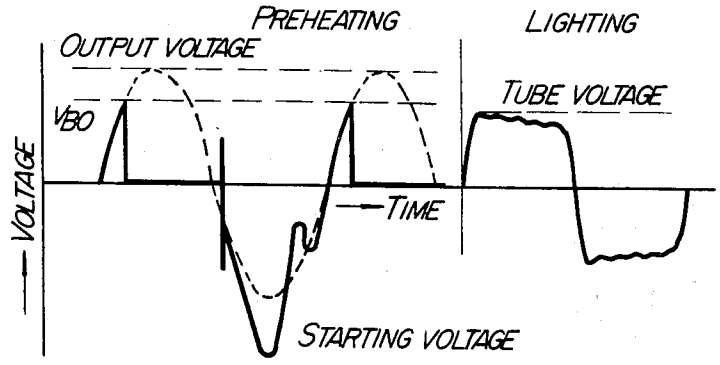


FIG. 17

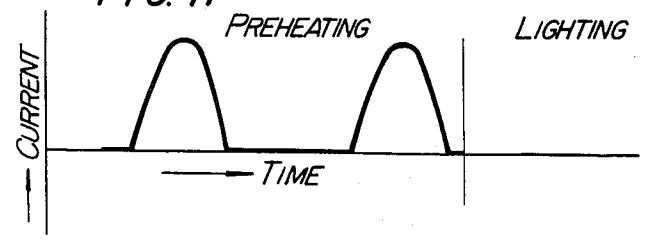


FIG. 18

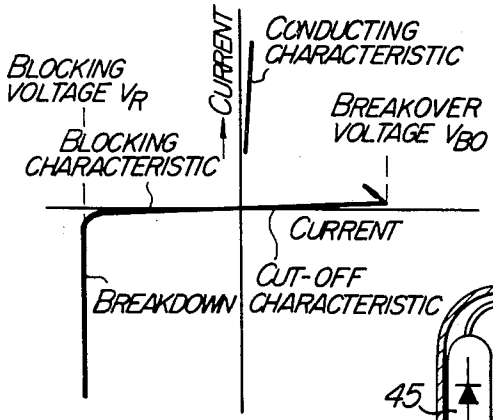
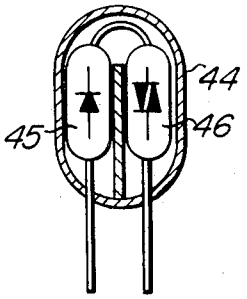


FIG. 19



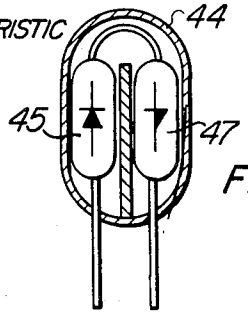


FIG. 20

STARTER DEVICE FOR A DISCHARGE LAMP

This invention generally relates to a starter device for a discharge tube, and more particularly to a starter device for lighting a preheating fluorescent discharge tube where in parallel to the fluorescent discharge tube a reverse blocking diode thyristor having a blocking voltage much larger than the breakover voltage is connected.

A conventional starter device as shown in FIGS. **1** and **2** consists of a manual switch **2** or a glow switch **3** connected in parallel to the fluorescent discharge tube, an a.c. source **4**, a switch **5** and a choke ballast **6**. A manual switch is inconvenient because it requires much time before starting while a glow switch has the problem of a shorter lifetime although the starting time is fast.

Therefore, this invention is aimed at removing the above-mentioned defects of the prior art and provides a novel starter device for a discharge tube.

The object of this invention is to provide a starter device for rapidly starting the fluorescent discharge tube where in parallel to the fluorescent discharge tube is connected a reverse blocking diode thyristor, the breakover voltage being lower than the maximum value of the rated voltage of the power source but higher than the operating voltage of the fluorescent discharge tube while the blocking voltage being sufficiently larger than the breakover voltage.

This invention has the following advantages:

1. The life of the starter is semipermanent because it is made of a semiconductor element.

2. The element has the advantage of being more economical.

3. Rapid starting is possible with the current limiting ballast.

4. The circuit construction is simple and minuature, and is therefore very favorable for production.

5. In comparison with a conventional device with a current limiting ballast for rapid starting, the inventive device is small in size and light in weight because a usual current limiting ballast can be employed.

6. Due to the electrical switching action, damage caused to the fluorescent discharge tube is smaller compared to a glow switch or a manual starter.

The invention will be explained hereunder with reference to the drawings, in which:

FIGS. **1** and **2** are the electric circuit diagrams of prior art glow switch and manual starter devices for a discharge tube;

FIG. **3** shows the electric circuit diagram of a starter device for a discharge tube according to one embodiment of this invention;

FIG. **4** shows the voltage-current characteristic of a reverse blocking diode thyristor used in the inventive device;

FIG. **5** shows the waveforms across the terminals *a* and *b* of the device shown in FIG. **3** during preheating and operating;

FIG. **6** shows the waveform of current flowing through the thysistor in the above device during preheating;

FIGS. **7** and **8** show the voltage current characteristics of a symmetrical diode thyristor and a diode respectively, which are used for obtaining the reverse blocking diode thyristor having the voltage-current characteristics shown in FIG. **4**;

FIG. **9** shows an electric circuit diagram of a starter device for a discharge tube according to another embodiment of this invention;

FIG. **10** shows the waveform of the voltage across both terminals of the discharge tube of FIG. **9** during the preheating and operating period of the tube;

FIG. **11** shows the waveform of the current flowing through the thyristor in the above device during preheating;

FIG. **12** shows an electric circuit diagram of a starter device for a discharge tube according to another embodiment of this invention;

FIG. **13** shows the waveform of the voltage across both terminals of the above discharge tube during preheating and operating;

FIG. **14** shows the waveform of the current flowing through the thyristor in the above device during preheating;

FIG. **15** shows an electric circuit diagram of a starter device for a discharge tube according to another embodiment of this invention;

FIG. **16** shows the waveform of the voltage across both terminals of the above discharge tube during preheating and operating;

FIG. **17** shows the waveform of the current flowing through the thyristor in the above device during preheating;

FIG. **18** shows the voltage current characteristic of a reverse blocking diode thyristor used for obtaining a starter; and

FIGS. **19** and **20** show the sectional and front view of a reverse blocking diode thyristor according to one embodiment of the starter device of this invention.

An embodiment of this invention will be explained with reference to FIGS. **3** to **8** hereinafter. In FIG. **3**, **7** is an a.c. power source, **8** is a fluorescent discharge tube both terminals of which are connected to the a.c. power-source through a switch **9** and a current limiting ballast **10**, **11** is a reverse blocking diode thyristor connected in parallel to the discharge tube **8**, and **12** is a noise preventing capacitor connected in parallel to the a.c. power source **7**. The reverse blocking diode thyristor **11** has such a switching characteristic as shown in FIG. **4**. Namely, at a given forward voltage (breakover voltage V_{BO}) the reverse blocking diode thyristor changes from the cut-off state to the conducting state. The breakover voltage V_{BO}satisfies the condition: maximum value of the rated output voltage of the power source > breakover voltage V_{BO} > the peak value of the operating voltage of the discharge tube **8**, while the blocking voltage V_R satisfies the condition; $V_R > >$ the maximum value of the rated output voltage of the power source.

The reverse blocking diode thyristor **11** having the voltage-current characteristics shown in FIG. **4** can be obtained by connecting in series a symmetrical diode thyristor having the voltage-current characteristics shown in FIG. **7** and a diode having the characteristics shown in FIG. **8**, the former having the characteristic: maximum value of the rated output voltage of the power source **7** > breakover voltage V_{BO} > the peak value of the operating voltage of the discharge tube **8**, while the latter having the characteristic: blocking voltage $V_R > >$ maximum value of the rated output voltage of the power source **7**.

The operation of the reverse blocking diode thyristor will be explained referring to FIGS. 5 and 6. In the circuit in FIG. 3, when the switch 9 is on, the rated output voltage of the power source 7 is higher than the breakover voltage V_{BO} is applied across the terminals *a* and *b* of the reverse blocking diode thyristor 11. The breakdown of the reverse blocking diode thyristor 11 makes the terminal *a b* conducting. The filament of the fluorescent discharge tube 8 reaches the preheating state. When the reverse blocking diode thyristor 11 changes from the conducting state to the cut-off state in each positive cycle of the power source, a high voltage is applied across both filaments of the fluorescent discharge tube 8 in the form of a kick voltage. Each negative cycle is blocked. By the half wave rectification a d.c. current is superimposed on the circuit. The current limiting ballast 10 causes the magnetic saturation and a sufficient preheating current flows through the electrode. In each negative half cycle the reverse blocking diode thyristor does not breakover so that the power source voltage is applied across the discharge tube 8 and effects starting. After several cycles of the filament preheating, the kick voltage, and the source voltage application, the discharge tube 8 begins to discharge and ignite. The turn-off of the conducting reverse blocking diode thyristor 11 is determined by the current flowing through the reverse blocking diode thyristor 11. In the circuit, the current lags behind the voltage due to the inductance of the current limiting ballast 10. So, the conduction of the thyristor is maintained during the initial part of the negative half cycle. Once the discharge begins, the voltage across terminals *a* and *b* of the reverse blocking diode thyristor 11 becomes equal to the operating voltage of the fluorescent discharge tube 8. The reverse blocking diode thyristor reaches cut-off and the fluorescent discharge tube 8 remains in the on state. The noise preventing capacitor 12, usually connected in parallel to the starter, often gives a higher voltage than the breakover voltage V_{BO} across the thyristor, whereby the thyristor is reignited. This is due to the charging and discharging of the capacitor during the lighting of the discharge tube 8, occurring when the assembly using this starter is used under such bad conditions that the temperature is decreased abnormally or the source voltage is raised abnormally. Because of this fact in this invention a noise preventing capacitor 12 of the order of 0.2 μ is inserted between the points *c* and *d*, i.e., between the input of the current limiting ballast 10 and the electrode input of the fluorescent discharge tube 8 whereby a similar effect is obtained.

Explanation of modified circuit diagrams with various auxiliary circuits added to the above basic circuit, where the reverse blocking diode thyristor is connected in parallel to the fluorescent discharge tube as a starter, will be made with reference to FIGS. 9 to 17. The reverse blocking diode thyristor used hereinafter has the characteristic as explained above, and may be a combination of a thyristor and a diode or a single element, included within the general term reverse blocking diode thyristor.

FIG. 9 shows a combination of a current limiting ballast and two reverse blocking diode thyristors. One end of the current limiting ballast 13 is connected to one end of the power source 14 while the other end thereof is connected to one end of the filament 16 of the fluorescent discharge tube 15 and to one end of reverse blocking diode thyristor 17. The other end of the filament 16 is connected to one end of the other filament 19 through the reverse blocking diode thyristor 18. One end of the filament 19 is connected to the other end of the power source 14 through a switch 20. The other end of the reverse blocking diode thyristor 17 is connected to the other end of the filament 19. A noise preventing capacitor 21 is inserted between the input side of the current limiting ballast B and the output side of the switch 20. The reverse blocking diode thyristors 17 and 18 are connected oppositely to each other, their characteristics being the same as previously stated.

The operation of the circuit of FIG. 9 is as follows. When the switch 20 is closed, the power source voltage is applied to the reverse blocking diode thyristors 17 and 18. If the voltage on the side of current limiting ballast is positive, the reverse blocking diode thyristor 18 reaches the breakover voltage V_{BO} and changes from the cut-off to the conducting state. The reverse blocking diode thyristor 17 maintains the blocking state due to its opposite polarity. Current flows in the direction of the current limiting ballast 13 — the filament 16 — the reverse blocking diode thyristor 18. The reverse blocking diode thyristor 17 becomes cut-off. No current flows through the filament 19, the preheating current flowing only through the filament 16. Next, when the polarity of the current limiting ballast 13 becomes negative, the reverse blocking diode thyristor 18 becomes off while the reverse blocking diode thyristor 17 becomes on. The current flows in the direction of the filament 19 — the reverse blocking diode thyristor 17 — the current limiting ballast 13. It is designed such that the time when the reverse blocking diode thyristor 17 changes from the on to off state does not coincide with the time when the reverse blocking diode thyristor 18 becomes on so that a pulse voltage is applied between the filaments 16 and 19 as shown in FIG. 10. The current waveform becomes as shown in FIG. 11. This time lag also exists between the time when the reverse blocking diode thyristor 18 changes from the on to off state and the time when the reverse blocking diode thyristor 17 becomes on. Thus, the current flows through the filaments 16 and 19 alternately. Pulse voltages are applied therebetween, whereby the fluorescent discharge tube 15 starts ignition. Once the discharge tube 15 is started, the reverse blocking diode thyristors 17 and 18 becomes cut-off due to the condition: the maximum value of the rated output voltage of the power source 14 > breakover voltage V_{BO} of the reverse blocking diode thyristors 17 and 18 > operating voltage of the discharge tube 15. So, the discharge is maintained. The start of the fluorescent discharge tube 15 is thus attained by the electrical switching action of the reverse blocking diode thyristors 17 and 18 so that the time required for the start is extremely short.

In FIG. 12, in order to increase the voltage applied to the discharge tube at starting a series connection of an auxiliary capacitor for starting and a symmetrical diode thyristor is connected in parallel to the fluorescent discharge tube. With only a capacitor the charge and discharge of the capacitor after operating of the fluorescent discharge tube makes the peak value of the

voltage waveform as high as the breakover voltage V_{BO} of the reverse blocking diode thyristors and occasionally causes reignition. To prevent this the symmetrical diode thyristor is connected in series to form an auxiliary circuit for starting. The breakover voltage V_{BO} of the symmetrical diode thyristor is equal to or larger than that of the reverse blocking diode thyristor. A further necessary condition is; the maximum value of the rated output voltage of power source > breakover voltage V_{BO} of the symmetrical diode thyristor > operating voltage of the discharge tube. By this arrangement the auxiliary capacitor for starting becomes electrically cut-off after the start of the tube operation. Thus, the circuit consisting of capacitor and the symmetrical diode thyristor operates only at the starting time. In FIG. **12**, one end of the current limiting ballast **22** is connected to one end of the power source **23** and the other end thereof is connected to one end of the filament **25** of the fluorescent discharge tube **24** and to a capacitor **26** of the auxiliary circuit. The capacitor **26** is connected in series to the symmetrical diode thyristor **27**, and this combination is connected between the filaments **25** and **28** of the discharge tube **24**. The reverse blocking diode thyristor **29** is also connected between the filaments **25** and **28** of the discharge tube **24**. The other end of the filament **28** is connected to the other end of the power source through a switch **30**. The noise preventing capacitor **31** is connected between the input side of the current limiting ballast **22** and the output side of the switch **30**.

The operation of the circuit in FIG. **12** is as follows. When the forward voltage applied to the reverse blocking diode thyristor **29** reaches the breakover voltage V_{BO} of the revere blocking diode thyristor **29**, the current flows in the direction of current limiting ballast **22** — filament **25** — reverse blocking diode thyristor **29** — filament **28**. In this case the capacitor **26** of the auxiliary circuit is charged and at the same time the symmetrical diode thyristor **27** reaches the breakover voltage V_{BO}. The impedance of the auxiliary circuit consists only of the impedance of the capacitor **26**, and is much larger than the resistances of the filaments **25** and **28**. Therefore, the current flowing through this circuit is small. When a reverse voltage is applied, no current flows through the filaments **25** and **28**. The charging voltage of the capacitor **26** is superposed on the voltage of the power source **23**, and hence the voltage applied to the fluorescent discharge tube **24** becomes higher than the power source voltage. The above action is repeated in accordance with the power source cycles whereby the preheating is effected. The high voltage together with the preheaing makes the discharge tube **24** start. Once after starting the discharge tube the reverse blocking diode thyristor and the symmetrical diode thyristor become both cut-off as their breakover voltages V_{BO} are higher than the operating voltage of the discharge tube. Thus, the discharge is maintained. FIGS. **13** and **14** show the waveforms of the voltage and the current across the terminals *e* and *f* during preheating and operating. The characteristic of the symmetrical diode thyristor **27** is shown in FIG. **7**.

FIG. **15** shows a starter circuit for a high output fluorescent discharge tube of the rapid starting type which uses a reverse blocking diode thyristor and an auxiliary capacitor for starting in the high output circuit. **32** is a power source, **33** is a current limiting ballast having four coils **34**, **35**, **36** and **37**, **38** is a switch, **39** is a fluorescent discharge tube having filaments **40** and **41** on both ends, **42** is a capacitor, and **43** is a reverse blocking diode thyristor. In this circuit composition, one filament **40** is connected to the coils **34** and **35** of the current limiting ballast **33**. The other ends of these coils are both connected to the power source **32**. The filament **41** is connected to the coils **36** and **37** of the current limiting ballast **33**. The other ends of these coils are both connected to the power source **32** through the switch **38**. The capacitor **42** is inserted between the connection point of the filament **40** and the coil **34** and the connection point of the filament **41** and the coil **37**. The reverse blocking diode thyristor **43** is inserted between the connection point of the filament **40** and the coil **35** and the connection point of the filament **41** and the coil **36**. The operation of this circuit is as follows. When the switch **38** is closed and a positive voltage is applied to the reverse blocking diode thyristor **43** by the power source **32**, the composite currents flow through the coil **34** and the filament **40** and through the coil **35** via the reverse blocking diode thyristor **43** and the coil **36** and through the filament **41** and the coil **37**. The capacitor **42** due to its high impedance allows no substantial current to pass. Thus, the preheating current flows in the direction of coil **34** of the current limiting ballast **33** — filament **40** — reverse blocking diode thyristor **43** — filament **41** — coil **37**. During the next negative voltage cycle the reverse blocking diode thyristor **43** becomes cut-off so that the voltage is applied only to the filament **40** and **41**. By charging, the voltage of the capacitor **42** reaches a high voltage across the terminal. The voltage is applied at the filament **40** and **41** as a starting voltage and the discharge tube **39** is started. The operation is done in accordance with the frequency of the power source **32**, and hence the fluorescent discharge tube **39** is rapidly started. Once the discharge tube is started, the voltage across the reverse blocking diode thyristor **43** becomes equal to the operating voltage of the tube and makes the reverse blocking diode thyristor **43** cut-off. So, the discharge of the fluorescent discharge tube **39** is maintained. FIGS. **16** and **17** show the waveforms of the voltage and the current between the terminals *g* and *h* of the discharge tube during preheating and operating.

The reverse blocking diode thyristor used in this invention has these characteristics: i.e., the breakover voltage for the forward direction V_{BO} < the blocking voltage for the backward direction V_R. The mass production of such reverse blocking diode thyristors is very difficult from the viewpoints of manufacturing technique and economy. The use of a silicon controlled rectifier element instead of the reverse blocking diode thyristor is complicated because of the necessity of the accessary circuit, and furthermore it is not so economical.

Hereinafter, explanation will be made of a method for obtaining the above-mentioned reverse blocking diode thyristor with reference to FIGS. **7**, **8** and **18**. A symmetrical diode thyristor whose characteristic is as shown in FIG. **7** and a publicly known diode whose characteristic is as shown FIG. **8** are used. The symmetrical diode thyristor changes from the cut-off to the conducting state when the terminal voltage exceeds a

certain value (the breakover voltage V_{BO}). The characteristic is in principle symmetric with respect to the voltage axis. The blocking voltage V_R of the diode is assumed to be larger than the breakover voltage V_{BO} of the symmetrical diode thyristor. Connected in series with the above two semiconductors and sealed together in a plastic or metal case, a reverse blocking diode thyristor whose characteristic is shown in FIG. 4 is situated. The characteristic of the reverse blocking diode thyristor in the forward direction is equal to that of the symmetrical diode thyristor while that in the backward direction is equal to that of the diode. The blocking voltage V_R is sufficiently larger than the breakover voltage V_{BO}. Instead of the symmetrical diode thyristor a conventional reverse blocking diode thyristor whose characteristic is as shown in FIG. 18, i.e., the breakover voltage V_{BO} in the forward direction is nearly equal to the blocking voltage V_R in the reverse direction, may be used for the same effect by connecting it in the same direction in series with the diode of FIG. 8 and sealing them in a plastic or metal case.

FIGS. 19 and 20 show reverse blocking diode thyristors thus obtained. Numeral 44 is a plastic or metal case, 45 is the diode, 46 is the symmetric diode thyristor, and 47 is the reverse blocking diode thyristor whose breakover voltage V_{BO} is nearly equal to the blocking voltage V_R.

The two semiconductors are individually sealed in a metal or plastic case and the series connection from them is also sealed in a similar case. Alternatively, lead wires are fitted to the unsealed semiconductors to connect them in series and this combination is sealed in a metal or plastic case.

Considering that the reverse blocking diode thyristors appearing in FIGS. 3 to 17 are obtained by sealing a series connection of either a symmetric diode thyristor or a reverse blocking diode thyristor having a breakover voltage V_{BO} nearly equal to the blocking voltage V_R with a diode having a blocking voltage V_R much larger than the breakover voltages of the above thyristors, the composite semiconductor has a blocking voltage V_R in the reverse direction sufficiently larger than the breakover voltage V_{BO} in the forward direction and serves for this purpose. Therefore in this invention, all single and composite elements whose characteristic are as shown in FIG. 4 belong to the reverse blocking diode thyristor and are available in FIGS. 3 to 17.

What is claimed is:

1. Apparatus, including a circuit for starting a fluorescent discharge tube, comprising: an AC power source; a fluorescent discharge tube connected across said AC source and having first and second opposed filaments; reverse blocking diode thyristor means connected between a first terminal of each of said filaments of said discharge tube, said thyristor means having a blocking voltage which is higher than the maximum rated output voltage of said AC source and a breakover voltage which is lower than said maximum rated voltage and higher than the peak value of the operating voltage of said discharge tube; switch means connected between one side of said AC source and a second terminal of said first filament; current limiting means connected between the other side of said AC source and a second terminal of said second filament; and capacitor means connected across said AC source.

2. Apparatus according to claim 1, further comprising: a symmetrical diode thyristor and a starting capacitor connected in series between said second terminals of said first and second filaments, said symmetrical diode thyristor having a breakover voltage lower than said maximum rated output voltage and higher than said peak operating voltage of said tube.

3. Apparatus according to claim 2, wherein said thyristor means comprises a single reverse blocking diode thyristor.

4. Apparatus according to claim 2, wherein said thyristor means comprises a series connection of a symmetrical diode thyristor and a diode, said symmetrical diode thyristor having said breakover voltage and said diode having said blocking voltage.

5. Apparatus according to claim 2, wherein said thyristor means comprises a series connection of a reverse blocking diode thyristor and a diode, said reverse blocking diode thyristor having said breakover voltage and a blocking voltage nearly equal to said breakover voltage, and said diode having a blocking voltage higher than the power source voltage.

6. Apparatus, including a circuit for starting a fluorescent discharge tube, comprising: an AC source; a fluorescent discharge tube having opposed filaments and connected across said AC source; reverse blocking diode thyristor means connected directly across said filaments and across said AC source, said thyristor means having a blocking voltage which is higher than the maximum rated output voltage of said AC source and a breakover voltage which is lower than said maximum rated voltage and higher than the peak value of the operating voltage of said discharge tube; switch means connected between one side of said AC source and a terminal of one of said filaments; current limiting means connected between the other side of said AC source and a terminal of the other filament; and capacitor means connected across said AC source.

7. Apparatus according to claim 6, wherein said thyristor means comprises a single reverse blocking diode thyristor.

8. Apparatus according to claim 6, wherein said thyristor means comprises a series connection of a symmetrical diode thyristor and a diode, said symmetrical diode thyristor having the breakover voltage lower than said maximum rated output voltage of said AC source and higher than said peak value of the operating voltage of the discharge tube, and said diode has a blocking voltage higher than said maximum rated output voltage.

9. Apparatus according to claim 6 wherein said thyristor means comprises a series connection of a reverse blocking diode thyristor and a diode, said diode thyristor having the breakover voltage lower than said maximum rated voltage of said AC source and higher than said peak value of said operating voltage and having a blocking voltage nearly equal to said breakover voltage, said diode having a blocking voltage higher than the power source voltage.

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