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[54] **CURRENT SUPERVISION CIRCUIT**
7 Claims, 2 Drawing Figs.

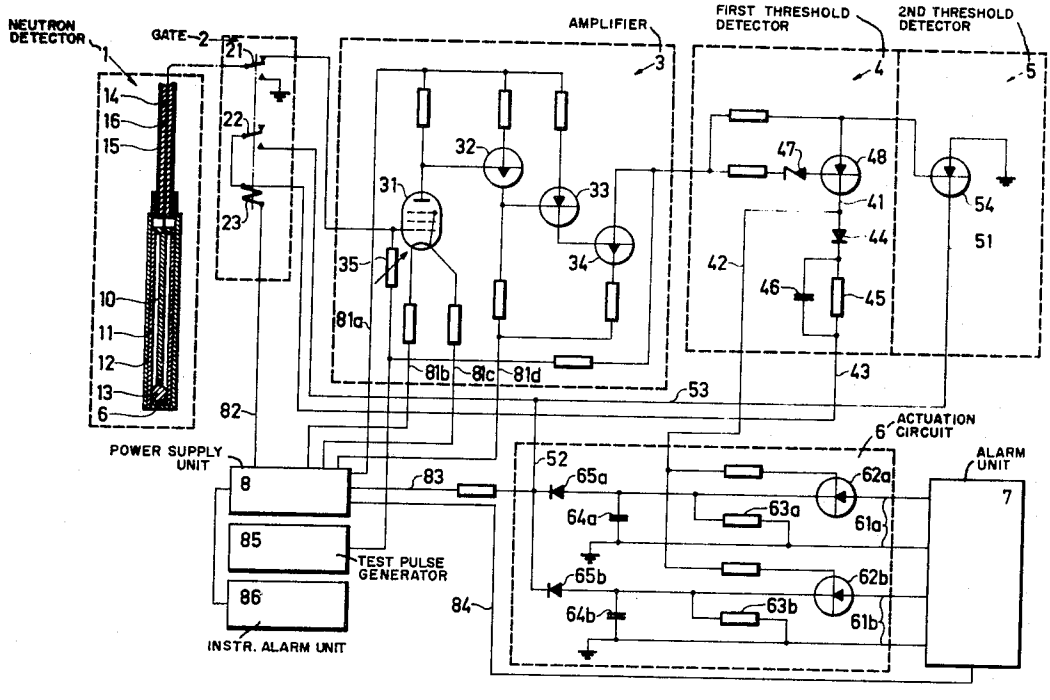
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[50] **Field of Search** 340/248–256, 228, 412–415; 250/83, 83.1, 83.3, 83.6; 307/235; 328/115–117, 146–149

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ABSTRACT: A circuit for supervising an electric current and giving an alarm when the current exceeds a predetermined upper limit defined by a first threshold detector, or drops below lower limit defined by a second threshold detector.



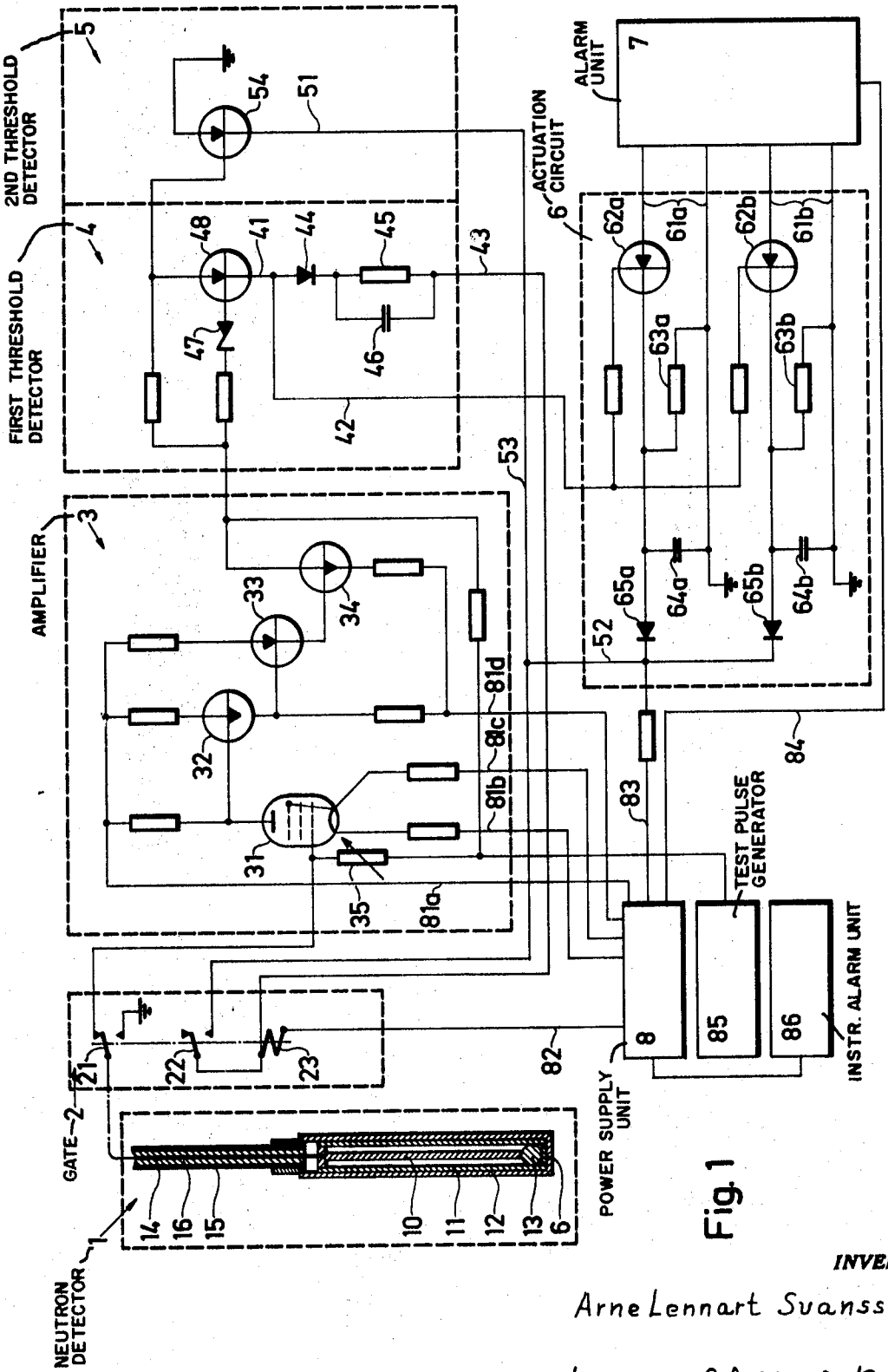


Fig. 1

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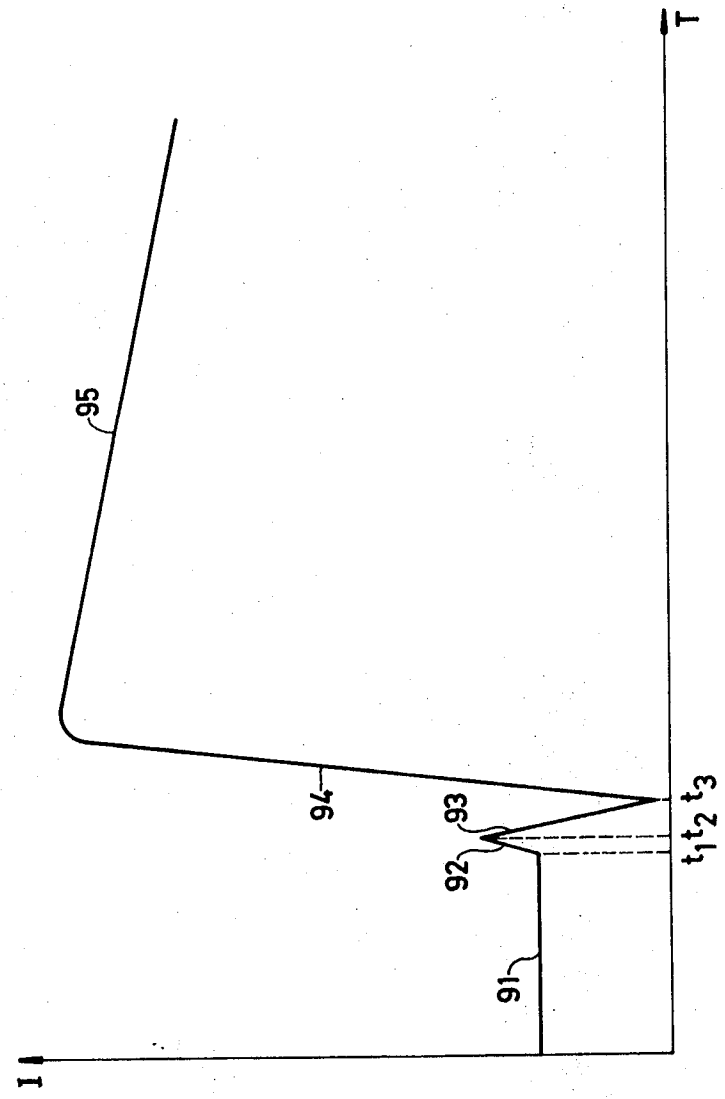


Fig. 2

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CURRENT SUPERVISION CIRCUIT

The present invention is concerned with a current supervision circuit for supervising possible excursions of a current from a normally present, and between a lower limit and an upper limit situated, and preferably substantially constant current value for providing supervision alarm when said current value exceeds said upper limit during a continuous first time period. The invention may be used for detecting, for example, a neutron flux, especially such a short and intensive neutron flux which may be created at a nuclear accident.

At the treatment of some fissionable materials like Pu–239 and U–235 there exists a risk that a critical system is created and that a so-called nuclear excursion will occur. Such an excursion may under certain circumstances give rise to a real explosion, but for most of the so far reported incidents, the only obvious sign that an excursion has occurred is a short but extremely strong radiation intensity from the system. Since persons staying in the vicinity of the place for the excursion then may receive a dangerous exposure of radiation, it is of utmost importance to get an alarm immediately.

Data based upon earlier occurred nonexpected excursions shows that a criticality accident will yield totally from 10^{14} to 10^{21} fissions with a duration which may vary from microseconds to minutes. The excursion is characterized by the burst of neutrons which always are emitted from the system. This burst has always an easily identifiable intensity peak with a very short duration from microseconds to milliseconds, often followed by a longer intensity plateau on which is included the main part of the total amount of the fission neutrons. There is always a big risk that the nuclear excursion described above may repeat itself several times.

Where a risk for a criticality accident exists, a selective monitoring and alarm system is required which is able to give information and alarm for every excursion which may occur independently of its duration or its magnitude. Since such an alarm must give rise to a complete evacuation of all people in the actual area, one must be absolutely sure that the number of false alarms is reduced to an absolute minimum and that the reliability of the monitoring system is as high as possible.

In order to be able to detect with certainty an excursion of extremely short duration, it is well known that it is possible to use a dose-measuring instrument which is based upon the application of neutron or gammasensitive detectors which are combined with some forms of data-handling units performing integrating functions. The reliability of the detectors, the necessity to use threshold limits to avoid integration of the background intensity and limitation in measuring ranges are factors which are difficult to overcome without making the detection system complicated and difficult to manage.

The invention has as its object to provide a current supervision circuit fed by, for example, a detection device with a detector which itself has the feature of performing an integration of the dose rate from a criticality excursion. Said detector, however, forms no part of the present invention.

The current supervision circuit, according to the invention, is characterized by the fact that the circuit comprises a first threshold detector and a second threshold detector, each said detector having as an input signal one and the same signal corresponding to the value of the supervised current, with said first threshold detector arranged to break the input signal to as well the second threshold detector as its own input terminal when the current exceeds said upper limit, and to for a predetermined second time period provide a change in its own working condition which brings about that a renewed supply to said first threshold detector within said second predetermined time period of an input signal corresponding to a current exceeding the upper limit will not result in a repeated breaking of said input signals; and, further, to within said predetermined second time period provide a renewed supply of the input signals to both threshold detectors, and with said second threshold detector arranged for providing for an input signal corresponding to a current value below said lower limit, a changed condition in an auxiliary circuit, which is also influenceable by said first threshold detector, during substantially said second predetermined time period, so that at the renewed supply of the input signals to both threshold detectors and when the input to said first threshold detector corresponds to a current value exceeding said upper limit, the influencing of said auxiliary circuit by said first threshold detector is arranged to result in the triggering of an alarm circuit.

The invention will be described in connection with the attached drawings:

FIG. **1** shows an embodiment of a current supervision circuit according to the present invention, combined with a neutron detector which supplies a current to be supervised by the current supervision circuit.

FIG. **2** is a graph showing the variations in the current delivered by an amplifier forming part of the circuit.

The neutron detector, which is shown in sections in FIG. **1**, is of the beta-current-type. It comprises an emitter in the shape of a rectangular plate **10** which preferably is composed of Rh 103 or Ag 109. The emitter is surrounded by an isolator **11** which preferably has a layer of polystyrene, polyethylene or—for high temperatures—aluminiumoxide. The insulator is surrounded by an envelope **12** which serves as a collector and which may consist of stainless steel. To the emitter is a hollow cylinder **13** fixed, made of stainless steel. The cylinder contains a radioactive beta particle emitting source, preferably Sr 90. To the detector is connected a coaxial cable, the outer conductor **15** of which is connected to the collector **12** and whose inner conductor **14** is connected to the emitter **10**. Between the conductors there is an insulating layer **16**, preferably of polyethylene or aluminiumoxide.

The function of the detector is as follows. The radioactive source in the cylinder **13** is continuously generating a current which is passing through the coaxial cable. This current serves as a check current. When the detector is exposed to neutron radiation, radioactive isotopes will be generated in the emitter **10**, viz, Rh 104 if the emitter contains Rh 103 and Ag 110 if the emitter contains Ag 109. These radioactive isotopes are short-lived with half-lives of the magnitude of a minute. They are decaying, emitting beta radiation which is generating an electric current proportional to the neutron flux. In the coaxial cable this current is added to the check current.

As may be seen from FIG. **1**, the above-described beta-current detector is connected to a linear amplifier **3** via an electronic gate **2**. This amplifier has been designed in such a way that it can accept an input signal from 10^{11}**2**A. to 10^{11}**0**A. without range switching. The output signal from the amplifier **3** gives to two threshold units or detectors, viz, a first threshold unit or detector **4** which will respond when the signal exceeds a preset value and a second threshold unit or detector **5** which will respond when the signal falls below a preset value. From the threshold units the signal will—if it it above or below the earlier mentioned threshold values—pass to the actuation circuit **6**. This circuit is arranged to give an alarm to alarm unit **7** if it receives signals from both threshold units. Further, the actuation circuit **6** is arranged to check the received information and to delay the outgoing alarm command until this checking has been made.

The device according to FIG. **1** comprises further on a test pulse generator **85**, the function of which will be described later on. The device comprises also a power supply **8** which is arranged to deliver a constant supply voltage to the units **2**, **3**, **6** and **7**. To the power supply unit **8** is connected an instrument alarm unit **86**. This is continuously checking the current delivered by the power supply. Should this current change noticeably, there is an indication that a fault has occurred in the system and unit **86** will therefore give alarm, i.e., an alarm which is different from the alarm given by alarm unit **7**.

If there is for example an open circuit in the coaxial cable **14–16**, the second threshold unit **5** will not receive any input signal. The unit **5** will then give an output signal to the actuation circuit **6** which will result in a change of the current delivered by the power supply **8**, and the instrument alarm unit **86** will therefore be actuated.

If because of a strong neutron irradiation of the neutron detector the input signal to the first threshold unit **4** exceeds the preset value, this threshold unit will give signals to the actuation circuit **6** as well as to the gate **2** which will no longer pass signals; and this condition of the gate will bring the second threshold unit **5** to give an output signal to the actuation circuit **6** and since this circuit now has received a signal also from the threshold unit **5**, it will give a signal to the alarm unit **7**, when the first threshold unit **4** delivers a signal for the second time when at the same time the gate **2** will get a signal which opens the gate. Here the attention is directed to FIG. **2**, where the abscissa T represents the time and the ordinate the current I. The first horizontal part **91** of the curve represents the check current which is generated by the radioactive source in the neutron detector. The source intensity is selected so that the check current lies between the preset values for the first and second threshold units. At the time t_1 the neutron detector **1** gets a strong neutron irradiation. The current will then rise rapidly in accordance with the part **92** of the curve. At the time t_2 the actuation circuit **6** receives a signal from the first threshold unit **4** and the gate **2** will no longer pass signals. As a result the current rapidly decreases according to the part **93** of the curve. At the time t_3 the actuation circuit **6** has received a signal from the second threshold unit **5** and gives alarm. At the same time gate **2** opened, which brings about that the current is rapidly increase as indicated by the part **94** of the curve. When the current has reached its maximum, it will start to decrease slowly according to the part **95** of the curve. The speed with which the current decreases is a function of the decay time of the nonstable isotope which has been formed. For supervision of an equipment where a criticality accident might occur, a decay time of 0.5–1 minutes is preferred.

The electronic parts of the system are also shown in FIG. **1**. The gate **2** has two make-and-break contacts **21** and **22**, which are actuated by the relay winding **23**. The amplifier **3** has an electrometer tube **31** in the input stage followed by three transistors **32–34** which form a feedback DC amplifier. The amplification factor is controlled by a potentiometer **35**. The first threshold unit **4** includes a transistor **48** and a zener diode **47** which in the known way is selected to conduct at a preset voltage. Further on, the unit **4** includes a diode **44**, a capacitor **46** and a resistor **45** connected parallel to the capacitor **46**. The second threshold unit **5** includes a transistor **54**, which is arranged to be nonconducting when the current from the amplifier **3** drops below a preset and for the transistor characteristic value, and to conduct when the current is higher than this value. The actuation circuit **6** is in principle composed of two identical circuits. This doubling of the circuits has been made for the reason that a fault in the auxiliary circuit will not be discovered as easily as a fault in another part of the system. Each circuit has a transistor **62***a*, **62***b*; a capacitor **64***a*, **64***b*; and a resistor **63***a*, **63***b* parallel to the capacitor and a diode **65***a*, **65***b*.

The operation of the electronic equipment will be explained, assuming as a starting point that the gate **2** is passing signals and that the signal from the amplifier **3** has a value between the upper limit and the lower limit and that thus zener diode **47** is nonconducting as is the transistor **48** in the first threshold unit **4**. The transistor **54** in the second threshold unit **5** is conducting.

If now such a situation occurs that the signal from the amplifier **3** exceeds the upper limit, the zener diode **47** will start to conduct and also the transistor **48** will begin to conduct. The transistor **54** will continue to conduct. This state of the transistor **54** results in a potential on leads **53** and **52**, which is near the ground potential; and, consequently, the capacitors **64***a* and **64***b* will have practically no charge, being already discharged by resistors **63***a* and **63***b*.

When the transistor **48** starts to conduct, the capacitor **46** will be charged, and a current will go through the relay winding **23** and the relay in the gate **2** will then actuate its make-and-break contacts **21** and **22**. When the contact **21** is actuated, the input to the amplifier **3** is cut off and thus there is no output signal from the amplifier **3**. As a consequence the zener diode **47** stops conducting and the transistors **48** and **54** will no longer pass current.

During the time when the transistor **48** was conducting, the transistors **62***a* and **62***b* received such a potential on their bases that the transistors **62***a* and **62***b* started conducting. As already said, the capacitors **64***a* and **64***b* had no charge and thus there was no current going to the alarm unit **7** via the leads **61***a* and **61***b* and no alarm was given.

When the winding **23** is energized and the signals to the threshold units **4** and **5** are cut off and the transistors **48** and **54** become nonconducting, the following events take place. The current through the winding **23** then ceases and the relay goes to its off position with the contacts **22** and **23** anew in the positions shown in FIG. **1**. When the relay is energized and thus the contact **22** is actuated, the capacitors **64***a* and **64***b* are charged in such a way that the plate connected to the diode **65***a* and **65***b*, respectively, is negative in relation to ground on account of the changed potential on leads **52** and **53**.

When the relay goes to its off position and the contacts **21** and **22** assume the positions shown in FIG. **1**, the input signal to the amplifier **3** will be reestablished, and the amplifier **3** will deliver an output signal to the threshold units **4** and **5**. The further operation depends on the value of the input and output signals when the gate **2** anew is passing the input signal.

Assume in the first place that the input signal has dropped so much that the output signal from the amplifier **3** is not capable of making the zener diode **47** conduct. The transistor **48** will then remain nonconducting and the potential on the lead **42** will have such a value that the transistors **62***a* and **62***b* are nonconducting. Although the capacitors **64***a* and **64***b* are charged, they cannot be discharged via the transistors **62***a* and **62***b* and no current goes to the alarm unit **7** via the leads **61***a* and **61***b*, respectively, and no alarm signal is given.

In the second place it is assumed that the input signal has not dropped or at least still has such a value that the output signal from the amplifier **3** is exceeding the upper limit. The zener diode **47** starts conducting and the transistor **48** also starts conducting. However, when the transistor **48** was conducting the first time, capacitor **46** was charged, as has been already stated, and the charge on this capacitor **46** is assumed to have not yet leaked away via the resistor **45**. The result is that the circuit which includes the transistor **48** and the relay winding **23** will have such changed working conditions that the current through the relay winding **23** is insufficient to energize the relay. Thus this second time gate **2** will not stop passing the input signal to the amplifier **3**, and the output signal from the amplifier **3** will persist and hold the zener diode **47** and the transistors **48** and **54** conducting.

With the transistor **48** conducting and the capacitor **46** charged, the potential on lead **42** is sufficient to make the transistors **62***a* and **62***b* conduct. As the capacitors **64***a* and **64***b* had been charged with the plate connected to the collector in the PNP-transistor **62***a* and **62***b*, respectively, negative with respect to ground the capacitors **64***a* and **64***b* will be discharged via the corresponding transistor **62***a*, **62***b*, and current goes via the leads **61***a*, **61***b* to the alarm unit **7**, and this time an alarm is given.

The requisite for an alarm signal is thus that the input signal exceeds a predetermined limit and gives rise to actuation of the gate **2** to stop the input signal followed by a return of the gate **2** to the state where the gate **2** passes the input signal and that then the input signal still has a value above the predetermined limit. This means that the input signal must have a value above the predetermined limit for at least a time period equivalent to the time period required for the sequence described here (1–2 seconds). If the input signal persists above the predetermined limit during a shorter time period, the sequence will take place, as has already been described in the first place, and no alarm signal will be given. This behavior is used to avoid that an alarm signal is given when disturbances of short duration take place and is also made use of for a periodical automatic function test. This function test is per-

formed by feeding short test signal pulses with high amplitude to the amplifier **3** from the test pulse generator **85**. If a fault is present in the device, the sequence will not be executed, and this fact can be detected by different methods, i.e., by measuring the total power consumption during such a test. If the current taken from the power supply assumes a value differing from the normal value, an instrument fault alarm is given.

From FIG. **1** it is evident that the capacitor **46** as well as the capacitors **64***a* and **64***b* are bridged by a resistor **45**, **63***a* and **63***b*, respectively. In order to obtain the desired function the time constant for each combination of a capacitor and a resistor, that is the combinations **45**, **46** and **63***a*, **64***a* and **63***b*, **64***b*, should exceed the time taken for the described sequence, and it has been found that a time constant of 3–4 seconds is a satisfactory value. If the time constant is too long, there will be a certain "dead-time" after each sequence.

Modifications, such as the use of an electronic gate **2** instead of a relay, are naturally possible within the scope of the invention as given by the attached claims.

What is claimed is:

1. In a circuit for supervising possible excursions of a signal having a value which normally lies intermediate predetermined upper and lower limits and which provides an alarm when said signal attains a value exceeding said upper limit and which is sustained during a predetermined time period, the combination comprising a power supply unit, an alarm unit, an actuation circuit interposed in the circuit connections between said power supply unit and alarm unit for controlling energization of said alarm unit, first and second threshold detectors connected to said actuation circuit for controlling the same, a gate normally enabled to apply said signal to said threshold detectors when the value of said signal lies between said upper and lower limits, said first threshold detector being responsive to a value of said signal exceeding said upper limit first to initiate a gate-influencing cycle during which said gate is first disabled and again enabled following termination of said time period, and secondly to deliver a signal to said actuation circuit, and thirdly to change its own operational state such that renewed application of a signal at a value exceeding said upper limit will initiate said gate-influencing cycle only if said renewed application takes place following termination of a first predetermined delay, said actuation circuit being normally held by said second threshold detector in a first state where it is not influenced by said signal from said first threshold detector, said actuation circuit being changed over during said gate-influencing cycle to a second state where it closes the circuit between said power supply unit and alarm unit when influenced by a signal from said first threshold detector, said second threshold detector being operative to reconvert said actuation circuit back to said first state following termination of said gate-influencing cycle only after termination of a second predetermined delay.

2. A supervisory circuit as defined in claim **1** wherein said first threshold detector comprises an RC-circuit having a time constant exceeding said time period in order to obtain said first delay, and wherein said actuation circuit also comprises an RC-circuit having a time constant exceeding said time period in order to obtain said second delay.

3. A supervisory circuit as defined in claim **2** wherein said first threshold detector comprises a transistor having a bias determined by a capacitor in said RC-circuit

4. A supervisory circuit as defined in claim **2** wherein said actuation circuit comprises a transistor in a triggering circuit to said alarm, said transistor being influenced by said signal from said first threshold detector and having its current supplied by a capacitor in said RC-circuit

5. A supervisory circuit as defined in claim **1** wherein said gate comprises a relay having a winding energized by a current controlled by said first threshold detector and actuating a first break contact in the signal path to said first and second threshold detectors and a second make contact to change said actuation circuit into said second state.

6. A supervisory circuit as defined in claim **1** and which includes a linear feedback direct current amplifier arranged in the signal path to said first and second threshold detectors.

7. A supervisory circuit as defined in claim **1** and which further includes an instrumentation alarm unit arranged to be triggered by said second threshold detector when the signal to said second threshold detector falls to a value below said lower limit during the time said gate is enabled.