Minutes from the EUSAS-BRANDFORSK WORKSHOP on Smoke Detection, Sept 26-27 1994

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Lunds tekniska högskola
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Department of Fire Safety Engineering
Lund Institute of Technology
Lund University

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EUSAS-BRANDFORSK WORKSHOP
on
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September 26-27, 1994

Department of Fire Safety Engineering
Lund University, Sweden

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EUSAS - BRANDFORSK - WORKSHOP

on

Smoke Detection

Introduction

As a part of current EUSAS activities a workshop organised by the Department of Fire Safety Engineering, Lund University, Sweden, in conjunction with the Swedish Fire Research Board (BRANDFORSK), will be held on 26-27th September 1994 at the University of Lund, **John Ericssons väg 1, Lund, Sweden.**

Conference Aims and Objectives

The workshop aims to bring together experts, designers, manufacturers and scientists from the Nordic countries and EUSAS-members who have a specific applied interest in the performance of smoke detectors.

The principle objective is to present and discuss the recent technical developments in this fast moving field with special emphasis on current research activities in the Nordic countries.

Program

Sept 26th Monday

13.00	Registration	
14.00	Introduction, welcome Prof S.E. Magnusson, Lund University (S)	
14.15	Information about AUBE 95 and EUSAS Prof Luck, University Duisburg (D)	
14.30	Presentation "The Role of the Initial Conditions in the Detection of Fires" Prof P.H. Thomas (UK)	Chairman Prof S.E. Magnusson, Lund University
15.15	Coffee break	
15.30	"CFD-modelling of Optical Density from EN54 Test Fires" Göran Holmstedt, Lund University (S)	
16.15	"Experimental Investigation of Influence of Porosity in Suspended Ceiling on Smoke Detection" Morten Aulund, Delta Electronics Testing (DK)	
17.00	"Comments on CFD-modelling of the Influence of Porosity on Smoke Movement through a Suspended Ceiling" Bror Persson, SP (S)	
19.00	Dinner	

Sept 27th Thuesday

09.00	"Measurements of Critical Lengths of Smoke Detectors" Maarit Tuomisaari, VTT (FIN)	Chairman Prof Luck, Univ Duisburg
09.45	"Early Smoke Detection" Finn Drangsholt, SINTEF (N)	
10.30	Coffee break	
11.00	"Simulation Techniques for Fire Detection Systems: Chances and Limits" Alexander Fischer, Universität Duisburg (D)	Chairman Dr Bror Persson, SP
11.45	"Comments on Test Methods"	
13.00	Close	

The Role of the Initial Conditions in the Detection of Fires

P.H. Thomas

Summary

Temperature and air speed values normally characteristic of a heated and ventilated room are compared with values for a fire in the room so that a first approximation can be calculated for size of fire overcoming the effects of the initial conditions.

Introduction

Fire detectors are of various types and many operate in response to some local condition, e.g. concentration of a gas, smoke visibility, degree of ionisation etc. We shall be concerned with these and not with those responding to a fire effect at a distance or flame oscillation, flame radiation.

Whatever happens locally is a result, at least in part, of the movement of the gases in a room. What is often forgotten is that when the fire starts the conditions are determined by what is already happening <u>before</u> the fire starts. Rooms are ventilated and heated or cooled - some are pressurised and all these effects affect certain aspects of the air and gas flow.

Some calculation models, be they "zone" models or CFD ones assume that
(a) the fire is the only heat source,
(b) the air is initially stationary,
in the room.

These assumptions are clearly incorrect but are quite satisfactory for assessing some feature of the fire when the fire wholly controls the flow pattern in the room. The question arises; when does this happen and what properties of the room and the fire control this?

It might appear that the height of the room is important. This may or may not be so and we shall explore this. Floor area also affects the rate at which a hot gas layer descends and this we also discuss in the context of room filling and stratification.

$$t_f = \frac{1.5\ A_{floor}\ \rho_A}{CQ^{1/3}\ h_m^{2/3}} \qquad (h_m << H) \tag{4}$$

This represent a characteristic filling time for the room - assumed to be initially uniform.

If the room is stratified the process is different. The temperature of the plume falls as the plume is diluted on rising. As the hot layer descends its temperature rises. This means that if there is initially a heated layer under the ceiling due, say, to solar or human heating the plume may stratify some distance below the ceiling. However this only seems to decrease the "filling time". Formula exist for the height a plume reaches when the initial condition is a gradient in temperature rising to a maximum under the ceiling (see Appendix I). Ordinary sprinklers are designed to operate at about 70°C temperature rise. One can demonstrate that such temperatures obtain at 2-3 times the flame height (which makes it essential for conventional sprinklers under a very high ceiling to be operated by some means, other than their own temperature rise). However these temperature rises are large enough for the fire to control the flow and temperature patterns in the room. It is far less obvious that this can be said when determining the siting of detectors.

The NFPA has suggested that a detector could be regarded as operating when the calculated temperature rise was 20°C. This was recognized as arbitrary but its main significance is its low value compared with that for a sprinkler.

The initial conditions

In a room, be it a domestic one, a place of public assembly or an industrial space, the conditions of temperature and gas velocity will vary during the day, the movement of people, the heating, the ventilation etc. They are knowable only in statistical terms but certain descriptions of them are not available. For example ventilation is often designed to effect a number of air changes per hour. If this is N then the time space average velocity

$$W = \frac{N \cdot V}{3600\,A_x}\ \text{m/s} \tag{5}$$

where V is the volume of the space and A_c is relevant cross sectional area: for flow up or down it is the floor area. Good design aims are to produce local velocities of less than 1/2 m/s. The residence time

$$t_p = \frac{3600}{N} \tag{6}$$

The heat release in a room $\dot{q}$ is less easy to characterise because it must depend on the degree of insulation, between the room and the exterior. For large buildings one needs to provide less heating per room than for small ones with a higher value of A_S/V_B where A_S is the area of the external envelope and V_B is the building volume. In England, for example the value of $\dot{q}$ per room will necessarily be more than in Sweden with its higher levels of insulation.

These are listed in Table 1.

Table 1.
Some characteristic values for time and velocity

PLUME	ROOM
$t_f = \dfrac{21\,A_{floor}\,\rho_o}{Q^{1/3}\,h_{min}^{2/3}}$	$t_R = \dfrac{3600}{N}$
$W_f = 3.4\left(\dfrac{gQ}{\rho_o C_p T_o}\right)^{1/3} \dfrac{1}{Z^{1/3}}$	$W_v = \dfrac{N\,V}{3600\,A_c}$
$W_e = 0.12\ W_f$	$W_{vmax} < \dfrac{1}{2}\ m/s$
Q kW	q kW

There are perhaps several conditions necessary for the fire to control the temperature and the flows in a ventilated and heated space. Two from the predicting discussion would appear to be

$$t_f << t_R \tag{8}$$

and

$$W_e >> W_v \tag{9}$$

We have not quoted exact values so much as typical or representative values and there are many comparisons one could make between characteristic plume and characteristic room conditions. Moreover the point of comparison e.g. the values of Z and h_m are arbitrary for this level of discussion.

For simplicity therefore we take

$$Z = h_m \tag{10}$$

and with $\rho = 1.23\ kg/m^3$
$C_o = 1\ kJ/kg$
$T_o = 293\ K$
$g = 9.81\ m^2/s$

we have

$$t_f = \frac{26\,A_{floor}}{Q^{1/3}\,h_m^{2/3}} \tag{11}$$

Conclusions

Normal heating and ventilation conditions mean that too small a fire cannot be detected by sensors responding to changes in flow or temperature. Order of magnitude arguments based on simple design criteria and plume theory suggest that the criteria determining the size of the fire necessary to control the flow and temperature rise depend on room height and area. the latter being particularly relevant for large floor areas.

The arguments re-inforce the need for CFD modelling of typical initial conditions in rooms and occupancies so their best design values can be ascertained perhaps on a probabilistic basis.

References

1. Recommended practice for smoke management in atria and malls. NFPA 92B. National Fire Protection Association, Quincy, MA, (1991).

2. Heskestad, G., Fire Safety Journal, 7, 25 (1984).

3. Morton, B.R., Taylor, G.I. and Turner, J.S., Proc. Roy. Soc. A234, 1 (1956).

i.e. had the horizontal entrainment velocity into the plume is proportional locally to the local vertical velocity.

The above equations (either using equation (A5) or equation (A6) with a continuity relation)

$$2\pi b w_e \rho_o = \frac{dm}{dz} \tag{A7}$$

give

$$m = B \left(\frac{\rho_o^2 g Q}{C_p T_o} \right)^{1/3} Z^{5/3} \tag{A8}$$

$$\frac{g\theta_c}{T_o} = \beta \left(\frac{gQ}{\rho_o C_p T_o} \right)^{2/3} \frac{1}{Z^{5/3}} \tag{A9}$$

$$W_c = k \left(\frac{gQ}{\rho_o C_p T_o} \right)^{1/3} \frac{1}{Z^{1/3}} \tag{A10}$$

$$W_e = \frac{5\alpha}{6} W_c$$

Conventional values for B, β, k and α are 0.21 for B, 9.1, 3.4 for the maximum centre line temperature rise θ_c and velocity W_c respectively and 0.15 for α.

Stratification

The modifications to plume theory when the ambient temperature (or density) varies in the vertical direction have been studied (3) and the height at which stratification occurs can be calculated theoretically. This has the same form as the result obtained by writing θ in equation (A9) as λz where λ is the vertical gradient: the constant is of the same order. For a simple approximation we write equation (A9) twice first with $Z = H$ and $\theta = \theta_{st} = \lambda H$ so that we define stratification as occuring in the limit case at the ceiling, and second θ_{st} being the excess of the ceiling over the floor level temperature.

Let $\theta = \theta_{fl}$ and $Z = Z_{fl}$

denote the condition at the mean position of the flame tip, one obtains the conventional

$$Z_{fl} \sim \theta^{2/5} \tag{A11}$$

One equation is divided by the other to eliminate Q and we obtain

$$\left(\frac{Z_{fl}}{H} \right)^{5/3} = \left(\frac{\theta_{st}}{\theta_{fl}} \right) \tag{A12}$$

CFD-modelling of Optical Density from EN54 Test Fires

Göran Holmstedt, Lund University

For a complete paper see "CFD-modelling applied to fire detection - Validation studies and influence of background heating" by P. Andersson and G. Holmstedt presented at the "10. Internationale Konferenz über Automatische Brandentdeckung - AUBE 95" held 4-6 April 1995 in Duisburg, Gemany, pp 429-438.

EUSAS - BRANDFORSK - WORKSHOP on Smoke Detection, Lund University
26 and 27 September 1994.

EXPERIMENTAL INVESTIGATION OF INFLUENCE OF POROSITY IN SUSPENDED CEILING ON SMOKE DETECTION

Morten Avlund, DELTA Electronics Testing, Denmark.

1. Background

The installation of smoke detectors in rooms with suspended ceilings constitutes a special problem. The installer must decide if it is necessary to install detectors below or above, or perhaps below and above the suspended ceiling dependening on the porosity of the suspended ceiling.

In Denmark the specifications for fire detection systems (*ref. /1/*) and door closing systems (*ref. /2/*) had the following installation requirements:

Fire detection systems

a) Detectors are not required above the suspended ceiling if the area of the openings is less than 10% of the total area.

b) Detectors must be installed both above and below the suspended ceiling if the area of the openings exceeds 10% of the total area.

Door closing systems

Requirements as for fire detection systems, however, detectors below the suspended ceiling are not required if the area of the openings exceeds 50% of the total area.

The requirements were fixed based on an estimate and have often given rise to discussions among fire detector installers, fire authorities and building owners. The question was if the detector coverage resulting from the requirements provided the optimum balance between early and reliable fire detection and installation and maintenance costs.

The project was sponsored by The Danish Insurer's Association and guided by an expert group with representatives from The Danish Insurer's Association, The Danish Institute for Fire Technology and DELTA Electronics Testing.

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The smoke density below and above the suspended ceiling was measured by MIC chambers. MIC no. 1 was placed below the suspended ceiling 60 cm from the centre of the room (see FIG. 2.). Another MIC (no. 2.) was placed on the tight ceiling right above MIC no. 1. In addition one ionization and one optical (scatter) detector was mounted next to the MICs.

The temperature was measured in 4 points on a vertical line, 60 cm from the centre of the room opposite to the MICs. The temperature sensors (TF) were placed just below and 0.5 m below the suspended ceiling and just below and 0.5 m below the tight ceiling, respectively.

5. *Test fires*

The test fires were burned at the centre of the floor. The experiments were carried out with two types of smoke generated by test fire types TF2 and TF4 in EN54 part 9 (ref. /3/), with characteristics as shown in FIG. 3 and FIG. 4.

The amount of fire material was downscaled to give an adequate smoke development in the test room. Estimates based on the volume ratios between the test room and the EN54-9 test room and a few practical experiments led to the following downscaling:

TF2: Smouldering wood fire: 2 pcs. beechwood sticks 1 x 2 x 3.5 cm
TF4: Open plastics fire: 1 pc. polyurethane strip 2 x 5 x 50 cm

6. *Results*

The experiments were carried out with each test fire and the following opening areas of the suspended ceiling: 0, 5, 10, 15, 20, 25, 30 and 50% (adjusted by removing one or more lists and distributing the rest so that the spacing between them were of equal size). For each opening area the smoke density below and above the the suspended ceiling is shown graphically in FIG. 5 to FIG. 12. In addition the alarm points for the smoke detectors are shown on the graphs.

The results of the smoke measurements can be summarized as follows:

The smoke density is higher below the suspended ceiling for opening areas up to 20%. The smoke density is comparable below and above the suspended ceiling when the opening area is 20 to 30%. If the opening area is 50% the density is higher above the suspended ceiling.

The temperature measurements (not shown) during the TF4 fire were in line with these results. The temperature was higher below the suspended ceiling up to 25%, comparable below and above the suspended ceiling for 30% opening area, and higher above the suspended ceiling for 50% opening area.

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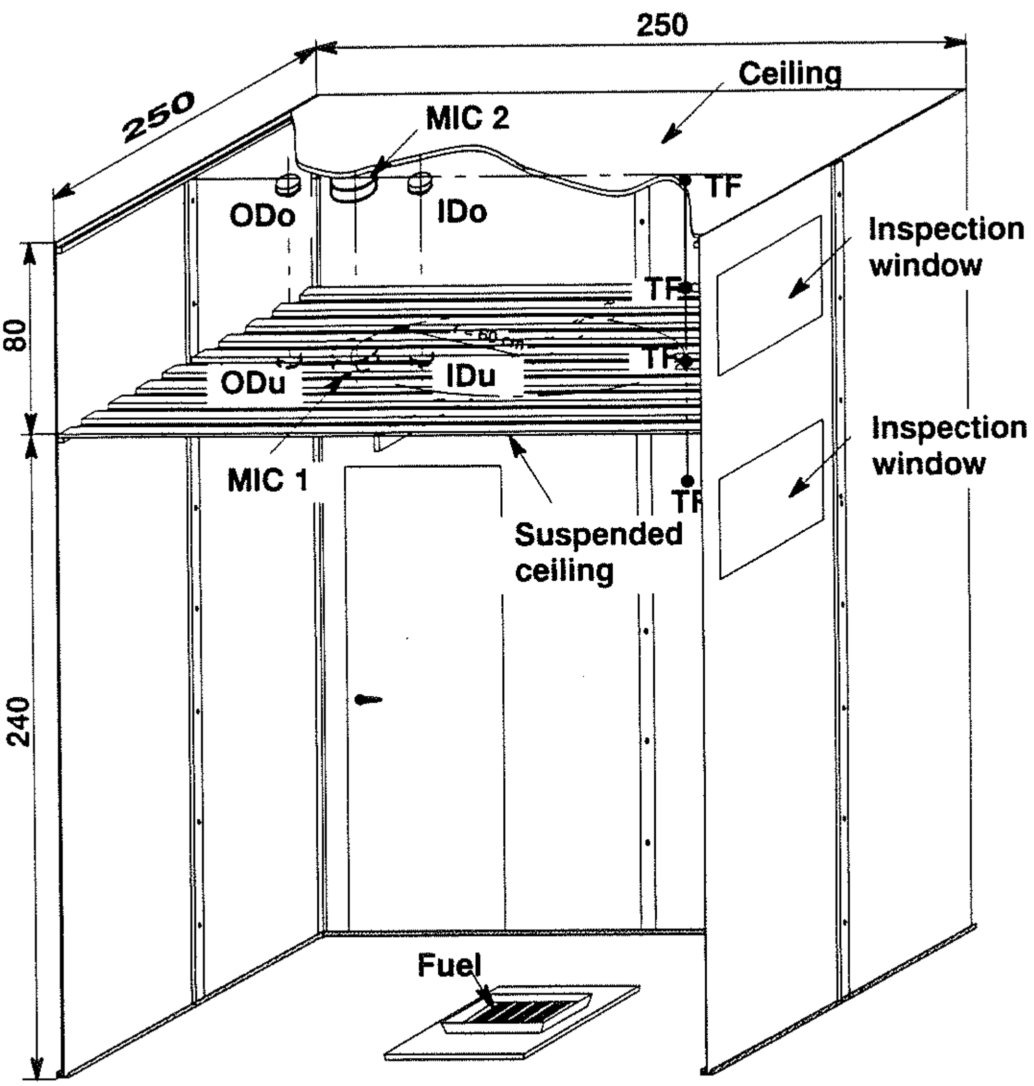
Test Room



ID : Ionization detector
OD: Optical (scatter) detector

028MA011.94

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TEST FIRES

(REF. EN54 PART 9, JULY 1982)

TF2: Smouldering pyrolysis fire (beechwood on hotplate)

Characteristic features:

- development of heat: can be neglected
- upcurrent: weak
- aerosol spectrum: predominantly visible
- visible portion: light, high scattering

Downscaling of fuel for experiments:
2 pcs. beechwood sticks 1 x 2 x 3.5 cm

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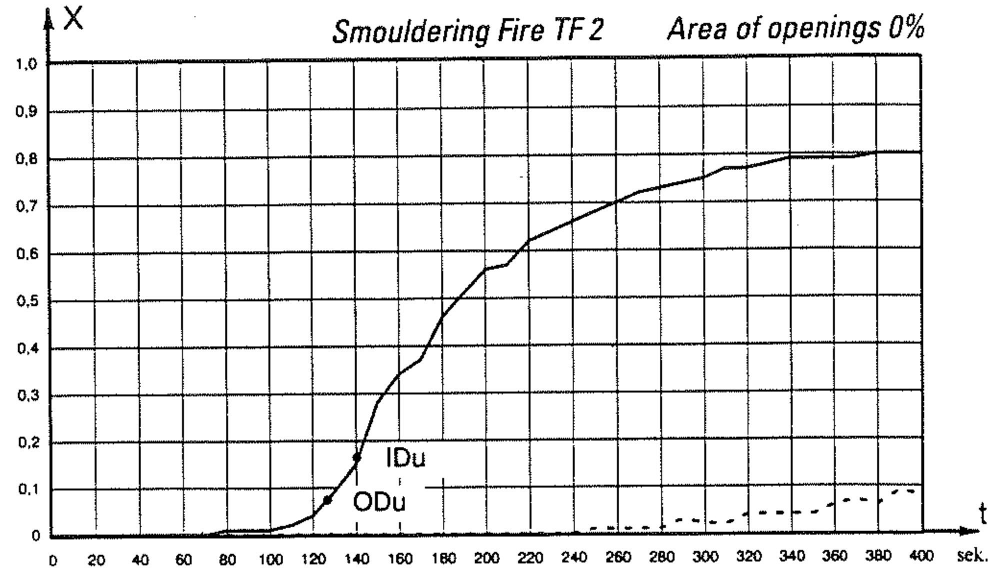
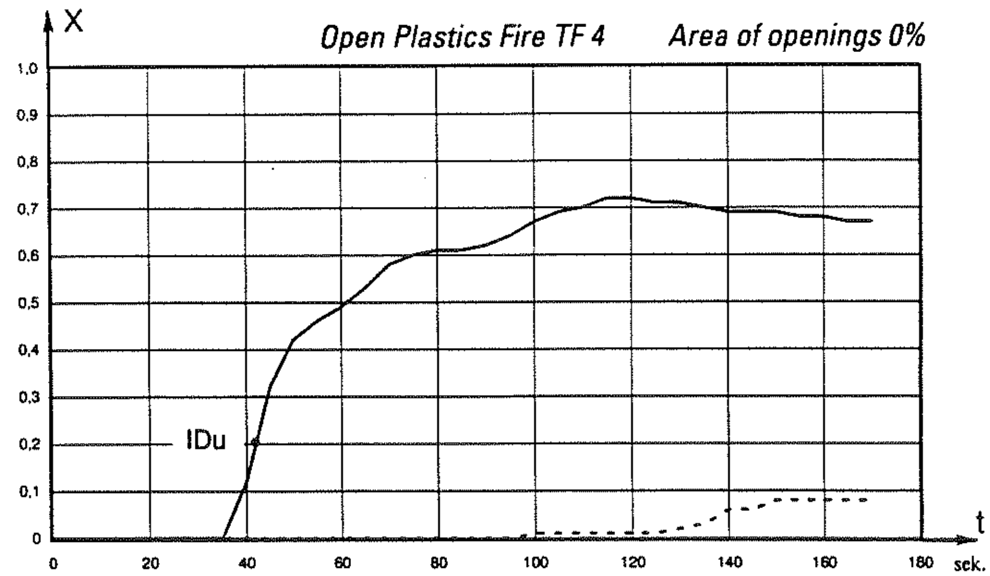


X_0 : - - - - - - - - - - - - **Over suspended ceiling**

X_U : ———————— **Under suspended ceiling**



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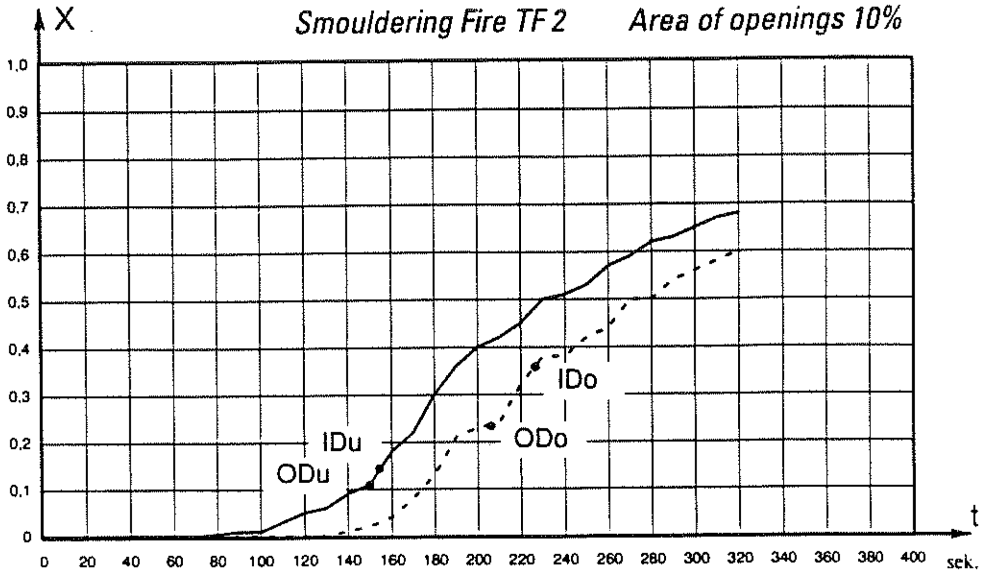
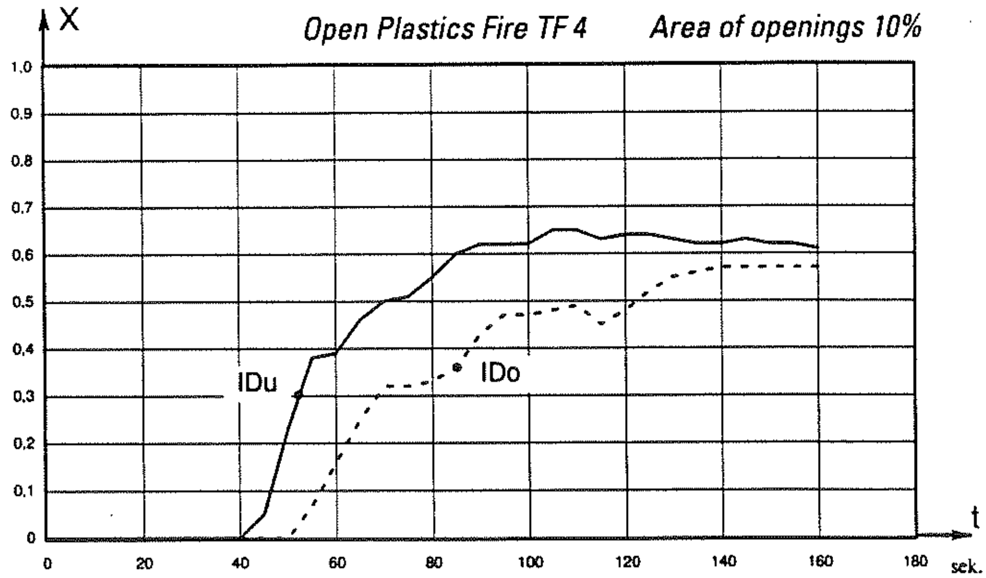


X_0 : - - - - - - - - - - - - **Over suspended ceiling**

X_U : ———————— **Under suspended ceiling**



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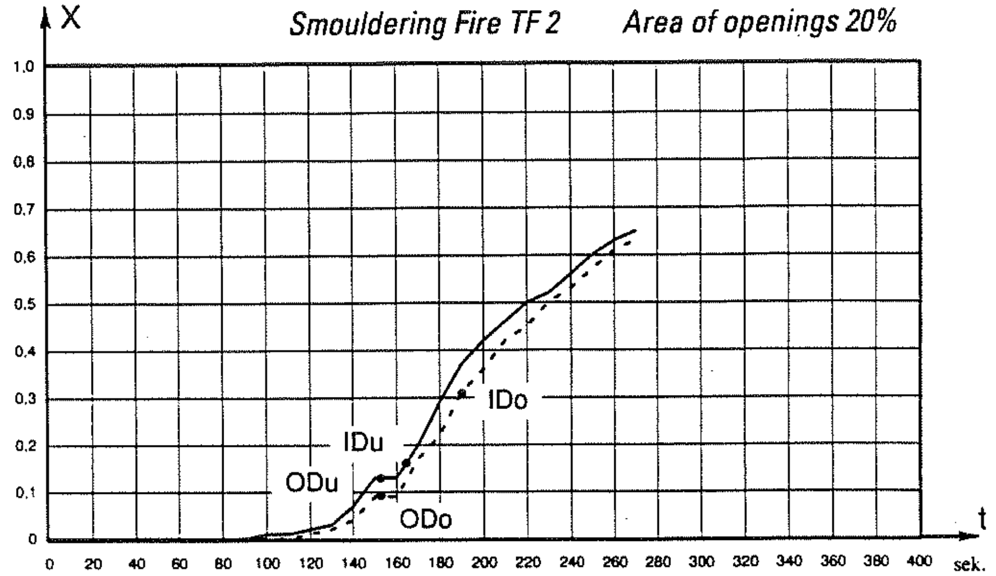

X_O : - - - - - - - - - - - - - ***Over suspended ceiling***

X_U : ———————— ***Under suspended ceiling***

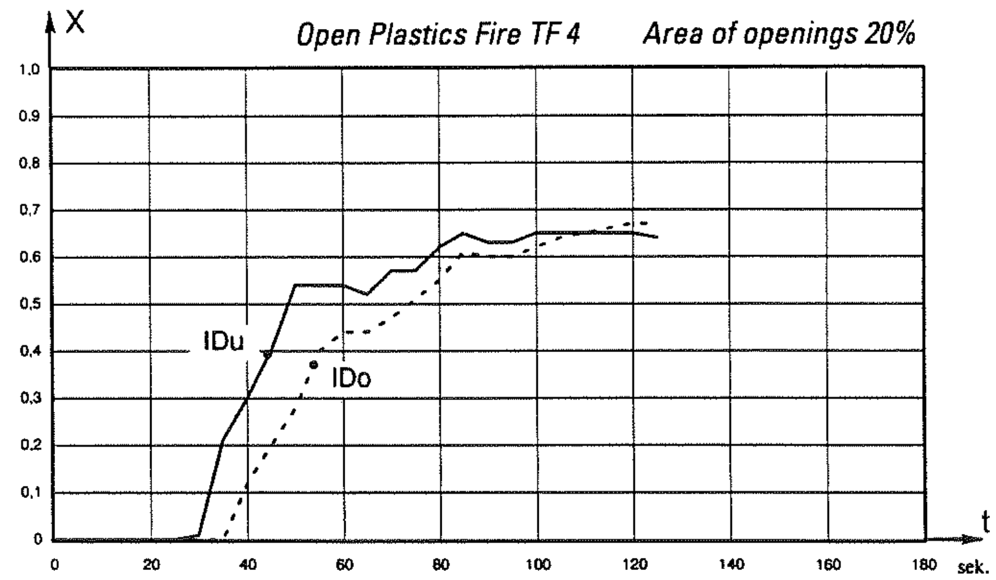

Fig. 11

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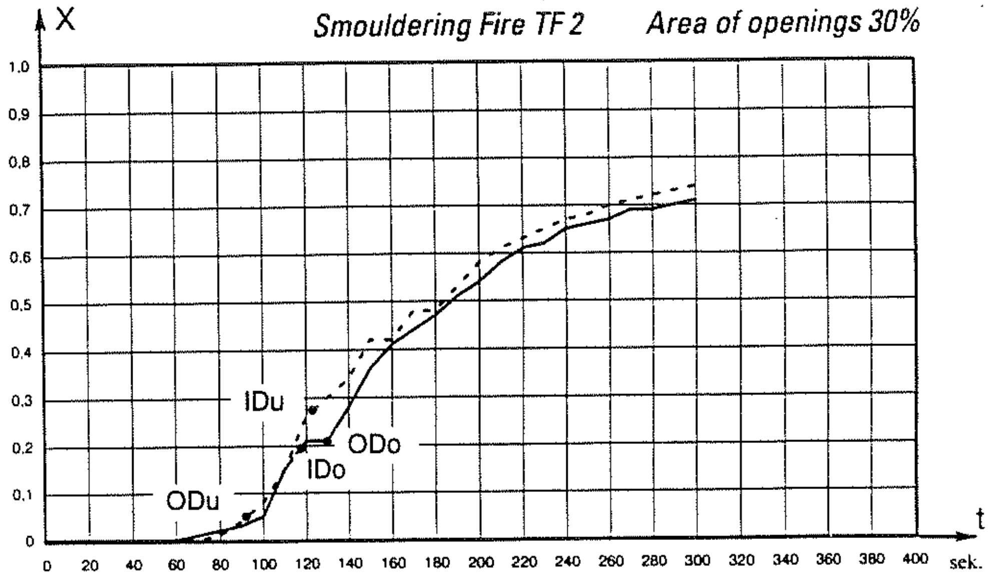
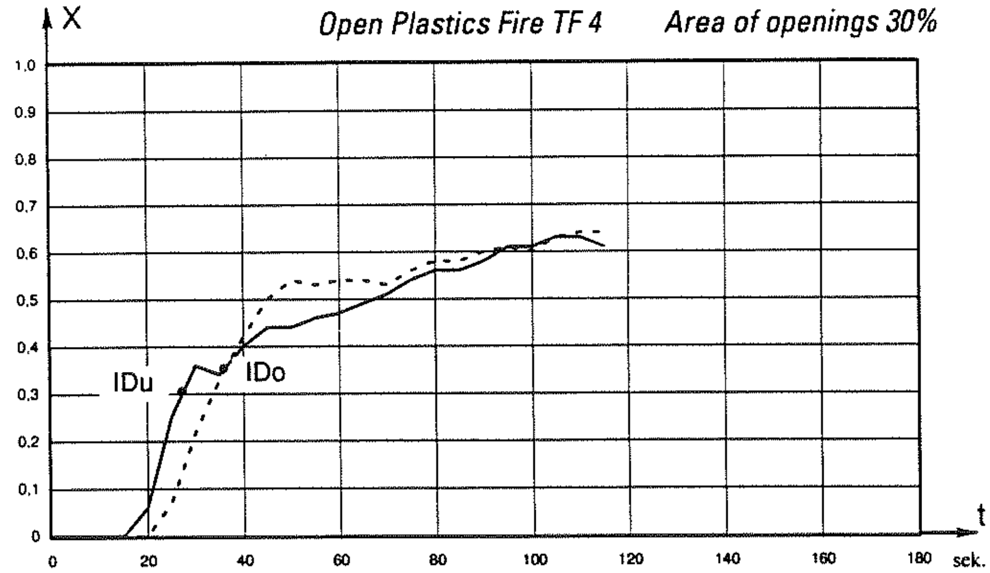


X_0 : - - - - - - - - - - **Over suspended ceiling**

X_U : ———————— **Under suspended ceiling**



Paper presented at the EUSAS - BRANDFORSK Workshop on Smoke Detection, Lund University, September 26 - 27, 1994.

Remarks on the Effect of a Porous Suspended Ceiling on Smoke Detector Response

by Bror Persson, SP Fire Technology, Borås

Summary

Some preliminary results of a CFD simulation of fire in a large industrial hall with a porous suspended ceiling is reported. The effect of the porosity on the response time of smoke detectors is discussed. The smoke detectors considered are characterised as low temperature detectors with no thermal lag. This is a crude description but reflects the present state of the art as far as engineering models of smoke detectors are concerned.

The problem has bearing on the optimum location of smoke detectors. It has been demonstrated elsewhere that the CFD technique has the capability of describing smoke spread due to fire and provide the necessary input for determining smoke detector response. However, more work is needed in developing suitable theoretical models for smoke detectors.

Introduction

The present work is part of a BRANDFORSK project carried out in collaboration between the Department of Fire Safety Engineering, Lund University and SP Fire Technology, Borås. For the computations a CFD program called JASMINE [1-3] has been used.

The capability of CFD programs to solve problems with smoke spread in complex geometries is well established, see e.g. [1-3]. Thus, it seems feasible to use the CFD technique as a basis for determining the optimum location of smoke detectors. The weak point at the present stage is the description of detector response and here a lot of work remains to be done. Still one can get valuable information from CFD simulations in studying the spatial variation of the smoke parameters involved in triggering the detectors. The CFD technique can provide detailed information about the smoke flow field in complex geometries and thus produce the necessary input to smoke detector models. The field variables computed are e.g. temperature, velocity, fuel mass fraction, oxygen concentration etc. These computed results can also be converted to other input parameters e.g. optical density if needed for a specific detector model, see e.g. [4].

In this paper the variation of the temperature field in a large industrial hall with a suspended ceiling is studied. In the absence of an appropriate model describing the response of smoke detectors, it is assumed here that the detector can be modelled as a low temperature detector with no thermal lag [5, 6]. This is of course a crude approximation but will nevertheless give useful information about the influence of different geometrical parameters on smoke detector response. The practical value of the technique will be still more pronounced for more complex room geometries. There are also a few alternative detector models described in [5-7]. However, these cannot be applied due to lack of data of characteristic parameters for the detectors when applied to real fires.

Calculations and Results

The simulations have been carried out with the CFD code JASMINE [1-3]. Detector response is assumed to take place at a certain temperature rise (ΔT) above the initial temperature, in the present case $\Delta T = 13$ °C, see [6]. The underlying reason for using a fixed temperature rise is that there seems to be an approximative correspondence between temperature rise and optical density in a smoke layer. This assumption is however disputed.

Figure 2 displays the results for detectors 21 - 23 located above the suspended ceiling in the case with 32% porosity. The response is in the order of 2 min for the location closest to the fire. The variation in response times between detectors are very much as expected.

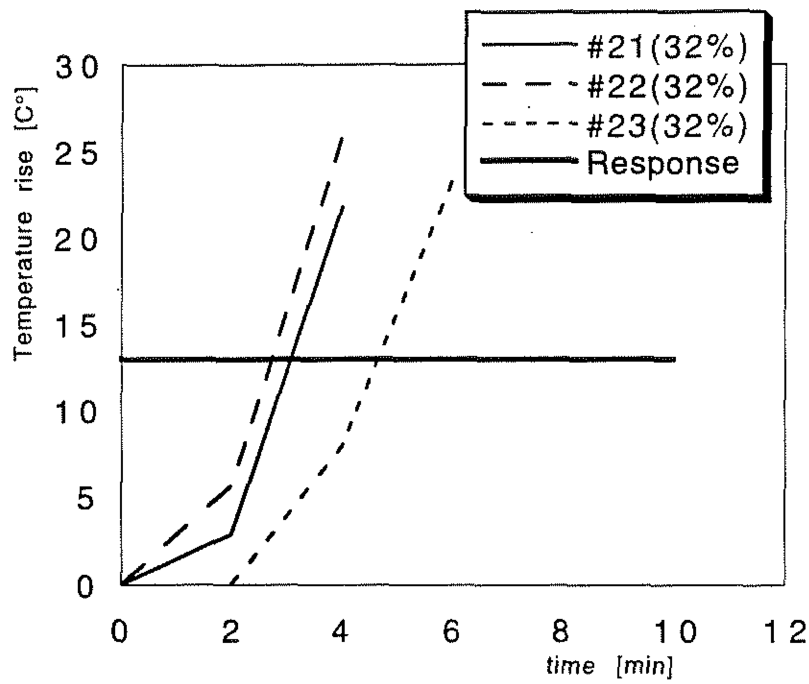


Figure 2. Temperature rise of detectors 21 - 23 located above the suspended ceiling with porosity 32%. Detectors respond at 13 °C temperature rise.

Figures 3 - 6 show the response at different locations in the hall for detectors positioned beneath and above the suspended ceiling. It is seen that a less porous ceiling can have a substantial effect upon the response time. When the porosity of the ceiling is sufficiently low, a detector location below the suspended ceiling is advantageous while the opposite is true for a ceiling with high porosity. However, it is to be stressed that the present results are only of qualitative nature. Nevertheless the results indicate the capability of the CFD technique to reveal the influence of the porosity upon the response.

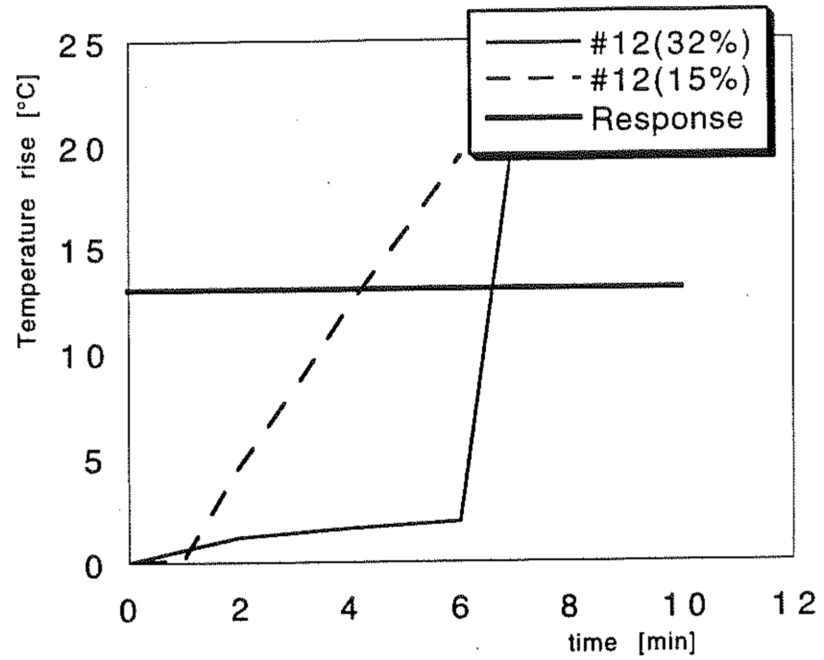


Figure 5. Temperature rise of detector 12 for different porosities. Detector responds at 13 °C temperature rise.

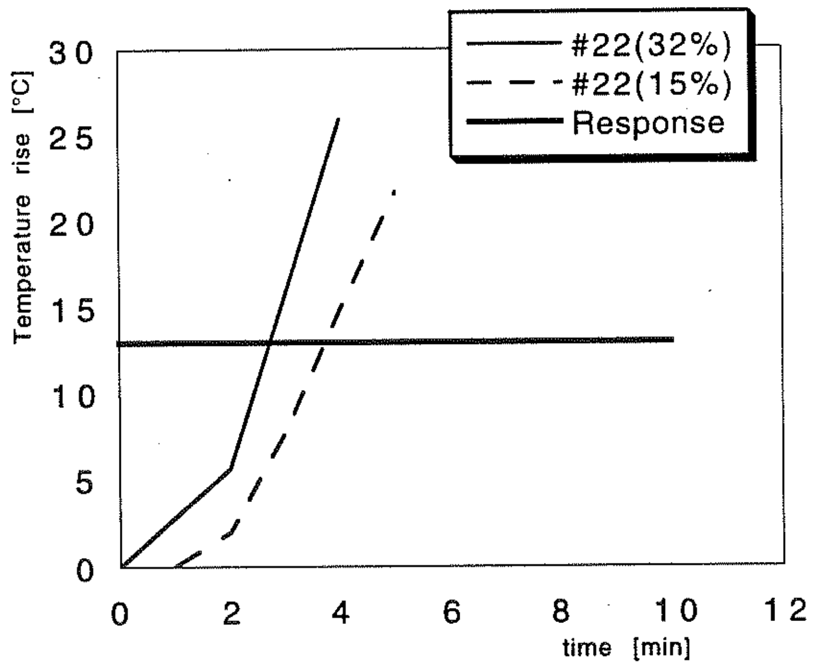


Figure 6. Temperature rise of detector 22 for different porosities. Detector responds at 13 °C temperature rise.

MEASUREMENTS OF THE CHARACTERISTIC LENGTHS OF SMOKE DETECTORS[1]

Maarit Tuomisaari
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A wind tunnel system with a constant rate of increase of smoke density under varying velocity conditions was used to characterize the dynamic performance of point-type smoke detectors. Two independent parameters, the static response threshold and the characteristic length of the detector were experimentally determined. These parameters are a measure of the detector quality and they can be used as input to calculation models.

1. BACKGROUND

The current standard sensitivity tests of point-type smoke detectors have effectively improved the product quality in the market. The sensitivity is evaluated by exposing the detectors to several smouldering and flaming test fires. The static and dynamic properties of the detector are taken into account by setting limits to the measured smoke density at response.

The sensitivity tests, however, do not produce input to calculation models that are becoming one the most important tools in fire safety engineering. Modelling of smoke detectors would require data in the same way as modelling of sprinklers and thermal detectors, the dynamic performances of which are described by static response temperatures and RTI values /1/.

The importance of the dynamic response properties can be realized by the fact that depending on smoke density increase rate, completely different apparent response thresholds are measured. The higher the increase rate is the higher thresholds are observed.

In this paper, in Chapter 2 a simple dynamic theory of smoke detectors is presented. An experimental system and procedure to determine the characteristic properties included in the theory as well as some results are described in Chapter 3. Chapter 4 contains the discussion.

2. THEORETICAL MODEL

The dynamics of any detector can be described by a conventional diffusion equation

$$\frac{dC_i}{dt} = \frac{C_u - C_i}{\tau} \tag{1}$$

[1]This paper is based on the publication *J.Björkman, M.A.Kokkala, H.Ahola, "Measurements of the Characteristic Lengths of Smoke Detectors", Fire Technology, 28 (1992), pp.99-109*

The essential parts of the wind tunnel system are (see figure 1):

1. Centrifugal fan and electrical heater with instruments to measure the air flow and to control its temperature

2. Aerosol generator

3. Aerosol distributor

4. Working section with the detector under test

5. Instruments for measuring the density and temperature of the aerosol

6. Tunnel outlet into the exhaust duct

The temperature in the tunnel can be controlled between the ambient and about 170°C, and the rate of rise of temperature between 0.15°C/min and 600°C/min. The flow velocity can be adjusted to a constant value between 0.2 and 1.0 m/s.

The aerosol for the smoke detector tests is produced by an aerosol generator in which pressurized air (max 3 bar) is purged through dioctylpthalate. The aerosol is stabilized and homogenized by leading it through a 0.12 m^3 vessel with a constant outflow. In the line to the wind tunnel there is a three-way valve, which divides part of the flow into the tunnel and the rest directly to the exhaust system. The aerosol is fed to the tunnel through a set of perforated tubes. By controlling the valve the rate of rise of the smoke density can be kept at any constant value between 0.04 and 3 dB/m/min with ± 8 %. The polydisperse aerosol is characterized by the ratio m/y = 1.14 ± 0.05 when the air pressure is 2 bar. The m/y ratio is proportional to the mass median particle diameter and it corresponds to that of the smouldering cotton test fire TF3 in EN54-9.

The unique property of the tunnel is that the time lag between the production of the aerosol and its appearance in the measuring section of the wind tunnel does not vary with the smoke density as in closed loop test tunnels. The open tunnel test system using stabilized fresh aerosol was designed to minimize the problems associated with agglomeration and aging of the aerosol and, therefore, the drop size distribution in the tunnel remains more or less constant.

The detector to be studied is fixed to the ceiling of the tunnel at a distance of 1.6 m from the aerosol inlet. The smoke density is measured both with a standard ionization chamber (MIC /5/) and an infrared smoke densitometer (SICK /6/). The valve is controlled and the detector status and smoke densities monitored by an HP 3497A data aquisition and control unit and a microcomputer.

3.2 Results

In order to determine the characteristic properties of the detectors, both the rate of rise of smoke density and the flow velocity were varied. The characteristic length and the response threshold were then determined by iterative fitting. The first cycle was done by determining m_r and L by fitting to equation (4). During the subsequent cycles the fit was done to equation (3) in which the correction to the rate of rise of smoke density was done by using the L obtained from the previous cycle.

The results for an ionization detector and a photosensitive detector are shown in figures 2 a) and b). The characteristic length of the ionization detector was 3.2 ± 0.2 m and that of the photoelectric detector 5.3 ± 2.7 m. The response threshold values were 0.62 ± 0.01 dB/m and 0.07 ± 0.03 dB/m, respectively.

The covers of the ionization and photoelectric detectors studied were identical. Yet the characteristic length of the photoelectric detector was 70 % longer. The difference may have been due to a long labyrinth shielding the sensor from external light.

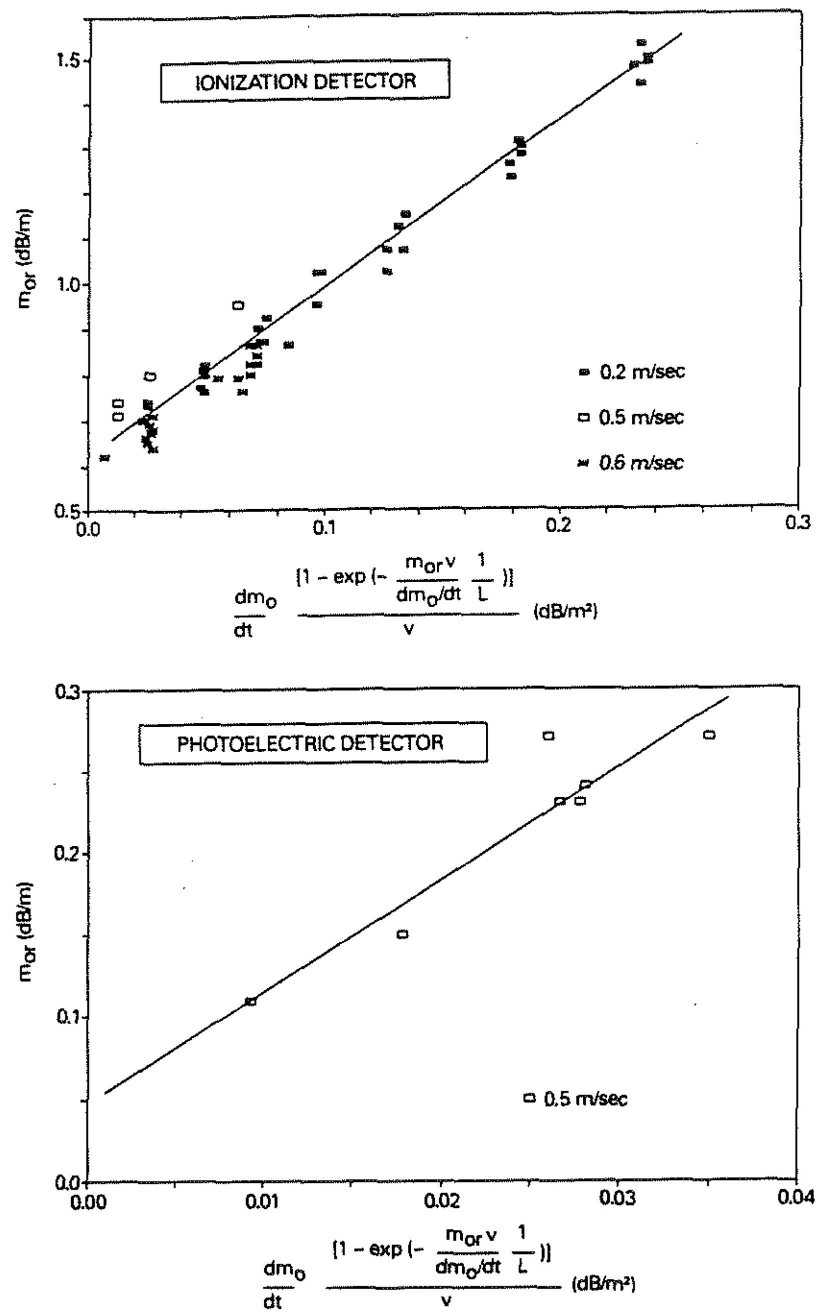

Figure 2. Optical smoke density at the response of smoke detectors as a function of the ratio of corrected rate of rise of smoke density and the flow velocity in the tunnel. The slope of the regression line is the characteristic length L of the detector, and the intercept with the vertical axis is the static response threshold of the detector.

REPORT

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TITLE

EARLY DETECTION OF SMOKE IN ELECTRICAL ROOMS

AUTHOR(S)

Finn Drangsholt

CLIENT(S)

Autronica Offshore as

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ABSTRACT

Autronica Offshore as has commissioned SINTEF to carry out full scale tests on early detection of a smouldering fire in an electrical cabinet and in a raised floor used for underfloor cabling. A total of 8 tests were carried out.

Smoke was produced by electrically overloading cable and by overloading circuit board resistors. The tests were carried out with either displacement ventilation or mixing ventilation, and with various air change rates. Additionally, tests were carried out with a lowered alarm trigger point.

KEYWORDS	ENGLISH	NORWEGIAN
GROUP 1	Fire	Brann
GROUP 2	Safety	Sikkerhet
SELECTED BY AUTHOR(S)	Detection (smoke)	Deteksjon (røyk)
	Ventilation	Ventilasjon
	Air diffusion design	Luftbevegelse

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1 INTRODUCTION

Due to the detrimental effect of halogen gas on the ozone layer, the authorities have decided that all fixed fire extinguishing installations containing halogen will have to be dismounted by year 2000. Consequently, many oil companies have established working groups to evaluate viable alternatives to halogen extinguishing systems. One alternative which is being evaluated, is early detection of smoke combined with manual extinguishing. This alternative is the subject of the tests in this report.

SINTEF Thermodynamics has been commissioned by Autronica Offshore AS to carry out full scale tests of early detection systems in the case of a smouldering fire and a blazing fire. The tests have been carried out in one of the test rooms at the Institute of Heating and Ventilation, at the Norwegian University of Technology (NTH) in Trondheim.

The tests were planned by Autronica. Autronica was also responsible for the choice and positioning of detectors, and logging the data.

The objective of the tests has been to investigate any differences in detection time between the different types and locations of detector. The tests involved different sources of smoke/fire, as well as various ventilation rates and ventilation methods.

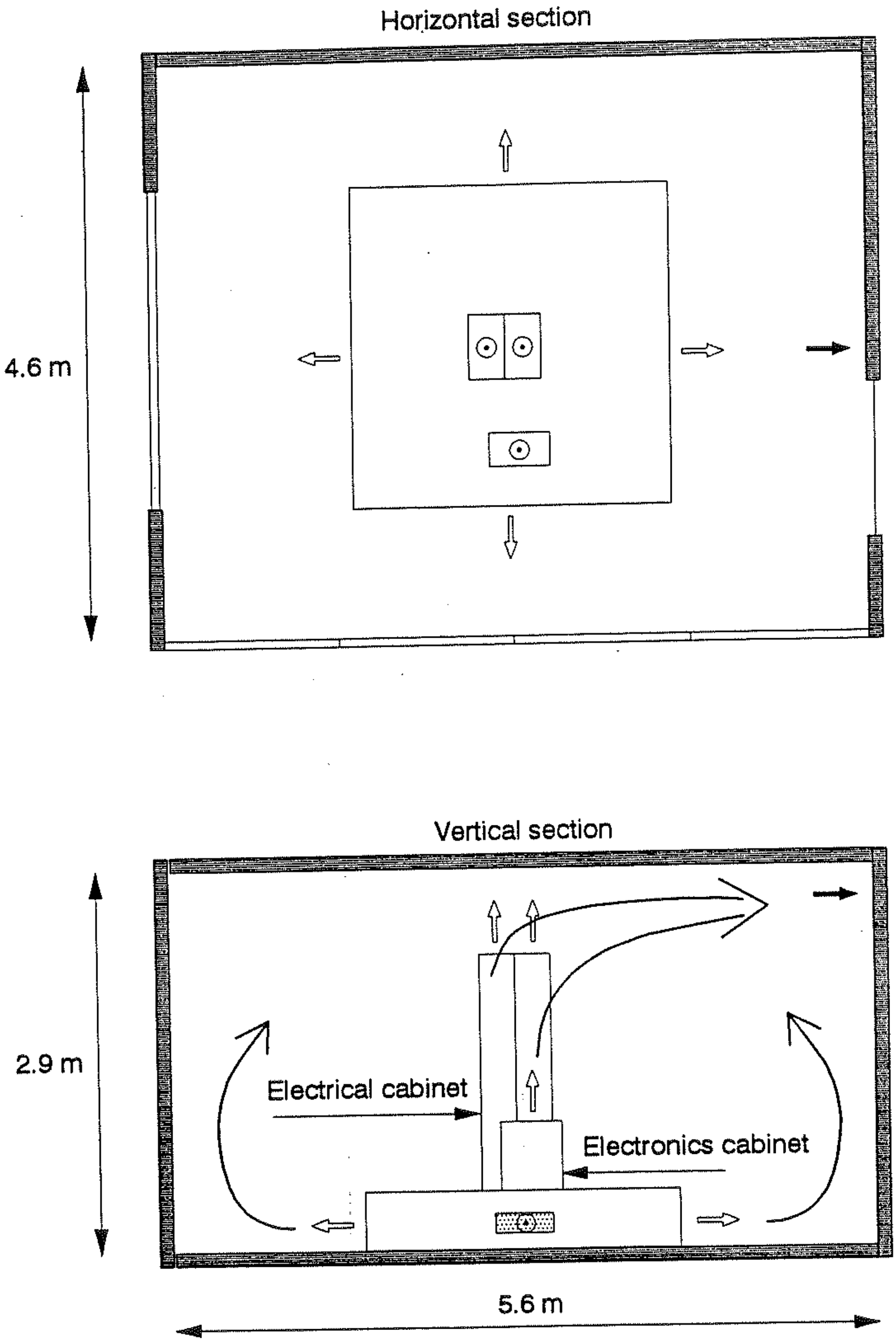


Figure 2.1 Ventilation of the test room by the displacement principle

2.2 Types of detector

Table 2.1 lists the detection equipment which was tested. The table also details each detector's principle of operation and number of detectors/channels.

Table 2.14 Detector types

Type	Principle	Note	Number
BH-31	Optical		2 units
BH-31/S	Optical	High sensitive	5
BH-31/A/S	Optical	Super sensitive	5
BJ-31	Ionic		2
BJ33/S	Ionic	High sensitive	5
BWP-43, BH-31/S	Optical	Duct adapter	1
BWP-43, BH-31/A/S	Optical	Duct adapter	1
AutroSense BW-50	Aspiration		2
VESDA E70D	Aspiration		1
VESDA Locator	Aspiration		6 spots
VESDA Scanner	Aspiration		3 spots

Optical point-smoke-detector BH-31
Standard point-smoke-detector for detection of relatively large smoke particles. It operates by measuring the light intensity of a reflected beam of infrared light. The alarm is triggered when the light attenuation due to smoke particles, reaches 2% per metre.

Optical point-smoke-detector BH-31/S
This detector is characterized as highly sensitive, and triggers an alarm when the light attenuation reaches 0.7% per metre.

Optical point-smoke-detector BH-31A/S
This detector is characterized as extremely sensitive. It triggers when the light attenuation reaches 0.5% per metre.

2.3 Detector locations

The detectors were positioned in groups in and above the electrical and electronics cabinets, in front of the extract grille and in the extract duct. Figure 2.3 shows the locations of the various detectors. The photographs in Appendix A also clearly show the detector locations.

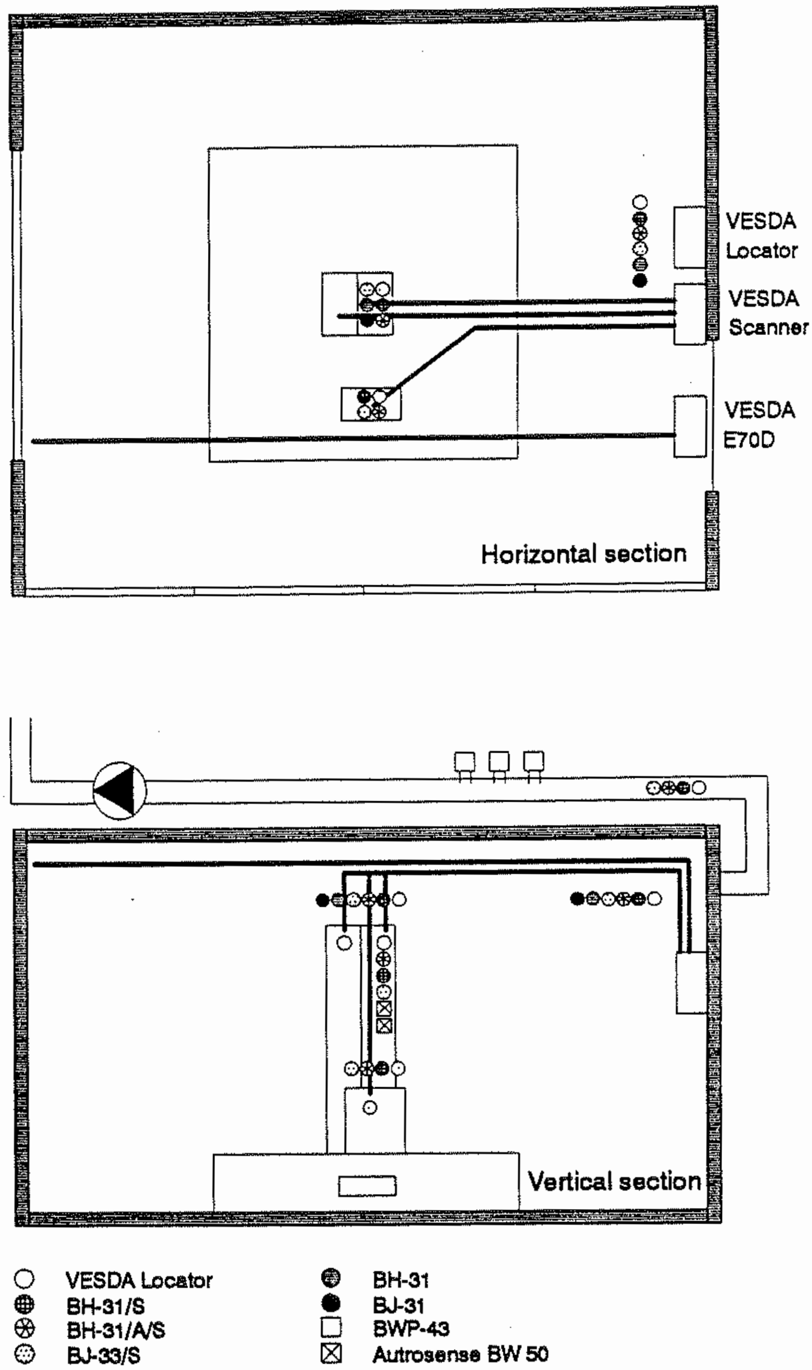
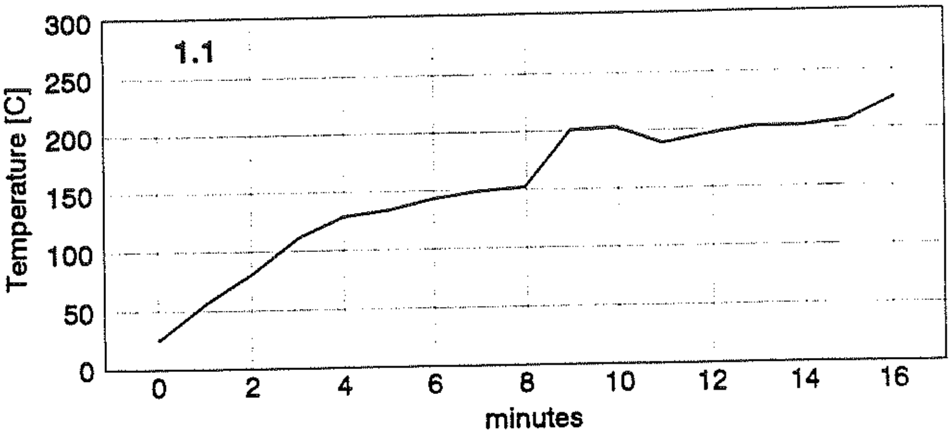
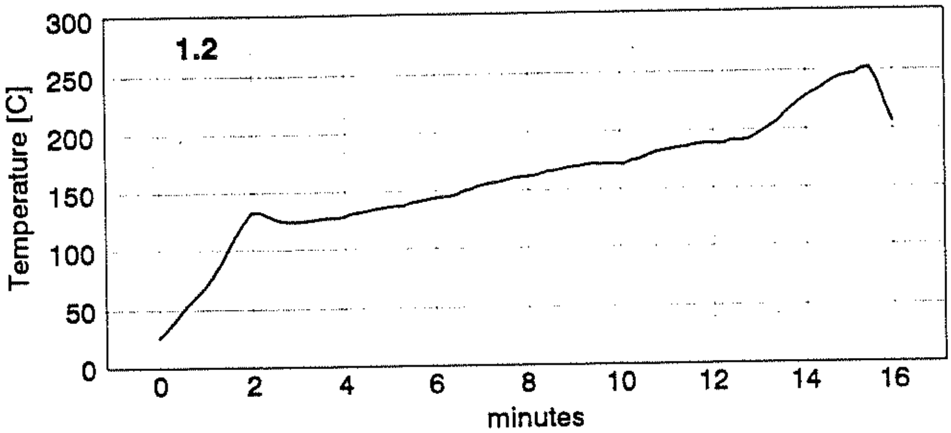


Figure 2.3 Locations of the different detectors





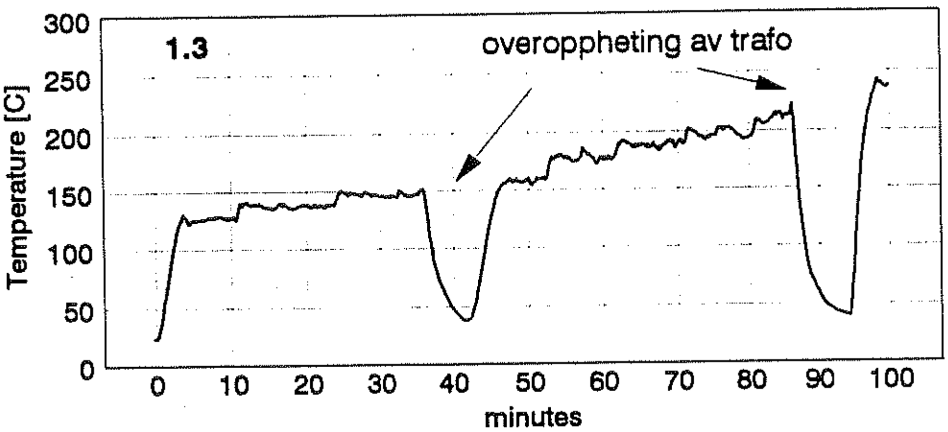


Figure 3.1 Temperature rise curves for tests 1.1, 1.2 & 1.3

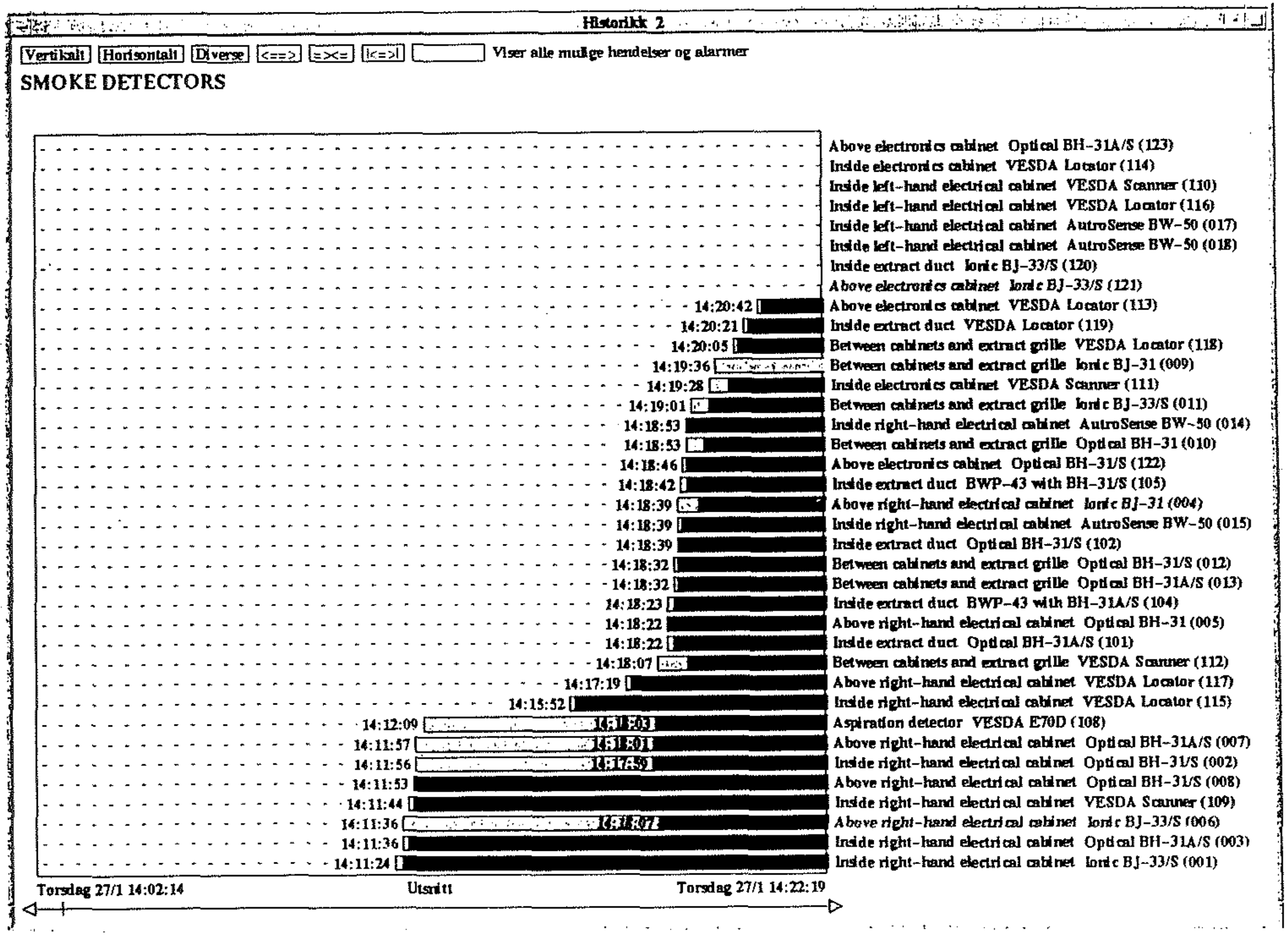


Figure 3.2 Test case 1.1 - smouldering fire in electrical cabinet

SINTEF

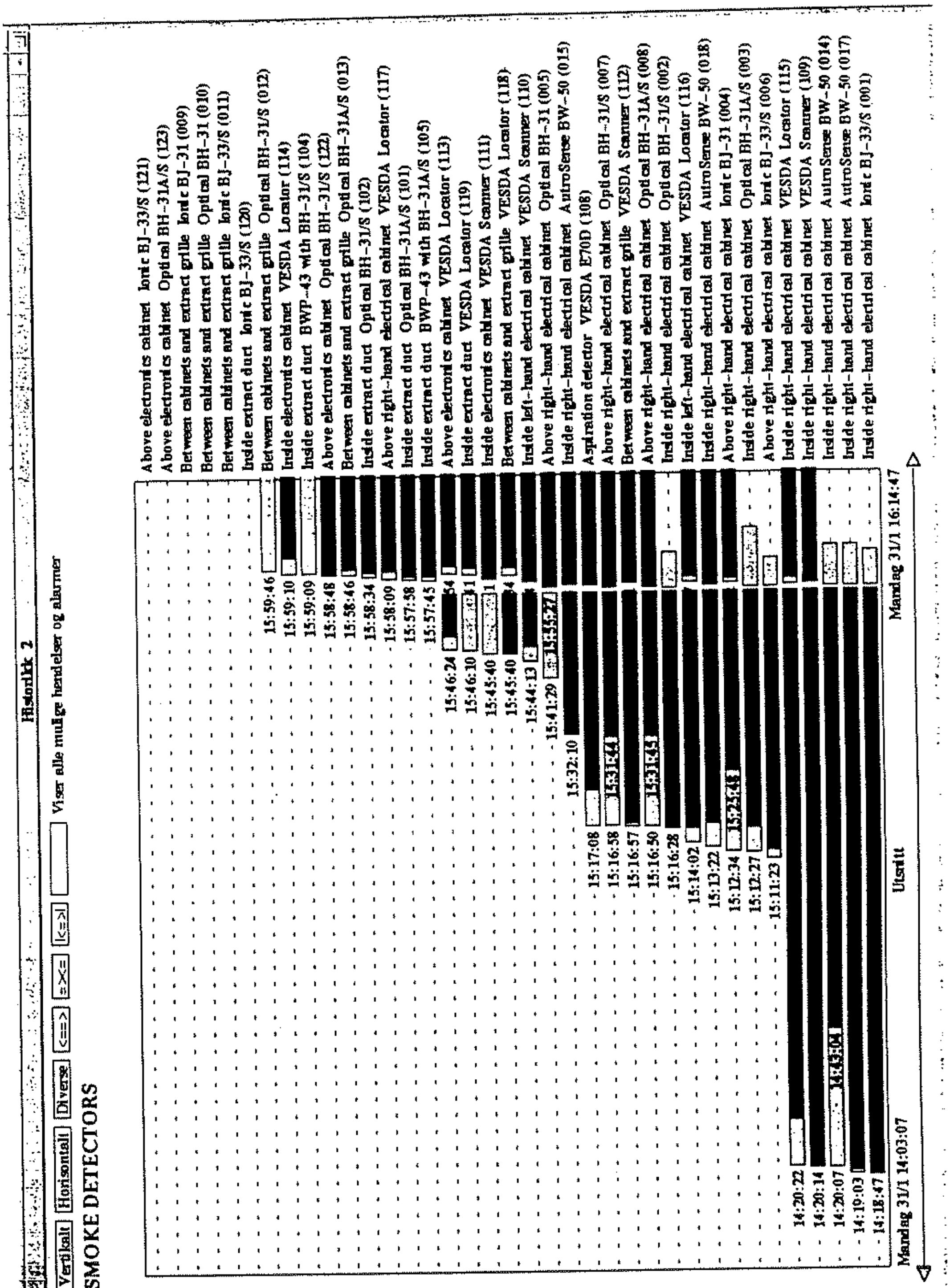


Figure 3.4 - Test case 1.3 - smouldering fire in electrical cabinet

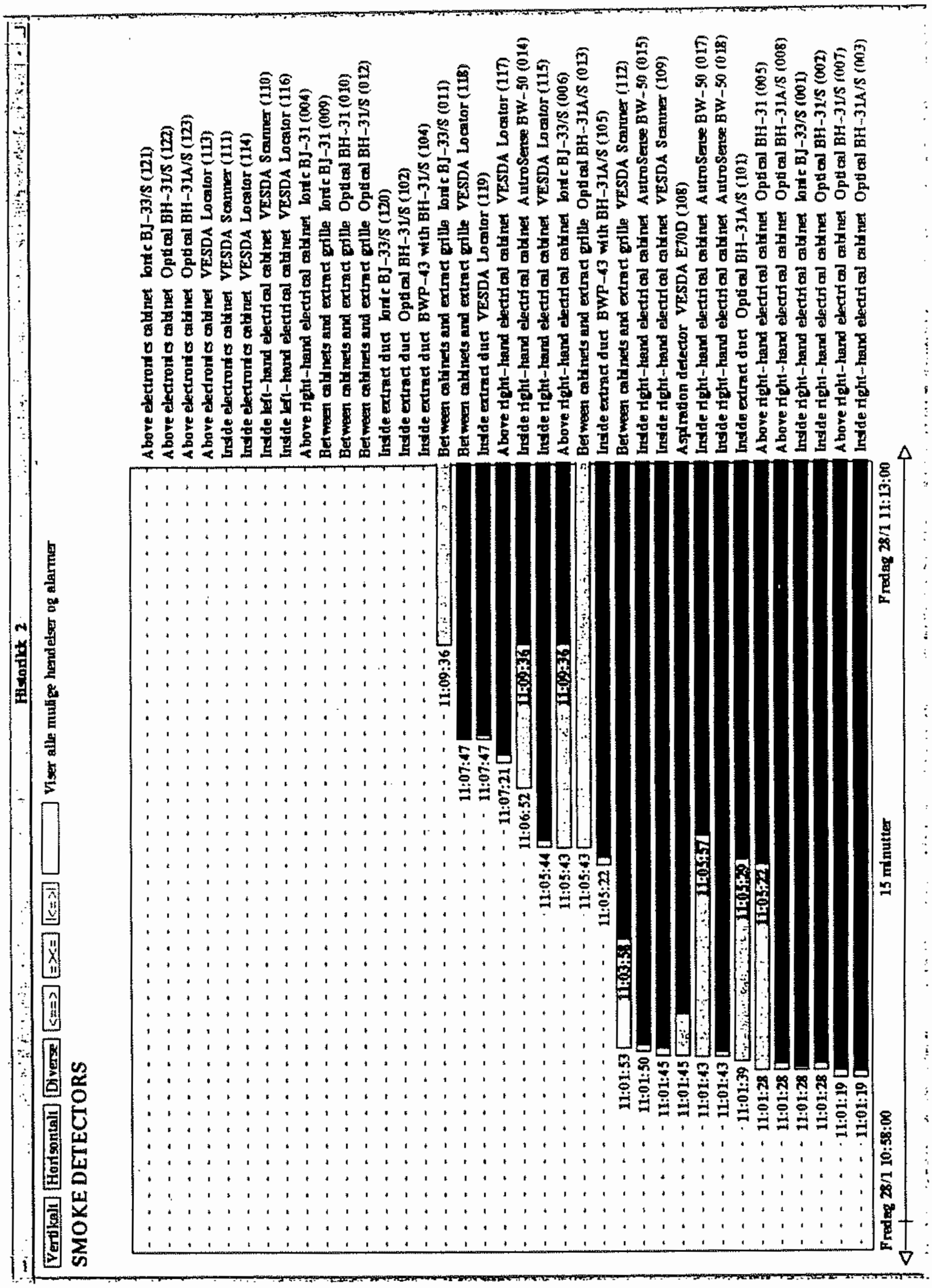


Figure 3.5 Test case 2.1 - smouldering fire in electrical cabinet

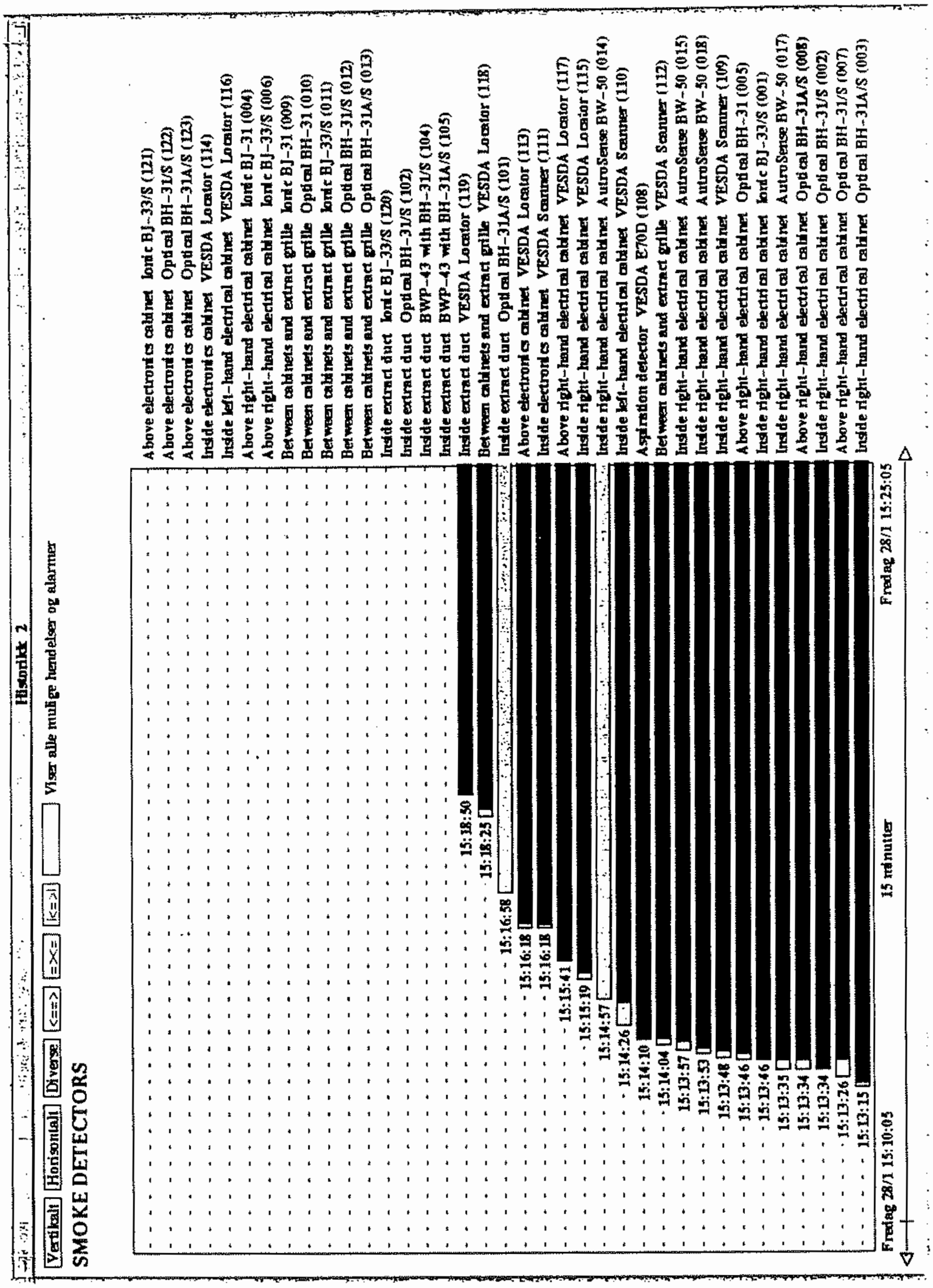


Figure 3.7 Test case 2.3 - smouldering fire in electrical cabinet

In test case 2.2, ten detectors triggered an alert/alarm 3.5-4 after the start of the test. At this time the circuit board current was 5A. Six of these detectors were inside the right-hand electrical cabinet (BH-31A/S, BJ-33/S, BH-31/S, AutroSense BH-31A/S, VESDA Scanner and Autrosense BH-31/S). Two more of the detectors were located above the cabinet (BH-31A/S and BH-31/S), and the remaining two detectors covered the whole room. The remaining detectors which indicated an alert/alarm during the test, triggered 5.5-7.5 minutes into the test

In test 2.3, ten detectors indicated an alert/alarm 3.5-4 minutes into the test. Seven of these were located in the right-hand electrical cabinet (BH-31A/S, BH-31/S, AutroSense BJ-33/S, BJ-33/S, VESDA Scanner, AutroSense BH-31A/S and AutroSense BH-31/S). The other three were located above the cabinet (BH-31A/S, BH-31/S and BH-31). The remaining detectors which detected smoke, triggered 5-9 minutes into the test.

In test 2.4, one detector (VESDA Scanner) triggered an alarm after only 1.5 minutes. This detector was located within the right-hand electrical cabinet. At this point in time the circuit board current was 2.5A. In the period 4-5 minutes into the test, 13 more detectors gave an alert/alarm. Eight of these were located inside the right-hand electrical cabinet (BH-31A/S, BJ-33/S, BH-31/S, AutroSense BH-31A/S & BJ-33/S, VESDA Locator, AutroSense BH-31/S & BJ-31). Three of the detectors were located above the cabinet (BH-31A/S, BH-31/S and BH-31), and the remaining two detectors covered the whole room. The remaining detectors which indicated an alert/alarm during the test, triggered in the period 5-8.5 minutes into the test.

A comparison of tests 2.1 and 2.2 shows that 6 of the detectors inside the right-hand electrical cabinet (BH-31A/S, BH-31/S, BJ-33/S, AutroSense BH-31A/S & BH-31/S and VESDA Scanner) and 2 of the detectors above the cabinet (BH-31A/S and BH-31/S), had the same detection times in both tests. The ventilation air change rate therefore had little effect on the detection time of these sensors.

Four detectors (VESDA Scanner, BH-31A/S, VESDA Locator and BJ-33/S) which were all located between the cabinet and the extract gave an alert/alarm at 12 air change rates per hour, whereas only one of these (VESDA Locator) gave an alert/alarm at 6 air changes per hour. These results are the opposite to that which would be expected at first sight. The results indicate that the room's airflow pattern has a greater bearing on detection time than do air change rate and average smoke concentration.

A comparison of test cases 2.1 and 2.3 shows that 7 of the detectors inside the right-hand electrical cabinet (BH-31A/S, BH-31/S, BJ-33/S, AutroSense BH-31A/S & BJ-33/S, VESDA Scanner and Autrosense BH-31/S & BJ-31) and 3 of the detectors above the cabinet (BH-31A/S, BH-31/S and BH-31), gave alerts/alarms at the same time in both tests. Two of the detectors in the cabinet (VESDA Locator and AutroSense BJ-31) and one detector above the cabinet, had detection times which were 3-4 minutes slower for displacement ventilation than for mixing ventilation. Further comparison of the tests shows that displacement ventilation and mixing ventilation resulted in changed detection times for the remaining detectors.

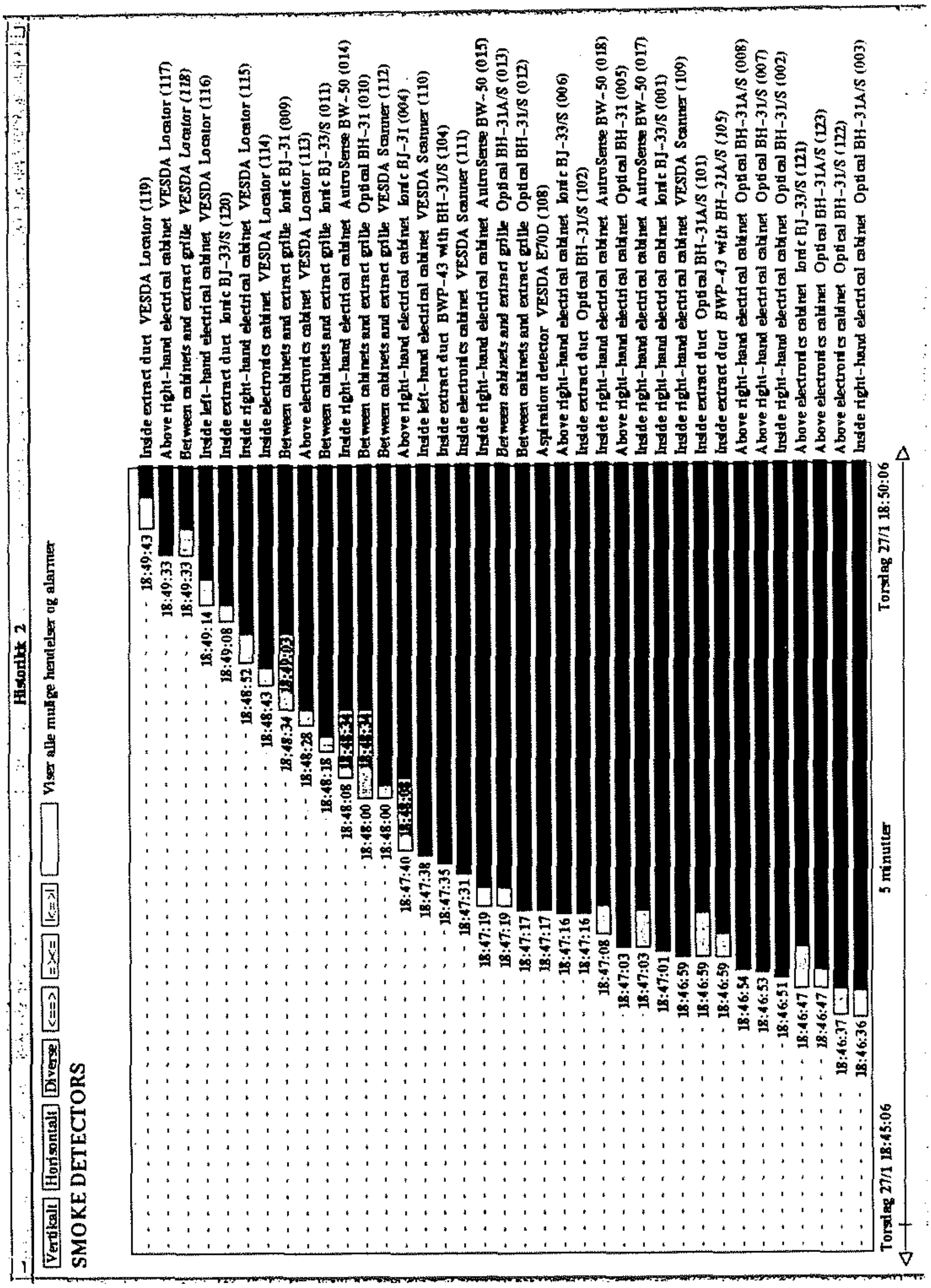


Figure 3.10 Test case 3.1 - smouldering fire under a raised floor

4 CONCLUSIONS

Eight test cases have been carried out, investigating the early detection of smoke from a smouldering fire in a room with electronics or electrical gear. The tests involved electrically overloading either a cable or resistors on a circuit board. Additionally, the ventilation principle, air change rate and alarm trigger sensitivity (ATS) have been varied. The following conclusions have been made:

- Detectors placed near the source of fire give the most rapid detection. In the case of a smouldering fire in an electrical cabinet, the detector should be placed in the cabinet's ventilation outlet. In the case of a smouldering fire in a raised floor, detectors should be placed in one or more of the floor's ventilation outlets.

- The extremely sensitive detectors BJ-33/S and BH-31A/S generally gave the earliest alarm, throughout the tests. For smouldering cable, the ionic detectors in the same cabinet as the cable, reacted first. For overheating of circuit board resistors, optical detectors located in the same cabinet as the circuit board, gave earliest detection.

- The distance between the source of fire and the detector, is a very important factor in the choice of detector. Larger distances seem to favour optical detectors. The reason for this is probably that small particles coagulate together, resulting in proportionately more large particles further from the source of smoke.

- The room's air flow pattern (and hence detector location) has more bearing on the detection time than do the air change rate and average smoke concentration.

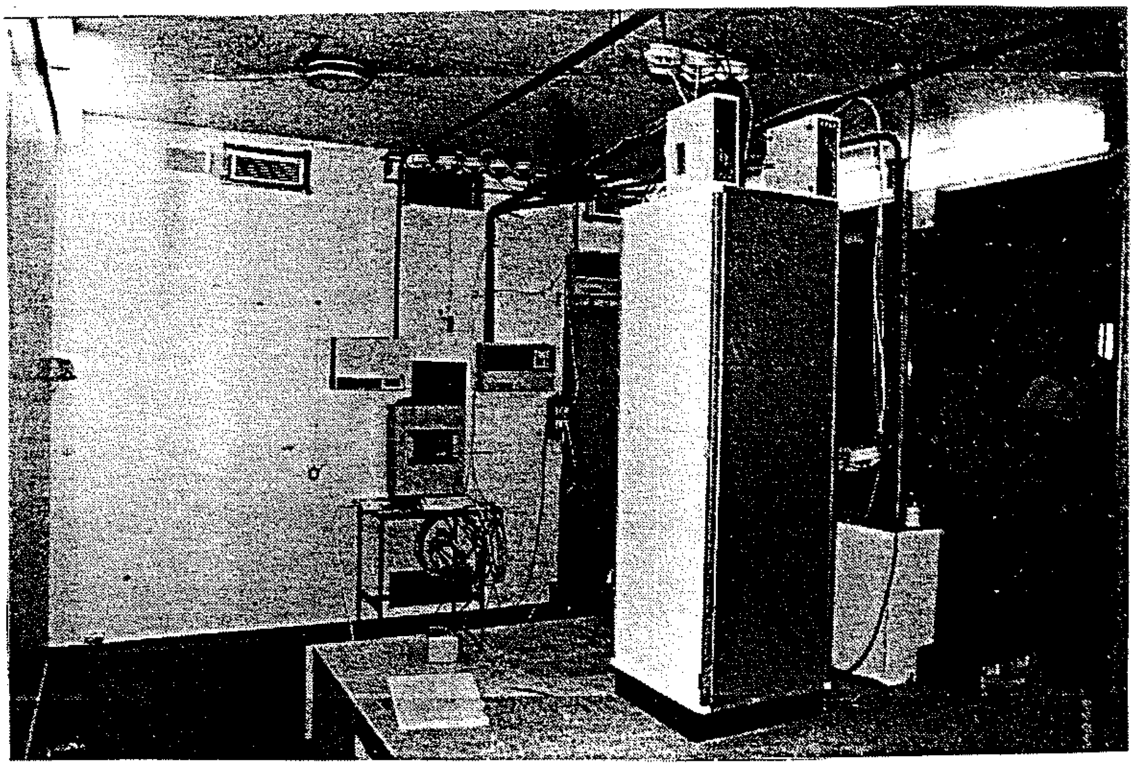
- Slower developing fires make more demands on detector choice and location than do fast-developing fires. For example, in test case 1.3 the ionic detector BJ-33/S located inside the electrical cabinet detected smoke 54 minutes earlier than the same detector type located above the cabinet.

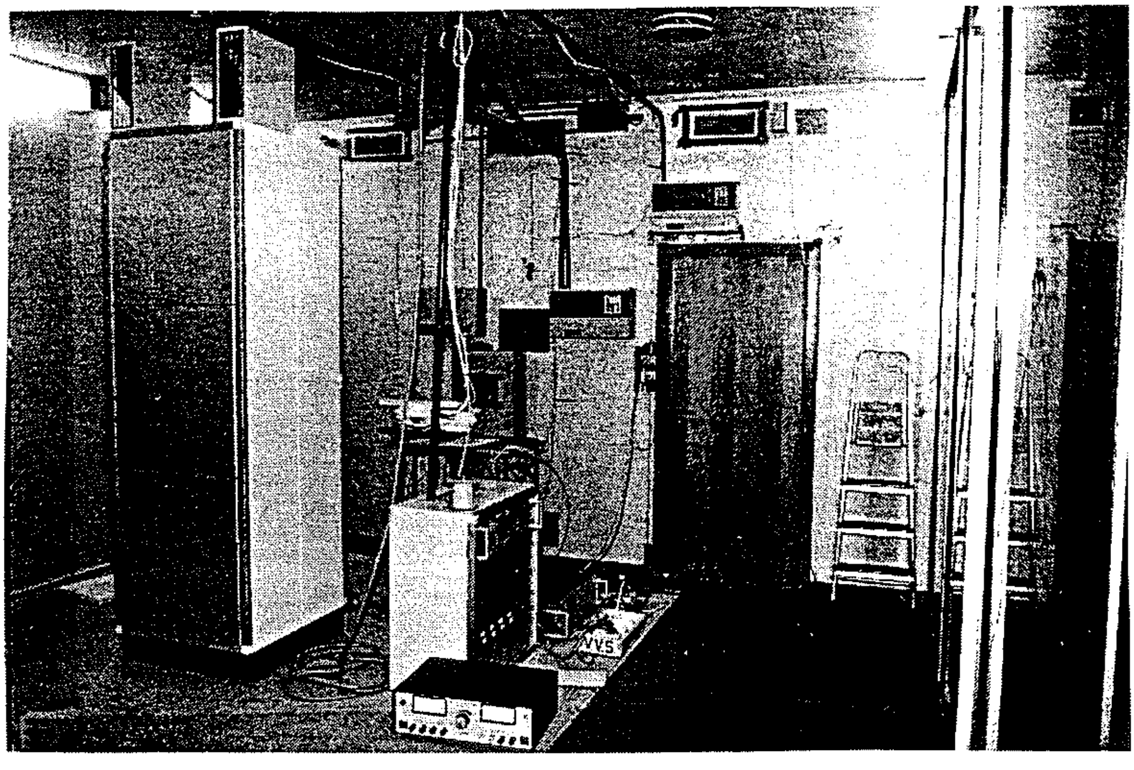
- Aspiration detectors which sample the air at may points in the air flow field, are advantageous in situations where it is difficult to place a detector inside or directly above the cabinet/object to be monitored.

Appendix A

Photos of detector locations

SINTEF





Appendix B

Photos of circuit board with overloaded resistors