Fog Nail
Der Sprinkler für danach

Markus Pulm, Ph.D.
Chief Fire Officer
Karlsruhe Fire Station

Fire fighting with closed doors and windows is an operation merely known from the use of stationary or partly stationary systems. When such systems are not available, fire fighters need to take action, find access to the fire and take up the fire fight, if no Fognail or similar device is at hand. Thanks to Fognail, it is now possible to bring water to the seat of fire through closed doors and windows, through walls and ceilings.

This report will inform the reader about how Fognail works, how well it performs and where it can be used. The facts given herein are mainly based on the results of a test fire carried out at the Research Centre for Fire Protection Technology at Karlsruhe University on 27th April 1999.

1. History

In the February and March issues of 'Brandhilfe' magazine, the author of this article voiced a thought that had previously been an intensely discussed controversy at Karslruhe Fire Station. The question raised was how to avoid damages caused by smoke through the application of a new fire fighting tactic. This idea has meanwhile been developed further, it has been presented to thousands of fire fighters (mainly from Baden-Württemberg) and been a topic of discussion over and over again.
More than just a few fire fighters have started rethinking and changing their approach. We now know of first successful applications in real-life operations in various towns and communities.

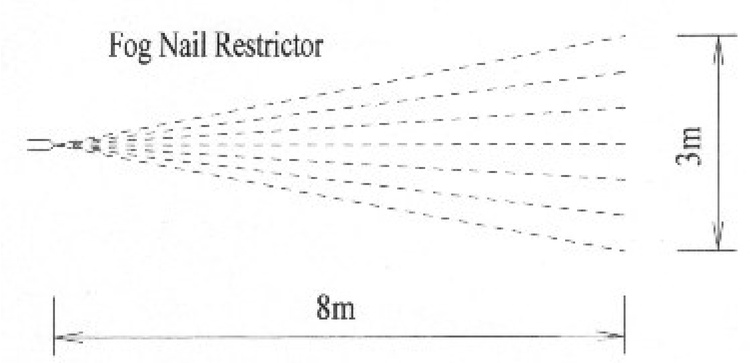
An indisputable fact that arose from all presentations is that every closed door that helps to contain fire and smoke is an effective means to reduce the spreading of fire and smoke. To open a door, behind which smoke has accumulated or a fire is burning, almost inevitably leads to an unwanted worsening of the situation. Even though a lot can be compensated for through the timely and skilled application of technical devices such as high-performance ventilators, the goal always has to be not to open closed doors during the fire fighting operation.

The discussions during presentations on the topic were dominated by these issues: Is it legal, responsible and doable to let a fire burn and to delay the attack in order to avoid smoke damages? Is it realistic to believe that a fire fighter could be kept from starting an immediate attack on a fire that is raging right behind the door in front of which he is standing?

It is certainly correct to renounce or delay a fire fighting action if the total damage can thereby be reduced. However, this raises the question if it would be possible to pursue both goals simultaneously with a quick and competent fire fighting operations while the door remains closed.

During one of his presentations to the managers of fire stations in Baden-Württemberg, the author voiced the following thought: ideally, a hole would have to be drilled into the door through which a lance could carry water into the room. After the presentation, the chief of the hosting fire station noted that such a device did not even need to be invented. It already existed and has been in use abroad for years.

2. Fognail



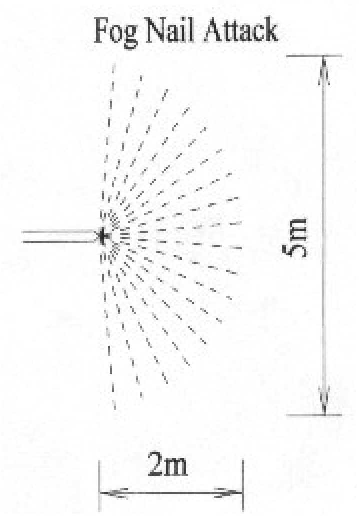


Exhibit. 1:
Fognail spraying patterns.
Fognail ***"Restrictor"***
produces a fan of water.
It reaches 2 metres into the room,
at a width of 5 metres.
Judging from its spraying pattern and its use,
Restrictor is comparable to a water shield.

With Fognail ***"Attack"*** *the water reaches 8 metres into the room, in the form of a cone and with a maximum width of 3 metres.*

Fognail is a kind of extinguishing lance at the tip of which finely dispersed water emerges. Water is provided through a D-hose and the common centrifugal pump of the vehicle. The manufacturer claims a water use of 70 litres per minute at 8 bar. The nail is brought to the area of fire through a prepared hole *(picture 1)*.

Picture 1:
Fognail "Restrictor" *in use.*
The water streams into the area of fire while the fire fighters stand protected behind a door or wall.

The hole can be made with the included hammer or using a drill with a diameter of 17,5 mm or more.
Thin materials such as wooden doors or car tin can be perforated with the nail being driven in by the hammer.
There are two kinds of Fognails that can be distinguished by their spraying patterns *(exhibit 1)*. The spraying pattern is determined by the layout of the nozzle's holes *(pictures 2 and 3)*.

Picture 2:
The tip of **Fognail "Restrictor"** with nozzles.
The coin is shown to illustrate the tip's size.
The nozzles are arranged to face each other, the emerging water jets collide in the centre and are diverted at an angle of 90 degrees. At the same time, the water is further turned into fog.

Picture 3:
The tip of **Fognail "Attack".**
The nozzles are located at one side only.
The emerging water jets are dispersed conically.

Fognail "Restrictor" is used preferably to build a blockade. It can also be applied to confine heat and lower the temperatures in the area of fire. It is not suitable for a targeted spraying of extinguishing agent onto the seat of fire *(picture 4)*.
Fognail "Attack", thanks to its greater width, can be more successful with a less fine dispersion of water when the water jet is pointed directly onto the heat source *(picture 5).*

Picture 4:
The spraying pattern of Fognail "Restrictor". Its spike with nozzles is visible in the centre of the water jet.

Picture 5:
The stream of FogNail "Attack" is bundled tighter. The drops are bigger.

According to the manufacturer, Fognail's extinguishing effect is based on two factors:
the cooling effect of the water and the oxygen-extinguishing effect of the immediately generated water vapour.

3 Goals to be reached using Fognail

3.1 Avoid smoke damages

The opening of a door results in a greater spreading of smoke. Escape routes might not be passable anymore and attacks will be more difficult to carry out. Harmful substances that cling to the soot settle on the furniture's surface as well as on the wall and thus lead to great material damage, high costs of decontamination and long downtimes. Whenever possible, a door should be kept closed. This can turn out to be the decisive advantage.

3.2 Fast stabilisation of the situation

When the situation can be relaxed with the help of Fognail, more time can be spent to plan and carry out an effective and adequate attack.

"Stabilising the situation" in this respect means:

- a noticeable reduction in temperature in the room and therefore
- a lesser force applied on the construction
- a slower reaction time
- a reduction of the combustion rate
- the prevention of flames leaking out of the windows and thus
- the prevention of a farther fire spread, e.g. to the cladding

3.3 Effective us of water

Water as a liquid extinguishing agent absorbs an energy of 4,2 kJ per kilogram when its temperature rises by one degree. When transformed to its gaseous state of aggregation (vaporisation), one kilogram of water absorbs 2258 kJ. When extinguishing water is used in a way that the greatest possible part vaporises, several positive effects can be achieved.

Even little water can help draw a lot of heat from the fire. Moreover, the water applied can leave the area of fire in the form of vapour, whereby water damaged is minimised. The generated water vapour also has an extinguishing effect. In order to reach a high rate of vaporisation, the water needs to reach the hot areas of the fire in the finest degree of dispersion.

These findings are not new, they have been applied in many modern fire fighting methods (high-pressure and impulse methods). However, the rapid vaporisation of the water used in these techniques holds quite a high risk for the fire fighters of getting hurt. Burns caused by water vapour have often occurred. Because of the short range of the finely dispersed water, the necessary safety distance can not be kept. This is why the water fog method has not made it big so far.

Earlier test at the research centre, for which steam jet blowers (high-pressure cleaners) were used, showed that no noticeable success was reached if insufficient amounts of water were pumped into the room per time unit. Although a reasonable extinguishing effect was reached in those areas where the water fog emerged, reignitions occurred when the fog jet was pointed towards a different target in the room.
Precondition for a successful attack with water fog is therefore that enough energy is drawn from the fire to achieve a lasting disturbance of the combustion processes. It is equally important to protect the fire fighters against the generated vapour. If this can be done, small amounts of water without added materials will result in excellent extinguishing effects and help avoid water damages.

3.4 Increased safety for fire fighters

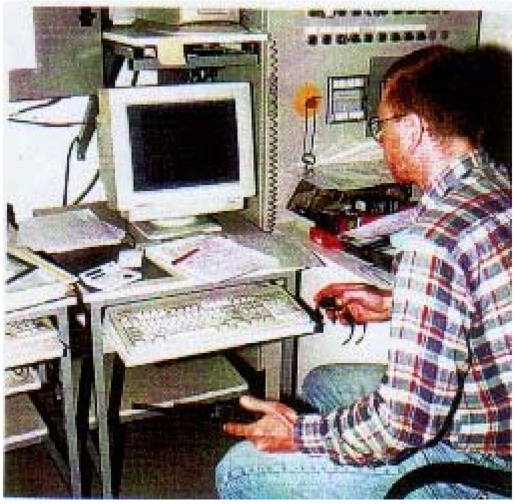
Opening the door to an area of fire means great risk to fire fighters. Flashes and an intense heat pose threats to the fire fighters when they open a door during the operation. The smoke moving towards the fire fighters is very hot and this heat represents an additional burden. It furthermore contains flammable pyrolysis products that could cause a backdraft above the fire fighters.

Another danger for the fire fighters arises when more special materials such as hazardous goods, compressed gas containers, radioactive material or dangerous biological agents are located in the room. Whenever it is possible to bring an extinguishing agent into the room without having to open the door, it will always increase safety levels of the operation.
In this case it is also possible to carry out a safe attack using water fog, since the intact door excludes the threat of hot vapour. This safety aspect has an even greater importance for fires of special buildings such as laboratories, where biological agents or radioactive materials are handled.

4. Characteristics – Test results

4.1 Test set-up

In order to test Fognail under real-life circumstances of a room fire and to be able to draw scientific conclusions, on 27th April 1999 a fire test was conducted at the Karlsruhe Neureut Research Centre’s test buildings, and in close co-operation with the Research Centre for Fire Protection Technology at Karlsruhe University and Karlsruhe fire station. A combustion room with a size of 25 square metres was made into a ‘living room’, equipped with a sofa, an armchair, a table and cupboards, and set on fire. The total weight of combustible material was 730 kilograms.
The room had a window and a door. The window opening allowed air to flow in and smoke to escape during the course of the trial. The door to the room was closed after ignition.
The room was equipped with six thermal elements that recorded the temperatures at the ceiling (five measure points) and 1.5 metres above the floor (one measure point). The entire room stood on a scale with the help of which data could be gained as to the combustion rate and the amounts of extinguishing agent remaining in the room (excluding escaping vapour). The data were sent into a neighbouring room in the research centre and put on record *(picture 6)*.



Picture 6:
Results are being recorded in a room next to the test area.
Important events (such as ignition, bursting of window glass, opening of a door) are communicated via radio,
in order to later identify the connection of measures taken and data recorded.

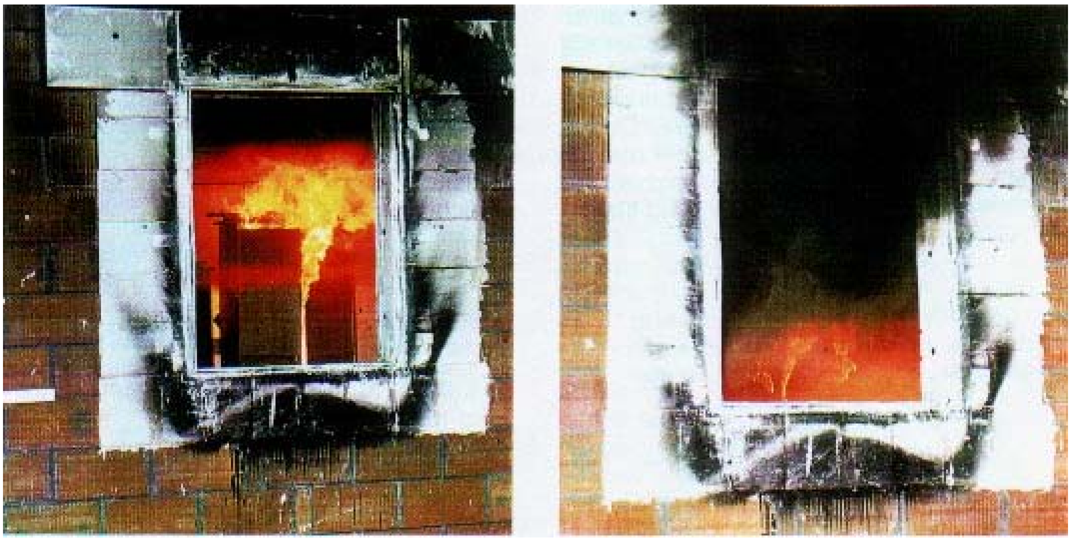
Especially for this test, next to the door a small hole was drilled into the wall of the combustion room. Because of the nature of the walls, drilling during the test would not have been possible.

4.2 The development of the fire

Around 10.40am a flammable liquid is set on fire under a cupboard in one corner of the room *(picture 7).*

Picture 7:
The test room, containing a total of 730 kilograms of diverse combustible materials at the start of the test.
Ignition takes place under a cupboard in a corner of the room.

Under the eyes of numerous visitors from fire stations and construction authorities, the fire develops into a full fire within minutes. Only four minutes after ignition the ceiling above the fire origin reaches temperatures of about 950 degrees Celsius. Hot fumes travel along the ceiling. Starting with the hot, heat-emitting layer of smoke, all combustible materials are charged with heat. Pyrolysis products rise upwards and mix with products of the combustion process. Flashover occurs already five to six minutes after ignition. All of a sudden, the surface of all combustible materials in the room are on fire. Thick black smoke escapes from the window. At times, the fire is barely visible from the outside. Once in a while, there is a backdraft in the cloud of smoke in the room. Shortly after, flames leak from the window opening. Backdrafts (smoke explosions) now also occur outside the room. In the following, smoke development lessens and high flames reach along the cladding *(pictures 8 to 11).*



Pictures 8 to 11.

After 17 minutes, 40 percent of all combustible material is burnt, the fire is fully developed. The command is given to fight the fire while the door is closed – using Fognail.

4.3 Phase 1:
Using Fognail "Restrictor"

Fognail „Restrictor" is used first *(exhibit 2)*. At this point in time, there are temperatures of about 1000 degrees at the ceiling and around 800 degrees at a height of 1.5 metres. Flames leak widely from the window *(picture 11)*.

Exhibit 2:
Using Fognail "Restrictor" in the test room in the fire test building at the Research Centre for Fire Protection Technology at Karlsruhe University.
As is clearly visible, no extinguishing agent has reached the corner of the room where the fire broke out. During the 7-minute use of Fognail, the fire in this corner seems to keep burning unchanged, yet is does not spread.
Points B 1 to B 7 mark the locations of the thermal elements.

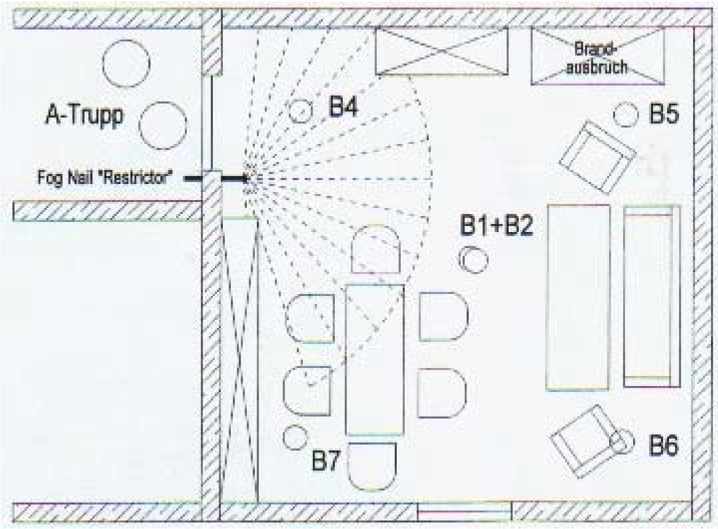


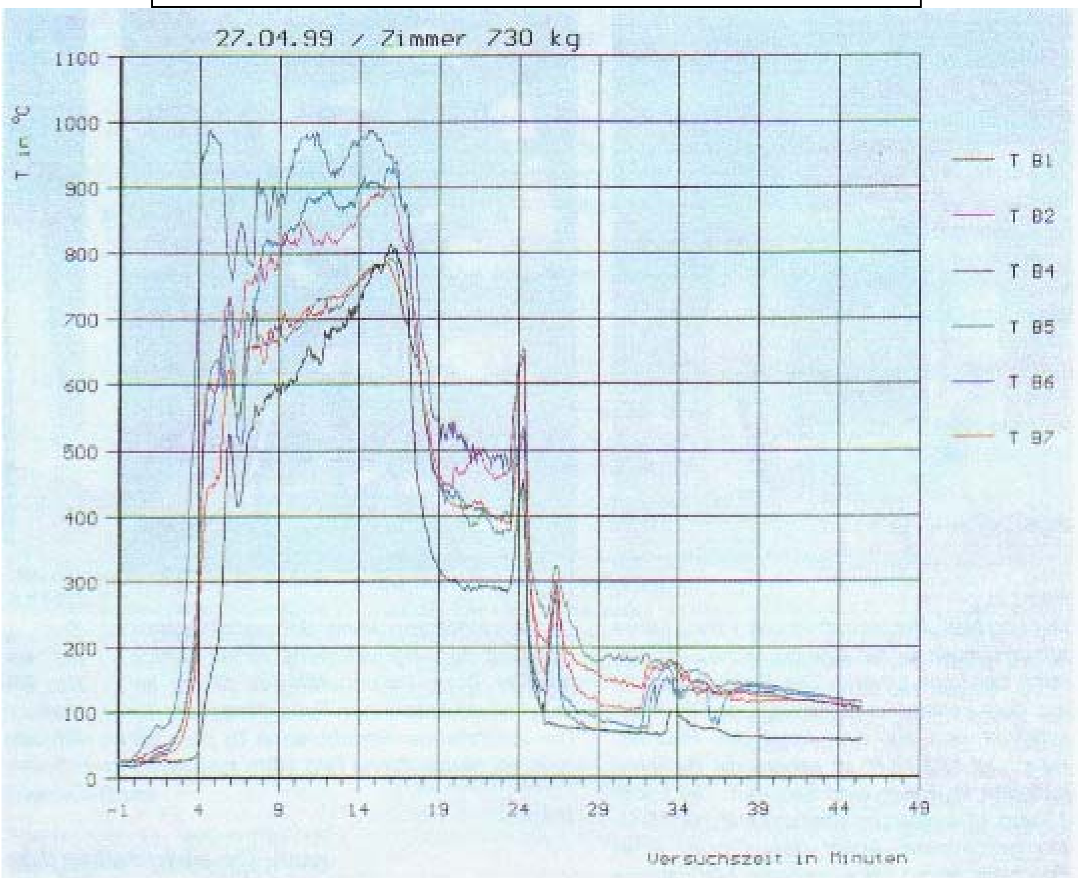
Exhibit 2:
Using Fognail "Restrictor" in the test room in the fire test building at the Research Centre for Fire Protection Technology at Karlsruhe University.
As is clearly visible, no extinguishing agent has reached the corner of the room where the fire broke out. During the 7-minute use of Fognail, the fire in this corner seems to keep burning unchanged, yet is does not spread.
Points B 1 to B 7 mark the locations of the thermal elements.

While the attack team, equipped with the usual protective clothing and breathing protection, approaches the door to the test room, the commander-in-chief takes position in front of the window in order to give the team continuos information on the development of the fire via radio. This is necessary since the fire fighters themselves have no view into the room even when positioned right in front of the closed door.
Already few seconds after Fognail has been in use, the force of the fire decreases noticeably *(picture 12).*

The leaking of flames through window openings is stopped within about 40 seconds. The fire is confined to an area in the corner where the fire broke out. This fire continues to burn undisturbed but does not develop into a total fire again. It seems that Fognail is not capable of completely extinguishing the fire. Still it has led to a stabilisation within seconds and thus to a noticeable ease of tension in the operation.
It took only seconds to ban the danger of flames spreading to the cladding. Astonishingly enough, no visible smoke leaks from the window during this period. The combustion process continues with a light flame, visibility conditions in the room are excellent. The scene seems unrealistic and reminds of simulated fires using gas flames, as they are known from television productions.

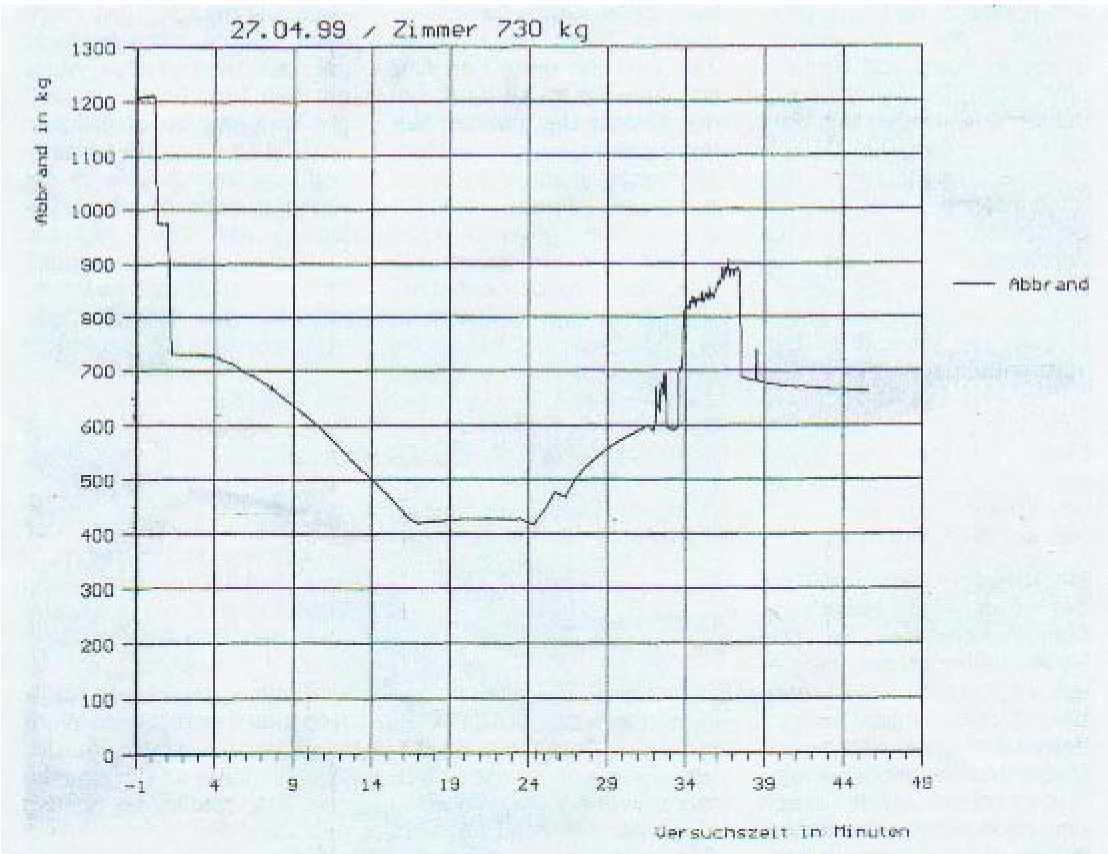
The optical impressions are confirmed by the temperature data that has been recorded in the adjoining room. Our unit was able to reduce the temperature of the ceiling area to 400 to 500 degrees within only four minutes.
The highest temperatures were recorded at the ceiling above the site of the fire outbreak, where the fire seems to just continue burning. At 1.5 metres from the floor, the temperature is still at 300 degrees Celsius. The drop in temperature took place immediately after the use of water was started *(exhibit 4).*

Exhibit 4:
Record of the temperatures in the combustion room (protocol of the Research Centre for Fire Protection Technology).
A total of six thermal elements were located in the room.



During the further supply of extinguishing agent through Fognail no additional reduction of the temperature can be achieved. The temperature can nevertheless be kept at 300 to 500 degrees. When the first Fognail is withdrawn after about seven minutes in order to be replaced by a second Fognail, temperatures in the room rise quickly and considerably. Through the window one can watch how at once the fire spreads again across the room. It can be concluded that the wooden pieces of furniture have remained dry despite the constant supply of water over the course of several minutes.
The recordings of the changes in weight show an almost even reduction of the weight of the room and its contents up until the time when the extinguishing agent was applied *(exhibit 5).*

Exhibit 5:
Reduction and increase in weight of the combustion room during trial
(Protocol of the Research Centre for Fire Protection Technology).



The loss of weight (combustion rate) during this phase is about 30 kilograms per minute. This means a theoretical heat stream of 9.7 megawatts (heating power of the fire). According to the research centre scientists' experience, this theoretical heat flow is reduced by the fact that parts of the combustible materials escape the room not burnt but in the form of carbon (soot) and pyrolysis products. The scientists estimate the actual heat flow of this fully developed room fire to be at about 5.5 megawatts. This figure is reduced from the start of the fire fight on, since combustion processes are altered. The combustion rate decreases due to the fire fighting action while the share of hydrocarbon that is not burnt but escapes from the room increases.

From the start of the use of Fognail, the weight remains constant. Since the fire continues burning, more solid combustible material turns into gaseous combustion products. This mass loss is obviously compensated by the amount of water that does not vaporise and thus remains in the room. The combustible material's reduction in mass can be estimated from the evaluation of the curve between minutes 23 and 24 of the test. It stands at around 13 kilograms per minute. This is when the first Fognail was removed from the room in order to prepare the application of the second nail.

During this phase a contribution to the weight by water is definitively zero. The conclusion therefore is that at most 13 kilograms of water brought in before per minute have not evaporated. With water blown in at a rate of 65 kg/mm, at least 52 kg/mm could successfully be vaporised. This equals a percentage of 80%. Energy absorption by the extinguishing water is at an estimated 2.5 to 3 megawatts in this phase of the trial.

Picture 12:
Fognail "Restrictor" has been in use for one or two minutes and has led to a noticeable ease of the operation.
No more flames are leaking from the window. The fire is confined to one corner of the room. Almost no smoke can be seen and visibility conditions in the room are excellent.
Pictures 13 and 14 were taken few minutes apart.
No other measures were necessary for the success of the operation than the use of Fognail.

Picture 13:
The attack team can wait and relax while Fognail does the job.
The team is not endangered. They do not have a view of the fire behind the door.
The amount of smoke escaping into the hall is low (refer to picture 16).

Picture 14:
A comparison: the amount of smoke developed in a conventional attack.
This picture was taken in a previous trial fire at the research centre a couple of months before.

Considering the set targets for this fire fight, a view into the hallway in front of the combustion room where the attack team worked reveals further remarkable effects. Instead of finding fire fighters on the ground, exposed to great heat radiation and with thick black smoke above their heads, we see two firemen standing upright in front of the door, almost bored. Next to the door, the Fognail in the wall does not even have to be supported. A thin layer of smoke has developed above the fire fighters, which however is in no way comparable to the impressions of previous test fires *(pictures 13 to 14).* In the beginning, the team seemed somewhat uncertain of the situation, since they were denied any view into the room and because of a lack of trust in the new technique yet to be developed.

4.4 Phase 2: Using Fognail "Attack"

When it becomes clear that "Restrictor" can confine the fire considerably but is not able to completely extinguish it, the decision is made to use Fognail "Attack" *(exhibit 3)*. The idea is to use this nail because of its greater reach to bring the water closer to the actual site of fire and interfere with the combustion processes still taking place. During this 1- or 2-minute process, the temperature in the room rises quickly by about 150 degrees. The fire starts spreading across the room again, which once more confirms the effectiveness of the first nail *(picture 15).*

As soon as the new nail comes into play, the situation in the combustion room changes immediately. The brightly illuminated room in the corner of which a burning fire without much smoke was clearly visible, turns dark. No more flames can be detected, however, more smoke is generated *(picture 16).*
Apparently, the combustion process could effectively be altered. This is confirmed by the data on the temperature-time graph *(exhibit 4).* At a height of 1.5 metres, temperatures sink to 800 degrees. The highest temperature below the ceiling is at less than 200 degrees. Fognail's effectiveness is furthermore illustrated by the slope in the graph after 25 minutes. At this point, the fire fight was shortly interrupted.

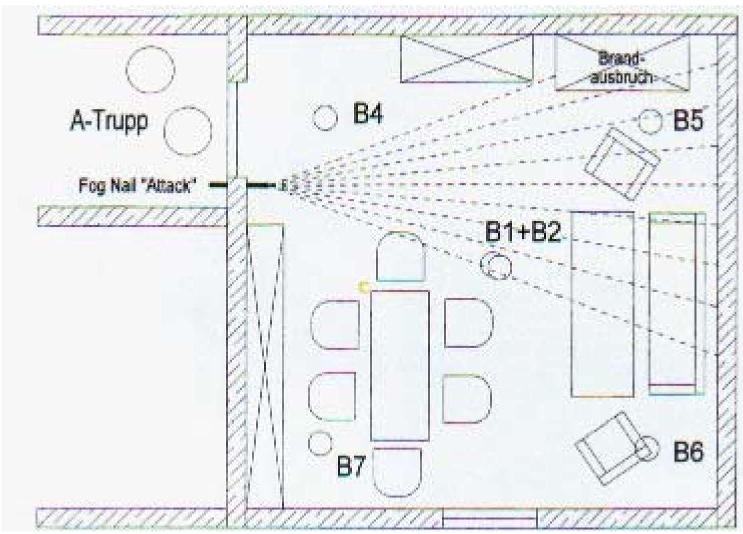
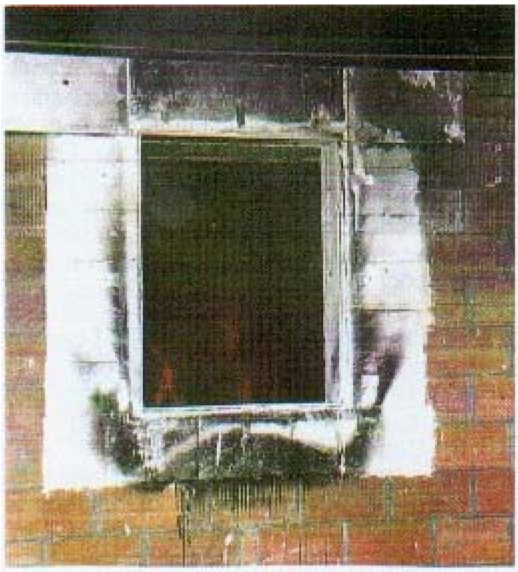
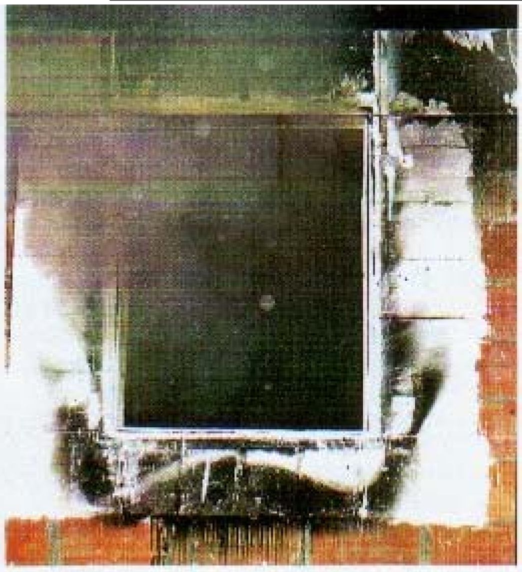


Exhibit 3:
The test room during the use of Fognail "Attack". The extinguishing agent reaches even that corner where the fire has managed to remain burning.
Within a few seconds, an obvious extinguishing effect is noticed.

Picture 15:
The phase of exchanging the two Fognails.
The fire starts to spread in the room again.
Temperatures rise again.

Picture 16:
Fognail "Attack" has been in use for a few seconds. Even the fire in the corner of the room has become a lot weaker.
A few minutes later, the fire is extinguished, except for some accumulations of glow.





The mass-time graph shows that the use of extinguishing agent was not as effective as with the first Fognail. The weight of the room contents increases during this phase. The share of the extinguishing agent that evaporates is considerably lower.
The fire fighters are still located outside the door to the combustion room. Apart from the Fognail that must now be held with one hand, they need hardly work.

Picture 17:
The room after the test.
From the beginning of the operation, it had been clear that nothing could be rescued.
It was therefore correct to give priority to the safety of the attack team and to minimising the spread of smoke.
A typical situation for the use of Fognail.

4.5 Phase 3: Follow-up extinguishing using the C-pipe

After successfully stabilising the situation in the room and gaining control of the fire merely through the use of Fognail, the test is halted. The attack team finds access to the combustion room and executes follow-up extinguishing with the help of a C-pipe. In a more serious setting, they might consider to climb through the window in order to still avoid smoke damages outside the room. Alternatively, a high-performance vent could be used in the hallway outside the door.

The situation in the room is completely stable and can be managed from the hallway at any point. This guarantees enough time for an effective approach to be used in the further course of the operation, and later damages can be avoided. Even when considering all safety aspects, the low temperatures in the room allow the fire fighters to access the room through the window.

5. Applications

There are plenty of possible applications for Fognails. They can be used for the usual fires in rooms as well as for cellar and attic fires. They are also useful to extinguish fires in hollow sections, intermediate ceilings and raised floors. They can be used to fight the fire or to build a blockade. The company’s video illustrates how just with the use of two Fognails a blockade is reached in an attic with no constructed separate section, effectively preventing the fire to spread to unaffected areas.
The manufacturer furthermore suggests the cooling of gas bottles in endangered areas of unmanned buildings as yet another possible application for Fognail.
Fognail can moreover be used for fires in cars. For instance, when the hood of a vehicle with its motor on fire can not be opened, Fognail can be driven through the hood. It will help extinguish the fire with the hood closed or to cool it down far enough so the hood can be reopened.
Suggestions are being made by Karlsruhe fire station to further improve Fognail. The nail could be modified by putting it on a long lance. In this way, Fognail could be directed through the window, right to the centre of the room on fire. Another devise is being revised that would attach Fognail and a long lance to the basket of a DLK:

The aim is to achieve an attack from the outside in which the extinguishing agent emerges in the centre of the room and in the form of water fog. With this approach, the window opening would remain unobstructed and hot fumes could easily escape. This would constitute another step towards a qualified outer attack.

6. Limits of use and problems

Fognails fire fighting method is based on the cooling and extinguishing effect of water and water fog. An extinguishing effect can only be reached when the agent is sprayed into hot zones. The tip of the nail needs to reach into the area of fire where the fire is already well developed. It makes no sense to drive a nail into the front door to an apartment when the hallway is not burning yet and therefore cold.
The results of the test let us assume that one nail is sufficient to successfully fight a fire in a room sized 20 square metres. The parallel use of several nails is advisable for bigger rooms, whereby one should try to bring fog to all areas of the room. It would obviously be advantageous to know the layout of the room as well as to locate the origins of fire and fight them with Fognail “Attack”.
The high vaporisation rate of the water enables an effective absorption of the reaction heat and a good extinguishing effect. Due to the fact that hardly any water remains in the room, all combustible materials keep dry, which can lead to reignition should the attack be stopped prematurely. This drawback has already been known from other procedures that are based on the use of water fog.
In a fire fight with Fognail large quantities of water vapour are released within a short amount of time. This vapour can cause serious burns for the attack team if they are not protected by a door or wall. A traditional attack on an active room fire with Fognail is taboo because of safety reasons.

An issue not yet addressed deals with the pressures in a room where windows remained intact and a Fognail is used. When the water is brought in, a temperature decline will cause the pressure to decrease. At the same time, however, the generated fog will result in an increase of the pressure, possibly leading to a dangerous situation. Should the door not resist the pressure and be pushed into the hallway, the fire fighters will at once be exposed to hot fumes and heated vapour.
According to the author, the question if Fognail can be used in a fully developed room fire when it is not confirmed if humans are still in that room can be ignored. When a fire has taken full control of a room and its temperatures make entering the room impossible, no life can sustain in such an environment anyway.

Even if one assumes that there still be someone living in the room, temperatures would have to be dropped drastically in order to be able to gain access to the room at all. This will always be reached with the use of water. The more effectively the water is brought into the room and the faster it contributes to the cooling of the room, the greater the share of vaporised water. Vapour thus means danger for living people in the room in any circumstance where water is used as the extinguishing agent.

7. Conclusions

Fognail is basically comparable to a sprinkler head that is brought to the area of fire after the outbreak. Often it will be possible to completely extinguish the fire, other times these devices will help reduce the intensity of the fire dramatically and thereby help to stabilise the situation and gain more time.
This trial at the Research Centre for Fire Protection Technology has largely confirmed the video footage in the manufacturer's advertising spots. It is indeed possible to seize control of active fires and to extinguish them using only extremely low amounts of water if water can be brought to the area of fire in the form of fog and if the problem of vaporisation can be solved. All this is possible with the use of Fognail.
In order to further optimise their application, we will need to gain more experience with the use of these devices. For instance do we need to find out when which nail should be ideally used, when it makes sense to use several nails or when to exchange them.

Fognail can certainly not cure all ills. It is nevertheless a sensible supplement to our equipment and opens up new possibilities for fire fighting, at least in Germany. Abroad Fognail is surely not unheard of. It can be found in American fire fighters' teaching materials and has been successfully used in Scandinavia, Israel and other countries for years.

An article by Markus Pulm, Ph.D. Chief Fire Officer at Karlsruhe fire station