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Halon 1301 History

Fire suppression systems in aircraft engine compartments, like most suppression systems, consist of two components; detection and agent delivery. Active aircraft engine fire protection has been evident since the mid 1900s (Hansberry, 1943; Tarbell and Keeler, 1950). Reports of this era suggest dedicated fire protection may be found earlier than the mid 1900s. Presently, the current level of safety for engine compartment fire protection is defined as an amount of Halon 1301 producing the minimum of a 6 percent volumetric concentration throughout the protected zone for a duration of one-half second. The development of the current level of safety has been an evolutionary process spanning better than fifty years. This process has involved the evaluation of many chemicals and associated technologies. To further complicate issues, aircraft propulsion itself was changing during this period (Gunston, 1995; Gunston, 1998). The bias of this discussion is directed towards United States Government work primarily within the Federal Aviation Administration (FAA), which by no means is the sole entity involved in the process. This body of work should not be considered the only source of information regarding this issue.

The development of the current level of safety has been a historical process. The major steps leading to current standards span the time frame from the 1940s to the present. Halogenated suppressants stored under pressure in appropriate hardware appear very early in the literature. One of the early reports suggesting active fire suppression in an engine compartment was written by Mr. H. L. Hansberry and published in 1943. The report discusses general fire protection considerations and provides design information for two fire suppressants, carbon dioxide and Halon 1001 (methyl bromide). Distribution of these chemicals is achieved through multiple nozzles located on a ring of tube which surrounds the engine power section. One should note that both suppressants are compressible fluids. By using compressible fluids, the technology for fire suppression is conceptually fixed. This fact has remained unchanged for the duration. Further, the propulsion mode for this period was the radial piston engine. Hansberry indicated 3,000 fire tests involving the Douglas DC-3, the Curtiss-Wright CW-20, and the Waco YKS-37 had been performed during this period (Hansberry, 1943, p. 1).

One of the first aircraft given propulsion fire protection consideration during its design stage was the Lockheed Constitution (Navy XR60-1) (Tarbell, 1953, p. 3). This aircraft possessed a radial piston power plant. Chemicals evaluated during this work involved carbon dioxide and Halons 1001 and 1011 (bromochloromethane). Further, during the evaluation of the Lockheed Constitution, different methods of engine nacelle fire suppression were considered (Tarbell, 1953, pp. 1-2, 20-28). Going one step further, over the entire span of this history, other methods of nacelle suppression have been suggested and evaluated.

Regarding the work on the Lockheed Constitution, the primary emphasis involved finding a simpler, yet more effective, way to deliver gaseous agents. The perforated tube, a relatively complex distribution system, was the standard approach until this effort. This concept was repetitiously cited as an element to possibly improve system performance. One approach evaluated involved storing the agent in small capsules located between cylinder heads within the nacelle. The agent was released by exploding the capsules. The capsule approach was determined to require more work, but was not well received. Another method of gaseous delivery was evaluated; generically referred to as a high rate discharge (HRD). The HRD method eliminated the complex distribution tubing but maintained the agent storage hardware. This method, or variations thereof, has come to be the primary method to distribute gaseous agents within the nacelle. Yet another method suggested for evaluation during this program involved the introduction of conditioned exhaust gases into the nacelle to inert the protected volume. The lack of work evident in later reports has shown the exhaust gas concept drew no widespread interest from the aviation community.

In this same vein of different approaches to nacelle fire suppression, three other suppressive methods have been attempted; the modification of a bottle to accept pressurization from a gas generator device, the use of dry chemical fire suppressants, and the restriction of air flow into the nacelle. The gas generator pressurized bottles were considered during a significant turbofan evaluation in the 1960s (Klueg and Demaree, 1969, pp. 86-91). Limited comparisons between squib and gas generator released pressurized bottles indicated the gas generator fired bottles performed much better in distributing the agent. However, 3 of the 41 tests were failures as the releasing system failed. No further pursuit of this concept was noted in later work until the advent of the solid propellant gas generator. At a minimum, dry chemicals have been evaluated on two separate occasions (Altman, date unknown; Bennett, et al., 1997a). Comments from the most recent work indicated no further interest in this method because the agent cleanup from a discharge would be too burdensome for operational considerations. The restriction of nacelle airflow in conjunction with agent discharge has also been suggested (Johnson, 1988, pp. 47, 56). This method was perceived to augment suppression system performance by eliminating air flow to the nacelle. Upon evaluation, the test fires were extinguished, however a re-ignition phenomena persisted. This effort had no later widespread interest.

During the 1940-50 time frame, a new propulsion method appears; the turbojet. An effort was planned to perform a fire protection analysis of the Ryan Fireball (Navy FR-4). Turbojet technology was changing rapidly and the FR-4 powerplant was deemed obsolete before any work had begun (Middlesworth, 1952, p. ii). The fire protection effort then changed to an evaluation of fire suppression agents available at the time. The effort included work with carbon dioxide and several halogenated agents which included three new ones not considered before; Halons 104, 1003, and 1202. From this effort, the distribution system is again identified as the main element impacting performance. Additionally, halogenated suppressants are recommended for further investigation (Middlesworth, 1952, p. 19). From this point, more work occurs with various halogenated agents and the distribution system evolved into a simple tube-based arrangement where the use of nozzles was minimized (Hughes, 1953; Hughes and Middlesworth, 1954; Hansberry, 1956). As can be seen in Table 1, Halon 1301 appeared in early 1956. Halon is briefly mentioned in the work on the Northrop F-89 Scorpion as reported by Mr. A. V. Young (1958, p. 19). Regarding this effort, nothing significant resulted from the work as the test fixture had degraded to a questionable integrity due to previous fire testing by the time the agent was used.

Another significant change occurred near this time; a change in the propulsive method once again. During the 1960s, the civil sector comes into the age of the turbofan engine. To uncover unknown complexities, a two-year effort evaluated the fire protection aspects of the Pratt and Whitney JT3D-1. From this work, the ranking of agent effectiveness was given in order of the most effective first, as Halon 1301, 1202, 1211, then 1011 (Klueg and Demaree, 1969, p. 117). From this time forward, Halon 1202 and 1301 underwent continual evaluation (Chamberlain, 1970; Sommers, 1970; Chamberlain and Boris, 1987; Johnson, 1988). Ten or so years later two additional efforts compared Halon 1301 and 1202. The result of these efforts indicated Halon 1301 performed better than Halon 1202 (Chamberlain and Boris, 1987, pp. 55-59; Johnson, 1988, pp. 41, 60).

Table 1. Fire Suppressants Evaluated in FAA Reports, 1943-1988

		Fire Suppressant (chemical or Halon name)								
Report Number	Date	CO_2	104	1001	1011	1003	2402	1202	1211	1301
31	Sep, 1943	x		x						
107	Apr, 1950	x								
184	Oct, 1952	x	x	x	x	x	x			
198	Apr, 1953	x		x	x			x		
205	Jun, 1953	x		x	x			x		
206*	Jun, 1953	x		x	x					
240	Jun, 1954				x			x		
260	Feb, 1956			x	x			x		x
365	Oct, 1958				x			x		x
403*	Sep, 1959	x		x	x			x		x
NA-69-26	Apr, 1969				x			x	x	x
FAA-DS-70-3*	Mar, 1970							x		x
FAA-RD-70-57	Nov, 1970									x
AFWAL-TR-87-2066	Nov, 1987							x		x
AFWAL-TR-88-2022	Jun, 1988							x		x

*Signifies work involved in developing gas concentration analysis equipment

All during this effort, in addition to finding a desirable fire extinguishant, one realizes the agent must be quantified in some way so its effectiveness can be measured. Early work in the span of time discussed here had been based on destructive testing. Results were quantified by agent weight and compared against fire extinguishment performance.

When considering the ability of a gaseous suppressant to put out a fire in an unknown dynamic environment, the most effective way to quantify it is to measure its concentration in the region of interest. During the middle 1950s, the U.S. Air Force (USAF) funded an effort to develop a gas analyzer capable of recording a discharge event in an engine nacelle (New and Middlesworth, 1953, p. 1). The device produced by Statham Laboratories measured a pressure drop of a binary gas mixture flowing across a porous plug at known temperature. Given one part of the binary mix being air, the unknown concentration of the second component can be calculated based on a known calibration curve. The first generation analyzer was known as the GA-1 and possessed 18 data gathering channels. The Statham Laboratories analyzer was later modified to the GA-2A having 12 data gathering channels (Demaree and Dierdorf, 1959, p. 3). This device is commonly known as the Statham analyzer. Today, the familiar variant is the Halonyzer II, as produced by Pacific Scientific HTL/Kin-Tech Division. Currently, Walter Kidde Aerospace, Pacific Scientific HTL/Kin-Tech, the Boeing Company, the French airworthiness authorities, and the FAA possess derivatives of the Statham analyzer.

Agent quantification begins transformation when the ability to capture the gas concentration appears. Agent evaluation changes from weight-based measure to concentration-versus-time profiles illustrating distribution in the protected zone. Three major reports dealing with concentration measuring equipment begin providing concentration and duration data for a given agent (New and Middlesworth, 1953; Demaree and Dierdorf, 1959; Chamberlain, 1970). The duration of one-half second of specified concentration is noted in work from Mr. J. E. Demaree and Mr. P. R. Dierdorf (1959, p. 13). The agents quantified are carbon dioxide and Halons 1011, 1001, 1202, and 1301. The quantification was based on "…numerous fire extinguishing tests conducted on full-scale powerplant installations at the Technical Development Center" (Demaree and Dierdorf, 1959, p. 13). Later on, issues such as operating the Statham analyzer, agent distribution, and system development are discussed in greater detail by Mr. G. Chamberlain (1970). Halon 1301 was identified as the most prominent agent, while Halon 1202 was next in importance with carbon dioxide remaining in service as well (Chamberlain, 1970, p. 1). Of particular interest in this report is further discussion of the current level of safety. Chamberlain introduces a flammability curve of n-heptane, air, and Halon 1301. The peak of the flammability region is approximately 6 percent volumetric Halon 1301 (Chamberlain, 1970, pp. 33-35). Soon after Chamberlain's report, Advisory Circular (AC) 20-100 is published in 1977; it reflected Demaree's, Dierdorf's, and Chamberlain's work.

As seen by this history, the development of the current level of safety has been quite involved. Through the span of time just described, the FAA was involved in the development of engine nacelle fire protection covering 51 individual aircraft models (Chamberlain, 1970, p. 54). In this era, we are now in the midst of the next generation of work pertaining to the concept of the equivalent level of safety. In essence, the problem is the same, but the approach is slightly different.

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