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Quadrant Model for Fighting Structure Fires

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Colophon

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Foreword

This working document, Quadrant Model for Fighting Structure Fires, concisely describes the fire service doctrine and quadrant model as it is understood by the Dutch fire service. This publication is a joint initiative of the Implementation Team Fire Service Doctrine, Process Team Fire Service Doctrine (both operating under Brandweer Nederland) and IFV's Brandweeracademie.
The purpose of this working document is to safeguard the – undisputed – knowledge that has been gathered and developed up until now. Its content can be used as input for the development of perspectives for action, training materials, scenarios and the like.

The quadrant model is the first practical instrument that the fire service doctrine produced and it is a tool for deciding which tactic to use when fighting a structure fire. The tragic events of the fire at De Punt in The Netherlands were the direct reason for developing the quadrant model for fighting structure fires. In this 2008 incident, three colleagues were killed during a fire in a hangar falling victim to an unexpected fire spread. The subsequent investigation into this fire made it clear that its tragic outcome could have happened to any other colleague in the country. It turned out that the fire service possessed insufficient knowledge of the development of fires when modern building materials are involved. It also showed that the way an interior attack was executed in those days was not geared to the risks that come with complex building structures.

For some firefighters, the events at De Punt resulted in a profound reflection upon the risks of suppressive operations in structure fires. Eventually, this led to the quadrant model which has been developed in close cooperation between firefighters in the field, Brandweer Nederland and the Brandweeracademie. The model shows the (tactical) choices which have not been standardised before.

During the development of the quadrant model, it was recognised that the fire service was in need of a joint doctrine, i.e. a theory behind the firefighting profession that supports the skills needed to safely and effectively conduct firefighting operations. The fire service doctrine has been developed out of a desire to learn from a fire which had fatal consequences, and this explains why firefighting is the first subject of the fire service doctrine.

This publication is purposefully presented as a working document. Our knowledge is not static; we are always specifically looking for further foundations and improvement. We learn from incidents and experiments, both at home and abroad. This document will have to be revised and updated, perhaps even in the near future.
The readerships Firefighting Knowledge and Fire Protection of the Brandweeracademie manage the content of this working document. We welcome your comments and suggestions for additions and/or revisions. Please send your feedback to onderwijscontent@ifv.nl stating: quadrant model for fighting structure fires.

Implementation Team Fire Service Doctrine
Readerships Fire Prevention and Firefighting Knowledge IFV/Brandweeracademie
Process Team Fire Service Doctrine

Content

Reader's Guide

This working document is about the background and possibilities of the quadrant model for fighting structure fires. Its content can be used as input for the development of perspectives for action, training materials, scenarios, and the like.

The working document is structured as follows.
Chapters 1 and 2 describe the underlying reasons and background for the development of the fire service doctrine and the quadrant model; the distinction between these two terms and how they relate to each other is discussed. Chapter 3 is about the fire service's objectives when fighting structure fires and about the incident characteristics that are decisive in such instances. In Chapter 4, the four quadrants of the quadrant model are described. Chapter 5 contains a concise explanation of the meaning of the quadrant model for firefighting operations. Chapter 6 makes a connection between the knowledge of prevention and of suppression, which is essential for successfully using the quadrant model.

The appendices 2, 3 and 4 contain information about the first steps towards the implementation of the quadrant model into the fields of equipment, instruction and training.

1. What is the fire service doctrine?

The Dutch fire service has to prevent, contain and fight fires, as is laid down in the Dutch Security Regions Act. The way in which the fire service chooses to perform those duties – why and how – is described in the fire service doctrine.

A doctrine is a collection of dogmas (ground rules, principles) that are undisputed within an occupational group. Doctrines often are coherent, well-rounded collections of ideas.

> In the fire service doctrine, the Dutch fire service articulates the fundamental and collective basic principles for firefighting operations that have the objective to prevent and contain incidents. The doctrine is the underlying theory of the fire service profession and has been deduced from research and the analysis of practical experiences.

The fire service doctrine describes how the fire service operates most safely and effectively. It is not a regulation or a procedure, but it provides knowledge and understanding.

So as to leave no doubt: the fire service doctrine will never be complete and always has to be adapted because we will continue to discover new aspects and possibilities. New experiences and research can lead to the adaptation of the doctrine.[4]

It is clear what the vision and goals of the fire service doctrine are: we aim for fewer incidents (fires), fewer (firefighter) victims and less damage, and at the same time we pay attention to the efficiency and effectiveness of our operations. The focus is no longer mainly on firefighting and suppression, but also on fire prevention and the controllability of fires and other incidents.
The fire service wants a more differentiated, smarter and more effective fire suppression service. Apart from that, the work has to be done more safely: we do not want to lose any more colleagues when performing our duties. With the fire service doctrine, the fire service clarifies the limits of its capacities as well.

1.1 Three levels within the fire service doctrine

The fire service doctrine comprises three levels:
- the strategic doctrine
- the tactical doctrine
- the operational doctrine.

[4] At the moment, the fire service doctrine is being developed for the area of responsibility fire. At a later stage, the other areas of responsibility (technical assistance, hazardous materials incident management and water accidents) will be further developed.
[5] The Fire Service on its Future

1.1.1 Strategic doctrine

In the *strategic doctrine,* the fire service outlines its public duties. How does the fire service execute its responsibilities? What can civilians and businesses do, and what are their responsibilities regarding the prevention and containment of fire?
In 2010, Brandweer Nederland described its strategic doctrine in the vision document *De brandweer over morgen*[5]. This document describes the fire service's public role with regard to fire safety and how the fire service can improve its execution thereof:

- The fire service wants to prevent fires, casualties and damage.
- The fire service will focus increasingly more on raising the fire safety awareness among civilians and businesses and wants to actively support them in assuming their own responsibility.
- The fire service will focus more on reducing the risk of fire in general (risk management).
- The fire service wants to extend its knowledge of fire through fire research and evaluation.
- Fire suppression needs to be innovated in order for the fire service to work more flexibly (tailor-made services) and fight fires more effectively and safely. With that, the fire service takes into account the changing risks that come with changing construction methods and use of materials.
- Finally, the fire service wants to be clear about the limits of its suppressive capabilities. The risks that remain after preventive measures have been taken cannot be entirely covered by suppression. Where fire suppression duties are concerned, the fire service usually has an obligation to perform to the best of its ability and not an obligation to produce a certain result.

1.1.2 Tactical doctrine

In its *tactical doctrine,* the fire service describes how choices are made to be able to carry out the assigned and/or chosen tasks. The tactical doctrine translates the strategic doctrine into risk management and incident management. For instance: What do we need in terms of capability of action, specific knowledge, skills and equipment and what is our maximum response time?

> The quadrant model is part of the tactical doctrine and it helps to make choices when fighting (structure) fires, both during the incident management process and in the planning and design phases.[6]

1.1.3 Operational doctrine

The *operational doctrine* indicates why an incident is managed in a certain way.

For example: if the operational objective is to rescue, the fire service can opt for an offensive interior attack with a high pressure fire hose.

The following terminology is used in the operational doctrine of the fire service doctrine (aimed at incident management).

[6] The quadrant model's line of thought also has consequences for the work of preventionists: based on expected operational tactics, a preventionist can enter into conversation with owners and link these tactics to the (business) interests of the owner/occupant. Such a conversation could subsequently lead to risk acceptance or to a higher level of fire prevention measures. In the middle of 2014, the Process Team Fire Service Doctrine was working on version 8 of the quadrant model, where this aspect is discussed in more detail. However, in the present version of the working document *Quadrant Model for Fighting Structure Fires* (2.0), version 7 of the quadrant model is used, which is the most recent version approved by the Process Team.

Strategy

The (operational) strategy refers to the objective the fire service wants to achieve with its suppressive operation, such as:

- rescue
- enable an evacuation
- prevent the fire from spreading to an adjacent building
- extinguish the fire.

Tactic

The (operational) tactic is the method that is used to manage the incident in accordance with the chosen objective. The fire service has four tactics (quadrant model) for fighting structure fires:

- defensive exterior attack
- offensive exterior attack
- defensive interior attack
- offensive interior attack.

Technique

The technique signifies the joint methods and means that are used to carry out the chosen tactic. For example:

- using a high pressure fire hose
- using a low pressure fire hose
- gas cooling
- ventilation
- compressed air foam
- fog nail
- piercing nozzle
- cold cut system.

Work method

The work method consists of an individual's detailed actions to execute a particular technique. How is a particular technique executed?

Figure 1 shows how the terms discussed in this paragraph are linked.

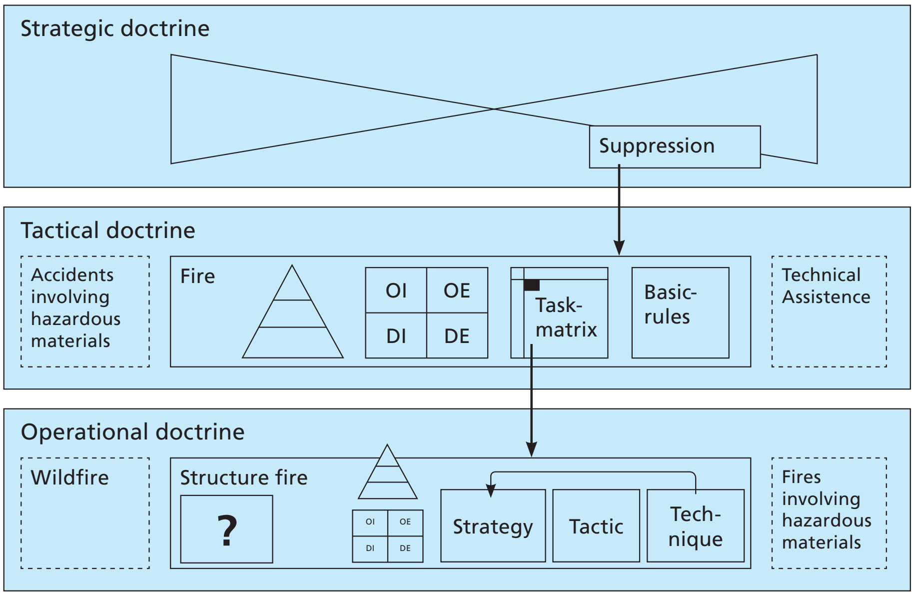

Figure 1: The connections between strategic, tactical and operational doctrines in relation to fighting structure fires (incident management)

2. From the fire service doctrine to the quadrant model

As part of the fire service doctrine, the fire service stimulates fire safety awareness and personal responsibility of both civilians and businesses. The projects and activities that are carried out in many regions in The Netherlands as part of the *Community Fire Safety* initiative are an example of this, as is the establishment of fire research teams.
The fire service has to possess knowledge of the causes of fire, fire development and the effect of fire protection measures to be able to learn from incidents and subsequently improve performance and lead towards profit for society.
Firefighting is in need of innovation, for instance regarding the further development of alternatives for the interior attack, other types of exterior attack, more effective firefighting methods, alternative ways of command, or variable staffing levels per unit.[7]
Apart from the need for innovation, there is also a need for the structural implementation of prevention knowledge into operational firefighting.

Changing circumstances of fires

The fire service has to adapt to the changing circumstances of fires. Over the last 25 years, fire dynamics have changed considerably. The use of synthetic materials, for instance, has expanded significantly and the construction industry started using radically different building methods. As a result, the fires of today produce much more hazardous gases, higher temperatures and are more often ventilation controlled (please refer to paragraph 3.1 for a further explanation). All of this results in high risks for firefighters.

Smoke is fuel

When there is a fire, the fire service turns up. However, it is of the utmost importance to recognise that the fire service does not just have to deal with fire, but with smoke as well. Smoke is to be considered as fuel because it causes fire spread and is full of danger. The fire service has to be able to read the smoke and use this as a departure point for reconnaissance. It is essential to remove and cool the smoke. A thorough knowledge of nozzle handling, gas cooling and ventilation techniques is needed to do this safely and responsibly.

Safety first

In firefighting operations, safety always has to come first. We no longer accept casualties and fatalities among fire service personnel as inevitable. Our motto must be “Out together, home together”. Therefore, the interior attack should only be used as a primary operational tactic if the circumstances are safe and the strictest requirements are met.

Innovation of firefighting operations

The fire service has to adapt its procedures to the decreased predictability of a fire, i.e. pay more attention to reconnaissance, focus on recognising a situation, think first, and then act. The fire service has to develop more standard operational tactics to enable the people in the field to make more specific choices. More than before, we have to be clear about an operation’s objective.

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[7] To achieve all this, Brandweeracademie, Brandweer Nederland and Compartment Fire Behaviour Training (CFBT) have instigated new research projects, such as literature study and practical experiments, and collaborate with research institutes worldwide.

2.1 New operational tactics using the quadrant model

Until recently, the fire service had in fact only two operational methods: the offensive interior attack and the defensive exterior attack. A defensive exterior attack would be carried out when the standard interior attack could no longer be executed; the fire service withdrew, gave up the building and shifted its focus to the prevention of the fire spreading to adjacent structures. But by now we are convinced that we can work much more safely and efficiently if we add the defensive interior attack and the offensive exterior attack to our tactics. And we are convinced that the (existing) offensive interior attack and defensive exterior attack are in need of improvement.
The quadrant model details alternatives for the interior attack and a different type of exterior attack.

The quadrant model is part of the tactical fire service doctrine and it is a tool for choosing a type of attack, each of the four quadrants has its own objectives.

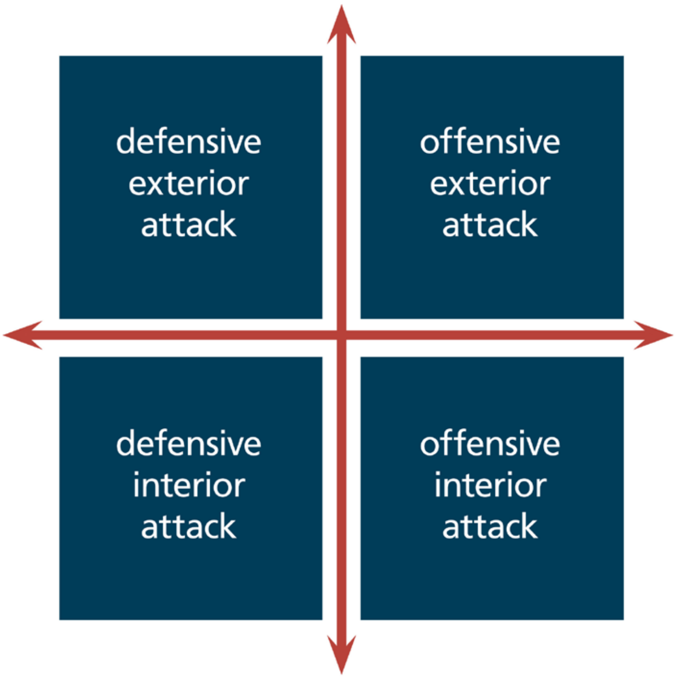

Figure 2: The quadrant model

The quadrant model provides a good basis and handles for determining the way in which to control and fight a particular fire. Operational commanders can use the quadrant model to decide upon the appropriate operational tactic for each objective.

2.2 Mission Command

In effect, the quadrant model adds two new operational tactics to the existing ones, and thus the person in charge is presented with more options to choose from. Based on the information from the reconnaissance, a more conscious decision has to be made about which operational tactic to use. This is different than before, when there were fewer options to choose from. The fire service would always carry out an interior attack, unless it was very clear that this was no longer possible. The introduction of the quadrant model changes the way the fire service carries out reconnaissance and there is more emphasis put on the objective of the operation. Mission command is introduced.

3. Characteristics determining the choice of operational objective

The fire service can have several objectives when dealing with a structure fire:
- rescue people
- (assist with or facilitate) the evacuation of the building
- create survivable conditions
- enable safe entry
- prevent the fire from spreading to adjacent buildings
- prevent the fire from spreading within a building
- extinguish the fire
- limit the environmental effects of a fire and its impact on society.

In choosing an objective and an operational tactic, the commander of the firefighting operation has to take into account the following incident characteristics (an explanation of the characteristics can be found later on in this chapter):
- fire characteristics
- building characteristics (building design and fire protection measures)
- human characteristics (behaviour of the people in the building).

An incident is always characterised by a combination of these characteristics, and the reconnaissance has to clarify which characteristics are significant. The person in charge has to determine how the characteristics interrelate in order to be able to choose the right quadrant. It is, therefore, of vital importance that efficient and full reconnaissance is carried out.

No commander of firefighting operations will deny that the fire characteristics determine the incident. For long, it has been assumed that the fire characteristics are what determine the type of fire (for instance, an interior fire or a conflagration), but it has been known for a long time now that it is not just the fire characteristics that mark an incident.

The (Dutch) qualifications 'small fire', 'middle-sized fire', and 'large fire' chiefly signify the personnel and equipment needed. The complexity of a building can be a reason to scale up an operation, just as can the fact that there are many people inside the building or that there are people who cannot leave without assistance. The three characteristics of fire, building and people are sometimes called the characteristics framework (see Figure 3). They are of great importance when forming a picture, judgement and decision about which quadrant is appropriate for the operation.

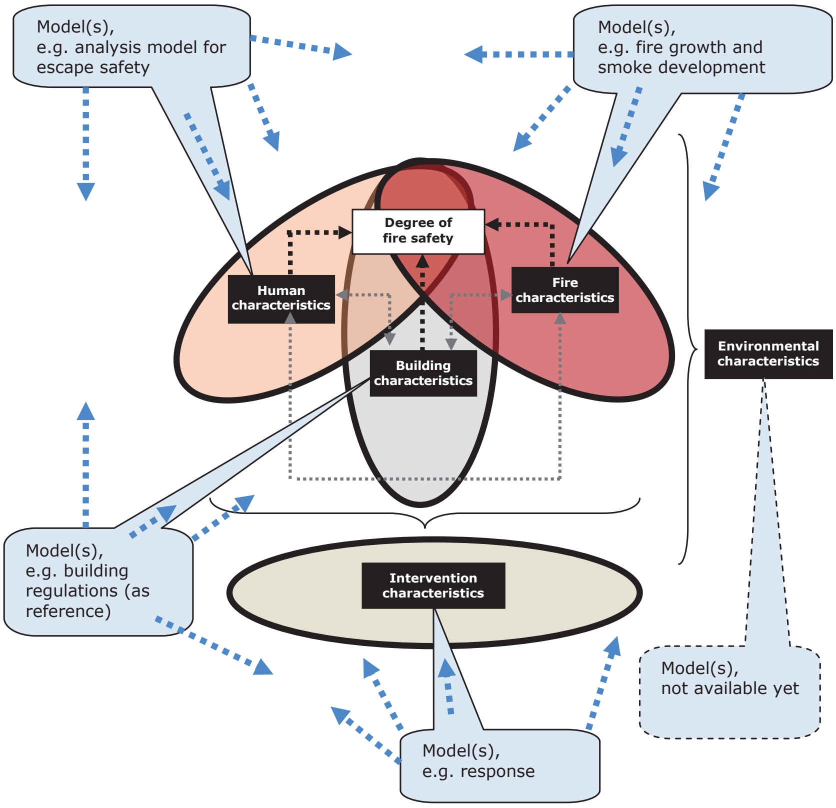

Figure 3: Characteristics framework

> The fire characteristics, building characteristics and human characteristics together characterise an incident and, therefore, largely determine the choice for a particular quadrant and accompanying tactic. Apart from this, the choice of tactic is also influenced by intervention and environmental characteristics.

A fire in an office building constitutes a different type of incident than the exact same fire (in location, size and fire characteristics) in a hospital. The various building characteristics also influence the incident. A fire in a club on a Saturday night at 3 AM constitutes a different type of incident than the exact same fire in the same building on a Monday afternoon at 3 PM when the building is used by the local model making society. The differences in the characteristics (behaviour) of the people present also have an impact on the incident.

3.1 Fire characteristics

We start this section by providing a short explanation of the terms fuel controlled and ventilation controlled.

Fuel controlled

A fire is fuel controlled when the increase or decrease of the combustion rate is determined by the amount of fuel involved in the fire. Many familiar types of combustion are fuel controlled, such as a candle flame, a stove or a fireplace. The majority of structure fires start out as fuel controlled; there is a small amount of combustible material involved and there is sufficient oxygen available.

Ventilation controlled

A fire is ventilation controlled when the combustion rate is controlled/determined by the amount of oxygen available. In the structure fire mentioned above, the ventilation controlled stage occurs after the fire has been burning for some time, increasingly more combustible materials are involved in the fire and the building remains sealed, i.e. there are no window breaks and the fire does not penetrate the roof or a wall. The combustion uses large amounts of oxygen which causes the oxygen/fuel ratio to decrease. When there is insufficient oxygen for the fuel to burn properly, the fuel controlled fire transfers into a ventilation controlled fire. Because of the high temperatures in the room or building, pyrolysis will continue which means that the fuel production continues as well.

Under-ventilated fire

If the above mentioned transfer from fuel controlled to ventilation controlled occurs before flashover takes place, this is called an under-ventilated fire.

Burning regime

The amount of air available determines which burning regime occurs; the burning regime plays an important role in the fire development.

In determining the fire characteristics and their possible consequences, the following issues are of importance:

- recognising the SAHF-signals[8]
  The SAHF-signals can help in answering the basic question: Which burning regime are we dealing with and can an interior attack be carried out safely? It is of special importance to determine whether the fire is fuel controlled, ventilation controlled or under-ventilated.[9]
- the manner and extent of the fire spread within the building
  The impact of the fire effects must also be considered: what are the consequences of heat and smoke for the occupants and for the building.

Background information
A short description of the SAHF-signals is given in this paragraph.

- Smoke (S): location of the smoke, volume, colour, density (optical and physical), buoyancy.
- Air Track (A): velocity, direction, smooth or turbulent, pulsating, whistling sounds.
- Heat (H): blistering or discolouration of paint work, black, dark or cracking windows, hot surfaces, sudden heat build-up.
- Flame (F): flame front location, flame front volume, flame colour and flame shape.

Manner and degree of the fire spread

Obviously, the manner and extent of the fire spread in the building are very important when determining the fire characteristics. This important observation provides input to the decision-making process regarding which tactic to use, i.e. which quadrant to choose.

- Are we dealing with a fire inside a building? In other words: is it mainly furniture and fittings that are on fire?
- Or are we dealing with a building that is on fire? Is the structure of the building already burning?

[8] In fact, it is about B-SAHF: the interaction between building and fire. The B-characteristics are described in paragraph 3.2.

[9] In order to provide an answer to these questions and to facilitate the application of the SAHF-model during operations, a simplification of the model is being developed in cooperation with, among others, the Brandweeracademie and CFBT.

Just like the SAHF-model, the cascade model also interprets this aspect of fire characteristics. The basic idea of the cascade model is that fire and smoke (in a building) can go through different physical, time sequential stages and that a fire can be influenced by interventions, successfully or otherwise. The cascade model focuses mostly on the extent of the fire, but also on the spreading of smoke.

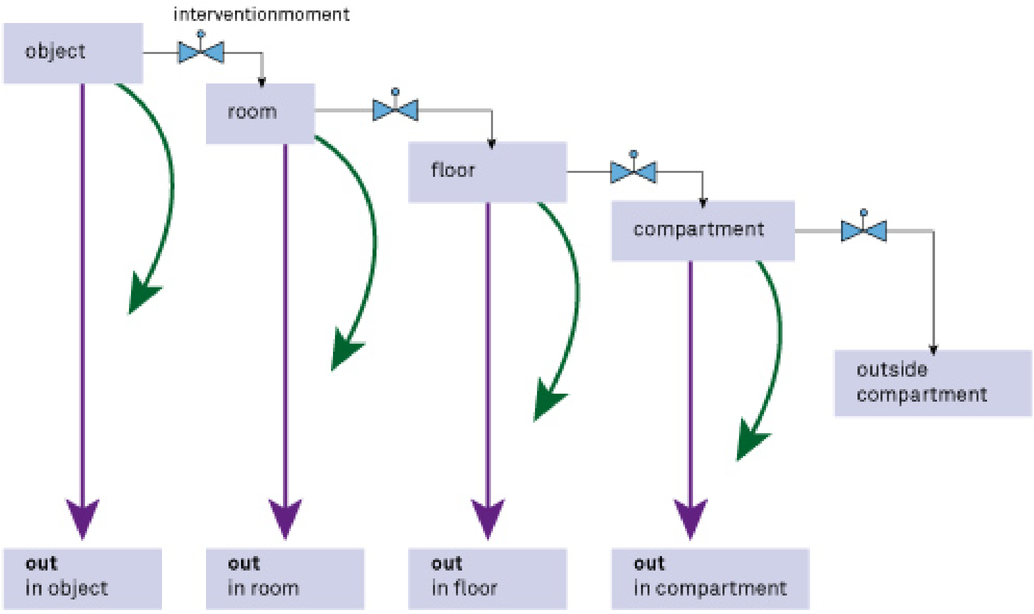

Figure 4: Cascade model

Due to various factors, a fire starts in an object (first cascade). This object can be a wide range of things: a wastepaper basket, a pan, a curtain, etc. This is the first stage of the fire. In many cases, the fire can still be extinguished with simple means or can be contained in another way. A successful intervention results in the fire being extinguished. There is a chance of the fire spreading to other objects in the room where the burning object is situated. Fire spread can be caused by direct flame contact, by heat radiation from the burning object or by hot gases. Whether this will happen depends on a number of factors.
Subsequently, it is possible for the fire to spread to other rooms on the same floor, in the fire compartment of even outside the fire compartment. Again, this depends upon a number of factors, for instance: At what point in time do the attempts to extinguish the fire start? Are there any other combustible materials near the fire, etc.?

As far as smoke spread is concerned, the cascade model assumes that smoke is always one cascade ahead of the fire.

Obviously, it depends upon the size and layout of the floors and/or fire compartments whether all cascades can actually be recognised. A floor and a fire compartment might be one and the same, or one fire compartment could consist of several floors. Hospitals, for instance, can have several fire compartments on one floor.

Smoke production

Smoke is fuel. If smoke spreads outside the burning fire compartment, then the smoke can directly cause the fire to spread since the fire gases can ignite outside the burning compartment. Therefore, the extent of smoke spread is an indication for the extent of fire spread to be expected.

3.2 Building characteristics

As far as the building characteristics are concerned, it is the building design that is most important, i.e. characteristics such as height[10], complexity, big building volumes, floors that are underground, etc. These characteristics have an influence on the development and the impact of fires and on firefighting possibilities and tactics. Firefighting in a building that consists of several floors is considerably different from fighting a fire in a single family home.

Figure 5: Fire in a high-rise building (University of Technology Delft, The Netherlands)

Building characteristics also concern the technical facilities that have been put into place regarding the building's fire safety. We discern two types of technical facilities:
- physical (passive) facilities, such as fireproof materials and fire and smoke compartmentalising.
- technical installation (active) facilities, for instance automatic extinguishing installations such as sprinkler systems.

The technical facilities have an influence on the fire and fire spread; a sprinkler system can start extinguishing the fire early on, and on the behaviour of the people that are still in the building when the fire starts, e.g. because of the location and design of emergency exits. In Chapter 6, the building characteristics are described more extensively and are linked to the operational objectives of the quadrant model.

[10] In high-rise buildings there is a risk of so-called wind driven fires because of the way these are built. This calls for a different approach of the operational tactic. Buildings with built-in garages in particular will constitute a much greater risk during an offensive interior attack. A wind driven fire starts out as an ordinary indoor fire, but when subsequently the windows in an exterior wall of the house break, the fire is suddenly supplied with large amounts of oxygen. Fire escalation takes place very rapidly due to the wind and the fire in the fire room becomes a fully developed fire. In this type of situation, the wind pushes the fire into the building. Wind driven fires can occur in all kinds of buildings, but high-rise buildings are the most susceptible due to their large wind exposure area.

3.3 Human characteristics

Human characteristics refer to the behaviour of the people who are still present in the building at the time of the fire and who might still be alive when the fire service operation starts. Human characteristics are determined by:

- physical factors
  People may not be able to leave without assistance, for instance because they are bedridden, have a handicap, have been using alcohol or drugs or because of psychological circumstances (also think of children).
- degree of attentiveness
  For instance, were people asleep at the time the fire started, or was the fire discovered during the daytime?
- organisational factors
  What instructions did the in-house emergency response teams give for the evacuation?

Human characteristics are also influenced by the fire characteristics (large amounts of smoke cause disorientation and loss of consciousness) and building characteristics (options for evacuation).

3.4 Intervention characteristics, chances of success for the chosen operational strategy

It follows that the choice for a particular quadrant (operational objective) is partly determined by assessing the incident's fire, building and human characteristics.
The intervention characteristics determine the extent to which a fire can be fought and, therefore, the (predictable) outcome. For instance, is a small fire extinguished right away by an occupant or an in-house emergency response team? And how effectively can the fire service operate?

When choosing an effective operational tactic it is essential that the fire service knows the location of the seat of the fire, knows how extensive the fire is (both in volume and capacity) and knows which fire protection facilities are present or lacking in the direct vicinity. On the basis of this information the fire service can assess if they are capable of applying sufficient extinguishing agent to limit the fire spread. If this is not the case, the fire will spread and the fire service has to predict how the fire will most likely develop. In situations like these, it might be wise to first choose a defensive operational technique, until there is sufficient operational capability (extinguishing agent, firefighting personnel, equipment) available.

When there are people inside the building, the first decision to be made is whether a rescue operation should be started, or whether it is more effective to start with extinguishing the fire. This decision is partly determined by the location of the victim(s) in relation to the seat of the fire and the size of the fire in relation to the available cooling power.

3.5 Environmental characteristics

Environmental characteristics also have an influence on fire, building, people and intervention characteristics. Environmental characteristics are concerned with the location of the building in relation to fire safety. Can the object be easily reached? How long does it take for the fire service to arrive? What is the distance between the object and adjacent premises?

The possibilities for intervention can also be limited by weather conditions. For instance, when tall buildings are involved, the wind might stir up the fire and cause a so-called wind driven fire. Extreme cold can cause (fire extinguishing) water to freeze and extreme heat has consequences for the length of an operation and for the recuperation time the operational firefighting personnel need.

4. Quadrant Model

The quadrant model is designed along two axes:
- exterior as opposed to interior
- defensive as opposed to offensive.

The quadrant model is a model that is used by commanders of firefighting operations to determine his or her operational tactic. It is, therefore, first and foremost a thinking model, and the lines between the quadrants symbolise the need to reconsider operational tactics during firefighting operations (a 'moment of transition').

The quadrant model is definitely not a procedure, but rather a tool for choosing the appropriate tactic and the appropriate resources. Not every fire has to be forced into the straitjacket of the quadrant model if that is not helpful in a particular situation.

The quadrant model can also help to gear risk management and incident response to each other.

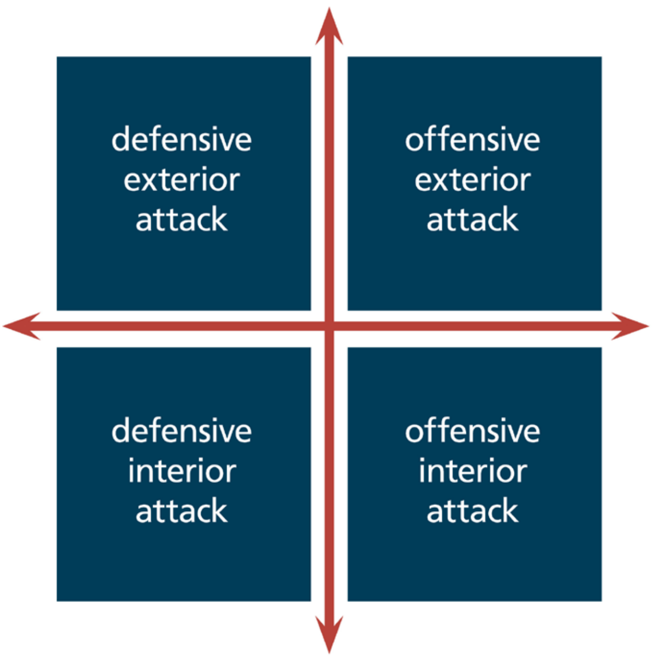

Figure 6: The quadrant model

4.1 Defensive exterior

The objective of a defensive exterior attack is damage control by:
- preventing fire spreading to adjacencies
- preventing environmental damage
- limiting the effects of smoke

A defensive exterior attack is used when a building is on fire: the seat of the fire cannot or can hardly be located and cannot be controlled with the means and opportunities available, there is a lot of smoke and the condition of the structure is such that the building might collapse at any time. Firefighting personnel operate outside the building, outside the collapse zone.[11]

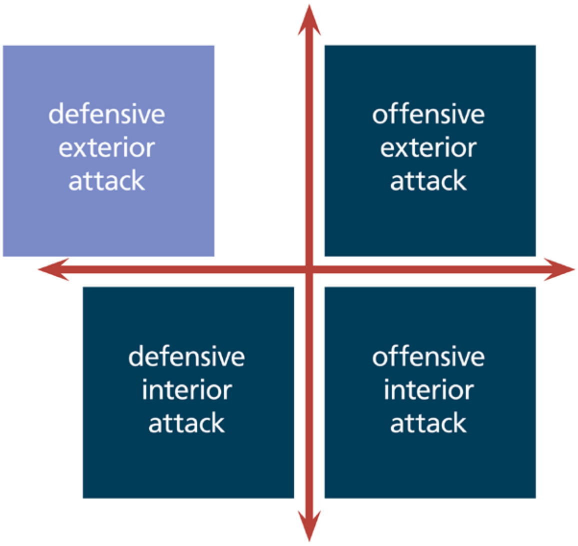

Figure 7: Defensive exterior attack

4.2 Offensive exterior

In an offensive exterior attack, firefighting personnel operate outside the building, but inside its collapse zone. An offensive exterior attack is carried out when it is not safe for the firefighter personnel to carry out an interior attack, and it can be a first step towards a defensive or an offensive interior attack. The construction of the building is deemed safe enough to deploy firefighting personnel inside the building's collapse zone.
The objectives of the operation are:

- improve survival conditions for any possible victims; there may be victims inside the building that cannot be rescued immediately via an interior attack and/or an interior attack is too dangerous
- enable safe entry by creating safe working conditions
- prevent fire spread
- extinguish the fire.

Knowledge of fire protection measures is of great importance to the choices in this quadrant. If the choice of attack/extinguishing techniques is geared to the objective of the operation, the chosen tactic can be successful and the objective be achieved. The chances of survival for possible victims can be improved faster, even without executing an interior attack, and subsequently, it may even be possible to carry out a rescue operation faster.

[11] The collapse zone is generally interpreted as 1.5 times a building's height.

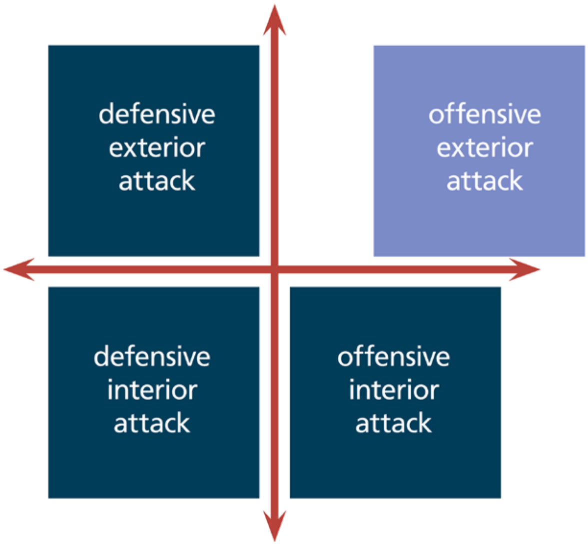

Figure 8: Offensive exterior attack

4.3 Defensive interior

In a defensive interior attack, firefighting personnel operate inside the building, inside an adjacent (sub-) fire compartment.[12] The objectives of a defensive interior attack are:

- facilitate an evacuation (keeping the separation between fire compartments intact)
- prevent fire spread (keeping the fire contained in the (sub-) fire compartment)
- damage control.

In a defensive interior attack, firefighting personnel enter the building, but the operation is restricted to that part of the building where there is no fire and of which it is certain that the structure is still intact. There is a fire in a building (furniture and fittings/inventory), not a building on fire. A defensive interior attack is always preparatory to an offensive interior attack.

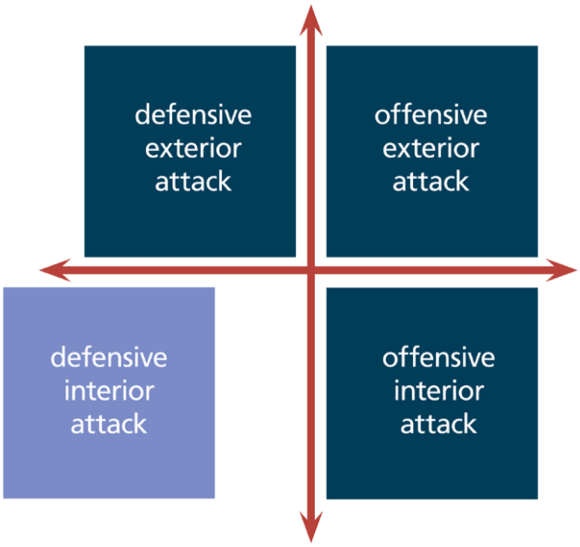

Figure 9: Defensive interior attack

[12] Fire prevention terminology often changes and does not necessarily become clearer. The definitions used in this reader are not the definitions used in the Dutch Buildings Decree 2012, but the definitions that are the most explanatory and are established with firefighters in the field, insofar as they are engaged in aspects of fire prevention.

4.4 Offensive interior

The objectives of an offensive interior operation are rescue and fighting fires. The firefighting personnel operate inside the building, inside the fire compartment. To operate safely inside a fire compartment, the conditions have to be such that hot gases cannot ignite. In other words, the gases have to be cooled and kept below the ignition temperature. The structural condition of a building has to be sound enough to be able to enter the building safely. The assessment whether or not to enter a building depends upon whether or not the objectives of the operation can be attained safely. Possible objectives are rescue and fire extinguishment which will immediately improve conditions for any victims. Until now, operations in this quadrant were known as the standard interior attack.

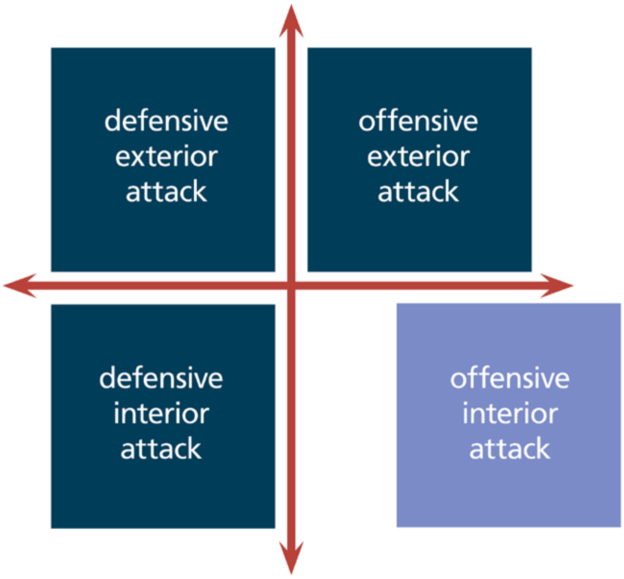

Figure 10: Offensive interior attack

4.5 Switching quadrants during operations

When a quadrant has been chosen, the operation does not necessarily stay in the selected quadrant. In the course of managing the incident, the commanding officer or duty officer might reconsider his or her decision and change to another tactic. A change of tactic can be the result of many causes. The circumstances of the fire can change – identifiable by for instance a changing smoke image – building characteristics can change and human characteristics can change as well. When a fire keeps burning, the risks of fire penetration or of collapse increase and the chances of survival for the people inside the building decrease. It is also possible that the operational strike capability is not sufficient and as a result a defensive technique has to be adopted. Or the other way around: the strike capability has increased to such an extent that an offensive attack can be carried out.

When switching quadrants, it is important to make sure that it is the result of a conscious choice. In addition, changes in tactic need to be clearly communicated to the other units and/or team members so that is it clear to everyone what the operation's new objective is.

It is also possible to use different tactics on different sides of the fire, for instance when there is an extensive fire in an industrial building. A defensive exterior attack can be carried out towards the adjacencies to prevent the fire from spreading to adjacent buildings through radiation; inside the building a defensive interior attack can be executed to keep the fire compartments up and to prevent the entire building from burning down.

5 Applying the quadrant model in firefighting operations

The quadrant model can be used in all stages of an operation. It is important that the commander of the firefighting operation constantly checks whether the chosen tactic is the right one, or in other words is appropriate for the chosen objective of the operation.

When the size or circumstances of an incident change (for instance because of an unexpected fire spread, or extra operational strike capacity), or when an objective changes (for instance after a successful rescue) the quadrant choice has to be reconsidered and changed if necessary.

5.1 Turn out

Based on the information in the turn out message the person in charge decides his or her primary objective and subsequently selects the most appropriate tactic, i.e. selecting the quadrant the person in charge (commanding officer or duty officer) wants to use at the start of managing the incident. The key question is how to attain the formulated objective.

The basic operational tactic is selecting the quadrant the commanding officer or duty officer wants to use at the start of managing the incident.

The person in charge will choose a tactic based on the content of the alarm, the job he or she expects based on the information available, the objective he or she wants to achieve, the resources available, his or her experience and knowledge of the area of coverage. The person in charge communicates his or her intentions to the rest of the team(s). The team prepares for the chosen tactic, appropriate technique(s) and work methods.

5.2 Reconnaissance

A thorough reconnaissance has to be carried out before executing a tactic. Reconnaissance is aimed at recognising fire, building and human characteristics. The reconnaissance has to show whether the chosen tactic can be put into actual practice, intervention and environmental characteristics are of importance here too.

Reconnaissance is the cyclic process of collecting, assessing and checking information. By forming a picture and a judgement of the situation, it is possible to make a conscious choice about the operation's objective (the outcome) and tactic (quadrant).

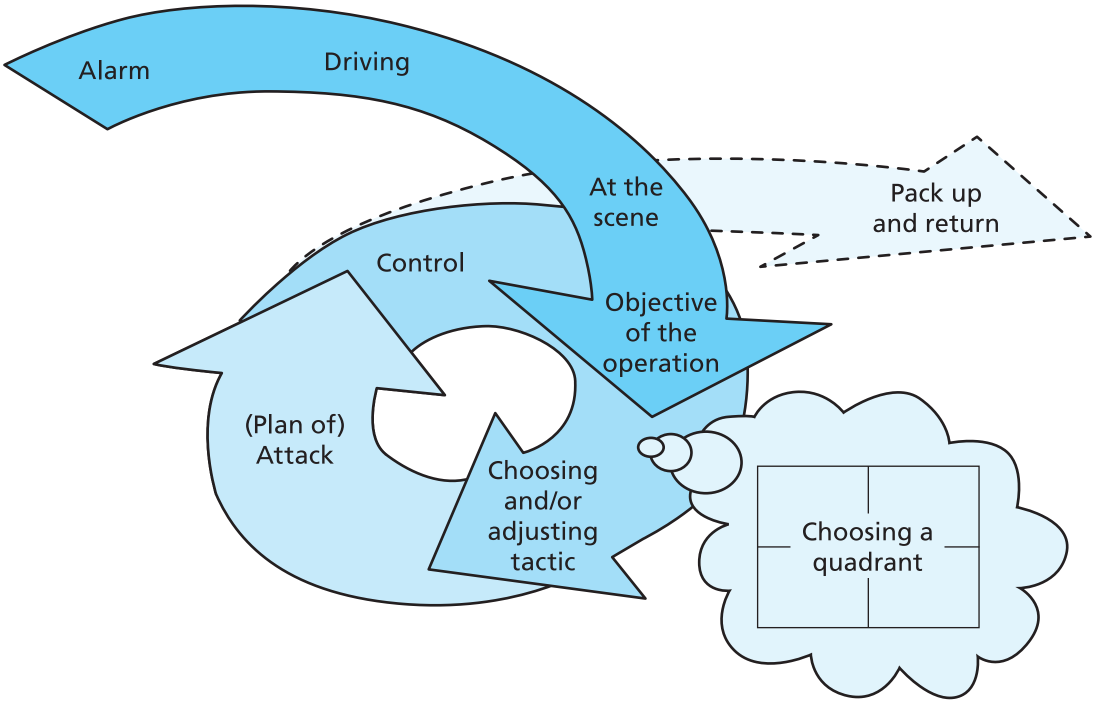

Figure 11: Diagram representing the application of the quadrant model during an operation (Reconnaissance Team Fire Service Doctrine)

Reconnaissance has to provide information on the following aspects:

- the scenario
  Is there a fire and, if so, is there a possible combination with hazardous substances? What are the choices and dangers? What is the expected fire development (regime change) in time and tempo, and what will be the effect of an intervention?
  When a situation is more complex, the operation will be scaled up and a more comprehensive thought process has to be passed through.
- the location of the fire
  Where is the seat of the fire located and what is the shortest route to get to it and attack it? How big is the fire? The answers to these questions help determine whether the seat of the fire can be reached from the outside and how much cooling power is needed to bring the fire under control.
  A thermal imaging camera can be a useful extra tool when performing exterior reconnaissance; it can be used to locate the seat of the fire inside the building. A clear understanding of where the seat of the fire is located and what the entry options are, lead to the shortest possible route of attack.
- human characteristics
  Are there any victims? Can they leave on their own, without assistance? But first and foremost: is a rescue operation feasible?
- fire characteristics
  What can be said about the burning regime (fuel controlled, ventilation controlled or under-ventilated), smoke indicators, visible flames, visible dynamics (cold or hot air flows)?
- building characteristics
  Type of building and the existing active and passive fire protection measures. Where are the entrances? What is the shortest route from the outside to the seat of the fire/the victims? Can the escape routes be used as routes of attack?

The result of the reconnaissance is that the tactic that was chosen when driving to the incident is either confirmed or adjusted. The final objective of the operation can now be determined. Reconnaissance remains a continuous process until the fire is under control.

5.3 Attack

The chosen tactic is either confirmed or adjusted based on the operation's objective and the outcomes of the reconnaissance. The commands for the attack are given and the commanding officer or duty officer checks the progress. If at any time the operation's objective needs to be adjusted, the tactic will have to be adjusted as well, from exterior to interior, from defensive to offensive, or vice versa.

5.4 Run down and aftercare

As the incident progresses, the dynamics slow down and fewer firefighting units are needed. With the command 'fire under control', the person in charge indicates that the incident is under control. Based on the progress check, a new objective is formulated and both the units deployed and the operation's objectives are adjusted accordingly. In this stage of the operation it is still important to keep confirming the objective of the operation and the best suitable way to go about achieving it.

6 Building characteristics, the link between prevention and suppression

As stated earlier, the fire service doctrine no longer focuses solely on fire suppression, but also on the prevention and controllability of fire and other incidents. In this, the connection between prevention and suppression is key.
The need to make this connection has been recognised for quite some time now, but an actual interpretation has been long in coming. In actual practice, this connection is often limited to, for instance, guiding firefighters through new complex buildings, or to informing them about the assumed scenario in the applicable building permits; based on that the fire service carries out an interior attack, or a defensive exterior attack. The latter example is in fact not what the connection between prevention and suppression should be about.

The quadrant model clarifies what this connection should be. When carrying out an offensive interior attack firefighters operate inside a burning fire compartment. Since fire prevention regulations take this into account, the necessary connection is obvious. However, the quadrant model provides two additional options for a defensive attack, signifying an attack that takes place from 'behind a line of defence'. These lines of defence are incorporated into the building as fire protection measures as well. This means that they have to be recognisable and have to be recognised and used during a fire extinguishing operation.

6.1 Defensive exterior

When the fire has developed to such a level that a safe and effective interior attack is no longer possible – not even after performing an offensive exterior attack first – then the commander of the firefighting operation has to opt for a defensive exterior attack. The attack is no longer focused on the burning building, but rather on its adjacencies. The building characteristics continue to be important since the operation is carried out next to a building where a fully developed fire is burning.

The fire inside the building is no longer (effectively) attacked during the defensive exterior attack and as a consequence the building might collapse. Whether this will actually happen (mainly) depends on the building's inventory and the relation between the fire-resistance of the building's load-bearing structure and the building's fire load. When a building collapses, the exterior walls usually collapse as well, but this does not always have to be the case; it depends on the fire-resistance requirements that were applied for the exterior walls, and these requirements depend on the building distance to adjacent buildings, that are already there or still have to be built.

A building that breaks down can pose severe risks for the firefighters at the scene (such as a collapse) and can result in the fire spreading to other buildings. There have been far too many victims among firefighters in the past due to insufficient knowledge.
In order to be able to make an informed decision about safely performing a defensive exterior attack, commanders of firefighting operations have to possess knowledge of:
- risks of buildings breaking down and interdependencies between fire load and fire duration
- fire-resistance of exterior walls and building distances to adjacencies.

6.2 Offensive exterior

In general, the objectives of an offensive exterior attack are:

> quickly improve survival conditions for the people that are still in the burning fire compartment

and

> improve the conditions inside the fire compartment to enable a safe entry by the fire service (create a safe working environment).

In these cases, the offensive exterior attack is performed in preparation for an offensive interior attack. As regards the latter attack, the fire characteristics, building characteristics and human characteristics apply that are described in section 6.4 under offensive interior attack hereafter.
An offensive exterior attack can also help prepare for a defensive interior attack.

In a limited number of cases, the offensive exterior attack's objective could be to prevent fire spread or to extinguish the fire. In these cases, the building characteristics have to be taken into account, as described previously under defensive exterior attack.

6.3 Defensive interior

It is possible to carry out a defensive interior attack when a building consists of more than one (sub-) fire compartment. To prevent the fire from spreading, an attack can be carried out from the adjacent fire compartment. In order to be able to make informed operational decisions, knowledge of a number of building characteristics is required, apart from knowledge of fire characteristics. It is a prerequisite for a defensive interior attack that the (sub-) fire compartment is sufficiently intact in order to operate safely from the adjacent fire compartment. If this is not the case or no longer the case, the defensive interior attack transfers into an offensive interior attack – since those conditions apply – with all the risks that entails.

Location and construction of (sub-) fire compartments

The aim of creating sub-compartments is to contain a fire for a period of time in the room of origin in order to be able to evacuate the surrounding spaces. Sub-compartments are found in buildings where an evacuation takes more time than usual such as hotels, prisons, hospitals and nursing homes. It is only after the surrounding rooms have been evacuated that the fire can be attacked.

When there are no floor plans available during a fire suppression operation – which is usually the case – the fire partition locations have to be (and can be) determined on the basis of indicators. This requires thorough reconnaissance.

Adjacent fire compartment breaking down

During a defensive attack, the burning (sub-) fire compartment is not entered and the firefighters operate from an adjacent fire compartment. For example, when there is a fire in a particular section of a hospital floor, the fire service operates from behind the fire partition of the fire compartment.
In cases where a sub-fire compartment exists, the fire service operates inside the fire compartment where the sub-fire compartment is located. For example, when there is a fire in a hospital room, the room is located in a fire compartment (the ward) on a floor.
If a burning (sub-) fire compartment should break down, it is important to know the consequences for the construction for the location where the firefighters are operating. Does only the burning section break down, or could this turn into a progressive collapse? Or is there perhaps a possibility of fire penetration? Knowledge about these risks is essential when choosing a safe location for firefighters to operate from.

Quality of the routes of attack

Defensive interior attacks are usually carried out inside larger buildings. It is important that under these circumstances the route of attack remains a safe route to return.
When carrying out a defensive interior attack, firefighters are usually dealing with a considerably developed fire. If this were not the case, they usually would have chosen the tactic of the offensive interior attack. Escape routes in larger buildings are usually fairly fire-resistant. It is, therefore, advisable to use these escape routes as routes of attack. This makes it pertinent that escape routes are recognised and that their fire-resistance is assessed during the fire suppression operation.

In order to be able to make an informed decision about safely performing a defensive interior attack, commanders of firefighting operations have to possess knowledge of the:

- indicators for fire partitions and escape routes
- risks of (sub-) fire compartments collapsing
- fire-resistance of escape routes
- smoke spread and its characteristics.

6.4 Offensive interior

During an offensive interior attack the firefighting units are deployed inside the burning fire compartment. A prerequisite for such an operation is that fire, heat and smoke development are such that entering the burning fire compartment is still an acceptable risk. Obviously, the fire characteristics play a crucial role here, but human characteristics and building characteristics are also essential during risk assessment.

Possibility for rescue

The commander of the firefighting operation has to assess whether it is likely that there are any people in the burning fire compartment. The assumption that there are still people inside a building is often based on, for instance, the original alarm.
The existing fire protection measures should be taken into account when assessing the chances for a successful rescue operation and when deciding whether to enter the burning fire compartment to perform a search.
The presence of a fire alarm system or an emergency evacuation system can be a sign that there are people inside the fire compartment, the presence of a sprinkler system be an indication for size of the fire and the temperature in the fire compartment.

Normative versus natural fire behaviour

The commander of a firefighting operation also has to have an indication as to how much time he or she has to carry out a rescue operation. In fire prevention, normative fire behaviour is used to provide the time frames in which, for instance, the fire service has to perform a rescue operation. Since the time frames are standard times, they can vary in actual practice (the natural fire behaviour), but they do give an indication of the time available for search and rescue.

Fire compartment breaking down

During an offensive interior attack the burning fire compartment is entered. In such instances, it is important to know whether a construction has been fireproofed and, if it has, how fire-resistant it is, measured in time. Depending on the type of building, its height and the way it is constructed, fire-resistance is 0, 30, 60, 90 or 120 minutes until break down.

Knowledge of fire-resistance is essential to be able to make an assessment about whether an offensive interior attack is possible and to be able to determine how long an operation inside the fire compartment can be carried out safely. If there is no such knowledge available, a defensive operation is the only alternative. An offensive interior attack can only be carried out when it is believed that the fire can be controlled or already is under control. Natural fire behaviour can be very quick and it might be too late to switch tactics at a later stage.

In order to be able to make an informed decision about safely performing an offensive interior attack, commanders of firefighting operations have to possess knowledge of:
> fire protection measures with regard to escaping and improving conditions for survival (fire alarm system, evacuation system, sprinkler system etc.)
> normative fire behaviour
> fire-resistance requirements for building construction and building materials.

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Appendix 1 - Quadrant model

(version 7, Process Team Fire Service Doctrine, Brandweer Nederland, Brandweeracademie)

EXTERIOR

DEFENSIVE

OFFENSIVE

INTERIOR

Defensive exterior attack

Objective

1. **Prevent fire spread**
2. **Limit (environmental and social) impact**

Explanation

- Firefighting personnel operate **outside the building, outside the collapse zone.**
- The burning building is no longer the focus of the attack.

Criteria

- The construction is in such a condition that the building might collapse.
- It is no longer possible to limit the damage to the building.

Building types

Any building

Offensive exterior attack

Objective

1. **Improve conditions for survival and enable a safe entry**
2. **Prevent fire spread**
3. **Extinguish the fire**

Explanation

- Firefighting personnel operate **outside the building.**
- Can be used to prepare for antother quadrant.

Criteria

- There could still be victims inside the building who cannot be rescued immediately through an interior attack.
- It is possible to operate within the collapse zone of the building since the construction is sound.
- An interior attack is (too) dangerous.

Building types

Mainly commercial buildings, buildings without compartimentalization and semi-detached buildings.

Defensive interior attack

Objective

1. **Enable evacuation from/rescue out of adjacent (sub-)fire compartments**
2. **Prevent fire spread, keep the fire within the (sub-)fire compartment**

Explanation

- Firefighting personnel operate **inside the building, inside an adjacent (sub-) fire compartment.**
- Can be used to prepare for another quadrant.

Criteria

- The (sub-)fire compartment cannot be safely entered (yet) because of the fire and/or smoke production.
- The ajacent (sub-)fire compartment can be safely entered.
- The building consists of more than one (sub-)fire compartment.

Building types

Mainly prisons, health care buildings, conference and assembly buildings, hotels and high-rise buildings.

Offensive interior attack

Objective

1. **Rescue**
2. **Fight the fire and the smoke within in the compartment**

Explanation

- Firefighting personnel operate **inside the building, inside the fire compartment.**

Criteria

- The fire and smoke spead has to be such that entering the fire compartment presents an acceptable risk.

Building types

Mainly houses.

Appendix 2 - The choice of equipment during operations

In this appendix, suggestions are given for fire extinguishing techniques and operational techniques to use in each of the four quadrants. The techniques should be regarded as mere suggestions. Through research and the use of (innovative) techniques we continue to gather information about using the techniques that are appropriate for the objectives of the quadrant model. These include, for example, the use of water curtains, fire-extinguishing gel, fire extinguishing robot, steam extinguishing with gas turbines, aerosol fire suppression en maybe other extinguishing gases or agents for a defensive or offensive exterior attack. And they include procedures to disperse, dissolve or control fire gases, for instance by using a combination of ventilation and extinguishing agents, piercing techniques and fire extinguishing robots. Then, there are of course the regular techniques, such as low pressure and high pressure fire hoses, which can be used without problems with all for quadrants.

There are several techniques available for the execution of each quadrant (each tactic), and each technique has its own work method. The execution of a tactic does not require specific resources, but some techniques can be more effective than others. A standard Dutch pump vehicle contains all equipment necessary to carry out all four tactics by means of one or more techniques.

A combination of different techniques usually produces the best results, it may even be necessary to combine techniques to be able to execute an effective suppression operation. A high pressure or low pressure fire hose can be combined with ventilation techniques to disperse the smoke. Another possibility is to create a safe environment by using a cold cutting system and follow up with an attack of the seat of the fire with a low pressure fire hose or compressed air foam.

The table below gives an overview of the option.

Techniek	Defensive exterior	Offensive exterior	Defensive interior	Offensive interior
Use of a high pressure fire hose		x	x	x
Use of a low pressure fire hose	x	x	x	x
CAF	x	x		x
Ventilation		x	x	x
Distributor nozzle		x	x	
Fognail		x	x	
Cold cut system		x	x	
DSPA		x	x	x
Water curtain	x			
Cool exterior walls	x			

Appendix 3 contains more details on a number of the (innovative) techniques.

1. Defensive exterior

The defensive exterior attack is aimed at damage control by way of:

- preventing the fire spreading to adjacencies
- preventing environmental damage.

In this case it is the impact area that is of specific importance.

The choice of resources is aimed at preventing the spread of both fire and smoke, and different methods can be used. In recent years, the fire service tends to use as little fire extinguishing water as possible to reduce environmental damage. This calls for further research on the most effective methods to prevent fire spread to adjacent buildings. The fire service predominantly used to deploy water cannons (from a fire extinguishing platform or otherwise) to get water onto the fire. Further research has to show whether the deployment of a water curtain or cooling the exterior walls might be more effective.

2. Offensive exterior

The fire service has several resources at its disposal that are very efficient during an offensive exterior attack. The use of innovative (and sometimes very old) operational techniques that make use of modern theories on smoke behaviour and fire growth, could improve any victim's chances of survival significantly, and there is no need for an interior attack. It is even possible to carry out rescue operations faster. Apart from this, it is always possible to carry out an exterior attack with a low pressure fire hose, high pressure fire hose or CAF, under the express condition that there are no firefighters inside the structure. The latter should always be the case though when executing an offensive exterior attack.

Piercing techniques

During an offensive exterior attack, the fire service can start out with piercing techniques. With these techniques an initial attack can be carried out from outside, without having to enter the building. The objective of the attack is to extinguish the fire[13] and cool the hot gases, thus creating a safe environment to work in and survivable conditions for any victims. Furthermore, the use of these techniques can prevent fire spread and fire gas ignition. Examples of these techniques are:

- distributor nozzle
- fog nail
- cold cut system.

These piercing techniques can be used in combination with a thermal imaging camera to locate the fire and monitor the impact of the attack. For extinguishing operations the techniques can be used in combination with ventilation, high pressure or low pressure fire hose.

Creating an opening in an exterior wall in combination with a fire extinguishing operation

Another way to perform an offensive attack from the outside is to create an opening in the outer wall of a building or in the roof and subsequently attack the fire directly. Creating an opening can vary from opening an (overhead) door, to using a demolition crane to make an opening in an exterior wall. Obviously, the availability of such equipment can be an issue and improvisation may be called for. The objective is always to create an opening by way of which the firefighting operation can get started. Because of the required throwing range, the seat of the fire is usually attacked with a low pressure fire hose or with one or more water cannons.

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[13] There always has to be a transition to an offensive interior attack to follow up with a high pressure fire hose, low pressure fire hose or CAF.

Ventilation
Ventilation techniques can be used to create survivable conditions for any victims located above or behind the fire room (the conditions for survival are much better in the rooms surrounding the fire), to disperse smoke and fire gases and to prevent fire spread. Ventilation can be used in combination with a thermal imaging camera to locate the seat of the fire. It is then easier to ventilate accurately and determine where ventilation openings would be the most effective. It is also possible to use ventilation in combination with compressed air foam, high pressure fire hose and low pressure fire hose.

Compressed air foam (CAF)
Firefighters are not required to enter the building when they want to use compressed air foam. Compressed air foam has a considerable throwing range. It is suitable for extinguishing or limiting the fire and for cooling fire gases, even though it is less effective in the latter case. Compressed air foam is often used after a piercing operation to directly attack the seat of the fire. An attack with compressed air foam can be combined with the use of positive pressure ventilation into adjacent rooms. This way, smoke spread, and the subsequent potential fire spread, can be prevented.

3. Defensive interior
Objectives of the defensive interior attack are:
- facilitate an evacuation (keeping the separation between fire compartments intact)
- prevent the fire from spreading (keeping the fire contained in the (sub-) fire compartment)
- damage control
- ventilate rooms that are not involved in the fire and are filled with smoke.

As far as applicable techniques are concerned, the defensive interior attack resembles both the offensive exterior attack (techniques that enable smoke and fire gas cooling and that extinguish the fire from the outside) and the offensive interior attack (aimed at extinguishing the fire).
Possible techniques are piercing techniques, ventilation and several other firefighting techniques. As far as fire extinguishing is concerned: it is mandatory that the fire compartment is still safe enough to be able to execute a defensive interior attack.

4. Offensive interior
The objectives of this attack are rescue and fighting both smoke and fire.
The firefighting personnel operate inside the building, inside the fire compartment. This is only an option when an attack can be carried out safely by for instance cooling gases or taking other necessary precautions.
Possible techniques are low pressure fire hose, high pressure fire hose and CAF. Additionally ventilation can be used to cool and disperse the fire gases.
The firefighters have to decide whether to rescue first (because they can) or to extinguish and ventilate first (because they have to). Sometimes valuable time can be gained by first extinguishing the seat of the fire; it is important to create as little steam as possible in doing this.

Appendix 3 - Operational techniques

› Distributor nozzle

Strategy (objective)
A distributor nozzle can be used to achieve the following objectives:
- firefighting personnel's safety: firefighters do not go inside the structure
- extinguish the fire
- cool fire gases
- damage control
- prevent fire spread
- reduce the risk of a back draft and/or flashover.

Fire behaviour
A distributor nozzle can be used during the following fire stages of the cascade model:
- the fire is limited to the room where it originated
- the fire is limited to the floor where it originated
- the fire is limited to the fire compartment, there are no flames breaking out.

The fire is ventilation controlled.

Extinguishing effects
Using a distributor nozzle has the following effects:
- controlling the fire
- cooling the fire gases.

Specific requirements
Standard (Dutch) pump vehicle:
- four persons: two to build the water supply and two to operate the device.

Possible combinations with other techniques

The following combinations are possible:

- thermal imaging camera in combination with the distributor nozzle
- distributor nozzle followed by ventilation
- distributor nozzle followed by high pressure fire hose
- distributor nozzle followed by low pressure fire hose.

A distributor nozzle can be used in combination with positive pressure ventilation of the adjacent rooms to prevent the smoke from spreading and thus prevent a potential fire spread. During a defensive interior attack this is, in fact, a requirement; the distributor nozzle is then used to create an initial cooling effect.

Effectiveness and advantages

- On average a distributor nozzle can take on 80 m^2. Please also refer to the specifications provided by the manufacturer. A bigger impact can be created by using more than one distributor nozzle.
- When a distributor nozzle is used correctly, fire and water damage can be relatively low since the water mist that is created extinguishes the fire more quickly and there is less water needed to control/extinguish the fire.
- Flow rate: 750 to 1,500 litres per minute, depending on the type. The higher the flow rate, the greater the area that can be potentially reached.

Limitations/disadvantages

- When using a distributor nozzle, firefighters are located close to the fire compartment, the façade, the wall, etc.
- Loss of time to build the water supply (about three minutes).
- The system is sensitive to dirty water: the outflow points become obstructed.
- The steam that is generated diminishes the chances of survival for the victims inside the fire room.
- When a distributor nozzle is inserted through a window, there is the risk of falling glass.
- It is often necessary to follow up with a high pressure fire hose, the throwing range of a distributor nozzle is not very far at right angles to the direction it is used.
- The use of a distributor nozzle is especially effective when there are no flames spreading out; the generated steam is then most effective.
- The distributor nozzle is less effective in open spaces. However, applying a distributor nozzle in a room with a fully developed fire where all the windows are gone can still be effective because of its considerable strike capability.
- Its effectiveness is determined by the layout of the rooms.

> Fog nail

Strategy (objective)
Fog nails can be used to achieve the following objectives:
- firefighting personnel's own safety: firefighters do not go inside the structure
- extinguish the fire
- cool fire gases
- prevent fire spread
- damage control
- reduce the risk of a back draft and/or flashover.

Fire behaviour
Fog nails can be used during all fire stages of the cascade model:
- the fire is limited to the room where it originated
- the fire is limited to the floor where it originated
- the fire is limited to the fire compartment, there are no flames breaking out
- the fire has spread outside the fire compartment, but there are no flames breaking out.

Ventilation controlled or under-ventilated fires.

Extinguishing effects
Using a fog nail has the following effects:
- controlling the fire
- cooling the fire gases.

Specific requirements
Standard (Dutch) pump vehicle:
- one person to operate the fog nail and one person to create an opening.

Possible combinations with other techniques
The following combinations are possible:
- fog nail in combination with thermal imaging camera
- fog nail followed by ventilation
- fog nail followed by compressed air foam
- fog nail followed by high pressure fire hose
- fog nail followed by low pressure fire hose.

A fog nail can be used in combination with positive pressure ventilation of the adjacent rooms to prevent the smoke from spreading and thus prevent a potential fire spread. During a defensive interior attack this is, in fact, a requirement.

Effectiveness and advantages

- Less fire damage and water damage because the fire is extinguished faster with less water.
- The fog nail can be connected to high pressure and is quickly ready-to-use.
- Flow rate: 70 litres per minute at 8 bar.
- There are two types of fog nails: defensive (length 1.50 metres) and offensive (short model).
- The fog nail has two set-ups. For fires in large buildings (factories) the defensive jet (spray) is the best suited. The offensive jet is more suitable for fires in small spaces.
- In larger spaces several fog nails can be used to create a fire stopping line.
- The fog nail hardly takes up any space and falls under the current Dutch branch regulations for standard equipment.
- The fog nail has also proved effective in car fires. There is no need to open the bonnet because the fire can be attacked through the openings for the headlights.

Limitations/disadvantages

- When using a fog nail, firefighters are located close to the fire compartment, the façade, the wall, etc.
- Loss of time due to the fact that a fog nails has to be connected. When using more than one fog nail, some type of layout system will have to be set up.
- It is necessary to follow up with a high pressure fire hose.
- Maintenance, since the nozzles are sensitive to blocking.
- Fire service personnel have to be trained and must practise how to execute a fog nail attack.
- With hard materials it can be necessary to use a concrete drill or a metal drill.
- There are risks involved when working on a roof.

> Cold cut system

Strategy (objective)
The cold cut system can be used to achieve the following objectives:
- firefighting personnel's own safety: firefighters do not go inside the structure
- control the fire
- cool gases
- prevent fire spread
- reduce the risk of a back draft and/or flashover.

Fire behaviour
A cold cut system can be used during the following fire stages in the cascade model:
- the fire is limited to object in which it originated
- the fire is limited to the room where it originated
- the fire is limited to the floor where it originated
- the fire is limited to the fire compartment, there are no flames breaking out.

Ventilation controlled and/or under-ventilated fires.

Extinguishing effects
Using a cold cut system has the following effect:
- gas cooling.

Specific requirements
Pump vehicle or a special vehicle on which the cold cut system has been built onto:
- two persons, one to operate the cold cut system and one to guard the safe zone.

Possible combinations with other techniques
The following combinations are possible:
- thermal imaging camera in combination with the cold cut system
- cold cut system followed by ventilation
- cold cut system followed by compressed air foam
- cold cut system followed by high pressure fire hose
- cold cut system followed by low pressure fire hose
- ventilation followed by the cold cut system.

A cold cut system can be used in combination with positive pressure ventilation of the adjacent rooms to prevent the smoke from spreading and thus prevent a potential fire spread.

Effectiveness and advantages

- The cold cut system can be used to cut through materials such as steel and concrete (roofs, walls, cavity walls and the like).
- The system can be safely used in combustible or explosive environments.
- The cold cut system only uses a limited amount of water compared to a high pressure fire hose, there is, therefore, less water damage and a lower risk of groundwater and surface water contamination.
- Compared to a high pressure fire hose, the water mist is carried further when using a cold cut system.
- In combination with a thermal imaging camera, the cold cut system can be used to attack the seat of the fire, even in places that are hard to reach such as attics, false ceilings, cellars and silos.
- Using a cold cut system creates a safer environment for an interior attack because the temperature can be brought down before the firefighters go inside.
- There are several techniques that can be added onto the cold cut system, such as remote control.
- The risks of causing a flashover or back draft are much smaller, since it is not necessary to create an opening to get the extinguishing agents into the building.
- The cold cut system is only suited for fires with limited heat release rates considering it relatively small cooling power and the objective of the operation.
- In some instances it is possible to use multiple cold cut system lances.

Limitations/disadvantages

- When using a cold cut system, firefighters are located close to the fire compartment, the façade, the wall, etc.
- It is always necessary to follow up with a high pressure fire hose.
- It is not possible to use the cold cut system - or not under a height of 1 metre - when there are people in the fire room. Any people in the fire room are most likely to be lying on the floor.
- Firefighting personnel have to be trained and have to practise using a cold cut system.
- When used in the wrong way, the jet of the cold cut system can bounce off a wall.
- Within a distance of 7 metres, a jet beam of a cold cut system is dangerous (the jet spreads after 7 metres).
- The time needed to cut with the cold cut system can last from 5 up to 60 seconds, depending on the material and its thickness,
- The cold cut system is relatively heavy to operate (response strength).

> Ventilation

Strategy (objective)

Ventilation techniques can be used to achieve the following objectives:
- firefighting personnel's own safety: firefighters do not go inside the structure
- create survivable conditions for any victims located in front of, above or behind the fire room
- disperse gases
- prevent fire spread
- damage control.

Fire behaviour

Ventilation techniques can be used during the following fire stages of the cascade model:
- the fire is limited to the room where it originated
- the fire is limited to the floor where it originated
- the fire is limited to the fire compartment, there are no flames breaking out
- the fire has spread outside the fire compartment, flames are breaking out.

The fire is fuel controlled or to a lesser extent ventilation controlled.

It is of the utmost importance to take natural flow paths into account when using fans. Obviously, this also applies to natural (as opposed to overpressure) ventilation. Once the flames are breaking out, the fire has created its own openings. There is usually no great impact on the fire in the fire room when ventilation techniques are applied at this stage of the fire. However, ventilation can be effective when there is an opening in the roof: firefighters that are inside the building find the flow of cooler air pleasant. Moreover, it can be effective to ventilate adjacent rooms when the flames are breaking out by creating overpressure in the adjacent rooms. This creates a safer working environment and the risk of a fire gas ignition or other forms of fire spread is reduced.

Extinguishing effects
Using ventilation techniques has the following effects:
- a decrease in temperature throughout the entire room
- dispersion of smoke and gases
- a better view of the victim and/or the seat of the fire
- reduced risk for operational personnel
- reduced risk of escalation of the fire when the fire is fuel controlled.

Specific requirements
- Excellent coordination and allocation of tasks within the entire team is needed when setting up ventilation techniques. All firefighters need to be aware of the consequences of ventilating.
- The order in which to make inflow and outflow openings.
- The choice between natural ventilation and overpressure ventilation (depending on the stage the fire is in).
- The driver/pump operator can be designated to operate the fan: depending on the incident the allocation of tasks has to be adjusted.
- It is essential to coordinate with the unit that conducts a search or fights the fire.
- Keep guard over/monitor the outflow openings to check for fire spread.

Attention! Only hose the outflow openings; never spray into the hot gases.

Possible combinations with other techniques
The following combinations are possible:
- thermal imaging camera in combination with ventilation
- ventilation in combination with compressed air foam
- ventilation in combination with a high pressure fire hose
- ventilation in combination with a low pressure fire hose.

Effectiveness and advantages
- Gases are dispersed when ventilating. In most cases this will slow down the fire spread, because fuel is removed.
- Ventilation creates a safer working environment for the operational firefighters.
- Ventilation creates better survivable conditions for any victims.
- Ventilation enables a quicker reconnaissance of the rooms.
- There is less smoke damage compared to an operation where only extinguishing agents are used.

Limitations/disadvantages
- When using ventilation, firefighters are located close to the fire compartment, the façade, the wall, etc.
- Ventilation can be difficult to put into practice, an extensive knowledge of fire, fire behaviour and the effects of inflow and outflow of air, is required.
- Ventilation requires excellent coordination between teams and units.
- Ventilation can cause the fire to intensify because the inflow of oxygen can create conditions that support optimal combustion. In these instances ventilation is counterproductive. This mostly occurs in bigger rooms and/or after a certain amount of time has passed.
- Ventilation is less suitable for larger spaces/buildings where it can turn out to be counterproductive. In these situations it can be difficult to get an overview of the entire room and there might be hidden or uncontrollable rooms.
- Ventilation is an additional task for a unit that has to perform all regular tasks as well.
- Ventilation calls for firefighters to have sufficient insight into the situation and for more coordination from the people in charge.
- The capacity of a fan is expressed the volume of air it can move per minute; a fan that is suitable for house fires can be unsuitable for fires in industrial buildings.

Recognising danger

- Positive pressure ventilation cannot be used with an under-ventilated fire.
- Basically, natural ventilation can be used during all fire stages, but firefighters have to be aware that opening doors has an impact on the fire development. The question is which is more manageable: the development of the fire or the increase of danger due to the accumulation and condensation of fire gases?

> Compressed air foam (CAF)

Strategy (objective)

Compressed air foam can be used to achieve the following objectives:

- firefighting personnel's own safety: firefighters do not go inside the structure
- extinguish or limit a fire (including electricity fires < 35,000 volts)
- create survivable conditions
- damage control.

The operational possibilities depend on the kind of foam that is used: standard compressed air foam (A) or alcohol-resistant foam (B). Compressed air foam can be used both indoors and outside.

Fire behaviour

Compressed air foam can be used during all fire stages of the cascade model:

- the fire is limited to the room where it originated
- the fire is limited to the floor where it originated
- the fire is limited to the fire compartment, there are no flames breaking out
- the fire has spread outside the fire compartment, flames are breaking out.

Extinguishing effects

Using compressed air foam has the following effects:

- extinguish the fire
- gas cooling (to a lesser extent)
- limit pyrolysis.

Specific requirements

Standard (Dutch) pump vehicle:

- two persons, one to operate the branch pipe, one to lead the fire hose/jet.

Possible combinations with other techniques

The following combinations are possible:

- thermal imaging camera in combination with compressed air foam
- DSPA followed by compressed air foam
- cold cut system followed by compressed air foam
- fog nail followed by compressed air foam
- compressed air foam followed by ventilation.

Compressed air foam can be used in combination with positive pressure ventilation of the adjacent rooms to prevent the smoke from spreading and thus prevent a potential fire spread.

Effectiveness and advantages

- With regard to extinguishing speed and cooling the gas layer there are hardly any differences between using a high pressure fire hose and compressed air foam.
- Compared to water, the same tank capacity generates 7 times more extinguishing agent when using compressed air foam.
- Longer throwing range than with a high pressure fire hose.
- Compressed air foam generates less steam compared to a high pressure fire hose, so:
  - no increase in volume, the fire is not pressed inside
  - firefighters experience lower temperatures compared to using a high pressure fire hose
  - visibility is better than with a high pressure fire hose.
- The system can be moved over great distances without losing pressure or power.
- It can rise up to 100 metres.
- It is possible to mount the system unto a hydraulic arm.
- There is hardly any collateral damage.
- After determining the optimal ratio, the system is immediately operational by using water from the tank. The flow rate is 150 litres per minute.

Limitations/disadvantages

- When using compressed air foam, firefighters are located close to the fire compartment, the façade, the wall, etc.
- Gas cooling with compressed air foam is less effective compared to a high pressure fire hose and low pressure fire hose.
- Compressed air foam leaves white traces that do not dissolve immediately.
- Firefighting personnel have to be trained and have to practise using compressed air foam.
- The foaming agent affects turnout gear (degreasing and penetrating effect), this has to be taken into account when cleaning turnout gear.
- Purchase, maintenance and operational costs.

> Dry sprinkler powder aerosol (DSPA)

Strategy (objective)
A DSPA (dry sprinkler powder aerosol) can be used to achieve the following objectives:
- firefighting personnel's own safety: firefighters do not go inside the structure
- create survivable conditions for any victims located above or behind the fire room
- reduce the risk of a back draft and/or flashover
- prevent the fire to spread.

Fire behaviour
A DSPA can be used during the following fire stages of the cascade model:
- the fire is limited to object in which it originated
- the fire is limited to the room where it originated.

Extinguishing effects
Using a DSPA has the following effects:
- extinguish the flames
- decrease in temperature throughout the room (60 m^3 per DSPA)
- use of DSPA has to be followed up immediately by a high pressure/low pressure fire hose or compressed air foam because the effect of a DSPA only lasts a short period of time.

Specific requirements
One person to activate the DSPA and throw it into the fire room.

Possible combinations with other techniques
The following combinations are possible:
- thermal imaging camera in combination with DSPA
- DSPA followed by compressed air foam
- DSPA followed by fog nail
- DSPA followed by distributor nozzle
- DSPA followed by a high pressure fire hose
- DSPA followed by a low pressure fire hose.

Effectiveness and advantages
- The DSPA extinguishes the flames during a short period of time; follow-up with a high pressure fire hose to cool hot materials can start immediately.
- There is less water damage compared to an operation with only a high pressure fire hose. The high pressure fire hose is only used to extinguish the fire.

Limitations/disadvantages
- When using a DSPA, firefighters are located close to the fire compartment, the façade, the wall, etc. Moreover, an opening has to be created (e.g. a window or a door) through which to throw the DSPA inside.
- The DSPA can only be used once and is, therefore, relatively expensive. For practice purposes, there are empty practice units and starters available.
- With bigger spaces (> 60 m^3) more DSPAs are needed.
- Since the aerosol mist blocks visibility, it is no longer possible to carry out a (quick) reconnaissance of the room. This situation can last up to several minutes.
- The DSPA cannot be used when there are victims in the room since inhaling the aerosol is dangerous.
- A DSPA is only effective when there is a fire in an enclosed space.
- The air flow has to be limited to prevent re-ignition and it is necessary to quickly follow up with the extinguishing operation.
- The extinguishing agent (potassium) can cause collateral damage for, for instance, electrical installations.
- The extinguishing agent sticks to face masks and equipment and is difficult to remove.
- Using a DSPA causes heat to move and start swirling.

Appendix 4 - Implementing the quadrant model in suppression operations

The quadrant model is a supporting tool for suppressive operations. It can help the fire operations officer make safe and effective choices.
Now that the quadrant model for fighting structure fires has been developed and is supported as part of the fire service doctrine, it has to be implemented into firefighting operations.

The use of the quadrant model in firefighting operations has to become part of the firefighting instruction and training. After introducing the quadrant model, it has to be referred to during the preparation for an exercise and in the actual exercise itself.

Introduction of the quadrant model

The first step of implementing the quadrant model is to introduce it during courses of instruction, refresher courses and during fire service meetings.
It is noteworthy that the quadrant model is meant to support firefighting personnel in carrying out their tasks and is meant to improve the safety and effectiveness of firefighting operations. The quadrant model is a supportive tool for tactical decision making and, therefore, important for the persons in charge. However, the quadrant model is important for all other firefighters as well: they will have to put the chosen tactic into actual practice by choosing the appropriate techniques and using the appropriate work methods.

Practising based on (illustrated) cases

It is highly recommended to conclude the introduction with a number of (illustrated) cases which deal with mission command, choosing a basic operational tactic and switching between quadrants (depending on objective and risk).

For persons in charge (commanding officers, duty officers and head duty officers) it is of utmost importance to further experiment with the model so they can gain more experience in using it. The (illustrated) cases have to be thoroughly prepared and be aimed at enhancing a sense for the usefulness of the model and improving the skills in using it. A good turnout message with additional information (provided or to be found in the prepared plans) will result in a basic operational tactic.
It has to be possible to get a clear picture of the scene; all approachable sides of the building have to be visualised. It is also important to provide the right amount of additional information to enable the participants to make an informed choice. The same goes for the attack stage: both the (visual) information and the feedback from the units deployed has to be prepared, in order to enable informed decision making about staying with the chosen quadrant or switching.

Training new techniques

It is important for the persons in charge to experiment with a new decision making tool. It is equally important for the firefighters to practise with new or improved techniques and work methods. The exercises have to focus on using multiple techniques in accordance with the applicable tactics (quadrants). It has to be made clear that the objectives of the attack can vary. Take, for example, the use of piercing techniques (fog nail, distributor nozzle or cold cut system). With an offensive exterior attack piercing takes place through the exterior wall and the extinguishing agent is brought into the burning fire compartment (room). With a defensive interior attack, piercing takes place through the compartment partition and the extinguishing agent is brought into the burning fire compartment (room).

Practising tactics, tactic known in advance

After experimenting with the application of the quadrant model and practising the various techniques that can be used, it is logical to follow up with a team exercise and execute a previously determined tactic. The basis of the exercise is the equipment of a standard (Dutch) pump vehicle.

Step by step practical exercises

The next logical step is to practise an attack: an objective is formulated and a tactic (quadrant) is chosen based on the available information. The execution takes place step by step. After every stage of the incident, the instructor or teacher will carry out a short intervention and discuss the considerations and outcomes. In the follow-up the entire exercise will be reviewed.

Practical exercises, full scenario

The final step of integration consists of practising a realistic scenario in which the practising unit or units are confronted with a simulation and dynamic fire behaviour, i.e. responding to the operation. From the initial alarm until the end of the operation, decisions are triggered, on the one hand, by the information the commanding officer can gather and, on the other hand, by the characteristics mentioned before (people, building and fire characteristics). These characteristics are simulated as realistically as possible and necessary.
The foundations of the choices, the flexibility in switching from one or more quadrants and the communication with the team are very important elements of this exercise. When reviewing the exercise these subjects are to be discussed thoroughly.

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