WATER-BASED FIRE-EXTINGUISHING AGENTS

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ABSTRACT

While water is undoubtedly the most widely used fire-extinguishing agent, it is not particularly efficient. Often, large quantities are required to extinguish a fire. In fact, water is usually not recommended for use on a hydrocarbon pool fire. Yet water is extremely attractive from an environmental point of view. This has become very important given the negative environmental implications of the Halon 1301, which is the fire-suppression agent in Army combat vehicles.

Water delivered as a spray is more effective against hydrocarbon fires than a stream of water. Water as a mist is even more effective. The delivery system influences the effectiveness of water. The major problem with using water in a combat vehicle is freezing at low temperatures. Additives can be added to lower the freezing point. Thus, water solutions may be usable under all expected operating conditions. Experiments have been conducted using sprays of water and water with additives to extinguish JP-8 pool fires. Additives were chosen to provide low freezing points to the water and to improve the fire-extinguishing capability of the water. As expected, sprays of just water were not particularly effective for extinguishing JP-8 pool fires. Water with calcium chloride, added to give a −55° C freezing point, showed no improvement in fire suppression over the baseline water tests. Other additives, however, showed remarkable improvements over the water case.

Introduction

The U.S. Army has been involved in the search for a replacement Halon 1301 ever since halons were identified as ozone-depleting agents in the Montreal Protocol of 1987. Halon 1301 is currently used in Army combat vehicles to suppress hydrocarbon fires in both crew and engine compartments. Several agents (perfluorocarbons) have been identified as nonozone depleting and of very low toxicity. However, other environmental concerns have been raised, such as the agents' potential contribution to global warming; while any global warming potential has not been accurately defined, there is a hesitancy to pick a halon replacement agent that may eventually be classed in an environmentally unacceptable group. This would require a new search for a replacement agent. A halon replacement with no environmental problems is desired. An attractive candidate for this role is water.

It has been found that water is not really very effective in extinguishing a hydrocarbon fire unless that water is delivered to the fire in the form of a mist (very small droplets). Large droplets of water are far less effective, and water in the form of a stream is still less effective. The principal problem with very small droplets of water is that they do not penetrate through the air easily. Large droplets have less air resistance than small droplets; hence, the large droplets travel more easily through air. But the large droplets can pass through a flame with little evaporation since their surface-to-volume ratio is small. The smaller mist droplets can evaporate easily in a flame, making them more efficient than the large droplets.

The approach reported in this paper is to add materials to water which can increase the efficiency of the large spray droplets. These large water-based droplets might approach the efficiency of the small mist droplets in extinguishing flame while retaining the ability to penetrate air more easily than mist droplets. The addition of salts to water might also solve the problem of the water freezing in vehicles during cold weather.

Experimental

The fuel used in this study was JP-8, which has been chosen by the Army as the single fuel for use on the battlefield. This fuel has a flashpoint above room temperature, typically about 50° C (122" F). The JP-8 used in this work had a flashpoint of 55° C (130° F).

A commercial airless paint sprayer was used to spray droplets of water-based agents onto fuel fires. Tests showed that the device sprayed water at the rate of 4.2 g/s.

The setup used in these fire-extinguishing experiments consisted of a pan, 14 cm in diameter x 6.3 cm high, into which 700 ml of JP-8 fuel was poured. The fuel surface was approximately 2.5 cm below the top of the container. Two strands of absorbent paper (wicks) were placed over the rim of the pan, dipping into the fuel.

The spray nozzle was placed 46 cm from the center of the fuel container, elevated 23 cm higher than the rim of the container. The nozzle was aimed at a point 2.5 cm above the top of the container. Tests showed that, when the sprayer was activated, water was collected in the pan at the rate of 1.35–1.50 g/s. A photograph of the setup is given in Figure 1.

For each test, the wicks were lit by a match, and eventually (1–5 min) the entire surface of the fuel became involved in the fire. The flame was allowed to burn for 60 s. The sprayer, containing the agent to be tested, was activated. The process was recorded on video film. The time to extinguishment was noted.

<u>Results</u>

Table 1 gives the fire-out times for sprays of water and 12 water-based solutions. Data are presented for agents at three temperatures: 5" C, 22" C, and 77" C. Each fire-out time in the table is an average of two to four tests. The sum of the fire-out times at the three temperatures are added to give an overall ranking, the lowest time being best. The physical state of the agents at –18" C is also given.

Figures 2–5 present, in graphical form, comparisons of the 12 water-based solutions with water as the baseline. It can be easily seen that while some of the solutions are significantly more effective than water, other solutions are less effective than water. All solutions were cooled to –18" C to determine which would remain liquid at low temperature.

The five agents which were liquid at –18" C are compared to water and each other in Figures 6 and 7. It can be seen that the 60% potassium lactate in water solution is the best performing of the solutions which have low temperature possibilities. It should be mentioned that one low-temperature agent, a 40% solution of potassium carbonate in water, was rejected from consideration due to its excessively caustic nature. Its pH was measured as 12.9. A pH above 12 identifies a material as hazardous waste requiring special treatment in cleanup and disposal.

Possible mechanisms by which the agents extinguished fuel fires include:

1. A cooling effect, by which evaporating droplets lower the flame temperature, leading to extinguishment.

2. A cooling effect by which droplets which fall into the liquid fuel lower the fuel temperature. This lowers the rate of evaporation of fuel. When the liquid is cooled below the firepoint, the flame is extinguished.

3. An oxygen depletion effect, by which evaporating droplets form steam, deplacing air. When the oxygen concentration falls low enough (approximately 16%), the fire will be extinguished.

4. Evaporation of water from a salt-containing agent will lead to the formation of solid particles in the flame zone. The particles can act as surfaces capable of quenching flames. The nature of the salt is very important in this case. Some solid particles are much more efficient than others in quenching flames.

Agents whose fire-out times approximate that of water may fall into the flame-cooling category. Agents with excessively long fire-out time, such as the 29% calcium chloride in water solution, probably fall into the liquid fuel cooling category. The highly efficient agents, such as the 60% potassium lactate and the 60% potassium acetate, probably fall into the solid particles quenching the flame category. The steam formation is probably mainly a contributing mechanism that aids in the extinguishing process by lowering the oxygen concentration and the rate of combustion. It is quite likely that all four mechanisms are functioning simultaneously. The nature of the dissolved salt and the temperature of the agent may determine the relative importance of each mechanism.

Future Work

The best performing agents (at this point in time, 60% potassium lactate in water is the best agent) will be tested using mist nozzles against the JP-8 fire. Then the agents which perform best as sprays and those which perform best as mists will be tested against large fires using multiple nozzles to dispense large quantities of agent in a short time. It will be determined if there are water-based agents which can be dispensed as sprays and be comparable to the best water-based mists.

Figure 1. Test Setup.

Table 1. Rankings of Fire-Extinguishing Sprays

Rank	Agent Agent	Time (5" C) (s)	Time (23" C) (s)	Time (77" C) (s)	Total Time (s)	State at –18" C
1	60% K Lactate	0.3	2.4	0.5	3.2	Liquid
2	60% K Acetate	1.8	1.0	0.5	3.3	Frozen
3	10%Na Br	2.4	0.7	3.1	6.2	Frozen
4	8% K Br in 29% $CaCl_2$	5.1	4.6	2.7	12.4	Liquid
5	29% CaI_2	7.6	3.4	5.4	16.4	Frozen
6	10%K Br	6.2	6.8	3.4	16.6	Frozen
7	12% Pyrocap in 29% $CaCl_2$	7.0	4.9	5.1	17.0	Thick Liquid
8	10% NH_4I	5.2	5.7	9.4	20.3	Frozen
9	12% Na Br in 29% $CaCl_2$	5.3	14.4	5.0	24.7	Liquid
10	Water	15.5	9.0	7.4	31.9	Frozen
11	10%Ammonium Citrate	8.4	9.3	17.4	35.1	Frozen
12	NH_4 Br	10.3	6.0	21.4	37.7	Frozen
13	29%$CaCl_2$	16.0	6.5	20.2	42.7	Liquid

FIGURE 2 WATER & VARIOUS AGENTS vs JP-8 FLAME

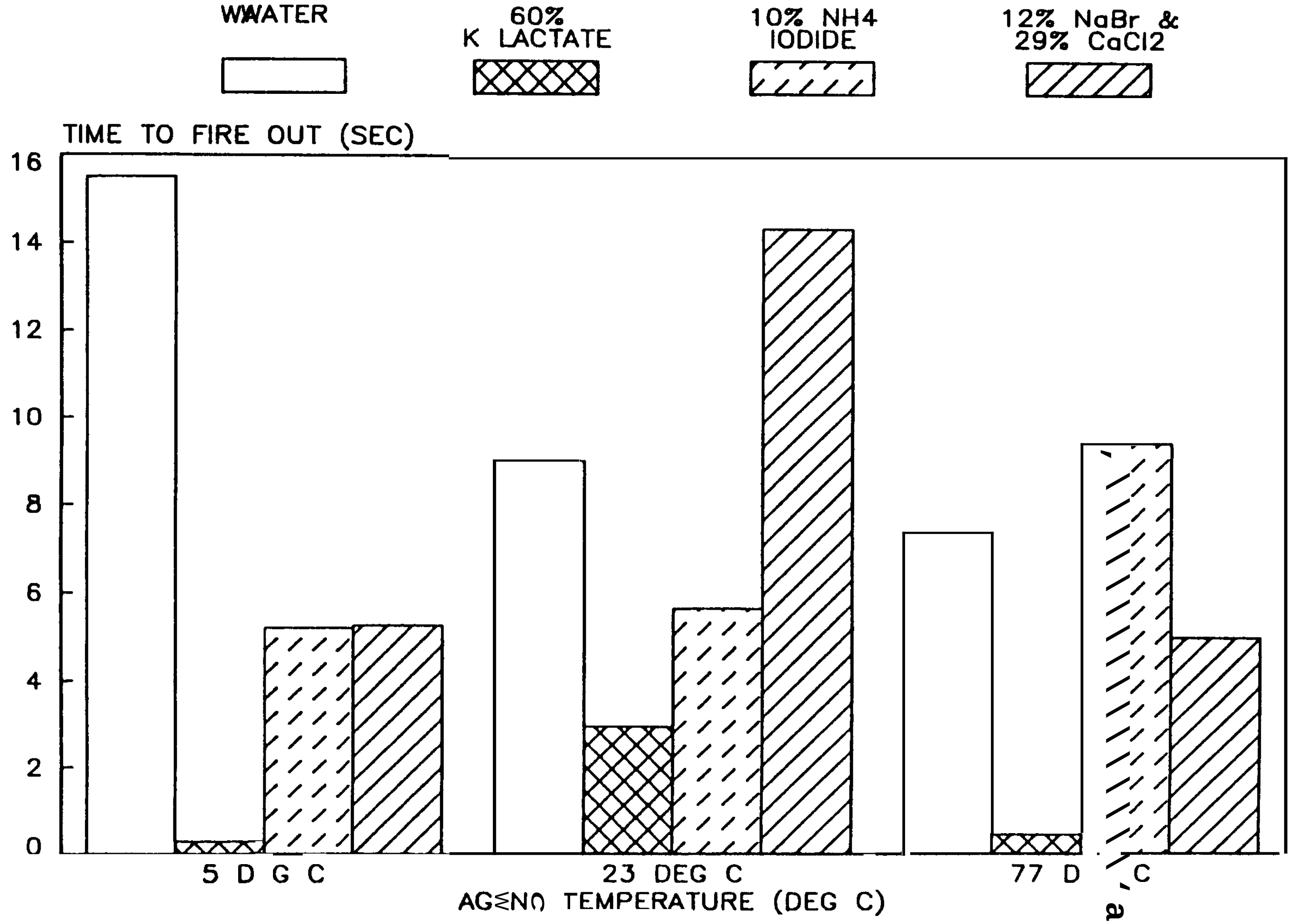

FIGURE 3 WATER & VARIOUS AGENTS vs JP-8 FLAME

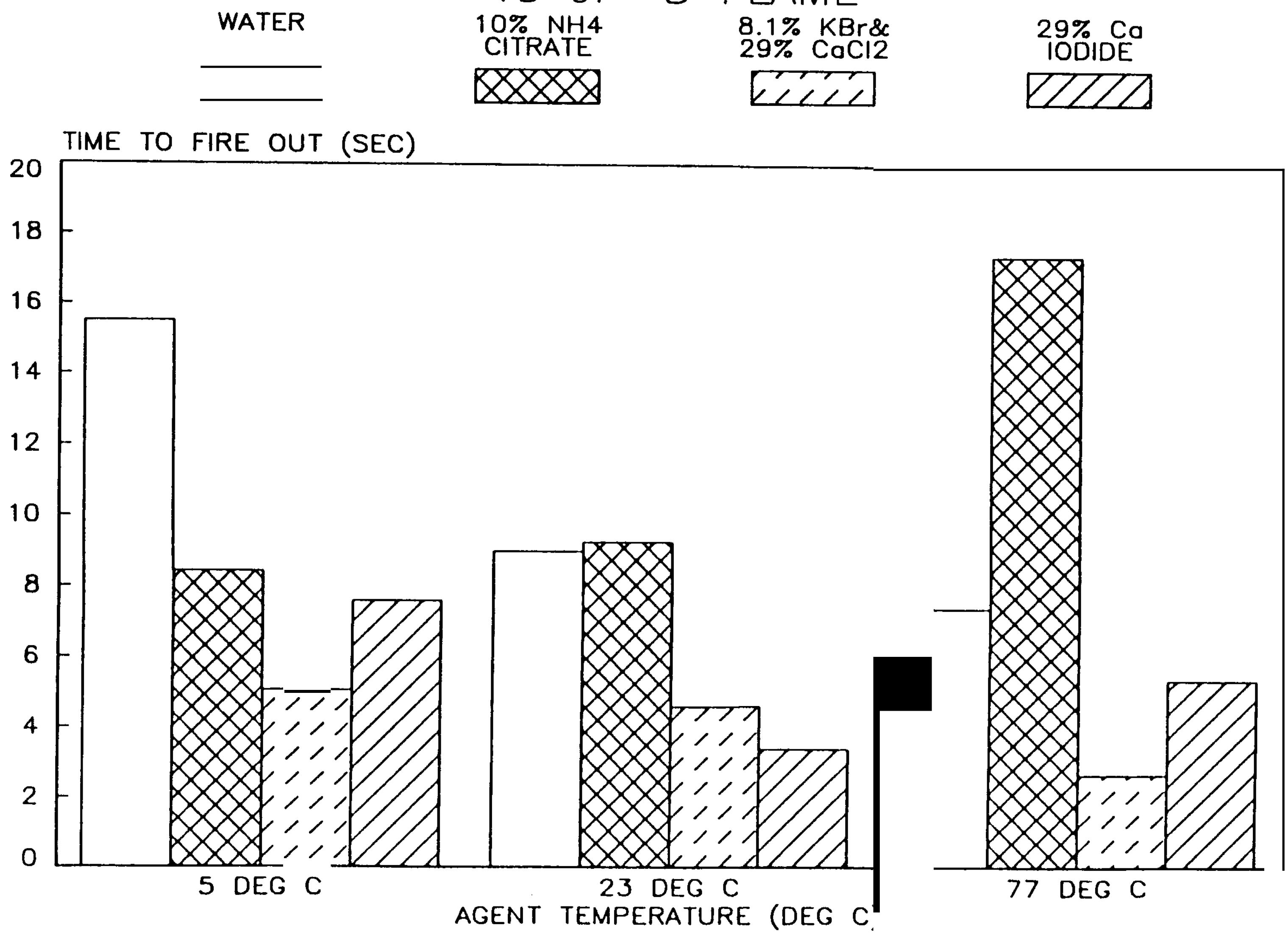

FIGURE 4 WATER & VARIOUS AGENTS
vs JP-8 FLAME

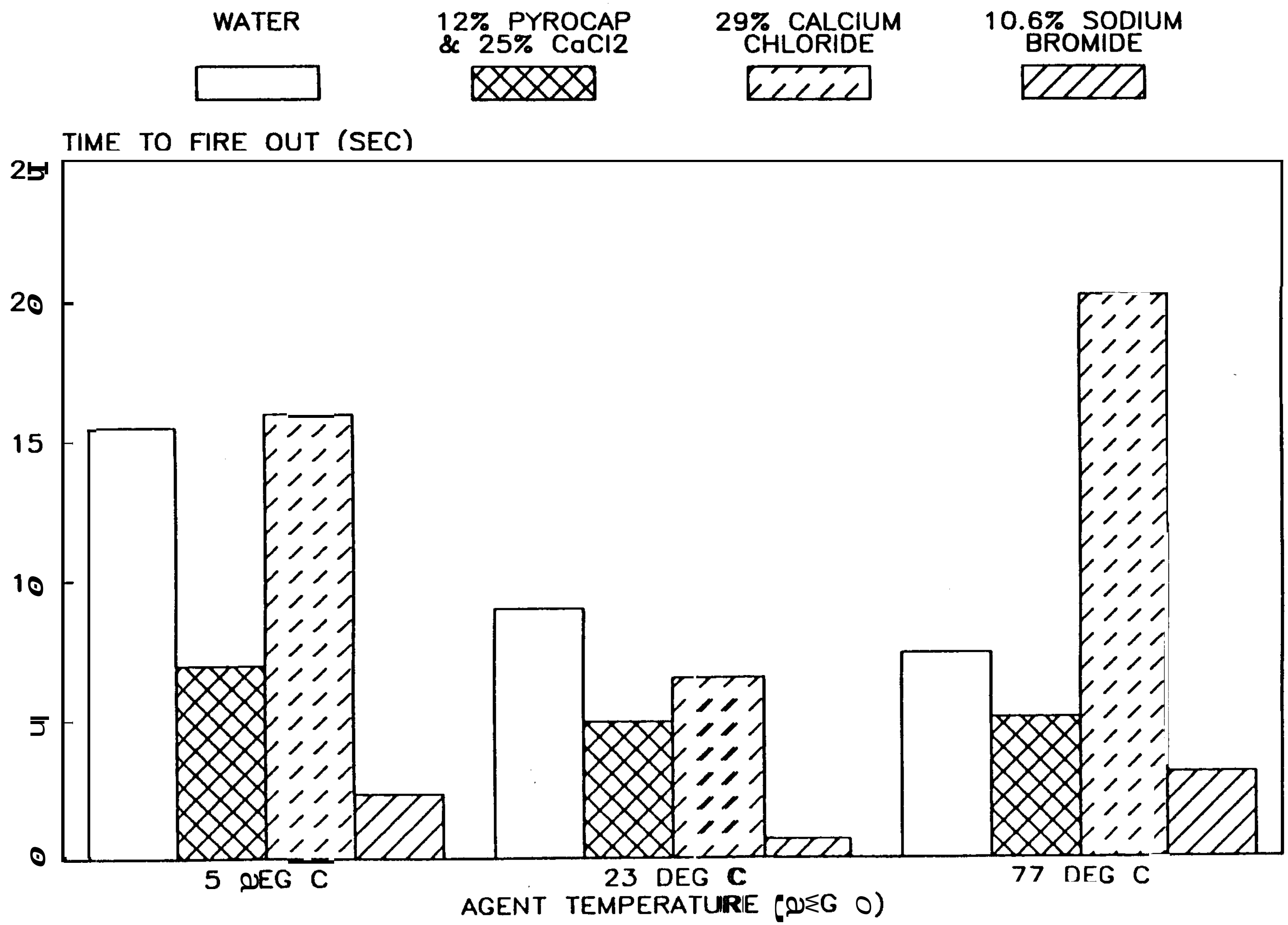

FIGURE 5 WATER & VARIOUS AGENTS vs JP-8 FLAME

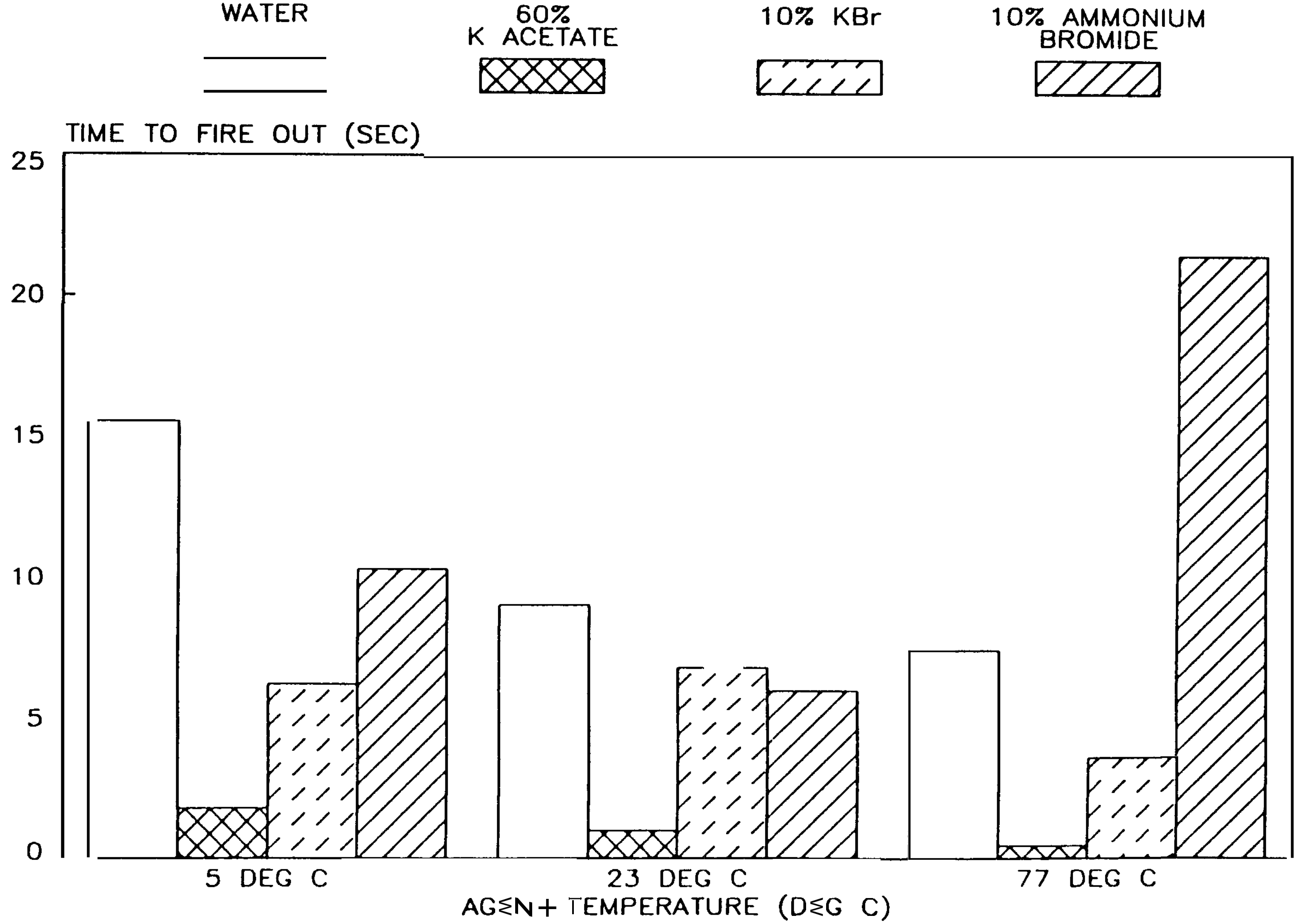

FIGURE 6 WATER & LOW TEMPERATURE AGENTS vs JP-8 FLAME

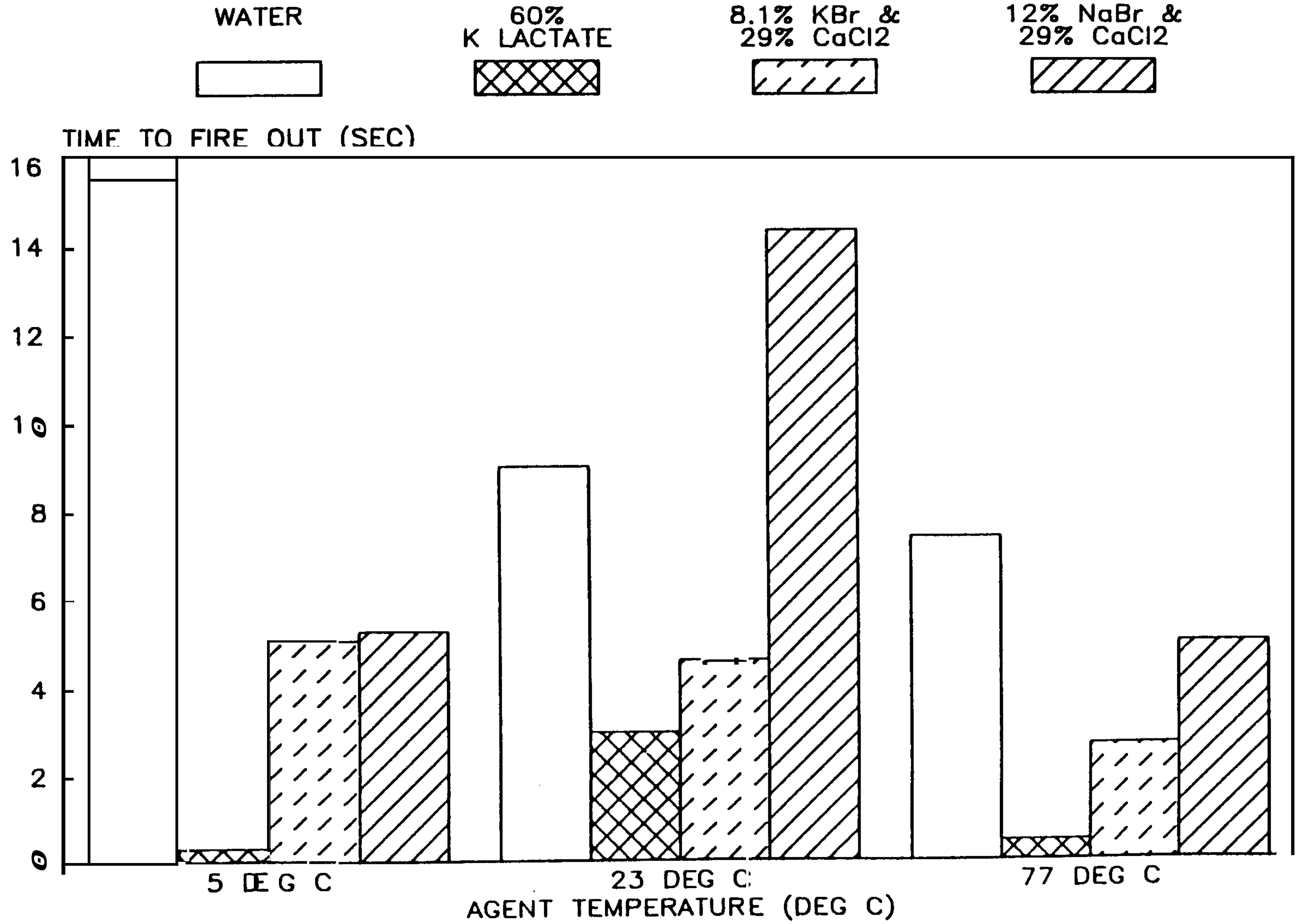

FIGURE 7 WATER & LOW TEMPERATURE AGENTS vs JP-8 FLAME