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THE USE OF WETTING AGENTS FOR FIREFIGHTING
I. REVIEW OF APPLICATION TO FIRES INVOLVING SOLIDS

by

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Summary

A review has been prepared on the use of wetting agents in the extinction of fires in forests and on heaths, fires involving fibrous and granular materials in bulk, and fires in buildings.

It is concluded that no case can be made for the general use of wetting agents in firefighting. However, it appears that there are certain situations, in each of the above fields, in which water containing a wetting agent can be more effective than plain water for extinguishing a fire.

An increase in the effectiveness of water for fire extinction is not alone sufficient to justify the use of wetting agents for firefighting. It is necessary to take into account all operational and economic factors, some of which, it is considered, can be evaluated only in full-scale trials under practical conditions.

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INTRODUCTION

This note reviews available information on the use of water containing wetting agents, commonly known as "wet water", for extinguishing fires involving solid materials.

Wetting agents are substances that, when added to water, are able to promote the rapid wetting and penetration of solids that are not wetted or penetrated easily by untreated water. This ability of wetting agents has led to their use in water for firefighting, notably in the United States, with the object of making more efficient use of the water applied to a fire and thus reducing both the amount of water and the time required to extinguish the fire. A reduction in the amount of water required is desirable, in rural areas, mainly because water may be scarce and transport difficult and, in urban areas, mainly because of the attendant reduction in water damage.

The use of wetting agents for the extinction of fires in solids appears to fall naturally into different fields of application distinguished by differences in firefighting problems and techniques. These fields are mainly:- forest and heath fires, fires involving fibrous and granular materials in bulk, and fires in buildings. The last two are closely related in warehouses and stores. The review has been subdivided accordingly.

The procedure adopted in this review has been, first, to outline briefly the problems in each field of application. A representative selection of the published experiences and opinions of Fire Brigade Officers and others who have used wet water is then given, and is followed by an account of tests carried out under more or less controlled conditions. Conclusions are given at the end of each section.

FOREST AND HEATH FIRES

General

A major application of wetting agents has been their use in fighting fires in forests and on heaths. These fires are usually fast moving, may cover large areas, and demand highly mobile firefighting equipment for their control. In forest fires, especially, the attack is commonly based on the use of knapsack pumps and light hose lines supplied with water from tank waggons. It frequently happens that all or most of the water required has to be carried to the site of the fire in the tank waggons. Thus the firefighting method and, often, the location of the fire, require the utmost economy in the use of water.

A characteristic of these fires is the persistence of deep smouldering in the combustible layer of dead and decaying vegetable matter that covers the mineral soil of heath and forest. Complete control of a fire often requires the trenching of this ground layer, down to mineral soil, round the affected area. Following control of the surface fire, extensive "mopping-up" is usually necessary in order to extinguish smouldering fires that remain in the combustible ground layer and in tree stumps, etc.

Practical experience

Published opinions of the value of wet water in forest firefighting, based on experience of its use in actual fires, suggest that wet water permits more rapid control of the fire and is especially effective in extinguishing fire in the combustible ground layer, into which it penetrates more readily than ordinary water.

Wet water was used extensively in fighting the Maine forest fires (1) of 1947 when it was stated that "on high hazard days with dry conditions the use of wetting agents is particularly successful in effecting faster and more complete extinguishment of the fire line and reducing the amount of patrol", but no numerical estimates of the advantages have been given. Trials in Rhode Island (2) demonstrated the readiness with which wet water could saturate a ground layer of dry "duff" (partly decayed vegetable matter) which was stated to be extremely resistant to penetration by ordinary water.

It has been reported that the use of wet water permits the deep soaking of rotten logs and hollow "snags" (dead standing trees) with "punk" cores, and fires therein may be reached and extinguished without the use of an axe(3).

Wet water has also been stated to be of value for the extinction of fire in grass, grain and stubble (4). The main difficulty in the grass fire described was, in fact, the extinction of smouldering in oak leaf-mould and, for this, wet water was more effective than plain water. In the grain and stubble fires the use of wet water reduced the number of rekindles.

Edson and Parker (5) have described a fire in pine forest, with a ground layer of pine needles, in the control of which both wet water and plain water were used. It was estimated by the Fire Department Chief in charge that at least twice the amount of fire line was extinguished per gallon of wet water as with plain water. In this and in other fires where wet water was used no rekindling occurred, and no re-wetting and overhaul was required, but rekindling occurred where plain water was used. Edson and Parker conclude that "experienced personnel utilising efficient operating techniques which include tank supplies of premixed solutions of wetting agents, booster lines and small spray or fog nozzles, can more rapidly extinguish the fire line and secure complete penetration and saturation of ground litter. The latter, if adequately performed, can eliminate trenching and result in substantial saving of man hours. Such saving of man hours and the complete extinguishment of forest fires in this area (Rhode Island) have more than offset the additional cost of wetting agent". These authors state that 3,500 ft. of fire line were extinguished for an expenditure of 27.50 dollars on wetting agents.

Controlled tests

Thompson(6), Zussman (7), and Parker (8) have briefly described tests carried out at the Factory Mutual Laboratories (Massachusetts), and by a firm of manufacturers, on the effectiveness of wetting agents for extinguishing test fires in wooden cribs. In the tests described by Thompson (6) the cribs consisted of douglas fir "two-by-fours" stacked in a 2 ft. square and 18 in. high. After a preburn time of 10 to 12 minutes the extinguishing agent was applied at a fixed rate from a spray nozzle over the fire, and the time taken for all glowing combustion to be extinguished was noted.

The results varied with the type and concentration of agents used. It appears that with certain wetting agents the test fire could be extinguished in approximately one third of the time required with plain water. There was no correlation between the firefighting efficiency of a wetting agent and its surface active properties such as foaming, wetting and penetration powers, and surface tension (7).

In an examination of a wetting agent by the Underwriters' Laboratories (9) the advantage obtained in using the agent for the extinction of a test fire in oak mill slabs was less than above. Thus, the time required to extinguish the fire with a solution of the agent was roughly two thirds of the time required with plain water. In these tests the fire was judged to be out when all of eight thermocouples, in fixed positions among the logs, indicated temperatures of less than 200°F. It is not stated whether this end point coincided with the complete extinction of all glowing combustion as in the tests described by Thompson (5). The rate of temperature reduction during application of the extinguishing liquid was from $1\frac{1}{2}$ to $2\frac{1}{2}$ times greater when the wetting agent was present than when it was absent, and the proportion of water that ran off the fire was reduced.

Results obtained by the manufacturers of the above wetting agent, and quoted in the Report of the Underwriters' Laboratories, (9) indicated a superiority over plain water that was somewhat greater than above for similar wetting agents when used to extinguish test fires in oak mill slabs and yellow pine.

Tests by van Hoogstraten (10) on the extinction of fires in small piles of wooden sticks showed no advantage in the use of wetting agents.

The above laboratory tests give no conclusive indication of the value of wetting agents for the extinction of fire in timber. In so far as the tests described by Thompson indicate an advantage in the use of wetting agents for the complete extinction of glowing combustion, they are consistent with reported results of tests by the United States Forest Service in Virginia (3) on the use of wetting agents in mopping-up after forest fires. In these tests an average of $\frac{1}{2}$ gal of wet water per stump ensured complete extinction but, with plain water, an application of $1\frac{1}{4}$ gal per stump was followed by 95 per cent rekindling.

Beall (11) has reported open-air tests on the extinction of fast burning heath fires (designated "flash-fuel fires") and fires in windrows of jack pine "logging slash". The extinguishing liquid was applied with hand pumps.

The averaged results of three tests showed that for control of the heath fires (i.e. extinction of the flames only) 20 per cent more wet water than plain water was required. This result was attributed to the foamy nature of the spray when wetting agent was present; in strong gusts of wind this spray was carried away and failed to reach the narrow fire line. On the fires in pine slash 20 per cent less wet water than plain water was required to extinguish both flames and smouldering.

"Differences in the time required to control and extinguish fires were not as great as differences in the volume of liquid used, and in general were too small to be of practical importance" (11).

Further test by Beall <u>et al</u> (12) with fires in sawdust piles indicated that about 23 per cent less wet water than plain water was required to extinguish them. On the other hand van Hoogstraten (10) found little or no difference between wet and plain water when used to extinguish smouldering fires in sawdust in a container with a perforated base.

It was concluded by Beall <u>et al</u> (12) that wet water was of doubtful value in the control of flash fires, especially under conditions of high wind; but wet water was likely to be superior to plain water for extinguishing fires of a deep burning type.

Fry and Smart (13), (14) compared wet and plain water for extinguishing test fires in cut samples of dry heath vegetation. Three wetting agents were tested at concentrations of 0·2 per cent; this was approximately the minimum concentration that gave the maximum lowering of surface tension. The extinguishing liquids were applied in the form both of a jet and a spray.

In thirty-eight tests (13) with fires in mixtures of grass, gorse, thistles, etc., and in ling "no significant difference was observed between water and the wettin agent solution, either in the time taken to extinguish the fire or in the amount of liquid used". This result is in agreement with that of Beall, (11) above, but has been criticised on the grounds that the concentration of the agents was probably too low and the agents used may have been unsuitable. Since it now appears that one of the agents used was of a similar chemical type (sodium higher alkyl sulphate) to one for which success in firefighting applications has been claimed in the United States (15), the latter criticism is not valid.

In further tests designed to assess the effectiveness of wetting agents for preventing spread of fire in dry grass (Molinia) it was found that, when the liquid was applied as a spray, the spread of flame from a dry zone into a wetted zone in a 6 inch layer of the grass could be prevented with an application of wet water equal to about half the quantity of plain water required. When the application was made with a jet the improvement obtained with wet water was somewhat less.

The value of wet water for preventing fire spread in forest ground litter has been investigated by Fons and McBride (16) who measured the rates of evaporation of water from pine needles and pine twigs wetted with plain water and wet water. Although the initial rate of evaporation for wet water was greater than for plain water from the pine needles, the rate of evaporation of the plain water eventually became the greater. For both the pine needles and the twigs the protection afforded by the spraying with wet water was greater than when plain water was applied. Applying the results of moisture content determinations to hypothetical forest fire situation it was estimated (in terms of the "fire danger index") that 60 minutes after spraying, the wet water gave an advantage of $1\frac{1}{2}$ in reducing the spread of fire in the pine needles. In other terms, while plain water would keep the moisture content above the danger value for 60 minutes, an application of wet water would do so for 95 minutes. In the above tests the liquids were applied in the form of a fine spray "until the samples were saturated"; it is not stated what relation existed between the quantities applied.

Small-scale laboratory tests by Beall et al (12) are related to the question of the reduction of fire spread. In these tests equal weights of oven-dried sphagnum moss were treated with equal quantities of plain water or with solutions of a number of wetting agents. The moss was then ignited and allowed to burn out, and the residue of unburned moss was taken as a measure of the protection afforded by the treatment. The results were expressed in terms of the quantity of liquid required to "fire-proof" a given weight of moss; on this basis the amount of wet water required was 20 per cent less than the amount of plain water required. Differences between wetting agents did not appear to be significant. Although the results of these tests indicated that an application of wet water could afford greater protection than an equal quantity of plain water, it is not certain whether this effect was due mainly to the greater spread of wet water or mainly to deeper penetration of the wet water into the moss substance and, hence, to the correspondingly retarded evaporation.

The most comprehensive studies of the use of wetting agents in forest fire fighting appear to be those in progress at the California Forest and Range Experiment Station of the United States Department of Agriculture. General conclusions from these investigations have been reported from time to time (17), (18), (19) but no detailed accounts of tests or results have been published. Recent conclusions (19) indicate that improvements in the technique and equipment used for fighting forest fires (20), and thorough training of the firefighting crews, can effect outstanding economies in the amount of water used. The economy effected is stated to be greater than can be obtained by the use of wetting agents. Further, it is only when such improved techniques are used that any advantage at all is gained from the use of wetting agents.

It appears that field tests do not confirm the indications of laboratory tests that wet water may be used with advantage for extinguishing flaming. The main application of wet water is likely to be in the "mop-up" of deep-seated fires in deep "duff" and rotten wood, where it permits fewer rekindles than does plain water.

No significant differences were found between different wetting agents, and it appears that the principle factors determining the choice of a wetting agent are likely to be the cost, the ease of handling, and the corrosive properties.

Conclusions

It cannot be said that any of the investigations for which results have been published are entirely satisfying, but the results obtained are fairly consistent with each other and with the conclusions reached in the investigations by the United States Department of Agriculture on the use of wetting agents for forest fire fighting.

Experimental evidence does not support the opinion, based on early experience in actual fires, that wetting agents are of appreciable value for the extinction of flaming in the initial control of forest and heath fires. It is doubtful whether this application of wetting agents is worth further investigation.

Tests indicate that wet water is more effective than plain water for preventing the spread of fire in undergrowth, and should be of value for controlling heath fires by wetting vegetation ahead of the fire(14).

Tests and practical experience both indicate that wetting agents can materially reduce the amount of water and the time required for "mopping-up" after the initial control of forest and heath fires and for extinguishing deep-seated fire in a combustible ground layer. It is doubtful whether the use of wetting agents could always safely eliminate trenching, as suggested by Eden and Parker (5), in areas where trenching is usually necessary. These applications imply that the decision to use wetting agents for forest and heath fires must be a local one depending on the nature and depth of the combustible ground layer in a given district.

The conclusions of the United States Department of Agriculture emphasise the importance of evaluating the use of wetting agents in the light of a study of all operational aspects of fire fighting. It may be expected that the results of such a study of forest and heath fire fighting will vary from one locality to another.

FIRES IN FIBROUS AND GRANULAR MATERIALS IN BULK

General

The majority of the fires in fibrous and granular materials involve commodities in storage. Fibrous materials include haystacks, corn ricks, baled straw etc., that are found mainly in rural areas, often in the open, and the cordage and textile fibres etc., and textiles, that are found mainly in warehouses and stores in urban areas. Granular materials include sawdust, grain, oilseeds and oilseed meals etc., either in bulk or in bags.

Fire in a stock of fibrous material spreads with great rapidity and often involves the whole stock before fire fighting can be begun. There is usually a considerable amount of flame and smoke. Fire penetrates deeply into stacks and leads to smouldering that continues after the surface fire has been controlled. Usually this internal smouldering can be extinguished only by dismantling the stacks and applying water to pockets of fire as they are discovered.

In granular materials the rate of development of a fire may be less than in fibrous materials and flame may be less in amount, or even absent. Deep-seated smouldering occurs and may be predominant, and digging-out, or the dismantling of stacks, is usually necessary for extinction of the fire.

In general, the extinction of fires in materials of the above types usually ties down men and appliances for periods that may vary from a few days to several weeks.

Experience

In a survey conducted by the journal Fire Engineering, (21) of experience in twelve Fire Departments in the United States, the opinion of the majority was that wet water is of value for extinguishing deep-seated fires in baled goods (rags, cotton etc.), mattresses, upholstery and clothing in dwellings and stores; rekindling is reduced or absent. In particular, Chief Long, (21) of the Danville Fire Department, Virginia, has found wet water very effective for extinguishing fires in cotton. The successful extinction of fires in haystacks (22) and forage (23), (24) (hay and/or straw) with wet water has been described, and wet water has been used to extinguish deep-seated fires in stocks of unbleached cotton fabric used in the rubber industry (25).

Examples have been given of the use of wet water to extinguish fires in large piles of loose and baled waste paper (26), (27). It is reported that the deep smouldering fires characteristic of this material can be extinguished in a shorter time than when plain water is used, and without the protracted overhaul that is otherwise usually necessary (26). Sweeney (27) has developed a technique of wetting the material, ahead of the main hose stream of plain water, with a solution of wetting agent of about four times the usual concentration applied with "booster lines". He has reported that on three occasions control of the fire was achieved by this means in two or three hours, without breaking down the stacks, and extinction was completed in less than 24 hours. Formerly, with plain water only, the extinction of such fires required up to a week or more. The reduction in the amount of water used, and in the time during which the material was allowed to smoulder, reduced the damage by water and smoke and permitted the salvage of a considerable proportion of the stock.

Wet water is reported to have been very effective for the extinction of fire in coal, both in store (28) and in the mine (29). A fire in a bunker was extinguished without digging out the coal.

A pile of celluloid scrap was extinguished sufficiently rapidly, by means of wet water, for half of it to be salvaged (22).

Controlled tests

Controlled tests on the value of wet water for the extinction of fires of the above type have been carried out mainly on fires in a number of different fibrous materials; tests with fires in granular materials are few. Tests on each will first be reviewed separately, beginning with fibrous materials.

Cotton A test has been described (30) in which wet water and plain water were used to extinguish fire in two 600 lb. bales of raw cotton that were ignited externally. After being allowed to burn for 2 hr. 19 min. one of the bales was successfully extinguished with a total application of 11.9 gal. of wet water. The other bale, which was allowed to burn for 3 hr. 11 min., continued to smoulder after 399 gal. of plain water had been applied; it was finally extinguished completely by an application of 14 gal. of wet water. In spite of the difference in the time of pre-burn allowed for the two bales it is clear that the wet water was considerably more effective than plain water for extinguishing the fire.

Thompson (6) measured the rate of penetration of wet water and plain water into raw cotton compressed to a density of 20 lb/ft.^{3}, as in a low density cotton bale. Whereas plain water showed practically no penetration after several hours, a solution of a wetting agent penetrated at the rate of almost a quarter of an inch per hour. It is evident that wet water should be more effective than plain water in overtaking and extinguishing the smouldering combustion that penetrates so readily into cotton bales.

<u>Flax</u> The Fire Brigade of Armentières and Tourcoing (31) compared plain water and wet water for the extinction of test fires in 220 lb. piles of flax bundles. Single tests only were carried out, with the plain water applied first with a plain nozzle and with a spray nozzle, and then with solutions of each of three wetting agents applied with the spray nozzle. The extinguishing liquid was applied, after a preburn time of 5 min., at an average rate of about 50 g.p.m. and at a pressure of about 65 lb/in^2.

The wetting agents reduced the time required to control the flames to about half the time required with the spray of plain water. The reduction of the time required for complete extinction was of this same order with two of the wetting agents. It was observed that the use of wetting agents increased the amount of smoke and steam during extinction and, with one of the wetting agents, this increase was sufficient to impede the attack on the fire.

<u>Kapok</u> van Hoogstraten (10) achieved the extinction of fire in kapok with a quantity of wet water that was about one third of the amount of plain water required. Only one test each was made with the wet water and plain water.

<u>Sisal</u> As a result of tests with piles of loose and semi-compressed sisal, in quantities of 190-400 ft.^{3}, Powell (32) concluded that wet water was more effective than plain water for extinguishing the deep-seated fire that normally persists in sisal after the surface fire has been extinguished. Complete extinction was not claimed, but it was stated that the remaining fire could be easily dealt with by pulling apart the bales and using hand application.

In these tests the water was applied for 3 minutes from sprinklers at 75 g.p.m. and at a pressure of 35 lb/in.^{2}. Powell suggests that an application of wet water of 0·40 gal. ft^{-2} min^{-1} from sprinklers should satisfy most requirements for similar fibrous materials.

<u>Straw</u> Fire extinction tests with wet water, in which wheat straw was used for the test fire, have recently been carried out in the Joint Fire Research Organization. A full account of the tests will be given in the second report of this series; a brief account is given below.

The experimental method was based on that of Bryan and Smith (33) in which the fire was supported on a table that rotated slowly, and the load on which could be measured hydraulically. The water was applied by a mechanically operated jet that oscillated in a vertical plane through the centre of the fire and was in a position chosen to cover the top and side of the fire. Comparison of wet and plain water was based on a determination, for each, of the number of extinctions in five tests with each of a series of increasing amounts applied. The criterion of extinction was failure to rekindle under specified conditions.

Tests showed that wet water was more effective than plain water for extinguishing a smouldering fire in the interior of a closely packed bale of straw. It was estimated from the results that, under the test conditions, from two to three times as much plain water as wet water was required to achieve a high frequency of extinction in replicated tests. Further tests in progress suggest that the advantage in the use of wet water may vary with the nature of the straw, or uniformity of the bale, and may not always be as great as above.

No difference in the effectiveness of wet and plain water was detected for the extinction of fires in straw packed at a lower density than in a bale, i.e. 2·2 lb. ft^{-3} instead of 7·5 lb. ft^{-3}. In the tests at the lower density the fire was started on the outside of the packed straw, but it penetrated beyond the direct reach of the water jet.

In these tests flames were extinguished so rapidly by both wet and plain water that no difference could be detected between the two types of water for this purpose. The application of wet water was accompanied by the emission of steam and smoke in quantities that were considerably larger than with plain water.

Successful extinction, with wet water, of a fire in a straw bale was usually accompanied by complete saturation of the bale and an average retention in the bale of about two pounds of water per pound of straw. With plain water the bales were never saturated and the average amount of water retained was about one pound per pound of straw. In the straw at low density the amounts of plain and wet water retained were both about two pounds per pound of straw.

It is concluded that wet water will be of value for the extinction of fires in straw that is densely packed and into which plain water will not penetrate readily.

<u>Granular materials</u> Conflicting results on the value of wetting agents for the extinction of fires in sawdust were obtained by Beall *et al* (12) and by van Hoogstraten (10) (described above under forest and heath fires).

van Hoogstraten (10) found no difference between wet water and plain water, in single tests, for the extinction of fire in cocoa bean waste (cocaobonenafval), which is less easily wetted than sawdust. But wet water was more effective than plain water for the extinction of a burning brown-coal briquette, in a test that differentiated between the rates of penetration of plain water and wet water through the briquette.

In tests on the control of coal mine fires Nagy *et al* (34) found no striking difference between wet water and plain water; but the tests were regarded as inconclusive.

Discussion

An indication of the possible value of wetting agents, for the extinction of fires of the type discussed in this section, can be obtained only for fires in fibrous materials. The results of tests on granular materials are inconclusive and further investigation is desirable.

Practical experience and the results of tests with fibrous materials are consistent and it is considered that the conclusion from the tests with wheat straw may reasonably be extended to all fibrous materials. Thus, a wetting agent will be of value for the extinction of fires in fibrous materials that are not easily wetted by plain water and are packed so densely that plain water will not penetrate readily.

It is not certain that small-scale tests such as the above permit a full assessment of the advantages to be gained from the use of wetting agents for large-scale fires in fibrous materials. Apart from any scale effect there may be in the relative efficiency of wet and plain water for the control and extinction of test fires, small-scale tests do not provide an estimate of the saving in water and in man-hours that might be effected by the use of wetting agents in the process of complete extinction following the control of fires in large stacks. Reported experience of fires in waste paper suggest that the saving might be large. In general, it is probable that only full-scale trials in actual firefighting can give an estimate of the saving for fires in any given material.

In urban areas, where fibrous materials are confined mainly to warehouses and other stores, water is relatively plentiful. Any reduction in the amount of water required to extinguish a fire, that the use of wetting agents might permit, is nevertheless desirable since the corresponding reduction in run-off will result in less water damage in the neighbourhood of the fire. On the other hand, the increased penetration accompanying the use of wetting agents may cause greater water damage to the material involved in the fire; especially where fire damage and water damage with plain water are often mainly superficial, as in cotton. Increased penetration may also lead to greater loading, and a correspondingly increased risk of collapse, of warehouse floors. Again the use of wetting agents in jute would probably accelerate the swelling which is normally a troublesome factor in the attack on jute fires; swelling can, in fact, be disastrous since it is capable of bursting warehouse walls. The importance of these possible disadvantages in the use of wetting agents will depend directly on the amount of wet water required to extinguish a given fire; this, again, is difficult to estimate without carrying out full-scale tests.

Both reported experience and tests indicate that wet water is considerably more effective than plain water for the extinction of fires in cotton. By analogy with experience of fires in baled paper it is probable that the more rapid extinction obtained with wet water would result in less damage to the cotton by smoke. There thus appears to be some justification for full-scale tests on the use of wet water for fires in cotton warehouses.

Conclusions

It is concluded that wet water will be, in many cases, more effective than plain water for the extinction of fires in fibrous materials in bulk. But the overall advantages to be gained by their use in actual fires is difficult to assess without full-scale trials.

The application of wet water to fires in granular materials needs further investigation.

FIRES IN BUILDINGS

Experience

On the basis of six years experience Wheeler (35) considers that wet water is superior to plain water for the extinction of fires in buildings. With wet water applied as a "low-velocity fog" he claims faster extinction with less water, less water damage, and no rekindles. Sweeney (27) has described the extinction of a fire, in an apartment dwelling, in ten minutes with an application of 60 gal. of wet water with a "low-pressure fog nozzle"; entry was possible after about five minutes' application. He estimated that between 1,000 and 2,000 gal. of plain water would have been used to extinguish the fire. Layman (36) has described a fire, involving four rooms of a single-storey wooden frame dwelling, that was extinguished with 140 gal. of wet water and 80 gal. of plain water applied with fog nozzles. The total volume of the rooms involved was 3,630 ft^3. The amount of water applied was therefore an average of about 60 gal. per 1,000 ft^3. It was noted in this fire that the large volumes of steam produced during the application of water cleared the rooms of smoke.

In a discussion of Layman's report (36) it is pointed out that the application of the wet water "fog", through the window of the most heavily involved room, resulted in control of the fire in an adjoining room through an open doorway.

Controlled tests

In tests on the extinction of fire in two wooden shacks (37) it was found that the amount of wet water used was roughly half the amount of plain water used. But these tests are somewhat inconclusive owing to differences in the construction of the shacks and in the behaviour of the fires.

Tests (30) were carried out, by the manufacturers of a wetting agent designed for fire fighting, on the extinction of fires in two identical model rooms, 8 x 8 x 8 ft., consisting of wooden frames lined with composition wallboard and containing furniture. The extinguishing agent was applied in each case by means of a sprinkler head located near the centre of the ceiling.

In each test, and after a preburn time of four minutes, the sprinkler was operated until entry into the room was possible; extinction was then completed by hand using a $\frac{3}{4}$ in. garden hose nozzle. The rates of application of the plain water were slightly greater than for the wet water; the rates were 7·2 and 6·0 gal. min^{-1} ft^{-2} respectively with the sprinklers, and 0·4 and 0·3 gal. min^{-1} ft^{-2} with the hand nozzles.

In the test with wet water entry into the room was possible after an application of 20 gal. with the sprinkler, lasting 40 seconds. Extinction was then completed with a further application, by hand, of 10 gal. in 5 minutes 45 seconds. Run-off appeared only during the sprinkler application and amounted to 10 gal.

With plain water, entry was not possible until 108 gal. had been applied in 3 minutes by the sprinkler. The final extinction by hand then took a further 11 minutes 20 seconds and required 24 gal. of water. The total run-off was 100 gal., 80 gal. of which appeared during the application by sprinkler.

Extinction with wet water was thus achieved with an application of about 40 gal. per 1,000 ft^3; but with plain water, an application of about 264 gal. per 1,000 ft^3 was necessary. The total times taken were 6 minutes 25 seconds and 14 minutes 20 seconds respectively.

Discussion

In view of the variability that occurs in fire extinction tests in general, it is felt that repetition of the above tests in model rooms would be desirable.

Nevertheless, the results indicate that the use of a wetting agent can reduce substantially the amounts of water and the times required both to control and to extinguish a fire in a room, and can reduce even further the amount of run-off.

The application of wet water, namely 40 gal. per 1,000 ft^3, is comparable with the total application of wet and plain water used by Layman to extinguish the dwelling house fire, i.e. about 60 gal. per 1,000 ft^3. These quantities are, nevertheless, from seven to ten times the minimum application of plain water that has been found effective for the control of full-scale fires in rooms under test condition elsewhere (see below). For the tests in the 8 ft-cube model room the need for this large application may have been due to a factor such as failure of the sprinkler to wet more than the floor and lower walls.

Full-scale tests on the extinction of fires in rooms have been carried out recently by Thomas and Smart (38) in association with the City of Birmingham Fire Service, and it is necessary to consider the use of wet water in the light of their results.

It was concluded from their tests that fully-developed fires in domestic rooms can be controlled with about 6 gal. of plain water per 1,000 ft^3 of room volume applied either as a jet or as a spray. Control of the fire was indicated by the relatively sudden emission of large volumes of steam from the windows. It was noticed that the above application was approached from higher values as the experience of the firemen in attacking the series of closely similar fires increased.

The value of 6 gal. per 1,000 ft^3 of room volume agreed with the results of other full-scale tests, reviewed elsewhere by Thomas and Smart (39), and represents a volume of steam of nearly twice the volume of the room.

It is an open question whether developments of technique or appliances will eventually make possible the control of all fires in buildings with an application of water as low as the above. While it is clear that the use of wetting agents to obtain a further reduction would hardly be worthwhile, the use of wetting agents might prove to be one, if not the only, method of achieving such a low application in general.

The rapid generation of steam, having a volume that is a small multiple of the volume of the room, plays an important role in the extinction of a fire in a room (39, (40). In several applications of wet water it has been remarked that more steam is produced than when plain water is used. It is possible, therefore, that wet water may be considerably more effective than plain water, for extinguishing fires in rooms, than open-air tests on fires in wooden-cribs, etc., can indicate. This possibility is consistent with the observation that the quantity of water required to extinguish a fire in a room increases as the ventilation is increased (39), (40).

Conclusions

There is evidence that wet water is more effective than plain water for extinguishing fires in rooms.

Recent studies of the extinction of fire in rooms suggest that control can be effected with quantities of plain water so low that further possible reduction by the use of wetting agents will not be worth while. However, the use of wetting agents as a means of achieving this low expenditure of water in general fire fighting practice needs to be considered.

GENERAL CONCLUSIONS

The use of wetting agents for firefighting has been surveyed for three fields of application namely, forest and heath fires, fires in fibrous and granular materials in bulk, and fires in rooms and buildings.

It is concluded that no case can be made for the general use of wetting agents in firefighting. However, it appears that there are certain situations, in each of the abovefields, in which water containing a wetting agent can be more effective than plain water for extinguishing a fire.

An increase in the effectiveness of water for fire extinction is not alone sufficient to justify the use of wetting agents for firefighting. It is necessary to take into account all operational and economic factors, some of which, it is considered, can be evaluated only in full-scale trials under practical conditions.

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