Nov. 22, 1966 A. E. FEINBERG ET AL 3,287,599

FAULT INDICATING FLUORESCENT BALLAST APPARATUS

Filed April 6, 1964 2 Sheets-Sheet 1

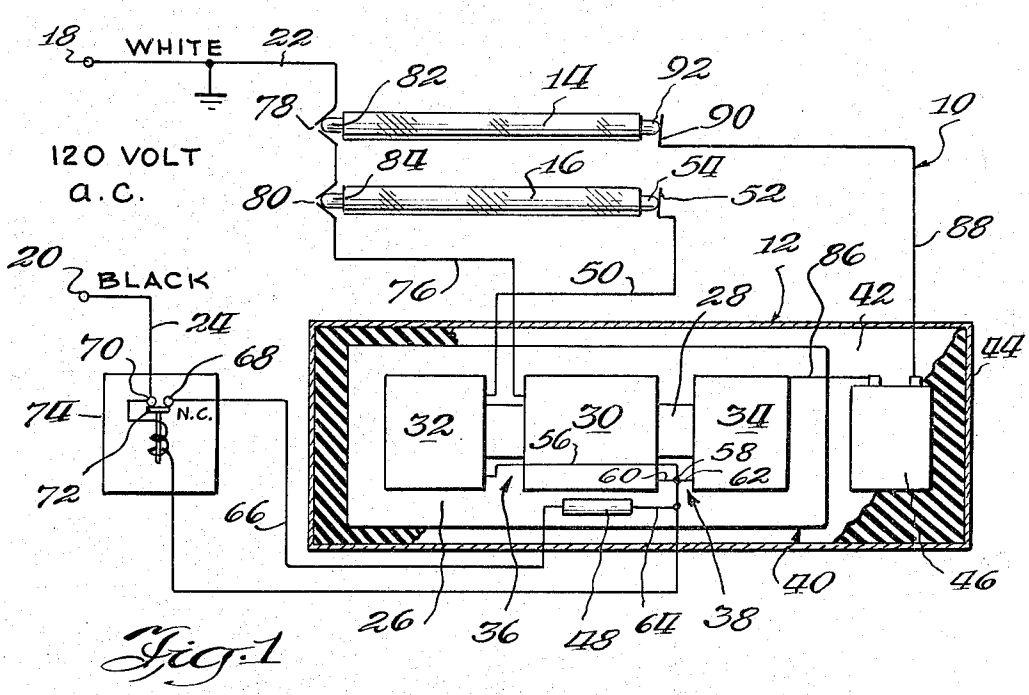
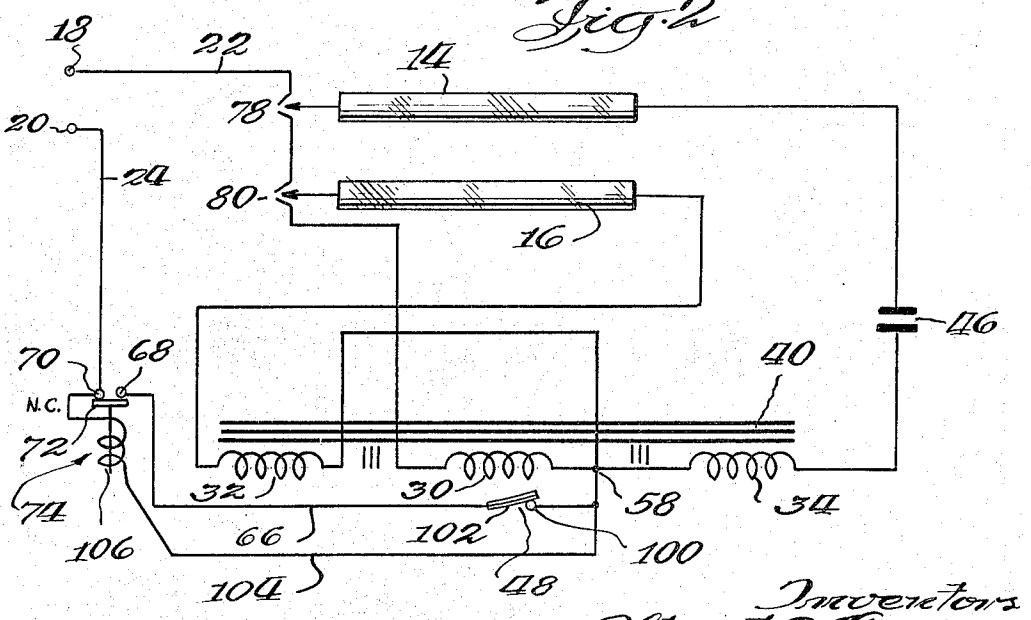



Fig. 1

Fig. 2




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FAULT INDICATING FLUORESCENT BALLAST APPARATUS

Filed April 6, 1964 2 Sheets-Sheet 2

Fig. 3

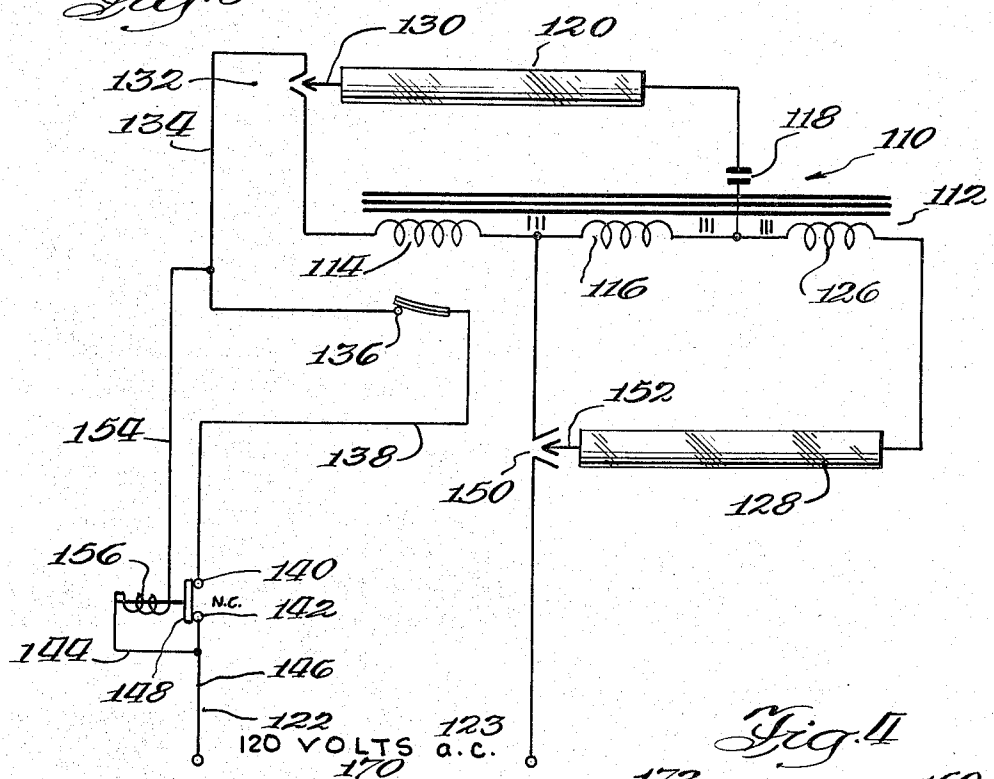
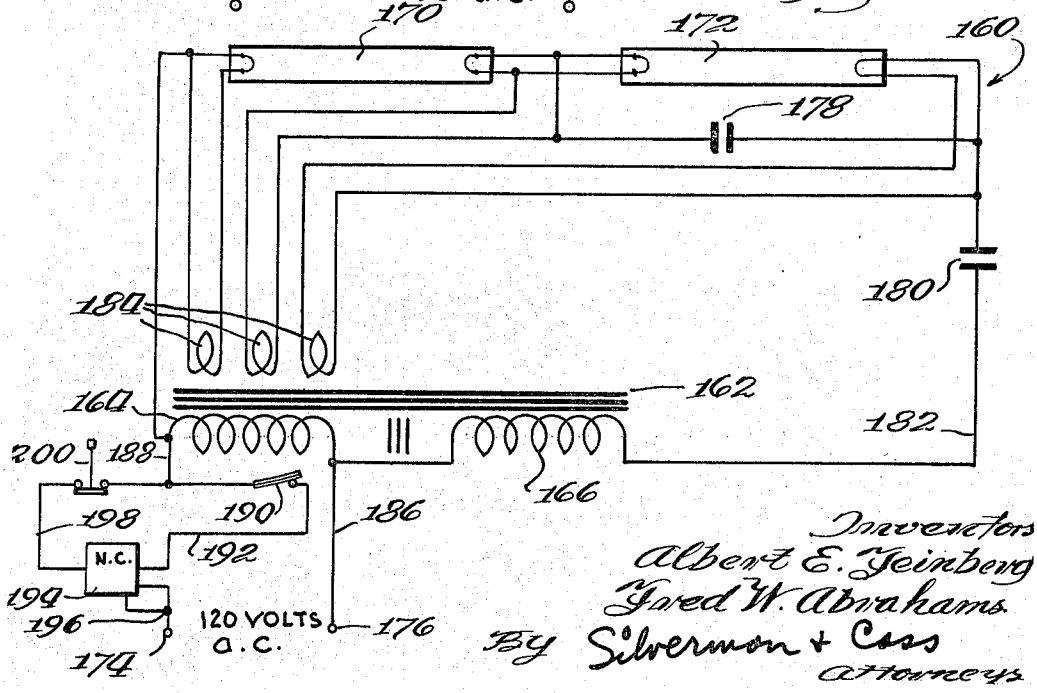



Fig. 4




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United States Patent Office 3,287,599 Patented Nov. 22, 1966



3,287,599

# FAULT INDICATING FLUORESCENT BALLAST APPARATUS

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Filed Apr. 6, 1964, Ser. No. 357,498
5 Claims. (Cl. 315—126)

This invention relates generally to ballasts for fluorescent lamps systems and more particularly is concerned with apparatus for indicating the existence of a fault in a ballast which is equipped with an automatic resetting thermostat and/or in the fluorescent lamp system including such ballast.

As well known, the modern fluorescent lamp is a negative resistance characteristic device and requires ballasting apparatus to impede the flow of current through the lamp once it has become ignited. The modern fluorescent lamp operates at a voltage substantially higher than that of the ordinary power lines available, even in industrial installations, and consequently transformation is required in addition to impeding current flow. By far the greater percentage of fluorescent lamp fixtures have two or more lamps mounted therein and the apparatus which furnishes the ballasting effect and transformation is likewise called upon to ignite a plurality of lamps and maintain the same in operation.

The fluorescent ballast art has acquired a high degree of sophistication by virtue of which many ingenious and economical arrangements and systems are capable of being constructed including ballasts which are easily obtainable and readily manufactured for use therewith.

Ballasts are known which ignite fluorescent lamps and furnish the operating voltage therefor, such a ballast having high leakage reactance built into it so that once the lamps become ignited and current flows through the windings affected by the high leakage reactance, current flow through the lamps is limited. Such a ballast may ignite the lamps one after the other so that a high voltage first will be applied to one lamp and then to the other, after which the lamps are operated in series. Other ballasts are known which have parallel circuits for the lamps.

Some fluorescent lamp systems in use have connections including so-called disconnect sockets for the lamps. The use of disconnect sockets is a safety measure since this type of socket with which an important phase of the invention hereinafter will be described has a pair of contacts which are open until and unless a terminal of the fluorescent lamp is inserted into the socket to bridge the contacts. Removal of the lamp will open the circuit including the contacts so that if, for example, the circuit is one in the primary winding of a transformer, the removal of the lamp will open the primary energizing circuit.

Another aspect of safety which has become more and more important in recent years is concerned with preventing the ballast itself from becoming destroyed through a fault or failure in the system, and preventing the ballast from becoming heated to a point where the potting compound therein escapes from the canister of the ballast and causes property and personnel damage in addition to the deleterious effects of escape of the potting compound from the ballast. Safety is also a factor in taking steps to prevent the condenser, usually potted with a ballast, from becoming overheated thereby causing the insulating oil from breaking down, vaporizing and bursting out of its canister. This, of course, could cause damage to property and personnel as well.

Ballast failure and/or heating up of ballasts may be caused by any one of many different factors. Several of these factors are faulty wiring, defective lamps, improper



connections and the like. As a general rule, the fault is first manifest in an increase in the heat generated by the ballast, and since the winding which normally has the highest current flowing therein is the primary winding, the heat normally will be greatest in the vicinity of the primary winding. One fault which especially produces this heating of the primary winding due to its drawing a greater than normal current is lamp rectification. Some fluorescent lamps, such as the so-called slimline or instant start lamps, act as rectifiers when one or both ends of the lamp become deactivated.

It has become common, therefore, to connect a fusible link or other disconnect means operated by high temperature in the primary circuit, such means being in the immediate vicinity of the primary winding. Fusible links render the ballast useless and hence in many ballasts an automatic reset thermostat is connected in series with the primary winding operable by an increase of temperature in the vicinity of the primary winding. Such a thermostat is advantageous where the cause of fault is external of the ballast so that once the fault has been cured, the ballast can operate satisfactorily.

An automatically resetting thermostat would be one which includes a bimetal member that is engaged with a contact at normal temperatures but swings away from the contact at abnormal temperatures. The arm having the bimetal and the contact are in series in the primary circuit so that when the bimetal member moves from contact, there will no longer be any current flowing in the primary. The primary, therefore, will cool and lower the temperature in its vicinity whereupon the bimetal will swing back to the contact and once more complete the circuit.

The user will recognize that a fault has occurred because the fluorescent lamps of the particular fixture will both go out if there are two lamps in the fixture. After a while the lamps will light once more since the cooling of the primary winding has permitted the bimetal member to return to its normal position engaging the contact of the thermostat. This cycle may repeat indefinitely if the temperatures are not too severe but even this arrangement may not save the ballast.

For the purposes of this discussion, it may be assumed that the user having seen the de-energizing of the fluorescent lamps realizes that there is a fault and will take steps to cure it.

In most installations the arrangement described is statisfactory but in a great many instances the fixture in which the fault occurs may be one of many. Two effects may occur. The recycling may occur a great many times with a gradual deterioration of the ballast, especially its condenser, so that finally the ballast fails at a fairly low temperature. The second factor is that a maintenance man may have to wait a considerable length of time between cycling to choose which one of a large installation of fixtures is the defective one. The time lost can be substantial where the cycling time of the thermostat is made relatively long to assure protection of the ballast, thermostat and lamps.

It is, therefore, an important object of the invention to provide apparatus for use with a ballast for fluorescent lamps having an automatic reset thermostat in circuit with the ballast which apparatus will deactivate the fixture once the thermostat operates and keep the fixture deactivated and incapable of being further activated without first completely disconnecting the power from the fixture.

A further object of the invention is to provide apparatus for indicating the fault in a fluorescent ballast without the need for expensive or complicated apparatus and without radically altering the wiring of the system and ballast.

Still a further object of the invention is to provide apparatus of the character described in which once a fault has occurred in a ballast and the ballast has been deactivated by an automatic reset thermostat built into the ballast, the ballast remains deactivated even after the ballast has cooled off and the thermostat has reset itself, the ballast remaining in this deactivated condition until the ballast has been electrically disconnected from the line.

In connection with the object set forth immediately above, it is a further object of the invention to provide a fluorescent ballast and lamp system in which after the ballast and its fluorescent lamps have been deactivated due to a fault and remain deactivated in accordance with the invention, the removal of a lamp from the fixture by the maintenance man or user will give control of the apparatus back to the thermostat so that upon reinsertion of an operative lamp in the fixture the entire fixture and ballast will be reactivated.

There are many other objects and advantages to this invention which will appear from a careful reading and examination of the description which follows, this description being the detailed disclosure required by statute directed to specific apparatus offered as preferred embodiments of the invention. In connection with this disclosure, the drawing illustrates the same diagrammatically and symbolically.

In the said drawing:

FIG. 1 is a combined circuit diagram and symbolic representation illustrating apparatus instructed in accordance with the invention, the ballast and system therein depicted being known as a lead-lag ballast and fluorescent lamp system.

FIG. 2 is a circuit diagram of the apparatus of FIG. 1 but in a more simplified form.

FIG. 3 is a circuit diagram of a fluorescent ballast and lamp system of the so-called series-sequence type having the invention associated therewith.

FIG. 4 is a circuit diagram of a fluorescent lamp ballast and system of the so-called rapid start variety in which a modified form of the invention has been embodied.

Generally, the invention is characterized by the provision of a relay of simple construction connected in a manner such as to be in series with the primary circuit when the solenoid of the relay is energized, thereby providing a by-pass circuit around the automatic thermostat. The relay is parallel with the thermostat and hence will automatically operate when the thermostat opens, withdrawing control from the thermostat. Only one additional lead is required, this being connected from that side of the thermostat which is connected to the primary winding to the contact of the relay that extends to the line. The relay contacts are inserted into the connection from the automatic thermostat to the same line so that when the relay solenoid is not energized, the bridging member of the relay closes the contacts but as soon as the solenoid is energized, those contacts are open and will remain open so long as current flows through the solenoid.

The circuit with which the solenoid and thermostat are associated is preferably one which includes so-called disconnect sockets, each lamp having one of its terminals engaged in such a socket so that the removal of the lamp will open the line in which the sockets are connected. In accordance with standard practice these disconnect sockets are also in series with the primary winding. Removal of a lamp will therefore open the primary winding. If the ballast and lamps have been deactivated by operation of the relay, the removal of a lamp from its socket will de-energize the relay solenoid turning the control of the apparatus back to the thermostat by virtue of the closing of the contacts of the relay.

As will be seen from the description below, in such circuits there is no need to provide a manual reset on the relay. In other circuits where there are no disconnect sockets, all that there need be is a simple switch anywhere in the primary circuit, to open that circuit for de-energizing the relay solenoid to restore control to the thermostat. The thermostat has, of course, cooled off in the meantime, and reset itself.



The basic concept of the invention is that of providing a relatively high impedance by-pass circuit having a relay in parallel with the automatic reset thermostat which (a) keeps the thermostat connection open, (b) remains energized so long as the power line is connected to the ballast, and (c) absorbs the greater portion of the total voltage in the series circuit including the primary winding and relay solenoid so that the current in the circuit is substantially less than the minimum magnetizing current which would energize the ballast. As a result, the fluorescent lamps are extinguished and there is no detectable heating effect in the ballast, so that the faulty fixture containing ballast and lamps is readily located.

Looking now at the drawing, in FIG. 1 the reference character **10** designates a ballast and fluorescent lamp system which comprises the ballast **12** and the two fluorescent lamps **14** and **16** connected together. This ballast and fluorescent lamp system is adapted to be energized from a suitable source of power such as a 120 volt A.C. line at the terminals **18** and **20** by means of leads **22** and **24** respectively extending to such terminals. Preferably the lead **22** is at ground potential and hence is designated "white" in FIG. 1.

The ballast **12** is substantially of conventional construction and in this case is of the so-called lead-lag variety. There is an elongate iron core **26** having a central winding leg **28** upon which are mounted a primary winding **30** and two secondary windings **32** and **34** at opposite ends of the central winding leg **28**. The exact construction of the code is immaterial to the invention although for the particular arrangement described, there will be shunts at **36** and **38** to result in a relatively high leakage reactance in the windings **32** and **34** during operation of the ballast.

The core **26** and the windings described comprise a transformer designated **40** that is preassembled and immersed in a potting compound **42** of asphaltic or similar nature contained in a steel canister **44** along with a condenser **46** of the oil immersed variety.

As previously mentioned, since the highest temperature achieved in the ballast will probably be in the vicinity of the primary winding **30**, an automatic reset thermostat **48** is positioned adjacent the winding **30** on top of the iron core **26** if desired.

The secondary **32** is the lag secondary and it has one of its terminals connected by the lead **50** to the contact **52** engaged by the pin **54** of the lamp **16**. The other terminal of the secondary winding **32** connects by way of the lead **56** to the junction **58**. This junction **58** is a point common with a terminal of the primary winding **30** through the lead **60**, the terminal of the lead secondary **34** through the lead **62** and one side of the thermostat **48** through the lead **64**. The primary winding **30** is energized by way of the thermostat **48** and the lead **66** through the contacts **68** and **70** and the bridging bar **72** of the relay **74** which will be described. Terminal **70** connects to the conductor **24**. The other terminal of the primary winding **30** connects by way of the lead **76** through the opposed contacts of two disconnect sockets **78** and **80** to the lead **22**. Obviously the pins **82** and **84**, being the left-hand terminal pins of the lamps **14** and **16** respectively, must be in place in the respective disconnect sockets **78** and **80** in order that the primary winding **30** be energized.

The lead secondary winding **34** has a terminal connected by way of the lead **86** to one side of the condenser **46**, the other side of the condenser being connected by the lead **88** to the contact **90** which is engaged by the pin **92** of the lamp **14**.

From the above description, it will be apparent to those skilled in the art that except for the relay **74** and

its contacts and bridging bar, the circuit is well-known, even to the inclusion of the disconnect sockets. In operation, each of the secondary windings is in autotransformer relationship with the primary winding **30** and therefore, the circuits of the respective lamps **14** and **16** ignite at about the same time and operate in parallel at a voltage reduced from the igniting voltage because of the high leakage reactance built into the transformer **40**. The effect of the condenser **46** is primarily for power factor correction although some stroboscopic correction is achieved.

As shown in FIG. 2, which is a simplified circuit diagram of FIG. 1, the automatic reset thremostat **48** has a contact **100** and a bimetal member **102** that is normally engaged against the contact **100** to close the circuit from the juncture **58** through the lead **66** of the contact **68** bridging bar **72**, contact **70** and the lead **24** to line terminal **20**. When the bimetal member **102** is subjected to heat of abnormal degree, it commences to move off the contact **100** and when it does, it will open the lead **66** thereby effectively de-energizing the primary winding **30** as well as the ballast windings **32** and **34** and the two lamps **14** and **16**. As soon as magnetizing current stops flowing in the primary winding **30** (disregarding the action of the relay **74** for the time being), the ballast starts to cool and after a time, depending upon the physical characteristics of the thermostat **48**, the bimetal member **102** will return to the contact **100** and establish an electrical connection and the cycle begins again.

The simple relay **74** prevents the restoration of the bimetal arm **102** to the contact **100** from activating the ballast and circuit. An electrical connection in the form of the lead **104** extends from the juncture **58** in series with the solenoid **106** to the contact **70**, bypassing the thermostat **48**, the lead **66**, the contact **68** and the bridging bar **72**. It is important to note that this bypass circuit is permanenly connected and therefore the relay **74** is fully automatic in operation. With the thermostat **48** closed, no current flows in the bypass circuit **104** and the solenoid **106** is not energized. The bridging bar **72** engages the contacts **68** and **70**. All of the current passing through the primary winding **30** will pass through the thermostat **48** and the lead **66** since there is no impedance in that circuit and the current prefers it to the impedance of the solenoid **106**. The primary winding draws the maximum of magnetizing current at this time, limited only by its own impedance. When, however, a fault occurs such as rectification in one or the other of the lamps **14** and **16**, causing the ballast **12** to heat up, the thermostat **48** will open. At this moment, current now flows through the bypass circuit. The solenoid **106** of the relay **74** is energized by this current and it pulls the bridging bar **72** away from the contacts **70** and **68** but remains in this condition since the solenoid is connected directly to the contact **70** which connects to the line. Tracing the circuit, it will be seen that it extends from the juncture **58** through the primary winding **30** and the two disconnect sockets **80** and **78**, the conductor **22** and back to the other side of the line **18**. From this point forward, therefore, so long as nothing occurs in a circuit, and providing the lamps **14** and **16** remain in place, the only current flowing through the ballast is that which is drawn due to the impedance of the solenoid **106** and the primary **30**.

The impedance of the solenoid **106** is much greater than the primary impedance on practically all ballasts which would have a thermostat. This could be of the order of ten times, so that for a ballast normally drawing 500 milliamperes, the flow of current is limited to something less than 50 milliamperes. The low current in the primary winding will not materially raise the temperature of the primary winding nor will it be sufficient to ignite or operate the lamps. Most of the potential drop in the series circuit described including the solenoid **106** and the winding **30**, will occur in the solenoid **106**.



Assuming the apparatus **10** is a part of a large installation, a maintenance man may merely look at the installation and see that one of the fixtures is not operating since its lamps are not illuminated. He therefore inspects and repairs the apparatus. During the course of doing so, or as a part of such activity, he will remove the lamps **14** and **16** and replace them or reinstall them. As soon as one of these lamps is removed, it breaks the circuit including the bypass thereby de-energizing the solenoid **106** and reconnecting the thermostat **48** to the line. In the meantime, the thermostat **48** will have cooled and restored its connection but such restoration will have no effect upon the ballast so long as the solenoid **106** is energized.

The circuit diagram in FIG. 3 illustrates a ballast and fluorescent lamp system **110** which is known as a series-sequence circuit. The construction and operation of the basic circuit is disclosed in U.S. Patent 2,558,293. In the apparatus, which uses instant start lamps similar to those of FIGS. 1 and 2, there is a transformer **112** which has its primary winding **114** and a high leakage reactance secondary winding **116** connected in series with a condenser **118** and a lamp **120**. When the primary winding **114** is energized from the line terminals **122** and **123**, there will be sufficient voltage developed in the windings **114** and **116** to ignite the lamp **120**. Current thereafter flows through the lamp **120** and the condenser **118**, as a result of which there is a phase reversal in the secondary winding **116**. The windings **114** and **116** are in additive relationship on open circuit and windings **116** and **126** are bucking during open circuit. When, however, the winding **116** carries the current resulting from the ignition and operation of the lamp **120**, there is a voltage in that winding which is now additive to that of **126** and the resultant voltage across the lamp **128** is sufficient to ignite that lamp. Prior to this time the lamp **128** did not have sufficient voltage.

During the operation, since the winding **116** develops a very high leakage reactance therein, current prefers to flow in series through the two lamps, the condenser **118** and the secondary winding **126**.

As shown herein, the left-hand terminal **130** of the lamp **120** is engaged in the disconnect socket **132** and from there current must flow through the lead **134** through the thermostat **136** of the lead **138**, the contacts **140** and **142** of the relay **144** to the line terminal **122** through a lead **146**. The bridging bar **148** normally connects the contacts **140** and **142**, this being a normally closed relay as is the relay **74** in FIGS. 1 and 2.

There is another disconnect socket **150** engaged by the left-hand pin **152** of the lamp **128**.

The bypass circuit in this case is connected from the lead **134** through a conductor **154** to a solenoid **156** of the relay **144** to the contact **142**.

The operation of this apparatus is quite similar with respect to the manner in which a fault will open the thermostat **136** thereby causing the bar **148** to be pulled off the contact **140** and **142**. The condition remains until one or the other or both of the lamps **120** and **128** are removed from their respective disconnect sockets **132** and **150**. Since the thermostat **136** resets itself because of cooling of the primary winding **114**, as soon as the circuit in series with the primary winding opens because of the removal of one or more lamps, the apparatus **110** is ready to be operated once more when the lamps are returned to their sockets.

In FIG. 4, there is illustrated a circuit typical of those which do not use disconnect sockets such that the completely automatic operation of the circuit cannot be achieveed in accordance with the invention. Illustrated is apparatus **160** in the form of a rapid start fluorescent lamp ballast and the circuit. The ballast in this case includes a transformer **162** having a primary winding **164** and a secondary winding **166** connected in autotransformer relationship with a pair of rapid start lamps **170** and **172**. It will be appreciated that these lamps are in

series. The apparatus is energized from a source of power consisting of conventional 120 volt line, the terminals being shown at **174** and **176**. The starting condenser **178** is connected across the lamp **172** whereas the power factor condenser **180** is connected to the right-hand terminal of the winding **166** through the lead **182**.

Each lamp has filaments at opposite ends thereof and filament windings are provided as shown at **184**. The connection of the filament windings and the circuit are familiar.

As shown, the primary winding **164** has one lead **186** which extends to the terminal **176** but the other terminal connects by way of the lead **188** through an automatic reset thermostat **190** to the lead **192** which extends the connection through the contacts and cross-bar (not shown) of the relay **194** to the lead **196** to the terminal **174**. The construction of the relay **194** is substantially the same as relays **144** and **74**. The bypass circuit around the thermostat **190** in this case consists of the lead **198** which like the other relays described is in series with the solenoid of the relay **194** and connects to the "hot" terminal as shown by the connection to the lead **196**.

There is a manual disconnect switch **200** in the lead **198** which serves the purpose of de-energizing the solenoid after the thermostat **190** is open, for giving control back to the thermostat **190**. When a fault occurs in the ballast such as to heat the same, as soon as the thermostat **190** opens, relay **194** will take over control and current will flow through the relay keeping its contacts open. In the case of circuits of the invention including the disconnect sockets, the removal of the lamp will serve to de-energize the solenoid but in a circuit such as described in FIG. 4, it is necessary manually to open the bypass circuit. For this reason, there is a manual disconnect switch **200**. When the user is ready to set the apparatus into operation once more, he presses the button or operates the switch of the manual disconnect **200** thereby opening the lead **198**. Since the ballast has cooled in the meantime and the thermostat **190** is now closed, it takes over controls so that current may now flow directly from the line terminals **174** and **176** through the primary winding **164** when the lamps are in place.

As pointed out, the circuit of FIG. 4 does not have all of the advantages of those of FIGS. 1, 2 and 3, but it serves the purpose of locating the fault before the maintenance man and prevents further operation and possible damage of the ballast once the thermostat **190** has operated.

Other variations are capable of being made within the scope of the invention as defined by the appended claims. What it is desired to secure Letters Patent of the United States is:

**1.** A fluorescent lamp and ballast system comprising: a transformer having a primary winding and at least one secondary winding inductively coupled to the primary winding, at least one fluorescent lamp connected in circuit with the secondary winding to be ignited and operated by the transformer, leads extending from two terminals of the primary winding and adapted to be connected respectively to two terminals of an A.C. power source, and one lead having an automatic reset thermostatic switch series connected therein and disposed adjacent said transformer to be sujected to the heat generated therein so that abnormal heat from said transformer will open said thermostatic switch, with respect to a fixed contact thereof, at a predetermined temperature and thereby open said lead to said primary winding to deenergize said transformer and extinguish said lamps, following which the switch will close after the transformer has cooled to a second lower temperature once more closing said lead to said primary winding energizing said transformer and reigniting said lamp unless otherwise prevented from doing so, a relay having normally closed contacts in series with said switch in said one lead and the relay having a solenoid connected in a circuit by-passing the switch and contacts, the solenoid impedance being substantially higher than the impedance of the primary winding whereby upon opening of said switch current will flow in said solenoid in series with said primary winding, the solenoid being mechanically connected to open said contacts when energized, and the solenoid adapted to draw a current smaller than required to energize the transformer but sufficient to keep the solenoid energized so that the subsequent closing of the switch will not affect the primary winding until the solenoid is deenergized and means for deenergizing the solenoid comprising circuit interrupting means in the series circuit of the primary winding and solenoid.

**2.** A circuit as claimed in claim **1** in which said circuit interrupting means comprises a second manually operable switch.

**3.** A circuit as claimed in claim **1** in which said circuit interrupting means comprises a disconnect socket and said lamp has a terminal thereof engaged in said socket so that removal of said lamp from said socket will deenergize said solenoid.

**4.** A circuit as claimed in claim **1** in which there is a pair of secondary windings and a pair of fluorescent lamps and each lamp is connected in series with one secondary winding, respectively, there being a condenser in series with one lamp.

**5.** A circuit as claimed in claim **1** in which there are two secondary windings and a condenser, one secondary winding and condenser being connected in a loop with one lamp, and the secondaries both being connected in a second loop with another lamp, the secondaries bucking an open circuit and the one secondary being loosely coupled to the primary winding.

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