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COMPRESSED AIR FOAM SYSTEMS

THE FIREFIGHTING MEDIUM OF THE FUTURE

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ABSTRACT

Water has been the traditional medium used for extinguishing fires for centuries as it is readily available, cheap and easy to handle. A new innovation that could improve the efficiency and effectiveness of water is Compressed Air Foam Systems (CAFS). This research project looked at the best practice being adopted and recommended, in both Germany and the USA.

The research found a dramatic reduction (86%) in water usage could be achieved, with the subsequent impact on the environment. The potential to improve the health and safety of fire-fighters and further potential cost benefits.

As the pressure increases on brigades to become more environmentally friendly, to modernise and respond to the needs and desires of our communities, innovative new techniques and equipment must be explored. This research project shows the potential of one system, that for relatively little investment, could satisfy those pressures.

INTRODUCTION

It is apparent that whilst many brigades are looking at new ways of dealing with fires, only a few are seeking to supplement the traditional means of extinguishing a fire, using water, with more modern firefighting media.

Compressed Air Foam Systems (CAFS) are already used widely in the United States, and have been for some five to ten years. More recently the system has begun to be utilised on mainland Europe. The author therefore chose Germany, Los Angeles County and Phoenix to undertake his research, visiting both fire departments and manufacturers.

Understandably because of the increased focus on safety and the environment, the author believes that research into this subject will be in some measure original to the British Fire Service. At the same time it should produce some robust research that will support the introduction of Compressed Air Foam Systems (CAFS), or at least justify the worth of further investigation of the use of the systems.

CAFS use very low quantities of foam to break down water's natural surface tension; which improves the water's extinguishing characteristics. Water has a high surface tension, which limits its ability to cool the fire and causes it to form into droplets. These droplets roll off the fuel, and the heat-absorption potential is impeded. CAFS allows more surface area of the water droplets applied to contact the combustible materials surface. This provides increased heat transfer through conduction and minimises steam and smoke production. (*Fire*, June 2000, Vol.93, no.1140, p.34)

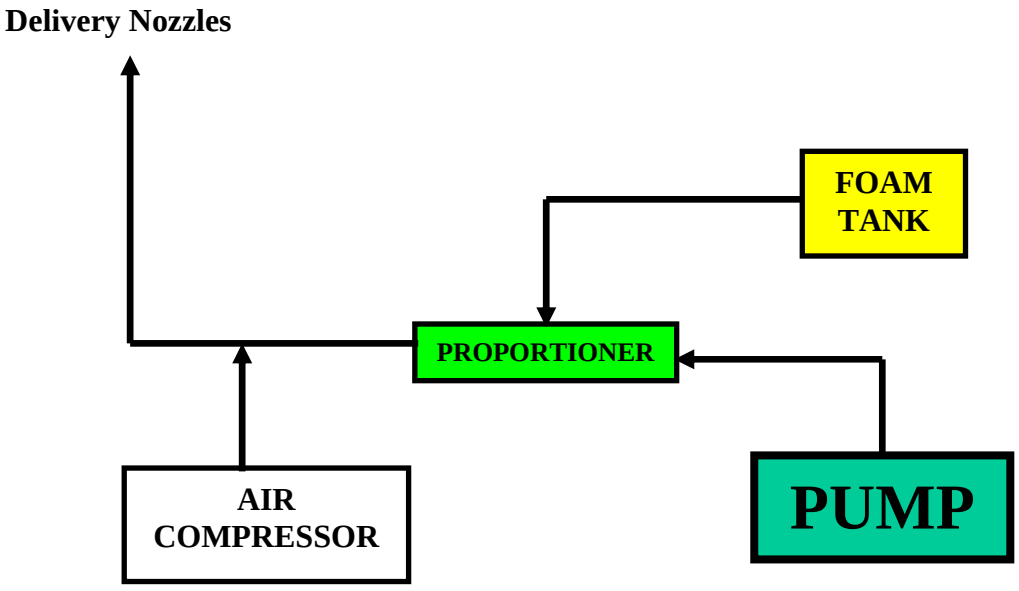

Figure 1. A Schematic diagram of a Compressed Air Foam System.

Figure 1, demonstrates schematically how a CAFS works. The foam concentrate, which is stored in either a fixed tank or in drums, is induced into the water from the fire pump by means of a proportioner. This proportioner is specially manufactured to be able to inject foam concentrate at the very low ratios required. Air is then introduced into the foam solution to agitate the solution and produce aerated foam, which is discharged through the delivery nozzles.

Liebson (1994, p.3) argues that this type of system will 'improve the safety of the firefighter, reduce operational stress and offer exceptional fire knockdown characteristics'. He also claims that this will produce benefits to the environment in terms of reduced water and fire damage, such as reduced run-off and reduced smoke emissions due to quicker knockdown.

RESEARCH HYPOTHESIS AND OBJECTIVES

Howard and Sharp (1983, p.39) define the scope of a study as being 'the opportunity to increase, reduce, or even confirm current beliefs'. The aim of this research project was therefore to examine the impact that the increased use of an alternative extinguishing medium, compared to the traditional method of extinguishing a fire by using water, will have and thereby be able to challenge and improve existing practices.

Having considered all of these factors and obtaining agreement with the Fire Service College tutors, the research project set out to test the hypothesis that:

> *'The use of Compressed Air Foam Systems will improve the efficiency and effectiveness of water in extinguishing Class A type fires.'*

The following research objectives were then developed to contribute to the testing of this hypothesis:

1. To identify the current practices being developed by brigades and their suppliers around the UK, Europe and in other areas of the world.
2. To identify best practice and gain a better understanding of the science and practicalities of Compressed Air Foam Systems from those brigades and suppliers researched.
3. To identify the legal obstacles to implementing these systems, such as health and safety and environmental regulations, encountered by these brigades and suppliers.
4. To identify costs associated with the introduction and use of Compressed Air Foam in the fire service environment.
5. To record the views and experiences of stakeholders with regard to introducing new products and changing tactics for the future
6. To draw conclusions from the research findings and recommend a way forward.

RESEARCH METHODOLOGY

The methodology adopted comprised six stages, namely, literature review, research process, research design, population and sample, interview questions and data analysis.

An initial literature search was undertaken to discover articles relevant to the subject area chosen. Saunders et al. (2000, p.44) state that 'you therefore need to establish what research has been published in your chosen area and to try to identify any other research that might currently be in progress.' Overall the literature review highlighted the paucity of research undertaken into the subject area.

In order to meet the research objectives the author had to decide on the process he was going to follow and how that data was to be collected and evaluated. Howard and Sharp (1983, pp.13-14) propose a model that contains seven steps to systematic research. The first four of these steps are related to the planning of the research and the remaining three to the effectuation stage. Hussey and Hussey (1997, p18) state that 'many of the characteristics of a good research project can be developed by adopting a systematic and methodical approach.'

It was agreed that the approach to be adopted would concentrate on qualitative research, conducting mainly semi-structured interviews and focus groups with appropriate involved personalities to gather their views and perceptions. These opportunities would also be used to gather further relevant data. Silverman (2001, p.259) states that the greatest strength of qualitative research is 'its ability to analyse what actually happens in naturally occurring settings.'

In the United Kingdom CAFS are only just beginning to be introduced. The first front-line pumping appliance to be manufactured and fitted with CAFS is about to be placed in service within East Sussex Fire Brigade. However, in the United States some fire brigades are quite advanced in the use of these systems. Others countries' fire brigades, on mainland Europe, such as Germany, are also seeking to develop the use of CAFS and are a little more advanced in their use than brigades within the United Kingdom.

The question facing the author was whether the research to be carried out was pure research or evaluation. Clearly the author was reliant on an existing body of knowledge and experience (deductive) and would be reflecting on his experiences and observations whilst undertaking the primary research phase (inductive).

Saunders et al (2000, p.46) also suggest that 'you need to focus on your research question(s) and objectives.' This led the author to structure the interview and focus group questions so that they met the research objectives, rather than trying to prove or disprove the hypothesis.

The hypothesis should therefore be viewed as a general statement that seeks to pull together that which the research objectives are trying to identify. The final draft of questions for the focus groups and the semi-structured interview questions were piloted with fire officers from around the United Kingdom.

The project design now had a number of different elements. Robson (1993, p.383) refers to this type of approach as triangulation and defines it, 'is an indispensable tool in real world research. It is particularly valuable in the analysis of qualitative data where the trustworthiness of the data is always a worry. It provides a means of testing one source of information against other sources.'

To assess the degree of success, or otherwise, achieved in relation to the introduction and use of compressed air foam systems, and to seek comparisons between different organisations in different countries, a brigade and manufacturer in Germany was visited during first week in November.

During the following two weeks in November, Los Angeles County and Phoenix Fire Departments were visited. Captains Darryl Dutton and Dave Carter arranged for their personnel to attend semi-structured interviews and focus groups with the author, from the two departments respectively. The Los Angeles County Fire Department, in particular, had conducted extensive full scale practical tests of the system. It had been arranged for the crews who participated in those tests to be interviewed. Arrangements had also been made to ride to incidents and witness Compressed Air Foam being used at incidents.

In the middle of this visit arrangements had also been made to visit a manufacturer's factory in Phoenix where the building of CAFS onto front line fire appliances is a specialism.

The semi-structured interviews each followed roughly the same format, with the same eight basic questions being put to each interviewee, for consistency. All of the semi-structured interviews were tape recorded and transcripted for accuracy.

As already stated, the questions were all designed to meet all of the project's objectives. Figure 2 below identifies the questions and the objectives to which each relates for the semi-structured interviews. This process was repeated for the focus group interview questions.

Each question seeks to meet more than one of the project's objectives. In many cases an objective is met by several questions, each answer building on the previous response and issues identified in the literature review. As the author has already stated that the research methodology of triangulation is being adopted, such overlapping and confirmation of responses is essential if the researcher is to be enabled to adequately verify his evidence.

1. What do you see as the main advantages/disadvantages of the product?	Objectives 1 & 2
2. Do you feel Compressed Air Foam has potential as: a) an additional firefighting medium, or b) a replacement for other firefighting media?	Objectives 1, 2, 4& 6
3. Do you see the use of Compressed Air Foam has having any benefit towards reducing the environmental impact of firefighting operations?	Objectives3, 4 & 6
4. Do you see the use of Compressed Air Foam has having any benefit towards improving the health, safety and welfare of fire-fighters at incidents?	Objectives3, 4 & 6
5. How would you judge the effectiveness of Compressed Air Foam compared to water in extinguishing Class 'A' fires?	Objectives 1, 2, 4 & 6
6. Would you: a) wish to see Compressed Air Foam used more widely, b) wish to see further research and development into its use carried out, or c) see no further use for Compressed Air Foam?	Objectives 4 & 6
7. How would you judge the cost compared to other fire fighting media?	Objectives 4 & 6
8. Overall do you believe that the development and introduction of Compressed Air Foam is a positive way forward in seeking to improve efficiency and effectiveness of firefighting operations?	Objectives 1, 2, 3, 4, 5 & 6

Figure 2. Semi-structured Interview Questions.

From the many methods available the author chose to use a technique recommended by Robson (1993, pp.275-6), called 'content analysis'. The first task in adopting this methodology is to categorise the questions. Robson (1993, p.277) recommends that 'these categories should be exhaustive and mutually exclusive.' Exhaustive ensures that everything relevant to the study is categorised, mutually exclusive ensures that anything to be analysed can only be categorised in one way.

For this project the author chose to use key words or phrases in context of the answer to enable him to weight the degree to which they are positive or negative in support of the category of analysis.

FINDINGS.

The author found a number of tests had been carried out on CAFS around the world, in particular the Palmdale Test Burns in California, United States during 2000/1, the research, in 1999, carried out by Dr C. M. Fleischmann at the University of Canterbury, New Zealand and work undertaken by Axel and Reiner (2000) at the Institute Research Station for Fire Protection Techniques, Karlsruhe University, Germany.

The author found that each of these tests were producing similar results. In each of the Palmdale tests measurements were taken from thermocouple trees, where measurement of temperature was taken at every twelve inches between 8 feet and 2 feet. The graphs of the eight minutes from attacking the fire, of measurements recorded from these thermocouples can be seen in figures 3 and 4 below.

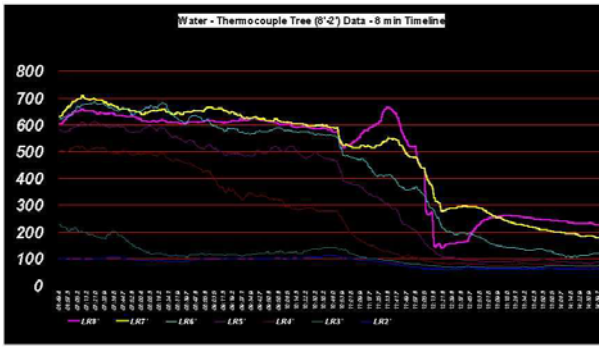

Figure 3. Results using water.

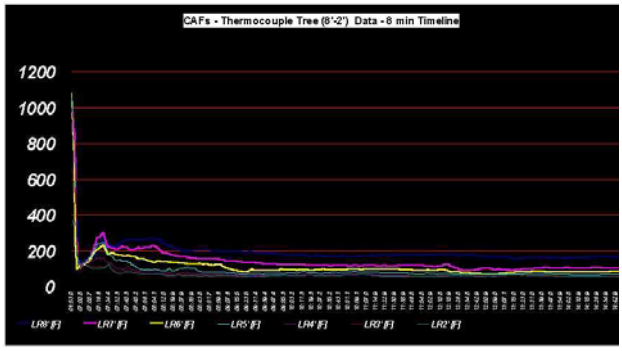

Figure 4. Results using CAFS.

As is clearly visible the reduction in temperatures for CAFS is almost immediate and within seconds every temperature reading has dropped to below 200ºC. With water especially the temperatures remain high in the compartment for the entire eight minutes shown in the graph. In a real fire scenario this would mean firefighters entering the compartment would have to work in more arduous conditions.

What is also reported is that upon application of the CAFS there is a minimum increase in temperature at ceiling levels as the water is rapidly turned into steam. However, because the thermo balance is not affected and the smoke layer does not drop below two feet, any casualty trapped in such a compartment would not be affected by this and would have more chance of being rescued alive because the firefighters would be entering the compartment more rapidly.

In total 17 semi structured interviews were carried out. A further 63 personnel, from 10 station crews participated the focus group discussions. These station crews all had fire engines fitted with CAFS and therefore had a number of year's experience and training in the use of the system. As expected these front line users were extremely open and honest in their answers and provided the author with a reality check as to the significance of the answers recorded in the semi structured interviews.

Each of the interviews then had to be analysed and scored. However to allow this scoring to begin it was first necessary to further categorise the research objectives and map these against both the objectives and the questions. (see figure 5 below.)

CATEGORY	OBJECTIVE	Semi-Structure	Focus Group
1. Effectiveness as a firefighting medium	1, 2, 5, 6	1, 2, 5, 8	1, 2, 5, 7, 8
2. Effectiveness with regards to environmental protection	3, 5, 6	1, 3, 8	2, 3, 5
3. Effectiveness with regards to health and safety	3, 5, 6	1, 4, 8	2, 4, 5
4. Effectiveness with regards to cost	4, 6	3, 4, 5, 7, 8	3, 4, 5, 7, 8
5. Additional or Replacement as a firefighting medium	1, 2, 5, 6	1, 2, 3, 4, 8	1, 2, 3, 4, 7, 8
6. Further Development required	4, 5, 6	2, 3, 4, 6, 8	1, 3, 4, 6

Figure 5. Cross-Mapping of Categories.

Having defined the categories it was now possible to apply the scores to both the semi-structured interviews and the focus groups. These were put into tabular form and mean scores for each interviewee against each category calculated. The same was done with the focus groups and it was interesting that the scores were very similar, with there being no more than one point difference between either the semi structured interviews and the focus groups.

Having scored the data against each of the categories, before conclusions could be finally drawn, further analysis was required to show the dispersion of opinion and to compare these between each category. The dispersion was shown graphically by placing each of two categories on a scaled axis, and doing this until every category had been plotted against every other category. With 6 categories this resulted in the exercise being repeated 15 times.

This data was plotted on the graphs by taking the average figure from each interview and the focus groups, and the point at which the two scores dissect is marked by a small circle shape. (an example of one of the dispersion graphs is shown in Figure 6).

To assess if the data plotted on these graphs is reliable the Statistica software package was used. From this piece of software the Pearson Product Moment correlation scores (r =) and significance scores (p =) were produced. Any correlation score above + or – 0.60 is classified has having a good correlation. Results with a significance score of less than 0.005 are classed as being significant. From these significant results reliable conclusions can be drawn. The results that are not classed as significant cannot be ignored, the information they produce may still be interesting, just not as statistically reliable.

The majority of the results plotted on this graph are in the top right portion, indicating that the interviewees agree that CAFS is effective in both areas. As can be seen the results show a high positive correlation and are significant.

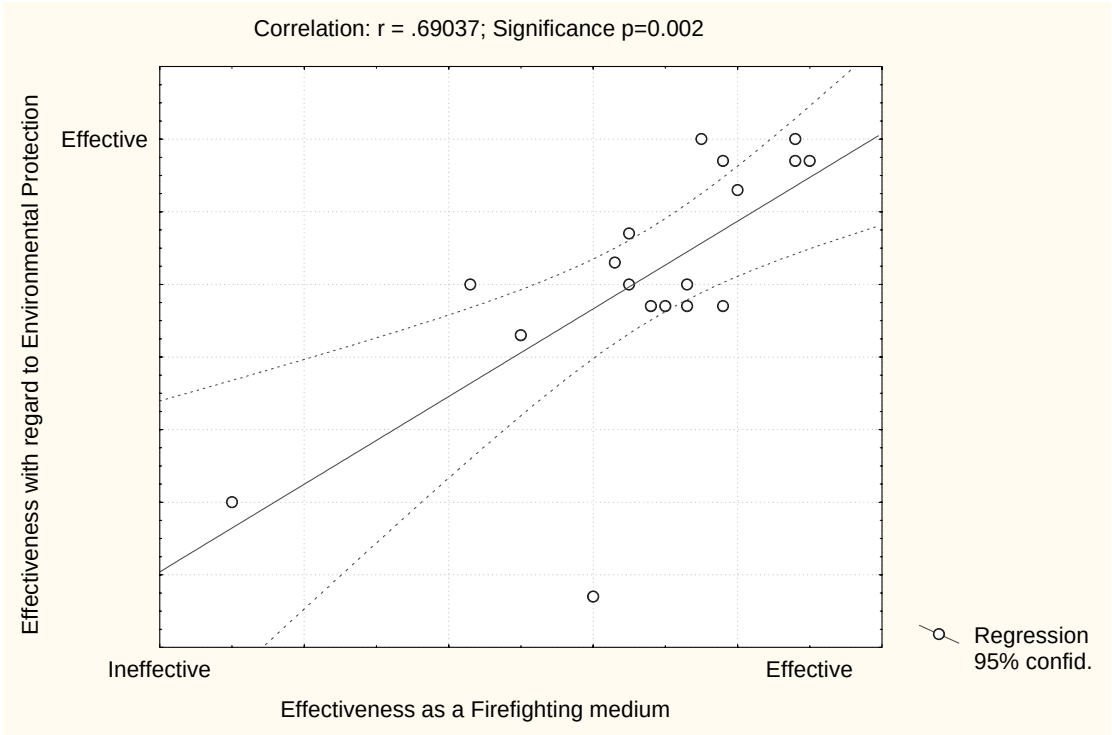

Figure 6. Effectiveness as a Firefighting Medium v. Effectiveness with regards to Environmental Protection.

CONCLUSIONS

Both the primary and secondary research data conclude the following to be the benefits of CAFS:

Effectiveness as a Firefighting Medium.

- **Faster, Safer more effective**. Compressed Air Foam reduced the temp from 600° to 200° around 75-80% faster than water.
- **Products of Combustion are reduced quicker**. Compressed Air Foam achieved knockdown 78% faster than water.

Effectiveness with regards to Environmental Protection.

- **Water Damage is dramatically reduced**. Compressed Air Foam used 14% of the amount of water or 86% less total product. Most of which is either used in extinguishing the fire or is absorbed into the fire loading, thereby hardly any run off is observed.
- **Reduced Environmental Impact**. Compressed Air Foam used 14% of the amount of water or 86% less total product and used 82% less Foam Concentrate..

Effectiveness with regards to Health and Safety.

- Compressed Air Foam reduced the ceiling temps from MAX° to 212° up to five times faster than water. Thermal Balance is maintained during temperature decrease.
- 1/3 Greater distance of streams, **providing firefighter safety**.
- Lines are lighter and more maneuverable.

The author's research discovered that the cost of installing the system to a new appliance adds approximately 10-15% to the total cost of the appliance. The training implications are not particularly onerous and the change to methodology of firefighting minuscule. The research indicates that the long term cost benefit, to the brigades and society in general far outweigh the initial investment.

Whilst all the research that the author was able to find into CAFS appears extremely positive the vast majority of users and manufacturers recognise that further research and development is necessary and the recommendations in the main report reflect this.

The overriding conclusion from this research project is that CAFS is a spectacular move forward in improving the efficiency and effectiveness of water in extinguishing Class A type fires. As Chief Brunacini, Phoenix Fire Department, (*Fire Rescue*, March 1999, vol.17, p.8) is reported to have once said; 'The policy comes down from God, and She says, 'Fire trucks are red, and they shall have CAFS.' From the experiences and evidence acquired in undertaking this research project the author is convinced that the same will be true in the United Kingdom within five years.

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