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# A New Concept for Automatic Detection and Extinction of Fires

D. Lay

Verband der Sachversicherer e. V.
Cologne, West Germany

Translated for:
Center for Fire Research
Institute for Applied Technology
National Bureau of Standards
Washington, D. C. 20234

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Final Report

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U.S. DEPARTMENT OF COMMERCE, Elliot L. Richardson, *Secretary*
James A. Baker, III, *Under Secretary*
Dr. Betsy Ancker-Johnson, *Assistant Secretary for Science and Technology*
NATIONAL BUREAU OF STANDARDS, Ernest Ambler, *Acting Director*

# PREFACE

This report is a translation of paper prepared by D. Lay and presented by him at the Seventh International Seminar on Problems in Automatic Fire Detection held in Aachen, Germany, on March 5-6, 1975. The Seminar was sponsored by the Institute for Electrical Communications Engineering in Aachen in conjunction with the Gesamthochschule in Duisberg.

This translation has been prepared to disseminate useful information to interested fire research personnel on a need-to-know basis and is not an original work of the Center for Fire Research.

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Richard G. Bright
Program for Fire Detection
and Control Systems
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# A NEW CONCEPT FOR AUTOMATIC DETECTION AND EXTINCTION OF FIRES

D. Lay

Abstract

The use of automatic fire detectors to trigger fire extinguishment systems has gone on for many years. Systems of this type use a variety of extinguishing agents including water, carbon dioxide and, most recently, the halogenated agents.

Automatic extinguishing systems with practically an unlimited supply of agent suffer from the fact that these systems often continue in operation long after the fire is out resulting in additional damage. This doesn't occur with those systems having limited supplies such as carbon dioxide systems and the like. However, these systems are only successful if: (1) their original design was correct; (2) no unanticipated changes are made in the area or materials to be protected; and (3) extinguishment commences at a time when successful extinguishment is possible.

This paper describes how the disadvantages enumerated above can be avoided, to a large extent, with a modified design for permanently-installed, automatic extinguishing systems and how systems can be provided which will only discharge extinguishment at the proper time and in the proper amount.

Key words: Automatic sprinklers; carbon dioxide; fire detection; fire extinguishment; flame detection; heat detection; smoke detection.

## 1. INTRODUCTION

In addition to pure fire detection systems, systems have also existed for years which not only detect a starting fire, but at the same time or a short time later also activate an extinguishing system. Because of the great significance attached to automatic fire detection systems in these combined detection and extinction systems, this paper is first of all occupied with problems connected with automatic fire detection. Then a technical concept will be indicated, by means of which fires can be reliably sensed, detected, and extinguished by appropriate extinguishing systems.

## 2. AUTOMATIC FIRE DETECTION

Hardly any other topic is discussed so frequently at national and international fire detection seminars as that of the error behavior of automatic fire detection systems. Such discussions are indeed motivated by the fact that, due to the constant increase in fire detection systems, the number of false alarms has also risen proportionately. Public fire departments are affected in the first instance, but also affected are those who operate fire detection and extinction systems, who must bear the cost not only for operating and maintaining the systems, but additionally for financial expense caused by false alarms.

There have long been indications that expense caused by false alarms will increase severely. Possibly, this cost will soon be so great that, when it is added to the financial expense for installing fire detection systems, that it will no longer stand in a proportionate relationship to the usefulness of the system. The manufacturers of fire detection devices were, therefore, well advised not to be closed-minded towards the justified objections of the localities concerned, but to search for suitable ways to reduce the number of false alarms, among other ways by using new technology. The result of such efforts are then devices by means of which certain causes of false alarms can at least be partially excluded. Still, economically-feasible, technically-practical embodiments, which affect a noticeable reduction of false alarms or remove them completely, have not become known. This is particularly valid for automatic fire detectors, which unfortunately not only give an alarm when fire characteristics are present, but are also known to set off an alarm when disturbances occur that resemble fires. Automatic fire detectors, therefore, are properly considered the most critical part of a fire detection system, as far as false alarms are concerned.

If, today, the technical possibility existed to remove the influence of disturbances by an economically-defensible change in the detector, e.g., by exchanging certain construction elements, there would be no question at what place the "lever" should be applied. But such solutions are unknown, so that a better interference-use behavior of fire detectors can be achieved only by changing their triggering threshold value. It need not be specially stressed how problematical it is to reduce the number of false alarms triggered by interferences, through changes in the triggering threshold value, without thereby, also simultaneously shifting the time at which true fires are recognized so that the alarm message incurs no impermissible delay for beginning the extinguishing operations. Obviously, isolated consideration of individual fire detectors does not result in new knowledge. It is, therefore, necessary to include not only the detector but the entire fire detection system in the considerations, and to consider its function also in connection with the requirements of defensive fire protection. Prominent domestic and foreign firms have followed this route for some time, and have thereby arrived at quite useful, but still — as I believe — not in every respect satisfactory results. This also pertains to such fire detection systems, among others, where a definite alarm organization is provided, by means of which manual activation of automatic alarm transmission is given to responsible personnel. Since the human person was recognized quite early as an unreliable link in the chain of necessary measures for fire protection, and was largely excluded from this chain, a large measure of freedom in decision and action is here again granted to him, so to speak by the back door.

In view of the high property values which are today under surveillance by automatic fire detection systems, it is understandable that the German Fire Underwriters want to avoid the risk of delayed alarms, because the magnitude of property damage resulting from such delays cannot be calculated. A useful computational factor for this cannot be found, if for no other reason than that nothing is, of course, less calculable than the behavior of human persons in certain dangerous situations. Without knowing the influence factor, only a global determination can, therefore, be made that such an alarm organization will narrow the reduction in risk connected with the installation of an automatic fire detection system. Consequently, it must follow that the fire underwriters can in no way grant the maximum discount customary for detection systems, in the case of fire detection systems with delays according to such concepts.

## 2.1. Two-Line Technology

The fire underwriter makes no objections against another technical measure, already familiar for a much longer time, which is particularly considered for combined fire protection systems. What is meant here are automatic fire detection systems which, for safety reasons, are designed in so-called two-line technology (cross zoning in U.S.) and which are widely used to control and activate automatic extinguishing systems.

As practice has shown, rather few false alarms occur under normal conditions with this technology, with which control of the principal detector or of the extinguishing system occurs only when in two different detection lines at least one fire detector has given an alarm. Nevertheless, the two-line technology has not yet been able to make itself prevalent in pure fire detection systems, because of the relatively high device-and-installation expense. The increased expense could be justified only for controlling extinguishing systems or where e.g., a high proportion of fire-like interferences occurs because of production processes, and the undesired alarms triggered thereby cannot be avoided by other means. This is particularly valid for fire protection systems where point-like smoke detectors are used as fire sensing elements.

To retain the basic sensitivity of the detection system, the two-line technology generally connects similar detectors with the central control in such a way that each detector is associated with only half of its normal surveillance range, and the same number of detectors is arranged in each detector line. As already mentioned, false alarms of fire detector systems and mistriggering of extinguishing systems can, in this fashion, be substantially reduced but not completely eliminated. The reason for this may lie in the fact that the same type of detector is used in both detector lines, thus e.g., smoke detectors are used in both detector lines, so that smoke or steam, which frequently arises in production processes, can never be prevented from accidentally triggering two detectors in different detector lines.

A detection system where different types of detectors are used in both detector lines, thus, e.g., smoke detectors in one and heat detectors in the other detector line, is more suited for fire detection systems, because of its greater reliability against false alarms, when public fire departments are automatically alarmed or extinguishing systems must be activated. Here a false alarm with all its consequences would be conceivable only when smoke interference as well as heat-like interference occur simultaneously, or when fire characteristics themselves appear as interferences, e.g. when welding. Despite this advantage, the system could scarsely attain prevalence in practice, however, because the system sensitivity is strongly reduced, especially for high rooms, by using heat detectors.

## 2.2. Radiation Detectors

If flame detectors, or, according to a new standard language, radiation detectors are used instead of the relatively inert heat detectors, the two-line technology permits realization, on the one hand, of equally high reliability against false triggering, but on the other hand also high sensitivity of the detection system. Furthermore, it can be supposed with great reliability that an extinguishing system will not be activated for smoldering fires, but only when flames have actually formed. However, it must in this case be presumed that radiation detectors will recognize a fire site even under heavy smoke formation and will be able to report it. As we have learned from Dr. Portscht at the last International Fire Protection Seminar, this requirement, however, is met only by such detectors whose sensitivity lies as far as possible in the infrared [1,2][1]. In the subsequent discussion of radiation detectors, infrared radiation detectors are, therefore, meant in principle.

The concept would certainly have become prevalent because of its great advantages, if radiation detectors would not react by also giving an alarm with interfering radiation. False alarms of radiation detectors caused by deceptions, such as modulated sunlight or light from incandescent lamps, are so frequent, however, that the cost arising from interruption of operations and initiation of fire protection can hardly be justified. At the same time, the radiation detector has a decisive advantage with respect to other automatic fire detectors. It is the only detector which can sense a reliable criterion for fire nearly with the speed of light and can give an alarm after a short time. If it could not be deceived by interfering radiation sources, extinction processes could be initiated by such detectors at precisely the right time, that is, when there is an actual fire.

The radiation detector has for this reason been utilized on and off for several years in very special systems in the Federal Republic, despite its tendency to trigger an alarm even for interfering radiation. We also know from England and Switzerland that the combination of smoke and radiation detectors, which has been mentioned here, is used for controlling extinguishing systems. Here as there, as far as I know, success has been achieved only sporadically in shielding radiation detectors from interfering radiation in such a way that no false alarms occur. Of course, these are not absolutely critical in application of two-line technology,

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[1] Numbers in brackets refer to the references listed at the end of this paper.

because the simultaneous occurrence of two different interferences and their triggering of an associated extinguishing system can scarely be counted on. But every alarm entails a certain disturbance and interference with the course of operations until the state of affairs is clarified. From this there not infrequently arises annoyance and dissatisfaction for the operators, despite effective detection or extinction systems. This surely also explains why this technology could not, until now, gain a solid footing in the Federal Republic.

In view of the large advantage of being able to very quickly sense and detect fires at the first occurrence of flames, it nevertheless seems rewarding to give a thought to the question whether radiation detectors cannot be used, despite their tendency to false alarms, in automatic fire detection systems, and here primarily in those that control automatic extinguishing systems. Their use would have to be such that their disadvantage would not have an interfering effect on the system in question. This requirement can be partially realized — this has already been established — by using radiation detectors in one detection line but detectors of a different type in a second line, and by connecting these electrically and hooking them up with the fire detection center in such a way that an attached main detector or extinguishing system is triggered only when at least one detector per detector line gives an alarm signal. In addition to radiation detectors, it is preferable to use smoke detectors because of their relatively high sensitivity or, should these be unsuitable because of the presence of smoke-like interferences, to use heat-differential detectors.

## 3. THE TECHNICAL CONCEPT

In the following, I now wish to present a concept which should meet the posed requirement even more fully. To make things clearer, figure 1 shows you a block circuit diagram of a combined detection and extinction system. Please do not look for a change in known techniques in the structure which is schematically shown here; for there are none. The difference from currently used techniques simply lies in the fact that the signals of the various fire detectors (in the diagram, the signals of the smoke and radiation detectors) are evaluated differently in the fire detection center under certain suppositions.

Differing electrical maintenance of the individual detector types or of the two detector lines means that false alarms from radiation detectors can no longer have interfering effects on the system, as far as human calculation can determine. This means in the first instance that the trigger action of a radiation detector may not set off a fire alarm in the central station; its triggering may consequently only be considered when a smoke detector or, under some circumstances, a heat detector, has triggered previously. Triggering radiation detectors must, therefore, be automatically reset after each fire signal, inasmuch as an alarm signal was not previously given by a smoke or heat detector. This statement also indicates that fire signals from smoke or heat detectors are evaluated in familiar fashion, and thus must be processed electrically in such a way that they are indicated at a suitable site and lead to internal or, under appropriate circumstances, to external alarm to locations providing aid.

It is understood as a matter of course, that a fire detection system with the performance characteristics proposed here must be adapted to local circumstances just like every other surveillance system. This is valid particularly for choosing requirements for connecting to the fire department. This can also be realized with a new concept in such a way that, supposing a short extinction delay, the principal detector goes off only when the fire characteristics of smoke and flame occur at the same time. A quite reliable opportunity is thereby afforded for alarming the fire department only when flames occur and are reported by the radiation detector. As an automatically operated guard, the radiation detector in this case takes on the task of a reconnoitering troop, so that such systems have the advantage, but not the disadvantages, of the initially-mentioned alarm organization.

Such special fire detection systems are more advantageous and also more interesting from the side of costs, especially when automatic extinguishing systems are activated thereby. Indeed they are suitable not only for the release and control of the extinction agent of the common extinguishing systems, but beyond this they have the additional advantage that their use avoids the basic disadvantages of conventional extinguishing systems. With extinguishing systems using limited amounts of extinguishing agent and using extinguishing agents such as carbon dioxide and the halons, such disadvantages lie in the fact that the systems bring the desired success only when all local circumstances have been appropriately and correctly taken into account in the design of these systems. Some local circumstances which should be taken into account include: (1) room utilization, (2) the influences on which the design is based not changing after the systems have been set up, and (3) that extinction is initiated at a point in time at which successful extinction is still possible. It is a further disadvantage that the abovementioned extinguishing systems have available only one "shot of extinguishing agent," when the manually-operated, subsequent flooding apparatus is disregarded. In practice, this means that every building equipped with these extinguishing systems can burn down when the first attempt at automatic extinction is unsuccessful or when rekindling takes place from glowing pockets and human assistance in extinguishment is not available.

For extinguishing systems with practically unlimited quantities of extinguishing agent and for the extinguishing agent water (e.g., sprinkler systems), disadvantages can result from the fact that the system is not turned off at the proper time after successful extinction, and the extinguishing agent, flowing out unnecessarily, causes greater damage.

You may perhaps be surprised when I now tell you that all these disadvantages can be removed with already known detection technology and with a further, relatively simple circuit-technological measure. It turns out that the radiation detectors must only be given the opportunity, for certain time intervals, of checking the success of extinction. When extinguishing systems with gaseous extinguishing agents are connected, this can be simply achieved by resetting the radiation detectors after the flooding period is completed and after an additional predetermined time, which I will call the effectiveness time. The success of extinction is checked with the aid of the radiation detectors after the effectiveness time of the extinguishing agent. According to our present experience, this time should lie between 10 and 15 seconds. If a radiation detector determines that after this time its triggering conditions are still fulfilled, which means that flames are still present, a second installment of extinguishing agent is immediately called forth by the control apparatus, the same amount as used during the first extinction. If extinction should fail even after this second extinction, repeated extinctions can follow automatically for as long as the supply of extinguishing agent lasts.

The principle of automatic follow-up extinction ensures that the extinguishing process is, in case of need, repeated at the right time, and a further defined amount of extinguishing agent is demanded from the supply of extinguishing agent. This correspondingly increases the concentration in the area to be extinguished. This connection is once again shown graphically in figure 2.

I also do not wish to hold back from you two exemplary embodiments. For this reason, I will show you a simple current plan for a small additional device, with which even older systems can be converted with a few adjustments in the circuit technology, so that they, too, will have the cited performance characteristics (see fig. 3). The additional device is suitably housed either in the housing of the fire detection center or in that of the control apparatus. Connection points 1 and 2 are brought to the detection line of the smoke or heat detectors, through a potential-free contact on the alarm relay ($AL_1$), which is generally present in fire detection centers. Points 3 and 4 are brought to the detection line of the radiation detectors, through a corresponding contact on the alarm relay ($AL_2$).

Let us now assume that alarm relay ($AL_2$) is energized by an alarm signal from the radiation detector. Contact $AL_2$ closes, whereby the reset relay (RU) pulls over $C_1$ for a short time (~1 s), and resets the detector line for the radiation detectors into their normal operating condition, with the aid of its potential-free contacts $ru_2$.

On the other hand, if a smoke or heat detector gives an alarm signal before the radiation detector, the alarm relay ($AL_1$) is activated, and through its' contact, also the relay (AR). The latter — if required because of certain conditions — goes into self-maintenance by closing its contact $ar_1$. With $ar_1$, contacts $ar_2$ and $ar_3$ close also, so that now the alarm relay (AS) can be activated through $ar_2$ when a radiation detector gives an alarm signal. Since contact $ar_3$ is already closed, the extinction command can now be given through $ar_3$ and $as_2$ , and thus the control apparatus can be controlled or the extinction alarm can be given and, after the preliminary warning time has run out, the extinguishing system can also be released. In extinguishing systems with gaseous extinguishing agents, the extinguishing system is generally released by activating an extinction magnet (solenoid valve), which is frequently excited through a relay in the control apparatus. The connection terminal 5 must be connected to ground potential, through a free contact of this extinction relay, so that the reset relay (RU) is activated through IO, diode $D_1$, and the combination $R_2C_2$, after each flooding, in about 12 s (the effectiveness time), and thereby resetting the radiation detectors, as already described.

If the first attempt at extinction should not be successful, the extinction process is repeated by a new signal from the radiation detector, and under appropriate circumstances is continued by further signals until the fire is definitively extinguished or the supply of extinguishing agent is used up.

In contrast to extinguishing systems with gaseous extinguishing agents, there need surely be no fear with sprinkler systems that the supply of extinguishing agent can be exhausted. Here the extinguishing system often still remains functioning long after the fire has been extinguished, so that the emerging water in many cases causes great consequential damage. As already mentioned, this disadvantage too can be removed relatively simply by means of the detection system. Care need only be taken that the input of extinguishing agent be turned off when the fire signals of the radiation detector cease, but that the extinguishing system, on the other hand, is again activated when the fire again develops anew in this operating condition. Technically, this can be realized by changing and complementing the electrical circuit of the described additional device, and by building a commercial fitting into the sprinkler system.

An example of the required technical-circuit change is shown in figure 4, where account has been taken of the fact that sprinkler systems are selectively operating extinguishing systems, whose extinguishing agent is released not by an automatic fire detection system, but automatically through its own temperature-sensitive elements.

The diagram shown, therefore, illustrates only the essential circuits, which are required for automatic control of extinguishing agent input. Thus all special devices, such as smoke detectors, as well as their alarm relays and circuits which are required only for early alarm but not for the extinguishing process or its control, can be dispensed with. The diagram is further conceived in such a way that the sprinkler system does not become incapable of functioning by disturbances in the connected electrical circuits, if it is presupposed that at least two radiation detectors are used per sprinkler system, that these are protected against the effects of heat, and that a break in the wire or a short circuit in the detector line is evaluated as an alarm criterion. In the normal operating state, the blocking valve is therefore always open, so that even failure of the electrical energy supply, of the extinguishing agent control, or another electric defect in the conduction system, cannot have a deleterious effect. Through condenser $C_3$, provision is therefore also made, that the extinction relay is brought into the "extinguish" position, when the supply voltage is applied, so that turning off the sprinkler system is possible only when a sprinkler bursts and when a plus potential reaches the circuit $R_4C_2$ through contact SP.-K of the alarm valve of the sprinkler system. Triggering radiation detectors then, only affect quick activation of the reset relay (RU), through contact $al_2$ of their alarm relay. They thus bring the detector line again into the normal operating state. Only after the sprinkler system is released (contact SP.-K closed), capacitor $C_2$ is discharged, upon resetting the radiation detectors through $D_1$ and $R_2$. Thus the field effect transistor ($T_1$) cannot become conducting. On the other hand, if the signals from the radiation detectors remain absent, a charge current can flow through $R_4$ to $C_2$, and the required triggering threshold of $T_1$ can be reached. In this case, the pulse given off by $T_1$ makes $T_2$ also conducting, and brings the anchor position of extinction relay (LO) into the position "off."

## 4. CONCLUDING REMARKS

The results, which we were able to gather in the past through experiment and through experience with local extinguishing systems of a new concept, are thoroughly positive. We, therefore, also believe that the effectiveness and reliability of automatic extinguishing systems can be significantly increased by the new concept.

But further experiments will still have to show whether the system is actually practicable. Should this be the case, the process would have the following advantages, among others.

1. The occurrence of the fire itself determines the required amount of extinguishing agent and thus, within certain limits, the concentration of extinguishing agent in the spaces to be protected. As a result, the mathematically-determined design of extinguishing systems with open nozzles and only a limited supply of extinguishing agent does not lead to failure with risks whose requirement for extinguishing agent has not yet been determined by experience, as when too small a concentration of extinguishing agent has been chosen because of ignorance of the required amount of extinguishing agent. Through automatic follow-up extinction, the extinction process is in fact repeated at the right time in cases where it is needed. Another precise amount of extinguishing agent is taken from the supply of extinguishing agent, which increases the concentration of extinguishing agent in the protected area.

2. Another advantage of this system conception is that errors in the calculation of amounts of the extinguishing agent to be used do not jeopardize success of extinction for risks not recognized during testing because the extinguishing system always automatically demands as much extinguishing agent as necessary to successfully complete extinction. Damaging influences result from use-changes in buildings or rooms, for example, by the storing of materials with other fire characteristics or by the changing of construction features, such as, the addition of openings in walls and ceilings.

Frequently, with automatic extinguishing systems, using a limited supply of extinguishing agent can lead to the originally calculated amount of extinguishing agent and concentration not being able to control the course of the fire. These damaging influences are reduced in the same fashion. The procedure, furthermore, guarantees that extinction does not happen at a point in time when extinction is unnecessary, i.e., one avoids supplying extinguishing agent at the first sign of smoke, when the fire would not be extinguished to such an extent that another flame-up would be possible later, and then, at that time, no extinguishing agent would be any longer available.

3. It is an advantage that the basic conception can be combined with present automatic fire extinguishing systems. Thus, its use does not require, among other things, a multiple increase in the supply of extinguishing agent and in the concentration of extinguishing agent. Therefore, no basic increase in expense is required for the extinguishing system to guarantee the extinction effectiveness of the system even with the special, previously not foreseeable, cases. The cited advantages thus need not be purchased through an expensive new system, which is decisive for the economy. It is, furthermore, an advantage that already-existing extinguishing systems can be converted without great expense, so that they, too, can obtain the cited advantages.

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[2] Portscht, R., Concerning the Time Behavior of Temperature Radiation as Characteristic of a Fire, Dissertation, T. H. Aachen (1970).

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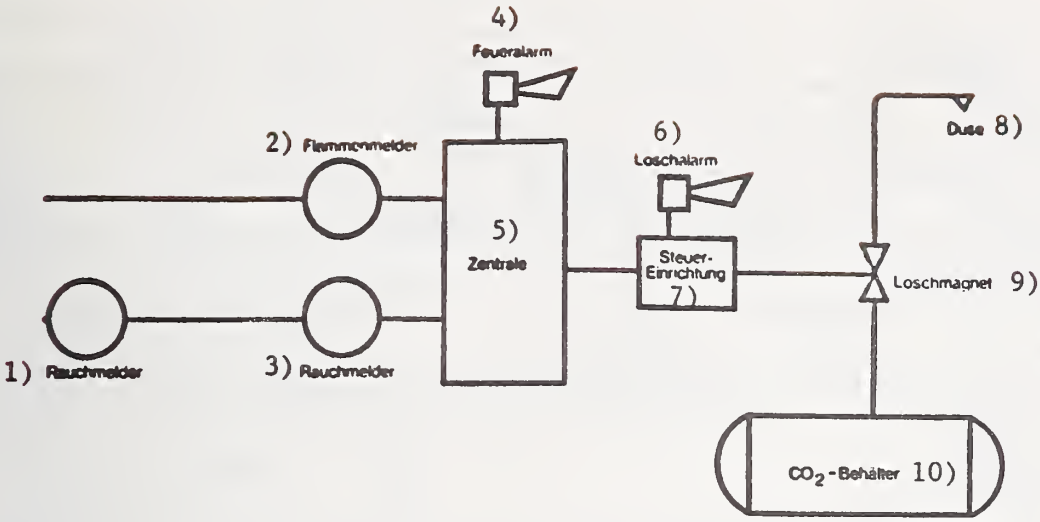


Figure 1. Automatic $CO_2$ Extinguishing System

| | | | |
|---|---|---|---|
| 1. | Smoke Detector | 6. | Extinction Alarm |
| 2. | Flame Detector | 7. | Control Apparatus |
| 3. | Smoke Detector | 8. | Nozzle |
| 4. | Fire Alarm | 9. | Extinction Magnet |
| 5. | Central Unit | 10. | $CO_2$ Container |

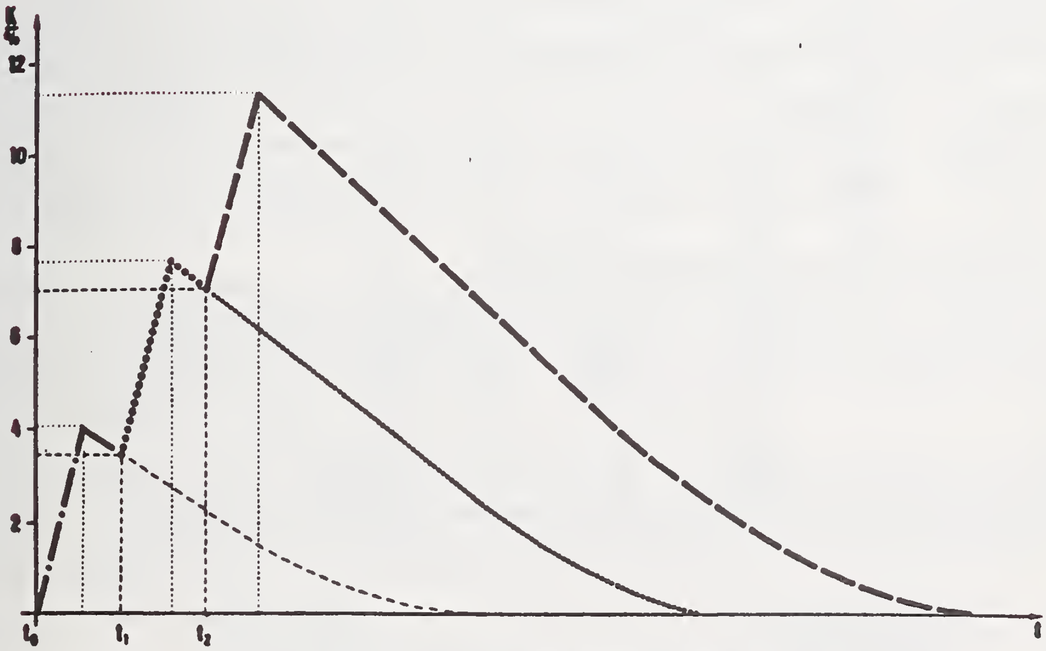

Figure 2. Buildup of the Extinguishing Concentration with Extinguishing Agent Halon

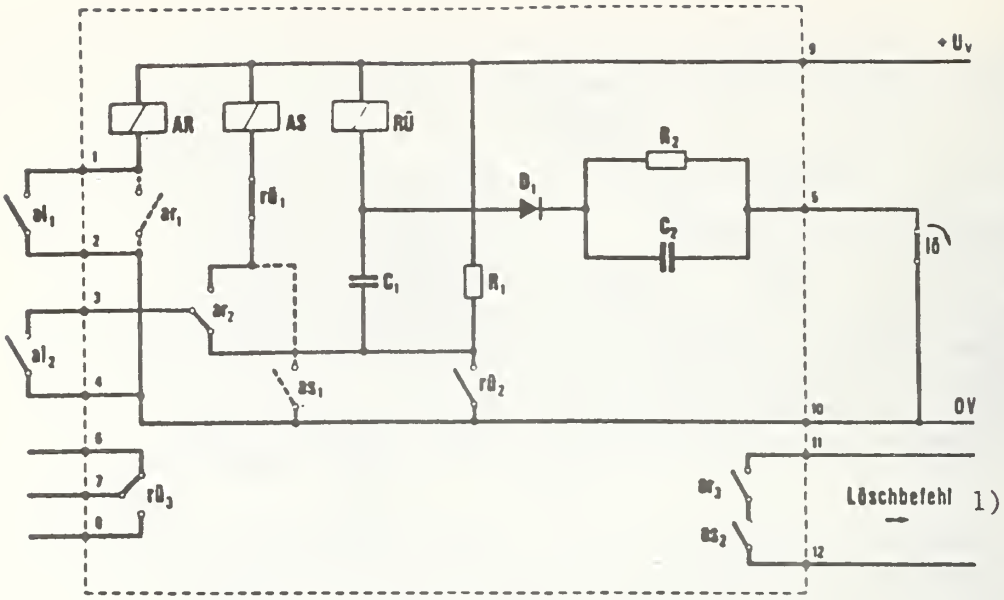


Figure 3. Exemplary Embodiment for Automatic Control of Extinguishing Systems with Gaseous Extinguishing Agents

1. Extinction Command

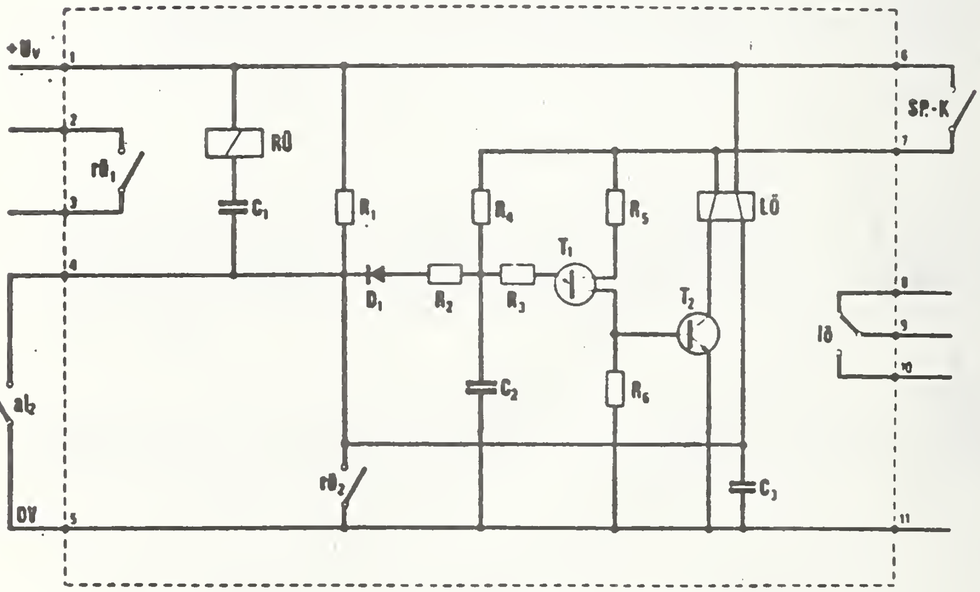


Figure 4. Exemplary Embodiment for Automatic Control of Sprinkler Systems

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SUPPLEMENTARY NOTES

ABSTRACT (A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.)

The use of automatic fire detectors to trigger fire extinguishment systems has gone on for many years. Systems of this type use a variety of extinguishing agents including water, carbon dioxide and, most recently, the halogenated agents.

Automatic extinguishing systems with practically an unlimited supply of agent suffer from the fact that these systems often continue in operation long after the fire is out resulting in additional damage. This doesn't occur with those systems having limited supplies such as carbon dioxide systems and the like. However, these systems are only successful if: (1) their original design was correct; (2) no unanticipated changes are made in the area or materials to be protected; and (3) extinguishment commences at a time when successful extinguishment is possible.

This paper describes how the disadvantages recommended above can be avoided, to a large extent, with a modified design for permanently-installed, automatic extinguishing systems and how systems can be provided which will only discharge extinguishant at the proper time and in the proper amount.

KEY WORDS (six to twelve entries; alphabetical order; capitalize only the first letter of the first key word unless a proper name; separated by semicolons) Automatic sprinklers; carbon dioxide; fire detection; fire extinguishment; flame detection; heat detection; smoke detection.

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