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AN EVALUATION FOR THE LOCATION AND TYPE OF HAND PORTABLE FIRE EXTINGUISHER USED ON BOARD THE AH-1 ARMY HELICOPTER

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Army Materiel Command
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This report evaluates various extinguishing agents for their desirability during inhabitable helicopter cockpit fires and states the most desirable agent as being Halon 1301. Graphs illustrating the concentration of Halon 1301 (% by volume) vs. time (seconds) for two extinguisher discharge conditions are presented. The applicability of the Air Force design criteria for fire extinguisher placement in the Army AH-1 helicopter is

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FOREWORD

The research discussed in this report was accomplished as part of the Safety Engineering Graduate Program conducted jointly by the USAMC Intern Training Center and Texas A&M University. As such, the ideas, concepts and results herein presented are those of the author and do not necessarily reflect approval or acceptance by the Department of the Army.

This report has been reviewed and is approved for release. For further information on this project contact Dr. G. D. C. Chiang, Intern Training Center, Red River Army Depot, Texarkana, Texas 75501.

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ABSTRACT

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This report evaluates various extinguishing agents for their desirability during inhabitable helicopter cockpit fires and states the most desirable agent as being Halon 1301. Graphs illustrating the concentration of Halon 1301 (% by volume) vs. time (seconds) for two extinguisher discharge conditions are presented. The applicability of the Air Force design criteria for fire extinguisher placement in the Army AH-1 helicopter is evaluated. The utilization of fire extinguishers in the Southeast Asia Conflict indicates that locating the extinguisher in the helicopter cockpit is not necessary. Relocation is an alternative to the total removal of the extinguisher and is recommended for safety reasons.

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During the course of this work, the author was employed by the U.S. Army as a career intern in the AMC Safety Engineering Graduate Program. He is grateful to the U.S. Army for the opportunity to participate in this program.

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CHAPTER I

INTRODUCTION

An incident on board an Air Force jet bomber involving the advertant functioning of a halogenated carbon type portable fire extinguisher has prompted the Air Force to provide a design requirement prohibiting the location of hand portable fire extinguishers in single place and tandem seating two place aircraft. According to Army Regulation AR 95-1 (1973), paragraph 3-28, "each Army aircraft will have a minimum of one operable fire extinguisher of the proper type installed and available during all flights". Besides this difference of opinion as to the need for an extinguisher in single place and tandem seating two place aircraft, different extinguishing agents are being used by both the Army and the Air Force for inhabitable compartment extinguishers.

The objective of this report is to evaluate the Air Force's decision, stated in the Air Force System Command Design Handbook (AFSC DH) 1-6, prohibiting the location of a hand portable fire extinguisher on board single place and tandem seating two place aircraft. This design criteria is directly applicable to Army helicopters, in particular the AH-1G, AH-1J, and the new AH-1Q. Also various types of extinguishing agents will be investigated for the possibility and desirability of using a different type agent than the one presently used by the Army. The desirability of an agent is the result of both the toxicity of its compounds and its capability to extinguish fires.

Chapter II covers the previous work done with hand portable fire extinguishers for aircraft use and the agents used in these extinguishers. The research and development done by the Air Force leading up to the design criteria stated in AFSC DH 1-6 will be reviewed. The Army's research and development will also be presented in this chapter.

Chapter III deals with the extinguishing abilities of the various agents, the physiological effects of the agents on the human body, the properties of the agent in the undecomposed and decomposed states, and the extent of damage caused to the hardware of the aircraft.

The description/layout of the Cobra cockpit and the expected exposure concentration of extinguishing agent will be discussed in Chapter IV. The accessibility and location of the extinguisher, the volume of the cockpit, the volume and flow diagram for the environmental control system and the back-up fan, the discharge rate of the extinguisher, and the toxicity of the material used for interior construction must also be considered at this time. From this information a hazard analysis can be constructed that shows the percent concentration of extinguishing agent versus time after discharge with the ECS operating.

Chapter V describes the past data on the extinguisher used in the AH-1 series of helicopters. Data from the United States Army Agency for Aviation Safety (USAAAVS), Fort Rucker, Alabama, shows in-flight in-cockpit fires and the extinguisher use matrix; where data from the Aviation System Command (AVSCOM), St. Louis, Missouri, shows removals of the extinguisher for various failure codes. AFSC DH 1-6 and information obtained with this handbook are also discussed. Chapter VI presents the results, conclusions, and recommendations for future research.

CHAPTER II

LITERATURE REVIEW

With the advancement of the helicopter, there has also been an advancement in fire protection on board the helicopter. The concepts of toxic free interior materials and location of fuel and electrical lines are not new to helicopter design. The post crash fire has almost been totally eliminated by the use of the crashworthy fuel system. If a fire does occur in-flight, then an extinguisher is needed that will quickly put out the fire with the least toxic by-products given off.

The Air Force made the decision concerning the need for an extinguisher in the cockpit around 1945. From all indications, the decision was based on the fact that there was no data showing that the extinguisher had been used. The major area for fire is the engine compartment, which cannot be controlled by the crew with a hand portable extinguisher. Twin engine jets are equipped with engine extinguishing systems which are discharged when a warning is received. Jets are also equipped with an ejection system which removes the crew from the disabled aircraft.

The only previous work done concerning the extinguisher in the Cobra was brought on by the "green house" effect of the closed canopy. The average temperature of the cockpit when the helicopter is on the ground with the doors closed and the sun shining was determined to be 203°F. This temperature caused the agent to reach the burst pressure of the burst disc in the extinguisher bottle. The result of the burst disc blowing was that the nozzle would fly off the discharge tube and travel around the cockpit. Various ideas were stated to eliminate this problem. One was to use a different agent and another was to paint the bottle white. As to removing the extinguisher from the aircraft, the Army has done no formal study at the present time.

Due to the limited area of the Cobra's cockpit, the physical, physiological, and toxic effects of various extinguishants must be considered. Carbon dioxide is one of these agents.

According to the National Fire Protection Association's Fire Protection Handbook (4)* and National Fire Codes (11), carbon dioxide has been used for many years for flammable liquid and electrical equipment fires. Its usage varies since it is a noncombustible, nonconductive

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* Numbers in brackets refer to numbered references in the List of References.

gas which spreads over a total area. Carbon dioxide is mildly toxic: it can cause unconsciousness and death if used in high concentrations in a fire area.

The dry chemical extinguishant was also discussed in the two books by the National Fire Protection Association. This agent has also been around for many years and in varied forms can be used on all classes of fires. Its toxicity has been rated as low but increased if taken as a direct shot. The limitations of the agent are with electrical systems using contact points and relays.

Halogenated extinguishing agents are among the most popular agents used today. In 1947 Purdue University started the first systematic study into the use of agents superior to methyl bromide. Their report on Fire Extinguishing Agents, July 1950, lists numerous agents which were tested. These tests were mainly for the extinguishing capabilities of the various developed compounds with little emphasis placed on the toxicity of the material. Ignition and Fire Suppression in Aerospace Vehicles, September 1972, deals more with the toxicity of the various Halon agents used. Some of the more widely used agents are Halon 1301, 1211, and 1011.

The National Fire Codes (11) and Fire Protection Handbook (4) combine all previous work completed on Halogenated agents. It was discovered that by changing the chemical bonds on various elements, the extinguishing ability of these compounds were increased or decreased. Some changes even produced an added effect to the already burning material. Through these two books, complete guidelines are set for the use of different Halon agents based upon the environment. Chapter III investigates the properties of extinguishing agents in more detail.

CHAPTER III

EXTINGUISHING AGENTS

Since the threat of fire is a factor governing the safe operation and completion of a mission for military combat aircraft, its prevention and control are critical. The best means of control is the elimination of all threat of fire, but this is not a realistic goal. The next best thing is to utilize an agent that has quick extinguishing capabilities and low toxic effect.

During past years the toxicity of an agent wasn't the major concern, but rather the capability of the agent to handle the various classes of fires, whether Class A: fires involving ordinary combustible materials, Class B: fires involving flammable or combustible liquids, or Class C: fires involving energized electrical equipment. In recent years though, the concepts have changed toward the development of an agent that offers both good fire fighting capabilities and low toxicity. Various agents must be evaluated for their possible use in the cockpit of the AH-1 helicopter series.

Dry Chemical

A dry chemical agent is a mixture of powders used to extinguish fires in various materials. Regular dry chemical has a bicarbonate base powder and is recommended for Class B and C fires while multipurpose dry chemical has an ammonium phosphate base powder and is effective for Class A, B, and C fires.

Dry chemical is considered very effective for use on flammable liquids and can be used on some types of electrical equipment. Its stability is acceptable at low and normal temperatures but since some of its components melt and become sticky at higher temperatures, an upper temperature limit of 140° F is normally recommended for storage. (4)

The compounds that make up a dry chemical agent are considered nontoxic, but if a discharge of sufficient quantity was to occur in an enclosed limited area, a breathing restriction would exist. Another adverse effect is the "cloud" of dispersed particulate in the air that would reduce, if not totally restrict vision of the crew. When the powder settles out of the air the cockpit would need to be totally cleaned and all unsealed electronic equipment would need replaced or repaired.

Carbon Dioxide

Carbon dioxide is an odorless, colorless, electrically non-conductive inert gas that is a suitable extinguishing agent. It has previously been used as an extinguishant for use in inhabitable areas. The toxicity of carbon dioxide is considered mild, though it can produce unconsciousness and even death at concentrations in the fire extinguishing range. At the 9% concentration value, loss of consciousness may occur within minutes. If death does occur from carbon dioxide, it is usually from suffocation and not from the toxic effects of the agent. Carbon dioxide is a desirable agent for many fire situations but cockpit areas is not one. The fog of carbon dioxide can restrict vision, an undesirable characteristic.

Halogenated Hydrocarbon

Halogenated hydrocarbon extinguishing agents which are desirable for cockpit use are dibromodifluoromethane (CBr_2F_2), bromotrifluoromethane ($CBrF_3$), and bromochloromethane (CH_2BrCl). These halogenated agents exhibit the most desirable characteristics, at the present time, for the extinguishment of fire and the physiological effects on personnel who come in contact with the agent. A halogenated compound is one which contains one or more atoms from an element of the halogen series, i.e., fluorine, chlorine, bromine, or iodine.

To classify the halogenated agents, a system of Halon numbers is used. The first digit represents the number of carbon atoms; the second digit, the number of fluorine atoms; the third, the number of chlorine atoms; the fourth, the bromine atoms; and the fifth, if any, the number of iodine atoms. (4) Table 1 shows the halon numbers for the agents used in this study.

Table 1

Halon Numbering System

Halon No.	Formula	Name
1301	$CBrF_3$	Bromotrifluoromethane
1202	CBr_2F_2	Dibromodifluoromethane
1011	CH_2BrCl	Bromochloromethane

The physical properties of the agents are shown by Table 2.

Table 2

Physical Properties of Agents

	Halon Number		
	1301	1202	1011
Molecular Weight	148.9	209.8	129.4
Boiling Point °F	-57.9	76.1	156.0
Freezing Point °F	-270.4	-229.9	-123.7
Liquid Density Lb/gal at 70°F	13.1	19.0	16.1

(Values obtained from AFSC DH 1-6, 1971)

The most desirable agent for cockpit use is one with high extinguishing capability and low toxic effects. Table 3 lists some physiological properties of the agents.

Table 3

Physiological Properties

	Approximate Lethal Concentration PPM Volume for 15 Minute Exposure Rate	
Halon No.	Natural Vapor	Decomposed Vapor
1301	800,000	14,000
1202	54,000	1,850
1011	29,000	4,000

(Values obtained from AFSC DH 1-6)

The presence of toxic vapors of Halon agents can be detected by smell, irritation, coughing, and lachrymation. For Halon 1301 the natural vapors are slight and ethereal while the decomposed vapors are acrid and irritating. The natural vapors of Halon 1202 are heavy and ethereal with decomposed products being extremely painful to inhale. Natural vapors of Halon 1011 have a sweet odor while decomposition products are extremely irritating. (6)

Underwriters' Laboratories, Inc. has established toxicity groupings for various agents and other vaporizing liquids and gases. Bromotrifluoromethane has a Group 6 rating, which is the least toxic rating. A Group 6 item is one which will not produce injury to human life when exposed to concentrations up to at least 20 percent by volume for approximately 2 hours. Dibromodifluoromethane is Group 4 which is lethal or will produce serious injury when exposure to concentrations of 2 to 2 1/2 percent by volume for approximately 2 hours. Bromochloromethane is a Group 3 item which has the same definition as the Group 4 items but the exposure time is for only about one hour. These classifications are acceptable as a means for ranking various agents according to the toxicity, but the exposure concentrations and durations should not be used as guidelines.

Threshold limit values (TLV) and emergency exposure limits (EEL) are important decision factors for an inhabitable cockpit fire extinguisher agent. Table 4 lists the TLV's and EEL's for the halogenated agents of concern as stated by Bottori et. al. (2)

When evaluating properties of extinguishing agents for use in inhabitable cabin areas, toxicity must be the primary determining factor. Though the overall effectiveness of Halon 1301 is not quite as good as Halon 1202, its' toxic and physiological properties are far less than Halon 1202. Since Halon 1301 is the best agent when toxicity is considered, it will be considered in greater depth.

Table 4

Exposure Limits - PPM

Halon No.	TLV - 8 hour day	EEL - 5 min.
1301	1,000[1]	60,000[2]
1202	100[1]	3,000[3]
1011	200[1]	10,000[3]

1 - American Conference of Governmental Industrial Hygienists (ACGIH)
2 - National Academy of Science, National Research Council (NAS/NRS)
3 - Unpublished estimates that are used as temporary guidelines by the Air Force

Halon 1301, bromotrifluoromethane, is a colorless, odorless gas with a density approximately 5 times greater than air. It is the lightest Halon agent at normal temperatures and its extinguishing capabilities range from flammable liquids to solid combustible materials with the exception of some active metals.

The natural vapor and decomposed vapor concentrations of the agent must be considered for the exposure to personnel. Natural or undecomposed Halon 1301 will produce minimal central nervous system effects at concentrations below 6 percent by volume for exposure times less than 5 minutes. Dizziness, impaired coordination, and reduced metal acuity show up with exposures of a few minutes at concentrations between 6 to 10 percent, but these effects are not incapacitating at exposures less than a minute. Between 15 and 20 percent there is a chance of unconsciousness and possible death if the exposure is prolonged. At concentrations above 10 percent the effects increase in intensity due to duration of exposure greater than one minute. At a duration of 30 seconds or less, there are no effects even at concentrations up to 15 percent. (11)

The decomposed vapors of Halon 1301 are produced when the agent comes in contact with a hot surface of 900°F or greater. The percent of agent decomposed is dependent on the surface area of the fire. Tests show that the extinguishment of a 25 square foot heptane fire in a 10,000 cubic foot enclosure within 0.5 seconds produced only 12 ppm hydrogen fluoride. The approximate lethal concentration (ALC) for hydrogen fluoride for a 15 minute exposure is 2500 ppm. Hydrogen fluoride is the most prevalent by-product given off by the decomposition of Halon 1301.

Chapter IV will discuss the cockpit volume and arrangement of equipment that maintain a constant flow of fresh air. Different situations will be evaluated to show what percent by volume of Halon 1301 might be expected in the cockpit when the extinguisher is discharged.

CHAPTER IV

HAZARD ANALYSIS

Fire on board a helicopter can create hazards to crewmembers from the inhalation of both smoke and fumes. Concern is given to the breathing restrictions imposed by smoke and fumes but no consideration is given their toxicity since cabin material will not produce toxic by-products when burned. The major problem is the elimination of the fire with an extinguishing agent, so that the vapors of the agent don't add to the already present hazards. Various components of the cabin area must be studied so that the effects of an extinguisher discharge can be evaluated. The cabin arrangement, the type of ventilation system used, and the discharge rate of the extinguisher are all important for the evaluation of the extinguisher discharge and the agent concentration.

The Cobra is a tandem seating two place helicopter. The pilot sits in the rear elevated seat and the copilot-gunner rides in the front seat. Both the pilot and copilot have full flight capabilities of the helicopter. There is only one hand portable fire extinguisher on the Cobra and its located to the left and slightly to the rear of the copilot's seat. The extinguisher is accessible to the copilot while he maintains flight configuration, that is, with seat belt and shoulder harness fastened. The pilot, on the other hand, has to remove his seat belt and shoulder harness and then physically move forward to be able to reach the extinguisher. This action by the pilot would require the copilot to fly the helicopter. At the present time, the extinguisher used in the Cobra is the standard Army one quart extinguisher filled with Halon 1301.

The Cobra, like most Army helicopters, is equipped with an environmental control system (ECS). The ECS mixes cold air with hot air to maintain a desired temperature level within the cockpit. The output of the ECS is approximately 200 cfm. If the ECS becomes inoperable, a backup system consisting of a transmission driven fan that circulates outside air at ambient temperature is available. The backup system has the capability of 850 cfm output. The air from both the ECS and the backup system is fresh air, not recirculated air.

The mode of operation for cockpit temperature control of the ECS is as follows. The ECS mixes cold air, 39°F dry bulk, with high temperature engine bleed air. The cold air is received from the heat exchanger located within the ECS. The pilot controls the rate of mixing for the desired temperature level as well as the cabin output of the system. If "air conditioning" is not required and ambient air can be used for the ventilation purposes, then the pilot can select the backup or ambient vent system. The air for this system is ram air that is blown through the cockpit by a transmission driven fan. The pilot can control the amount of air that flows through the system by a flapper valve located in the inlet duct of the system. It is possible for both the output of the environmental control system and the ambient ventilation system to be shut off by the pilot. If this is the case, there is always air flow to the pilot's seat cushion, which is controlled by a separate valve.

Since the cockpit can be considered a vented enclosure, the effects of Halon 1301 concentration can be determined. To obtain usable units, various values must be considered. First is the discharge time for the extinguisher, which is a standard Army one quart size. Specifications call for a discharge time of 22 ± 5 seconds at $70^{o}F$ to disperse 95% of the agent (3). For the worst case condition, the extinguisher would discharge 100% of its contents in a time span of 17 seconds. Second is the extinguisher discharge rate, which is the ratio of the liquid density of the agent to the discharge time. The liquid density of Halon 1301 is 13.1 lbs./gal. which is equivalent to 3.275 lbs./qt. The discharge rate equals

0.1926 lbs./seconds. The rate of ventilation must also be considered. For this paper it will be considered that any time the helicopter is operated, there is some type of ventilation used. Therefore the ECS displacement will be used for calculation since its value is the lesser of the two methods of ventilation. Also, consideration must be given to the situation when both the ECS and ambient fan air are both off. The only ventilation air in the cockpit is that which is continuously forced through the pilot's seat cushion since it is assumed that this air would not be shut off. With the ECS operating the rate of ventilation is approximately 3.3 cfs, while the value for ventilation rate with both the ECS and backup system off is not as easily obtained. A value of approximately 45 cu. ft. will be used for all calculations involving the cabin area.

To know the actual effects that can be expected to be received if an extinguisher is discharged in the cockpit, the concentration-time relationship is important. The cabin area can be considered a totally flooded ventilated area. From the <u>National Fire Codes</u> (11), an equation was obtained for the effects of ventilation on the concentration-time relationship as follows:

$$C = \frac{R(1-e^{-Et/V})}{0.00391\ E} \qquad (4.1)$$

where

C is the agent concentration, percent by volume,
R is the discharge rate, lb./sec.,
E is the ventilation rate, cu. ft./sec.,
V is the enclosed volume, cu. ft.,
t is the time, sec.,
e is the natural logarithm base, 2.71828, and
0.00391 - correction constant for Halon 1301.

Substituting into the equation the values for each variable we have for the ECS "on" situation:

$$C = \frac{49.258(1-e^{-Et/45})}{E} \tag{4.2}$$

for the concentration at each time t after discharge of the extinguisher starts ($t_o = 0$).

Since extinguisher discharge will stop after 17 seconds, the concentration-time relationship will change. The new relationship is given by the equation as follows:

$$C = C_o e^{-ET/V} \tag{4.3}$$

where

C_o is the agent concentration at end of discharge, percent by volume,
T is the time after discharge stops, sec.,
C is the agent concentration, percent by volume,
E is the ventilation rate, lb./sec.,
V is the enclosed volume, cu. ft.,
e is the natural logarithm base, 2.71328.

With the ECS operating the equation becomes,

$$C = C_o e^{-ET/45} \tag{4.4}$$

where the concentration of agent decreases as the time T increases.

Figure 1 illustrates the concentration-time relationship from 0 to 60 seconds with the ECS on and ventilation rates of 1.2, 1.6, 2.4, 2.8, and 3.3 cfs. This figure not only shows the maximum expected concentration at 17 seconds for each flow rate, but also illustrates the time that the concentration is between 6-10% and 10-15%.

Table 5 lists the time that is spent within each concentration range for each of the five flow rates.

Table 5

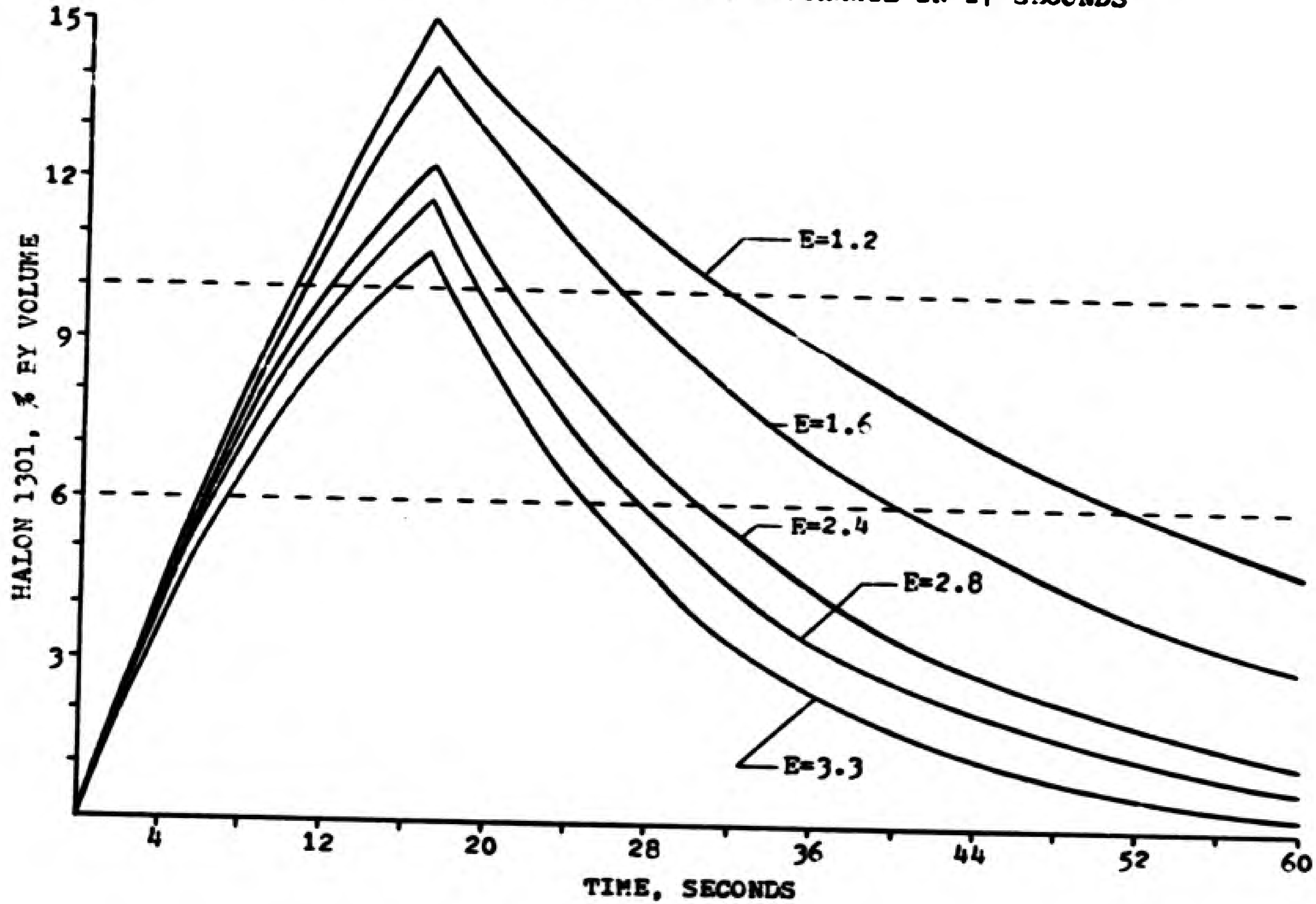
Time Values in Seconds
(17 seconds duration with 100% discharge)

	Concentration Range		
Flow Rate, cfs	6-10%	10-15%	Total Time
1.2	23.5	21.5	45
1.6	18.5	15.5	34
2.4	15.5	8.5	24
2.8	15.0	6.0	21
3.3	15.0	3.0	18

At a concentration of 6-10%, no harmful effects will be noticed if the exposure duration is less than or equal to 60 seconds. For 10-15 % concentrations, the maximum exposure time is 30 seconds. As shown by Table 1, no flow rate will yield an exposure time above maximum.

Considering the case where the extinguisher still discharges 100% but in a time span of 27 seconds instead of 17 seconds, equation 4.1 becomes,

FIGURE 1
CONCENTRATION vs. TIME FOR 100% DISCHARGE IN 17 SECONDS



$$C = \frac{31.023(1-e^{-Et/45})}{E} \qquad (4.5)$$

where R (discharge rate, lb./sec.) is 0.1213. Equation 4.4 remains the same for the concentration-time relationship after the discharge stops.

Figure 2 illustrates the concentration-time relationship from 0 to 60 seconds with the ECS on and ventilation rates of 0.8, 1.2, and 3.3 cfs. For a ventilation rate of 0.8 cfs, it is observed that at 60 seconds the percent concentration of Halon 1301 is above the 6% level. This presents an undesirable situation and should be evaluated in more depth when low flow rates are used (E is less than or equal to 1.0 cfs).

For flow rates of 1.2 and 3.3 cfs, the concentration values are less than those values presented in Table 1.

Figure 3 shows agent concentration vs. ventilation rate for constant times of 17 and 27 seconds. Values for the ventilation rate were substituted into equations 4.1 and 4.5 to obtain the concentrations. The 15% concentration level was chosen as a maximum permissible value since exposure times for concentrations above 15% can cause unconsciousness or possible death. The values of ventilation rate corresponding to the 15% concentration is approximately 1.2 and 0.8 cfs for discharge duration of 17 and 27 seconds respectfully. The ventilation rates are the

FIGURE 2
CONCENTRATION vs. TIME FOR 100% DISCHARGE IN 27 SECONDS

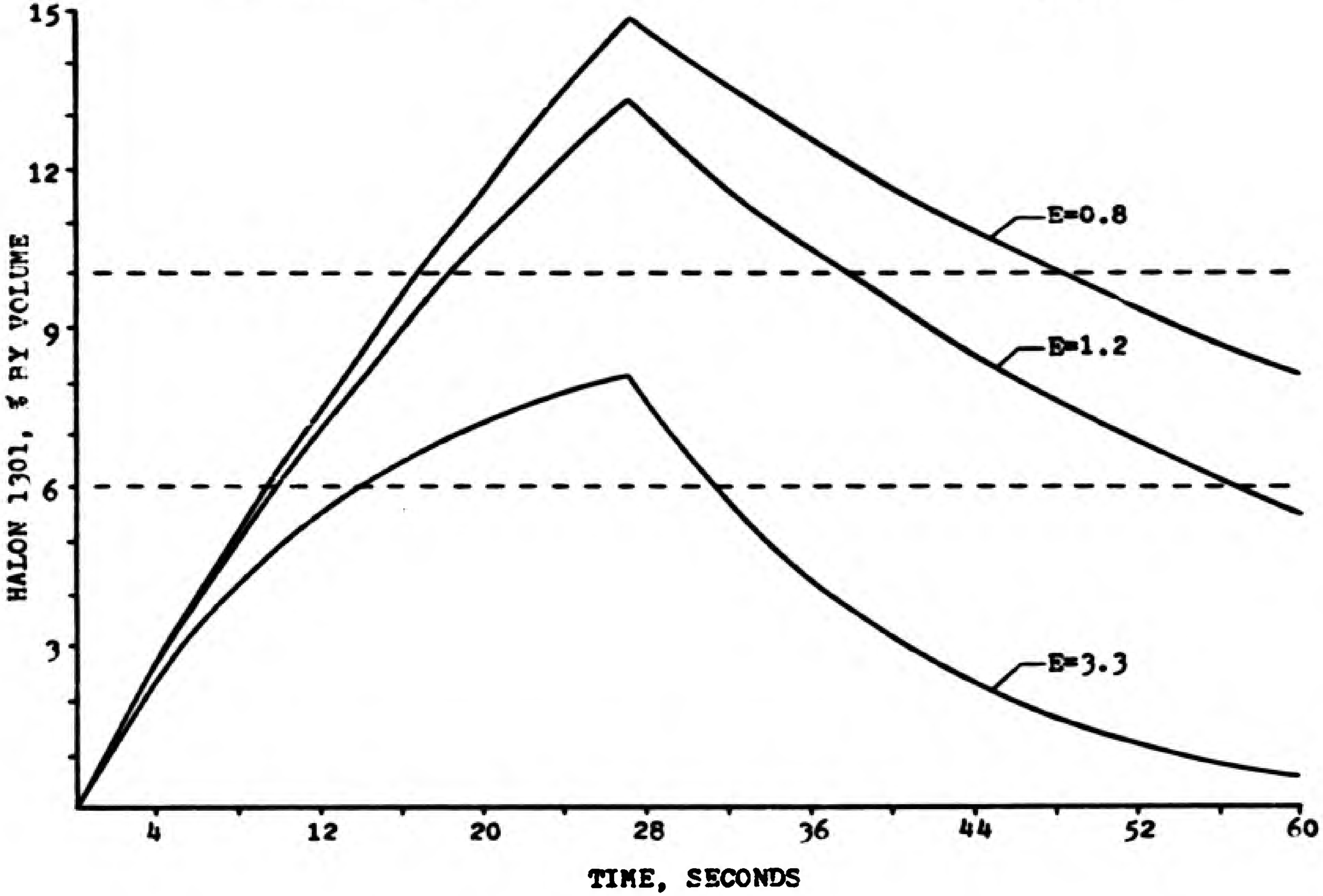
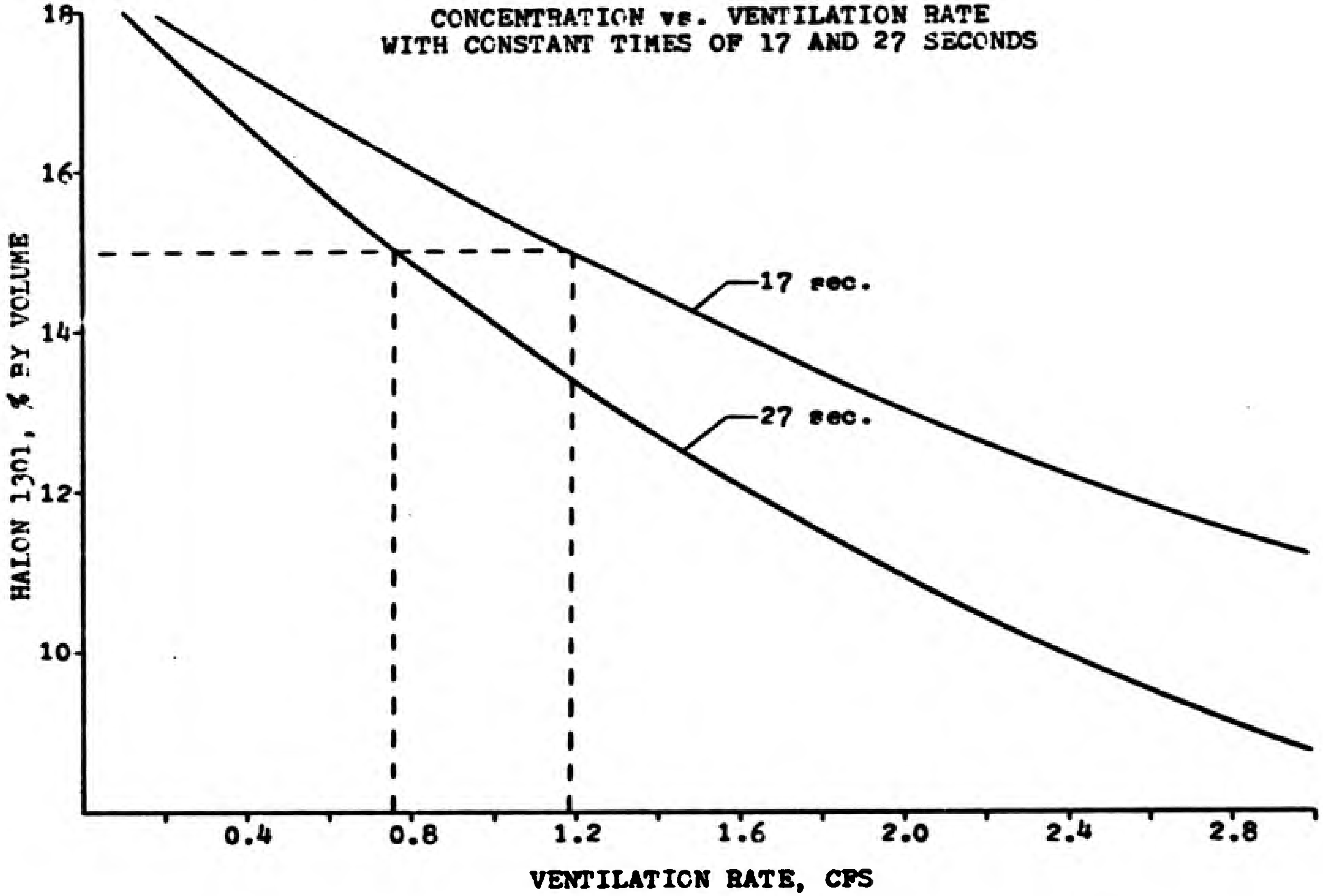


FIGURE 3

CONCENTRATION vs. VENTILATION RATE
WITH CONSTANT TIMES OF 17 AND 27 SECONDS



minimum that can be used and maintain the 15% concentration.

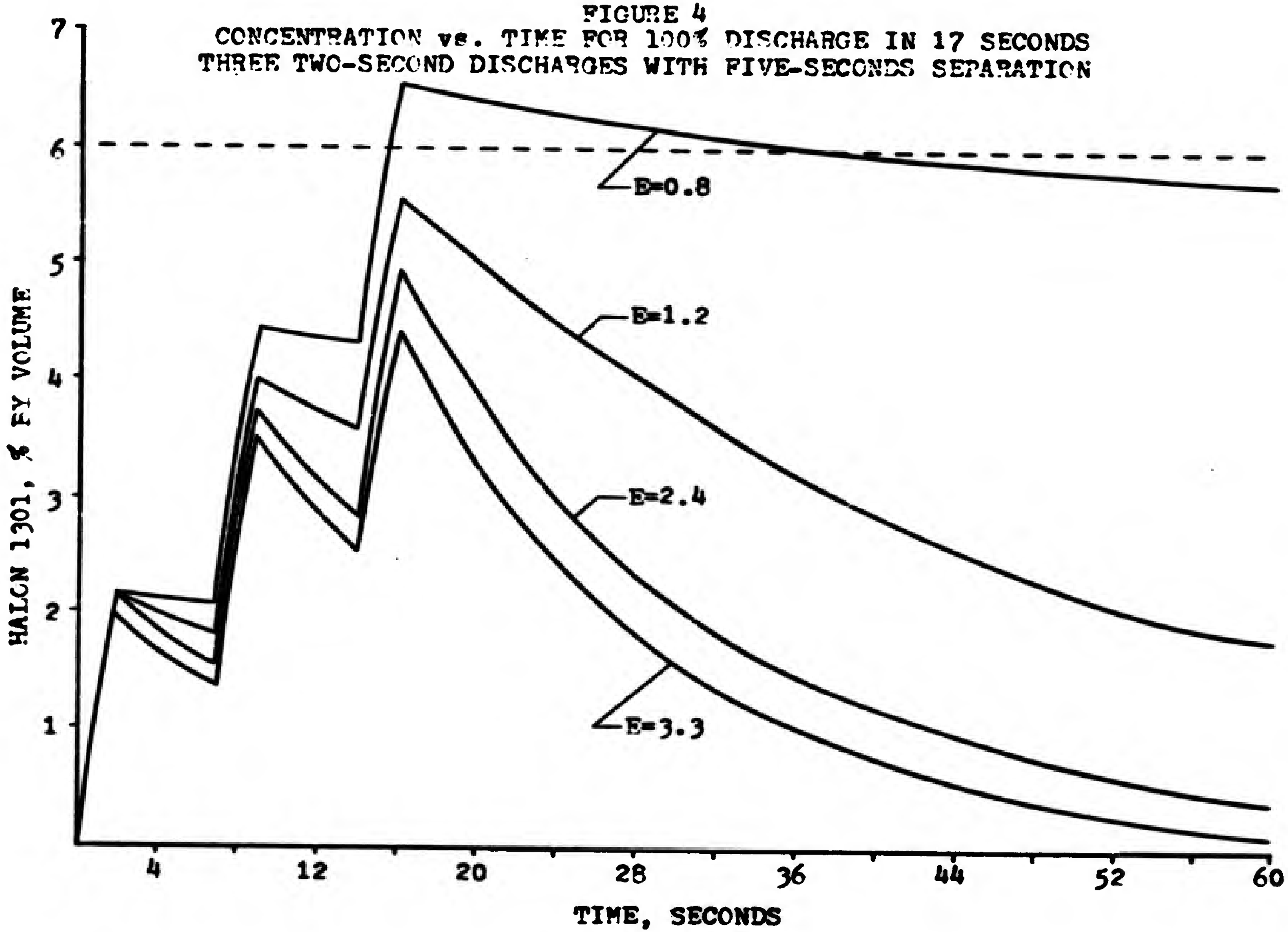
To obtain a more realistic idea of the potential agent concentrations in the cockpit during an extinguisher discharge a hypothetical situation was developed. The extinguisher was discharged three times for two seconds duration each with a five second separation with no agent being discharged.

Figure 4 shows the concentration-time relationship for this situation. Ventilation rates of 0.2, 1.2, 2.4, and 3.3 cfs were used with equations 4.2 and 4.4 when a total discharge of the extinguisher would occur in 17 seconds. It is observed that only a flow rate of 0.2 cfs will cause the concentration of Halon 1301 to exceed the 6% level for a period of approximately 20 seconds. A flow rate of 0.2 cfs could be considered as a "natural" flow rate, that is, the normal leakage of air through the cockpit when the ventilation is not operating.

All calculations in this chapter used either 95% or 100% extinguisher discharge with a 17 or 27 second discharge duration. When the extinguisher is used for shorter durations (i.e. 8 seconds) than those presented here, the expected concentration of Halon 1301 will be significantly less than that shown by Figures 1 and 2.

So far this evaluation has only been concerned with

FIGURE 4
CONCENTRATION vs. TIME FOR 100% DISCHARGE IN 17 SECONDS
THREE TWO-SECOND DISCHARGES WITH FIVE-SECONDS SEPARATION



the ECS operating. Another case that must be considered is when both the ECS and backup system are shut off. The pilot has the option of leaving his seat cushion ventilation on when the others are shut off. If this is the case, it is questionable whether the 1.2 cfs minimum value is maintained. When the extinguisher is discharged with this condition existing, concentrations greater than 15% would be reached in a shorter time and the clearing rate decreases as the ventilation rate decreases.

For a realistic evaluation of the hazards involved in the cabin area, all aspects leading up to an extinguisher discharge must be considered. Since the electrical system is the primary area where fire can occur, it is the main area of concern. When fire does occur in this system, the smoke and fumes produced are in such quantities that vision would be reduced to near zero conditions. The standard procedure for this condition is to throw the main circuit breaker, then slow the helicopter to 40 knots (46 mph) and open both the pilot's and copilot's doors. This eliminates all power to the electrical system and provides a free flow of fresh air through the cockpit to remove the smoke and fumes. If the extinguisher was discharged at this time, the concentration levels would be far less than those reached with the ECS operating.

Chapter V discusses the use and requirements of the fire extinguisher for the past and present time period.

CHAPTER V

EXTINGUISHER USE AND NEED

At the present time there is a difference of opinion as to the need and placement of the hand portable fire extinguisher for single place and tandem seating two place aircraft. The Air Force feels that it is not necessary to have an extinguisher located in the cockpit of such aircraft. On the other hand, the Army requires that all aircraft have an extinguisher accessible to the crew at all times. This difference of opinion can be more fully understood by looking at the different types of aircraft flown by both the Army and Air Force.

The Air Force flies fixed winged jet powered aircraft that are covered by their design criteria. These planes require a runway for landings and takeoffs which is probably located at an Air Force base. Ground personnel are present to service the aircraft as well as watch for any malfunction during start-up. If a fire should occur at this time, fire extinguishers are available for use.

If a fire occurs during flight, the action taken depends on the location of the fire. For engine fires the pilot has the capability of discharging the engine extinguisher system which eliminates the fire and also the power. If the fire is located in the cockpit, the pilot can shut off all electrical power to determine if the fire is electrical. If so, he has essentially stopped the burning since the cockpit material will not sustain combustion. When the fire is located somewhere else on the aircraft, there is not much that the pilot can do to extinguish or control the fire. In the case where the pilot cannot control or eliminate the fire, or he looses his engine, he must try to land the aircraft if possible. If nothing can be done to save the aircraft, the pilot uses the ejection system and leaves the disabled plane.

The Army aircraft that could be included in the Air Force design criteria is the AH-1 (Cobra) series helicopter, since it is a tandem seating two place aircraft. The Cobra, being a rotor wing aircraft, has the capability of landing and taking off from almost anywhere. When the Cobra is at its base of operation flight personnel are present at refueling and during the startup procedure watching for any malfunction, such as fire. While on the ramp, flight personnel have easy access to fire extinguishers if the need arises. The problem exists with the Cobra's capability to land at remote sites, as was the case in VietNam to take on fuel. The extinguishers used by the ground personnel were not always within reach when needed, so the extinguisher from the cockpit had to be used.

Another case to consider is when the pilot is forced to land because of a false indication from a warning light. The pilot would make an emergency landing and shut the helicopter down. After physical inspection of the area indicated by the warning light, if no valid indication is found that a problem exists, then the pilot can restart the helicopter and return to base. As required by Army regulation, there must be a fire guard present when an aircraft is started.

The Cobra, like most single engine aircraft, is not equipped with an engine compartment extinguishing system. Since there is the possibility of landing and shutting the Cobra down at a remote sight, it would seem ironic to post a fire guard during starting and not have an extinguisher present.

To determine the actual need for the fire extinguisher another factor that could be considered is the past data on extinguisher use. Maintenance action data collected on the hand portable fire extinguisher, FSN 4210555 8837, used in the Cobra cockpit indicates 19 maintenance actions reported to the Reliability and Maintainability Improvement Techniques (RAMIT) Division, Aviation System Command (AVSCOM), St. Louis, Missouri for FY 70. During this time period 158,559 flight hours were recorded for the AH-1G fleet. A maintenance action occurs when a component is removed from the aircraft for any reason. At this time a failure code is assigned to each removal. The failure codes for the 19 actions were checked to see if there were any removals for low pressure. There were six different codes recorded and none indicated low pressure which would be assumed to mean that the extinguisher had discharged.

Assuming that the best failure code was not used to describe the removal, data collected by the United States Army Agency for Aviation Safety (USAAAVS), Ft. Rucker, Alabama was also studied. This data covered the period from FY 71-FY 74 and indicated an in-flight fire with extinguisher used. Two cases occured for this condition, but upon further investigation by USAAAVS it was found that neither case involved in-flight fires nor did they involve the Cobra.

Chapter VI will summarize and conclude this paper.

CHAPTER VI

CONCLUSIONS AND RECOMMENDATIONS

As shown in Chapter V, the portable extinguisher does not have a high usage rate. From the maintenance data obtained at AVSCOM, only 19 actions in 158,559 flight hours were recorded during FY 70 for the extinguisher. None of the 19 actions indicated that the extinguisher was removed for low pressure, which would indicate a discharge. The data collected by USAAAVS for the time period FY 71-74 did not indicate any in-flight fire with extinguisher use.

Since a fire in the cockpit would generate a large quantity of smoke, the prime concern is to rid the cockpit of the smoke. A fire which is not in the electrical system would be of such magnitude that the portable extinguisher would have no significant effect for the extinguishment of this type of fire.

It is concluded by this study that the Air Force design criteria prohibiting the location of a hand portable extinguisher in the cockpit of single place and tandem seating two place aircraft is applicable to the Army AH-1 helicopter.

It is recommended that the feasibility of locating the extinguisher in an access bay be studied, since there has been certain situations when the extinguisher has been used on the ground. The location of the extinguisher should be in such a place as to be accessible when the Cobra is laying on its side, as is the case after most crashes.

If an extinguisher is to remain in the cockpit of the AH-1, it is recommended that Halon 1301 be used as the agent. As determined in Chapter III, Halon 1301 exhibited the best qualities of the agents studied. It has an approximate lethal concentration of 800,000 PPM (natural vapor) for a 15 minute exposure rate and a 5 minute emergency exposure limit of 60,000 PPM.

Figure 3 shows the concentration vs. ventilation rate for constant times of 17 and 27 seconds. Using this figure, it can be seen that ventilation rates of 1.2 and 0.8 cfs are needed to maintain a concentration of 15% maximum for 17 and 27 seconds respectively. Figure 1 illustrates the concentration-time relationship during and after extinguisher discharge for ventilation rates of 1.2 and 3.3 cfs for 100% discharge in 17 seconds. All this establishes the point, that with a ventilation rate between 1.2 and 3.3 cfs and 100% extinguisher discharge in 17 seconds, no crewmember will receive an over exposure to Halon 1301.

Figure 2 shows the same relationship, but for a 27 second discharge duration. At ventilation rates of 1.2 cfs or more, there is no danger of over exposure of Halon 1301. When the ventilation rate is at 0.8 cfs there is not sufficient flow to remove the Halon 1301 to the acceptable limit within 60 seconds, therefore, low flow rates are not recommended.

One problem might arise with the assumption that ventilation will be used, since the pilot has the capability of regulating all cabin ventilation. Because all crewmembers are required to wear Nomex (fire resistant) flight clothes and protective helmets, it is only logical that ventilation will be used to remove the stuffiness and heat inside the all glass canopy cockpit.

All calculations, graphs, and tables pertaining to the concentration-time relationship were computed using a discharge of 100% and 95% agent. In actuality, if a cabin fire occured it would not be of the magnitude that would require a continuous discharge of the extinguisher. Therefore, with a ventilation rate of 1.0 cfs or greater the concentration obtained in the cabin would not cause any danger to the crew. Figure 4 illustrates this point by showing the concentration received from three two second duration discharges.

The last conclusion concerning the potential concentration in the cabin deals with the procedure used when smoke is detected in the cockpit. The standard procedure is to cut the main circuit breaker for all electrical power and slow the helicopter to 40 knots (46 mph), then open both the pilot's and copilot's doors and proceed until the smoke is cleared. If the extinguisher was discharged at this time the concentration would be far below any level of danger. What could be considered as an added safety factor is the fact that Halon 1301 is five times heavier than air. Any agent concentration that wasn't removed by the large quantity of air flowing through the cockpit would remain at the lower portion of the cabin out of the breathing zone of the crew.

An assumption that was made before the agent concentration could be calculated was that the cockpit be considered a totally flooded area. For the cockpit to actually be a totally flooded area there would need to be multiple discharge points for the extinguishant. Since the AH-1 has only one extinguisher, the cockpit would not be a totally flooded enclosure in the strictest sense. Therefore, all values of extinguishing agent concentration presented in the graphs of Chapter IV are higher than those values that would actually be received.

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