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[54] **STARTING UNIT FOR HEATED GAS DISCHARGE TUBES**

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[51] **Int. Cl.** **H05b 41/18**

[58] **Field of Search** ....315/DIG. 5, DIG. 7, 101–103, 315/106, 172, 176, 205, 207, 239, 240, 273, 289, DIG. 2

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[57] **ABSTRACT**

A starting unit for heated gas discharge tubes, particularly fluorescent gas tubes which includes a heating circuit containing both tube electrodes and a controlled electronic switch.

6 Claims, 3 Drawing Figures

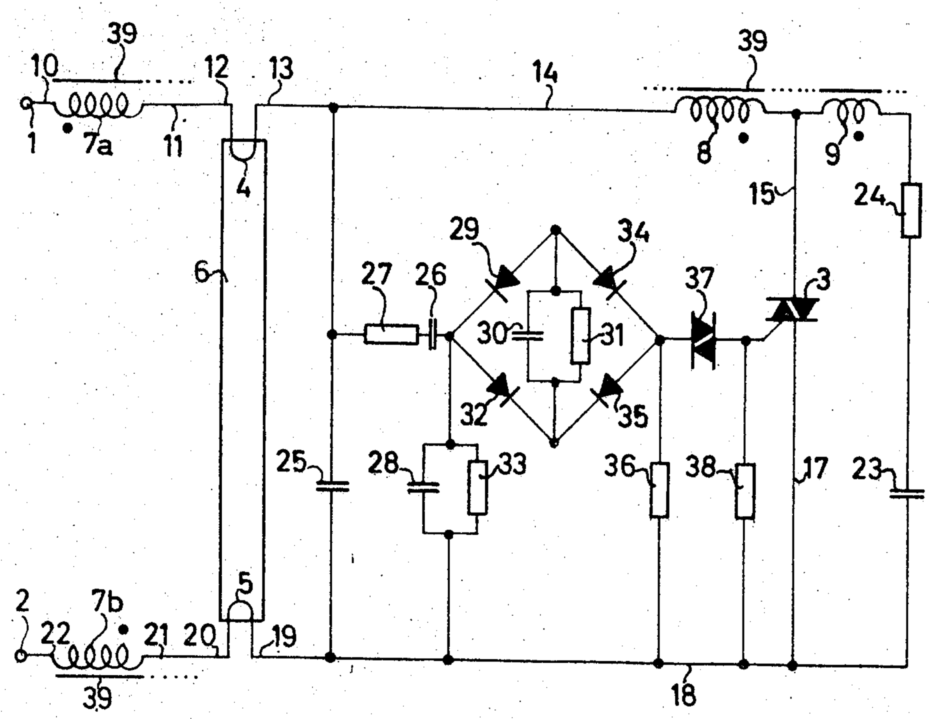

FIG. 1a

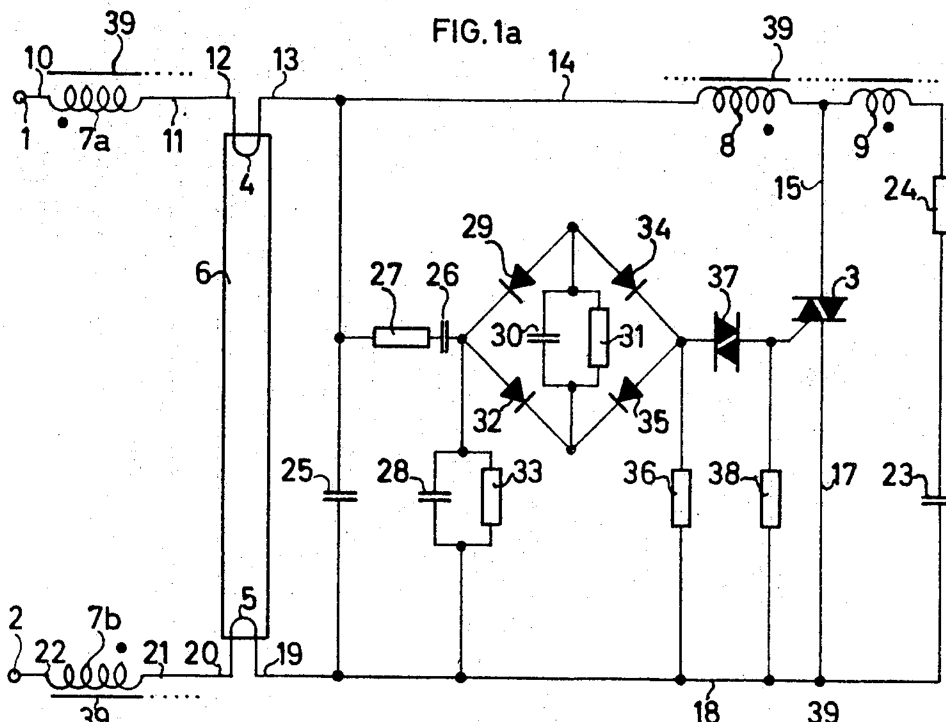

FIG. 1b

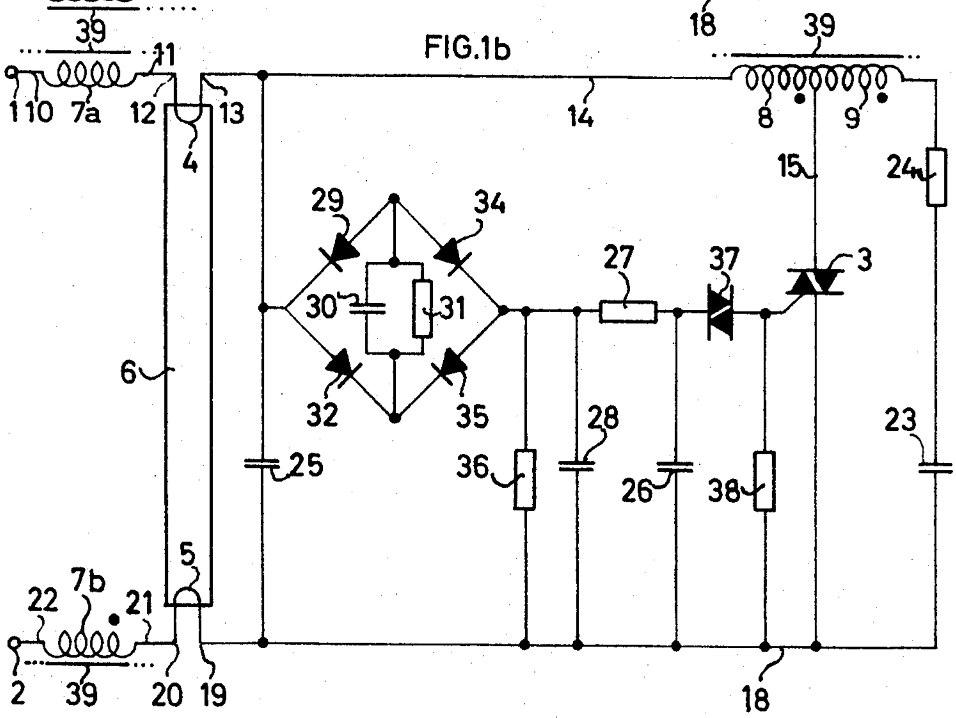

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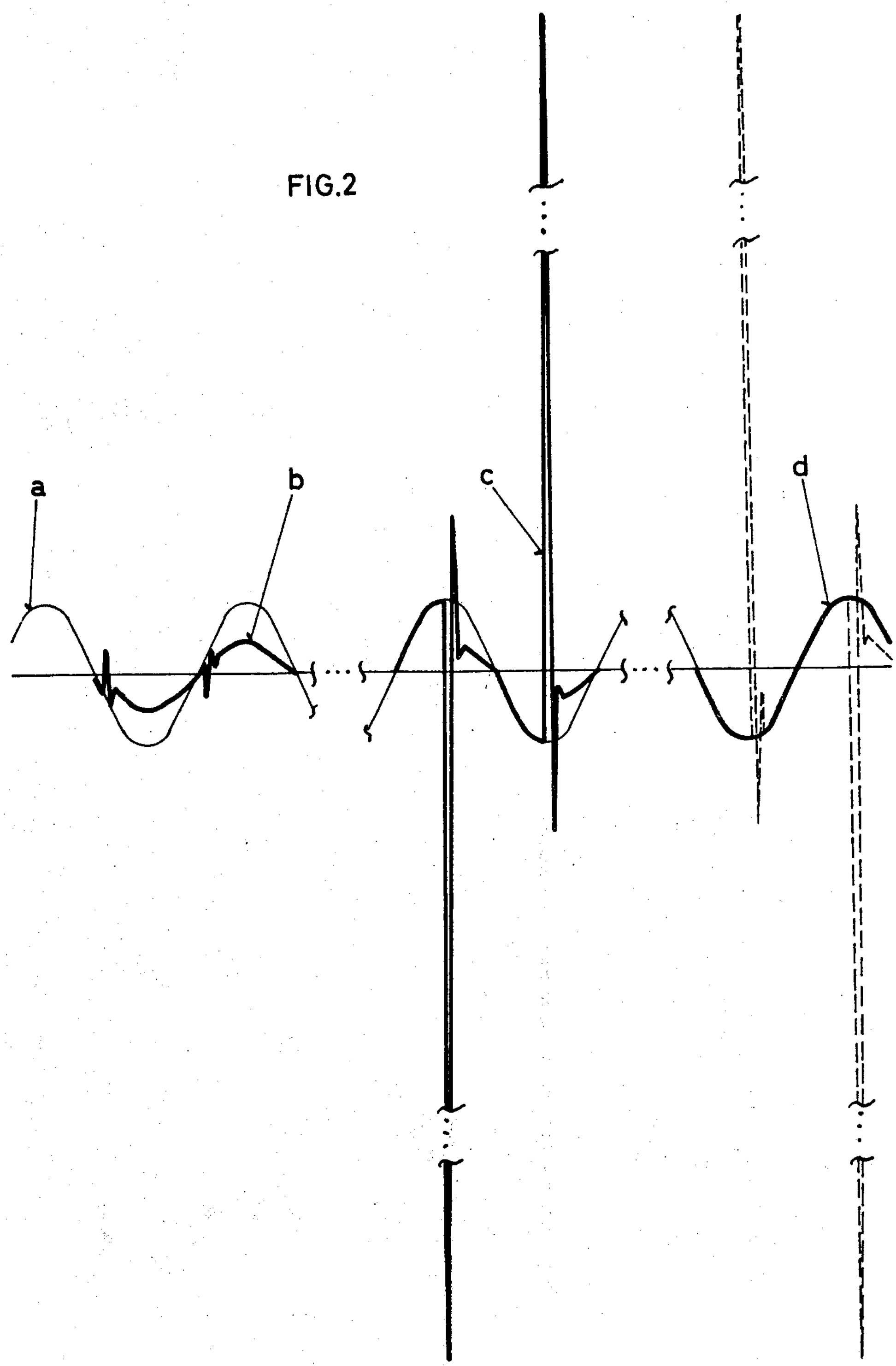
FIG.2



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STARTING UNIT FOR HEATED GAS DISCHARGE TUBES

The present invention concerns a starting unit for heated gas discharge tubes, in particular fluorescent gas tubes, comprising a heating circuit which, besides containing the tube electrodes, includes a controlled electronic switch.

The Swiss Pat. No. 431,716 describes a starting unit for fluorescent gas tubes which comprises a choke coil fitting at the input end of the tube and further comprises a heating circuit in which the tube electrodes are only heated until the tube is triggered when the mains voltage is applied to the ballast unit.

The major drawback of that known system is that when a fault arises, i.e., when the tubes are not triggerable (deactivated cathodes, faulty gas fill, etc.), the choke winding burns out. Fuse protection would not be possible because of the very close tolerances and would have unduly reduced operating dependability. For this reason and because of other disadvantages, that system was not approved for trade by the Swiss authorities. Further, the German Pat. No. 949,419 describes a starter-less unit requiring a special tube. This tube, being little in demand, is not readily obtainable everywhere and, despite its relatively high price, only has a short service life, because at room temperature it tends to be subject to cold starting. Also, this system contains mechanical switch contacts and elements dependent on ambient temperature which tend to cause trouble.

It is therefore the object of the present invention to provide a starting unit which requires no special tube, which contains no moving parts subject to mechanical wear, which calls for no precautions in the event of the tube being spent or useless, and which has an optimum cosine power factor. Moreover, the system described can be manufactured simply and at a reasonable cost. This object is achieved hereunder for a starting unit in that the heating circuit contains the secondary winding of an auto-transformer, that the electronic switch has in parallel with it a series circuit which comprises the primary winding of the auto-transformer and a capacitor and in which, with the switch switched on, the capacitor is discharged through the primary winding of the auto-transformer, thus giving rise to trigger voltage impulses stepped up by the auto-transformer, that there is a control circuit which is connected to the tube electrodes on the input side and whose output is connected to the control electrode of the electronic switch and which includes a voltage-dividing circuit with a timing component for developing a time-dependent signal corresponding to the temperature change produced by the heating in the tube electrodes, with the result that the switch-on moment of the electronic switch is displaced approximately proportionally to the temperature of the tube electrodes from small phase angles of the tube voltage up to a phase angle associated with a voltage limit value within the range of a peak value of the tube voltage, while, once the limit value is exceeded, the electronic switch is blocked, and that the timing component is associated with means which, with the switch blocked, vary the time-dependent signal at a quicker rate than would correspond to the temperature behavior of the non-loaded tube electrodes, so that, after several voltage cycles, the switch is repeatedly switched on and occasional trigger voltage impulses arise.

The starting unit described is safeguarded against permanent starting, cannot burn out, has reactive-current compensation due to the very design of the circuit, and cold starting is not possible even in the most adverse circumstances. While in known starting units the heating current during the preheating of the tube cathodes is determined by the current-limiting choke alone or, in the case of starter-less units, by a heat transformer or an L-C resonant circuit, in the system claimed hereunder it is practically only the ohmic resistance, substantially reduced as compared with known circuits, of the choke wire that acts as ballast element, resulting in a heating current which is several times greater than that of known starting units, but which is only sustained for as long as the temperature conditions at the tube electrodes permit.

In the ballast winding, there are concurrently two different circuits. A heating current several times greater which passes through the ballast winding and through the lamp heating, but which should never, and can never, pass through the lamp striking range, would indeed be far too high to be tolerable as effective value for the tube and the choke winding. However, being a current surge which is exactly dosed by time and which can be stopped by the tube at any time, it keeps within safe limits, and its intensity is only little below the zone which would cause an emission-damaging cross-triggering across the heating coil. This harmful zone begins at a value about 15–20 times that of the normal power, according to type of lamp. The result is a very fast-heating ballast unit resulting in a tube heat-up rate resembling that of the incandescent bulb.

A particularly advantageous feature of the invention claimed hereunder consists in the fact that the timing component has a discharge time which is about proportional to the non-loaded tube electrodes. As a result, when a tube which is still warm is switched on, the tube is not unduly heated; instead, the starting program develops according to the momentary temperature expected at the tube electrodes. As all windings are arranged on the same iron core and their directions are opposed to each other, there is practically no overall inductance towards outside. As a vectorial impedance increase on the ohmic resistance, there merely remains a negligible inductance difference and a small dissipation inductance.

The chief and most conspicuous practical features of the system described are flicker-free starting with an unusually short heat-up period and without cold starting, the absence of moving or wearing parts, and the non-use of special tubes, such as tubes with triggering aid in known starter-less operation

The present invention is now to be described by way of example with reference to the accompanying drawing, in which

FIG. 1*a* shows the circuit diagram of the first embodiment;

FIG. 1*b* shows the circuit diagram of a second embodiment;

FIG. 2 shows a time diagram of the three different starting phases.

The circuit shown in FIG. 1*a* comprises a choke coil which is connected to the mains terminals **1** and **2** and which, in the example shown, consists of two winding halves **7***a* and **7***b* which add up together. In an asymmetrical construction, the two winding halves would be consolidated into a single winding, while for mains voltages of 110 volts they would be formed as a leakage-reactance transformer. Both winding halves are arranged on a common core **39**. The winding half *7a* is connected through a lead **10** to the mains terminal **1**, while the second end **11** of that winding is connected through a lead **12** to an electrode **4** of the glow discharge tube **6**. The second winding half *7b* is connected through a lead **22** to the second mains terminal **2**. While its second end **21** is connected through a lead **20** to the second electrode **5** of the tube **6**. The output **13** of the first tube electrode **4** is connected through a lead **14** to two windings **8** and **9** which act as auto-transformer and which are also arranged on the choke core **39**. The winding direction of this auto-transformer with respect to the choke windings *7a* and *7b* is indicated by dots in FIG. **1**. From the output of the auto-transformer winding **9** acting as primary winding, there is a connection across a capacitor **23** and a resistor **24** to the connection **19** on the second tube electrode **5**. This series connection comprising the auto transformer winding **9**, the capacitor **23** and the resistor **24** has in parallel with it the switching range of an electronic switch, such as an alternating current thyristor (Triac).

When the switch **3** is closed, it closes a heating circuit **1, 10,** *7a*, **11, 12, 4, 13, 14, 8, 15, 3, 17, 18, 19, 5, 20, 21,** *7b*, **22, 2** with a very high current. Owing to the winding direction, indicated by dots, and the correspondingly selected number of turns, there is practically no inductance in that circuit. The arrangement resembles a double-wound induction-free resistance, meaning that only the small ohmic resistance of the winding wire and the heat coils form a low impedance. The ballast inductance *7a* and *7b* is by no means nullified thereby and remains fully effective as an important lamp burning-current limit even during heat-up.

The tube electrodes **4** and **5** have in parallel with them a capacitor **25** acting as an interference suppressor. Moreover, connected to the tube electrodes is the input of a control circuit, described below, serving to control the switch **3**. The control circuit consists of the series connection of a capacitor **26** and a resistor **27**, followed by a voltage divider, which is led towards the base line **18** and comprises a capacitor **28** and a resistor **33**. Connected to the voltage divider is a bridge rectifier circuit which consists of the diodes **29, 32, 34** and **35** and whose direct current branch includes a timing component consisting of the parallel connection of a capacitor **30** and a resistor **31**. The output of the bridge rectifier is passed across a resistor **36**, led as a voltage divider towards the base line **18**, and connected to a trigger diode **37** whose second connection is linked to the control electrode of the electronic switch **3** across another resistor **38**, also acting as a voltage divider with respect to the base line **18**.

The arrangement shown in FIG. **1***b* corresponds in its essential function to that in FIG. **1***a*. The only difference is that the timing component is arranged before the divider acting as limiter, viz. the capacitor **28** and the resistor **27**. Moreover, the resistor **33** shown in FIG. **1***a* and the phase-correcting capacitor **26** are dispensed with.

The following describes the three starting operation programs of the circuit arrangement shown in FIG. **1***a*.

1. Switch-on program

During the first cycles following connection of the terminals **1** and **2** to the mains, the switch **3** remains switched on (conductive) almost across all the half-waves, because input and output of the bridge rectifier is also short-circuited through the initially still discharged timing component **30, 31**. By the phase-shifting voltage divider **26, 27, 28, 33**, the trigger diode **37** and, with it, the Triac are triggered right at the start of each halfwave. As there is no, or nearly no, voltage applied to the alternating current capacitor **23** at the switch-on moment, no triggerable voltage peaks arise in the auto-transformer **8, 9**, and only the cathode heating is very intensive. While the heating coil approaches the glow stage, the timing component **30, 31** becomes charged, and the trigger points on the sinusoidal half-waves shift towards the peak voltage (FIG. **2**). As long as the Triac is switched on over nearly a full halfwave, the windings are short-circuited, resulting in mains voltage division. This means that about half the mains voltage is applied across the tube, preventing it from striking during heat-up (FIG. **2***b*). Only when the trigger points shift towards the peak of the mains voltage does the mains voltage rise towards the no-load value, and the effective heating current falls slightly, because the cycles are no longer completely switched through.

2. Starting program:

The size of the delay capacitor **30** is such that readily heating tube cathodes glow towards the end of the switch-on phase and are therefore ready for triggering. For the other lamps, which are still too little heated at the beginning of the starting phase, the heating current about five times the normal continues. At the same time, triggerable high-voltage peaks arise across the tube, because the voltage available at the store capacitor **23** rises from halfwave to halfwave the more the trigger points shift. The auto-transformer steps up these voltages proportionally to increasingly higher trigger peaks until the tube fires. As soon as the tube burns, the control voltage collapses and instantaneously falls below the level required for triggering the trigger diode with the Triac. While in the first phase the electronic switch only effects the heat-up, in the second phase it controls a reduced heating, but also controls the triggering.

3. Protective program:

If, for some reason, the tube is not capable of burning, e.g. because of gas fill is not right or the cathode emission capacity has deteriorated or the mains voltage is too low, the starting phase must not continue indefinitely, because the windings are only designed for normal operation, and not for an excessive and prolonged heating current. In this case, the rectifier timing component effects blocking against prolonged starting. It becomes charged sufficiently to stop the control action. Owing to the absence of the trigger voltage peaks, it discharges somewhat again, and a heating and triggering impulse arises. As a result, the timing component begins to oscillate up and down in voltage at the rate of once or twice a second, resulting in an effective current of the magnitude of the rated lamp current, which is tolerable for prolonged periods. Owing to the occasionally arising triggering and heating impulses, the tube still receives the chance of reaching the normal burning stage after possible elimination of the fault

(FIG. 2, curve *d*). The resistor **31** regulates that valve, and it is also this resistor that restores the timing component to its initial position at the end of the burn. Moreover, the time constant of the RC component **30/31** is such that it agrees with the cool-down time of the tube cathode, for the event that after a short burning pause part of the first switch-on program or, if applicable, also the second starting program should be suppressed, because otherwise the tube would become unduly overheated.

The capacitor **23**, which is connected in series with the current-limiting resistor **24** and the primary winding **9** of the auto-transformer, is so dimensioned that the ballast unit, which would normally be inductive owing to the winding of the auto-transformer, is reactive-current-compensated. If there is no unduly strong coupling between the various windings, the capacitor **23** will also serve as a choke for the unit against possible control audio frequency superimposed on the mains. Beyond that, the capacitor **23** protects the electronic switch **3** against dangerous overvoltages occasionally arising in the mains. Owing to the reactive-current compensation of the capacitor **23**, the effective mains current may fall to about half the normal value, depending on the type of glow discharge tube used. Accordingly, the cross-section of the wire for the choke windings *7a* and *7b* and for the auto-transformer **8, 9** may be smaller by about half as compared with known systems of the type. The resultant saving in winding space also permits a shorter and lighter choke core **39** to be used.

FIG. **2** shows the voltage curves of the fluorescence tube for the three switching phases described above. Curve *a* represents the mains voltage, given as a constant, e.g. **220** volts, while curve *b* represents the tube voltage during the switch-on phase. In this, triggering peaks of only very small amplitude arise shortly after the zero transitions of the mains voltage. The amplitude of the tube voltage has a peak value of about half the mains voltage amplitude. Curve *c* shows the tube voltage during the starting phase. Here, in the embodiment shown, the trigger voltage peaks are about 1,000 to 3,000 volts. During the protective phase, which only becomes effective when the starting phase fails to trigger the tube, the tube is again under the mains voltage which, as shown by curve *d* is accompanied by occasional triggering impulses.

During the switch-on phase, current peaks of **4A**, for instance, arise, while the rated current of the tube is 0.4 A, for instance. In the starting phase, the current falls to peak values of 2.5 A, for instance. Similarly high current peaks also arise during the protective phase, together with the occasional trigger voltage impulses.

In the preferred embodiment, the following values were adopted for the various circuit elements. It must be remembered, though, that the optimum values vary according to the particular type of lamp.

Resistor	24	maximum	15 ohms
	27	approx.	33K
	31	"	10M
	33	"	33K
	36	"	2.2M
	38	"	1K
Capacitor	23	approx.	3.5 nF
	25	"	10
	26	"	220
	28	"	100
	30	"	150

Winding quota (related to sum of all turns)

7a	25%
7b	25%
8	45%
9	5%

The circuit components are so dimensioned that even tubes with weak electrodes are ready for burning after the switch-on phase. Yet this phase only lasts a few hundredths of a second. The reduced voltage at the tube electrodes also prevents short and quick-trigger-ing tubes from cold starting during this switch-on phase. Actual heat-up is effected within milliseconds, while in all known systems it requires full seconds. Thus, owing on the inertia of the human eye, a fluorescent gas tube operated with the starting unit claimed hereunder comes alight completely flicker-free.

What is claimed is:

1. Starting unit for heated gas discharge tubes, in particular fluorescent gas tubes, comprising a heating circuit which includes the tube electrodes, a controlled electronic switch, and the secondary winding **(8)** of an auto-transformer **(8,9)** arranged in a series connection; the electrode switch **(3)** has in parallel with it a series connection which consists of the primary winding **(9)** of the auto-transformer and a capacitor **(23)** and in which, with the switch switched on, the capacitor is discharged through the primary winding **(9)** of the auto-transformer, giving rise to trigger voltage impulses stepped up by the auto-transformer; the tube electrodes **(4,5)** have connected to them a control circuit **(26 to 38)** whose output is connected to the control electrode of the electronic switch, the control circuit including a bridge component having a timing component **(30, 31)** connected across it for the purpose of developing a time-dependent quantity corresponding to the temperature change in the tube electrodes caused by the heating, with the result that the switch-on moment of the electronic switch is displaced approximately proportionally to the temperature of the tube electrodes from small phase angles of the tube voltage up to a phase angle associated with a voltage limit value located in the range of the peak value of the tube voltage, while, once that limit value is exceeded, the electronic switch is blocked; and the timing component is provided with means **(36)** which, with the switch blocked, vary the time-dependent quantity at a quicker rate than would correspond to the temperature behavior of the non-loaded tube electrodes, so that, after several mains voltage cycled, the switch is repeatedly switched on and occasional trigger voltage impulses arise.

2. Starting unit according to claim **1**, characterized in that the timing component, has a drop-off time which is approximately proportional to the cool-down time of the non-loaded tube electrodes.

3. Starting unit according to claim **2**, characterized in that the timing component consists of a capacitor **(30)** which is arranged in a bridge rectifier **(29, 32, 34, 35)** and which has in parallel with it a high-ohmic resistance **(31)** allowing for the cool-down time of the non-loaded tube electrodes.

4. Starting unit according to claim **1**, characterized in that a trigger diode (**37**) is arranged between the timing component and the control electrode of the electronic switch.

5. Starting unit according to claim **4**, characterized in that there is arranged between the timing component and the trigger diode a resistor (**36**) by which, with the switch blocked, the discharge time of the timing component (**30**) is reduced.

6. Starting unit to claim **1**, characterized in that the capacitor (**23**) is so dimensioned that the system is reactive-current-compensated during operation and that overvoltage protection is provided for the electronic switch (**3**).

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