ELECTRONIC ALERTNESS CONTROL

Filed Dec. 30, 1964 5 Sheets-Sheet 1

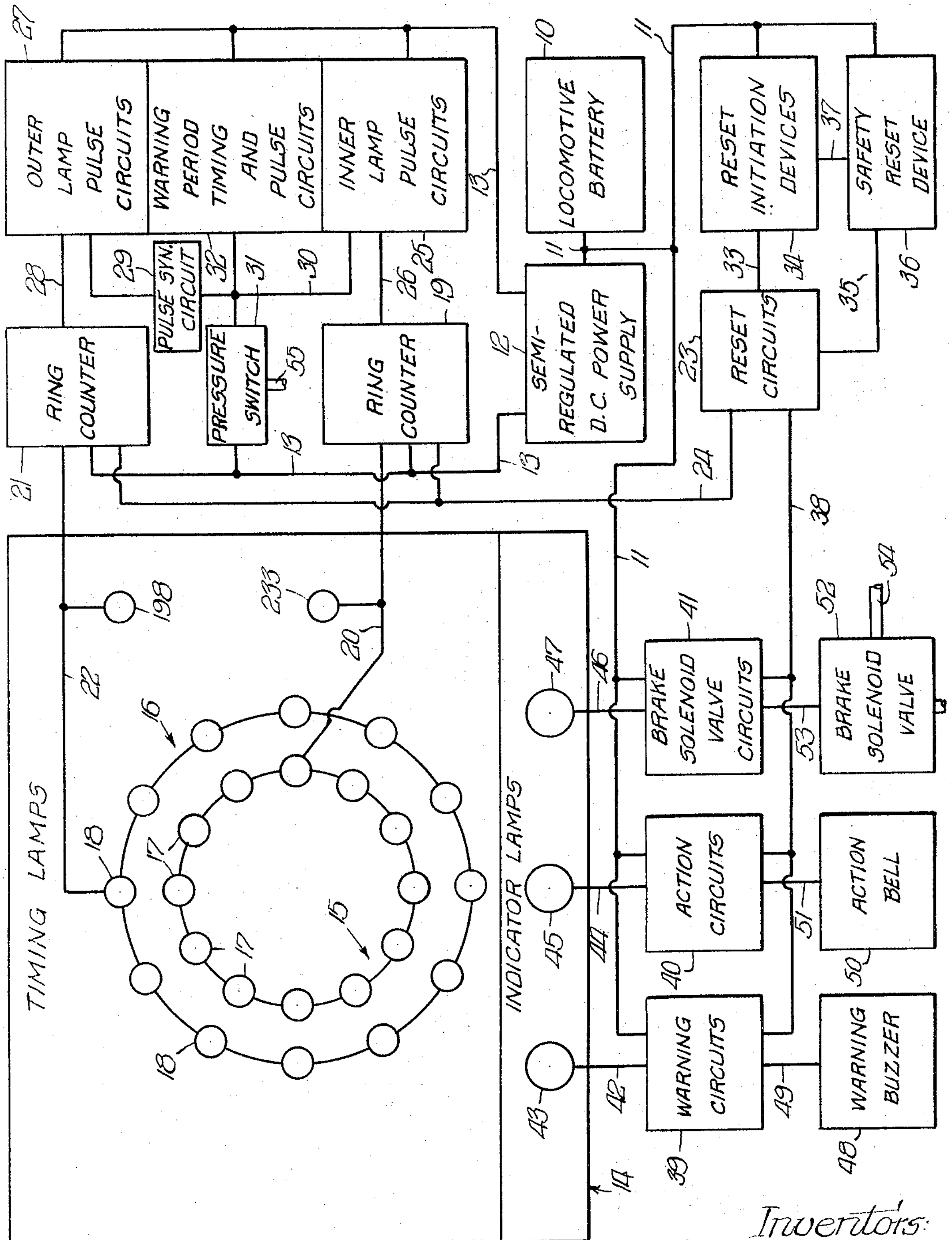

Fig. 1

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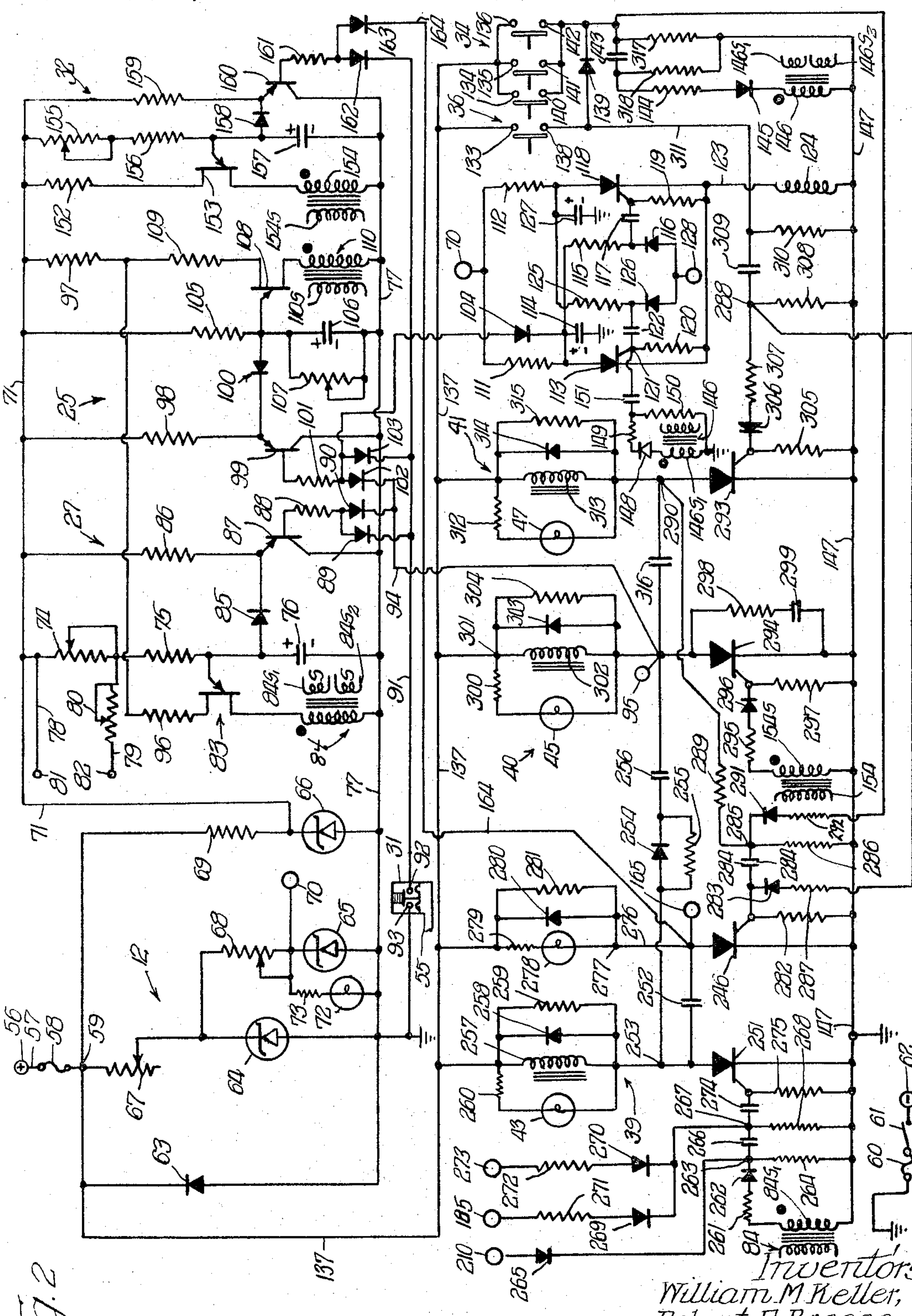

Fig. 2

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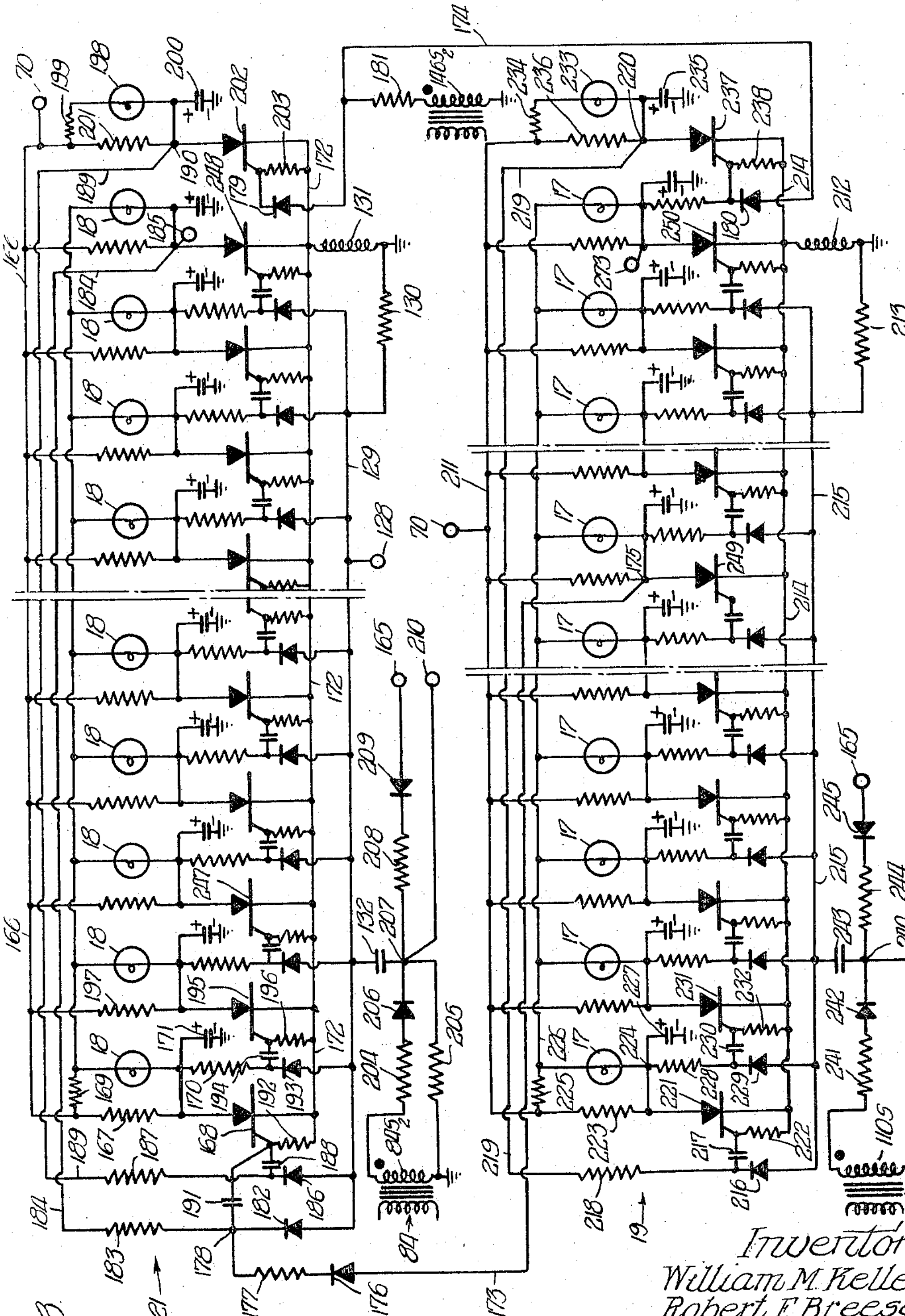

Fig. 3

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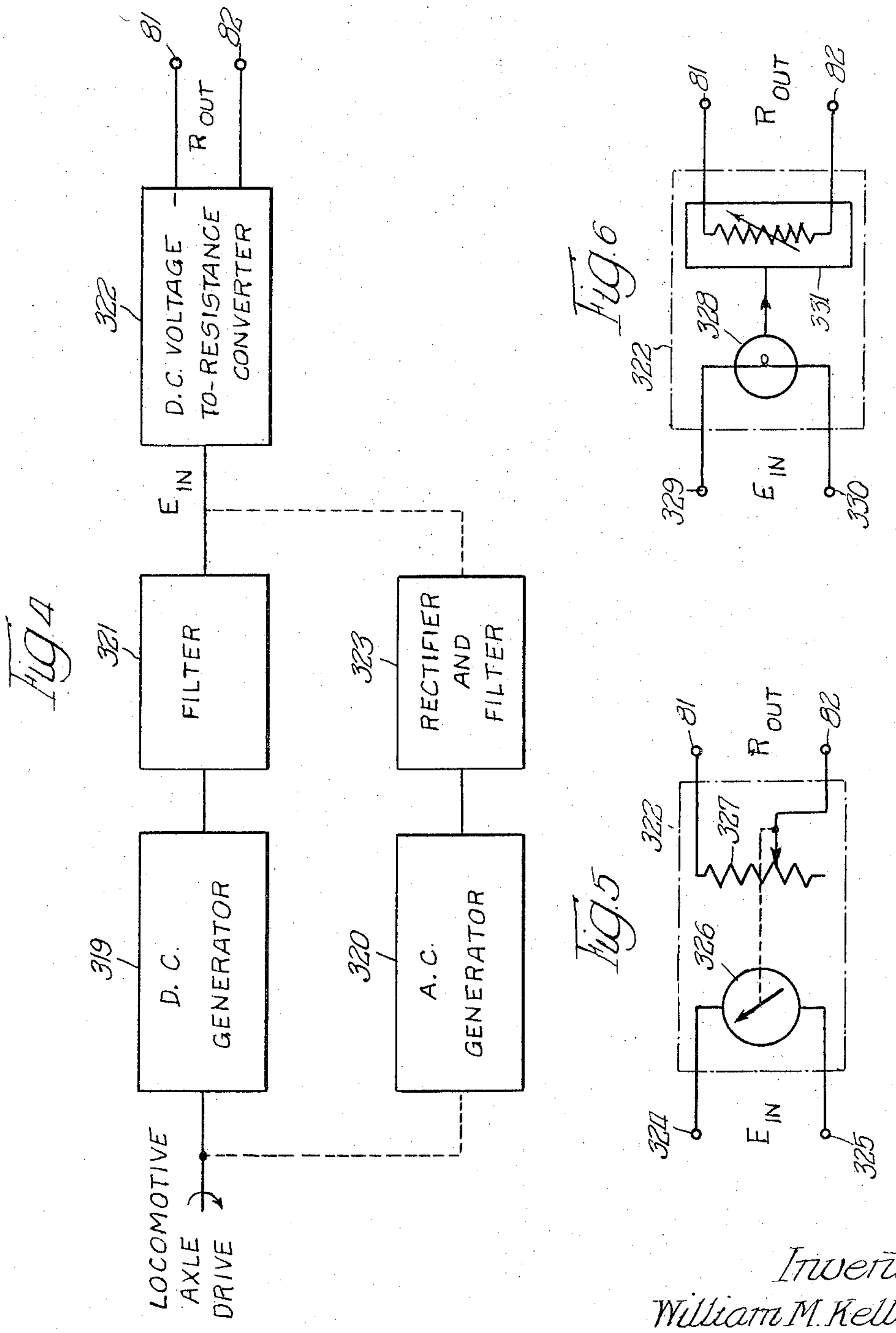

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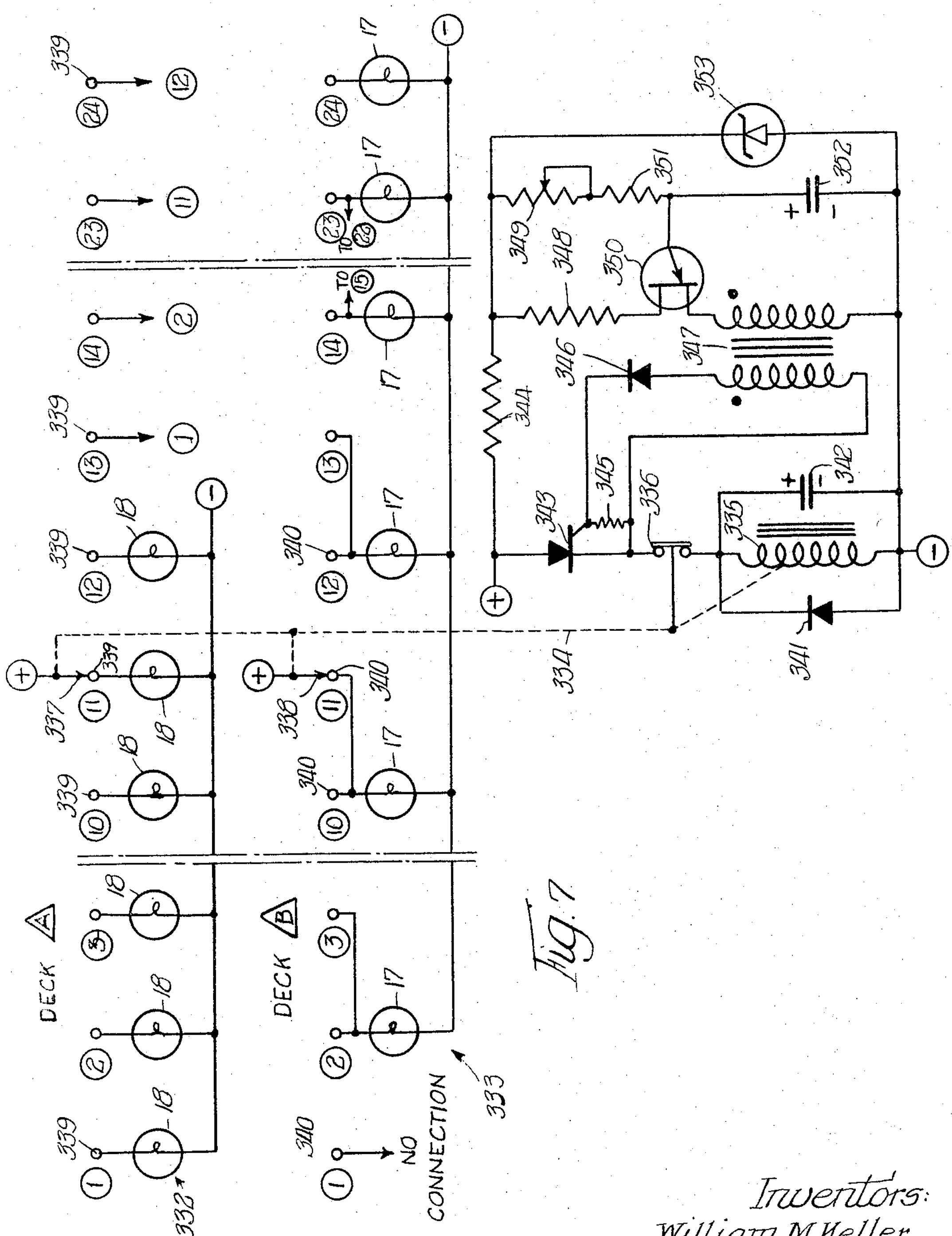

Fig. 7

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ELECTRONIC ALERTNESS CONTROL

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16 Claims. (Cl. 303—19)

This invention relates to an electronically controlled timing device that is utilized as a prompter to require certain responses from a human operator engaged in controlling machines or processes which require that the operator be alert at all times to insure his own safety and the safety of others. In the event the operator becomes incapacitated through sickness or death or is otherwise inattentive, then the device will operate after a predetermined time period to first sound alarms to alert the operator and then, if the operator still fails to respond, to shut down or stop the machinery or processes being supervised by the operator.

While the timing device described herein is used in the cab of a railroad locomotive and is designed to stop the locomotive and train in the event the locomotive engineer is incapacitated or not alert, it should be apparent that my timing device can also be used in conjunction with the operation of other types of vehicles and machines. The device can also be used in conjunction with processes and operations which require that the operator be alert to perform certain duties.

While it can be expected that the engineer in charge of a railroad locomotive will be alert to his responsibilities, it is also true that any human operator can become drowsy or fall asleep even though he conscientiously tries to prevent this from happening. Furthermore, the human operator can, of course, be stricken unconscious or dead, and such an event can occur quickly with no warning. Thus, there are many contingencies which can arise during the time that the locomotive engineer is in charge of the locomotive and train, and means must be provided to aid the engineer and to initiate safety measures when the engineer is not responding to his duties in a normal manner.

The need for safety means to aid the railroad locomotive engineer or to back-up the engineer in case he becomes incapacitated has long been recognized in the railroad industry and various means have been designed over the years for this purpose. For example, railroad locomotives have in the past been equipped with brake apparatus comprising a "dead man" or safety control valve device which is operative to initiate the application of the vehicle brakes unless the engineer maintains pressure on a pedal or hand grip. Unfortunately, these safety control features will be nullified if the engineer should become ill or stricken in such a way so as to maintain the pedal or hand grip depressed, or if someone should tamper with the apparatus to retain it in operative position.

Means have also been provided to initiate emergency brake applications on vehicles in the event that the operator is not making the customary movements normally associated with the operation of the vehicle. Other means have been provided which initiate the emergency brake application on the vehicle unless the operator resets certain timing apparatus at periodic intervals. While both types of means have been helpful to some degree, they have not been entirely satisfactory for use in a railroad locomotive because they have tended to distract the attention of the locomotive engineer from his normal duties and, in addition, have restricted his movements within the cab of the locomotive.

As the operation of modern railroad trains has required higher speeds, it has become apparent that a safety device which will be of aid to the locomotive engineer must be so designed that its operation will be certain, but at the same time such device must not unduly distract the attention of the engineer nor restrict his normal movements. Furthermore, a safety device of this type must be provided which will defy attempts to tamper with the device to circumvent the operation of the device and render a valuable safety aid useless.

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Therefore, it is a primary object of my invention to provide a timing device which can be used in conjunction with the operation of a railroad locomotive to provide a series of preliminary signals to the railroad locomotive engineer and which will act to stop the locomotive by a service brake application in the event that the engineer does not acknowledge the preliminary signals.

It is a further object of my invention to provide such a timing device wherein the preliminary signals will include both visual and audible signals to the engineer.

It is another object of my invention to provide a timing device providing visual signals for a railroad locomotive engineer which will be readily observable but which will not unduly distract the attention of the engineer from his normal duties in the locomotive cab.

It is a still further object of my invention to provide means associated with a timing device in a locomotive cab and which can be readily adjusted to vary the period of time during which preliminary signals are given to the locomotive engineer before any brake application is initiated by the device.

It is a further object of my invention to provide reset means operable by the locomotive engineer at any time during the series of preliminary signals so that the timing device is reset on a new cycle of preliminary signals and a brake application of the locomotive is prevented.

It is yet another object of my invention to provide a timing device which will be an aid to a railroad locomotive operator and which will operate even though certain components of the device are malfunctioning or are removed from the device.

The timing device includes an indicator lamp panel which can be mounted in the cab of a railroad locomotive where it is conveniently visible to the engineer. On this panel there are two concentrically disposed circles of individual electrical lamps and the individual lamps in each circle are sequentially turned on and off by suitable electronic circuits of the device. The circuits are so designed that the sequential advance of the respectively illuminated lamps in the outer circle will be at a faster rate than that of the inner circle. It can be appreciated that if there are the same number of lamps in the two circles of lamps, the outer circle of illuminated lamps will "catch up" with the inner circle of illuminated lamps at some instant of time after the cycle has been started. The rate at which the outer circle of lamps will "catch up" with the inner circle of lamps can be varied by suitable means in the electronic circuits. As an example, in a model of the device the adjustment is such that the outer circle of illuminated lamps advances at a rate twice that of the inner circle of illuminated lamps, and the outer circle of illuminated lamps "catches up" with the inner circle of illuminated lamps every two minutes. When this occurs, suitable audible warning means such as a buzzer can be made to operate so as to warn the engineer that a certain period of time has elapsed since the commencement of the visual moving lamp display.

If for any reason the engineer is incapable of acknowledging the warning buzzer and resetting the lamp display for another cycle of operation, other electronic circuitry of the device will continue to operate. After a predetermined time period the circuitry will initiate other audible signal means such as a bell and cause the air brake solenoid valve of the locomotive to operate to make a service application of the train brakes. At any time up to the point where the bell sounds and the brake application is made, the engineer can reset the sequential lamp display and the advancing lamp cycle is repeated.

Thus, in the normal course of events, and assuming the engineer is alert or not incapacitated, the sequential or advancing lamp display will be reset periodically within the time limits of the device by the manual operation of the engineer and no service brake application will be initiated by the device. If, however, for some reason the engineer is not alert or is incapacitated, then the sequence of events described above will occur and the locomotive and train will be stopped. In this event additional circuit means are provided in the device whereby the engineer can release the brakes and restart the timing device.

The complete operation of the timing device will be clear from the detailed description to follow, and in conjunction with the drawings wherein:

FIG. 1 is a block diagram showing the schematic arrangement of the indicator lamp panel and associated circuits, valves, and reset devices.

FIG. 2 shows a schematic diagram of circuits of the device which provide the power supply, the pulse circuits, and other circuits used to operate the timing device.

FIG. 3 is a schematic diagram of the electronic circuits designed to sequentially illuminate the lamps in the inner and outer circles of lamps on the indicator lamp panel.

FIG. 4 is a schematic diagram showing external speed-control circuitry which can be used in conjunction with the timing device.

FIG. 5 is a schematic diagram showing one form of the converter used in the external speed-control circuitry.

FIG. 6 is a schematic diagram which shows another form of converter for use in the external speed-control circuitry.

FIG. 7 is a schematic diagram which shows another arrangement for sequentially illuminating the lamps in the inner and outer circles of lamps on the indicator lamp panel.

FIG. 1 shows a schematic block diagram of one form of the timing device. The direct current power source to operate the device is shown as a locomotive battery **10**, but it should be understood that the low voltage control system which is available on the locomotive can also be used to supply the power for the device. The power source will be approximately 60 to 80 volts direct current. Lead **11** connects the locomotive battery **10** to certain components of the circuit and to a semi-regulated D.C. power supply **12**. This power supply **12** is designed to furnish 28 volts D.C. to other components of the device, and the power leads to these components have all been numbered **13** for convenience.

On an indicator lamp panel, generally indicated at **14**, there are two concentric circles or series of individual electric lamps, the inner circle of which is generally designated at **15** and the outer circle of which is generally designated at **16**. Each circle includes twelve individual lamps **17** and **18**, respectively, and the inner circle of lamps **15** is operatively connected to ring counter **19** through lead **20**, while the outer circle of lamps **16** is operatively connected to ring counter **21** through lead **22**. The ring counters **19** and **21** are operatively connected together and to the reset circuits **23** through lead **24**.

Ring counter **19** is connected to inner lamp pulse circuits **25** through lead **26** and ring counter **21** is operatively connected to the outer lamp pulse circuits **27** through lead **28**. Inner lamp pulse circuits **25**, outer lamp pulse circuits **27** and pulse synchronizing circuits **29** are connected together through lead **30**. This lead **30** is also connected to the pressure switch **31** and to the warning period timing and pulse circuits **32**. The reset circuits **23** are connected through lead **33** to reset initiation devices **34** and through lead **35** to a safety reset device **36**. Reset initiation devices **34** and the safety reset device **36** are operatively connected by lead **37**.

Lead **38** operatively connects the reset circuits **23** to the warning circuits **39**, action circuits **40**, and the brake solenoid valve circuits **41**. The warning circuits **39** are connected through lead **42** to an indicator lamp **43** on indicator lamp panel **14**. The action circuits are connected through lead **44** to an indicator lamp **45** likewise located on indicator lamp panel **14**. The brake solenoid valve circuits **41** are connected through lead **46** to an indicator lamp **47** also located on the indicator lamp panel **14**.

A warning buzzer **48** is connected to the warning circuits **39** through lead **49**. Action bell **50** is connected through lead **51** to action circuits **40**, and a brake solenoid valve **52** is connected through lead **53** to the brake solenoid valve circuits **41**. The brake solenoid valve **52** is connected through piping **54** to the air brake system of the locomotive which is not illustrated. Likewise, the pressure switch **31** is connected through piping **55** to the air brake system of the locomotive.

Assuming that the railroad locomotive is stopped with the brakes applied and the engineer is preparing to move the locomotive, the engineer will then apply electric power from the locomotive battery **10** or other suitable power source on the locomotive to the timing device by operating an electrical switch in the lead **11** shown on FIG. 1. This switch is not shown in FIG. 1 but will be described in connection with the description of FIG. 2 where this switch is shown at **61**. After this has been done, the engineer can start the operation of the timing device by operating the safety reset device **36** which is a manually operated electrical switch. If the safety reset device is momentarily operated by the engineer, the reset circuits **23** are energized to close the brake solenoid valve **52** through brake solenoid valve circuits **41** and the brakes on the locomotive can then be released by the engineer. At the same time, the indicator lamp **47** on the indicator lamp panel **14** is energized to indicate that the brake solenoid valve **52** has been closed.

When the reset circuits **23** are energized, the ring counters **19** and **21** are also energized and the inner lamp pulse circuits **25** and outer lamp pulse circuits **27** operate to deliver electrical pulses to the respective ring counters and to initiate the sequential energization of the individual lamps **17** and **18** in the inner and outer lamp circles **15** and **16**.

The timing cycle during which the individual lamps in the outer lamp circle and the inner lamp circle are progressively energized is under the control of the respective ring counters **21** and **19** and continues until such a time that the lamps at the twelve o'clock position in both the inner and outer lamp circles **15** and **16** are simultaneously energized. This time interval can be adjusted to suit various needs and, as will be explained later, the adjustment can be made dependent upon the speed at which the locomotive is traveling At any time during the timing cycle prior to the time when the respective lamps in the inner and outer lamp circles have advanced to the point where they are simultaneously energized at the twelve o'clock position, the engineer can reset the ring counters and associated pulse circuits through the reset initiation devices **34**, and the timing cycle is re-initiated. The reset initiation devices **34** are electrical switches operable manually by a foot pedal, or other means.

However, assume that the engineer is incapacitated or inattentive for some reason, and the timing cycle has progressed to the point where the lamps **17** and **18** at the twelve o'clock position in both the inner and outer lamp circles **15** and **16** are energized before the engineer resets the lamp circuits. Then at this point or time the warning circuits **39** operate to energize the warning buzzer **48** and the indicator lamp **43**. During the warning period, which follows the operation of buzzer **48** and indicator lamp **43** and which involves a predetermined time period of a few seconds, the engineer can still reset the timing device to start a new timing cycle by using the reset initiation devices **34**. If he does so, the sequential energization of the electric lamps in the inner and outer lamp circles **15** and **16** is re-initiated and the warning circuits **39** operate to turn off the warning buzzer **48** and to de-energize the indicator lamp **43**.

However, assuming that the engineer still does not heed the warning buzzer **48** and indicator lamp **43**, then at the end of the predetermined warning period the action circuits **40** will operate to energize the action bell **50**. At the same time, the action circuits will energize the indicator lamp **45** and operate in conjunction with the brake solenoid valve circuits **41** to de-energize the brake solenoid valve **52**. When the brake solenoid valve **52** is de-energized, the air brake system on the locomotive is vented and there will be a service application of the brakes on the locomotive. After the brakes have been applied, it will be necessary for the locomotive engineer to use the safety reset device **36** before he can release the brakes and start a new timing cycle of the timing device in the manner previously discussed.

FIGS. 2 and 3 of the drawing show the circuits which are indicated by the blocks on FIG. 1 of the drawings, and reference is now made to these figures for a more detailed description of these circuits and the operation thereof. In order to facilitate an understanding of the circuits involved in the timing device, the reference numbers used in FIG. 1 will also be used to designate the corresponding circuits shown in FIGS. 2 and 3. Also, it is believed that it will be helpful if the circuits to be discussed are set forth under appropriate headings which correspond to the designation used on the schematic block diagram of FIG. 1.

Semi-regulated D.C. power supply

Referring to FIG. 2, the semi-regulated direct current power supply is generally indicated at **12** to correspond to the reference numeral used in FIG. 1 of the drawing. The lead from the positive terminal **56** of the power supply is indicated at **57**, and fuse **58** is connected in lead **57** before the terminal connection point **59**. Referring to the lower left-hand corner of FIG. 2. It can be seen that the negative side of the system includes fuse **60** and electrical switch **61** connected in series to the negative terminal **62** of the power supply. Diode **63** is connected between fuses **58** and **60** to prevent damage to the components of the timing device in case of reversed power input leads.

The semi-regulated power supply **12** includes zener diodes **64**, **65** and **66**. The cathode of zener diode **64** is connected to the variable power resistor **67** and to the variable power resistor **68** which in turn is connected to the cathode of the zener diode **65**. The resistor **69** is connected between the common terminal point **59** and the cathode of the zener diode **66**. The anodes of each of the three zener diodes are connected to the negative terminal of the power supply.

The power resistor **67** and zener diode **64** constitute the main regulator section with the cathode voltage of the zener diode **64** being around 36 volts D.C. The second portion of the regulator section consists of the power resistor **68** and the zener diode **65** with the cathode voltage of the zener diode **65** chosen to be approximately 28 volts D.C. A terminal indicated at **70** is connected to the cathode of zener diode **65** and is the positive terminal for a 28 volt supply to furnish power for the ring counter circuits **19** and **21**, to be described in detail later.

The portion of the regulator section which includes the power resistor **69** and the zener diode **66** is designed so that the cathode voltage of the zener diode is approximately 28 volts D.C. This voltage is furnished to the pulse circuits **25**, **27** and **32** through lead **71**, and these circuits will be described later.

Two separate 28 volt D.C. sources have been provided in the semi-regulated D.C. power supply **12** so as to prevent the periodic negative voltage transients which occur at the cathode of zener diode **65**, due to the operation of the ring counters **19** and **21**, from causing any malfunctions in the pulse circuits **25**, **27** and **32** shown in the upper right-hand portion of FIG 2.

Lamp **72** and resistor **73** are connected across zener diode **65** so that the lamp can be operated from the 28 volt cathode voltage of zener diode **65** and will indicate when the semi-regulated D.C. power supply is on. This lamp **72** can be mounted on the indicator lamp panel **14** or at some other suitable location in the locomotive cab.

Outer lamp pulse circuits

The outer lamp pulse circuits **27** are shown on FIG. 2 immediately to the right of the semi-regulated D.C. power supply **12**. These circuits include a potentiometer **74**, resistor **75** and capacitor **76** connected in series between the lead **71** and lead **77** connected to the positive and negative terminals, respectively, of the D.C. power supply. Leads **78** and **79** are connected to opposite sides of the potentiometer **74** and there is a potentiometer **80** in lead **79**. Terminals **81** and **82** on leads **78** and **79**, respectively, are provided for external speed control circuitry which will be described later.

The emitter of an unijunction transistor, generally indicated at **83**, is connected between resistor **75** and capacitor **76**. Base one of this unijunction transistor **83** is connected to the primary winding of a transformer generally indicated at **84**. The other side of the primary winding of this transformer **84** is connected to the negative terminal of the power supply through the common lead **77**. The two secondary windings of transformer **84** are labelled **$84S_1$** and **$84S_2$**. The secondary winding **$84S_1$** is shown in the lower left-hand corner of FIG. 2, and secondary winding **$84S_2$** is shown on FIG. 3. The connections from the secondary windings of transformer **84** to the other circuits of the timing device will be described later.

The anode of diode **85** is also connected between resistor **75** and capacitor **76**, and the cathode of diode **85** is connected to one side of resisor **86** and to the emitter of transistor **87**. The other side of resistor **86** is connected to the positive terminal of the power supply through lead **71**. The collector of transistor **87** is connected to lead **77** and to the negative terminal of the power supply. The base of the transistor **87** is connected to one side of the resistor **88**, and the other side of resistor **88** is connected to the anodes of diodes **89** and **90**. The cathode of diode **89** is connected to lead **91**, and lead **91** is connected to a contact **92** in the pressure switch generally indicated at **31**. The other contact **93** of switch **31** is connected to the negative terminal of the power supply. The function and operation of this pressure switch **31** in conjunction with the circuits now being described will be further described later. The cathode of diode **90** is connected to lead **94**, and lead **94** extends to a terminal **95**. The connections to the other circuits extending from this terminal **95** will also be described later.

The operation of the outer lamp pulse circuits generally indicated at **27** on FIG. 1, and shown in detail on FIG. 2 of the drawings, can now be described. When the timing device is turned on, and assuming that no external speed control circuitry is associated with the timing device, the capacitor **76** charges up through a total equivalent timing resistance which is equal to the series resistance sum of the potentiometer **74** and the resistor **75**. However, if external speed control circuitry, to be described later, is connected across terminals **81** and **82**, a variable electrical resistance is added in parallel with potentiometer **74**. This, of course, will be effective to vary the equivalent timing resistance and the charging rate of capacitor **76**. As the potential on the positive plate of the capacitor 76 reaches the peak point voltage of the emitter of the unijunction transistor 83, this transistor will turn on and discharge the capacitor 76 through the primary winding of the transformer 84. This produces sharp rise-time voltage pulses in the secondary windings of the transformer 84 which are then used to operate other portions of the timing device to be described later.

The resistance in the base two circuit of the unijunction transistor 83 consists of the series resistors 96 and 97 that are connected to lead 71 with a total value sufficient to provide temperature compensation of the unijunction transistor 83 at the operating voltage of 28 volts. The potentiometer 74 can be adjusted to produce output pulses from this circuitry at any desired interval and, as an example, was set to provide output pulses at exactly five-second intervals in models of the timing device which have been tested.

The pulse sequence of these outer lamp pulse circuits 27 can be interrupted by the operation of the transistor 87. If the cathodes of diodes 89 and 90 are grounded either individually or simultaneously, the diodes or diode will become forward biased into conduction, thus allowing base current to flow from the base of the transistor 87 through the limiting resistor 88 to ground so that transistor 87 will be turned on. When transistor 87 starts to conduct, the collector current is limited by resistor 86 and the potential at the emitter of the transistor 87 drops from a positive voltage of 28 volts toward a much lower potential, slightly above ground. Since the cathode of the diode 85 is connected to this emitter, the diode 85 is now forward biased, and therefore, conducts, thus clamping the positive plate of the capacitor 76 to the same potential or close to ground potential. Under these conditions the positive plate of the capacitor 76 can never charge up through resistors 74 and 75 to the peak point voltage of the unijunction transistor 83, and thus this transistor is unable to periodically turn on and produce output pulses. When the cathodes of diodes 89 and 90 are disconnected from ground, the transistor 87 turns off and the normal sequential pulse generations of the unijunction transistor 83 and associated circuitry resumes operation as above described.

Inner lamp pulse circuits

The inner lamp pulse circuits 25 are shown immediately adjacent and to the right of the outer lamp pulse circuits 27 just described. One side of a resistor 98 is connected to lead 71 and the other side of this resistor is connected to the emitter of a transistor 99, and to the cathode of a diode 100. The collector of transistor 99 is connected to lead 77 and the base of the transistor 99 is connected to one side of resistor 101. The other side of the resistor 101 is connected to the anodes of diodes 102, 103 and 104. The diode 104 forms part of other circuits which will be described more in detail later.

The cathode of diode 102 is connected through lead 94 to the terminal point 95, while the cathode of diode 103 is connected to the lead 91 going to the pressure switch 31. The anode of diode 100 is connected between one side of resistor 105 and one side of capacitor 106. The other side of resistor 105 is connected to lead 71 and the other side of capacitor 106 is connected to lead 77. A potentiometer 107 is connected across the capacitor 106.

The emitter of an unijunction transistor 108 is also connected between resistor 105 and capacitor 106. Base two of unijunction transistor 108 is connected to one side of resistor 109 and the base one is connected to the primary winding of a transformer generally indicated at 110. The other side of resistor 109 is connected to one side of the resistor 97. The other side of the primary winding of transformer 110 is connected to lead 77 and to the negative terminal of the power supply. The secondary winding of transformer 110 is designated as 110S. This secondary winding 110S is also shown on

FIG. 3, and the connections from this secondary winding 110S to the ring counter 19 will be described later.

The operation of the inner lamp pulse circuitry is similar to that of the outer lamp pulse circuits. Capacitor 106 charges up through resistor 105 until it reaches a maximum potential determined by the voltage divider action of the series resistances 105 and 107. The value of the potentiometer 107 is set in advance such that the maximum potential that can be reached by the top plate of the capacitor 106 is slightly less, approximately 1 or 2 volts, than the actual peak point potential of the emitter of the unijunction transistor 108 in the absence of any synchronization pulse occuring across the resistance 97 due to the operation of the unijunction transistor 83 and its associated circuitry.

The base two resistance of the unijunction transistor 108 consists of the series resistors 97 and 109 with a total value sufficient to provide temperature compensation of the transistor 108 at the operating voltage of 28 volts.

It should be noted that the resistor 97 is common to the base two circuits of both unijunction transistor 83 and unijunction transistor 108 and the circuit is used to provide a highly accurate synchronization of the output pulses from both of these transistors. Thus, if there is a charge on the capacitor 106 such that the potential of the top plate of this capacitor is just slightly less than the firing potential of the unijunction transistor 108 and the unijunction transistor 83 fires, then transistor 108 will also fire in synchronization with the transistor 83. When the unijunction transistor 108 turns on, the capacitor 106 discharges through the primary winding of the transformer 110 producing a sharp rise-time voltage pulse in the secondary winding 110S of transformer 110 which is used to operate other portions of the circuitry in a manner to be discussed later.

The pulse sequence of these circuits can be interrupted by the operation of the transistor 99 through its associated circuitry and occurs if the cathodes of the diodes 102, 103 and 104 are grounded either singularly or simultaneously to cause them to conduct and turn on the transistor 99. The collector current of this transistor 99 is limited by the resistor 98 and as the potential at the emitter of the transistor 99 falls toward a potential slightly above ground, diode 100 clamps the positive plate of the capacitor 106 to the same potential, thus stopping the periodic pulse generation operations of unijunction transistor 108. If the cathodes of the diodes 102, 103 and 104 are ungrounded, then the transistor 99 is turned off and the unijunction transistor 108 and associated circuitry is returned to normal operation.

Pulse synchronizing circuits

The lamps 18 in the outer lamp circle 16 are energized by the appropriate pulse circuits at a rate twice that of the lamps 17 in the inner lamp circle 15. In order to insure this ratio of pulse delivery, it is necessary to synchronize the outer lamp pulse circuits and the inner lamp pulse circuits, and the circuitry involved for this purpose is shown at the lower right-hand section of FIG. 2.

The positive terminal 70 of the direct current power supply is connected to resistors 111 and 112. Resistor 111 is connected to the anode of silicon controlled rectifier 113. The cathode of diode 104 is connected between resistor 111 and the anode of the silicon controlled rectifier 113 and to one plate of capacitor 114. The other plate of the capacitor 114 is connected to ground. The connection between the cathode of diode 104 and capacitor 114 also extends to one side of resistor 115. The other side of resistor 115 is connected to the cathode of diode 116 and to one plate of capacitor 117. The other plate of capacitor 117 is connected to the gate of silicon controlled rectifier 113 and to a resistor 119. One side of resistor 112 is connected to the anode of silicon controlled rectifier 118. The other side of resistor 119 is connected to the cathode of silicon controlled rectifier 113 and to a common connection of resistor **120** and the cathode of the silicon controlled rectifier **113**. The other side of resistor **120** is connected to a terminal point **121**. The gate of silicon controlled rectifier **113** and one side of capacitor **122** are also connected to this terminal **121**.

The cathodes of silicon controlled rectifiers **113** and **118** are connected through lead **123** to one terminal of an air core inductor **124**. The other plate of capacitor **122** is connected to a common connection between one side of resistor **125** and the cathode of a diode **126**. The other side of resistor **125** is connected to one plate of capacitor **127** and to the common connection between the resistor **112** and the anode of silicon controlled rectifier **118**. The other plate of capacitor **127** is connected to ground.

The anodes of diodes **116** and **126** are connected together and to a terminal point **128**. This terminal point **128** is also shown near the center portion of FIG. 3, and is connected to a lead **129** which connects the anodes of the diodes of all stages of the outer ring counter circuit. One side of resistor **130** is connected to this lead **129** and the other side of the resistor **130** is connected to ground and to one side of an air core inductor **131**.

The circuits involved to synchronize the outer lamp and inner lamp pulse circuits operate in the following manner. Referring again to FIG. 2, when power is first applied to the timing device, both silicon controlled rectifier **113** and silicon controlled rectifier **118** remain blocking. The activation of the safety reset device **36** to start the operation of the timing device turns on the silicon controlled rectifier **113** by means of circuitry described below. When the silicon controlled rectifier **113** turns on, it clamps the lower end of resistor **101** to a potential slightly above ground because of the clamping action of diode **104**. This activates the transistor **99** and associated circuitry so that the potential of the top plate of the capacitor **106** is clamped at a sufficiently low potential to prevent the firing of the unijunction transistor **108**.

At the end of the first pulse cycle for the outer lamp circuits, the unijunction transistor **83** fires and a pulse is delivered through the secondary winding $84S_2$ of transformer **84** associated with the ring counter **21**, through capacitor **132** to the lead **129** and to the terminal **128**, as shown in FIG. 3. As shown on FIG. 2, terminal **128** is common to the anodes of both diodes **116** and **126** so that this pulse passes through diode **116** and capacitor **117** to the gate of silicon controlled rectifier **118**, and this rectifier is turned on. The sudden increase in current flow through the inductor **124** together with the action of the capacitor **114** turns off the silicon controlled rectifier **113**. When silicon controlled rectifier **113** is turned off, the anode of diode **104** rises to a value of approximately 28 volts and transistor **99** and associated circuitry is turned off. This allows the capacitor **106** to start charging to more positive values which will be sufficient to fire the unijunction transistor **108** at some later time.

When the unijunction transistor **83** fires again, the unijunction transistor **108** will now fire because of the proper charge on the capacitor **106**. The pulse through transformer **84** will also be transmitted through lead **129** and terminal **128** to the anodes of the diodes **116** and **126**. This pulse will pass through the diode **126** and the capacitor **122** to the gate of the silicon controlled rectifier **113** to turn on this rectifier. The sudden increase in current flow through the air core inductor **124**, together with the action of the capacitor **127**, turns off the silicon controlled rectifier **118**. When the silicon controlled rectifier **113** turns on, it again starts the operation of transistor **99** and associated circuitry so that the unijunction transistor **108** is prevented from firing as previously described.

From the above description it can be seen that the circuit arrangement is designed to make the unijunction transistor **108** and associated circuitry inoperative during every other pulsing of the transformer **84** through the action of the unijunction transistor **83**. This produces a pulse rate synchronization which is constant irregardless of the setting of the potentiometer **74** and the timing period of the pulse circuitry can be varied uniformly by means of external speed control circuitry which will be discussed later.

The operation of the safety reset device generally indicated at **36** on FIGS. 1 and 2, and the operation of the reset initiation devices generally indicated at **34** on FIGS. 1 and 2 of the drawings, will also cause the activation of the silicon controlled rectifier **113**. As disclosed on FIG. 2, contacts **133**, **134**, **135** and **136** of the safety reset device **36** and reset initiation devices **34**, respectively, are connected to the positive terminal of the direct current supply for the timing device by means of lead **137**. Contact **138** of the safety reset device is connected to the anode of diode **139** while the corresponding contacts **140**, **142** and **142** of the reset initiation devices are connected to the cathode of the diode **139** and to one plate of capacitor **143**. The other plate of the capacitor is connected to one side of resistor **144**. The other side of the resistor **144** is connected to the anode of a diode **145** and the cathode of this diode is connected to one side of the primary winding of transformer **146**. The other side of the primary winding of the transformer **146** is connected to the negative or ground terminal of the power source for the device through a lead **147**.

Transformer **146** has two secondary windings, one of which $146S_1$ is shown on FIG. 2 associated with the silicon controlled rectifier **113** and the other of which $146S_2$ is shown on FIG. 3 at the right central portion thereof. Referring specifically to FIG. 2, it can be seen that one side of the secondary winding $146S_1$ of transformer **146** is grounded while the other side is connected to the anode of diode **148**. The cathode of this diode is connected to resistor **149** and the other side of resistor **149** is connected to one side of resistor **150** and to one plate of capacitor **151**. The other side of resistor **150** is grounded and the other plate of the capacitor **151** is connected to the terminal point **121**.

With the above described arrangement, the operation of the safety reset device **36** or any of the reset initiation devices **34** cause the activation of silicon controlled rectifier **113** in the following manner. A positive pulse appearing in the primary winding of the transformer **146**, due to the closing of any of the switches in the safety reset device **36** or reset initiation devices **34**, results in a positive pulse appearing in each of the two secondary windings of transformer **146**. In the case of the circuitry shown on FIG. 2, this pulse passes from secondary winding $146S_1$ through the diode **148**, resistor **159**, capacitor **151** and to the gate of silicon controlled rectifier **113**. If the silicon controlled rectifier **113** happens to be on at this instant, it remains turned on. However, if the silicon controlled rectifier **113** is off at this instant, it is turned on, thus turning off the silicon controlled rectifier **118** in the manner described above. Thus the proper sequence of lamp circle timing pulses is synchronized in an exact 2:1 ratio whether the timing device is initially activated or is acknowledged through the use of the reset initiation devices.

Warning period timing and pulse circuits

The warning period timing and pulse circuits generally indicated at **32** on FIGS. 1 and 2 of the drawings include the circuits shown immediately to the right of the inner lamp pulse circuits previously described. Resistor **152** is connected between lead **71** and base two of an unijunction transistor **153**. The base one of this unijunction transistor is connected to one side of the primary winding of a transformer **154** having a secondary winding **154S**. The other side of the primary winding is connected to lead **77**. A potentiometer **155**, a resistor **156** and a capacitor **157** are connected in series between lead **71** and lead **77**. The emitter of the unijunction transistor **153** is connected between the resistor **156** and the capacitor **157** and to the anode of diode **158**. The cathode of the diode **158** is connected to one side of resistor **159** and to the emitter of transistor **160**. The other side of resistor **159** is connected to lead **71** while the collector of the transistor **160** is connected to the lead **77**. The base of transistor **160** is connected to one side of resistor **161** and the other side of the resistor **161** is connected to the anodes of diodes **162** and **163**. The cathode of diode **162** is connected to the lead **91** and to the contact **92** of pressure switch **31**. The cathode of diode **163** is connected by lead **164** to a terminal point **165** and the connections from this terminal point to other parts of the circuits will be described later.

The operation of the warning period timing and pulse circuits will now be described. The capacitor **157** charges up through a total equivalent resistance equal to the series resistance sum of the potentiometer **155** and resistor **156** until the potential of the positive plate of capacitor **157** reaches the peak point voltage of the emitter of the transistor **153**. When this occurs, the unijunction transistor **153** turns on and discharges the capacitor **157** through the primary winding of transformer **154**. This produces a sharp rise-time pulse in the secondary winding **154S** of the transformer **154** shown associated with the other circuits near the center lower portion of FIG. 2, and the operation of these circuits will be discussed later.

Base two resistance of unijunction transistor **153** is provided by resistor **152** which is of the proper value to provide temperature compensation of transistor **153** at the operating voltage of 28 volts. The potentiometer **155** can be adjusted to provide any desired length of warning period, as for example, 5 to 30 seconds.

The timing and pulse generation sequence of the warning period timing and pulse circuits can be interrupted by the operation of the transistor **160** and associated circuitry. If, for example, the cathodes of either diode **162** or diode **163** are grounded through the pressure switch **31** or other circuits connected to the terminal **165**, the transistor **160** is turned on with the collector current of transistor **160** being limited by the resistor **159**. The emitter potential of transistor **160** then falls from 28 volts toward slightly above ground potential and diode **158** clamps the positive plate of capacitor **157** to this same potential. This stops the periodic pulse generating operation of the unijunction transistor **153**. If the cathodes of the diodes **162** and **163** are not grounded, the transistor **160** is turned off and the unijunction transistor **153** and associated circuitry operate as previously described.

The grounding of the cathodes of diodes **89**, **103** and **162** occurs if a brake application of sufficient magnitude is made by the locomotive engineer at any time when the outer lamp pulse circuits, the inner lamp pulse circuits, and the warning period timing and pulse circuits are operating. When a brake application is made the reduction in brake system air system air pressure causes the pressure switch **31**, with normally open contacts **92** and **93**, to close and connect lead **91** from the cathodes of diodes **89**, **103** and **162** to ground or the negative terminal of the battery. When this occurs there is a cessation of the progressive lamp illuminations around both the outer circle of lamps **16** and the inner circle of lamps **15** so that only the particular lamp or lamps that were illuminated at the instant the pressure switch was activated remain illuminated. The release of the locomotive brakes at some future time then reactivates the pulse circuits **27**, **25** and **32** and the illuminated lamp sequence continues from the point where it left off until the completion of the timing cycle.

At this point it should be noted that all three of the timing and pulse generation circuits, namely the outer lamp pulse circuits **27**, the inner lamp pulse circuits **25** and the warning period timing and pulse circuits **32** start operating as soon as the 28 volt supply voltage becomes available from the semi-regulated voltage supply **12**. Unless the cathodes of the appropriate diodes **89**, **90**, **102**, **103**, **104**, **162** and **163** are grounded in some manner, periodic timing pulses will appear at the output of the secondary windings **84**S_1, **84**S_2, **110S** and **154S** of the respective transformers **84**, **110** and **154**.

Ring counter 21

The circuits for the ring counter indicated at **21** on FIG. 1 are shown in detail in the upper half of FIG. 3. The ring counter is a twelve stage counter, but as the stages are identical the circuit diagram has been broken between stage **5** and stage **9**. The individual lamps **18** of the outer circle of lamps **16** are shown in FIG. 3, and there are twelve individual lamps as shown on FIG. 1 of the drawings.

Power is furnished to the circuits of the ring counter **21** through the positive terminal **70** of the semi-regulated D.C. power supply **12** and through the lead **166**. The negative or ground terminal of the power supply is connected to one side of the air core inductor **131** in the ring counter.

While a plurality of the stages of the ring counter have been shown in association with their corresponding lamps **18**, it can be seen that each of these stages is of similar design so it is believed sufficient to identify and describe the arrangement of several associated stages. Considering the first stage shown at the left-hand portion of the outer ring counter **21**, it can be seen that there is a resistor **167**, one side of which is connected to lead **166** and the other side of which is connected to the anode of the silicon controlled rectifier **168**. Another resistor **169** is connected between lead **166** and one side of the lamp **18**. The other side of the lamp is connected between the resistor **167** and the anode of silicon controlled rectifier **168** and also to one side of resistor **170** and one plate of capacitor **171**. The other plate of the capacitor **171** is connected to the negative or ground terminal of the power source. The purpose of the resistor **169** is to reduce the 28 volt D.C. potential to the required lamp potential.

The cathode of the silicon controlled rectifier **168** is connected to lead **172**, and this lead **172** provides a common lead for connection of the cathodes of all the silicon controlled rectifiers in the outer ring counter **21**. The air core inductor **131** is connected between lead **172** and the negative or ground terminal of the power supply.

The ring counter **21** is directly connected to the ring counter **19** through lead **173** shown at the left-hand side of FIG. 3, and through lead **174** shown at the right-hand side of this figure. Lead **173** runs to terminal point **175** and the connections to this point will be described later in conjunction with the description of ring counter **19**. Diode **176** is in lead **173** and the cathode of this diode is connected to one side of resistor **177**. The other side of this resistor is connected to a terminal point **178**.

Lead **174** connects the anodes of diode **179** in ring counter **21** and diode **180** in ring counter **19**. It should be pointed out at this point that a secondary winding **146**S_2 of the transformer **146** is shown at the central right-hand section of FIG. 3, and it will be recalled that the other secondary winding **146**S_1 of this transformer **146** was previously discussed in conjunction with synchronizing circuits between the outer and inner lamp pulse circuits. This secondary winding **146**S_2 is connected at one side to ground and at the other side to resistor **181**. The resistor **181** is in turn connected to the lead **174**.

Referring again to the upper left-hand portion of FIG. 3, diode **182** is shown connected in lead **129** with the cathode being connected to the terminal point **178**. One side of a resistor **183** is connected to this terminal point **178** and the other side to a lead **184** that terminates at terminal point **185** near the right-hand side of FIG. 3. Another diode **186** also has its anode connected to lead **129** and its cathode connected to one side of the resistor **187** and to one plate of capacitor **188**. The other side of the resistor **187** is connected through lead **189** to a terminal point **190** shown to the right of terminal point

185. One plate of capaictor 191 is connected to the terminal point 178 while the other plate of this capacitor 191 is connected to the gate of the silicon controlled rectifier 168, a plate of capacitor 188, and one side of resistor 192. The other side of the resistor 192 and the cathode of the silicon controlled rectifier are connected to the lead 172.

The anode of a diode 193 is connected to lead 129 and the cathode of this diode is connected to one side of the resistor 170 and one plate of a capacitor 194. The other plate of the capacitor 194 is connected to the gate of a silicon controlled rectifier 195 and to one side of a resistor 196. The cathode of the silicon controlled rectifier 195 and the other side of the resistor 196 are connected to the lead 172. The anode of silicon controlled rectifier 195 is connected to one side of resistor 197 and the other side of this resistor 197 is connected through lead 166 and to the positive terminal of the power supply of 28 volts shown as terminal 70.

It is not thought necessary at this time to further label the electrical components of the circuits associated with the twelve lamps, 18, of the ring counter circuit 21 because it can be seen that each of the lamps 18 is associated with circuits similar to those just described. However, it should be noted that at the upper right-hand side of FIG. 3 there is a lamp 198, the function of which will be described later, and this lamp is in series with a resistor 199 and a capacitor 200 between lead 166 and the ground or negative terminal of the power supply. This lamp 198 can be located on the indicator lamp panel 14 as shown in FIG. 1. There is a resistor 201 connected between lead 166 and terminal point 190, previously mentioned, and a connection between this terminal point 190 and the anode of a silicon controlled rectifier 202. Terminal point 190 is also connected between lamp 198 and capacitor 200. The cathode of diode 179 is connected to the gate of the silicon controlled rectifier 202 and to one side of a resistor 203. The other side of the resistor 203 and the cathode of the silicon controlled rectifier are connected to lead 172.

At the left center portion of FIG. 3, one side of the secondary winding $84S_2$ of transformer 84 is shown connected to resistor 204. The other side is connected to one side of resistor 205 and to ground. The other side of the resistor 204 is connected to the anode of a diode 206, and the cathode of diode 206 is connected to terminal point 207. The other side of the resistor 205 is also connected to terminal point 207. Capacitor 132 is connected between terminal point 207 and the lead 129. One side of resistor 208 is connected to this terminal point 207 and the other side of the resistor 208 is connected to the cathode of diode 209. The anode of this diode 209 is connected to terminal point 165, and it will be recalled that this terminal point 165 is also shown in the lower left-hand portion of FIG. 2. There is also a connection between the terminal point 207 and a terminal point 210, which terminal point 210 is also shown at the left-hand portion of FIG. 2. The operation of the circuits in the ring counter 21 and associated circuits in the timing device will be discussed at some length later after a description of the circuits of the ring counter 19.

Ring counter 19

At this point attention is directed to the lower portion of FIG. 3 where the circuits of the ring counter 19 are shown. In the circuit diagram shown on FIG. 3, the circuits have been broken as indicated because as in the case of the ring counter 21, the circuits associated with each of the lamps 17 are the same, and it will be understood that the complete circuit for the ring counter 19 will include circuits for each of the twelve lamps 17 found in the inner lamp circle 15. As was done in the description of the circuits of the ring counter 21, only some of the components of the circuit will be labelled and described, as it is not believed necessary to completely label each of the components in the identical circuits associated with each of the lamps 17.

Terminal 70 is the positive terminal of the power supply and is connected to lead 211 to furnish 28 volts direct current to the ring counter 19 and the negative or ground terminal of these circuits is connected to one side of the air core inductor 212 and to one side of the resistor 213. The other side of the air core inductor 212 is connected to a lead 214 to which each of the cathodes of the twelve silicon controlled rectifiers for each lamp circuit is connected. The other side of the resistor 213 is connected to lead 215.

Referring to the left-hand portion of FIG. 3, the anode of diode 216 is shown connected to lead 215 and the cathode of this diode is connected to one plate of capacitor 217 and one side of resistor 218. The other side of resistor 218 is connected through lead 219 to a terminal point 220, shown at the right-hand side of the figure, and the connections from this terminal point will be explained later. The other plate of the capacitor 217 is connected to the gate of the silicon controlled rectifier 221 and to one side of resistor 222. The other side of the resistor 222, as well as the cathode of the silicon controlled rectifier 221, are connected to lead 214.

The anode of the silicon controlled rectifier 221 is connected to one side of resistor 223 and to a terminal point 224. The other side of the resistor 223 is connected to one side of resistor 225 and to lead 211. Resistor 225 is designed to reduce the voltage applied to the lamp 17 and is connected to this lamp and to a lead 226 associated with each of the lamps 17 in the circuit. Lamp 17 is also connected to terminal point 224 as is one plate of capacitor 227 and one side of resistor 228. The other plate of the capacitor 227 is connected to ground and the other side of the resistor 228 is connected to the cathode of a diode 229 and to one plate of capacitor 230. The anode of diode 229 is connected to lead 215 and the other plate of the capacitor 230 is connected to the gate of silicon controlled rectifier 231 and to one side of resistor 232. The other side of the resistor 232 and the cathode of the silicon controlled rectifier 231 are connected to the lead 214.

Turning to the right-hand section of the circuits for the ring counter 19, a lamp 233 is shown connected in series with a resistor 234 and a capacitor 235. This lamp can be located on the lamp indicator panel 14 shown on FIG. 1 of the drawings. The capacitor 235 is grounded to the negative terminal of the power supply while the resistor 234 is connected to lead 211 and to the positive terminal of the power supply at 70. Lead 211 is also connected to resistor 236 and the other side of resistor 236 is connected to terminal point 220 as is the connection between the lamp 233 and the capacitor 235. The anode of silicon controlled rectifier 237 is connected to terminal point 220, while the cathode of this silicon controlled rectifier is connected to lead 214. The gate of the silicon controlled rectifier 237 is connected to resistor 238 and to the cathode of diode 180. The other side of the resistor 238 is likewise connected to the lead 214.

The secondary winding 110S of the transformer 110, previously mentioned, is shown at the lower left-hand corner of FIG. 3, and it can be seen that one side of this secondary winding is grounded and is connected to one side of resistor 239. The other side of the resistor 239 leads to a terminal point 240. The other side of the secondary winding 110S of transformer 110 is connected to a resistor 241 and the other side of the resistor 241 is connected to the anode of diode 242. The cathode of the diode 242 is connected to the terminal point 240 and capacitor 243 is connected between terminal point 240 and the lead 215. There is also a connection to the terminal point 240 from one side of the resistor 244 and the other side of the resistor 244 is connected to the cathode of diode 245. The anode of the diode 245 is connected to terminal point **165**, previously mentioned in conjunction with the circuits of ring counter **21**.

When the timing device is initially turned on, 28 volts direct current is applied to the circuits of the ring counters **19** and **21** and initially each of the silicon controlled rectifiers in the two ring counters are turned off and none of the lamps **17**, **18**, **198** and **233** are energized. However, when the safety reset device **36** is momentarily activated by the locomotive engineer, the silicon controlled rectifier **246**, shown in the lower left-hand portion of FIG. 2, is turned on by means of a network which will be described later. When the silicon controlled rectifier **246** is turned on, the anode voltage of this rectifier drops to slightly above ground potential which removes the direct current bias at the terminal point **165** from the network composed of diode **205**, capacitor **132**, resistor **208** and diode **209** shown associated with the ring counter **21** and from the similar network of ring counter **19**. This same momentary activation of the safety reset device **36** also causes a current flow in the primary winding of transformer **146** through capacitor **143**, resistor **144** and diode **145**. This in turn causes a positive pulse to appear in the secondary winding **146**S_2 of the transformer **146** shown at the central right-hand portion of FIG. 3. This pulse passes through the resistor **181**, then through the diode **179** into the gate circuit of the silicon controlled rectifier **202** and turns this rectifier on. This allows a current flow through the resistor **201** and energizes the lamp **198**.

When the silicon controlled rectifier **202** is turned on, the anode voltage of the rectifier is slightly above ground potential and thus removes the direct current bias from the network composed of diode **186**, capacitor **188** and resistor **187**. The first positive pulse occurring in the secondary winding **84**S_2 of the transformer **84** due to the operation of the outer lamp pulse circuit **27**, previously described, passes through resistor **204**, diode **206**, capacitor **132** and to the lead **129**. Since the direct current bias at the junction of diode **186**, capacitor **188** and resistor **187** was removed when the silicon controlled rectifier **202** was turned on, the positive pulse continues through diode **186** and capacitor **188** into the gate circuit of the silicon controlled rectifier **168** and turns it on. This allows a current flow through the resistor **167** and energizes the first lamp **18**. It should be noted that this particular positive pulse also appears simultaneously at the anodes of all the pulse input diodes of the various stages of the ring counter **21**, but that all of the diodes except diode **186** are reverse biased by their respective interstage coupling networks, and in each case this direct current voltage bias originates at the anodes of the preceding silicon controlled rectifier stages since all of these silicon controlled rectifiers are turned off. Thus, the positive pulse from the outer lamp pulse circuits **27** is blocked from the gate circuits of all of the silicon controlled rectifiers in the ring counter **21** except the gate circuit of silicon controlled rectifier **168**.

When the silicon controlled rectifier **168** turns on, several events occur. First, the anode to cathode current flowing in the rectifier **168**, which is the sum of the currents through resistor **167** and lamp **18**, passes through the lead **172** and the air core inductor **131** to ground. This causes a positive voltage transient to appear at the top connection of the inductor **131**, which, in conjunction with the operation of the capacitor **200**, reverse biases the silicon controlled rectifier **202** so that it turns off, thus de-energizing the resistor **201** and extenguishing the lamp **198**.

Secondly, with the silicon controlled rectifier **168** turned on, its anode potential is slightly above ground, and therefore the direct current voltage bias on the interstage coupling network, composed of the diode **193**, capacitor **194** and the resistor **170**, is removed. This prepares the second stage, including the silicon controlled rectifier **195** and the second lamp **18** in the ring counter **21** for activation when the next positive pulse is received at the anode of diode **193**.

Thirdly, when the silicon controlled rectifier **202** is turned off as the result of the turn on of silicon controlled rectifier **168**, the direct current voltage bias to the diode **186**, capacitor **188** and resistor **187** network is restored and this prevents any following positive pulses appearing at the anode of diode **186** from reactivating silicon controlled rectifier **168**.

The second positive pulse appearing in the secondary winding **84**S_2 of the transformer **84** as the result of the operation of the outer lamp pulse circuits **27** will activate the silicon controlled rectifier **195** through diode **193** and silicon controlled rectifier **168** is turned off. In a manner described in the preceding paragraph, the circuits associated with the next silicon controlled rectifier **247** are prepared to receive the following positive pulse to be delivered to the ring counter circuit **21**. This process continues repetitiously for positive pulses three through eleven, respectively, until finally the twelfth positive pulse turns on the silicon controlled rectifier **248**. At this time all of the other silicon controlled rectifiers in the ring counter circuits **21** are turned off.

When the silicon controlled rectifier **248** is turned on, its anode potential will be slightly above ground and the direct current bias is removed from the network composed of diode **182**, capacitor **191** and resistor **183**. It should also be noted that there is a second source of direct current bias for this network originating at the anode of the sixth stage silicon controlled rectifier **249** of the ring counter **19** shown at the lower portion of FIG. 3. This voltage bias passes through lead **173**, diode **176** and resistor **177** to the terminal point **178**. Since the ring counter **21** advances from stage to stage at a rate that is twice that of the ring counter **19**, it is evident that when silicon controlled rectifier **248** is activated for the first time, the silicon controlled rectifier **249** will also be activated. Since the anode potential of the silicon controlled rectifier **249** under these conditions is also slightly above ground, the three-way junction point or terminal **178** is unbiased and the thirteenth positive pulse appearing at the anode of diode **182** from the secondary winding **84**S_2 of transformer **84** will pass through this diode **182**, capacitor **191**, and into the gate circuit of silicon controlled rectifier **168** to turn it on for the start of the second cycle of operation of this ring counter **21**. It should be particularly noted that this second cycle of operation of ring counter **21** can only be initiated under the conditions in which both the silicon controlled rectifier **248** and silicon controlled rectifier **249** are turned on.

The fourteenth positive pulse from pulse circuits **27** then turns on silicon controlled rectifier **195** and turns off silicon controlled rectifier **168**, as previously explained. This process continues for positive input pulses Nos. fifteen through twenty-three, respectively, until silicon controlled rectifier **248** is once again turned on by positive pulse twenty-four. Under these conditions only silicon controlled rectifier **248** and silicon controlled rectifier **250** in the ring counters **21** and **19**, respectively, are turned on. Although the silicon controlled rectifier **248**, when turned on, removes the source of direct current bias from one end of resistor **183**, the silicon controlled rectifier **249** is still turned off and supplies a direct current voltage bias to one end of resistor **177**. This causes the diode **182** to remain reverse biased and, although more positive input pulses continue to occur at the anode the diode **182** to remain reverse biased and, although turn on. Under these conditions, silicon controlled rectifier **168** will not turn on. Under these conditions, silicon controlled rectifier **248** remains turned on indefinitely until some future time when the reactivation of the silicon controlled rectifier **202** sets up the network composed of diode **186**, capacitor **188** and resistor **187** so that a positive input pulse can turn on the silicon controlled rectifier **168** and restart a new timing cycle.

It should be noted that the diode **176** is used to prevent any voltage feedback from the anode of silicon controlled rectifier **248** via resistors **183** and **177** to the anode of the silicon controlled rectifier **249**, which under certain conditions could cause malfunctioning of the circuits. It is for the same reason that the diode **209** is used to prevent any voltage feedback from the terminal point **207** to the terminal **165** and the anode of the silicon controlled rectifier **246** shown on FIG. 2. The resistors shown at **205** and **130** are bleeder resistors and are used in the interval between pulses from the secondary winding **84**S_2 of transformer **84** to remove any residual charges remaining on both plates of the capacitor **132**.

The operation of the ring counter **19** involves the application of the 28 volt direct current to the circuit, and initially all the silicon controlled rectifiers in the ring counter **19** are turned off and none of the lamps **17** in the circuit is energized.

As previously discussed, the momentary activation of the safety reset device **36** turns on the silicon controlled rectifier **246** and removes the direct current voltage bias at terminal **165**. It should be noted that this bias point **165** is common to both the ring counter **19** and ring counter **21**. At this same time a positive pulse appears in the secondary winding **146**S_2 of the transformer **146** and this pulse passes through the resistor **181**, through lead **174** to diode **180** and into the gate circuit of the silicon controlled rectifier **237** to turn this rectifier on. This allows a current flow through resistor **236** and energizes lamp **233**.

When the silicon controlled rectifier **237** is turned on, the anode voltage of this rectifier is slightly above ground potential thus removing the direct current bias from the network composed of diode **216**, capacitor **217** and resistor **218**. The first positive pulse occurring in the secondary winding **110S** of the transformer **110** due to the operation of the inner lamp pulse circuits **25** passes through the resistor **241**, diode **242**, capacitor **243** and to the lead **215** connecting all of the anodes of the diodes associated with the various stages of the ring counter. Since the direct current bias at the junction of diode **216**, capacitor **217** and resistor **218** was removed when the silicon controlled rectifier **237** was turned on, this input pulse continues through diode **216** and capacitor **217** into the gate circuit of the silicon controlled rectifier **221** to turn it on. This permits a current flow through resistor **223** and energizes the first timing lamp **17**. It should be noted that this particular input pulse also appears at the anodes of all the pulse input diodes of the various stages of the ring counter **19**, but all of these diodes are reverse biased by their respective interstage coupling networks, and in each case this direct current voltage bias originated at the anodes of the preceding silicon controlled rectifier stages since all of these silicon controlled rectifiers are turned off. Thus, the first positive input pulse is blocked from the gate circuits of all of the silicon controlled rectifier stages in the ring counter **19** except the silicon controlled rectifier **221**.

When silicon controlled rectifier **221** turns on, several events occur. First, the anode to cathode current flowing through rectifier **221**, which is the sum of the currents through resistor **223** and lamp **17**, passes through lead **214** and the inductor **212** to ground. This causes a positive voltage transient to appear at the top connection of inductor **212**, which, in conjunction with the operation of the capacitor **235**, reverse biases the silicon controlled rectifier **237** so that it turns off, thus de-energizing resistor **236** and extinguishing lamp **233**.

Secondly, with the silicon controlled rectifier **221** turned on, its anode potential is slightly above ground so that the direct current voltage bias on the interstage coupling network composed of diode **229**, capacitor **230** and resistor **228** is removed. This prepares the second stage in the ring counter **19** for activation when the next positive input pulse is received at the anode of diode **229**.

Thirdly, when the silicon controlled rectifier **237** is turned off, a direct current voltage bias is restored to the network consisting of diode **216**, capacitor **217** and resistor **218**, thus preventing any following positive input pulses appearing at the anode of diode **216** from reactivating silicon controlled rectifier **221**.

The second positive input pulse appearing in the secondary winding **110S** of transformer **110** from pulse circuits **25** activates the silicon controlled rectifier **231**, which turns off silicon controlled rectifier **221** and prepares the following silicon controlled rectifier in the next stage for the next positive input pulse. This process continues repetitively for input pulses Nos. three through eleven until finally the twelfth input pulse turns on silicon controlled rectifier **250**. At this time all of the other silicon controlled rectifiers in the ring counter **19** are turned off, and under these conditions, rectifier **250** remains turned on indefinitely until some future time when the reactivation of the silicon controlled rectifier **237** sets up the network composed of diode **216**, capacitor **217** and resistor **218** so that the next positive input pulse can turn on the silicon controlled rectifier **221** and restart a new timing cycle.

Diode **245** is used to prevent any voltage feedback from the terminal point **240** to the terminal **165** which, under certain operating conditions, could cause malfunctioning of the circuits. The resistors **239** and **213** are bleeder resistors and are used to remove residual charges on the plates of the capacitor **243**.

Warning circuits

The circuits involved in the warning circuits **39** are shown at the lower left-hand portion of FIG. 2. A silicon controlled rectifier indicated at **251** has its cathode connected to the ground or negative terminal of the power supply and its anode connected to one plate of a capacitor **252**, and a terminal point **253**. The other plate of the capacitor **252** is connected to the terminal **165**, previously discussed. Diode **254** and parallel resistor **255** are connected in series with a capacitor **256** between terminal point **253** and terminal point **95**.

Lamp **43**, a solenoid coil **257**, a diode **258** and a resistor **259** are all connected in parallel between the second terminal point **253** and the lead **137** running to the positive terminal of the power supply for the timing device. The lamp **43** has a resistor **260** in series therewith to provide for the correct voltage for the lamp.

As shown at the extreme lower left-hand corner of FIG. 2, a secondary winding **84**S_1 of transformer **84** is connected to resistor **261** and to the ground terminal of the device. The resistor **261** is connected to the anode of diode **262** and the cathode of this diode is connected to terminal point **263**. A resistor **264** is connected between terminal point **263** and ground and the cathode of a diode **265** is also connected to this terminal **263**. The anode of the diode **265** is connected to terminal **210**, and it will be recalled that this terminal is associated with the circuit arrangement for the outer ring counter **21** shown on FIG. 3.

A capacitor **266** is connected between terminal **263** and terminal **267**. A resistor **268** is connected between terminal **267** and the ground terminal, and the cathodes of diodes **269** and **270** are likewise connected to terminal point **267**. The anode of diode **269** is connected to a resistor **271** and the other side of this resistor is connected to terminal **185** which, it will be recalled, is associated with the anode of the silicon controlled rectifier **248** in the ring counter **21**, as shown on FIG. 3. The anode of diode **270** is connected to resistor **272** and the other side of this resistor is connected to terminal **273**. Terminal **273** is shown connected to the anode of the silicon controlled rectifier **250** of the ring counter **19** on FIG. 3. Referring again to FIG. 2, one plate of capacitor

274 is connected to the terminal 267 and the other plate of this capacitor is connected to the gate of silicon controlled rectifier 251 and to one side of the resistor 275 which is grounded to the negative terminal of the power supply.

Silicon controlled rectifier 246, previously mentioned, has its cathode connected to the ground terminal of the circuit and its anode is connected to the terminal point 165 and through lead 276 to another terminal point 277. A lamp 278 with associated resistor 279, diode 280 and resistor 281 are connected in parallel between terminal 277 and lead 137 to the positive terminal of the power supply. This lamp 278 can be mounted on the indicator lamp panel 14 or at any other suitable location in the locomotive cab. The gate of the silicon controlled rectifier 246 is connected to resistor 282, the cathode of diode 283 and a plate of capacitor 284. The resistor is connected to ground and the other plate of capacitor 284 is connected to a terminal point 285. Resistor 286 is connected between terminal point 285 and ground. The anode of the diode 283 is connected through a resistor 287 to a terminal point 288 and the connections to this terminal 288 will be discussed later. Resistor 289 is connected in series between terminal point 285 and a terminal point 290 and the connections to this terminal point 290 will also be discussed later. A diode 291 and a resistor 292 are connected in series between terminal 285 and one plate of capacitor 143 shown at the right-hand side of FIG. 2.

From the circuit ararngements just discussed, it can be seen that if the silicon controlled rectifier 251 is turned on that the lamp 43 will be energized and the solenoid coil 257 will also be energized to sound a buzzer or whistle. The diode 258 which is associated with the solenoid 257 is designed to suppress inductive voltage transients generated by solenoid 257 whenever the silicon controlled rectifier 251 turns off.

Considering the gate circuitry of the silicon controlled rectifier 251, it can be seen that there are two separate networks in series and the first is composed of the diode 265, diode 262, capacitor 266 and resistor 264. The direct current voltage bias appearing at the anode of diode 265 is taken from terminal 210, and this terminal 210 is connected to the terminal point 207 in the circuits associated with the ring counter 21, as illustrated on FIG. 3. Since the direct current voltage bias at this point 207 is actually derived from the anode of the silicon controlled rectifier 246 or the terminal point 165 as shown both on FIGS. 2 and 3, it is evident that the direct current voltages bias appearing at the terminal point 263 will be present when the silicon controlled rectifier 246 is turned off and will be absent when this silicon rectifier 246 is turned on.

If a direct current voltage bias is present at the terminal point 263, this bias voltage causes current to flow from the anode of the silicon controlled rectifier 246 or terminal point 165 through diode 209, resistor 208, diode 265 and resistor 264 to ground. As a result, the diode 262 is reverse biased and will not conduct when positive pulses appear at its anode from the secondary winding $84S_1$ of the transformer 84.

There is a second network composed of the resistor 271, diode 269, capacitor 266, capacitor 274 and resistor 268 and the parallel arrangement of resistor 272, diode 270 and the capacitors 266 and 274 and resistor 268. The direct current voltage bias which appears at the upper terminal of resistor 271 is taken from terminal 185 associated with the anode of the silicon controlled rectifier 248 in the ring counter circuit 21. The direct current voltage bias appearing at the upper terminal of the resistor 272 is taken from the terminal 273 which is associated with the anode of the silicon controlled rectifier 250 of the ring counter 19. If the silicon controlled rectifier 248 is turned off, current flows from the anode of this silicon controlled rectifier through terminal 185, through resistor 271, diode 269 and resistor 268 to ground. Likewise, if the silicon controlled rectifier 250 is turned off, current flows from the anode of this silicon controlled rectifier to terminal 273, through resistor 272, diode 270 and the resistor 268. In either case, the current flow through the resistor 268 to ground causes the right-hand plate of capacitor 266 and the left-hand plate of capacitor 274 to become positively charged. Under these conditions, any positive pulse appearing in the left-hand plate of capacitor 266 will be blocked and thus prevented from passing through capacitor 266 and capacitor 274 to the gate of silicon controlled rectifier 251.

From the above discussion it should be evident that the direct current voltage bias appearing at the terminal point 267 will be absent only when both silicon controlled rectifiers 248 and 250 are turned on, and this will occur only at the end of the period during which the outer circle of lamps 16 will have completed two cycles of lamp energization and the inner circle of lamps 15 will have been energized for one cycle.

When positive pulses appear in the secondary winding $84S_1$ of the pulse transformer 84 they pass through resistor 261 and diode 262 to the terminal 263. If the silicon controlled rectifier 246 is turned on, terminal 165 and terminal 263 will be slightly above ground potential. Thus, the direct current voltage bias is removed from this terminal 263 and the positive pulses can pass through capacitor 266 to the terminal point 267. If both the silicon controlled rectifiers 248 and 250 are turned on, then terminals 185 and 273 are each slightly above ground potential, This removes the direct current voltage bias from the terminal 267 and the positive pulses can continue through capacitor 274 to the gate of the silicon controlled rectifier 251 to turn this rectifier on.

The lamp 278 is energized when the warning lamp 43 and the signal associated with the solenoid 257 have been de-energized. Referring to the silicon controlled rectifier 246 which activates the load resistor 281 and the lamp 278 when the rectifier is on, it can be seen that there are two separate circuits through which pulses can arrive at the gate of the rectifier 246 and turn it on. In one case, a positive pulse appearing at the junction 288 will pass through the limiting resistor 287 and diode 283 into the gate of the silicon controlled rectifier 246 to turn this rectifier on. In the second case, a positive voltage appearing at the right-hand plate of capacitor 143 causes current to pass through the limiting resistor 292, diode 291, to the terminal 285 and through the resistor 286 to ground. If the silicon controlled rectifier 293, which will be described later, is turned on, there is no direct current voltage bias applied by means of resistor 289 to the terminal point 285 and therefore, no potential drop across the resistor 286 resulting from current flow through resistor 285 to ground. Therefore, any positive voltage pulse appearing at the right-hand plate of the capacitor 284 is coupled into the gate circuit of silicon controlled rectifier 246 and this rectifier is turned on. It should be noted that if the silicon controlled rectifier 293 is turned off, the steady state current flow from the anode of the silicon controlled rectifier 293 through resistor 289 and resistor 286 to ground causes the diode 291 to become reverse biased, thus preventing the turn on of silicon controlled rectifier 246 when voltage is applied to the anode of the diode 291.

Action circuits and brake solenoid valve circuits

The circuits involved in the action circuits 40 are shown at the lower central portion of FIG. 2 and include the silicon controlled rectifier 294 which operates in conjunction with the brake solenoid valve circuits 41. The silicon controlled rectifier 294 has a gate circuit including resistor 295 and diode 296. The cathode of the silicon controlled rectifier 294 is connected to the lead 147 and to the negative terminal of the power supply. A resistor

297 is connected from the gate of the rectifier 294 to the lead 147. Resistor 298 and capacitor 299 are connected in series between the anode and the cathode of the silicon controlled rectifier 294. The resistor 298 and the capactior 299 are so connected in order to minimize the rate of rise of applied voltage effects which might cause the silicon controlled rectifier 294 to turn on prematurely when the timing device is initially turned on.

The indicator lamp 45 with associated resistor 300 is connected between terminal 95 and terminal 301. A solenoid coil 302, a diode 303 and resistor 304 are connected to the anode of silicon controlled rectifier 294 through terminal point 95 and to the positive terminal of the power supply through terminal 301 and lead 137.

The brake solenoid valve circuits 41 are shown in conjunction with the silicon controlled rectifier 293. The cathode of the silicon controlled rectifier 293 is connected to lead 147 and the anode is connected to terminal 290. A resistor 305 is connected between the gate of the rectifier and the lead 147 and there is also a diode 306 and resistor 307 connected in series between the gate of the rectifier 293 and the terminal point 288. Resistor 308 is connected between terminal 288 and lead 147 and one plate of capacitor 309 is also connected to the terminal 288. The other plate of capacitor 309 is connected through resistor 310 to lead 147 and through lead 311 to the contact 138 of the safety reset device 36 and to the anode of diode 139.

Lamp 47 with associated resistor 312, solenoid coil 313, diode 314 and resistor 315 are all connected in parallel between the terminal 290 and the lead 137 going to the positive terminal of the power supply. Capacitor 316 is connected between terminal point 95 and terminal point 290. The solenoid 313 is associated with the brake solenoid valve, shown generally at 52 on FIG. 1 of the drawings.

The silicon controlled rectifier 293 can be turned on when a positive pulse appears at the terminal 288 and passes through the resistor 307 and diode 306 to the gate of the rectifier.

We now come to the mode of operation of the warning circuits 39, action circuits 40 and brake solenoid valve circuits 41 with the associated signal and valve means. Referring specifically to FIG. 2 of the drawings, when the timing device is initially turned on the power is applied to these circuits, but all of the silicon controlled rectifiers 251, 246, 294 and 293 remain turned off. If the safety reset device 36 is momentarily closed by the engineer, the following events will occur. A positive pulse will be delivered through lead 311, capacitor 309, resistor 307 and diode 306 to the gate of the silicon controlled rectifier 293 to turn this rectifier on. When the rectifier 293 is turned on, current will flow through the solenoid coil 313, the lamp 47 will be energized, and the anode voltage of silicon controlled rectifier 293 will fall to slightly above ground potential and thus remove the direct current voltage bias applied to the gate circuitry of silicon controlled rectifier 246 via resistor 289.

The positive pulse which appears at terminal 288 also passes through resistor 287 and diode 283 into the gate of silicon controlled rectifier 246 to turn this rectifier on. The turn on of rectifier 246 causes the activation of the lamp 278, and the anode potential of silicon controlled rectifier 246 will fall to slightly above ground potential. When the anode potential of silicon controlled rectifier 246 falls, the cathode of diode 163 is grounded and this stops the operation of the warning period timing and pulse circuits 32, as previously described. The fall of the anode potential of silicon controlled rectifier 246 also removes the direct current voltage bias at the terminal 165 to thereby set up one of the conditions necessary to start the operation of both of the ring counters 19 and 21. This fall of anode potential at terminal 165 also removes the direct current voltage bias at terminal 210, in the manner previously described, and this unbiases the pulse network through terminal 263 to the gate circuitry of silicon controlled rectifier 251.

A positive potential also appears at the right-hand plate of capacitor 143 because of the conduction of forward biased diode 139 and this then causes a positive pulse to appear at the junction of capacitor 143 and the resistor 318 which then passes through the resistor 144 and diode 145 into the primary winding of transformer 146. This causes a positive pulse to appear in the secondary winding $146S_2$ of transformer 146, shown at the right-hand edge of FIG. 3, and this pulse will pass through resistor 181 and diode 179 into the gate of silicon controlled rectifier 202 which turns on this rectifier. This same voltage pulse will also turn on silicon controlled rectifier 237 by passing through diode 180 into the gate circuitry of this rectifier. It will be recalled that this is one of the conditions necessary to start the operation of both of the ring counters 21 and 19.

A positive potential appearing momentarily at the junction of capacitor 143 and the resistor 317 also causes a current to flow momentarily through resistor 292, diode 291 and resistor 286 to ground. However, when the silicon controlled rectifier 293 was turned on as previously described, the voltage bias at the terminal 285 was removed and hence this current flow through the resistor 286 to ground causes another positive pulse to appear in the gate circuit of silicon controlled rectifier 246 to turn on this rectifier via a second circuit path. It should be noted that the pulses into the gate circuit of silicon controlled rectifier 246 via the two separate circuit paths probably reach the gate circuit of this rectifier almost simultaneously although the pulse via the diode 291 cannot pass through capacitor 284 until silicon controlled rectifier 293 has been turned on.

It should also be noted that if any of the reset initiation devices 34 had been momentarily activated instead of the safety reset device 36, only the step involving the positive pulse to the primary winding of transformer 146 and the resultant turn on of silicon controlled rectifiers 202 and 237 would have occurred. Thus, although silicon controlled rectifiers 202 and 237 would have turned on, silicon controlled rectifiers 246 and 293 would have remained turned off. With silicon controlled rectifier 246 turned off, the ring counters 19 and 21 could not have started operating because of the anode potential bias voltage at terminal 165. With the silicon controlled rectifier 293 turned off, the locomotive brakes would remain applied as in a service application.

Assuming, then, that both the ring counters 19 and 21 have operated during a time period so that silicon controlled rectifier 248 of the ring counter circuits 21 and silicon controlled rectifier 250 of the ring counter circuits 19 have turned on, this removes the direct current voltage bias at both terminals 185 and 273 with the result that the next pulse appearing in the secondary winding $84S_1$ of pulse transformer 84 passes through resistor 261, diode 262, capacitor 266 and capacitor 274 into the gate of silicon controlled rectifier 251 and turns this rectifier on. When the rectifier 251 is turned on, the following events will occur. First, the solenoid coil 257 will be activated to sound a suitable signal, such as a buzzer or whistle, and the warning lamp 43 will also be activated. Secondly, the silicon controlled rectifier 246 will be turned off through the capacitor 251 and when the rectifier 246 is turned off, the lamp 278 will also be turned off. In addition, the turn off of the silicon controlled rectifier 246 results in the ungrounding of the diode 163 and starts the warning period timing and pulse circuits 32. Direct current voltage bias is again established at terminal 165 which prevents any further operation of either of the ring counters 19 and 21 and the re-establishment of the direct current voltage bias at terminal 210 which prevents any more pulses from transformer 84 from reaching the gate circuit of silicon controlled rectifier 251.

If no acknowledgement signal from the reset initiation devices **34** is received from the locomotive operator prior to the end of the warning period, a positive pulse appears in the secondary winding **154S** of the transformer **154** due to the normal operation of the unijunction transistor **153** and its associated circuitry. This pulse passes through resistor **295** and diode **296** to the gate of the silicon controlled rectifier **294** and turns this rectifier on. When the silicon controlled rectifier **294** is turned on, the following events will occur. There will be an activation of the solenoid coil **302** to sound the action bell **50** and the lamp **45** will be illuminated. The cathodes of diodes **90** and **102** will be grounded and this will cause both the outer lamp pulse circuits **27** and the inner lamp pulse circuits **25** to cease operation.

In addition, the silicon controlled rectifier **293** will be turned off by means of the capacitor **316** and when the silicon controlled rectifier **293** is turned off, the following will take place. There will be a deactivation of the solenoid coil **313** which will cause the operation of the brake solenoid valve **52** and there will be a service application of the brakes of the train. The lamp **47** will also be turned off to indicate this condition. Furthermore, there will be a restoration of the direct current voltage bias to the gate circuits of the silicon controlled rectifier **246** through the resistor **289**.

When silicon controlled rectifier **294** is turned off, the silicon controlled rectifier **251** will also be turned off through capacitor **256**, diode **254** and resistor **255**. It should be noted at this point that the purpose of the diode **254** and resistor **255** network is to provide a unidirectional commutation of the associated silicon controlled rectifiers. As an example, in the situation where silicon controlled rectifier **251** is conducting and the rectifier **294** is blocking, the sudden turn on of the silicon controlled rectified **294** by means of its gate circuitry results in the turn off of the silicon controlled rectifier **251**. If, however, the situation is reversed whereby the silicon controlled rectifier **294** is conducting and the rectifier **251** is blocking, the sudden turn on of the rectifier **251** by means of its gate circuitry does not turn off the silicon controlled rectifier **294**. From FIG. 2 it is evident that capacitors **316** and **256** are connected in series between the anodes of silicon controlled rectifier **251** and silicon controlled rectifier **293**. In the absence of the diode **254** and resistor **255** network, and in the case where the rectifier **293** is conducting and the rectifier **251** is blocking, as during the pre-warning period of the device's operation, the sudden turn on of the silicon controlled rectifier **251** at the start of the warning period will usually result in the simultaneous turn off of the rectifier **293**. This, of course, is an undesirable mode of operation and is eliminated by this diode and resistor network. The diode **254** will allow the high values of discharge current from capacitor **256** to pass in only one direction and the resistor **255** will allow the left-hand plate of the capacitor **256** to charge up or bleed to ground, depending on whether the rectifier **251** is blocking or conducting, respectively.

When the silicon controlled rectifier **251** turns off, the solenoid coil **257** is deactivated and the lamp **43** is also deactivated.

As a result of the previously described operations, the silicon controlled rectifier **294** is turned on while silicon controlled rectifiers **251**, **246** and **293** are turned off. It should be pointed out that under these conditions, the warning period timing and pulse circuits **32** are operational since the rectifier **246** is turned off and the cathode of diode **163** remains ungrounded. Periodic pulses will continue to be generated in the secondary winding **154S** of the transformer **154** and this will insure that the silicon controlled rectifier **294** remains turned on.

The timing device will remain in this state indefinitely, with the locomotive brakes applied until some future time when the momentary activation of the safety reset device **36** will permit the locomotive engineer to release the locomotive brakes and restart the entire timing cycle over again in the manner previously explained.

If an acknowledgment is made by the locomotive operator during the warning period by means of the momentary activation of the reset initiation devices **34**, the direct current potential appearing at the junction of capacitor **143** and resistor **317** will cause the following events to occur. First, a positive pulse appears at the junction of capacitor **143** and resistor **318** which passes through resistor **144** and diode **145** into the primary winding of the transformer **146**. This causes a positive pulse to appear in the secondary winding **$146S_2$** of the transformer **146** which activates the silicon controlled rectifiers **202** and **237** to reset the outer lamp pulse circuits and the inner lamp pulse circuits in a manner previously explained. There is also a momentary current flow from the junction of capacitor **143** and resistor **317** through resistor **292**, diode **291** and resistor **286** to ground. Since silicon controlled rectifier **293** is still turned on, the direct current voltage bias fed to the terminal **285** is not present and this flow of current through resistor **286** to ground causes a positive pulse to appear at the gate of silicon controlled rectifier **246** and turn the rectifier on. When the rectifier **246** is turned on, the following events will take place. The lamps **278** will be activated, silicon controlled rectifier **251** will be turned off through the capacitor **252** and this results in the turn off of the solenoid coil **257** and the turn off of the lamp **43**.

Also, when the silicon controlled rectifier **246** is turned on, the cathode of diode **163** is grounded which causes the warning period timing and pulse circuits to stop operating at some point in its timing period prior to the appearance of a pulse in the secondary winding **154S** of the transformer **154**. In addition, when the rectifier **246** is turned on, the direct current bias voltage is removed from terminal **165** which then allows the ring counters **19** and **21** to start operating in a new cycle and the direct current bias voltage is also removed from terminal **210** so that the silicon controlled rectifier **251** can operate at the end of the newly initiated pre-warning period.

From the above sequence of events it is evident that when the timing device was acknowledged by the engineer or locomotive operator, it was reset such that a new timing cycle was initiated and since the silicon controlled rectifier **293** remained turned on, the locomotive brakes remained in a released condition.

If an acknowledgment signal is received from the locomotive operator at any time during the pre-warning period by means of the momentary activation of the reset initiation devices **34**, the direct current potential appearing at the junction of the capacitor **143** and resistor **317** causes a pulse in the secondary winding **$146S_2$** of transformer **146** to turn on or reset silicon controlled rectifiers **202** and **237** in the ring counters **21** and **19**, respectively, in a manner previously described. At the same time, the silicon controlled rectifier **246** will be turned on and the results of this operation are the same as that previously described in conjunction with the acknowledgment of the locomotive operator during the warning period. However, since the silicon controlled rectifier **246** is already turned on, the positive pulse into the gate of the silicon controlled rectifier **246** is redundant but actually does no harm. The turn on of the silicon controlled rectifiers **202** and **237** in the ring counter turns off the particular silicon controlled rectifier in each ring counter that happens to be conducting at the instant the acknowledgment signal is received, and the ring counters then start a new timing cycle over again as previously explained.

It is apparent from the above discussion that during any timing cycle of the timing device, the locomotive will travel a certain distance depending on the speed at which the locomotive is moving. Obviously, the potential hazards to the train and personnel increase with locomotive speed due to the fact that if the engineer becomes incapacitated or is inattentive for any reason, the train will continue its movement forward a greater distance before a brake application is initiated by the timing device. In order to prevent these dangerous situations, means have been provided to automatically shorten the timing cycle of the timing device with increased train speed so that the engineer must acknowledge the timing device at more frequent intervals and these means are described below.

Referring to FIG. 4 of the drawings, a block diagram of the basic external speed control circuitry is shown associated with a suitable locomotive axle drive. This locomotive axle drive can drive either a direct current generator **319** or an alternating current generator **320**. If the generator is a direct current generator, the output is filtered though filter **321** and delivered to the direct current voltage-to-resistance converter **322**. If an alternating current generator **320** is used, the output of the generator is fed to a rectifier and filter shown at **323**, and this output is then delivered to the direct current voltage-to-resistance converter at **322**. This converter **322** is designed to convert increasing direct current input voltage into a decreasing output resistance and is connected through terminals **81** and **82**, shown at the upper middle portion of FIG. 2, in the outer lamp pulse circuits **27**, previously described.

Referring to FIG. 5, one form of the voltage-to-resistance converter **322** is shown and the circuit arrangement is such that there is a linear decrease in the output resistance to terminals **81** and **82** with a linear increase of the input voltage delivered by the axle driven generator and applied to the circuit through terminals **324** and **325**. This arrangement includes the galvanometer movement **326** which is connected to terminals **324** and **325**. This galvanometer movement is mechanically coupled to a linear taper potentiometer **327**, and potentiometer **327** is connected to terminals **81** and **82**. This type of converter can be used to provide means so that the timing device has a total timing period which charges in inverse proportion with an increasing locomotive or train velocity. Thus, for example, at higher speeds the locomotive engineer would be required to acknowledge the timing device at more frequent intervals than at lower speeds of the locomotive.

Referring to FIG. 6 of the drawings, another form of converter is shown, and this converter provides a non-linear decrease of output resistance with a linear increase of input voltage. The input voltage is fed to an incandescent lamp **328** from the axle driven generator through terminals **329** and **330**. The lamp **328** is associated with a photoresistor **331** and the photoresistor **331** is connected to terminals **81** and **82**. As the lamp output increases with increased voltage, the resistance of the photoresistor **331** decreases in a non-linear manner. This type of non-linear voltage-to-resistance converter can be used to provide a two-level timing rate for the timing device, as for example, one that operates at one rate below a predetermined locomotive speed, and at another rate above this same speed.

The circuits heretofore described for use in the timing device depend on solid state ring counters and pulse circuits with associated circuits for actuation of the alarms and brake application. These circuits have proved dependable and efficient but the invention is not limited to such electronic circuits. Another form of the invention is shown in FIG. 7 and illustrates the use of a stepping relay to provide for the sequential energization of the lamps **17** and **18** in the inner and outer circle of lamps **15** and **16**, respectively. This stepping relay is under the control of pulse circuits shown on FIG. 7 and the operation of the stepping relay in conjunction with these pulse circuits will now be described.

In order to simplify FIG. 7, only two decks of the stepping relay have been shown and these decks control the energization of lamps **17** and **18**. However, it should be understood that other decks on the stepping relay can be used in an appropriate manner to actuate alarms and the brake solenoid valve associated with the timing device.

Referring now to FIG. 7, deck A of the stepping relay is indicated generally at **332**, and immediately below this deck a second deck B of the relay is indicated generally at **333**. The armature **334** for both decks is shown in dashed lines and is associated with the stepping relay coil **335** and with interrupting contact **336**. The armature **334** carries contacts **337** and **338** which are associated with the stationary contacts **339** and **340** of decks A and B, respectively, in the stepping relay. Each of the decks A and B have twenty-four stationary contacts **339** and **340**, respectively, but it should be understood that the number of contacts can be chosen to provide for any desired number of lamps **17** and **18**.

Each contact **339** in deck A is connected to one side of any associated lamp **18** and each lamp has its other side connected to the negative terminal of the power supply. The positive terminal of the power supply is connected to contacts **337** and **338** on the armature. In order to simplify this figure, the circuits have been broken as indicated between the lamps three and ten in deck A and in deck B. As thus shown, the lamp **18** adjacent the negative terminal of the power supply in deck A is the twelfth lamp **18** in the outer circle of lamps **16**. The remaining contacts **339** to the right of this lamp, namely the thirteenth through the twenty-fourth contact, are not all shown but the circuits have been broken between lamps fourteen and twenty-three in both deck A and deck B. The thirteenth through the twenty-fourth contacts **339** in deck A are connected to the first through twelfth contacts, respectively, in this deck so that as the armature contact **337** moves across the complete set of contacts **339**, each of the individual lamps **18** in the outer circle of lamps **16** will be energized twice.

Deck B differs from deck A only in that each lamp **17** is connected to two adjacent contacts **340** so that as the contact **338** on armature **334** is progressively moved along through the action of the stepping relay coil **335**, two lamps **18** will be energized for each lamp **17** that is energized. Thus, it is apparent that the sequential energization of lamps in the outer circle of lamps **16** will be at twice the rate as that of the lamps in the inner circle of lamps **15** in the manner previously described.

The stepping relay coil **335** is tied in parallel with an inductive surge protection diode **341** and the capacitor **342**. These three elements are connected in series with the stepping relay interrupting contact **336** and between the cathode of silicon controlled rectifier **343** and the negative terminal of the power supply. The anode of this silicon controlled rectifier is connected to the positive terminal of the power supply and to one side of resistor **344**. The gate of the silicon controlled rectifier **343** is connected to one side of a resistor **345** and to the cathode of diode **346**. The other side of the resistor **345** is connected to the cathode of the rectifier **343** and to one side of the secondary winding of the pulse transformer **347**. The anode of diode **346** is connected to the other side of the secondary winding of this transformer.

Resistor **344** is connected to one side of resistor **348** and to one side of potentiometer **349**. The other side of resistor **348** is connected to base two of unijunction pulse transistor **350** and base one of this transistor is connected to one side of the primary winding of the pulse transformer **347**. The other side of this primary winding is connected to the negative terminal of the power supply. Resistor **351** and capacitor **352** are connected in series between one side of the potentiometer **349** and the negative terminal of the power supply. The emitter of the transistor **350** is connected between resistor **351** and capacitor **352**. A zener diode **353** is connected between one side of resistor **344** and the negative terminal of the power supply.

The stepping relay as shown in FIG. 7 of the drawings operates in the following manner. The silicon controlled rectifier 343 in this application is a relay control device. The silicon controlled rectifier is normally non-conducting but when its gate circuit is pulsed by means of appropriate positive timing pulses from pulse transformer 347 via the diode 346, the silicon controlled rectifier goes into conduction and allows current to flow through the stepping relay coil 335. As this coil acts to advance the relay armature 334 to the next contact positions, it also momentarily opens the normally closed interrupting contacts 336. This reduces the anode to cathode current flow through the silicon controlled rectifier 343 to zero so that this rectifier reverts to its original non-conducting state and thus terminates the cycle of events until the receipt of the next positive timing pulse at some later time.

Positive timing pulses in the pulse transformer 347 are controlled through the action of the unijunction pulse transistor 350. When power is applied to the circuits of the device the capacitor 352 starts to charge up through potentiometer 349 and resistor 351. As the capacitor 352 charges up it reaches a proper firing potential so that the unijunction transistor 350 goes into conduction and the capacitor 352 is discharged through this transistor and through the primary winding of the pulse transformer 347. This causes a positive pulse of the proper amplitude and time duration to be generated in the secondary winding of the pulse transformer 347. This pulse is then applied to the gate of the silicon controlled rectifier 343 as previously mentioned. Upon the completion of the discharge of the capacitor 352 through the unijunction transistor 350, this unijunction transistor becomes non-conducting and the timing cycle starts over again. The net result of this sequence of events is the periodic production of timing pulses from the pulse transformer 347 which serves to advance the stepping relay armature to the next contact position.

While the timing device has been described in conjunction with its use on a railroad locomotive as a safety device, it should be apparent to those skilled in the art that this device can also be readily adapted for industrial uses. There are many situations in the various fields of industry where a human operator controls or supervises the operation of numerous machines or processes, and the success of these operations depends ultimately on the fact that such operator is alert and is following the operations carefully. In order to provide means whereby these operations can be controlled in the event that the human operator is not alert or is incapacitated, the timing device described herein can be used as a safety device in conjunction with such operations in a very effective manner. Moreover, this timing device is arranged and constructed in such a manner that it cannot be easily tampered with or rendered ineffective to accomplish its function as a safety device.

Two embodiments of the timing device have been shown and either embodiment is designed to function effectively in any field where there is a need for such a safety device. The embodment of the device shown in FIGS. 1, 2 and 3 of the drawings utilizes solid state components. This particular construction has many advantages such as compactness, durability, low electrical current consumption, and low maintenance costs due in part to the fact that there are few moving parts in the device. However, such a device also involves a relatively large initial investment and therefore the second embodiment of the device which uses a stepping relay and is shown in FIG. 7 of the drawings has been disclosed as an example of a relatively less expensive device.

While, as indicated in the preceding paragraph, the choice of the particular embodiment of the timing device will necessarily depend on economic considerations and other factors, it should be apparent that either embodiment of the timing device provides a reliable safety aid which can be used to advantage in many situations in the fields of transportation and industry.

The invention is not restricted to the details of the illustrated and described embodiments but is susceptible

to modifications and adaptations which will occur to those skilled in the art.

We claim:

1. In a timing device, visual display means including two separate series of electrical lamps, first and second circuit means adapted to sequentially energize and de-energize each lamp in the first and second series respectively, said first and said second circuit means being so synchronized that the lamps in one series are thereby sequentially illuminated at a rate different from that of the other series, a third circuit means associated with said first and second circuit means and effective to energize signal means when the complete set of lamps in one series has been illuminated a predetermined number of times more than the complete set of lamps in the other series, fourth circuit means effective a predetermined time after said signal means are energized to energize a second signal means, manually operated means associated with the circuits of the timing device to reinitiate the simultaneous commencement of the sequential energization of the lamps in each of the two series and de-energize said signal means at any time prior to the energization of the said second signal means.

2. A timing device as set forth in claim 1 wherein additional circuit means are connected between said first circuit means and said second circuit means, said additional circuit means being effective to prevent more than one cycle of lamp illuminations in one series unless there has been a predetermined number of lamp illuminations in the other series.

3. A timing device as recited in claim 1 wherein means are associated with said first circuit means and said second circuit means to adjust the relative rates at which said lamps are energized and de-energized in said first and second series of lamps.

4. A timing device as defined in claim 1 wherein there is a second manually operated means effective when operated to reinitiate the simultaneous commencement of the sequential energization of the lamps in each of the two series and to de-energize said additional signal means.

5. A timing device as recited in claim 1 wherein additional circuit means are associated with each lamp to permit the device to continue to operate in the event of a failure of any lamp in either series.

6. The timing device as set forth in claim 1 wherein there is another means associated with said fourth circuit means to de-energize said signal means when said second signal means is energized.

7. A timing device for use on a railroad locomotive including a visual display panel, said panel having a plurality of series of electrical lamps, circuit means adapted to sequentially illuminate the lamps of each series at different rates, additional circuit means effective to energize first signal means at a time when both lamp series simultaneously complete their respective cycles wherein each of the lamps in the series has been illuminated and extinguished, a circuit means associated with said additional circuit means and effective to energize second signal means at a predetermined time after the operation of said first signal means, means operable by the locomotive operator to reinitiate the sequential lamp illumination cycle in each series so as to prevent the operation of said first signal means or said second signal means.

8. The timing device as recited in claim 7 wherein additional means are provided whereby the rates at which the lamps are illuminated can be adjusted.

9. The timing device as in claim 8 wherein said additional means includes means responsive to the speed of the locomotive.

10. A timing device as in claim 7 wherein other means operable by the locomotive engineer are provided to de-energize the second signal means and reinitiate the si-

multaneous commencement of the sequential energization of the lamps in the two series.

11. A timing device as set forth in claim **7** wherein said second signal means includes an audible signal together with circuits designed to operate valve means in the air brake system of the locomotive to apply the brakes when said second signal means is energized.

12. A timing device as recited in claim **11** including electrical switch means in the air brake system, said electrical switch means being associated with said first and second circuit means whereby the sequential illumination of the lamps in the plurality of series of lamps is halted when brake application is manually initiated from the locomotive cab, said electrical switch means being effective to permit a continued sequential illumination of said lamps in each series when the locomotive brakes are subsequently released.

13. An electronically controlled timing device including a source of electrical energy operatively connected to a first series of lamps and a second series of lamps, solid state electronic lamp pulse circuit means and solid state electronic ring counter circuit means associated with said first series of lamps, solid state electronic lamp pulse circuit means and solid state electronic ring counter circuit means associated with said second series of lamps to sequentially energize and de-energize each lamp in each of said series in a predetermined time sequence, in combination with circuit means to energize a warning signal after a predetermined number of cycles of lamp energization in each of said series, and manually operated means associated with the circuits of the timing device to reinitiate the simultaneous commencement of the sequential energization of the lamps in each of the series.

14. A timing device as set forth in claim **13** wherein additional circuit means are associated with the circuit means for energizing a warning signal to energize a second signal a predetermined time after the energization of said warning signal if the said manually operated means has not been actuated to reinitiate the sequential energization of the lamps.

15. The timing device recited by claim **14** installed on a locomotive wherein said additional circuit means effect a brake application after said predetermined period of time in the absence of an actuation of said manually operated means to reinitiate the simultaneous commencement of the sequential energization of the respective lamps in each of the series.

16. The combination defined by claim **15** which includes means responsive to the speed of the locomotive for controlling the rate at which the lamps are energized in each of said series of lamps.

No references cited.

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UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,312,508 April 4, 1967

William M. Keller et al.

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 10, line 16, for "140, 142 and 142" read -- 140, 141 and 142 --; line 49, for "resistor 159" read -- resistor 149 --; column 11, line 55, for "brake system air system air pressure" read -- brake system air pressure --; column 13, line 1, for "capaictor" read -- capacitor --; column 16, lines 67 through 69, for "the diode 182 to remain reverse biased and, although turn on Under these conditions, silicon controlled rectifier 168 will not turn on." read -- of diode 182, the silicon controlled rectifier 168 will not turn on. --; column 19, line 30, for "ararngements" read -- arrangements --; line 49, for "voltages" read -- voltage --; column 20, line 31, for "potential," read -- potentia --; column 22, line 64, for "capacitor 251" read -- capacitor 252 --; column 23, line 36, for "rectified" read -- rectifier --; column 24, line 26, for "lamps" read -- lamp --; line 65, for "counter" read -- counters --; column 25, line 39, for "charges" read -- changes --; column 27, line 56, for "embodment" read -- embodiment --.

Signed and sealed this 7th day of November 1967.

(SEAL)
Attest:

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