

# HALON REPLACEMENT IN AIRPLANE LAVATORY TRASH RECEPTACLE EXTINGUISHERS

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## INTRODUCTION

The production of halons has been banned by international agreement due to their ozone-depletion potential (ODP). Cargo compartments, engines, lavatories, and handheld fire extinguishing systems on commercial airplanes have successfully used halon fire suppression agents for years.

This report explains the methodology necessary to approve the use of Halon 1301 replacement agents in the airplane lavatory trash receptacle fire extinguisher (Lavex) bottles (Figure 1). The design concept of the lavatory fire extinguisher is simple. The extinguishing bottle is filled with a pressurized extinguishing agent. Two nozzles (for redundancy) extend from the bottle and are inserted into the waste compartment. At the end of each nozzle is a fusible tip. This tip is held in place by eutectic solder. When the temperature inside the waste compartment reaches the melting point of the eutectic, the tip is forced off by the pressure of the agent. The agent escapes through the nozzles and extinguishes the fire. The Lavex bottle is the first agent/bottle combination to undergo extensive testing by Boeing to show the “equivalent level of safety” to Halon 1301.

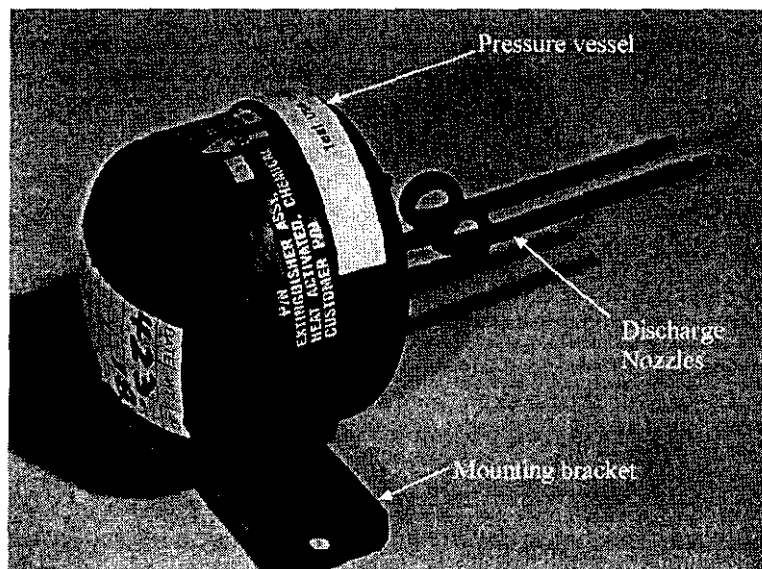


Figure 1. Lavex bottle configured for tests

The Federal Aviation Administration (FAA) published Minimum Performance Standard (MPS) [1]: the test apparatus, and the data collection system are crucial in determining the performance of the agent/bottle assembly in a laboratory environment. However, 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. Both tests are required before any alternative fire extinguishing agent can be certified for installation in an airplane lavatory (Figure 2).

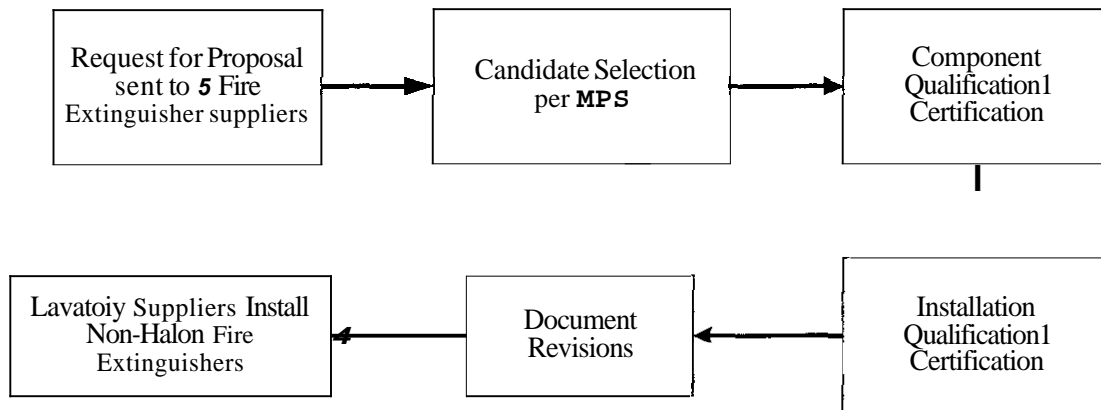


Figure 2. Lavex qualification / certification process.

### 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. 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 receptacles 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 criterion; 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 whether 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 and (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 duplicate Halon 1301 performance by constructing the same size test box following the supplier’s test procedures and by using 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 were standardized, repeatability with bottles at temperatures at 30 °F and below was achieved with Halon 1301.

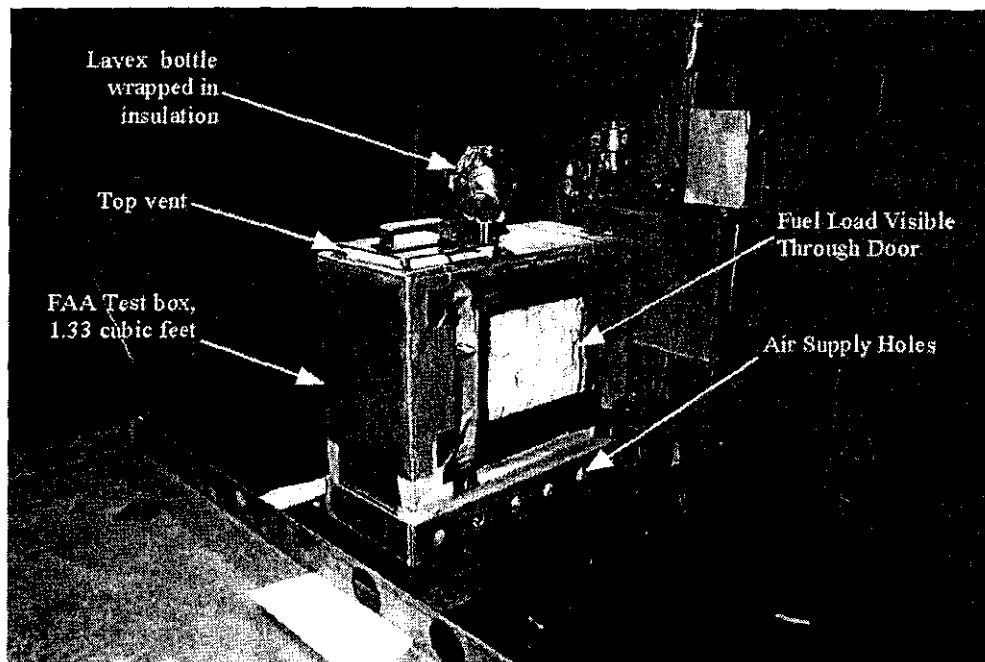


Figure 3. Test apparatus with bottle and fuel load.

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.

### BOEING PARTICIPATION

Boeing participation in halon replacement started in 1993 by working together with extinguisher companies to stabilize the supply of recycled halons 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 ever since. Key Boeing personnel became involved when the working group started drafting the MPSs for lavatory trash receptacle, handheld 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
- (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.

The qualification/certification process required dedicated funding resources, engineering review of supplier data, testing and FAA approval. This internal effort had to be done in addition to all of the normal airplane design and production support work. Approval was granted to proceed in 2000.

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 (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.

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 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 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.

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\* 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.

† DMIRs are FAA trained employees of industry firms who are designated by FAA to perform FAA tasks, such as conformity.

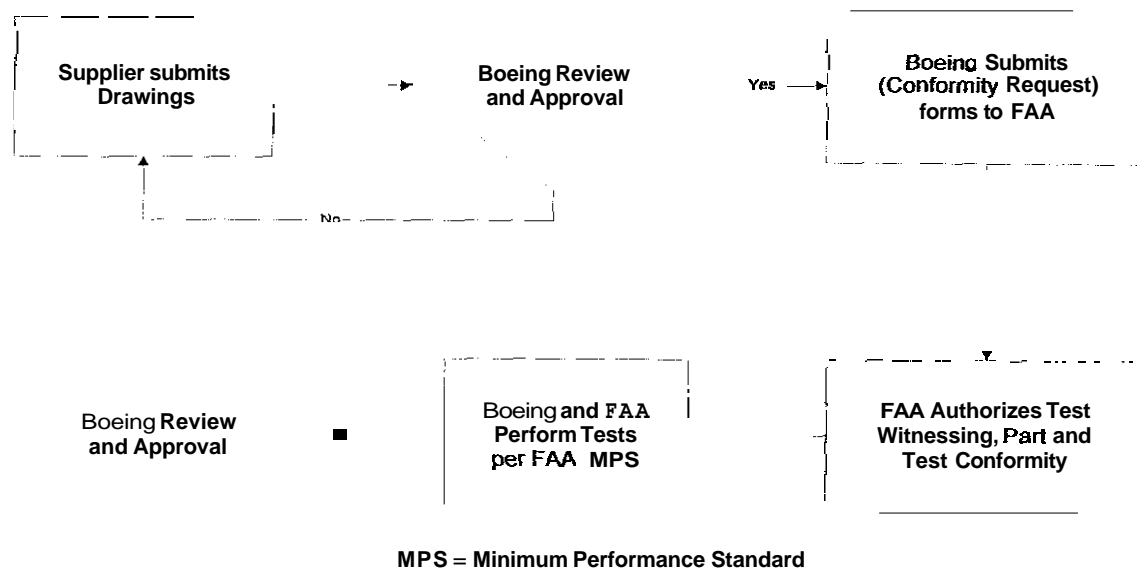


Figure 4. Candidate selection process.

The procedure was the same for each supplier. At least one Halon 1301 bottle was tested as a benchmark, and testing was performed to the FAA test procedure (Appendix D, MPS). After the halon test was completed, Lavex bottles were tested with the alternative agent. Each supplier had provided seven non-halon conformed bottles for this test. One of the success criteria was that five bottles in succession had to put out the fire. No reignition or burning embers could remain. In addition, the bottle had to discharge within 60 sec 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™. Both suppliers with FE-36™ and the supplier with FM-200™ passed their tests. FE-36™ appeared to be equivalent to halon in its firefighting ability. FM-200™ was observed to put out fires completely with little or no residual smoke immediately after discharge (Figure 5).

The only bottle that did not meet the MPS used Envirogel™ agent. This agent failed the first two tests due to reignition. The second temperature peak in Figure 6 represents reignition. This fire had to be manually extinguished with a handheld 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 sec.

## LESSONS LEARNED

A number of lessons were learned in the process of completing these tests. We determined that it was not clear 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 provided. For example, if the third bottle failed, it was not possible to pass this test during the testing exercise.

During the second test, we found that the test box had several leak paths, and the extinguishing agent was leaking out. Because of this problem with the box, we had to disqualify that test. 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 (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.

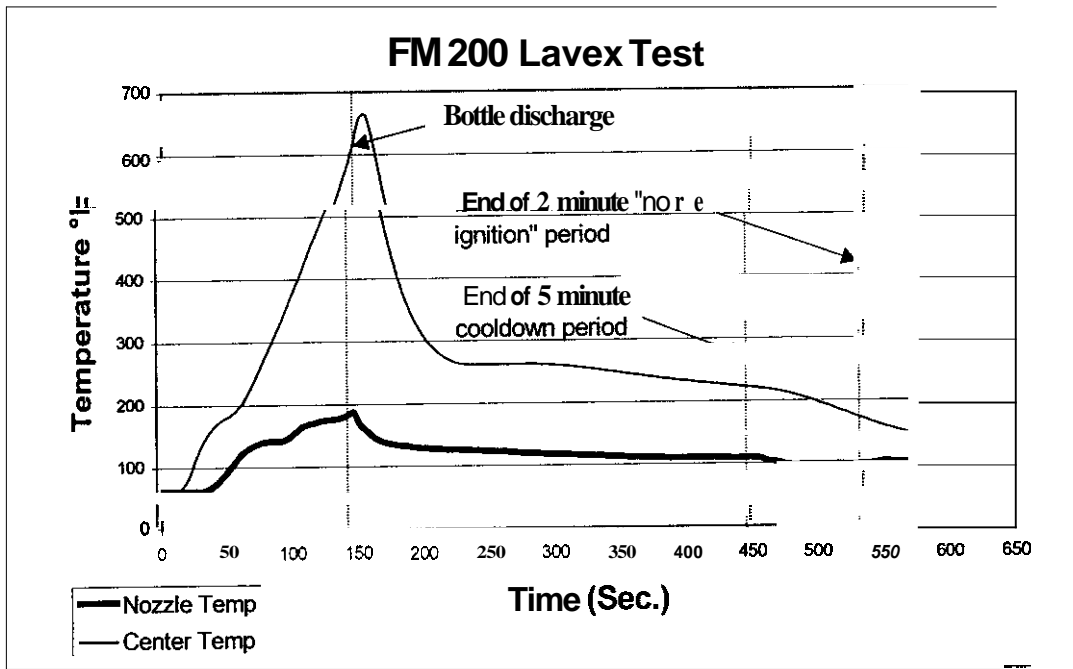


Figure 5. Example of successful test.

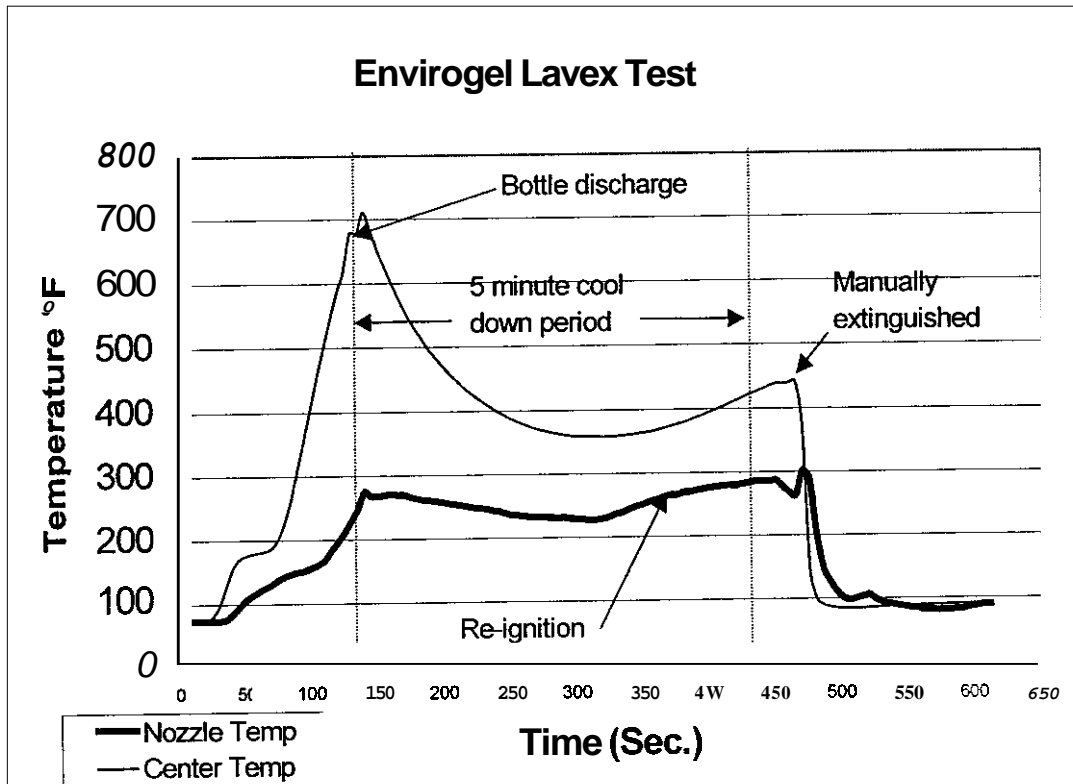


Figure 6. Example of test failure due to re-ignition.

Another problem encountered was that the FAA MPS procedure showed three thermocouple locations. 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 read the temperature at the discharge tube eutectic tips accurately. The MPS specifies a maximum duration of 60 sec between reaching the activation at the discharge tip(s) and initial discharge of the extinguishing agent. In fact, the FAA test box and data recording system did have four thermocouples installed, but the MPS needed to be revised to show the fourth thermocouple and explain its function.

We found that the thermocouple placement affected the results. The reason for the faster discharge times during these tests than in previous tests performed by Boeing (Seattle) became evident. 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 almost touched the eutectic tips. Up to that point, we had received satisfactory results in **our** tests with all bottles discharging within 60 sec of reaching the activation temperature. In the next two tests, a Boeing DER located the thermocouple. In both tests, the times were longer than the required 60 sec. 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 in. 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 the two previous tests due to an inconsistency in thermocouple placement.

The testing 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 consistency of test methodology.

## **COMPONENT QUALIFICATION/CERTIFICATION PROCESS**

Once the suppliers have passed the testing per the FAA 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 (Figure 7). 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.

The documents will be reviewed for compliance to the Boeing SCD. The drawings must reference the bottle manufacturing processes, materials, and dimensions as well as the qualification test report. The ATP is the procedure for the testing done on every part prior to shipment. The QTP is a checklist of how the supplier will show that the component meets all of the requirements in 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. The next step is to initiate the qualification test process. 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 in the laboratory using a procedure similar to the MPS. Boeing tests these bottles in the same orientation and nozzle position in which the lavatory supplier installs the bottles on the airplane. The orientation could possibly make a difference as the lavatory suppliers generally install these bottles at an angle due to space considerations. The current installations using Halon **1301** bottles have been certified using this method. The CTP will be approved using an FAA form (81 **10-3**) signed by the relevant DERs and submitted *to* the FAA for review and approval. Once approved by the FAA, a Request for Conformity form (8120-10) is submitted to the FAA by the relevant DER for the test bottles and 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 using the FAA form 81 10-3 again, signed by the relevant DERs (Figure 7).

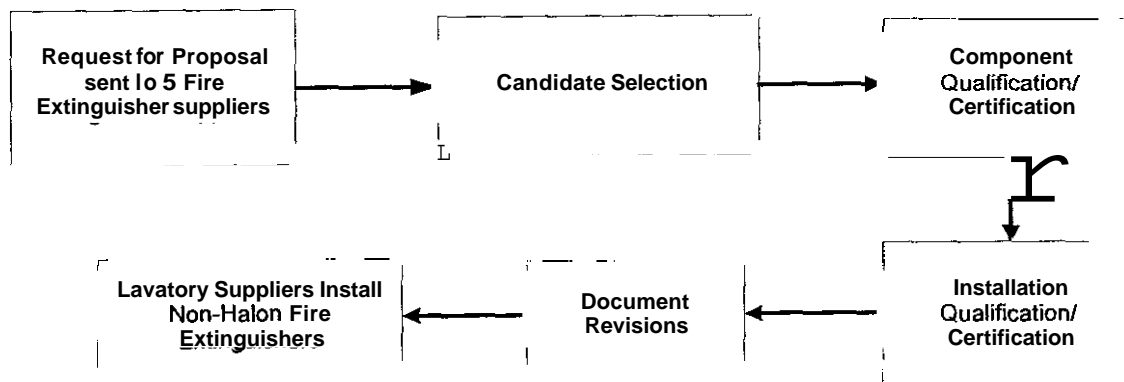


Figure 7. Lavex qualification /certification process.

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 SCD for every current model of airplane to identify the non-halon bottle as the preferred option to the Halon 1301 bottle. The SCDs 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. The lavatory suppliers are then authorized to install the new non-halon agent/bottle assembly in lavatories manufactured from that point onward.

## REFERENCES

1. Marker, Timothy, *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, NJ, 1997.
2. Boeing Specification Control Drawing, *Extinguisher Assembly, Heat Activated-Chemical*, Rev. J, 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, Belgium, 1998.