THE DUTCH SAFETY BOARD

Fire, De Punt, 9 May 2008

Investigation into the deaths of three firefighters while tackling a fire

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The Hague, October 2009

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CONSIDERATION

During the afternoon of 9 May 2008 a unit of the municipal fire service of Tynaarlo turned out for a fire in a warehouse of a water sports company in De Punt. Although the firefighters did see smoke coming from the warehouse whilst driving to the site, the size of the fire seemed to be less serious than initially thought when they arrived. The commander took the decision to send four of his crew inside with the instructions to explore and to extinguish any sources of a fire they may find. Shortly after the officers entered the warehouse, they were caught unawares by a sudden explosive that made the fire spread. Three of the crew were caught by the fire and could not escape. They did not manage to escape from the burning building nor could they be rescued by their colleagues. After they had used their air supply, the three firefighters died.

The accident is linked to the fact that the firefighters were surprised by the sudden spread of the fire. After all, if they had been able to predict the sudden spread of the fire, they would not have entered the building and the accident would not have occurred. The commander and his crew, however, did not see any signs that pointed towards an approaching disaster. They interpreted the situation as being completely safe. The question that should now be asked is whether there were indeed no indications of a hazard and, should there have been some kind of indication, why the firefighters did not regard it as such.

The Dutch Safety Board reconstructed the progression of the fire as from the moment it was discovered until the sudden spread of the fire to answer this question.

1.1 Facts

The fire started in the storeroom; a separate room at the rear of the warehouse. The fire initially developed fiercely in the storeroom that was connected to the large warehouse room through one narrow door opening but the lack of fresh air meant that it was smothered. Such a type of fire that rages in a semi-closed room in which the oxygen supply is the limiting factor takes on a pulsating nature in which moments of sudden blazing fire and en mass emission of smoke alternate with smothering stages during which seemingly tranquillity prevails. Two of these cycles had taken place in De Punt before the fire brigade arrived. In the meantime, the fire produced much non-combusted toxic gases that flowed for many minutes through the open door of the storeroom to the large warehouse room and accumulated there below the roof at some distance of the fire. While the toxic gases were spreading below the roof, it mixed with fresh air to become an explosive air/toxic gas mixture.

When the fire service arrived, the fire was in an apparent phase of tranquillity. While a minute earlier the smoke was still leaving the building through the opening of the large tilting door, smoke could now not be seen at all at the front of the building. The commander and his crew interpreted the situation as being safe because they did not see the smoke concentration that was collecting below the roof. Four firefighters went inside with the instructions of exploring and extinguishing any sources of fire. Shortly after the firefighters had entered the warehouse, the fire in the storeroom reached the next peak phase and the smoke concentration below the roof of the warehouse explosively combusted. A fierce fire resulted over the full length of the warehouse. The fire concentrated itself in the large door opening so that the way back was cut off for the firefighters.

1.2 Cause of the accident

The Dutch Safety Board has identified the fatal sudden spread of the fire as a flue gas explosion. It could occur because a large quantity of non-combusted toxic gases collected at a distance from the fire and could mix with fresh air at this location to become an explosive air/toxic gas mixture, which, subsequently, actually exploded. A committee who investigated the fire at the instructions of the Municipality of Tynaarlo initially gave a different explanation for the sudden spread of fire but retracted this explanation in its final report.

The Dutch Safety Board, moreover, has arrived at the conclusion that when the commander (i.e. the person in charge) took the decision to fight the fire from inside, a seriously threatening situation was already involved. This situation, however, was not identified as such by the firefighters. They entered the building without being aware of the danger that was literally hanging over their heads. A minute or so later fate struck.

1.3 Lack of know-how

The Dutch Safety Board has asked itself why the firefighters were caught unawares by the gas explosion or, in other words, why they did not see the approaching disaster coming. The Dutch Safety Board has determined within this context that the risk assessment of the commander and his crew was based on their known hazard indications such as raising heat (that can lead to flashover) and relative level at which the building was shut (where opening the door can lead to backdraft) prior to deciding to enter the building. Heat, however, was not involved in any way and the door to the warehouse was already open; it was even wide open. The firefighters, therefore, assumed the situation was safe and went inside without hesitation. This fatal decision was not taken from carelessness but rather from ignorance in the opinion of the Dutch Safety Board. The firefighters were not aware of the gas explosion phenomenon and were, therefore, not capable of recognising the signs that indicate that this phenomenon can occur. A lack of know-how has, therefore, led to insufficient observation and the incomplete observation, subsequently, led to an inadequate risk assessment.

1.4 Fire service training subject matter

The involved firefighters had all the national diplomas that are legally mandatory for holding their ranks and to perform their duties. They were, therefore, trained in accordance with the applicable standards. The Dutch Safety Board has, therefore, concluded that the cause of their lack of know-how did not reside with the firefighters themselves or the Municipality of Tynaarlo that is responsible for training its personnel as the employer. The Dutch Safety Board verified the content in relation to the package of standard study material (linked to the mandatory fire service examinations) where it turned out that only flashover and backdraft were mentioned with regard to the different forms of a sudden spreading of fire and that the toxic gas explosion phenomenon as took place in De Punt was missing in the standard study material.

Know-how about the different forms of sudden spreading of fire is of primary importance to ensure a correct assessment of the risks is possible when considering an internal attack within a structure. The officer in charge must consider those risks in comparison to the expected yield of an internal attack within a structure: rescue of victims and/or retention of equipment. The commander or the officer in charge, however, finds little help in arriving at a responsible and safe choice between carrying out an internal attack within a structure or not in the study material.

Of the series of fatal accidents in which the Dutch fire service has been involved the past few decades most occurred when carrying out an internal attack. Within this category, most of the victims by far fell from amongst fire service personnel due to a sudden spread of the fire. The Dutch Safety Board has the suspicion that a toxic gas explosion was involved in a number of these cases as occurred in the De Punt case. This cannot be stated with absolute certainty because a toxic gas explosion has not been recognised as such up to now and, therefore, it has not been registered.

1.5 Know-how and study material development

Firefighters who operate inside structures are exposed to serious risks including elements collapsing, disorientation and types of sudden spreading of fire. Since the toxic gas explosion phenomenon is not included in the subject matter of standard fire service training, the Dutch Safety Board has asked itself which parties are the indicated ones to include this phenomenon in the curriculum and teaching material.

With regard to the quality of fire service personnel, shared responsibility is involved: the municipality is responsible for training its personnel as the employer while the Dutch Minister of the Interior and Kingdom Relations is responsible for the training system. The Minister has set frameworks with regard to content through the fire service examination regulations for training purposes; the fire service examination agency (Nbbe) tests whether the candidates meet the requirements on behalf of the Minister. The Minister has given the responsibility for the specifics for these frameworks or, rather, the care for the subject matter for all fire service training to the Nederlands Instituut voor Brandweer en Rampenbestrijding (Nibra; Netherlands Institute for Fire Service and Disaster Management, which later became the NIFV, Nederlands Instituut Fysieke Veiligheid; Netherlands Institute for Physical Safety). The Dutch Safety Board would like to note within this context that this care has not been added to the statutory tasks of the Nibra (NIFV) with the exception of officer training. Both know-how development and study material production have always remained permitted tasksfor the Nibra (NIFV) and not legal ones (in accordance with the Dutch Fire Services Act 1985), which in practical terms means that structural funding for the execution of this task has not been arranged. The Dutch Safety Board is of the opinion that the NIFV must be enabled (legally) to perform these tasks optimally in the interest of the safety of fire service personnel.

A limitation of the current system is that not all sources of know-how are sufficiently used. A structured input of innovative know-how coming from science and scientific literature, for example, is not available. Connections with international scientific and technical institutions are required for this. Excellent literature is available in the field of the sudden spread of fire, in particular, from Sweden and the United Kingdom but this information is not within the reach of the Dutch fire services through the study material. For that matter, the Dutch Safety Board has come to realise that the study material for the fire services is also lagging behind in other European countries with regard to technical/scientific know-how development. Sweden is the leading exception with regard to this; Swedish firefighters have been taught and trained for many years now in all types of the sudden spread of fire including toxic gas explosions. As the second European country, the United Kingdom has also now decided to update the study material with regard to the sudden spread of fire. The Netherlands could be the third country to follow suit due to the fire in De Punt. The Dutch Safety Board is, for that matter, of the opinion that the European umbrella organisations for the fire services can have a useful role with regard to a better distribution of new know-how and insights.

A second category of innovative know-how concerns empiricism, which can produce a systematic registration and assessment of fires and accidents. This would, in the opinion of the Dutch Safety Board, also entail a good option to strengthen know-how development for the fire services. It is true that up to now assessments of fire service performance become available mainly in the form of reports from the Dutch Public Order and Safety Inspectorate but lessons learned that arise from these assessments do not always find their way into the study material of the fire services. Recently, a few fire service organisations (Apeldoorn, Rotterdam, Tilburg and Enschede) have taken the initiative of systematically investigating fires to learn lessons from them. This example deserves to be continued but the Dutch Safety Board would like to point out the disadvantages of having a fragmented approach in place. If many local fire service organisations start to carry out investigations independently, investigation results will not be shared as a matter of course let alone be processed in the study material. Local differences have arisen with regard to the execution, which have made it difficult to compare or compile investigation results. Fires can be investigated uniformly and can form an immediate link with the body that transfers the results of the investigation to the study material when a central approach is used, for example, by having a supraregional organisation take charge of the investigation.

1.6 General conclusion

The subject matter of the fire service training material is incomplete with regard to “internal attacks” and the related risks of the sudden spreading of fire. The study material deserves to be supplemented with regard to this issue where the sources of new know-how such as international literature and fire and accident studies can be better used.

Incomplete professional knowledge can lead to inefficient and basically unsafe work performance. Fire risks that we are not sufficiently aware of, will not be recognised in practical terms either. The accident in De Punt was the tragic consequence of this.

RECOMMENDATIONS

Prior observation: The Dutch Safety Board has taken cognisance of the intentions of the Minister of the Interior and Kingdom Relations (letter to the Dutch House of Representatives dated 3 June 2009) to put the care of the supraregional tasks with regard to the fire services in the hands of a support organisation to be newly established and to place it under the responsibility of the joint security regions and/or the Veiligheidsberaad (Safety Consultation Organisation).

The Dutch Safety Board would like to note within this context that when responsibilities are really transferred, the recommendations below that are now directed to the Minister of the Interior and Kingdom Relations are also automatically intended for the new responsible party.
The Dutch Safety Board is aware of the Lerend Vermogen Brandweer (Fire Service Learning Capability) Programme and the proposed rules and regulations with regard to the quality care in the security regions. The recommendations below form a supplement to these.

Recommendations made to the Dutch Minister of the Interior and Kingdom Relations

1. Ensure that there is an effective distribution of new know-how in the area of the sudden spreading of fire including the toxic gas explosion phenomenon by processing it in the study and exercise material used by the fire services.

2. Ensure that the subject matter of the fire service training courses is aligned with international professional literature, in particular, with regard to the safety of repressive performance.

3. Improve fire service know-how development and increase within this context the attention paid to safety by ensuring that there is a systemic and central registration and assessment of fires and accidents and that the learned lessons that arise from this are processed efficiently in the study and exercise material used by the fire services.

4. Formulate the learning objectives in the examination regulations in such a way that they are unequivocal, guiding and inspiring to all parties who/that are involved in the design and execution of fire service training.

Recommendation made to the VNG (Vereniging van Nederlandse Gemeenten; association of Netherlands municipalities):

5. In anticipation of the amendment of the study and exercise material to be used by the fire services with regard to the sudden spreading of fire in general and toxic gas explosions in particular, provide your members with the awareness of the risks entailed by these phenomena and the conditions under which they may occur.

Pieter van Vollenhoven
Chairman of the Dutch Safety Board

Ms M. Visser
General Secretary

LIST OF ABBREVIATIONS

A

AI	Labour Inspectorate
Arbo	working conditions
AS	appliance

B

BLEVE	Boiling Liquid Expanding Vapor Explosion
BM	chief fireman
BWT	fireman on duty
BWT1	fireman on duty first class
BZK	Ministry of the Interior and Kingdom Relations

C

°C	degree Celsius
CDR	commander
COHb	carboxyhaemoglobin

D

DGMR	Consultancy for construction, industry, traffic, environment and software
DIN	Deutsches Institut für Normung

E

EFSCA	European Fire Services Colleges Association
EN	European standard

F

FEU	Federation of the European Union Fire Officer Associations
FRS	Fire Research Station (VK)

G

GHOR	Medical Aid for Accidents and Disasters

H

HBM	manager chief fireman
HBT	manager chief fireman on duty

I

IOOV	Public Order and Safety Inspectorate
ISO	International Organization for Standardization

K

°K	degree Kelvin
kW	kilowatt

L

LEL	lower flammability limit
LEL	Department for teaching and subject material
LOBO	National consultation platform for education firemen
LPO	National platform for regional training coordinators

M

MJ	Megajoule
MW	Megawatt

N

Nbbe	Netherlands Bureau for Firefighting Exams
NFPA	National Fire Protection Association (VS)
Nibra	Netherlands Institute for Firefighting and Disaster Management
NIFV	Netherlands Institute for Safety Nibra
NVBR	Netherlands Association for Firefighting and Disaster Management

O

OBM	adjunct chief fireman
OM	Public Prosecutor’s Office
OvD	Duty Officer

P

PUR	polyurethane foam

R

RAC	Regional Emergency Centre
RBA	National Academy for the firebrigade
RI&E	risk inventarisation and evaluation
RRC	Board of Regional Chief Fire Officers

S

SBOiN	Foundation firebrigade training netherlands
Stb	Bulletin of Acts, Orders and Decrees
SZW	Ministry of Social Affairs and Employment

T

TAS	fire engine
TS	fire engine

U

UEL	upper flammability limit

V

VNG	Association of Netherlands Municipalities
VROM	Ministry of Housing, Spatial Planning and the Environment

W

WBC	thermal imaging camera

Z

ZBO	autonomous administrative authority

1. INTRODUCTION

On 9 May 2008 at approximately 14.15 hours, a unit from the municipal fire service of Tynaarlo was called out to a fire in a shed at a water sports company in the village of De Punt. Although the fire service could see a lot of smoke coming out of the shed as they were driving towards the scene, on arrival the extent of the fire did not seem to be all that bad. The officer-in-charge decided to send four of his crew inside in order to investigate and extinguish the seat of the fire if found. Shortly after entering the shed, the firefighters were taken unawares by a sudden spread of the fire. Three of them were trapped by the fire. They were unable to escape from the burning building or to be rescued by their colleagues. After they had used up their breathing air supply, the three firefighters died from asphyxiation.

The officer-in-charge and his crew did not foresee the sudden fire spread. The survivors declared afterwards that there were no signs to indicate the imminent tragedy: there was good visibility in the shed and the only smoke of any significance was at the back; there was no elevated temperature and the large door to the shed stood wide open. The firefighters took the situation to be perfectly safe.

1.1 Reason for the investigation

Since the end of the 1970s, firefighting from inside a property, so-called inside fire attack, has become standard procedure for the Netherlands fire service. The reason for this is that the method is fast and effective: in practice, choosing the alternative - outside fire attack - is akin to abandoning the burning building. In addition, inside fire attack may be necessary in order to rescue any victims.

These clear advantages of inside fire attack are set against the risks involved. Firefighting from inside a property is a precarious business. Broadly speaking, there are two hazards which threaten a firefighter: collapse of the building which can result in him being engulfed, and sudden fire spread which can result in the firefighter becoming disorientated or trapped. The accident in De Punt fell into the latter category.

The accident in De Punt was not an isolated incident. Since 1980, 22 firefighters have died carrying out an inside fire attack, most of whom lost their lives as the result of a sudden fire spread. The Dutch Safety Board saw this as sufficient reason to carry out an investigation into the accident in De Punt in order to find an answer to the following question:

- How did three firefighters come to lose their lives while fighting the fire in De Punt?

1.2 Investigative questions

It became clear even during the initial considerations that there was a connection between the fatal outcome of the firefighting operation in De Punt and the impossibility for the firefighters involved to foresee the sudden fire spread. For if the person in charge (the officer-in-charge) had been aware of the possibility that a sudden fire spread could occur, he would not have decided on an inside fire attack (as there were no victims to rescue) and the accident would not have happened. That brings the Dutch Safety Board to the following investigative questions:

- How did the fire service come to be taken unawares by the sudden fire spread?
- What possibilities are there to improve the ability of the fire service to anticipate sudden fire spread?
- What knowledge is available to the fire service relating to sudden fire spread?

1.3 Limitation of the investigation

The Dutch Safety Board defines the accident as follows: the occurrence of an unforeseen sudden fire spread as a result of which three firefighters became trapped by the fire.

In this respect, the Board does not regard the start of the fire as being part of the accident and therefore does not regard it as being part of the investigation either. The development of fires in buildings is taken to be a given that ought not to lead to firefighters losing their lives. Therefore the Board has not investigated the cause of this fire.
For similar reasons, the investigation does not include the actions of the fire service after the development of the emergency situation. No rescue action would have had any effect on the accident or the problem resulting from it.

1.4 Method

In order to be able to answer the questions as to how the sudden fire spread was able to take the fire service unawares, why the fire service did not see any indications warning them of the sudden fire spread and whether there were any such signals, it is necessary to understand the mechanism of the fire and its development. For that reason, an important part of the investigation involved putting together a reconstruction of the fire and the sudden fire spread. In order to do this, the Dutch Safety Board listened to the evidence of people who had been witness to the early stages of development of the fire, i.e. during the period before the first fire service unit appeared on the scene. These included members of staff working for the water sports company, one of the owners, customers of the company and a person who happened to be passing by. Information relating to the burning object (the shed) was obtained from one of the owners and from the contractor who built the property. The Board collected photographic material showing the burning object both before and during the fire. Finally, another important source of information was the building itself and the evidence left within it by the fire.

The reconstruction of the fire was supported by the Laboratory for Fuel Technology and Heat Transfer at the University of Ghent (B).
For the purpose of reconstructing the actions of the first fire service unit and relating the actions of the fire service to the behaviour of the fire, interviews were conducted with the officer-in-charge and with the three remaining members of his crew. Because none of the other fire service units arrived on the scene until the sudden fire spread had taken place, these have also been left out of consideration.
One of the three firefighters who died was carrying a thermal imaging camera, an instrument that identifies objects which differ in temperature from their environment, during the inside fire attack. The thermal imaging camera was later found in the burnt-out shed. In order to find out whether any digital images were still stored on the camera, it was given to a laboratory specialising in that field. However, that investigation showed that there was no facility for storing image data on the camera (appendix 6).

In order to find out what knowledge is available to the fire service relating to sudden fire spread, an inventory was drawn up of all the teaching material, formal and informal, on this subject. This part of the investigation was supported by the Netherlands Institute for Safety, Nibra.

1.5 Other investigations into the fire in De Punt

1.5.1 Labour Inspectorate

The Labour Inspectorate carried out an investigation into the way action was taken by the fire service in relation to the accident and into the role of the municipal executive[1] which, as their employer, is responsible for the conditions within which the fire service personnel have to carry out their work.
The Inspectorate was unable to find any connection between a violation of the Working Conditions Act by the Executive or officials from the municipality of Tynaarlo and the occurrence of the fatal accident.

1 In this case, the Municipal Executive of Tynaarlo. Both the village of De Punt where the accident happened and Eelde where the barracks of the fire service unit involved in the accident is based are located within this municipality.

1.5.2 VROM Inspectorate

The VROM Inspectorate carried out an investigation into the granting and enforcement of the building permit and environmental permit for the boatshed in De Punt. The Inspectorate found shortcomings in respect of the granting of the permits as well as inspection and enforcement in respect of building regulations. The Inspectorate did not find any deviations from environmental legislation. The Inspectorate has stated that it was unable to find any connection between the shortcomings found and the start and development of the fire.

1.5.3 Public Prosecutor's Office

The Public Prosecutor's Office has been carrying out an investigation into any criminal offences connected with the occurrence of the fire. One of the owners of the water sports company was sentenced to three months in prison as a result of the incident. Both the owner and the Public Prosecutor's Office have lodged an appeal against the conviction. KEMA helped the Public Prosecutor's Office with the technical part of this investigation.
As yet, the Public Prosecutor's Office has not carried out an investigation into the occurrence of the fire in relation to the accident involving the three firefighters[2].

1.5.4 Helsloot committee (municipality of Tynaarlo)

Through the NVBR[3], the Netherlands Association for Firefighting and Disaster Management, the municipality of Tynaarlo set up a committee of experts chaired by Prof. Helsloot from Amsterdam and asked this committee to carry out an exploratory investigation into the origin and development of the fire and the deployment of the fire service in relation to their training and proficiency.
On 18 June 2008, so six weeks after the fire, the Helsloot committee published its findings in the form of a quick scan. The main conclusions drawn by the committee were as follows:

- The 'sandwich panels' which had been used for the roof of the shed played an important part in the unexpectedly rapid spread of the fire. These building components pose considerable risks in the event of a fire. The fire service was not aware of this risk.
- When the inside fire attack started, smoke was already present below the roof of the shed but for various reasons, it was not clearly visible to the fire service.
- Firefighters always carry out an inside fire attack unless there are clear indications that it is unsafe to do so. There were no such clear indications in De Punt. Therefore any firefighter would have taken the same action in that situation.
- There was no way to rescue the three victims because it was not possible to get sufficient equipment to the scene in time.
- The rescue and salvage operations were not coordinated satisfactorily. The fire service officers involved did not have sufficient skills for this. According to the committee, the latter conclusion is valid on a national scale.
- Nationally, the fire service does not have effective practiced emergency procedures to be followed if its own officers go missing.

The committee assessed the actions of the firefighters in De Punt. It was concluded that the officer-in-charge from the first fire service unit to arrive did not indeed assess the situation effectively, that no coordinated rescue action was carried out and that the Officer on Duty (OvD) did not fulfil his supervisory role. Nevertheless, the committee does not attach blame to anyone because the firefighters were lacking in knowledge, they were not practiced enough in handling emergency situations and in view of his training and experience, not much could be expected of the Officer on Duty.

Therefore the recommendations made by the Helsloot committee focus primarily on the organisation of the fire service at national level. One of the statements made by the committee is that the fire service will have to invest in firefighting skills, increase its knowledge relating to these and adapt procedures, teaching material, training and exercises to this knowledge.

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2 Status as in September 2009
3 Netherlands Association for Firefighting and Disaster Management

The committee only provides a limited answer to the question as to the lack of what knowledge played a role in the fatal outcome of the actions of the fire service in De Punt. It mentions the hazard of the 'sandwich' roof panels that the fire service was not aware of but does not, for example, specify that the strong development of smoke encountered by the firefighters as they arrived on the scene should also have been identified as an indication of risk.

The Helsloot committee focuses mainly on the human actions taken and searches for explanations in cognitive scientific theories relating to observations, the processing of information and decision-making under pressure. The report issued by the committee is less emphatic in its analysis of the development of the fire and the fatal acceleration that occurred during this development. Because the reconstruction of the fire is not complete, the committee cannot specify the knowledge that would have enabled the fire service to carry out the most effective action required in order to prevent the accident.

The Dutch Safety Board carried out calculations for the committee's scenario which sees the outgassing roof panels as the cause of the accident, but is only able to conclude that the sandwich roof panels only contributed marginally to the sudden fire spread. The calculations relating to this scenario can be found in appendix 4.

On 15 April 2009, the Helsloot committee issued a second, more comprehensive report on the fire in De Punt. Besides the fire and the accident, this report also looks at the large-scale efforts of the fire service, the actions of the emergency services, instructions and after-care. The crucial role of the sandwich panels, as pointed out in the first report, does not appear in the second report. In the second report issued by the committee, the explanatory statements made regarding the sudden fire spread largely correspond to those made by the Dutch Safety Board.

1.5.5 DGMR

Following the issue of the report by the Helsloot committee, a number of producers of insulating materials, having united to form the 'Knowledge Platform on Insulation in De Punt', commissioned the consultancy company DGMR to carry out further investigation into the possible role of the sandwich panels.

DGMR issued a report in September 2008 and concluded that the conclusion drawn by the Helsloot committee, that outgassing sandwich panels caused the sudden fire spread in the shed, was not based on facts.

2. FACTUAL INFORMATION

On Friday 9 May 2008 at 14.10 hours, the volunteer fire service from Tynaarlo, stationed at Eelde, is called out to a fire at company B in De Punt (municipality of Tynaarlo) by the Regional Emergency Centre (RAC) in Drenthe. The water sports company is known to the local fire service.

A good four minutes after the alarm is raised, the first fire service vehicle leaves the barracks at Eelde. On board are an officer-in-charge, a driver/pump operator and five crew members[4]. According to procedure, the first four members of the crew are given the job-related numbers 1 to 4 inclusive.
Two of the crew members know the shed well; one even knows it very well because he used to work on stock cars there on a regular basis. On their way to the scene, this person tells his colleagues about the risky items which are present in the shed: acetylene and other gas cylinders, motor fuels, paint and other flammable liquids.

On approaching the fire (almost seven minutes after the alarm is raised), the firefighters see a considerable quantity of light brown smoke coming out from the back of the elongated (75 m) shed. The smoke is not rising as a plume but remains close to the ground, 'rippling' in a north-westerly direction so to speak. The officer-in-charge reports the smoke to the RAC and notifies the RAC that the fire is a 'medium-sized fire', which means that he considers it necessary for a second fire service unit[5] to attend the scene. When the vehicle gets to the roundabout next to the shed, the officer-in-charge notices that the smoke is travelling straight across the road and that it is so thick that it is hindering traffic. The officer-in-charge asks the RAC to arrange for the road to be closed.

The appliance then turns onto the industrial site. The driver stops the vehicle in front of the shed to the right of an eight metre wide roller door which is wide open. The crew get out. Now they cannot see any smoke. A policeman already present tells the officer-in-charge that there is a fire in a room on the left at the back of the shed. He also says that there are no people left in the building.

The firefighters can see inside through the large door opening. They notice that visibility is perfectly good in the shed: only at the very back of the elongated area on the left-hand side do the men see a small quantity of thin smoke of the same brownish colour as the smoke which was also visible outside.

During a brief conversation with the crew, the officer-in-charge decides what action to take. Based on his observations at the front of the shed and the perceived absence of hazards (they have observed not much smoke, no fire, no high temperature and an open area in which visibility is good), he decides to carry out an inside fire attack[6]. The officer-in-charge sends four of his crew inside with instructions to 'investigate and extinguish the seat of the fire if found'[7]. The officer-in-charge himself goes to investigate the outside.

The driver/pump operator takes up his position at the back of the vehicle in order to operate the pump and the 'fifth crew member' runs in the direction of the road in order to look for an underground fire hydrant.

The four men, who have put on their breathing apparatus while driving along, run inside one after the other. 'Number 1' is carrying a thermal imaging camera, an instrument that is used to locate sources of heat like the seat of a fire. 'Number 2' is carrying with him a fire hose (a so-called high-pressure hose). Because he has to drag the hose along, he finds it hard to keep up with his colleagues. "Not so fast!", 'Number 2' shouts to them[8].

4 This is one crew member more than the national standard.
5 In this case, even a *third* fire service unit because a second vehicle had already left Eelde fire station. It is usual for two consecutive vehicles to turn out from Eelde.
6 'Inside fire attack' is fire service jargon for firefighting inside a property.
7 The deployment of a four-man crew differs from the national standard, which stipulates that two-man crews are to be deployed.
8 Evidence of the officer-in-charge. 'Number 2' himself cannot remember saying anything.

When the four are about 15 metres inside the shed, 'Number 2' notices that the fire hose is stuck. He gives the nozzle end of the hose to one of his colleagues while he himself runs outside in order to free the hose.
Outside, at the vehicle, he quickly uncoils a many metres of hose from the reel in order to give it some slack, while grumbling to himself that 'they are going too fast'[9]. He then goes back inside[10] where, with his back to his colleagues, he pulls on the hose again in order to drag the length of hose which he uncoiled into the shed.

At that moment, 'Number 2' experiences a powerful blast wave which causes him to fall forwards. Suddenly there is a column of fire and pitch black smoke. Metal sheets are falling down. 'Number 2' can no longer see but he knows that the door opening is in the direction of the hose which he was just pulling on. Following the hose, he crawls outside on his hands and knees.

'Number 2' has only just got out when the large overhead door crashes down. Standing in front of the shed, 'Number 2' feels an incredible heat. He wonders despairingly why his three colleagues have not come out, like him. He tries to contact them on his walkie-talkie but his calls go unanswered.

The officer-in-charge also tries to make contact with the three men in the shed but he notices that his walkie-talkie is not working, so he takes the walkie-talkie of his driver/pump operator. The officer-in-charge reports to the Regional Emergency Centre that his men are missing. The Regional Emergency Centre responds by increasing the level of deployment as a result of which more men and equipment are sent to the scene.

During the first 30 minutes after the sudden fire spread, no attempt is made to retrieve the three men from the burning building. Individual initiatives to enter via side doors are defeated when the conditions are judged to be too hot or too dangerous. Having arrived at the scene later on, the Officer on Duty (OvD) forbids anyone to enter the building on several occasions.

Further actions are limited to the use of hoses which are directed through door and window openings with the intention of bringing the temperature down, in the hope that the three may still be able to find a way out of the burning shed themselves.

After half an hour, when the fire has been subdued and the smoke has started to clear, the crew cautiously enter the shed. The three victims are then found in quick succession and brought outside. Attempts at resuscitation are unsuccessful – the three men are dead.

9 Same as the previous footnote
10 It is uncertain how far inside 'Number 2' gets when he re-enters the shed. According to the officer-in-charge, he did not get inside a second time at all but because the officer-in-charge had already started to investigate the outside at that time, this evidence is uncertain. Considering the position of the fire engine where 'Number 2' had just uncoiled a length of hose, the Board considers it likely that 'Number 2' had pulled the hose *in* or *in the vicinity of* the door opening.

14.09.04[11]	RAC[12] Groningen receives a report of a fire from one of the owners[13].
14.09.25	RAC Groningen relays the report of the fire to RAC Drenthe.
14.10.30	RAC Drenthe alerts the fire station in Eelde.
14.14.38	TS 31-11[14] answers the call. RAC to TS 31-11: "Fire in meter cupboard at company B."
14.14.58	Daughter of owner makes second report: "The area at the back of the shed is on fire. There is a great deal of smoke."
14.15.35	RAC to TS 31-11: "The back of the shed is fully ablaze".
14.16.16	Report made by someone living nearby to RAC: "There is a major fire opposite us".
14.16.44 14.17.10 14.17.37	RAC calls TS 31-11 on its way to the fire. RAC provides information on water supplies. TS 31-11 on approaching the shed: "I have sight of the building, I can see the smoke already. I would say it was a medium-sized fire". TS 31-11 on approaching the shed: "The road must be closed… the smoke is travelling across the road… it's very bad smoke…".
14.18.03	AS 31-31[15] turns out. RAC to AS 31-31: "prio1 due to water supply".
14.20.45	RAC calls TS 31-11. No response.
14.21.42	TS 31-11 to RAC: "Things have got completely out of hand. I have lost men from my own crew."

Table 1 Messages sent to and from the Regional Emergency Centre in Drenthe

11 The clock at the emergency centre in Groningen was running 4 seconds behind the one at the control centre in Assen. This has been corrected in the table. All the times specified in the table are according to the clock at the control centre in Assen.
12 RAC: Regional Emergency Centre
13 Tynaarlo is a municipality in the province of Drenthe. However part of the municipality, including Eelde, has the Groningen area code 050. As a result, reports made via a landline will be put through to the control centre in Groningen instead of the one in Assen.
14 TS 31-11: first vehicle from Eelde
15 AS 31-31: second vehicle from Eelde

3. ASSESSMENT FRAMEWORK

3.1 Introduction

The results of the investigation will be assessed based on an assessment framework. This framework has the following three constituent parts:

1. Relevant current laws and regulations in the sector within which the incident occurred;
2. Standards, guidelines and insights from that sector;
3. The safety management assessment framework of the Dutch Safety Board.

The first two parts of the assessment framework are sector-specific and their content is determined to a great extent by the type of incident. The third part of the assessment framework is a general part that describes the expectations of the Dutch Safety Board in respect of the way in which the parties involved implement their own responsibility for safety in practice.

3.2 Laws and regulations

3.2.1 Introduction

This section looks at current laws and regulations which are relevant to the repressive actions of the fire service and specifically the relevant knowledge required. In this particular case, this concerns the Fire Services Act, the municipal Fire Safety Regulations, the Working Conditions Act (3.2.2) and the Firefighters Decree (3.2.3).

3.2.2 Fire Services Act, Fire Safety Regulations and Working Conditions Act

The 1985 Fire Services Act forms the statutory basis of the fire service organisation. Section 1 of this act sets down the task of the fire service as being "to fight fire, in the broad sense of the word, as well as to fight hazards for people and animals in the event of non-fire-related accidents". The Fire Services Act does not specify how the fire service should carry out these tasks.
In addition, municipalities are obliged to draw up Fire Safety and Emergency Relief regulations within which the tasks and the scope of the personnel and equipment of the municipal fire service are to be defined. These regulations will not contain any procedures relating to the action to be taken by the fire service.

The Working Conditions Act governs the safety of employees. The employer, in this case the municipality of Tynaarlo, is obliged to look after the health and safety of its employees and to operate a policy that is aimed at ensuring the best possible working conditions (Section 3). The employer is also obliged to draw up a risk inventory and evaluation (RI&E) which must contain a description of the hazards involved, the risk limitation measures and the risks for special categories of employees (Section 5) amongst other things. All this also applies to the fire service. Because certain risks are unavoidable for the fire service when repressive actions are carried out, the fire service can invoke the so-called exemption clause in the Working Conditions Act. In brief, this clause stipulates that when preventing, containing or limiting an incident, the fire service may take risks in order to be able to carry out its tasks.

In order for the Working Conditions Act to be correctly applied to deployment too, the fire service must always weigh up the expected result against the risks of deployment. When trying to save lives, the fire service may take more risks than when trying to limit damage.

3.2.3 Firefighters Decree

The 1991 Firefighters Decree contains provisions relating to the appointment and training of fire officers. This Decree stipulates that the competent authority (municipal executive or the regional fire service board) may only appoint or promote a person to one of the positions if, in each case, that person holds a diploma relating to the training for the position in question as specified in the Decree on Firefighters' Training for National Exams (1988 Official Journal, 545). In other words: each fire officer must have been trained and examined at the appropriate level for his position.

3.3 Standards and guidelines

Because the Firefighters Decree lays down obligations relating to the training of all fire officers, the subjects taught as part of this training determine the knowledge available to firefighters to a considerable extent. In practice, the whole package of subjects is regarded as a normative framework for the way in which the fire service carries out its tasks, including the repressive actions it takes. The course material is published by the Netherlands Institute for Safety Nibra (NIFV). Chapter 7 looks at the content of the package of subjects for the fire service in more detail.

Besides the regular subjects taught (in preparation for the compulsory exams), the written course material also mentions other publications, the majority of which are also published by the NIFV, which do not come under the requirements from the Firefighters Decree and which the fire service is therefore not obliged to cover. Examples of such publications which cover subjects like sudden fire spread and other hazards associated with repressive actions include Flashover and backdraft (1999), Repressive ventilation (2002), Fire behaviour (2005) and A new look at the use of hose pipes (2008). Chapter 7 discusses the content of these textbooks, which could be regarded as informal guidelines.

3.4 Safety management

The Dutch Safety Board has five general considerations which are taken into account when investigating whether, and if so how, parties have implemented their own responsibility for safety. Safety management relates to the way in which organisations implement their responsibility with regard to safety, in addition to their compliance with applicable current legislation, standards and directives. It is about the way in which responsibilities are distributed and risks to the parties involved are mapped out and systematically managed, for example. In order to enable this process to be carried out and made transparent and to create opportunities for continuous improvement, a specific structure is required within the organisation. This structure is called the safety management system. Various incidents in the past have shown that the structure of the safety management system and the way in which the parties involved implement it play a crucial role in the management and maintenance and the continuous improvement of safety.

In its investigations, the Dutch Safety Board has five general safety considerations which are taken into account when investigating whether, and if so how, parties implement their own responsibility for safety. The Minister of the Interior and Kingdom Relations has been informed about this by the Dutch Safety Board in a letter[16].

1. Gaining a demonstrable insight into safety-related risks in order to create a basis for the approach to safety.
   The starting points for achieving the required level of safety are:
   - to explore the whole system, and
   - to draw up an inventory of the associated risks.

2. Demonstrable and realistic approach to safety.
   In order to prevent and manage undesirable events, a realistic and practical approach to safety (or safety policy) must be drawn up and agreed. This approach to safety is based on:
   - relevant current legislation;
   - applicable standards, guidelines and best practices from the sector, the organisation's own insights and experiences and the safety objectives set up specifically for that organisation.

16 Letter from the Dutch Safety Board to the Minister of the Interior and Kingdom Relations dated 17 November 2005, ref. OVV2005-010999

3. Implementing and maintaining the approach to safety.
   The approach to safety is implemented and maintained and the risks identified are managed by:
   - drawing up a description of the way in which the approach taken to safety is put into practice, focusing on specific objectives and including the resulting preventive and repressive measures;
   - a transparent, clearly defined and generally accessible assignment of responsibilities in respect of safety on the shopfloor with regard to the implementation and maintenance of safety plans and measures;
   - clear definition of the personnel and expertise required for the various tasks.

4. Tightening up the approach to safety.
   The approach to safety is to be continually assessed and tightened up based on:
   - (risk) assessments carried out periodically and at least after each and every change to the starting points used with regard to safety, observations, inspections and audits (proactive approach);
   - a system for monitoring, investigating and carrying out expert analysis of all aspects of near-accidents and actual accidents (reactive approach).

5. Management, involvement and communication.
   The management of the parties/organisations involved must:
   - ensure internally that expectations regarding safety objectives are clear and realistic and that there is support for the continuous improvement of safety on the shopfloor;
   - issue clear external communications regarding general procedures, the way of assessing these, procedures to be followed in the event of deviations, etc., based on clearly defined and documented arrangements with the local community.

4. PARTIES INVOLVED

4.1 Introduction

This section describes the main actors and outlines their responsibilities in relation to the fire in De Punt.

4.2 National organisations involved

This sub-section looks at the following actors:
- Ministry of the Interior and Kingdom Relations (BZK)
- Public Order and Safety Inspectorate (IOOV)
- Netherlands Bureau for Firefighting Exams (Nbbe)
- Netherlands Institute for Safety Nibra (NIFV)
- Netherlands Association for Firefighting and Disaster Management (NVBR)

4.2.1 Ministry of the Interior and Kingdom Relations (BZK)

The responsibilities of the Minister of the Interior and Kingdom Relations include being responsible for the quality of public administration and public order and safety (including the organisation of the police, fire service and crisis management). One of the tasks of the Minister of the Interior and Kingdom Relations is to check the way in which the administrative body of a municipality or a fire service region carries out its tasks relating to the prevention of, the preparation for and the fighting of a fire, accident or disaster.

The responsibility for checking on compliance with the rules regarding the safety, reliability, normalisation and standardisation of fire service and rescue equipment lies with officials appointed by the Minister of the Interior and Kingdom Relations. These appointed supervisory officials include officials employed by the Directorate for Firefighting and Disaster Management of the Ministry of the Interior and Kingdom Relations.[17]

The tasks of the Directorate for Firefighting and Medical Assistance in Accidents and Disasters of the Ministry of the Interior and Kingdom Relations are as follows[18]:
- To set quality and performance requirements for the organisation, the personnel and the equipment of the fire service organisation; these requirements are not (yet) anchored in law;
- To work on strengthening the administrative organisation of the fire service;
- To develop policy in respect of all the tasks of the fire service, with an emphasis on proactive and preventive measures.

Ministry of the Interior and Kingdom Relations and the training/examination of fire service personnel
The role of the Ministry of the Interior and Kingdom Relations in respect of the training and examination of fire service personnel is a complex one. In principle, it is left to the free market to develop and issue teaching materials but in practice, this is only carried out by the NIFV. A limited number of teaching materials published by the NIFV have been drawn up on the instruction of the Ministry of the Interior and Kingdom Relations. The Netherlands Bureau for Firefighting Exams (Nbbe, see also below) is responsible for and involved in the development of examination regulations. The Minister of the Interior and Kingdom Relations approves and finalises these regulations. The Minister monitors the quality of the examination process and the management of the Nbbe. After the exam has been held, the Nbbe advises the Minister on the awarding of diplomas to candidates.

Public Order and Safety Inspectorate (IOOV)
The Public Order and Safety Inspectorate supervises the way in which public order and safety are

17 Decree on officials, 1985 Fire Services Act
18 At the time of the incident in 2008

looked after at system level on behalf of the Minister of the Interior and Kingdom Relations. This supervision is directed at the way in which provincial, regional and municipal administrative bodies carry out their tasks. The IOOV does not check on compliance by the bodies. Strictly speaking, the IOOV could supervise the quality of the teaching materials used for fire service training. After all, it can address the public bodies that come under its supervision if the quality of the teaching materials that they use to carry out their tasks is suboptimal. However, that does not happen in practice.
The annual inspection programme containing priorities and topics is set up based on a risk analysis. The inspection activities which arise from this may include compliance with specific rules by (individual) bodies.
The IOOV carries out investigations into incidents, accidents and disasters as occasion arises.

4.2.2 Labour Inspectorate

The Labour Inspectorate (AI) forms part of the Ministry of Social Affairs and Employment (SZW). The Labour Inspectorate supervises the performance of tasks given to employers and employees under the Working Conditions Act. The main task carried out by the Labour Inspectorate in respect of the fire service is to investigate accidents at work. If the Labour Inspectorate comes across violations or criminal offences during these investigations, it takes appropriate enforcement action. If necessary, the Labour Inspectorate can work as an extension of the Public Prosecutor's Office.

4.2.3 Netherlands Institute for Safety Nibra (NIFV)

The Netherlands Institute for Safety Nibra is an autonomous administrative authority[19]. The institute provides officer training for the fire service which involves taking a national exam at the end. The institute is also involved in:

- the provision of other training in firefighting and disaster management culminating in a national diploma and assigned by the Minister of the Interior and the organisation of exercises in that field;
- the recruitment and selection of candidates for training programmes and courses;
- the development of teaching material and instruction methods for training purposes;
- the formulation of exam regulations for training which does not involve taking a national exam at the end;
- the development, maintenance and provision of expertise in firefighting and disaster management; and
- the performance of other activities to enhance the expertise of personnel in firefighting and disaster management or the operation of the organisations they work for.

The NIFV considers its mission to be 'to help prevent, limit and combat the violation of the safety of human beings and their surroundings in respect of (medical) assistance, fire, explosion, hazardous substances, forces of nature and infrastructure. This includes administrative and operational process management.'

Therefore the NIFV sees its task as being 'to develop knowledge and contribute towards professional development within the fire service, medical assistance in accidents and disasters (GHOR), crisis management and leadership development in order to improve physical safety.'

The NIFV has set up 'academies'. The Fire Service Academy develops teaching material and provides (officer) training, in-service training and exercises for the fire service. Readerships in Fire Engineering and Fire Prevention have been set up in order to promote exchange between research, education and the practising profession.

Readership in fire engineering
The purpose of the readership is to enable the integrated development of knowledge and skills relating to fire, the fire service and firefighting. Newly acquired professional knowledge and insights are applied as directly as possible in fire service training and in-service training and exercise programmes.

19 Section 18, 1985 Fire Services Act

NIFV Editorial Committee for Firefighting and Crisis Management
The NIFV manages documents which are published by the Ministry of the Interior and Kingdom Relations. The Editorial Committee for Firefighting and Crisis Management has been set up and given formal ultimate responsibility for the content of these documents.[20] The editorial committee is made up of representatives of the fire service, municipalities, the GHOR, the police, universities, the Ministry of the Interior and Kingdom Relations and the NIFV.

The tasks of the editorial committee include the appointment of editorial teams. These teams draw up both binding and advisory (draft) (knowledge) documents relating to the knowledge domains 'proaction and prevention', 'preparation, repression and after-care' and 'disaster management and medical assistance in accidents and disasters'. An editorial team consists of independent members with content-related and/or practical knowledge of subjects from the relevant knowledge domain. After being drawn up by the editorial committee, the definitive binding documents are decided on by the Minister of the Interior and Kingdom Relations and the chairman of the Safety Umbrella Organisation (Safety Consultative Body). The editorial committee has a secretary who makes proposals regarding activities for promoting the implementation of documents and increasing support for them.

4.2.4 Netherlands Association for Firefighting and Disaster Management (NVBR)

The Netherlands Association for Firefighting and Disaster Management is the industry association of and for firefighting and disaster management in the Netherlands. The association has set up a network or project group for each topic made up of people from the field with specific expertise on the topic in question. The key tasks of the association are:
- to look after the interests of the fire service profession;
- to organise collaboration within the fire service field;
- to supply services and individual service to the members;
- to control and manage the association.

The board of the NVBR is assisted by the Board of Regional Chief Fire Officers on which the chief fire officers from the 25 fire service regions sit. In addition, the board is advised by the advisory board which consists of two local fire service commanders from each region.

As an industry association without any powers of assertion, the NVBR serves as a network organisation for its members. The highest decision-making body is the Board of Regional Chief Fire Officers (RRC). The RRC appoints relevant topics and creates programmes which are developed within networks and work and project groups. The NVBR has been the initiator of, or involved on behalf of the industry in, a large number of projects, ranging from multidisciplinary training and exercises to information management. The Project on the Quality of Fire Service Personnel in which the NVBR, the BZK, VNG, NVBR, NIFV and Nbbe are involved is one of the most striking projects.

Each programme is controlled by a programme board on which the Board of Regional Chief Fire Officers and NVBR networks are represented. Firefighting is one of those programmes and it is specifically targeted at the fire service column. In particular, this programme is responsible for the repressive tasks of the fire service and is therefore the programme most relevant to this investigation.

The Firefighting programme board covers five networks including the Training and Exercise Network. This network is involved in:
- the National Fire Service Training Board (LOBO). This board carries out adjustments between representatives of the regional training institutes, the NIFV and the Nbbe. Knowledge and experience relating to fire service training are also exchanged within this forum. The LOBO was recently involved in the realisation of the National Protocol for

20 From the NIFV annual report for 2007: In 2007, the Editorial Committee for Firefighting and Crisis Management approved the following documents:
- Assistance with Preparations For Handling Train Incidents
- Containment of Fire
- Training Guide (status change)
- Vision on fire safety in cells and cellular buildings
- Vision on fire safety in healthcare buildings

Life-Saving Actions by the Fire Service. In addition, the LOBO approved the participation of four members of the LOBO in the pilot project crew A.

- the National Platform for Regional Exercise Coordinators (LPO). The task of the LPO is to provide advice and carry out monitoring activities and it has played an important role in the adoption of the Training Guide.

4.2.5 Netherlands Bureau for Firefighting Exams (Nbbe)

The Netherlands Bureau for Firefighting Exams (Nbbe) has been an autonomous administrative authority since 1994 and its task is to look after the development, implementation, organisation and holding of national exams relating to the fire service, medical assistance in accidents and disasters and disaster management. The Nbbe is also involved in issuing exemptions and certificates, determining exam results and providing advice to the Minister of the Interior and Kingdom Relations regarding the awarding of diplomas.[21] The Nbbe is responsible for the development of exams, the organisation of exams, supervision during exams and the assessment and determination of results up to and including the awarding of certificates and diplomas. Because of its task as the examiner of fire service education in the Netherlands, the Nbbe fulfils a crucial role in the realisation of training within the Netherlands Fire Service. The Nbbe is the only body in the Netherlands – at least within the current set-up of fire service education – that is allowed to hold exams. With a very limited number of exceptions, i.e. for fire service divers, diplomas or certificates are valid for an indefinite period.
The Nbbe is dependent on examination fees for its financing. External financing (through grants) is applied for for development activities, such as e-learning.

4.2.6 Association of Netherlands Municipalities (VNG)

The Association of Netherlands Municipalities has a general assembly, a board, a board of directors, a Labour Affairs Board (CvA), permanent policy committees, provincial departments and advisory committees.

The tasks of the VNG are as follows:

- To look after the interests of all the municipalities under different types of government. The lower house of the Netherlands' parliament, the Cabinet and social organisations are important partners.
- To provide services: to advise all the members on the latest developments (proactively) and to provide advice for individual members (on request).
- The platform function is exercised via VNG committees, provincial departments, conferences, seminars and consultations with members.

4.3 Regional organisations involved

This section looks at the regional actors:

- Safety Region of Drenthe
- Drenthe Fire Service
- Municipality of Tynaarlo

4.3.1 Safety Region

The Safety Region[22] is responsible for firefighting, medical assistance in accidents and disasters (GHOR), disaster management and crisis management and the management of a single control centre for the police, fire and ambulance services. The organisation focuses on physical safety, disaster management and crisis management in the region. The mayors of all twelve municipalities in Drenthe sit on the safety board.

21 1985 Fire Services Act, article 18g, second paragraph
22 The Safety Regions Act will come into force in 2009. There will then be 25 safety regions, to match the police regions.

4.3.2 Drenthe Fire Service

In Drenthe, the twelve municipal fire brigades work together. The twelve fire brigades in Drenthe operate a total of 36 fire stations (one of which, in Emmen, is manned 24 hours a day). Most of the fire stations are manned by volunteer firefighters (paid members of staff on call). These volunteers come to the barracks when called up to answer a call. The municipality of Tynaarlo has three fire stations: Eelde, Vries and Zuidlaren. The Tynaarlo fire service has approximately seventy firefighters, all volunteers. Approximately twenty firefighters are attached to the Eelde fire station which is nearest to De Punt. The station has a station chief, a deputy station chief, officers-in-charge, drivers and crew members who have trained, or are being trained, as sub-leading firefighters.
The basis of a fire service unit is a appliance. Each fire station has at least one appliance. A unit is under the command of an officer-in-charge who decides on how to deploy his men. If a number of units are deployed, an officer on duty takes over management of the operation. However, the officer-in-charge will remain in charge of his own crew.

4.3.3 Municipality of Tynaarlo

Under the Fire Services Act, each municipality has a municipal fire service. The municipal executive controls the organisation, management and task of the municipal fire service. In each case, the rules regarding organisation relate to the scope of the personnel and equipment of the municipal fire service.

The municipal executive has the task of appointing, suspending and dismissing the personnel of the municipal fire service.
As the portfolio manager within the municipal executive[23], the mayor is responsible for: a. the prevention, containment and fighting of fire, the limiting of fire risks, the prevention and limitation of the consequences of accidents involving fire and all related issues, and b. the limitation and combating of risks for people and animals in the case of accidents not involving fire[24].
The municipality of Tynaarlo laid down the rules with regard to the tasks and organisation of the fire service in the Fire Safety and Emergency Relief regulations in 1999.

Under the Working Conditions Act, as an employer the municipality is obliged to look after the health and safety of its fire service personnel. This duty includes drawing up a risk inventory and evaluation (see section 3). The municipality of Tynaarlo produced the latest version of its risk inventory in February 2008.

In its capacity as an employer, the municipality is also responsible for ensuring that fire service personnel are properly equipped to carry out their task. This also includes training and proficiency ('instruction', article 8 of the Working Conditions Act). However, the municipality is not responsible for the content of training. As already mentioned, the Minister of the Interior and Kingdom Relations defines the exam requirements in exam regulations, based on which the NIFV determines the content of the teaching material. The Nbbe determines whether the candidates have met the requirements and advises the minister on this. The minister awards the diplomas[25]. The municipality is not involved in the process.

23 Within the municipal executive, the mayor usually has firefighting in his portfolio. In the event of a fire, in the operational situation, he has ultimate responsibility as the commander-in-chief.
24 1985 Fire Services Act, article 1
25 1985 Fire Services Act, article 15

5. RECONSTRUCTION OF THE BEHAVIOUR OF THE FIRE

5.1 The burning object

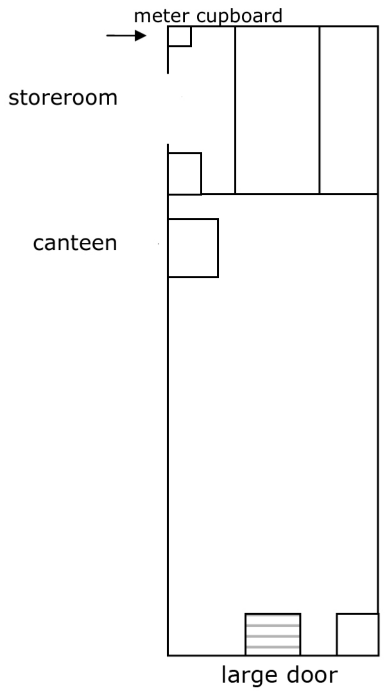


Fig. 1 The shed

The burning object is a large shed (25 x 75 m) which is used to garage and carry out maintenance on recreational boats. The wall of the shed consists of a brick wall 1.2 m high and single-walled steel cladding up to a height of 5.5 m. The gable roof with a ridge height of 8.5 m consists of double steel panels filled with polyurethane foam (PUR), so-called sandwich panels, which are supported by a steel support structure with wooden cross-beams.
At the back of the shed are three smaller rooms, each 20 m deep, separated from the main shed area by means of an internal stone wall. The ceiling in these rooms, consisting of wooden beams with 'underlaid' wooden boards, is also the floor of the attic above. The attic is open to the large shed area.
The room at the back on the left-hand side is a storeroom which was also used as a maintenance area for stock cars (see photograph 3). On the left-hand side at the back of this area is a wooden meter cupboard containing safety fuses, an electricity meter and a gas meter. The top section of the outside wall, as well as the ceiling, is thermally insulated with spray polyurethane.
At the front of the shed is a large overhead door measuring 8 x 5 metres. This door was open during the fire.

Photograph 1   Front of the shed with overhead door open

Photograph 2   Front of the shed after the fire. The hole above the door opening was created at the time of the sudden fire spread when part of the front was blown out.

Photograph 3 The inside of the storeroom. On the left-hand side at the back, with the door open, is the meter cupboard where the fire started. The yellowish coating on the higher parts of the walls is exposed polyurethane foam.

Fig. 2a. Cross-section of the shed

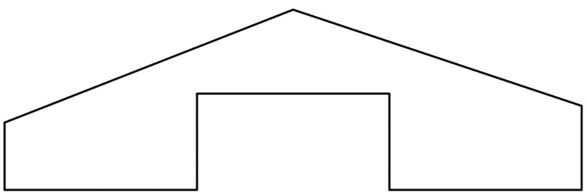


Fig. 2b Front of the shed with door opening

5.2 The behaviour of the fire prior to the arrival of the fire service

The fire started at the site of the meter cupboard[26], on the left-hand side at the back of the storeroom. No-one was present in that area at that time. However, three of the company's employees were working at the back of the large area in the shed. At about 14.07 hours (appendix 3), one of them was going towards the canteen when a crackling noise caught his attention and he saw the fire which had started through the open door of the storeroom. At that time, the flames filled the area between the top right-hand side of the meter cupboard and the ceiling of the storeroom. There was also a lot of smoke coming out of it. The employee shouted 'Fire, fire, fire, call the fire service!' He grabbed a fire-extinguisher from the canteen, ran with it into the storeroom and sprayed the whole of the contents onto the flames. A second employee glanced inside the storeroom and raced out of the shed to warn the owner of the company[27] and to get her to call the fire service. The second employee then ran back to his two colleagues in the shed and confirmed to them that the fire service had been called. The attempts made by the first employee to put out the fire had no effect. He left the storeroom and was given a new fire-extinguisher by the third employee. However, the first employee hesitated before going back into the storeroom because the room was already full of thick smoke. The third employee gave him a wet cloth which he held in front of his face so that he could attempt to go in again. However that proved to be impossible because the smoke meant that he could not see anything. With the door still open and the sound of the fire crackling, the men left the storeroom and ran through the shed to get outside. The first employee noticed that a thick curling cloud of smoke was drifting through the ridge of the shed. Outside, the second employee climbed onto a tractor with the intention of bringing a large boat which was sitting on a trailer in the shed to safety. The first employee helped him to do this and coupled the trailer to the tractor in the shed. At that moment, another thick cloud of smoke came rolling along the ridge of the shed above the men's heads. The first employee shouted: "Drive, drive, let's get out of here!" When he got outside, the first employee saw that the curling smoke was already drifting outside through the large door opening. At that moment, the first fire service vehicle arrived.

Prior to the arrival of the fire service, a number of people had already noticed the fire outside the building as well, as at the back of the building, a considerable quantity of brownish smoke was coming out from the edge of the roof. A person who happened to be passing by, who knew the company very well, decided to go into the shed to size up the situation. There he found, according to his statement, a threatening situation: high up at the back he saw fire, there was a lot of smoke, he heard the crackling of fire and the sound of falling objects. Frightened by what he saw, this witness left the shed again immediately. He was inside for no more than ten seconds. Once outside, he saw the curling smoke emerging around the edges of the large door opening. He agreed with the employees of the company who came out of the shed at the same time that they should not let anyone else enter the shed.

Two policemen also arrived on the scene before the arrival of the fire service, during the phase when the two members of staff were trying to bring the boat on the trailer to safety. They proceeded along the left-hand side wall[28] of the building and also noticed that there was a lot of smoke coming out from under the edge of the roof. A few moments later, they heard a bang in the shed which made them run for safety. Looking inside through the door opening, one of the two could still see a reddish-orange glow at the back of the shed.

The other people who were in and around the shed prior to the arrival of the fire service were customers of the company. One of them was working on his boat which was garaged in the shed; two of the people who were present at the site ran into the shed in order to bring a large mast to safety, at roughly the same time as the two employees were trying to bring the boat on the trailer outside.

26 The occurrence of the fire has been brought to the attention of the Public Prosecutor's Office.

27 The company in De Punt is owned by a married couple. The male owner was not present at the time of the fire. Therefore the alarm was raised by the female owner.

28 One of the two policemen stated off his own bat that he had been proceeding along the right-hand side. This does not tally with the statement of his colleague who said that they had both been proceeding along the left-hand wall of the shed. Because the latter statement contains spoken words ('Let's get out of here!' in reaction to the bang), the Board considers this statement to be the most probable. For the police officer would not have said the words if he had been on his own.

The observations of these customers match those of the members of staff: the strong development of smoke in the storeroom during the attempts made by the first employee to put out the fire and smoke which was rolling along the ridge of the roof towards the main entrance.
A number of customers noticed that smoke was already coming out of the large door opening before the fire service arrived.

5.3 The behaviour of the fire after the arrival of the fire service

The first fire service vehicle to arrive was a appliance from the station in Eelde which arrived at the scene approximately 9½ minutes[29] after the owner called the fire service. On board were an officer-in-charge, a driver/pump operator and five crew members.

On approaching the fire, the firefighters saw a considerable quantity of brownish-yellow or brownish-white smoke coming out from the back of the shed. The sight of this smoke prompted the officer-in-charge to send a further message reporting a 'medium-sized fire'. In addition, on account of the density of the smoke, the officer-in-charge asked for the nearest road to be closed to traffic.

On arrival, not 90 seconds[30] after the officer-in-charge had scaled up the fire to a 'medium-sized fire' on account of the smoke development, the situation seemed to have suddenly changed completely. According to the firefighters, no smoke was visible at the front of the shed where a wide overhead door (8 m) stood wide open. The firefighters could see inside through the large door opening. Visibility was perfectly good in the shed: only at the very back of the elongated area on the left-hand side could the firefighters see a small quantity of thin smoke of the same brownish colour as the smoke which was also visible outside.

The officer-in-charge decided to carry out an inside fire attack. He sent four of his crew inside with instructions to 'investigate and extinguish the seat of the fire if found'[31].

The four men ran inside, one after the other. 'Number 1' was carrying a thermal imaging camera, an instrument that is used to locate sources of heat like the seat of a fire. 'Number 2' was carrying with him a fire hose (a so-called high-pressure hose).

When the four had got about 15 metres inside the shed, 'Number 2' noticed that the fire hose had stuck. He ran back outside in order to free the hose. Outside, at the vehicle, he quickly uncoiled a few metres of hose from the reel in order to give it some slack. He then went back inside[32] where, with his back to his colleagues, he pulled on the hose again in order to drag the length of hose which he had uncoiled into the shed.

At that moment, 'Number 2' experienced a powerful blast wave which caused him to fall forwards. Suddenly there was fire and pitch black smoke. Following the hose, he crawled outside on his hands and knees. Outside, by the large door opening, 'Number 2' felt an incredible heat.

Other witnesses also noticed the sudden fire spread. Some of them described a dull bang ("boo-oom") or a blast wave, followed by the emergence of a large quantity of black smoke from the large door opening. Whirling flames could be seen in the column of smoke. The heat could even be felt many metres away. The blue coating on the outside of the shed shrivelled up.

At the very back of the shed, the fire broke through the roof so that the flames were leaping up there too. The fire appeared to remain relatively calm in the middle part of the shed.

As a result of the actions taken by the various fire service units that rushed to the scene to put out the fire, including the one from Eelde airport, approximately half an hour after the sudden fire spread the fire started to become subdued. After consultation, a number of officers-in-charge took the initiative to enter the shed. Shortly after that, they found the bodies of their three colleagues.

29 See appendix A for the times
30 See appendix A for the times
31 The deployment of a four-man crew differs from the national standard which stipulates that two-man crews are to be deployed.
32 The exact position of 'Number 2' is uncertain. See Chapter 2.

Photograph 4 Back of the shed when the fire was fully ablaze. The yellow arrow is pointing to the 'V' pattern on the outside wall. The yellow dotted line indicates the outline of the meter cupboard located on the other side of the wall.

5.4 Analysis of the behaviour of the fire

The fire started in the meter cupboard on the left-hand side at the back of the storeroom. The three employees of the company present all stated that that is where the first flames were seen. During the fire, a characteristic 'V' pattern could be seen on the outside of the shed, with the point of the 'V' pointing towards the meter cupboard (see photograph 4). This fire pattern confirms the statements made by the three members of staff.

The first attempt to put out the fire using a fire-extinguisher, made by the first employee, was unsuccessful. This can be explained if the employee directed the fire-extinguisher at the flames which were visible above the meter cupboard. It is likely that the source of the fire was located inside the meter cupboard and as the door of the cupboard was closed (i.e. not as seen in photograph 3), the actual seat of the fire remained out of reach of the fire-extinguisher.

The employee was not able to make a second attempt to put out the fire, which he wanted to do shortly after, because by then, the storeroom was no longer accessible. That indicates that the fire developed extremely rapidly. In addition, a fourth witness, a customer who was present in the shed, stated that after the first attempt to put out the fire, the development of smoke in the storeroom suddenly increased dramatically. The accelerated fire development can be explained by looking at photograph 3. The employees stated that they saw flames above the meter cupboard. The flames seen were probably coming from the cupboard at the points where holes had been drilled for feeding through electrical wires, on the right-hand side of the cupboard in photograph 3. It is here that the flames must have come into physical contact with the exposed polyurethane foam that had been applied to the wall behind the meter cupboard, amongst other places.

Polyurethane foam is an aerated, flammable material. Admittedly, if the foam meets fire safety requirements[33], it cannot be ignited by a small flame (e.g. a candle) but a larger thermal load will cause it to catch fire irrevocably. Because the polyurethane foam had been applied to the wall and ceiling of the storeroom without any protection (i.e. without any protective cladding), the fire will have spread rapidly across a large area.

Considering the rapid development of the fire from the start, the Board wishes to point out that the first employee exposed himself to considerable risk with his attempt to put out the fire. In the twenty metre-deep storeroom where there were cars and a lot of platforms had been set up, he could easily have become disorientated in the smoke. Smoke from burning polyurethane contains highly toxic components which can quickly result in fatality. Therefore it is good that the employee gave up on making a second attempt to put out the fire.

Based on knowledge relating to the fire behaviour of polyurethane, it is likely that the fire in the storeroom reached the flashover stage within 1 to 2 minutes (Appendix 3). The three members of staff have already fled from the shed.

Interlude: flashover

Flashover is a transition phase when a developing fire turns into a fully developed fire, during which all the flammable objects within an area ignite more or less simultaneously.
Flashover occurs when the temperature of the smoke gases in the fire compartment rises. When this reaches a high enough level (approximately 600 °C), the gases give off so much heat (approximately 20 kW/m²) that all flammable materials (furniture, floor coverings, etc.) start to outgas and burst into flames.
Contrary to commonly held misconceptions, flashover is not a sudden event like an explosion but a phase during the development of a fire. However in fire service circles, all kinds of sudden fire spread are referred to as 'flashover'. It is important to make a clear distinction between the different fire mechanisms because the conditions within which they occur differ considerably and because backdrafts and smoke gas explosions are often of a violent nature and present the fire service with an even greater hazard than flashovers.

From the moment the whole car workshop is on fire, the large fire load[34] in this area becomes significant. The polyurethane wall and ceiling cladding, the softwood support beams and the wooden panels in the ceiling enable the fire to develop a high intensity[35] within a short period of time. Photograph 3 shows that stacks of tyres, rolls of plastic and jerrycans possibly containing oil and/or petrol were present in the room, all items which contributed to the fire load.

In the case of this type of high-intensity fire which occurred in a (semi-)enclosed area, the volume of oxygen available quickly becomes a limiting factor. It follows from calculations (appendix 4) that the volume of oxygen in the storeroom must have been used up within 60 to 90 seconds. Admittedly, fresh air was being supplied via the open access door (the door between the storeroom and the large shed area) but this door is small in relation to the volume of the storeroom. Moreover, a flow of smoke gases was passing through the same door opening in the opposite direction, from the storeroom into the large shed area. This powerful outgoing flow 'obstructed' the inflow of fresh air.

Due to the limited supply of oxygen, after its initial strong development, the fire is smothered within 60 to 90 seconds of the flashover[36]. However, the temperature in the room, more than 600 °C during the post-flashover stage, will remain high for some time, as a result of which the process of outgassing from wood, polyurethane and other materials (pyrolysis) will continue without the released gases burning.

33 European standard EN 1305-1
34 The fire load is the calorific value of objects within a room per square metre of floor space. The fire load is traditionally expressed in equivalent softwood/m².
35 Estimated at 10 mW, see appendix 3
36 Smothering: a reduction in the intensity of the combustion process due to a lack of oxygen.

As a result, the smothered fire in the storeroom may have emitted large quantities of decomposition products, in the form of unburnt smoke gases, via the open door. These smoke gases then spread at the level of the ridge of the roof, along the entire length of the shed. It is this spread of smoke which was seen by the members of staff present, the customer in the shed and the passer-by who went into the shed in order to size up the situation.

A fire of this type which develops within a semi-enclosed room within which the supply of oxygen is the limiting factor has a pulsating character (see Interlude). Moments when the fire suddenly flares up and massive amounts of smoke are emitted alternate with periods of relative calm. Consequently, that explains why, after the three members of staff had fled from the shed, they saw their chance to go back into the shed in order to bring a boat on a trailer to safety. In addition, a customer ran into the shed during this phase in order to rescue his property. While the men were in there, a new wave of smoke rolled through the shed, from the back to the front. They fled outside for the second time and then noticed that the curling smoke was already coming out from under the edge of the large door opening. Shortly before the arrival of the fire service, a number of customers and a passer-by also saw smoke coming out through the large door opening. Shortly after that, when the first firefighters alighted from their vehicle, no smoke could be seen at the front of the shed. The fire had then entered the next phase of relative calm.

Interlude: The pulsating fire.
A fire within a fully enclosed room is not usually allowed to go on for long. The fire consumes the oxygen present in the air (21%) as a result of which the combustion process slows down. The blazing fire will then turn into a smouldering fire and eventually go out altogether. The fire is then smothered.
The behaviour of a fire becomes more complex if the room is not fully enclosed but has a small opening through which fresh air can flow in and smoke gases can flow out, e.g. via an open door. In this case too, the blazing fire will turn into a smouldering fire, for the fire will consume more air than can flow in via the door opening and create a shortage of oxygen again. In the literature, this is referred to as the ventilation-controlled behaviour of a fire.

When a fire is ventilation-controlled, smoke gases will still continue to be produced but they will be less hot which will cause the temperature in the room to drop. The volume of gases in the room will drop as a result, thus allowing fresh air to enter via the door opening. When the fresh air mixes with the unburnt smoke gases and the mixture comes into contact with smouldering particles, the fire will flare up again. After flaring up, the fire will start to consume the oxygen again and this will set off the process of smothering again. As a result, this will create pulsating fire behaviour during which peak phases will alternate with periods of relative calm.

One particular characteristic of pulsating, ventilation-controlled fires is that they continuously produce smoke gases which do not burn in the oxygen-poor environment. A dangerous situation will arise if these gases drift into another room where they are able to mix with fresh air to form an explosive mixture. If the air/smoke gas mixture comes into contact with an ignition source, it can then ignite explosively.
In view of this hazard, firefighters should keep a lookout for phenomena which point to a pulsating fire.

Flows of smoke gases mix with the surrounding air as a result of turbulence[37]. This process must also have taken place as the smoke travelled along underneath the roof of the shed. As a result of this, the volume of smoke increased, on the one hand, and the mixture ratio between the flammable components in the smoke and oxygen was such that it enabled the explosive combustion of the air/smoke gas mixture, on the other.

The observation made that, shortly before the arrival of the fire service, the curling smoke was coming out from under the top edge of the large door opening shows that the bottom of the layer of smoke gas was level with the top of the door opening.

37 Eng.: entrainment

Therefore, from that level up to the ridge, the roof of the shed was filled with a packet of flammable smoke gases a maximum of 4 metres thick.

In this situation, contact with an ignition source could actually cause the mass of smoke gas underneath the roof to ignite. The fire in the storeroom may have caused ignition, for example as a result of it breaking through at the point above the meter cupboard where wires had been fed through into the attic. Another possibility is that tongues of fire or spreading fire[38] entered the storeroom via the door opening and came into contact with the mass of flammable smoke gas.

Interlude: backdraft and smoke gas explosion
In a ventilation-controlled fire, the development of the fire is determined by the availability of oxygenated fresh air. If there is no supply of fresh air to the seat of the fire, then the fire will smoulder and eventually go out due to the lack of oxygen. However, if there is a supply of fresh air to the seat of the fire, though limited, then the development of the fire will also be restricted and a high volume of unburnt or only partially burnt smoke gases will be produced. If the supply of fresh air to the seat of the fire increases, the unburnt smoke gases will then be able to ignite as soon as they mix with the incoming flow of fresh air. The fire will then flare up.
If the flow pattern within the building suddenly changes, i.e. as a result of a window breaking or a door being opened, the fire may flare up dramatically. We call this a backdraft (or backdraught).
The fire service is familiar with the backdraft phenomenon and has developed a special procedure for opening doors which takes account of the backdraft hazard.

A special situation arises if the unburnt smoke gases accumulate in another part of the building away from the location of the fire. In that case, the unburnt smoke gases are easily able to mix with oxygen-rich air without them igniting – as they are out of reach of the seat of the fire and as a result, there is no source of ignition.
As long as ignition is kept at bay and the fire continues to burn elsewhere in the building, the mass of smoke gas can continue to grow and mix with oxygen-rich air. As a result of this, a so-called premix air/smoke gas mixture (see also the interlude below) will be produced. A premix is highly incendive: a small ignition source is enough to cause the mixture to ignite whereby explosive combustion can occur which, unlike flashover or backdraft, may be accompanied by a large blast wave. This phenomenon is referred to in the literature as a smoke gas explosion. *The mechanism is no different to explosions involving other gases such as natural gas or petrol vapour, for example.*

A detailed discussion of the phenomena smoke gas explosion, backdraft and flashover, paying special attention to the differences between these, can be found in the publication 'Enclosure Fires' *by Swedish fire expert* Lars-Göran Bengtsson (2001).

The explosive combustion of the mass of smoke gas occurred, i.e. a blast wave formed which was experienced by various people outside the building. One of the steel panels above the large door opening was blown out as a result of the blast wave (see photograph 2). 'Number 2', the firefighter who had been pulling on the fire hose in or within the vicinity of the large door opening, was knocked off his feet by the blast wave. Most of the witnesses experienced the explosion as a dull boom rather than a sharp bang: bbboom..! This description points to a drawn-out and therefore less powerful explosion. The fact that the windows of the building remained intact also indicates a less explosive force, more a dull boom than a sharp bang.

Immediately after the explosion, a full blaze started which engulfed the whole building but which mainly became manifest in the large door opening where big flames and thick clouds of smoke emerged outside.

The low force of the explosion and the major fire which immediately followed indicate that a rich mixture of smoke gas exploded in the shed, i.e. a gas mixture containing a relatively high quantity

38 Spreading fire: glowing particles from the seat of the fire which spread with the smoke gases.

of fuel in relation to the amount of oxygen (see Interlude). The explanation for this is that after the explosive combustion, the rich mixture still contained a lot of flammable components which were able to mix with the oxygen-rich outside air in and around the large door opening, causing a fierce fire at exactly that spot.

In addition, the sudden increase in temperature led to the disintegration of the sandwich panels in the roof while the core layer of polyurethane burst into flames. The strong heat given off also caused various boats and a caravan, again in the vicinity of the door opening, to burst into flames. The full blaze which began in this way was so strong that it took the fire service half an hour to get it under control.

When the smoke gas explosion occurred, the three firefighters were at least 15 metres inside the shed, possibly more. They had been inside for more than a minute by then (appendix 3). It is likely that the three, whose attention was directed towards the area at the back of the shed (for they knew that the fire was there), saw the front of the ignited mass of smoke gas coming towards them. This must have happened so quickly that the three did not have time to take the most obvious route to safety, namely via the access door leading outside. As mentioned earlier, after the smoke gas explosion the fire was concentrated in the large door opening because that is where it was being mixed with fresh air from outside. Therefore, the fire blocked the way back to the three firefighters. Because the three bodies were found in totally different places within the shed, it seems that the men became separated from each other as a result of the powerful effect of the smoke gas explosion which probably made them disorientated and caused them to start looking for a way out of the burning shed separately, away from the main entrance where a strong fire had developed.

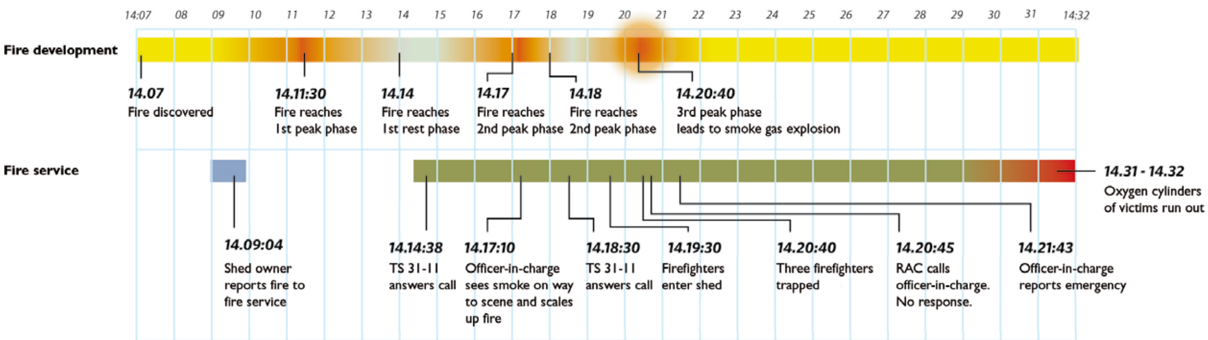


Fig 3 Timeline

Interlude: rich, poor and stoichiometric mixture

Smoke is a mixture of gases containing small liquid and solid particles. All the constituents of smoke may be flammable to a greater or lesser extent. We call the flammable components fuel. Fuels commonly found in smoke include carbon monoxide, acrolein (from the combustion of wood and plastics) and hydrogen cyanide gas (from the combustion of polyurethane).

Fuel can only burn if it is mixed with air in a certain ratio. The lowest concentration of fuel at which an air/fuel mixture is able to burn is referred to as the lower flammability limit or LFL. The highest concentration at which an air/fuel mixture is able to burn is referred to as the upper flammability limit or UFL.

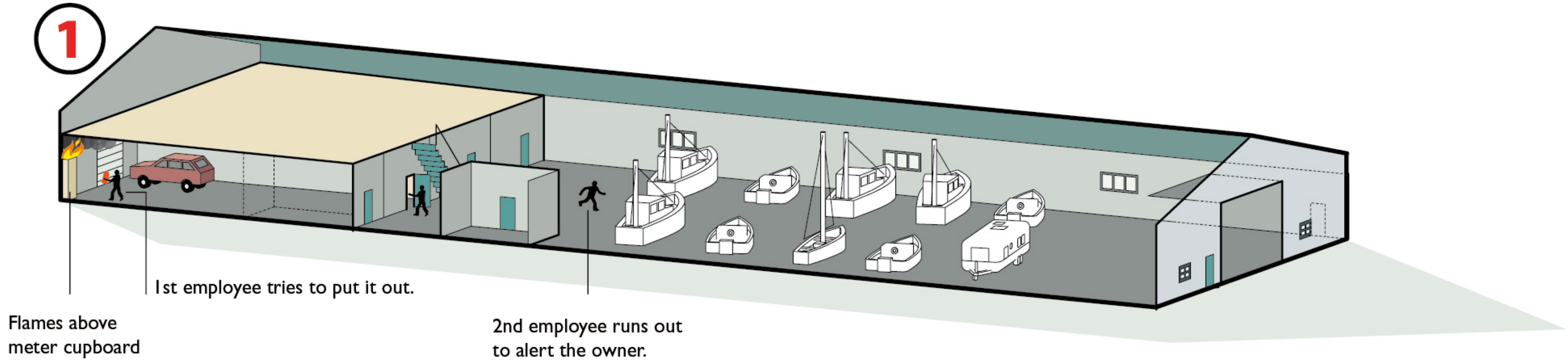
Between the LFL and the UFL is a point at which the air-fuel ratio is optimal, i.e. at which the air/fuel mixture contains precisely enough oxygen for all the fuel to burn completely. We call this a stoichiometric mixture. The combustion of a stoichiometric mixture is described as ideal, i.e. it occurs at maximum speed, with maximum conversion of energy and with maximum pressure build-up. This principle has many technical applications including the combustion engine in a car where, if it is tuned properly, a stoichiometric air/fuel mixture will be burned in the cylinders.

If the fuel concentration is lower than in the stoichiometric ratio, it is referred to as a poor mixture. If the fuel concentration is higher than in the stoichiometric ratio, it is referred to as a rich mixture. The combustion of rich and poor mixtures is less violent (less explosive) than that of a stoichiometric mixture. In the analogy of the combustion engine, if the engine cylinders are supplied with a poor or rich mixture, it will lose power. If the mixture is rich, not all the fuel will burn and the engine will emit dirty exhaust gases which are still flammable.

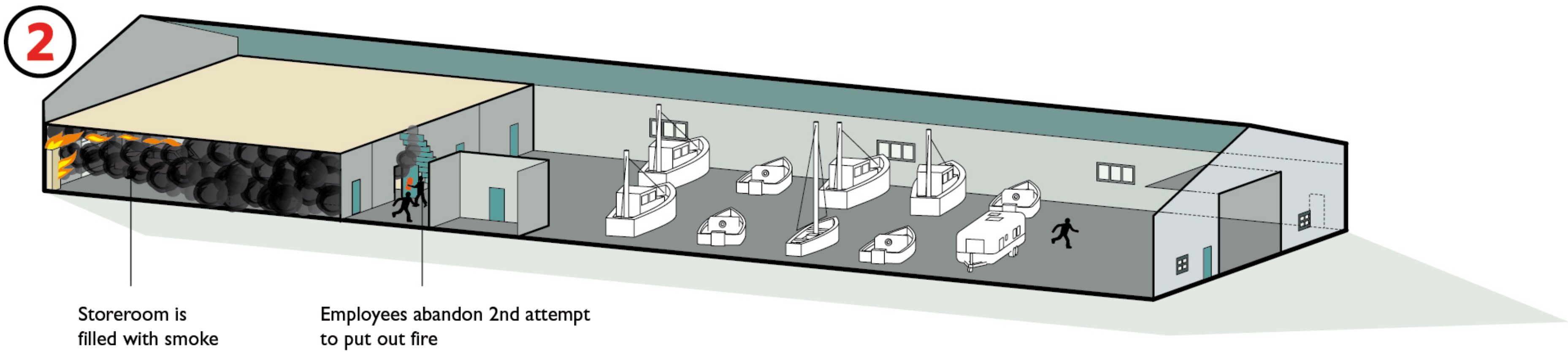
The same thing happens during the combustion of smoke gases. There is no fire after the explosion of a poor smoke gas mixture because all the fuel has been burnt during the explosive combustion. At most, the explosion will leave behind local seats of fire where easily flammable substances such as paper are located. On the other hand, a strong fire may ensue after the explosion of a rich smoke gas mixture. For not all the fuel has been burnt and as a result of the turbulence created by the explosion, the remaining fuel is mixed with air again. As a result, the fire continues after the explosion.

The timeline analysis (appendix 3) shows that after the smoke gas explosion, the three men used up their supply of breathing air within approximately 10 to 11½ minutes. Two of the three subsequently died from asphyxiation. Because they did not remove their masks from their faces, which is the normal reaction when your breathing air supply runs out, it is likely that they lost consciousness earlier on due to overheating. The third firefighter had removed his breathing mask. The amount of carboxyhaemoglobin (COHb) in the blood of this victim was high[39] which shows that he must have inhaled smoke for a short time after removing his breathing mask until he died from smoke poisoning and asphyxiation.

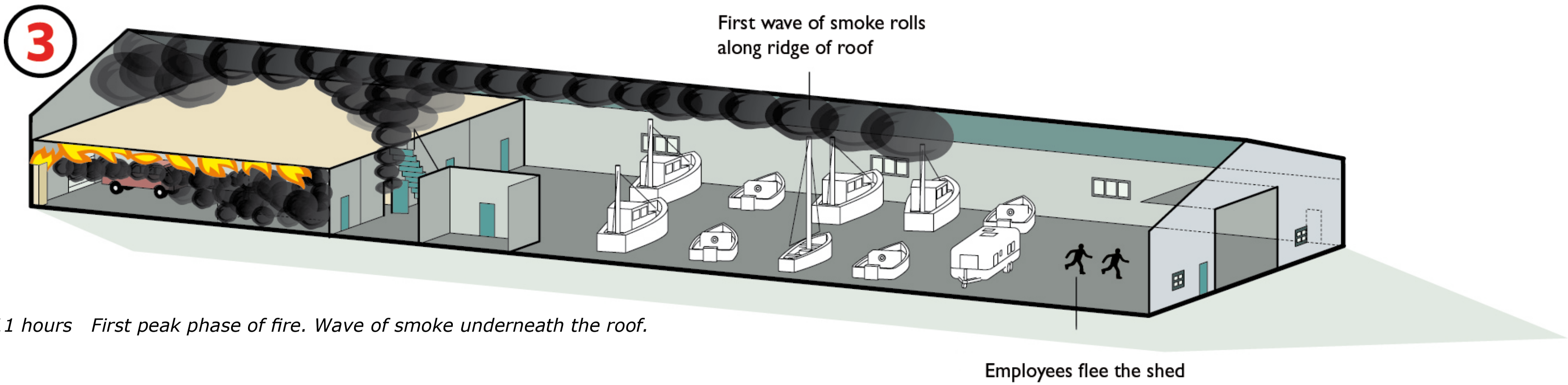
39 [COHb] = 37.3%



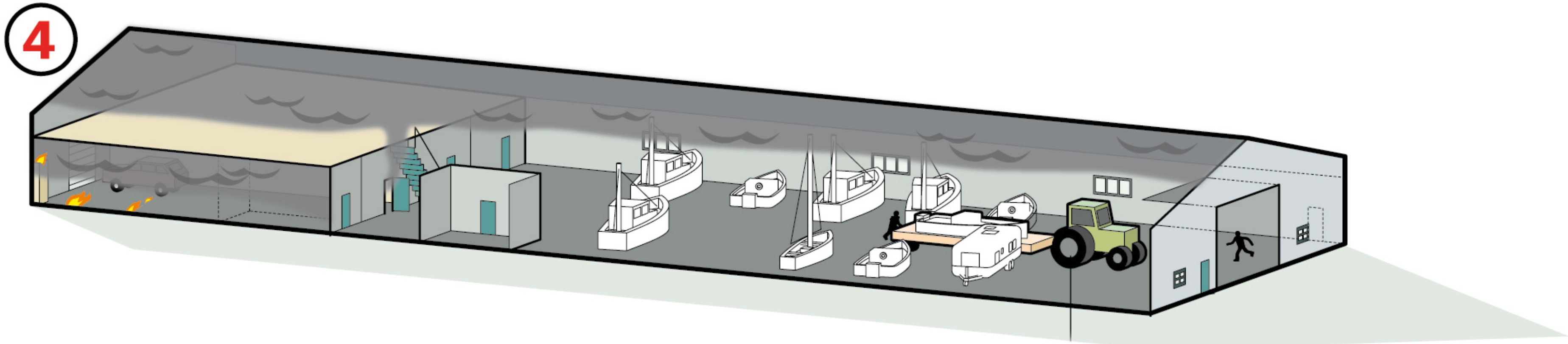
14.07 hours Fire above meter cupboard discovered by employees. 1st employee tries to put it out.



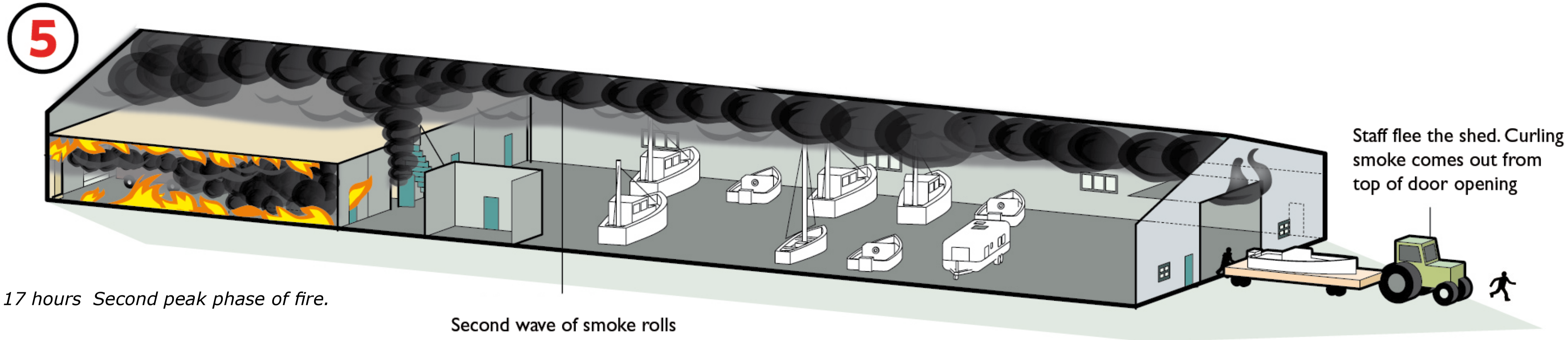
14.09 hours Rapid fire spread in storeroom.



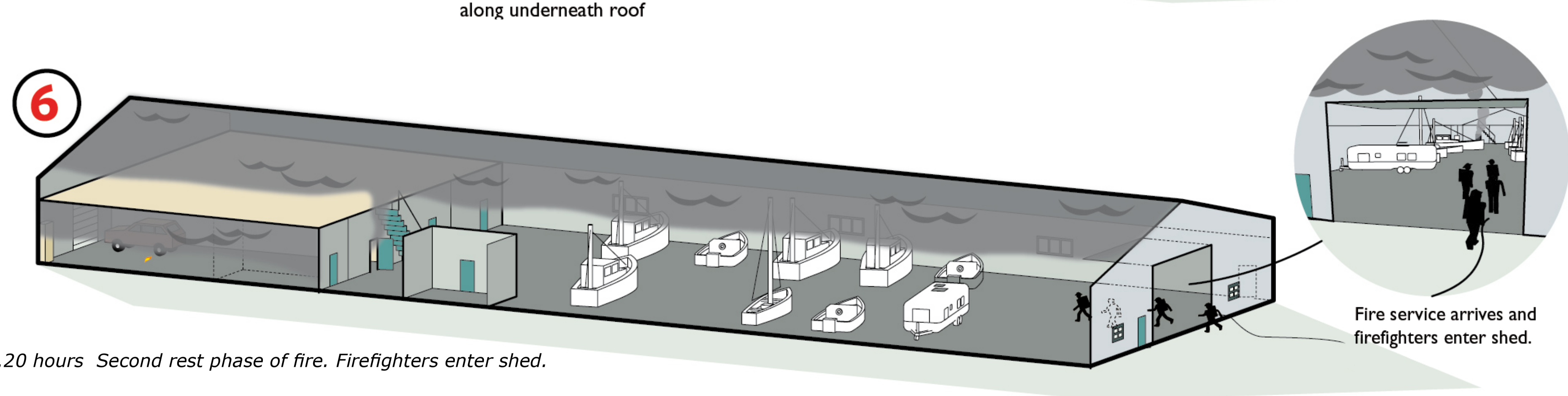
14.11 hours First peak phase of fire. Wave of smoke underneath the roof.



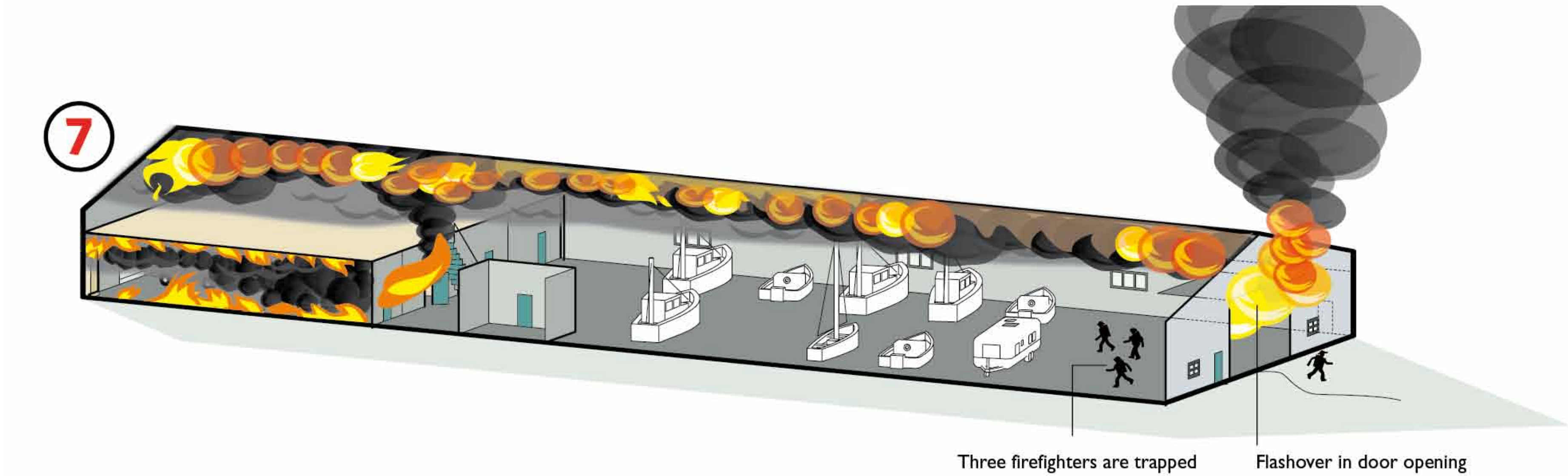
14.14 hours First rest phase of fire.



14.17 hours Second peak phase of fire.



14.20 hours Second rest phase of fire. Firefighters enter shed.



14.21 hours Third peak phase of fire, smoke gas explosion below roof. Firefighters are trapped.

6. ANALYSIS OF THE FACTS OF THE CASE

Three firefighters lost their lives during the fire in De Punt because shortly after they had entered the burning object, they became trapped when the fire suddenly spread.

A decision was made by the officer-in-charge prior to them entering the building. He basically has two strategies to choose from, namely to attack the fire from inside or from outside the building or, as they are referred to in fire service jargon, inside or outside fire attack. In principle, that choice is based on weighing up the expected result of the two strategies, on the one hand, and estimating the risks involved, on the other. In this case, the image that the officer-in-charge had formed of the situation was such that he considered that an inside fire attack would have positive results (effective firefighting) and that the associated risk was low. That is why he opted to carry out an inside fire attack. Just over a minute later, it became clear how fatal that choice had been.

The question which needs to be answered now is: How could the officer-in-charge have - in retrospect, wrongly - formed the image that the fire situation was sufficiently safe to carry out an inside fire attack? In order to do this, the Board will consider the times when the officer-in-charge was given information on which the image of the fire that he formed was based and adjusted. The first image was formed on leaving the barracks when the officer-in-charge received information from the Regional Emergency Centre (RAC) which was supplemented by his own men who were familiar with the company premises. When the Regional Emergency Centre made contact again later, the officer-in-charge was given new information. The third time was on the way to the fire when the officer-in-charge saw the burning shed for the first time; finally, the fourth time was when the vehicle arrived at the scene at the front of the shed where the officer-in-charge took in the situation and he was provided with information by a police officer.

6.1 First image formed: information from the RAC on leaving the barracks

At 14.14:38[40] hours, the officer-in-charge from TS31-11 reported to the RAC Drenthe that he had answered the call. As is customary, the RAC gave him the information that was known at that time about the fire, i.e. fire in the meter cupboard at company B.
The indication 'fire in a meter cupboard' created the image of a fire of limited size, for a meter cupboard is a small object. In addition, the company B. was known to the occupants of the appliance. One of them even knew the exact position of the meter cupboard because he regularly tinkered around with sports cars with the owner's son in the room where it was situated. The men exchanged this information, including details regarding the presence of gas cylinders and hazardous substances. Because of this, the crew, including the officer-in-charge, formed the image of 'a small fire in a small compartment at the back of the shed' early on.

6.2 Second image formed: information from the RAC on the way to the fire

The RAC received further information from the daughter of the company owner and relayed this information to TS31-11 at 14.15:35 hours with the words: "The back of the shed is fully ablaze". The officer-in-charge may have concluded from this information that the fire was no longer confined to a single room. In any case, he would have abandoned the idea of 'a very small fire' (i.e. in a meter cupboard).

6.3 Third image formed: the officer-in-charge catches sight of the shed on the way to the fire

During a subsequent conversation, the RAC mentioned that they had already received several other reports. The person at the control centre assumed that 'It will be a real blaze'. At the same time, at 14.17:10 hours, the officer-in-charge caught sight of the shed for the first time. He saw a lot of smoke and on the basis of this, decided to scale the fire up to a 'medium-sized fire'.

40 Times in accordance with appendix A

Increasing the level of deployment before getting to the scene, considering the limited information, is a step which should be noted. On the other hand, on one or two occasions the officer-in-charge was given indications which point to there being more danger than he initially supposed. As a result, an image of a fast-growing fire was formed. When that image was confirmed by the sudden sight of a considerable quantity of smoke, the officer-in-charge did not waste any time in scaling up the operation.

Just how much smoke there was became clear a few moments later when the appliance reached the roundabout near to the shed. There was so much thick smoke that the officer-in-charge did not see an oncoming passenger car until the very last minute. The officer-in-charge then instructed the RAC to close the road to traffic.

The officer-in-charge from TS 31-11 gave these latest instructions to the RAC approximately one minute before arriving at the scene (appendix 3). The conclusion that the officer-in-charge saw a considerable amount of smoke coming out of the shed at that time can be related to the statements of the members of staff, customers and a passer-by which said that the situation in the shed got rapidly worse shortly before the arrival of the fire service. One of the members of staff described how a new wave of smoke rolled along the ridge of the roof. The passer-by, the last person left in the shed, told of an extremely threatening situation. Several people stated that just before the arrival of the fire service, the curling smoke was coming out from the edges of the large door opening. In view of the independent yet simultaneous observations of strong smoke development made by the firefighters at the roundabout on their way to the scene, on the one hand, and by the witnesses in the shed, on the other, it is likely that the observations of both parties were attributable to the same peak phase which the pulsating fire in the storeroom was going through at that time.

6.4 Fourth image formed: TS 31-11 arrives at the scene

Between the time they left the fire service barracks and the time they arrived at the shed, the officer-in-charge and his crew had scaled up their image of the fire, from a small fire in a meter cupboard to a fire which would require the deployment of several units. Approximately one minute before getting to the scene, the officer-in-charge and his crew got the impression that there was more to the situation than a small fire which was confirmed by the large quantity of thick smoke travelling across the roundabout.
When appliance 31-11 drove onto the premises, parked at the front of the shed and the firefighters got out, their image of the fire changed again but now in the opposite direction. At the front of the shed, there was no smoke at all to be seen. There was nothing of any note to be seen inside the shed either. Standing in front of the large door opening, you could see clearly to the back of the shed: there was no fire, no noise, all that could be seen were threads of smoke high up at the back on the left-hand side (i.e. above the storeroom) of the same brownish colour as the smoke which had already been seen outside. "Number 2" from the unit gave the following description of the situation: "There was nothing in particular to indicate that there was a major fire or the seat of a fire. Visibility was good. There was nothing wrong. If felt as if you could drive the vehicle inside to put out the fire and then drive back out again."

The good visibility in the shed also gave the officer-in-charge the impression that on reflection, the fire could have been worse. After briefly consulting with his crew, he sent his numbers 1 to 4 inclusive inside. He began to investigate the outside of the building on the right-hand side himself. More than a minute later, fate struck unexpectedly.

6.5 The apparent versus the actual fire situation

The previous section explained how the fire which initially developed strongly, in the semi-enclosed space inside the storeroom, took on a pulsating character. That means that a situation was created where periods of strong fire development during which the storeroom deposited large quantities of smoke gases within the shed area alternated with periods of relative calm during which admittedly, unburnt smoke gases continued to be produced but there was no longer any driving smoke development.

Between the time the fire was discovered and the arrival of the fire service, at least two phases of accelerated fire development occurred. Both times, the members of staff present fled the shed and both times they noticed a threatening cloud of smoke rolling along underneath the ridge of the roof from the back to the front.
During the period between the two phases of accelerated fire development, the fire entered a period of relative calm. The members of staff and a customer made use of this and went back into the shed in order to bring property to safety. The female owner, who came to size up the situation during this phase, saw nothing much of any importance and thought to herself "What a fuss".

The calm turned out to be false as a new phase of accelerated fire development followed which made the people present flee the shed again. A passer-by, who went into the shed in order to size up the situation during this phase, found what he described as an 'extremely threatening situation'. At the same time, the officer-in-charge from TS 31-11 which was on its way to the scene saw so much smoke outside the building that he considered the traffic to be at risk and asked the RAC to close the road.

A minute later, when the driver of TS 31-11 parked his vehicle at the front of the shed, the scene appeared to be calm again. The curling smoke which had just been seen coming out of the large door opening was no longer visible. The officer-in-charge and his crew members were seriously misled by this. The absence of fire and (visible) smoke led them to wrongly draw the conclusion that the fire was not as big as they had initially thought. However in reality, the fire had only entered the next phase of relative calm – in other words: temporary calm. However, the threat of a major hazard was very close: the whole ridge of the roof was filled with a layer of a flammable air/smoke gas mixture up to 4 metres thick that could explode at any moment. Had they looked up round the edge of the door opening, they would have seen the packet of smoke. However, they did not do that. The firefighters' gaze was fixed on the place where, according to their information, the seat of the fire must have been, on the left-hand side at the back of the shed. That was where they needed to be, that was where the fire which they had come to put out was. Because the bottom of the layer of smoke gas was at a height of approximately 5 metres, the firefighters were able to see the inside of the shed underneath the packet of smoke without being aware of it and they established that visibility was good. This was enough for the officer-in-charge to regard the situation as safe. On his command, the four crew members entered the shed and went straight to their target, without being aware of the great danger that was literally hanging above their heads.

6.6 The fatal trap

How can it have happened that the officer-in-charge and his crew were so misled by the situation and that they failed to notice the mass of smoke which was hanging at a height of just five metres? There is no clear-cut answer which can be given to this question. A wide variety of factors were involved. First of all, mention needs to be made of a number of circumstances which might have made it difficult for the firefighters to see the layer of smoke.

1. Friday 9 May 2008 was a clear sunny day. The sun was high in the sky and was shining directly on the front of the shed when TS 31-11 arrived at the scene. The door opening must have looked like a big dark hole within which it must have been difficult for anyone standing outside to get a good view of the inside of the shed.
2. The door to the shed is an overhead door of the type that on opening pivots upwards and inwards. The firefighters were standing in front of the door when it was open – i.e. the door above the door opening protruded 5 metres inside and an observer who was standing in the door opening would not have had direct sight of the layer of smoke as a result.
3. There were no skylights in the roof of the shed. One of the easiest ways to see smoke is when there is light shining through it – the particles in smoke diffuse the light so that the beam of light becomes visible to the observer. Therefore that was not the case in the shed in De Punt.
4. One characteristic feature of the rest phase which the fire was in is that the flow of the layer of smoke gas has stagnated: it no longer has any 'drive'. The turbulence in the layer of smoke gas which the members of staff noticed on leaving the shed has disappeared. A stagnating, at most gently waving layer of smoke gas is more difficult to see than a turbulent mass of smoke.

Therefore there is sufficient reason to assume that the layer of smoke gas in the shed was difficult to see - at least for the casual observer. If the firefighters had actively looked for it, by looking up round the edge of the door opening, for example, they would have seen the thick packet of smoke. They did not do this as a result of which they were not mindful of the presence of smoke.

The operational division of the fire service is aware of the phenomenon where the firefighter focuses his attention so strongly on the object, a fire, an accident or a victim, that he fails to pay enough attention to hazards in the vicinity. This is a very common source of accidents. This phenomenon may have played a part in De Punt as well: for the firefighters were aware early on of the location of the fire, namely the meter cupboard which was known to be in the storeroom, on the left-hand side at the back of the shed. On arrival at the scene, this information was confirmed by one of the policemen present. Final confirmation was provided by the threads of brown smoke which were seen on the left-hand side at the back of the shed – and only there. There is no doubt that the firefighters will have directed their attention towards that spot at the back of the shed and not towards any hazards in other parts of the building as they were a long way from the seat of the fire.

This brings up another question for discussion: To what extent is ‘smoke’ actually considered as a hazard to firefighters? As explained earlier, before deciding on an inside fire attack the officer-in-charge weighs up the expected result against the estimated risks. Therefore he will draw up a brief inventory of risks which will include only those elements which he also identifies as a risk. If he does not know ‘smoke’ to be a source of danger, then he will not pay any attention to ‘smoke’.

This is illustrated by the moment on the way to the scene when the officer-in-charge caught sight of the burning shed for the first time. The officer-in-charge, who was in conversation with the RAC just at that moment, saw a considerable quantity of smoke coming out of the building and scaled up the operation, without a moment’s hesitation, to a ‘medium-sized fire’. The reason for this is that based on subsequent messages, the RAC had already suggested several times that the fire had already grown to a considerable size. The officer-in-charge saw the smoke as confirmation of the suspicions of the RAC and that is why he did not have to stop and think before scaling up the situation. In other words, to him the smoke was an indication of the size of the fire and not of the danger of the fire. In addition, the description ‘medium-sized fire’ does in fact mean that the level of deployment of fire service personnel has to be adjusted due to the size of the fire. The crew in TS 31-11 followed the same line of thinking as their officer-in-charge: the large quantity of smoke was not seen as a hazard but regarded as an indication that the fire had grown in size. To them, scaling up to a ‘medium-sized fire’ was a logical step. Or, as one of them said later: It was not a fire for a single appliance.

The officer-in-charge contacted the RAC once again regarding the development of smoke, namely when TS 31-11 got to the roundabout near to the shed. At that time, there still seemed to be much more smoke than they had seen the first time but again, the officer-in-charge did not see this as an indication of a hazardous fire situation. The danger he saw related to the safety of the traffic: so the officer-in-charge asked the RAC to arrange for the road to be closed. During a later conversation with the Dutch Safety Board[41], the officer-in-charge confirmed that he did not associate the considerable quantity of smoke with the particularly hazardous nature of the fire.

When TS 31-11 arrived at the scene, at the front of the shed, the firefighters saw hardly any smoke – none at all outside and a negligible quantity inside. While the smoke had prompted the scaling up of the situation 90 seconds earlier, the reverse was now the case: the absence of a lot of smoke gave the idea that the size of the fire was not as bad as it could have been. The officer-in-charge did not withdraw his request for the situation to be scaled up to a ‘medium-sized fire’ – that is not the usual procedure – but he did choose a plan of action which was suitable for a ‘small fire’, namely an inside fire attack, to be carried out by a single crew who, armed with a high-pressure hose, were to track down the seat of the fire and put it out. The positive outcome of this approach was clear to the officer-in-charge: extinguishing a fire quickly means that the building will be saved and fire damage will be kept to a minimum. The absence of risks to his men was also clear to the officer-in-charge: there was no danger of collapse, there was no perceptible heat to indicate an

41 Conversation at the station in Eelde, 11 February 2009.

approaching flashover and there was no closed door that could cause a backdraft if it were opened. On the contrary, the door stood invitingly open.
The reason why the large mass of smoke gas which has collected underneath the ridge of the roof escaped the attention of the officer-in-charge is that he was not actively looking out for it. Because he did not see smoke as a risk. Neither the officer-in-charge nor his crew were adequately aware of the intrinsic danger of smoke, namely that it can combust in a certain composition. The phenomenon of smoke gas explosion where smoke which does not have to be hot and does not have to be behind a closed door can still lead to explosive combustion was not known, or was hardly known, to the firefighters.

It was a distressing situation as there were several people at the site around the shed who were aware of the threatening situation in the shed and who would have been able to warn the firefighters about it. The fact that the officer-in-charge did not ask any of them for information (except for a policeman) shows that he had a clear idea about the fire and that he was sure about what he had to do. When the person in charge has a complete picture of the situation, he does not need any more information – he must go ahead with his plan of action.

Did the four firefighters, who went inside 75 seconds before the smoke gas explosion, notice the layer of smoke gas underneath the roof while they were in the shed? This question cannot be answered with certainty. 'Number 2', the only one of the four to survive the accident, has no recollection on this point. That is understandable as the hose which he was carrying with him got stuck shortly after going in and he remained in the company of his three colleagues only briefly. However, it does seem likely that numbers "1", "3" and "4" will have noticed the mass of smoke which was hanging just 3 metres above their heads in a 55 metre long space at some point. But they did not see this as any reason to abort the inside fire attack and go outside. Also, they did not identify the mass of smoke underneath the ridge of the roof as being life-threatening.

Establishing that the firefighters involved did not see a large quantity of smoke as an indication of danger and that no attention was paid to the presence of smoke when assessing the risks involved brings up the question as to what knowledge the firefighters possessed relating to the flammability of smoke gases and what they had learned during their training about smoke gas explosions and other forms of sudden fire spread which are some of the main safety risks involved when fighting a fire from inside a building. In order to do this, the next section comprises an inventory drawn up by the Board of the subject matter, training and other teaching materials which provide the fire service with knowledge relating to these subjects.

7. WHAT IS TAUGHT WITHIN THE FIRE SERVICE REGARDING SUDDEN FIRE SPREAD?

7.1 Introduction

In the previous section, it was concluded that the fire service unit in question entered the burning shed without having any idea of the danger which they were exposing themselves to. The firefighters did not notice the mass of smoke gas which was hanging underneath the roof of the shed and they were also not aware of the fact that such a mass of smoke gas, even without there being a high temperature or a change in the flow pattern, can lead to explosive combustion. This conclusion brings the Board to the next question as to what knowledge the fire service from Tynaarlo, and the Dutch fire service in general, possesses regarding the phenomena of sudden fire spread.

7.2 The municipality of Tynaarlo

As an employer, the municipality of Tynaarlo is obliged to provide its personnel with "adequate information regarding activities to be carried out and the associated risks" (Working Conditions Act, article 8, paragraph 1). In respect of the fire service, this stipulation has been conceived in terms of training and exercises, paying special attention to the safety of operational actions. The 1991 Firefighters Decree, which states that every fire officer must be trained according to the rank that he holds, is also in force.

The municipality of Tynaarlo acted properly in this respect. Decisions made by the Municipal Executive regarding the appointment and promotion of fire service personnel did not take effect until the personnel in question had met the requirements regarding diplomas. Two members of the fire service crew involved were even over-qualified for the position of firefighter which they occupied when the operation was carried out in De Punt.

Unlike training, no statutory requirements have been set for exercises for the fire service. However, there is a Training Guide which is to be considered as the national standard for exercises. The Tynaarlo fire service followed the Training Guide. The municipality of Tynaarlo organises the annual in-service training course Safety during Repressive Action specially for officers-in-charge. The officer-in-charge from the fire service crew involved had also attended this in-service training course.

Finally, the municipality of Tynaarlo has drawn up a risk inventory for its fire service organisation and has included in-service training and exercise elements in the plan of approach based on it.

In summary, it can be said that the municipality of Tynaarlo has met both the statutory requirements and the informal guidelines followed within the industry in respect of training and exercises for its fire service personnel. Therefore shortcomings in the technical knowledge of the firefighters involved cannot be traced back to inadequate training but to the content of the training which they have received. The content of this training is laid down in writing in a large number of learning modules and publications which are used nationally. The Netherlands Institute for Safety Nibra (NIFV)[42] is the leading publisher of these.

7.3 National Curriculum for the fire service

In the past, the Ministry of the Interior and Kingdom Relations had an important say when it came to realising the content of 'fire service policy'. Subsequently, the Ministry has seen it as being less and less its role to be involved in determining the content for the fire service. Instead, it concentrates on its key tasks and has been leaving content and implementation to the field more and more. Fire service training is a good example of this: the Minister of the Interior and Kingdom

42 Formerly the Netherlands Institute for Firefighting and Disaster Management (Nibra)

Relations has made himself responsible for the training system as a whole but in the process only sets out frameworks in the form of exam regulations. During the 1990s last century, the minister passed on the implementation of these frameworks, or management of the content taught within fire service training, to the Nibra (subsequently NIFV). The performance of this task was laid down by law by means of an amendment to the 1985 Fire Services Act. It is notable that only the provision of officer training is described as the statutory task of the NIFV: all other types of training are designated as permitted tasks. Therefore the NIFV is not obliged to define and maintain the curriculum for fire service training. The NIFV does carry out these tasks but due to their status as permitted tasks, there are no arrangements for structural financing for these.

In the teaching materials of the NIFV, a distinction can be made between subjects which form part of the modular training structure of the fire service and which constitute training for the compulsory national exams and other publications which do not form part of the modular training structure and which therefore the fire service is not obliged to include. In the follow-up to this report, the Board talks about regular subjects taught if it is referring to textbooks which relate to the compulsory modules (appendix 5) as opposed to other publications which are not part of the modular training structure.

The NIFV adjusts the content of the regular subjects taught to fit in with the framework exam regulations published by the Netherlands Bureau for Firefighting Exams (Nbbe) on the instruction of the Minister of the Interior and Kingdom Relations (BZK). The development and issue of the other publications is a task which the NIFV more often than not carries out on its own initiative.

This section provides details of the information regarding sudden fire spread which can be found in the various textbooks and publications and details on which fire service officers are provided with this information.

7.4 Regular subjects taught

The fire service has a modular training structure. The learning modules have been arranged in a matrix according to rank and task/position (see appendix 5). The compulsory nature of the learning modules is prescribed in the Firefighters Decree which stipulates that every fire officer must be trained and examined at the appropriate level for the rank that he holds. However, not every rank within the fire service (of which there are 17) is linked to a level of training. That applies to the ranks of firefighter (BWT), firefighter 1st class (BWT1), leading firefighter (OBM), sub-officer (BM), officer (AHBM), chief fire officer (HBM) and commander (CDR). These ranks are then related back to operational positions, as shown in the table below.

Rank group	Rank	Operational position
Officer	Commander (CDR)	(Chief) officer on duty (OvD/HovD)
	Chief fire officer (HBM)	
	Officer (AHBM)	
Sub-officer	Sub-officer (BM)	-
	Leading firefighter (OBM) *	Officer-in-charge
	Sub-leading firefighter (HBT)	
Crew member	Firefighter 1st class (BWT1)	Crew member
	Firefighter (BWT) *	

Table 2 Training levels within the fire service. Asterisks indicate levels where knowledge relating to sudden fire spread forms part of the curriculum taught.

In the case of the ranks of officer (AHBM) and chief fire officer (HBM), in 2005 the set module packages were replaced by "competence-related training", the so-called courses for fire service management. These include the training required in order to become an officer on duty (OvD) and a chief officer on duty (HOvD). At the end of 2008, the NIFV also brought job-related textbooks for crews and officers-in-charge onto the market.

7.5 Knowledge regarding sudden fire spread in regular subjects taught

The Minister of the Interior has set down requirements regarding the content of all national exams for the fire service[43] in the exam regulations. So the regulations indirectly determine the content of the subjects taught – for exam candidates should be able to pass the exam by applying the knowledge they have acquired on these subjects. However, the regulations were put together on a general basis and do not contain any specific requirements for knowledge relating to sudden fire spread. Neither do exam regulations contain any requirements regarding inside fire attack. To all intents and purposes, that means that all the knowledge relating to this field was developed on the initiative of the fire service (including the Nibra/NIFV) without the involvement of the government.

At the request of the Dutch Safety Board, the Netherlands Institute for Safety Nibra (NIFV) drew up an inventory of the information relating to sudden fire spread which can be found in the subjects taught and textbooks (see appendix 7).

One striking discovery made as a result of the inventarisation was that the officer modules do not contain any information relating to sudden fire spread, at least nothing that is not already included in the lower modules. As a consequence of this, the officers-on-duty (OvDs) and chief officers-in-duty (HovDs) who are in charge of large and complex firefighting operations have not acquired any more knowledge relating to sudden fire spread during their training than the fire service personnel they are in charge of.

The two lower operational levels, firefighter/crew member and leading firefighter/officer-in-charge, do include information regarding sudden fire spread. However that has not always been the case. For the leading firefighter/officer-in-charge, the first editions of teaching materials which paid attention to the phenomena of sudden fire spread were published in 2001. In earlier editions, the subject is either not discussed or only extremely briefly. The first substantial reading material for the firefighter on sudden fire spread was not published until 2003. Therefore all fire officers who were trained before then – which at the present time is the majority – have not gained any substantial theoretical knowledge regarding these phenomena during their training.

The learning module Firefighter Repression[44] contains several pages on two forms of sudden fire spread, flashover and backdraft. The module does not establish any connection between the two phenomena but does mention a number of differential characteristics such as a cloud of gas high up in the room and a rapid increase in temperature in the case of a flashover and the formation of whirling smoke, deposits on the windows and whistling sounds in the case of a backdraft. Besides flashover, the learning module mentions yet another phenomenon, rollover, that could precede a flashover. The module does not follow the definitions that are used in international literature, in particular by the NFPA[45]. Although the section contains a wealth of photographs and diagrams of burning living rooms, it does not seem to provide the reader with any convenient details on how to recognise the various phenomena in practice and how to tell them apart. Certainly for candidates starting at firefighter level, this reading material is confusing and difficult to fathom.
In the section entitled The dangers of smoke, the module Firefighter Repression does mention that smoke can cause fire spread. However, the flammability of smoke is not discussed in any detail.

The learning module Leading Firefighter Repression[46], designed for prospective officers-in-charge, is significantly thicker but does not devote much more space to the subject of sudden fire spread than the module Firefighter Repression. This module also discusses the phenomena of flashover

43 Article 15 in the 1985 Fire Services Act
44 Nibra, 10th edition, 2003
45 National Fire Protection Association
46 Nibra 7th edition, 2002

and backdraft. The clarity of the layout has been improved by including a table containing the characteristics of the two phenomena and the differences between them. According to the accompanying text, it can roughly be said that a flashover occurs as a result of a build-up in temperature while a backdraft occurs as a result of the addition of oxygen. The two phenomena are not related to each other in this module either. However, the module Leading Fire Officer Repression comes out ahead in terms of clarity when compared with Firefighter Repression. The confusing rollover has disappeared from the text. On the other hand, this module does not contain a separate paragraph on the dangers of smoke.

As already stated, all the higher modules designed for the management personnel within the fire service do not contain any additional knowledge relating to the phenomena of sudden fire spread or how to combat it. Therefore, fire officers who take command in the event of medium-sized and large fires are not superior to the personnel they are in charge of as far as this subject is concerned.

7.6 Knowledge regarding sudden fire spread in other textbooks

Since the turn of the century, Nibra has brought out a number of new textbooks which contain more information on the phenomena of sudden fire spread than the regular subjects taught which form part of the modular training structure.

In 1999 Flashover and backdraft, was published as a supplement to the regular subjects taught at the operational level of officer-in-charge (leading firefighter). In particular, more attention has been paid in this edition to repressive firefighting techniques. For the first time, the phenomena of flashover and backdraft are placed in a context where they relate to each other.

This was followed by Repressive ventilation in 2002. This publication pays even more attention to repressive firefighting techniques including that of forced ventilation which can be used to drive out smoke from a burning object. The authors give increased safety as one of the benefits of ventilation. It is odd that 'the discharge of smoke' and 'the discharge of fire gases' are covered in separate sections, as if they were two different products. The publication lacks clarity on this point. The unclear term rollover appears again.

In 2005, the Nibra brought out a textbook entitled Fire behaviour. This publication pays considerable attention to the role of smoke or fire gases as appropriate within the burning process for the first time. The smoke gas explosion is more or less described under the heading 'Backdraft in another room' as a 'cold backdraft'. It is confusing that this terminology does not concur with the (international) literature on this subject.

At the end of 2005, the package Safe repressive action was brought out, designed as an in-service training course for officers-in-charge. As the title suggests, this publication pays considerable attention to the risks of repressive action. However, the phenomena of sudden fire spread are again limited to flashover and backdraft. Smoke gas explosion is missing. Indicators which signal an approaching flashover or backdraft are shown in a clearly structured diagram. That diagram serves as a useful tool for the officer-in-charge, but if used as a 'checklist', it could lead to the conclusion being drawn wrongly that there is no risk of sudden fire spread.

2008 saw the publication of a version of Safe repressive action designed for officers on duty (OvDs). This does not contain any additional information relating to sudden fire spread compared with the version for officers-in-charge.

Finally, A new look at the use of hose pipes was published in 2008. This is a follow-up to Fire behaviour to which a substantial section has been added on firefighting techniques. A separate section covers the safety and effectiveness of inside fire attack within which two procedures are specified as being extremely important: the door procedure and the temperature check. The authors stress that the opening of the door is perhaps the most critical moment of the inside fire attack. Although this theorem may be correct in itself, the casual reader might understand it to mean that there is not that much to an inside fire attack within a building where the door is already wide open.

In summary, it can be said that admittedly, these textbooks do not provide adequate information in all respects, but that this information does contain more detail than the brief paragraphs on sudden fire spread contained in the regular modular subjects taught. However, the terms used are confusing and do not concur with international standards used such as ISO[47], NFPA[48] or FRS[49].

Therefore, the content of the 'other textbooks' extends further than that of the regular textbooks used for the compulsory exams, although on the other hand, the circulation of the former category is limited. Sales figures from the NIFV, the successor of the Nibra and publisher of the textbooks, have revealed a pattern where in the year of publication, approximately 200 to 350 copies of a textbook are sold, with the selling of 750 copies of the publication 'Fire behaviour' serving as a favourable exception. The NIFV itself is indeed one of the biggest buyers of these books. In the second year of publication, sales figures dropped by roughly 50% and in subsequent years, no more than a few dozen copies are sold to customers.

These sales figures are very poor considering that there is a total of just under 30,000 firefighters in the Netherlands. The NIFV added the critical observation on this point that a number of textbooks are bought by fire service instructors who use them for their lessons and training so that at least some of the knowledge is conveyed to the target group verbally. It is also suspected that in fire service circles, it is not unusual for publications to be photocopied so that the actual circulation is greater than you would presume given the sales figures.

7.7 Unused sources: international literature

The shortcomings pointed out in both the regular learning modules and in other textbooks indicate insufficient or a total lack of concurrence with the international literature on the specialist subjects in question. In countries such as Sweden, England and New Zealand, outstanding literature has been published on the subjects of fire dynamics, indoor fire and sudden fire spread, including smoke gas explosions[50]. However, the Board also points out that in a lot of other European countries, the information from literature has not been incorporated in the textbooks for the fire service, or at least not adequately. A clear exception is Sweden, where there is a successful working partnership between universities and knowledge and training institutes for the fire service. International umbrella fire service organisations, such as the FEU[51] or EFSCA[52], would gain a great deal by disseminating available knowledge between participating countries.

7.8 Unused sources: empirical data

In 2004, the Public Order and Safety Inspectorate (IOOV) published two reports[53] in which it concluded that the fire service could and should learn a lot more from its own actions and that knowledge must be shared more often and more extensively. The recommendations made focus on consciously learning from (its own) accidents and developing clear and accessible descriptions and documentation relating to fire service accidents (in the form of case studies) in order to enable the fast spread of important lessons amongst other things. In 2006, following a fire at a discotheque in Amsterdam[54], the Dutch Safety Board also recommended that the municipalities should carry out systematic investigations into fires with the intention of learning from them.

Despite these recommendations, it seems that there are a limited number of types of accident (sudden fire spread, collapse, drowning during diving exercises) that keep occurring. On the face

47 International Organisation for Standardisation
48 National Fire Protection Organisation (USA)
49 Fire Research Station (UK)
50 For example Lars-Göran Bengtsson – Enclosure Fires. Räddnings Verket (2001); Paul Grimwood – Euro Firefighter (2008); B.J. Sutherland – Smoke explosions. Fire Engineering Research Report 99/15 (1999)
51 Federation of the European Union Fire Officer Associations
52 European Fire Services Colleges Associations
53 Safety awareness among fire service personnel (IOOV, 2004) and Professional competence in the fire service (IOOV, 2004)
54 Fire on 15 May 2005 at the Kingdom Venue disco in Amsterdam

of it, the results of accident investigations have not been incorporated in the training and exercises for fire service personnel effectively enough to enable personnel to identify hazards or behave in the correct safe manner as required. The systematic recording and assessment of accidents is inadequate and results of assessments which are carried out are not distributed nationally.

7.9 Summary of conclusions

The regular subjects taught from which the fire service gets its knowledge only provide brief information regarding the different forms of sudden fire spread. The phenomenon of smoke gas explosion, like the one which occurred in De Punt, is not described in the regular subjects taught. Personnel in higher operational positions are not taught any more about sudden fire spread than crew members and officers-in-charge.

However, additional information regarding sudden fire spread can be found in a number of non-compulsory textbooks which the NIFV has published over the past few years, even though they do not concur with international literature on this subject. However, the print numbers for these documents are low and lead us to suspect that the information they contain hardly touches the vast scope of the fire service.

New knowledge, both from international literature and systematic assessments of fires and accidents, is not incorporated in teaching material adequately.

Smoke gas explosions and other forms of sudden fire spread, in conjunction with the method of inside fire attack often used in the Netherlands, are the main cause of serious accidents involving fire service personnel. Firefighters can only protect themselves against this danger if they are knowledgeable about it and understand the phenomena. Therefore the Board carefully confirms that the brief and incomplete coverage of this subject as part of the regular subjects taught is having direct repercussions on the health and safety of fire service personnel at work.

8. CONCLUSIONS AND RECOMMENDATIONS

8.1 Conclusions

1. Three firefighters lost their lives during the fire in De Punt because a large quantity of flammable smoke gases which had accumulated in the building and which was not noticed by the fire service suddenly combusted explosively. The three were taken unawares by the smoke gas explosion and were then no longer able to escape from the burning building.

2. The smoke gas explosion can be explained by a combination of factors including the presence of a large quantity of flammable material in the room where the fire started, the fact that that area was relatively enclosed and the way the space had been divided up inside the building which allowed the smoke gases to accumulate in an area away from the location of the fire.

3. The firefighters involved were not familiar with the phenomenon of smoke gas explosion and as a result of this, were not able to recognise signals that the phenomenon might occur. Based on the actual knowledge possessed by the officer-in-charge and his crew, it was not possible for them to anticipate the sudden fire spread.

4. The subjects taught from which fire service personnel draw their knowledge only offer brief information on the phenomena of sudden fire spread. The phenomenon of the smoke gas explosion which occurred in De Punt is not described as part of the regular subjects taught. Personnel in higher operational positions are not taught any more about sudden fire spread than crew members and officers-in-charge. Publications have been brought out which contain more information on sudden fire spread than the regular textbooks but these do not concur with international standards used on this subject. Moreover, this information hardly seems to touch the scope of the fire service.

5. The fire service is not receptive enough to impulses from outside in connection with developing its knowledge. Science, research and international literature play no role of any significance as far as the development of knowledge within the fire service is concerned. As a result, the training package of the fire service does not contain knowledge elements which are present outside the fire service.

6. The fire service does not make sufficient use of empirical data from practice in order to develop its knowledge. There is no systematic recording or assessment of fires and accidents. Information which does become available is not distributed adequately.

8.2 Recommendations

Preliminary comment:
The Board has taken note of the intention of the Minister of the Interior and Kingdom Relations (letter to the Lower House dated 3 June 2009) to place super-regional tasks relating to firefighting in the hands of a new support organisation to be set up and to make this organisation the responsibility of the joint safety regions or the Safety Consultative Body as appropriate.
The Board wishes to point out with regard to this that as soon as there any actual transfers of responsibility, the recommendations below which are currently directed at the Minister of the Interior and Kingdom Relations will, of course, also be intended for the new party responsible.
The Board is familiar with the Learning Capacity of the Fire Service programme and the proposed regulations in respect of quality management in the safety regions. The recommendations below are in addition to these.

Recommendations for the Minister of the Interior and Kingdom Relations

1. Ensure that new knowledge relating to sudden fire spread, including the phenomenon of smoke gas explosion, is disseminated effectively by incorporating it in the subjects taught and exercises within the fire service.
2. Ensure that the content of fire service training, particularly with regard to the safety of repressive actions, concurs with international literature on the subject.
3. Improve the development of knowledge within the fire service and increase the attention paid to safety by ensuring the uniform, central recording and assessment of fires and accidents and by ensuring that points learned from these are incorporated effectively in the subjects taught and exercises within the fire service.
4. Formulate teaching objectives in the exam regulations in such a way that they are clear, provide direction and are inspiring for all parties involved in the organisation and implementation of education within the fire service.

Recommendation for the Association of Netherlands Municipalities:

5. Before adapting the subjects taught and exercises within the fire service relating to sudden fire spread in general and smoke gas explosions in particular, provide your members with information on the dangers of these phenomena and the conditions in which they can occur.

The government bodies to which a recommendation has been issued must take a stand in respect of following up this recommendation within six months of the publication of this report and notify the minister concerned of this. Non-government bodies or individuals to which or to whom a recommendation has been issued must take a stand in respect of following up the recommendation within a year and notify the minister concerned of this. A copy of this response is to be sent to the chairman of the Dutch Safety Board and the Minister of the Interior and Kingdom Relations at the same time.

APPENDIX 1 JUSTIFICATION OF THE INVESTIGATION

Report and investigation by the Dutch Safety Board
The Dutch Safety Board has a wide scope of activity and, apart from any legal obligations to carry out investigations, is at liberty to choose to investigate accidents for its own purpose and using its own methods. The Dutch Safety Board aims to identify the actual causes of accidents and ascertain any systematic safety-related shortcomings connected with them.

On 9 May 2008, the Dutch Safety Board heard via the media about the fire and the three firefighters who had lost their lives while tackling it. The next morning, investigators from the Board carried out an initial inspection of the burning object and general information relating to the accident was requested from the Drenthe Regional Police. In the three weeks which followed, further investigation was carried out on the burning object, through collaboration with the Laboratory for Fuel Technology and Heat Transfer at the University of Ghent (B), and interviews were conducted with various witnesses. These included members of the Tynaarlo fire service, in particular the survivors from the first fire service unit from the fire station in Eelde, members of the Drenthe Regional Police, the owners and employees from the water sports company involved and other witnesses who were present at the premises during the fire or had happened to be passing by at the time. A number of witnesses from the latter category contacted the Dutch Safety Board on their own initiative.

Besides information which it had collected itself, the Board also received research material from the Public Prosecutor's Office and from the Coordinating Group for Investigations set up by the municipality of Tynaarlo following the accident.
It became clear to the Board as a result of the provisional analysis of the information obtained from these sources that a sudden, strong fire spread had occurred prior to the death of the three firefighters. This sudden fire spread was not foreseen by the firefighters. The Board also found out that even afterwards, the people involved were still in the dark as to the cause of the sudden fire spread. For the Dutch Safety Board, this was enough reason to decide to carry out a full investigation into the fire in De Punt.

Other investigations
Besides the Dutch Safety Board, a number of other bodies have also carried out investigations into the accident. On the instruction of the municipality of Tynaarlo, a committee headed by professor Helsloot from Amsterdam carried out an investigation into the fire and the actions of the municipal fire service. The Labour Inspectorate of Groningen carried out an investigation into the role of the municipality and that of its fire service within the framework of the Working Conditions Act. The Public Prosecutor's Office has been carrying out an investigation into any criminal offences relating to the occurrence of the fire which is still going on in October 2009. The VROM Inspectorate carried out an investigation into the granting and maintenance of the building permit and environmental permit for the industrial building in De Punt. Following the issue of the report by the Helsloot committee, the consultancy company DGMR carried out an investigation into the role of building components from the shed in the development of the sudden fire spread.

Internal organisation
The members of the project team are listed below:

P.J.J.M. Verhallen	project leader/investigator
T.M.H. van der Velden	investigator
E.J. Willeboordse	analyst

The following people also assisted with the project:
S.H. Akbar
W. Boutkan
M.F. Jager
S. Pijnse van der Aa
S.M.W. van Rossenberg

The project team was assisted by a guidance committee made up of external experts and two board members. This guidance committee also assisted with the investigation carried out by the Board into an accident involving a fire service diver in Terneuzen (12 March 2008) that was carried out at approximately the same time as the investigation into the fire in De Punt.

The members of the guidance committee are listed below:

Annie Brouwer-Korf	chairman
J.A. Hulsenbek	member of the Dutch Safety Board, earlier part of the investigation
J.P. Visser	member of the Dutch Safety Board, latter part of the investigation
H.A.G. Kruise	
P. Verlaan	
M.T.W. Gaastra	
R.A. van Hulst	
A.K.W. Gaillard	
B.A.J. Mes	
D.W. de Cloe	
P.J.P.M. van Lochem	

The project team used the coordinating activities of the Coordinating Group for Investigations from the municipality of Tynaarlo for the purpose of the investigation into the burning object, the interviews with the firefighters and witnesses and the collection of written information.

Assistance and advice

For the purpose of the investigation, the Board made use of expert advice and assistance provided by the following bodies:

- **Laboratory for Fuel Technology and Heat Transfer, Fire Safety Department, at the University of Ghent, Belgium**

This laboratory is affiliated to Warringtonfiregent NV.
The laboratory created a reconstruction of the fire based on an investigation of the burning property, supplemented by information from interviews, sound recordings from the Regional Emergency Centre, video images and photographic material. Appendix 4 to this report contains the hypotheses which were formulated and tested by the laboratory in order to produce the ultimate reconstruction of the fire. This part of the investigation was carried out by Dr B. Sette and Prof. Dr P. Vandevelde.

- **Netherlands Institute for Safety Nibra (NIFV).**

The NIFV drew up an inventory of the knowledge relating to the phenomena of sudden fire spread which the fire service possesses, based on its examination of the subjects taught and exercises. This part of the investigation was carried out under the guidance of Dr M.G. Duyvis.

APPENDIX 2 INSPECTION COMMENTS

The Dutch Safety Board Act states that the parties involved will be given 30 days to submit their written comments on the findings in a draft report drawn up the Board. The parties involved can specify any inaccuracies in the material which the Board may rectify in the definitive report.

Following positive recommendations from the guidance committee and after approval by the Board on 21 April 2009, the draft report (excluding the deliberation and recommendations) was presented to the NIFV, the municipality of Tynaarlo, the NVBR, the IOOV, the Ministry of the Interior and Kingdom Relations and the Nbbe for the purpose of assessing the accuracy (or inaccuracy) of the material. Where relevant, the Dutch Safety Board incorporated the comments received in the definitive final report. Because in the final analysis, the Board removed a number of contemplative sections relating to the fire service training system from the draft report, a number of inspection comments are no longer relevant. The comments to which this does not apply but which have not been incorporated by the Board are included in this appendix along with the reasons why the Dutch Safety Board has not made changes to the report based on these points.

Comments from the Netherlands Institute for Safety Nibra (NIFV)

- According to the NIFV, the Board is wrong to talk about compulsory and non-compulsory subjects taught. The NIFV states that the only compulsory modules are those which it is compulsory for candidates to be examined on. By talking about compulsory teaching material, produced by the NIFV, the NIFV feels that it is being unjustly held responsible for the event in De Punt.

Response from the Dutch Safety Board: The position taken by the NIFV is correct; there is no compulsory teaching material. A candidate may decide for himself what knowledge he needs in order to pass the exam. Where the draft report mentioned 'compulsory teaching material', the Board has changed this to 'the teaching material for the compulsory modules' or 'the regular subjects taught'.
The Board wishes to point out with regard to this that in practice, the fire service does regard the books published by the NIFV as compulsory teaching material – for there is nothing else available.

- The NIFV states that the report does not pay enough attention to exercises and in-service training for fire service personnel, as this is the responsibility of the municipality according to the Working Conditions Act.

Response from the Dutch Safety Board: It does indeed follow from the Working Conditions Act that the municipality, as the employer, has to provide training for its employees in connection with the duties they perform. Therefore, in the report, the Board has specified the activities that the municipality of Tynaarlo has developed in connection with exercises and in-service training for its fire service (section 7). At the same time, it cannot simply be said as to whether the municipality has complied with the Working Conditions Act by doing this. This has only provided a framework. No standards have been set for the implementation of this and so there are no ways to check on it either. Requirements have only been set with regard to fire service training and, in that respect, the municipality of Tynaarlo has its business in order.
The second reason why the Board has not investigated exercises and training in detail is that it is necessary to acquire theoretical knowledge first before skills can be developed. So for example, it is not possible for exercises on how to deal with sudden fire spread to be carried out effectively if personnel are not familiar with and do not have an understanding of these phenomena. Even if the fire service from Tynaarlo had already spent time carrying out exercises, the accident would still have happened because the personnel would not have been able to identify the smoke gas explosion and the associated context of fire phenomena.

- Section 6 of the report mentions the circumstances which may have caused the visibility of the smoke to be restricted. The NIFV states that these circumstances make it unlikely that the crew members would have been able to see it clearly even if they had possessed sufficient knowledge. According to the NIFV, the question can be put again: Did they or did they not possess sufficient knowledge?

Response from the Dutch Safety Board: The circumstances mentioned caused the direct visibility of the smoke to be restricted. That does not alter the fact that the smoke was visible, namely that it could have been seen by looking up round the edge of the door. The Board follows the reasoning that if the firefighters had had sufficient knowledge regarding the possibility that the smoke could combust explosively, they would have actively been cautious of this hazard and they would have seen the smoke. The Board has explained this way of thinking in section 6.

- The NIFV quotes the following from section 7:
  "One striking discovery made as a result of the inventarisation was that the officer modules do not contain any information relating to sudden fire spread."
  The NIFV wonders why this is described as striking. It is the crew members and officers-in-charge who must be able to apply this basic knowledge. According to the NIFV, the officer-on-duty (OvD) and certainly the chief officer-on-duty (HOvD) do not get close enough to be able to interpret the behaviour of the fire in detail. Also, everything there is to say regarding sudden fire spread is also related to crew members and officers-in-charge.

Response from the Dutch Safety Board: The Board considers it to stand to reason that modules for higher ranks also deliver a higher cognitive level. However, the opposite is the case.
The Board does not agree with the statement made by the NIFV that the (chief) officer-on-duty was too far away from the fire to be able to interpret the behaviour of the fire. As any person in charge of an operation knows, it is quite necessary to stand at a distance in order to get a clear overview of the situation. The Board considers it to be a distinct task of the officer-on-duty or the chief officer-on-duty to form the clearest possible picture of the behaviour of the fire. Not until the person in charge understands how a fire has developed will he be able to tackle it effectively and safely.
Nor does the Board agree with the statement made by the NIFV that everything there is to say regarding sudden fire spread is also related to crew members and officers-in-charge. As specified in the report, the Board considers the information provided by the teaching material on this subject to be extremely brief and insufficient for the purpose of training firefighters to carry out their task safely.

- Section 7 of the report discusses the learning module Leading Firefighter Repression: "The two phenomena (flashover and backdraft) are not placed in a context where they relate to each other in this module either." The NIFV wonders what context the Board is referring to.

Response from the Dutch Safety Board: With regard to context, the Board is referring to the relation between the physical and chemical processes which result in both flashover and backdraft. One example of a publication within which flashover, backdraft and smoke gas explosion are described within a context where they relate to each other is "Enclosure fires" by Swedish author Lars Göran Bengtsson. As the Board sees it, placing phenomena in a context where they relate to each other, certainly in a textbook, makes it easier to get a clear understanding of the situation.

- The NIFV does not agree with a comment which the Board makes on the publication Fire behaviour within which it is suggested - wrongly according to the Board - that 'smoke' and 'fire gases' are two different products. According to the NIFV, they are. The NIFV states that the combustion products of a fire consist of fire gases and (as yet) unburnt soot particles. The soot particles are visible and are referred to as smoke. The fire gases are not visible and therefore are not referred to as smoke. However, they are often the most dangerous, according to the NIFV.

Reaction from the Dutch Safety Board: The Board uses the definition of the NFPA (921-3.3.137). Smoke is a mixture of solid and liquid particles and gases given off by material that undergoes pyrolysis or combustion, along with a quantity of air mixed in. Under this definition, fire gases are a component of smoke and not a separate substance.

- According to the NIFV, in section 7 the Board states that the door procedure described in the publication A new look at the use of hose pipes could lead a person to conclude that it is always safe to carry out an inside fire attack from inside a building with the door open. The NIFV points out with regard to this that this is not stated anywhere.

The NIFV also points out that the temperature check also forms part of the phased plan for a safe and effective inside fire attack which must be carried out immediately on entry. As far as the NIFV is aware, that check was not carried out in De Punt.

Response from the Dutch Safety Board: The quote mentioned was not reproduced in its entirety. The Board quotes the following from the NIFV publication: "The opening of the door is perhaps the most critical moment of the inside fire attack". The Board states with regard to this that the casual reader might understand it to mean that in the case of a building with an open door, as the most critical step does not need to be taken, the risk is relatively small.
With regard to the temperature check mentioned, the Board wishes to point out that this could also create the impression that if this check produces a negative result (smoke gases are not hot), that would mean that there was little or no danger. As the Board explained in the report, smoke gases which are not hot can also combust explosively. The content of unburnt components and the ratio with air are more important as factors determining the explosiveness of smoke than temperature is.

- According to the NIFV, in the final part of section 7 the Board creates the impression that teaching material is the only source of knowledge for firefighters. The NIFV points out the availability of technical journals, websites, internet forums and international technical literature. The NIFV also draws attention to its own publications, i.e. Safe repressive actions for officers-in-charge.

Response from the Dutch Safety Board: The Board is aware of the data media mentioned by the NIFV and has also specified these in the report. The main objection of the Board does not relate to the content of this information but to the fact that the fire service is not obliged to include these and that therefore there is no guarantee at all that the knowledge of fire service personnel will exceed the content of the subjects taught within the compulsory modules.

Comment from the municipality of Tynaarlo
- The municipality points out that in section 1, the Board writes that the Helsloot committee does not specify that the strong development of smoke seen by the firefighters on their way to the scene should also have been identified as an indication of risk. However, in the Helsloot report, the municipality reads that the firefighters did interpret the sight of this smoke as being dangerous.

Response from the Dutch Safety Board: The Helsloot committee writes that the fire service crew did perceive the smoke which they could see on their way to the scene as a hazard (p. 12), so that the absence of smoke was taken to indicate an absence of hazards (p. 15). The Board does not agree with the committee on this. The firefighters saw the smoke as an indication of the size of the fire and as a threat to traffic safety but not as an indication of a dangerous fire situation. The Board verified this idea in a separate conversation with the officer-in-charge which took place on 11 February 2009.

Comment from the Ministry of the Interior and Kingdom Relations (BZK).
- The Ministry of the Interior and Kingdom Relations points out that various aspects of the actions taken by the fire service are not analysed at all or only briefly, such as procedures, equipment (walkie-talkie seemed to be faulty), safety measures (e.g. in order to ensure the effective withdrawal of personnel deployed) and the supply of information (was the officer-in-charge provided with all the relevant information in good time?). According to the Ministry of the Interior and Kingdom Relations, elements of this accident which may have been of value have been lost as a result and the focus is one-sided, being directed at education and the education system.

Response from the Dutch Safety Board: It is true that the way in which action was taken by the fire service unit in question deviated from customary procedure on a number of points; there were also technical problems. Besides the deviations mentioned by the Ministry of the Interior and Kingdom Relations, the Board also specifies the following: answering the call with more than six people in one vehicle, the turning out of a second vehicle with additional personnel to reinforce the first group deployed, the attendance of personnel off their own bat and with their own vehicle and

finally the deployment of a four-man crew to tackle the fire. The Board included all these deviations in the reconstruction of the facts of the case but did not elaborate on them in the analysis.
The reason for this lies in the method used by the Board for investigating accidents: the Board identifies the causes or probable causes of an accident, then investigates the backgrounds of these causes and examines whether there are any systematic safety-related shortcomings. By doing this, facts found which have no causal connection with the accident will automatically fall outside the framework of the investigation. The Board recognises that non-causal facts might also become valuable elements. However, an investigation that takes all possible elements into consideration becomes an assessment. However valuable that may be, the Board focuses on the causes of the accident because that is where the key lies to preventing comparable accidents in the future.

Comment from the Netherlands Association for Firefighting and Disaster Management (NVBR)

- The NVBR points out that the observations made by a number of customers and a passer-by, as formulated in section 5, do not seem to be consistent with the observations made by the firefighters. The NVBR wonders whether this is due to careless wording or, if that is not the case, why the Dutch Safety Board does not mention this inconsistency in the observations specifically. The reason for doing this is the importance of the question as to how it could have happened that the officer-in-charge was so misled that he failed to notice the mass of smoke.

Response from the Dutch Safety Board: In the opinion of the Board, this is not a question of an inconsistency in observations. Taking all the witness statements together, including those of the fire service, they provide a picture of alternating fire behaviour during which periods of strong fire development with turbulent smoke emissions alternate with periods of relative calm. The Board interprets this picture as a pulsating fire, the result of a limited supply of fresh air to the fire compartment (the storeroom).

The fire service was unlucky in that they arrived just at the time when the fire had entered a rest phase. As a result of this, the curling smoke which had just been seen coming out of the large door opening was no longer visible at the front of the building. Therefore the officer-in-charge had no direct sight of the smoke and as a result failed to notice the large mass of smoke which was hanging underneath the roof of the shed.

The Board has set out the model of the pulsating fire, and included the relevant statements of the witnesses and the fire service, in sub-section 5.4 (Analysis of the behaviour of the fire).

- The NVBR quotes from section 6 that the Board considers it likely that, while the firefighters were in the shed (between the time they went in and the smoke gas explosion), they will have noticed the layer of smoke gas at some point. The NVBR wonders how this assumption relates to the preceding interpretation in which the firefighter focuses his attention so strongly on the object (the fire) that he fails to pay enough attention to hazards in the vicinity.

Comment from the Board: The Board worked out by means of estimation (see also appendix 3, timeline) that the three men had been in the shed for one minute and ten seconds when the smoke gas explosion occurred and that the mass of smoke was three metres above their heads before the explosion, in a 55 metre long space. Even if their perception was limited to some extent, it is still possible that they saw the very large - and also very close - mass of smoke during the period of more than one minute they spent in the shed. Of course, it is impossible to ascertain what the three men actually saw. However, the Board believes that it described the uncertainty regarding this adequately.

- The NVBR quotes the following from the same section:
  "It is only clear that if the three subsequent victims did notice the layer of smoke gas, they did not see this as any reason to abort the inside fire attack and go outside. Also, they did not identify the mass of smoke underneath the ridge of the roof as being life-threatening."
  The NVBR states that this 'if-then relation' cannot be verified, as the victims are dead. It is therefore wrong to formulate ideas using terms such as 'It is clear that if..., then…'.

Comment from the Dutch Safety Board: It is no longer possible to find out what the victims saw or what they thought. However, it has been established that they did not go outside – as their bodies were found inside the shed. Therefore the claim that "they did not see this as any reason to abort the inside fire attack and go outside" is true in any case, so even after expressing a reservation ("… if they did notice the layer of smoke gas..."). Therefore the sentence quoted by the NVBR is logical and correct.

- The NVBR points out that the dissemination of knowledge alone is not enough to produce learning capacity and consequently safe conduct.

Comment from the Dutch Safety Board: The Board shares this view. A lot more than knowledge is required: exercises, the development of skills, the gaining of experience, the sharing of experience, retraining and in-service training, etc. However, the Board is also of the opinion that knowledge is a prerequisite for enabling effective and safe action. To stay with the example of De Punt: even if the firefighters had been extremely experienced and extremely well-trained, it would still have been impossible for them to anticipate the smoke gas explosion because they knew nothing about the phenomenon. The firefighters did not know that even if the door is wide open and even if there is no heat, it may still be possible for smoke to combust explosively.

APPENDIX 3 TIMELINE

Messages sent to and from the Regional Emergency Centre (RAC) in Assen are logged and identified using time labels. This log (table 3) has been used as the basis for the reconstruction of the timeline within which the sequence of events is related to time.

1	14.09:04[55]	RAC[56] Groningen receives a report of a fire from one of the owners[57].
2	14.09:25	RAC Groningen relays the report of the fire to RAC Drenthe.
3	14.10:30	RAC Drenthe alerts the fire station in Eelde.
4	14.14:38	TS 31-11[58] answers the call. RAC to TS 31-11: "Fire in meter cupboard at company B."
5	14.14:58	Daughter of owners makes second report: "The area at the back of the shed is on fire. There is a great deal of smoke."
6	14.15:35	RAC to TS 31-11: "The back of the shed is fully ablaze".
7	14.16:16	Report made by someone living nearby to RAC: "There is a major fire opposite us".
8 9 10	14.16:44 14.17:10 14.17:37	RAC calls TS 31-11 on its way to the fire. RAC provides information on water supplies. TS 31-11 on approaching the shed: "I have sight of the building, I can see the smoke already. I would say it was a medium-sized fire". TS 31-11 on approaching the shed: "The road must be closed… the smoke is travelling across the road… there is a lot of bad smoke…".
12	14.20:45	RAC calls TS 31-11. No response.
13	14.21:42	TS 31-11 to RAC: "Things have got completely out of hand. I have lost men from my own crew."

Table 3 Messages sent to and from the Regional Emergency Centre in Assen

A number of important events cannot be given times directly from the RAC log. However, the times when these events took place can be estimated in a number of different ways. These events are:

- the discovery of the fire;
- the first accelerated fire development
- the second accelerated fire development
- the arrival of appliance TS 31-11
- the entering of the shed
- the sudden fire spread
- the running out of the victims' breathing air supply.

1. The discovery of the fire

The fire was discovered at some point by the first employee of the company. He called upon his colleague (the second employee) to call the fire service. The second employee responded to this request not by making the call himself but by alerting the owner who was at home. The owner then called the control centre in Groningen at 14.09:04 hours (table 3).

It became clear from the witness statements that the second employee did not leave the shed immediately in order to warn the owner. For he was able to tell the owner that the first employee was trying to put out the fire and therefore he must have stood looking on for at least a few moments.

55 The clock at the emergency centre in Groningen was running 4 seconds behind the one at the control centre in Assen. This has been corrected in the table. All the times specified in the table are according to the clock at the control centre in Assen.
56 RAC: Regional Emergency Centre
57 Tynaarlo is a municipality in Drenthe but has the Groningen area code 050. As a result, reports made via a landline will be put through to the control centre in Groningen instead of the one in Assen.
58 TS 31-11: first vehicle from Eelde.

On the other hand, another witness who was outside at the site stated that the second employee rushed to the owner's house at top speed. That led the witness to conclude that something was up.

The distance covered by the second employee from the door of the storeroom to the owner's house was 150 metres. At a speed of 10 km/h (moderate pace), the second employee would have covered this distance in 54 seconds. However, the second employee also had to open a door (to the house) on his way to the owner. Therefore, it is reasonable to estimate that it took him a minute to get to the owner.

Other estimated periods of time between the discovery of the fire and making contact with the RAC Groningen:

Second employee watches the first employee trying to put out the fire:	20 s
Second employee runs to the owner:	60 s
Second employee informs owner:	20 s
Owner calls the fire service:	20 s

So a total of 2 minutes passed between the discovery of the fire and the telephone call. That means that the fire was discovered at around 14.07:04.

In order not to give any false idea of accuracy, the time of the discovery of the fire has been rounded down here to 14.07 hours.

2. Two phases of accelerated fire development

It can be concluded from the statements of the employees of the water sports company who were present in the shed that the fire went through two phases of accelerated fire development prior to the arrival of the fire service. On two occasions, the employees saw a wave of smoke rolling along underneath the ridge of the roof. Both times, the employees found the situation so threatening that they fled the shed.

The first wave of smoke occurred after the first employee had made an unsuccessful attempt to put out the fire and after he had reconsidered his intention to make a second attempt to put it out.

According to the employees, the second wave of smoke occurred shortly before the fire service arrived. When the fire service arrived, there was no-one left in the shed.

It is likely that the waves of smoke inside the shed corresponded to the smoke emissions which were seen by various witnesses outside the shed. According to a number of witnesses, this smoke was coming out through the cracks in the roof.
So it may have been the first wave of smoke that caused the owners' daughter to call the fire service at 14.14:58 hours in order to report that there was "a great deal of smoke" amongst other things.

Besides the employees, the second wave of smoke was also reported by a passer-by who went into the shed in order to size up the situation and by a customer who was present at the premises. All these witnesses stated that this event occurred shortly before the arrival of the fire service. Therefore, it is likely that the wave of smoke is connected with the large quantity of smoke observed by the officer-in-charge which led him to scale up the situation to a 'medium-sized fire' on the way to the scene (14.17:10 hours).

Between the two phases of accelerated fire development, the fire appeared to be relatively calm, both inside and outside the shed. The members of staff and a customer made use of this and went back into the shed in order to bring property to safety. The owner, who came to size up the situation during this phase, saw nothing much of any importance and thought to herself "What a fuss".

Time of the first accelerated fire development

After the second employee had asked the owner to call the fire service (1-1-2), he ran back to join his colleagues again who were still in the shed, near to the storeroom. The second employee then went out again via the nearby door in the side wall on the right-hand side where he saw that smoke was coming out from underneath the roof and went back inside via the same route to tell his colleagues what he had seen. The three employees then left the shed while "a gigantic cloud of smoke was drifting along the ridge of the shed".

The time it took to carry out these actions is estimated below:

Second employee runs after his colleagues into the shed after alerting the owner:	60 s
Second employee confirms to his colleagues that the fire service has been called:	15 s
Second employee runs outside via the side door (25 m away):	20 s
Second employee sees smoke outside:	15 s
Second employee runs back inside via the side door:	20 s
Second employee rejoins his colleagues and tells them what he has seen:	15 s

Therefore there is at least 2 minutes and 25 seconds between the moment when the second employee gets the owner to call the fire service and the moment when he joins his colleagues for the last time, before they all leave the shed.
That means that the first accelerated fire development must have occurred later than 14.11:29 hours, rounded up to 14.11:30 hours.

It was 14.14:58 hours when the owners' daughter telephoned the RAC in Assen and reported (amongst other things) that there was a great deal of smoke. Taking into account a reaction time of one minute (the time between the daughter noticing the smoke and telephoning the fire service), the first accelerated fire development must have occurred before 14.14 hours.

The end result of this estimation is that the **first accelerated fire development** occurred **between 14.11:30 hours and 14.14 hours.**

Time of the second accelerated fire development
All the witnesses, both inside and outside the shed, mention a second accelerated fire development shortly before the arrival of the fire service. Inside the building, the employees, a customer and a passer-by experience a threatening, or even extremely threatening, situation while people present at the site see the curling smoke coming out of the large door opening. However when the fire service gets to the scene, these phenomena are no longer to be seen.

On the way to the scene at 14.17:10 hours, the officer-in-charge from the first fire service unit sees so much smoke that he contacts the RAC and scales up the operation. 27 seconds later, as he is getting nearer to the shed, the officer-in-charge sees so much smoke travelling across the road that he arranges for the road to be closed in order to protect the safety of the traffic.

It is unlikely that the massive emission of smoke started before 14.17:10. If there had been a lot of smoke development earlier, the officer-in-charge would have noticed it earlier. For the smoke was driving across the airport in Eelde (air traffic was stopped there for some time on account of the smoke) and the entire airfield can be seen quite clearly from the road from Eelde to De Punt. It is therefore likely that the second accelerated fire development started shortly before 14.17:10 hours, rounded off to 14.17 hours.

The end result of this estimation is that the **second accelerated fire development** started at **around 14.17 hours**, and certainly continued until 14.17:37 hours, but **was over** by the time the fire service arrived (**14.18:30 hours**, see below).

3. The arrival of the fire service.
The officer-in-charge from the first fire service unit did not report his arrival to the RAC. However shortly before arriving at the scene, he was still in radio contact with the control centre: from this piece of information, it is possible to estimate the time of arrival of TS 31-11 at the front of the shed.

At 14.17:37 hours, the officer-in-charge from the first fire service unit reported that the smoke was travelling across the road and that therefore the road had to be closed. At that moment, TS 31-11 reached the roundabout near to the shed and only had another 200 metres to go before reaching the parking area in front of the shed. Within those 200 metres, the vehicle had to exit

and accelerate off the roundabout, slow down in order to make a sharp turn onto the site, then accelerate again, slow down and come to a standstill on arrival in front of the shed. The average speed of the vehicle along this short section will not have been high – assuming an average of 12 km/h, the vehicle would have taken one minute to get from the roundabout to the scene.
The short space of time of one minute between noticing the large quantity of smoke at the roundabout and the absence of (visible) smoke when the fire service vehicle arrived at the scene corresponds to the multiple witness statements which mention a threatening fire development directly before the arrival of the fire service. A number of witnesses, including the first employee, recall the curling smoke coming out of the large door opening, even along with the arrival of the fire service.

Based on the above, the estimated **time of arrival of the fire service** is approximately **14.18:37 hours.** In order not to give a false idea of accuracy, this time has been rounded down to 14.18:30 hours.

4. The entering of the shed

Between the time of arrival and the time when they enter the shed, the firefighters carry out a number of necessary actions. They alight from the vehicle, take in the situation and the officer-in-charge gathers information (from a policeman). The driver/pump operator puts his pump into operation, the storage section of the vehicle is opened in order to take out the equipment required (thermal imaging camera) and the high-pressure hose is uncoiled from the reel. The men prepare their personal equipment for use. The officer-in-charge prepares his plan of action and, after a brief consultation, gives his orders. Finally before going in, the crew members connect their breathing apparatus to their breathing masks.

Therefore there are a lot of actions that have to be carried out but they can be carried out quickly. What is more, there are indications that in this case, the firefighters made a fairly swift entry. They were on familiar territory. According to one witness statement, crew member 'Number 2', who came back out again after entering the shed because his hose had got stuck, grumbled: 'They are going too fast'. Taking this into account, it is likely that from the time of arrival, the fire service crew took no more than one minute before starting the inside fire attack.

Based on this assumption, it is estimated that the firefighters entered the shed at approximately 14.19:30 hours.

5. The sudden fire spread

Data relating to the events which followed the arrival of the fire service can be taken from the logs for the breathing apparatus (Bodyguard) of the three firefighters who lost their lives (table 4).

The data in table 4 can be interpreted as follows:
The first column shows the pressure in the breathing air cylinders at the start of deployment. It can be seen from this that the cylinders, which are designed with a filling pressure of 300 bar, had all been filled properly.

The second column shows time t(0) when the equipment records the first time air is used. This corresponds with the moment when the user connects his breathing apparatus to his breathing mask. This action is carried out directly before entering the burning object.

The third column indicates time t(1) when the equipment registers a sudden increase in temperature. Before this moment, a constant temperature of 23 °C is measured; after this moment, the equipment registers a continuous rise to above 60 °C. The Dutch Safety Board interprets this increase in temperature as being due to the sudden fire spread.

Apart from that, the equipment does not measure the ambient temperature but the internal temperature of the Bodyguard. The measured value is approximately the same as the physiological temperature for the user.

The fourth column indicates time t(2) when the breathing air supply in the cylinders of the three firefighters ran out.

Finally, the fifth column indicates the temperature at t(0), at the start of deployment, and the sixth column indicates the temperature at t(2), the moment when the breathing air supply ran out.

If time t(1) is indeed the time of the sudden fire spread, it is immediately clear that the time data from the breathing apparatus cannot correspond with the times recorded by the RAC (table 3). For according to table 4, the sudden fire spread would have had to occur between 14.23:34 and 14.23:40 hours. However in table 3, the officer-in-charge relays his message to the RAC, reporting that things have got completely out of hand and that he has lost his men, two minutes earlier at 14.21:42 hours. That is not possible.

It is concluded that the times recorded by the Bodyguards and those recorded by the RAC Assen cannot be used together. The times recorded by the Bodyguards can only be compared with each other. Therefore in table 5, which is otherwise the same as table 4, the absolute times have been replaced with times in relation to the time when the breathing air was first used t(0).

In table 5, it is now easy to see that the sudden rise in temperature occurred at 1 minute and 10 seconds (1st firefighter), 1 minute and 10 seconds (2nd firefighter) and 1 minute and 20 seconds (3rd firefighter) respectively after the three turned on their breathing apparatus. These data can be interpreted as showing that the sudden fire spread occurred less than 1 minute and 10 seconds after the three firefighters had entered the shed.

After the three firefighters (together with their fourth colleague, "Number 2") entered the shed at approximately **14.19:30 hours**, they were trapped by the **sudden fire spread** at approximately 14.20:40 hours.

	Cylinder pressure at t(0)	t(0) when air is first used	t(1) increase in temperature	t(2) end of air supply	Temp. at t(0)	Temp. at t(2
1	314 bar	14.22:30	14.23:40	14.35:11	23°C	68°C
2	318 bar	14.22:25	14.23:35	14.33:34	23°C	60°C
3	317 bar	14.22:14	14.23:34	14.33:58	23°C	67°C

Table 4 Data read out from breathing apparatus (Bodyguard) of the three victims.

Column 1: Pressure in the breathing air cylinders at the start of deployment.
Column 2 : Time t(0) when air is first used
Column 3 : Time t(1) start temperature increase
Column 4 : Time t(2) end of air supply
Column 5 : Initial temperature, at time t(0)
Column 6 : Temperature at end of air supply, at time t(2)

	Cylinder pressure at t(0)	t(0) when air is first used	t(1) increase in temperature	t(2) end of air supply	Temp. at t(0)	Temp. at t(2
1	314 bar	0 min.00'	1min 10'	12 min 41'	23°C	68°C
2	318 bar	0 min.00'	1min 10'	11 min 09'	23°C	60°C
3	317 bar	0 min.00	1 min 20'	11 min 44'	23°C	67°C

Table 5 The absolute times from table 2 have been replaced here by the time in relation to t(0), when air is first used.

The estimated time of the sudden fire spread - 14.20:40 hours - concurs with the data from the RAC in table 3. At 14.20:45 hours, immediately after the sudden fire spread, the RAC calls the officer-in-charge from TS 31-11 who fails to answer the call. At 14.21:42 hours, i.e. 1 minute after the sudden fire spread, the officer-in-charge reports the emergency situation which has arisen to the RAC. The response time of one minute is reasonable because at the time of the sudden fire spread, the officer-in-charge had already started his investigation of the outside and so had to go back to the front of the shed. When he got there, he noticed that three of his men were missing. He tried to call the three firefighters on his walkie-talkie, noticed that the battery was dead and then swapped his walkie-talkie for the one being used by the driver/pump operator. Only then did the officer-in-charge report to the RAC that his men were missing.

Because it is reasonable to assume that it took the officer-in-charge a minute to carry out these actions, the time of the mobile phone conversation between the officer-in-charge and the RAC (table 3) confirms the estimated time of the sudden fire spread (14.20:40 hours).

Looking back at the whole behaviour of the fire, it is concluded that from the start of the fire, with flames approximately one metre high above the meter cupboard, it took 13 minutes and 40 seconds to develop into a full blaze which engulfed the whole 75 metre-long shed.

6. The running out of the victims' breathing air supply

Table 5 shows that after the sudden fire spread, the three firefighters used up their breathing air supply in 11 minutes and 31 seconds (first firefighter), 9 minutes and 59 seconds (second firefighter) and 10 minutes and 24 seconds (third firefighter) respectively. In other words, their breathing air cylinders ran out of air at the rounded-off time of between 14.31 hours and 14.32 hours.

7. Frequency of the pulsating fire

Based on the assumption that the smoke gas explosion which caused the sudden fire spread was initiated by a new peak phase of the fire, following two earlier peak phases which are related to time in this appendix, all the details can be put together to get an idea of the pulsation frequency of the fire.

These details, all approximate of course, are as follows:
(1) The first peak phase of the fire occurred between 14.11:30 and 14.14 hours;
(2) The second peak phase of the fire occurred between 14.17 and approximately 14.18 hours;
(3) The third peak phase which lead to the smoke gas explosion started at 14.20:40 hours.

Between the start of the second peak phase and the third peak phase is a period of 3 minutes and 40 seconds, rounded up to 3¾ minutes. Therefore the pulsation frequency of the fire is once every 3¾ minutes. If this pulsation frequency is at all constant, the first peak phase of the fire must have started approximately 3¾ minutes before the second, so at approximately 14.13:15 hours. That time falls within the estimated range (1).

It is concluded that the fire in the storeroom was a pulsating fire with the peak phases occurring at a **frequency of 3¾ minutes**, the first at approximately 14.13:15 hours, the second at approximately 14.17 hours and the third which lead to the smoke gas explosion at approximately 14.20:40 hours.

14.07	Fire discovered.
14.09:04	Owner of shed reports fire to the fire service.
14.11:30	Fire reaches first peak phase.
14.14	Fire enters first rest phase.
14.14:38	TS 31-11 answers call.
14.17	Fire reaches second peak phase.
14.17:10	Officer-in-charge sees smoke on the way to the scene and scales up situation.
14.18	Fire enters second rest phase.
14.18:30	TS 31-11 arrive at the scene.
14.19:30	Firefighters enter the shed.
14.20:40	Third peak phase leads to smoke gas explosion. 3 firefighters are trapped.
14.20:45	RAC calls officer-in-charge. No response.
14.21:43	Officer-in-charge reports emergency situation to RAC.
14.31-14.32	Breathing cylinders of victims run out of oxygen.

Table 6 Chronological overview of the main events. The times shown in bold type are times recorded by the RAC Groningen and the RAC Drenthe; all the other times are estimated.

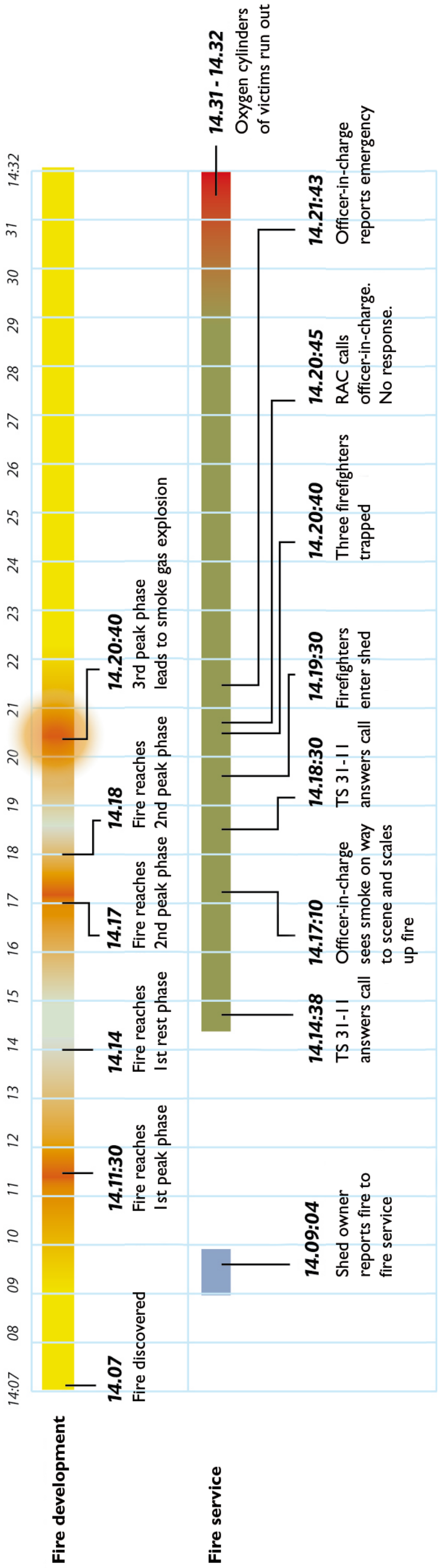


Fig. 5 Graphic diagram of timeline

APPENDIX 4 HYPOTHESES RELATING TO THE BEHAVIOUR OF THE FIRE STUDIED

Introduction
In order to arrive at the reconstruction of the initial fire described in Section 5, a number of hypotheses were tested first. These tests are contained in this appendix. The text printed in italics at the start of each section explains the hypothesis.

The hypothesis which was accepted earlier on by the Helsloot committee[59], namely that the sudden fire spread was caused by the "sandwich panels" in the roof structure of the shed, is tested in section 7. However based on the tests, the Dutch Safety Board rejects this hypothesis.

This appendix was drawn up by the Laboratory for Fuel Technology and Heat Transfer at the University of Ghent (B).

1. Hypothesis: Spray PUR insulation caused rapid flashover in storeroom

The exposed spray PUR insulation caused rapid flame spread in the storeroom. This resulted in an abrupt increase in the heat output of the fire and in the production of a great deal of smoke.

We did not know the composition of the insulation. According to DGMR[60], it would be Resifoam AL 650 containing expanding agent HCFC-141b with a probable fire classification of class B2 in accordance with DIN 4102. This fire class is comparable with class E in accordance with EN 13501-1. These fire classes indicate that – under the conditions from the test method – the product is able to withstand the application of a small flame (type: cigarette lighter) to the product. However, it also indicates that – under the conditions as described in ISO 9705 – the product can create flashover conditions in a room within two minutes[61].

In the test method described in ISO 9705, a heat output of 100 kW was initially used. Based on the evidence of the employee who noticed the fire – he saw flames above the cupboard and heard crackling – and based on the materials present – wooden back wall, electrical wires and plastic installation tubes – it is more than reasonable to assume that, shortly after the first attempt to put out the fire, it quickly recovered to an output of 100 kW.

Based on the probable fire class and based on the behaviour of comparable products, the pre-heated ceiling, consisting of wood and spray PUR insulation, would have been fully ablaze within the two minutes. It may have happened even faster. For the witnesses also describe the situation in that way. After abandoning his second attempt to put out the fire, •••• hurried the others outside, constantly looking back. He saw deep black clouds of smoke rolling towards the front underneath the ridge. On reaching the front of the shed, the layer of smoke gas had grown to almost the height of the side walls.

Based on the inventory of materials present and their position, such a rapid flame spread can only be explained by the materials used for the ceiling. In terms of flammable materials present in sufficient quantities, the only ones which fit the criteria are the wooden cross-beams and the spray PUR insulation. Because of its good insulating properties (low heat conduction coefficient) and low density[62] (38 kg/m^3), the product breaks down much quicker into flammable gases than the wooden beams with a typical density of around 450 kg/m^3.

Decision: Both the witnesses and the facts mention rapid flame spread in the storeroom. This rapid flame spread can only be explained by the rapid involvement of the ceiling. Thermal properties and the specified fire class point towards the spray PUR insulation as the cause of this rapid spread. The hypothesis is retained as possible.

59 *Investigation into the fire with fatal outcome in De Punt* - Helsloot committee/NVBR, June 2008
60 *Behaviour of the fire in the boat shed in De Punt – F.2008.1024.00.R001* – DGMR, September 2008
61 If the product is in class E according to EN 13501-1 and not class D
62 Source: http://www.resina.nl/page.php?id=3&categoryId=MTc= (Jan. 2009)

2. Hypothesis: An oscillating fire was raging in the storeroom

This hypothesis supposes that the oxygen concentrations in the storeroom were extremely low and that, as a result of this, throbbing combustion occured which oscillated between active (smouldering) combustion in the storeroom and the rapid, powerful emission of flames and/or (partially burnt) smoke gases in the shed.

Based on a calorific value of 18 MJ/kg for wood and 23 MJ/kg for PUR, it can be calculated that on ignition, the ceiling would have delivered an estimated heat output of 10 MW. In the case of a fully developed fire, this output could even have gone up to above 15 MW just for the wooden beams). The amount of oxygen that could flow in through the door corresponds to an output of 3 to 4 MW[63]. As a result of this, certainly due to the depth of the storeroom (20 m), extremely low concentrations of oxygen would have occured.

Consequently, the fire entered a smouldering phase and appeared to 'calm'. This allowed oxygen to penetrate deeper into the storeroom where it mixed with hot flammable gases and ignited (explosively). A mass of gases was then hurled into the shed from the storeroom.

It is most likely that such a cycle occurred between the time of flashover and the time when the two police officers who were walking around the outside reached the storeroom. While walking along the side wall, ●●● and ●●●● heard a bang. ●●● said: 'Let's get out of here'. They both ran back to the front of the building. There ●●●● noticed that the smoke slowly began to get blacker. Another witness who was standing four metres inside the shed at that time described the experience as follows: At that moment, a fast-moving, jet-black thick cloud of smoke suddenly crept across the floor towards Mr ●●●●●. He realised that he was in a dangerous position and ran out of the shed quickly.

Initially, after the failed attempt to put out the fire, everything seemed to be going very quickly and getting out of hand. Then the situation entered a phase during which nothing seemed to be quite as threatening (4 to 5 people were busy trying to tow property out of the shed). Suddenly, presumably at around 14.17 hours, black smoke gushed out from the storeroom and the situation was regarded as life-threatening again. Around this time, on seeing the smoke while on the way to the scene, TAS 31-11 scaled up the situation to a medium-sized fire.

At around 14.19 hours, standing in front of the shed, the fire service did not see anything special in the shed. Standing with my crew in front of the open overhead door, we could see inside the shed. We could see the inside of the shed clearly. I did not see any real flames. The fire in the storeroom appeared to have entered its 'rest phase' again.

At around 14.21 hours, the throbbing storeroom fire had come to the end of a cycle again and hurled gases and flames into the shed which ignited the gases underneath the ridge of the roof.

Decision: The large fire load in conjunction with the relatively small ventilation opening (the door) enabled the fire in the storeroom to quickly develop into a smouldering fire with extremely low concentrations of oxygen. This realised the main prerequisite for a throbbing fire. When compared with the witness statements, the fire did indeed seem to be pulsating at a frequency of around five minutes. The hypothesis is retained as possible.

3. Hypothesis: Smoke gases in storeroom resulted in smoke gas explosion

This hypothesis supposes that within a short space of time, the storeroom could produce sufficient partially burnt smoke gases to create a rich smoke gas mixture underneath the ridge of the roof of the shed within a period of about 10 minutes.

There is a period of about 10 minutes between the moment that the ceiling of the storeroom became fully involved and the presumed smoke gas explosion. The following questions need to be answered:

1. What quantity of flammable gases would have needed to be present underneath the ridge to constitute a rich smoke gas mixture?
2. Was there sufficient fuel present in the storeroom in order to create this mixture?
3. Could this mixture be formed quickly enough?

63 The principle of oxygen depletion. The combustion of 1 m³ oxygen (at 25 °C) will release an output of 17.2 MJ regardless of the fuel used. The standard uncertainty for this value is 5%.

Based on the supposition that the ridge of the shed (75 m x 25 m x 5.5/8.5 m) was filled with smoke gases to a height of 5 m above the ground, this would give a volume of 3750 m³. This corresponds to a volume of oxygen of 785 m³ (supposing 20.95% by volume oxygen). With an ambient temperature of 25 °C, such a volume, in the event of stoichiometric combustion, will produce a heat output of 13,500 MJ63. Therefore, an equivalent of at least 13,500 MJ of unburnt gases is required to constitute a rich smoke gas mixture. It should also be mentioned here as an aside that in practice, the smoke gas mixture will not be uniform and that the mixture will be richer in some zones than in others.

With a depth of 20 metres and a width of 8 metres, the storeroom has a floor area – minus the office space – of around 140 m². It is reasonable to assume that the spray PUR insulation was applied with an average thickness of 40 mm just between the wooden beams. This corresponds to a total volume of PUR of 4.6 m³ or 175 kg with a density of 38 kg/m³. With a supposed calorific value of 23 MJ/kg, the potential energy contribution of this insulation on the ceiling is 4000 MJ. Therefore, the energy contribution of just the spray PUR insulation is not enough to be able to explain the smoke gas explosion.

The wooden beams with section dimensions of 0.22 m x 0.07 m represent a volume of 5.4 m³ and a weight of 2425 kg with a density of 450 kg/m³. With a calorific value of 18 MJ/kg, this corresponds to an energy value of 43,650 MJ which is more than enough to provide the energy required.

In the event of fire behaviour in accordance with ISO 834[64], the average burning rate of solid wood is between 0.6 mm/min and 0.8 mm/min depending on the type of wood. Let us suppose a burning rate of 0.7 mm/min on the three exposed sides of the wooden cross-beams over a period of 10 minutes, then 560 kg[65] of wood will be 'burnt' with an estimated total energy content of 10,000 MJ. The wooden cross-beams in conjunction with the spray PUR insulation against the ceiling could produce an estimated 14,000 MJ of energy within a period of 10 minutes.
At least part of this would have been used to maintain the combustion process. On the other hand, other sources of energy such as the underlayment (8800 MJ[66]), the rubber tyres present and the remaining fire load have not been taken into account.

Decision: The storeroom would have needed to produce the equivalent of at least 13,500 MJ of flammable gases within a period of barely 10 minutes. The spray PUR insulation could only produce a small part of this energy required. The vast majority of the energy required would have to be produced by the wooden cross-beams and other flammable materials such as the underlayment, rubber tyres and suchlike. The hypothesis is retained as possible.

4. Hypothesis: Explosion was not connected to smoke gases

This hypothesis supposes that the explosion witnessed by various people was not connected to the accumulated unburnt smoke gases but to a gas cylinder, petrol tank or any other comparable object.

An explosion involving sealed vessels containing a liquid is called a BLEVE (Boiling Liquid Expanding Vapour Explosion). These explosions are normally extremely powerful and destructive. However, no traces were found which might indicate such an explosion.

Moreover, one of the witnesses described the explosion not as a dull bang, but rather a drawn-out explosion ("Bbbboom").

Decision: BLEVE explosions are extremely powerful and would have left visible traces. No such evidence was found. In addition, the sound recordings made while interviewing witnesses do not fit with such an explosion. The hypothesis is not retained.

64 Standardised fire behaviour based on a 'typical' house fire during which mainly cellulose-like materials are burnt.
65 (350 m beam * (0.22 m * 2 + 0.07 m)) * 0.0007 m/min * 10 min * 450 kg/m³ * 18 MJ/kg
66 140 m² * 0.0007 m/min * 10 min * 500 kg/m³ * 18 MJ/kg

5. Hypothesis: Spread to other workshops before smoke gas explosion

This hypothesis supposes that before the explosion, there was spread to and full involvement of the aluminium workshop and/or the engine workshop.

It is of interest to find out whether or not the two other workshops were fully involved in the fire before the explosion occurred. If they were involved, they will also have produced unburnt gases.

0 shows a view of the wooden cross-beams in the aluminium workshop. The burnt areas can be seen clearly here on the top and the sides of the beams. Generally speaking, there are no burnt areas to be seen on the underside. That indicates that the fire travelled from the ceiling to the workshop and not the other way round.

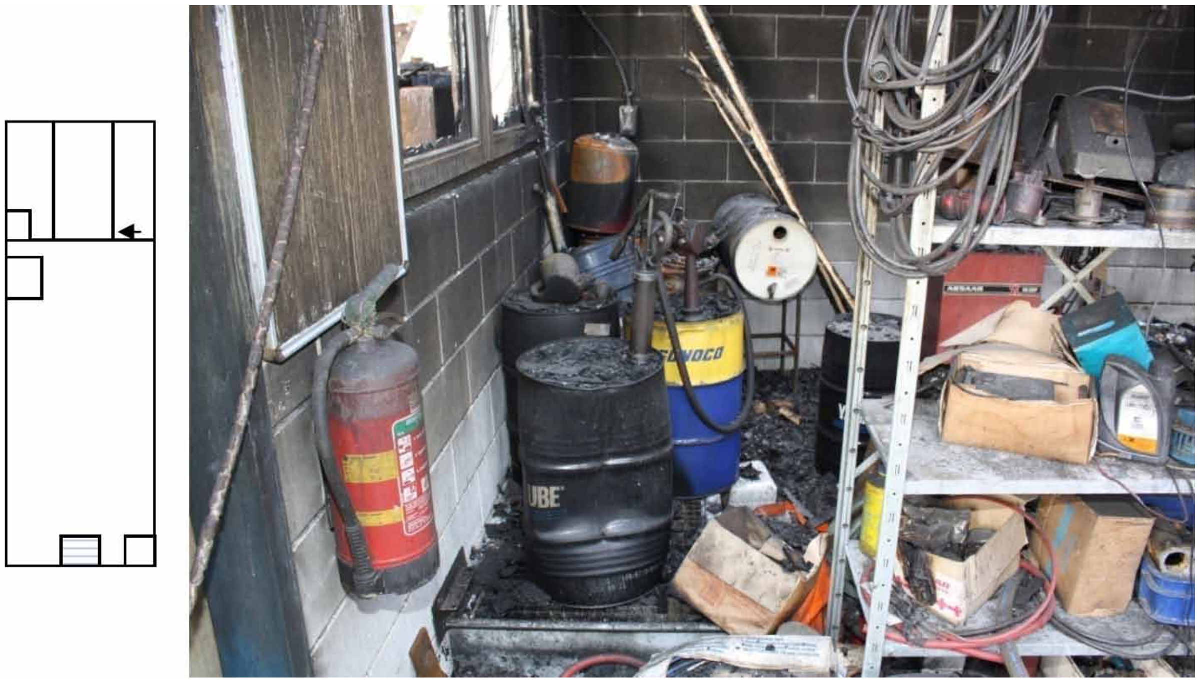
In addition, various items made of paper and cardboard were found in the area which were still relatively undamaged, such as a wall calendar and a roll of cardboard packaging, for example.

Photograph 5 Aluminium workshop – thermal attack from attic to workshop

The picture in the engine workshop is the same. Here, even part of the underlayment is still intact here and there which also indicates burning from above (0). Pieces of spray PUR insulation were also found in this workshop.

We also find relatively undamaged cardboard items here (0).

Photograph 6 Engine workshop – thermal attack from attic to workshop



Photograph 7 Engine workshop

Decision: Investigation of the workshops after the fire clearly shows that the fire gained access to the workshops from above – through the underlayment. Therefore, the workshops were not substantially involved in the fire at the time of the explosion and therefore the hypothesis is not retained.

6. Hypothesis: Fire travelled quickly to ceiling above workshops

This hypothesis is based on the assumption that the fire travelled quickly from the storeroom to the open attic above the workshops. From here, the fire then caused the gasification of the roof structure later on.

Based on the statements provided, the fire load at the top of the attic seemed to be limited to cardboard packaging material that should not have been stored above the storeroom.

Let us suppose that a sizable fire has developed sufficiently quickly in the open attic and the flames are reaching up to the ridge of the shed. The chance of unburnt smoke gases and flammable vapours then accumulating underneath the ridge of the shed and slowly building up from a poorly flammable mixture to a rich mixture is negligible. Ignition would have occurred earlier on - before the mixture could build up and form a rich mixture.

Decision: An open flame at the top of the attic space which is large enough to be able to help the gasification of the roof structure is diametrically opposed to the accumulation of flammable gases underneath the ridge of the roof. Therefore, the hypothesis is not retained.

7. Hypothesis: Gasification of roof panels created explosive gas mixture

The sandwich panels used for the roof of the shed play a crucial role in this hypothesis. The heating up of the sandwich panels caused outgassing and consequently a layer of unburnt gases was formed underneath the roof. This happened sufficiently quickly within approximately 10 minutes. At some point, these gases were ignited which led to an explosive fire spread.

The addendum to this appendix contains an estimate of the heat output released in the storeroom. Part of this heat output was transported via smoke gases to the ridge of the roof. It is only possible to approximate the precise heat output but it is estimated to be in the order of on average 2 MW during the period of the fire up until the smoke gas explosion.

We will now carry out a calculated estimation of how long it would have taken the PUR core of the roof structure to arrive at a temperature of 500 K if the initial temperature is 300 K. A thermogravimetric study[67] carried out on nine different types of PUR foam has shown that there are two distinct stages of disintegration. The first stage of disintegration, with a weight loss of 35 to 45%, occurs within the temperature range from 440 K to 600 K. The second stage of disintegration peaks at around 750 to 850 K. Weight loss is limited to approximately 10% for temperatures below 500 K.

Assuming that the steel panels in the sandwich panels are 0.7 mm thick, with a density of 7900 kg/m³ and a thermal capacity of 480 J/kg.K, with an estimated roof area of 1930 m² that will mean that there would have been 1.35 m³ of steel to heat up. The energy required in order to increase the temperature by 200 K is 1024 MJ.

On the other hand, the air volume in the roof must also be heated up to 500 K. For the sake of simplicity, it will be supposed here that the temperature of the gases underneath the ridge of the shed is uniform and that the convection coefficient between gas and roof is infinite, i.e. they are at the same temperature.
For the purpose of the calculation, we will assume that the average density of the gas mixture is 0.8825 kg/m³ for a total ridge volume of 3750 m³ and use a thermal capacity of 1000 J/kg.K. The energy required in order to increase the temperature by 200 K is 660 MJ.

That brings the total energy required to 1684 MJ. With an average heat output of 2 MW released by the storeroom, this level of energy is reached after 842 seconds or 14 minutes.

With this, the PUR foam which has good insulating properties would not yet have been heated up to 500 K. For the material will be governed by a temperature gradient from 500 K up to the temperature on the – non-exposed – outside. This is taken as being equal to 300 K for the purpose of this approximate estimation. The temperature profile for the PUR foam is taken to be linear.

It is assumed that the PUR foam will convert 10% of its weight into flammable gases at a temperature above 440 °K. This corresponds to 30% of the PUR foam. It is also assumed that all the gases released migrate inside the shed.

67 Vandevelde P., Detailed study of the ignition phenomenon of materials, University of Ghent (1975)

On the roof is a total volume of 58 m³ of PUR foam or 2316 kg. 30% of this will convert 10% of its weight or 69.5 kg into flammable gases. Taking a calorific value of 22.7 MJ/kg[68], this corresponds to a potential from unburnt gases of 1575 MJ 14 minutes after the start of the fire.

That is nowhere near enough to create a rich gas mixture underneath the ridge in the shed.

The integral energy content of 500 m² of roof panels would have had to outgas in order to create a stoichiometric mixture underneath the ridge of the roof. Therefore, the local gasification of a few dozen square metres – in the corner above the storeroom, for example – would not have been enough either.

Decision: A rough estimation of the increase in temperature underneath the ridge of the roof shows that the sandwich roof panels would not have been able to gasify quickly enough in order to be able to cause a smoke gas explosion themselves. The hypothesis is not retained.
However, that does not rule out the possibility that a limited form of gasification occurred which contributed towards the build-up of flammable gases and vapours underneath the ridge of the roof. However, this contribution is estimated at a maximum of 10%.

Addendum: Heat output released and gas temperature in the storeroom
The heat output that was released in the storeroom after flashover from the moment the fire was ventilation-controlled is determined by the amount of oxygen that flows into the storeroom. The formula below is often referred to in the literature for estimating the amount of oxygen that flows into an area:

$m_{air} \approx 0.5 A\sqrt{H}$ in kg/s

where

A is the area of the door opening (0.9 m x 2.1 m @ 1.89 m²);
H is the height of the door opening (2.1 m).

According to the oxygen depletion theory63, this potentially corresponds to a heat output of 3 MJ/kg air or 13.1 MJ/kg O2. In the case of the storeroom, that means a heat output of 4.1 MW. A lot of this heat output will be used to maintain combustion. Some of it will escape from the storeroom and will be transported to the ridge of the shed via the smoke gases.

The storeroom has a very small opening factor, i.e. a very small door opening via which air can get in compared to the volume. As a result, the temperature in the storeroom will be relatively low.

The opening factor is defined by the ratio:

$$\frac{A\sqrt{H}}{A_T} = 0.00781$$

where AT is the total wall and ceiling area (not the floor!). AT is estimated at 350 m². Theoretical models supported by experimental tests[69] have shown that opening factors with a value of around 0.085 give the highest average gas temperature in a compartment which can get to 1000 °C and above at the start of a ventilation-controlled fire. With lower values, this temperature drops systematically. With an opening factor of 0.02, the theoretical starting temperature is already below 550 °C. That indicates that the average gas temperature in the storeroom, once ventilation-controlled, will drop considerably and is way below 550 °C. That explains why the blue coating on the outside of the storeroom was still present when attempts were made to put out the fire at the back of the building (see photograph 4 in section 5).

68 Babrauskas, V., Ignition Handbook Fire Science Publishers (2003)
69 Drydale, D., An Introduction to Fire Dynamics, John Wiley and Sons Ltd. (1985)

APPENDIX 5 MODULAR TRAINING STRUCTURE OF THE FIRE SERVICE

Master of Crisis and Disaster Management

Management in the fire service	Information and communication	Crisis management	Strategic leadership	Law, ethics and society	Work organisation

Commander

The fire service in a changing society	Public administration	Risk and safety	Policy and networks	Disaster management	Financial management

Job-related training

Chief Officer-on-Duty	Advisor on Hazardous Substances	Tactical Manager	Policy and Management Advisor	Risk and Safety Specialist	Planning and Disaster Management Specialist
Officer-on-Duty	Operations Manager	Fire Prevention Specialist	Training and Exercise Specialist		

Leading firefighter

505 Training, Exercises & Guidance	506 Communications	507 Engineering division	508 Repression
501 Social skills	502 Organisation		

Sub-officer

406 Equipment	407 Aviation firefighting	408 Petrochemicals	409 Tank incidents	410 Repression
401 Combustion and extinguishing	402 Organisation	403 Hazardous substances	404 Repression	405 Social skills

Sub-leading firefighter

303 Fire prevention supervisor	304 Identification of hazardous substances	305 First aid	307 Firefighting at source
301 Organisation & Management	302 Repression		

Firefighter 1st class

203 Pump operator	204 First aider	206 Aviation firefighting	207 Collective protective clothing	208 First aid for large-scale operations
209 Repression				

Firefighter

101 Repression	102 Life-saving actions	103 Personal protective equipment

013 Chief instructor
011 Specialist subject Collective protective clothing
010 Specialist subject Personal protective equipment
012 Specialist subject Technical assistance
009 Specialist subject Fire service diver
001 Instructor
015 Dive team leader
Fire service control centre worker
002-004 Fire service diver
005-008 Fire service driver

Compulsory module
Optional module
Supplementary training (conclusion official)
Other supplementary training

APPENDIX 6 EXAMINATION OF THE THERMAL IMAGING CAMERA

One of the firefighters who died was carrying a thermal imaging camera. A thermal imaging camera is an instrument that converts temperature contrasts into visible images. The fire service can use a thermal imaging camera to locate the seat of a fire, for example.

After the fire, the thermal imaging camera of the crew members who died was found in the shed. In order to find out whether any thermal images of the inside of the shed were still stored on the instrument, the Dutch Safety Board gave the camera to the specialist technical investigation bureau Arepa Benelux BV.

This examination showed that no image material was still stored on the thermal imaging camera.

AREPA

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Stuknummer OVV:
Dossiercode: 08002059
Registratie-datum: 31 DEC 2008
In behandeling bij: Verhallen
Naam: | Afdoening:
ONDERZOEKSRAAD VOOR VEILIGHEID

The Dutch Safety Board
F.a.o. Mr P. Verhallen
PO Box 95404
2509 CK 'S-GRAVENHAGE

Date: 29 December 2008
Our reference: PB/AvM
Your reference:

Subject: Report on findings

Dear Mr Verhallen,

We have enclosed with this letter our report on findings relating to our inspection of a thermal imaging camera.

We hope that we have provided you with sufficient information.
Yours sincerely,
AREPA BENELUX B.V.

P. Benschop
Director

Enclosure: Report on findings.

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Report on findings

Customer : The Dutch Safety Board
PO Box 95404 2509 CK
THE HAGUE

Contact : Mr P. Verhallen

Date 26 November 2008

Type of order To inspect a thermal imaging camera manufactured by Bullard, type T3XT, bearing serial number 40150

Purpose of the investigation To find out whether any thermographic images are or have been stored in the internal memory of the camera during use

General information

On 26 November 2008 at 09.00 hours, Mr Verhallen visited Arepa Benelux B.V. in Amersfoort. After providing a brief and concise description of the circumstances in which the thermal imaging camera had been used and subsequent events, the camera was handed over to us for inspection.

The object

We were given a thermal imaging camera manufactured by Bullard, type T3XT, bearing serial number 40150, including the battery, handgrip and retractable strap. Please refer to appendix I for the technical specifications. Photographs of the object can be found under appendix II.

When the object was disassembled, it was found that it did not have an internal memory for storing data such as time and/or images. There were also no accessories integrated in the handgrip such as a transmission system and/or a handheld receiver which could possibly have been used for storing and/or sending data to other stations.

There is no possibility at all for data to be stored or sent to an external station as appropriate using the said thermal imaging camera in this design. These statements are endorsed by both the importer in Oss, VTN Veiligheidstechniek Nederland B.V., and the manufacturer E.D. Bullard Company in Cynthiana, KY in the USA (appendix III).

Conclusion

No images have been recorded using the thermal imaging camera in our possession. It is also not possible to do so without the necessary accessories.
We currently still have the camera which is being kept at our premises in an appropriate air-conditioned room. We can make arrangements with you to bring the camera to any address you choose in the Netherlands and hand it over to you personally.

We hope that we have provided you with sufficient information.

P. Benschop

Arepa Benelux
B.V.

APPENDIX 7 INVENTORY OF EXAM REQUIREMENTS, READING AND TEACHING MATERIAL AND EXERCISES RELATING TO SUDDEN FIRE SPREAD

The Netherlands Institute for Safety Nibra (NIFV) has drawn up an inventory of the reading and teaching material and exercises available to the fire service relating to sudden fire spread. The management summary relating to this is given below.

Findings
The picture that emerged from the inventarisation of reading and teaching material, additional publications, other sources of information, exam requirements and exercise and training facilities was that the attention paid to the topics under investigation increased dramatically around 2004. Before 2001, minimal or even no attention was paid to these topics during training and exercises. A lot of the fire officers who currently hold repressive positions were trained before 2004. As a result, the possibility should be taken into account that a considerable number of fire officers in the Netherlands will not be familiar with the topics under investigation from the training they have been given and may have little knowledge regarding these.
The approach and main findings from the inventarisation process in relation to each component are described below.

Inventarisation of exam requirements

Approach
In order to draw up an inventory of the exam requirements for knowledge regarding the phenomena of sudden fire spread and inside fire attack, the exam regulations ('General Fire Service Exam Regulations') of the Netherlands Bureau for Firefighting Exams (NBBe) were studied. There are three versions of these: one from 1996, one from 1998/1999 and the version from 2000. According to the NBBe, these three (bundled) publications provide a true and fair picture of the subjects on which candidates are examined.
The subjects relevant to this investigation which are specified in the exam requirements are: sudden fire spread, the behaviour of materials and structures in the event of fire and safety awareness.

Findings relating to exam requirements
The exam requirements in the 'General Fire Service Exam Regulations' have been (consciously) put together on a general basis. The exam regulations do not contain any specific requirements for knowledge relating to the phenomena of sudden fire spread or inside fire attack.

Inventarisation of reading and teaching material

Approach
The reading and teaching material from the NIFV from the period 1992 to the present day and other relevant publications issued by the NIFV from this period were searched using the following search terms:

- 'flashover' and 'flame spread';
- 'backdraft' and 'flashback';
- 'fire spread', 'sudden fire spread' and 'rapid fire spread'
  (hits were only recorded if a connection was established with inside fire attack, flashover or backdraft);
- 'inside fire attack'.

Status of additional publications
The additional publications issued by the NIFV, such as 'Flashover & backdraft' (1999), do not form part of compulsory fire service training. The NIFV uses these publications for in-service training activities such as courses, workshops and practices; these in-service training activities are optional.

Findings relating to reading and teaching material and additional publications
The subjects of 'flashover' and 'backdraft' are covered in the module 'Firefighter Repression'. The

information provided was very limited until 2004 but in the 10th edition from 2004, the attention paid to these subjects increased significantly. In the new module 'Crew Member 1 Firefighting' from 2008 (which can be seen as an updated version of the module 'Firefighter Repression'), even more attention is paid to these subjects.

In the module 'Leading Firefighter Repression', the attention paid to flashover and backdraft increases steadily from 2001. The module 'Officer Repression' follows the module 'Firefighter Repression' as far as the subjects of flashover and backdraft are concerned.

In 1999, the NIFV issued a publication entitled 'Flashover & backdraft'. As the title suggests, this publication contains a lot of information relating to the phenomena of flashover and backdraft. The recent publications 'Fire behaviour' (2007) and 'A new look at the use of hose pipes' (2008) also address these topics. The reading material that the Nibra published in 2005 for the in-service training of officers-in-charge ('Safe repressive action') - likewise non-compulsory - also pays a relatively considerable amount of attention to flashover and backdraft. The phenomenon of '(sudden) fire spread' is also discussed within it.

The subject of '(sudden) fire spread' is first discussed in the modules 'Leading Firefighter Repression' from 1995 and 'Firefighter Personal Protection' from 1996, albeit rather briefly. This topic is also mentioned in the module 'Firefighter Personal Protection' from 2001. The new module 'Crew Member 1 Firefighting' from 2008 looks at this topic in more detail.

What is noticeable about the subject of 'inside fire attack' is that there are hardly any critical appraisals of this subject at all in the reading and teaching material. There are no or hardly any discussions regarding the considerations to be made when making a responsible decision on whether or not to carry out an inside fire attack. More emphasis is put on the safety aspects of inside fire attack in more recent teaching material but at the same time it is stated that outside fire attack is often less effective and in some situations even pointless. Only in the 'Self-Assessment' section from the module 'Leading Firefighter Hazardous Substances' from 2006 and 2007 is it stated that "on account of flashover, going inside for any other purpose than making a rescue [is] questionable in the event of a normal fire".

Inventarisation of exercise and training facilities

Approach
The extent to which fire brigades carry out realistic exercises relating to certain aspects of firefighting is linked to the priority given to these aspects and to the available budget for exercises. That makes it difficult to provide a clear cross-section of exercise practice in the Netherlands. After consulting with the customer, it was decided to look at the exercise practice of fire brigades who approach the subjects of this investigation in different ways: a fire brigade that does not particularly pay much attention to the phenomena of sudden fire spread and a fire brigade that pays particular attention to this topic. Relevant officers from three different fire brigades were interviewed in connection with this investigation.
Of course, the result does not provide a complete picture of exercise practice in the Netherlands but it does give an idea of the variation in exercise practice relating to the phenomena of sudden fire spread and inside fire attack.

Findings relating to exercise and training facilities
Firefighting exercises carried out by fire brigades are virtually all directed at inside fire attack. The reason for this is mainly a practical one: carrying out exercises at exercise locations is often an expensive business and fire brigades will not pay "to stand outside". In addition, there are no adequate strategies for outside fire attack.

There is also an extremely wide range of flashover training facilities which the majority of fire brigades make use of. One of the drawbacks of this type of training is that it can give fire service officers a false sense of security and the idea that a flashover can be 'dealt with'. One of the advantages of this type of training is that it does provide an insight into the way in which a flashover develops and the way in which a flashover can be prevented or which fire-extinguishing equipment to use as appropriate.

The Dutch Safety Board

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