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Fire alarm detectors with low rates of false alarms

by

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ABSTRACT

This thesis describes a project in which the underlying causes of unreliability and incidence of false alarms in fire alarm systems is studied with a view to the design of an improved, more reliable system. Information gained from the answers to questionnaires circulated to fire officers and other officials concerned with fire detection and prevention in the field has been used as a data base for the study together with a survey of the various types of fire detectors and alarm systems in common use at present.

Work has progressed to the development of two different types of opto-electronic smoke detector and the development of a new fire detection principle, named the "SENSI-CHECK" principle. Both improved smoke detectors incorporate ideas resulting from the study for increasing the reliability of detection and for reducing the number of false and unwanted alarms without reducing the sensitivity to genuine alarms. The detectors have undergone trials both under laboratory conditions and on site with excellent results. Using the SENSI-CHECK idea conventional type detectors are able to monitor their sensitivity and report on their state at all times without initiating false alarms and offer high sensing integrity to real fires.

The SENSI-CHECK principle has proved that multistate conventional detectors can offer a higher sensitivity to

real fires than simple two state detectors. Their four possible states (undersensitive, normal, oversensitive and fire), when compared with the two-state conventional detector windows, normal or fire, represent arguably the best that can be achieved by this class of detector. It is expected that future improvements will depend on the introduction of new generation of fire alarm detection systems. One such system is based on multiloop analogue sensor circuits in which analogue information from a number of sensors is analysed by a central controller unit using fire analysis algorithms which interpret the signal patterns by comparison with known fire signal "signatures". Prospects for these systems are reviewed in the light of experience gained by the author in work for his company.

ACKNOWLEDGMENTS

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Special thanks are also due to Electronic Alarms Ltd and Hakuto International (UK) Ltd who have suggested and financially sponsored this research work.

INTRODUCTION

The purpose of this research work was to identify the causes of unwanted fire alarms and provide the necessary tools for developing improved fire detection equipment having minimum false alarm rates.

The research was originally suggested and sponsored by Electronic Alarms Ltd, (a fire alarm systems manufacturer). The promising results and the subject of the study itself proved to be of even greater interest to another firm. Hakuto International (UK) Ltd, (a fire detection equipment supplier), who found the results of the preliminary work so interesting they took over the sponsorship and guidance of the research project.

The research programme as described in this thesis is outlined below:

Chapter 1 describes the four basic types of fire detector, Chapter 2 discusses the causes and incidence of false alarms, Chapter 3 describes the design and performance of an advanced smoke detector, Chapter 4 describes the SENSI-CHECK principle, Chapter 5 describes the test programme followed to evaluate the performance of the detectors and Chapter 6 discusses the results and reports the conclusions of the research work.

CHAPTER 1

FIRE DETECTION DEVICES

1.1 Giving warning of fire

The first consideration for the safety of life and property from fire, is to ensure that once a dangerous situation is recognised the fact must be communicated to a control alarm station. This sounds the alarm to warn people that they are in danger and that arrangements which have previously been made to cope with such a situation are to be put into effect. Also this, must inform the fire brigade that there is a fire and put any automatic actions in operation, e.g. close doors, open windows, disable lift operation etc..

The British standard B.S. 3116 :Part 4: 1974 and B.S. 5839: Part 1: 1980, requires that adequate means of detecting a fire must be provided and detailed instructions of how this is to be done are given.

There are basically two ways of initiating a fire alarm: (a) Automatically by using automatic fire detectors or sensors and (b) manually by operating a fire alarm trigger device. The automatic fire detection devices are the subject of the following paragraphs.

1.2 Automatic fire detection devices

Automatic fire detection devices are specifically designed to sense only one particular fire characteristic: heat, smoke, gas or flame. Different materials when they burn release different amounts and combinations of these characteristics. Thus the key to correct design of detection devices is to understand the stages of fire development at which each of the above characteristics becomes evident. After ignition has occurred, and the invisible products of combustion are being released, visible smoke is also being produced, the fire produces flames and a degree of illumination, and the temperature in the vicinity of the fire rises rapidly or reaches an elevated level.

The types of detectors designed to operate at one of these particular stages are as follows:

(a) Heat detectors
(b) Smoke detectors
(c) Gas detectors and
(d) Flame detectors

Fire detectors are also classified according to the basis of where the fire alarm decision making takes place i.e. at the detector itself, (called a conventional detector) or at the control panel, (called an analogue sensor). However, whichever type of alarm decision making is used, both detectors and sensors operate and use the same principles in detecting a fire.

Because of the various conditions that occur in the development of a fire no one type of detector can be said to be the most suitable for all applications and the final choice has to depend on individual circumstances. This is a major drawback of the present devices and identifies a need for some research work to be done on combined types of detectors. However, until something is done it may be useful to install different types of detectors in the same area or to install both a detection system and an extinguishing system such as sprinklers combined together.

Up to the present time thousands of different types of fire detection devices have been developed. But basically the four main principles of detection mentioned above have been followed. It is beyond the scope of the present work to individually examine the various detectors introduced over the years, since all of them are based on the well known principles of detection, (heat, smoke, gas and flame). However a list of all other different types of detectors used in industry since 1970, is provided in Appendix A, at the end of this report.

The following sections discuss the four individual principles of operation and detection:

1.2.1 Heat detectors

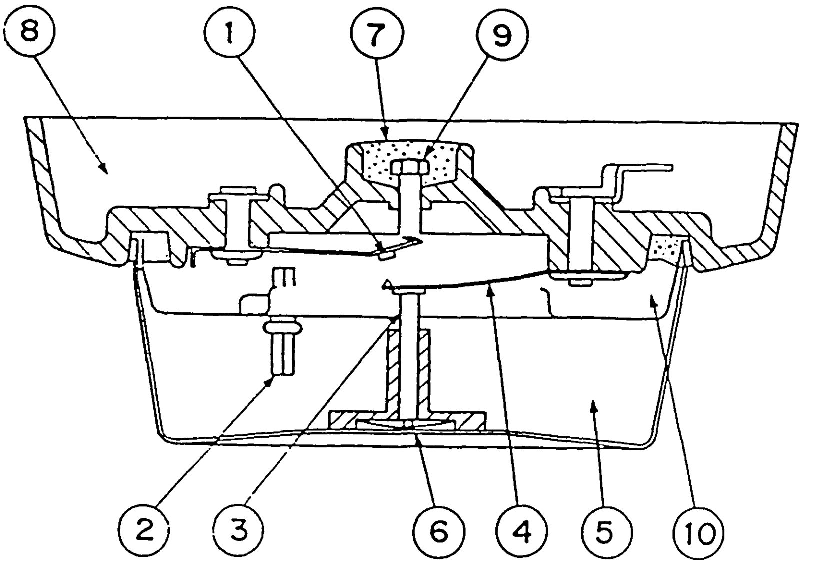
The most general way of detecting the outbreak of a fire is to sense the accompanying temperature rise. This can be broadly divided into (1) a method which makes use of thermal expansion due to the temperature rise of air in a pipe installed in the area to be protected and (2) a method utilizing the deformation of a bimetallic element due to the temperature rise or diaphragm actuated by expansion of air.

At present, the latter method is more widely used for fire detection, and it can be subdivided into two methods. One detects a rapid increase in temperature (rate-of-rise), and the other detects ambient temperature, giving an alarm when the ambient temperature reaches a predetermined value (fixed-temperature).

In addition, there is the heat detector, (shown in Fig.1.1), which combines the rate-of-rise and fixed-temperature functions in one unit in detecting change of temperature.

The fixed-temperature function consists mainly of the bimetal disk and the rod which elevates a diaphragm to make a contact. When temperature reaches a predetermined value, the bimetal disk will instantaneously reverse and act through the rod to make a contact.

The rate-of-rise function consists of the diaphragm and the air chamber. Where the ambient temperature increases at a slow rate, the expanded air in the air chamber leaks through the vent tube. However, if the rate of rise in temperature exceeds the predetermined value, the diaphragm is elevated by rapid expansion of air to make a contact.



1. P.G.S contacts
2. Vent tube
3. Rod
4. Diaphragm
5. Bimetal
6. Bimetal
7. Seal
8. Pressure equalizer
9. Adjustment screw
10. Second air chamber

Fig.1.1 Construction of a combined heat functions detector

1.2.2 Smoke detectors

Smoke detectors are more costly than heat detectors but provide considerably shorter response times and subsequently higher false alarm rates due to their increased sensitivity. Photo-electric smoke detectors are used to detect smoke and operate by using the properties that light is reflected or absorbed by smoke particles. Both physical properties are used to provide two forms of detector: the light scatter type and the obscuration type.

A photo-electric smoke detector which employs the light scatter principle operates by electrically detecting the scattering of light rays from a light source, the rays being reflected by the fine particles contained in smoke, in the same way that light rays from the sun entering a dark room strike dust particles, causing them to sparkle.

A photo-electric smoke detector which uses the light obscuration principle operates by electrically measuring the amount of light reduction caused by the absorption of light by smoke particles.

1.2.2.1 Principle of light scatter smoke detector

As shown in Fig.1.2, a light emitting diode is mounted on one side of the smoke chamber and a photo-diode is mounted on the opposite side in such a way that it is not exposed to direct light from the light emitting diode, and so, in the absence of smoke receives little or no light.

When smoke enters the smoke chamber, the light scattered by the smoke will reach the photo-diode and generate a minute current in it. This current is detected and used to create an alarm.

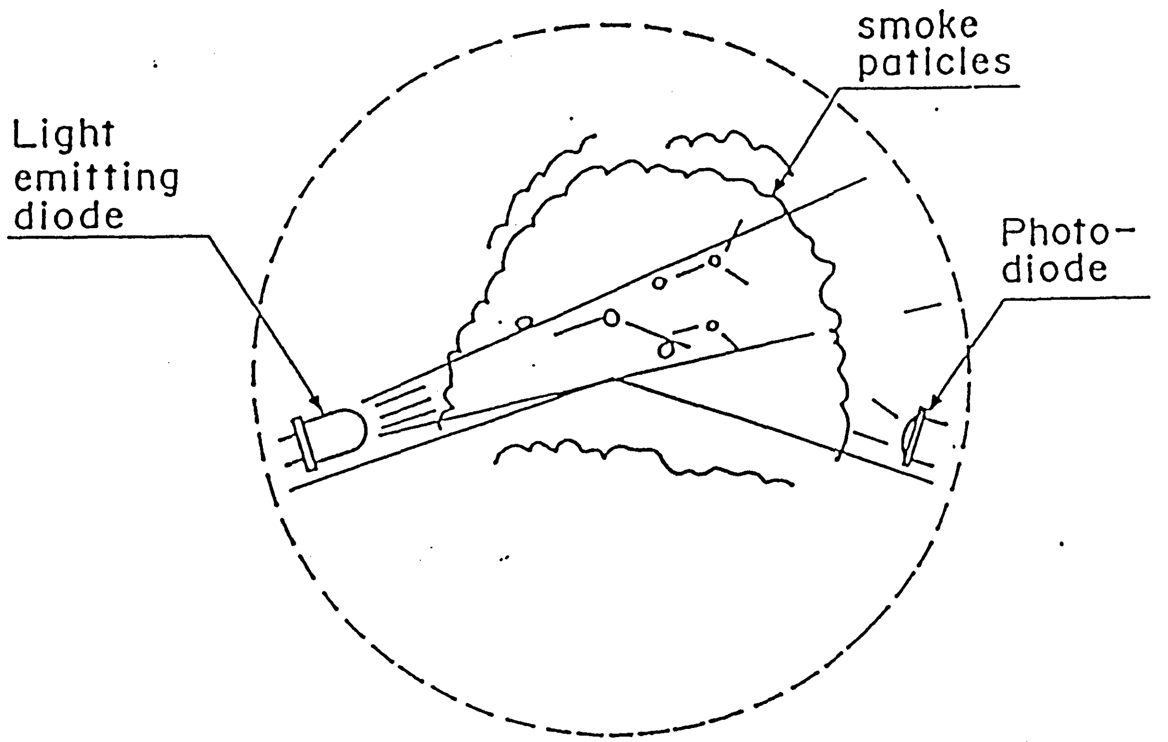


Fig.1.2 Principle of light scatter smoke detector

1.2.2.2 Principle of obscuration type smoke detector

As shown in Fig.1.3, a light emitting diode is mounted on one side of the smoke chamber and a photo-diode is mounted directly opposite to it and so the light leaving the light emitting diode is continually received by the photo-diode.

When smoke enters the smoke chamber, the light beam is attenuated by being absorbed by smoke particles, so that the amount of light reaching the photo-diode is reduced. The resulting voltage change across the photo-diode is detected and used to generate an alarm.

Because a photo-electric smoke detector detects minute change in light, the detector is liable to be affected by light entered into the smoke chamber, and there is a risk of false alarm for the light scatter type detector and a risk of misoperation for the obscuration type detector. To prevent this, the smoke chamber is constructed like a labyrinth in order to keep out external light.

Moreover, in order to prevent unwanted reflection of light rays within the smoke chamber, all faces are painted matt black. After installation, dust may gradually accumulate within the detection chamber, affecting the light emission from the light emitting diode, thus causing the sensitivity of the detector to change. Moreover, if there is a large amount of dust particles in the air close to the detector, the dust may enter it and appear as smoke, and so cause the detector to alarm.

For the above reasons, therefore, a photo-electric smoke detector should not be installed in dusty locations.

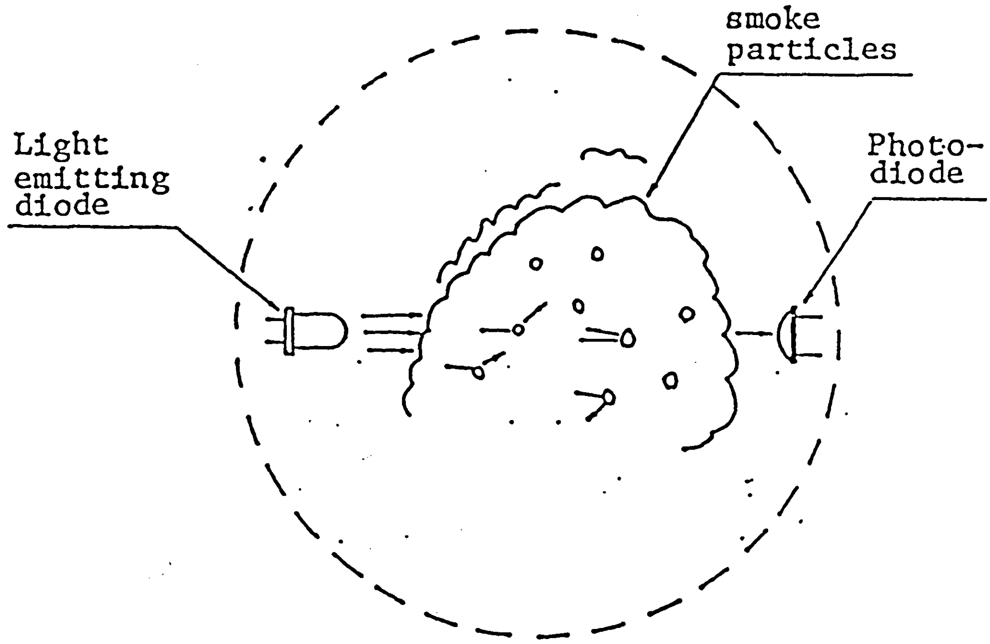


Fig.1.3 Principle of obscuration type smoke detector

1.2.3 Gas detectors

The most common type of gas detectors is the ionisation gas/smoke detector. This type of detector is sometimes, misleadingly, said to belong in the smoke detectors family, even though its detection mechanism is based on gas detection principles (ionised air). An ionisation smoke detector operates by detecting changes in a minute current flowing through ionised air between two electrodes, resulting from the presence of products of combustion. This phenomenon has been known for over 50 years and is employed in early warning fire alarm systems.

Recently, along with advances in electronic technology including the development of the FET, the reliability of the ionisation smoke detector has been gradually increasing and it is now widely used.

In principle, the ionisation smoke detector is particularly sensitive to small, invisible particles of the order of 0.1µm which are given off initially when a fire breaks out. It can thus be used as an effective early warning device. On the other hand, it is relatively insensitive to smouldering smoke owing to large smoke particle size. Early detection of this kind of smoke is carried out using a photo-electric smoke detector.

An ionisation smoke detector consists basically of a smoke chamber and electronic circuits. The smoke chamber plays an important role in detecting smoke which entered the chamber.

Fig.1.4 shows the basic principle of the ionisation smoke detector. Americium 241 (Am^{241}) is employed as a radioactive source for ionising the air between the electrodes in order to provide a conductive path. the radioactive source Am^{241} primarily emits strong α rays which cause ionisation.

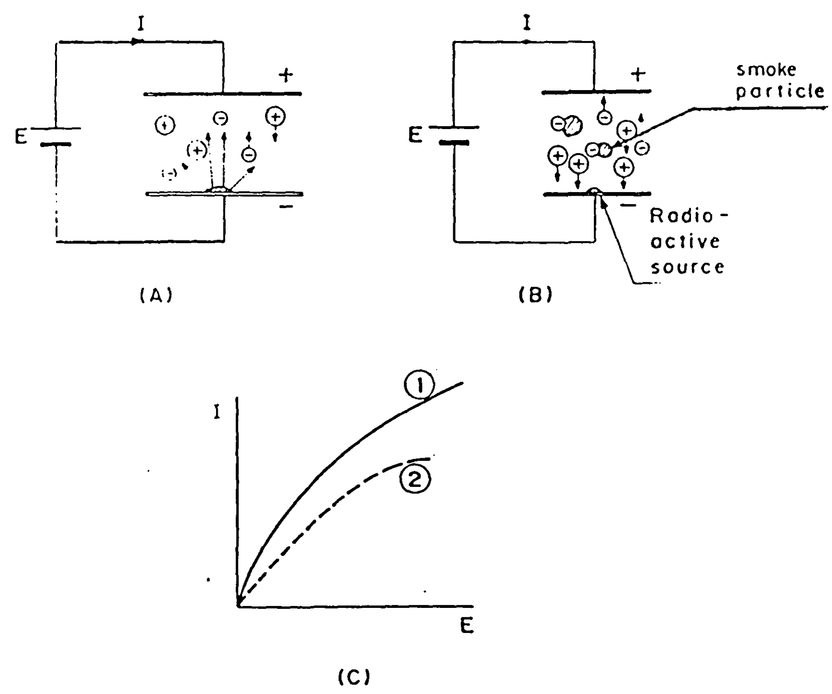


Fig.1.4 Principle of smoke detection applying change of ion current

As shown in Fig.1.4A, the air between the electrodes is ionised by the α rays, causing a very small current to flow between the electrodes. As shown in Fig.1.4C, as the voltage applied across the electrodes is increased, the ion current increases. When the strength of the radioactive source is constant, however, this ion current approaches saturation. Curve (1) in Fig.1.4C shows the relationship between voltage and ion current when the smoke is absent, and Curve (2) shows this relationship when the smoke is present. When smoke exists between the electrodes, positive and negative ions attach themselves to smoke particles, so that the weight of the ions increases, causing the mobility to be reduced. As a result, the positive and negative ions rejoin and the ionisation current falls off (see Fig.1.4B).

The higher the smoke concentration, the more pronounced is this fall-off in current. It is thus possible to utilize this change of current to detect the presence of smoke. Because this current is extremely small and also the change in current is small, two smoke chambers are arranged in parallel in practice to form a differential arrangement. One chamber is constructed so as to allow smoke to enter freely, whereas the other does not. The change in current through each chamber is output after being converted into a voltage.

The current flowing between the electrodes is small, and they must be supported with an insulating material which has a very high insulation resistance. A circuit with very high impedance is also more easily influenced by external electrical noise. In order to eliminate such noise, the circuit must be carefully designed and be statically shielded.

Although the smoke chamber must be constructed to allow smoke to enter it freely, it must be designed so that it is relatively uninfluenced by wind. To this end, the smoke chamber must be properly designed and manufactured under rigid quality control.

1.2.4 Flame detectors

The ultraviolet flame detector uses a UVtron that absorbs the feeble ultraviolet light contained in flames. The detection is in the form of a discharge pulse train with the help of the photo-electric effect and electron avalanche phenomenon. The detector has a counter circuit which prevents malfunctions from taking place, due to single-shot or momentary UV rays, such as lightning or cosmic radiation.

The UVtron has an anode and cathode face-to-face and is filled with argon (see Fig.1.5).

A high voltage is applied between the two electrodes. At a certain voltage (V_1), a dielectric breakdown occurs and a large current flows suddenly, discharging the UVtron. The voltage versus current characteristics of the UVtron are shown in Fig.1.6. The operating points are selected with the value of resistor Rs.

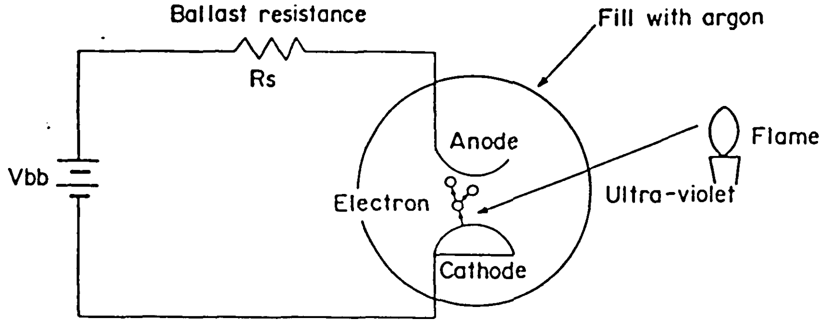


Fig.1.5 Basic circuit of ultraviolet rays tube

Next, consider the case where voltage is applied to the UVtron with irradiation of ultraviolet rays. The ultraviolet rays cause the cathode to emit photo-electrons, when the current flowing is increased, the additional flow triggers an electron avalanche, resulting in a lower voltage (V_2).

Voltage V_{bb} is set between V_1 and V_2. When the discharging is initiated it causes a current flow into the circuit. This occurs when ultraviolet rays are irradiated to the bulb (glow discharge).

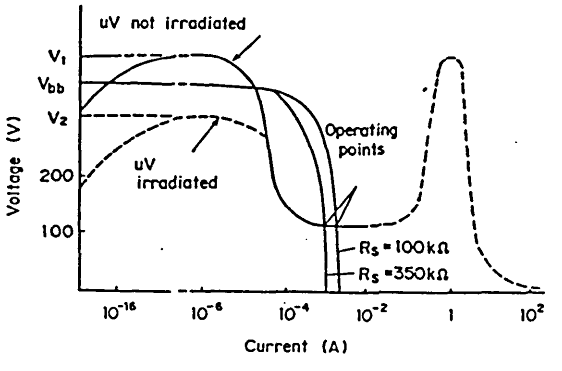


Fig.1.6 UVtron V - I characteristics

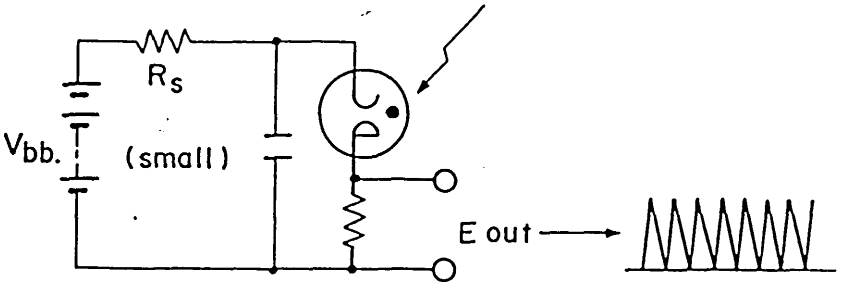


Fig.1.7 Glow discharge

In Fig.1.8, the operating points are set in the glow area with a relatively large current flowing in the circuit. If a larger Rs is used, the operating points can be set between two areas, (a) the Downside area and (b) the Glow area, as shown in Fig.1.8. When in an alarm state the UVtron emits short pulses repeatedly and laterally between (a) and (b). This method assures proper operation of the UVtron with relatively low operating current.

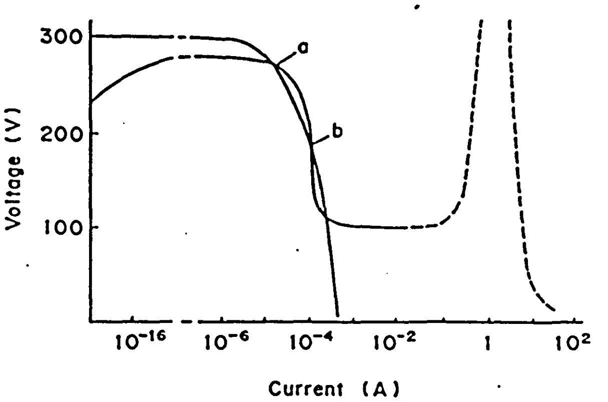


Fig.1.8 Downside operation characteristics (ultraviolet rays irradiated)

1.3 Fire detection devices developed since 1970

Two year's research work on the various types of fire detection devices developed since 1970, has concluded that two principal types of detectors are the most effective fire detection devices in protecting life and property. One of these is the ionisation type detector. This can detect fires at its very early stages, even before smoke is visible and the other type is the optical light scatter detector, which can detect visible smoke only.

A list of all the fire detection devices considered, organized primarily by the fire characteristics being detected, is given in Appendix A. The results of this investigation were published by Hakuto International (UK) Ltd as a Professional Guide. The report is known as "Which Fire Detector to Choose" and gives quidelines on how to and which type of detector to choose. At the end of this report a list of all the considered and examined fire detection devices is included. The list is subdivided by detection technique. A description of the mode of operation of each device is summarised; known or expected applications of each device are listed, and unique characteristics or other features of each device are given. References cited in these tables are listed at the end of the paper and identify sources of further information on each device.

CHAPTER 2

UNWANTED FIRE ALARM SIGNALS

2.1 Introduction

This Chapter summarises the results of an investigation into Unwanted Fire Alarm Signals arising from Automatic Fire Alarm Systems. A questionnaire, circulated to fire officers and other officials concerned with fire detection (see Appendix A3) was used in collecting this information.

2.2 Definitions of fire signals

To avoid ambiguity, the following terms are used throughout the Report:

(a) Fire Signal

Any signal indicating "Fire" transmitted from protected premises to a Fire Brigade.

(b) Genuine Fire Signal

A fire signal given when there is a fire or the situation would shortly develop into a fire.

(c) Unwanted Fire Signal

Any fire signal other than a genuine fire signal i.e. accidental, malicious, malfunction or unidentified.

(d) Accidental Fire Signal

A fire signal originating from the automatic fire alarm system resulting from:

i) response to physical conditions identical or similar to those caused by fire, or

ii) operation of the system in good faith by a person who believes there is a fire.

(e) Malicious Fire Signal

A fire signal originating by deliberate operation of the automatic fire alarm system by a person knowing that there is no fire in the protected premises.

(f) Malfunction Fire Signal

A fire originating from the automatic fire alarm system caused by:

i) detector malfunction of a system component including degeneration of a component under existing environmental conditions, or

ii) incorrect response of any part of the system to physical conditions more severe than those intended to withstand without giving rise to a fire signal, or

iii) misoperation of the system by the user or by maintenance personnel while carrying out maintenance procedures or testing without first informed the Fire Brigade, or

iv) other known reasons in external systems e.g. fluctuation of pressure of the water supply of a sprinkler system connected to the Fire Brigade by the fire alarm system, or

v) defect or interruption in the British Telecom transmission system between the protected premises and the fire signal receiving station.

(g) Unidentified Fire Signal

A fire signal the cause of which cannot be positively identified.

2.3 Analysis of unwanted fire signals
(Arising from automatic fire detection systems)

It must be appreciated that it was never the intention of this research work to carry out an in-depth analysis of the results of the exercise particularly because of the manpower which would be required for such a task. However, certain key factors came to light.

The results of such investigation into incidents notified to Electronic Alarms Ltd showing the principal causes of unwanted fire signals is given in Table 2.1 and shown in Fig.2.1. Two thousand, two hundred and eight unwanted fire signal incidents involving 1411 fire detection and alarm systems were studied and analysed during a 30 month period.

2.4 Causes of unwanted fire signals
(Excluding malicious fire signals)

Technical faults in systems was the largest single cause, 21.6% (see Table 2.1 *3), including 45 suspect smoke detectors (36 Optical and 9 Ionisation). There was no recorded evidence to indicate which faults were the results of poor quality control on the part of the manufacturer or

Table 2.1 The principal causes of unwanted fire signals

ACCIDENTAL (29.8%)		
Ventilator Stopped	1.4%	*6
Boiler Blow Back	1.4%	*6
Steam	1.4%	*12
Wind	0.7%	*13
Exhaust Gases	4.7%	*6
Tobacco Smoking	5.4%	*8
Blow Back of Heating System	0.7%	*6
Cooking	4.0%	*6
Break Glass Unit (see *1)	4.7%	*10
Other Causes	5.4%	*9
MALICIOUS (4.1%)		
Break Glass Unit (see *2)	3.4%	
Detector Operated (see *2)	0.7%	
MALFUNCTION (64.1%)		
Drift of sensitivity	14.0%	*5
Dust/Insects in Detector	4.7%	*5
Damage to: Detector	8.0%	*4
Wiring	5.4%	*4
Other Parts	0.7%	*4
Technical Fault in Systems	21.6%	*3
Signals From Other Systems	6.7%	*7
Fault in Transmission System	3.0%	*11
UNIDENTIFIED (2.0%)		
Cause cannot be found	2.0%	*14

*1 By person believing fire exist *2 Operated deliberately

*3 to *11 refer to Fig.2.1 and subsequent text

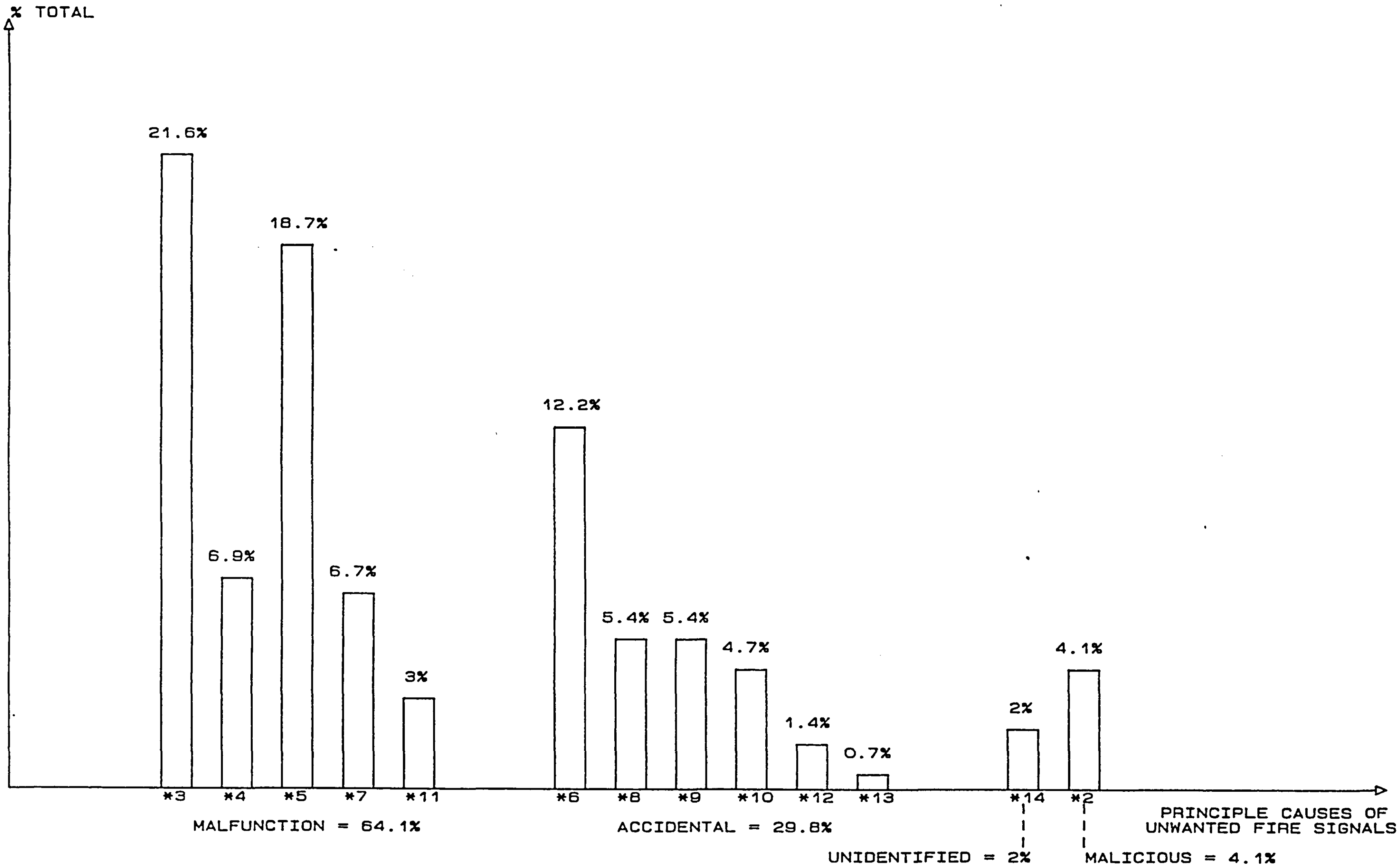


Fig.2.1 The principal causes of unwanted fire signals

inadequate or incorrect maintenance of the detectors or damage by the user to the system. Eight incidents were attributed to electrical interference on the supply line to the detectors.

Direct impact and other damages together accounted for 14.1%, (see *4), of all unwanted fire signals.

Drift of smoke detector sensitivity with dust and insects caused 18.7%, (see *5), of all unwanted fire signals with dust and insects being the main responsible cause.

Extraneous smoke caused 12.2%, (see *6), of all unwanted fire signals. Considerations as to the adjustment of the sensitivity of the detecting devices may reduce this nuisance but due attention should be given to ensuring that the sensitivity is adequate to cover the perceived risk and within the limits specified in the appropriate British Standards.

Signals from other systems caused 6.7%, (see *7), of all unwanted fire signals. Six of these unwanted fire signals were from the same installation and caused by corroded or leaking sprinkler which generated a signal from the water flow switch causing the alarm system to operate; the user of the premises having failed to ensure that the installation was adequately maintained. Signals caused by sprinkler water pressure alarm supplier and/or specifier should have insisted on including a delay in the sprinkler signal circuit to eliminate signals caused by water pressure fluctuation.

Tobacco smoking caused 5.4%, (see *8), of all unwanted fire signals. To eliminate such fire signals there must be greater discipline over the use of the premises, improved smoke detector design, and proper attention being given to the correct citing of detectors.

Under accidental fire signals a further 5.4%, (see *9), of all unwanted fire signal were due to other causes. Such categories include fumes from caustic solutions placed near detectors and a process machine that sprayed chemicals onto detectors.

Misoperation by the user or maintenance personnel caused 14.1%, (see *4) of all unwanted fire signals. In all but one case, such unwanted fire signals were caused by electrical contractors, British Telecom engineers or maintenance personnel.

Intentional operation of manual call points in the belief that a fire exists also accounted for 4.7%, (see *10), of all unwanted fire signals.

Fault in transmission system caused 3.0%, (see *11), of all unwanted fire signals. It should not be overlooked that the agreement covering the communication link to the Fire Service station is invariably between the user and the receiving station direct.

Extraneous heat caused 1.4%, (see *12), of all unwanted fire signals and it would appear that this nuisance could be reduced by better attention to the selection and citing of heat detectors.

Wind or draught was responsible for only 0.7%, (see .*13), of all unwanted fire signals.

In 2.0%, (see *14), of cases the cause could not be identified.

The above analysis formed the basis for the development of an improved smoke detector. It was concluded that the principal cause of unwanted alarms after the Techical fault (21/.6%) in systems was the Drift of detectors sensitivity (14.0%). A detector was therefore designed based on ideas resulting from the study in increasing reliability of fire detection and reducing the number of false alarms without reducing the sensitivity to genuine alarms.

2.5 Graphical analysis of unwanted fire signals

An analysis of all unwanted fire signals based upon reports raised at the time of their attendance at incidents is given in Tables and Figures 2.1 to 2.4 as follows:

Table and Fig. 2.1 shows the principal causes of unwanted fire signals. Table and Fig. 2.2 shows the number of unwanted fire signals arising from different types of protected premises. Table and Fig. 2.3 shows the causes of unwanted fire signals arising from hospital installations. Table and Fig. 2.4 shows the time of day unwanted fire signals were received.

A considerable degree of success has been achieved by the industry, in containing unwanted fire signals attributable to faults in fire alarm systems. Unfortunately, the number of unwanted fire signals arising from actions or inactions of the occupiers of the premises has not been so successfully contained and the number of unwanted fire signals from this source continues to rise.

The continuing high level of unwanted fire signals arising from installations in hospitals is of major concern particularly as the Fire Protection Systems Industry have taken all possible steps within their power to limit such signals from such installations.

There will always be some unwanted fire signals from fire detection and alarm systems and it is considered that there has to be some form of deterrent to control such signals. Some users have adopted a reasonable attitude but believe that the lack of legislative support deprives them of the desired degree of effective control.

Table 2.2
The number of unwanted fire signals arising from different types of protected premises
(May 1985 to November 1987)

Year	Residential	Hotels	Hospitals	Others	Total
May'85 to May'86	98=11.5%	176=20.8%	83=9.8%	489=57.9%	846
May'86 to May'87	108=11.8%	193=21.2%	106=11.6%	505=55.4%	912
May'87 to Nov'87 *	83=18.4%	95=21.1%	78=17.3%	194=43.2%	450

Note: * six months period

Total number of unwanted fire signals .... = 2208

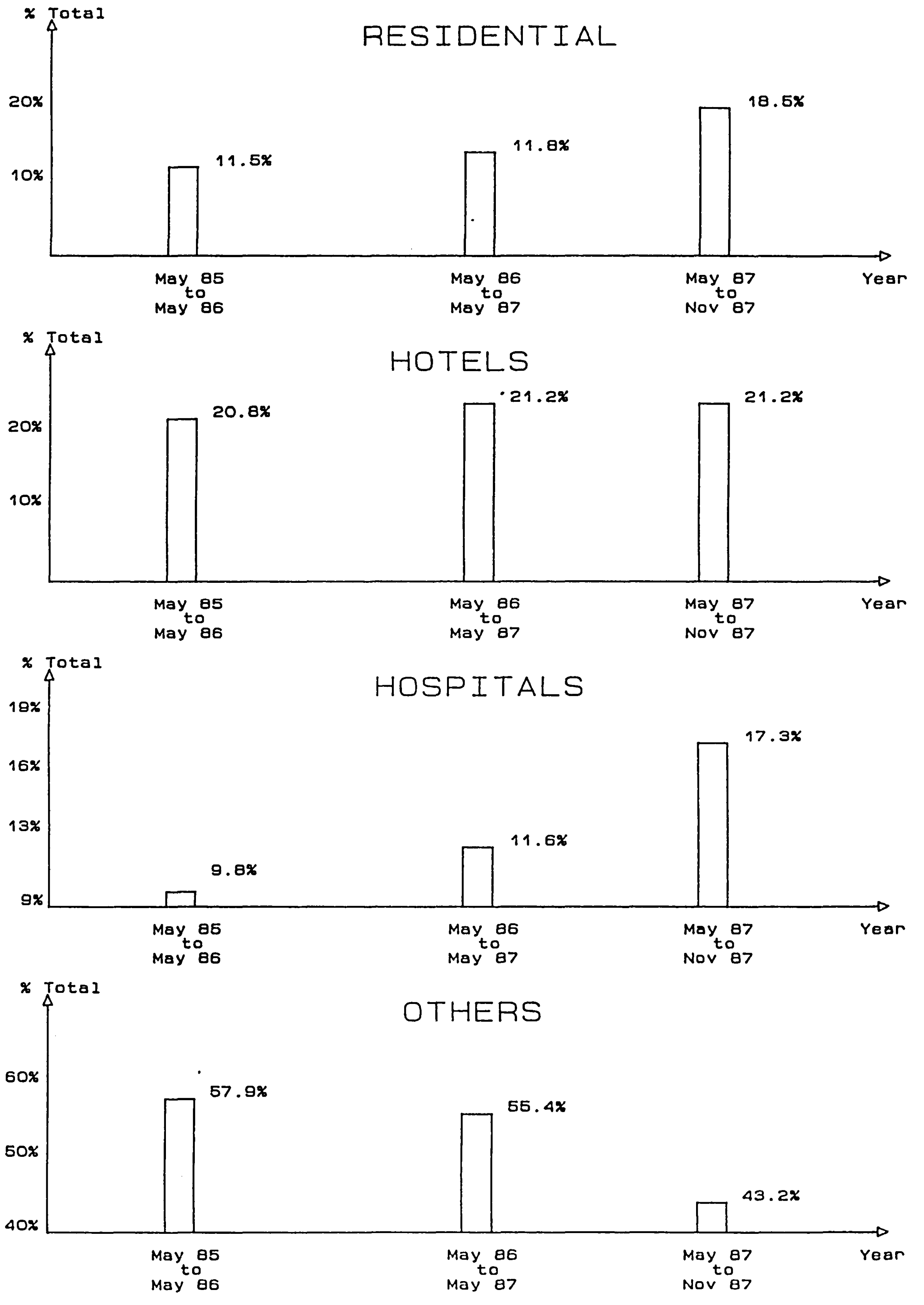


Fig.2.2 Unwanted fire signals arising from different types of protected premises for years 1985-1987

Table 2.3
The causes of unwanted fire signals arising from Hospital installations
(May 1985 to November 1987)

	Number of UFS	Percentage of total
ACCIDENTAL (18.1%)		
Fumes from cooking etc.	18	8.5%
Operated with good intent by staff	10	3.6%
Smoke from external source	9	3.0%
Steam	7	1.8%
Smoking materials	7	0.6%
Short circuit caused by leaking water	6 +	0.6% +
	55	18.1%
MALICIOUS (8.5%)		
Patient/inmate operated alarm	39	8.5%
	39	8.5%
MALFUNCTION (68.0%)		
Faults in system	49	27.7%
Insects	28	15.1%
Dust	15	6.6%
Damage by workmen etc.	15	6.6%
Electrical storm	11	4.8%
Maintenance personnel working on system	10	3.6%
Misoperation by occupiers	10 +	3.6% +
	138	68.0%
UNIDENTIFIED (5.4%)		
Cause cannot be found	35	5.4%
Total	267	100.0%

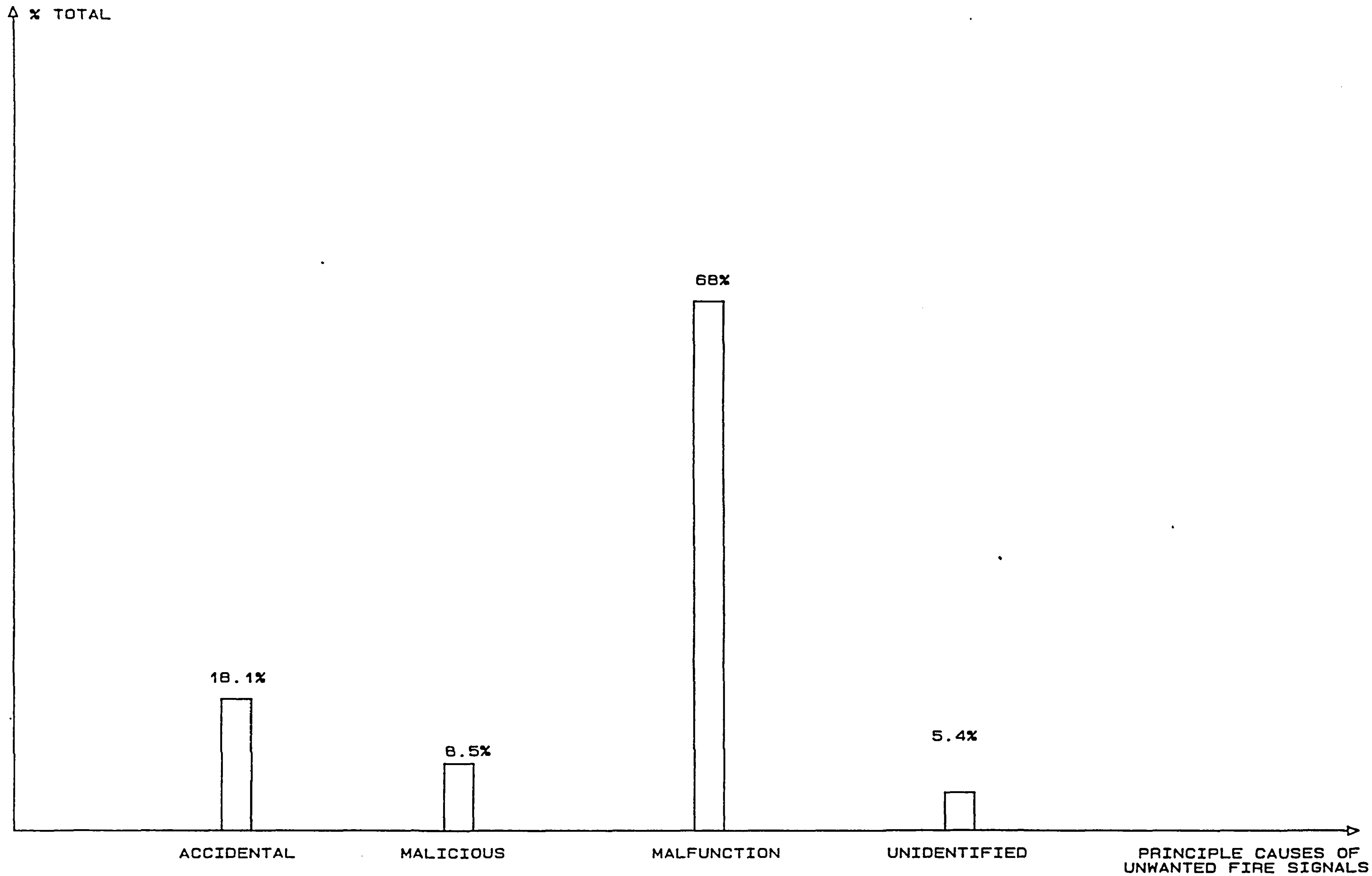


Fig.2.3 Causes of unwanted fire signals arising from Hospital installations

Table 2.4
The time of day unwanted fire signals were collected
(May 1985 to November 1987)

YEAR	Monday to Friday	Day 08.00 to 17.00 Hrs	Night 17.00 to 08.00 Hrs	% Day	% Night
May'85 to May'86	504	291	213	64.6%	35.4%
May'86 to May'87	577	309	268	55.8%	44.2%
May'87 to Nov'87	354	205	149	57.1%	42.9%

YEAR	Satar. to Sunday	Day 08.00 to 17.00 Hrs	Night 17.00 to 08.00 Hrs	% Day	% Night
May'85 to May'86	342	217	221	48.1%	51.9%
May'86 to May'87	335	163	172	46.2%	53.8%
May'87 to Nov'87	96	53	43	53.5%	46.5%

Note: The causes and time of unwanted fire signals arising from Hospital installations were not directly relevant to the detector design but to the detection system design in general.

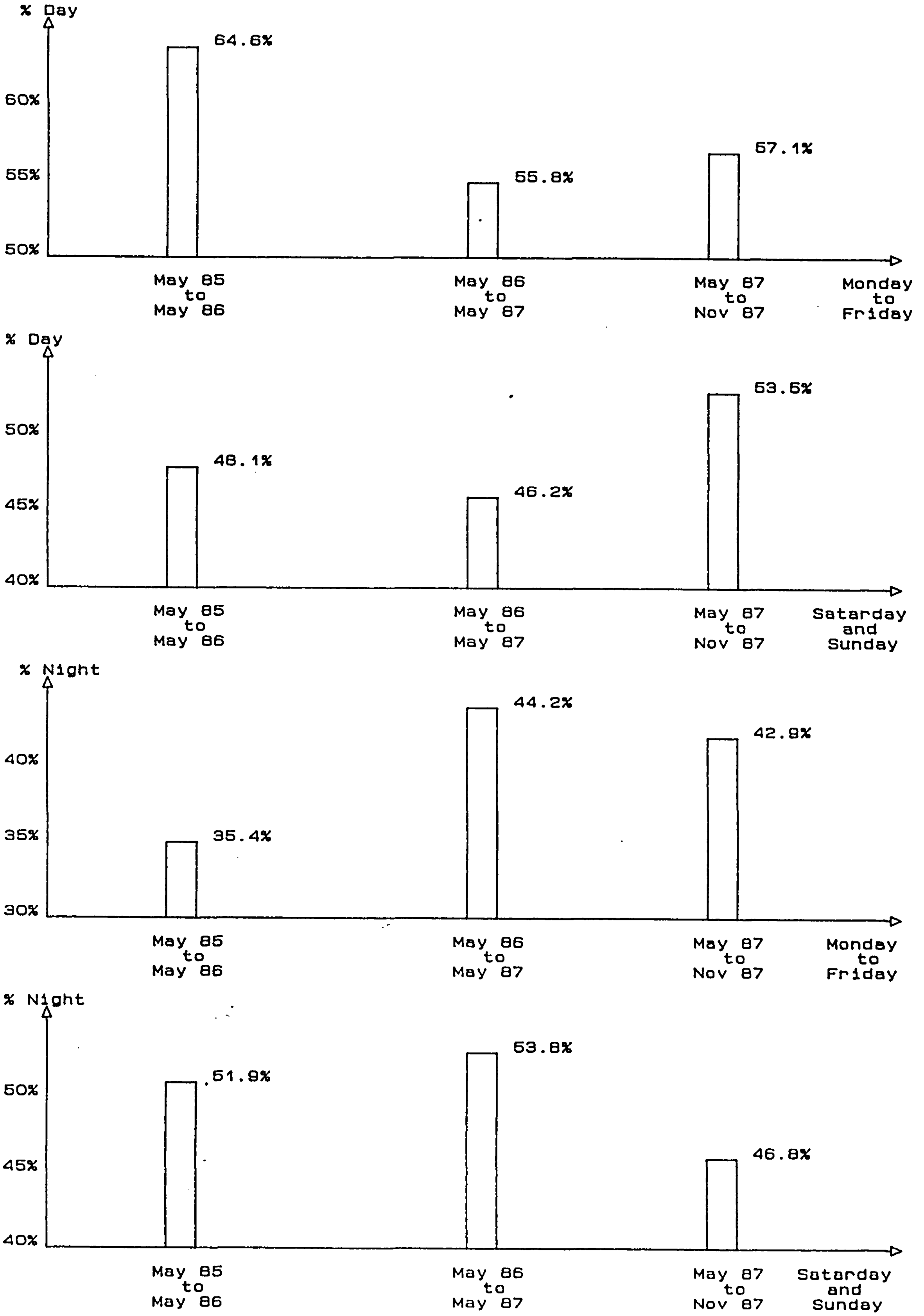


Fig.2.4 Time of day the unwanted fire signals were collected

2.6 Measures against unwanted fire signals

It is not possible for specific recommendations to be made as to the corrective treatment to be given to systems of different kinds and different manufacture.

Most false alarms are caused by phenomena that simulate a fire. Both old and new systems contribute their shares to the absolute number of false alarms received at fire houses. When new systems are installed, the false alarm problem can be kept within reasonable limits right from the start if the planning and execution are based on sound experience. But a fast answer is also required for existing systems if the overall problem is to be solved. The solution offering the best chance of success at relatively modest cost is a Monitored Alarm Organization and new methods of checking Alarm Plausibility.

2.7 New possibilities in combating false alarms

The use of "addressable" detector systems, with each detector having its own address, has become "state of the art" in detection engineering. It permits still faster localization of incipient danger, which is highly desirable. In addition these systems make it possible to establish the cause of false alarms reliably and thus to bring the false alarm problem under control more quickly. But they cannot solve the problem by themselves. The aforementioned measures such as the Monitor Alarm Organization and Plausibility Checking will have to be combined.

The most promising approach of all for reducing false alarms is the creation of security systems with a higher level of "intelligence". The latest system designs are moving in this direction.

If two fire alarm control systems of differing "intelligence" are compared, the more "intelligent" one will be capable of taking over part of the human judgement function. In other words it will be better equipped to decide whether an alarm is really justified, i.e. whether a fire simulating phenomenon has caused the response.

One very promising example now under development is the analysis of analogue signals from sensors. This requires the replacement of today's threshold detectors by sensors capable of communicating continuous changes of condition to a peripheral computer in the form of analogue signals. The computer using fire analysis algorithms analyses the analogue signals which then takes decisions and executive actions. More about analogue systems and fire analysis algorithms can be found in Chapter 6.

CHAPTER 3

THE NEWLY DEVELOPED SMOKE DETECTOR

3.1 Introduction

This Chapter describes one of the two opto-electronic smoke detectors which were developed for this study, (the OESD-1). This uses the principle of picking up light back-scattered from smoke particles and if and when a threshold level is exceeded it triggers an alarm. In the next chapter it will be seen how this detector lends itself to the novel SENSI-CHECK principle. The technical specifications of the OESD-1 type detector is shown below:

Detection principle	: Light scattered
Rated voltage	: 24V DC smoothed or full-wave rectified
Working voltage	: 20V to 30V DC
Mean current consum.	: 35µA at 24V DC
Surge current	: 200 µA at power-on
Relative humidity	: 95%
Working temperature	: -20°C to +60°C
Storage temperature	: -30°C to +70°C
Colour	: White
Weight	: 270g with detector base
Dimensions	: 100mm dia. x 93.6mm height

3.2 General description

The opto-electronic detector, is a high sensitivity smoke monitoring device. It has an alarm control circuitry, which is sealed and protected against most environmental changes. It offers unique features and a number of advantages over any other market available units. It provides a double check of any initiated alarm condition before it latches itself in an alarm state. It offers a sensitivity monitor terminal that allows threshold adjustments to be made on site. It is made in two parts; the detector head and the detector base, allowing simplicity of installation and maintenance. The detector head accommodates the sensing, monitor and trigger circuitry, while the detector base accommodates the latching circuitry, the fire alarm indicator lamp and all wire terminals for communication with a monitor/control panel.

The opto-electronic detector, offers a detection method that responds in actual fire situations in an optimum way for detecting smouldering fires with the minimum of false alarms. As there is a general tendency in modern buildings to use more non-combustible or flame-proof materials, it is increasingly probable that smouldering fires will occur and the opto-electronic detector is ideally suited to this situation.

3.3 Principle of operation

The opto-electronic detector operates on the light scatter principle. The 'sampling' chamber of the detector, which is protected from ambient light by a labyrinth (see Fig.3.1), contains an infra-red LED light source and a silicon photo-diode light receiver. The LED is pulsed for a short duration approximately every 2.6 seconds and under normal supervisory conditions infra-red light is prevented from reaching the photo-diode by a light trap.

When combustion products enter the 'sampling' chamber, infra-red light from the LED is scattered by the smoke particles. Some of this scattered light reaches the photo-diode producing a pulsed electrical signal. When a pulse exceeding a predetermined level occurs coincidentally with the supply pulse to the LED, the signal is evaluated by differentiator and comparator circuits so that a logic pulse is transmitted to a counter. If the counter receives two consecutive pulses then a latching output circuit is activated, but the counter is reset to zero if two consecutive pulses are not received. This provides first order protection against false triggering.

The detector can be reset by temporarily removing its power supply, thereby releasing the latched output circuit.

3.4 Block/circuit diagrams and construction details

The detection unit consist of two parts; the chamber and the base. Depicted if Fig. 3.2 and 3.3 are respectively the block and circuit diagrams of the detector unit chamber and in Fig. 3.11 to Fig. 3.14 are the block and circuit diagrams of the two different types of detector unit bases. Appendix B shows all relevant artwork sketches, component layout diagrams and list of components.

Figure 3.0 on page 42B shows the detector and base circuits in series as block diagrams, while Fig. 3.3 on page 46 shows the circuit diagram of the detector head.

Activation of the alarm effectively short circuits the detector head (fire detection circuit) and the increased current pulls the relay in the base. With the relay energised the fire alarm switching resistor is connected across the systems end of line resistor thereby decreasing the zone circuit resistance and increasing the current taken from the control and indicating equipemnt. This increase of current at the control panel is interpreted as a fire alarm.

The construction details of the smoke detector are given in Appendix C. The appearance of the smoke detector and the two accompanied detector bases is given in Photo 3.1.

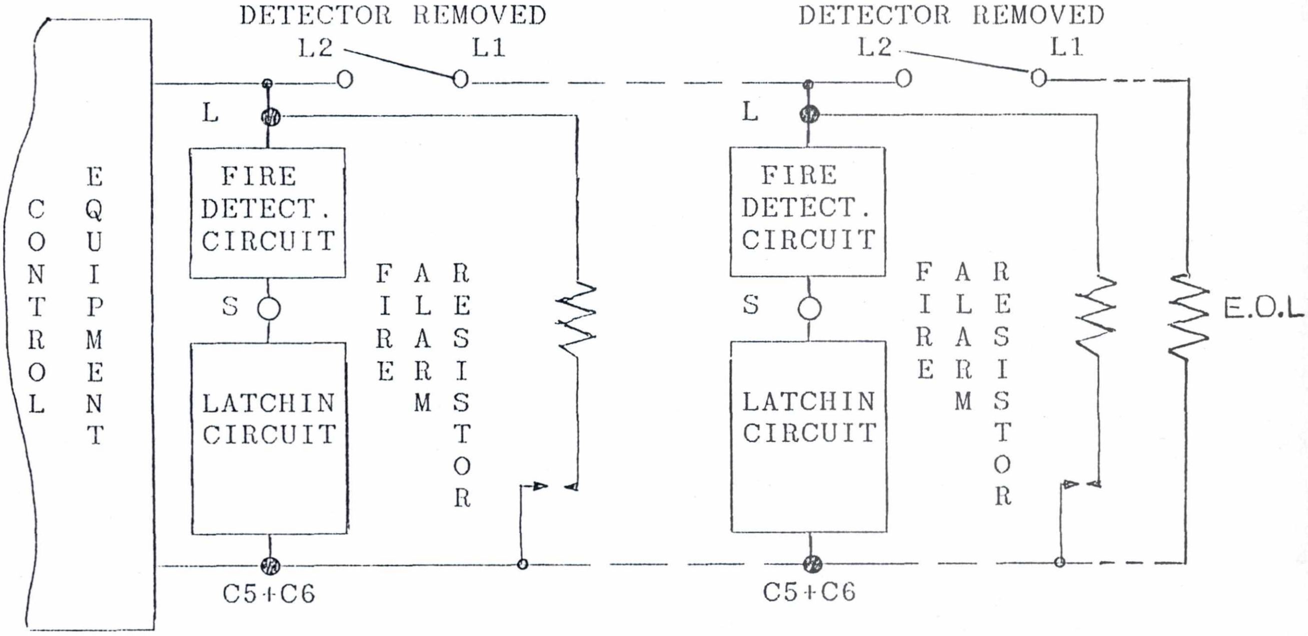


Fig.3.0 Overall fire detection diagram

Photo 3.1 Model OESD-1: Opto-electronic smoke detector
Model OESDB-1: Detector base (left)
Model OESDB-2: Detector base (right)

3.5 Summary of operation

The supply voltage which is connected across terminals L and C is rectified and applied to the constant voltage circuit via the noise suppressor. The regulated voltage is supplied to the various control circuits in sequence. At power switch-on, the current limiter suppresses surge current flowing to the capacitors. About 30 seconds later, i.e., after the capacitors have been charged, and a constant voltage reached, the oscillator circuit starts operating. It causes the LED to glow for a duration of 130 micro-seconds at intervals of about 2.6 seconds. At the same time, the circuit sends clock signals to the counter circuit. In the absence of smoke, the amount of scattered light is very small and little voltage is generated in the photo-diode. As a result, the counter circuit is not triggered.

When smoke from a fire enters the smoke chamber of the detector, some of the light scattered by smoke particles reaches the photo-diode. The output voltage of the diode is compared with reference voltage in the comparator circuit. If the output exceeds a pre-determined level, a signal is applied to the counter circuit. When two consecutive signals in synchronism with the clock pulse are applied to the counter circuit, it delivers a trigger signal to the switching circuit. Any signals not synchronous with the lighting of the LED or with the clock pulse, or any other signals that are not received continuously are ignored, in which case the circuit is reset. When the switching circuit is triggered, the line between terminals L' and S' is shorted by the thyristor. This cause the indicator lamp on the base to come on and allow response current to flow back to the control panel to initiate an appropriate action.

A. Photo-diode
B. Lens
C. LED
D. Scattering light beam
E. Light emitting region
F. Light beam
G. Smoke particles
H. Labyrinth element
I. Insect screen
J. LED-Pd holder

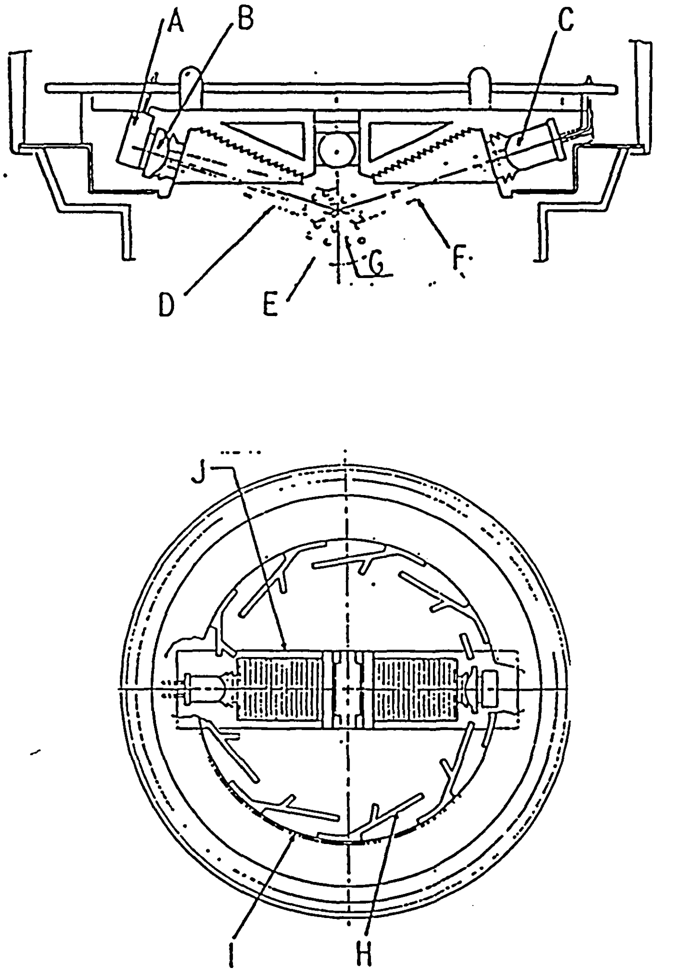


Fig.3.1 Structure of detector unit

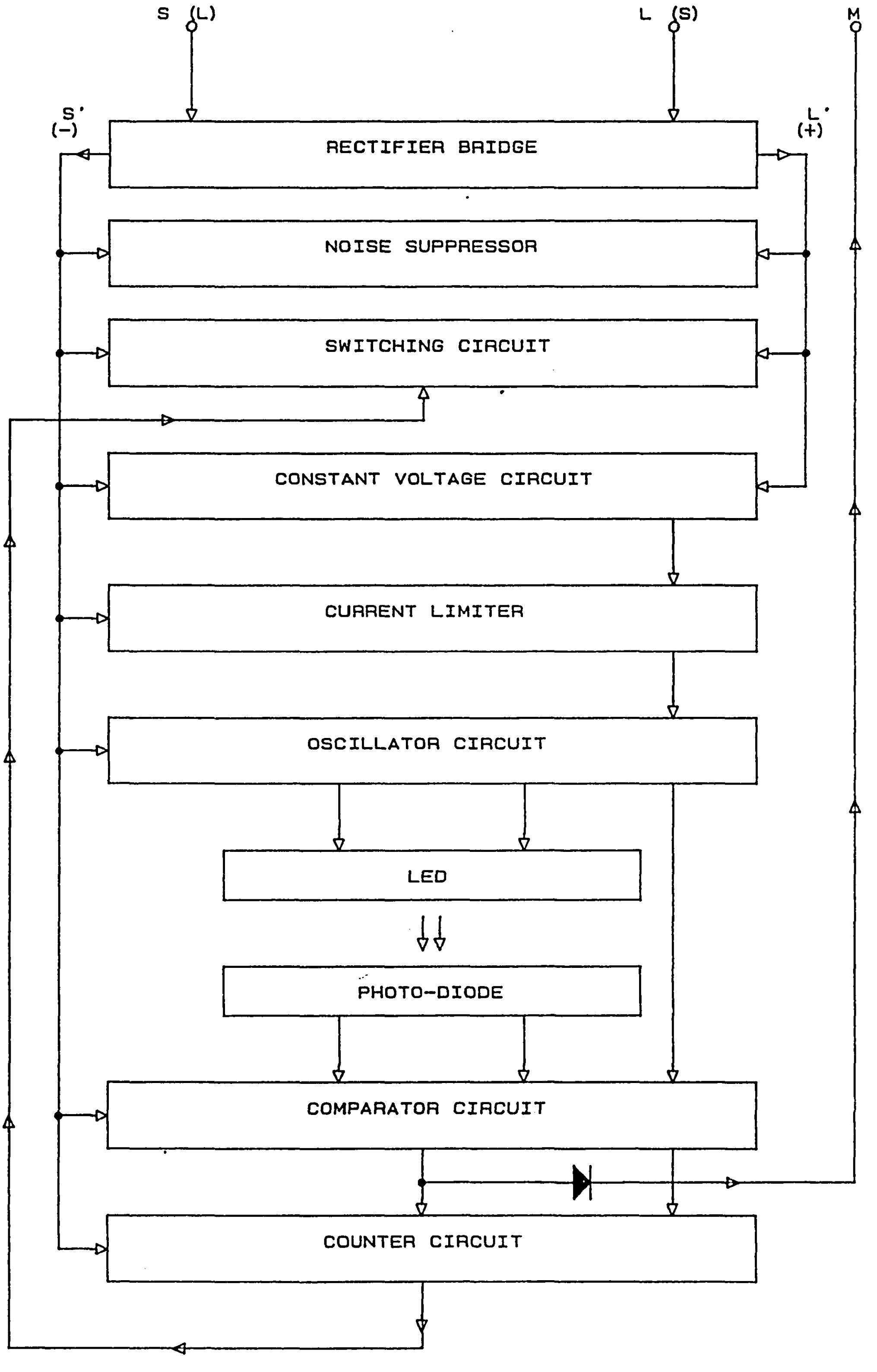
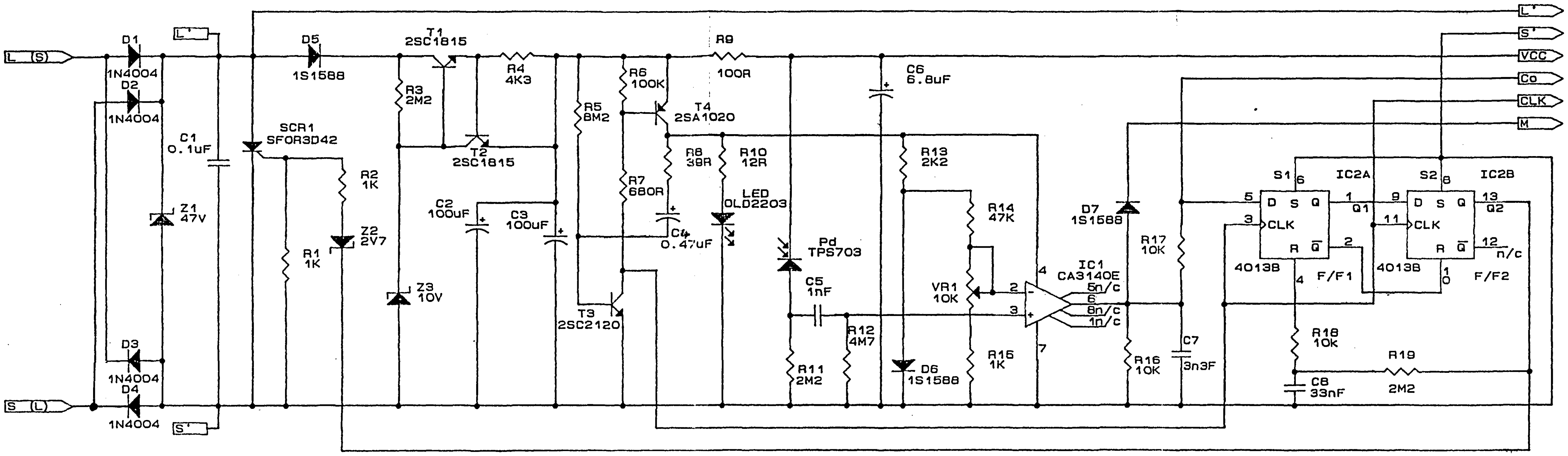


Fig.3.2 Model OESD-1: Opto-electronic smoke detector (chamber) block diagram



Notes:
(1) All resistors to be 1%, OW25 at 70C unless otherwise specified.
(2) All resistor values in Ohms.
(3) All capacitors to be electrolytic unless otherwise specified.

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Title: OPTOELECTRONIC SMOKE DETECTOR (HEAD)		
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Fig.3.3 Model OESD-1: Opto-electronic smoke detector (chamber) circuit diagram

3.6. Details of operation

It is suggested to use the circuit diagram shown in the previous page while studying the following notes. It may be necessary to refer to this diagram for explanation.

A bridge rectifier circuit formed by diodes D1 to D4 is so designed that input power is applied to the internal circuits with normal polarity independent of which polarity is applied. The detector head can therefore be plugged-in to the detector base without having to worry about correct polarity.

A noise suppression circuit which uses zener diode Z1 and capacitor C1 to absorb momentary high voltage noise is used to prevent the internal circuit from malfunctioning. The allowable input voltage of the detector is 30 Volts filtered D.C or full-wave rectified D.C.. In case of the full-wave rectification, the peak voltage will be at 42.2 Volts. A 47V zener diode is therefore used.

Diode D5 is used to block any current from capacitors C2 and C3 from flowing back to the thyristor SCR1 through resistor R4 and emitter collector of transistor T1 when the supply is removed.

Zener current flowing through resistor R3 to zener diode Z3, produces a voltage of approximately 10 volts across Z3. At the same time, base current flowing into transistor T1 allows sufficient amount of current to be supplied to the circuits. When the current flowing to R4 is enough to drop 0.6 Volts between the base and emitter of transistor T2, T2 turns ON and bypasses the T1 base current thus turning OFF T1. This limits the T1 supply current to approximately 130μA. As a result, the initial charging current to C2 and C3 reaches 130μA and these capacitors take 20 to 30 seconds to fully charge.

Transistors T3, T4, capacitor C4, and resistors R5, R6, R7, R8 form the oscillator circuit. Transistor T4 directly drives the LED. Since base current flows to T3 via R5, T3 begins to turn ON. At the same time, base current flows to T4 via R7 and this transistor begins conducting. As large base current flows to T3 through R8 and C4, T3 turns ON completely and T4 also turns ON completely to flash the LED and switch the comparator reference input circuit ON. When C4 is fully charged, the base current of T3 becomes extremely small. As a result, T4 starts to switch off and its collector voltage starts to fall. This fall drives T3 base off through C4, resulting in a further turn off of T4. A regenerative action ensures in T3 and T4 switching off rapidly. C4 is now holding the base of T3 negative but current through R5 will slowly discharge C4 until the base of T3 is brought again into conduction. This sequence of operations is repeated to provide continue oscillation as shown in Fig.3.4.

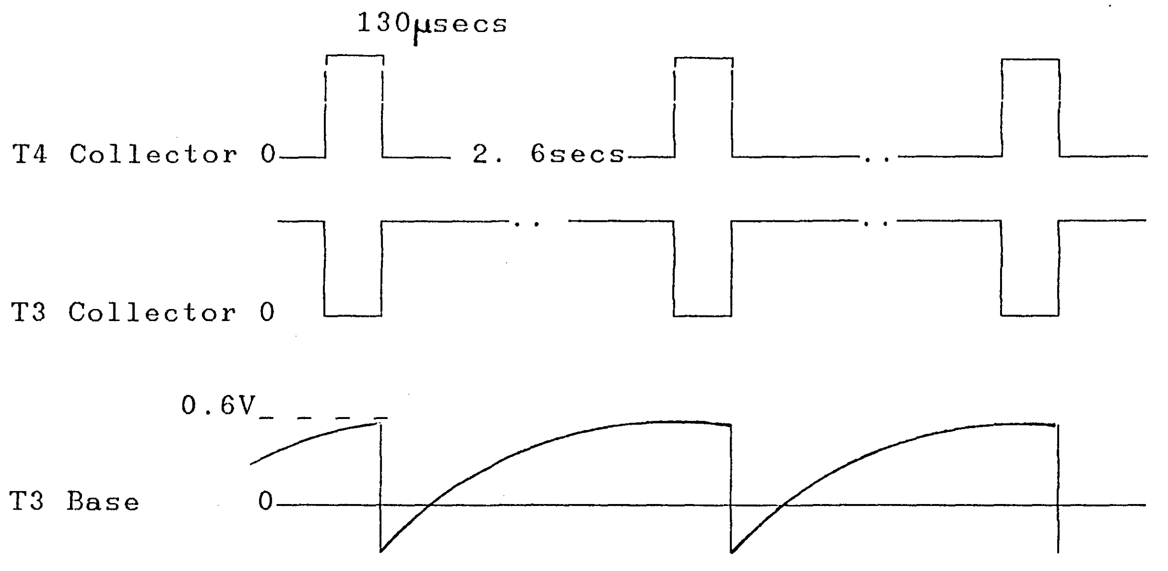


Fig.3.4 Oscillator timing waveforms

While both T3 and T4 are completely ON, the LED glows for a period of approximately 130 microseconds. These transistors stay OFF during the pulse interval, i.e., approximately 2.6 seconds. The duty cycle is 130 microseconds / 2.6 seconds = 1/500,00.

The current (IL) flowing to the LED depends on R10 and is approximately 500 mA.

The photo-diode Pd is reverse biased. Normally, a voltage of less than 10mV appears across resistor R11. But when scattered light due to the presence of smoke enters the photo-diode, a pulsed current larger than normal flows through the diode and increases the voltage. This is differentiated across resistor R12 through the differentiator circuit consisting of capacitor C5 and resistor R12. Resistors R11 and R12 are of similar values. Thus the equivalent circuit that can be used to calculate the output across R12 is shown in Fig. 3.5.

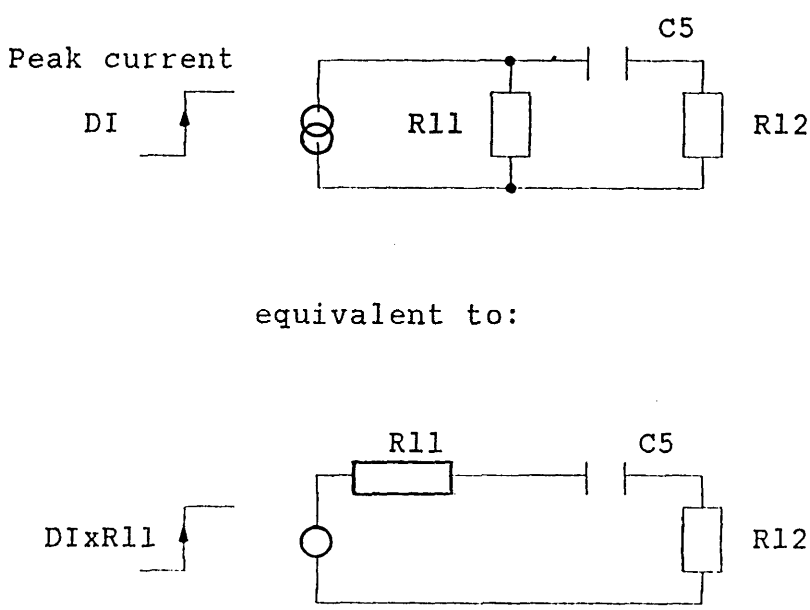


Fig.3.5 Differentiator equivalent circuit

The comparator circuit is active only while the LED stays ON because power is supplied to the comparator synchronously with the lighting of the LED.

In the absence of smoke, the voltage at R12 remains low and the comparator output pulse width is short as shown in Fig.3.6(a). As smoke enters the circuit and the resulting scattered light causes an increased photo-diode output, the output pulse width expands gradually as shown in Fig.3.6(b) and Fig.3.6(c).

When the output pulse width becomes equal to the LED drive pulse width, it is maximum and does not increase further even if the smoke density increases.

A close look at the trailing edge of this pulse discloses that, as in Fig.3.7, the comparator output stays at a high level for approximately 2 micro-seconds even after the LED drive pulse reaches a zero level. This is because of propagation delay time in the comparator plus delay time from capacitor C7 of the comparator output.

The comparator output is applied to the counter circuit IC2, which consists of two D-type flip-flops. They read data input D1 when the clock signal rises. This means that the comparator output is read at the trailing edge of the LED drive pulse.

Therefore, the output of Q1 in the flip-flop 1 goes high when the comparator output pulse width becomes equal to the LED drive pulse width. Since there are two flip-flops connected in the counter circuit, the output level of Q2 in the flip-flop 2 goes high only after two output pulses enter the circuit consecutively. If two pulses do not enter consecutively, Q1 goes low again and resets to the initial condition, (see Fig.3.8).

When Q2 goes high, the SCR1 is triggered and voltage is applied to the delay circuit consisting of C8 and R19.

After the time constant (approximately 60msec) determined by C8 and R19, the flip-flop 1 reset input R1 goes high. As a result, the flip-flop is reset and the SCR1 trigger voltage decreases to zero.

When the output level of Q2 in the flip-flop 2 goes high, trigger current flows through zener diode Z2 and resistor R2, causing thyristor SCR1 to turn ON. However, this does not occur unless the flip-flop 2 Q2 output is greater than the Z2 voltage (2.7V) plus the voltage drop across R2 and SCR1's voltage drop. The hold-on current of the SCR1 is 1 to 3 mA.

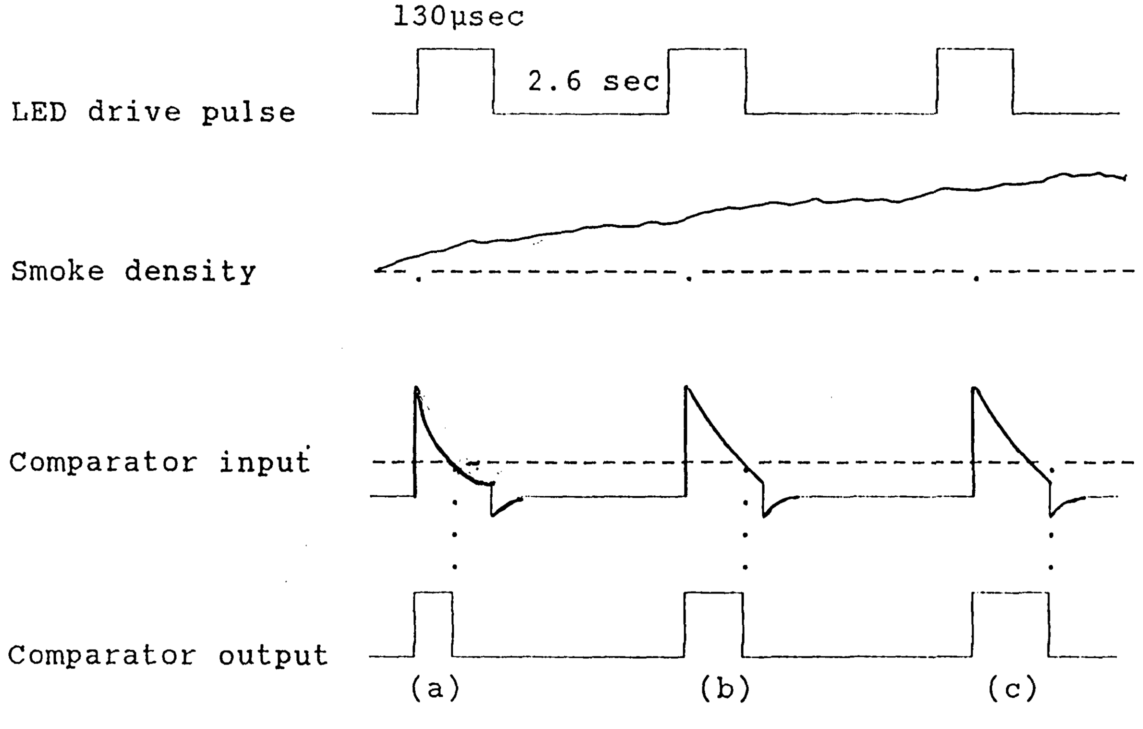


Fig.3.6 Comparator input/output characteristics

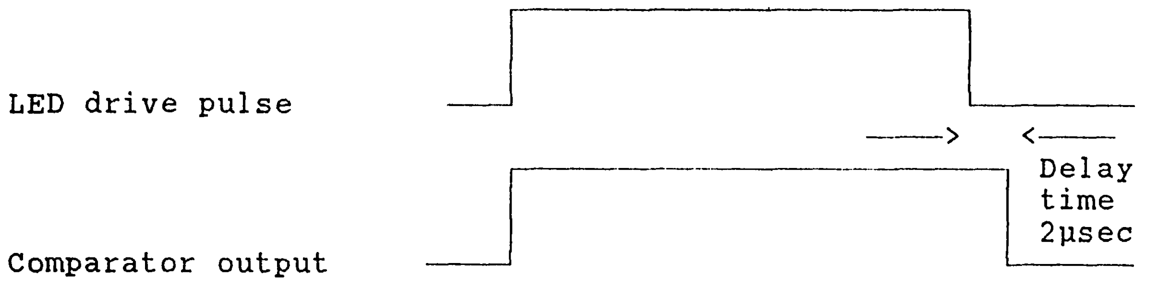


Fig.3.7 Comparator output delay time

It is possible to connect a detector to a densitometer, (an instrument that consists of a smoke box and a sensitivity monitor for testing opto-electronic type smoke detectors, see Appendix D), and monitor detector sensitivity.

The detector has been designed such that the comparator output, (which is the detectors sensitivity reading), to be delivered from a monitor terminal. This terminal, known as M allows the detector sensitivity to be monitored. The output pulse width of each comparator pulse differs depending on the set sensitivity of the detector. In other words, each detector has its own pulse width. The monitoring device converts the pulse width into a current for display and when the detector is triggered the current reading is latched. The reading is translated into a percentage per metre obscuration as described in Appendix D. The densitometer described in Appendix D has been extensively used during the process of designing and testing the detector.

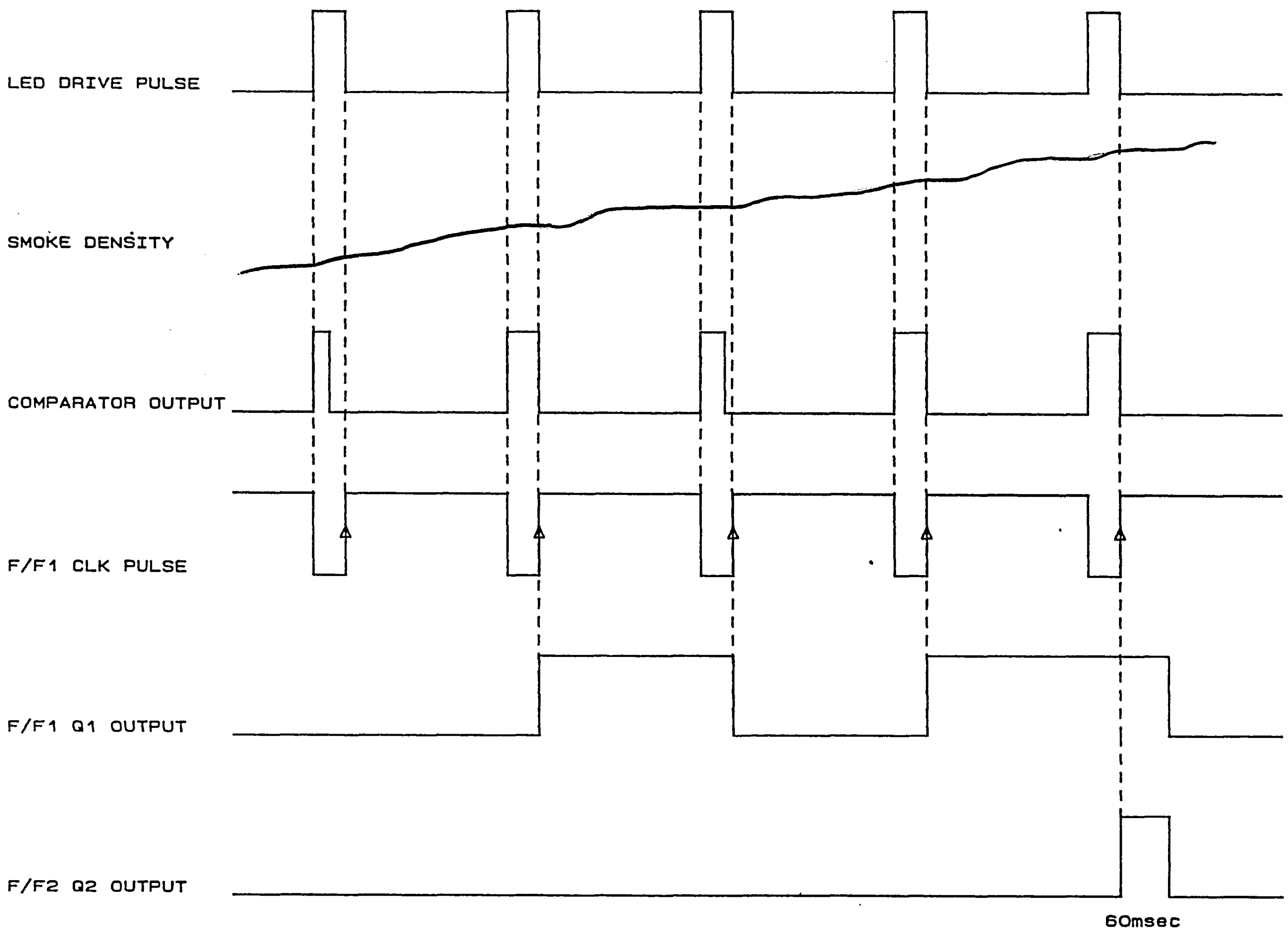


Fig.3.8 Counter circuit outputs

Another way of testing the sensitivity of the detector is by using an ordinary oscilloscope. A resistor connected across the M and S' terminals of the detector can be used to display on an oscilloscope screen the output pulse of the comparator circuit. The width od this pulse determines the sensitivity of the detector at every clock pulse. Depicted in Fig. 3.9 is a typical waveform of a normal-mode output pulse as displayed on the screen of an oscilloscope.

If the inside of the detector chamber gets dirty and this produces a sensitivity change, then the width of the comparator pulse is changed, indicating that the detector must be cleaned.

To bring the detector into the alarm state, a pin may be inserted in the hole of the head. When it initiates an alarm, the comparator output pulse width expands and becomes equal to the LED drive pulse width.

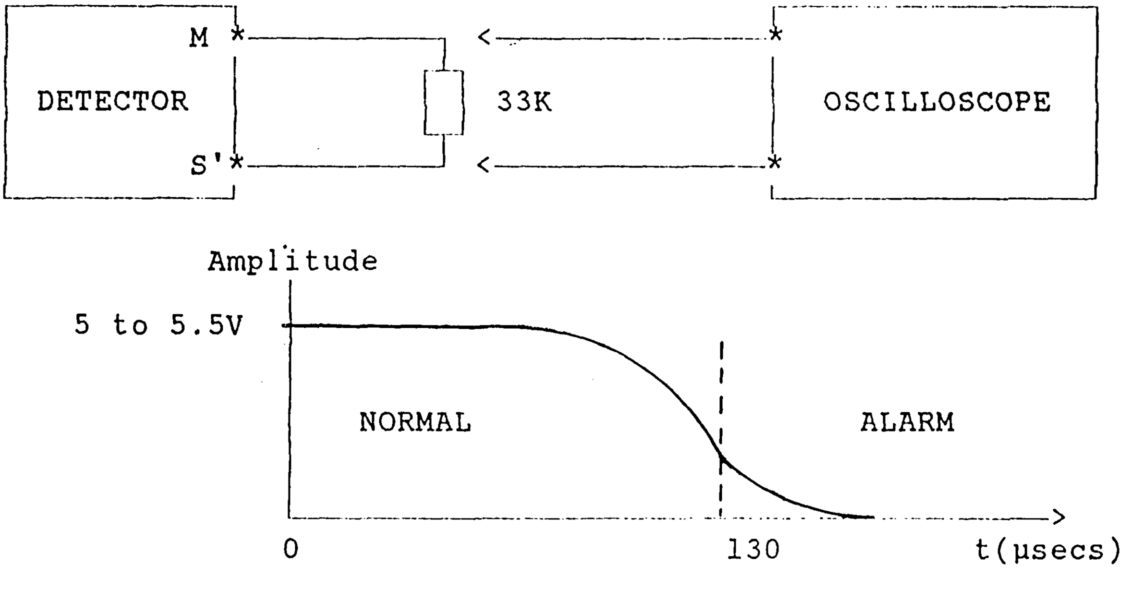


Fig.3.9 A typical waveform of a comparator output signal

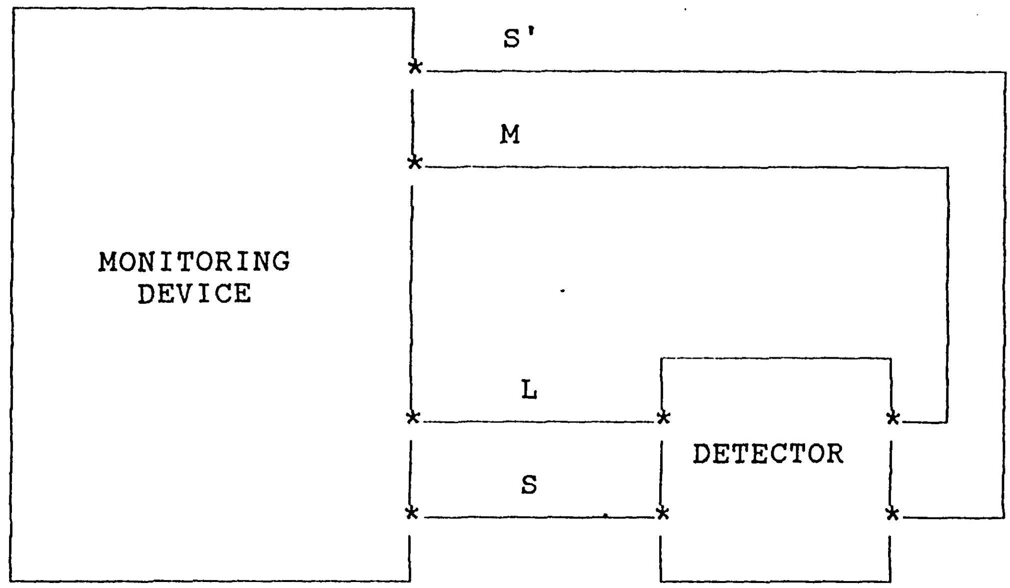


Fig.3.10 Monitoring device

3.7 Detection unit (base)

A conduit box is generally used when installing detectors. The detector base has therefore been designed to take advantage of this and with the screw pitch equal to those of the conduit box, a simple solid connection is ensured.

After the detector base is fixed to the conduit box, it is possible to connect all wires to the terminals of the detector base. The detector head can be mounted subsequently to the detector base. This helps prevent damage and contamination that may occur during construction.

The following headings describe the functional details of the two detector bases. Appendix B shows all relevant technical details of both model OESDB-1 and OESDB-2. Both types of detector base make use of relay contacts for switching an alarm. The OESDB-1 model offers detector removed facility i.e. when its detector head is removed a fault is transmitted back to the control and indicating equipment. The OESDB-2 model uses a latching type relay to minimize current consumption when in alarm and it has a wide operating voltage. It offers all the facilities of the OESDB-1 model plus a set of voltage free change-over contacts for remote switching hence its more expensive than OESDB-1.

3.7.1 Model OESDB-1: Details of operation

The detector unit base of model OESDB-1 block and circuit diagrams are shown on Figs 3.11 and 3.12 respectively. The internal circuit of the detector base consist mainly of the following:

(a) Latching switching circuit: Relay RL1, Capacitor C1, Resistors R1, R2, and R3.

(b) Indicator lamp circuit: Light emitting diode LED, and resistors R1, R2 and R3.

(c) Detector removed circuit: Transistor T1, Resistor R4 and Diodes D5 and D6.

(d) Polarity protection circuit: Diodes D1, D2, D3 and D4.

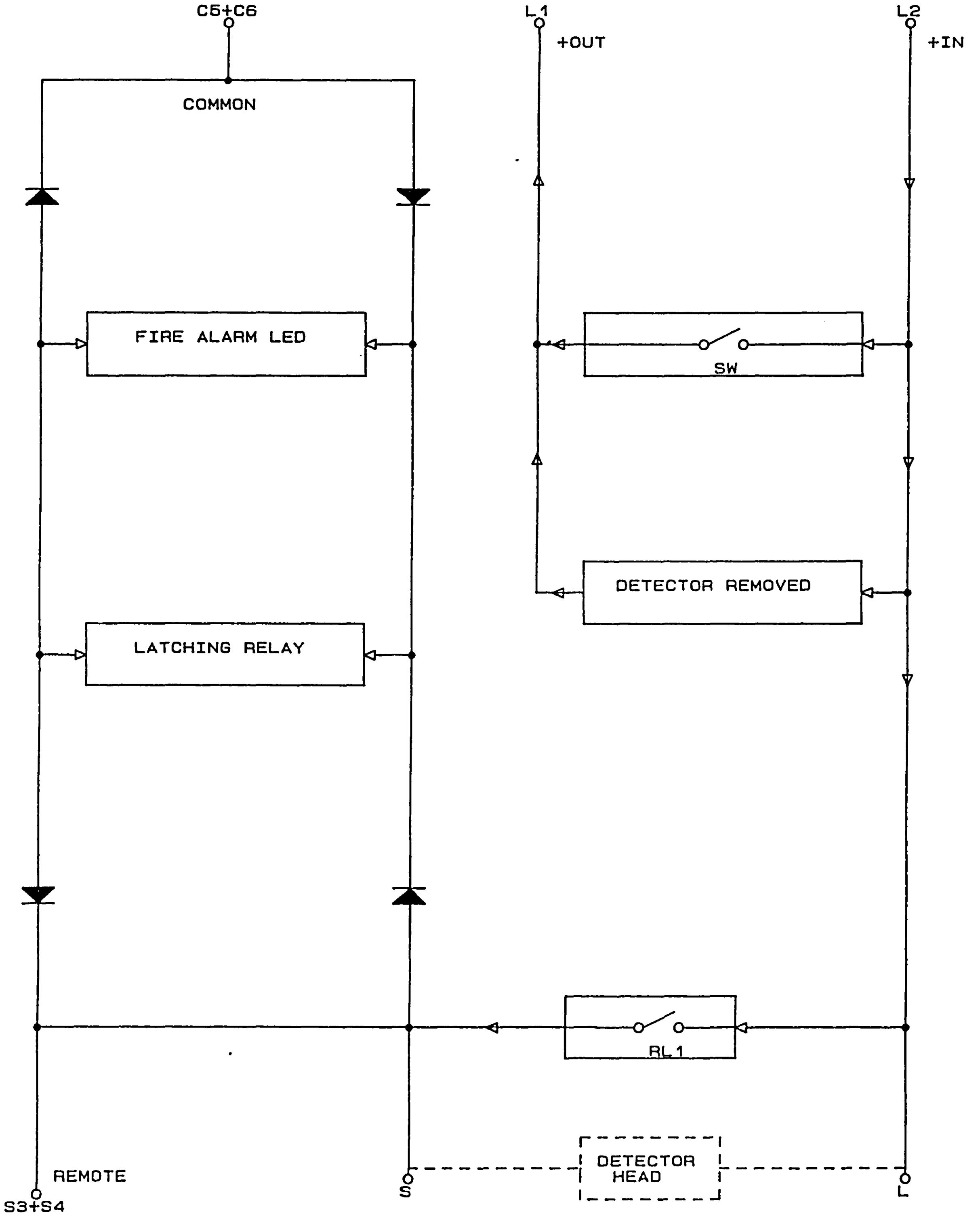
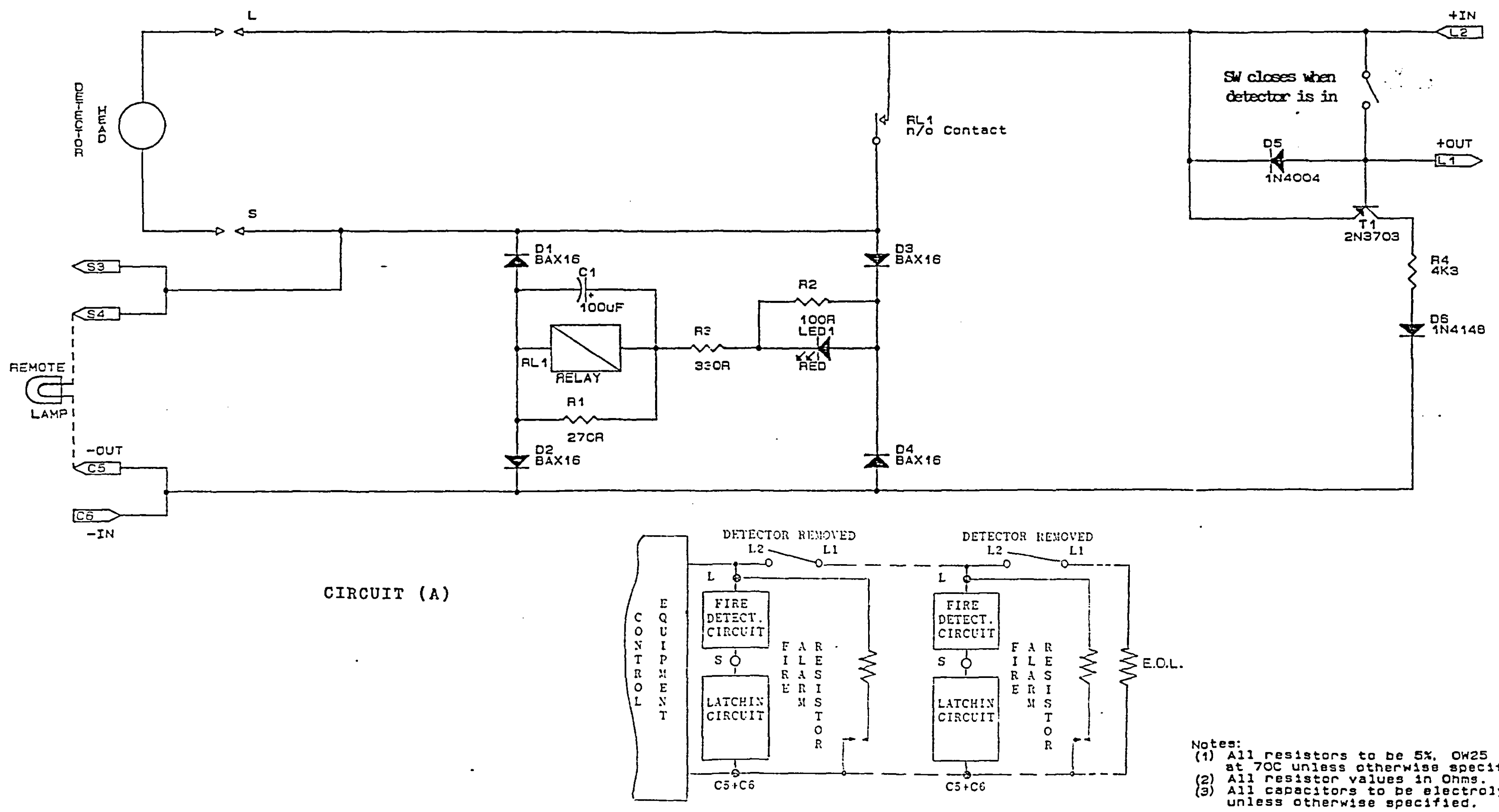


Fig.3.11 Model OESDB-1: Detector unit (base) block diagram



Notes:
(1) All resistors to be 5%, 0W25 at 70C unless otherwise specified.
(2) All resistor values in Ohms.
(3) All capacitors to be electrolytic unless otherwise specified.

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Fig.3.12 Model OESDB-1: Detector unit (base) circuit diagram

When a supervising current from the detector base flows through switch SW to the detector head, (via terminal L with respect to terminals S), relay RL1 remains un-energized and the LED does not light up.

When an alarm is sensed, thyristor SCR1 in the detector head latches, terminals L' and S' are short circuited and the voltage differential between terminals L and S drops down to around 2 x diode voltage drop.

This energizes the relay, which latches itself in this state via its own contact RL1. At the same time the LED lights up, and if a remote lamp is connected to the circuit, a current passes, lighting up the remote lamp. If the LED is an open-circuit, the current passes through R2 to hold the relay energized.

When an alarm is triggered the detector base exhibits a resistance of about 470 ohms, made by the parallel and series combination of R1, RL1, R3 and R2. This resistance appears in parallel with the system's end of line resistor. A higher response current is therefore allowed to flow back to the control panel which is interpreted by the control panel as a fire alarm condition.

Electronic Alarms Ltd, use two-wire systems, whereby detectors and sounders/bells are connected across the same two wires via polarity protection diodes. When in monitor condition, the sense polarity forward biases all detectors while keeping all sounders/bells reverse biased, ie. in a mute condition. When an alarm is detected, the system reverses the monitor polarity to "alert" polarity, forward biases all sounders/bells and reverse biases all detectors via their polarity protection diodes. The idea behind the two-wire system is the simplicity of installation (2-wires needed to be routed round a building and not 4), and cost effectivness (a cheap method that saves both material and costly labour).

3.7.2 Model OESDB-2: Details of operation

The detector unit base block and circuit diagrams are shown on Figs 3.13 and 3.14 respectively. The internal circuit of the detector base consists mainly of the following:

(a) Alarm set switching circuit: Relay K1(set) and transistor Q3

(b) Alarm reset switching circuit: Relay K1(reset) and transistors Q1 and Q2

(c) Indicator lamp circuit: LED and resistors R3 and R6

When a supervising current from the detector base flows through switch SW to the detector head, (via terminal L with respect to terminals S), relay K1 remains un-energized and the LED does not light up.

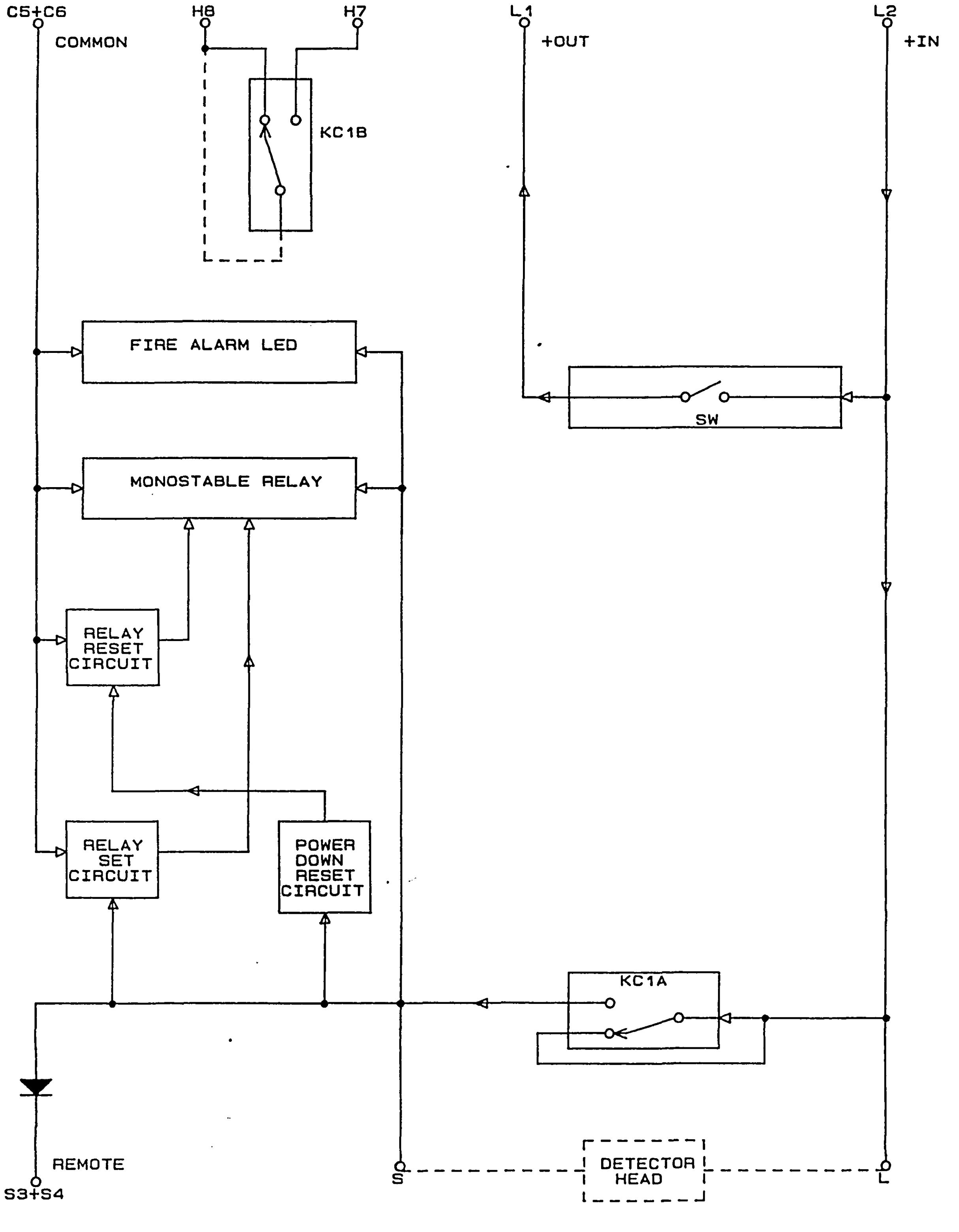
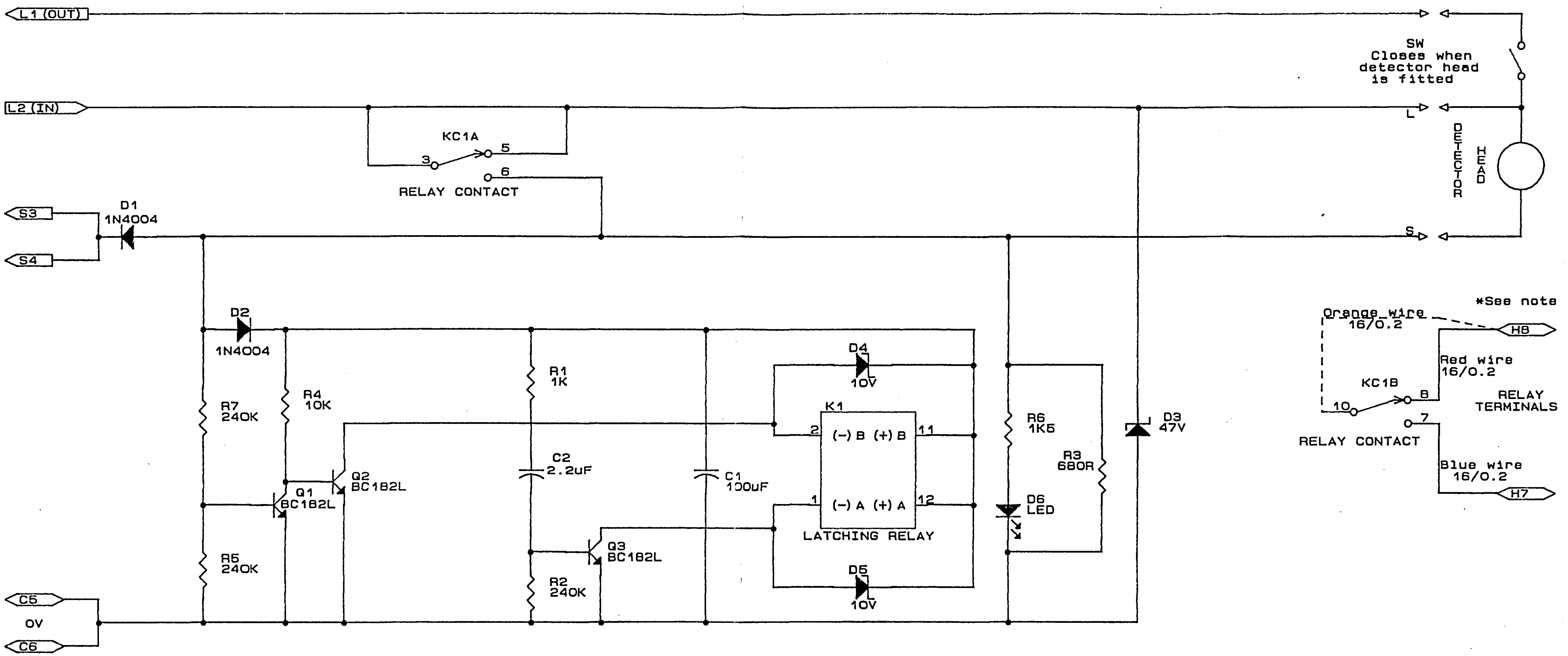


Fig.3.13 Model OESDB-2: Detector unit (base) block diagram



Notes:
(1) All resistors to be 5%, 0W25 at 70C unless otherwise specified.
(2) All resistor values in Ohms.
(3) All capacitors to be electrolytic unless otherwise specified.
(4) All capacitors to be radial unless otherwise specified.
(5) Solder orange wire to terminal H7 for n/c operation or to terminal H8 for n/o operation.

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Fig.3.14 Model OESDB-2: Detector unit (base) circuit diagram

Relay KC1A contacts are open keeping the two lines L and S not shorted. Similarly the second pair of relay contacts KC1B remains either open or closed pending on they way it was selected.

When an alarm is sensed by the detector head, the voltage across terminals S and L drops to around 1.4V. This is because terminals L' and S' in the detector head are short circuited by thyristor SCR1. Transistor Q3 momentarily turns on and monostable relay K1 is set. The relay contacts switch over, KC1A latches the alarm condition and KC1B operates the remote (voltage free) contacts. Terminals S3 and S4 are shorted to terminals L1 and L2 and if a remote lamp is wired across S3 and S4 and C5 and C6 this turns on. With terminals S3 and S4 now positive with respect to C5 and C6, alarm response current flows back to the control and indicating equipment via R3 and R6. The alarm LED is switched on to identify the detector in alarm.

If the control and indicating equipment in use has a current limited power supply, the resistor combination R3 and R6 will force the supply voltage to drop. With a supply voltage of say 24V, current limited to 10mA the voltage will drop down to around 4.7V. This will not affect the operation of the detector. The use of the monostable relay which once set will remain so until is reset ensures that no power is consumed. The current limited supply will be wholly devoted to the operation of the alarm and remote LED.

On alarm condition capacitor C1 becomes fully charged. Transistor Q1 switches on, keeping transistor Q2 off. However, when the control and indicating equipment is reset, (the supply voltage is removed), transistor Q1 no longer can hold transistor Q2 off. Transistor Q2, supplied with charge from capacitor C1, turns on to reset the relay, switch over its contacts and re-establish normal operating conditions.

3.8 Technical evaluation

The opto-electronic smoke detector head and bases have been technically evaluated both in the laboratory and on site. All tests were based on the European standards EN54: Part 7 "Specification for point-type smoke detectors using scattered light". The test programme of this evaluation, being very similar to the technical evaluation of the SENSI-CHECK detector is reported in Chapter 5 accompanied with all observations, results and conclusions made.

CHAPTER 4

THE SENSI-CHECK PRINCIPLE

4.1 Introduction

The SENSI-CHECK detector unlike any other smoke detector continuously checks its own sensitivity and gives a pre-alarm signal on contamination. Certain threshold windows are set from which the sensitivity of each reading is compared. If found to be over or under the normal window a pre-alarm is initiated. Pulse techniques are used to minimize current consumption, with 2 current pulses over the fire threshold level triggering a fire alarm, and with 4 current pulses over or under the computation threshold window, triggering a service alarm. The technical specifications of the SOESD-1 type detector is shown below:

Detection principle	: Light scattered
Rated voltage	: 24V DC smoothed or full-wave rectified
Working voltage	: 20V to 30V DC
Mean current consum.	: 55µA at 24V DC
Surge current	: 250µA at power on
Relative humidity	: 95%
Working temperature	: -20°C to +60°C
Storage temperature	: -30°C to +70°C
Colour	: White
Weight	: 320g with detector base
Dimensions	: 100mm dia. x 118.6mm height

4.2 General description

The operation of the SENSI-CHECK (model SOESD-1) opto-electronic smoke detector like its predecessor (model OESD-1) uses the principle of picking up light back-scattered from smoke particles.

In the event of a fire, the combustion products enter the portion of the detector which is exposed to light rays form the LED. The photo-diode receives a part of the rays and transmits a signal to an electronic circuit.

In the event of contamination from say dust particles, when these enter the portion of the detector which is exposed to light rays from the LED, are accumulated on the surface of both the LED and the photo-diode. The light output of the LED is reduced by the dust layer and the photo-diode sensitivity is also reduced as it too has dust on it. This will result in the detector being no longer sensitive enough to detect a fire. Alternatively if moisture is accumulated within the chamber because it has the effect of deflecting light, the detectors sensitivity is increased. When either of these two conditions occur the SENSI-CHECK detector is designed to monitor its sensitivity and initiates a pre-alarm.

4.3 Details of operation

Figure 4.1 shows the block diagram of the SENSI-CHECK detector and Fig. 4.2 shows just the SENSI-CHECK part of the circuit diagram (the other part is the same as that described under Chapter 3). Like its predecessor the SENSI-CHECK detector is made of two parts the detector head and the detector base. Figs 4.8 and 4.9 give the block and circuit diagrams of the SENSI-CHECK detector base and Appendix C gives all the construction and manufacturing details.

The comparator circuit IC1 of the Opto-electronic smoke detector described in Chapter 3, annotated as Co, provides a smoke concentration reading on the +ve edge of each clock pulse. The reading is used to decide if a fire alarm condition has been developed or not. The decision is based on the width of the comparator output pulse. When the pulse width is fully expanded to 130 μsecs and remains at this level for two consecutive clock pulses it delivers a trigger signal to the fire alarm switching circuit and this is interpreted as a fire alarm condition. Any signals not synchronous with the lighting of the LED or with the clock pulse, i.e. comparator output pulses of less than 130 μsecs wide, (or even a single 130 μsecs wide pulse), are not clocked-in, in which case the counter is reset.

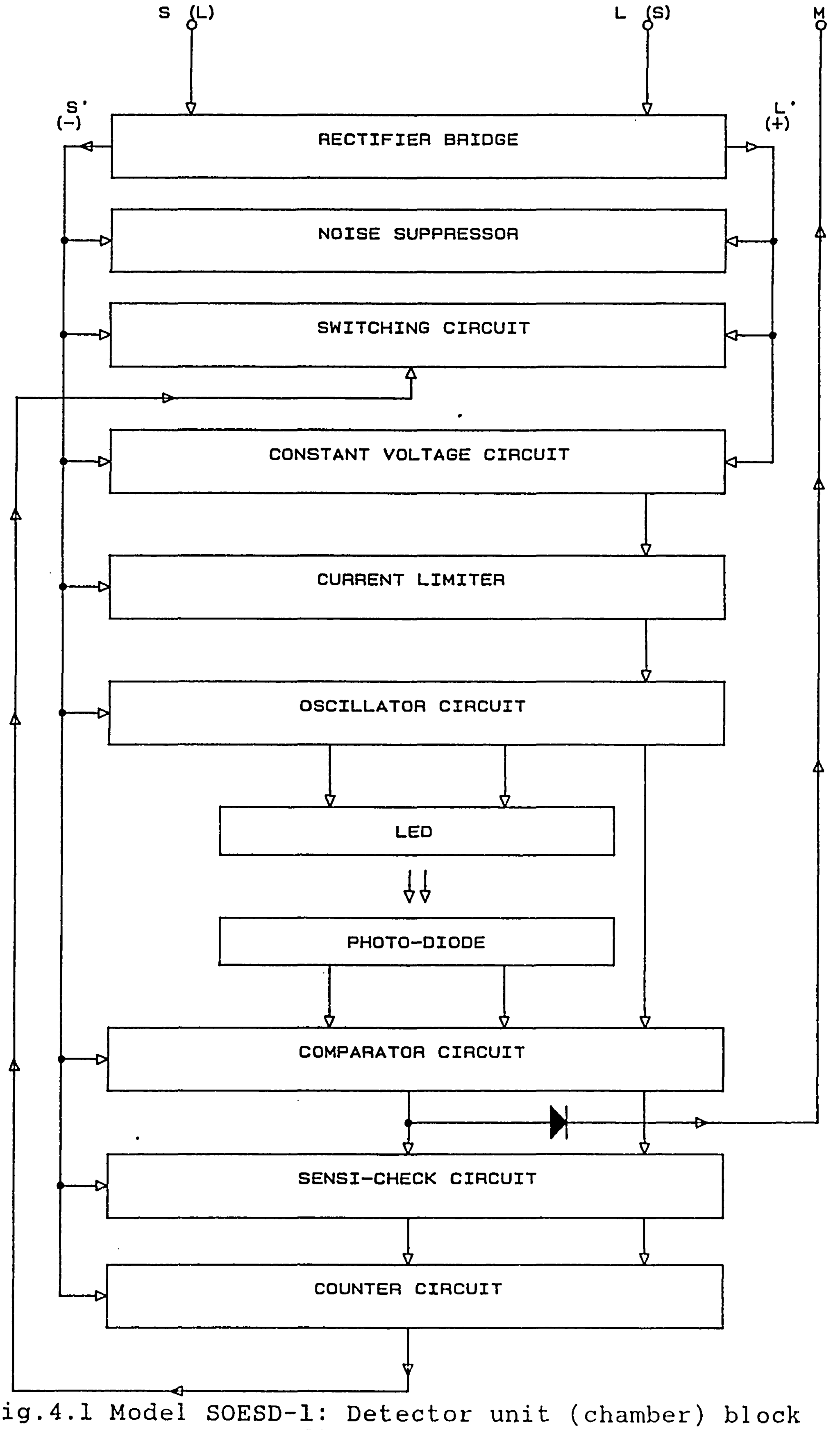
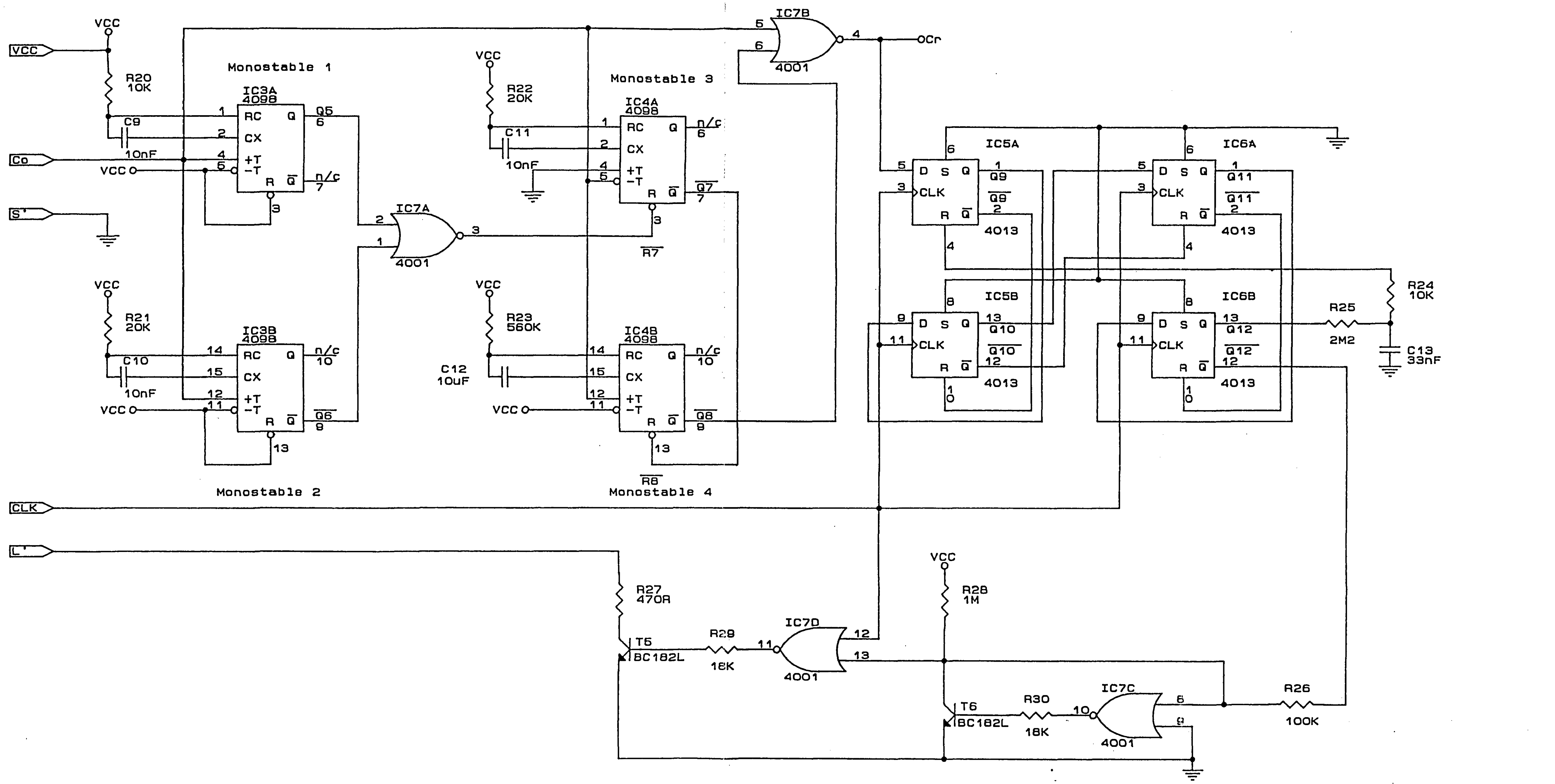


Fig.4.1 Model SOESD-1: Detector unit (chamber) block diagram



Notes:
(1) All resistors to be 1%, OW25 at 70C unless otherwise specified.
(2) All resistor values in Ohms.
(3) All capacitors to be polystyrene unless otherwise specified.

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Fig.4.2 Model SOESD-1: Detector unit (chamber) circuit diagram

Using the Sensitivity check option, the comparator output is further interrogated to show any drift in sensitivity. This is achieved by setting safe, sensitive limits of operation, in the form of sensitivity check, reference windows. A pulse width of 50 to 100 μsecs has been considered as the safe in sensitivity operation window where the detector is set to be functioning normally.

Four consecutive pulses of over or under 50 to 100 μsecs wide are required to be applied in synchronism with clock pulses to the 4-stage counter circuit if the latter is to trigger an alarm, otherwise the circuit is reset back to normal monitor conditions.

4.4 The SENSI-CHECK windows

Four monostables are used to set the sensitivity windows and check any sensitivity drift of incoming data from the comparator circuit output Co. These are shown in the circuit diagram of Fig. 4.2. Monostable 1, IC3A sets the lower limit of 50 μsecs, monostable 2, IC3B sets the upper limit of 100 μsecs and monostables 3 and 4 of IC4A and B respectively do all the decision making of normal or out of specification readings. The duration of these monostables pulses can be calculated by the formula shown below:

$$T = 0.5 \times C \times R$$

Monostables 1 output Q5 = 0.5 x 0.01uF x 10K = 50 µsecs

Monostables 2 output Q6 = 0.5 x 0.01uF x 20K = 100 µsecs

Monostables 3 output Q7 = 0.5 x 0.01uF x 20K = 100 µsecs

Monostables 4 output Q8 = 0.5 x 80uF x 430K = 17 secs

FIRE	
	130 µsecs
OVERSENSITIVE	
	100 µsecs
NORMAL	
	50 µsecs
UNDERSENSITIVE	
	0 µsecs

Fig.4.3 The Sensitivity check windows

4.5 Circuit operation

The comparator output rising edge triggers monostables 1, 2 and 4 as shown in Fig. 4.2. Output Q5 from monostable 1 and Q6' from monostable 2 are NORed together by IC7 gate A. The NOR output of gate A is used to control (enable/disable) the reset line R7', of monostable 3. Since both monostables, 1 and 2 are triggered at the same time, monostables 3 reset line R7', is enabled (reset) for the first 50 µsecs, (controlled by monostable 1), and inhibited for the following 50 µsecs, (controlled by monostable 2). So, the NOR output of IC7A, by controlling the reset line of monostable 3, allows the latter to be triggered only by the falling edge of the comparator output pulse, Co. This only occurs provided that the -ve edge of the Co output pulse happens 50 µsecs after its +ve edge, but not later that 100 µsecs, i.e. if the comparator output pulse is within the time limits 50 to 100 µsecs (normal operating condition).

Output Q7' from monostable 3 controls the reset line R8', of monostable 4. On the -ve edge of the comparator output pulse Co, monostable 3 is triggered, that is, if it is allowed to do so, by the NOR gating of IC7A, as described above. Output Q8' from monostable 4 and the comparator output data Co, are both NORed together by IC7B, to form the counter data Cr. This is of logic zero for a normal signal, (50 to 100 µsecs wide), or logic one for an out-of-specification signal, (below 50 µsecs or above 100 µsecs wide). Therefore monostables 3 and 4 is where the decision making takes place and where all output comparator pulses Co are subject to interrogation to reveal their sensitivity to fire, that is, if they are under, normal or over sensitive.

On the -ve edge of each 130 µsecs clock pulse, the 4-stage counters input data port Cr is interrogated. If found to be at logic one for over four consecutive clock pulses, the counter output Q12 turns ON for a short time (60 msecs) while the counters output Q12' is turned off for this period. The turn-on time is controlled by the R24, R25 and C13 timing components.

The turn-on signal of Q12 resets the counter circuit via its R24 connection while the turn-off signal of Q12' triggers the service alarm latch circuit.

4.5.1 The four possible conditions

For each of the four conditions given below, corresponding timing diagrams are shown in Figs. 4.4, 4.5, 4.6 and 4.7.

(a) normal sensitivity, no alarm operation
(b) service alarm, out of specification (oversensitive) operation
(c) service alarm, out of specification (undersensitive) operation
(d) fire alarm operation

Right at the top of these diagrams is the CLK (clock) waveform (t_{on}=130µsecs) and directly below is the Co comparator data pulse waveform. The waveforms that follows those of the CLK and Co outputs are the various monostable input and output pulses as described before.

4.6 Detection unit (base)

The base of the SENSI-CHECK detector is very similar to that of the standard opto-electronic smoke detector. The SENSI-CHECK idea has been developed with the user in mind so

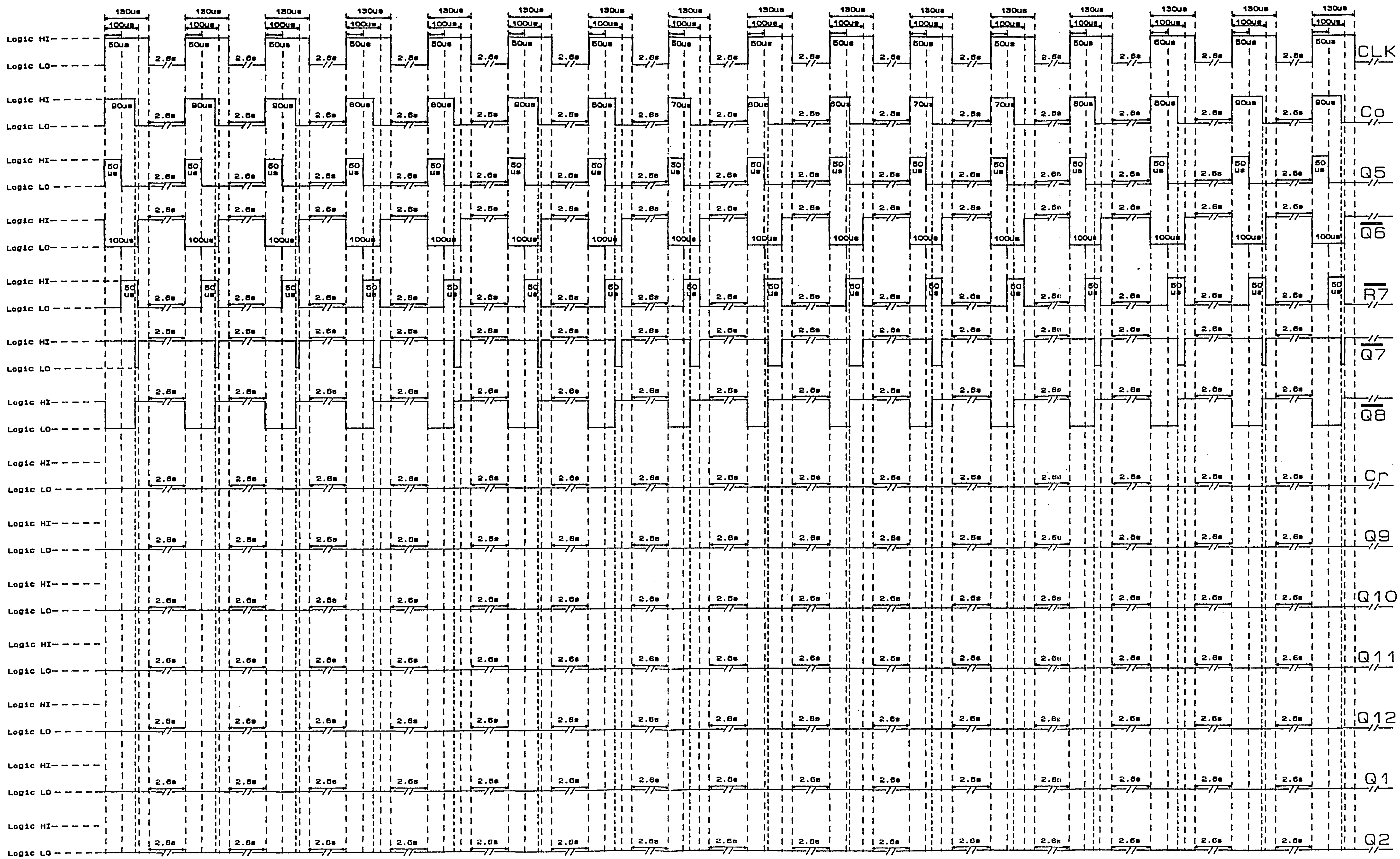

Fig.4.4 Normal sensitivity timing diagrams

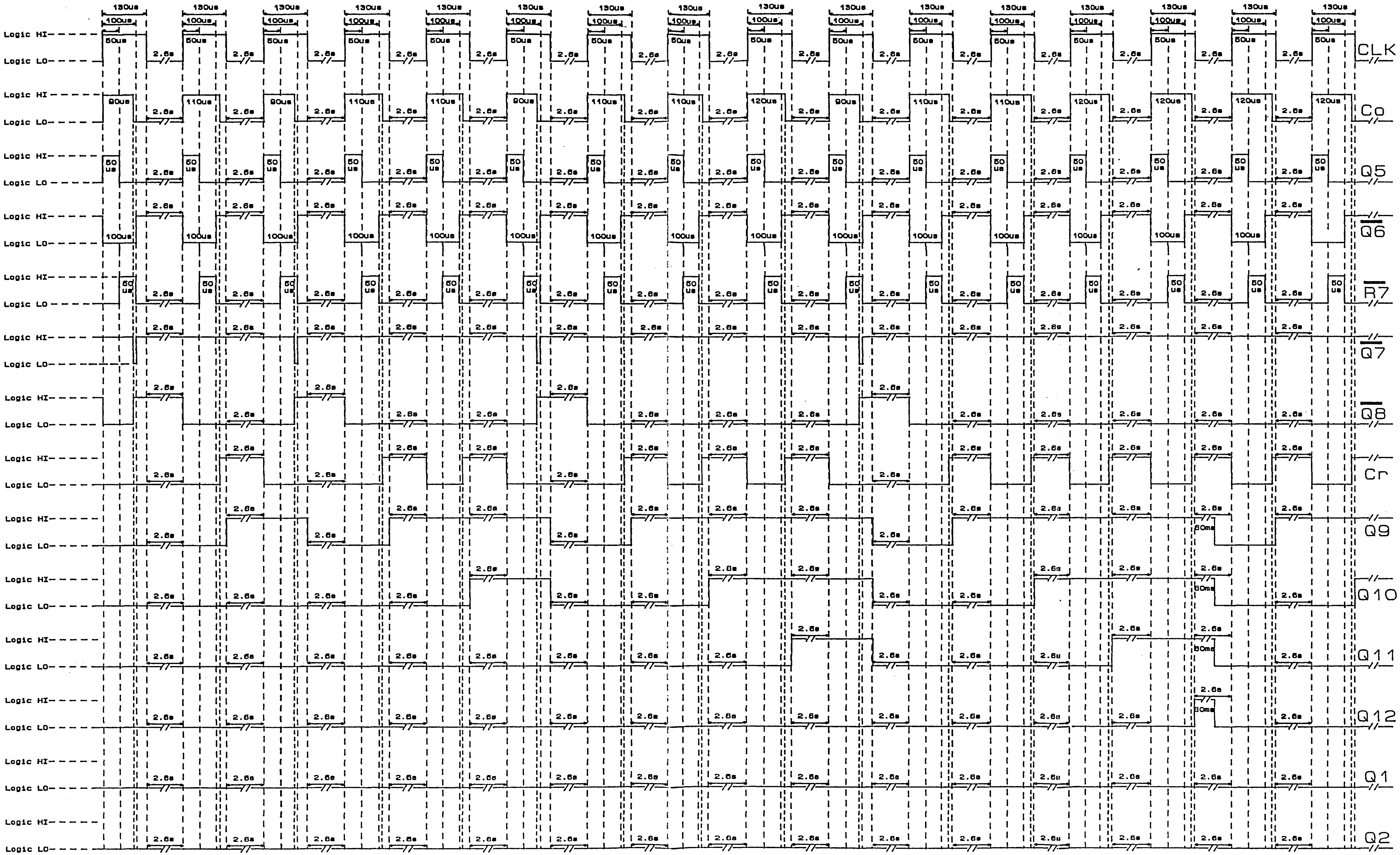

Fig.4.5 Oversensitive condition timing diagrams

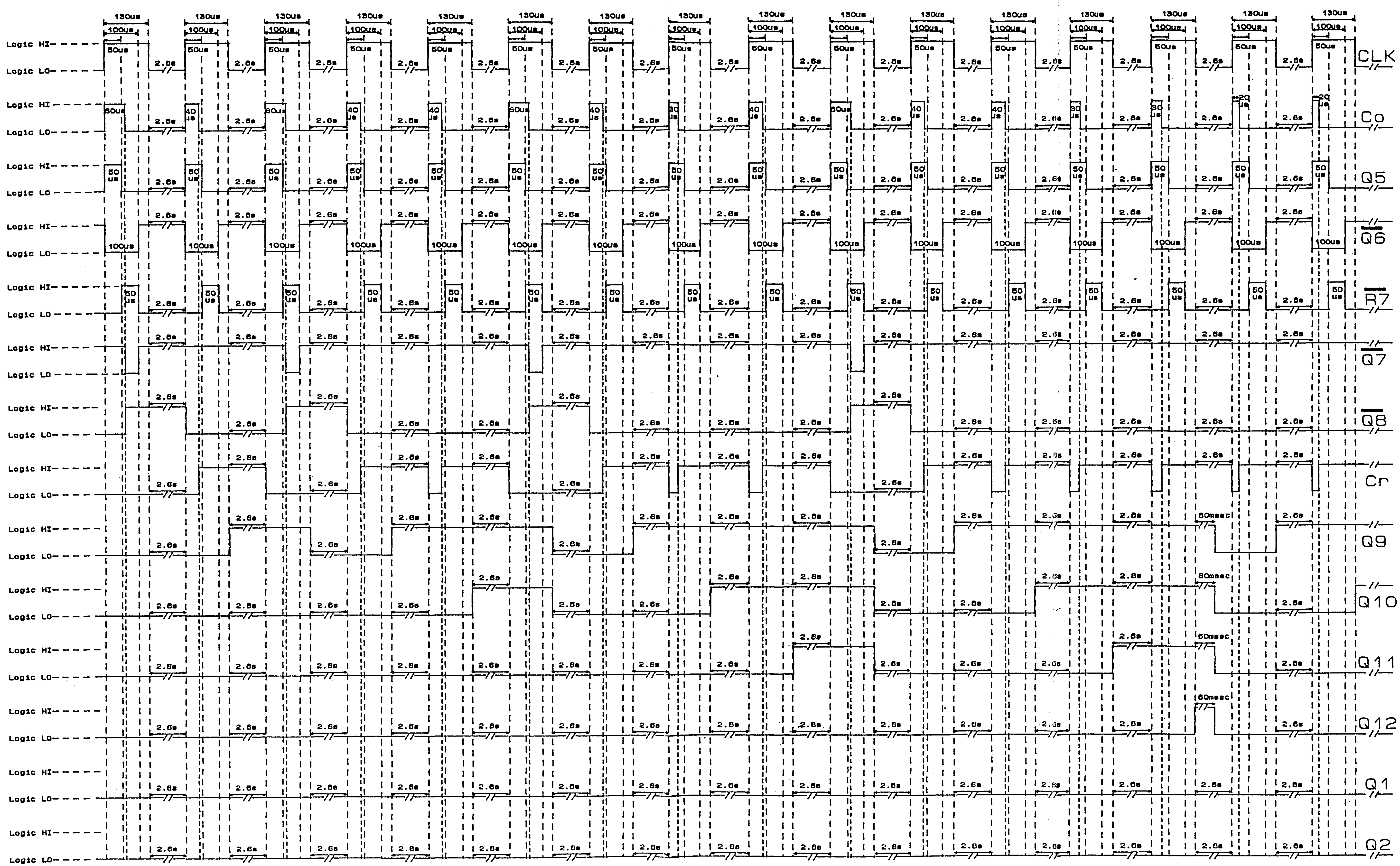

Fig.4.6 Undersensitive condition timing diagrams

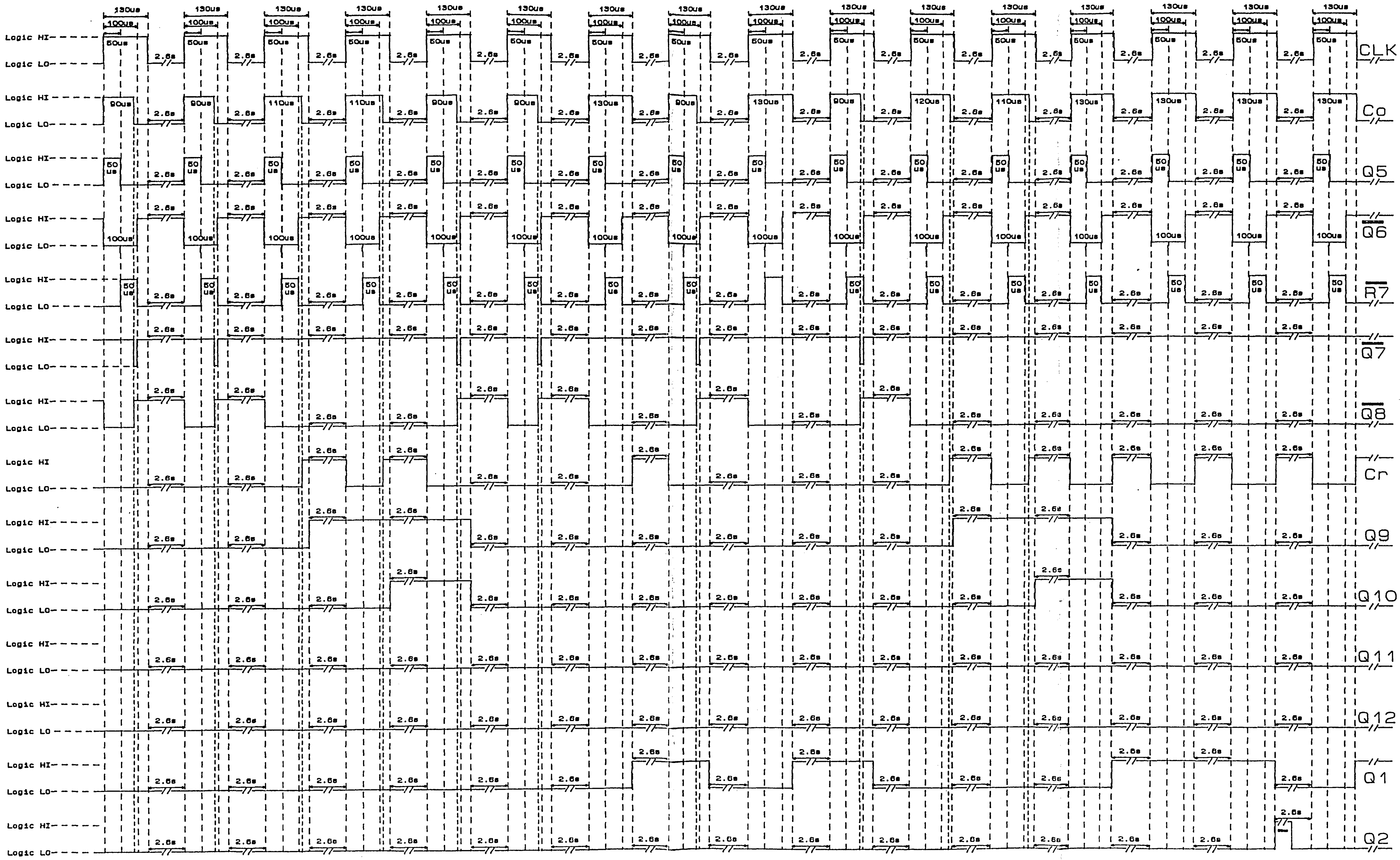

Fig.4.7 Fire condition timing diagrams

that a conventional system can be easily modified to a SENSI-CHECK system by simply replacing conventional detectors by SENSI-CHECK detectors, with no modification to existing wiring or any other alterations to the system.

4.6.1 Details of operation

The detector unit base block and circuit diagrams are shown on Figs 4.8 and 4.9 respectively. The internal circuit of the detector base consists mainly of the following:

(a) Alarm LED circuit

(b) Remote indicator switching circuit

For the mechanical details of the SENSI-CHECK base, artwork sketch, components layout diagram and list of components, see Appendix B.

When a supervising current from the detector base flows through to the detector head, the alarm LED does not light up and transistor T1 is off.

When an alarm is sensed by the detector head the voltage across terminals S and L drops to around 1.4V as terminals L' and S' in the detector head are connected together by thyristor SCR1. The LED in the base lights up and after a short delay transistor T1 switches on to

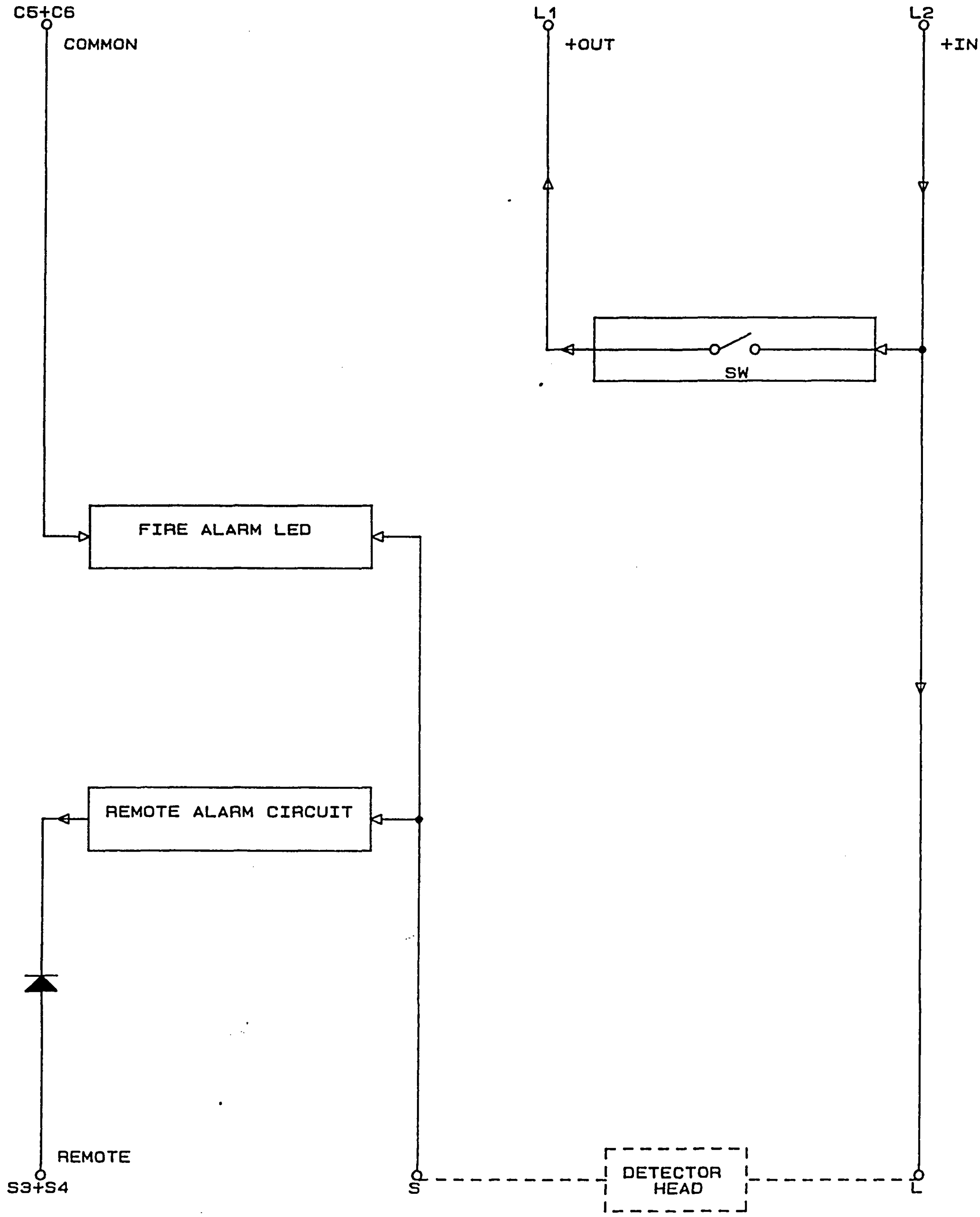

Fig.4.8 Model SOESDB-1: Detector unit (base) block diagram

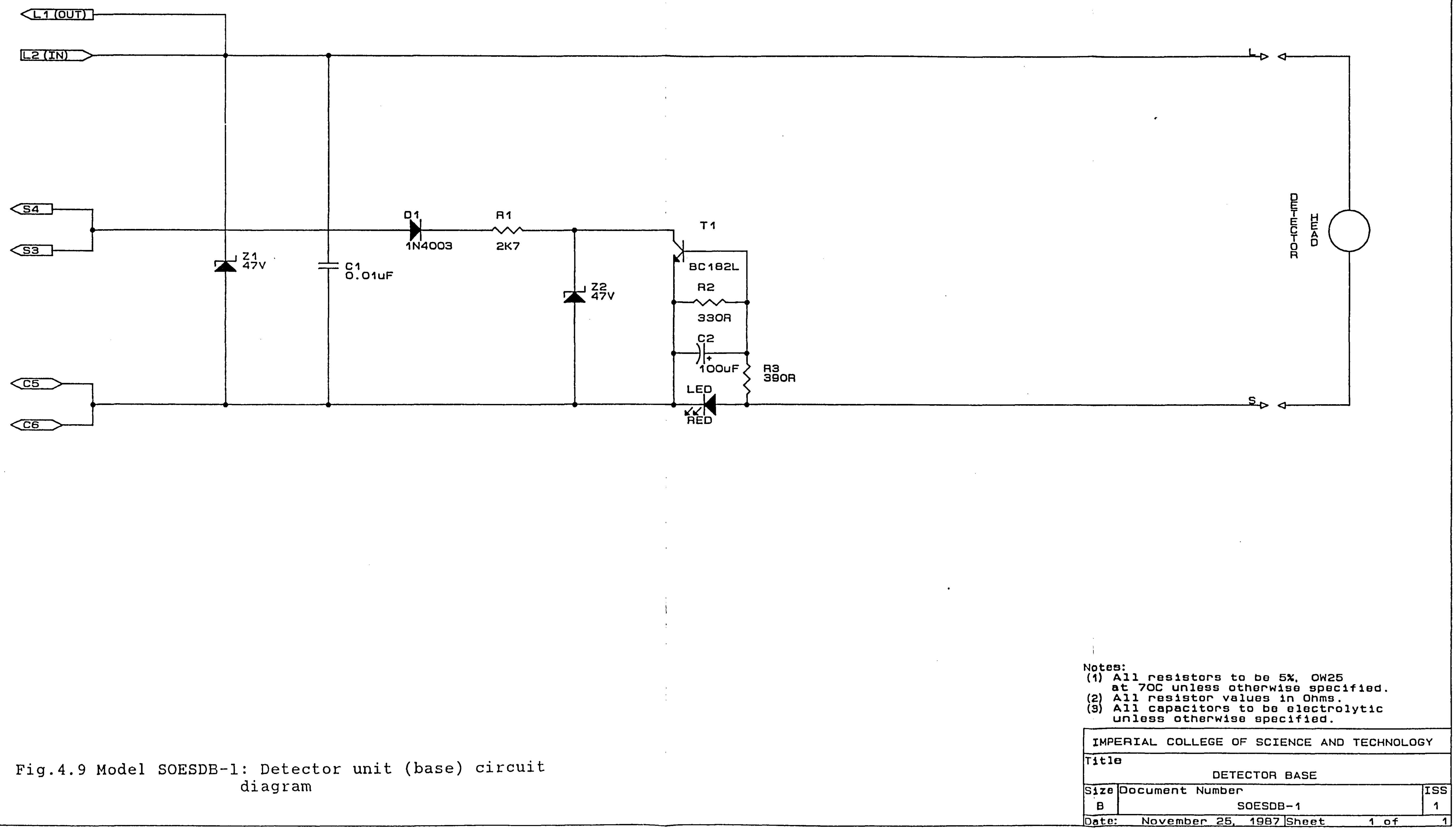

Fig.4.9 Model SOESDB-1: Detector unit (base) circuit diagram

illuminate the remote LED if wired. Response current is allowed to flow back to the control panel where the alarm is latched. The calculation of delay TD is:

$$TD = -C2((R2xR3)/(R2+R3))xln(1-((R2+R3)/R2)xK)$$

$$TD = 17.9 \times 1.44 = 25.8 \text{ msecs}$$

where K = VBE/ VLED

VBE= 0.7V and VLED= 2V

R1 = 2K2 , R2 = 130R, R3 = 390R

When a service alarm is triggered terminals L and S are not connected together, (like in a fire alarm condition). A 470R resistor is switched on and off between these two terminals at the rate of the clock pulse. When the resistor is switched on, the base LED is illuminated allowing response current to flow back to the control panel. The control panel monitors the current change and indicates a fault. The detector in trouble can be easily identified by its flashing LED. Thus an LED permanently illuminated indicates a fire alarm condition whilst a flashing LED indicates a service alarm condition.

4.7 Technical evaluation

The SENSI-CHECK smoke detector and base have been both technically evaluated in the laboratory and on site. All tests were based on the European Standards EN54:Part 7 "Specification for point-type smoke detectors using scattered light" and EN54:Part 9 "Method of test of sensitivity to fire". The test programme of this evaluation, is reported in Chapter 5.

CHAPTER 5

TECHNICAL EVALUATION

5.1 Introduction

The object of this technical evaluation was to examine the performance of the two smoke detectors, models OESD-1 and SOESD-1, and to confirm that the SENSI-CHECK principle can improve smoke detection reliability by reducing false and unwanted alarms without reducing the sensitivity to genuine fires.

Tests were carried out both under laboratory conditions and on sites. The tests in the laboratory were based on the European Standard EN54:Part 7 which specifies the requirements, test methods and performance criteria for point type detectors that operate using the scattered light principle.

The tests on site were carried out on detectors in three different types of installation: a closed car park area - chosen because of its high concentration of exhaust smoke and soot, an electronic components storage area - chosen because of slowly accumulating dust, and a kitchen area - chosen because of its high humidity. All sites and detector locations were carefully chosen because of their tendency to give repeated false alarms, and have generally been identified as troublesome areas. In particular the kitchen was chosen because it is considered by industry to be the most unsuitable environment for installing smoke detectors. Normally in areas like this only heat detectors are used for fire detection.

Furthermore, accelerated contamination tests of dust and soot were carried out to examine the SENSI-CHECK detectors' superiority over other conventional types of smoke detector presently available in the market. As a result of these tests the SENSI-CHECK detector has been proved to reduce false alarms considerably, and does not need regular cleaning, but rather alerts the user when changing is required. This raises confidence in the reliability of the detector. calibration).

5.2 Performance

The technical evaluation has shown that both types of detector comply with the most important parts of EN54:Part 7 and that the SENSI-CHECK principle performed exceptionally well, and has not signal a single false alarm for a period of well over two years to date. Sixteen service alarm calls have been received so far, nine from the detector installed in the car park area, four from the detector installed in the electronic component stores area and three from the kitchen area. All these alarm calls were carefully investigated and all except the detector installed in the kitchen area, were because of reduced sensitivity from accumulated dust and soot within the detector chamber. The reason for service calls received from the detector in the kitchen, was because of increased detector sensitivity from accumulated damp within the chamber. Employing the SENSI-CHECK detector enables smoke detection to be used successfully in kitchen areas after all, without to have to suffer from any false alarms and having to be cleaned regularly. The detector itself lets the user know when it needs cleaning.

5.3 Testing and instrumentation

All instruments, test equipment and accessories used in evaluating the performance of the two detectors are either individually described under each test or are referred to in Appendix D.

The EN54:Part 7 tests are described under heading 5.5. After the evaluation of the detectors to EN54 standards accelerated contamination tests were carried out as described in 5.6.

5.4 Measurements

Where no specific tolerances or limits are specified in the methods of test, a general tolerance of 5% is assumed.

(a) Methods of test

The response threshold was measured in a wind tunnel meeting the requirements of Appendix D1. Unless otherwise specified in specific tests, the air velocity in the tunnel was 0.2±0.04m/s, the air temperature was 23±5°C and the detector had the orientation giving the lowest response threshold. The tunnel was initially clear of smoke and the detectors were initially in their normal condition for at least 15 min unless otherwise was required by a specific test. Smoke was generated as described below and, at the moment of transition to the alarm condition, the smoke density was measured using an Ionisation chamber instrument (MIC) as described in Appendix D2 and recorded as the response threshold.

(b) Smoke generation

The test smoke used was obtained by heating filter paper, (Whatmam no.2), weighing between $80g/m^2$ and $110g/m^2$, on an electric heating element. The amount of paper used and the temperature of the heater was adjusted so that the optical density of the smoke increased at a rate not exceeding 0.2db/m per minute to a maximum value of at least 1.5db/m, when measured on the MIC instrument.

5.5 EN54:Part 7 - Methods of tests and test schedules

The detectors were inspected and tested in accordance with the requirements of the following clauses specified in standard EN54:Part 7.

EN54:Part 7 Clause	Title
3	General
5	Switch-On test
6	Repeatability test
7	Directional dependence test
8	Reproducibility test
9	Variation of supply voltage test
10	Air movement test
11	High ambient temperature test
12	Ambient light test
13	Vibration test
14	Humidity test
15	Shock test
16	Impact test
17	Corrosion test
18	Insulation resistance test
19	Dielectric strength test
20	Low ambient temperature test
21	Fire sensitivity test

Six standard OESD-1 and six SENSI-CHECK SOEDS-1 detectors were tested instead of sixteen that EN54 requires. All detectors were calibrated to a sensitivity of 0.16±0.02db/m using the MIC instrument. The tests were carried out in accordance with the schedule of table 5.1. Tests on individual detectors were carried out in the order shown in table 5.1, reading from top to bottom.

Table 5.1 Tests schedule for smoke detectors

CLAUSE	TEST	DETECTORS					
		1	2	3	4	5	6
5	Switch-on	*					
6	Repeatability		*				
7	Directional Dependence			*			
8	Reproducibility	*	*	*	*	*	*
9	Variation of supply voltage	*					
10	Air movement			*			
11	High ambient temperature					*	
12	Ambient light				*		
13	Vibration					*	
14	Humidity				*		*
15	Shock						*
16	Impact				*		
17	Corrosion			*		*	
18	Insulation resistance	*					
19	Dielectric strength	*					
20	Low ambient temperature		*				
21	Fire sensitivity (EN54-Pt.9)		*	*	*	*	

5.6 EN54:Part 7 - Tests, observations and results

Where applicable in each test, the detectors under test were connected to supply and indicating equipment (Firetwin 1/2) supplied by Electronic Alarms Ltd, (see Appendix D3).

All detectors were subjected to basic tests and fire sensitivity tests. In the basic tests (clause 5 to 20) the detectors were tested in various ways to determine whether they are basically capable of withstanding certain ambient conditions that may occur in practice, so as to be sufficiently certain that the detectors will remain functional for a sufficiently long period of practical use, or at least for a period between two services or inspections, (not applicable for the non-SENSI-CHECK detector), of the installed fire detection systems. Furthermore the basic tests verify the constancy of the response threshold of the individual detector and the similarity of response threshold of detectors relative to one another. The behaviour of the detectors in the case of fire was not examined in the basic tests.

In Clause 21, the fire sensitivity tests according to EN54:Part 9, the detectors were subjected to various real test fires in a fire test room. In this way, the response behaviour of the detectors to real fires was verified and the sensitivity of the detectors to various defined fires was determined.

Appendix E list all tests carried out in a format that states the purpose of each test, the inspection procedure, assessment carried out and comments made.

CHAPTER 6

CONCLUSIONS

6.1 Summary of findings

The underlying causes of unreliability and incidence of false alarms in fire alarm systems have been studied. These together with information gained from the answers to questioners (see Appendix A3) and from a survey on the various types of fire detectors and alarm systems have identified three major problems:

(a) the second highest percentage of false alarms is due to detector drift of sensitivity,
(b) the inability of a detector to inform the user of its lost sensitivity in detecting fires, and
(c) the inability of a detector to inform the user of its abnormal sensitivity increase in detecting fires, which normally leads to false alarms

Two different types of opto-electronic smoke detector have been developed as solutions to the above problems. These detectors have undergone rigorous testing and one of them is now a saleable product, having being approved by the European Standard EN54:Pt.7. The SENSI-CHECK detector in particular which is able to monitor its sensitivity and report on its state at all times without false alarming, seems to offer high sensing integrity to real fires. The SENSI-CHECK principle has proved that multistate conventional detectors can offer a higher sensitivity to real fires than simple two state detectors, and represents arguably the best that can be achieved by this class of detector. The SENSI-CHECK system has brought about a dramatic reduction in service cost and incidence of nuisance alarms. When compared with conventional systems the SENSI-CHECK systems seems to offer:

1. Minimum service cost
2. More reliable performance
3. Identification of only problematic detectors which can be cleaned/replaced at normal service check by qualified or even unqualified personnel
4. Minimum of nuisance alarms
5. High system integrity and people's confidence

However, the development of the two state and multi state SENSI-CHECK detector and the investigation into unwanted fire alarms has also led to the conclusion that conventional detectors have a number of drawbacks:

1. precise location of fire unknown
2. no knowledge of impending danger prior to fire
3. extensive wiring
4. no compensation for detector contamination

6.2 Future work

Fire analysis algorithms working with analogue sensors seem to be the next stage in the improvement of method of fire detection. Analogue sensors have already been developed by the author as part of his work for his company. Basic fire analysis algorithms have also been developed by the author and are currently under evaluation.

Analogue sensors can provide continuous on site information of fire conditions as a function of time. This information can be sampled periodically by the central control panel and indicating equipment and using fire analysis algorithms the fire size and growth can be predicted after filtering out the various noise factors.

The signals coming from analogue sensors contain useful information and noise. The types of noise and the remedies (fire analysis algorithms) used to eliminate noise and improve the integrity of automatic fire alarm systems are given below:

1. Sensor reference level changes

A sensor can be contaminated resulting in a variation of its reference level, "zero drift".

By using the control panel to continuously monitor the output of each sensor, the zero point values (the output level with no smoke or heat present) of all sensors can be stored in the control panel memory.

A sensor's sensitivity variation due to zero point drift can therefore be compensated for by renewing the memorized values in the control panel.

2. Transients

- Electrical, e.g. spikes on power lines and high frequency electromagnetic fields.

-Deceptive phenomena, e.g. signal rises caused by a burning paper; an indoor barbecue; an aerosol spray, e.t.c.

The calibrated output values of each sensor can be periodically sampled and subjected to digital filtering. The noise component can therefore be eliminated by taking temporal averages of the sensor's output values.

This operation can result in a more reliable averaged value which is then used in the fire analysis procedure to determine the fire size and growth rate so that an alarm decision can be made.

The averaged data value, now relatively free from fluctuations due to transients, can be compared with two pre-set threshold levels:

1. Fire Analysis level and,

2. Alarm level.

When the data value is below the Fire Analysis level and the Alarm level, only the data sampling and filtering procedures are applied.

When the data value is between the Fire Analysis level and the Alarm level, evolution of the sensor's output can be approximated by a trend curve described by a polynomial method using the sensor's old data values in the memory.

By extrapolating the polynomial curve, a prediction can be made of the output value of the sensor after a given time period. If the predicted output value exceeds the Alarm level, a pre-alarm can be initiated.

The exact values of the Fire Analysis level and the Alarm level can be adjusted in accordance with the ceiling height of the room where the sensor is installed. This permits a correct alarm decision to be made with respect to the size of the fire, taking into account the height of the ceiling.

With these techniques a more reliable decision making can be made and the analogue system is far less likely to cause a false alarm than a conventional system.

From work carried out so far it appears that analogue fire detection and fire analysis algorithms will be the ultimate for fire detection and combatting false alarms, and predicting fire at very early stages.

Because of the various conditions that occur in the development of a fire no one type of detector, (conventional or analogue), can be said to be the most suitable for all applications and the final choice has to depend on individual circumstances. This is a major drawback of the present devices and identifies a need for some research work to be done on combined types of detectors. However, until something is done it may be useful to install different types of detectors or sensors in the same area or to install both a detection system and an extinguishing system such as sprinklers combined together.

APPENDICES

APPENDIX A

FIRE DETECTORS

1. Which detector type to choose

2. Fire detection devices since 1970

3. Unwanted fire alarm signals investigatory check list

APPENDIX A1

WHICH FIRE DETECTOR TYPE TO CHOOSE

1. What the fire alarm companies are offering

For many years Fire alarm companies had operated with little sophistication in regard to product (heat detectors being virtually the only means of automatically detecting fires and electrically connected manual fire alarm systems) and these were the supplement to the automatic water sprinkler. It is only over the last 15-20 years that product development has produced highly sophisticated equipment with which it is possible to detect most known forms of fire phenomena. Over the last two years a major improvement to fire detection by complicated microprocessor based analogue sensing, addressability and intelligent signal analysis has taken place. Fire alarm detection has widely improved with the minimum of unwanted false alarms.

With so many various types of Fire detectors we can with skill provide the right product to optimise detection possibility. In order that this can properly controlled however, people need to be properly educated and trained to understand, evaluate and produce designs which:

(a) provide the early warnings that are possible and necessary, thereby reducing loss of life, capital and production, and

(b) ensure a system with minimal unwanted alarms by choosing the right detector for the right place, and therefore ensure satisfactory performance which thereby promotes a high level of confidence for the user

2. What the user should be looking for

It is in the users interest to be as selective in the procurement of providing an effective fire alarm system as any other piece of capital equipment or investment intended to help the business make a profit.

The user must be aware of the need to effectively maintain his system. He must delegate the day-to-day operation of the system to an employee skilled and/or trained in this area, to the standard he expects from any tradesman or professional employee, or he must delegate this responsibility to an organization which can effectively do this for him.

This means not only testing the system but ensuring the installation is not abused.

He must think before changing the occupancy of rooms, the type of work done in the rooms.

He must be advised of the changes in the construction and the effects on the fire alarm system.

Finally the user, must demand the interest and responsibility of his fire alarm advisers, and act promptly on their advice.

3. What the fire alarm advisers and consultants can offer

Advisers might be fire brigades, local authorities, factory inspectors, architects, consulting engineers or insurance companies. Their function is to give advice enabling a "fire plan" to be evolved.

Advisers are properly skilled in the many aspects of fire knowledge and the advice they give is expert and sound.

The advisers are individually trained to a level of competency which ensures that the various facets of a "fire plan" are evaluated carefully before providing instruction. This might mean consulting individual risk specialists in order that a most comprehensive study on the user requirements can be made.

After advisers, come consultants who include consulting engineers and other professional people who specify and request tenders from manufacturers and installers. Consultants are aware of the many products available and are able to offer a defence which will effectively reduce a fire possibility or contain to minimal proportions any fire outbreak.

The three particular points always taken into account by consultants are as follows:

(a) Aesthetic requirements are of lesser priority. The purpose of fire equipment is to be effective and easily recognizable. Detection devices are placed in the most effective position with their potential optimised. To hide, screen or mask for aesthetic purposes a devise and consequently reduce its performance is not acceded to.

(b) System designs are not unnecessarily complicated. Zoned alarms, two-stage alarms, light signals, special sounders, etc, are widely used. The prime purpose of a fire alarm system is never allowed to be lost because the designer had in mind designed to attract some accolade of public recognition.

(c) The consultant always thinks about the occupiers of a premises. He design systems which can be easily understood and/or assimilated. He always considers a real fire alarm as a point at which real 'panic' can take place.

4. Which fire alarm detector to choose

One of the consequences of introducing more sensitive and sophisticated fire detection components to the market is the need to be more selective in the use of such components and give careful analysis to their principles of operation ensuring that the best tool for the job is used to give maximum protection to life and property and minimum trouble to the user and the brigade from false alarms and other system deficiencies. But with so many different types of detectors in the market which one to choose to have the best results?

Two year's research work on the various types of fire detection devices, has concluded that two principal types of smoke detectors are the most effective fire detection devices in protecting life and property. One of these is the Ionisation spot type smoke detector, that can detect fire at its very early stages, before even smoke is visible. The Ionisation type detector is sensitive to smoke particles of 0.01 to 0.1 micron. The other type of detector is the Optical light scatter spot type smoke detector. The Optical smoke detector is sensitive to visible smoke of 0.2 to 10 microns. Comparison of the effectiveness of the two detector types shows that the Ionisation detector has a distinct detection advantage over the Optical detector for fires generating small particle sizes. In selecting which type of detector to use in any given situation, the first step is to assess the hazard, the type of fire likely to occur, where and when, and the characteristics of a fire in the incipient stages.

In the next pages a list of fire detection devices organized primarily by the fire characteristic being detected is given. The list is further subdivided by detection technique. A description of the mode of operation of each device is summarized; known or expected applications of each device are listed; and unique characteristics or other remarks on each device are given. References sided in these tables are listed at the end of the paper and identify sources of further information on each device. These are aimed to assist the user in choosing the right detector type for the best safety results. However, before choosing a detector there are a number of questions that need first to be asked.

5. Questions to ask

Is it a life safety or property protection that is required? Life safety requires attention to hazards of smoke in escape routes at night time or its effect on incapacitated inmates. Property protection requires attention to highly flammable situations and rapid fire detection may be necessary.

What type of occupancy will the premises have? Are the occupants able or infirm and with or without supervision?

What are the periods of premises occupation?

Is the building occupied with able people for 24 hours of the day or does it involve an unattended sleeping risk.

What is the type and size of the fire load?

Is the fire likely to be generated in bedding and furniture or from flammable processes?

What are the likely fire causes? Is the fire likely to be caused by occupants or plant malfunctions?

Is it likely to be wilful or accidental?

Slow smouldering fires with low initial heat source compared to fire load will enable the small particles to agglomerate into lesser quantity/density of larger, slower moving particles. Fires creating these conditions often emanate from the following materials: bedding, furniture, lagging, high density storage, plastic materials such as p.v.c.. Materials which are typically found in residential life safety and entertainment risks.

Distance between the fire and the detectors positions can significantly affect the detector response. The greater the distance the larger and less concentrated the particle sizes become, due to the agglomeration and condensation changes which can take place as soon as the particles leave the fire source.

APPENDIX A2

INFORMATION PACKAGE

(Fire detection devices since 1970)

1. Introduction

This paper provides the results of two year's research work on the various types of fire detection devices developed since 1970.

It constitutes a part of a main research work, carried out at the Imperial College of London University on behalf of Electronic Alarms Ltd, concerning the application of some new ideas and techniques to improve fire detection in general, minimize nuisance alarms, cut down on routine servicing calls and improve the integrity of conventional, decentralized smoke detectors and fire alarm systems.

The paper provides a list of fire detection devices organized primarily by the fire characteristic being detected. It is further subdivided by detection technique. A description of the mode of operation of each device is summarized; known or expected applications of each device are listed; and unique characteristics or other remarks on each device are given. References sided in these tables are listed at the end of the paper and identify sources of further information on each device.

2. MANUAL/ELECTRIC FIRE DETECTION

2.1 Break glass

Description: Fire alarm break-glass units utilizing a switch brought into operation by breaking a glass located on the front of the unit. These devices are the familiar red boxes sided at a height of about 1.4 metres from floor level. Their siding is such that the occupants of a building do not have to travel more than 30 metres to reach the call point in the event of a fire. These units are manufactured to B.S. 5634:Part 1, according to which they are located on exit routes, floor landings, exits to open air and other areas to ensure direct indication of the zone in which the fire exists.

Applications:
- -Manual/electric fire detection
- -Watchmen supervisory service
- -Fire control equipment actuation

Unique characteristics:
- -Very widely used
- -Only effective where people are present
- -Generally high operational reliability
- -Glass requires replacement after actuation

References: 1,2,3,4,5

2.2 Pull box

Description: Familiar fire alarm pull boxes utilizing coded or noncoded alarm switching. For coded operation, they contain mechanically or electrically driven motors which turn a code wheel to successively open and close an electric circuit to identify location (also, digital transmission can be used). Location is generally in the normal path of exit travel, and not more than 200 ft apart.

Applications:

-Manual/electric fire detection
-Watchmen supervisory service
-Fire control equipment actuation

Unique characteristics:

-False alarms caused by people are a problem in some areas
-Only effective where people are present
-Generally high operational reliability
-Low maintenance
-In common use for a long time
-Overall effectiveness is dependent on the people in the area

References: 1,2,3,4

2.3 Call box

Description: Fire alarm call boxes, which provide direct voice communication with caller to gain specific information.

Applications:

-Manual fire detection

Unique characteristics:

-Relatively new to fire communications use

References: 2

3. HEAT ENERGY DETECTORS

3.1 Fixed temperature types

Description: Designed to alarm when the temperature of the operating element reaches a specific point. Specified actuation temperatures range from 55°C to 78°C.

Applications:

-General spot detection
-General area detection (small area)
-Suitable for releasing device service

Unique characteristics:

-Subject to fewer inadvertent alarms than other detector types due to its simplicity of design
-Limited to environmental temperature conditions
-Very high reliability
-Many various types are in common use today
-Low sensitivity to Class A and C fires, high sensitivity to Class B fires

References: 2,3,5,6,7,8

3.1.A Eutectic metal type

Description: Eutectic metals, alloys of bismuth lead, tin, and cadmium, are the operating elements which melt rapidly at a predetermined temperature. Electric alarm

actuators are commonly designed in two ways:
(a) Eutectic metal is placed in series with a normally closed circuit; fusing of the metal opens circuit and triggers alarm
(b) Eutectic metal is used as solder to secure a spring under tension; fusing releases spring and opens circuit.

Applications:

-Most common in sprinkler head element
-Very common in restaurant automatic kitchen systems as fusible links
-General spot detection
-General area detection

Unique characteristics:

-Device requires replacement after actuation
-Somewhat slow in operation compared to other detectors (especially in well ventilated and air conditioned buildings)
-Maintainability and stability is generally very high
-In common use

References: 2,8

3.1.B Glass bulb type

Description: Frangible glass bulbs similar to those used in some types of sprinkler heads can be used as actuating mechanisms. The bulb contains a liquid and a small air bubble. The bulb is used as a strut to maintain circuit contacts. As heat is absorbed, pressure is build up in bulb due to the bubble expansion; the rapid increase in pressure actuates the alarm upon the bulb's shattering.

Applications:

-Common in high temperature applications
-Some general spot detection
-General area detection

Unique characteristics:

-Requires replacement after activation

References: 2,8

3.1.C Continuous line types

Alternative to spot fixed temperature detection using various designs:

3.1.C1 Pair of wires

Description: A pair of wires in a normally open circuit. Conductors are insulated from each other by a thermoplastic of known fusing temperature, twisted and installed under tension. When design temperature is reached insulation melts, actuating the alarm.

Applications:

-Used where continuous line heat detection is desirable

Unique characteristics:

-Reliability, stability and maintainability not yet established.
-Not self restoring
-"Twisto-wire"
-"Protectwire"

References: 2,8

3.1.C2 Capillary tube and semiconductor material

Description: Similar device using semiconductor material and a stainless steel capillary tube. The capillary tube contains a coaxial centre conductor. A small current normally flows through the semiconductor, except under fire conditions where the semiconductor resistance decreases, allowing a larger current to flow and thus actuating alarm.

Applications:

-Used successfully in aircraft engine cells

-Used successfully in cable trap

Unique characteristics:

-Self restoring

References: 2,8

3.1.C3 Capacitor cable

Description: Special capacitor cable, a ceramic core surrounded by a metal wire and covered with a metal sheath. The line capacitance at any point varies directly with the local temperature. Sophisticated electronics continuously polls several points along the line and displays results on an oscilloscope initiating an alarm when temperature is too high in any area.

Applications:

-Used successfully in high temperature areas

Unique characteristics:

-Self restoring

-Relatively new on market

-Location of high temperature area is accurate within 1 or 2 metres

References: 8,9,10,11

3.1.C4 Thermoplastic hose

Description: Thermoplastic fire sensing hose, pressurised with 30 to 40 psi air pressure. Heat due to fire softens the hose which will ultimately rupture when its temperature is approximately equal to 80°C. The decrease in pressure initiates an alarm at the control box via a low pressure switch.

Applications:

-Designed for coal mine use

Unique characteristics:

-Very durable in situations where adverse conditions prevail which are destructive to electronic circuits

-Hose requires replacement after actuation

References: 12

3.1.D Bimetal types

Description: The bimetal mechanism is a sandwich of two metals having different coefficients of thermal expansion. When heated, differential expansion causes stresses in the assembly which are resolved by bending or flexing toward the metal with the lower expansion rate. There are generally three common designs; see 2.1.D1, 2.1.D2 and 2.1.D3.

Applications:
- General spot detection
- General area detection

Unique characteristics:
- Self restoring

References: 2,8

3.1.D1 Bimetal strip

Description: This forms a direct part of the electric circuit. Heat may cause expansion in the direction of the contact points which are then opened.

Applications:
- General spot detection
- General area detection

Unique characteristics:
- Lack of positive rapid action
- The gradual bending as heated may result in inadvertent alarms from jarring or vibration before design temperature is reached

References: 8

3.1.D2 Snap disk

Description: A bimetallic disk formed in a concave shape in its unstressed condition. As disk is heated stresses developed cause convex reversal of disk, which is used to actuate alarm. (Cone reversal is instantaneous at design temperature).

Applications:
- General spot detection
- General area detection

Unique characteristics:
- Not as susceptible to inadvertent alarms as bimetal strip
- In common use

References: 8

3.1.D3 Rate compensated

Description: This is a metal cylinder containing two metal struts which are the alarm contacts. With a rapid increase in temperature the shell expands, rapidly closing the struts. Under slowly increasing temperature both the shell and struts expand until the contacts close. The cylinder and struts are the two metals, but they are not bonded together.

Applications:
- General spot detection
- General area detection

Unique characteristics:
- In common use
- Rate compensated heat detection
- "Rate anticipation" type

References: 8

3.1.E Synthetic filament transducers

Description: Synthetic thread type transducers may be of use in fire detection. Device would consist of thread(s) under tension. Heat due to fire causes the threads to stretch and ultimately fail. Loss of tension can initiate an alarm.

Applications:

-None known

Unique characteristics:

-Research conducted in Russia on this principle (approximately 1970)

-Some U.S. patents on this principle

-None are known to be on the market

References: 13

3.1.F Metal oxide thermistors

Description: Certain metal oxides, whose electrical resistance decreases by several orders of magnitude within a few degrees of a reasonable alarm point, can be used as fixed temperature fire detectors.

Applications:

-Spot type applications

Unique characteristics:

-Low cost

References: 14

3.1.G Laser types

Description: (see smoke and fire gas detectors)

3.2 Rate of temperature rise types

Description: One effect a fire has on its surrounding environment is to generate a rapid increase in temperature of the air above a fire. The rate of rise detector will function when the rate of temperature rise exceeds approximately (8.33°C)/min. Normal changes in ambient temperature are compensated for within the detector.

Applications:

-General spot detection

-General area detection

-Suitable for releasing device service

Unique characteristics:

-Reacts to rate of temperature rise for faster operation than fixed temperature device

-Inadvertent alarms may be caused due to heating systems, machines, etc

-High stability

-Average reliability

-Low maintenance

-In common use

-Medium sensitivity to Class A fire; high sensitivity to Class B fires; low sensitivity to Class C fires

-Less sensitive if ambient temperature is high

References: 5,6,8

3.2.A Pneumatic type

Description: The expansion of gas when heated in a closed system is used to generate the mechanical force and actuate alarm contacts. Line systems consist of a metallic tubing in a loop configuration attached to the ceiling. Spot applications consist of heat collecting air chambers.

Applications:

-General spot and line detection
-General area detection

Unique characteristics:

-Self restoring
-In common use
-Spot type units become more sensitive with age if dust clogs vent hole

References: 8

3.2.B Thermoelectric type

Description: Various thermoelectric properties of metal have been successfully applied in devices for heat detection. The properties used are the generation of voltage between bimetallic junctions (thermocouples) at different temperatures, and variations in rates of resistivity change with temperature.

Applications:

-General spot detection
-General area detection
-Some line type applications

Unique characteristics:

-Series linked thermocouples (thermopiles) greatly increase sensitivity of detection

References: 15

4. SMOKE SENSING DEVICES

4.1 Ion chamber type

Description: Reacts to the aerosol components of combustion. Responds best to particle sizes between 0.01 and 0.1 micron. Normal sensitivity range is 0.5 to 3.5% / ft obscuration. The basic detection mechanism of an ionisation detector consist of an alpha or beta radiation source in a chamber containing positive and negative electrodes. The radiation in the chamber ionises the O_2 and N_2 molecules in the air between the electrodes causing a small current flow when voltage is applied. When aerosols and smoke enter the chamber ion mobility is decreased, and the resulting decrease in current actuates the alarm.

Applications:

-General spot detection
-General area detection
-Suitable for some releasing device applications in limited cases

Unique characteristics:

-Most models have adjustable sensitivity within a narrow range
-Some designs are subject to changes in sensitivity with varying velocities of air entering the chamber
-Sensitivity also affected by humidity and/or altitude (low pressure)
-Average maintainability and stability
-Some designs are not applicable for applications where high ambient radioactive levels are present, resulting in reduced sensitivity

-Self restoring
-In common use
-High sensitivity to Class A and B fires and medium sensitivity to Class C fires
-More sensitive to flaming fires than smouldering fires

References: 2,6,8

4.2 Photoelectric type

Description: Reacts only to aerosol components of combustion. Responds best to particle sizes greater than 0.5 micron. The presence of aerosols generated during the combustion process affects the propagation of light as it passes through the air. Two effects of the aerosol/air mixture are utilized to detect the presence of fire:

(a) Attenuation of the light intensity integrated over the entire beam path length

(b) Scattering of light in the forward direction and at various angles to the beam path

Smoke detectors which utilize item (a), consist of a light source, collimating lens system, and a photosensitive cell.

Smoke detectors utilizing item (b) operate on the forward scattering of light which occurs when smoke particles enter a normally dark chamber. They basically consist of a light source, photocell , and a special chamber to utilize the scattering principle. Normal range of sensitivity is 0.5 to 2.5% light obscuration/ft.

Applications:
-General spot detection
-Projected beam detection over large open areas

Unique characteristics:
-Continuous exposure of light accelerates the aging of photocells, which implies increased maintenance and possible failure
-Average sensitivity, maintainability, and stability
-Foreign matter in air way cause inadvertent alarm
-Self restoring
-In common use
-High sensitivity to Class A fires; low sensitivity to some Class B fires; medium sensitivity to Class C fires (better than ion type)
-More sensitive to smouldering fires than flaming fires
-New LED types offer more reliability than older types

References: 2,5,6,8

4.3 Resistance bridge type

Description: Employs an electron grid-bridge circuit. Increases of smoke particles and moisture present in products of combustion bring about impedance changes which upset the balance of the grid-bridge circuit causing an electronic triggering device to initiate an alarm. Atmospheric changes due to normal environmental conditions are accepted by the grid-bridge circuit and the bridge is kept in balance.

Applications:
-General spot detection
-General area detection
Unique characteristics:
-Some difficulty with inadvertent alarms due to moisture and airborne contaminants
-Average sensitivity, maintainability, and stability
-Self restoring
-Less sensitive to plastics fires than cellulose fires
-Continually losing popularity
References: 2,8

4.4 Particle ionisation type

Description: Determines submicron particle concentration by measuring the variation in electrical charge due to the pressure of ionized particles. Positive and negative ions are separated and the negative ions' are used to measure a potential which is related to the concentration of particles present.
Applications:
-Volume sampling (single and multizone applications)
Unique characteristics:
-Alarms in incipient stage of fire
References: 8

4.5 Condensation nuclei type

Description: Uses a technique by which micron or submicron particles can be made to act as condensation nuclei on a "one particle, one droplet" basis; the concentration of particles is measured by photoelectric methods (normally set to alarm at 2.2×10^{10} particles/ft^3.
Applications:
-Intermittent sampling in multizone systems with one central analyzing device
-High valued areas, e.g., museums, art galleries etc.
Unique characteristics:
-Gaining popularity
-High maintenance required
-Alarms in incipient stage of fire
-Extremely sensitive
-Wide range of sensitivity
References: 8,15

4.6 Quartz crystal incipient type

Description: Air is pumped through a separator which selectively directs only submicron size aerosols (approximately 0.7 micron) to a jet nozzle type impactor, where 50% of the mass products greater than 0.3 micron in size are deposited on the face of the sensing crystal. The addition of mass through impaction of the sensing crystals causes a decrease in the resonant frequency of that crystal. A difference between the beat frequency of the sensing crystal and an identical reiterative crystal, caused by a fire condition, will actuate an alarm. Normally set to alarm at 1800 g/m^3

Applications:

-Volume sampling (single zone)

-Multizone intermittent sampling systems should be feasible

-Developed for use in space shuttle; has been shelved due to device 3.7

Unique characteristics:

-False alarm free operation claimed

-Insensitive to changes in gravity

-Alarms in incipient stage of fire

-Has alarm reset to reconfirm incipient fire condition

-Insensitive to changes in air currents and ducts (can operate in air currents up to about 300 m/min

-Initiates fail-safe signal when maintenance is required

-Relatively new

-Requires 5 watts power consumption

-Has been shelved due to device 3,7

References: 16

4.7 Modified ion chamber type

Description: Predecessor of device 3.6. Uses same type of impactor and air pump mechanism, but with ionisation chambers substituted in place of the quartz crystals. Only particles less than 2 microns in size are directed through the sensing chamber.

Applications:

-To be used in the space shuttle and in advanced naval craft

Unique characteristics:

-Has same characteristics as Device 3.6

References: 17

4.8 Laser types

Description: Detects heat by reaction to changes in the index of refraction of the air along the beam of the path. This change in refractive index can cause variations in the velocity of the laser beam. This phenomenon is utilized by monitoring the changes in the beam path due to heat. Detects smoke by responding to the presence of visible products of combustion of a fire in the same manner as an ordinary light beam.

Applications:

-Projected beam detection across large areas

Unique characteristics:

-Ambient light can have an adverse effect on smoke detection

-Detection time varies with air velocity and ambient light

-Reliability, maintainability, and stability are not established

-Relatively new

-Not known to be commercially available yet

-Excellent for large, open area detection

References: 8

5. FIRE GAS SENSING DEVICES

5.1 Catalytic semiconductor gas detector

Description: Uses a bulk N-type catalytic semiconductor thermistor, which responds with a large decrease in resistance when exposed to reducing or combustible gases, due to catalytic oxidation. In simple application, the operating element is placed in series with an alarm device and the power source in the quiescent condition acts as a high resistance to block the flow of current to the alarm circuit. During a fire the element resistance drops and current flows to the alarm circuit.

Applications:
-General area detection
-General spot detection

Unique characteristics:
-Relatively new
-Value as a detector is not fully established
-Self restoring
-Possible contamination of sensor
-Inadvertent alarms possible due to response to gases which are not fire signatures
-Reliability, maintainability, and stability have not been established but are questionable
-e.g. "Taguchi"
-Research needed in developing gas selective catalysts
-Offshoot from gas leak detection
-Poor response to plastics fires

References: 8

5.2 Infrared type CO_2 detector

Description: IR energy in the range of 4.22 to 4.31 microns is used to detect CO_2, the only gas to have an absorption in this range. Increased CO_2 concentration is measured by an exponential decrease in voltage due to photo-detector resistance. Can detect a wide range of CO_2 concentrations.

Applications:
-Volume detection
-Used successfully in African gold mines

Unique characteristics:
-Extremely sensitive
-Very expensive
-e.g., "Spanair System" developed for gold mines in 1980
-Requires more power than conventional detectors
-Continuous monitoring
-Has advantages over conventional mine air sampling systems due to the elimination of the time lag caused by air travel through sampling hoses
-Similar devices are being developed to detect methane and carbon monoxide

References: 18

5.3 Field effect transistor hydrogen sensor

Description: Smoke contains a small amount of hydrogen, the amount depending on the degree of combustion.

More hydrogen is evolved in the early and dying-out stages of fire development than during the developed fire condition. Because of this, the hydrogen output can be used to detect the early stages of a fire. Pd-gate n-channel silicon field effect transistors can be used for this purpose. Hydrogen gas is absorbed at the metal surface and metal-oxide interface which causes a change in the threshold voltage of the MOS transistor and this change is easily measured.

Applications:

- Should be useful for general fire detection

Unique characteristics:

- Value as a fire detector is not established
- Spinoff from hydrogen leak detection
- New concept
- No mention in literature of possible false alarm problems
- No mention in literature of sensor contamination problems
- Self-resetting
- 150°C temperature necessary for sensing element operation

References: 19, 20, 21

5.4 Argon type detector

Description: Operates on the principle of ionisation of foreign molecules by collision with high energy Ar atoms leading to high concentrations of Ar (see Ref. 4 for additional explanation of operation). Gas sensor beta or alpha radiation is used as a background current source.

Applications:

- Should be useful for general fire detection

Unique characteristics:

- New concept (probably not on market)
- CO and CO_2 cannot be detected by this method
- Best suited for very small concentrations of gases
- Ref. 4 indicated that hybridization of this type and ionisation type would be a very good combination reducing false alarms

References: 22

5.5 Flame ionisation type

Description: An H_2 - O_2 flame, which is used as one of the electrodes, is used to induce electron emission in various types of organic and inorganic molecules having low work functions. Electrodes under imposed voltages are used to collect the resulting ions.

Applications:

- Should be useful for general fire detection

Unique characteristics:

- No fire detectors developed using this principle are known
- High sensitivity, reasonable stability, moderate flow insensitivity and linearity are reported for these devices
- Continuous flow of H_2 is necessary for detector operation
- Might be of value in a hybrid setup

References: 22

5.6 Thermal conductivity sensors

Description: A set of matched metal filaments or thermistors is used to follow changes in thermal conductivity. A reference gas is passed over a reference junction while the gas in question passes through the detection element. Resistance of the detection element changes with respect to the reference junction.

Applications:

-Should be useful for general fire detection

Unique characteristics:

-Ref. 4 explains how this device could be incorporated in a fire detector

References: 22

5.7 Fuel cell devices

Description: Analogous to an electromechanical cell where conventional fuel reacts as the anode while O_2 or air reacts as the cathode. Carbon monoxide fuel cells may be feasible in this type of fire detection.

Applications:

-Should be useful for general fire detection

Unique characteristics:

-Ref. 4 explains how this device could be incorporated in a fire detector

References: 22

5.8 Oxygen depletion type

Description: Oxygen depletion occurring in a fire situation may be useful for detection purposes. Probably best in a hybrid setup. Detection mechanisms may be primary galvanic cells; types of battery in which electricity is generated in proportion to O_2 partial pressure (many variations with different anodes and cathodes).

Applications:

-Should be useful for some fire detection applications

Unique characteristics:

-e.g., solid electrolyte fuel-cell device similar to Survivair's device used in underwater diving

References: 8,23

6. FLAME DETECTORS

6.1 Flame detectors

Description: Several methods are used to detect fires by sensing the radiant energy from smouldering or flaming combustion.

Applications:

-General area detection

-Best applied in areas where flame will initiate before smoke

Unique characteristics:

-Fibre optics may be used in conjunction with these

-Self restoring

-Interference from solar radiation is a major problem, causing inadvertent alarms

-Advantage of large area surveillance by rapidly responding to the designed level of actuation anywhere in its range of vision

References: 5,8

6.2 Infrared type

Description: Basically consists of filter and lens system to screen out unwanted wavelengths and focus incoming energy of photocells. Normally designed to receive either the total IR component of flame or flame flicker in the range of 1.5 to 10 Hertz or 4 to 15 Hertz.

Applications:

-General area detection

Unique characteristics:

-Generally high sensitivity and speed of response

-Generally low stability

-Low sensitivity to Class A and C fires; high sensitivity to Class B fires

-Medium reliability and maintainability

References: 8

6.3 Ultraviolet type

Description: Same operating principle as IR type except operating in the UV range (0.7 to 0.3 micron) in which they are insensitive to both sunlight and artificial light.

Applications:

-General area detection

Unique characteristics:

-Problems of response to electric arcs and lighting, causing inadvertent alarms

-High sensitivity and speed of response

-Low sensitivity to Class A fires; high sensitivity to Class B and C fires

-Medium reliability, maintainability, and stability

References: 8

6.4 Combination IR-UV

Description: Combination of the above types into one unit.

Applications:

-General area detection

-Applied successfully in hyperbaric chambers, and aircraft minicomputers

Unique characteristics:

-High sensitivity and speed of response

References: 8

7. MISCELLANEOUS DETECTORS

7.1 Ultrasonic type

Description: Sets up a stable standing wave in the area to be supervised. Movement of air caused by hot gases from a fire disturbs the wave pattern. The disturbance is monitored by an ultrasonic receiver which is used to trigger an alarm. A spinoff of intrusion detection technology.

Applications:
-Volume surveillance

Unique characteristics:
-High sensitivity
-Supervised area must be unoccupied, for the sensor detects any movement

References: 22,24

7.2 Rate of temperature rise, fixed temperature combination

Description: Combination of two different detection mechanisms described previously, incorporated into one unit. The two most common types are:
(a) vented hemispherical diaphragm for the ROR mechanism, and
(b) spring retained eutectic metal as the fixed temperature mechanism

Applications:
-General spot detection
-General area detection

Unique characteristics:
-Advantage of quick response to rapidly developing fires by use of the ROR mechanism, while the fixed temperature elements respond to the slowly developing fires
-Generally high maintainability, stability and reliability
-In common use
-Medium sensitivity to Class A fires; high sensitivity to Class B fires; low sensitivity to Class C fires

References: 8

7.3 Resistance bridge-ionisation combination

Description: Combination of the two previously described devices into one unit, each mechanism having its own bridge circuit which together must trigger a main electronic gate.

Applications:
-General spot detection
-General area detection

Unique characteristics:
-Reduces inadvertent alarms due to the required activation of both mechanisms
-Stability, maintainability, and reliability are average
-In common use

References: 8

7.4 Electrostatic detection

Description: An insulated wire grid placed over and under the entire surveillance area can be used to measure "charged particles" extracted from flames. Charged particles accumulate and are detected in the form of an electric current.

Applications:
-Fire surveillance of entire grated area

Unique characteristics:
-Many possible sources of inadvertent alarms such as household appliances

-Devices may only be useful at nighttime (low activity)
-Possible security applications of this device
-None of these devices has been marketed
References: 25

7.5 Ionisation/fixed temperature combination

Description: Combination of two different detection mechanisms described previously, incorporated into one unit. Activation of alarm is by either mode of detection.

Applications:
-General spot and area detection

Unique characteristics:
-Added thermostat serves as a backup detector in case of ionisation failure, or as a primary detector in case of high heat buildup without smoke

References: None

7.6 Photoelectric/fixed temperature combination

Description: Combination of two different detection mechanisms described previously, incorporated into one unit. Actuation of alarm is by either mode of detection.

Applications:
-General spot and area detection

Unique characteristics:
-Added thermostat serves as a backup detector in case of photoelectric smoke detector failure, or as a primary detector in case of high heat buildup without smoke

References: None

7.7 Catalytic/semiconductor fixed temperature combination

Description: Combination of two different detection mechanisms described previously, incorporated into one unit. Actuation of alarm is by either mode of detection.

Applications:
-General area detection

Unique characteristics:
-Added thermostat serves as a backup detector in case of gas detector failure, or as a primary detector in case of high heat buildup without gases

References: None

7.8 Acoustical fire detection

Description: Sound waves of various frequencies are emitted by the combustion of materials. With the advent of new technology in acoustical transducers, it may now be economically feasible to utilize them as fire sensors, either using combustion generated sounds or degradation sounds of a doped material as a fire signature.

Applications:
-General area detection

Unique characteristics:
-Does not require a line of sight configuration unlike other quick response detectors
-Doping agents with characteristic degradation frequencies may eliminate false alarms, if necessary

References: 25

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APPENDIX A3

UNWANTED FIRE SIGNAL INVESTIGATORY CHECKLIST

ANY FIRE SIGNAL OTHER THAN A GENUINE FIRE SIGNAL I.E. ACCIDENTAL, MALICIOUS, MALFUNCTION OR UNIDENTIFIED)

Method of use: Please investigate and discuss the questions with the user in the order in which they occur. Please mark "/" for "YES" and "X" for "NO", where words are bracketed cross out those which do not apply and give brief details where asked. It is appreciated that not all the information may be available at the time of attendance at the incident but it would be helpful if any information which is not so available could be obtained by means of follow-up action.

(1) An unwanted fire signal was reported from the premises

____

Address: ____________________ Tel. No.: __________

(2) The unwanted fire signal was initiated at __________

hours on ______________________________________

(3) The responsible person at the time of the incident was:

____

who confirmed that there was no fire nor a situation which would have shortly developed into a fire, and yet there was:

(3.1) A "FIRE" alarm indication at the control unit ____ on

AREA: ________________ ZONE: __________(with/without)

the alarm sounders (automatically/manually) turned-ON.

(3.2) A "FAULT" alarm indication at the control unit ____ on

AREA: ________________ ZONE: __________(with/without)

the alarm sounders (automatically/manually) turned-ON.

(3.3) No indication at the control unit and yet the alarm sounders were automatically turned-ON.

(3.4) Other (please ask the person responsible to comment on what happened).

____

(4) Was the unwanted fire signal initiated by either an automatic or manual call point/s?

(5) Was there an indication of operation of a fire detector or a manual call point?
Operated device type and location (please specify).

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(6) Have there been any changes recently? ________ If "YES"

please tick and comment on the nature of the changes.

(6.1) Change in space heating
(6.2) Builders' work
(6.3) Builders' damage
(6.4) Change in process
(6.5) Change in occupancy
(6.6) Any insect problem
(6.7) Other (please specify)

These changes occurred within the last week ____, month ___, 6 months ____ .

(7) Was the fire brigade called?
If "YES" please tick one of the following:
The fire brigade was called by:
(7.1) Staff using exchange telephone
(7.2) By direct line signal
(7.3) By automatic dialling machine
(7.4) By other means (please specify)

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(8) Is there an unwanted fire signal history for the installation?
(Please comment)

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(9) Is there an unwanted fire signal history for the district?
(Please comment)

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(10) Is there a time pattern for the unwanted fire signal occurrence?
(Please comment)

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(11) The fire signal cause has been identified as follows:

ACCIDENTAL

-Overheating:
By steam
By welding
By ventilator stop
By boiler blow back
By other causes (please specify)

-Smoke formation:
By welding
By cooking
By exhaust gases
By tobacco smoking
By blow back of heating system
By other causes (please specify)

-Light variation:
By effect of light variation
By other causes (please specify)

-Other causes:
By detector actuated accidentally
By alarm button operated accidentally
By other causes (please specify)

MALICIOUS

-Mischief:
By alarm button operated deliberately
By detector actuated deliberately
By other causes (please specify)

MALFUNCTION

-Misoperation:
Misoperation by the user
Misoperation by maintenance personnel
By other causes (please specify)

-Inadequate maintenance:
Dust in smoke detector
By other causes (please specify)

-Damage:
Damage to detector
Damage to wiring
Damage to the other parts
-Fault in the system:
By technical fault in detection system
By other causes (please specify)

____

UNIDENTIFIED

-Cause cannot be found ______ (any comments, what is your personal theory?)

____

____

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Your name: ______________________________ Date: __________

APPENDIX B

HARDWARE COMPONENTS

1. Opto-electronic smoke detector model OESD-1 (head) artwork

2. Opto-electronic smoke detector model OESD-1 (head) components layout diagram

3. Opto-electronic smoke detector model OESD-1 (head) list of components

4. Opto-electronic smoke detector model OESDB-1 (base) artwork and components layout diagram

5. Opto-electronic smoke detector model OESDB-1 (base) list of components

6. Opto-electronic smoke detector model OESDB-2 (base) artwork and components layout diagram

7. Opto-electronic smoke detector model OESDB-2 (base) list of components

8. Opto-electronic smoke detector model SOESD-1 (head) artwork

9. Opto-electronic smoke detector model SOESD-1 (head) components layout diagram

10. Opto-electronic smoke detector model SOESD-1 (head) list of components

11. Opto-electronic smoke detector model SOESDB-1 (base) artwork and components layout diagram

12. Opto-electronic smoke detector model SOESDB-1 (base) list of components

13. Opto-electronic smoke detector models OESD-1 and SOESD-1 construction details

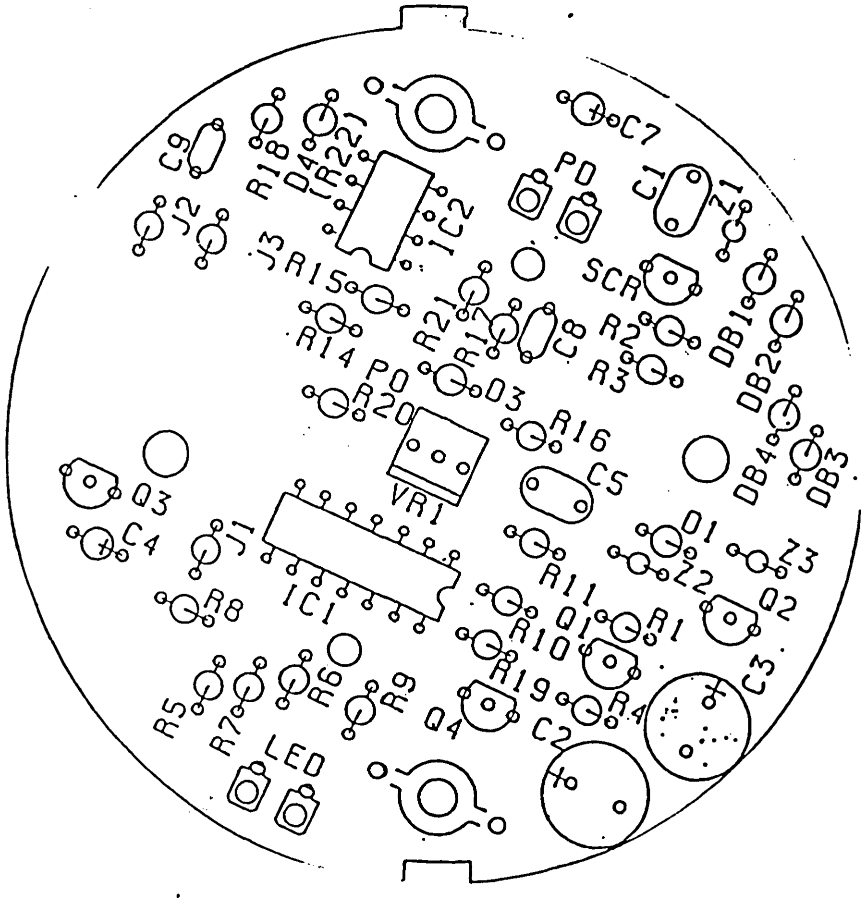
14. Smoke detector monitoring device - densitometer

APPENDIX B1

Opto-electronic smoke detector model OESD-1 (head) artwork

APPENDIX B2

Opto-electronic smoke detector model OESD-1 (head) components layout diagram



APPENDIX B3

LIST OF COMPONENTS

PROJECT: Opto-electronic smoke detector model OESD-1 (head)

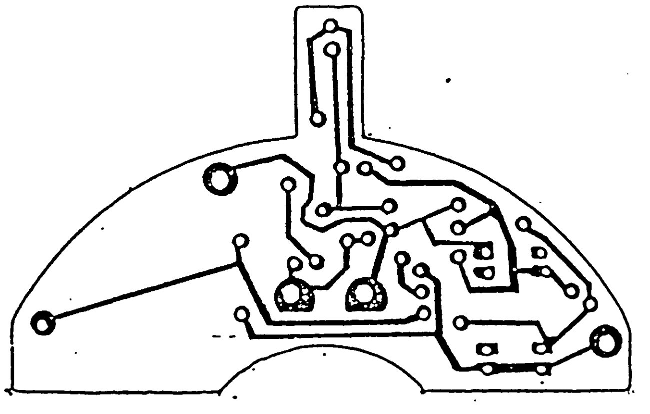
PAGE 1 OF 2 JOB NO. OESD-1

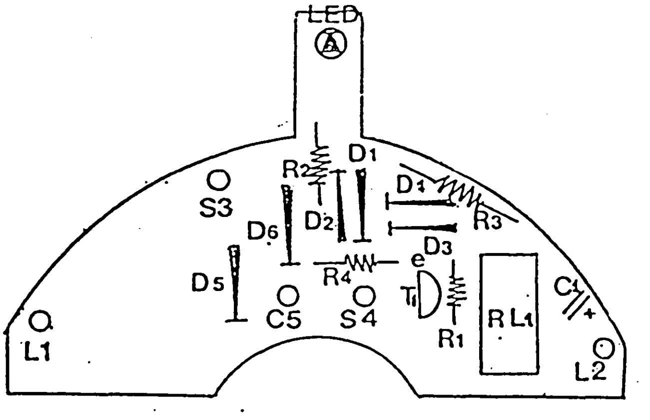
Q/TY	DESCRIPTION	ANNOTATION
1	4013B Dual D type flip-flop	IC2
1	3140 Comparator circuit	IC1
2	2SC1815-Si-NPN-Vce=50V-IC=150mA	T1-T2
1	2SC2120-Si-NPN-Vce=30V-Ic=800mA	T3
1	2SA1020-Si-PNP-Vce=50V-Ic=2A	T4
1	SFOR3D42-Si-Vrrm=200V-It=300mA	SCR1
4	1N4004-Si-Vrrm=400V-If=1A	D1-D2-D3-D4
3	1S1588-Si-Vr=35V-Io=120mA	D5-D6-D7
1	05Z47-Si-Vz=47V-P-0.5W	Z1
1	05Z2.7-Si-Vz=2.7V-P=0.5W	Z2
1	05Z10-Si-Vz=10V-P=0.5W	Z3
1	OLD2203-GaAlAs-Vr=6V-P=200W	LED
1	TPS703-Si-Vr=20V-Id=1nA	Pd
2	Polyester film 33nF to 0.1uF	C1-C8
1	Tantalum-0.47uF-35V	C4
1	Aluminium-100uF-16V	C2-C3
1	Polyester film-1nF-50V	C5
1	Polyester film-3.3nF-50V	C7
1	Tantalum-6.8uF-16V	C6
3	Carbon-2M2-1W5-5%	R3-R16-R19

Q/TY	DESCRIPTION	ANNOTATION
3	Carbon-1K-1W4-5%	R1-R2-R15
1	Carbon-4K3-1W4-5%	R4
1	Carbon-8M2-1W4-5%	R5
1	Carbon-100K-1W4-5%	R6
1	Carbon-680R-1W4-5%	R7
1	Carbon-39R-1W4-5%	R8
1	Carbon-12R-1W4-5%	R10
3	Carbon-10K-1W4-5%	R18-R16-R17
1	Carbon-2K2-1W4-5%	R13
1	Carbon-47K-1W4-5%	R14
1	Carbon-4M7-1W4-5%	R12
1	Carbon-100R-1W4-5%	R9
1	Carbon-10K-1W4-5%-Trimmer	VR1
4	Zero ohm resistors	J1-J2-J3-J4
1	14-pin DIL IC socket	IC2
1	8-pin DIL IC socket	IC1
1	Printer circuit board OESD-1	
1	LED and Pd holder	
2	Soldered terminals	
4	Inserted terminals	

APPENDIX B4

Opto-electronic smoke detector model OESDB-1 (base) artwork
and components layout diagram





APPENDIX B5

LIST OF COMPONENTS

PROJECT: Opto-electronic smoke detector model OESDB-1 (base)

PAGE 1 OF 1 JOB NO. OESDB-1

Q/TY	DESCRIPTION	ANNOTATION
1	Red colour LED	LED
1	Aluminium-100uF-10V	C1
1	Carbon-270R-1W4-5%	R1
1	Carbon-100R-1W4-5%	R2
1	Carbon-330R-1W4-5%	R3
1	Carbon-4K3-1W4-5%	R4
6	1N4004-Si-Vrrm=400V-If=1A	D1-D2-D3-D4-D5-D6
1	Relay-5V-55R	RL1
1	2SA1020-Si-PNP-Vce=50V-Ic=2A	T1
1	Printer circuit board-E.A.L.	

APPENDIX B6

LIST OF COMPONENTS

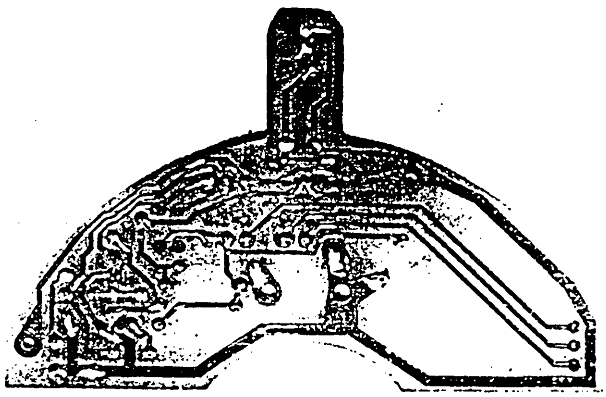
PROJECT: Opto-electronic smoke detector model OESDB-2 (base)

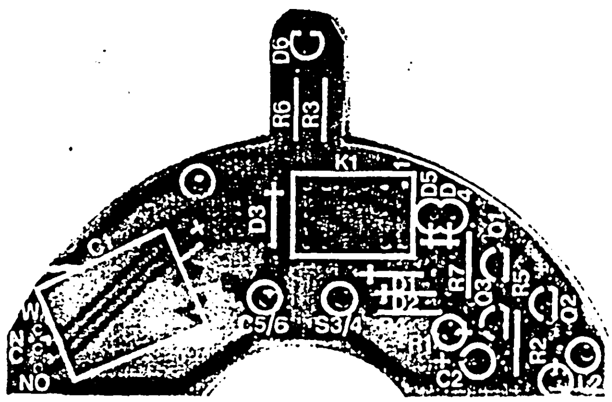
PAGE 1 OF 1 JOB NO. OESDB-2

Q/TY	DESCRIPTION	ANNOTATION
1	Red colour LED	D6
1	Aluminium-100uF-50V	C1
1	Carbon-1K-W25-5%	R1
3	Carbon-240R-W25-5%	R2-R5-R7
1	Carbon-680R-W50-5%	R3
1	Carbon-1K5-W50-5%	R6
2	1N4004-Si-Vrrm=400V-If=1A	D1-D2
1	47V-W50-ZENER	D3
2	10V-W50-ZENER	D4-D5
1	2.2uF-35V-TANTALUM CAPACITOR	C2
3	BC182L-TRANSISTORS	Q1-Q2-Q3
1	G5AK-234P-5V RELAY	K1
1	OESDB-2 PRINTED CIRCUIT BOARD	

APPENDIX B7

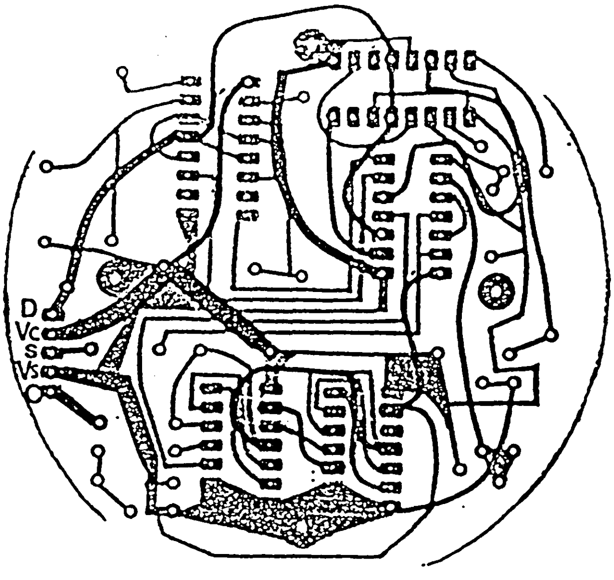
Opto-electronic smoke detector base model OESDB-2 (base) artwork and components layout diagram

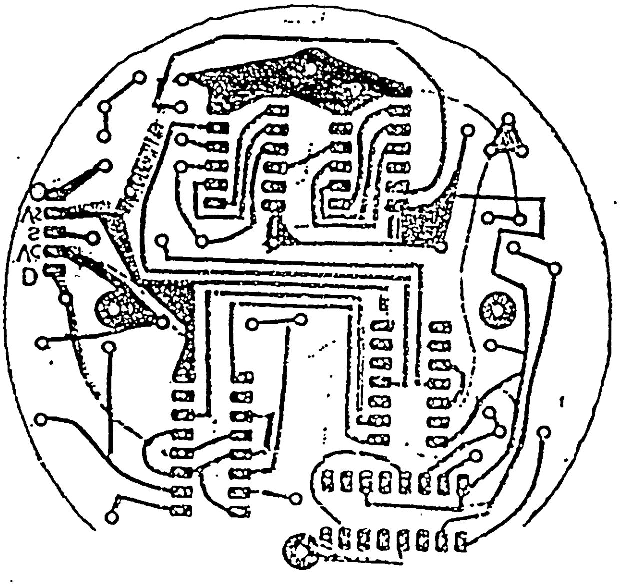




APPENDIX B8

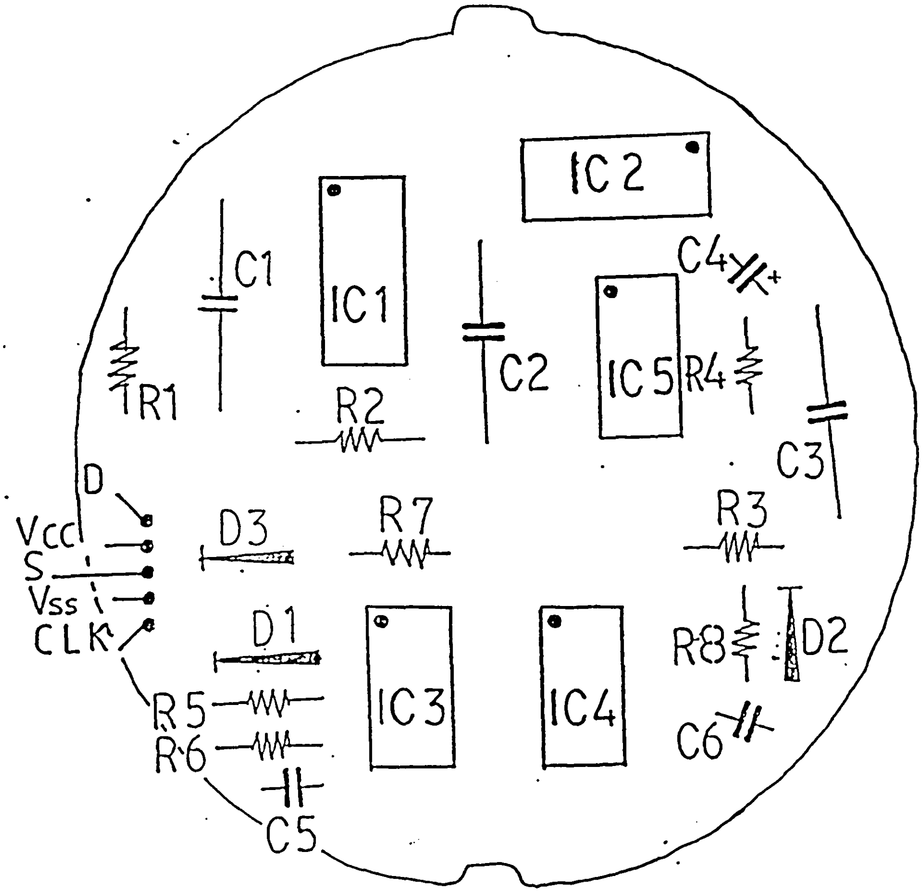
Opto-electronic smoke detector model SOESD-1 (head) artwork





APPENDIX B9

Opto-electronic smoke detector model SOESD-1 (head) components layout diagram



APPENDIX B10

LIST OF COMPONENTS

PROJECT: Opto-electronic smoke detector model SOESD-1 (head)

PAGE 1 OF 2 JOB NO. SOESD-1

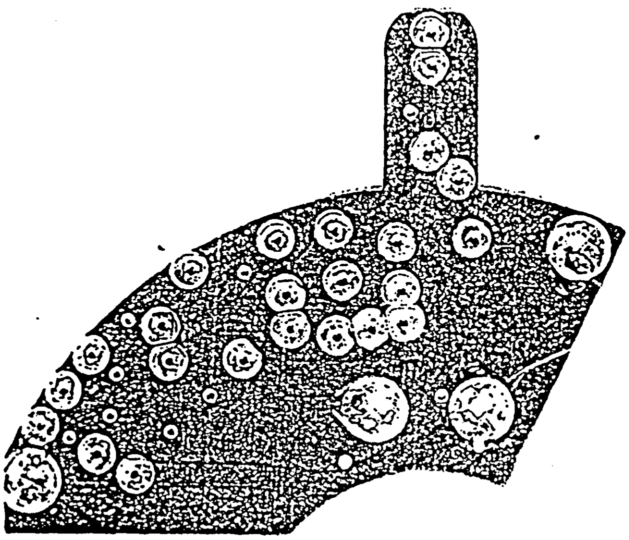
Q/TY	DESCRIPTION	ANNOTATION
2	4098	IC3-IC4
1	4001B	IC7
2	4013	IC5-IC6
2	BC182L	T5-T6
2	10K-W25-5%	R20-R24
2	20K-W25-5%	R21-R22
1	560K-W25-5%	R23
1	2M2-W25-5%	R25
1	100K-W25-5%	R26
2	18K-W25-5%	R29-R30
1	1M-W25-5%	R28
1	470R-W25-5%	R27
3	10nF-50V-POLYESTER CAPACITORS	C9-C10-C11
1	10uF-16V-TANTALUM CAPACITOR	C12
1	33nF-50V-POLYESTER CAPACITOR	C13

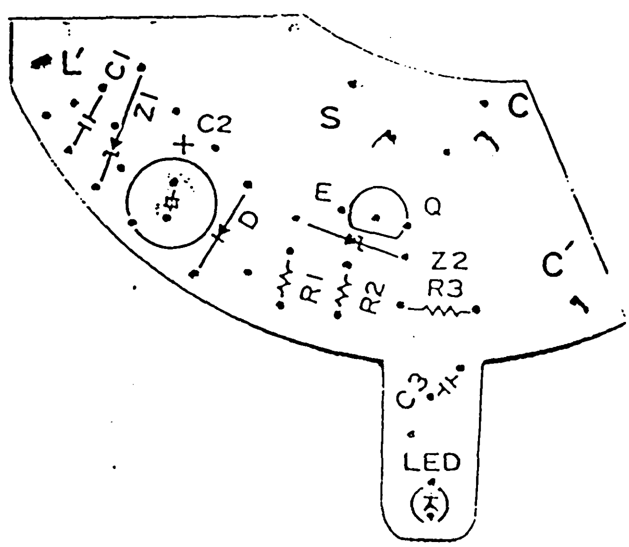
 JOB NO. SOESD-1

Q/TY	DESCRIPTION	ANNOTATION
3	Carbon-1K-1W4-5%	R1-R2-R15
1	Carbon-4K3-1W4-5%	R4
1	Carbon-8M2-1W4-5%	R5
1	Carbon-100K-1W4-5%	R6
1	Carbon-680R-1W4-5%	R7
1	Carbon-39R-1W4-5%	R8
1	Carbon-12R-1W4-5%	R10
3	Carbon-10K-1W4-5%	R18-R16-R17
1	Carbon-2K2-1W4-5%	R13
1	Carbon-47K-1W4-5%	R14
1	Carbon-4M7-1W4-5%	R12
1	Carbon-100R-1W4-5%	R9
1	Carbon-10K-1W4-5%-Trimmer	VR1
4	Zero ohm resistors	J1-J2-J3-J4
1	14-pin DIL IC socket	IC2
1	8-pin DIL IC socket	IC1
1	Printer circuit board OESD-1	
1	LED and Pd holder	
2	Soldered terminals	
4	Inserted terminals	

APPENDIX B11

Opto-electronic smoke detector model SOESD-1 (base) artwork and components layout diagram





APPENDIX B12

LIST OF COMPONENTS

PROJECT: Opto-electronic smoke detector model SOESDB-1 (base)

PAGE 1 OF 1 JOB NO. SOESDB-1

Q/TY	DESCRIPTION	ANNOTATION
1	Red colour LED	LED
1	Aluminium-100uF-10V	C2
1	Carbon-390R-W25-5%	R3
1	Carbon-330R-W25-5%	R2
1	Carbon-2K7-W25-5%	R1
1	1N4003 DIODE	D1
1	BC182L TRANSISTOR	T1
2	47V-W5-ZENERS	Z1-Z2
1	0.01uF-50V-POLYESTER CAPACITOR	C1
1	SOESDB-1 PRINTED CIRUIT BOARD	

APPENDIX C

CONSTRUCTION DETAILS

Opto-electronic smoke detector models OESD-1 and OESSD-1 construction details

1.Introduction

The construction of the opto-electronic smoke detector models OESD-1 and OESSD-1 is very similar. Both detectors consist of three main parts:

(a) the outer cover,
(b) the smoke chamber and
(c) the main body

The outer cover and the smoke chamber is identical in both detectors but the main body of the OESSD-1 detector is almost twice the height of that of the OESD-1. The OESSD-1 accommodates two printed circuit boards since it has more electronics than the OESD-1 model and hence it is bigger.

Depicted in Fig.1 is the assembly drawing diagram of the detectors.

2. Outer cover

The outer cover has a labyrinthian construction to prevent the entry of external light into the smoke chamber, while permitting smoke to flow freely into it. The cover can be removed from the detector body using a screwdriver. The labyrinth element and the insect screen located outside it can readily be removed for easy access for inspection and cleaning.

3. Smoke chamber

Along the centerline of the outer cover is the smoke chamber. A light-emitting diode (LED) is mounted at one end of the chamber to provide a working light source. Developed specifically for use with optical detectors, the LED emits a slender, strong beam. Mounted at the other end of the smoke chamber is a photo-diode whose location is immune from direct light from the LED. A plastic lens, placed in front of the photo-diode, effectively condenses scattered reflections of smoke particles.

The LED and photo-diode are arranged with such an angle that scattered reflections in a forward direction by smoke particles can be readily detected. This configuration ensures both an increased amount of light signals entering the photo-diode receiver and high, stable detection performance in the presence of noise.

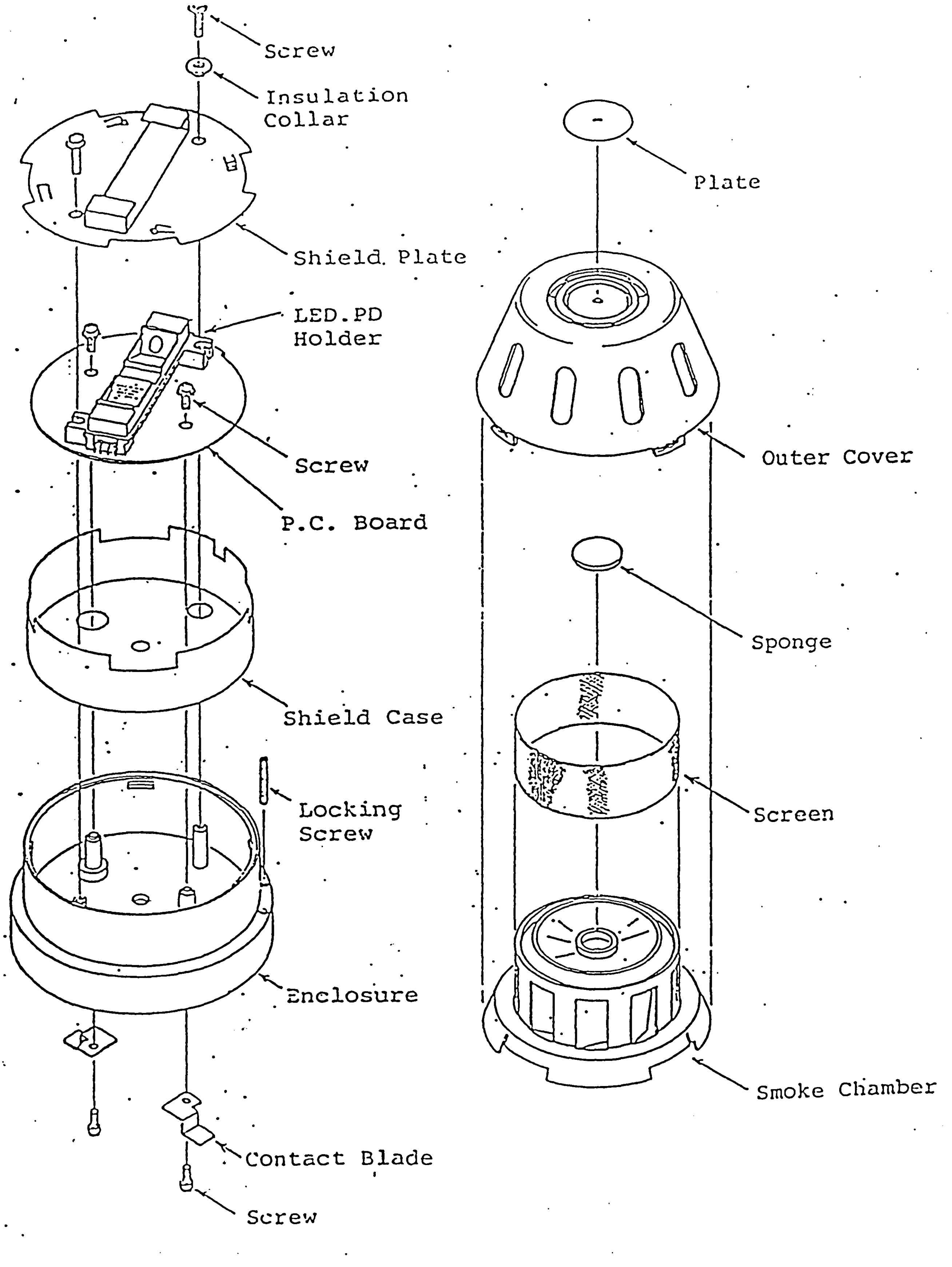


Fig.1 Smoke detector assembly drawing

4. Body

The end product as is currently sold by the author sponsors, has metal shield plate and a shield case for protecting the circuitry against electrical noise. The circuitry is also coated with an insulating paint for full protection against moisture, corrosive gases, and other environmental hazards.

APPENDIX D

INSTRUMENTATION

1. Wind tunnel

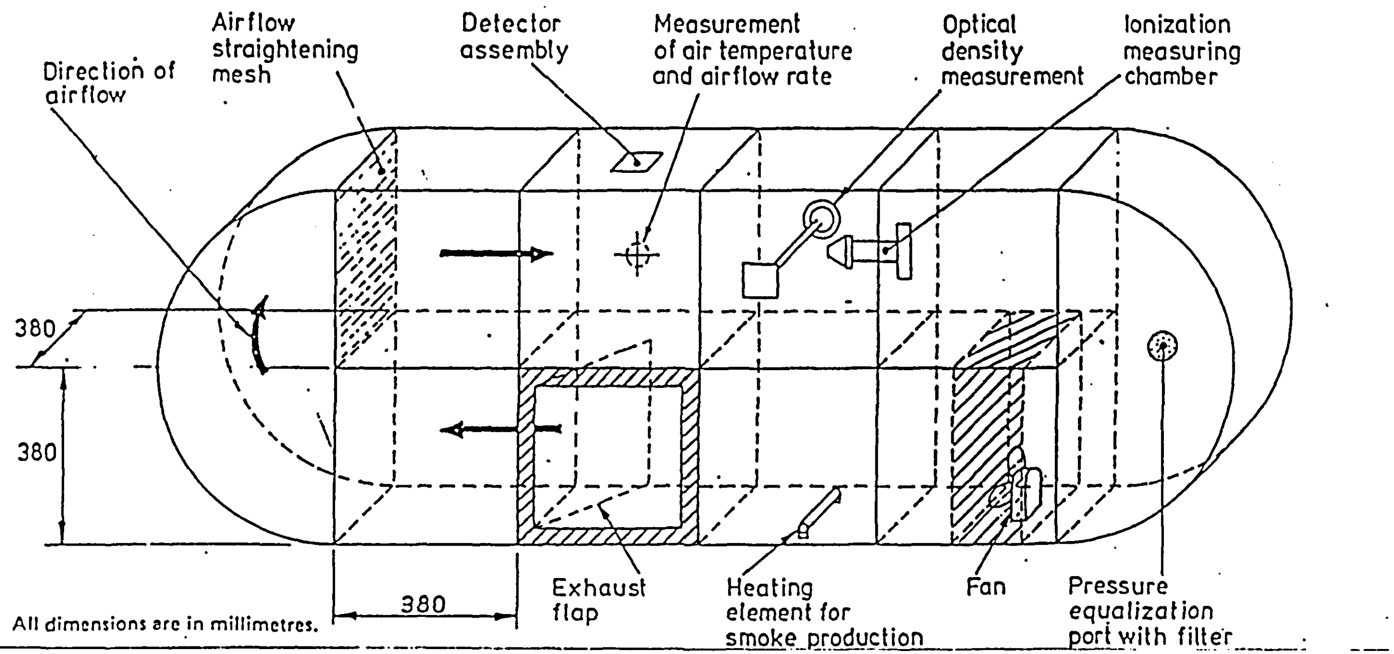
2. MIC instrument

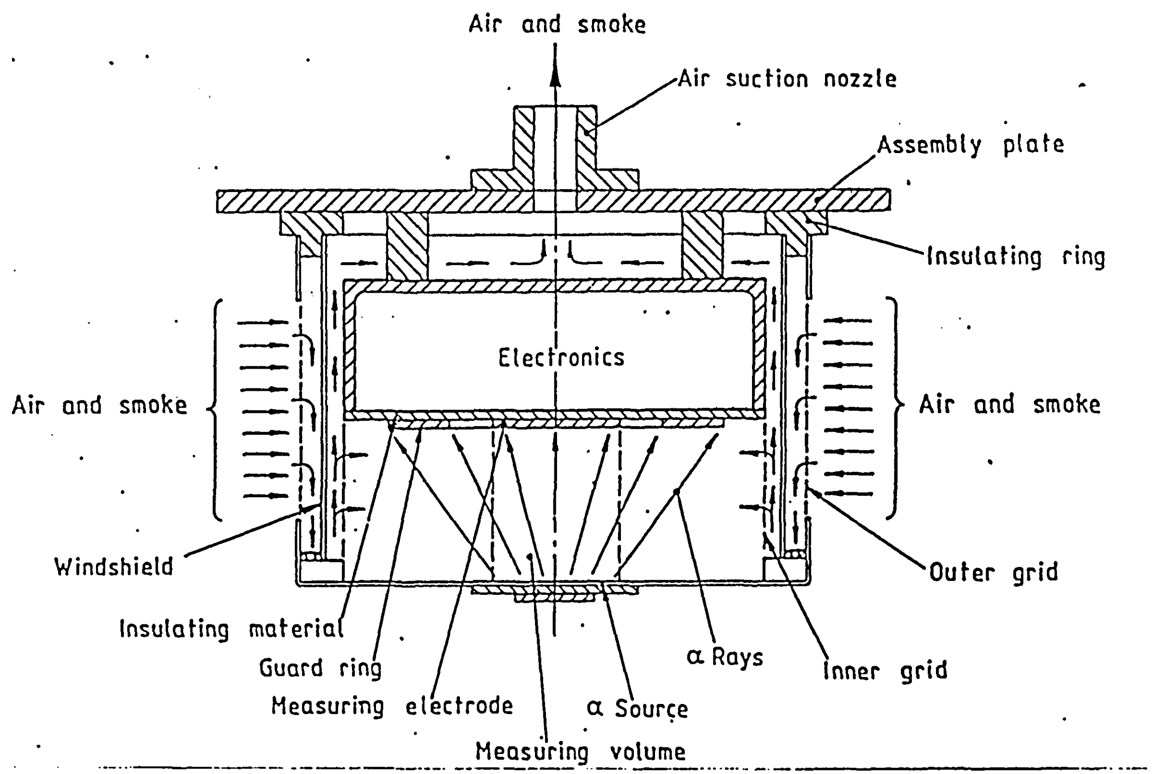
3. Electronic Alarms Ltd control and indicating equipment

4. TSE-A100 smoke detector tester (Densitometer)

5. Measurement of the response threshold values
   in the wind tunnel

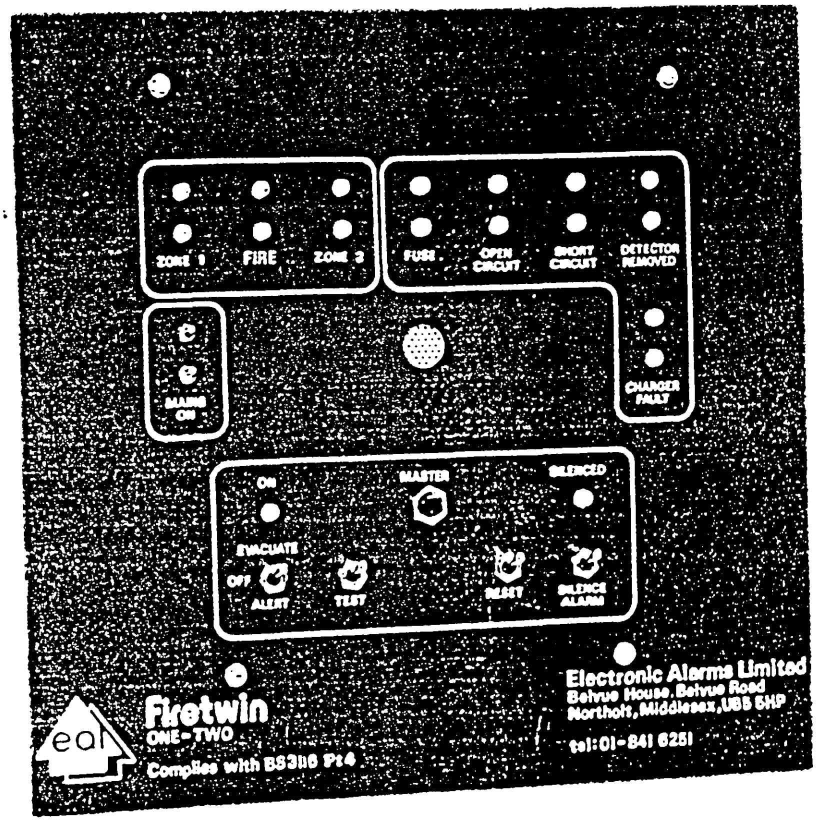
WIND TUNNEL


Direction of airflow
Airflow straightening mesh
Detector assembly
Measurement of air temperature and airflow rate
Optical density measurement
Ionization measuring chamber
380
380
380
Exhaust flap
Heating element for smoke production
Fan
Pressure equalization port with filter
All dimensions are in millimetres.


Air and smoke
Air suction nozzle
Assembly plate
Insulating ring
Electronics
Air and smoke
Air and smoke
Windshield
Outer grid
Insulating material
Guard ring
Measuring electrode
Measuring volume
α Source
α Rays
Inner grid

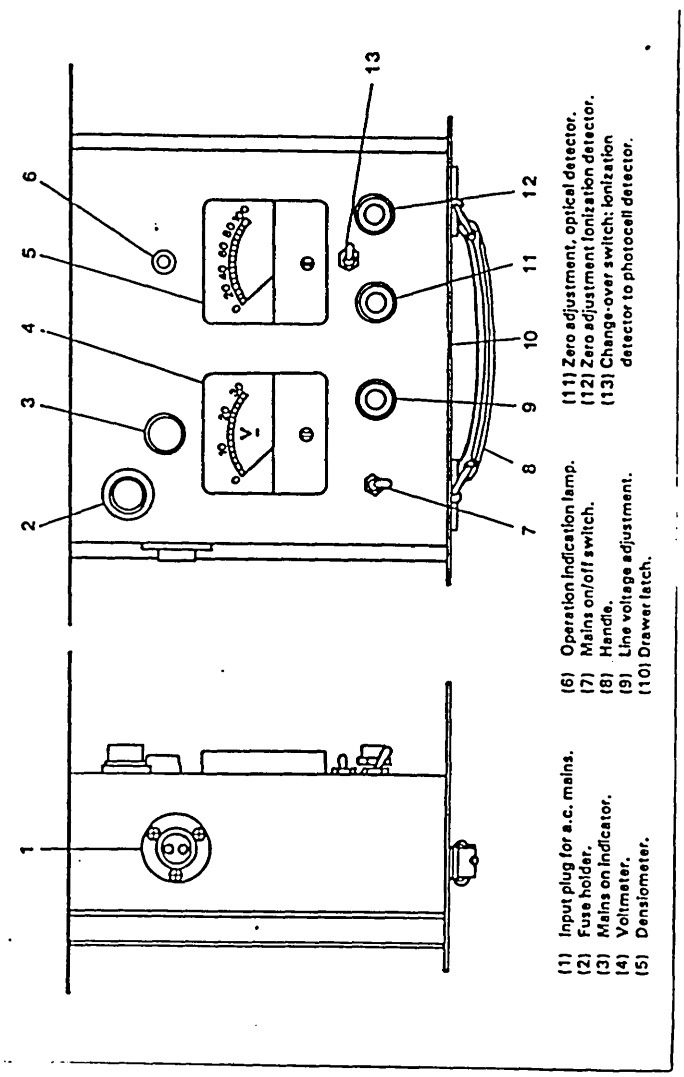
APPENDIX D3

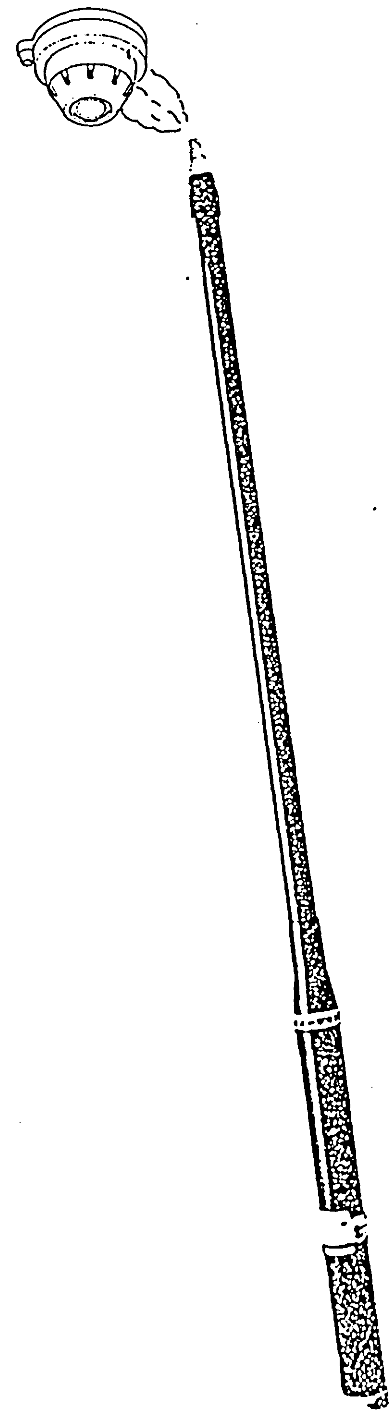
E.A.L. Control and indicating equipment



APPENDIX D4

TSE-A100 smoke detector tester (Densitometer)





APPENDIX D5

Measurements of the response threshold values in the wind tunnel

1. Test method

The detector provided for the test was installed in the wind tunnel in its normal operating position with the fastenings provided for this purpose. The detector was connected to its control and indicating equipment for 20min before commencing measurements. The air velocity in the wind tunnel in the proximity of the detector was 0.2±0.04 m/s for all tests unless a different value was expressly indicated, e.g. the test according to clause 10.

The air temperature in the wind tunnel was 23±5°C, unless a different value was expressly indicated, e.g. the test according to clause 11.

In all the measurements of the response threshold of a particular type detector, other than the High ambient temperature test, the air temperature in he wind channel was not varied more then 5°C, unless a different value is expressly indicated, e.g. the test according to clause 11.

In all tests the supply voltage to the detectors was between 99% and 101% of its nominal supply voltage, unless a different value was expressly indicated, e.g. the test according to clause 9.

Before commencing each measurement the wind tunnel and the detector to be tested was free from aerosol. All aerosol density measurements were carried out in the proximity of the detector. A test aerosol was fed into the wind tunnel so that:

dm/dt < 0.2 db/m/min (see below for definition of m)

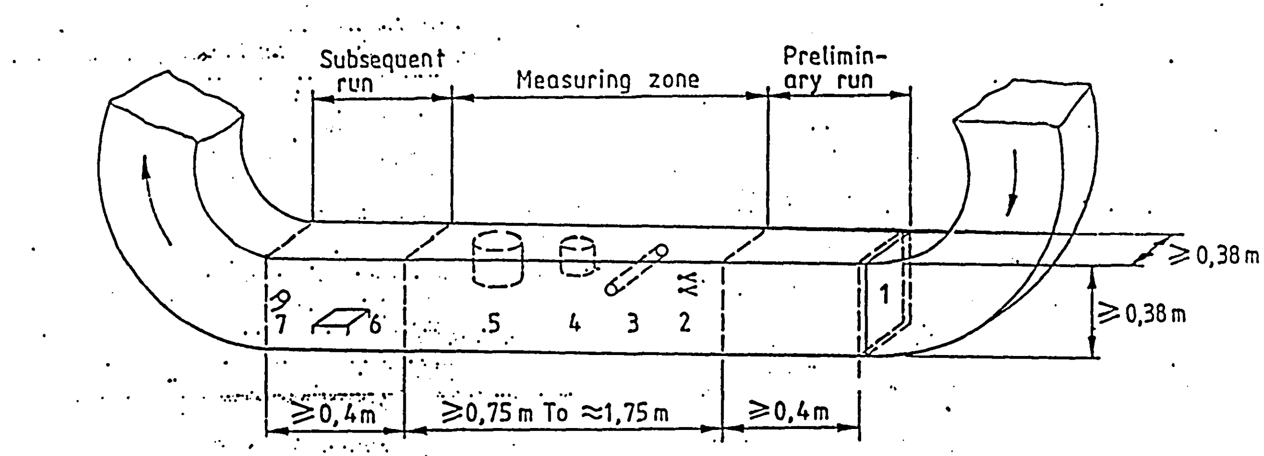
The initial selected rate of increase in aerosol density was similar for all measurements in the wind tunnel. At the moment of response of the detector the value m was recorded.

2. Wind tunnel

A closed circuit wind tunnel capable of air velocities between 0.1m/s and 1m/s was used. A picture of the wind tunnel used together with its control and indicating equipment is shown next page. The air temperature in the wind tunnel was capable of being raised from 20°C and 50°C at a rate of <1°C/min.

A plan of the measuring section, and the position of the measuring instruments and smoke detectors being tested are shown in Figure 1.

Photo 1 Wind tunnel and associated control and indicating equipment



(1) Sieve/Net
(2) Measurement of flow rate and temperature
(3) Optical measurement (light transmission method)
(4) Detectors to be tested } mounting on cover plate
(5) Ionization measuring chamber } mounting on cover plate
(6) Heating element
(7) Aerosol supply

Fig.1 Arrangement of smoke detectors and test apparatus in the wind tunnel

3. Test aerosol

A poly-dispersive aerosol was used as the test aerosol.The maximum of its particle size distribution was between 0.5µm and 1 µm. The refractive index of the aerosol particles was approximately 1.4.

4. Response threshold value, measuring instruments

4.1 Optical method

The response threshold value of optical smoke detectors is characterised by the absorbance index of the test aerosol measured at the moment of response.

The absorbance index is designated m and given in units of decibels per metre (db/m). The definition equation

$$m = (10 / d) \log_{10} (Po / p)$$

applies for the absorbance index, where

d = the optical measuring length in the test aerosol (measured in m);
Po = the radiated power received without the test aerosol;
P = the radiated power received with the test aerosol.

The measuring instruments used were based on those properties described in the European standard EN54:Pt.7 Annex B.

Before and after each test in which response threshold values were measured, the indication shown on the measuring instruments were compared with an indication in clean air. If there was a discrepancy of more than 0.02db/m between the two measured values of such a pair, the response threshold value measured was deemed invalid and the measurement was repeated.

4.2 Ionisation method, ionisation measuring chamber

The measuring device was used for continuously measuring aerosol concentrations in the range of the response threshold values of smoke detectors using ionisation. The device is fully described in 'Investigation of ionisation chamber for reference measurements of smoke density' by M. Avlund, published by Elektronikentralen, Danish Research Centre for Applied Electronics, Venlighedsvej 4,DK-2970 Horsholm, Denmark.

APPENDIX E

TEST, RESULTS AND OBSERVATIONS

Clause 3 - GENERAL REQUIREMENTS

Clause 3.1 - Data

Purpose:

The purpose of this investigation was to check if the detectors were indented for marketing as separate units for installation and if they were marked with sufficient operational data.

Inspection:

There was no sufficient data marked on either the detector head or base to allow the detectors to be operated in accordance with the requirements of the standard.

Assessment:

The requirements of this clause was not met.

Comments:

The detectors were not intended for marketing but were prototypes.

Clause 3.2 - Marking

Purpose:

The purpose of this investigation was to check if the detectors purporting to comply with the requirements of this standard were marked by: (a) the number of this standard (EN54:Part 7), and (b) the name and trademark of the organization accepting liability for compliance of the detector with this Part of EN54, and (c) the type number of the detector.

Inspection:

The detector heads were not marked with the standard number EN54:Part 7 or the manufacturers name but were marked with the detector type designation.

Assessment:

The requirements of this clause were not met.

Comments:

The detectors were not intended for marketing but were prototypes.

Clause 3.3 - Individual indication of operation

Purpose:

The purpose of this investigation was to check if the detectors were provided with an indicating lamp, or equivalent visual indication, by which the individual detector releasing an alarm could be identified.

Inspection:

There was an LED indicator located in the side of the detector mounting base which an individual detector could be identified when an alarm was given. Failure of the LED did not prevent correct operation of the detector.

Procedure:

Both detectors were mounted to their bases after both have being separately, (statically), tested. A smoke pole, (model TSE-A100 supplied by Hakuto International (UK) Ltd - see Appendix D4), was used to test the detectors with their base LED first left intact and later removed.

Assessment:

The requirements of these clause were met.

Clause 5 - Switch-On test

Purpose:

The purpose of this test was (a) to measure and confirm that the ratio of the response threshold values $m_{max}:m_{min}$ was not greater than 1.6, and that the lower response threshold value m_{min} was not less than 0.05db/m, and to (b) check that the detectors did not emit either a fault signal or an alarm signal during the course of this test. The test period was for seven days.

Observation:

No false alarm nor fault signal was given by any of the specimens during the seven day period of energization.

Procedure:

The response threshold value of the detectors was measured as described in Appendix D5. The detectors remain connected to their supply and indicating equipment for seven days without interruption. After this period the response threshold value was once more determined according to Appendix D5. The flow direction was arbitrary, but it was the same for both measurements. The greater response threshold value was given the symbol m_{max}, the lesser value was given the symbol m_{min}.

Measurements:

Model OESD-1

Initial response threshold value:
m = 0.17db/m
Response threshold value after seven days energization:
m = 0.16db/m

Model SOESD-1

Initial response threshold value:
m = 0.17db/m
Response threshold value after seven days energization:
m = 0.16db/m

Assessment:

Model OESD-1

$m_{max}:m_{min}$ = 1.06 (requirement <1.6)
m_{min} = 0.16db/m (requirement >0.05db/m)
The requirements of this clause were met.

Model OESD-1

$m_{max}:m_{min}$ = 1.06 (requirement <1.6)
m_{min} = 0.16db/m (requirement >0.05db/m)
The requirements of this clause were met.

Clause 6 - Repeatability test

Purpose:

The purpose of this test was (a) to measure and confirm that the ratio of the response threshold values $m_{max}:m_{min}$ was not greater than 1.6, and that the lower response threshold value m_{min} was not less than 0.05db/m, and to (b) check that the detectors did not emit either a fault signal or an alarm signal during the course of this test.

Observation: The variation of response threshold values (m) measured was:

Model OESD-1	Model SOESD-1
0.17±(0.01db/m)	0.16(±0.01db/m)

Procedure:

The response value of the detector was measured six times as described in Appendix D5. The flow direction was arbitrary, and it was the same for all six measurements.

Measurements:

Test code	Response threshold value m in db/m	
	OESD-1	SOESD-1
a	0.17	0.16
b	0.17	0.17
c	0.16	0.16
d	0.18	0.17
e	0.16	0.15
f	0.17	0.17

Assessment:

Model OESD-1

$m_{max}:m_{min}$= 1.125 (requirement <1.6)

m_{min}= 0.16db/m (requirement >0.05db/m)

The requirements of this clause were met.

Model SOESD-1

$m_{max}:m_{min}$= 1.13 (requirement <1.6)

m_{min}= 0.15db/m (requirement >0.05db/m)

The requirements of this clause were met.

Clause 7 - Directional dependence test

Purpose:

The purpose of this test was to measure and confirm that the ratio of the response threshold values $m_{max}:m_{min}$ was not greater than 1.6, and that the lower response threshold value m_{min} was not less than 0.05db/m.

Observation:

The initial orientation was with the detector base LED positioned downstream from the direction of airflow. Orientation of both specimens was in a clockwise direction viewed from above.

Procedure:

The response threshold value of the detectors was measured as described in appendix D5. A total of 8 measurements were taken for each specimen, the detector being rotated 45° about a vertical axis between each measurement, so that the measurements were taken for eight different flow directions. The detector faces facing the air flow for which the maximum and minimum response threshold values were measured, were marked accordingly.

Measurements:

Orientation	Response threshold value m in db/m	
	Model OESD-1	Model SOESD-1
0°	0.14	0.14
45°	0.15	0.14
90°	0.15	0.15
135°	0.15	0.15
180°	0.16	0.16
225°	0.15	0.15
270°	0.14	0.14
315°	0.15	0.15

Assessment:

<u>Model OESD-1</u>

$m_{max}:m_{min}$= 1.14 (requirement <1.6)
m_{min}= 0.14db/m (requirement >0.05db/m)
The requirements of this clause were met.

<u>Model SOESD-1</u>

$m_{max}:m_{min}$= 1.14 (requirement <1.6)
m_{min}= 0.14db/m (requirement >0.05db/m)
The requirements of this clause were met.

<u>Clause 8 - Reproducibility</u>

Purpose:

The purpose of this test was to measure and confirm that the ratio of the response threshold values $m_{max}:m_{min}$ was not greater than 1.6, and that the lower response threshold value m_{min} was not less than 0.05db/m.

Observation:

The mean response threshold value m of model OESD-1 was 0.173db/m and of model SOESD-1 was 0.172db/m.

Procedure:

The response threshold values of the detectors were measured and recorded as described in Appendix D5 for the most unfavourable flow direction.

Measurements:

Specimen no.	Response threshold value m in db/m	
	Model OESD-1	Model SOESD-1
1	0.18	0.17
2	0.18	0.18
3	0.17	0.16
4	0.17	0.17
5	0.18	0.17
6	0.16	0.18

Assessment:

Model OESD-1

$m_{max}:m_{min}$= 1.125 (requirement <1.6)
m_{min}= 0.16db/m (requirement >0.05db/m)
The requirements of this clause were met.

Model SOESD-1

$m_{max}:m_{min}$= 1.125 (requirement <1.6)
m_{min}= 0.16db/m (requirement >0.05db/m)
The requirements of this clause were met.

Clause 9 - Variation of supply voltage test

Purpose:

The purpose of this test was to measure and confirm that the ratio of the response threshold values $m_{max}:m_{min}$ was not greater than 1.6, and the lower response threshold value m_{min} was not less than 0.05db/m.

Observation:

The response of the two detectors was measured at the supply voltage limits as specified.

Procedure:

The response threshold value of the detectors were measured twice as described in Appendix D5, for the most unfavourable flow direction, once at the upper limit of 30 Volts and the other at the lower limit of nominal supply voltage of 20 Volts.

Measurements:

Model OESD-1

Response threshold value at lower limit: m = 0.15db/m
Response threshold value at upper limit: m = 0.16db/m

Model SOESD-1

Response threshold value at lower limit: m = 0.15db/m
Response threshold value at upper limit: m = 0.16db/m

Assessment:

Model OESD-1

$m_{max}:m_{min}$= 1.07 (requirement <1.6)
m_{min}= 0.15db/m (requirement >0.05db/m)
The requirements of this clause were met.

Model SOESD-1

$m_{max}:m_{min}$= 1.07 (requirement <1.6)
m_{min}= 0.15db/ (requirement >0.05db/m)
The requirements of this clause were met.

Clause 10 - Air movement test

Purpose:

The purpose of this test was:

(a) to measure and confirm that the ratio of the response threshold values:

$$0.625 < (m(0.2)_{max}+m(0.2)_{min}):(m(1.0)_{max}+m(1.0)_{min}) < 1.6$$

and

(b) that the detectors did not emit either a fault signal or an alarm signal during the course of this test.

Observation:

No false alarm nor fault signals were generated when subjected to an air velocity of 5m/sec for 5 minutes, nor during the brief exposure to a 10m/sec gust.

Procedure:

(a) Response

The response threshold value of the detectors were measured twice as described in Appendix D5, for the most and least favourable flow directions.

(b) False alarm behaviour

The detectors were placed in a wind tunnel and were subjected to an aerosol-free air flow at a velocity of v = 5m/sec and then to a gust lasting 2 seconds at a velocity of v = 10m/sec. The most favourable flow direction was used.

Measurements:

Model OESD-1

Most sensitive orientation:
Response threshold value at 0.2m/sec:
m = 0.14db/m
Response threshold value at 1.0m/sc:
m = 0.11db/m
Least sensitive orientation:
Response threshold value at 0.2m/sec:
m = 0.16db/m
Response threshold value at 1.0m/sec:
m = 0.13db/m

Model SOESD-1

Most sensitive orientation:
Response threshold value at 0.2m/sec:
m = 0.13db/m
Response threshold value at 1.0m/sc:
m = 0.12db/m
Least sensitive orientation:
Response threshold value at 0.2m/sec:
m = 0.14db/m
Response threshold value at 1.0m/sec:
m = 0.12db/m

Assessment:

Model OESD-1

$(m(0.2)_{max}+ m(0.2)_{min}) : (m(1.0)_{max}+ m(1.0)_{min}) = 1.25$
(requirement >0.625 and <1.60)
The requirements of this clause were met.

Model SOESD-1

$(m(0.2)_{max}+ m(0.2)_{min}) : (m(1.0)_{max}+ m(1.0)_{min}) = 1.13$
(requirement >0.625 and <1.60)
The requirements of this clause were met.

Clause 11 - High ambient temperature test

Purpose:

The purpose of this test was (a) to measure and confirm that the ratio of the response threshold values $m_{max}:m_{min}$ was not greater than 1.6, and that the lower response threshold value m_{min} was not less than 0.05db/m and to (b) check that the detectors did not emit either a fault signal or an alarm signal during the course of this test.

Observation:

No false alarm nor fault signal was emitted during this test.

Procedure:

The detectors were installed in the wind tunnel in their normally operating position with the most unfavourable flow direction and connected to their control and indicating equipment. The air temperature in the wind tunnel was T = 23°C. The air temperature in the wind tunnel was later increased to 50°C at a rate of < or = 1°C/min. After the detectors have been subjected to the increased temperature for at least one hour their response threshold (at the increased temperature) was measured as described in Appendix D5.

Of the two response threshold values measured for the detector in the tests in accordance with clause 8 and 11, the greater is given by the symbol m_{max}, the lesser value is given in the symbol m_{min}.

Measurements:

Model OESD-1

Response threshold value from reproducibility test:
m = 0.18db/m
Response threshold value at conditioning temperature:
m = 0.11db/m

Model SOESD-1

Response threshold value from reproducibility test:
m = 0.17db/m
Response threshold value at conditioning temperature:
m = 0.11db/m

Assessment:

Model OESD-1

m_{max}/m_{min} = 1.64 (requirement <1.60)
The requirements of this clause were met.

Model OESD-1

m_{max}/m_{min} = 1.55 (requirement <1.60)
The requirements of this clause were met.

Clause 12 - Ambient light test

Purpose:

The purpose of this test was to check (a) if while switching the fluorescent lights on and off and during the period in which all the lights are on, the detectors did not emit either a fault warning or an alarm signal, and (b) that in each directional alignment of the detector the ratio of the response threshold values $m_{max}:m_{min}$ was not greater than 1.6.

Observations:
No false alarm nor fault signals were given during the course of these tests.

(a) Test method

A dazzling device, (see Fig.1), was inserted in the wind tunnel. The detectors were installed in this device in their normal operating position in the most unfavourable flow direction and then connected to their control and indicating equipment.
The first lamp was switched on for 10sec, and then switched off for 10sec , ten times. The sequence was repeated for each of the other three lamps in turn. The four lamps were then connected as two pairs of opposite lamps and the sequence was repeated for each pair in turn. After that all four fluorescent lights were switched on. After a period of at least one minute the response threshold value for each detector was measured as described in Appendix D5.
All four lights were switched off. Each detector was then rotated in any direction by 90° about its vertical axis and the above process was repeated.
The lights were switched off, and after a period of at least one minute the response threshold values was measured for each specimen as described in Appendix D5.
In each directional alignment of the detector, the maximum response threshold value is given the symbol m_{max}, and the minimum response threshold value is given the symbol m_{min}.

(b) Dazzling apparatus

The apparatus shown in Fig.1 was constructed so that it could be inserted in the wind tunnel and there occupy just one flue section as specified in EN54:Part 7:Annex K2. It was cube-shaped. Four of the cube faces were closed and lined on the inside with high gloss aluminium foil; two opposing cube faces were open so that the test smoke could flow through the device. Circular fluorescent lamps (32W) with a diameter of 312mm were fitted to the closed surfaces of the cube (edge length 350mm), (type 'White de luxe', approximate colour temperature 3800K).
To obtain a stable output of light, the tubes were aged for 100 hours and discarded after 2000 hours.
The detectors were installed in the centre of the upper cube face (see Fig.1) so that light could play on them from above, below and from two sides. The electrical connections of the fluorescent lamps was such that there could be no interference with the detection system through electrical signals.

Measurements:

<u>Model OESD-1</u>

Least sensitive orientation: Response threshold value from reproducibility test:
m = 0.17db/m
Response threshold value during conditioning:
m = 0.16db/m
Response threshold value after conditioning:
m = 0.14db/m

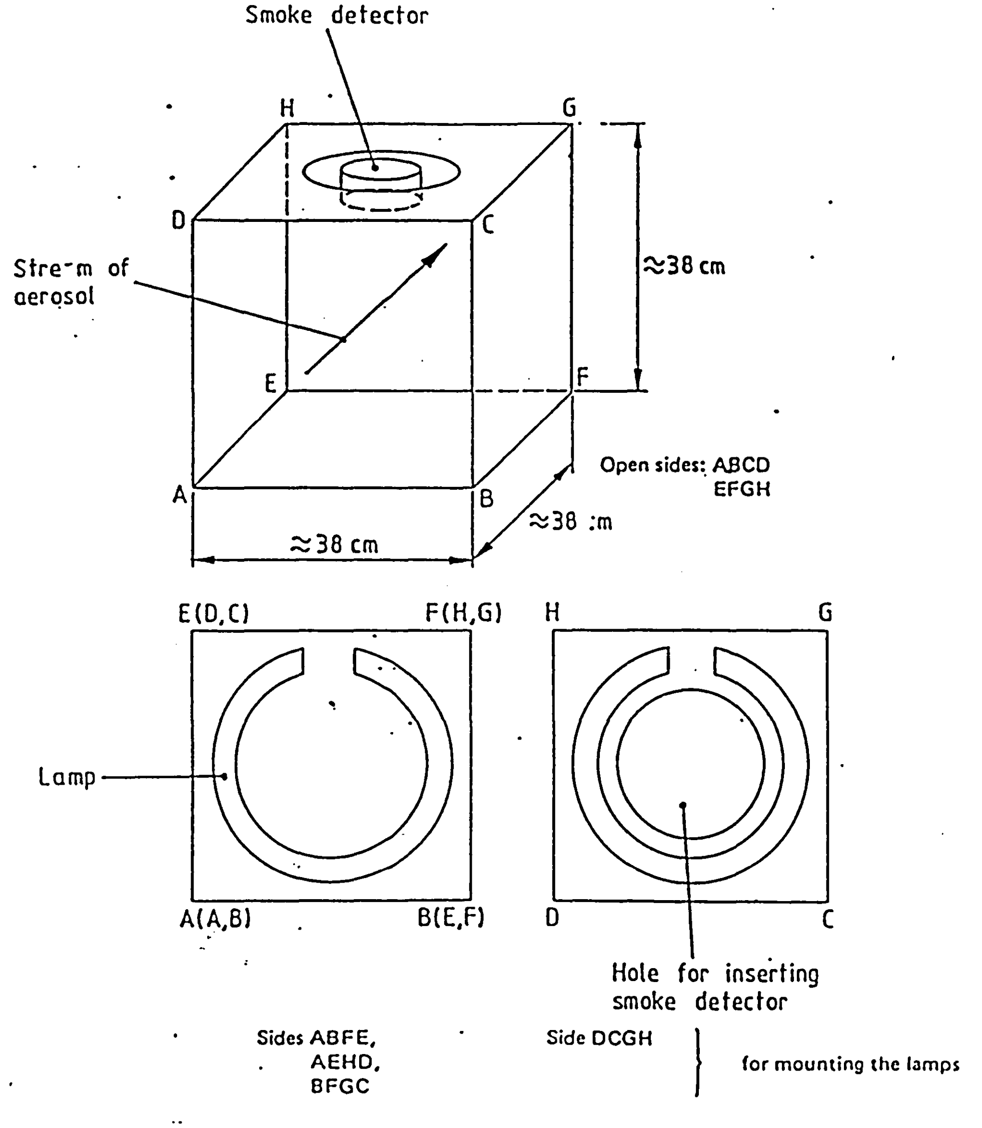


Fig.1 Dazzling apparatus

Specimen rotated 90° from above:
Response threshold value from reproducibility test:
m = 0.17db/m
Response threshold value during conditioning:
m = 0.14db/m
Response threshold value after conditioning:
m = 0.15db/m

Model SOESD-1

Least sensitive orientation:
Response threshold value from reproducibility test:
m = 0.16db/m
Response threshold value during conditioning:
m = 0.14db/m
Response threshold value after conditioning:
m = 0.14db/m
Specimen rotated 90° from above:
Response threshold value from reproducibility test:
m = 0.16db/m
Response threshold value during conditioning:
m = 0.15db/m
Response threshold value after conditioning:
m = 0.14db/m

Assessment:

Model OESD-1

$m_{max}:m_{min}$ = 1.21 (requirement <1.60)
Specimen rotated 90° from above:
$m_{max}:m_{min}$ = 1.21 (requirement <1.60)
The requirements of this clause were met.

Model SOESD-1

$m_{max}:m_{min}$ = 1.14 (requirement <1.60)
Specimen rotated 90° from above:
$m_{max}:m_{min}$ = 1.14 (requirement <1.60)
The requirements of this clause were met.

Clause 13 - Vibration test

Purpose:

The purpose of this test was (a) to measure and confirm that the ratio of the response threshold values $m_{max}:m_{min}$ was not greater than 1.6, and that the lower response threshold value m_{min} was not less than 0.05db/m and to (b) check that the detectors did not emit either a fault signal or an alarm signal during the course of this test.

Observation:

No false alarms nor fault signal was emitted during this test.

Procedure:

The detectors were mounted in their normal operating position and were each in turn secured on their detector base. The test was carried out at a temperature of 20°C. The detectors were each in turn connected to the control and indicating equipment and subjected to sinusoidal vibrations in a vertical direction. The frequency of vibrations swept from 5Hz to 60Hz at a rate of 1.8±0.2 octaves/hour. A single such sweep was made. This process took about 2 hours. The maximum acceleration (m/s^2) of the detector at its point of installation was:

$$0.7 \times (f\pm10\%)^{0.5}$$

where f is the instantaneous frequency in Hz. The test was repeated, once in a horizontal direction of acceleration and one in a second horizontal direction of acceleration perpendicular to the first.

The response threshold value was measured as described in Appendix D5 in the most unfavourable flow direction.

Of the two response values from each specimen measured in the tests, in accordance with clauses 8 and 13, the greater is given the symbol m_{max}, the lesser value is given the symbol m_{min}.

Measurements:

<u>Model OESD-1</u>

Response threshold value from reproducibility test:
m = 0.18db/m
Response threshold value after conditioning:
m = 0.14db/m

<u>Model SOESD-1</u>

Response threshold value from reproducibility test:
m = 0.17db/m
Response threshold value after conditioning:
m = 0.14db/m

Assessment:

<u>Model OESD-1</u>

$m_{max}:m_{min}$= 1.29 (requirement <1.6)

<u>Model SOESD-1</u>

$m_{max}:m_{min}$= 1.21 (requirement <1.6)

The requirements of this clause were met.

<u>Clause 14 - Humidity test</u>

Purpose:

The purpose of this test was (a) to measure and confirm that the ratio of the response threshold values $m_{max}:m_{min}$ was not greater than 1.6, and that the lower response threshold value m_{min} was not less than 0.05db/m and to (b) check that the detectors did not emit either a fault signal or an alarm signal during the course of this test.

Observation:

No false alarms nor fault signal was emitted during the course of this test.

Procedure:

(a) Test method: Without being connected to their control and indicating equipment the detectors were predried for at 28 hours in a drying oven at a temperature of 40±5°C.

Immediately afterwards the detectors were connected to their control and indicating equipment and subjected to the following conditions in a climatic test chamber:

Ambient temperature: 40±2°C

Relative humidity: 92±2%

Duration of test: 4 days

The response threshold value for each of the detectors was measured with the most unfavourable flow direction as described in Appendix D5 within 5 min of removal from the climatic test chamber.

After the humidity test, the detectors were subjected for three days to the following standard climate, whilst a transition period of 2h was adhered to:

Ambient temperature: 20±2°C

Relative humidity: 63±3%

The transition from one climate to another was such that there was no misting over or dew formation and that no condensation water drips on to the detectors.
The response threshold value of the detectors was then measured as described in Appendix D5 in the most unfavourable flow direction. For each detector separately, of all the response threshold values measured in the tests in accordance with clauses 8 and 14, the maximum value is given the symbol m_{max}, the minimum value is given the symbol m_{min}.
(b) Climatic test chamber: The climatic test chamber used was constructed such that at the points where the detectors were located, the above mentioned temperature and relative humidity could be maintained within the specified tolerances given in EN54:Part 7. There was no misting-over and no dripping of condensation water on to the detectors. An air circulation system was used for this purpose. However, it was possible to shield the detectors from the air flow so that the flow rate in their vicinity was not greater than 0.5m/sec. At the smoke detector, the temperature set up was not fluctuating by more than ±0.5°C within the tolerance range given above.

Measurements:

<u>Model OESD-1</u>

Response threshold value from reproducibility test:
m = 0.16db/m
Response threshold value after 4 days conditioning:
m = 0.18db/m

<u>Model SOESD-1</u>

Response threshold value from reproducibility test:
m = 0.18db/m
Response threshold value after 4 days conditioning:
m = 0.23db/m

Assessment:

<u>Model OESD-1</u>

$m_{max}:m_{min}$= 1.12 (requirement <1.6)
The requirements of this clause were met.

<u>Model SOESD-1</u>

$m_{max}:m_{min}$
84 = 1.11 (requirement <1.6)
The requirements of this clause were met.

<u>Clause 15 - Shock test</u>

Purpose:

The purpose of this test was (a) to measure and confirm that the ratio of the response threshold values $m_{max}:m_{min}$ was not greater than 1.6, and that the lower response threshold value m_{min} was not less than 0.05db/m and to (b) check that the detectors did not emit either a fault signal or an alarm signal during the course of this test.

Observation:
No false alarm nor fault signal was emitted during the course of this test.

Procedure:
The detectors were mounted by means of screws, at the centre of the underside of a timber beam in their normally operating position and were then connected to the control and indicating equipment. The timber beam used was American White oak (Quercus michauxii Nutt), and had cross-sectional dimensions of 100mmx50mm. It was clamped on its narrower face to two oak supports of 50mm width and of sufficient height that the detectors did not touch the floor. The supports were placed freely on edge at 900mm centres on a level concrete floor and at right angles to the longitudinal axis of the beam. A cylindrical steel block weighing 1kg was dropped five times on to the centre of the upper horizontal face of the beam from a height of 700mm. The area of impact of the weight was $18cm^2 \pm 10\%$. The block was guided by suitable means so as to strike the beam with its longitudinal axis vertical. The apparatus used is shown in Fig.2. After the test the response threshold value of the detector were measured as described in Appendix D5 in the most unfavourable flow direction.
Of the two response values from each specimen measured in the tests, in accordance with clauses 8 and 15, the greater is given the symbol m_{max}, the lesser value is given the symbol m_{min}.

Measurements:

<u>Model OESD-1</u>

Response threshold value from reproducibility test:
m = 0.15db/m
Response threshold value after conditioning:
m = 0.16db/m

<u>Model SOESD-1</u>

Response threshold value from reproducibility test:
m = 0.15db/m
Response threshold value after conditioning:
m = 0.16db/m

Assessment:

<u>Model OESD-1</u>

$m_{max}:m_{min}$= 1.07 (requirement <1.6)
The requirements of this clause were met.

<u>Model SOESD-1</u>

$m_{max}:m_{min}$= 1.07 (requirement <1.6)
The requirements of this clause were met.

<u>Clause 16 - Impact test</u>

Comment:
This test was not performed because it was beyond the scope of this evaluation and because it required specialised equipment that was not available.

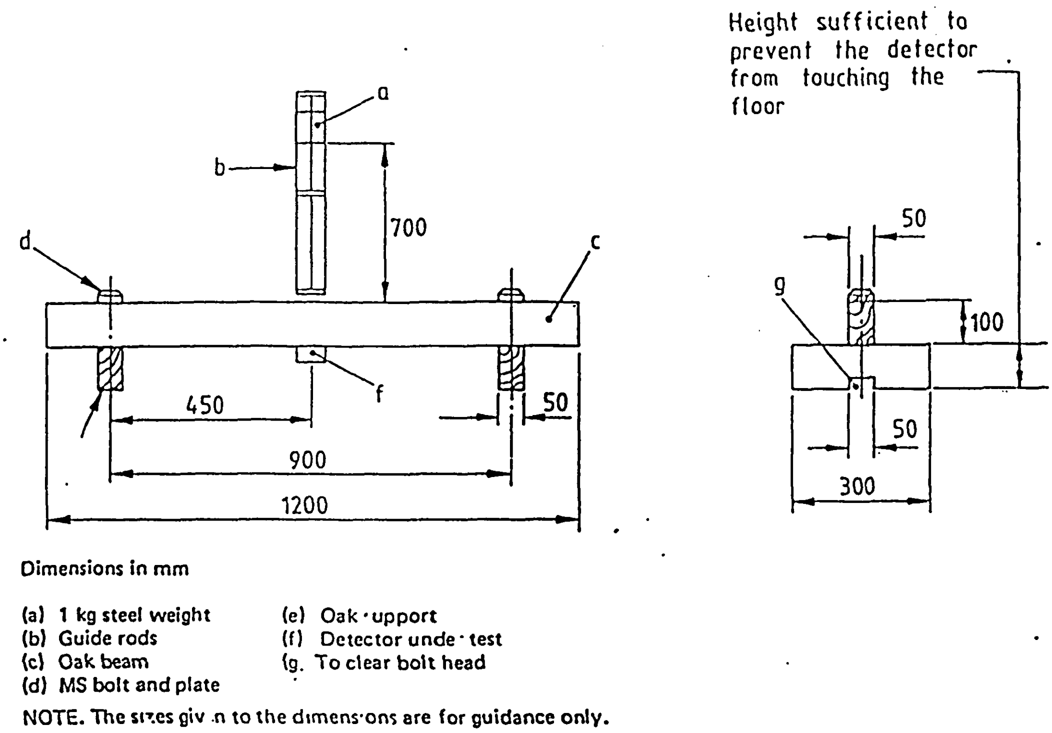


Fig.2 Shock test apparatus

<u>Clause 17 - Corrosion test</u>

Comment:

This test was not performed because it was beyond the scope of this evaluation and because it required specialised equipment that was not available.

<u>Clause 18 - Insulation test</u>

Purpose:

The purpose of this test was (a) to measure and confirm that the insulation resistance was >10Mohms after pre-conditioning and greater than 1Mohm after the test and to (b) check that the detectors did not emit either a fault signal or an alarm signal during the course of this test.

Observation:

No false alarm nor fault signal was emitted during the course of this test.

Procedure:

The detectors were conditioned for 28h under the following conditions:

Temperature: within 24°C to 26°C

Relative humidity: within 90% to 95%

The detectors were mounted in their normal operating position on a metal plate which was regarded as the earth connection. A voltage of 500V (d.c.) was applied for 60secs between the metal plate and the terminals of the detector which were interconnected.

The insulation resistance was then determined, (see below). The detectors were then tried in an oven at a temperature between 35°C to 45°C to prevent he formation of condensation. Immediately afterwards the detectors were placed in a climatic chamber, and subjected to the following conditions for 10 days:

Ambient temperature: within 38°C to 42°C
Relative humidity: within 90% to 95%

At the end of this period the detectors were conditioned at a temperature of between 24°C to 26°C and relative humidity of between 90% to 95% for about 60min. The insulation resistance was then again measured as described above.
The same climatic test chamber used for the 'humidity' test was also used here, with the only difference that the above mentioned temperature and relative humidity was maintained within the tolerances specified above rather than the values specified for the humidity test.

Measurements:

Model OESD-1

Insulation resistance after pre-conditioning: >100Mohm
Insulation resistance after conditioning: >100Mohm

Model SOESD-1

Insulation resistance after pre-conditioning: >100Mohm
Insulation resistance after conditioning: >100Mohm

Assessment:

Model OESD-1

The requirements of this clause were met as neither measurement was less than the specified limits of 10Mohm and 1Mohm respectively.

Model SOESD-1

The requirements of this clause were met as neither measurement was less than the specified limits of 10Mohm and 1Mohm respectively.

Clause 19 - Dielectric strength test

Purpose:

To test if a breakdown or flashover occurred when detectors were installed in places of high dielectric strength.

Observation:

No breakdown or flashover occurred when the detectors were subjected to this test.

Procedure:

The detectors were first subjected to the following climatic conditions for 28hrs:

Temperature: within 24°C to 26°C
Relative humidity: within 48% to 53%

The detectors were mounted in their position on a metal plate which was regarded as the earth connection. Using a voltage generator capable of delivering a sinusoidal voltage of between 40Hz and 60Hz, with an adjustable amplitude of 0V to 1500V r.m.s. (effective value), and a constant short-circuit current of 10A r.m.s. (effective value), an increasing test voltage was applied between the metal plate and the short-circuited connecting wires.

This was carried out as follows: The test voltage was increased from 0V to 500V at a rate of 100V/sec and maintained at the final magnitude for 60secs.

Assessment: The requirements of this clause were met.

<u>Clause 20 - Low ambient temperature test</u>

Purpose:

To test if during the fall in temperature and during the stabilization period no fault signal or alarm signal was emitted from the detectors and that the ratio of the response threshold values mmax:mmin was not greater than 1.6.

Observation:

No false alarm, nor fault signal was emitted during this test.

Procedure:

The detectors were connected to their supply and indicating equipment and placed in the test chamber at a temperature of between 15°C and 25°C for a period of an 1h. The air temperature in the test chamber was then reduced to -20°C at a rate of -0.6°C/min. The detectors were left at this ambient temperature for one hour to allow their temperature to stabilize. The conditions in the test chamber were such that condensation or ice could not be formed on the detector.At the end of the stabilization period, the detector was removed from the chamber and kept for a period of 90 minutes at an ambient temperature between 15°C and 25°C and at a relative humidity of not more than 70%. The response threshold values were measured in turn for each detector and recorded as described in Appendix D5 for the most unfavourable flow direction. Of the two response threshold values measured for each of the detectors in the tests in accordance with clauses 8 and 20, the greater value was given the symbol m_{max}, the lesser value is given the symbol m_{min}.

Measurements:

<u>Model OESD-1</u>

Least sensitive orientation:
Response threshold value from reproducibility test:
m = 0.18db/m
Response threshold value after conditioning:
m = 0.20db/m

<u>Model SOESD-1</u>

Least sensitive orientation:
Response threshold value from reproducibility test:
m = 0.18db/m
Response threshold value after conditioning:
m = 0.20db/m

Assessment:

<u>Model OESD-1</u>

$m_{max}:m_{min}$= 1.11 (requirement <1.6)
The requirements of this clause were met.

<u>Model SOESD-1</u>

$m_{max}:m_{min}$= 1.11 (requirement <1.6)
The requirements of this clause were met.

Clause 21 - Fire sensitivity test

Comment:

EN54:Part 7 requires that detectors shall be tested in the manner described in EN54:Part 9 using test fires TF2, TF3, TF4 and TF5. This test programme was not carried out because a fire test laboratory of the specifications described in EN54:Part 9 was not available.

Accelerated contamination tests

Purpose:

The purpose of these tests was to prove the superiority of the SENSI-CHECK detector over other conventional type detectors in that it minimises false alarms and identifies itself when out of calibration.

Observations:

The SENSI-CHECK detectors always initiated a service alarm call instead of a false fire alarm call when under the same circumstances as other types of conventional detectors (including model OESD-1). Where other detectors needed to be checked on a regular basis to see if they were working within specifications the SENSI-CHECK detector proved that this was not necessary. When the detector was out of calibration it initiated a service alarm. It must be emphasised that undersensitive detectors known as dead detectors cannot be identified. However, the SENSI-CHECK detector proved to be an exception as a drop of its sensitivity below a certain threshold would initiate a service alarm.

Procedure:

(a) White dust test

Conventional detectors from six different suppliers including model OESD-1 were place in a wind tunnel where they were subjected to an aerosol of baby powder (talc) air flow at a velocity of v = 0.2 m/sec for seven days. The most favourable direction was used. White dust was released on a daily basis. The detectors were connected to their control and indicating equipment as specified by the manufacturer. After 36 hours the SENSI-CHECK detector initiated a service alarm call. At this stage the test was stopped. The smoke chamber was cleaned from all dust and then the detectors were subjected to a smoke response test. None of the detectors alarmed at their calibrated smoke density value. The experiment was continued until the smoke density reached unacceptable levels of above 0.4db/m obscuration before any detector was triggered. The result proves the superiority of the SENSI-CHECK detector over its conventional counterparts on its ability to let the user know of its inability to detect fire. No detector other than the SENSI-CHECK in the market as yet can inform its user that it has lost its ability to detect smoke.

(b) Brown dust and soot test

The above experiment was repeated after the detectors were vacuum cleaned and tested. This time dust and soot were used instead of white powder. The soot and dust were collected from an electric carpet cleaner dust bag. The dirt was first passed through a mesh (0.1µm) before it was gradually released in the smoke chamber. The same results were obtained as above with the exception that the detectors seem to start responding to smoke densities well above 0.7 db/m. It can be therefore suggested that soot and dust are more effective in decreasing detectors sensitivity than white dust.

(c) Vapour test

The six above detectors were installed on the ceiling of a kitchen room wire to their control and indicating equipment as specified by the manufacturers. An electric wall heater equipped with a shower head was used to heat up water and let it flow in a sink. The steam from the boiling running water gradually reached the detector heads and by ensuring that this was kept at minimum the detectors were monitored for alarms. After 43 hours one of the detectors initiated a false alarm. The tests were continued and after 43.3 hours when a service alarm call was received from the SENSI-CHECK detector. At this moment the heater was switched off and both kitchen door and windows were opened to let all steam out. The result proves the superiority of the SENSI-CHECK detector over its conventional counterparts on its ability to let the user know of its increased sensitivity which is not necessarily due to a true alarm but because of deceptive phenomena. The fact that one of the detectors was triggered before anything else happened proves how badly these detectors are designed.

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