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FIG. 1.

The diagram illustrates a two-channel system. On the left, a vertical structure labeled 13 contains two input ports, LP1 and LP2. On the right, a vertical structure labeled 14 contains two output ports, PC1 and PC2. Two horizontal lines connect the inputs to the outputs: the top line is labeled 15 and connects LP1 to PC1; the bottom line is labeled 16 and connects LP2 to PC2. A curved arrow labeled 11 points to the line between LP2 and PC2.

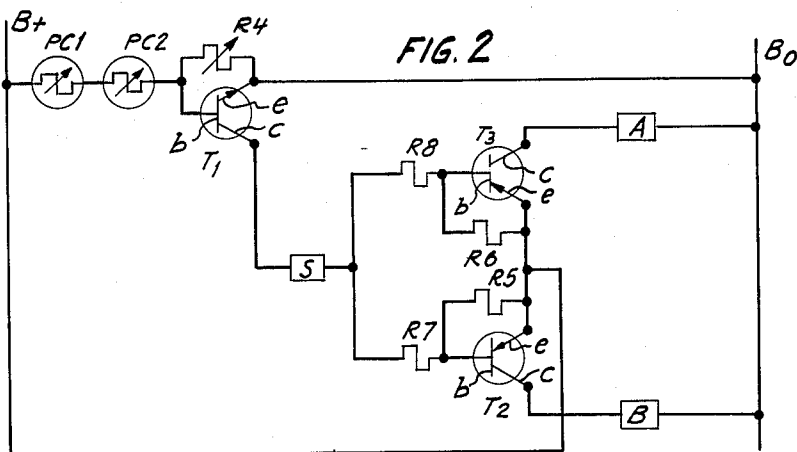


FIG. 3.

The schematic diagram (FIG. 3) illustrates a control circuit. It features a power supply $B+$ connected to a network of relays and switches. The circuit includes relays $C1$, $C2$, $CX1$, C , CX , and $C4$, switches $K5$ and PB , and a solenoid $S1$. The circuit is connected to a common return $B0$. The diagram shows the following components and connections: $B+$ is connected to $C1$, which leads to a parallel combination of $LP1$ and $LP2$. $C1$ also leads to $C2$. $C2$ leads to $CX1$, which then leads to C . C also leads to PB . $C2$ also leads to a parallel combination of $A1$ and $S1$. $A1$ leads to $B1$, which leads to CX . $S1$ leads to $A2$, which leads to $B2$, which leads to CX . $K5$ is connected to $C3$, which leads to CX . $C4$ is connected to PB and $B0$. All components are connected to a common return $B0$.

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March 22, 1966

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ELECTRICAL SAFETY CONTROL

3,242,341

Filed June 10, 1965

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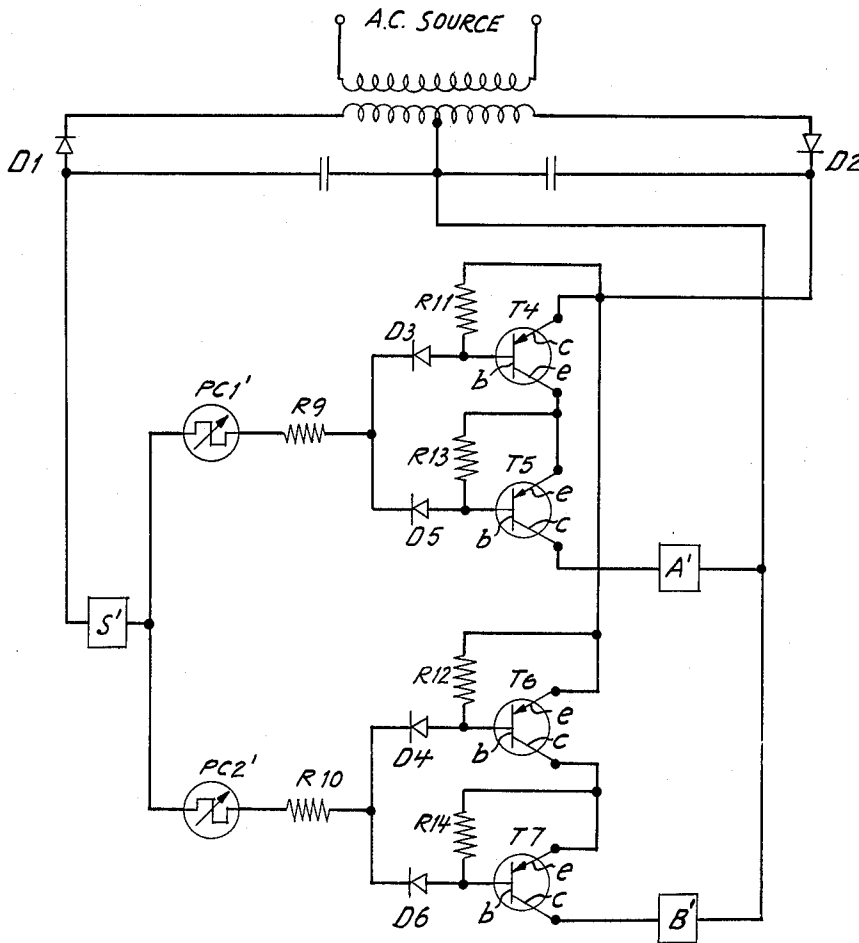


FIG. 4.

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ELECTRICAL SAFETY CONTROL

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Filed June 10, 1965, Ser. No. 463,000

10 Claims. (Cl. 250—221)

The invention relates to electrical safety control mechanisms responsive to the presence of physical objects within a predetermined guarded area, and is a continuation-in-part of my copending application Serial Number 165,995, filed January 9, 1962, now abandoned.

It is common present day practice to utilize a power driven conveyor mechanism to transport articles, upon which work operations are to be performed, from and to a work area. In certain such installations, the articles are removably secured to the conveyor mechanism the movement of which is under the control of an operator. Mechanical shields are normally provided along substantially the entire path of travel of such a conveyor mechanism in order to physically prevent obstructions from being inadvertently placed into the path of travel of the conveyor mechanism and the work articles carried thereby to obviate damage to either and to the obstruction. However, when the conveyor is not in motion, it is desirable to provide access at the work area to the articles being conveyed without necessitating the prior removal of a mechanical shield and its subsequent replacement into guarding position. It is also desirable, while providing such free access at such work area, to detect, under conditions where the conveyor mechanism is in motion, the movement of any potentially obstructing object into such work area.

In the prior art, various safety controls utilizing detecting mechanisms of either the mechanically actuated or electrically operating type have been provided and arranged to operate in response to detection of an obstructing object in the area being guarded from a first condition to a second condition to stop the conveyor mechanism. However, in order properly to protect the transported articles and conveyor mechanism from damage by obstructing objects and obviate injuring such interfering objects, as for example, the operator's arm, it is desirable that failure of the safety control or malfunction of its circuit components results in the control being operated to the condition which effects stopping of the conveyor mechanism, notwithstanding that the path of travel of such conveyor mechanism is then unobstructed. Such operation of a safety control may be termed "fail safe" operation. In addition, it is also desirable to arrange such safety controls to indicate malfunctions of its own circuit components and prevent restarting of the conveyor mechanism until such malfunctions have been remedied.

It is therefore an object of this invention to provide an improved electrical safety control for detecting obstructing objects in a predetermined guarded area.

A further object is to provide an improved electrical safety control which, in the absence of detection of obstructing objects, is operable from a first certain to a second certain control condition and, in response to such detection, automatically operates back to such first certain control condition.

Another object is to provide an electrical safety control for guarding a predetermined area by detecting and responding to the presence of obstructing objects in such area and, in addition, indicating malfunctions of its own circuit components.

Still another object is to provide such an electrical safety control which, in addition to indicating malfunc-

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tions of its own circuit components, prevents reactivation of the control until such malfunctions are remedied.

The invention contemplates providing an electrical safety control which utilizes object detecting means for an area to be protected, which detecting means are adapted for detecting obstructing objects within such area. In the absence of such a detection, the detection means produce a signal in an electrical circuit, which signal is amplified and utilized thereby to allow the actuation of main control means from a first certain condition to a second certain condition. Upon detection of an obstructing object, the main control means automatically are actuated back to first certain condition. The signal amplifying and utilizing circuit arrangement of one embodiment is such that any malfunction of the electrical circuit components, including the circuit wiring, results in the control being actuated back to its first certain condition.

In carrying out the invention, according to such embodiment, which will be described in detail hereinafter, two transmitters of radiant energy are mounted at one side of an entranceway to a work area in position to project two beams of radiant energy across such entranceway and upon corresponding receivers mounted at the opposite side thereof. The transmitters and receivers are mounted in such fashion that a physical object positioned or moving into such entranceway must interrupt either or both energy beams and normally interrupts both.

Under conditions where the respective beams are unobstructed, each of the receivers produces an individual signal in a first stage of an electrical control circuit. Such first stage is arranged to respond to the simultaneous presence of both input signals by producing a signal amplified output signal. This amplified output signal is applied simultaneously to two electrically isolated output amplifier stages which independently respond thereto. The output amplifier stages, therefore, are individually responsive to the simultaneous presence of both the receiver input signals, and, in turn, to interruption of either of the energy beams.

A main control is provided and is arranged to respond to the simultaneous presence of the individual amplified output signals from both of the second stage amplifiers to operate from a first certain to a second certain condition, indicating that the work area is presently clear of obstructing objects. Under conditions where either or both the receiver input signals are not simultaneously present, or both the second stage output signals are not simultaneously present, the main control is automatically actuated back to its first certain condition, signifying that an obstructing object is present in the work area, notwithstanding that such may not be the case. The circuit arrangement is such that failure of either of the radiant energy transmitters or their associated receivers, or an open circuit in the control circuitry results in the main control being actuated to its first condition, indicating that an obstruction has been detected. In addition, various possible malfunctions of the electrical components of the first and second stage amplifiers causes the control to operate back to its first condition. This is accomplished by the provision of supervisory means in the amplifier circuits, which means responds to certain "short circuits" thereof, and is also effective to prevent reactivation of the main control to its second certain condition, until the fault has been remedied.

Features and advantages of the invention will be seen from the above, from the following description when considered in conjunction with the drawings, and from the appended claims.

In the drawings:

FIGURE 1 is a schematic representation of an entrance-

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way with two object detectors of the radiant energy beam type mounted in position to detect objects standing in or passing through the entranceway;

FIGURE 2 is a simplified schematic wiring diagram of a portion of one embodiment of the subject electrical safety control with the circuits arranged in "across-the-line" form;

FIGURE 3 is a simplified schematic wiring diagram of the remaining portion of the electrical safety control shown in FIGURE 2 also with the circuits arranged in "across-the-line" form; and

FIGURE 4 is a simplified schematic wiring diagram of a portion of another embodiment of the subject electrical safety control.

For convenience, the invention will be described as an electrical safety control for a power driven conveyor of work articles for detecting and indicating the presence of physical objects in an entranceway or access way to the path of travel of such conveyor, and as utilizing two object detecting mechanisms mounted in such entranceway; it being understood that without departing from the scope of the invention only one, or more than two, detecting mechanisms may be provided and the subject control used wherever it is desired to detect and indicate the presence of physical objects in a given area; the physical dimensions of the area to be guarded dictating the number of object detecting mechanisms of a particular type which must be actually utilized in a given installation for proper protection.

Referring to FIGURE 1, two radiant energy transmitters LP1, LP2 are mounted on entranceway structure 13 at one side of an entranceway, generally designated 11, in position to project their respective energy beams 15, 16 across entranceway 11 and onto oppositely disposed corresponding receivers PC1, PC2 mounted on entranceway structure 14. Radiant energy transmitters LP1, LP2 are indicated in the circuitry of FIGURE 3 as being two incandescent lamps bearing the same letter and numeral designations, while their corresponding radiant energy receivers PC1, PC2 are similarly indicated in the circuitry of FIGURE 2 as being photoconductive cells of the RCA 7412 type; it being understood that appropriate optical systems (not shown) are provided for focusing light rays generated by lamps LP1, LP2 onto light sensitive areas of their corresponding photoconductive cells PC1, PC2 which are excited thereby. Cells PC1, PC2, when unexcited by light energy, characteristically exhibit a relatively high resistive impedance to current flow, which impedance quickly and substantially decreases whenever the cells are sufficiently excited by light energy. Such substantial impedance reduction is maintained so long as sufficient excitation of the cells persists.

Unidirectional power from any suitable source (not shown) is supplied over supply line B+, Bo to the circuitry of FIGURES 2 and 3.

Electromagnetic switches employed in one embodiment of the electrical safety control are designated: first detector switch A, second detector switch B, supervisory switch S, main control switch C and auxiliary main control switch CX. In the wiring diagrams, the foregoing identifying letters are applied to the coils of the electromagnetic switches, and, with reference numerals appended thereto, are applied to the contacts of the switches to differentiate between different sets of contacts on the same switch; all contacts being shown for the unoperated condition of the switches.

In the circuitry of FIGURE 3, KS designates a manually operated switch of the knife switch type, while PB designates a push button type switch, spring biased to normally open condition.

The circuitry of FIGURE 2 basically comprises a two stage direct resistance coupled amplifier arranged to provide two independent amplified signal outputs in response to simultaneous excitation of both photoconductive cells PC1, PC2 by light beams 15, 16 of FIGURE 1. An

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NPN transistor T1 is provided in the first stage of the amplifier and, in the second stage, two complementary PNP transistors T2, T3 are utilized; each of such transistors having base *b*, emitter *e* and collector *c* electrodes. In one tested embodiment of the amplifier satisfactory operation has been obtained by using a RCA 2N35 transistor for T1, and RCA 2N109 transistors for T2 and T3.

Base electrode *b* of transistor T1 is connected through series connected photoconductive cells PC1, PC2 to supply line B+, and through adjustable biasing resistor R4 to its emitter electrode *e* and supply line Bo. Collector electrode *c* of transistor T1 is connected through coil S of the supervisory switch to the respective base electrodes *b* of output stage transistors T2, T3 by means of coupling resistors R7, R8, respectively. Coupling resistors R7, R8 are selected of equal and sufficient ohmic value to apply the amplified output signal from the first stage amplifier equally to second stage transistors T2, T3, while effectively isolating the output transistor circuits one from the other.

The respective emitter electrodes *e* of transistors T2, T3 are connected to their corresponding base electrode *b* by biasing resistors R5, R6, respectively, and in common directly to supply line B+. The respective collector electrodes *c* of transistors T2, T3 are connected to supply line Bo through coil B of the first detector switch and coil A of the second detector switch, respectively.

In order to describe the operation of the subject safety control mechanism, assume that power is applied over supply lines B+, Bo to the circuitry of FIGURES 2 and 3. Under such conditions, lamps LP1, LP2 (FIGURE 3) are in extinguished condition, and photoconductive cells PC1, PC2 (FIGURE 2) present a relatively high resistive impedance to current flow in the base circuit of first stage transistor T1, which impedance is conjunction with the nonconducting bias applied to base electrode *b* through biasing resistor R4 from supply line Bo is sufficient to maintain transistor T1 in nonconducting condition. Also assume that adjustable biasing resistor R4 is adjusted to a certain ohmic value such that, under conditions where transistor T1 is caused to conduct through its emitter-collector circuit, as will be described hereinafter, the collector current is of a certain magnitude, say of approximately 2 milliamperes, for purposes to be explained hereinafter.

Also assume that biasing resistors R5, R6 of transistors T2, T3, respectively, are selected of such ohmic value that, in the absence of an amplified signal to their respective base circuits from first stage transistor T1, they are biased to nonconducting condition from supply line B+.

Next assume that the entranceway is clear of any obstructing objects, and the operator depresses push button switch PB (FIGURE 3) to closed condition, completing a circuit for coil C of the main control switch; the circuit extending from supply line B+ through contacts B1, A1, S1 and CX1 (all presently engaged), coil C and push button PB to supply line Bo. Switch C operates, engaging its self-holding contacts C2, C4, enabling the operator to release push button PB which, under the influence of its biasing spring (not shown), returns to open condition. Switch C also engages its contacts C1, completing an energizing circuit for lamps LP1, LP2 which illuminate, projecting light beams 15, 16 (FIGURE 1) onto photoconductive cells PC1, PC2 respectively, thereby exciting such cells. Control switch C, in addition, engages its contacts C3 (FIGURE 3), preparing a circuit for coil CX of the auxiliary main control switch, for purposes to be explained hereinafter.

Such simultaneous excitation of both photoconductive cells PC1, PC2 and the consequent relatively substantial reduction of their respective characteristically high resistance impedance reduces the impedance to current flow in the base circuit of transistor T1 sufficiently to cause such transistor to conduct current through its base-emitter cir-

cuit, and, in turn, cause a greater conduction of current (of the aforementioned assumed 2 milliamperes magnitude) through its emitter-collector circuit; the latter circuit extending from supply line B+ through the parallel emitter-base circuits of transistor T2, T3, respectively, coil S of the supervisory switch and through the collector-emitter circuit of transistor T1 to supply line B0.

Supervisory switch S is selected so as to be insufficiently energized for operation by the flow of current of such magnitude through its coil, and therefore remains in released condition. For purposes to be explained hereinafter, switch S is selected so as to operate only under conditions where it is energized a substantially greater amount, say by a current flow through its coil in excess of 10 milliamperes, which current was found to yield the desired operation in one tested embodiment. However, the aforementioned current conduction through the respective emitter-base circuits of transistors T2, T3 causes correspondingly larger currents to flow in their respective collector-emitter circuits (extending through coils B and A), and is of sufficient magnitude to cause output transistors T2, T3 to conduct at saturation.

In recapitulation, the circuit components are selected so that, under conditions where both photoconductive cells PC1, PC2 are simultaneously excited a predetermined amount, current of insufficient magnitude to cause operation of switch S flows in the collector-emitter circuit of transistor T1, but of sufficient magnitude to cause output transistors T2, T3 to be driven to saturation.

With saturation current flowing through the respective emitter-collector circuits of transistors T2, T3, it may be noted, for purposes to be explained hereinafter, that substantially negligible impedance, approximating a "short circuit" condition, appears across their respective emitter-collector electrodes. First detector switch A and second detector switch B are selected so as to operate under conditions where saturation current flows in the emitter-collector circuits of their respective transistors T3, T2 and, consequently, through their associated energizing coils. Therefore, upon sufficient simultaneous excitation of photoconductive cells PC1, PC2 and the consequent conduction at saturation of transistors T2, T3, both switches A and B operate, engaging their respective contacts A2, B2 (FIGURE 3) and separating their respective contacts A1, B1 in the circuit of main control switch C, thereby indicating that entranceway 11 (FIGURE 1), adjacent to the path of travel of the conveyor mechanism (not shown) is clear of obstructing objects.

Next assume that the operator closes manual switch KS (FIGURE 3), completing the previously prepared circuit for coil CX of the auxiliary main control switch through presently engaged contacts C3 of the main control switch. Switch CX, upon operation, separates its contact CX1 but without effect, since the holding circuit for coil C is maintained presently engaged contacts A2, B2.

Operation of auxiliary main control switch CX may be utilized, in any well known manner, to effect energization of motive mechanism (not shown) for driving the aforementioned work conveyor mechanism. Release of auxiliary main control switch CX may likewise be utilized, in any well known manner, to effect stopping of the power driven work conveyor mechanism.

Next assume that, with the conveyor mechanism in motion and the object detecting mechanism in operation, guarding entranceway 11 from potentially obstructing objects, an interfering object interrupts light beam 16 of photoconductive cell PC2. Such interruption of light beam 16 removes the excitation from photoconductive cell PC2, causing it to substantially increase the resistive impedance in the base-emitter circuit of transistor T1. This relatively substantial increase in resistive impedance is sufficient to cause current conduction in the collector-emitter circuit of transistor T1 to be reduced to substantially zero, removing the "conduct" signal applied to the

respective emitter-base circuits of output transistors T2, T3, thereby, in turn, causing them to be returned to nonconducting condition by the nonconducting bias applied to their respective base electrodes b through their associated biasing resistors R5, R6 from supply line B+. As current through the collector-emitter circuits of output transistors T2, T3 falls below saturation value, switches B and A return to released condition.

First detector switch A and second detector switch B, upon releasing, separate their respective contacts A2, B2, (FIGURE 3), interrupting the circuit through coil C of the main control switch, and reengage their respective contacts B1, A1, without effect at this time. Switch C releases, separating its self-holding contacts C2, C4, in preparation for subsequent operations, and its contacts C1, interrupting the circuits for lamps LP1, LP2 which deenergize and extinguish. Lamps LP1, LP2, upon extinguishing, remove excitation beams 15, 16 (FIGURE 1) from photoconductive cells PC1, PC2. Control switch C, in addition, separates its contacts C3, interrupting the circuit for coil CX of the auxiliary main control switch which releases, stopping the conveyor mechanism to obviate impact between the conveyor mechanism or the work articles carried thereby with the obstructing object.

In order to reactivate the safety control and conveyor mechanism, the operator must reopen knife switch KS and then depress push button PB to reenergize control switch C through contacts B1, A1, S1 and CX1. Control switch C, upon operation, reengages its contacts C1, reactivating lamps LP1, LP2, and its self-holding contacts C2, C4. Switch C also reengages its contacts C3, preparing an energizing circuit for coil CX of the auxiliary main control switch for restarting movement of the conveyor mechanism upon subsequent reclosing of knife switch KS.

Next assume that light beam 16 (FIGURE 1), is still obstructed, causing photoconductive cell PC2 to remain in unexcited condition. Under such circumstances, transistors T1, T2 and T3 (FIGURE 2) remain in nonconducting condition and output switches A, B remain in released condition, maintaining their respective contacts A2, B2 (FIGURE 3) separated. Next assume that switch KS is closed, causing switch CX to operate and separate its contacts CX1, thereby interrupting the self-holding circuit for coil C of the main control switch which releases. Switch C separates its contacts C3, interrupting the circuit for coil CX of the auxiliary main control switch to prevent movement of the conveyor mechanism. It is thus seen that the subject electrical control allows the conveyor mechanism to be reactivated only under conditions where, when knife switch KS is reclosed, contacts A2, B2 of the first and second detector switches, respectively, are engaged, indicating that the entranceway is presently clear of obstructing objects.

It is also seen that both photoconductive cells PC1, PC2, must be sufficiently excited by light simultaneously in order to cause output switches A, B to operate and allow the conveyor mechanism to be put into motion. Stated in another manner, it is necessary only to block either one of beams 15, 16, thereby removing excitation from one of photoconductive cells PC1, PC2 to raise the resistive impedance of the base circuit of transistor T1 sufficiently to cause the deenergization and release of output relays A, B, and, in turn, stopping and disabling of the conveyor mechanism.

In order to demonstrate the "fail safe" characteristics of the subject safety control mechanism, assume that either one of the light sources LP1, LP2, say LP2, ceases to function. In such a case, excitation is removed from photoconductive cell PC2, resulting in the release of first and second detector switches A, B, and in turn, control switches C and CX to effect stopping of the conveyor mechanism, as has been previously described.

A "fail safe" operation is similarly obtained, under conditions where an "open circuit" occurs in the circuitry

of FIGURE 2 or 3. For example, assume that an "open circuit" occurs in coil S of the supervisory switch. Under such conditions, the emitter to collector path of transistor T1 is interrupted, resulting in output transistors T2, T3 returning to nonconducting condition with the consequent deenergization and release of first and second detector switches A, B, respectively. These detector switches, upon releasing, as has been previously described, cause control switches C and CX to release to extinguish lamps LP1, LP2 and effect stopping of the conveyor mechanism. The same "fail safe" operation is obtained should an "open circuit" occur in the energizing or holding circuits of the coil C of the control switch, or in the circuit of coil CX of the auxiliary main control switch. The safety control also "fails safe" should an "open circuit" occur in the emitter-collector circuits of either of output transistors T2, T3 (FIGURE 2) say, for example, in the circuit of coil A of the first detector switch. In such a case, switch A releases and separates its contacts A2 (FIGURE 3), interrupting the self-holding circuit of coil C of the main control switch to effect, as has been previously described, extinguishment of lamps LP1, LP2 and the release of auxiliary main control switch CX to stop the conveyor mechanism.

To further demonstrate the "fail safe" characteristics of the subject electrical safety control, as for example, in response to "short circuit" type malfunctions which may occur in the circuitry of FIGURES 2 and 3, assume that a "short circuit" occurs between the respective emitter *e* and base *b* electrodes of either of output transistors T2 or T3, say of transistor T3. This causes transistor T3 to be biased from supply line B+ to nonconducting condition, notwithstanding that the entranceway is presently clear of obstructing object. As transistor T3 ceases to conduct through its emitter-collector circuit, extending through coil A of the first detector switch, switch A releases and separates its contacts A2 (FIGURE 3) in the circuit of coil C to effect stopping of the conveyor mechanism, as has been previously described.

Next assume that a "short circuit" occurs between the emitter-base electrodes of transistor T1. In such a case, the transistor becomes biased from supply line B+ to nonconducting condition, removing the amplified signal previously applied through its emitter-collector circuit to the respective base circuits of output transistor T2, T3. This causes the latter transistors, in turn to cease conducting through their respective emitter-collector circuits, causing switches A and B to release and effect stopping of the conveyor mechanism, as has been previously described.

Further assume that either one or both of photoconductive cells PC1, PC2, say cell PC2, becomes "short circuited" to present substantially zero impedance. In such a case, notwithstanding that light excites both photoconductive cells PC1, PC2, the resistive impedance in the base circuit of transistor T1 is reduced to a point where the current conducted in its emitter-collector circuit, extending through coil S of the supervisory switch, increases sufficiently to cause switch S to operate. The supervisory switches utilized in one tested embodiment of the subject control was selected to operate when current in excess of 10 milliamperes flowed through its coil. Switch S upon operation, separates its contacts S1 (FIGURE 3), interrupting the self-holding circuit of coil C of the main control switch; which circuit extends from supply line B+ through contacts C2 (presently engaged), contacts S1, contacts A2 and B2 (both presently engaged, indicating that the entranceway is clear) coil C and contacts C4 (presently engaged) to supply line B-. As has been previously described, switch C, upon releasing extinguishes lamps LP1, LP2 and causes the deenergization and release of auxiliary main control switch CX to effect stopping of the conveyor mechanism. In addition, main control switch C cannot be reenergized to allow restarting of the conveyor mechanism until the

fault has been corrected. This is so, since contacts S1 remain open, preventing completion of the energizing circuit for coil C through contacts B1, A1, CX1, coil C and push button PB.

Likewise, a "short circuit" occurring between the emitter-collector electrodes of transistor T1, or between its base-collector electrodes causes sufficient current to flow in the emitter-collector circuit of transistor T1 and through coil S of the supervisory switch to cause operation of such switch, causing, as has been previously described, stopping of the conveyor mechanism, extinguishment of lamps LP1, LP2, and preventing the subsequent reactivation of the detector and conveyor mechanism until the fault has been corrected. A "short circuit" occurring between the base-collector electrodes of either of output transistors T2, T3, likewise, causes sufficient current flow in the circuit of coil S of the supervisory switch to cause it to operate to stop the conveyor mechanism and extinguish the lamps.

Next assume that a "short circuit" occurs between the emitter-collector electrodes of either of output transistors T2, T3 say, for example, between the emitter-collector electrodes of transistor T2. Under such circumstances, switch B, whose coil is connected in the emitter-collector circuit of transistor T2, remains operated, notwithstanding that excitation is removed from either or both photoconductive cells PC1, PC2 by interruption of their respective energy beams, or otherwise, and the consequent return of transistors T1 and T3 to nonconducting condition. As transistor T3 ceases to conduct, switch A releases, separating its contacts A2 (FIGURE 3) thereby interrupting the circuit for coil C of the main control switch to effect stopping of the conveyor mechanism and extinguishment of the lamps, as has been previously described. In addition, switch A reengages its contacts A1, preparing an energizing circuit for coil C of the main control switch. However, since, as has been stated, switch B is inadvertently maintained in operated condition, its contacts B1 remain separated, preventing completion by means of push button PB of the prepared energizing circuit for coil C of the main control switch and the consequently reactivation of both the conveyor mechanism and the object detecting mechanism, until the fault has been remedied. It may be noted that such a "short circuit" of the emitter-collector electrodes of either of transistors T2 or T3 appears to be normal conduction of the transistors. This is so, since, as has been previously explained, the transistors T2, T3, when both photoconductive cells PC1 and PC2 are fully excited, conduct at saturated current, in which saturated condition the impedance between their respective emitter-collector electrodes are substantially negligible. Therefore, a "short circuit" between such electrodes increases the emitter-collector current only a negligible amount above the normal saturated current.

FIGURE 4 shows a schematic circuit diagram of a portion of a second embodiment of the subject electrical safety control. In carrying out the invention according to such second embodiment (described in detail hereinafter), the circuit shown in FIGURE 4 is interrelated with the circuit arrangement of FIGURE 3 in the same general manner as the FIGURE 2 circuitry is interrelated with the circuit arrangement of FIGURE 3, as described hereinabove with respect to the first embodiment. In the second embodiment, as in the first embodiment, two transmitters of radiant energy are mounted at one side of an entranceway to a work area in position to project two beams of radiant energy across such entranceway and upon corresponding receivers mounted at the opposite sides thereof. The receivers, PC1' and PC2', correspond to receivers PC1 and PC2 and operate in conjunction with radiant energy transmitters LP1 and LP2, shown in FIGURES 1 and 3. It should be noted that although only two transmitter and receiver pairings are illustrated in the second embodiment, the novel control arrangement

lends itself to operation with any number of pairs, as will be evident from the following description. The description is directed to a two pair arrangement to provide an analogy with the first embodiment which shows two pairs and which also lends itself to operation with any number of pairs.

More specifically, the second embodiment is directed to a circuit including detector switches A' and B' and supervisory switch S' which operates in conjunction with the control mechanism components shown in FIGURE 3 in the same logical manner as detector switches A and B, and supervisory switch S, respectively cooperate therewith as discussed hereinabove. The logical operating sequence for the components of FIGURE 3, as described with respect to the first embodiment, also applies to the second embodiment. Further, photoconductive cells PC1' and PC2' function when energized by rays from radiant energy transmitters LP1 and LP2 in the same general manner as photoconductive cells PC1 and PC2 of the first embodiment function when energized by rays from the transmitters. Thus, electromagnetic switches employed in the second embodiment of subject electrical safety control, which are designated as first detector switch A', second detector switch B', supervisory switch S', main control switch C and auxiliary main control switch CX, are distinguished in some instances from the switches of the first embodiment by prime superscripts; however, the same identifying letters without prime superscripts identify the associated contacts shown in FIGURE 3, which identifying letters have reference numerals appended thereto to differentiate between different sets of contacts on the same switch. Therefore, in the second embodiment first detector switch A' has contacts A1 and A2, second detector switch B' has contacts B1 and B2, etc.

The circuitry of FIGURE 4 basically comprises a signal detecting and amplifying circuit for each photoconductive cell employed and which circuitry is arranged to provide simultaneous independent amplified signal outputs in response to excitation of both photoconductive cells (PC1' and PC2') by light beams 15 and 16 (see FIGURE 1). Each signal detector and amplifier includes one stage of amplification having a pair of transistors. The output signal from each signal detector and amplifier is associated with a corresponding output relay (A' and B'), the contacts of which control a motive mechanism in the manner described above with respect to output relays A and B. Referring, for example, to the amplification stage comprising transistors T4 and T5, the components values are selected such that transistors T4 and T5 are biased to saturation when photoconductive cell PC1' is in its excited condition. In one tested arrangement of the second embodiment, amplifier operation has been obtained by using Amperex 2N2429 PNP transistors for T4 and T5 and a collector voltage of approximately 25 volts. Output relay A', connected in the collector circuit as shown, is selected to operate in response to a saturation current of approximately 25 milliamperes, which is determined by the 500 ohm impedance of the energizing coil of relay A' and the substantially "short circuit" saturation condition of transistors T4 and T5. When photoconductive cell PC1' is in its nonexcited state its impedance increases to a level much in excess of that required to provide the signal level necessary to switch transistors, T4 and T5 to a nonconducting stage. Transistors T4 and T5 operate independent of each other by virtue of isolating diodes D3 and D5, thus even if one transistor experiences a short circuit between its collector and emitter electrodes the remaining transistor will continue to operate and only prevent flow in the output relay A' in response to the nonexcited condition of photoconductive cell PC1'.

The amplification stage comprising transistors T6 and T7 is substantially identical to the stage comprising transistors T4 and T5 explained above. When both stages of

amplification are operating in saturation in response to photoconductive cells PC1' and PC2' in their excited state, the simultaneous operation of relays A' and B' permits operation of the motive mechanism. To this end manual switch KS (FIGURE 3) is closed in sequence with the associated logical switching in the same manner as described for the operation of the first embodiment.

Similar to the first embodiment, supervisory switch S' is selected such that it remains in the released condition in response to the flow of current present when the photoconductive cells are not energized. Switch S' operates only under conditions where such current exceeds a predetermined level, e.g., 15 milliamperes was found to yield the desired operation in the abovementioned tested arrangement in which R9 is 470 ohms, R13 is 1000 ohms, and R11 is 235 ohms. Thus, in the event that the current flow through either photoconductive cell (PC1' and PC2') increases to the extent that the current flow through S' exceeds 15 milliamperes, even though all the transistors remain in saturation, supervisory switch S' provides deenergization of the motive mechanism and prevents reenergization of same until the circuit malfunction (e.g. a shorted cell) is corrected and proper current flow is restored.

From the above description of the second embodiment of the instant invention it is seen that certain unique "fail safe" features are demonstrated with respect to the particular controlled mechanism. In addition to those "fail safe" features common to the first embodiment, the second embodiment is specifically concerned with a safe fail condition in which operation is not interrupted by failure of either transistor of each pair. As pointed out above, when a short circuit exists between the emitter and collector electrodes of any transistor, safe operation is maintained by virtue of the supervisory switch and the isolated condition of the remaining transistor in the stage in which failure occurs.

It may thus be seen that the subject electrical safety control utilizes one or more object detecting means to detect the presence of obstructing objects within an area being guarded thereby, and responds to such detection by any one of such detecting means by operating to a certain control condition. In addition, while the safety control is of simple and economical design, it contemplates automatic response to malfunctions of its own circuit components by operating to the aforementioned certain control condition, thereby maximizing its ability to control other mechanisms safely.

As changes can be made in the above described construction and many more apparently different embodiments of this invention can be made without departing from the scope thereof, it is intended that all matter contained in the above description or shown on the accompanying drawing be interpreted as illustrative only and not in a limited sense.

What is claimed is:

1. An electrical control comprising:

- (a) a two stage direct resistance coupled amplifier having a first stage amplifier and at least two electrically isolated independently operating amplifiers in its output stage for producing independent isolated output signals in response to a signal from the first stage amplifier;
- (b) object detecting means responsive to the presence of a physical object within a predetermined guarded area for applying a certain signal as an input to said first stage amplifier when the guarded area is free of objects;
- (c) main control means going from a first to a second control condition responsive to the simultaneous presence of the independent isolated output signals, and in the absence of said simultaneous presence of said independent signals automatically being returned to said first control condition; and

(d) supervisory means connected to the first stage amplifier to actuate said main control means back to said first control condition and preventing actuation of said main control means to said second control condition when the first stage signal exceeds a predetermined amount.

2. An electrical control as set forth in claim 1 wherein said two stage direct resistance coupled amplifier includes a source of unidirectional power having a positive terminal and a negative terminal, an NPN transistor having base, emitter and collector electrodes, a photo-conductive cell having a resistive impedance of a certain ohmic value and adapted when excited by at least a predetermined magnitude of light energy for substantially reducing its resistive impedance, said cell being series connected between said positive terminal and said base electrode of said NPN transistor, the emitter electrode of said NPN transistor being connected directly to said negative terminal and through an adjustable biasing resistor to its associated base electrode, a pair of PNP transistors, each having base, collector and emitter electrodes, the latter being electrically connected to each other and in common to said positive terminal, a pair of biasing resistors, one for each of said PNP transistors connecting the emitter electrode of its associated transistor to its respective base electrode for biasing said transistor to nonconducting condition, a pair of isolating resistors, one for each of said PNP transistors connecting the base electrode of their respective associated transistor to the collector electrode of said NPN transistor, said isolating resistors being of sufficient ohmic value to resistance couple their respective PNP transistors to said NPN transistor while effectively electrically isolating said PNP transistor one from the other, the collector electrodes of said PNP transistors being connected to said negative terminal, said adjustable biasing resistor being adjusted to a certain ohmic value for biasing said NPN transistor to nonconducting condition when said photo-conductive cell is in unexcited condition and for causing, under conditions where said photo-conductive cell is excited by at least predetermined magnitude of light energy, conduction through the emitter-collector circuit of said NPN transistor of an amplified signal of at least a certain magnitude to cause said PNP transistors to conduct saturation current through their respective emitter-collector circuits, and wherein said supervisory means includes an electromagnetic switch having an energizing coil connected in the collector circuit of said NPN transistor, said electromagnetic switch being actuated to operated condition only under conditions where said first stage signal exceeds said predetermined amount.

3. An electrical control as set forth in claim 1 wherein said supervisory means consists of an electromagnetic switch having an energizing coil electrically connected in the common input to said output stage amplifiers from said first stage amplifier, said electromagnetic switch being actuated to operated condition under conditions where said first stage signal passing through said energizing coil exceeds a predetermined magnitude.

4. An electrical control responsive to the presence of physical objects within a certain guarded area, said control comprising:

- (a) input signal producing means having object detecting means for detecting the presence of such objects, said input signal producing means in the absence of such detection producing an input signal of at least a certain magnitude and in the presence of such detection attenuating its input signal to less than certain magnitude;
- (b) at least two independently operating signal producing means for producing independent output signals in response to a signal of at least said certain magnitude from the input signal producing means when the guarded area is free of objects;

(c) main control means going from a first to a second control condition responsive to the simultaneous presence of the independent output signals, and in the absence of said simultaneous presence of said independent signals automatically being returned to said first control condition; and

(d) supervisory means connected to the input signal producing means to actuate said main control means back to said first control condition and preventing actuation of said main control means to said second control condition when the input signal exceeds said certain magnitude by at least a predetermined amount.

5. An electrical control as set forth in claim 4 wherein said input signal producing means includes at least two object detecting means for individually detecting the presence of said objects.

6. An electrical control responsive to the presence of physical objects within a certain guarded area, said control comprising:

- (a) input means including object detecting means for detecting the presence of such objects, said object detecting means including at least two radiant energy transmitters mounted at one side of said guarded area in position to project beams of radiant energy across said guarded area to the opposite side thereof and at least two corresponding radiant energy receivers mounted at the opposite sides in alignment respectively with said transmitted beams of energy and responsive thereto for operation from an unexcited state to an excited state;
- (b) at least two independently operating signal producing means connected to said input means for producing independent output signals in response to a certain signal level present when said radiant energy receivers are in the excited state;
- (c) main control means going from a first to a second control condition responsive to the simultaneous presence of said independent output signals, and in the absence of said simultaneous presence of said independent signals automatically being returned to said first control condition; and
- (d) supervisory means connected to the input means to actuate said main control means back to said first control condition and preventing actuation of said main control to said second control condition when the input signal level exceeds said certain level by at least a predetermined amount.

7. An electrical control as set forth in claim 6 wherein said supervisory means consists of an electromagnetic switch having an energizing coil electrically connected to a parallel circuit arrangement having branches which each includes a radiant energy receiver connected in series with an independently operating signal producing means.

8. An electrical control as set forth in claim 6 wherein each independently operating signal producing means includes two series connected signal amplifiers having input signal terminals, isolation means connected to each input signal terminal for electrically isolating each from the other, and a common input terminal connected to said isolation means, said common input terminal connected in series with a radiant energy receiver and said supervisory means.

9. An electrical control comprising:

- (a) a source of unidirectional power;
- (b) input means including a common terminal and a plurality of photoconductive cells each having a certain ohmic value in its unexcited condition and adapted when excited by a predetermined magnitude of light energy for reducing its resistance to a predetermined value, said photoconductive cells being connected to said common terminal;
- (c) a plurality of radiant energy transmitters each associated with a particular photoconductive cell and adapted for energization by said power source;

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- (d) independently operating signal producing means connected in series with each photoconductive cell for producing an output signal when the associated photoconductive cell is in its excited condition;
- (e) control means comprising an electromagnetic switch having an energizing coil connected to the output of each independently operating signal producing means, said control means adapted to deactuate said source of power in the absence of said output signal; and
- (f) supervisory means comprising an electromagnetic switch having an energizing coil connected to the common input terminal in series with said photoconductive cells for monitoring the presence of a predetermined input signal level and preventing energization by said source of power when said level is exceeded.

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- 10. An electrical control as set forth in claim 9 wherein said independently operating signal producing means includes; two transistors in which the emitter of one is connected to the collector of the other, means for biasing both transistors to operate in saturation, isolation means for connecting the bases of said transistors to said common input terminal, said isolation means including diodes for isolating one base from the other, and means for connecting the associated energizing coil of said control means in series with said transistors for energization when saturation current flows through both of said transistors.

No references cited.

- 15 RALPH G. NILSON, *Primary Examiner.*