Halon Replacement Tests for Aircraft Lavatory Trash Receptacle Extinguishers

Presented to:

International Aircraft
Fire & Cabin Safety
Research Conference

October 25, 2001

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Introduction

Cargo compartments, engines, lavatories and hand held fire extinguishing systems on commercial airplanes have successfully used Halon fire suppression agents for years. The production of Halons has been banned by international agreement due to their Ozone Depletion Potential (ODP).

The Federal Aviation Administration (FAA) developed a Minimum Performance Standard (MPS) for Lavatory Trash Receptacle Automatic Fire Extinguishers [1] (Lavex) to ensure all replacement agents exhibit “an equivalent level of safety” to Halon 1301. The Lavex bottle is the first agent/bottle combination to undergo extensive testing by Boeing.

This report explains the test preparation, test results and findings from the recent MPS tests as well as a brief explanation of the follow-on testing that Boeing performs before any non-halon replacement Lavex bottles are authorized for use on its airplanes.

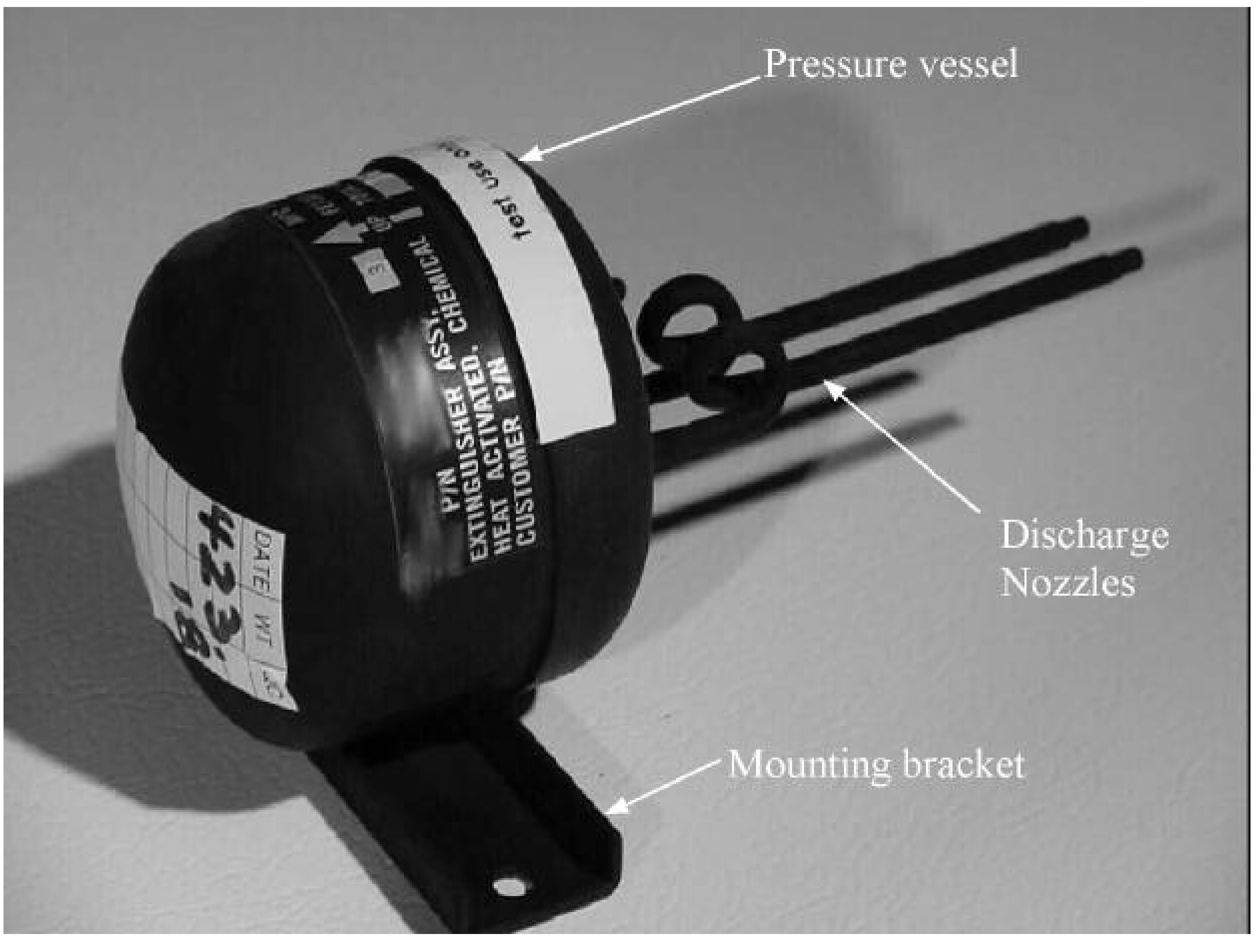


Figure 1 – Lavex bottle configured for tests

The MPS is not the only test criterion a new replacement agent must meet. A supplier qualification test program as presented in the Boeing specification control drawing (SCD) [2] must be successfully completed. Also, a Boeing developed test to determine the performance of the agent/bottle combination as typically installed in an airplane must be met. These additional tests must be successfully completed before any alternative fire extinguishing agent can be certified for installation in an airplane lavatory. See Figure 2.

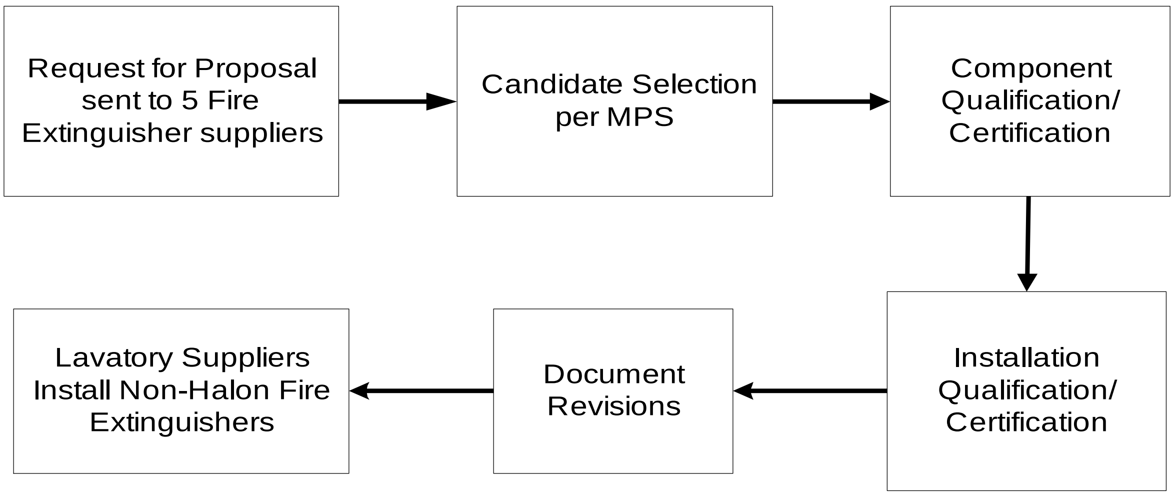


Figure 2. Lavex Qualification/ Certification Process

Brief History

The Boeing Company created a specification drawing in 1974 to identify the requirements for a fire extinguisher in the trash receptacle of airplane lavatories. It specified Halon 1301 as the extinguishing agent and mandated that the bottle meet certain performance criteria [2]. These bottles were to be used in airplanes to improve safety beyond an FAA Airworthiness Directive issued in 1974.

In 1986 the FAA made it mandatory that transport category airplanes have trash receptacle extinguishers in the lavatories. (FAR 121.308)

In 1991, the FAA required that all new airplanes must have an extinguishing method for the trash receptacle before they can be delivered. (FAR 25.854(b))

Halon production was ceased in industrialized nations due to its ODP under the 1994 Montreal Protocol. Many countries have since imposed limitations on its use, importation, transportation and disposal. A few candidate alternative extinguishing agents were identified, but Boeing and the FAA needed proof that any new agent possessed "an equivalent level of safety" to Halon 1301. Passenger safety on board airplanes is considered the most important criteria; hence, an "essential use" exemption was granted to continue usage of Halons on commercial airplanes until a satisfactory replacement could be found.

A proactive supplier of Lavex bottles initiated research to create a test protocol that could be used to determine if an alternative agent is equivalent to Halon 1301 in extinguishing performance. The test was devised to:

1) establish the threshold at which Halon 1301 would extinguish a fire
2) represent a typical, reproducible fire threat.

In addition, the airline industry preferred an agent that was easy to clean up and would not be subject to freezing if the temperature in the trash compartment remained below freezing.

The FAA undertook the task of developing a Minimum Performance Standard and to replicate the test apparatus, procedure and fire threat to validate that the supplier's test protocol was truly repeatable. The FAA tried to replicate Halon 1301 performance by constructing the same size test box following the supplier's test procedures and by duplicating the same fuel load. (Figure 3). A number of variables made a difference in test results and repeatability. For example, it was noticed that the humidity in Atlantic City in August is about 90%RH, but the MPS required the towels to be conditioned to about 50%RH. The extra moisture content created a lower heat release fire, which led to inconsistent test results. Once the moisture content of the towels was tightly controlled and the fire load weight and volume was standardized, repeatability with bottles at temperatures at 30°F and below was achieved with Halon 1301.

While the FAA was creating the MPS, the market availability of extinguishing agents with lower ODP was improving [3]. The evidence of technical progress prompted political support to lower the limits of ozone depleting substances like Halons.

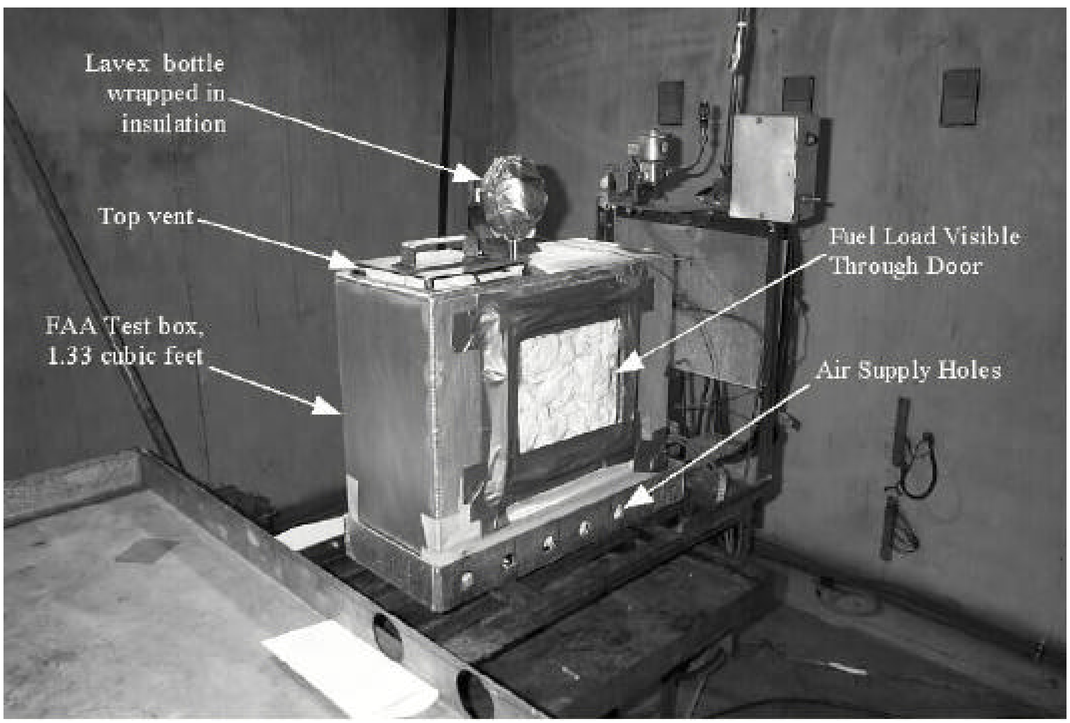


Figure 3. Test apparatus with bottle and fuel load

Boeing Participation

Boeing participation in Halon replacement started in 1993 by working together with extinguisher companies to stabilize the supply of recycled Halon for all of its airplanes in service. Boeing became a member of the FAA sponsored International Halon Replacement Working Group (IHRWG) in 1993 and has participated since. Key Boeing people became involved when the working group started drafting each MPS for lavatory trash receptacle, hand held portable, cargo compartment, engine and auxiliary power unit extinguishers. They helped create harmonization of wording within the airplane industry and clarification of the performance criteria for the replacement agent in each MPS. The MPS for Lavex bottles was released in 1997 with appendix D representing the actual test method.

In anticipation of a replacement agent meeting the released MPS, Boeing revised its internal Lavex specification in 1998 to:

1) replace the word "Halon" with "extinguishing agent",
2) make a unique decal indicating which type of replacement agent is in the new Lavex bottles and
3) create a new part number differentiating this new bottle from all others.

Many people outside of Boeing thought that with the creation of a new part number, non-halon bottles could be installed on Boeing airplanes immediately. However, the Boeing effort to replace Halon in Lavex bottles was just beginning. Before any part can be installed on an airplane, it must be shown to meet all of the Boeing requirements (qualified) and FAA requirements (certified) for that part in a specific installation.

A small team developed a plan and a strategy for candidate selection prior to qualification and certification of non-Halon Lavex bottles. A Request for Information (RFI) was sent to five potential suppliers of non-Halon Lavex bottles to ask for their participation in the candidate selection process. After review of their responses, four suppliers were informed that Boeing was willing to witness their products being tested to the MPS as the first step towards airworthiness certification. The FAA was willing to bring their test box out of 'mothballs' and to help run the MPS tests. Boeing engineers volunteered to help the FAA Technical Center run the tests, and Boeing FAA Designated Engineering Representatives (DER) were sent to witness these tests.[†] A letter was written documenting the agreements reached with the suppliers, the FAA and Boeing personnel on the testing methodology to be used. See figure 4.

Status to Date

On December 11-15, 2000, the Boeing team went to the FAA William J Hughes Technical Center in Atlantic City, New Jersey to test the four suppliers' non-Halon Lavex bottles to the MPS. Each supplier was required to provide a minimum of seven non-Halon bottles. The four suppliers used three different alternative agents: FM-200™, FE-36™, and Envirogel™. Each supplier was assigned a separate day for testing to maintain the proprietary nature of the test data.

[†] DERs are engineers who are employed by firms in the aerospace industry and are trained and recognized by the FAA to approve certification data. Candidate DERs are required to work closely with the FAA for at least a year before they are granted their designation.

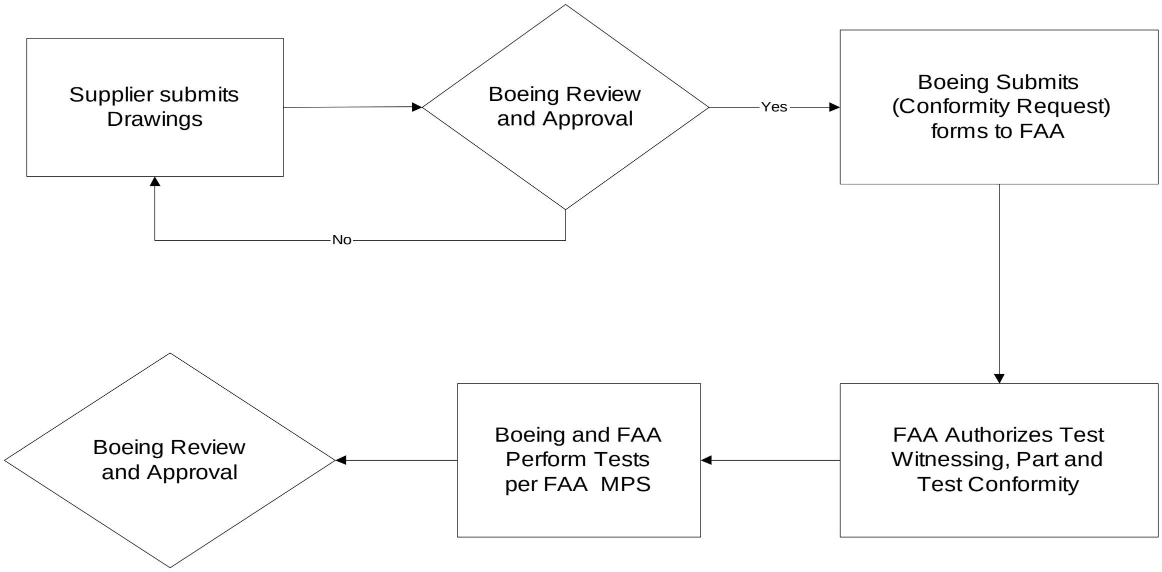


Figure 4. CANDIDATE SELECTION PROCESS

Each supplier also had to provide at least three Halon 1301 bottles as a benchmark. If the Halon bottles and non-Halon bottles did not pass the MPS test, then it might be concluded that the bottle design and not the alternative agent was the mode of failure. In addition, we requested each supplier to make a slight modification to their bottles so that the discharge nozzles were pointing straight down rather than at an angle. This would put all of them in accord with the MPS test apparatus.

All bottles with alternative agents were required to have FAA conformity prior to these tests. The FAA will not consider a test to be official or acceptable without test article conformity. FAA conformity consists of physical inspection and verification of every part to released engineering drawings. In addition, conformity includes verification of all records considered essential in the manufacturing of the test bottle. Conformity must be performed by designated agents of the FAA. In this case these agents were Designated Manufacturing Inspection Representatives (DMIR).[‡] Bottle conformities were requested by a Boeing DER using an FAA form 8120-10. (In one case, the supplier was located in the UK. Conformity of this test article was delegated by the FAA to the UK Civil Aviation Authority (CAA). Because of bi-lateral agreements between the FAA and the CAA, conformity may be delegated from one governmental agency to the other.)

In addition to the requirement of conformed test articles, all FAA certification tests must be witnessed by delegates of the FAA. In our case, two members of the Boeing team were FAA DERs. One DER represented the FAA for Boeing twin-aisle airplanes; the other represented the FAA for Boeing single-aisle airplanes.

Our procedure was the same for each supplier. At least one Halon 1301 bottle was tested as a benchmark. After the Halon test was completed, we tested Lavex bottles with the alternative agent. Each supplier had

[‡] DMIRs are FAA trained employees of industry firms who are designated by the FAA to perform FAA tasks such as conformity.

provided seven non-Halon conformed bottles for this test. Testing was performed to the FAA test procedure in appendix D of the MPS. One of the success criteria was that five bottles in succession had to put out the fire. No re-ignition or burning embers could remain. In addition, the bottle had to discharge within 60 seconds of the temperature of the bottle discharge tube(s) reaching the activation temperature.

Test Results

Two of the suppliers used FE-36™ as their alternative agent. One supplier used FM-200™, and another used Envirogel™. Lavex bottles with FE-36™ and those with FM-200™ passed their tests. FE-36™ appeared to be equivalent to Halon in its fire fighting ability. FM-200™ was observed to put out fires completely with little or no residual smoke immediately after discharge. See Figure 5.

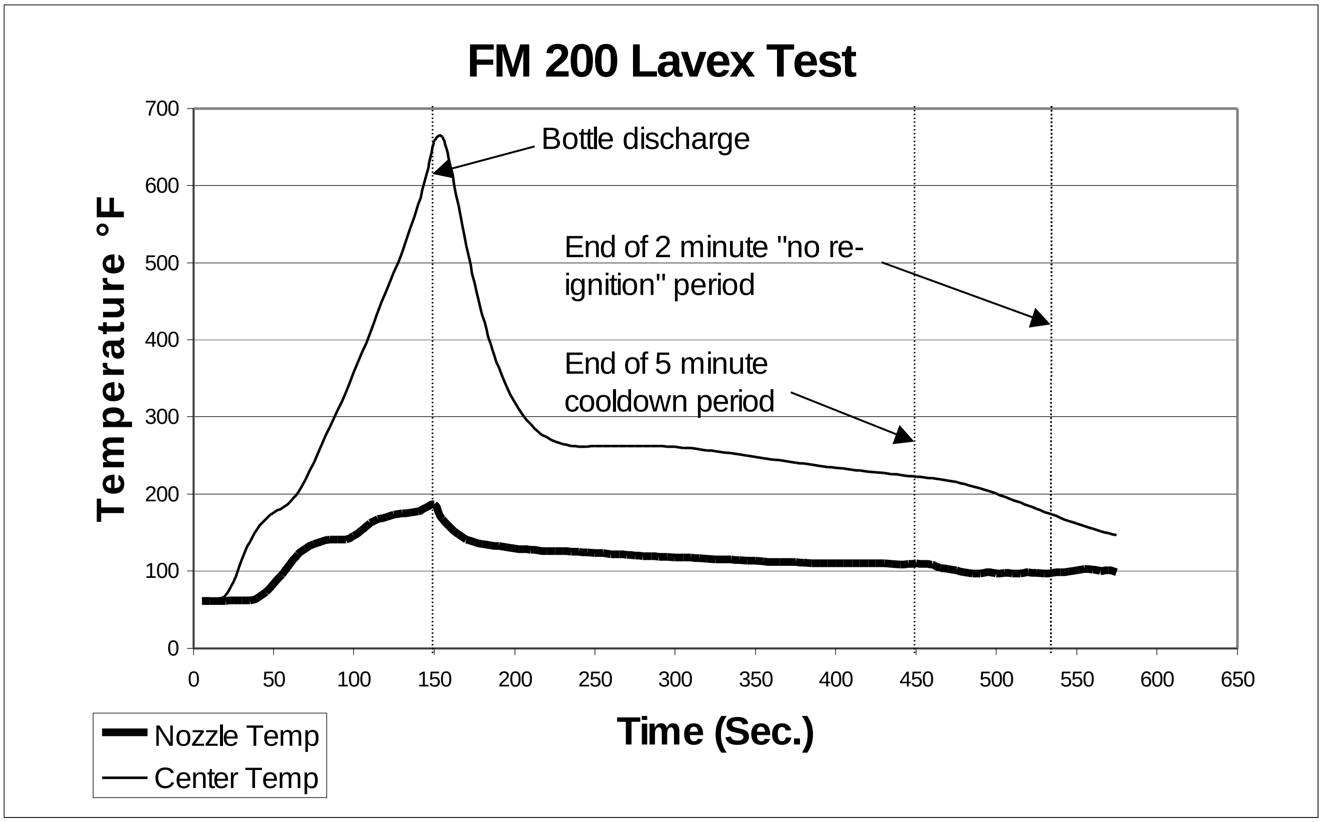


Figure 5. – Example of successful test

The only replacement agent that did not meet the MPS was Envirogel™. This agent failed the first two tests due to re-ignition. The second temperature peak in Figure 6 represents re-ignition. This fire had to be manually extinguished with a hand held fire extinguisher.

The third test using this agent passed. The fourth Envirogel™ test did not pass due to the eutectic tip not discharging within the required 60 seconds.

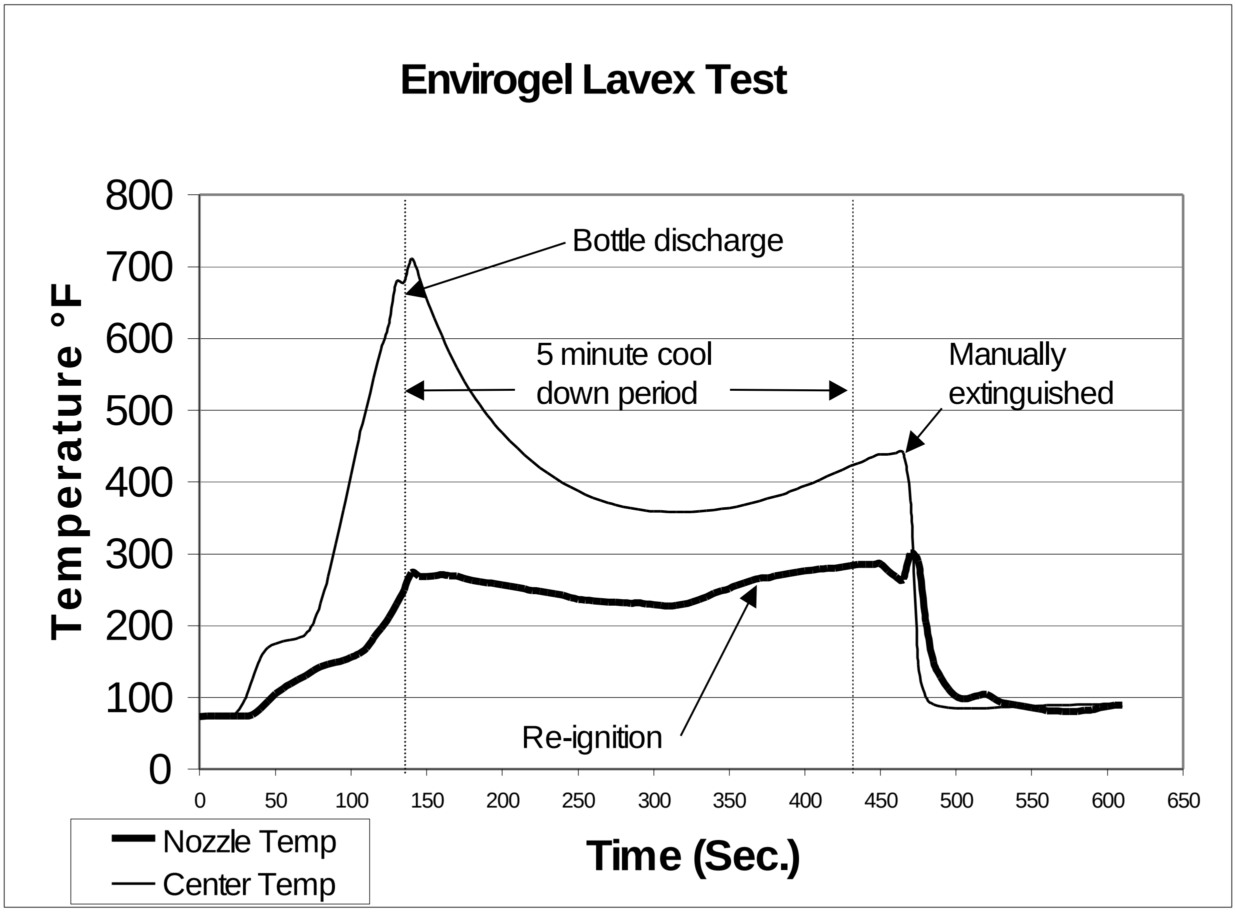


Figure 6. Example of test failure due to re-ignition

Lessons Learned

There were a number of lessons learned in the process of completing these tests. It was determined that it wasn't clear in the original release of the MPS what the FAA had intended when they required that five bottles had to pass. The FAA clarified the procedure by stating that five bottles must pass *in succession* out of the seven bottles that were provided. For example, if the third bottle had failed, it was not possible to pass this series of tests using the agreed number of seven bottles.

During the second test, we noticed that the test box had several leak paths and the extinguishing agent was leaking out. Holes provided in the bottom of the box to give the fire a chance to build remained partially open when the slider was activated to close them. (See figure 3) At the instant the agent is discharged from the bottle, these holes are supposed to be closed per the MPS to simulate a closed bottom receptacle similar to the one found in airplane lavatories. The second test was declared a non-test due to excessive leakage and the box was repaired to provide a tighter seal at the slider.

Another problem that we encountered was that the FAA procedure only had three thermocouple locations shown in their MPS procedure. One thermocouple was located on the bottle itself to record surface temperature. A second thermocouple was located outside of the box to record ambient temperature. A third thermocouple was in the center of the test box. This location indicated the temperature in the center of the test box, but it was too far away to accurately read the temperature at the tip of the discharge tube.

In fact, the FAA test box and data recording system did physically have four thermocouples installed, but the MPS needed to be revised to show the fourth thermocouple and explain its function. This thermocouple reads the temperature at the tip to determine elapsed time between reaching activation temperature at the discharge tip and initial discharge of the extinguishing agent. The MPS specifies a maximum elapsed time of 60 seconds.

The thermocouple placement also affected the results. Elapsed time until discharge during tests number 12 and 13 became wildly excessive. The cause was determined when a different person installed the thermocouple. In most of the tests, the FAA engineer had located the fourth thermocouple so that it was almost touching the eutectic tips. Up to that point, we had received satisfactory results in our tests with all bottles discharging within 60 seconds of reaching the activation temperature. In tests 12 and 13, a Boeing DER located the thermocouple. These test times were longer than the required 60 seconds. These tests were initially classified as failures. In the following tests where the FAA engineer located the thermocouple, satisfactory results were again obtained. An investigation found that the Boeing DER had located the thermocouple about 5/8 inch away from the tips. The closer location of the thermocouple gave a more accurate reading of the temperature at the nozzle ends and we had to disqualify tests 12 and 13 due to an inconsistency in thermocouple placement.

The remaining 15 tests went quickly and accurately when each person was delegated only a few tasks to perform. The consistency of quality paper crumpling, thermocouple placement, time keeping, observations and record keeping from test to test was important to the fairness to all participants. The delegation of specific tasks ensured uniformity of test proceures.

Component Qualification/Certification Process

Once the suppliers have passed the tests per the MPS, the next step is for them to submit Drawings, an Acceptance Test Procedure (ATP) and a Qualification Test Procedure (QTP) to Boeing for review and comment/approval. Qualification tests include tests such as vibration tests, burst tests and corrosion analysis. These tests will be used to qualify the bottle to the Boeing SCD. Compliance can be shown by test, similarity to a previously tested part or by analysis.

A Boeing DER then reviews and approves these documents using a FAA form 8110-3 showing compliance to the QTP. Then the QTP is reviewed with the FAA and a Request for Conformity (form 8120-10) is submitted to the FAA by the relevant DER. The FAA arranges for conformity of the test parts and setup and authorizes a test witness. The supplier then performs the testing per the QTP and reports failures immediately to Boeing for disposition before proceeding. Once the testing has been successfully completed a Qualification Test Report (QTR) is submitted to Boeing for review and comment/approval. Boeing approves the QTR using an FAA form 8110-3 signed by the relevant DERs.

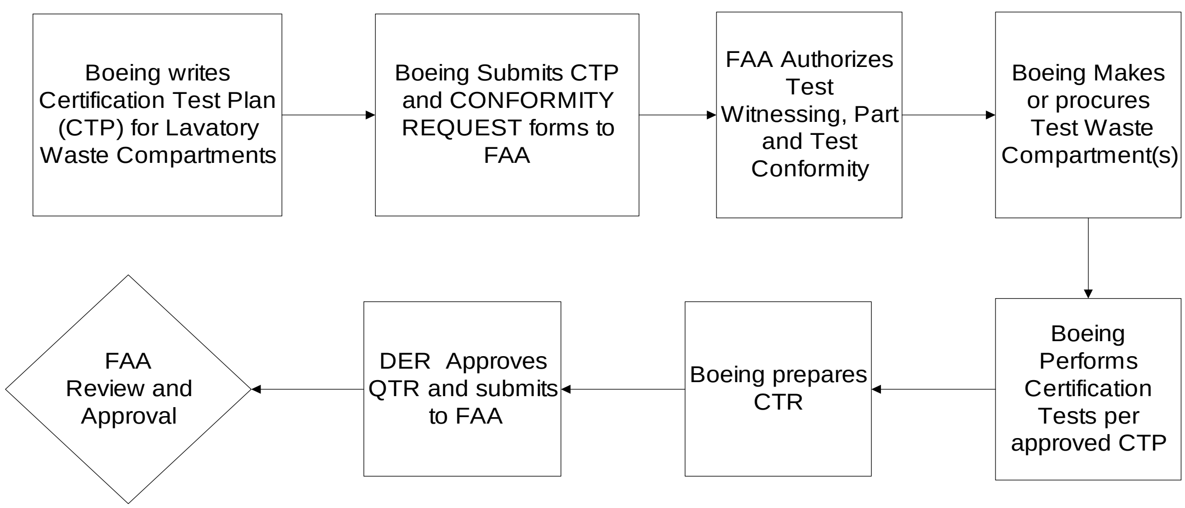
Installation Certification Process

Once the component has been qualified, Boeing then certifies the installations of the component in the airplane per a Certification Test Plan (CTP). The CTP specifies that the testing will be accomplished in a simulated lavatory waste receptacle using a procedure similar to the MPS. Boeing tests these bottles in a 3 cubic foot test box using the same orientation and nozzle position in which the lavatory supplier installs the bottles on the airplane. Lavatory suppliers may install these bottles at different angles due to space considerations and the orientation could make a difference in extinguisher performance. The current

installations using Halon 1301 bottles have been certified using this method. The CTP will be approved by the relevant DERs and submitted to the FAA for review and approval.
Once approved by the FAA, a Request for Conformity is submitted to the FAA by the relevant DER for the test bottles and test setup. The FAA arranges for conformity of the test parts and setup and authorizes a test witness. Boeing then performs the testing per the CTP. Once the testing has been successfully completed, a Certification Test Report (CTR) is submitted to the FAA for review and approval and then signed by the relevant DERs. See Figure 7.

The last step in the process is to revise all of the documentation to allow installation of the non-Halon Lavex bottles. This requires revision of the Boeing lavatory drawings for every current model of airplane to identify the non-Halon bottle as the preferred option to the Halon 1301 bottle. These drawings are then sent to the lavatory suppliers for their incorporation into their respective lavatory drawings and Component Maintenance Manuals (CMM). Boeing then revises the Airplane Maintenance Manuals (AMM) and Illustrated Parts Catalog (IPC) for spare parts availability.

Finally the lavatory suppliers are thereafter authorized to install the new non-Halon agent/bottle assembly in lavatories manufactured from that point onward.



CTP = Certification Test Plan
SCD=Specification Control Document
CTR= Certification Test Report

Figure 7. Lavex Installation Qualification/Certification Process

References

1. Timothy Marker, *Development of a Minimum Performance Standard for Lavatory Trash Receptacle Automatic Fire Extinguishers*, Final Report No. DOT/FAA/AR-96/122, FAA Technical Center, Atlantic City, New Jersey, February 1997.

2. Boeing Specification Control Drawing, *Extinguisher Assembly, Heat Activated-Chemical*, Rev. J, November 1998 (Boeing Proprietary)

3. Commission of the European Communities, *Proposal for a Council Regulation (EC) on substances that deplete the ozone layer*, No. COM(1998) 398 final, Brussels, 1998.