THE INFLUENCE OF FUEL'S PACKING RATIO UPON EXTINGUISHING HIGH INTENSITY FOREST, BUSH AND GRASSLAND FIRES WITH 2RS-SYSTEM®

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ABSTRACT

Fuel's packing ratio is a well-known parameter in modeling of behavior of forest, bush and grassland fires. There exists a packing ratio where the fire intensity of a given burning fuel has a maximum value. Otherwise the packing ratio can be sued to determine the capacity of fire fighting systems. Fires of fuel with a packing ratio of the highest fire intensity are most difficult to extinguish. By means of this packing ratio conditions the capacity of 2RS-System® - an explosive hose fire fighting system - is determined.

INTRODUCTION

The fight against high intensive fire fronts while extinguishing forest, bush and grassland fires has always been one of the most difficult problems. With help of 2RS-System® such high intensive fires can be extinguished. A blasting cord is inserted into plastic coated hoses. The hoses are filled with water and foam agents and exploded in or in front of the fire. The water accelerated by the explosion is spread almost simultaneously in form of water droplets onto the fire. Thus the burning fuel is cooling quickly and even very large flames are extinguished.

Classifying the applicability of 2RS-System® means dealing with the intensity of the fire. The well-known Byram formula, published in 1959, determines the intensity of a fire front in linear dependence on the heat value of fuel, the mass of fuel and the spread rate of the fire front. Thus, a fire intensity of 500 KW/m is typical of a surface fire and a fire intensity of 12.000 KW/m is typical of a fully developed crown fire. The Byram formula is also used to determine the level of danger while fighting fires. Fire fronts with an intensity of up to 3.000 KW/m can still be fought by manpower. If the intensity is larger, then the heat radiation of the flames does not allow firemen to approach. This is where 2RS-System® can help. It is proved, that 2RS-System® can break down fire fronts with an intensity up to 18.000 KW/m.

However the experience with 2RS-System® has made clear, that it is not enough to calculate the fire intensity by means of the Byram formula in order to understand whether a fire can be extinguished or not. In the Byram formula the fuel mass is measured in kg per m^2, the third dimension is not considered. However it is vital to take into account the packing ratio. A low packing ratio, i.e. spare fuel availability, means a low spread rate. An increase in fuel density means an increased spread rate. The reason for this is an increase in heat production and an acceleration of both heating process and pyrolysis gas production. This remains true up to a certain point, which means when the spread rate will decrease as a result of oxygen starvation caused by the burning fuel. Thus, there is a certain value of packing ratio at which fire fronts reach their maximum intensity (Rothermel 1972).

The packing ratio not only influences the fire's intensity but also the penetration and coverage of the extinguishant. Fuels with a lower packing ratio penetrate easier than fuels with a higher packing ratio. Fires with a maximum fire-intensive packing ratio are the most difficult to extinguish.

The terms and significance of the packing ratio have been undisputed since Rothermel's forest fire model, nevertheless, it is rarely used in describing fire behavior. "Fuel per m^2" is frequently used. Unfortunately, this is not enough to determine the extinguishability of particular vegetation. In recent years efforts have been renewed to re-emphasize the importance of the "packing ratio" as a valid parameter, necessary not only for modeling fire behavior but also for developing fire extinguishing methods. This paper reports on experiments conducted to investigate how differently packing ratios influence fire extinguishing by 2RS-System® and to establish the capacity of 2RS-System® while extinguishing fires of fuel with packing ratio of the highest fire intensity.

PROGRAM OF EXPERIMENTS

The following problems were treated:

- Determine the water distribution and the extinguishing range of 2RS-System®.
- Find out the packing ratio of dry pine brushwood with the highest fire intensity.
- Find out the packing ratio in natural pine forest.
- Determine the extinguishing reach by burning fuel with highest fire intensity packing ratio.
- Determine the penetration reach of fuel with highest fire intensity packing ratio.
- Investigate the influence of foam agents.
- Check the extinguishing capacity of 2RS-System® under real conditions.

CONDUCTING EXPERIMENTS

At first the water distribution of different types of explosive hoses was measured without any burning material involved. We placed 20 trays (1 m long each) on both sides of the hose and then measured the volume of water in it. As the extinguishing range we defined the area, where the water volume is more than 0.2 liter per m^2.

Experiments with burning materials were carried out by means of wire frames with a length of 5.10 m, a width of 40 cm and a height of 80 cm. These frames were subdivided into “boxes” with a length of 30 cm, so that each frame consisted of 17 boxes. Each of the boxes was filled with the same mass of brushwood. The packing ratio has been determined by the ratio of brushwood mass to the space of the box.

The wire frames were mounted differently, e.g., horizontally one behind the other (LxWxH: 10.20x0.40x0.80 m^3) or one on the other (LxWxH: 5.10x0.40x1.60 m^3) or both vertically (LxWxH: 1.60x0.40x5.10 m^3), etc.

Figure 1 shows a single frame in vertical position with burning material of a very high packing ratio. Figure 2 shows the extinguishing of the burning material by 2RS-System®. The number of burning boxes which were extinguished determined bye extinguishing reach.

Figure 1. A single vertical frame with brushwood.

Figure 2. Extinguishing at highest fire intensity.

Figure 3. Determining of the penetration depth.

To determine the penetration depth we checked how many boxes we can fill with no-burning material to extinguish a burning box behind this material (See Figure 3).

RESULTS

We measured that the packing ratio with the highest fire intensity for dry pine brushwood is 10 kg per m^3. Such high packing ratio, however, occurs very rarely in natural forests. Table 1 shows the packing ratio values for some typical conditions of pine forests in Germany.

Type of Wood	Packing Ratio (kg/m^3)
6-year old pine	5.33
10-year old pine	1.75
40-year old pine	1.21
10-year old spruce	0.95
40-year old spruce	0.62

Table 1. Packing ratio of natural pine forest.

The results of experiments with water distribution, extinguishing range, extinguishing reach in materials with packing ratio of highest fire intensity and penetration depth are summarized on a parameter sheet for each type of hose. Table 2 shows some of the measured parameters and Figure 4 shows an example of a parameter sheet.

Hose Type	Exting. Range	Exting. Reach
Single Ø 14 cm	8 m	1.8 m
Single Ø 18 cm	10 m	2.4 m
Single Ø 25 cm	12 m	3.0 m

Table 2. Parameters for some types of hoses.

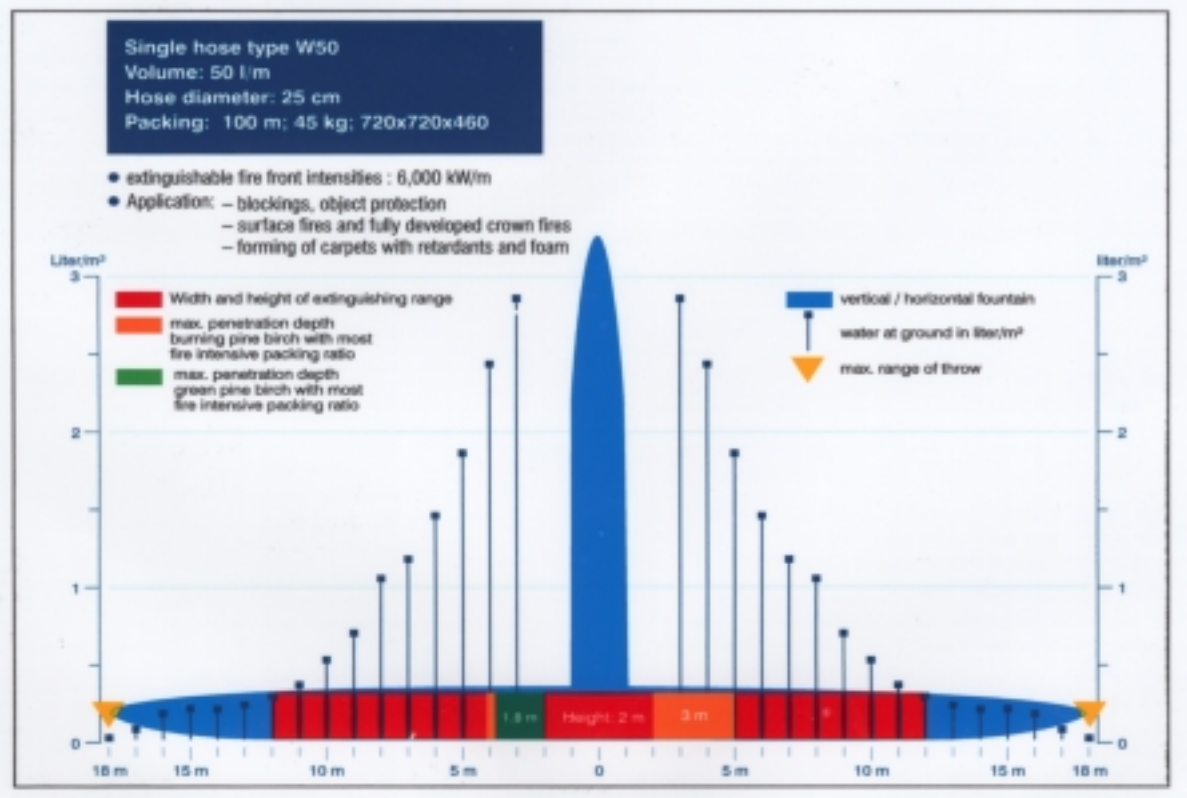

Figure 4. Parameter sheet for a single hose type.

All extinguishing parameters mentioned above refer to 2RS-System® hoses filled with pure water. Series of experiments with water and different types of well known foam agents for forest fires showed that the fire extinguishing capacity of 2RS-System® is improved by 50% with only 0.5% of foam agent added. The improvement is due to the fact that foam helps to keep and sustain coating of the burning material (See Figure 5).

TESTS UNDER REAL CONDITIONS

The results of experiments allowed us to conduct fire extinguishing test with fires under real conditions. Figure 6 shows a typical Canarian pine forest on a slope with trees 25 m high. In the middle of the forest a fully developed crown fire could arise (See Figure 7). Figure 8 shows the 2RS-System® in work and Figure 9 shows the trees after extinguishing the crown fire.

Figure 5. Coating of the fuels with foam.

Figure 6. Canarian pine forest.

Figure 7. Fully developed crown fire.

CONCLUSION

Fuel's packing ratio is a very important parameter not only for modeling forest fires but also to evaluate the capacity of fire fighting systems. Fires of fuel with a packing ratio of highest fire intensity are most difficult to extinguish. The packing ratio is a reproducible parameter, with which extinguishing systems and/or the efficiency of added retardants etc. can be compared. In this way, we could determine the extinguishing possibilities of 2RS-System®.

Figure 8. 2RS-System® extinguishing the forest fire.

Figure 9. Crowns after extinguishing.

REFERENCE

Rothermel, R. C. (1972). *A mathematical model for predicting fire spread in wildland fuels.* USDA For. Serv. Res. Pap. INT-115, 40 p.