Simulating the Distribution of Halon 1301 in an Aircraft Engine Nacelle With HFC-125

Douglas A. Ingerson

August 1999

DOT/FAA/AR-TN99/64

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U.S. Department of Transportation
Federal Aviation Administration

NOTICE

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
DOT/FAA/AR-TN99/64		

4. Title and Subtitle	5. Report Date
SIMULATING THE DISTRIBUTION OF HALON 1301 IN AN AIRCRAFT ENGINE NACELLE WITH HFC-125	August 1999
	6. Performing Organization Code
7. Author(s)	8. Performing Organization Report No.
Douglas A. Ingerson	
9. Performing Organization Name and Address	10. Work Unit No. (TRAIS)
Fire Safety Section Federal Aviation Administration William J. Hughes Technical Center Atlantic City International Airport, NJ 08405	11. Contract or Grant No.
12. Sponsoring Agency Name and Address	13. Type of Report and Period Covered
U.S. Department of Transportation Federal Aviation Administration Office of Aviation Research Washington, DC 20591	Technical Note
	14. Sponsoring Agency Code ANM-112

15. Supplementary Notes

16. Abstract

The primary fire suppressant used in commercial aircraft engine nacelles and auxiliary power units is Halon 1301. The period of fire suppression system development and its certification testing may be an arduous task requiring the discharge of substantial quantities of fire suppressant. Additionally, to demonstrate compliance with federal regulations, engine nacelle fire suppression systems are discharged in flight or at varying conditions simulating flight. These tests are recorded and evaluated with specialized gas analysis equipment. Currently, the certification process requires releasing Halon 1301 to accomplish such approvals.

Based on the Montreal Protocol and its amendments, the halon family of fire suppressants has been eliminated from production. This action is in response to the destructive capacity of halon with respect to the ozone layer within the atmosphere. This technical note describes a procedure for utilizing an ozone-friendly simulant during fire suppression system development and certification testing. It demonstrates a realistic potential to eliminate the release of Halon 1301 for purposes other than actual fire suppression. This step is perceived as an interim process to assist with the reduction of Halon 1301 release during the transition to chemicals which meet the intent of the Montreal Protocol.

17. Key Words	18. Distribution Statement
Halon 1301 simulation, Aircraft engine nacelle, Certification, Fire extinguishment, Gas distribution, HFC-125, Extinguishing agent concentration recorder, Pentafluoroethane	This document is available to the public through the National Technical Information Service (NTIS), Springfield, Virginia 22161.

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	29	N/A

Form DOT F1700.7 (8-72) Reproduction of completed page authorized

ACKNOWLEDGEMENTS

The author wishes to express gratitude to the following:

Mr. Mark Kay of the Boeing Company for providing the ability to evaluate Halon 1301 simulation further; Mr. William Leach and Mr. Marco Tedeschi of the United States Navy; and Mr. William Meserve, Mr. Duane Van Ostrand, and Mr. Don Yang of Pacific Scientific HTL/Kin-Tech for continual support of the Halonyzer II.

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EXECUTIVE SUMMARY

Halogenated fire suppressants, members of the ozone depleting substances governed by the Montreal Protocol and its amendments, have been eliminated from domestic U.S. production. Quantities are currently recycled and stored for future use. Further, future use will likely be restricted. The Federal Aviation Administration (FAA) William J. Hughes Technical Center has compared results from testing by FAA, industry, and other US Government facilities and concluded that the use of HFC-125 as a simulant in place of Halon 1301 affords an applicant with an acceptable, environmentally friendly regulatory alternative to fire suppressant testing with Halon 1301. This report recommends that the FAA take immediate action to provide guidance to industry on the use of HFC-125 as a fire extinguishing simulant.

At this time, the primary fire suppressant used in commercial aircraft engine nacelles is Halon 1301. The period of fire suppression system development and its certification testing may be an arduous task requiring the discharge of substantial quantities of fire suppression agent. Further, to demonstrate compliance with federal regulations, engine nacelle fire suppression systems are discharged in flight or at varying conditions simulating flight. Between 4 and 8 pounds of Halon 1301 are vented into the atmosphere for each fire zone test. These tests are recorded and evaluated with specialized gas analysis equipment. Currently, the certification process requires releasing Halon 1301 to accomplish such approvals.

Work by the United States Navy (USN), National Institute of Standards and Technology (NIST), Kidde Technologies Incorporated, the Boeing Company, and Shorts Brothers PLC have demonstrated HFC-125 is a viable chemical to simulate the Halon 1301 discharge characteristics found in an engine nacelle application. Having this background information, personnel at the William J. Hughes Technical Center worked to provide additional data supporting this concept. For the near term, this concept offers the option to minimize the release of Halon 1301 for needs other than actual fire suppression activities.

INTRODUCTION

PURPOSE.

In a typical test program, approximately 4 to 25 pounds of Halon 1301 are discharged to the atmosphere in an effort to demonstrate compliance with Federal Aviation Administration (FAA) regulations. This release frequently constitutes a single test to achieve certification. Larger quantities are released during fire suppression system development.

Some of the current efforts in aircraft fire protection involve reducing the use of or replacing the current halogenated fire suppressants. In support of this direction, additional data has been generated to illustrate the concept of using HFC-125 as a simulant for Halon 1301 during an engine nacelle discharge test. Potential applications for using this concept exist in system development and certification testing for fire suppression systems in aircraft engine nacelles. The procedure described here for using HFC-125 to simulate the distribution of Halon 1301 within an aircraft engine nacelle is explicitly just for that purpose. As currently understood, this procedure has nothing to do with predicting a quantity of HFC-125 for use in fire extinguishment.

BACKGROUND.

With the restrictions for using ozone depleting substances potentially increasing, others have worked to find and evaluate a chemical currently deemed environmentally acceptable to demonstrate Halon 1301 distribution within an aircraft engine nacelle during agent discharge. This work demonstrated HFC-125 is an adequate simulant for Halon 1301 in the engine nacelle environment. William J. Hughes Technical Center personnel have collected additional data which further supports the use of HFC-125 as a simulant.

DISCUSSION

DEVELOPMENT OF A SIMULANT.

RECENT HISTORY. To be deemed acceptable with respect to the Federal Aviation Regulations, a Halon 1301 suppression system must effectively distribute agent within an engine nacelle. The current level of safety has been historically defined as a quantity of Halon 1301 providing a volumetric concentration of 6% for a duration of one-half second throughout the protected zone within the nacelle. Work is occurring which will lead to the eventual replacement of Halon 1301 as the primary fire suppressant in an engine nacelle. However, at this time, Halon 1301 remains the suppressant of choice. Although minimal information on the near-term replacement of Halon 1301 is available for the commercial engine nacelle, the suppression system development and certification processes offer an opportunity to reduce the use of Halon 1301 by using a simulating chemical in its place.

Through 1994-95, the United States Navy (USN) contracted the National Institute of Standards and Technology (NIST) to determine an acceptable chemical which would be capable of simulating Halon 1301 during an aircraft engine nacelle discharge (Womeldorf and Grosshandler, 1995). The recommendation was based on screening materials in two separate material databases and experimentally testing the final three candidates. NIST recommended HFC-125 as the desired simulant for Halon 1301 (Womeldorf and Grosshandler, 1995, p. 605). Additionally, the USN contracted Kidde Technologies to evaluate HFC-125 further (Mitchell, 1994; Mitchell, 1995). During this same time frame, Shorts Brothers PLC of Ireland (Riordan, 1995) and the Boeing Company (Kaufmann et al., 1995) also pursued using HFC-125 as a simulant for Halon 1301 during engine nacelle discharge testing. Simply stating the collective results, HFC-125 has the ability to travel plumbing, vaporize, and disperse in a manner very similar to Halon 1301 when stored and delivered in a certain fashion.

MILITARY SPECIFICATION MIL-E-22285. The United States Navy has acted strongly enough regarding simulating halon distribution that they have amended military specification MIL-E-22285 (1996) to reflect the use of HFC-125 in place of Halon 1301 for qualification (certification) demonstration.

> 4.3.2.2 Distribution Testing - Under actual or simulated cruise conditions, the system shall be discharged, and compliance with 3.8 shall be verified by use of an appropriate method for measuring agent concentration. Bromotrifluoromethane (CF_3Br, halon 1301) shall not be used to conduct the discharge test. Instead, pentafluoroethane (CHF_2CF_3, HFC-125) shall be the only approved halon 1301 simulant during discharge testing. Simulant concentration and discharge duration shall meet the requirements of 3.8 and 3.9, respectively.

The military specification further describes the conditions to use HFC-125 as a simulant for Halon 1301.

> 4.3.2.2.1 Simulant fill parameters. The discharge test cylinder(s) shall be filled with pentafluoroethane to an amount equivalent to 77 percent of the actual suppression system agent weight, based on an equivalent liquid fill ratio of the halon 1301 bottle being simulated. Nitrogen pressurization of the test cylinder(s) shall be equivalent to that of the actual suppression system cylinder.

Cumulative work to this point has shown HFC-125 is a viable simulant to demonstrate Halon 1301 distribution in an engine nacelle fire suppressant system. Guidance describing the specifics of performing the bottle fill is available. However, one potential issue affecting the data for such a simulant test is the operation of the gas analysis equipment.

ADDITIONAL HFC-125 SIMULANT CONSIDERATIONS AND INFORMATION.

GAS ANALYSIS EQUIPMENT. The primary gas analysis methodology for the engine nacelle environment is pressure dependent. The analyzers are based on a pressure transducer sensor arrangement formerly produced by the Statham Instrumentation Company (New and Middlesworth, 1953; Demaree and Dierdorf, 1959). The sensors are found in either an original Statham analyzer or the Pacific Scientific/HTL Kin-Tech Halonyzer II. Either analyzer is capable of being calibrated for binary gas mixtures of which one constituent is air, as in the cases of HFC-125 and Halon 1301 nacelle distribution tests.

Each binary gas mixture has a unique calibration curve. Test data from Statham-derivative analyzers are then converted into a useable format by mathematical manipulation of relative measurements against this calibration curve, which is created prior to testing. When performing a Halon 1301 test, a calibration curve for Halon 1301 would be referenced to produce a volumetric concentration profile for that test. Likewise, for a test with HFC-125, reference to the HFC-125 calibration information is considered the normal approach.

Consider a simulation test for Halon 1301 using HFC-125. The subtlety of the test data accurately portraying the volumetric concentration profile lies in the manipulation of that same data. While performing an HFC-125 simulant test to determine the Halon 1301 distribution, an analyzer operator would have the choice of producing an HFC-125-based volumetric concentration profile as converted by reference to either the HFC-125 or Halon 1301 calibration curve.

The Boeing Company and Shorts Brothers PLC have each produced simulant test data using Statham-derivative analyzers. The methods to produce volumetric concentration profiles describing the Halon 1301 distribution varied between evaluations for each company. For the Shorts Brothers PLC effort, eight tests were run. The analyzer was operated by Kidde Technologies. Four of these tests were HFC-125 discharges to simulate the Halon 1301 distribution. Of these four tests, the data presented were left in their relative concentration format; therefore, they were not subject to considerations of conversion to volumetric concentration. During the Boeing effort, eight tests were run using there own Pacific Scientific HTL/Kin-Tech Halonyzer II analyzer. For this effort, four Halon 1301 tests and four HFC-125 discharges were captured. For each HFC-125 test, the data were converted with the calibration curve for Halon 1301. The resultant volumetric concentration profiles then were corrected to an effective HFC-125 volumetric concentration profile which was then treated as an equivalent to the Halon 1301 certification criteria (Kaufmann et al., 1995, pp. 214-216).

<u>APRIL 1998 TEST CONFIGURATION AND METHOD</u>. William J. Hughes Technical Center personnel have recently been involved in nacelle fire suppression system development work by providing gas analysis data to the USN. During an April 1998 visit, a series of two tests were run back to back. One test was a Halon 1301 discharge and the other was an HFC-125 discharge. The statistics for the test conditions are given in table 1. The HFC-125 test was configured to simulate the Halon 1301 test. Each charge was delivered to the same compartment at the same test conditions through the same plumbing. The gas analyzer used was a Pacific Scientific HTL/Kin-Tech Halonyzer II (serial number one). The analyzer was calibrated that morning for both Halon 1301 and HFC-125 in accordance with manufacturer specifications. Each test was recorded with the calibration curve matching the gas discharged. The volumetric concentration data were taken from the analyzer by computer communication port and then arranged with computer software resulting in the final graphs.

The graphs illustrating the comparison between the agents are shown by clusters of three analyzer channels. The channel clusters for each agent on each graph are offset along the time axis for clarity. These graphs are presented as figures 1 through 4. The concentration profiles across the 12 analyzer probes for each test are shown in figures 7 and 8. For purposes of quantitative comparison, data are listed in table 2 and graphically presented in figures 5 and 6.

APRIL 1998 TEST RESULTS. The qualitative comparisons are readily identifiable. As seen when comparing the concentration profiles found in figures 1 through 4, the results are striking. The similarity between agents is also demonstrated readily by the overall concentration profiles, as shown by figures 7 and 8. With small deviation, the traces from either test can be seen to describe each agent both in the growth and decay phases of the distribution in a nearly one-to-one aspect. The peak values between each agent are also comparable.

Quantitatively, three characteristics have been used to evaluate the comparison of these two tests. The results are tabulated in table 2.

1. Initial concentration growth during agent discharge was evaluated for both agents. This was done by determining elapsed times from the zero concentration baseline to the 4, 6, 8, and peak percentage concentration values for all channels for both agents. These times are compared between agents for each channel.

2. The peak concentration values for all channels for both agents was determined and compared.

3. The elapsed time each channel equaled or exceeded 6 percent volumetric concentration was calculated and compared for all channels for both agents.

Between the agents, the variation in elapsed time for each channel to pass through the post-discharge growth phase is calculated to be an average difference of 23 milliseconds. Regarding the peak concentration values between the agents, the variation across the channels is calculated to be an average difference of 0.27 percent volumetric concentration. The variation between agents associated with the time each channel was at or above 6 percent volumetric concentration is calculated to be an average difference of 175 milliseconds. When considering the values in table 2, negative values indicate the HFC-125 data were actually smaller in magnitude in either duration or concentration; a positive value indicates the opposing condition. In summary, for this pair of tests, the largest absolute differences between the agents reflect 0.3 second and 0.7 percent volumetric concentration.

When looking at the data in table 2, it is noted that the average behavior of HFC-125 is slightly conservative; having a lower concentration profile when compared to Halon 1301. This concept is illustrated by noting the average difference in the elapsed times during the agent concentration growth fluctuating between -150 and +225 milliseconds. The cumulative average of these differences across all 12 channels is -23 milliseconds, which is approaching zero. Generally, this indicates the growth between the agents in this environment is sufficiently similar. However, the strongest support for the slight conservative behavior is noted when considering the comparisons between the peak concentration values and the elapsed times the agents are at or above 6 percent volumetric concentration. Regarding the peak concentration values, with the exception of two channels, the maximum HFC-125 values are smaller than the corresponding Halon 1301 values. The worst case is a difference of 0.7 percent volumetric concentration. For the elapsed times each agent is at or above 6 percent volumetric concentration, the differences in value do not exceed 0.3 second, again with Halon 1301 exceeding the HFC-125 values. On average, the values indicate HFC-125 performed more conservatively than Halon 1301. However, since the magnitude of these differences is small enough, HFC-125 can be seen to effectively mimic Halon 1301 in this application when evaluated as described.

Based on this data and prior work, the procedure for performing a suppression system discharge test by using HFC-125 as a simulant for Halon 1301 would require the following.

1. The agent bottle would be loaded with HFC-125 to a weight equaling the desired Halon 1301 charge weight multiplied by a factor of 0.77. The bottle would then be super pressurized with nitrogen, just as the associated Halon 1301 bottle would be.

2. Conduct the test in the manner needed.

3. Gathered relative data from a Statham-derivative analyzer would then be converted by calibration data specific to HFC-125 to produce the volumetric concentration profile for the associated discharge test.

4. The performance of the HFC-125 distribution would then be evaluated at the same criteria as that for Halon 1301, 6 percent volumetric concentration for the half-second duration. The acceptability of the tested fire suppression system would be determined, dependent on the distribution profile found in 3, when compared to the current Halon 1301 acceptance criteria.

By following these procedures, the expected behavior of HFC-125 would reasonably mimic Halon 1301 and provide an adequate indication for its distribution. Regarding the demonstrated conservatism of HFC-125, it would not be expected to adversely impact the expected Halon 1301 weight required to meet the intent of the applicable aviation regulations.

<u>HISTORICAL TEST DATA REVIEW</u>. HFC-125 was observed to behave conservatively with respect to Halon 1301 during the April 1998 testing. However, the error is not so significant to preclude one-to-one comparisons between HFC-125 and Halon 1301 when considering the distribution of an engine nacelle fire suppression system. During the on-going effort of halon replacement, a historical review of pertinent aspects related to engine nacelle fire suppression has taken place. Several reports provide agent distribution profiles for specific nacelles (Sommers, 1970; Chamberlain and Boris, 1987; Kaufmann et al., 1995). The purpose here is to illustrate that HFC-125 will readily indicate the success or failure in some of the historical test data currently available. The primary historical comparisons will be a function of using older, publicly available data generated by the Federal Aviation Administration and making inferences from this data based on the April 1998 testing. A brief discussion is provided regarding the work of Mr. Kaufmann et al. illustrating further simulant success. Regarding FAA data, there are assumptions built into this discussion.

1. Although the analyzers used to generate the historical profiles presented and the more recent April 1998 testing were not the same units, the principle operating concepts are identical. Therefore, proportional relationships for measurements and associated errors can be used to relate the analyzers and are considered a legitimate tool to illustrate the concept of Halon 1301 simulation.

2. Based on results from the April 1998 testing, the exponential growth of each agent is treated as though they are the same.

3. The profiles used in this discussion will be treated in a manner where the effects of HFC-125 altering an existent Halon 1301 profile do so in a uniform manner across all channels.

The differences between HFC-125 and Halon 1301 distribution profiles observed during the April 1998 testing, as seen in table 2, ranged between ±300 milliseconds and -0.7/+0.1 percent volumetric concentration. By applying these tolerances to some historical concentration profiles, figures 9 through 13, it can be seen that HFC-125 presents a viable option to preclude test-based Halon 1301 discharges.

The analysis based on this historical data addresses three cases when considering Halon 1301 simulation. These cases are used to illustrate the impact on the predictive ability of HFC-125 from the worst-case differences between the Halon 1301 and HFC-125 distributions. Specifically, the cases are the successful, faulty, and marginally successful Halon 1301 nacelle distribution tests.

The first case is a condition where the HFC-125 distribution negates an amply acceptable Halon 1301 distribution. An ample distribution is considered a typical exponential growth/decay profile that adequately meets the certification criteria by a large margin. When considering the concentration profiles presented as figures 9 through 11, for an HFC-125 concentration profile to falsely indicate a compliant Halon 1301 distribution would require the HFC-125 profile to fall far short of the Halon 1301 profile. The opposing condition of HFC-125 overexaggerating the Halon 1301 profile is not critical for this situation.

Figure 9 provides the most constraining test in these examples. By this example, the Halon 1301 relative concentration profile exceeded the certification criteria by a factor of 1.4 with respect to concentration. Likewise, at the certification concentration, the duration was exceeded by a factor of 2.6. These two facts illustrate the Halon 1301 distribution was comfortably larger than the certification criteria and demonstrates the suitability of HFC-125 as a simulant for this case.

Based on Advisory Circular 20-100 (1977), the 15 percent relative concentration seen in figures 9 and 10 corresponds to a volumetric concentration of 6 percent Halon 1301. Key volumetric concentration data are converted from relative concentration data found in figure 9 and plotted against their associated durations in figure 14. The middle trace in figure 14 represents the most restrictive channel with respect to certification found in figure 9, that being channel 7. The alteration of these values by the worst-case HFC-125 differences shifts the trace down and to the left by values of 0.7 percent volumetric concentration and 0.3 second. This provides an approximation for the worst-case HFC-125 simulation of this compliant distribution as 7.3 percent volumetric concentration for a duration of one-half second. In short, the profile provided by an HFC-125 simulation of Halon 1301 would still have predicted an acceptable distribution. Further, by inspection, one can reasonably expect the remaining two profiles shown in figures 10 and 11 to be predicted compliant by using HFC-125 as well.

The second case is a situation where the HFC-125 distribution inflates to falsely indicate an unacceptable Halon 1301 profile as acceptable. The conservative tendency of the HFC-125 distribution with respect to Halon 1301, as seen in the April 1998 testing, indicates this situation is of minimal possibility. However, by inspection of figure 12, one can easily see an HFC-125 profile represented by an overexaggeration of the existing Halon 1301 profile by +0.1 volumetric concentration and 0.3 second, upper bounds from the April 1998 testing, would not produce a falsely complaint Halon 1301 profile.

The third case to consider is the marginally successful Halon 1301 distribution test. Figure 13 illustrates a prime example for this condition. If using HFC-125 to indicate the ability of a Halon 1301 distribution system which is marginal, difficulty will be encountered when evaluating the results and taking the known differences between the chemicals into consideration. Although Halon 1301 and HFC-125 are not the same chemical, cumulative testing to date has shown their respective characteristics are similar enough that HFC-125 may be used to reasonably mimic the distribution of Halon 1301. Yet, there are differences and this must be taken into consideration when evaluating marginally successful agent distributions.

Given a case where a suppression system barely meets certification criteria by demonstration with HFC-125, one should consider the possibility of the suppression system being faulty from the perspective of Halon 1301 distribution. To ensure adequate systemic safety, agent quantity should be increased to allow a reasonable margin of comfort with respect to certification criteria. Specific guidance is not provided as this will frequently be based upon experience and will always depend upon the characteristics of a specific installation. The historical examples provided in figures 9 through 11 are indicative of this practice.

Additional information indicating the predictive ability of HFC-125 regarding Halon 1301 was published by the Boeing Company in 1995. The work involved a Pacific Scientific HTL/Kin-Tech Halonyzer II. The process used to manipulate analyzer data was different than described previously. However, the tangible aspects of storing and delivering the agents remained consistent with simulation procedures previously cited. Although the procedures used to produce and evaluate the distribution profiles from the suppression system were different, they did demonstrate that HFC-125 is a reasonable chemical to use for simulating Halon 1301 distribution. The cumulative effort spanned four pairs of comparative tests and resulted with HFC-125 accurately indicating all Halon 1301 distributions (Kaufmann et al., 1995, pp. 3, 5) with respect to certification criteria.

The results from the Boeing Company successfully demonstrated HFC-125 as a realistic simulant for Halon 1301 in this application. However, the Boeing Company and William J. Hughes Technical Center efforts are subtlety different. The technical difference between the test results produced by either effort lied in the operation of the analyzer. The Boeing Company effort produced all records for the HFC-125 tests while having the Halon 1301 calibration curve resident in the analyzer memory (Kaufmann et al., 1995, p. 3). This forced the creation of an “effective” HFC-125 concentration which was based on the Halon 1301 calibration curve in the analyzer memory at the time of the testing. This “effective” value was then used to evaluate the simulant profiles for acceptable certification. The William J. Hughes Technical Center effort captured each test with the respective calibration curve resident in the analyzer memory. By performing the testing in this manner, no “effective” HFC-125 concentration was required to perform the evaluation. The evaluation was made directly against the time and concentration parameters of the certification criteria.

Additional investigation of this concept is planned during the initial phase of the engine compartment portion of the Halon Replacement Project underway at the FAA William J. Hughes Technical Center. Varying conditions such as fire extinguisher bottle fill density, temperature, and pressurization will be investigated.

CONCLUSIONS

1. As illustrated by these test results, observations, and historical review, the concept of simulating the distribution of Halon 1301 by using HFC-125 in accordance with prescribed procedures is viable.

2. The prescribed procedures for performing an HFC-125 simulation test for a Halon 1301 distribution in an engine nacelle are:

    a. The agent bottle is loaded with HFC-125 to a weight equaling the Halon 1301 weight multiplied by a factor of 0.77.

    b. Pressurize the bottle with nitrogen, just as the associated Halon 1301 bottle would be.

    c. Conduct the nacelle distribution test in the manner required.

    d. Relative data gathered from a Statham-derivative analyzer are converted by calibration data specific to HFC-125 to produce the volumetric concentration profile for the associated discharge test.

    e. The acceptability of the fire suppression system is determined by the HFC-125 distribution profile found in 2.d. above when compared to the current Halon 1301 acceptance criteria of 6 percent volumetric concentration for a duration of one-half second.

3. This concept offers an interim opportunity to reduce halon emissions during certification and system development testing.

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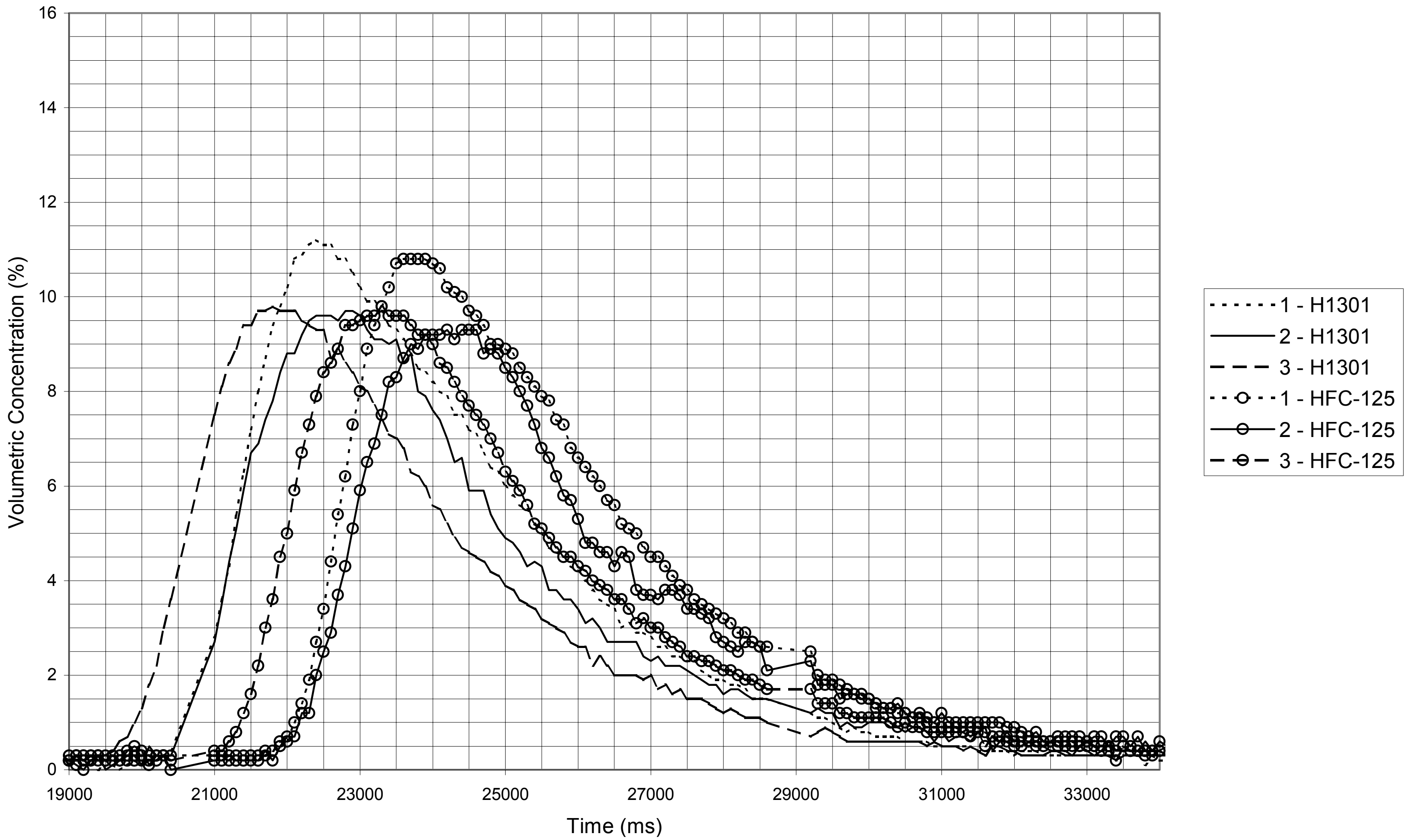

FIGURE 1. HFC-125 AND HALON 1301 COMPARISON, CHANNELS 1-3

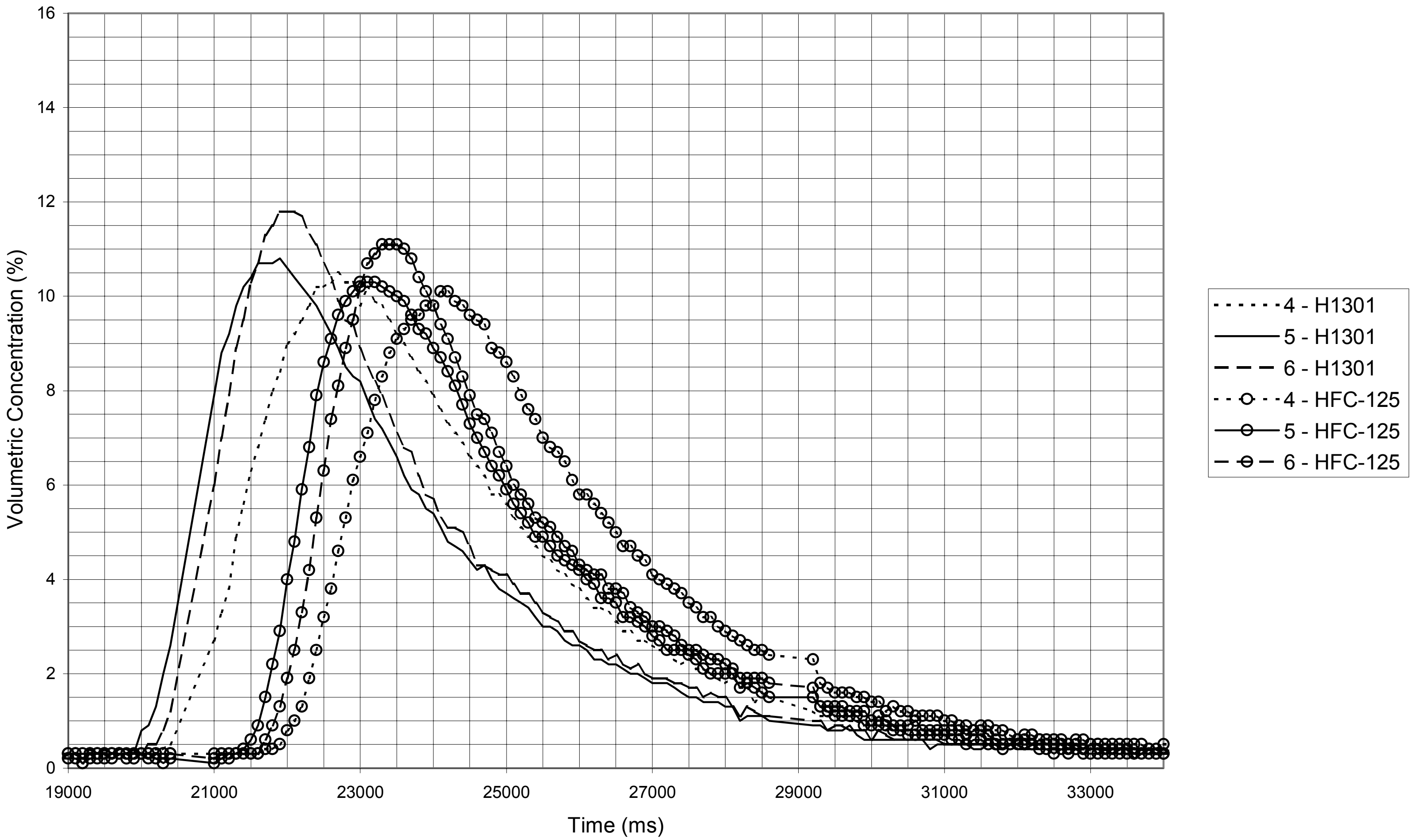

FIGURE 2. HFC-125 AND HALON 1301 COMPARISON, CHANNELS 4-6

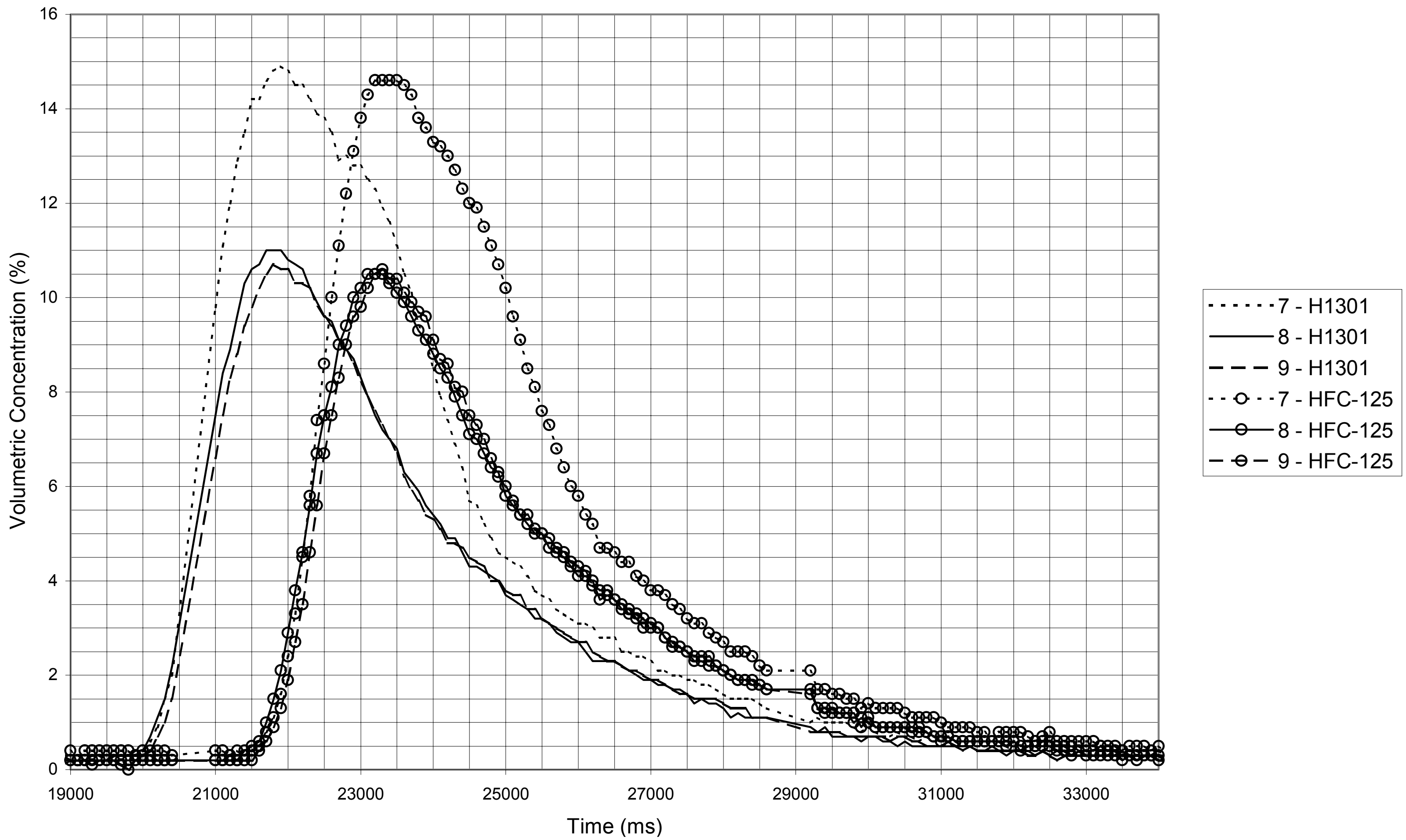

FIGURE 3. HFC-125 AND HALON 1301 COMPARISON, CHANNELS 7-9

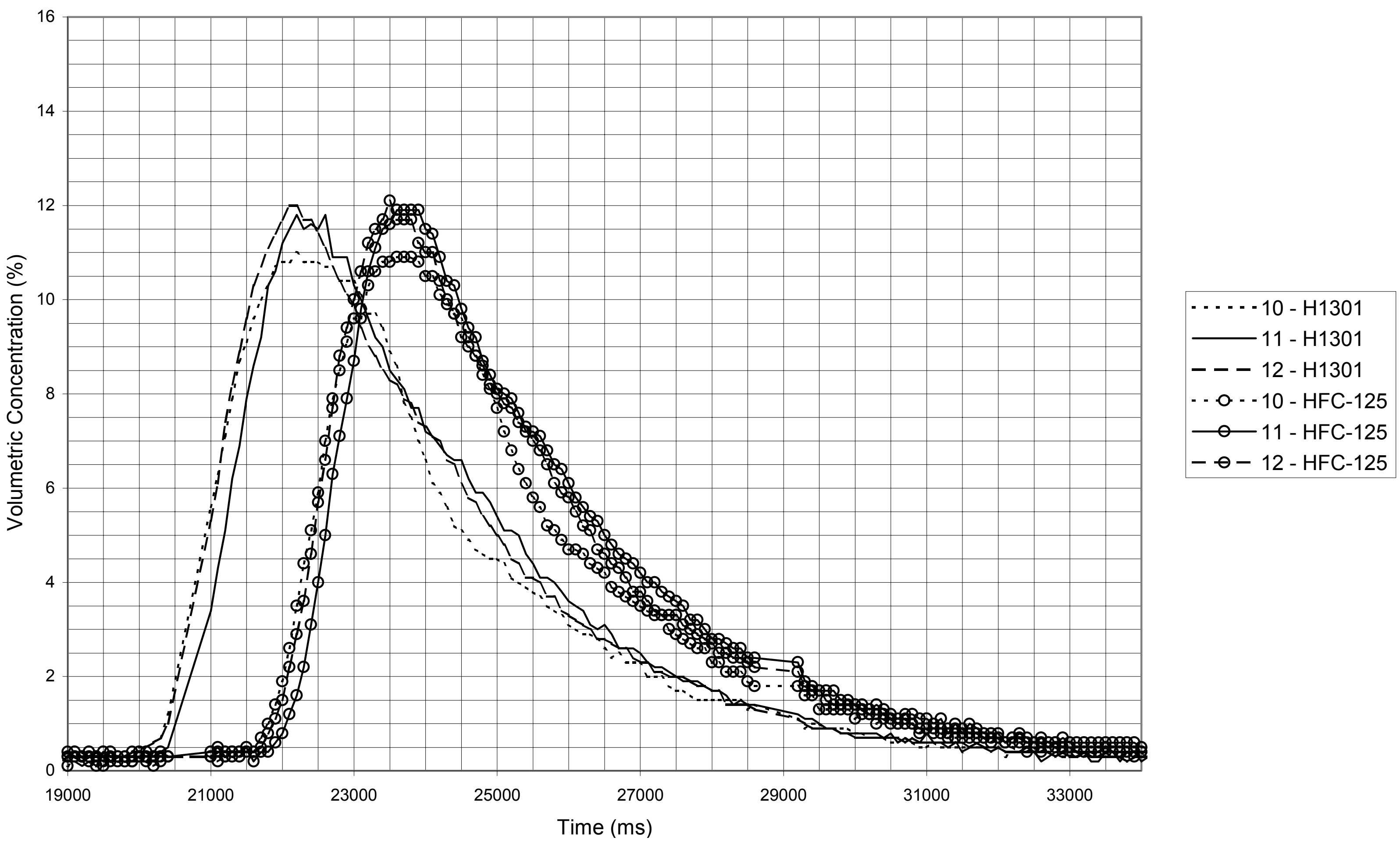

FIGURE 4. HFC-125 AND HALON 1301 COMPARISON, CHANNELS 10-12

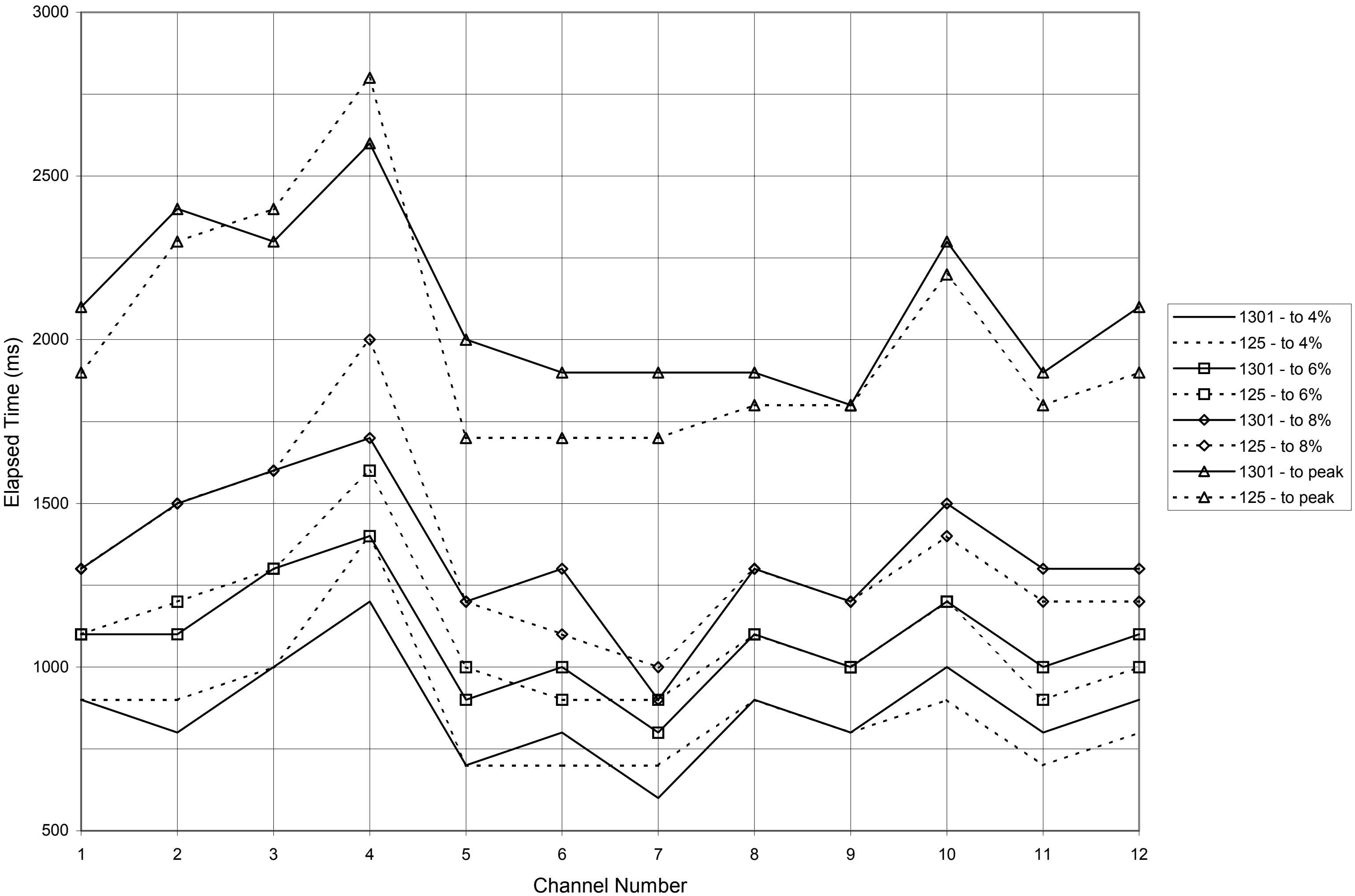

FIGURE 5. COMPARISON OF ELAPSED TIMES DURING POST-DISCHARGE EXPONENTIAL GROWTH

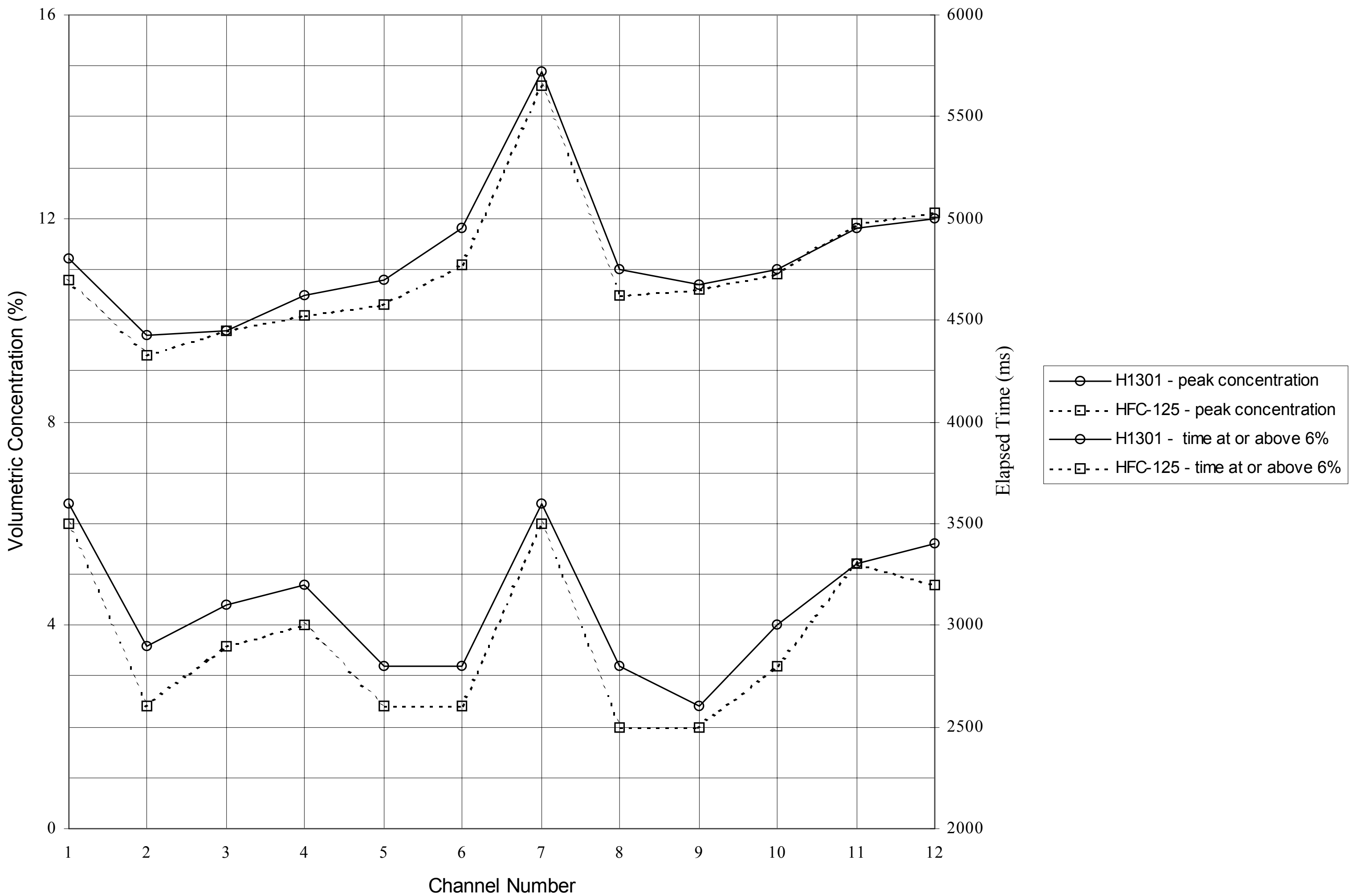

FIGURE 6. COMPARISON OF PEAK CONCENTRATIONS AND COMPLIANT ELAPSED TIMES

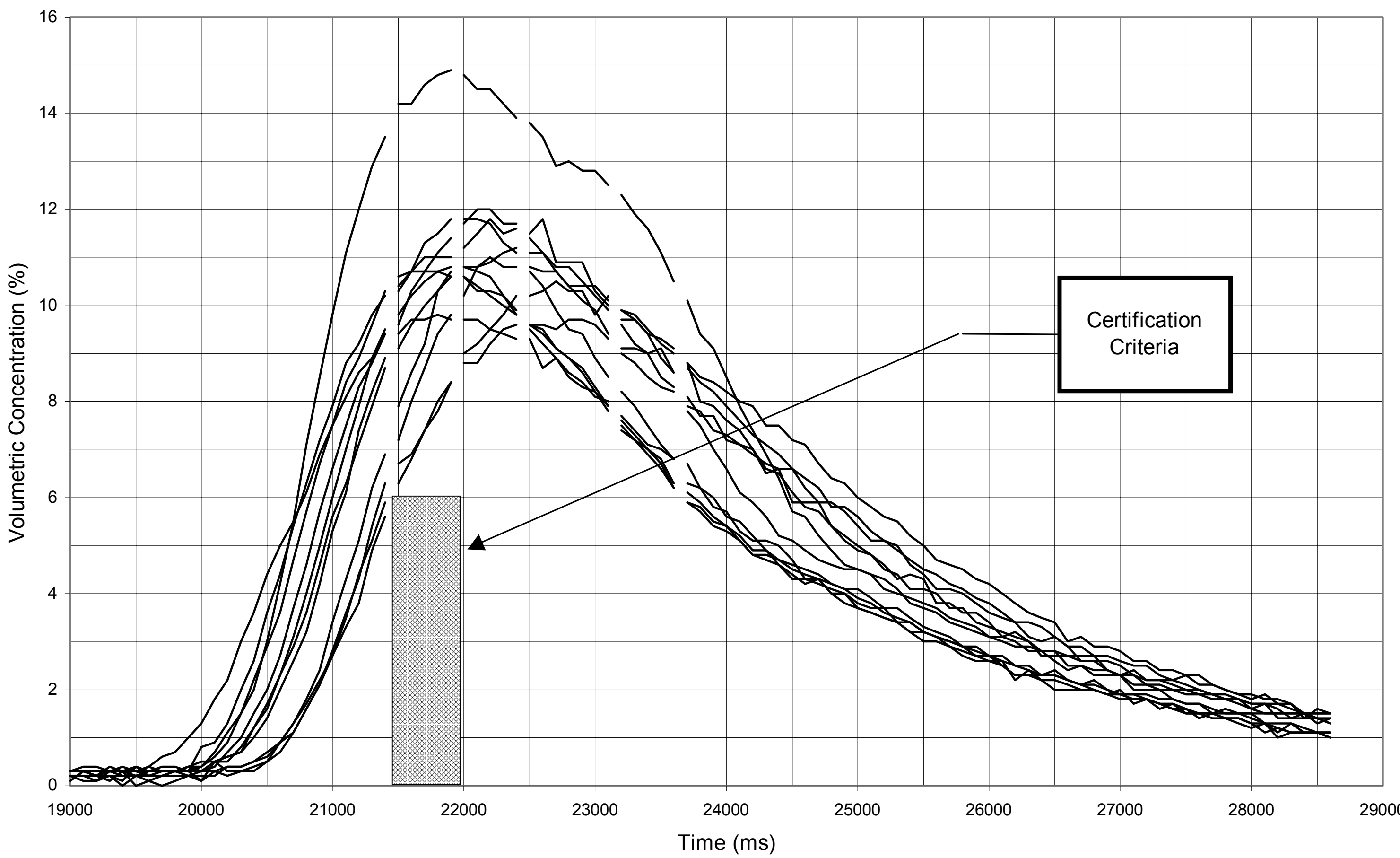

FIGURE 7. HALON 1301 DISTRIBUTION PROFILE, APRIL 1998

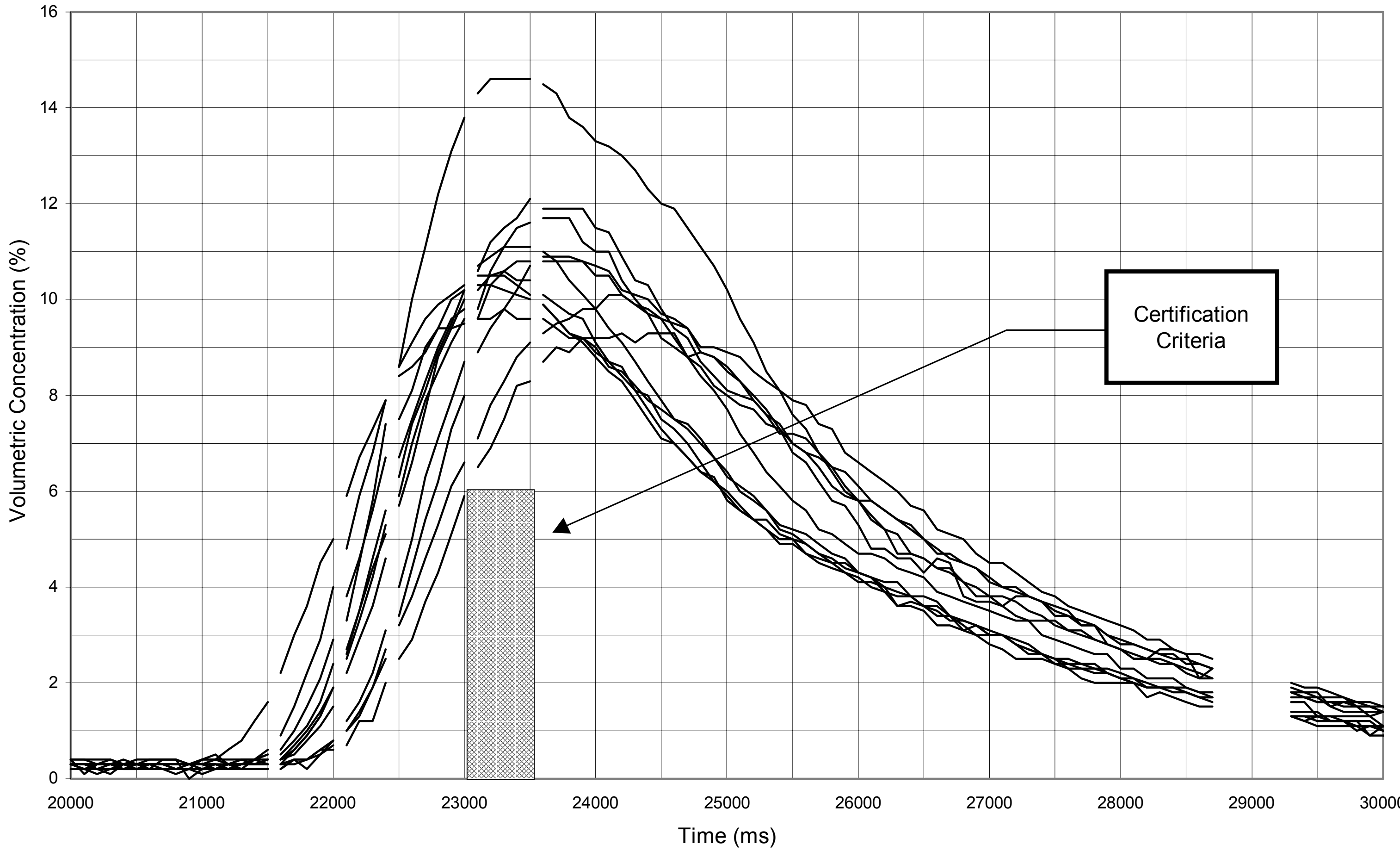

FIGURE 8. HFC-125 DISTRIBUTION PROFILE, APRIL 1998

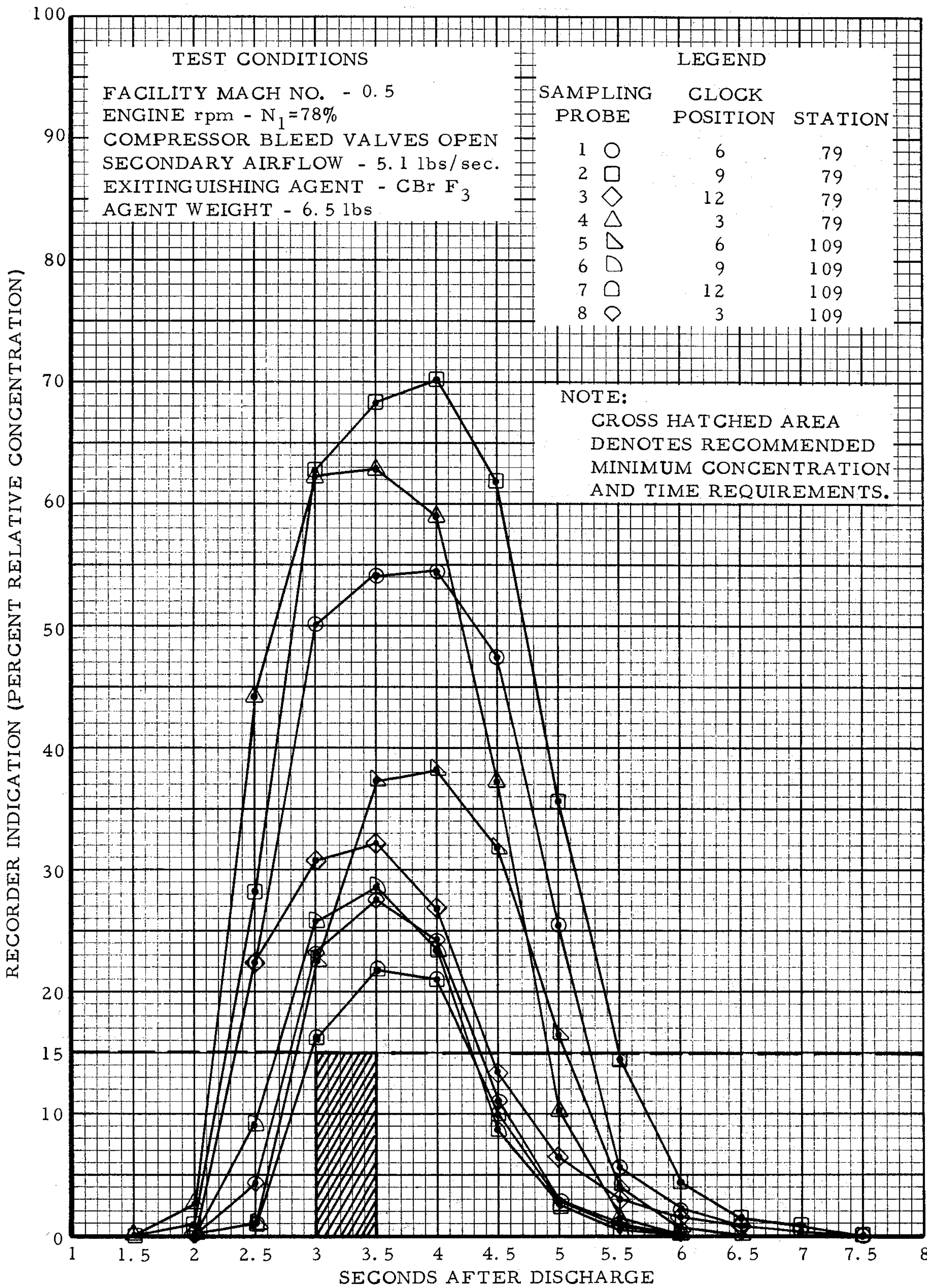

FIGURE 9. LOCKHEED C-140 JET STAR CONCENTRATION PROFILE AT $N_1 = 78\%$
(Sommers, 1970, p. 34)

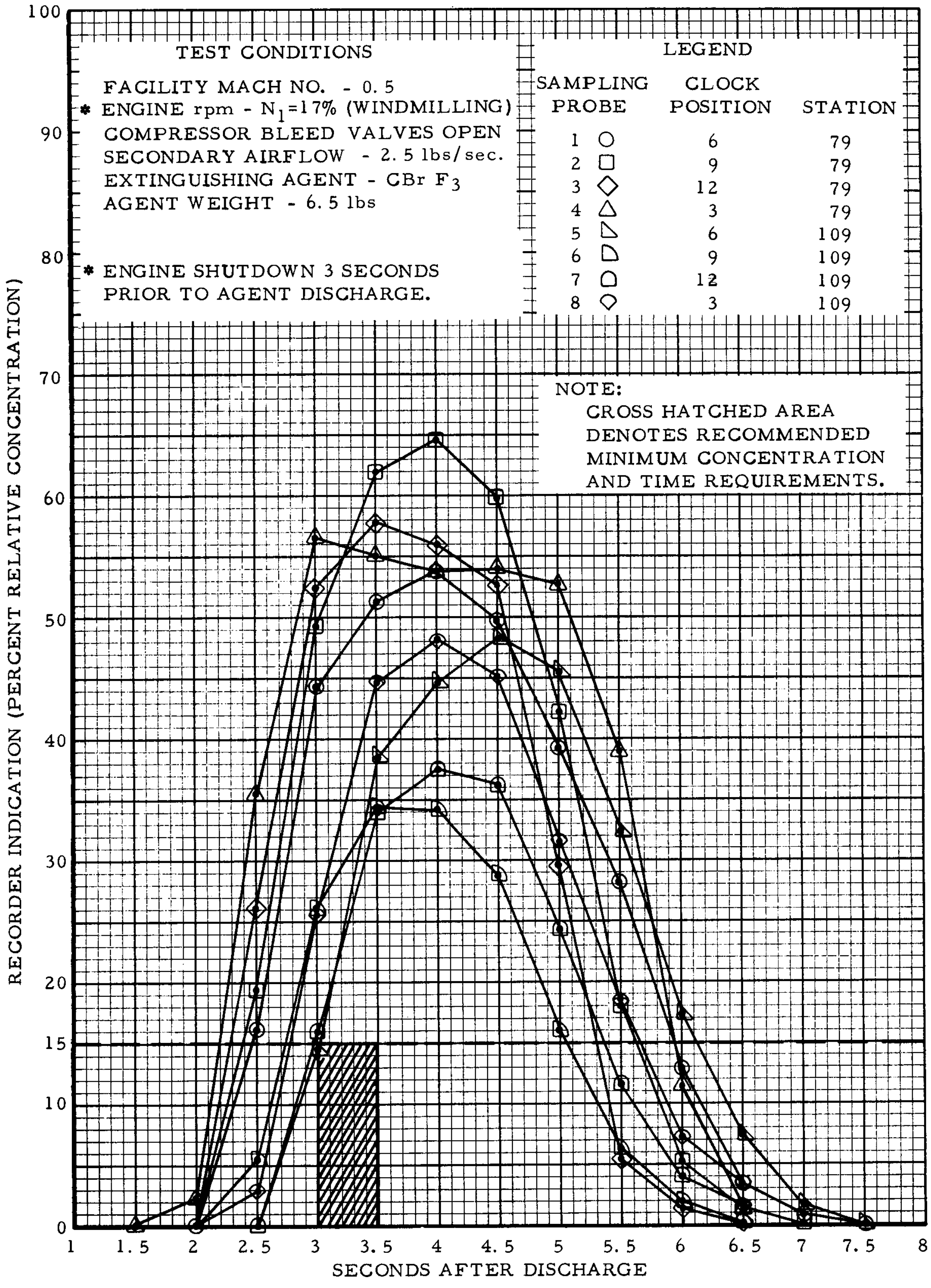

FIGURE 10. LOCKHEED C-140 JET STAR CONCENTRATION PROFILE AT $N_1 = 17\%$
(Sommers, 1970, p. 33)

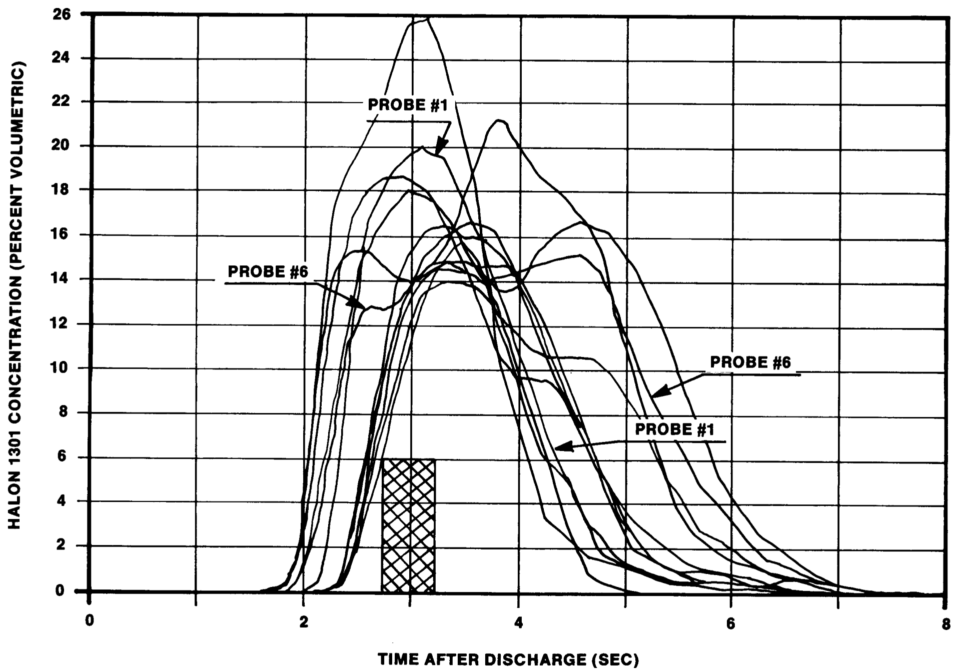

FIGURE 11. GENERAL DYNAMICS F/EF-111 AGENT CONCENTRATION PROFILE FOR TEST 1301-8 (Chamberlain and Boris, 1987, p.57)

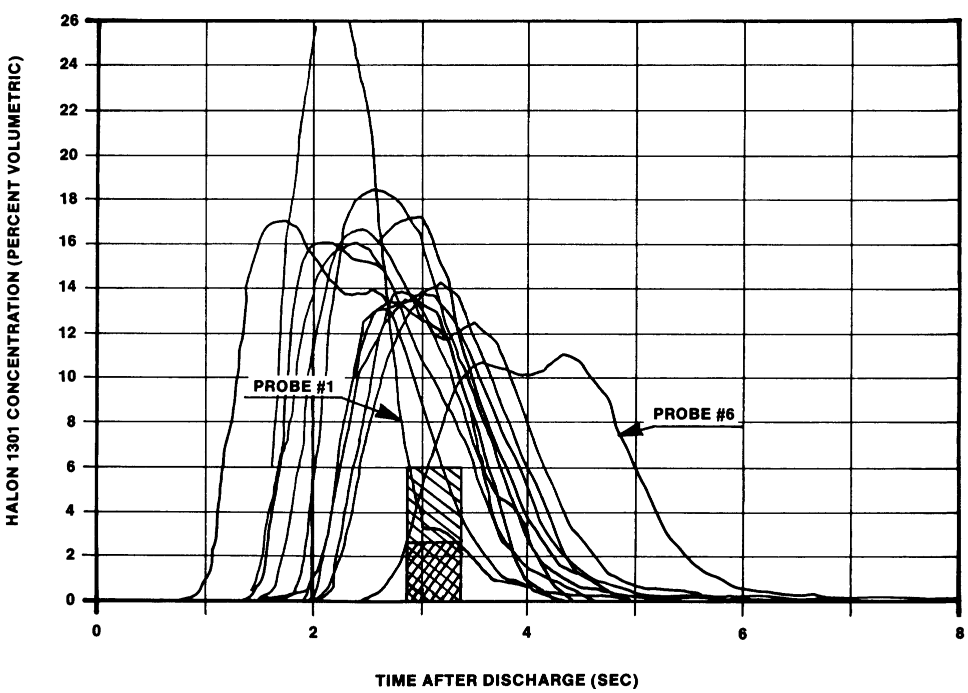

FIGURE 12. GENERAL DYNAMICS F/EF-111 AGENT CONCENTRATION PROFILE FOR TEST 1301-2 (Chamberlain and Boris, 1987, p.49)

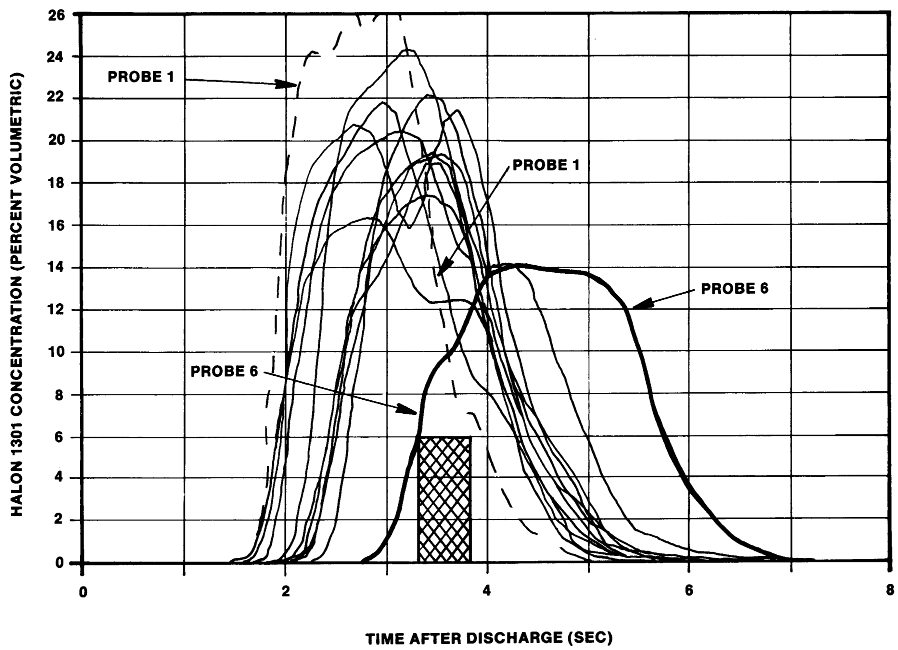

FIGURE 13. GENERAL DYNAMICS F/EF-111 AGENT CONCENTRATION PROFILE FOR TEST 1301-3 (Chamberlain and Boris, 1987, p. 50)

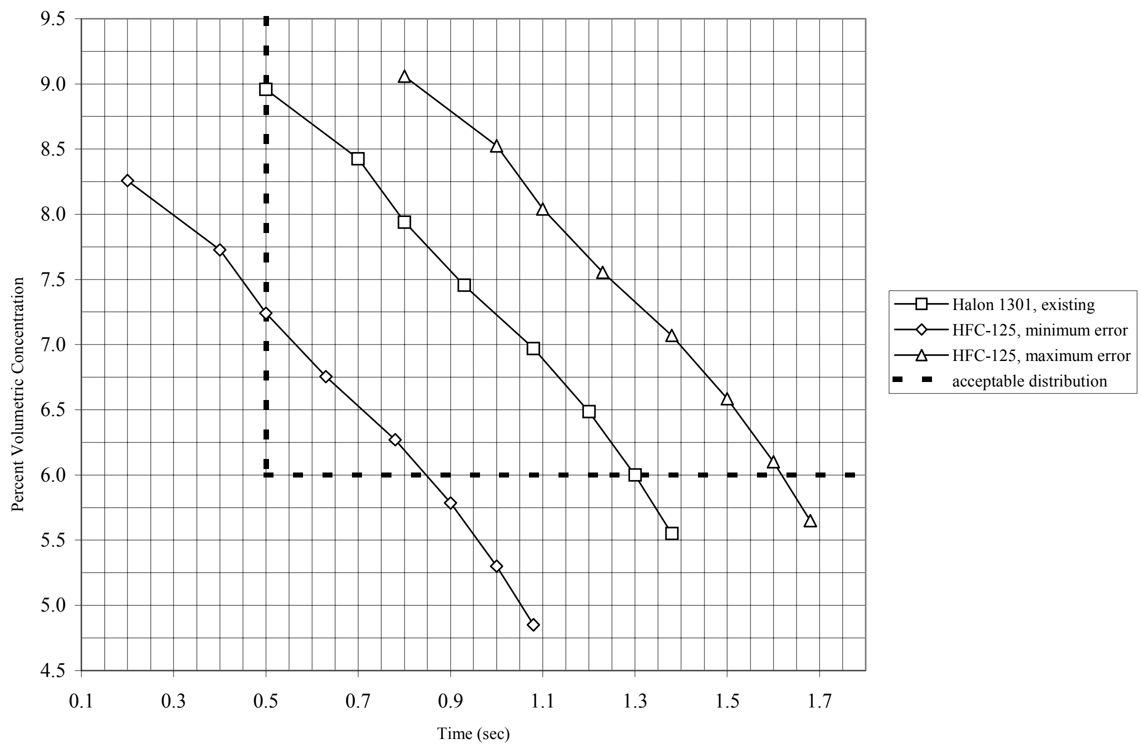

FIGURE 14. ILLUSTRATION OF HFC-125 VARIATION FOR AN ACCEPTABLE HALON 1301 TEST

TABLE 1. NACELLE STATISTICS FOR APRIL 1998 SIMULANT TEST PAIR

Parameter	Units	General	Halon 1301	HFC-125
ambient temperature	°F (°C)	64 (18)		
barometric pressure	inch Hg (mm Hg)	30.2 (767)		
relative humidity	%	42		
nacelle airflow rate	lb/s (kg/s)	2.1 (0.95)		
nacelle ventilation rate	changes/min	2-3		
inlet airflow temperature	°F (°C)	107 (42)		
agent fill density	lb/ft^3 (kg/m^3)		49.0 (785)	37.9 (607)
agent charge weight	lb (kg)		5.50 (2.50)	4.25 (1.93)
bottle pressure	psig (Bar)		600 (41.3)	600 (41.3)
bottle temperature	°F (°C)		64 (18)	64 (18)

TABLE 2. VOLUMETRIC CONCENTRATION CHARACTERISTICS, APRIL 1998 SIMULANT TESTS

Elapsed time for Halon 1301 to achieve volumetric concentration from zero baseline (ms)	Analyzer channel number 1	2	3	4	5	6	7	8	9	10	11	12
4% Halon 1301	900	800	1000	1200	700	800	600	900	800	1000	800	900
6% Halon 1301	1100	1100	1300	1400	900	1000	800	1100	1000	1200	1000	1100
8% Halon 1301	1300	1500	1600	1700	1200	1300	900	1300	1200	1500	1300	1300
peak Halon 1301	2100	2400	2300	2600	2000	1900	1900	1900	1800	2300	1900	2100
Difference in elapsed time from Halon 1301 to achieve volumetric concentration (ms)	(negative sign indicates the HFC-125 value is smaller in magnitude than the corresponding Halon 1301 value)											
4% HFC-125	0	100	0	200	0	-100	100	0	0	-100	-100	-100
6% HFC-125	0	100	0	200	100	-100	100	0	0	0	-100	-100
8% HFC-125	0	0	0	300	0	-200	100	0	0	-100	-100	-100
peak HFC-125	-200	-100	100	200	-300	-200	-200	-100	0	-100	-100	-200
Average difference between elapsed times	-50	25	25	225	-50	-150	25	-25	0	-75	-100	-125
Average difference of the averaged times and data span	-23 milliseconds, +248/-127											
Peak volumetric concentration (%V/V)												
Halon 1301	11.2	9.7	9.8	10.5	10.8	11.8	14.9	11.0	10.7	11.0	11.8	12.0
HFC-125	10.8	9.3	9.8	10.1	10.3	11.1	14.6	10.5	10.6	10.9	11.9	12.1
Difference between values	-0.4	-0.4	0	-0.4	-0.5	-0.7	-0.3	-0.5	-0.1	-0.1	0.1	0.1
Average difference between peak values and data span	-0.27% volumetric concentration, +0.37/-0.43											
Elapsed time for concentration equaling or exceeding 6% volumetric concentration (ms)												
Halon 1301	3600	2900	3100	3200	2800	2800	3600	2800	2600	3000	3300	3400
HFC-125	3500	2600	2900	3000	2600	2600	3500	2500	2500	2800	3300	3200
Difference between values	-100	-300	-200	-200	-200	-200	-100	-300	-100	-200	0	-200
Average difference between elapsed times and data span	-175 milliseconds, +175/-125											