IN SEARCH OF AN AGENT FOR THE PORTABLE FIRE EXTINGUISHER

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INTRODUCTION

In Spring 1986, the United States Air Force (USAF) began developing a cost effective training replacement for the fire extinguishing agent used in the portable fire extinguishers.',' The primary objective of the USAF research effort was to find an agent suitable for the 150-lb flightline extinguisher. The research to date has resulted in several products which are commercially available? However, these products lack several characteristics which are required for a viable long-term flightline candidate." In the early stages of the USAF halon replacement program chlorofluorocarbons (CFC) were first investigated. One commercialized CFC based product included NAF-BLITZ. In September 1987 the Montreal Protocol was signed into effect. The result has been a ban on halon and CFC production which will eventually eliminate their use. Therefore, the research has focused on four parameters: (1) environmental (near zero ODP and GWP), (2) toxicity (less than or equivalent to Halon 1211), (3) effectiveness (drop in), and (4) availability. The most readily available compounds were from the halocarbon family (HCFCs, HFCs, HBFCs, FICs, and FC). The commercial products listed in the Environmental Protection Agency (EPA) Significant New Alternative Policy (SNAP) Program are listed in Tables 1 and 2. These agents meet three out of four of the required parameters; but all lack at least one requirement. In the fall, 1994 the Advanced Agent Program was initiated.[5] The results to date are a list of additional compounds which include phosphonitrides, metal complexes, and silicon compounds. The USAF sponsored halon replacement research has resulted in large amounts of data, several new test methods, databases, and national and international committee appointments.

TABLE 1. COMMERCIALIZED STREAMING AGENTS.

Agent	Chemical	Formula	Trade Name
HCFC-123	Dichlorotrifluoroethane	$CHCl_2CF_3$	DuPont "FE-232"
HCFC-124	Chlorotetrafluoroethane	$CHClFCF_3$	DuPont "FE-241"
HCFC Blend B	Expander Gas Plus Primarily		American Pacific
HCFC-123	Dichlorotrifluoroethane	$CHCl_2CF_3$	"Halotron I"
HCFC Blend C	Proprietary additive plus		North American
HCFC-123	Dichlorotrifluoroethane	$CHCl_2CF_3$	Fire Guardian
HCFC-124	Chlorotetrafluoroethane	$CHClFCF_3$	"NAF P-111"
HFC-134a	1,1,1,2-Tetrafluoroethane	CH_2FCF_3	
HCFC Blend D	Proprietary additive plus		North American
HCFC-123	Dichlorotrifluoroethane	$CHCl_2CF_3$	Fire Guardian "NAF-BLITZ"
HFC-227ea	Heptafluoropropane	CF_3CHFCF_3	Great Lakes "FM-200"
HFC-236fa	1,1,1,3,3,3-Hexafluoropropane	$CF_3CH_2CF_3$	DuPont "FE-36"
FC-5-1-14	Peffluorohexane	$CF_3(CF_2)_4CF_3$	3M Company "CEA-614"
FIC-13I1	Trifluoroiodomethane	CF_3I	Pacific Scientific "Triodide"; West Florida Ordnance "Iodoguard"

TABLE 2. ENVIRONMENTAL AND TOXICITY PROPERTIES OF STREAMING AGENTS.

Agent	ODP	GWP	Atmospheric Lifetime, yrs	NOAEL, Vol. %	LOAEL, Vol. %
Halon 1211	3		15	0.5	1.0
HCFC-123	0.02	93	1.4	1.0	2.0
HCFC-124	0.02	480	6	1.0	2.5
HCFC Blend B					
HCFC-123	0.02	93	1.4	1.0	2.0
HCFC Blend C					
HCFC-123	0.02	93	1.4	1.0	2.0
HCFC-124	0.02	480	6	1.0	2.5
HFC-134a	0.0	1300	15	4.0	8.0
HCFC Blend D					
HCFC-123	0.02	93	1.4	1.0	2.0
HFC-227ea	0.0	3300	41	9.0	10.5
HFC-236fa	0.0	8000	250	10.0	15.0
FC-5-1-14	0.0	6800	3200	40	>40
FIC-13I1	0.0001	<5	<1 day	0.2	0.4

FIRE EXTINGUISHMENT

Typical fire extinguishment involves one of the following: (1) Removing the fuel from the fire, (2) limiting oxygen to the fire (smothering), **(3)** removing heat from the fire (quenching), or **(4)** breaking the unhibited chain reaction of the combustion process. Agents which primarily use the first three methods are physical agents, and agents primarily using the fourth method are chemical agents. Water is an example of a physical agent, whereas, Halon 1211 is an example of a chemical agent.

VARIABLES

There are a number of variables which can effect extinguishment when considering portable extinguishers. For example, there are variables associated with the fire itself. One type of fuel can bum hotter than another, and can therefore be more difficult to extinguish. The ambient conditions, such as temperature can come into play. There are also variables associated with the extinguisher components, including the nozzle, cylinder, and valve. Different nozzle diameters will produce different flow rates, thereby effecting agent performance extinguishment times. The application pattern can have a significant effect, as can the technique used to fight the fire. Different fill ratios will create varying flow rates over the discharge time. In essence, there are a number of variables associated with a portable extinguisher that can effect the performance of an agent. The effectiveness of a halon-replacement agent cannot be determined simply by loading chemical into a Halon 1211 extinguisher, pressurizing the cylinder to its specified pressure (for Halon 1211), and using the same Halon 1211 nozzle. Such a test could potentially make a good agent appear ineffective. All the variables discussed above need to be considered with portable fire extinguishers.

TEST METHODS

Testing agents on medium and large-scale fires can often be costly and time consuming. Therefore, methods to test agents on a smaller scale have been developed. NMERI has two methods for testing streaming agents in the laboratory. The first involves the NMERI cup burner designed **for** liquid agents, and the second involves the NMERI laboratory scale discharge extinguishment (LSDE) apparatus. The cup burner is used to determine extinguishment concentrations to compare agents performance. Figure 1 shows the liquid agent cup burner setup. With the LSDE, shown in Figure 2, comparisons are based on flow rates and extinguishment times. Figure **3** shows an example of typical LSDE test results. The agent with the lowest critical application rate curve, Halon 1211, is the more effective agent. At any given flow rate, Halon 1211 has the shortest extinguishment time, and uses less agent for extinguishment.

The LSDE is unique, in that it has a nozzle which pivots up and down around a longitudinal axis perpendicular to the nozzle to pan line, allowing the discharge direction to be moved up and down (vertical motion), but preventing side to side horizontal motion. The nozzle produces a fan pattern. The pivot arm moves the spray from the front of the pan to the back, thereby simulating field tests. The amount of agent discharged is determined with a digital readout laboratory scale. Nitrogen overpressure is delivered to the top of the holding cylinder, and different nitrogen pressures and a metering valve are used to obtain desired flow rates. Agent is fed from the holding cylinder to the nozzle through a flexible nylon tube. A control box is used to activate a solenoid valve, thereby controlling the discharge of agent. A timer, attached to the control box displays the discharge time. The solenoid and timer are activated manually with toggle switches.

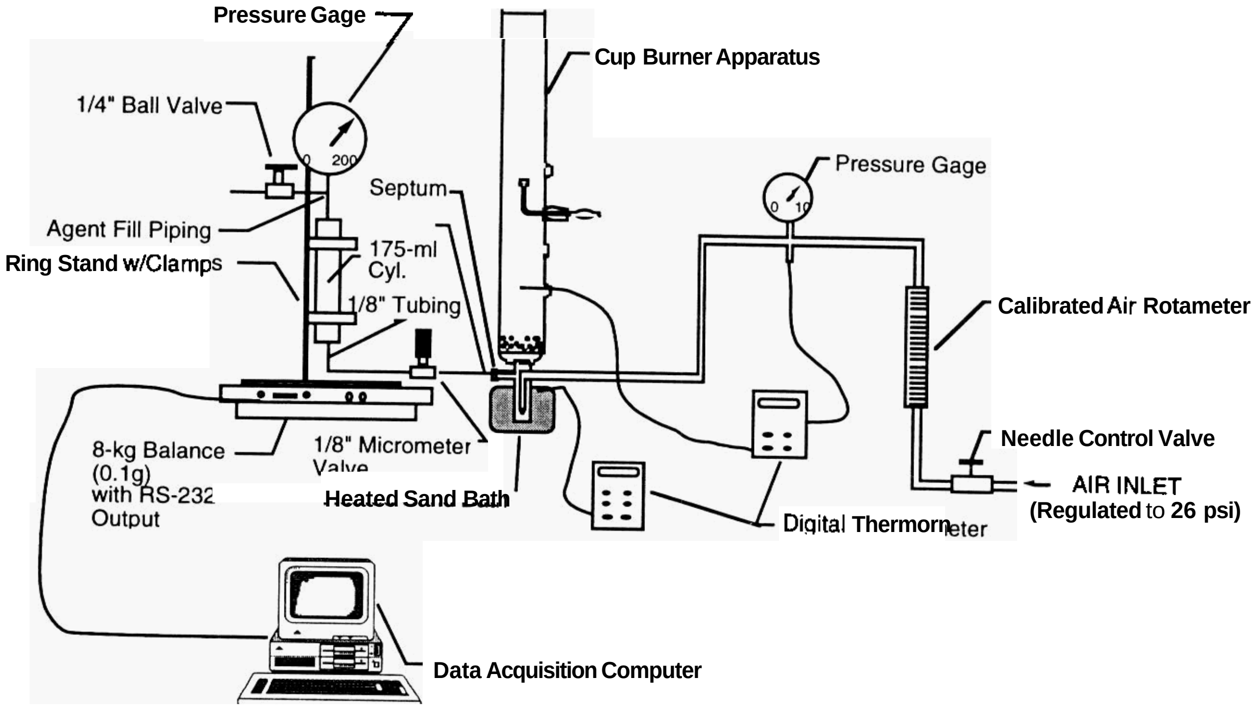


Figure 1. Liquid Agent Cup Burner Setup.

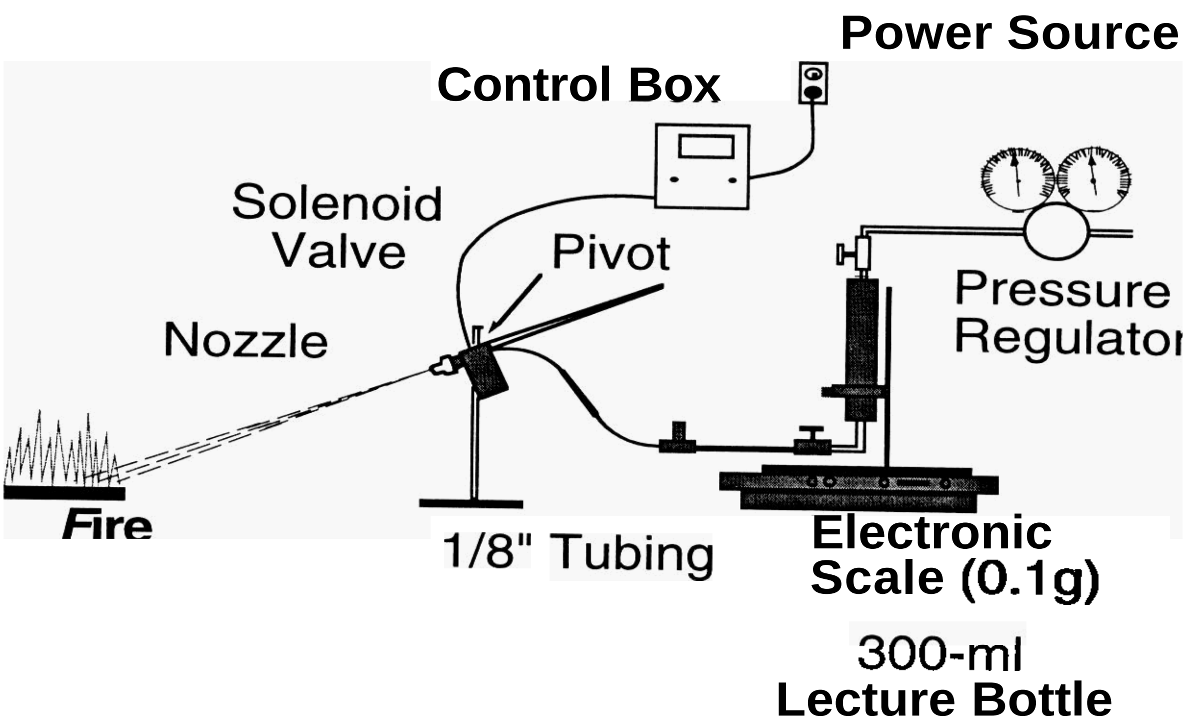


Figure 2. Laboratory Scale Fire Test Apparatus.

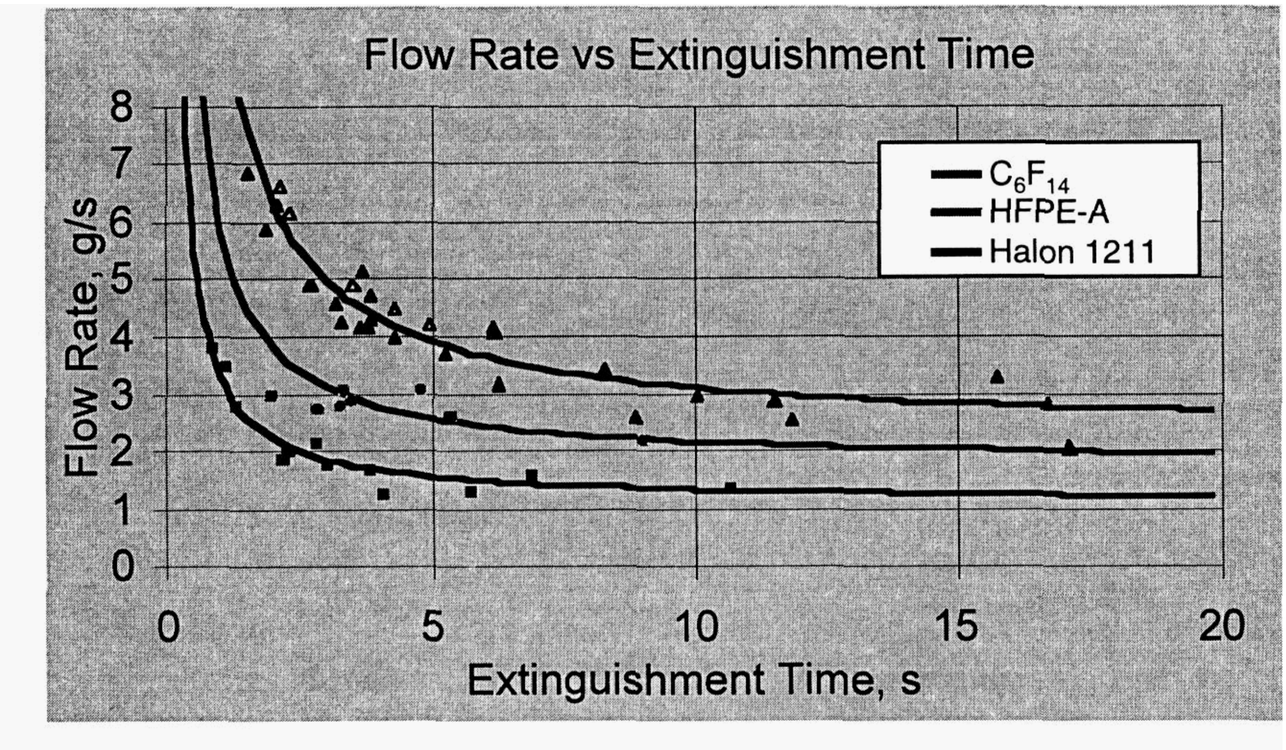


Figure 3. Typical Laboratory Scale Discharge Extinguishment Test Results.

Square steel fuel pans are utilized for the tests. The fuel pan is contained within an aluminum structure closed on all four sides and open at the top. **A** door is located on the side for access into the box. The entire box is located within a laboratory hood to prevent the release of combustion products into the laboratory.

Laboratory test results can be used to develop parameters for the next step in the testing process; small scale field tests. Small-scale field tests are performed with the NMERI Small-scale constant flow rate extinguisher (**SS** CFRE). The extinguisher is made of stainless steel, and like the LSDE used in the laboratory, provides a constant flow rate of agent to the fire (Figures **4** and *5).* Varied pressures and different nozzles are used to obtain specific flow rates so that critical application curves can be obtained. This provides another method for comparing agents on a small scale, eliminating the time variability of flow rates associated with portable extinguishers. It also provides important information relevant to the portable

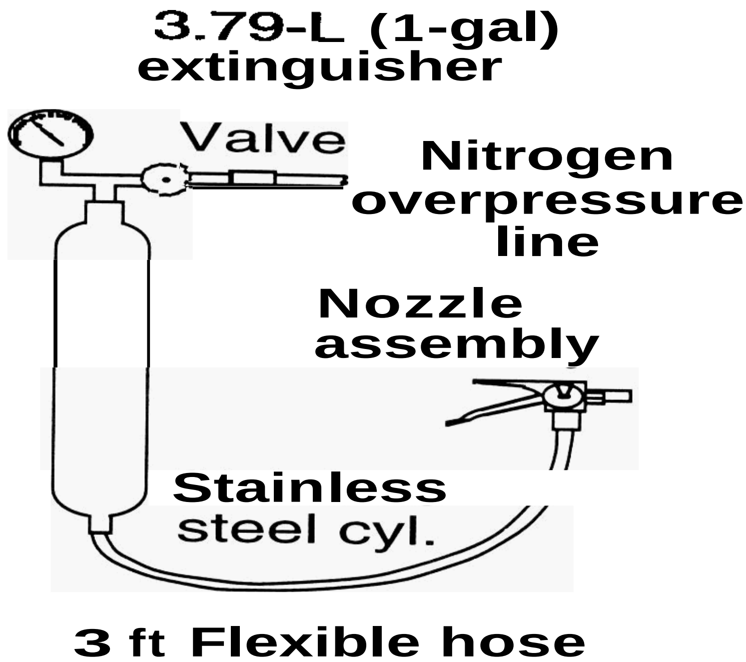


Figure 4. Small-Scale Constant Flow Rate Extinguisher (**SS** CFRE).

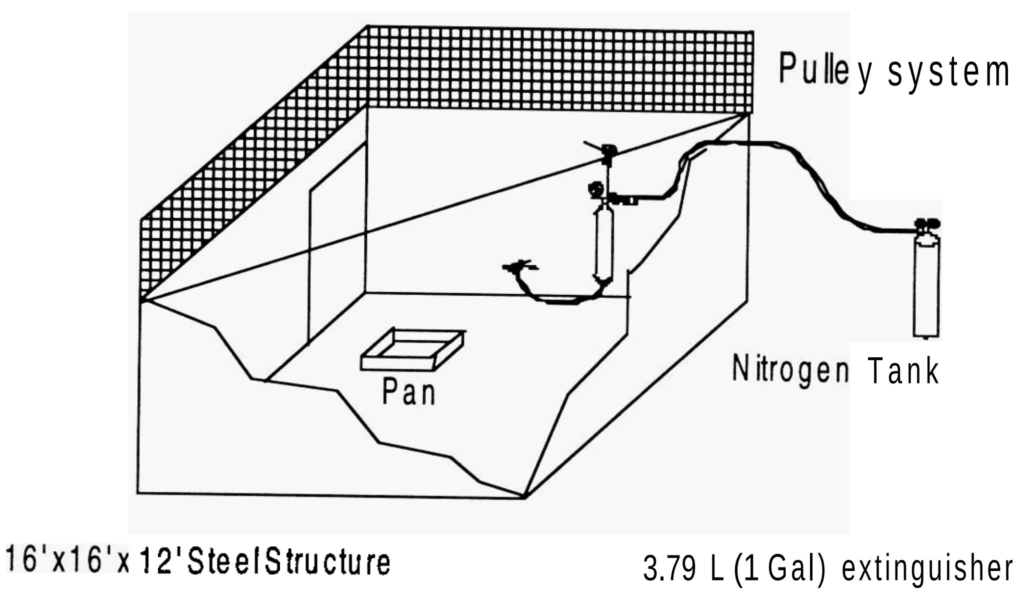


Figure 5. Small-Scale Constant Flow Rate Extinguisher (SS CFRE) Test **Setup.**

extinguisher. The minimum flow rate required to extinguish a particular fire size can be determined, and design considerations, such as selecting an appropriate nozzle to provide the necessary flow rate can be made. **If** an extinguisher does not provide the necessary flow rate then the fire will not be extinguished.

The next step in the testing process is to look specifically at portable extinguishers. The most desirable design solution is to find an existing extinguisher which can be used **for** the agent being tested. **If** an existing Halon 1211 extinguisher can be used by making simple nozzle modifications and selecting an appropriate fill ratio and nitrogen pressure, then the cost **of** re-manufacture can be avoided. At NMERI, tests are conducted to evaluate flow rates and discharge patterns of extinguishers with various combinations of nozzles, fill densities, and nitrogen pressures (Figure *6).* Data is taken which shows the weight decrease **of** the extinguisher over time, providing the flow rate over time (Figure 7), and the pressure drop in the cylinder and nozzle over time (Figure 8), which are correlated with the flow rate data.

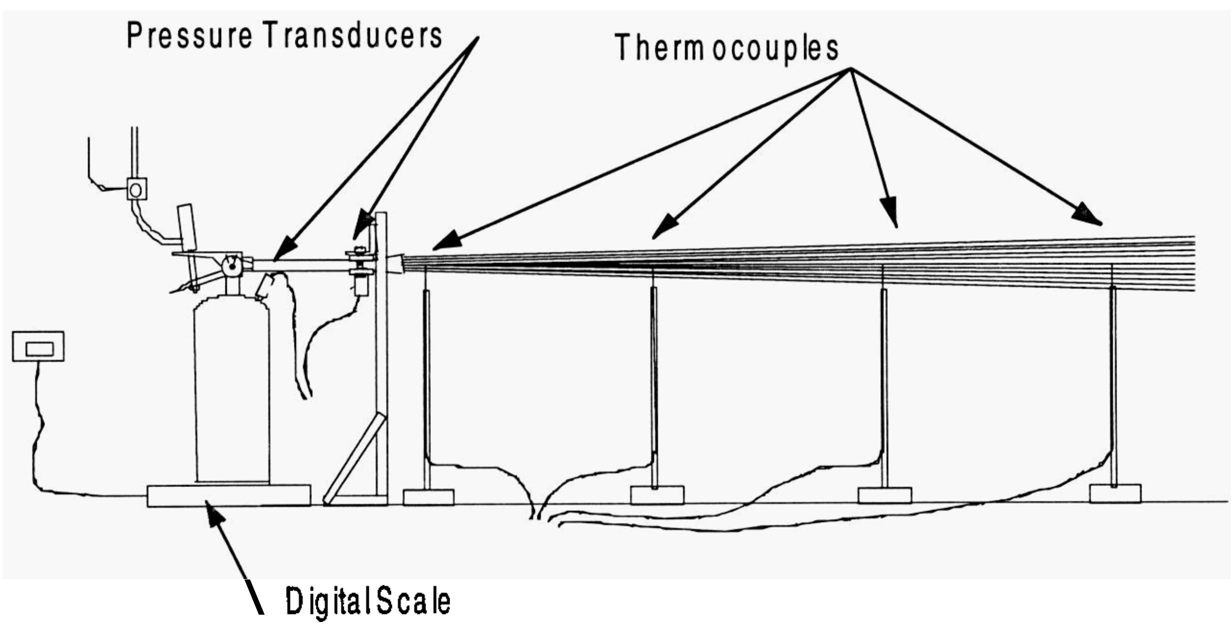
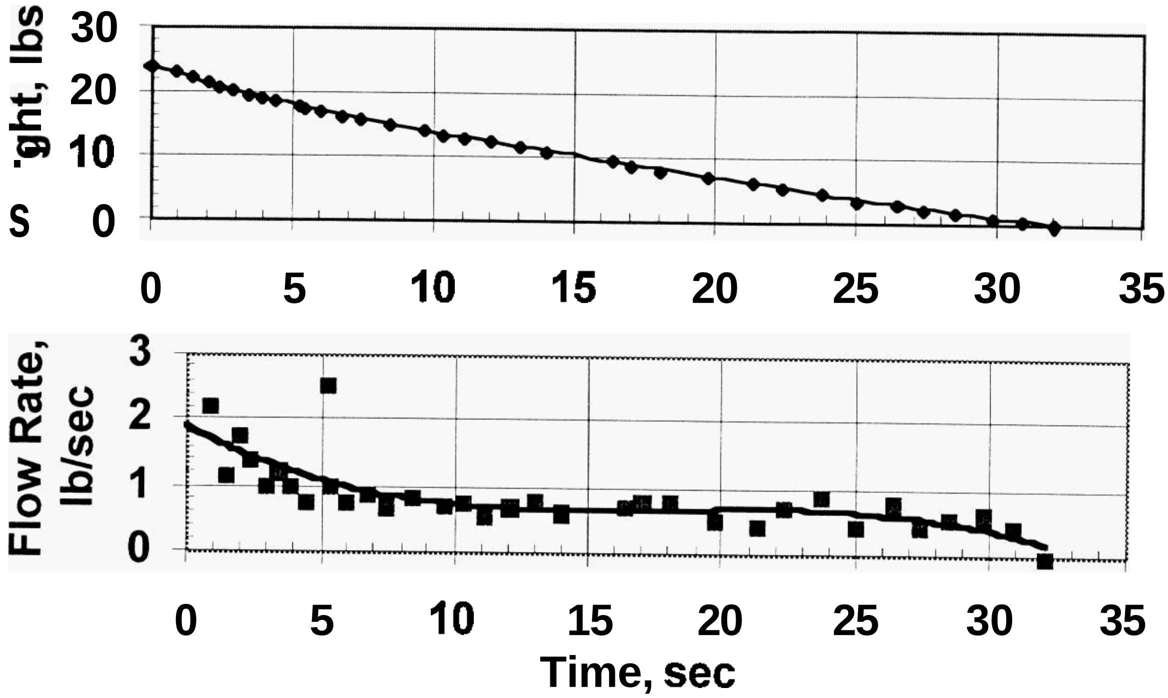
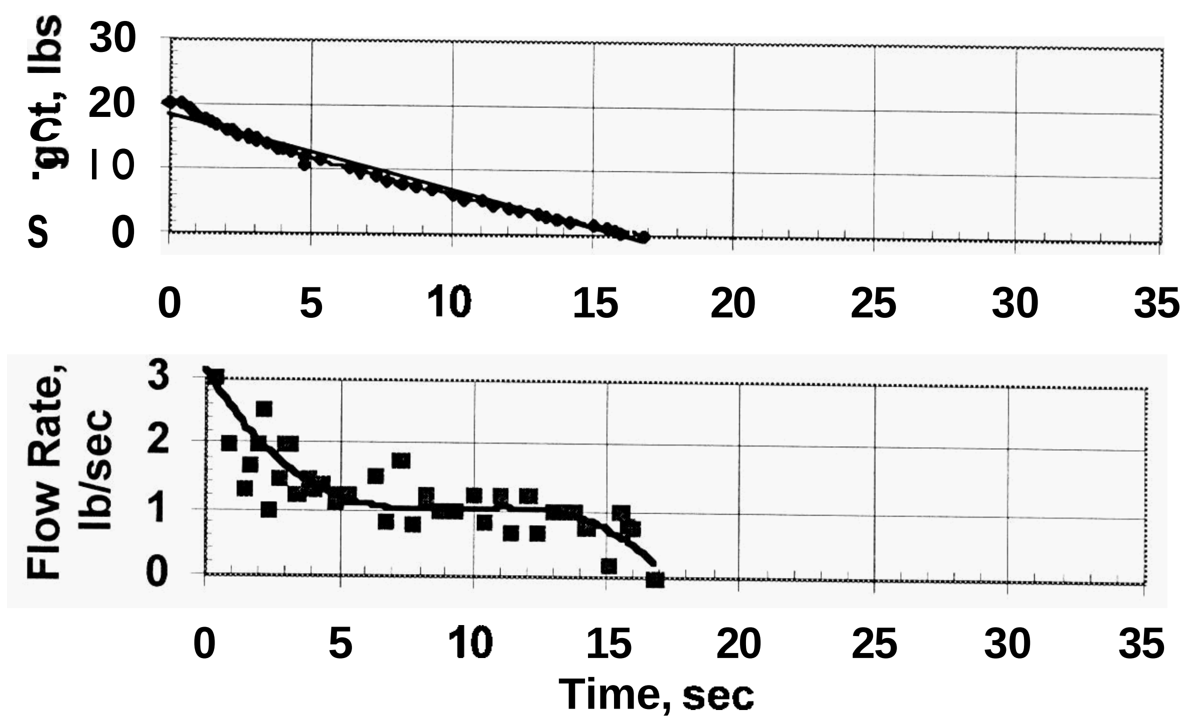


Figure *6*. Flow Rate and Pattern Evaluation Test Setup.



a) Small Nozzle.



b) Large Nozzle.

Figure 7. Typical Flow Rate Data.

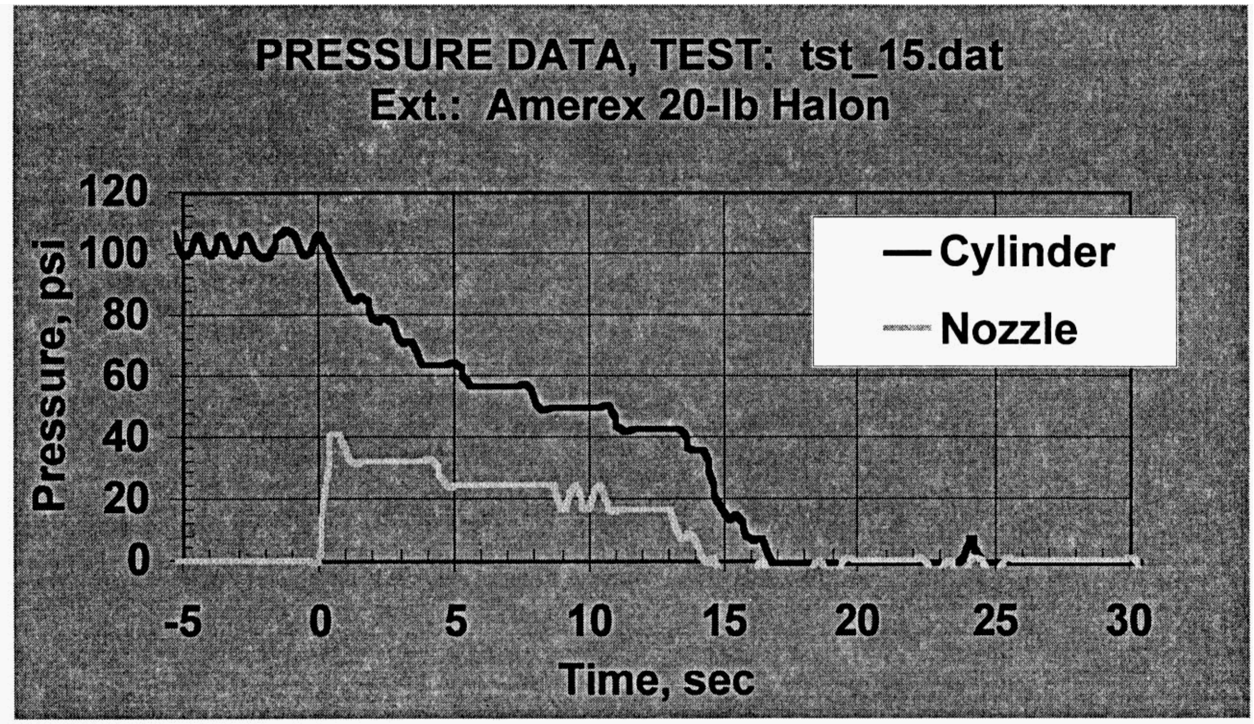


Figure 8. Typical Pressure Data.

Thermocouples, placed at selected distances from the nozzle, assist in the evaluation of cooling and throw distance of the agent as time progresses (Figure **9).** With the data obtained from these tests, selected nozzles, fill densities, and nitrogen pressures are used for medium-scale fire tests (25, 32, and 75 ft^2). Different fuels are used for the test fires, including *n*-heptane, **JP-4,** JP-5, Jet **A,** diesel, and gasoline. The extinguisher sizes tested (used) range from a 5 up to 150 lb halon extinguishers. Testing has also been done at a large scale with 150 ft^2 fires and 3- dimensional 75 ft^2 fires.

AGENT SELECTION

As part of the testing procedures, considerations need to made for selecting the appropriate agent for the application. How "clean is clean?" Can powders, water, foams, or combinations thereof meet your requirements? Knowing the critical extinguishment flow rate

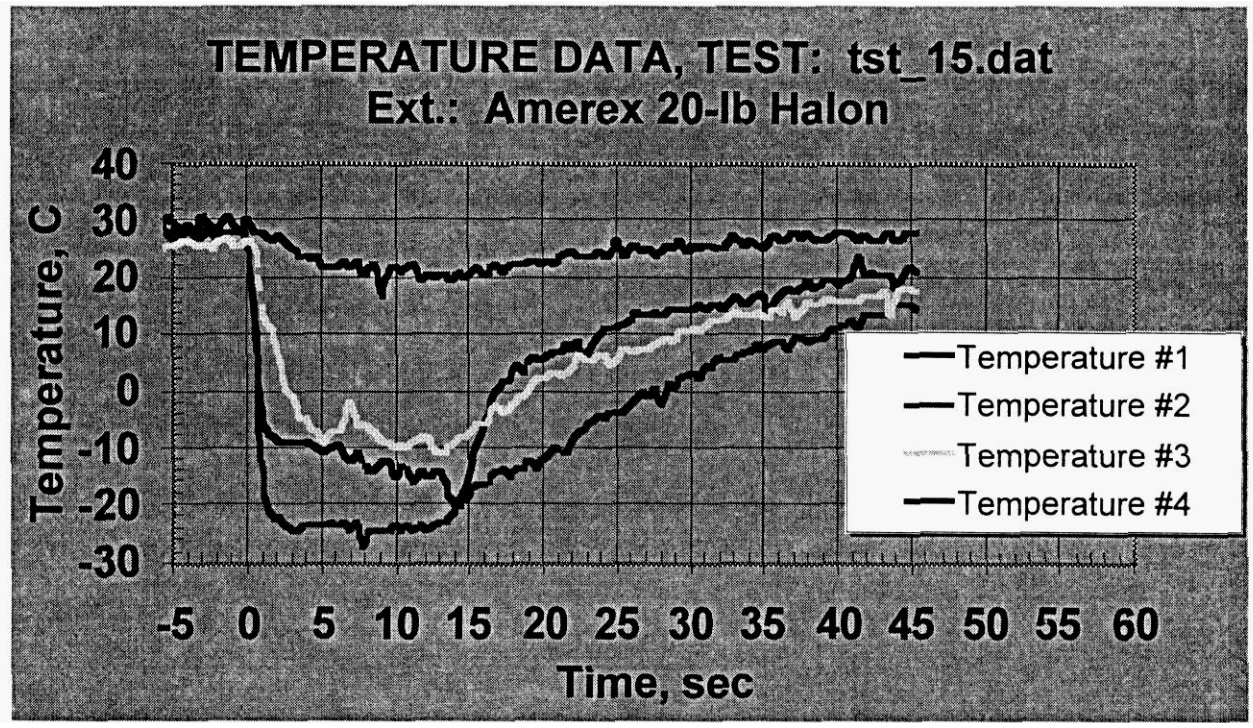


Figure **9.** Typical Temperature Data.

(Q_c), can the extinguisher discharge agent for a specified time, perhaps 10 seconds, and still maintain this flow rate? It **is** best to have an agent with the lowest Q_c, thereby using the least amount of agent, and one which has reduced toxicity? Again, all the variables effecting extinguishment, including fire type, n o d e size, cylinder pressure and fill ratio, valve type, and application technique must be considered.

SUMMARY

Over the years a number of agents have been tested in portable extinguishers. These include HCFCs such as FE-232, R-22, R-134a, and FE-241; HFCs such as FM-200, FE-25, FE-36; FCs such as CEA-614, CEA-410; FICs such as CF_3I, C_3F_7I; water-based solutions such as halide salts, foams, salt and foam mixtures; and blends such as NAF P-III, Halotron, and Envirogel. There are currently two companies with UL listed halon replacement portable fire extinguishers; Buckeye, Inc., with Halotron I, and Amerex, Inc. with CEA-614. Several other companies are in the process of getting their agents and extinguishers UL listed. To date, there are no true chemical agents available that have a low toxicity and can provide the effectiveness equal to Halon 1211. Advanced agents are the likely alternatives where a "clean" agent is required. There are currently no non-clean alternatives that are available for most applications, and "trade-offs" are required.

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