United States Patent

Macdonald

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[54] **SAFETY DEVICE FOR MACHINES**

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[52] **U.S. Cl.** **317/124,** 250/220, 250/221, 317/127

[51] **Int. Cl.**.....**G02f 1/28**

[58] **Field of Search** .....317/124, 127; 250/220, 221; 340/258 R, 258 B

[56] **References Cited**

UNITED STATES PATENTS

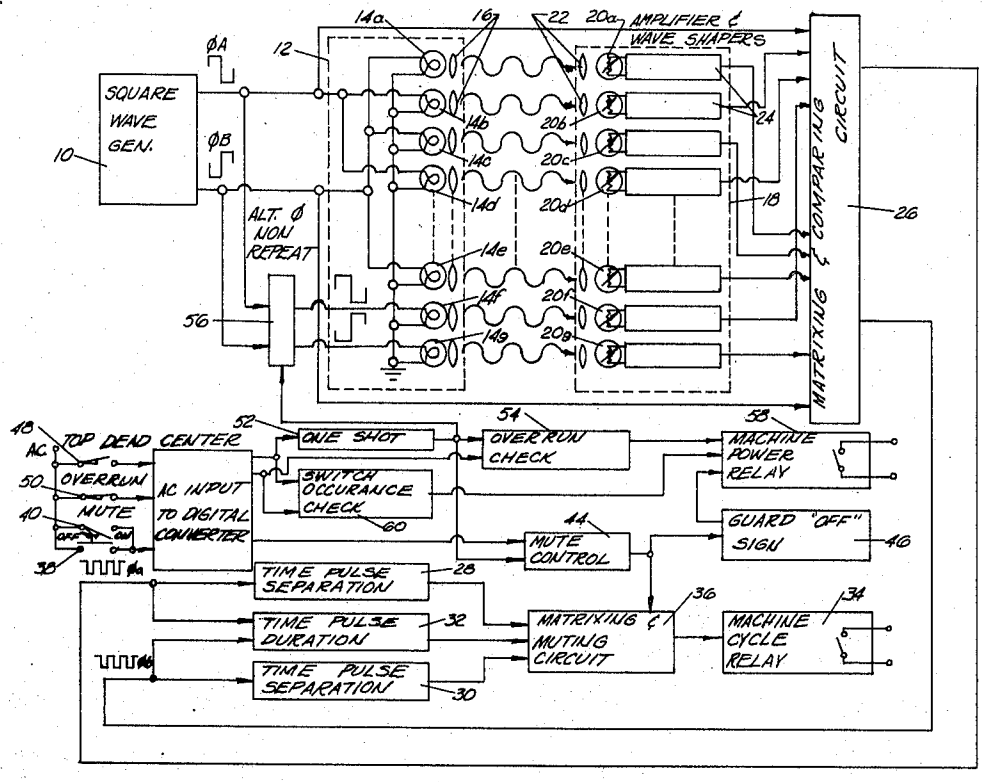
2,631,273	3/1953	Bagno	340/258 B
3,181,035	4/1965	Adams et al.	317/127
3,370,284	2/1968	Bagno	250/221 X
3,612,884	10/1971	Linardos	317/124
3,543,260	11/1970	Engh	340/258 B
2,912,683	11/1959	Bagno	340/258 B

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[57] **ABSTRACT**

Photo-electric guard for machines, having a plurality of light sources and a corresponding plurality of photo-responsive devices. Each light source is powered by a modulated electric supply and is aimed at the corresponding one of the photo-responsive devices. The output of each photo-responsive device is reshaped and compared with the input to the light source, and any mismatch is effective to stop further machine operation.

13 Claims, 3 Drawing Figures



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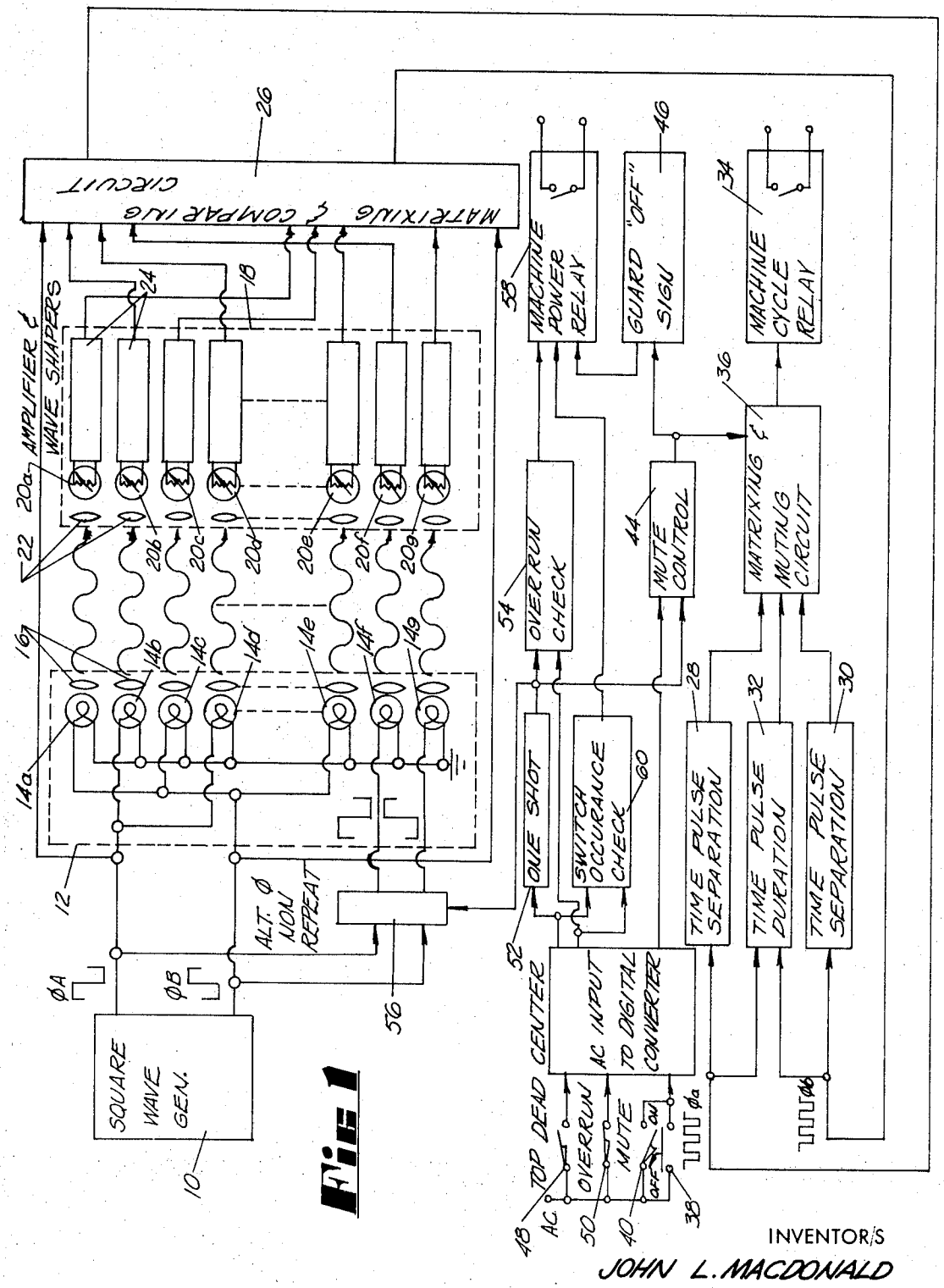


Fig 1

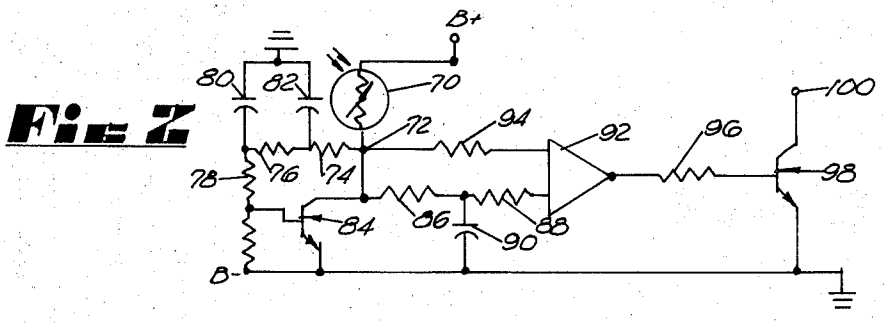
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Fig 2



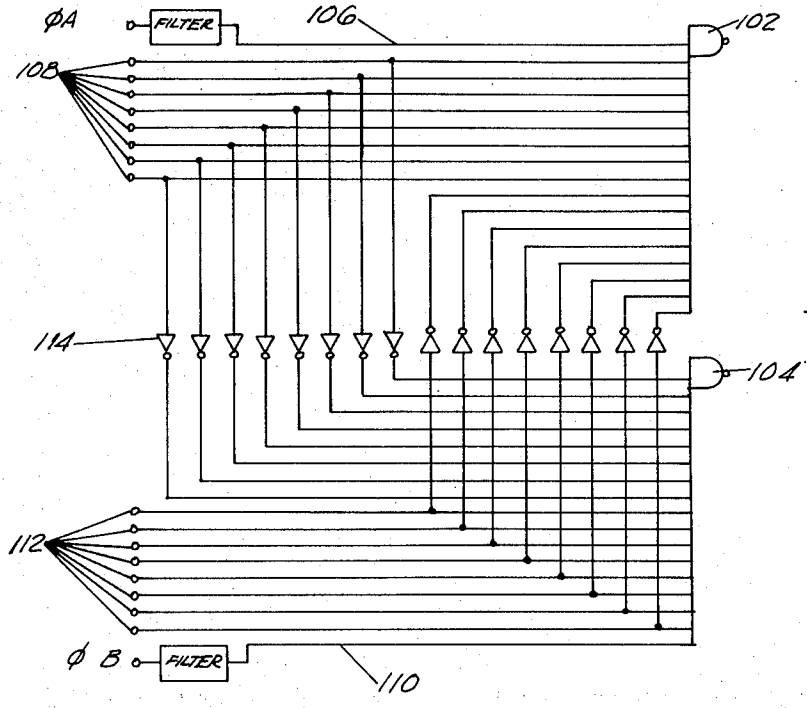


Fig 3

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SAFETY DEVICE FOR MACHINES

BACKGROUND OF THE INVENTION

This invention relates generally to a safety device for a variety of machine tools, and particularly to a photoelectric safety device adapted for use with presses and the like having a reciprocating ram.

Ram type machines of the type here under consideration have always presented a potential safety problem by virtue of the severity of the injury to personnel during the downward stroke of the machine cycle. This long extant safety problem is compounded by the rapid advance of machine tool technology and particularly advanced control technology.

Mechanical guarding mechanisms are very difficult to apply, in large part because of the material handling problems and the ability of such machines to utilize different dies and the like and/or sizes of material. It is generally recognized by the skilled worker in the art that a guarding system which has to be removed or changed with every new set-up will often be omitted or improperly installed and adjusted.

Other safety assists such as palm buttons or pull out devices for the operator are widely used, but these devices may not always be used during die changes or parts tryouts. In addition, they do not protect a third person such as a material handler or a supervisor who may also be in a hazardous area.

The art has also attempted to utilize photo-electronic safety devices. Generally speaking, all such photo-electronic safety systems utilize a light source which is focused on a photo-electronic cell or receiver. Often, a plurality of light sources and photo-electronic receivers are arranged in parallel rows to define a "curtain" adjacent the hazardous area. If the transmitted light is blocked or is not received by the photo-electronic receiver, a signal is produced which will instantly stop the machine.

Photo-electronic guard systems of the type now known suffer from several serious disadvantages. In the first place, all known systems are particularly susceptible to changes in ambient lighting. The ambient lighting problem is particularly acute in the case of machine tools which are operated 24 hours a day. Specifically, if the ambient light increases in a particular situation (such as daybreak), a condition can arise in which the operator could break the transmitted light curtain without affecting the output of the photo-electronic receiver. The potential danger of such a condition should be obvious.

The problem of changes in ambient lighting may in part be alleviated by the provision of manual sensitivity adjustments. Experience with such systems has shown that the machine tool operator must spend valuable time adjusting the sensitivity of the device rather than working at the machine.

A related problem with currently available photo-electronic guarding systems is the problem of alignment. For example, if a light source is not properly aligned or is accidentally jarred or bumped into an improperly aligned position, a light source can be projected on two receivers at once. If this should occur, there is a potentially dangerous area in the light curtain through which the operator could put his hand or arm without interrupting the light on the corresponding photo-electronic receiver.

Bearing the foregoing comments in mind, it is an object of this invention to provide a photo-electronic safety device which will fully protect the operator and other personnel without decreasing working efficiency.

A more specific object of the invention is to provide a photo-electronic guarding system which does not require sensitivity adjustments for changes in ambient lighting conditions.

It is another object of the invention to provide a photo-electronic guarding system which includes a logic control circuit for monitoring machine control functions as well as the output of the photo-electronic receivers.

Still a further object of the invention is to provide a photo-electronic guarding system of "fail no-fault" design; that is, a system in which any malfunction in the system or associated circuitry will immediately shut down the machine.

SUMMARY OF THE INVENTION

In its broadest terms, this invention contemplates a plurality of light sources and a corresponding number of photo-electronic responsive devices arranged to guard the danger zone of a machine tool. Each light source is powered by a modulated electric supply, effective to modulate the intensity of the light emitted by the light sources. The resulting output of the photo-electronic receivers is reshaped to compensate for variations introduced by the incandescent light sources, and the output is compared with the modulated supply. In the event there is any mismatch or lack of identity between the two signals, the machine tool will be stopped immediately.

The logic control circuitry associated with the guarding system, in addition to monitoring the comparisons briefly noted above, will also monitor a variety of specific machine functions.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a schematic, block diagram of the photo-electronic guarding system of this invention.

FIG. 2 is an electrical schematic diagram showing the automatic ambient light adjust, amplifier and wave reshaper associated with each photo-electronic receiving device.

FIG. 3 is an electrical schematic view showing the matrixing and comparing circuitry.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring first to FIG. 1, the general arrangement of components and method of operation will be described. A square wave generator is indicated generally at **10**. For present purposes, the square wave generator **10** puts out two square wave outputs 180° out of phase. These outputs are indicated in the drawing as "Phase A" and "Phase B."

The transmitter stand indicated generally at **12** includes a plurality of incandescent light sources **14***a* through **14***g*. It will of course be understood that any desired number of light sources may be utilized, and that the light sources may be arranged in any desired pattern. For example, the light sources may be arranged to define a "curtain" which may be either

horizontally or vertically arranged, depending on a variety of conditions.

The Phase A and Phase B outputs of the square wave generator **10** are connected to alternate lamps in parallel. Specifically, Phase A output is connected to the lamps **14***b*, **14***d*, and **14***f*, while the Phase B output is connected to the lamps **14***a*, **14***c*, **14** *e*, and **14** *g*.

The transmitter stand **12** also includes a lens **16** for each of the light sources **14***a* through **14***g*, by means of which the illumination of the respective lamps may be focused on a corresponding photo-sensitive receiver.

The receiver stand indicated generally at **18** includes a photo-electronic receiver **20***a* through **20***g* corresponding in position and arrangement to the light sources **14***a* through **14***g*. Each of the photo-electronic receivers **20***a* through **20***g* is provided with a lens **22** for focusing the respective light beam.

The receiver stand also includes an amplifier and wave shaper **24** for each of the photo-responsive devices **20***a* through **20***g*. The circuitry for the amplifier and wave shaper is shown in FIG. **2** and will be described in more detail hereinafter. For present purposes, it will be understood that since the light sources **14***a* through **14***g* are incandescent, the intensity of the emitted light will not be a perfect square wave; it will however, vary at the same rate as the input square wave. The amplifier and wave shaper **24** is designed to reshape the modulated output of the photo-electronic receivers **20***a* through **20***g* into a square wave.

The matrixing and comparing circuit indicated generally in FIG **1** at **26** is shown in more detail in FIG. **3**. It will be seen that the matrixing and comparing circuit **26** receives the outputs from all of the amplifier and wave shapers **24**; the circuitry combines all like phase outputs and compares them with the output of the same phase from the generator **10**. When they compare correctly, there will be an output pulse for each cycle of each phase from the circuit **26**.

The digital outputs for each phase from the matrixing and comparing circuit **26** is fed to the three timing circuits indicated in FIG. **1** at **28**, **30** and **32**. The circuits **28** and **30** are identical, and are arranged to measure the spacing of the digital pulses from the matrixing and comparing circuit **26**. The timing circuit **32** measures the duration of each pulse from both digital phase outputs. A change in the output of any one of the timing circuits **28**, **30** and **32** could be used with a nand gate to actuate the machine cycle relay **34**, thereby stopping the machine instantly.

It will be recognized by the skilled worker in the art that the photo-electronic guarding system, as thus far described, will be effective during the entire machine cycle. In many applications, this is not desirable. In the first place, it is only the down stroke of the ram which presents a substantial safety problem; there is relatively little danger to the operator or other personnel during the up stroke. In this connection, it is common practice for an operator to enter the danger zone during the ram return stroke, as, for example, to remove a finished piece, to adjust the workpiece for a subsequent stroke, and the like. It is desirable that the machine operation not be stopped by these actions of the operator. Secondly, in the specific case of a press brake, the bending or forming portion of the cycle at the bottom of the downward stroke will generally lift the edge of the workpiece upwardly into a position where it may block the transmitted light signal. It will be obvious that this action of the workpiece should not stop further machine operation.

Thus, it is possible to add to the circuitry described above provision for muting or rendering inoperative the photo-electronic guarding system during specified portions of the machine cycle.

To this end, a matrixing and muting circuit **36** is interposed between the outputs of the timing circuits **28**, **30** and **32**, and the machine cycle relay **34**.

Muting of the photo-electronic guarding system is controlled, in the embodiment shown, by either the manual key select switch **38** or the mute cam switch **40**. These switches, along with the others to be described hereinafter, are connected to an AC input to digital converter **42**. The AC input to digital converter will change the input signal to digital pulses. It may consist of a transformer, full wave rectification, a resistor divider network, filter network, and a group of nand gates used in a Schmidt trigger circuit.

Digital signals representing the position of the key select switch **38** and the mute cam switch **40** will be transmitted from the AC input to digital converter **42** to the mute control circuit **44**; the output of the mute control circuit **44** may go to both the matrixing and muting circuit **36**, as well as to a visual guard "off" sign **46**.

The input to the matrixing and muting circuit **36** will mute or prevent actuation of the machine cycle relay, even though the other input to the matrixing and muting circuit **36** would indicate an interruption in the transmitted light.

The guard "off" sign **46** is a visual indication to the operator that the photo-electronic guard system is not in operation. The sign may include a translucent face plate having appropriate lettering on the back side, so that the lettering is not visible unless the internal lights are on. Thus, an operator will instantly know whether or not the photo-electronic system is in operation. Operation of the guard-off sign **46** is monitored. Failure of guard-off sign **46** to indicate an unguarded condition will result in actuation of machine power relay **58**, shutting down the machine until repairs are made.

It will be recalled that early in this specification, reference was made to the utilization of the logic control circuits of this invention for monitoring a variety of machine control functions. The embodiment illustrated in FIG. **1** shows schematically the top dead center cam switch **48** and the overrun cam switch **50**. In ordinary operation, the top dead center cam switch is utilized to stop the machine tool after each complete cycle. In other words, this switch should be effective to stop the ram at its top dead center position following each "up" stroke. The overrun cam switch **50** is, in effect, a check on the adjustment of the press. In other words, upon actuation of the top dead center cam switch **48**, the ram should stop at its top dead center position. Through wear and/or lack of proper adjustment, the ram may overrun its top dead center position. The overrun cam switch **50** is arranged to detect a condition wherein the overrun is outside of normal tolerance limits.

As seen in FIG. **1**, both the top dead center cam switch **48** and the overrun cam switch **50** are connected to the AC input to digital converter circuit **42**. Actua-

tion of the top dead center cam switch **48** is effective to trigger a one shot **52**. The pulse from the one shot **52** triggers a second one shot identified in FIG. **1** as the overrun check **54**. The pulse from the one shot **52** also actuates the alternate phase non-repeat circuit **56**. It will be seen that the Phase A and Phase B output of the square wave generator **10** are connected to the lamps **14***f* and **14***g* across the alternate phase non-repeat circuit **56**. The alternate phase non-repeat circuit **56** includes flip-flops and gating circuitry effective so that the pulse from the one shot **52** will alternately interrupt the Phase A or Phase B input to the lamps **14***f* and **14***g* respectively for the period of that pulse.

It will be apparent to the skilled worker in the art that an interruption in the supply to one of the lamps **14***f* or **14***g* will mean that the corresponding photo-responsive device **20***f* or **20***g* receives no modulated light signal. This in turn will mean that the output of one of the amplifier and wave shapers **24** will not match the input in the matrixing and comparing circuit **26**, so that its output will cause a change in output of one of the timing circuits **28**, **30**, and **32**, acting through the matrixing and muting circuit **36** to actuate the machine cycle relay, stopping the machine.

It will also be noted that the output pulse from the one shot **52** is delivered to the mute control circuit **44** which will trigger a flip-flop to reset the circuit to the non-muting position.

The overrun check **54**, as already indicated, is a second one shot which produces a pulse of a specified time duration. This pulse is used to measure the stopping time of the ram at top dead center. If the overrun cam **50** is depressed before the period of the overrun check **54** elapses, a signal will be transmitted to the machine power relay **58** preventing further operation of the machine until the necessary period has elapsed.

It will also be observed in FIG. **1** that the top dead center cam switch **48** and the overrun cam switch **50** are used to check each other. That is, an output from the AC input to digital converter indicating the position of each of the switches is transmitted to the switch occurrence check **60**. If either cam switch fails, the output of the switch occurrence check **60** to the machine power relay **58** will stop the machine.

Preferably, each of the two switches **48** and **50** are checked twice during an individual machine cycle.

Referring now to FIG. **2**, an electrical schematic diagram is given which shows in more detail the amplifier and wave shaper **24** generally described above. It is this circuitry which, in addition to amplifying and reshaping the received light signal, automatically adjusts for changing ambient light conditions.

A photocell is indicated at **70**, and is connected on one side to a suitable source of direct current. It will be recognized that the signal lead **72** of the photocell will have a varying DC voltage, depending upon the light intensity received by the photocell **70**. As indicated earlier, there will be the rapid variations in intensity caused by the modulated light source, as well as more gradual changes in ambient lighting conditions. Ambient light causing gradual changes of voltage at signal lead **72** of the photocell **70** is monitored by the ambient light correction circuit, including resistors **74**, **76** and **78**, capacitors **80** and **82**, and transistor **84**, which is a time delayed negative feedback path which maintains an average voltage at photocell signal lead **72**. This time delay circuit responds only to gradual changes in ambient light and not to the rapidly changing modulated light. Both the corrected ambient light signal voltage and the rapidly modulating light signal voltages appearing at signal lead **72**, are applied to resistors **86** and **94**, which are input paths to the operational amplifier **92**. Input path of resistors **86** and **88** and capacitor **90** comprises a time delay circuit which blocks rapidly changing modulated light voltages and responds only to the gradual change of ambient light. Input path through resistor **94** responds to both ambient light and modulated light. The operational amplifier inputs have a signal difference of only the rapidly modulating light.

The output of the operational amplifier **92** is connected across the resistor **96** to the base of the power transistor **98**. The combined effect of the operational amplifier **92** and power transistor **98** is to reshape the output of the photocell **70** into a square wave. In other words, an incandescent light source is incapable of generating a true square wave output; hence, the signal received by the photocell **70** might be described as a "rounded" square wave. The combined high gain of the operational amplifier and the transistor **98** serves to reshape the wave and give a square wave output at the terminal **100**.

FIG. **3** is an electrical schematic diagram showing the matrixing and comparing circuit indicated in FIG. **1** at **26**. As already indicated, this circuit is designed to combine and compare all light phase outputs from the amplifier and wave shaper circuits **24** with the corresponding phase output from the square wave generator **10**. When they compare correctly, there will be an output pulse for each cycle of each phase from this circuit.

FIG. **3** shows a matrixing and comparing circuit which will accommodate outputs from 16 amplifiers nand wave shapers as described above. The circuit includes two seventeen input NAND-gates, **102** and **104**. The NAND-gate **102** is hard wired by the line **106** to the Phase A output of the square wave generator **10**, The contacts **108** will be connected to the amplifier and wave shapers **24** associated with a light source energized by the Phase A supply. Similarly, the NAND-gate **104** is hard wired as at **110** to the Phase B output of the square wave generator **10**, while the contacts **112** receive the output from the amplifier and wave shapers associated with the light sources energized by the Phase B supply. All inputs from the wave shapers of both phases are inverted by the inverters **114** and fed to the opposite NAND gate.

It will be recognized by the skilled worker in the art that the foregoing systems compares only "lows." Each time there is a full and complete comparison, there will be an output pulse from the NAND gate. If any wave shaper **24** output stops in either the "high" or "low" state, one of the two NAND gates will not give an output.

No specific circuitry has been shown for the remaining components identified in FIG. **1**. It is believed that in the light of the objectives to be accomplished as set forth earlier, development of the digital circuitry for obtaining the result is well within the purview of the skilled worker in the art.

While the described embodiment of the invention relates to a guard system for a machine tool having a reciprocating ram, it will of course be understood that it is equally applicable to any machine tool for other operation wherein an operating cycle, for safety reasons, should be interrupted upon the presence of personnel in a predetermined danger zone.

No limitations are to be inferred or implied from the foregoing exemplary embodiment, except insofar as specifically set forth in the claims which follow

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. A photo-electronic guard system for a machine comprising:
   a. at least one light source;
   b. means for supplying a modulated current to said light source to produce a modulated light signal;
   c. a photo-responsive device arranged to receive said modulated light signal;
   d. circuit means associated with said photo-responsive device for producing an output in response to said modulated light signal, said circuit means including a time delay feedback circuit whereby to maintain substantially constant potential across said photo-responsive device and prevent an output of photo-responsive device to ambient light changes;
   e. comparator circuit means for comparing said output in response to said modulated light signal with said modulated current supply; and
   f. means for stopping said machine at any time said output in response to said modulated light signal fails to match said modulated current supply.

2. The guard system claimed in claim 1 wherein said means for supplying a modulated current to said light source comprises a square wave generator.

3. The system claimed in claim 2 wherein the frequency of modulation of said current is on the order of 500 cycles per second.

4. The guard system claimed in claim 1 including means for amplifying said output in response to said modulated light signal.

5. The guard system claimed in claim 1 including means for reshaping said response output in to said modulated light signal to eliminate variations introduced by said light source and to conform said response to said modulated current.

6. The guard system claimed in claim 1 wherein said comparator circuit means comprises means for receiving said response output in to said modulated light signal; means for receiving said modulated current; and means for producing an output pulse for each cycle in which said response and said modulated current match.

7. The guard system claimed in claim 6 wherein said means for stopping said machine comprises means for receiving said output pulses from said comparator circuit means; and means responsive to a change in frequency or duration of said pulses to stop said machine.

8. The guard system claimed in claim 7 wherein said means responsive to a change in frequency or duration of said pulses includes a timing circuit adapted to receive and measure the spacing between said pulses; a second timing circuit adapted to receive and measure the duration of each said pulse; each said timing circuit being adapted to produce a changed output in response to a predetermined change in input, said changed output being effective to stop said machine.

9. The guard system claimed in claim 1 including means for muting said guard system during a portion of the cycle of said machine.

10. The guard system claimed in claim 9 including means for indicating to an operator the period in which said system is muted.

11. The guard system claimed in claim 1 including means for automatically stopping said machine at a specified point in each cycle.

12. The guard system claimed in claim 1 wherein said means for stopping said machine at a specified point in each cycle comprises a circuit for interrupting the supply of current to at least one light source.

13. The apparatus claimed in claim 1 including logic circuit means for verifying the condition of machine controls prior to continuation of machine operation, and preventing continuation of operation in the event any such control does not function properly.

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