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Alternative Approach for Fire Suppression of Class A, B, and C Fires in Gloveboxes

ABSTRACT

Department of Energy (DOE) Orders and National Fire Protection Association (NFPA) Codes and Standards require fire suppression in gloveboxes. Several potential solutions have been and are currently being considered at Los Alamos National Laboratory (LANL). The objective is to provide reliable, minimally invasive, and seismically robust fire suppression capable of extinguishing Class A, B, and C fires; achieve compliance with DOE and NFPA requirements; and provide value-added improvements to fire safety in gloveboxes. This report provides a brief summary of current approaches and also documents the successful fire tests conducted to prove that one approach, specifically Fire Foe™ tubes, is capable of achieving the requirement to provide reliable fire protection in gloveboxes in a cost-effective manner.

INTRODUCTION

DOE Standard 1066 and NFPA 801 require automatic fire suppression to be installed in gloveboxes and, potentially, fume hoods as well. These regulatory requirements stem from actual fire incidents. The need for some form of automatic fire suppression is very real due to the nature of glovebox operations and the materials contained within gloveboxes and fume hoods. For the purpose of this report, we refer to gloveboxes and fume hoods as one category, called enclosures.

Significant resources are spent annually within the DOE Complex to analyze, evaluate, and develop engineered and administrative controls, develop surveillances, and audit the execution of Authorization Basis programs. These resources are expended in an effort to minimize the potential effects of an enclosure fire to workers and the public, facility and programmatic assets, and program mission delivery. Many of these controls rely on worker intervention to either extinguish the fire or to retard its growth, exposing the worker to potentially lethal conditions. Additionally, this approach does not address conditions in which a worker is not present or during off-shift events. While a worker may be able to contain an enclosure fire and not be exposed to any detrimental effects, the resulting political fallout from such an event could significantly delay or prevent a program or even a facility from restarting operations.

The preceding discussion simply reinforces the need for some form of cost-effective automatic fire suppression to be installed in enclosures. The features of several existing and proposed fire suppression systems are described below.

Water-based suppression systems are capable of providing fire suppression and are inherently reliable. However, they require penetrations into the glovebox and present a potential dilemma in the event of sprinkler/nozzle activation with respect to volume of water discharged and the disposal mechanism for potentially contaminated water. Toppling of a glovebox during a seismic event would eliminate fire suppression in the enclosure with this type of system. Additionally, the volume of water flow from a broken pipe would far exceed the volume of water flow from a

sprinkler, which would compromise the ability of the overhead sprinkler system to suppress a fire. A dedicated water mist system would be incapacitated, but not affect the overhead suppression system.

Inertion is another approach to minimize the potential for fire by providing an oxygen deficient atmosphere that does not support combustion in the enclosure. As such, inertion is not a "fire suppression" system. The inertion systems are installed to support process requirements typically involving pyrophoric metals. Inertion is the predominant approach throughout the DOE Complex to minimize the possibility of fire in enclosures. Fire mitigation is reliable up to the point at which the inert atmosphere can be maintained. Toppling of a glovebox during a seismic event or loss of electrical power to the vacuum equipment would disrupt the inertion and the atmosphere intended to mitigate the possibility of a fire.

Dry chemical systems, similar to kitchen hood systems, have been proposed and mocked up, but not subject to actual fire tests to prove their viability. However, dry chemical systems would require penetrations into the enclosure and seismic modifications to the glovebox, adding considerable expense to this unproven system. Toppling of a glovebox during a seismic event would potentially damage piping or the agent cylinder, compromising its ability to suppress fire. Additionally, the heat detector located in the ceiling, which acts as a means of activation for the dry chemical system, would now be located on the side of the glovebox, adversely affecting the response time for this suppression system if it were still functional after a seismic event.

Fire Foe™ is a self-contained fire extinguisher that would be mounted to the interior of the enclosure via four to six bolts. Fire Foe™ provides a reliable means of fire suppression. (See appendices for fire test data.) The tubes are seismically robust, and toppling of a glovebox during a seismic event would not affect the Fire Foe™ tube. Therefore, the tube would remain functional and provide an active means of fire suppression in the enclosure.

FIRE FOE™ TUBES

Fire Foe™ tubes are a self-contained, heat intelligent, fire extinguisher that is UL Listed for Class B (i.e., liquid pool fires) and Class C (i.e., energized electrical circuits) fires in enclosures of 15, 30, 60, 100, and 130 ft^3. The manufacturer also produces a larger tube for 250-ft^3 enclosures. The 250-ft^3 tube was not subject to UL testing and does not carry the UL mark. The 250-ft^3 tube is manufactured to the same standards and with the same equipment used to produce the smaller UL-Listed tubes. Fire Foe™ tubes do not carry a Class A (i.e., ordinary combustibles) listing because there is no nationally recognized test for Class A fires in enclosures.

The Fire Foe™ tubes contain Envirogel®, which is a mixture of sodium bicarbonate powder (micro-ground) and two clean agent suppressants:, FE-25™ and FE-36™. The sodium

bicarbonate disperses with the clean agent suppressants and coats the contents of the enclosure to prevent re-ignition of combustibles.

Research into the clean agent suppressants revealed they are both listed for Class A, as well as Class B and C fires. According to the technical bulletins for each clean agent suppressant:

- FE-25™ "The accepted Minimum Extinguishing Concentration (MEC) for FE-25™ for Class-A fires is 6.7% based on the Class-A fire test requirements found in Underwriters Laboratories' (UL) Standard 2166. For Class-B fires, the MEC is 7% based on cup-burner tests with n-heptane fuel.... FE-25™ is an ideal replacement for Halon 1301 for the total flooding of enclosures. It can be used in applications where people are normally present (normally occupied spaces) for Class-A fire assets."
- FE-36™ "DuPont™ FE-36™ is the most widely used zero ozone depleting replacement for Halon 1211 in portable fire extinguishers and is approved for use in Class-A, -B, and –C fires."

The technical bulletins for FE-25™ and FE-36™, included in Appendix E, indicate extinguishing characteristics of the clean agent suppressants, which leads us to believe the tubes could be utilized to extinguish Class A fires. In addition, the manufacturer of the tube was confident Fire Foe™ tubes would prove successful for extinguishing Class A fires.

The Fire Foe™ tube is constructed of Nylon 6,6 (PA66) that is 0.065" (1.65-mm) thick with a milled strip that is 0.055" (1.4-mm) thick for standard temperature tubes and 0.085-in. (2.16-mm) thick with a milled strip that is 0.075" (1.9-mm) thick. The thinner milled strip is intended to be the release/rupture point at tube activation. The milled strip is identified by a strip of black tape to facilitate alignment of the tube for optimal discharge during installation. Tubes are sealed at the ends with 12L14 carbon steel caps. One end of the tube is fitted with a fire extinguisher-type gauge, which provides an easy means to inspect the tube to ensure it is properly pressurized. The operating range of the gauge is 75 psi to 121 psi (i.e., the green band of the gauge). The other end of the tube is fitted with a threaded fitting and spring-loaded plunger assembly that is utilized to fill, pressurize, and seal the tube. Tubes can be manufactured with 304 stainless steel end caps instead of 12L14 carbon steel to suit glovebox working environments.

Fire Foe™ uses patented technology and specially formulated heat-intelligent nylon tubes, eliminating the need for additional heat detectors. There is no need for an initiating device to activate the tube or any type of power supply, making Fire Foe™ a cost-effective, automatic fire extinguishing system. The narrow tube profile and bolt-on simplicity save time and money when fitting or retro-fitting this fire suppression system, minimizing downtime and loss of productivity.

Standard tubes are effective in ambient operating temperatures up to 175°F (80°C) and are accredited by UL up to 130°F (55°C). High-temperature tubes are suitable for use in ambient operating temperatures up to 220°F (105°C). The manufacturer can provide dummy tubes with heat recording labels to help determine maximum ambient operating temperature in the

enclosure, with the dummy tubes installed in locations actual Fire Foe™ tubes would be installed.

Fire Foe™ reacts to all fires, slow burning over time as well as flash fires. Tubes are normally pressurized to 100 psi at room temperature. Below 175°F (80°C), the Fire Foe™ tube is stable. When the heat from a fire climbs above 175°F (80°C), the Fire Foe™ triggers the heat-intelligent nylon tube, which begins to activate (i.e., soften). High-temperature tubes will begin to self-activate above 240°F (115°C). As the temperature rises, the internal pressure of Envirogel® increases, eventually rupturing the tube along a milled release strip, releasing the Envirogel®. At 316°F (150°C), standard temperature tubes discharge instantly. The Envirogel® undergoes a phase change from gel to gas, which instantly interrupts the combustion process, absorbing heat and chemically extinguishing the fire. The non-toxic and non-corrosive sodium bicarbonate powder travels with the gas, coating any combustible material to prevent re-ignition.

Tubes are vibration- and corrosion-resistant, unaffected by low temperatures, and will not activate before the pre-determined temperature has been reached (500 successful individual activations were performed sequentially to secure UL approval).

Fire Foe™ is provided with an integral pressure gauge for easy monitoring. Additionally, the tubes are available with an integral pressure switch that can be tied into the fire alarm system for monitoring. Periodic maintenance can be accomplished by a visual inspection of the gauge located on the end of the tube. A log should be maintained to confirm that the pressure is still within the acceptable range (i.e., green band on gauge).

DEVELOPMENT OF TEST PROTOCOL

LANL's ES-DE Fire Protection Division developed a phased test plan to minimize financial exposure to LANL in the event proof-of-concept tests were not successful. The initial phase was comprised of proof-of-concept testing at the manufacturer's facility. Successful proof-of-concept testing would be followed up with subsequent phases that consisted of Nationally Recognized Testing Laboratory (NRTL) fire testing based on the developed test protocol.

As previously stated, there is not a nationally recognized test for Class A fires in enclosures. We used this to our advantage to develop a test protocol tailored to needs here at LANL. Specifically, the Class A combustibles would consist of a wood crib, boxes of Kim-wipes, and Tygon tubing. Class B combustibles would be comprised of acetone and cutting oil. Class C combustibles would consist of wire bundles comprised of #16 AWG, #18 AWG, and coaxial cables. The test protocol was prepared in conjunction with QuickFire, the manufacturer of Fire Foe™ tubes. Due to the lack of a Class A listing for any tubes, we developed the test protocol based on the largest tube (i.e., 250 ft^3) tube manufactured by QuickFire to yield the greatest benefit to the Laboratory. (See Appendix B, Test Protocol Developed between LANL and QuickFire.)

PROOF-OF-CONCEPT TESTING

LANL provided sketches and details to QuickFire to permit the manufacturer to fabricate a glovebox mock-up at its facility to perform fire tests. Dimensions of the mock-up were 8'L x 5'W x 6'H, yielding a 250-ft^3 enclosure. Pictures of the enclosure are included in Appendix C, Fire Foe™ in 250 CF Glove Box – Proof-of-Concept Test Report. LANL provided windows, window gaskets, gloves, and HEPA exhaust filters identical to equipment used on gloveboxes at LANL.

When the glovebox mock-up was completed, the manufacturer installed thermocouples to record the temperature profile in the enclosure, pressure transducers to record the pressure profile in the enclosure, and a blower and ducting to provide the airflow indicated in the test protocol. The thermocouples and pressure transducers were connected to a computer to record data for all proof-of-concept fire tests. Airflow was measured with an anemometer and set to 250 cfm (i.e., one air change per minute). The airflow used for the fire tests is greater than that used for gloveboxes, and more consistent with fume hoods, thus opening the door to the possibility that the tubes could be used in fume hoods—and providing a dual-use benefit of the tubes for LANL. The air intake opening was adjusted to provide negative pressure as indicated in the test protocol. Negative pressure is required in the enclosure, with respect to the room in which it is located, to ensure the glovebox does not discharge its contained environment to the surrounding room in the event of a glove breach or other breach of the enclosure. The requirement to maintain negative pressure was a concern because of the fact that the internal pressure inside the Fire Foe™ tube is approximately 600 psi at rupture, which intuitively would generate a pressure surge. The concern was unfounded, as activation of the tube resulted in a negative pressure spike, actually pulling the gloves into the enclosure.

Summary of Proof-of-Concept Test Results

QuickFire performed numerous fire tests at its facility in accordance with our co-established test protocol. Fire tests were performed utilizing Class A combustibles, Class B combustibles, and Class C[1] combustibles fires and various combinations of combustibles to confirm the Fire Foe™ tube is capable of successfully extinguishing all three classes of fires in enclosures. Class A combustibles used for this series of fire tests consisted of wood cribs constructed of nominally 1"D x 2"W x 10"L pine into a 10" cube stuffed with crumpled newspaper to represent a deep-seated fire.

[1] Class C fires are energized electrical equipment, and the requirement is for the extinguishing agent to be electrically non-conductive. Envirogel® is already listed for Class C fires as a non-conductor. The intent of our fire test was to prove that the insulation for electrical equipment and wiring would be successfully extinguished (similar to Class A and Class B combustibles).

The individual proof-of-concept fire tests performed by QuickFire are referred to as "Test Protocol #" in its report, "Fire Foe™ in 250 CF Glovebox Proof-of-Concept Test Report" (Appendix C).

QuickFire performed 10 proof-of-concept tests at –¾" water column (i.e., glovebox negative pressure requirement) that were 100% successful. The proof-of-concept tests used various combustibles as defined in the test protocol. Successful testing led to an additional set of tests that were performed September 20, 2010, at QuickFire's facility in Fort Wayne, IN, and witnessed by LANL representatives Mark S. Rosenberger and James A. Tsiagkouris of ES-DE Division. The pressure was adjusted to –¼" water column for this next series of fire tests to more closely reflect actual glovebox conditions found at LANL. An additional four proof-of-concept tests were performed that were also 100% successful.

The positive pressure surge envisioned at tube activation/rupture proved to be unfounded, as the pressure surge was negative due to the phase change and cooling effect of Envirogel®. The only positive pressure changes were the result of involvement of combustibles during the fire tests.

The Fire Foe™ tube was located along the longitudinal centerline of the glovebox mock-up for all 14 proof-of-concept tests performed at the manufacturers' facility. As we worked through proof-of-concept testing, we realized that even though the centerline of the glovebox was the optimal location for the tube, it was not the most accessible location for attachment of the tube. Additionally, equipment or processes used in the glovebox may preclude locating the tube in the centerline of the enclosure. We requested additional fire tests with the tube located closer to the side of the enclosure, which would have a two-fold benefit: allowing easy access to the tube from the glove ports and providing redundancy of suppression via installation of tubes on each side of the enclosure. QuickFire performed additional proof-of-concept tests with the tube located nominally 6" below the ceiling and 6" from the side wall; the tests were 100% successful. All fire test conditions were maintained for a minimum of 5 minutes after activation of the Fire Foe™ tube to confirm there was not any re-ignition of combustibles or any remaining embers that would support continued combustion in accordance with UL guidelines. Table 1 shows a summary of the test results.

Table 1. Summary of Proof-of-Concept Test Results

Fire Test No.	Type of Combustibles	Time from Ignition to Activation of Fire Foe™ Tube (minutes:seconds)	Approximate Ceiling Temperature at Tube Activation
1	Class B[1]	2:03	370°F
2	Class B	0:56	465°F
3	Class B	1:29	430°F
4	Class A[2] and B	1:25	340°F
5	Class A and B	2:31	355°F
6	Class A and B	1:16	255°F
7	Class A, B and C[3]	2:33	305°F
8	Class A, B and C	1:07	390°F
9	Class A, B and C	2:06	325°F
10	Class A, B and C	2:18	n/a
11	Class A, B and C	1:58	315°F
12	Class B and C	3:05	322°F
13	Class B and C	5:59	270°F
14	Class A, B and C	3:45	545°F[4]

[1]Class B Liquid pool fires - Acetone and preheated cutting oil

[2]Class A Wood crib, and crumpled newspaper and Tygon tubing

[3]Class C Coaxial cable, #16 THHN, and #18 THHN

[4]130 ft³ tube installed in 250 ft³ enclosure

Additional proof-of-concept fire tests were performed to document that the tube would successfully extinguish fires even with various tube locations within the enclosure. At the end of this entire testing cycle, the gloves in the gloveboxes were still intact and pliable without any breaches, but they did have some discoloration because of their proximity to the fire. The windows did not suffer any damage or clouding, and the window gaskets showed no signs of fire damage.

NRTL TESTING

Successful proof-of-concept testing permitted us to proceed with NRTL testing, which was to be witnessed by LANL representatives. Intertek, an NRTL, agreed that testing and set-up would be easier if the glovebox mock-up remained at QuickFire's facility. Follow-up NRTL testing was performed October 19, 2010, and witnessed by LANL representatives Mark S. Rosenberger and James A. Tsiagkouris. (See Appendix D, Intertek Report No. 100238106SAT-001.) The purpose of contracting with an NRTL was to provide independent verification of the test results. Additionally, the NRTL has the ability to provide long-term inspections at the manufacturer's facility to guarantee to LANL that tubes are manufactured to the same specifications as the tubes used for fire tests.

Summary of NRTL Test Results

NRTL monitored and recorded the six tests that were performed. The Fire Foe™ tube successfully extinguished fire tests 1, 3, 4, 5, and 6. For this series of fire tests, we used a UL 1975 wood crib assembly (pictured in Appendix D). The UL 1975 wood crib has a smaller heat release rate than the wood crib used for the proof-of-concept fire tests. To initiate the fire test, the wood excelsior inside the base of the wood crib was ignited and allowed to burn for 1 minute prior to introduction of acetone. The pressure wave generated when the acetone became involved in the fire had an extinguishing effect on the wood crib fire. This effect is evident in fire test no. 2 as the fire burned out prior to reaching a temperature that was sufficient to activate the tube. To minimize the extinguishing effect experienced during introduction and involvement of acetone, we decided to allow the wood crib to burn for 2 minutes for fire tests 5 and 6. Table 2 summaries the NRTL test results.

Table 2. Summary of NRTL Test Results

Fire Test No.	Type of Combustibles	Time from Ignition to Activation of Fire Foe™ Tube (minutes:seconds)	Approximate Ceiling Temperature at Tube Activation	Approximate Pressure Change at Tube Activation
1	Class A[1], B[2], and C[3]	4:21	311	-9" WC
2	Class A, B and C	Fire burned out	-	-
3	Class A, B and C	6:11	430°F	-3.5" WC
4	Class A, B and C	2:52	340°F	-6" WC
5	Class A, B and C	3:13	355°F	-14.5" WC
6	Class A, B and C	3:42	255°F	-12" WC

[1]Class A UL 1975 wood crib and Tygon tubing

[2]Class B Liquid pool fires - Acetone and preheated cutting oil

[3]Class C Coaxial cable, #16 AWG, and #18 AG bundle of wires

ENVIRONMENTAL IMPACT

Based on fire tests performed to validate this suppression system, Fire Foe™ tubes typically discharge within four minutes in the event of a fire in the enclosure. The resulting discharge will introduce the Envirogel® into the enclosure. At the time of discharge, the Envirogel® will consist of the components and forms listed in Table 3.

Table 3. Envirogel® Components and Forms

Component	Form
Sodium Bicarbonate	Powder
Nitrogen	Gas
DuPont FE-25™	Gas
DuPont FE-36™	Gas

Dupont, Inc., manufactures the fire extinguishing agents FE-25™ and FE-36™ as Halon 1301 replacements. Both agents have been Significant New Alternatives Policy (SNAP) program-approved by the Environmental Protection Agency (EPA) and are suitable for direct release to the atmosphere as ozone non-depleting agents.

The products of combustion that will be produced in a fire event cannot be fully anticipated because they are dependent on the contents of the enclosure and the materials involved in the fire. However, consistent with any industrial fire event, the agents will interact with the combustion process and will generate a number of compounds that are adverse to health safety and the environment.

In the event of a small fire, it would be fully anticipated, as long as the exhaust system remains functional, that the products of combustion would be contained by the primary exhaust system. This would provide filtering of the smoke prior to discharge to the environment. If the fire were to involve gloves in a glovebox or be at the face of a hood, then the products could be discharged into the adjacent air spaces. This smoke is fully anticipated to be processed by the secondary air handling systems supporting the affected facility. This type of scenario is normally addressed as part of the Authorization Basis for a facility but would have to be reviewed for any potential impact to the bounding design basis accidents that have been developed.

Decommissioning

Decommissioning of the tubes presents several challenges, listed below:

- Potential radiological surface contamination on the tube
- Relieving internal pressure of the tube
- Disposal of the tube contents
- Disposal of the tube

We have explored methods to decommission the tubes. We propose the following steps for disposal of tubes that are not provided with an integrated pressure switch:

1. Identify the tube for decommissioning.
2. Remove the identified tube from the mounting bracket.
3. Remove the screw end cap from the tube, exposing the spring-loaded valve.
4. Screw in the pressure relief tool and attach a capture bag to the discharge end of the relief tool.
5. Engage spring-loaded valve by rotating the tube and release internal pressure; any contents of the tube will be captured in the attached bag.
6. Empty the remaining contents of the tube into the bag.
7. Cut tube as required to accommodate removal of tube from the enclosure.

In the event of potential radiological surface contamination, the tubes will have to be disposed of as contaminated waste. Due to the nature of the tube's surface materials, it is not anticipated they

could be adequately decontaminated to allow for a free release from the environments in which they are installed. Therefore, decommissioning will have to be performed inside the enclosure or transferred to a dedicated enclosure for decommissioning.

Once the pressure in the tube is relieved, and the contents of the tube (i.e., sodium bicarbonate powder) are removed, the body of the tube can easily be cut, by a hand or power saw, into shorter lengths as required to support removal from the enclosure by standard means. The cut sections of tube targeted for waste would simply be processed out of the enclosure as non-compactable waste.

The nitrogen gas used to charge the tube could be released in the enclosure itself and allowed to discharge with the exhaust air from the glovebox through the facility's filtered exhaust system. Additionally, at atmospheric pressure, the FE-25™ and FE-36™ clean agent suppressants that comprise the Envirogel® vaporize and are carried out with the nitrogen gas. This leaves only the sodium bicarbonate powder in the tube, which would be processed with the spent tube and disposed of as non-compactable waste.

Accidental Discharge

There is always the possibility of an accidental discharge of the tube. One scenario would be premature failure of the tube. The most likely cause of this would be a standard temperature tube placed in an environment in which it sees higher than anticipated ambient temperatures, similar to the failure mechanism of a fire sprinkler in this type of environment. For a fire sprinkler, this type of failure would result in the fire suppression system activating and discharging water from the activated sprinkler into the protected area. In the event of a tube discharge, the result would be similar; the tube would rupture and the agent would be released into the protected enclosure.

Another scenario would be mechanical impact resulting in a puncture or breach of the tube. Once again, this scenario would be similar to a fire sprinkler placed in a physical location where the sprinkler could be damaged by physical impact. In the case of a sprinkler, physical damage could result in damage that causes it to leak or could result in the thermal element being dislodged, causing a full flow from the sprinkler. In either case, the result is the same: the fire suppression system would be impaired and water would be flowing in the facility. The tubes are more robust than a sprinkler but could be punctured, which would result in the agent being discharged from the tube into the protected enclosure. In this scenario, the tube would have to be replaced.

Following the battery of fire tests performed to prove Fire Foe™ extinguishes Class A, B, and C fires in enclosures, a puncture test was performed and recorded to help understand what would happen if a tube was accidentally physically damaged. The test results showed that the agent would discharge in powder form. If a glovebox technician was present at the time of damage, there would be positive visual indication of the agent discharging from the tube. Conversely, if a glovebox technician was not present at the time of the accidental discharge, there would be

visible indications in the form of sodium bicarbonate powder coating the interior of the enclosure and its contents.

SEISMIC CONSIDERATIONS

Seismic considerations for systems, structures, or components (SSCs) installed in several LANL facilities are of extreme importance. Seismic events present real and challenging problems in designing engineering controls, which must ensure that these facilities are safe after a design basis event. One of the most challenging accident scenarios considered as part of the Authorization Basis analysis is the post-seismic fire event. In accordance with DOE Standard 1066 requirements, automatic fire suppression is required to be installed in all gloveboxes. The following is a listing of the best candidates to fulfill this requirement:

1. Water-based suppression (i.e., fire sprinklers, and water mist)
2. Dry chemical
3. Inertion
4. Fire Foe™ Tubes

Each of the above systems could be installed in an enclosure, but each one presents its own set of challenges in a post-seismic fire scenario.

Water-Based Suppression

Fire Sprinkler

Fire sprinklers are arguably the most cost-effective means of automatic fire suppression available. Fire sprinklers have a history of effective fire suppression in many environments. Fire sprinklers can either be piped to the overhead fire suppression system or piped independently to each enclosure. These systems draw from water sources located outside of the facility they are protecting. However, the presence of water within the enclosures at LANL can present major problems for many processes, primarily the criticality of the materials present in the enclosures.

Given a seismic event, the water distribution system may not be intact and, therefore, no water would be available to the fire sprinkler system. Even if the outside water supply were to survive the seismic event, several issues remain with the seismic response of the facility and its contents. Facility interior walls could shear the suppression piping, and equipment within the facility could shift and damage the piping, resulting in loss of water to the system. Another concern as a result of a seismic event is that of the enclosure itself. The enclosure could tip over if the support stand failed. This would result in the sprinkler piping breaking and water being discharged from the system, but not into the enclosure, which would also compromise the ability of the overhead system to suppress a fire.

Water Mist

Water mist fire suppression systems use a limited-volume water supply and deliver the water at a high velocity through a nozzle designed to atomize the water stream into a fog. These systems are designed to use much smaller amounts of water than fire sprinkler systems—an advantage when considering criticality concerns. In another advantage, water mist systems are typically designed with independent water supplies. These systems are fully listed and recognized for distribution over time, which would allow for their application in environments that require active exhaust systems. System downtime would be minimal if the water mist system discharged as long as spare discharge nozzles, water, and gas cylinders were available.

However, water mist systems are still vulnerable to seismic response of the facility and its contents just as the standard fire suppression system is. Additionally, water mist systems are more complex than traditional fire suppression systems and, therefore, not as reliable.

An additional concern is the life cycle cost of the system. Because water mist systems are limited supply systems, several of them would have to be installed to support a single facility. These systems, similar to dry chemical systems, are required to be subjected to periodic inspection, testing, and maintenance (ITM) at a minimum of six-month intervals. The periodic ITM will increase the overall operational costs of the facility significantly.

Dry Chemical

Dry chemical systems use dry powder fire suppression agents to suppress a fire. These systems have dedicated limited supplies similar to the water mist system. These systems avoid the criticality concerns that the water-based systems present.

However, they are also susceptible to the seismic response of the facility and its contents. These systems, due to their complexity, have the same reliability concerns as water mist systems. They also have the same life cycle costs that the water mist systems have because of the ITM requirements.

Dry chemical systems are not allowed for "discharge-over-time" applications when installed as listed by UL or Factory Mutual (FM). Additionally, NFPA 17, "Standard for Dry Chemical Extinguishing Systems," does not permit them to be installed as discharge-over-time applications. Current systems being incorporated at LANL have installed flow restriction devices that prolong the duration of the agent discharge. Installation of these flow restriction devices places the overall system outside of its approved NRTL listing requirements. While they may use an ABC-listed extinguishing agent, dry chemical systems are only listed for BC enclosure fire applications since there is no nationally recognized standard test for Class A enclosure fires. To satisfy these issues, an extensive testing plan will need to be developed and executed before installing a dry chemical system in an enclosure is possible.

Inertion

Inertion, while not technically a fire suppression system, needs to be discussed at part of this report because it is currently the predominant method used to mitigate fires in enclosures. Typical inertion systems are installed in enclosures that perform processes or handle materials that may react in an environment containing oxygen. These systems typically dehumidify the atmosphere and displace oxygen with nitrogen or argon, lowering the oxygen content. The resultant oxygen concentration is less than 1% compared with the 21% present in the air we breathe. This controlled low level of oxygen does not support the combustion process. Inertion systems are typically package units that are sized, selected, and installed as part of the overall enclosure.

The systems are relatively complex with vacuum pumps, inert gas regulation, system controls, oxygen and humidity monitors, etc. The systems have good reliability as long as electrical power is maintained. Inertion within the enclosure would be lost in the event the system is de-energized or loses power. Additionally, inertion systems are vulnerable to the same seismic response issues of the facility and its contents as water-based fire suppression and dry chemical systems. However, inertion is more dependent on enclosure integrity than water-based fire suppression and dry chemical systems. Therefore, in a post-seismic fire event, inertion capabilities would be compromised by the loss of a window, glove, or gasket.

As previously stated, inertion systems are not fire suppression systems, but rather a means to create an atmosphere that does not support combustion. This complicates the fire alarm interface for monitoring and fire department response to alarms generated by the system. Engineering evaluations will have to be performed to determine which portions of these systems would have to be monitored and what the proper alarm response would be. This presents potential Authorization Basis impacts that would have to be evaluated.

Fire Foe™ Tube

As described in previous sections of this report, the Fire Foe™ tube is a self-contained, self-actuating extinguisher. The tube contains a proprietary mixture of FE-25™, FE-36™ and micro ground sodium bicarbonate called Envirogel® as its extinguishing agent. The tubes, similar to the dry chemical system, do not use water, thus avoiding potential criticality concerns within the enclosures. The tubes are mounted entirely within the enclosure, eliminating the need for open or water-filled piping to be installed through the enclosure and, therefore, not expanding the enclosure envelope. This reduces potential issues that may increase the leak path factor associated with an enclosure. Leak path factors result from additional penetrations through the glovebox and subsequently affect the design basis calculations.

Issues associated with seismic events are greatly reduced because the tubes are a passive engineering control. They do not require any support SSC to be functioning in a post-seismic event for them to be able to function. Post-seismic event issues are further reduced if the

installation is done in accordance with the proposed general design criteria, which would require redundant tubes be installed within an enclosure. If an enclosure were to fall over at any angle up to 90° degrees from the vertical, a tube would still be in the upper portion of the enclosure and exposed to heat generated by any fire within the enclosure. If the fire is of sufficient energy, the tube will activate to extinguish the fire.

Unlike the dry chemical system, the Fire Foe™ tubes are specifically listed and have been tested for environments that have up to one air change per minute. This provides a Listed and tested solution for discharge-over-time applications that are required for environments exhausting the enclosure to the atmosphere. This airflow rate exceeds typical exhaust flow rates for gloveboxes and is more in line with flow rate requirements for fume hoods.

The tubes are currently UL Listed for Class B and C fires in enclosures up to 130 ft^3. As discussed in earlier sections of this report, the individual agents comprising the Envirogel® mixture are listed as Class A, B, and C extinguishing agents. This report documents the successful completion of fire testing that demonstrates, and has been verified by an independent NRTL, that the tubes are capable of extinguishing Class A, B, and C fires in enclosure up to 250 ft^3 with airflow equivalent to one air change per minute.

However, the Fire Foe™ tubes may not be suitable for installation in every glovebox at LANL because of the varying environments within the enclosures. High alpha radiation environments are a concern because these particles deposit all of their energy at the surface of the material they contact. Additionally, there may be aqueous chemical environments that attack the nylon tube in a manner that will result in an abbreviated unacceptable service life. Radiation exposure tests addressing the alpha contamination issues should be performed, and an evaluation of the aqueous chemical environment for each candidate enclosure will have to be evaluated prior to installation. These more aggressive environments will have to be reviewed to ensure they are compatible with the Fire Foe™ tube.

RADIOLOGICAL AGE TESTING

Currently, the manufacturer does not list a recommended service life for the tube. The manufacturer does offer a five-year warranty on the tube. This warranty covers manufacturing and material defects for that period of time. In discussions of a service life for tubes installed at LANL, the driving concern is how the Nylon 6,6 will react over time in a radiological environment.

Alpha radiation presents the greatest challenge to the service life and integrity of the tube because alpha particles deposit their energy at the surface of the material. The average depth of penetration at the surface is 25 to 30 microns. This depth is nominally 2% of the wall thickness of the tube.

Initial literature reviews of Nylon 6,6 indicate that it will respond better in a radiological environment than Teflon. The issue with the published literature for Nylon 6,6 is that the literature does not present damage due specifically to alpha radiation; the nomographs typically present radiological damage information based on a combined radiation field. The most relevant information available are the results of the Teflon testing performed by LANL.[2] Results of this testing showed that at 10^9 rad, the Teflon samples showed cracking, and at 10^{11} rad, the Teflon evaporated. Due to the lack of specific data for Nylon 6,6, some type of testing and/or material monitoring should be established until a service life can be formally established for the tubes in radiological environments.

Accelerated age testing could be conducted by applying (i.e., painting) Uranium 238 (U238) to coupons of the Nylon 6,6, allowing the samples to age for specified periods, then cleaning the sample by removing the U238 from the coupon and analyzing the surface characteristics by comparing them to control sample of Nylon 6,6. A second approach would be to take coupons of the material and place them in various enclosures with varying environments and analyze the surface characteristics at specified intervals. A combination of these two approaches could be used to provide information to establish and formalize a service life for the tubes.

The accelerated age testing by applying U238 would present the most conservative results due to the high activity levels and heat generated by U238 particles relative to other materials. In the case of coupon monitoring, a methodology of monitoring the enclosure environment over the course of the testing period would have to be developed and executed to provide meaningful data for determining radiological service life effects. A formal experimental plan will need to be developed and executed to obtain definitive information.

DESIGN CRITERIA

The following design criteria are considered the minimum guidance for manufacture and installation of the tubes within enclosures at LANL:

Tube:

1. Tube body shall be constructed of Nylon 6,6.
2. Two activation temperatures shall be provided:
   a. Standard Temperature: 175°F for installation in enclosures without heat-generating equipment.
   b. High Temperature: 220°F for installation in enclosures with heat-generating equipment.
3. Tube end caps shall be constructed of 304 stainless steel (SS).
4. Pressure gauge assembly shall be 304 SS.

[2] "Characterization of the Alpha-Radiation Effects on Polytetraflouroethylene," Lakis, Rollin, et al., 2000.

5. Nominal wall thickness of the tube body shall be
   a. Standard temperature: 0.065" +/- 0.005"
   b. High temperature: 0.085" +/- 0.005"
6. Wall thickness of machined activation strip:
   a. Standard temperature: 0.055" +/- 0.005"
   b. High temperature: 0.075" +/- 0.005"
7. Machined activation strip shall start along the tube body 1.75" +/- 0.25" from the end cap.
8. Machined activation strip shall be 0.875" +/- 0/125" wide, along the longitudinal axis of the tube.
9. Tube shall be capable of being discharged within the enclosure.
10. Tube shall be capable of being fitted with a pressure switch capable of being monitored by a fire alarm system.
11. The pressure switch shall be a normally open dry contact type capable of being placed within the same environment as the tube.
12. Mounting bracket assembly shall be manufactured from 304 SS.

Location

1. The tube shall be rigidly mounted within the enclosure.
2. The tube centerline shall be placed at 4" +/-2" from the ceiling of the enclosure and a minimum of 4"+/- 0.5" from the wall of the enclosure.
3. The activation strip should be orientated in such a direction that it ensures coverage throughout the enclosure. Nominally, the discharge strip shall be orientated away from the nearest wall and at a 45° angle downward (i.e., 225° or 315°).

Size and Number of Tubes

1. Tube sizing shall be based on gross volume, or net volume as determined by a registered professional engineer. Maximum volume that can be protected by the Fire Foe™ is 250 ft^3. If the enclosure cannot support the tube length, then an engineering evaluation shall be performed for the enclosure and its contents. Tube size will then be based on the net volume of the enclosure.
2. As a means of redundancy, two tubes shall be installed in each enclosure. If the enclosure or process cannot support this configuration, then an engineering evaluation shall be performed.

Service Life

As discussed in the previous section, the manufacturer does not publish a service life for the tubes. The following are the service life recommendations. Installation of the tubes in high alpha

radiation and aqueous chemical environments is not recommended until material-aging studies can be completed.

1. Service life of tubes in non-U238 radiological environments is five years.
2. Service life of tubes in U238 radiological environments is unknown.
3. Service life in aqueous chemical environments is unknown.

INSTALLATION METHODOLOGY

Specific instructions are required for each installation because each enclosure is unique with respect to layout and design to accommodate unique processes and hazards. The following set of generic installation instruction is provided as a baseline to initiate the development of specific installation instructions.

1. Identify the size of the tube to be installed. This is based on the gross or net volume of the enclosure up to 250 ft^3. Net volume could be calculated to size the tube, but an engineering evaluation must be performed.
2. Determine support locations within the enclosure. Mounting brackets shall be located so that they attach to the tube 6" +/- 2" from each end, and not greater than 36" between brackets. For 250-ft^3 tubes, a bracket shall be required mid-span of the tube.
3. Prepare the enclosure to accept the brackets as required. For gloveboxes, the recommended process is to spot weld 0.25" threaded studs to the identified locations. For hoods, the recommended process is to through-bolt and seal the bracket to the hood wall at the identified locations.
4. In accordance with facility procedures, introduce the tube into the enclosure.
5. Clamp the tube in place according to the manufacturer's instructions.
6. Ensure the tube is properly orientated within the enclosure and that the pressure gauge is visible from a window of the enclosure to facilitate reading the pressure gauge.
7. If a pressure switch is provided with the tube, follow facility work control procedures to tie in the pressure switch to the facility fire alarm system. Activation of the pressure switch shall generate an alarm signal.
8. Perform an overall visual inspection of the installation.

MONETARY CONSIDERATIONS

Cost comparisons between the fire suppression systems discussed in this report are difficult to evaluate because of the many factors that influence the final cost. For example, installation costs vary dramatically between LANL's different facilities. This also applies to ITM costs based on the level of training and access requirements. (See Appendix A, Comparative Analysis.)

Wet-pipe sprinkler systems materials and installation costs are measured in the low tens of thousands of dollars. Fire sprinkler costs are typically the lowest if the facility is already

protected with a sprinkler system. However, if the water supply cannot support the required expansion to provide suppression in enclosures, providing a dedicated fire sprinkler system becomes cost prohibitive.

Water mist and dry chemical systems materials and installation costs are measured in the high tens of thousands of dollars and possibly hundreds of thousands of dollars for retrofit applications. These systems are pre-engineered and require design and calculations to support the selection of equipment. They also require design of required facility SSCs to support the installation. Additionally, depending on the location of the system, seismic calculations and structural modifications may be required. The long-term ITM costs will add significantly to the Life Cycle Cost (LCC) of the systems. ITM costs will be measured in tens of thousands of dollars on an annual basis. These costs don't consider replacement of these systems as they age and become obsolete.

Fire Foe™ tube material costs are measured in hundreds of dollars. Installation costs are currently projected to be measured in hundreds of dollars for new work and thousands of dollars for retrofit applications. ITM requirements for the tubes are low and expected to be measured in thousands of dollars annually. Replacement and disposal of the tubes at the end of their service life are anticipated to be measured in tens of thousands of dollars. Replacement of the expended tube is expected to be measured in thousands of dollars.

Inertion systems acquisition and installation is currently measured in terms of hundreds of thousands of dollars.

All of these values are based on the authors' experience with costs associated with different projects at LANL.

FUTURE ASPIRATIONS

The Fire Foe™ technology presents a fire suppression tool that is capable of meeting challenges that previously would have required more complex and costly solutions. Several possibilities that exist with this technology are very exciting. These possibilities result from the unique nature of the materials and applications that are present within the DOE Complex. One of the areas that is the most exciting and presents a potential solution to fires unique to the DOE Complex is determining if the delivery system can be used successfully with other types of extinguishing agents (e.g., Metal X) for other classes of fires. Additionally, this tool provides another solution to the fire suppression problem of providing protection to individual high-value or key pieces of equipment or apparatus in remote or hazardous environments, and thus also reduces the potential risk of program downtime caused by ineffective systems.

CONCLUSION

Fire Foe™ tubes are a robust, reliable, and minimally invasive means of fire suppression for the majority of gloveboxes at LANL. The tubes are available for standard and high-temperature applications. Tubes are relatively easy to install and mounted/secured to the interior of the enclosure with four to six bolts (depending on the size of the tube) and would not require penetrations through the glovebox shell. The tubes are easily monitored by a fire alarm system with an integrated pressure switch. Inclusion of a pressure switch would require a single glovebox feedthrough for one or two pairs of 16 AWG wires if the Fire Foe™ tube is connected to the fire alarm system for monitoring.

It is our intent to specify redundancy for this application by requiring two Fire Foe™ tubes to be installed, with one located on each side of the glovebox. This redundancy in the system would have an added benefit in a seismic event; if the glovebox toppled onto its side, there would still be an active Fire Foe™ tube located near the ceiling of the glovebox. If the tube located near the bottom of the glovebox is punctured or ruptured when the glovebox topples, it would potentially coat combustibles preventing ignition. The tube located near the top of the glovebox would remain intact and ready to extinguish a fire.

Proof-of-concept fire tests have been documented to prove Fire Foe™ tubes successfully extinguish Class A, B, and C fires in a glovebox enclosure when tested under conditions that are in line with an actual glovebox working environment at LANL. The successful proof-of-concept fire tests were followed by additional fire tests that were witnessed by Intertek, an NRTL. All fire test data and test reports are included in the appendices.

As mentioned earlier in the report, QuickFire manufactures a range of tubes targeted to specific volumes of enclosures. These tubes are scaled in their dimensions and contents for the volume of the enclosure that is to be protected. By selecting the 250-ft^3 Fire Foe™ tube for our fire tests and proving it is successful at extinguishing Class A, B, and C fires in enclosures, it affords us the scalability of the Fire Foe™ product line, permitting installation of the full range of tubes in enclosures with Class A, B, and C combustibles.

Appendix A: Comparative Analysis

The two tables on the following pages comprise a comparative analysis of major attributes for the fire suppression and fire mitigation systems discussed in this report. This comparative analysis is purely qualitative. Numerical values are only provided to facilitate development of a relative ranking of the various systems. The results of the ranking clearly show that Fire Foe™ tubes offer the greatest value and should be considered for installation in enclosures. There are several issues beyond this analysis that will influence the final decision pertaining to the type of fire suppression installed in an enclosure.

	Penetration into the enclosure	Support SSC required to function	Passive activation	Fire alarm monitoring capability	Complexity of decommissioning	Disposal	Ease of installation	Seismic survivability	Criticality	Suppression system qualified for Class A, B, and C enclosure fires	Level of iTM	System complexity	Cost	Score [1]
Sprinkler	Required $_0$	Required $_0$	Y $_1$	Y $_1$	M $_1$	L $_2$	G $_3$	P $_1$	B $_0$	Y $_1$	L $_2$	L $_2$	L $_2$	16
Water Mist	Required $_0$	Required $_0$	N $_0$	Y $_1$	M $_1$	M $_1$	F $_2$	P $_1$	B $_0$	Y $_1$	H $_0$	M $_1$	H $_0$	8
Dry Chemical	Required $_0$	Required $_0$	N $_0$	Y $_1$	M $_1$	M $_1$	F $_2$	P $_1$	G $_3$	N $_0$	H $_0$	M $_1$	H $_0$	10
Inertion	Required $_0$	Required $_0$	N/A	Y $_1$	M $_1$	M $_1$	F $_2$	P $_1$	G $_3$	N/A	H $_0$	H $_0$	H $_0$	9
Fire Foe™	Not required $_1$	Not required $_1$	Y $_1$	Y $_1$	M $_1$	M $_1$	G $_3$	G $_3$	G $_3$	Y $_1$	L $_2$	L $_2$	L $_2$	22

Required = 0
Not required = 1

B = Bad = 0
P = Poor = 1
F = Fair = 2
G = Good = 3

L = Low = 2
M = Medium = 1
H = High = 0

Y = Yes = 1
N = No = 0

N/A = Not Applicable
Unk = Unknown

Notes:

1 - All scoring is relative with higher values given to the more desirable characteristics.

2 - The term "Passive" for the purposes of this comparison means the system is not dependent on a signal from another system or device to activate.

3 - Die to criticality safety concerns water based fire suppression systems may not be permitted.

	Ease of installation	Seismic survivability	Criticality	Level of ITM	System complexity	Cost	Suppression system qualified for Class A, B, and C fires
Sprinkler	G 2	P 1	B 0	L 2	L 2	L 2	N 0
Water Mist	F 2	P 1	B 0	H 0	M 1	H 0	Y 1
Dry Chemical	F 2	P 1	G 3	H 0	M 1	H 0	N 0
Intertion	F 2	P 1	G 3	H 0	H 0	H 0	N/A
Fire Foe™	G 3	G 3	G 3	L 2	L 2	L 2	Y 1

Required = 0

Not required = 1

B = Bad = 0

P = Poor = 1

F = Fair = 2

G = Good = 3

L = Low = 2

M = Medium = 1

H = High = 0

N/A = Not Applicable

Y = Yes = 1

N = No = 0

Unk = Unknown

Appendix B: Test Protocol Developed between LANL and QuickFire

LANL Test Protocol: Fire Foe 48" Standard Tube in 250 Cubic Foot Glovebox

Glovebox Design and Manufacture:

1. Design a glove box with dimensions 8' X 5' X 6' (l X b X h) with 250 cubic feet volume of frame and panel construction. Box to be constructed in 14 gauge mild steel and to be as airtight as practicable but to include one doorway or hatch for easy access. Box to incorporate 2 off ¾" full length hanging rails approx 1" below ceiling. Box to incorporate glove ports and glove fixings, glass window panels. Box to incorporate fixed negative pressure differential of ½" or ¼"water and fixed airflow of one air change (250 cubic feet) per minute by means of 8" diameter inlet/exhaust pipes centered 8" below ceiling height on side panels. Exhaust will be through 8" flanged spool piece (provided by LANL) which will house an inline HEPA air filter, with pressure measurement transducers mounted below and above the HEPA filter in existing ¾" N.P.T. ports (female thread).

2. Design a rack with dimensions 4' X 2' constructed of a 2" X 2" angle steel frame with number 8 expanded metal grid standing 20" inches off the floor of the box.

3. Windows, gloves and/or glove aperture blanking plates to be affixed to the box per fittings supplied.

   Install multiple pressure transducers in glovebox. Beginning with one placed between the gloveports at the lowest level and every 18 inches above for a total of 4 stacked vertically +2 additional pressure transducers as indicated in Line Item No. 1 for a total of 6 pressure transducers.

4. Install one glass observation window with removable internal blanking plate (soot and residue protection) to enable clear vision of box interior and contents status post fire and tube activation.

5. Install one copper Acetone filling pipe extending through front panel extending to position in centre of box floor and approx 5" above floor, complete with external shut-off valve and 1 pint measuring reservoir.

6. Install one off 1" diameter "keyhole" with external closing plate in front panel of the box at suitable height above the floor.

7. Affix Fire Foe™ tube fixings at one position in the box

8. Submit drawing of proposed glove box and incorporated rack to LANL for their approval. LANL to countersign drawing to record such approval.

9. Manufacture glove box to such approved specification and drawing. Gloves, glove fixing assemblies and/or glove aperture blanking plates and window panels complete with sealing arrangements to be free-issue supply from LANL and to be incorporated into the glove box manufacture.

10. Final glove box assembly to be photographed and photos submitted to LANL prior to use.

11. Install thermocouples on the top, bottom, sides and ends of the enclosure to measure temperature profile before during and after activation

Proof-of-Concept Fire Testing:

The following fire test program will be carried out. In each test one off Fire Foe tube will be mounted in the tube fixings within the box. Each test will be timed from ignition of material to flame extinguishment. All times to be recorded. In Test Protocol 3 plus two further tests under Test Protocol 8 conditions shall be pressure monitored before, during and after tube discharge. Such pressure monitoring shall be automatically recorded in real time. Prior to each test the airflow will be verified and recorded. Each test will be videoed from outside the box. After each test the box will remain closed and stable for 5 minutes.

Tests:

1. Place 1 pint of Acetone in a pan of dimensions 19.5" X 19.5" X 4". Place the pan on the floor of the box. Close hatch/door. Set and verify the required pressure differential and airflow. Ignite Acetone using hand held taper or lance manipulated through the key hole. Observe, videotape and record. *Object: Prove Fire Foe extinguishes acetone fire in isolation in the 250 cu ft glove box.*

2. Place 2 gallons of specified (pre-heated) cutting oil in a pan of dimensions 19.5" X 19.5" X 4". Place the pan on the floor of the box. Close the hatch/door. Set and verify pressure differential and airflow. Ignite cutting oil using hand held taper or lance manipulated through the key hole. Observe, videotape and record. *Object: Prove Fire Foe extinguishes cutting oil fire in isolation in the 250 cu ft glove box.*

3. Place 1 pint of Acetone in the external reservoir. Place an empty pan of dimensions 19.5" X 19.5" X 4" in the centre of the box floor under the copper filling pipe. Place 2 gallons of specified (pre-heated) cutting oil in a pan of dimensions 19.5" X 19.5" X 4" on the floor of the box. Place one wood-crib UL Standard xxx measuring 3" X 3" X 8" on the floor of the box. Close hatch/door. Set and verify the required pressure differential and airflow. (A) Ignite both wood cribs using hand held taper or lance manipulated through the keyhole. Allow both cribs to burn for 60 seconds then open the external valve and drain the Acetone held in the external reservoir into the empty pan and if applicable, (B) ignite acetone and cutting oil using hand held taper of lance manipulated through the keyhole. Observe, videotape and record A/B. Record pressure variance

before, during, after tube activation in real time. *Object: Prove Fire Foe extinguishes Class A UL specified crib in the presence of accelerants in the250 cu ft glave box.*

4. Place 1 pint of Acetone in a pan of dimensions 19.5" X 19.5" X 4". Place 2 gallons of specified (pre-heated) cutting oil in a pan of dimensions 19.5" X 19.5" X 4". Place both pans on the floor of the box. Place 5 off 500ml plastic squirt-bottles (two of which shall be empty and three of which shall be partly filled with specified combustible liquid e.g. alcohol) on the floor of the box. Place 5 off 500ml plastic squirt-bottles two of which shall be empty and three of which shall be partly filled with alcohol on the rack. Close hatch/door. Set and verify required pressure differential and airflow. Ignite the acetone and the cutting oil using a hand held taper or lance manipulated through the key hole. Observe, videotape and record. *Object: Prove that Fire Fae extinguishes Class A fire in empty and partially filled squirt bottles at two levels in the250 cu ft glove box.*

5. Place 1 pint of Acetone in a pan of dimensions 19.5" X 19.5" X 4". Place 2 gallons of specified (pre-heated) cutting oil in a pan of dimensions 19.5" X 19.5" X 4". Place both pans on the floor of the box. Place 2 off boxes of chem-wipes (one of which shall be open with a number of chem-wipes removed the other shall be un-opened) on the floor of the box. Close hatch/door. Set and verify the required pressure differential and airflow. Ignite the Acetone and the cutting oil using a hand held taper or lance manipulated through the keyhole. Observe, videotape and record. *Object: Prove that Fire Fae extinguishes Class A fire in partially filled and un-braached boxes of chem-wipes in the 250 cu ft glave box.*

6. Place 1 pint of Acetone in a pan of dimensions 19.5" X 19.5" X 4". Place 2 gallons of specified (pre-heated) cutting oil in a pan of dimensions 19.5" X 19.5" X 4". Place both pans on the floor of the box. Place 3 meters of Tygon tubing on the floor of the box. Place 3 meters of Tygon tubing on the rack. Close hatch/door. Set and verify required pressure differential and airflow. Ignite the Acetone and cutting oil using a hand held taper or lance manipulated through the key hole. Observe, videotape and record. *Object: Prove that Fire Fae extinguishes Class A fire in Tygan tubing at multiple levels in the250 cb ft glove box.*

7. Place 1 pint of Acetone in a pan of dimensions 19.5" X 19.5" X 4". Place 2 gallons of specified (pre-heated) cutting oil in a pan of dimensions 19.5" X 19.5" X 4". Place both pans on the floor of the box. Suspend vertically 5 off wire bundles of #16THHN wires from the ceiling mounted rails. Suspend vertically 2 off wire bundles of #18THHN wires from the ceiling mounted rails. Suspend vertically 2 off bundles of 2 coaxial cables from the ceiling mounted rails. All wires to be bound together with plastic twist ties in a single 9-bundle group. Vertical bundles shall be suspended at varying heights above the Acetone/cutting oil. Close hatch/door. Set and verify the required pressure differential and airflow. Ignite the Acetone and cutting oil using a hand held taper or lance manipulated through the keyhole. Observe, videotape and record. . *Object: Prove that Fire Fae extinguishes Class A & C fires in vertically suspended cable bundles at multiple levels in the 250 cu ft glove box.*

8. Place 1 pint of Acetone in the external measuring reservoir. Place an empty pan of dimensions 19.5" X 19.5" X 4" in the centre of the box floor under the copper filling pipe. Place 2 gallons of specified (pre-heated) cutting oil in a pan of dimensions 19.5" X 19.5" X 4" and place on the

floor of the box. Place one wood crib UL Standard xxx measuring 3" X 3" X 8" on the floor of the box. Place 5 off 500ml plastic squirt-bottles two of which shall be empty and three of which shall be partly filled with alcohol on the floor of the box. Place 2 off boxes of chem-wipes (one of which shall be open with a number of chem-wipes removed the other shall be un-opened) on the floor of the box. Place 3 meters of Tygon tubing on the floor of the box. Suspend vertically 5 off wire bundles of #16THHN wires from the ceiling mounted rails. Suspend vertically 2 off wire bundles of #18THHN wires from the ceiling mounted rails. Suspend vertically 2 off bundles of 2 coaxial cables from the ceiling mounted rails. All wires to be bound together with plastic twist ties in a single 9-bundle group. Vertical bundles shall be suspended at varying heights above the Acetone/cutting oil. Close hatch/door. Set and verify the required pressure differential and airflow. (A) Ignite both wood cribs using hand held taper or lance manipulated through the keyhole. Allow wood crib to burn for 60 seconds then open the external valve and drain the Acetone in the external reservoir into the empty pan and if applicable, (B) ignite Acetone and cutting oil using hand held taper of lance manipulated through the keyhole. Observe, videotape and record A/B. *Object: prove that Fire Foe extinguishes the full range of Class A/B/C fires of varying types of specified materials at varying levels in the250 cu ft glove box.*

9. Repeat the above specified test 8 four further times in succession in the presence of designated personnel from LANL. In 2 consecutive tests record pressure variance before, during, after tube activation in real time. Observe, videotape and record.

Independent Verification by NRTL (Intertek)

NRTL to conduct above specified Test 8 five times in succession at the NRTL and verify according to results.

Appendix C: Fire Foe™ in 250 CF Glove Box – Proof of Concept Test Report

(See attached document.)

QuickFire
FIRE SUPPRESSION TECHNOLOGY

FIRE FOE

FIRE FOE IN 250 CF GLOVE BOX

PROOF OF CONCEPT TEST REPORT

Version *1.2*

10/12/2010

VERSION HISTORY

Version #	Implemented By	Version Date	Approved By	Approval Date	Reason
1.0	Markus Novosel	*09/21/2010*	James Geyer	*10/06/2010*	*Provide information on proof of concept test.*
1.1	Markus Novosel	*10/07/2010*	James Geyer	*10/07/2010*	Discrepancies between DVD and written report corrected.
1.2	Holli Armstrong	10/12/2010	James Geyer	10/12/2010	Update

Table of Contents

1.0 INTRODUCTION

1.1 PURPOSE

This *FIRE FOE IN 250 cf GLOVE BOX* Test Report provides a summary of results of the tests performed to provide proof of concept that Fire Foe is capable of extinguishing the full range of Class A/B/C fires of varying types of specified materials at varying levels in a 250 cu. ft. glove box. See Appendix for test protocol developed between QuickFire and LANL.

2.0 TEST SUMMARY

Project Name: *Fire Foe In 250 cf Glove Box*
System Name: *FT 250 Fire Foe tube*
Test Protocol Number: *1, 3, 4, 8, 9, and 10*
Description: 15 individual tests, hereafter known as events, were conducted using the *"LANL Test Protocol: Fire Foe 56.5" Tube in 250 Cubic Foot Glove Box"* as guidance with the exception of protocol numbers 9 and 10 which were ad hoc. Various configurations of class A/B/C fires were used to test the effectiveness of the Fire Foe tube as a fire extinguishing mechanism. Glove box internal conditions consisted of airflow of 250 CFM and a static pressure of –0.75 in. H_2O for test protocols 1, 3, 4, and 8. Events conducted under test protocols 9 and 10 were done with airflow of 190 CFM and static pressure of –0.25 in. H_2O. Protocol 2 was not recorded because combustion could not be sustained using exclusively oil. Protocol 5 was not utilized because materials could not be obtained in time for the event. Protocol 6 and 7 were combined with protocol 8.
Additional Comments: All test events indicated a successful application of Fire Foe within the prescribed parameters. The following sections 2.1 through 2.6 provide detailed descriptions of the test protocols used in this project.

2.1 TEST PROTOCOL 1

Test Owner: *QuickFire*
Test Date: *09/16/2010 – 09/17/2010*
Glove Box Contents:

- 1 pint acetone in pan

Procedure: Place 1 pint of acetone in a pan of dimensions 19.5" X 19.5" X 4". Place the pan on the floor of the box. Close door. Verify the required pressure differential. Ignite acetone using electronic ignition. Observe and record.
Objective: Prove Fire Foe extinguishes acetone fire in isolation in the 250ft³ glove box.

2.2 *TEST PROTOCOL 3*

Test Owner: *QuickFire*
Test Date: *09/18/2010*
Glove Box Contents:

- External pre-fill reservoir with 1 pint acetone
- 1 - 19.5"X19.5"X4" metal pan (empty)
- 1 - 19.5"X19.5"X4" metal pan containing 2 gallons heated oil
- 2 - 10" X 10" X 10" wood cribs

Procedure: Place 1 pint of acetone in the external reservoir. Place an empty pan of dimensions 19.5" X 19.5" X 4" in the center of the box floor under the copper filling pipe. Place 2 gallons of preheated oil in a pan of dimensions 19.5" X 19.5" X 4" on the floor of the box. Place one wood-crib measuring 10" X 10" X 10" on the floor of the box. Place one wood crib measuring 10" X 10" X 10" on the rack. Close the door. Verify the required pressure differential. (A) Ignite wood cribs using hand-held taper manipulated through the keyhole. Allow cribs to burn for 120 seconds then open the external valve and drain the acetone held in the external reservoir into the empty pan and if applicable, (B) ignite acetone and oil using hand-held taper manipulated through the keyhole. Observe and record A/B. Record pressure variance before, during, after tube activation in real time.
Objective: Prove Fire Foe extinguishes Class A crib fire in the presence of accelerants in the 250 cu ft glove box.

2.3 *TEST PROTOCOL 4*

Test Owner: *QuickFire*
Test Date: *09/18/2010*
Glove Box Contents:

- 1 - 19.5"X19.5"X4" metal pan containing 1 pint acetone
- 1 - 19.5"X19.5"X4" metal pan containing 2 gallons heated oil
- 2 - 500ml plastic bottles partially filled with acetone
- 3 - 10" X 10" X 10" wood cribs
- Group of newspaper and fiber towels

in a pan of dimensions 19.5" X 19.5" X 4". Place 2 gallons of specified (preheated) oil in a pan of dimensions 19.5" X 19.5" X 4". Place both pans on the floor of the box. Place one wood-crib measuring 10" X 10" X 10" on the floor of the box. Place two wood cribs measuring 10" X 10" X 10" on the rack. Place 2 each 500ml plastic bottles (which shall be partly filled with acetone) on the rack. Close the door. Verify required pressure differential. Place group of newspaper and fiber towels on the floor of the box. Ignite the acetone and the oil using a hand-held taper manipulated through the keyhole. Observe and record.
Objective: Prove that Fire Foe extinguishes Class A fire in partially filled plastic bottles in the 250 cu ft glove box.

2.4 *TEST PROTOCOL 8*

Test Owner: *QuickFire*
Test Date: *09/18/2010*
Glove Box Contents:

- External pre-fill reservoir with 1 pint acetone
- 1 - 19.5"X19.5"X4" metal pan (empty)
- 1 - 19.5"X19.5"X4" metal pan containing 2 gallons heated oil
- 1 - 10" X 10" X 10" wood crib
- 3 - 500ml Plastic bottles partially filled with acetone
- 2 - 500ml Plastic bottles empty
- Group of newspaper and fiber towels
- 3 meters vinyl tubing
- 1 Wire Bundle Consisting of
  - 5 - #16THHN wires
  - 2 - #18THHN wires
  - 2 - coaxial cables

Procedure: Place 1 pint of acetone in the external measuring reservoir. Place an empty pan of dimensions 19.5" X 19.5" X 4" in the center of the box floor under the copper filling pipe. Place 2 gallons of preheated oil in a pan of dimensions 19.5" X 19.5" X 4" and place on the floor of the box. Place one wood crib measuring 10" X 10" X 10" on the floor of the box. Place 5 each 500ml plastic bottles (two of which shall be empty and three of which shall be partly filled with acetone) on the floor of the box. Place group of newspaper and fiber towels on the floor of the box. Place 3 meters of vinyl tubing on the floor of the box. All wires to be bound together with wire bundle shall be suspended above the acetone/oil. Close the door. Verify the required pressure differential. (A) Ignite wood crib using hand-held taper manipulated through the keyhole. Allow wood crib to burn for 120 seconds then open the external valve and drain the acetone in the external reservoir into the empty pan and if applicable, (B) ignite acetone and oil using hand-held taper manipulated through the keyhole. Observe and record A/B.
Objective: Prove that Fire Foe extinguishes the full range of Class A/B/C fires of varying types of specified materials at varying levels in the 250 cu ft glove box.

2.5 *TEST PROTOCOL 8A*

Test Owner: *QuickFire*
Test Date: *09/18/2010*
Glove Box Contents:

- External pre-fill reservoir with 1 pint acetone
- 1 19.5"X19.5"X4" metal pan (empty)
- 1 19.5"X19.5"X4" metal pan containing 2 gallons heated oil
- 2 10" X 10" X 10" wood cribs
- 3 500ml Plastic bottles partially filled with acetone
- 2 500ml Plastic bottles empty
- Group of newspaper and fiber towels
- 3 meters vinyl tubing

- 1 Wire Bundle Consisting of
  - 5 - #16THHN wires
  - 2 - #18THHN wires
  - 2 - coaxial cables

Procedure: Place 1 pint of acetone in the external measuring reservoir. Place an empty pan of dimensions 19.5" X 19.5" X 4" in the center of the box floor under the copper filling pipe. Place 2 gallons of preheated oil in a pan of dimensions 19.5" X 19.5" X 4" and place on the floor of the box. Place one wood crib measuring 10" X 10" X 10" on the floor of the box. Place one wood crib measuring 10" X 10" X 10" on the rack. Place 5 each 500ml plastic bottles (two of which shall be empty and three of which shall be partly filled with acetone) on the floor of the box. Place group of newspaper and fiber towels on the floor of the box. Place 3 meters of vinyl tubing on the floor of the box. Suspend 5 each wire bundles of #16THHN wires from the ceiling mounted rails. Suspend 2 each wire bundles of #18THHN wires from the ceiling mounted rails. Suspend 2 each bundles of 2 coaxial cables from the ceiling mounted rails. All wires to be bound together with cable ties in a single 9 bundle group. Bundles shall be suspended above the acetone/oil. Close the door. Verify the required pressure differential. (A) Ignite wood crib using hand-held taper manipulated through the keyhole. Allow wood crib to burn for 120 seconds then open the external valve and drain the acetone in the external reservoir into the empty pan and if applicable, (B) ignite acetone and oil using hand-held taper manipulated through the keyhole. Observe and record A/B.

Objective: Prove that Fire Foe extinguishes the full range of Class A/B/C fires of varying types of specified materials at varying levels in the 250 cu ft glove box.

2.6 TEST PROTOCOL 9

Test Owner: *QuickFire*
Test Date: *09/20/2010*
Glove Box Contents:

- 1 - 10" X 10" X 10" wood crib
- 4 - 500ml plastic bottles partially filled with acetone
- 1 Wire Bundle Consisting of
  - 5 - #16THHN wires
  - 2 - #18THHN wires
  - 2 - coaxial cables

Procedure: Place one wood crib measuring 10" X 10" X 10" on the floor of the box. Place 4 each 500ml plastic bottles partly filled with acetone on the floor of the box. All wires to be bound together with cable ties in a single 9 bundle group. Wire bundle shall be suspended above the box floor. Close the door. Verify the required pressure differential. (A) Ignite wood crib using hand-held taper manipulated through the keyhole. Observe and record A/B.

Objective: Prove that Fire Foe extinguishes the full range of Class A/B/C fires of varying types of specified materials at varying levels in the 250 cu ft glove box.

2.7 TEST PROTOCOL 10

Test Owner: *QuickFire*
Test Date: *09/20/2010*
Glove Box Contents:

- External pre-fill reservoir with 1 pint acetone
- 1 - 19.5"X19.5"X4" metal pan (empty)
- 1 - 10" X 10" X 10" wood crib
- 4 - 500ml Plastic bottles partially filled with acetone
- 1 Wire Bundle Consisting of
  - 5 - #16THHN wires
  - 2 - #18THHN wires
  - 2 - coaxial cables

Procedure: Place an empty pan of dimensions 19.5" X 19.5" X 4" in the center of the box floor under the copper filling pipe. Place one wood crib measuring 10" X 10" X 10" on the floor of the box. Place 4 each 500ml plastic bottles which shall be partly filled with acetone on the floor of the box. All wires to be bound together with cable ties in a single 9 bundle group. Wire bundle shall be suspended above the pan. Close the door. Verify the required pressure differential. (A) Ignite wood crib using hand held-taper manipulated through the keyhole. Allow wood crib to burn for 120 seconds then open the external valve and drain the acetone in the external reservoir into the empty pan. Observe and record A/B.
Objective: Prove that Fire Foe extinguishes the full range of Class A/B/C fires of varying types of specified materials at varying levels in the 250 cu ft glove box.

3.0 TEST ASSESSMENT

The test protocols provided a sufficient number of conditions to account for all foreseeable situations requiring the use of a fire extinguishing mechanism inside a 250 cu. ft. glove box. The collected data provided a comprehensive sample of results demonstrating the effectiveness of Fire Foe.

4.0 TEST RESULTS

All protocol objectives were achieved during testing (i.e. Fire Foe will extinguish A/B/C type fires of various specified materials). Secondary information indicated the amount of damage done to the contents and structure of the box by the fire and by the discharge of the Fire Foe tube itself. Fire damage to cables and wiring ranged from none to moderate while damage to vinyl tubing ranged from moderate to heavy. Plastic acetone bottles sustained light to moderate damage from the heat but their contents remained unaffected. The various wipes and papers on the floor were unaffected by the fire. With the exception of minor soot deposits on the ceiling, the box and integral systems (e.g. the gloves, transducers, and thermocouples, were not adversely affected by the fire). All fire damage was a factor of the location of the box's contents with respect to the fire, the ignition material used, and the promptness of the extinguisher discharge. The discharge of the Fire Foe tube did not damage the glove box, windows, gaskets, or gloves or contents of the enclosure. An anticipated positive pressure spike from the discharge of the Fire Foe tube never occurred. Instead, a sudden and brief pressure drop occurred as the discharged Envirogel promptly cooled the heated air. The integrity of the glove box and its seals remained unaffected throughout all of the tests.

4.1 TEST SYSTEM

The test system consists of a glove box with dimensions 8' X 5' X 6' (l X w X h) with 250 cubic feet volume of frame and panel construction. The box is constructed in 14 gauge mild steel and is as air-tight as practicable. It includes one doorway for easy access. The box incorporates 2 each 3/8" full length hanging rails approx 1" below ceiling. Also incorporated are glove ports and glove fixings, as well as glass window panels. The box's system incorporates fixed negative pressure differential of 0.5" or 0.75" water and fixed air flow of one air change (250 cubic feet) per minute by means of 8" diameter inlet/exhaust pipes centered 8" below ceiling height on side panels. To ensure mixing of the air stream inlet airflow was ducted and diffused. Exhaust is through 8" flanged spool piece (provided by LANL) which houses an inline HEPA air filter, with pressure measurement transducers mounted below and above the HEPA filter in existing ¾" N.P.T ports (female thread).

Six pressure transducers are installed in the box. One transducer has been placed between the glove ports at the lowest level as well as one transducer every 18" to give a total of 4 transducers stacked vertically. These transducers are in addition to the 2 pressure transducers as specified in Line Item No 1 above.

Included is a glass observation window with removable internal blanking plate (soot and residue protection) to enable clear vision of box interior and contents status post fire and tube activation.

One copper Acetone filling pipe extending through front panel extending to position in center of box floor and approx 5" above floor, complete with external shut-off valve and 1 pint measuring reservoir.

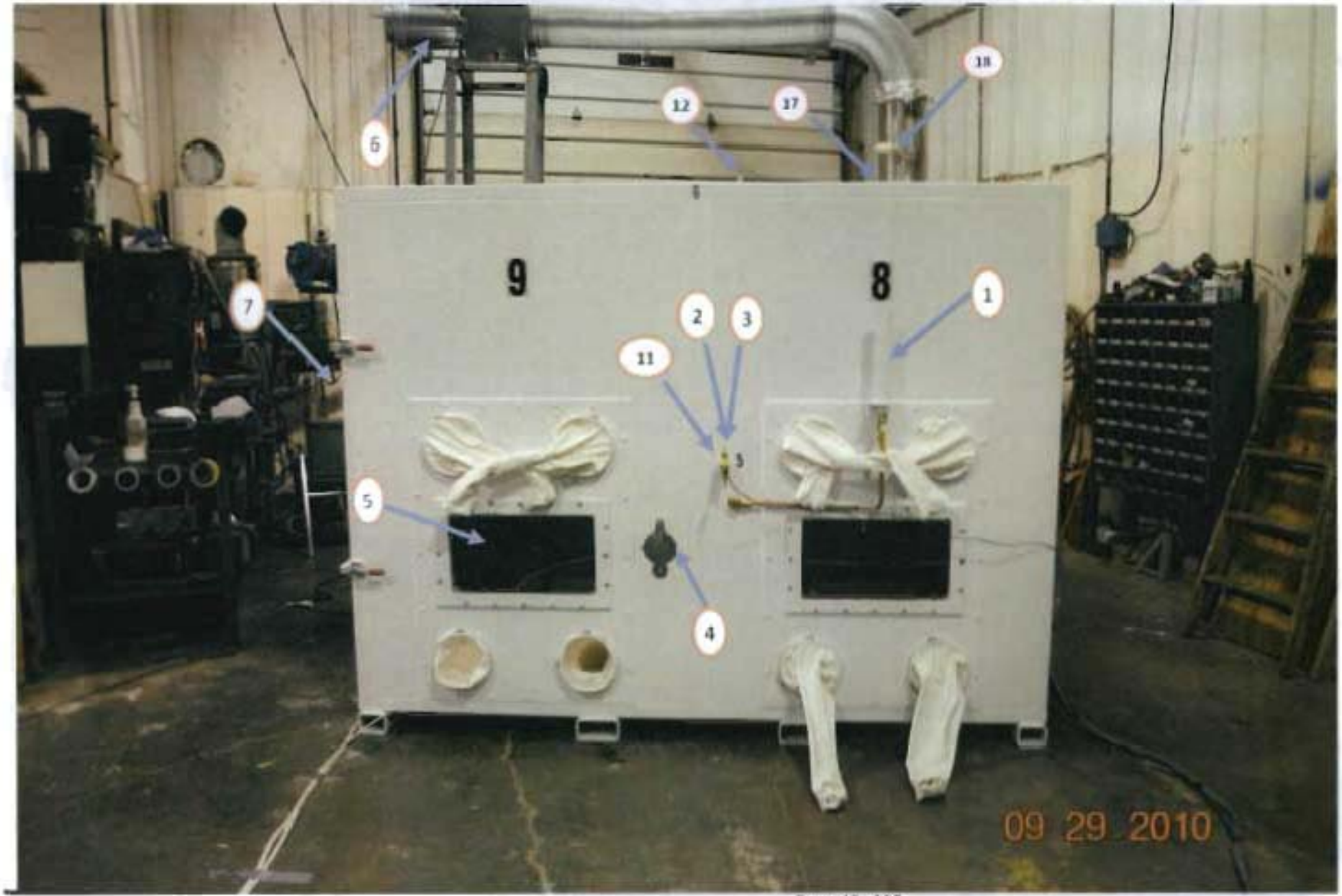
A 3" diameter "keyhole" with external closing plate in front panel of the box at suitable height above the floor.

Six thermocouples are mounted on the top panel, bottom panel, side panels and end panels of the box to measure the temperature profile within the box in these positions before, during and after activation.

The Fire Foe tube is located in the center of the box and attached to the ceiling ≈ 2" from the ceiling to the tube.

A rack with dimensions 4' X 2' constructed of a 2" X 2" angle steel frame with number 8 expanded metal grid standing 20" inches off the floor of the box.

In each test one Fire Foe tube was mounted in the tube brackets within the box. Each test was timed from ignition of material to flame extinguishment and times were recorded. In all Test Protocols, conditions were pressure monitored before, during and after tube discharge. Such pressure monitoring was automatically recorded in real time. Each test was recorded from outside the box. After each test the box remained closed and stable without re-ignition for 5 minutes post extinguishment in accordance with UL regulations or as standardized by UL.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1	500 ml Acetone Reservoir
2	0 to -2 Magnehelic Connections
3	0 to -30 Magnehelic Connections
4	Keyhole for Lighting
5	Video Camera location
6	Fan
7	Thermo Couple #1
8	Thermo Couple #2
9	Thermo Couple #3
10	Thermo Couple #4
11	Thermo Couple #5
12	Thermo Couple #6
13	Pressure Transducer #7
14	Pressure Transducer #8
15	Pressure Transducer #9
16	Pressure Transducer #10
17	Pressure Transducer #11 – Before HEPA Filter
18	Pressure Transducer #12 - After HEPA Filter


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2 PERFORMANCE TESTING – TEST RESULTS

The table below summarizes the results of performance testing utilizing protocols 1,3,4, and 8, a model FT250 Fire Foe tube, with the box airflow at 250 CFM and static pressure at –0.75 in H_2O:

Event ID	Test Protocol	Date Tested	Pass/Fail	Approximate Temperature Peak	Ignition to discharge (seconds)	Comments
1	1	09/16/2010	Pass	370°f	122.82	
2	1	09/17/2010	Pass	465°f	56.06	
3	1	09/17/2010	Pass	430°f	89.45	
4	3	09/18/2010	Pass	340°f	85.20	
5	3	09/18/2010	Pass	355°f	150.86	
6	3	09/18/2010	Pass	255°f	76.16	
7	4	09/18/2010	Pass	305°f	153.08	
8	8	09/18/2010	Pass	390°f	67.00	
9	8	09/18/2010	Pass	325°f	126.00	
10	8	09/18/2010	Pass	NA	138.00	This Event used a variation of protocol 8 with an extra wood crib. Temperature was not recorded.
11	8	09/20/2010	Pass	315°f	118.30	This Event used a variation of protocol 8 with an extra wood crib.

4.3 AD HOC TESTING – TEST RESULTS

The table below summarizes the test cases employed for ad hoc testing utilizing protocols 9 and 10, which were improvised by LANL personnel at our test site. A model FT250 Fire Foe tube was used for events 12 and 13, a model FT130 Fire Foe tube for event 14, and the box airflow was at 190 CFM and static pressure at –0.25 in H_2O for all three events:

Event ID	Test Protocol	Date Tested	Pass/Fail	Approximate Temperature Peak	Ignition to discharge (seconds)	Comments
12	9	09/20/2010	Pass	322°f	184.90	
13	9	09/20/2010	Pass	270°f	479.79	
14	10	09/20/2010	Pass	545°f	225.20	FT 130 TUBE

5.0 VARIANCES

Initial test protocols required airflow of 250 CFM and a static pressure of -0.50" or -0.25" H_2O, however, box configuration precluded those stated conditions. The decision was made to maintain 250 CFM airflow and a more achievable static pressure of -0.75" H_2O. After slight modifications to the box, a new airflow of 190 CFM and static pressure of –0.25 was achieved upon the recommendation of LANL personnel. Testing showed that the altered conditions had no significant effect on the results.

6.0 TEST INCIDENTS

Initial fire test with 8" HEPA exhaust filter installed realized a 10% reduction in the gross air flow through the box after the tube discharged.

6.1 RESOLVED TEST INCIDENTS

To maintain airflow through the box the 8" HEPA exhaust filter was removed for subsequent tests.

7.0 RECOMMENDATIONS

All test events resulted in success. Although the tubes were sized to meet the volume requirements of the test protocol, other models could be used to address issues of scalability for additional volume requirements. Three variables affected the timely discharge of Fire Foe tubes: the type of fire ignition material, the exact fire location within the box, and the box's internal airflow. These variables would be neutralized by the use of more than one tube per glove box. Multiple tube use per box would ensure closer proximity to the fire and remove one or more tubes from internal airflow.

APPENDIX A: Test Report Approval

The undersigned acknowledge they have reviewed the *FIRE FOE IN 250 cf GLOVE BOX* **Test Report** and agree with the approach it presents. Changes to this **Test Report** will be coordinated with and approved by the undersigned or their designated representatives.

Signature: _____ Date: _____

Print Name: _____

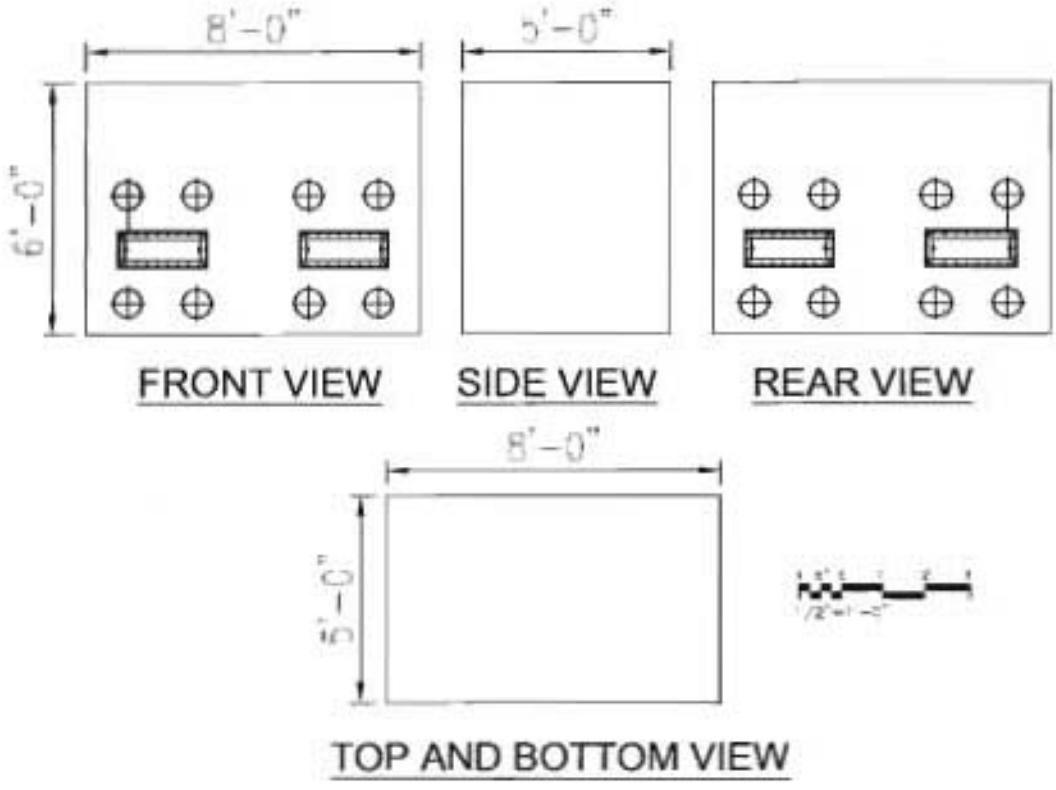
Title: _____

Role: Project Manager

APPENDIX B: REFERENCES

For raw data graphs as well as video and photographic records of test events 01 through 14, see Fire Foe Proof of Concept DVD.

APPENDIX C: DRAWING



APPENDIX D: PROTOCOL AGREEMENT

LANL Test Protocol: Fire Foe FT250 Tube in 250 cubic foot glove-box

Glove box design and manufacture:

1. Design a glove box with dimensions 8' X 5' X 6' (l X w X h) with 250 cubic feet volume of frame and panel construction. Box to be constructed in 14 gauge mild steel and to be as air-tight as practicable but to include one doorway or hatch for easy access. Box to incorporate 2 off ¾" full length hanging rails approx 1" below ceiling. Box to incorporate glove ports and glove brackets, glass window panels. Box to incorporate fixed negative pressure differential of ½" or ¼" water and fixed air flow of one air change (250 cubic feet) per minute by means of 8" diameter inlet/exhaust pipes centered 8" below ceiling height on side panels. Exhaust will be through 8" flanged spool piece (provided by LANL) which will house an inline HEPA air filter, with pressure measurement transducers mounted below and above the HEPA filter in existing ¾" N.P.T ports (female thread).

2. Design a rack with dimensions 4' X 2' constructed of a 2" X 2" angle steel frame with number 8 expanded metal grid standing 20" inches off the floor of the box.

3. Windows, gloves and/or glove aperture blanking plates to be affixed to the box per fittings supplied.

4. Install 6 pressure transducers in the box. One transducer will be placed between the glove ports at the lowest level and thereafter one transducer will be placed every 18" to give a total of 4 transducers stacked vertically. These transducers are in addition to the 2 pressure transducers as specified in Line Item No 1 above.

5. Install one glass observation window with removable internal blanking plate (soot and residue protection) to enable clear vision of box interior and contents status post fire and tube activation.

6. Install one copper Acetone filling pipe extending through front panel extending to position in centre of box floor and approx 5" above floor, complete with external shut-off valve and 1 pint measuring reservoir.

7. Install one off 1" diameter "keyhole" with external closing plate in front panel of the box at suitable height above the floor.

8. Affix Fire Foe tube brackets at specified position in the box

9. Submit drawing of proposed glove box and incorporated rack to LANL for their approval. LANL to countersign drawing to record such approval.

10. Manufacture glove box to such approved specification and drawing. Gloves, glove fixing assemblies and/or glove aperture blanking plates and window panels complete with sealing arrangements to be free-issue supply from LANL and to be incorporated into the glove box manufacture.

11. Install thermocouples on the top panel, bottom panel, side panels and end panels of the box to measure the temperature profile within the box in these positions before, during and after activation.

Proof of Concept Fire Testing:

Deviations from this protocol are noted in the Test Summary 2.0 Section of this document.

The following fire test program will be carried out. In each test one off Fire Foe tube will be mounted in the tube fixings within the box. Each test will be timed from ignition of material to flame extinguishment. All times to be recorded. In Test Protocol 3 plus two further tests under Test Protocol 8 conditions shall be pressure monitored before, during and after tube discharge. Such pressure monitoring shall be automatically recorded in real time. Prior to each test the airflow will be verified and recorded. Each test will be videoed from outside the box. After each test the box will remain closed and stable for 5 minutes.

Tests:

1. Place 1 pint of Acetone in a pan of dimensions 19.5" X 19.5" X 4". Place the pan on the floor of the box. Close hatch/door. Set and verify the required pressure differential and air flow. Ignite Acetone using hand held taper or lance manipulated through the key hole. Observe, videotape and record. *Object: Prove Fire Foe extinguishes acetone fire in isolation in the 250 cu ft glove box.*

2. Place 2 gallons of specified (pre-heated) cutting oil in a pan of dimensions 19.5" X 19.5" X 4". Place the pan on the floor of the box. Close the hatch/door. Set and verify pressure differential and air flow. Ignite cutting oil using hand held taper or lance manipulated through the key hole. Observe, videotape and record. *Object: Prove Fire Foe extinguishes cutting oil fire in isolation in the 250 cu ft glove box.*

3. Place 1 pint of Acetone in the external reservoir. Place an empty pan of dimensions 19.5" X 19.5" X 4" in the centre of the box floor under the copper filling pipe. Place 2 gallons of specified (pre-heated) cutting oil in a pan of dimensions 19.5" X 19.5" X 4" on the floor of the box. Place one wood-crib UL Standard 1975 measuring 10" X 3" X 6" on the floor of the box. Place one wood crib UL Standard 1975 measuring 10" X 3" X 6" on the rack. Close hatch/door. Set and verify the required pressure differential and air flow. (A) Ignite both wood cribs using hand held taper or lance manipulated through the key hole. Allow both cribs to burn for 60 seconds then open the external valve and drain the Acetone held in the external reservoir into the empty pan and if applicable, (B) ignite acetone and cutting oil using hand held taper of lance manipulated through the keyhole. Observe, videotape and record A/B. Record pressure variance before, during, after tube activation in real time. *Object: Prove Fire Foe extinguishes Class A UL specified crib in the presence of accelerants at two levels in the250 cu ft glove box.*

4. Place 1 pint of Acetone in a pan of dimensions 19.5" X 19.5" X 4". Place 2 gallons of specified (pre-heated) cutting oil in a pan of dimensions 19.5" X 19.5" X 4". Place both pans on the floor of the box. Place 5 off 500ml plastic squirt-bottles (two of which shall be empty and three of which shall be partly filled with specified combustible liquid e.g. alcohol) on the floor of the box. Place 5 off 500ml plastic squirt-bottles (two of which shall be empty and three of which shall be partly filled with specified combustible liquid e.g. alcohol) on the rack. Close hatch/door. Set and verify required pressure differential and air flow. Ignite the acetone and the cutting oil using a hand held taper or lance manipulated through the key hole. Observe, videotape and record. *Object: Prove that Fire Foe extinguishes Class A fire in empty and partially filled squirt bottles at two levels in the250 cu ft glove box.*

5. Place 1 pint of Acetone in a pan of dimensions 19.5" X 19.5" X 4". Place 2 gallons of specified (pre-heated) cutting oil in a pan of dimensions 19.5" X 19.5" X 4". Place both pans on the floor of the box. Place 2 off boxes of Kim-wipes (one of which shall be open with a number of Kim-wipes removed the other shall be un-opened) on the floor of the box. Place 2 off boxes of Kim-wipes (one of which shall be open with a number of Kim-wipes removed the other shall be un-opened) on the rack. Close hatch/door. Set and verify the required pressure differential and air flow. Ignite the Acetone and the cutting oil using a hand held taper or lance manipulated through the key hole. Observe, videotape and record. *Object: Prove that Fire Foe extinguishes Class A fire in partially filled and un-broached boxes of Kim-wipes at two levels in the 250 cu ft glove box.*

6. Place 1 pint of Acetone in a pan of dimensions 19.5" X 19.5" X 4", Place 2 gallons of specified (pre-heated) cutting oil in a pan of dimensions 19.5" X 19.5" X 4". Place both pans on the floor of the box. Place 3 meters of Tygon tubing on the floor of the box. Place 3 meters of Tygon tubing on the rack. Close hatch/door. Set and verify required pressure differential and air flow. Ignite the Acetone and cutting oil using a hand held taper or lance manipulated through the key hole. Observe, videotape and record. *Object: Prove that Fire Foe extinguishes Class A fire in Tygon tubing at multiple levels in the250 cu ft glove box.*

7. Place 1 pint of Acetone in a pan of dimensions 19.5" X 19.5" X 4". Place 2 gallons of specified (pre-heated) cutting oil in a pan of dimensions 19.5" X 19.5" X 4". Place both pans on the floor of the box. Suspend vertically 5 off wire bundles of #16THHN wires from the ceiling mounted rails. Suspend vertically 2 off wire bundles of #18THHN wires from the ceiling mounted rails. Suspend vertically 2 off bundles of 2 coaxial cables from the ceiling mounted rails. All wires to be bound together with plastic twist ties in a single 9-bundle group. Vertical bundles shall be suspended at varying heights above the Acetone/cutting oil. Close hatch/door. Set and verify the required pressure differential and air flow. Ignite the Acetone and cutting oil using a hand held taper or lance manipulated through the key hole. Observe, videotape and record. . *Object: Prove that Fire Foe extinguishes Class A & C fires in vertically suspended cable bundles at multiple levels in the 250 cu ft glove box.*

8. Place 1 pint of Acetone in the external measuring reservoir. Place an empty pan of dimensions 19.5" X 19.5" X 4" in the centre of the box floor under the copper filling pipe. Place 2 gallons of specified (pre-heated) cutting oil in a pan of dimensions 19.5" X 19.5" X 4" and place on the floor of the box. Place one wood crib UL Standard 1976 measuring 10" X 3" X 6" on the floor of the box. Place 5 off 500ml plastic squirt-bottles (two of which shall be empty and three of which shall be partly filled with alcohol) on the floor of the box. Place 2 off boxes of Kim-wipes (one of which shall be open with a number of Kim-wipes removed the other shall be un-opened) on the floor of the box. Place 3 meters of Tygon tubing on the floor of the box. Suspend vertically 5 off wire bundles of #16THHN wires from the ceiling mounted rails. Suspend vertically 2 off wire bundles of #18THHN wires from the ceiling mounted rails. Suspend vertically 2 off bundles of 2 coaxial cables from the ceiling mounted rails. All wires to be bound together with plastic twist ties in a single 9 bundle group. Vertical bundles shall be suspended at varying heights above the Acetone/cutting oil. Close hatch/door. Set and verify the required pressure differential and air flow. (A) Ignite wood crib using hand held taper or lance manipulated through the key hole. Allow wood crib to burn for 60 seconds then open the external valve and drain the Acetone in the external reservoir into the empty pan and if applicable, (B) ignite Acetone and cutting oil using hand held taper of lance manipulated through the keyhole. Observe, videotape and record A/B. *Object: prove that Fire Foe extinguishes the full range of Class A/B/C fires of varying types of specified materials at varying levels in the250 cu ft glove box.*

Repeat the above specified test 8 four further times in succession in the presence of designated personnel from LANL. In 2 consecutive tests, record pressure variance before, during, after tube activation, in real time. Observe, videotape and record.

Appendix D: Intertek Report No. 100238106SAT-001

(See attached document.)

TEST REPORT

REPORT NUMBER: 100238106SAT-001_Rev1
ORIGINAL ISSUE DATE: October 25, 2010
REVISED DATE: November 16, 2010

EVALUATION CENTER
16015 Shady Falls Road
Elmendorf, TX 78112
Phone: (210) 635-8100
Fax: (210) 635-8101
www.intertek.com

RENDERED TO

QuickFire USA LLC
1936 W. Main Street
Fort Wayne, IN 46808

PRODUCT EVALUATED: QuickFire Fire Foe™ FT250 Automatic Fire Extinguisher Tube
EVALUATION PROPERTY: Fire Extinguisher Capability

Report of Testing QuickFire Fire Foe™ FT250 Automatic Fire Extinguisher Tube for compliance with the applicable requirements of the following criteria: *Los Alamos National Laboratory (LANL) Test Protocol: Fire Foe™ Standard Tube in 250 Cubic Foot Glove Box, Section 8*

1 Table of Contents

2 Introduction

Intertek Testing Services NA (Intertek) has conducted testing for QuickFire USA LLC, on QuickFire Fire Foe™ FT250 Automatic Fire Extinguisher Tube, to evaluate its fire extinguisher capability. Testing was conducted in accordance with **Los Alamos National Laboratory (LANL) Test Protocol: Fire Foe™ Standard Tube in 250 Cubic Foot Glove Box, Section 8**. This evaluation began October 18, 2010 and was completed October 20, 2010.

The purpose of these tests was to evaluate the fire extinguisher capability of the FT250 Automatic Fire Extinguisher tube as installed in a 250 ft^3 steel glove box. No nationally recognized test standard was used to conduct these tests. All testing was conducted as per the client provided LANL Test Protocol, Section 8.

3 Test Samples

3.1. SAMPLE SELECTION

Testing was conducted on-site at the QuickFire USA LLC testing facility, located at 3630 Illinois Road, Fort Wayne, IN 46804, between the dates of October 18 – 20, 2010. Testing was conducted under the supervision of Intertek representative, Victor M. Burgos. Samples were not independently selected for testing by any Intertek personnel.

3.2. SAMPLE AND ASSEMBLY DESCRIPTION

The client describes the QuickFire Fire Foe™ Automatic Extinguisher System as follows:

"Fire Foe™ tubes use heat sensitive nylon tubing together with our patented sealing systems to both contain and release the Envirogel® extinguishing agent...Envirogel® is a unique blend of liquefied extinguishing gases combined with a small percentage of micro-ground dry powder which is held in the container as a gel..." (Ref. 1)

Refer to Appendix D for the Envirogel® MSDS. The tested samples were designated as FT250, and described to have the following specifications:

Model	FT250
Tube Outer Diameter	1-1/2"
Cut Tube Length	56-1/2"
Max Volume of Protected Space	250 ft^3
Envirogel® Amount	4.0 lbs
Envirogel® Fill Pressure	100 psi

The tubes contained two steel end caps. One end cap is fitted with a 300 psi pressure gauge, similar to a fire extinguisher gauge. The tubes also contained a longitudinal machined section with dimensions of 52-1/2" long x 7/8" wide x 1/50" deep, marked with a black line, intended to be the release point of activation/discharge.

The FT250 tubes were installed inside a steel glove box, one each per test. The steel box had approximate dimensions of 8' long x 5' wide x 6' high, and was constructed of 14GA steel. It also included one (1) access door and four (4) work stations with viewing windows and working gloves. Each working station consisted of two (2) pairs of gloves, two above and below the window. The glove materials were a combination of lead-lined and butyl. Replacement gloves were located on site, and were only replaced after each test if they were damaged. The FT250 tubes were attached to the ceiling of the glove box using three (3), two-bolt tube brackets, which in turn were attached to tack welded steel brackets, which were attached to the ceiling by a single bolt.

For each test, a series of consumables were placed inside the steel glove box prior to testing. All of the materials for these tests were purchased by the client. Each test contained the number and types of consumables as described in the LANL Test Protocol, Section 8 (located in Appendix C), with the following changes:

1) One (1) UL 1975 wood crib, with a minimum of 20 g of wood excelsior stuffed on the lower crib. The crib was installed on the floor of the steel glove box, underneath the FT250 tube extinguisher
2) 500 ml of Acetone, to be stored in a reservoir outside the box and released through a copper pipe and fill valve a minimum of 1 minute into the test. Two types of Acetone were used; Klean-Strip® and Sherwin-Williams
3) 2 gallons of pre-heated cutting oil to at least 220°F. The oil was stored in an external reservoir tank just prior to the start of the test. The oil was heated inside a stainless steel pot using an external natural gas burner. The type of cutting oil used was DR Lubricants KO 704-L
4) Five (5) 500 ml Nalgene® plastic squirt bottles. Additional 250 ml bottles from a different manufacturer were purchased due to insufficient 500 ml bottles present on-site. For each test, two of the bottles remained empty and the other three were partially filled with Acetone. No predetermined amount of volume of Acetone was specified for each bottle under the LANL Test Protocol. The bottles were positioned on the floor of the steel glove box at different locations
5) 2 boxes of Kimwipes® Kimtech Science® Brand Wipes (14.7" x 16.6"). One box was to remain closed and one opened with wipes pulled out from the top
6) 3 meters of Tygon tubing, rolled together and placed on the floor of the steel glove box surrounding the wood crib
7) One wire bundle of 9 wires, bound together with plastic zip ties approximately 6" – 8" apart. The wire bundle consisted of the following types of wires and cable; 1) five 16GA wires, 2) two 18GA wires, and 3) two coaxial cables. The wire bundle was suspended from the ceiling at the center of the steel glove box. Approximate length of wires was 8'
8) One in-line Flanders® Pureform® Nuclear HEPA air filter, rated at 50 cfm, Model F0604152. The filter was installed inside an 8" diameter stainless steel air duct, located at the ceiling left hand side of the steel glove box. The filters were found to have bi-directional flow applications

Refer to Appendix B for all sample assembly photos.

4 Testing and Evaluation Methods

The test assembly was instrumented with six, 24GA, Type K, fiberglass jacketed thermocouples. Each thermocouple was installed through an external port of the glove box and allowed to protrude inside approximately 6". The thermocouples were designated as follows:

1) TC #1 – Located close to the left side of the access door, mid height of the interior, designated as Panel #1
2) TC #2 – Located at the left panel, mid height of the interior, designated as Panel #2
3) TC #3 – Located at the left panel, approx 3" from the floor, designated as Panel #2
4) TC #4 – Located at the front panel (opposite location from the access door), mid height of the interior, designated as Panel #5
5) TC #5 – Located at the right panel, mid height of the interior, underneath the FT250 tube extinguisher, designated as Panel #8
6) TC #6 – Located at the ceiling, center of the steel glove box, designated as Panel #6

The setup was also instrumented with two pressure transducers. Both transducers were located on the left panel wall of the steel glove box, as viewed from the access door (designated as Panel #2). Transducer #1 was located approximately 3" from the floor. Transducer #2 was located approximately 3" from the ceiling. The output of the six thermocouples and two pressure transducers was monitored via a 32 channel, National Instruments LabVIEW™ SignalExpress data acquisition unit. The DAQ was programmed to scan and save data every 10 Hertz (10 scans every 1 second). Refer to Appendix B for all sample setup photos.

Prior to testing, the targeted flow conditions for the tests were -0.25" Water Column (WC) at 250 cfm (one full air exchange per minute), as defined by the LANL Test Protocol. The air speed was measured using a UEI Digital Vane Anemometer, Model DAFM3, provided by the client.

Refer to the LANL Test Protocol, Section 8, located in Appendix C, for further details.

4.1. TEST STANDARD 1

All testing was performed in accordance to the **Los Alamos National Laboratory (LANL) Test Protocol, Fire Foe™ Standard Tube in 250 Cubic Foot Glove Box, Section 8.**

4.1.1. Deviation From Standard Method

- As previously stated, the purpose of these tests was to evaluate the fire extinguisher capability of the FT250 Automatic Fire Extinguisher tube as installed in a 250 ft^3 steel glove box. No nationally recognized test standard was used to conduct these tests.

5 Testing and Evaluation Results

5.1. RESULTS AND OBSERVATIONS

Test #1: Intertek Project Number G100238106SAT-001A; QuickFire Experiment No. 17

The test was initiated on Tuesday, October 19, 2010. The ambient temperature and relative humidity at the time of the test were recorded to be 61°F and 34%, respectively. The following personnel were present to witness the test:

- Jim Geyer, Mark Novosel, and Aaron Sieber, representing QuickFire
- Mark Rosenberger and Jim Tsiagkouris, representing Los Alamos National Laboratory

The lower half of the UL 1975 wood crib was filled with 24.5 g of wood excelsior. The access door was sealed and the air blower was turned on. The air pressure and air flow inside the chamber were established to be -0.24" Water Column (WC) at 260 cfm. The preheated cutting oil was poured into the fluid holding reservoir at a temperature of 225°F. The oil valve was opened and the all the heated oil was allowed to be poured into the steel pan. The test was initiated as soon as the wood excelsior was ignited.

Observations made during the test are listed below:

Time (min:sec)	Observation
0:00	The test was initiated at 10:33 AM. Wood excelsior inside crib was ignited
1:00	Acetone reservoir opened, acetone manually ignited
1:35	Kimwipes closest to wood crib burning
3:50	Oil fire reduced, crib continuing to burn
4:21	Activation of FT250 tube extinguisher – Mark 5 min observation period
5:04	Box visibility clear
7:00	Crib smoldering, but not reigniting
7:40	Red ambers visible inside crib
8:17	Red ambers extinguished inside crib
9:21	5 minute observation period ended, no reignition of consumables
9:40	The test was terminated

Post Test Notes:

- No reignition of any consumables inside the glove box
- Approximately 60% of the crib was consumed
- One plastic acetone bottle was breached. A secondary bottle was melted at the bottle lid, but was not breached
- Wire insulation and Tygon tubing melted, but did not ignite
- 3 gloves were damaged during the test: 1) Station #3, lower RHS lead-lined glove, bubbling and melting of the fingers; 2) Station #8, lower RHS butyl glove, melting and breaching of all fingers; and 3) Station #3, upper RHS butyl glove, pin hole located up towards the collar section

Test #2: Intertek Project Number G100238106SAT-001B; QuickFire Experiment No. 18

The test was initiated on Tuesday, October 19, 2010. The ambient temperature and relative humidity at the time of the test were recorded to be 63°F and 32%, respectively. The following personnel were present to witness the test:

- Jim Geyer, Mark Novosel, and Aaron Sieber, representing QuickFire
- Mark Rosenberger and Jim Tsiagkouris, representing Los Alamos National Laboratory

The lower half of the UL 1975 wood crib was filled with 20.9 g of wood excelsior. The access door was sealed and the air blower was turned on. The air pressure and air flow inside the chamber were established to be -0.26" Water Column (WC) at 248 cfm. The preheated cutting oil was poured into the fluid holding reservoir at a temperature of 255°F. For this test, the FT250 tube extinguisher was installed 7-1/4" down from the ceiling and 5-5/8" from the RHS wall. The test was initiated as soon as the wood excelsior was ignited.

Observations made during the test are listed below:

Time (min:sec)	Observation
0:00	The test was initiated at 2:06 PM. Wood excelsior inside crib was ignited
0:23	Oil was allowed to flow inside the steel pan
1:00	Acetone reservoir opened, acetone manually ignited
2:15	Acetone fire diminishing
3:00	Crib continuing to burn
3:40	Acetone fire continuing to diminish
6:00	Crib flame diminishing
6:50	Acetone fire out
7:30	Tubing burning
8:08	Crib flame continuing to diminish
9:00	The test was terminated, fire burned itself out – No activation of FT250 tube extinguisher

Post Test Notes:

- No activation of FT250 tube extinguisher. Softening of the plastic tubing visible, but no breach of the tube occurred
- Approximately 95% of the crib was consumed
- All glove box seals OK. All Acetone bottles intact
- Wire insulation and Tygon tubing melted, but did not ignite
- The oil was not dumped prior to the start of the test. It was dumped 23 seconds into the test
- The acetone did not flow into the left side of the oil pan where the pre-heated oil was located. After the test, the oil pan was found to not be level and was slightly off to the right side. In turn, the oil fire was minimal in comparison to the other tests. This was also observed by the temperatures recorded during the test

Test #3: Intertek Project Number G100238106SAT-001C; QuickFire Experiment No. 19

The test was initiated on Tuesday, October 19, 2010. The ambient temperature and relative humidity at the time of the test were recorded to be 67°F and 31%, respectively. The following personnel were present to witness the test:

- Jim Geyer, Mark Novosel, and Aaron Sieber, representing QuickFire
- Mark Rosenberger and Jim Tsiagkouris, representing Los Alamos National Laboratory

The lower half of the UL 1975 wood crib was filled with 20.6 g of wood excelsior. The exhaust HEPA filter from Test #2 was reused for this test. The access door was sealed and the air blower was turned on. The air pressure and air flow inside the chamber were established to be -0.25" Water Column (WC) at 219 cfm. The preheated cutting oil was poured into the fluid holding reservoir at a temperature of 320°F. The oil valve was opened and the all the heated oil was allowed to be poured into the steel pan. The test was initiated as soon as the wood excelsior was ignited.

Observations made during the test are listed below:

Time (min:sec)	Observation
0:00	The test was initiated at 3:02 PM. Wood excelsior inside crib was ignited
1:00	Acetone reservoir opened, acetone ignited
1:02	High positive pressure event from ignition of acetone, crib extinguished, blower deactivated suddenly. Acetone was not manually lit
2:42	Blower reactivated
3:00	Crib smoldering
3:28	Reignition of crib
4:20	Crib fire increasing in intensity
5:00	Acetone fire diminishing
5:10	Crib continuing to burn
6:11	Activation of FT250 tube extinguisher – Mark 5 min observation period
6:39	Box visibility clear
10:00	No change, no reignition of consumables
11:11	5 minute observation period ended – no reignition of consumables
11:30	The test was terminated

Post Test Notes:

- FT250 extinguishing tube fully detached from holding brackets. Two of the three tack welded holding brackets broke off from the ceiling. Rear of tube sheared off.
- No reignition of any consumables inside the glove box
- Approximately 70% of the crib was consumed
- Closed Kimwipe box intact. Open Kimwipe box slightly burned (closest to crib)
- All glove box seals OK.
- Wire insulation and Tygon tubing melted, but did not ignite

Test #4: Intertek Project Number G100238106SAT-001D; QuickFire Experiment No. 20

The test was initiated on Tuesday, October 19, 2010. The ambient temperature and relative humidity at the time of the test were recorded to be 66°F and 31%, respectively. The following personnel were present to witness the test:

- Jim Geyer, Mark Novosel, and Aaron Sieber, representing QuickFire
- Mark Rosenberger and Jim Tsiagkouris, representing Los Alamos National Laboratory

The lower half of the UL 1975 wood crib was filled with 21.0 g of wood excelsior. The access door was sealed and the air blower was turned on. The air pressure and air flow inside the chamber were established to be -0.24" Water Column (WC) at 255 cfm. The preheated cutting oil was poured into the fluid holding reservoir at a temperature of 330°F. The oil valve was opened and the all the heated oil was allowed to be poured into the steel pan. The test was initiated as soon as the wood excelsior was ignited.

Observations made during the test are listed below:

Time (min:sec)	Observation
0:00	The test was initiated at 4:13 PM. Wood excelsior inside crib was ignited
0:45	Acetone reservoir opened
0:48	High positive pressure event from ignition of acetone. Acetone was not manually lit
1:55	Crib and oil fire out
2:00	Acetone continuing to burn
2:52	Activation of FT250 tube extinguisher – Mark 5 min observation period
3:33	Box visibility clear
6:00	No change, no reignition of consumables
7:52	5 minute observation period ended – no reignition of consumables
8:00	The test was terminated

Post Test Notes:

- FT250 extinguishing tube ruptured at the top center holding bracket location
- No reignition of any consumables inside the glove box
- Approximately 10% of the crib was consumed
- Closed Kimwipe box intact. Open Kimwipe box mostly burned (closest to crib)
- All glove box seals OK.
- Wire insulation melted, but did not ignite. Tygon tubing intact
- 4 of the 5 plastic acetone bottles knocked over, but no acetone spill present

Test #5: Intertek Project Number G100238106SAT-001E; QuickFire Experiment No. 21

The test was initiated on Tuesday, October 19, 2010. The ambient temperature and relative humidity at the time of the test were recorded to be 65°F and 30%, respectively. The following personnel were present to witness the test:

- Jim Geyer, Mark Novosel, and Aaron Sieber, representing QuickFire
- Mark Rosenberger and Jim Tsiagkouris, representing Los Alamos National Laboratory

The lower half of the UL 1975 wood crib was filled with 21.9 g of wood excelsior. The access door was sealed and the air blower was turned on. The air pressure and air flow inside the chamber were established to be -0.25" Water Column (WC) at 245 cfm. The preheated cutting oil was poured into the fluid holding reservoir at a temperature of 350°F. The oil valve was opened and the all the heated oil was allowed to be poured into the steel pan. The test was initiated as soon as the wood excelsior was ignited. For this test, the wood crib was allowed to burn for 2 minutes prior to the acetone pour and ignition.

Observations made during the test are listed below:

Time (min:sec)	Observation
0:00	The test was initiated at 5:47 PM. Wood excelsior inside crib was ignited
0:46	Kimwipe box closest to crib ignited
2:00	Acetone reservoir opened and manually ignited inside glove box
3:13	Activation of FT250 tube extinguisher – Mark 5 min observation period
4:20	Box visibility clear
6:30	No change, no reignition of consumables
8:13	5 minute observation period ended – no reignition of consumables
8:20	The test was terminated

Post Test Notes:

- No reignition of any consumables inside the glove box
- FT250 tube extinguisher ruptured approximately 4" – 6" from the pressure gauge
- Station #8, lower LHS lead-lined glove, burned at the elbow location
- Approximately 70% of the crib was consumed
- Closed Kimwipe box intact. Open Kimwipe box mostly burned (closest to crib)
- Wire insulation and Tygon tubing melted, but did not ignite
- 2 of the 5 plastic acetone squirt bottles knocked over, but no acetone spill present. All acetone bottles fully intact

Test #6: Intertek Project Number G100238106SAT-001F; QuickFire Experiment No. 22

The test was initiated on Tuesday, October 19, 2010. The ambient temperature and relative humidity at the time of the test were recorded to be 66°F and 30%, respectively. The following personnel were present to witness the test:

- Jim Geyer, Mark Novosel, and Aaron Sieber, representing QuickFire
- Mark Rosenberger and Jim Tsiagkouris, representing Los Alamos National Laboratory

The lower half of the UL 1975 wood crib was filled with 22.7 g of wood excelsior. The access door was sealed and the air blower was turned on. The air pressure and air flow inside the chamber were established to be -0.24" Water Column (WC) at 262 cfm. The preheated cutting oil was poured into the fluid holding reservoir at a temperature of 330°F. The oil valve was opened and the all the heated oil was allowed to be poured into the steel pan. The test was initiated as soon as the wood excelsior was ignited. For this test, the wood crib was allowed to burn for 2 minutes prior to the acetone pour and ignition.

Observations made during the test are listed below:

Time (min:sec)	Observation
0:00	The test was initiated at 6:37 PM. Wood excelsior inside crib was ignited
0:21	Kimwipe box closest to crib ignited
2:00	Acetone reservoir opened and manually ignited inside glove box
2:10	Positive pressure event. Blower shut down automatically
2:28	Blower restarted
3:00	Acetone fire continuing to burn
3:42	Activation of FT250 tube extinguisher – Mark 5 min observation period
4:13	Box visibility clear
5:15	No change, no reignition of consumables
7:30	No change
8:42	5 minute observation period ended – no reignition of consumables
8:50	The test was terminated

Post Test Notes:

- No reignition of any consumables inside the glove box. The crib was found to be smoldering, but did not reignite
- FT250 tube extinguisher ruptured approximately at the center bracket location
- Approximately 90% of the crib was consumed
- Closed Kimwipe box intact. Open Kimwipe box mostly burned (closest to crib)
- Wire insulation and Tygon tubing melted, but did not ignite
- 4 of the 5 plastic acetone squirt bottles knocked over, but no acetone spill present. All acetone bottles fully intact

6 Conclusion

Intertek Testing Services NA (Intertek) has conducted testing for QuickFire USA LLC, on QuickFire Fire Foe™ FT250 Automatic Fire Extinguisher Tube, to evaluate its fire extinguisher capability. Testing was conducted in accordance with **Los Alamos National Laboratory (LANL) Test Protocol: Fire Foe™ Standard Tube in 250 Cubic Foot Glove Box, Section 8.** This evaluation began October 18, 2010 and was completed October 20, 2010.

The tables below summarize the results obtained for these tests:

Intertek Test Number	Tube Activation Time (min:sec)	TC 1 (deg F)	TC 2 (deg F)	TC 3 (deg F)	TC 4 (deg F)	TC 5 (deg F)	TC 6 (deg F)	Temperature Average at Activation (deg F)
1	4:21	263	263	158	273	253	261	245.2
2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3	6:11	178	157	116	152	260	192	175.8
4	2:52	326	324	156	295	328	350	296.5
5	3:13	330	331	176	322	365	429	325.5
6	3:42	412	395	212	383	438	458	383.0

Intertek Test Number	Activation of FT250 Automatic Fire Extinguisher Tube?	Reignition of Consumables after 5 minutes?	Met Conditions of LANL Test Protocol?
1	YES	NO	YES
2	NO	N/A	N/A
3	YES	NO	YES
4	YES	NO	YES
5	YES	NO	YES
6	YES	NO	YES

The conclusions of this test report may be used as part of the requirements for Intertek product certification, pending additional product review. Authority to Mark must be issued for a product to become certified.

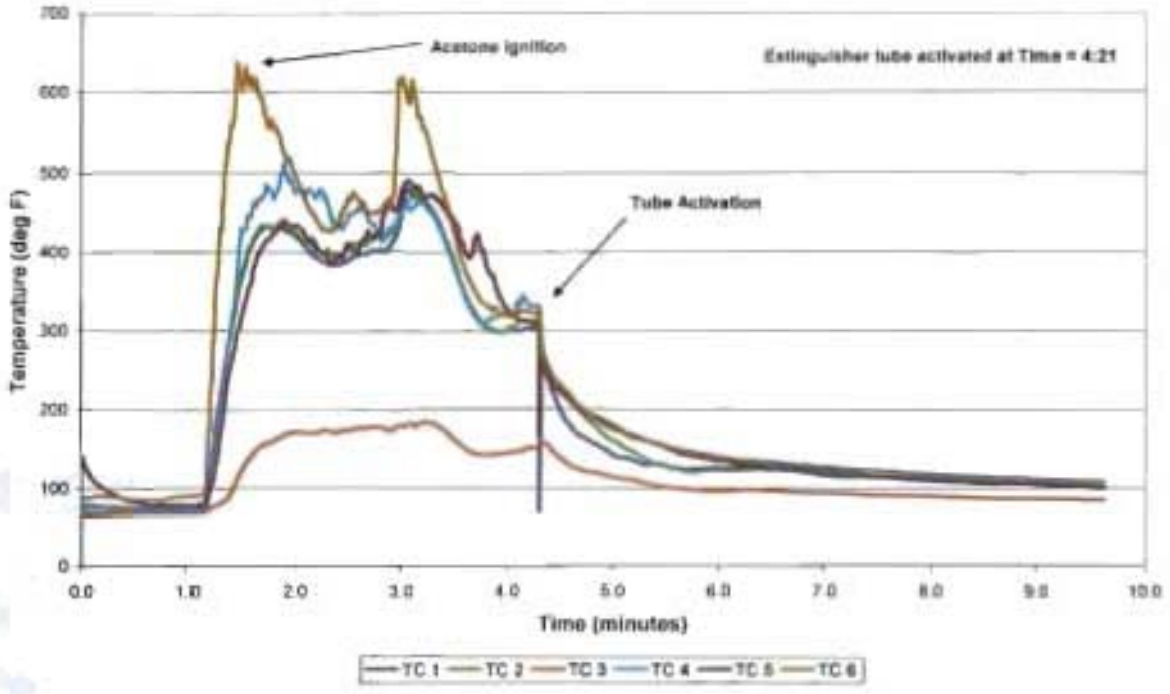
INTERTEK TESTING SERVICES NA, INC

Reported by: _____
Victor M. Burgos
Test Engineer, Fire Resistance

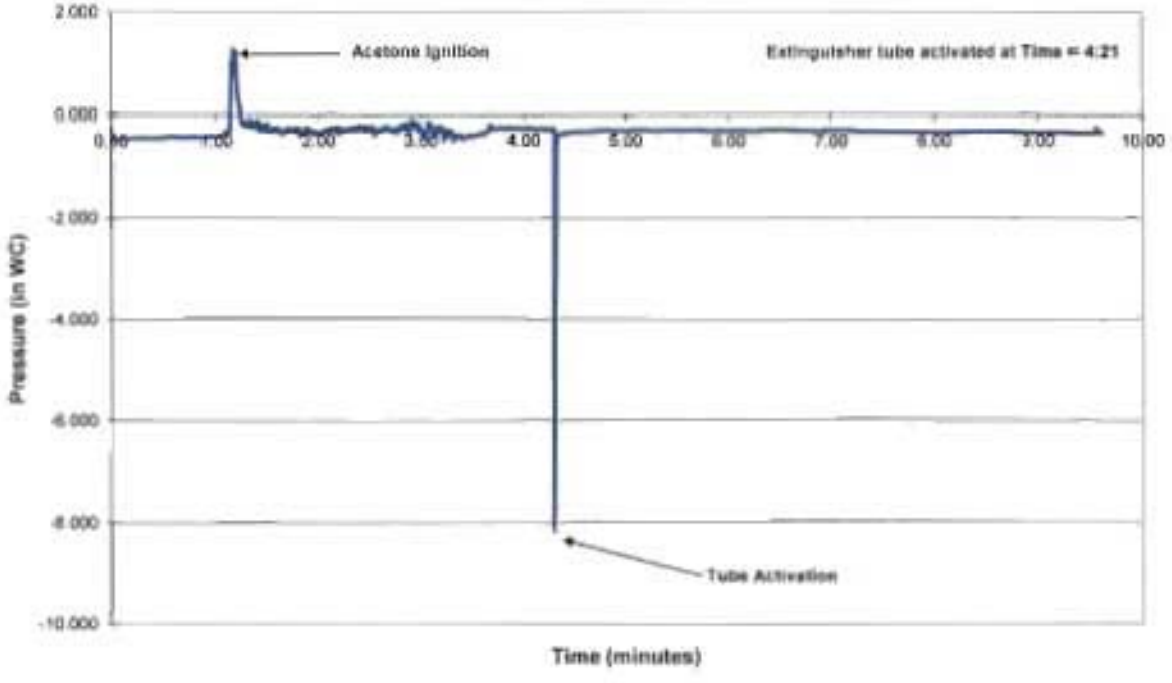
Reviewed by: _____
Mike Dey
Operations Manager

APPENDIX A
Test Data

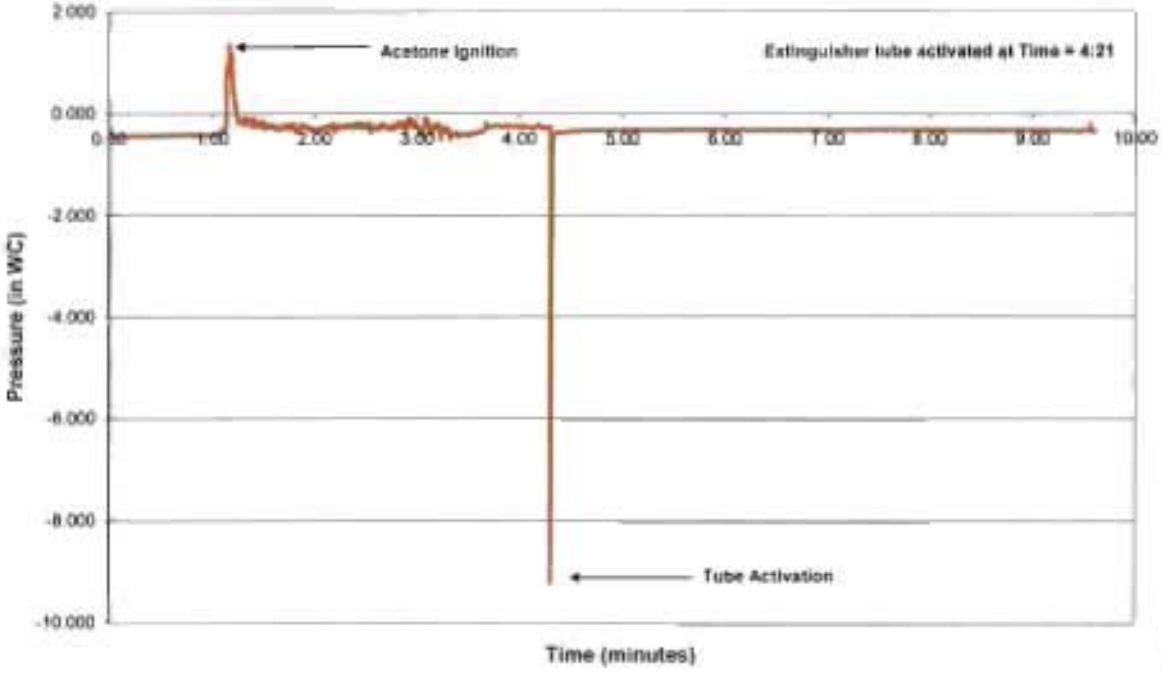
Interior Glove Box Temperatures
G100238106SAT-001A QuickFire Test 1



Internal Glove Box Pressures for Transducer 1
G100238106SAT-001A QuickFire Test 1



Internal Glove Box Pressure for Transducer 2
G100238106SAT-001A QuickFire Test 1



Intertek

Date: 19-Oct-10
Eng. Initials:

Client: QuickFire USA LLC
Project No: G100238106SAT-001A
Test No: 1
Product: QuickFire Fire Foe FT250 Tube Fire Extinguisher
Engineer: Victor M. Burgos, Intertek - San Antonio
Test Method(s): Los Alamos National Laboratory (LANL) Test Protocol, Section 8

INTERNAL GLOVE BOX TEMPERATURES

Time (sec)	Time (min)	TC 1 (deg F)	TC 2 (deg F)	TC 3 (deg F)	TC 4 (deg F)	TC 5 (deg F)	TC 6 (deg F)	
0.0	0.000	75	70	67	71	129	85	
10.0	0.167	77	71	67	77	104	91	
20.0	0.333	75	71	68	77	91	89	
30.0	0.500	74	71	69	76	83	86	
40.0	0.667	74	71	69	75	79	85	
50.0	0.833	74	71	69	75	79	88	
60.0	1.000	73	71	69	75	79	90	Acetone ignition
70.0	1.167	75	90	72	77	92	138	
68.6	1.143	73	77	69	75	83	94	
68.7	1.145	73	77	69	75	83	94	
68.8	1.147	73	77	69	75	83	94	
68.9	1.148	73	77	69	75	83	94	
69.0	1.150	73	78	70	75	84	95	
69.1	1.152	73	78	70	75	84	95	
69.2	1.153	73	78	70	75	84	95	
69.3	1.155	73	78	70	75	84	95	
69.4	1.157	73	78	70	75	84	95	
69.5	1.158	74	79	71	76	86	104	
69.6	1.160	74	79	71	76	86	104	
69.7	1.162	74	79	71	76	86	104	
69.8	1.163	74	79	71	76	86	104	
69.9	1.165	74	79	71	76	86	104	
70.0	1.167	75	80	72	77	92	138	
70.1	1.168	75	80	72	77	92	138	
70.2	1.170	75	80	72	77	92	138	
70.3	1.172	75	80	72	77	92	138	
70.4	1.173	75	80	72	77	92	138	
70.5	1.175	78	84	73	79	93	168	
70.6	1.177	78	84	73	79	93	168	
70.7	1.178	78	84	73	79	93	168	
70.8	1.180	78	84	73	79	93	168	
70.9	1.182	78	84	73	79	93	168	
71.0	1.183	87	89	73	95	95	171	
71.1	1.185	87	89	73	95	95	171	
71.2	1.187	87	89	73	95	95	171	
71.3	1.188	87	89	73	95	95	171	
71.4	1.190	87	89	73	95	95	171	
71.5	1.192	100	95	74	101	96	183	
71.6	1.193	100	95	74	101	96	183	
71.7	1.195	100	95	74	101	96	183	
71.8	1.197	100	95	74	101	96	183	
71.9	1.198	100	95	74	101	96	183	

72.0	1.200	107	108	75	113	100	229
72.1	1.202	107	100	75	113	100	229
72.2	1.203	107	100	75	113	100	229
72.3	1.205	107	100	75	113	100	229
72.4	1.207	107	100	75	113	100	229
72.5	1.208	116	110	76	122	104	235
72.6	1.210	116	110	76	122	104	235
72.7	1.212	116	110	76	122	104	235
72.8	1.213	116	110	76	122	104	235
72.9	1.215	116	110	76	122	104	235
73.0	1.217	129	122	76	129	108	278
73.1	1.218	129	122	76	129	108	278
73.2	1.220	129	122	76	129	108	278
73.3	1.222	129	122	76	129	108	278
73.4	1.223	129	122	76	129	108	278
73.5	1.225	145	130	77	138	112	290
73.6	1.227	145	130	77	138	112	290
73.7	1.228	145	130	77	138	112	290
73.8	1.230	145	130	77	138	112	290
73.9	1.232	145	130	77	138	112	290
74.0	1.233	153	137	77	147	121	310
74.1	1.235	153	137	77	147	121	310
74.2	1.237	153	137	77	147	121	310
74.3	1.238	153	137	77	147	121	310
74.4	1.240	153	137	77	147	121	310
74.5	1.242	163	142	78	156	127	348
80.0	1.333	244	245	84	253	209	501
90.0	1.500	376	369	124	429	325	614
100.0	1.667	426	433	153	467	400	662
110.0	1.833	430	436	165	478	431	549
120.0	2.000	421	425	172	475	435	496
130.0	2.167	397	417	170	473	405	449
140.0	2.333	384	399	173	449	388	426
150.0	2.500	389	407	178	442	406	470
160.0	2.667	397	409	177	454	421	450
170.0	2.833	401	414	176	422	450	462
180.0	3.000	444	455	180	449	478	619
190.0	3.167	467	470	182	462	481	573
200.0	3.333	445	440	180	443	457	501
210.0	3.500	385	391	163	384	439	422
220.0	3.667	331	330	148	326	402	368
230.0	3.833	302	305	143	313	371	336
240.0	4.000	301	301	146	323	329	326
250.0	4.167	303	314	150	340	313	324
258.6	4.310	304	316	153	333	169	311
258.7	4.312	304	316	153	331	169	311
258.8	4.313	304	316	153	331	169	311
258.9	4.315	304	316	153	331	169	311
259.0	4.317	71	288	156	309	275	283
259.1	4.318	71	288	156	309	275	283
259.2	4.320	71	288	156	309	275	283
259.3	4.322	71	288	156	309	275	283
259.4	4.323	71	288	156	309	275	283
259.5	4.325	281	279	157	294	266	279
259.6	4.327	281	279	157	294	266	279
259.7	4.328	281	279	157	294	266	279
259.8	4.330	281	279	157	294	266	279

Tube Activation

260.0	4.333	274	271	159	284	280	273
270.0	4.500	203	227	139	228	223	233
280.0	4.667	170	203	126	202	205	208
290.0	4.833	157	180	120	186	192	189
300.0	5.000	144	161	115	175	180	178
310.0	5.167	136	149	112	168	169	166
320.0	5.333	131	136	108	161	160	160
330.0	5.500	130	129	102	153	153	155
340.0	5.667	125	122	100	149	143	148
350.0	5.833	126	122	97	145	139	143
360.0	6.000	127	124	96	140	136	139
370.0	6.167	127	125	96	138	132	137
380.0	6.333	129	124	98	131	126	136
390.0	6.500	130	124	97	127	124	134
400.0	6.667	129	124	96	124	123	131
410.0	6.833	128	123	95	122	121	130
420.0	7.000	125	121	94	120	117	127
430.0	7.167	122	119	93	118	115	126
440.0	7.333	119	118	93	117	115	124
450.0	7.500	116	117	92	116	114	122
460.0	7.667	115	116	91	115	113	122
470.0	7.833	114	115	91	115	111	120
480.0	8.000	113	113	90	113	110	118
490.0	8.167	111	112	89	112	109	118
500.0	8.333	110	111	89	111	108	116
510.0	8.500	109	109	88	110	106	115
520.0	8.667	107	109	87	109	106	113
530.0	8.833	107	107	87	108	106	114
540.0	9.000	106	107	87	107	105	112
550.0	9.167	105	106	86	106	103	111
560.0	9.333	104	105	86	104	102	110
570.0	9.500	103	104	85	103	101	110

Intertek

Date: 19-Oct-10
Eng. Initials:

Client: QuickFire USA LLC
Project No: G100238106SAT-001A
Test No: 1
Product: QuickFire Fire Foe FT250 Tube Fire Extinguisher
Engineer: Victor M. Borges, Intertek - San Antonio
Test Method(s): Los Alamos National Laboratory (LANL) Test Protocol, Section 8

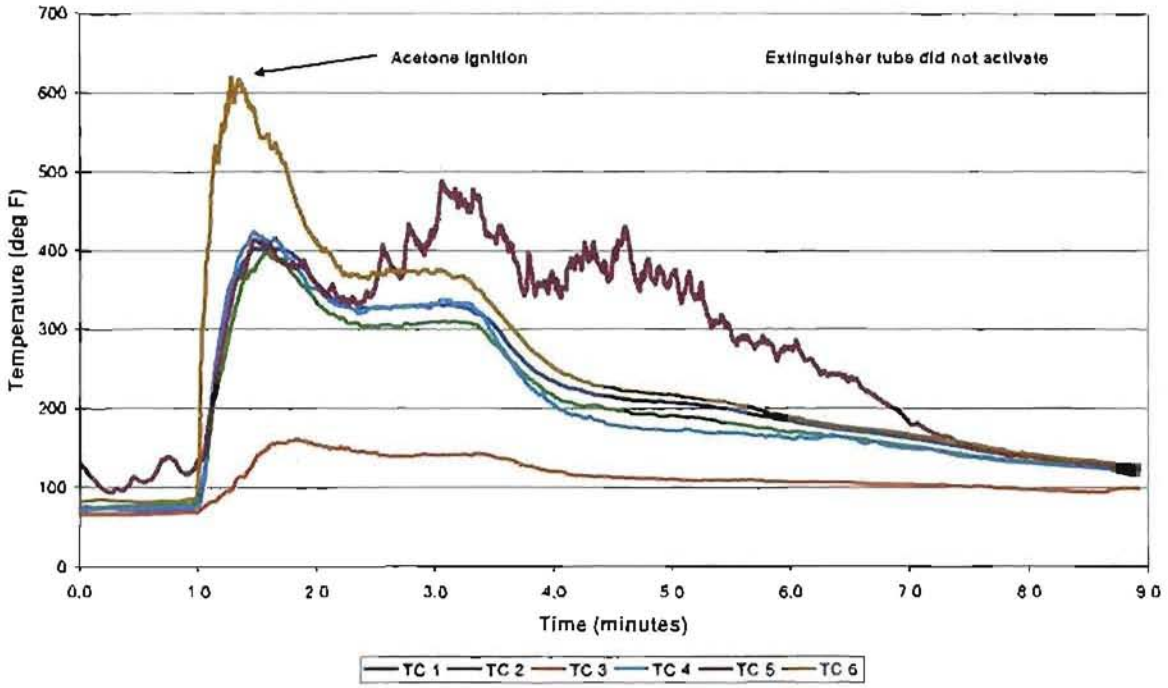
INTERNAL GLOVE BOX PRESSURES

Time (min)	Transducer 1 (in WC)	Transducer 2 (in WC)	
0.000	-0.240	-0.240	
0.167	-0.456	-0.451	
0.333	-0.431	-0.431	
0.500	-0.427	-0.427	
0.667	-0.427	-0.422	
0.833	-0.414	-0.418	
1.000	-0.410	-0.435	Acetone ignition
1.143	-0.182	-0.082	
1.145	-0.182	-0.082	
1.147	0.979	0.915	
1.148	0.979	0.915	
1.150	1.022	0.873	
1.152	1.022	0.873	
1.153	0.763	0.736	
1.155	0.763	0.736	
1.157	0.724	0.831	
1.158	0.724	0.831	
1.160	1.043	0.977	
1.162	1.043	0.977	
1.163	0.968	0.939	
1.165	0.968	0.939	
1.167	1.027	1.097	
1.168	1.027	1.097	
1.170	1.209	1.346	
1.172	1.209	1.346	
1.173	1.276	1.222	
1.175	1.276	1.222	
1.177	1.101	1.014	
1.178	1.101	1.014	
1.180	0.914	0.927	
1.182	0.914	0.927	
1.183	0.914	0.802	
1.185	0.914	0.802	
1.187	0.780	0.910	
1.188	0.780	0.910	
1.190	1.031	1.147	
1.192	1.031	1.147	

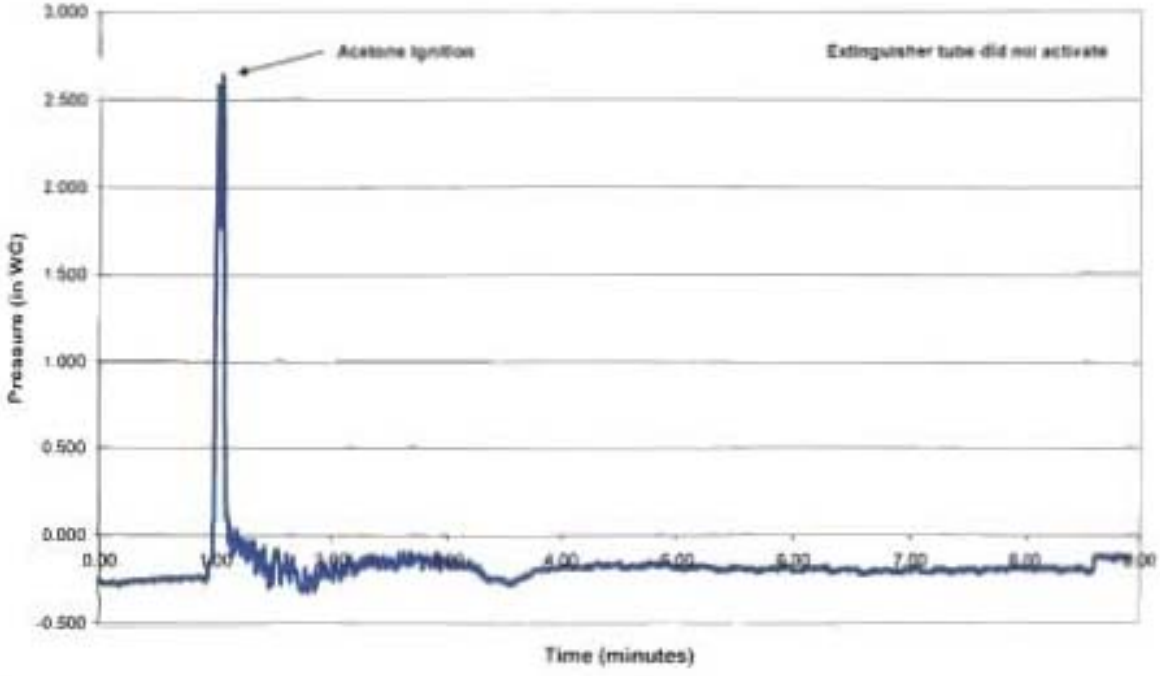
1.193	1.085	1.155	
1.195	1.085	1.155	
1.197	1.234	1.118	
1.198	1.234	1.118	
1.200	1.008	0.840	
1.202	1.008	0.840	
1.203	0.796	0.628	
1.205	0.796	0.628	
1.207	0.480	0.462	
1.208	0.480	0.462	
1.210	0.455	0.454	
1.212	0.455	0.454	
1.213	0.450	0.412	
1.215	0.450	0.412	
1.217	0.378	0.333	
1.218	0.378	0.333	
1.220	0.306	0.254	
1.222	0.306	0.254	
1.223	0.218	0.200	
1.225	0.218	0.200	
1.227	0.223	0.229	
1.228	0.223	0.229	
1.230	0.149	0.105	
1.232	0.149	0.105	
1.233	0.072	0.068	
1.235	0.072	0.068	
1.237	0.084	0.122	
1.238	0.084	0.122	
1.240	0.141	0.117	
1.242	0.141	0.117	
1.333	-0.219	-0.206	
1.500	-0.144	-0.173	
1.667	-0.348	-0.319	
1.833	-0.381	-0.352	
2.000	-0.377	-0.331	
2.167	-0.306	-0.302	
2.333	-0.248	-0.215	
2.500	-0.294	-0.269	
2.667	-0.248	-0.260	
2.833	-0.244	-0.269	
3.000	-0.265	-0.252	
3.167	-0.219	-0.248	
3.333	-0.468	-0.464	
3.500	-0.414	-0.435	
3.667	-0.281	-0.277	
3.833	-0.269	-0.265	
4.000	-0.256	-0.265	
4.167	-0.252	-0.260	
4.310	-0.281	-1.676	Tube activation neg pressure spike
4.312	-0.281	-1.676	
4.313	-8.137	-9.204	
4.315	-8.137	-9.204	

4.317	-7.443	-5.579
4.318	-7.443	-5.579
4.320	-4.026	-2.959
4.322	-4.026	2.959
4.323	-2.183	-1.540
4.325	-2.183	-1.540
4.327	-1.099	-0.813
4.328	-1.099	-0.813
4.330	-0.584	-0.469
4.333	-0.493	-0.464
4.500	-0.302	-0.352
4.667	-0.294	-0.343
4.833	-0.290	-0.343
5.000	-0.306	-0.352
5.167	-0.273	-0.352
5.333	-0.285	-0.339
5.500	-0.294	-0.346
5.667	-0.277	-0.314
5.833	-0.294	-0.306
6.000	-0.298	-0.323
6.167	-0.285	-0.323
6.333	-0.290	-0.348
6.500	-0.281	-0.339
6.667	-0.285	-0.314
6.833	-0.298	-0.314
7.000	-0.290	-0.346
7.167	-0.302	-0.327
7.333	-0.310	-0.346
7.500	-0.302	-0.314
7.667	-0.315	-0.323
7.833	-0.302	-0.331
8.000	-0.319	-0.331
8.167	-0.331	-0.335
8.333	-0.306	-0.339
8.500	-0.310	-0.335
8.667	-0.302	-0.339
8.833	-0.306	-0.339
9.000	-0.327	-0.339
9.167	-0.319	-0.343
9.333	-0.319	-0.348
9.500	-0.335	-0.339

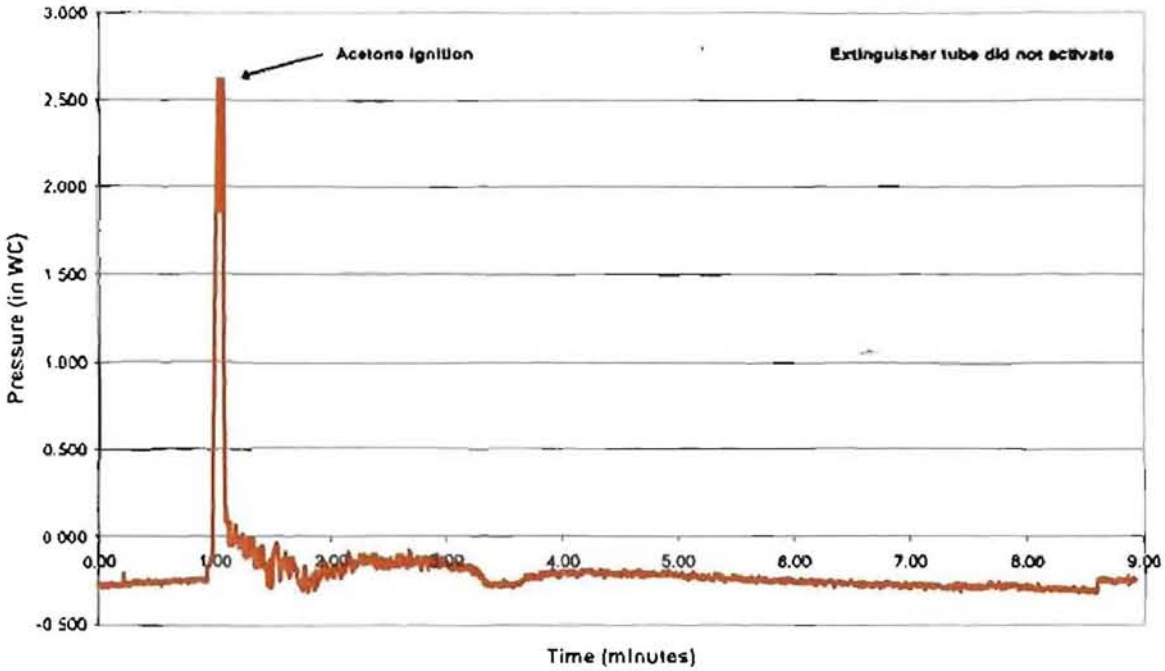
Interior Glove Box Temperatures
G100238106SAT-001B QuickFire Test 2



Internal Glove Box Pressures for Transducer 1
G100238106SAT-001B QuickFire Test 2



Internal Glove Box Pressure for Transducer 2
G100238106SAT-001B QuickFire Test 2



Intertek

Date: 19-Oct-10
Eng. Initials:

Client: QuickFire USA LLC
Project No: G100238106SAT-001B
Test No: 2
Product: QuickFire Fire Foe FT250 Tube Fire Extinguisher
Engineer: Victor M. Burgos, Intertek - San Antonio
Test Method(s): Los Alamos National Laboratory (LANL) Test Protocol, Section 8

INTERNAL GLOVE BOX TEMPERATURES

Time (sec)	Time (min)	TC 1 (deg F)	TC 2 (deg F)	TC 3 (deg F)	TC 4 (deg F)	TC 5 (deg F)	TC 6 (deg F)	
0	0.000	73	70	67	72	129	81	
10	0.167	74	75	67	72	102	85	
20	0.333	73	76	67	74	98	83	
30	0.500	72	77	67	74	109	82	
40	0.667	72	78	68	74	127	83	
50	0.833	72	79	69	75	125	83	
59	0.983	76	82	69	76	129	86	
59.1	0.985	76	82	69	76	129	86	
59.2	0.987	76	82	69	76	129	86	
59.3	0.988	76	82	69	76	129	86	
59.4	0.990	76	82	69	76	129	86	
59.5	0.992	76	83	69	76	134	87	
59.6	0.993	76	83	69	76	134	87	
59.7	0.995	76	83	69	76	134	87	Acetone ignition
59.8	0.997	76	83	69	76	134	87	Positive press spike
59.9	0.998	76	83	69	76	134	87	
60	1.000	76	84	70	77	134	105	
60.1	1.002	76	84	70	77	134	105	
60.2	1.003	76	84	70	77	134	105	
60.3	1.005	76	84	70	77	134	105	
60.4	1.007	76	84	70	77	134	105	
60.5	1.008	77	85	71	78	134	122	
60.6	1.010	77	85	71	78	134	122	
60.7	1.012	77	85	71	78	134	122	
60.8	1.013	77	85	71	78	134	122	
60.9	1.015	77	85	71	78	134	122	
61	1.017	79	87	72	79	134	109	
61.1	1.018	79	87	72	79	134	109	
61.2	1.020	79	87	72	79	134	109	
61.3	1.022	79	87	72	79	134	109	
61.4	1.023	79	87	72	79	134	109	Max press spike
61.5	1.025	84	89	73	81	134	258	
61.6	1.027	84	89	73	81	134	258	
61.7	1.028	84	89	73	81	134	258	
61.8	1.030	84	89	73	81	134	258	
61.9	1.032	84	89	73	81	134	258	
62	1.033	96	91	74	88	136	301	
62.1	1.035	96	91	74	88	136	301	
62.2	1.037	96	91	74	88	136	301	
62.3	1.038	96	91	74	88	136	301	
62.4	1.040	96	91	74	88	136	301	
62.5	1.042	102	97	75	97	138	312	
62.6	1.043	102	97	75	97	138	312	
62.7	1.045	102	97	75	97	138	312	
62.8	1.047	102	97	75	97	138	312	
62.9	1.048	102	97	75	97	138	312	

63	1.050	109	183	78	107	140	321
63.1	1.052	109	183	78	107	140	321
63.2	1.053	109	183	78	107	140	321
63.3	1.055	109	183	78	107	140	321
63.4	1.057	109	183	78	107	140	321
63.5	1.058	116	196	77	116	148	342
63.6	1.060	116	196	77	116	148	342
63.7	1.062	116	196	77	116	148	342
63.8	1.063	116	196	77	116	148	342
63.9	1.065	116	196	77	116	148	342
64	1.067	125	176	78	126	157	356
64.1	1.068	125	176	78	126	157	356
64.2	1.070	125	176	78	126	157	356
64.3	1.072	125	176	78	126	157	356
64.4	1.073	125	176	78	126	157	356
64.5	1.075	133	189	79	140	167	388
64.6	1.077	133	189	79	140	167	388
64.7	1.078	133	189	79	140	167	388
64.8	1.080	133	189	79	140	167	388
64.9	1.082	133	189	79	140	167	388
65	1.083	146	197	80	159	178	405
65.1	1.085	146	197	80	159	178	405
65.2	1.087	146	197	80	159	178	405
65.3	1.088	146	197	80	159	178	405
65.4	1.090	146	197	80	159	178	405
65.5	1.092	168	151	80	176	196	416
65.6	1.093	168	151	80	176	196	416
65.7	1.095	168	151	80	176	196	416
65.8	1.097	168	151	80	176	196	416
65.9	1.098	168	151	80	176	196	416
66	1.100	182	162	81	186	197	427
66.1	1.102	182	162	81	186	197	427
66.2	1.103	182	162	81	186	197	427
66.3	1.105	182	162	81	186	197	427
66.4	1.107	182	162	81	186	197	427
66.5	1.108	198	172	81	196	196	472
66.6	1.110	198	172	81	196	196	472
66.7	1.112	198	172	81	196	196	472
66.8	1.113	198	172	81	196	196	472
66.9	1.115	198	172	81	196	196	472
67	1.117	198	182	82	216	207	487
67.1	1.118	198	182	82	216	207	487
67.2	1.120	198	182	82	216	207	487
67.3	1.122	198	182	82	216	207	487
67.4	1.123	198	182	82	216	207	487
67.5	1.125	210	192	82	232	212	496
67.6	1.127	210	192	82	232	212	496
67.7	1.128	210	192	82	232	212	496
67.8	1.130	210	192	82	232	212	496
67.9	1.132	210	192	82	232	212	496
68	1.133	219	200	82	234	217	520
68.1	1.135	219	200	82	234	217	520
68.2	1.137	219	200	82	234	217	520
68.3	1.138	219	200	82	234	217	520
68.4	1.140	219	200	82	234	217	520
68.5	1.142	231	211	83	245	225	533

68.6	1.143	231	211	83	245	226	533	
68.7	1.146	231	211	83	246	226	533	
68.8	1.147	231	211	83	245	226	533	
68.9	1.148	231	211	83	246	226	533	
69	1.150	241	215	83	256	237	525	
69.1	1.152	241	215	83	256	237	525	
69.2	1.153	241	215	83	256	237	525	
69.3	1.155	241	215	83	256	237	525	
69.4	1.157	241	215	83	256	237	525	
69.5	1.158	250	221	84	261	245	514	
69.6	1.160	250	221	84	261	245	514	End pos pressure
69.7	1.162	250	221	84	261	245	514	
69.8	1.163	250	221	84	261	245	514	
69.9	1.165	250	221	84	261	245	514	
80	1.333	367	333	111	384	385	614	
90	1.500	401	383	140	421	412	566	
100	1.667	401	388	157	414	390	523	
110	1.833	392	366	161	379	380	457	
120	2.000	367	336	154	352	357	411	
130	2.167	338	318	149	332	346	382	
140	2.333	325	309	146	324	331	371	
150	2.500	328	304	144	329	356	370	
160	2.667	330	304	140	329	376	374	
170	2.833	330	307	140	331	413	374	
180	3.000	331	310	141	333	432	372	
190	3.167	331	311	142	333	479	367	
200	3.333	322	306	143	327	489	354	
210	3.500	306	292	138	292	417	327	
220	3.667	274	258	134	259	389	299	
230	3.833	248	234	125	224	350	271	
240	4.000	235	217	120	206	360	251	
250	4.167	225	207	116	191	377	239	
260	4.333	219	204	114	187	413	229	
270	4.500	216	198	112	178	397	226	
280	4.667	211	194	112	176	383	225	
290	4.833	210	194	111	173	382	220	
300	5.000	207	192	111	172	370	218	
310	5.167	206	189	109	173	340	214	
320	5.333	203	186	109	169	304	210	
330	5.500	196	181	103	165	291	206	
340	5.667	193	178	110	167	282	200	
350	5.833	190	175	108	166	282	194	
360	6.000	185	170	107	162	278	189	
370	6.167	180	168	107	162	269	184	
380	6.333	176	165	107	166	245	180	
390	6.500	173	163	107	162	238	176	
400	6.667	170	160	105	157	220	174	
410	6.833	166	156	104	152	204	171	
420	7.000	163	152	104	150	192	167	
430	7.167	159	149	103	149	172	164	
440	7.333	156	145	102	143	164	160	
450	7.500	150	141	101	139	152	156	
460	7.667	145	138	101	136	146	151	
470	7.833	142	134	100	133	140	146	
480	8.000	139	133	98	131	139	142	
490	8.167	137	131	97	129	137	139	
500	8.333	134	129	96	127	133	136	
510	8.500	132	127	95	126	132	135	
520	8.667	130	124	96	124	129	132	
530	8.833	128	118	99	121	125	130	

Intertek

Date: 19-Oct-10
Eng. Initials:

Client: QuickFire USA LLC
Project No: G100238106SAT-001B
Test No: 2
Product: QuickFire Fire Foe FT250 Tube Fire Extinguisher
Engineer: Victor M. Burgos, Intertek - San Antonio
Test Method(s): Los Alamos National Laboratory (LANL) Test Protocol, Section 8

INTERNAL GLOVE BOX PRESSURES

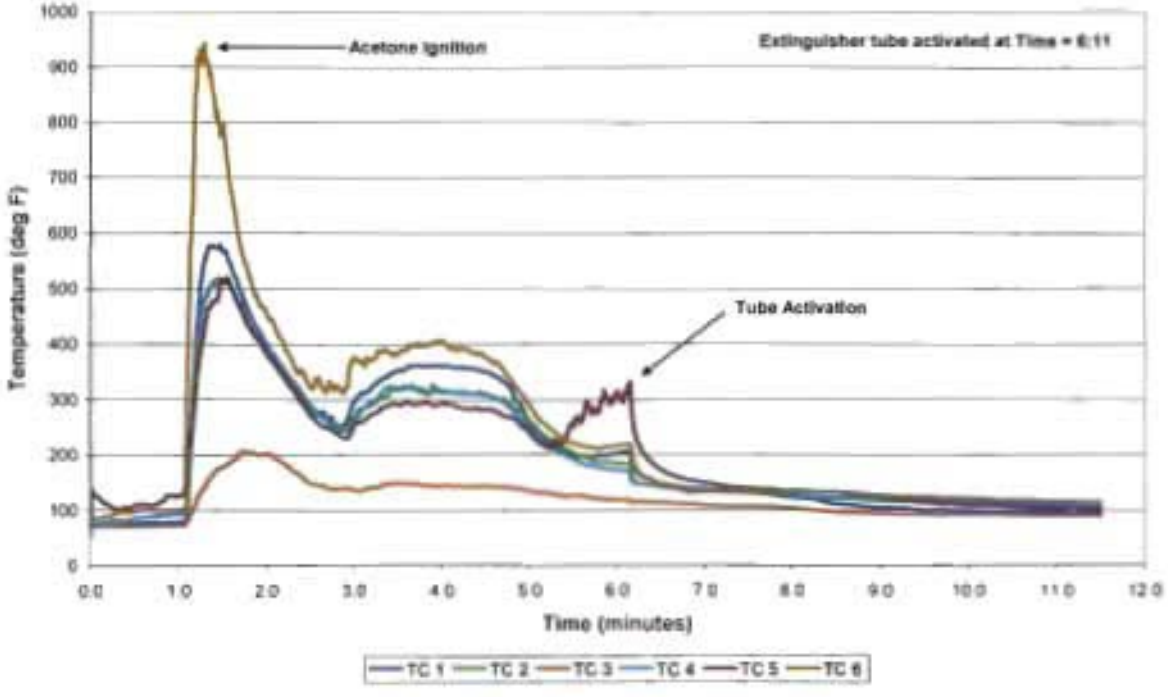
Time (min)	Transducer 1 (in WC)	Transducer 2 (in WC)	
0.000	-0.240	-0.240	
0.166	-0.281	-0.285	
0.332	-0.247	-0.260	
0.498	-0.256	-0.256	
0.665	-0.239	-0.252	
0.832	-0.235	-0.260	
0.983	-0.123	-0.115	
0.985	-0.123	-0.115	
0.987	-0.110	-0.065	
0.988	-0.110	-0.065	
0.990	0.076	0.134	
0.992	0.076	0.134	
0.993	0.222	0.711	
0.995	0.222	0.711	Acetone activation
0.997	1.040	1.097	Positive pressure spike
0.998	1.040	1.097	
1.000	1.264	1.359	
1.002	1.264	1.359	
1.003	1.500	1.659	
1.005	1.500	1.659	
1.007	1.828	1.783	
1.008	1.828	1.783	
1.010	1.849	1.918	
1.012	1.849	1.918	
1.013	1.912	2.089	
1.015	1.912	2.089	
1.017	2.248	2.248	
1.018	2.248	2.248	
1.020	2.339	2.442	
1.022	2.339	2.442	
1.023	2.468	2.621	Max positive pressure spike
1.025	2.468	2.621	
1.027	2.584	2.505	
1.028	2.584	2.505	
1.030	2.327	2.312	
1.032	2.327	2.312	
1.033	2.169	2.066	

1.035	2.168	2.086
1.037	2.033	1.880
1.038	2.033	1.880
1.040	1.770	1.909
1.042	1.770	1.909
1.043	2.078	2.156
1.045	2.078	2.156
1.047	2.206	2.186
1.048	2.206	2.186
1.050	2.136	2.185
1.052	2.136	2.185
1.053	2.231	2.322
1.055	2.231	2.322
1.057	2.314	2.480
1.058	2.314	2.480
1.060	2.588	2.617
1.062	2.588	2.617
1.063	2.646	2.592
1.065	2.646	2.592
1.067	2.534	2.484
1.068	2.534	2.484
1.070	2.401	2.315
1.072	2.401	2.315
1.073	1.912	1.591
1.075	1.912	1.591
1.077	1.235	1.056
1.078	1.235	1.056
1.080	0.955	0.807
1.082	0.955	0.807
1.083	0.673	0.649
1.085	0.673	0.649
1.087	0.544	0.437
1.088	0.544	0.437
1.090	0.362	0.275
1.092	0.362	0.275
1.093	0.101	0.084
1.095	0.101	0.084
1.097	0.101	0.147
1.098	0.101	0.147
1.100	0.151	0.167
1.102	0.151	0.167
1.103	0.069	0.076
1.105	0.069	0.076
1.107	0.097	0.097
1.108	0.097	0.097
1.110	0.078	0.126
1.112	0.078	0.129
1.113	0.105	0.105
1.115	0.105	0.105
1.117	0.093	0.059
1.118	0.093	0.059
1.120	-0.007	-0.019

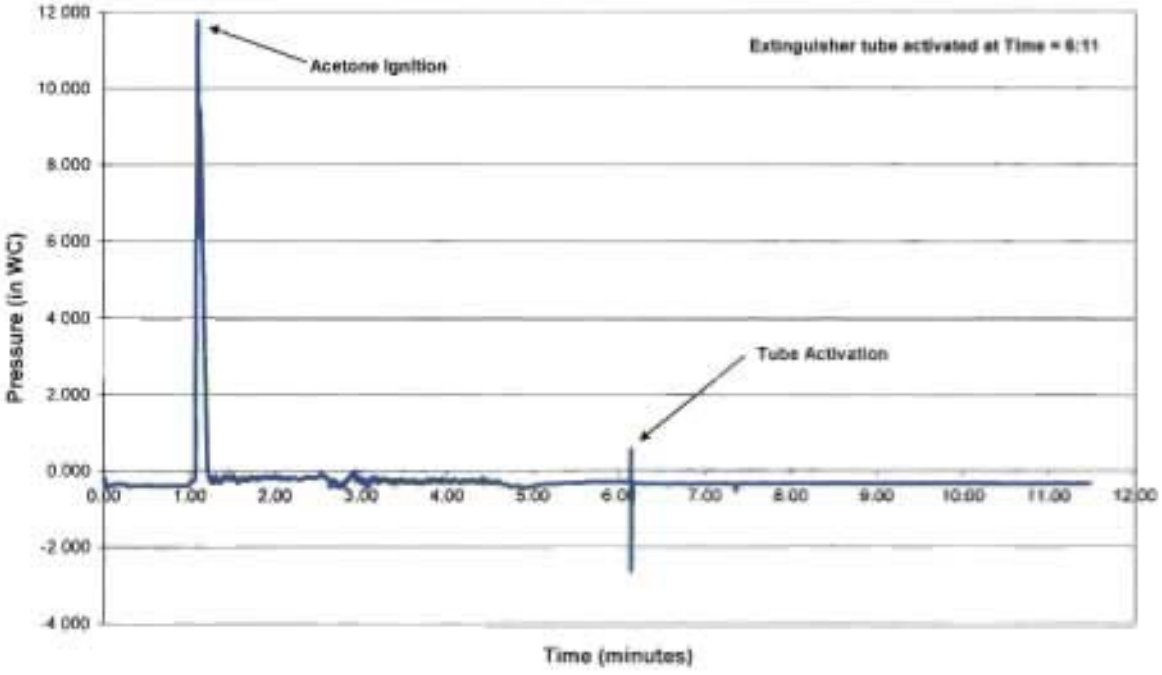
1 122	-0 007	-0 019	
1 125	-0 048	-0 053	
1 125	-0 048	-0 053	
1 127	-0 027	-0 018	
1 128	-0 027	-0 019	
1 130	-0 023	-0 026	
1 132	-0 023	-0 026	
1 133	0 010	-0 030	
1 135	0 010	-0 029	
1 137	0 002	-0 035	
1 138	0 002	-0 035	
1 140	0 043	-0 060	
1 142	0 043	-0 060	
1 143	0 014	-0 049	
1 145	0 014	-0 049	
1 147	-0 119	-0 057	
1 148	-0 119	-0 057	
1 150	-0 036	-0 003	
1 152	-0 036	-0 003	
1 153	-0 023	-0 003	
1 155	-0 023	-0 003	
1 157	0 002	-0 010	
1 158	0 002	-0 010	
1 160	-0 025	-0 011	**End positive pressure event**
1 162	-0 023	-0 011	
1 163	-0 044	-0 044	
1 165	-0 044	-0 044	
1 165	-0 044	-0 044	
1 332	-0 081	-0 073	
1 498	-0 164	-0 219	
1 665	-0 223	-0 227	
1 832	-0 247	-0 235	
1 998	-0 218	-0 215	
2 165	-0 135	-0 094	
2 332	-0 148	-0 140	
2 498	-0 127	-0 152	
2 665	-0 164	0 144	
2 832	-0 135	-0 148	
2 998	-0 135	-0 144	
3 165	-0 164	0 185	
3 332	-0 235	0 273	
3 498	-0 256	-0 269	
3 665	-0 247	-0 248	
3 832	-0 206	-0 235	
3 998	-0 177	-0 210	
4 165	-0 177	-0 240	
4 332	-0 152	-0 206	
4 498	-0 100	-0 223	
4 665	-0 177	0 206	
4 832	-0 156	-0 223	
4 998	-0 173	-0 219	
5 165	-0 181	0 235	

5.332	-0.189	-0.219
5.498	-0.181	-0.227
5.665	-0.185	-0.252
5.832	-0.177	-0.264
5.998	-0.181	-0.248
6.165	-0.193	-0.269
6.332	-0.214	-0.256
6.498	-0.189	-0.256
6.665	-0.214	-0.273
6.832	-0.202	-0.269
6.998	-0.189	-0.277
7.165	-0.198	-0.277
7.332	-0.210	-0.293
7.498	-0.193	-0.289
7.665	-0.177	-0.293
7.832	-0.198	-0.293
7.998	-0.189	-0.285
8.165	-0.181	-0.306
8.332	-0.214	-0.302
8.498	-0.185	-0.302
8.665	-0.125	-0.244
8.832	-0.123	-0.256

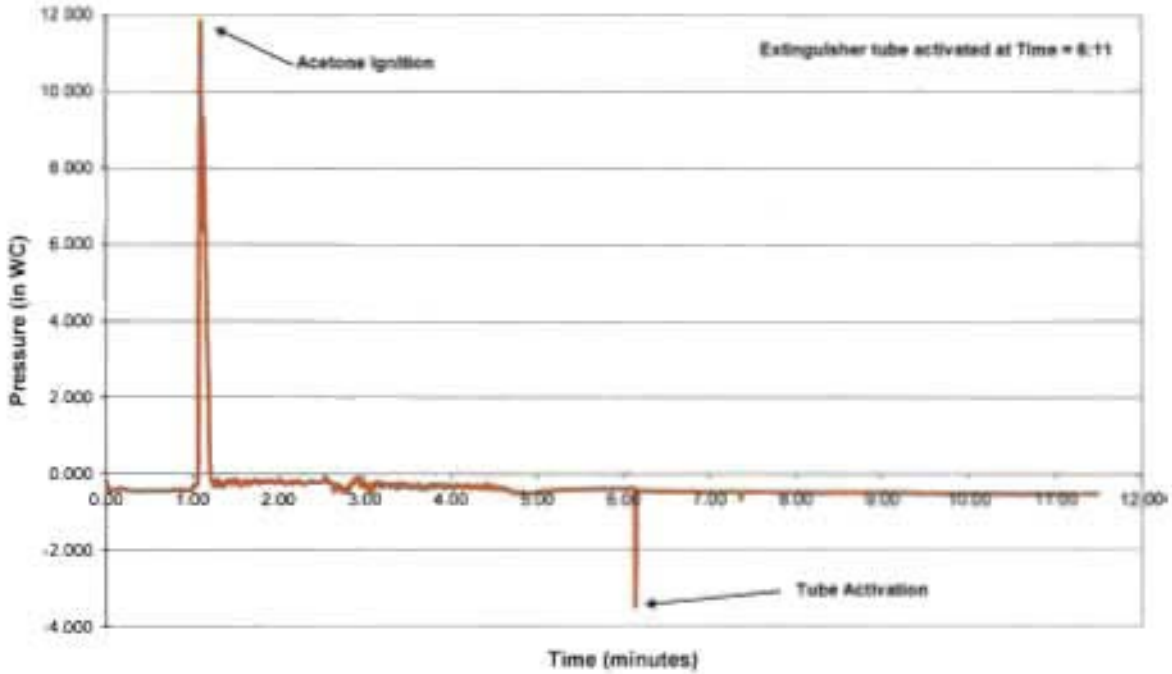
Interior Glove Box Temperatures
G100238106SAT-001C QuickFire Test 3



Internal Glove Box Pressures for Transducer 1
G100238106SAT-001C QuickFire Test 3



Internal Glove Box Pressure for Transducer 2
G100238106SAT-001C QuickFire Test 3



Intertek

Date: 19-Oct-10
Eng. Initials:

Client: QuickFire USA LLC
Project No: G100238106SAT-001C
Test No: 3
Product: QuickFire Fire Foe FT250 Tube Fire Extinguisher
Engineer: Victor M. Burgos, Intertek - San Antonio
Test Method(s): Los Alamos National Laboratory (LANL) Test Protocol, Section 8

INTERNAL GLOVE BOX TEMPERATURES

Time (sec)	Time (min)	TC 1 (deg F)	TC 2 (deg F)	TC 3 (deg F)	TC 4 (deg F)	TC 5 (deg F)	TC 6 (deg F)	
0	0.000	73	74	71	71	92	83	
10	0.167	75	78	72	78	111	89	
20	0.333	78	82	72	80	103	97	
30	0.500	79	85	72	86	109	98	
40	0.667	79	89	72	88	109	101	
50	0.833	77	91	73	91	118	101	
60	1.000	79	93	73	92	126	101	
64.9	1.080	81	95	74	94	139	102	Acetone ignition
64.9	1.082	81	95	74	94	139	102	
65	1.083	81	95	74	94	146	103	Pos press spike
65.1	1.085	81	95	74	94	146	103	
65.2	1.087	81	95	74	94	146	103	
65.3	1.088	81	95	74	94	146	103	
65.4	1.090	81	95	74	94	146	103	
65.5	1.092	82	97	77	96	217	106	
65.6	1.093	82	97	77	96	217	106	
65.7	1.095	82	97	77	96	217	106	
65.8	1.097	82	97	77	96	217	106	
65.9	1.098	82	97	77	96	217	106	Max pos press spike
66	1.100	86	125	80	96	235	311	
66.1	1.102	86	125	80	98	235	311	
66.2	1.103	86	125	80	98	235	311	
66.3	1.105	86	125	80	98	235	311	
66.4	1.107	86	125	80	98	235	311	
66.5	1.108	90	144	82	101	224	366	
66.6	1.110	90	144	82	101	224	366	
66.7	1.112	90	144	82	101	224	366	
66.8	1.113	90	144	82	101	224	366	
66.9	1.115	90	144	82	101	224	366	
67	1.117	122	146	85	117	218	395	
67.1	1.118	122	146	85	117	218	395	
67.2	1.120	122	146	85	117	218	395	
67.3	1.122	122	146	85	117	218	395	
67.4	1.123	122	146	85	113	218	395	
67.5	1.125	160	146	87	141	217	463	
67.6	1.127	160	146	87	141	217	463	
67.7	1.128	160	146	87	141	217	463	
67.8	1.130	160	146	87	141	217	463	
67.9	1.132	160	146	87	141	217	463	
68	1.133	182	170	90	162	220	548	
68.1	1.135	182	170	90	162	220	548	
68.2	1.137	182	170	90	162	220	548	
68.3	1.138	182	170	90	162	220	548	
68.4	1.140	182	170	90	162	220	548	
68.5	1.142	203	187	93	163	229	581	
68.6	1.143	203	187	93	163	229	581	
68.7	1.145	203	187	93	163	229	581	
68.8	1.147	203	187	93	163	229	581	
68.9	1.148	203	187	93	163	229	581	

69	1.150	217	210	97	393	229	568	
69.1	1.152	217	210	97	393	229	568	
69.2	1.153	217	210	97	393	229	568	
69.3	1.155	217	210	97	393	229	568	
69.4	1.157	217	210	97	393	229	568	
69.5	1.158	244	230	100	219	250	635	
69.6	1.160	244	230	100	219	250	635	
69.7	1.162	244	230	100	219	250	635	
69.8	1.163	244	230	100	219	250	635	
69.9	1.165	244	230	100	219	250	635	
70	1.167	275	252	105	256	264	659	
80	1.333	565	487	153	491	481	911	End gas pressure
90	1.500	570	518	177	511	515	757	
100	1.667	516	465	194	487	479	611	
110	1.833	451	443	205	441	424	512	
120	2.000	403	396	203	401	385	459	
130	2.167	364	362	188	362	348	419	
140	2.333	329	327	169	322	313	355	
150	2.500	291	291	150	285	272	322	
160	2.667	276	267	143	264	251	315	
170	2.833	253	251	139	246	236	329	
180	3.000	295	269	136	269	254	278	
190	3.167	315	288	140	291	270	371	
200	3.333	338	309	146	316	297	368	
210	3.500	352	318	149	322	292	391	
220	3.667	360	320	148	329	291	401	
230	3.833	361	311	145	315	286	397	
240	4.000	369	317	145	314	293	404	
250	4.167	357	312	144	313	288	391	
260	4.333	357	311	144	311	283	385	
270	4.500	359	314	144	308	283	378	
280	4.667	338	299	142	299	274	382	
290	4.833	302	287	139	278	264	327	
300	5.000	256	262	135	249	241	280	
310	5.167	233	235	132	225	215	257	
320	5.333	212	218	129	209	221	235	
330	5.500	209	204	127	193	253	221	
340	5.667	196	194	126	182	291	214	
350	5.833	189	187	120	176	297	213	
360	6.000	205	185	119	175	318	217	
369.2	6.153	207	183	118	171	334	220	Tube Activation
369.3	6.155	207	183	118	171	334	220	
369.4	6.157	207	183	118	171	334	220	
369.5	6.158	207	181	116	165	301	218	
369.6	6.160	207	181	116	165	301	218	
369.7	6.162	207	181	116	165	301	218	
369.8	6.163	207	181	116	165	301	218	
369.9	6.165	207	181	116	165	301	218	
370	6.167	188	167	114	157	283	210	
380	6.333	156	145	115	145	197	169	
390	6.500	148	143	114	144	174	165	
400	6.667	144	140	113	141	162	160	
410	6.833	141	137	111	140	154	122	
420	7.000	129	125	109	139	150	134	
430	7.167	128	124	106	137	146	138	
440	7.333	134	123	107	135	142	137	
450	7.500	132	122	106	133	140	136	
460	7.667	130	120	107	131	138	134	
470	7.833	128	120	106	131	137	134	
480	8.000	124	117	104	129	136	134	
490	8.167	122	120	101	126	135	133	
500	8.333	118	121	98	124	132	133	
510	8.500	111	121	97	123	132	133	
520	8.667	110	120	96	123	130	132	

530	9.833	108	115	86	123	126	129
540	9.666	104	112	94	122	125	127
550	9.167	104	115	90	122	126	125
560	9.333	103	116	93	120	117	125
570	9.500	103	115	92	119	114	125
580	9.667	101	113	92	118	112	123
590	9.833	99	114	92	116	111	122
600	10.000	98	113	93	115	109	121
610	10.167	96	113	92	114	108	121
620	10.333	97	112	92	113	108	118
630	10.500	97	111	91	112	107	118
640	10.667	97	111	91	111	105	116
650	10.833	95	110	90	110	105	117
660	11.000	95	109	90	109	103	116
670	11.167	94	108	90	108	103	116
680	11.333	94	107	90	107	102	115

Intertek

Date: 19-Oct-10
Eng. Initials:

Client: QuickFire USA LLC
Project No: G100238106SAT-001C
Test No: 3
Product: QuickFire Fire Foe FT250 Tube Fire Extinguisher
Engineer: Victor M. Burgos, Intertek - San Antonio
Test Method(s): Los Alamos National Laboratory (LANL) Test Protocol, Section 8

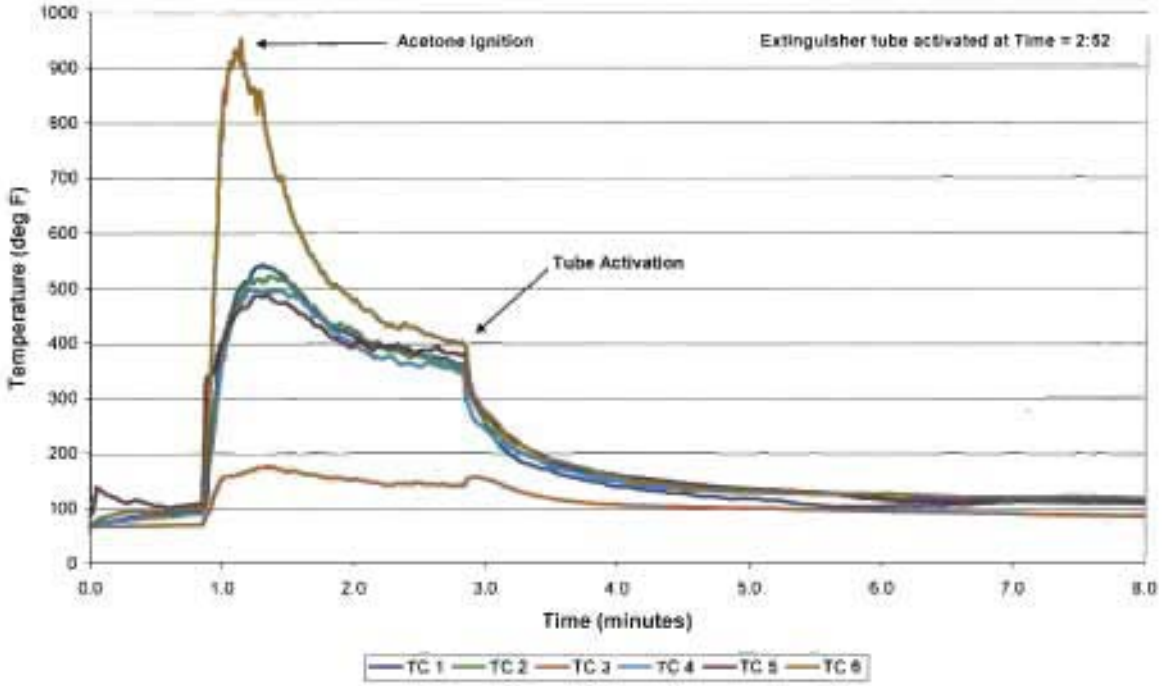
INTERNAL GLOVE BOX PRESSURES

Time (min)	Transducer 1 (in WC)	Transducer 2 (in WC)	
0.000	-0.253	-0.250	
0.167	-0.328	-0.383	
0.333	-0.402	-0.437	
0.500	-0.394	-0.416	
0.667	-0.402	-0.450	
0.833	-0.390	-0.404	
1.000	-0.390	-0.396	
1.080	-0.070	0.256	Acetone activation
1.082	-0.070	0.256	
1.083	1.682	3.167	Positive pressure spike
1.085	1.682	3.167	
1.087	3.895	5.283	
1.088	3.895	5.283	
1.090	6.801	8.132	
1.092	6.801	8.132	
1.093	9.433	10.495	
1.095	9.433	10.495	
1.097	11.406	11.773	
1.098	11.406	11.773	Max positive pressure spike
1.100	11.779	11.832	
1.102	11.779	11.832	
1.103	11.044	10.068	
1.105	11.044	10.068	
1.107	9.546	9.374	
1.108	9.546	9.374	
1.110	9.417	9.095	
1.112	9.417	9.095	
1.113	8.574	7.787	
1.115	8.574	7.787	
1.117	7.000	6.397	
1.118	7.000	6.397	
1.120	6.129	6.372	
1.122	6.129	6.372	
1.123	6.818	7.414	
1.125	6.818	7.414	
1.127	8.109	8.556	
1.128	8.109	8.556	

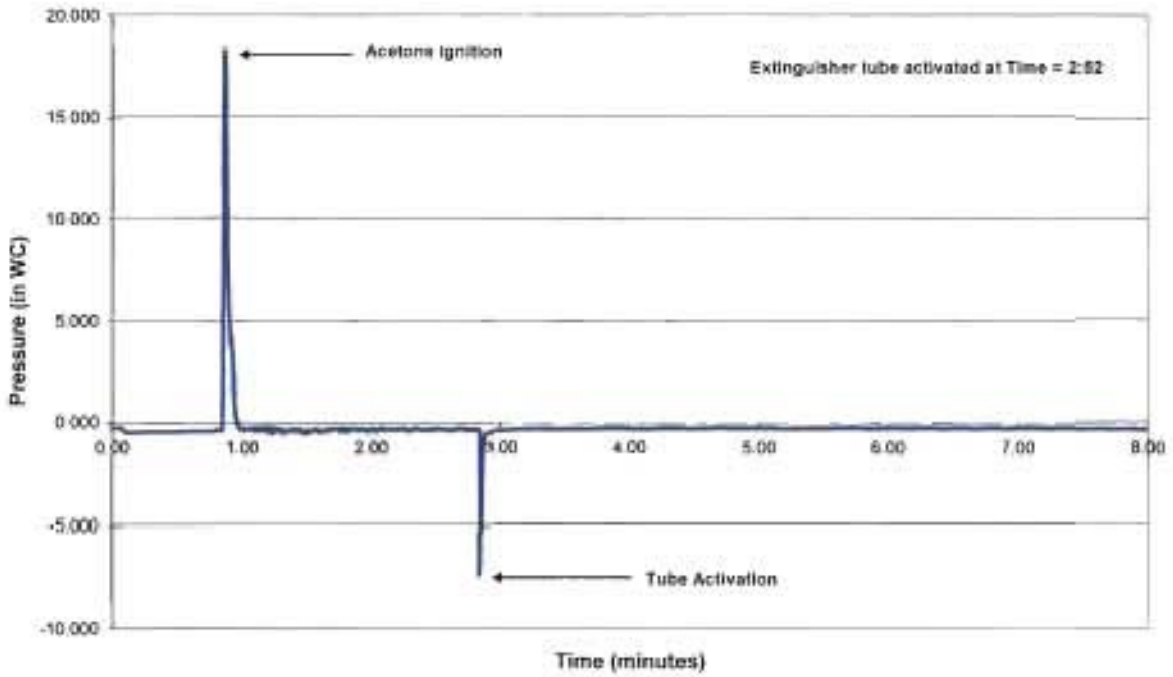
1.130	8.694	9.120	
1.132	8.694	9.120	
1.133	9.417	9.286	
1.135	9.417	9.286	
1.137	8.865	8.543	
1.138	8.865	8.543	
1.140	8.632	8.331	
1.142	8.632	8.331	
1.143	7.951	7.850	
1.145	7.951	7.850	
1.147	7.706	7.763	
1.148	7.706	7.763	
1.150	7.490	7.219	
1.152	7.490	7.219	
1.153	6.976	6.958	
1.155	6.976	6.858	
1.157	6.780	6.538	
1.158	6.785	6.538	
1.160	6.237	5.952	
1.162	6.237	5.952	
1.163	5.784	5.566	
1.165	5.784	5.566	
1.167	5.277	5.093	
1.333	-0.244	-0.263	**End of positive pressure event**
1.500	-0.203	-0.196	
1.667	-0.265	-0.225	
1.833	-0.170	-0.176	
2.000	-0.141	-0.151	
2.167	-0.200	-0.204	
2.333	-0.220	-0.221	
2.500	-0.174	-0.213	
2.667	-0.382	-0.362	
2.833	-0.274	-0.300	
3.000	-0.224	-0.267	
3.167	-0.236	-0.225	
3.333	-0.249	-0.284	
3.500	-0.307	-0.325	
3.667	-0.278	-0.317	
3.833	-0.261	-0.309	
4.000	-0.288	-0.329	
4.167	-0.261	-0.304	
4.333	-0.274	-0.346	
4.500	-0.332	-0.367	
4.667	-0.348	-0.400	
4.833	-0.402	-0.475	
5.000	-0.415	-0.468	
5.167	-0.361	-0.425	
5.333	-0.328	-0.392	
5.500	-0.311	-0.409	
5.667	-0.290	-0.383	
5.833	-0.307	-0.375	
6.000	-0.296	-0.367	

6.153	0.563	-3.464	**Tube activation**
6.155	0.563	-3.464	
6.157	-2.636	-2.775	
6.158	-2.636	-2.775	
6.160	-2.001	-1.695	
6.162	-2.001	-1.695	
6.163	-1.370	-1.139	
6.165	-1.370	-1.139	
6.167	-0.884	-0.815	
6.333	-0.352	-0.446	
6.500	-0.352	-0.446	
6.667	-0.344	-0.458	
6.833	-0.361	-0.470	
7.000	-0.340	-0.450	
7.167	-0.336	-0.479	
7.333	-0.336	-0.466	
7.500	-0.344	-0.479	
7.667	-0.336	-0.462	
7.833	-0.344	-0.466	
8.000	-0.328	-0.483	
8.167	-0.340	-0.483	
8.333	-0.328	-0.479	
8.500	-0.315	-0.458	
8.667	-0.319	-0.470	
8.833	-0.319	-0.487	
9.000	-0.336	-0.483	
9.167	-0.319	-0.475	
9.333	-0.311	-0.475	
9.500	-0.332	-0.491	
9.663	-0.336	-0.512	
9.747	-0.311	-0.483	
9.830	-0.336	-0.495	
9.913	-0.323	-0.495	
9.997	-0.323	-0.491	
10.080	-0.319	-0.495	
10.163	-0.303	-0.512	
10.247	-0.311	-0.516	
10.330	-0.328	-0.495	
10.413	-0.328	-0.516	
10.497	-0.332	-0.524	
10.580	-0.336	-0.508	
10.663	-0.319	-0.520	
10.747	-0.340	-0.516	
10.830	-0.323	-0.512	
10.913	-0.323	-0.529	
10.997	-0.340	-0.520	
11.080	-0.328	-0.516	
11.163	-0.319	-0.508	
11.247	-0.348	-0.520	
11.330	-0.336	-0.512	
11.413	-0.332	-0.512	
11.497	-0.336	-0.512	

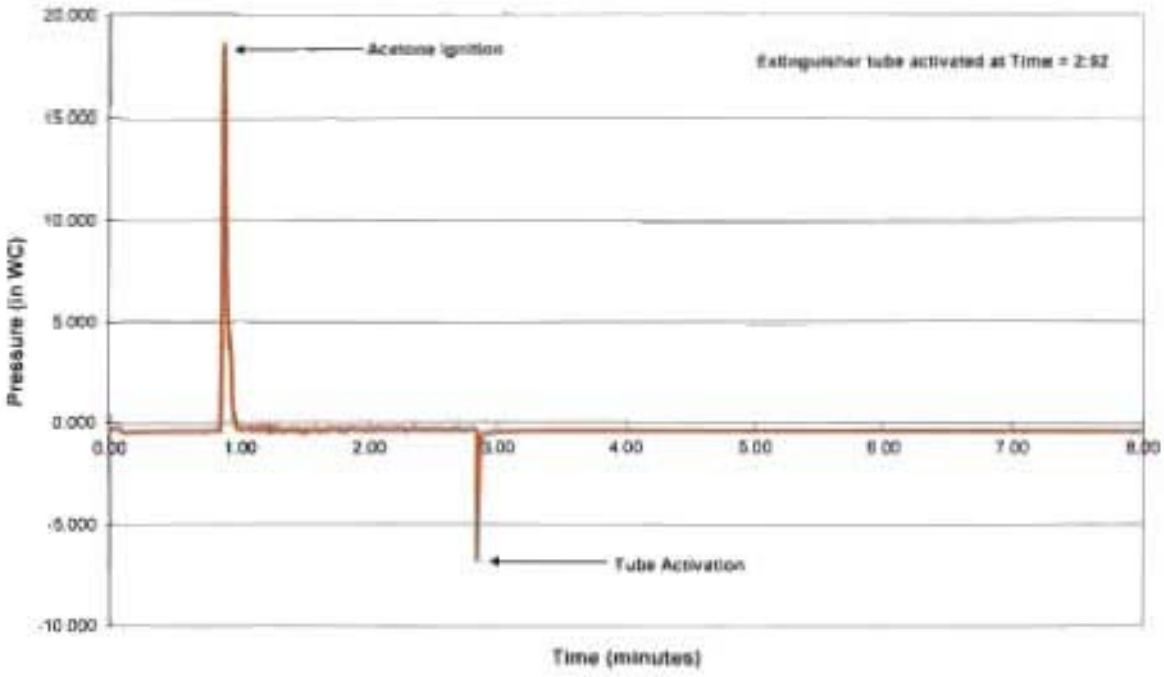
Interior Glove Box Temperatures
G100238106SAT-001D QuickFire Test 4



Internal Glove Box Pressures for Transducer 1
G100238106SAT-001D QuickFire Test 4



Internal Glove Box Pressure for Transducer 2
G100238106SAT-001D QuickFire Test 4



Intertek

Date: 19-Oct-10
Eng. Initials:

Client: QuickFire USA LLC
Project No: G100238106SAT-001D
Test No: 4
Product: QuickFire Fire Foe FT250 Tube Fire Extinguisher
Engineer: Victor M. Burgos, Intertek - San Antonio
Test Method(s): Los Alamos National Laboratory (LANL) Test Protocol, Section 8

INTERNAL GLOVE/ BOX TEMPERATURES

Time (sec)	Time (min)	TC 1 (deg F)	TC 2 (deg F)	TC 3 (deg F)	TC 4 (deg F)	TC 5 (deg F)	TC 6 (deg F)	
0	0.000	72	72	69	70	68	74	
10	0.167	77	75	69	77	124	90	
20	0.333	85	81	69	82	118	96	
30	0.500	89	84	70	85	108	97	
40	0.667	93	86	71	87	106	99	
50	0.833	96	84	72	91	111	104	Acetone Ignition
51.1	0.852	96	84	72	99	110	104	
51.2	0.853	96	84	72	91	110	104	Foe press spike
51.3	0.855	96	84	72	91	110	104	
51.4	0.857	96	84	72	91	110	104	
51.5	0.858	96	84	75	93	155	106	
51.6	0.860	96	85	75	93	155	106	
51.7	0.863	99	86	75	95	155	106	
51.8	0.863	96	85	75	93	155	106	
51.9	0.865	96	85	75	93	155	106	
52	0.867	106	100	79	96	225	111	
52.1	0.868	106	100	79	96	225	111	
52.2	0.870	106	100	79	96	225	111	
52.3	0.872	106	100	79	96	225	111	
52.4	0.873	106	100	79	96	225	111	
52.5	0.875	101	144	84	107	328	162	Mist press spike
52.6	0.877	101	144	84	107	328	162	
52.7	0.878	102	144	84	107	328	162	
52.8	0.880	102	144	84	107	328	162	
52.9	0.882	102	144	84	107	328	162	
53	0.883	110	167	89	132	340	210	
53.1	0.885	110	167	89	132	340	210	
53.2	0.887	110	167	89	132	340	210	
53.3	0.888	110	167	89	132	340	210	
53.4	0.890	110	167	89	132	340	210	
53.5	0.892	129	189	92	153	343	231	
53.6	0.893	129	189	92	153	343	231	
53.7	0.895	129	189	92	153	343	231	
53.8	0.897	129	189	92	153	343	231	
53.9	0.898	129	189	92	153	343	231	
54	0.900	162	185	95	166	343	254	
54.1	0.902	162	185	95	166	343	254	
54.2	0.903	162	185	95	166	343	254	
54.3	0.905	162	185	95	166	343	254	
54.4	0.907	162	185	95	166	343	254	
54.5	0.908	161	189	97	170	343	317	
54.6	0.910	161	189	97	170	343	317	
54.7	0.912	161	189	97	170	343	317	
54.8	0.913	161	189	97	170	343	317	
54.9	0.915	161	189	97	170	343	317	
55	0.917	202	221	103	194	344	371	
55.1	0.918	202	221	103	194	344	371	
55.2	0.920	202	221	103	194	344	371	
55.3	0.922	202	221	103	194	344	371	
55.4	0.923	202	221	103	194	344	371	

55.5	0.835	223	240	112	205	340	424	
55.6	0.837	223	240	112	205	340	424	
55.7	0.838	223	240	112	205	340	424	
55.8	0.839	223	240	112	205	340	424	
55.9	0.841	223	240	112	205	340	424	
56	0.843	249	269	125	229	348	433	
56.1	0.845	249	269	125	229	348	433	
56.2	0.847	249	269	125	229	348	433	
56.3	0.849	249	269	125	229	348	433	
56.4	0.850	249	269	125	229	348	433	
56.5	0.852	273	279	125	230	388	526	
56.6	0.853	273	279	125	230	355	536	
56.7	0.855	273	279	125	230	355	536	
56.8	0.857	273	279	125	230	355	536	
56.9	0.858	273	279	125	230	355	536	
57	0.860	299	290	130	259	364	506	
57.1	0.862	299	290	130	259	364	506	
57.2	0.863	299	290	130	259	364	506	
57.3	0.865	299	290	130	259	364	506	
57.4	0.867	299	290	130	259	364	506	
57.5	0.868	315	309	135	281	374	612	
57.6	0.870	315	309	135	281	374	612	
57.7	0.872	315	309	135	281	374	612	
57.8	0.873	315	309	135	281	374	612	
57.9	0.875	315	309	135	281	374	612	
58	0.877	339	322	140	296	383	687	
58.1	0.878	339	322	140	296	383	687	
58.2	0.880	339	322	140	296	383	687	
58.3	0.882	339	322	140	296	383	687	End pos pressure
58.4	0.883	339	322	140	296	383	687	
58.5	0.885	383	331	144	312	391	782	
60	1.000	397	360	155	395	408	840	
70	1.167	512	496	167	465	458	987	
80	1.333	528	518	174	496	488	778	
90	1.500	543	513	168	468	472	655	
100	1.667	465	470	194	484	444	565	
110	1.833	455	430	156	425	410	504	
120	2.000	414	424	155	396	401	491	
130	2.167	409	402	142	378	398	449	
140	2.333	569	388	147	397	398	429	
150	2.500	381	377	148	356	389	424	
160	2.667	374	365	146	359	388	405	
170	2.833	363	355	144	345	382	400	
170.7	2.845	363	356	143	343	381	394	
170.8	2.847	363	356	143	343	381	394	Tube Activation
170.9	2.848	363	356	143	343	381	394	
171	2.850	363	348	156	310	358	387	
171.1	2.852	365	344	156	310	358	387	
171.2	2.853	363	344	156	310	358	387	
171.3	2.855	363	344	156	310	358	387	
171.4	2.857	363	344	156	310	358	387	
171.5	2.858	342	336	153	298	339	369	
171.6	2.860	342	336	153	298	339	369	
171.7	2.862	342	336	153	298	339	369	
171.8	2.863	342	336	153	298	339	369	
171.9	2.865	342	336	153	298	339	369	
172	2.867	326	329	156	298	329	359	
172.1	2.868	326	329	156	298	329	359	
172.2	2.870	329	329	156	298	328	359	
172.3	2.872	329	329	156	298	328	359	
172.4	2.873	326	329	156	298	329	359	
172.5	2.875	319	316	157	289	322	337	
172.6	2.877	319	316	157	289	322	337	
172.7	2.878	319	316	157	289	322	337	
172.8	2.880	319	316	157	289	322	337	

172.9	2.882	319	316	157	269	322	317
173	2.883	314	310	156	262	316	327
173.1	2.885	314	310	156	262	316	327
173.2	2.887	314	310	156	262	316	327
173.3	2.889	314	310	156	262	316	327
173.4	2.890	314	310	156	262	316	327
173.5	2.892	309	305	159	276	311	319
173.6	2.893	309	305	159	276	311	319
173.7	2.895	309	305	159	276	311	319
173.8	2.897	309	305	159	276	311	319
173.9	2.898	309	305	159	276	311	319
174	2.900	303	302	156	271	307	313
174.1	2.902	305	302	158	271	307	313
174.2	2.903	305	302	158	271	307	313
174.3	2.905	305	302	158	271	307	313
174.4	2.907	305	302	158	271	307	313
174.5	2.908	299	298	158	267	303	307
174.6	2.910	299	298	158	267	303	307
174.7	2.912	299	298	158	267	303	307
174.8	2.913	299	298	158	267	303	307
174.9	2.915	299	298	158	267	303	307
175	2.917	295	294	159	264	299	303
175.1	2.918	295	294	159	264	299	303
175.2	2.920	295	294	159	264	299	303
175.3	2.922	295	294	159	264	299	303
175.4	2.923	295	294	159	264	299	303
175.5	2.925	292	289	159	261	295	300
175.6	2.927	292	289	158	261	295	300
175.7	2.928	292	289	158	261	295	300
175.8	2.930	292	289	158	261	295	300
175.9	2.932	292	289	159	261	295	300
176	2.933	288	288	159	259	291	297
176.1	2.935	288	288	159	259	291	297
176.2	2.937	288	288	159	259	291	297
176.3	2.938	288	288	159	259	291	297
176.4	2.940	288	288	159	259	291	297
176.5	2.942	283	283	159	257	288	295
176.6	2.943	283	283	159	257	288	295
176.7	2.945	283	283	159	257	288	295
176.8	2.947	283	283	159	257	288	295
176.9	2.948	283	283	159	257	288	295
177	2.950	280	280	158	255	286	291
177.1	2.952	280	280	158	255	286	291
177.2	2.953	280	280	158	255	286	291
177.3	2.955	280	280	158	255	286	291
180	3.000	259	260	155	246	272	276
190	3.167	204	221	148	215	225	229
200	3.333	182	196	139	196	200	200
210	3.500	171	184	126	176	189	190
220	3.667	158	173	114	159	176	179
230	3.833	149	163	110	156	168	169
240	4.000	140	152	108	150	161	159
250	4.167	137	147	106	144	152	149
260	4.333	132	142	105	139	152	146
270	4.500	129	138	105	136	147	142
280	4.667	123	135	104	135	143	137
290	4.833	119	134	103	133	140	134
300	5.000	119	131	102	132	137	132
310	5.167	116	130	102	130	133	130
320	5.333	112	130	100	129	133	130
330	5.500	105	129	100	129	131	127
340	5.667	104	127	98	129	127	127
350	5.833	105	124	97	128	121	127
360	6.000	105	121	96	126	119	129
370	6.167	109	118	95	127	118	126

380	6.333	107	117	95	125	115	124
390	6.500	108	116	95	123	114	122
400	6.667	109	116	94	121	116	122
410	6.833	111	114	93	118	117	121
420	7.000	113	113	92	116	118	123
430	7.167	114	113	91	114	118	123
440	7.333	114	112	91	112	118	123
450	7.500	114	111	90	112	116	124
460	7.667	114	112	88	111	116	123
470	7.833	115	111	88	111	115	122

Intertek

Date: 19-Oct-10
Eng. Initials:

Client: QuickFire USA LLC
Project No: G100238106SAT-001D
Test No: 4
Product: QuickFire Fire Foe FT250 Tube Fire Extinguisher
Engineer: Victor M. Burgos, Intertek - San Antonio
Test Method(s): Los Alamos National Laboratory (LANL) Test Protocol, Section 8

INTERNAL GLOVE BOX PRESSURES

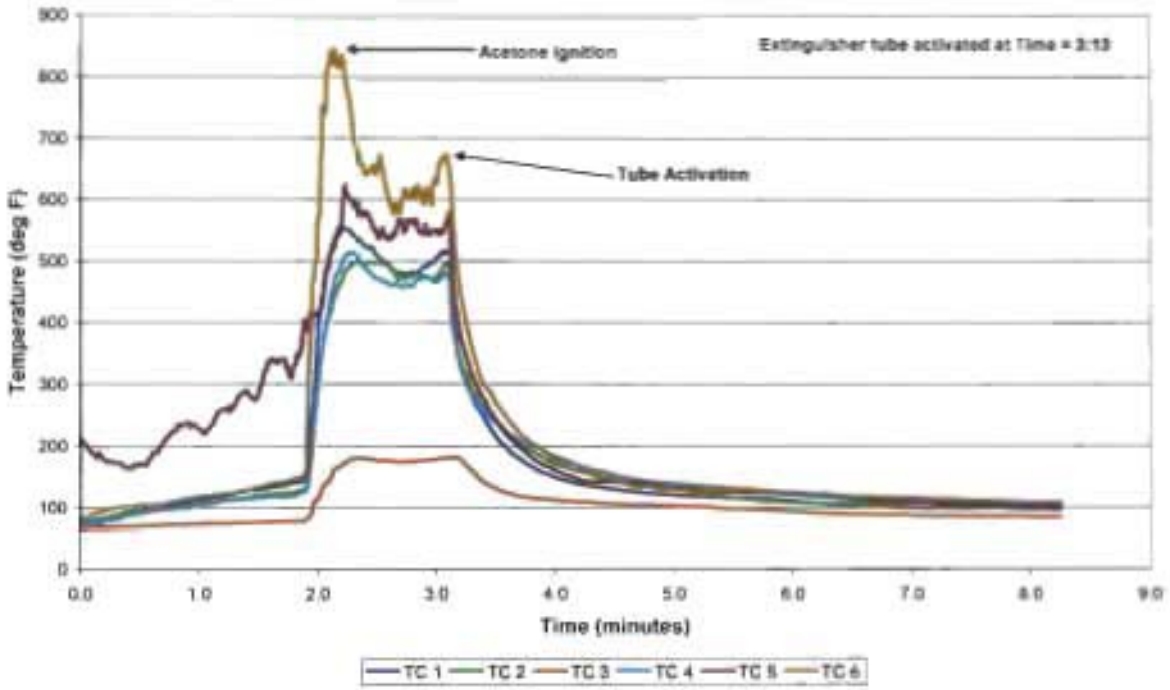
Time (mins)	Transducer 1 (in WC)	Transducer 2 (in WC)	
0.000	-0.250	-0.250	
0.167	-0.454	-0.470	
0.333	-0.408	-0.416	
0.500	-0.421	-0.400	
0.667	-0.396	-0.404	
0.833	-0.350	-0.379	Acetone activation
0.852	-0.288	-0.134	
0.853	0.111	0.837	Positive pressure spike
0.855	0.111	0.837	
0.857	2.332	3.507	
0.858	2.332	3.507	
0.860	5.467	8.481	
0.862	5.467	8.481	
0.863	12.417	14.418	
0.865	12.417	14.418	
0.867	15.356	16.967	
0.868	15.356	16.967	
0.870	18.288	18.284	
0.872	18.288	18.284	
0.873	18.246	18.528	
0.875	18.246	18.528	Max positive pressure spike
0.877	18.279	17.956	
0.878	18.279	17.956	
0.880	17.320	15.950	
0.882	17.320	15.950	
0.883	14.784	13.737	
0.885	14.784	13.737	
0.887	12.591	11.616	
0.888	12.591	11.616	
0.890	10.603	9.585	
0.892	10.603	9.585	
0.893	8.464	7.584	
0.895	8.464	7.584	
0.897	6.887	6.405	
0.898	6.887	6.405	
0.900	5.919	5.654	
0.902	5.919	5.654	

0.903	5.356	5.201	
0.905	5.356	5.201	
0.907	5.089	4.973	
0.908	5.089	4.973	
0.910	4.806	4.574	
0.912	4.806	4.574	
0.913	3.997	3.735	
0.915	3.997	3.735	
0.917	3.769	3.727	
0.918	3.769	3.727	
0.920	3.968	4.230	
0.922	3.968	4.230	
0.923	4.254	3.868	
0.925	4.254	3.868	
0.927	3.590	3.623	
0.928	3.590	3.623	
0.930	3.574	3.374	
0.932	3.574	3.374	
0.933	3.158	2.859	
0.935	3.158	2.859	
0.937	2.386	1.932	
0.938	2.386	1.932	
0.940	1.514	1.323	
0.942	1.514	1.323	
0.943	1.095	0.916	
0.945	1.095	0.916	
0.947	0.764	0.759	
0.948	0.764	0.759	
0.950	0.728	0.597	
0.952	0.728	0.597	
0.953	0.418	0.235	
0.955	0.418	0.235	
0.957	0.231	0.248	
0.958	0.231	0.248	
0.960	0.266	0.211	
0.962	0.266	0.211	
0.963	0.207	0.173	
0.965	0.207	0.173	
0.967	0.138	0.094	
0.968	0.138	0.094	
0.970	-0.014	0.003	
0.972	-0.014	0.003	**End of positive pressure event**
0.973	-0.043	-0.101	
0.975	-0.043	-0.101	
1.000	-0.266	-0.267	
1.167	-0.284	-0.321	
1.333	-0.466	-0.437	
1.500	-0.466	-0.491	
1.667	-0.313	-0.279	
1.833	-0.284	-0.304	
2.000	-0.292	-0.275	
2.167	-0.321	-0.321	

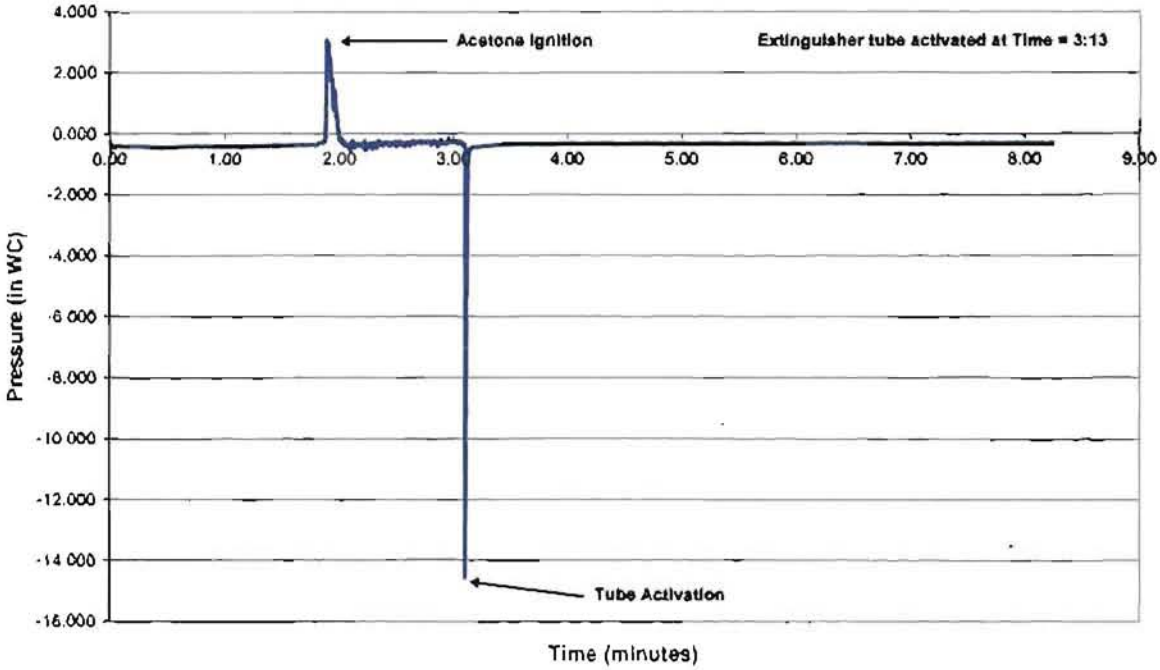
2.333	-0.333	-0.325	
2.500	-0.313	-0.304	
2.667	-0.250	-0.259	
2.833	-0.350	-0.329	
2.845	-0.346	-0.387	
2.847	-4.269	-6.736	Tube activation
2.848	-4.269	-6.736	
2.850	-7.404	-6.383	
2.852	-7.404	-6.383	
2.853	-5.477	-4.805	
2.855	-5.477	-4.805	
2.857	-4.236	-3.713	
2.858	-4.236	-3.713	
2.860	-3.219	-2.783	
2.862	-3.219	-2.783	
2.863	-2.368	-2.019	
2.865	-2.368	-2.019	
2.867	-1.695	-1.488	
2.868	-1.695	-1.488	
2.870	-1.280	-1.172	
2.872	-1.280	-1.172	
2.873	-0.989	-0.915	
2.875	-0.989	-0.915	
2.877	-0.811	-0.773	
2.878	-0.811	-0.773	
2.880	-0.674	-0.666	
2.882	-0.674	-0.666	
2.883	-0.603	-0.616	
2.885	-0.603	-0.616	
2.887	-0.562	-0.570	
2.888	-0.562	-0.570	
2.890	-0.537	-0.562	
2.892	-0.537	-0.562	
2.893	-0.516	-0.537	
2.895	-0.516	-0.537	
2.897	-0.512	-0.533	
2.898	-0.512	-0.533	
2.900	-0.495	-0.516	
2.902	-0.495	-0.516	
2.903	-0.479	-0.504	
2.905	-0.479	-0.504	
2.907	-0.466	-0.495	
2.908	-0.466	-0.495	
2.910	-0.466	-0.495	
2.912	-0.466	-0.495	
2.913	-0.462	-0.499	
2.915	-0.462	-0.499	
2.917	-0.458	-0.479	
2.918	-0.458	-0.479	
2.920	-0.454	-0.483	
2.922	-0.454	-0.483	
2.923	-0.450	-0.475	

2.925	-0.458	-0.475
2.927	-0.458	-0.487
2.928	-0.458	-0.487
2.930	-0.458	-0.483
2.932	-0.450	-0.483
2.933	-0.441	-0.466
2.935	-0.441	-0.466
2.937	-0.454	-0.462
2.938	-0.454	-0.462
2.940	-0.437	-0.462
2.942	-0.437	-0.462
2.943	-0.437	-0.466
2.945	-0.437	-0.466
2.947	-0.429	-0.454
2.948	-0.429	-0.454
2.950	-0.412	-0.454
2.952	-0.412	-0.454
2.953	-0.421	-0.470
2.955	-0.421	-0.470
3.000	-0.400	-0.433
3.167	-0.362	-0.387
3.333	-0.329	-0.369
3.500	-0.342	-0.367
3.667	-0.337	-0.375
3.833	-0.317	-0.383
4.000	-0.342	-0.367
4.167	-0.342	-0.371
4.333	-0.317	-0.371
4.500	-0.346	-0.375
4.667	-0.317	-0.375
4.833	-0.325	-0.375
5.000	-0.337	-0.383
5.167	-0.346	-0.392
5.333	-0.335	-0.375
5.500	-0.325	-0.404
5.667	-0.325	-0.371
5.833	-0.346	-0.383
6.000	-0.325	-0.396
6.167	-0.333	-0.387
6.333	-0.313	-0.392
6.500	-0.321	-0.375
6.667	-0.337	-0.396
6.833	-0.329	-0.392
7.000	-0.333	-0.383
7.167	-0.333	-0.379
7.333	-0.317	-0.396
7.500	-0.342	-0.400
7.667	-0.325	-0.404
7.833	-0.333	-0.416

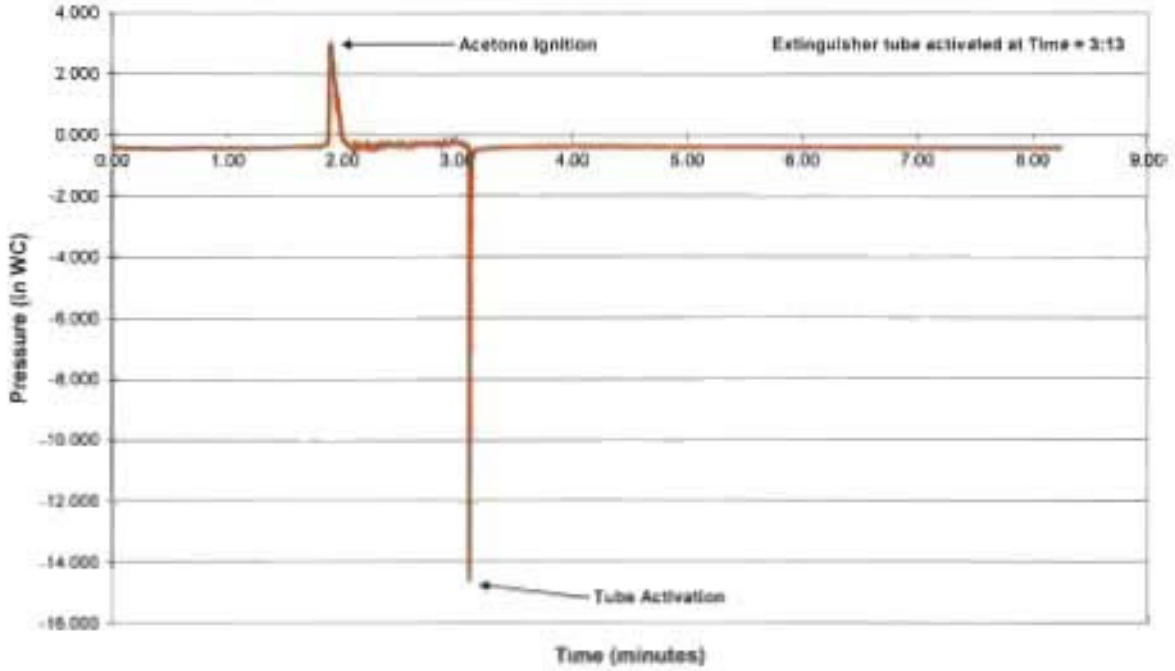
Interior Glove Box Temperatures
G100238106SAT-001E QuickFire Test 5



Internal Glove Box Pressures for Transducer 1
G100238106SAT-001E QuickFire Test 5



Internal Glove Box Pressure for Transducer 2
G100238106SAT-001E QuickFire Test 5



Intertek

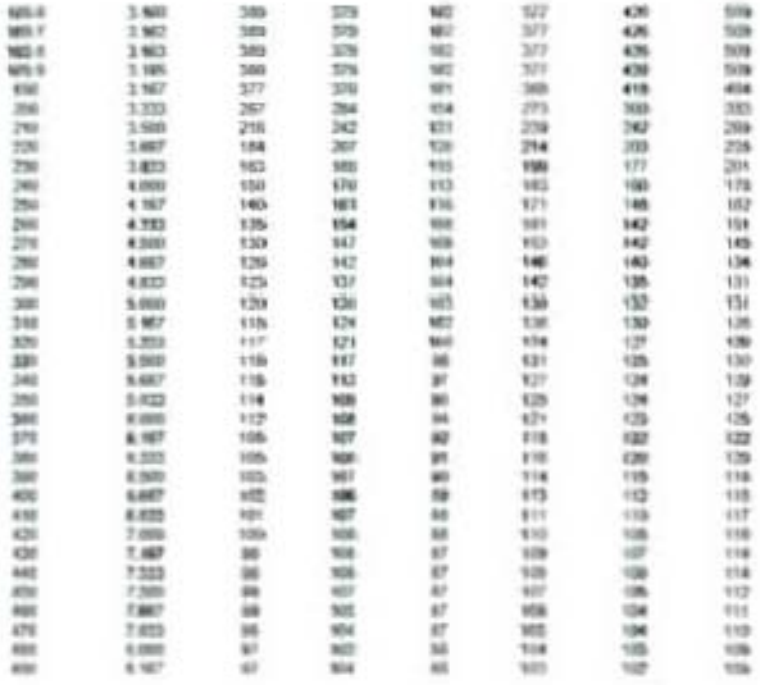
Date: 19-Oct-10
Eng. Initials:

Client: QuickFire USA LLC
Project No: G100238106SAT-001E
Test No: 6
Product: QuickFire Fire Foe-FT360 Tube Fire Extinguisher
Engineer: Victor M. Burgos, Intertek - San Antonio
Test Method(s): Los Alamos National Laboratory (LANL) Test Protocol, Section II

INTERNAL GLOVE BOX TEMPERATURES

Time (sec)	Time (min)	TC 1 (deg F)	TC 2 (deg F)	TC 3 (deg F)	TC 4 (deg F)	TC 5 (deg F)	TC 6 (deg F)	
0	0.000	75	74	66	74	214	83	
10	0.167	75	82	69	73	186	93	
20	0.333	89	88	70	82	173	101	
30	0.500	93	91	71	90	169	105	
40	0.667	99	96	72	96	168	109	
50	0.833	107	101	73	99	237	112	
60	1.000	113	107	74	104	228	118	
70	1.167	115	110	75	109	257	122	
80	1.333	125	114	76	113	282	127	
90	1.500	129	120	76	118	298	133	
100	1.667	135	124	78	118	336	141	
110	1.833	141	127	78	121	344	150	
113.2	1.887	144	130	79	125	403	153	Acetone Ignition
113.3	1.889	144	130	79	125	403	153	
113.4	1.890	144	130	79	125	403	153	
113.5	1.892	145	130	79	126	405	155	
113.6	1.893	145	130	79	126	405	155	
113.7	1.895	145	130	79	126	405	155	
113.8	1.897	145	130	79	126	405	155	
113.9	1.898	145	130	79	126	405	155	
114	1.900	147	132	81	127	386	161	
114.1	1.902	147	132	81	127	386	161	Max pos pressure
114.2	1.903	147	132	81	127	388	161	
114.3	1.905	147	132	81	127	388	161	
114.4	1.907	147	132	81	127	389	161	
114.5	1.908	150	134	82	130	392	256	
114.6	1.910	150	134	82	130	392	256	
114.7	1.912	150	134	82	130	392	256	
114.8	1.913	150	134	82	130	392	256	
114.9	1.915	150	134	82	130	392	256	
115	1.917	156	140	83	134	396	311	
115.1	1.918	156	140	83	134	396	317	
115.2	1.920	156	140	83	134	396	317	
115.3	1.922	156	140	83	134	396	317	
115.4	1.923	156	140	83	134	398	317	
115.5	1.925	165	153	85	141	400	346	
115.6	1.927	166	153	85	141	400	349	
115.7	1.928	166	153	85	141	400	349	
115.8	1.930	166	153	85	141	400	348	
115.9	1.932	166	153	85	141	400	348	
116	1.933	267	162	87	162	417	379	
116.1	1.935	267	162	87	162	417	379	
116.2	1.937	267	162	87	162	417	379	
116.3	1.938	267	162	87	162	417	379	
116.4	1.940	267	162	87	162	417	379	
116.5	1.942	225	170	88	160	415	409	
116.6	1.943	225	170	88	160	415	409	
116.7	1.945	225	170	88	160	415	409	
116.8	1.947	225	170	88	160	415	409	
116.9	1.948	225	170	88	159	415	409	

117	1.950	243	185	92	197	407	466	
117.1	1.952	243	185	92	197	407	468	
117.2	1.953	243	185	92	197	407	468	
117.3	1.955	243	185	92	197	407	468	
117.4	1.957	243	185	92	197	407	468	
117.5	1.958	255	201	100	211	414	469	
117.6	1.960	255	201	100	211	414	469	
117.7	1.962	255	201	100	211	414	469	
117.8	1.963	255	201	100	211	414	469	
117.9	1.965	255	201	100	211	414	469	
118	1.967	269	221	106	229	412	481	
118.1	1.968	269	221	106	229	412	481	
118.2	1.970	269	221	106	229	412	481	
118.3	1.972	269	221	106	229	412	481	
118.4	1.973	269	221	106	229	412	481	
118.5	1.975	294	241	112	245	413	499	
118.6	1.977	294	241	112	245	413	499	
118.7	1.978	294	241	112	245	413	499	
118.8	1.980	294	241	112	245	413	499	
118.9	1.982	294	241	112	245	413	498	
119	1.983	323	263	112	258	416	500	
119.1	1.985	323	263	112	258	416	500	
119.2	1.987	323	263	112	258	416	500	
119.3	1.988	323	263	112	258	416	500	
119.4	1.990	323	263	112	258	416	500	
119.5	1.992	348	284	113	270	415	561	
119.6	1.993	348	284	113	270	415	561	
119.7	1.995	348	284	113	270	415	561	
119.8	1.997	348	284	113	270	415	561	
119.9	1.998	348	284	113	270	415	561	
120	2.000	372	305	114	289	418	574	End pos pressure
130	2.167	539	456	165	480	554	613	
140	2.333	539	458	182	510	594	678	
150	2.500	510	497	177	473	540	680	
160	2.667	461	474	174	464	557	590	
170	2.833	460	477	175	470	561	624	
180	3.000	507	475	180	466	547	627	
186.8	3.113	519	494	182	475	572	644	Tube Activation
186.9	3.115	519	494	182	475	572	644	
187	3.117	520	472	181	469	527	624	
187.1	3.118	520	472	181	469	527	624	
187.2	3.120	520	472	181	469	527	624	
187.3	3.122	520	472	181	469	527	624	
187.4	3.123	520	472	181	469	527	624	
187.5	3.125	469	430	182	442	495	593	
187.6	3.127	469	430	182	442	495	593	
187.7	3.128	469	430	182	442	495	593	
187.8	3.130	469	430	182	442	495	593	
187.9	3.132	469	430	182	442	496	593	
188	3.133	443	409	183	420	471	568	
188.1	3.135	443	409	183	420	471	568	
188.2	3.137	443	409	183	420	471	568	
188.3	3.138	443	409	183	420	471	568	
188.4	3.140	443	409	183	420	471	568	
188.5	3.142	422	392	182	408	453	546	
188.6	3.143	422	392	182	408	453	546	
188.7	3.145	422	392	182	408	453	546	
188.8	3.147	422	392	182	408	453	546	
188.9	3.148	422	392	182	408	453	546	
189	3.150	405	383	182	391	437	525	
189.1	3.152	405	383	182	391	437	525	
189.2	3.153	405	383	182	391	437	525	
189.3	3.155	405	383	182	391	437	525	
189.4	3.157	405	383	182	391	437	525	
189.5	3.158	389	379	182	377	426	509	



Intertek

Date: 19-Oct-10
Eng. Initials:

Client: QuickFire USA LLC
Project No: G100238106SAT-001E
Test No: 5
Product: QuickFire Fire Foe FT250 Tube Fire Extinguisher
Engineer: Victor M. Burgos, Intertek - San Antonio
Test Method(s): Los Alamos National Laboratory (LANL) Test Protocol, Section 8

INTERNAL GLOVE BOX PRESSURES

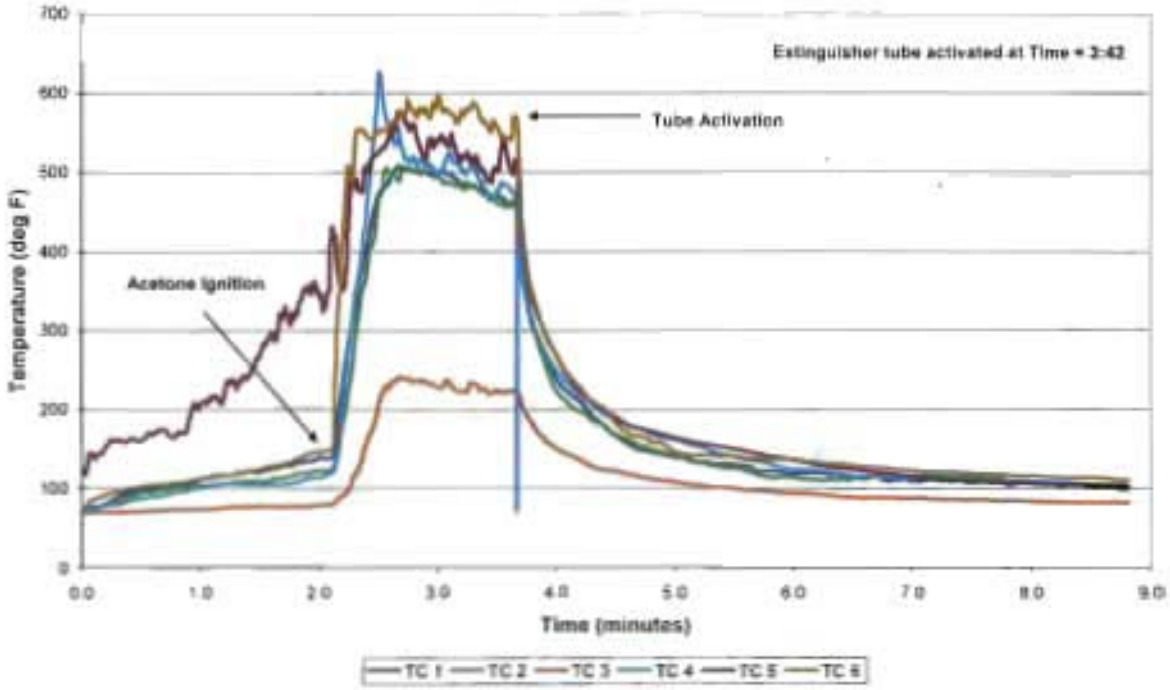
Time (min)	Transducer 1 (in WC)	Transducer 2 (in WC)	
0.000	-0.250	-0.250	
0.167	-0.421	-0.424	
0.333	-0.433	-0.416	
0.500	-0.441	-0.445	
0.667	-0.417	-0.428	
0.833	-0.404	-0.416	
1.000	-0.417	-0.416	
1.167	-0.412	-0.412	
1.333	-0.392	-0.416	
1.500	-0.383	-0.391	
1.667	-0.367	-0.387	
1.833	-0.304	-0.324	
1.887	-0.039	0.157	Ignition of Acetone - start of positive pressure spike
1.888	-0.039	0.157	
1.890	0.915	1.840	
1.892	0.915	1.840	
1.893	3.075	2.869	
1.895	3.075	2.869	
1.897	2.760	2.748	
1.898	2.760	2.748	
1.900	2.934	2.997	
1.902	2.934	2.997	Max positive pressure spike
1.903	2.934	2.976	
1.905	2.934	2.976	
1.907	2.946	2.961	
1.908	2.946	2.961	
1.910	2.967	2.827	
1.912	2.967	2.827	
1.913	2.556	2.445	
1.915	2.556	2.445	
1.917	2.324	2.225	
1.918	2.324	2.225	
1.920	2.145	2.250	
1.922	2.145	2.250	
1.923	2.477	2.403	
1.925	2.477	2.403	
1.927	2.153	2.036	

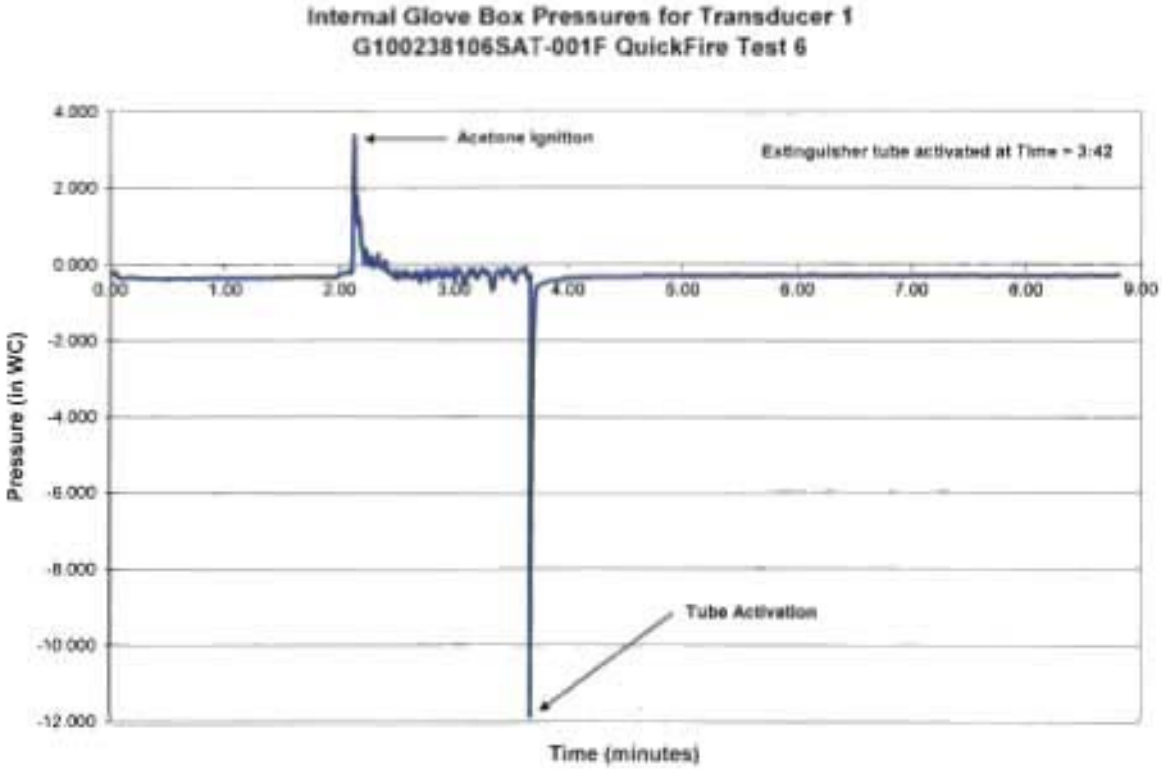
1.928	2.153	2.096	
1.930	2.029	1.993	
1.931	2.029	1.993	
1.933	1.839	1.809	
1.935	1.839	1.809	
1.937	1.736	1.717	
1.938	1.736	1.717	
1.940	1.709	1.758	
1.942	1.709	1.758	
1.943	1.601	1.568	
1.945	1.601	1.568	
1.947	1.460	1.266	
1.948	1.460	1.266	
1.950	1.152	0.979	
1.952	1.157	0.979	
1.953	0.829	0.799	
1.955	0.823	0.780	
1.957	0.797	1.000	
1.958	0.797	1.000	
1.960	0.911	0.871	
1.962	0.911	0.871	
1.963	0.937	1.274	
1.965	0.937	1.274	
1.967	1.431	1.258	
1.968	1.431	1.258	
1.970	1.136	1.062	
1.973	1.136	1.062	
1.973	0.987	0.822	
1.975	0.987	0.822	
1.973	0.575	0.525	
1.978	0.575	0.525	
1.980	0.536	0.668	
1.982	0.536	0.668	
1.983	0.724	0.656	
1.985	0.724	0.656	
1.987	0.507	0.348	
1.988	0.507	0.348	
1.990	0.268	0.195	
1.992	0.268	0.195	
1.993	0.160	0.049	
1.995	0.160	0.049	
1.997	-0.010	0.170	
1.998	-0.010	0.170	
2.000	0.122	0.033	**End positive pressure event**
2.167	-0.304	-0.324	
2.330	-0.362	-0.358	
2.500	-0.255	-0.299	
2.667	-0.321	-0.333	
2.833	-0.238	0.262	
3.000	-0.271	-0.265	
3.113	-9.704	-14.582	**Tube Activation**
3.115	-9.704	-14.582	

3.117	-14.558	-11.658
3.118	-14.558	-11.658
3.120	-9.289	-7.117
3.122	-9.289	-7.117
3.123	-5.328	-4.103
3.125	-5.328	-4.103
3.127	-3.096	-2.429
3.128	-3.096	-2.429
3.130	-1.807	-1.470
3.132	-1.807	-1.470
3.133	-1.114	-1.018
3.135	-1.114	-1.018
3.137	-0.803	-0.802
3.138	-0.803	-0.802
3.140	-0.695	-0.727
3.142	-0.695	-0.727
3.143	-0.641	-0.656
3.145	-0.641	-0.656
3.147	-0.541	-0.557
3.148	-0.541	-0.557
3.150	-0.491	-0.528
3.152	-0.491	-0.528
3.153	-0.471	-0.503
3.155	-0.471	-0.503
3.157	-0.479	-0.515
3.158	-0.479	-0.515
3.160	-0.500	-0.528
3.162	-0.500	-0.528
3.163	-0.495	-0.519
3.165	-0.495	-0.519
3.167	-0.458	-0.499
3.333	-0.383	-0.416
3.500	-0.354	-0.391
3.667	-0.321	-0.391
3.833	-0.336	-0.370
4.000	-0.325	-0.370
4.167	-0.321	-0.362
4.333	-0.313	-0.362
4.500	-0.334	-0.378
4.667	-0.325	-0.378
4.833	-0.334	-0.399
5.000	-0.313	-0.391
5.167	-0.334	-0.399
5.333	-0.300	-0.403
5.500	-0.321	-0.387
5.667	-0.329	-0.407
5.839	-0.317	-0.403
6.000	-0.321	-0.407
6.167	-0.313	-0.403
6.333	-0.317	-0.412
6.500	-0.304	-0.407
6.667	-0.321	-0.420

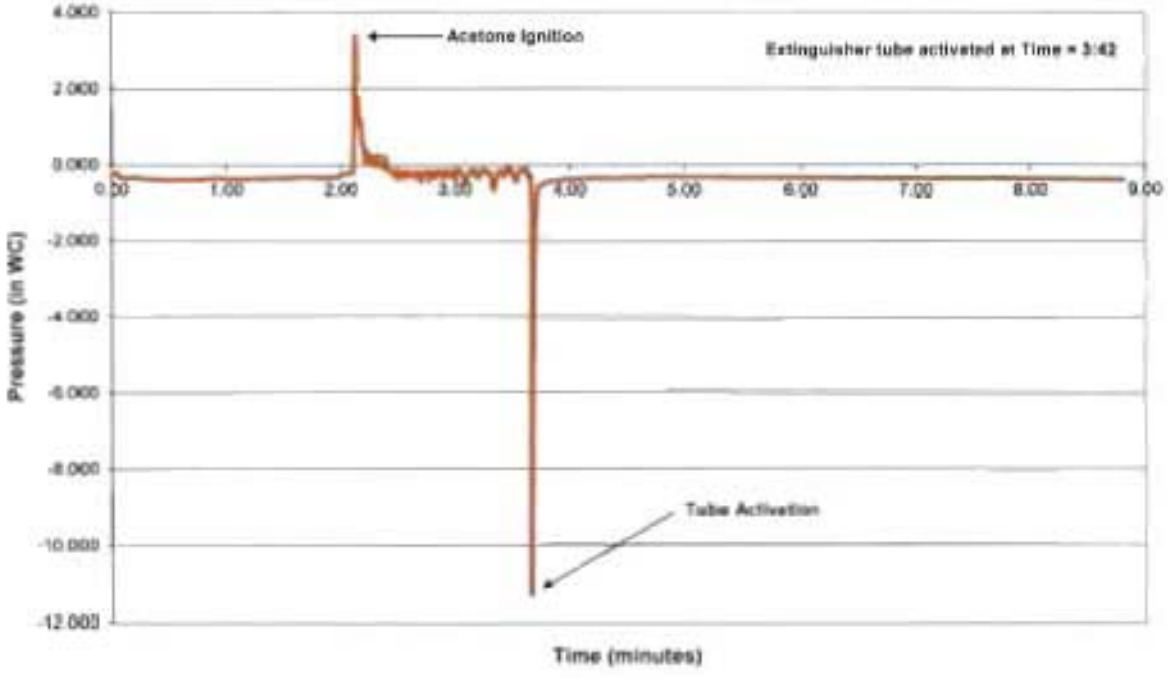
6.833	-0.342	-0.416
7.000	-0.338	-0.424
7.167	-0.317	-0.412
7.333	-0.321	-0.432
7.500	-0.309	-0.432
7.667	-0.317	-0.436
7.833	-0.317	-0.424
8.000	-0.313	-0.428
8.167	-0.338	-0.424

Interior Glove Box Temperatures
G100238106SAT-001F QuickFire Test 6




Internal Glove Box Pressures for Transducer 1
G100238106SAT-001F QuickFire Test 6
Acetone ignition
Extinguisher tube activated at Time = 3:42
Tube Activation
Pressure (in WC)
Time (minutes)
4.000
2.000
0.000
-2.000
-4.000
-6.000
-8.000
-10.000
-12.000
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00

Internal Glove Box Pressure for Transducer 2
G100238106SAT-001F QuickFire Test 6



Intertek

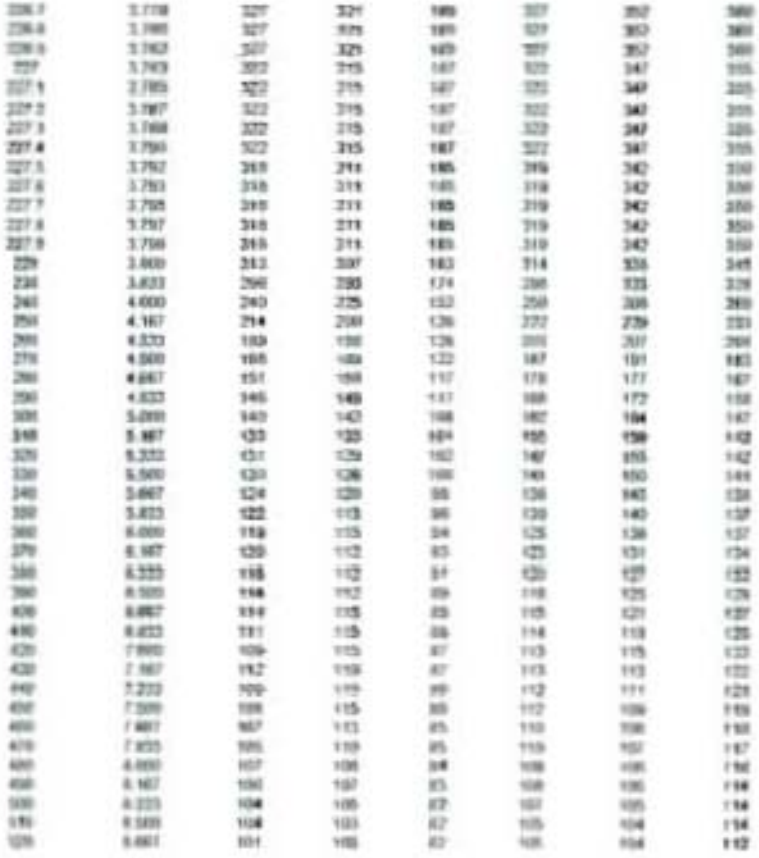
Date: 19-Oct-10
Eng. Initials:

Client: QuickFire USA LLC
Project No: G100238106SAT-001
Test No: 6
Product: QuickFire Fire Foe FT280 Tube Fire Extinguisher
Engineer: Victor M. Burgos, Intertek - San Antonio
Test Method(s): Los Alamos National Laboratory (LANL) Test Protocol, Section 9

INTERNAL GLOVE BOX TEMPERATURES

Time (sec)	Time (min)	TC 1 (deg F)	TC 2 (deg F)	TC 3 (deg F)	TC 4 (deg F)	TC 5 (deg F)	TC 6 (deg F)	
0	0.000	72	72	70	70	127	76	
10	0.167	78	78	71	78	144	90	
20	0.333	82	85	71	83	160	98	
30	0.500	90	95	72	88	161	102	
40	0.667	103	98	73	91	176	105	
50	0.833	109	103	74	95	172	108	
60	1.000	111	104	74	101	257	112	
70	1.167	117	106	75	106	259	116	
80	1.333	121	109	77	106	257	120	
90	1.500	122	110	78	105	268	125	
100	1.667	127	113	77	105	322	130	
110	1.833	134	115	78	109	357	139	
120	2.000	139	123	79	114	373	148	
127	2.117	140	125	80	121	419	150	Acetone Ignition
127.1	2.118	140	125	80	121	419	150	
127.2	2.120	140	125	80	121	419	150	
127.3	2.122	140	125	80	121	419	150	
127.4	2.123	140	125	80	121	419	150	
127.5	2.125	142	127	82	122	417	158	
127.6	2.127	142	127	82	122	417	158	
127.7	2.128	142	127	82	122	417	158	
127.8	2.130	142	127	82	122	417	158	
127.9	2.132	142	127	82	122	417	158	Max pos pressure
128	2.133	145	129	82	123	421	239	
128.1	2.135	145	129	82	123	421	239	
128.2	2.137	145	129	82	123	421	239	
128.3	2.138	145	129	82	123	421	239	
128.4	2.140	145	129	82	123	421	239	
128.5	2.142	148	132	84	126	403	257	
128.6	2.143	148	132	84	126	403	257	
128.7	2.145	148	132	84	126	403	257	
128.8	2.147	148	132	84	126	403	257	
128.9	2.148	148	132	84	126	403	257	
129	2.150	153	135	85	133	387	300	
129.1	2.152	153	135	85	133	387	304	
129.2	2.153	153	135	85	133	387	304	
129.3	2.155	153	135	85	133	387	304	
129.4	2.157	153	135	85	133	387	304	
129.5	2.158	151	137	86	149	376	327	
129.6	2.160	151	137	86	149	376	327	
129.7	2.162	151	137	86	149	376	327	
129.8	2.163	151	137	86	149	376	327	
129.9	2.165	151	137	86	149	376	327	
130	2.167	151	144	88	151	356	344	
140	2.333	258	316	125	367	479	554	End pos pressure
150	2.500	470	466	240	519	525	551	
160	2.667	506	451	240	534	577	565	
170	2.833	501	504	251	528	580	573	
180	3.000	498	493	250	497	536	594	
190	3.167	492	494	224	510	519	585	

220	3.675	471	455	227	71	505	553	Tube Activation
220.1	3.676	471	455	227	71	505	553	
220.2	3.677	471	455	227	71	505	553	
220.3	3.678	471	455	227	71	505	553	
220.4	3.680	471	455	227	71	505	553	
220.5	3.682	471	455	227	71	505	553	
220.6	3.683	471	455	227	71	505	553	
220.7	3.685	471	455	227	71	505	553	
220.8	3.687	471	455	227	71	505	553	
220.9	3.688	471	455	227	71	505	553	
221	3.690	451	436	221	408	472	522	
221.1	3.695	451	436	221	408	472	522	
221.2	3.697	451	436	221	408	472	522	
221.3	3.698	451	436	221	408	472	522	
221.4	3.699	451	436	221	408	472	522	
221.5	3.692	424	412	217	393	452	489	
221.6	3.693	424	412	217	393	452	489	
221.7	3.695	424	412	217	393	452	489	
221.8	3.697	424	412	217	393	452	489	
221.9	3.698	424	412	217	393	452	489	
222	3.700	412	395	212	383	438	458	
222.1	3.702	412	395	212	383	438	458	
222.2	3.703	412	395	212	383	438	458	
222.3	3.705	412	395	212	383	438	458	
222.4	3.707	412	395	212	383	438	458	
222.5	3.708	401	381	207	373	423	438	
222.6	3.710	401	381	207	373	423	438	
222.7	3.712	401	381	207	373	423	438	
222.8	3.713	401	381	207	373	423	438	
222.9	3.715	401	381	207	373	423	438	
223	3.717	390	374	204	364	409	423	
223.1	3.718	390	374	204	364	409	423	
223.2	3.720	390	374	204	364	409	423	
223.3	3.722	390	374	204	364	409	423	
223.4	3.723	390	374	204	364	409	423	
223.5	3.725	379	366	200	358	396	410	
223.6	3.727	379	366	200	358	396	410	
223.7	3.728	379	366	200	358	396	410	
223.8	3.730	379	366	200	358	396	410	
223.9	3.732	379	366	200	358	396	410	
224	3.733	368	358	196	351	389	401	
224.1	3.735	368	358	196	351	389	401	
224.2	3.737	368	358	196	351	389	401	
224.3	3.738	368	358	196	351	389	401	
224.4	3.740	368	358	196	351	389	401	
224.5	3.742	359	350	196	344	379	391	
224.6	3.743	359	350	196	344	379	391	
224.7	3.745	359	350	196	344	379	391	
224.8	3.747	359	350	196	344	379	391	
224.9	3.748	359	350	196	344	379	391	
225	3.750	350	342	194	339	371	382	
225.1	3.752	350	342	194	339	371	382	
225.2	3.753	350	342	194	339	371	382	
225.3	3.755	350	342	194	339	371	382	
225.4	3.757	350	342	194	339	371	382	
225.5	3.758	343	334	192	334	364	373	
225.6	3.760	343	334	192	334	364	373	
225.7	3.762	343	334	192	334	364	373	
225.8	3.763	343	334	192	334	364	373	
225.9	3.765	343	334	192	334	364	373	
226	3.767	335	326	191	331	357	366	
226.1	3.768	335	326	191	331	357	366	
226.2	3.770	335	326	191	331	357	366	
226.3	3.772	335	326	191	331	357	366	
226.4	3.773	335	326	191	331	357	366	
226.5	3.775	327	319	189	327	352	360	
226.6	3.777	327	319	189	327	352	360	



Intertek

Date: 19-Oct-10
Eng. Initials:

Client: QuickFire USA LLC
Project No: G100238106SAT-001F
Test No: 6
Product: QuickFire Fire Foe FT250 Tube Fire Extinguisher
Engineer: Victor M. Burgos, Intertek - San Antonio
Test Method(s): Los Alamos National Laboratory (LANL) Test Protocol, Section 8

INTERNAL GLOVE BOX PRESSURES

Time (mins)	Transducer 1 (in WC)	Transducer 2 (in WC)	
0.000	-0.240	-0.240	
0.167	-0.327	-0.327	
0.333	-0.352	-0.381	
0.500	-0.385	-0.394	
0.667	-0.360	-0.377	
0.833	-0.352	-0.356	
1.000	-0.352	-0.361	
1.167	-0.360	-0.369	
1.333	-0.348	-0.356	
1.500	-0.331	-0.352	
1.667	-0.314	-0.323	
1.833	-0.339	-0.327	
2.000	-0.252	-0.253	
2.117	-0.103	0.104	Acetone pour and positive pressure event
2.118	-0.103	0.104	
2.120	0.811	1.640	
2.122	0.811	1.640	
2.123	2.289	2.504	
2.125	2.289	2.504	
2.127	2.866	3.189	
2.128	2.866	3.189	
2.130	3.389	3.413	
2.132	3.389	3.413	Max positive pressure spike
2.133	3.053	2.683	
2.135	3.053	2.683	
2.137	2.260	1.867	
2.138	2.260	1.867	
2.140	1.662	1.528	
2.142	1.662	1.528	
2.143	1.537	1.700	
2.145	1.537	1.700	
2.147	1.691	1.582	
2.148	1.691	1.582	
2.150	1.571	1.660	
2.152	1.571	1.660	
2.153	1.687	1.771	
2.155	1.687	1.771	

2.157	1.774	1.642	
2.158	1.774	1.642	
2.160	1.450	1.242	
2.162	1.450	1.242	
2.163	1.139	1.084	
2.165	1.139	1.084	
2.167	1.031	1.030	
2.335	0.093	0.146	**End of positive pressure spike**
2.500	-0.331	-0.232	
2.667	-0.256	-0.256	
2.833	-0.256	-0.273	
3.000	-0.231	-0.261	
3.167	-0.260	-0.240	
3.333	-0.580	-0.605	
3.500	-0.148	-0.145	
3.667	-0.289	-0.265	
3.675	-0.265	-1.149	**Tube activation**
3.677	-7.879	-11.301	
3.678	-7.879	11.301	
3.680	-11.856	-11.209	
3.682	-11.856	-11.209	
3.683	-10.304	-9.295	
3.685	-10.304	-9.295	
3.687	-8.207	-7.215	
3.688	-8.207	-7.215	
3.690	-6.330	-5.542	
3.692	-6.330	-5.542	
3.693	-4.848	-4.247	
3.695	-4.848	-4.247	
3.697	-3.668	-3.209	
3.698	-3.668	-3.209	
3.700	-2.776	-2.403	
3.702	-2.776	-2.403	
3.703	-2.096	-1.797	
3.705	-2.096	-1.797	
3.707	-1.585	-1.453	
3.708	-1.585	-1.453	
3.710	-1.307	-1.187	
3.712	-1.307	-1.187	
3.713	-1.062	-0.996	
3.715	-1.062	-0.996	
3.717	-0.933	-0.880	
3.718	-0.933	-0.880	
3.720	-0.800	-0.767	
3.722	-0.800	-0.767	
3.723	-0.738	-0.701	
3.725	-0.738	-0.701	
3.727	-0.659	-0.639	
3.728	-0.659	-0.639	
3.730	-0.617	-0.601	
3.732	-0.617	-0.601	
3.733	-0.572	-0.568	

3.735	-0.572	-0.568
3.737	-0.563	-0.560
3.738	-0.563	-0.560
3.740	-0.568	-0.560
3.742	-0.568	-0.560
3.743	-0.551	-0.556
3.745	-0.551	-0.556
3.747	-0.547	-0.539
3.748	-0.547	-0.539
3.750	-0.518	-0.531
3.752	-0.518	-0.531
3.753	-0.522	-0.510
3.755	-0.522	-0.510
3.757	-0.526	-0.514
3.758	-0.526	-0.514
3.760	-0.522	-0.539
3.762	-0.522	-0.539
3.763	-0.514	-0.527
3.765	-0.514	-0.527
3.767	-0.522	-0.531
3.768	-0.522	-0.531
3.770	-0.514	-0.510
3.772	-0.514	-0.510
3.773	-0.501	-0.502
3.775	-0.501	-0.502
3.777	-0.493	-0.498
3.778	-0.493	-0.498
3.780	-0.489	-0.514
3.782	-0.489	-0.514
3.783	-0.485	-0.493
3.785	-0.485	-0.493
3.787	-0.480	-0.489
3.788	-0.480	-0.489
3.790	-0.472	-0.485
3.792	-0.472	-0.485
3.793	-0.468	-0.481
3.795	-0.468	-0.481
3.797	-0.468	-0.460
3.798	-0.468	-0.460
3.800	-0.476	-0.469
3.833	-0.439	-0.444
4.000	-0.389	-0.369
4.167	-0.343	-0.356
4.333	-0.314	-0.340
4.500	-0.310	-0.340
4.667	-0.285	-0.315
4.833	-0.285	-0.311
5.000	-0.277	-0.348
5.167	-0.277	-0.323
5.333	-0.277	-0.311
5.500	-0.285	-0.323
5.667	-0.285	-0.336

5.833	-0.273	-0.332
6.000	-0.281	-0.340
6.167	-0.252	-0.336
6.333	-0.281	-0.336
6.500	-0.277	-0.340
6.667	-0.277	-0.344
6.833	-0.285	-0.340
7.000	-0.265	-0.323
7.167	-0.273	-0.348
7.333	-0.277	-0.348
7.500	-0.273	-0.336
7.667	-0.281	-0.344
7.833	-0.260	-0.352
8.000	-0.281	-0.348
8.167	-0.294	-0.356
8.333	-0.260	-0.344
8.500	-0.285	-0.361
8.667	-0.277	-0.365

APPENDIX B
Test Photographs

Setup and Materials

Pressure Gauge end of Fire Foe™ tube

FT 250 Fire Foe™ extinguisher tube

Fill pressure relief end for Fire Foe™ tube

Steel Glove box setup

Access door and Panel #1 view

Panels #2 and #3 view of glove box

Panels #4 and #5 view of glove box

Roof view of exhaust duct. The lower stainless steel section housed the HEPA filter

Exhaust duct and blower assembly

Oil pan, Acetone pan, and fill tubes

Air inlet duct inside glove box

Exhaust port in ceiling panel

TC #5 and Acetone fill tube

TC #6 and exhaust port in ceiling

Intertek pressure transducer #2 (QuickFire designation #10)

TC #3 and Intertek pressure transducer #1 (QuickFire designation #7)

QuickFire digital vane anemometer

TC #6 at roof location

Cutting oil pre-fill reservoir

Cutting oil

Acetone

18GA (left) and 16GA wires

Wire bundle with 16GA wire, 18GA wire, and coaxial cable

UL 1975 wood crib with no wood excelsior

Exhaust HEPA filters

500 ml Nalgene squeeze bottles

Open box of Kimwipes

Test 1 – QuickFire Experiment #17

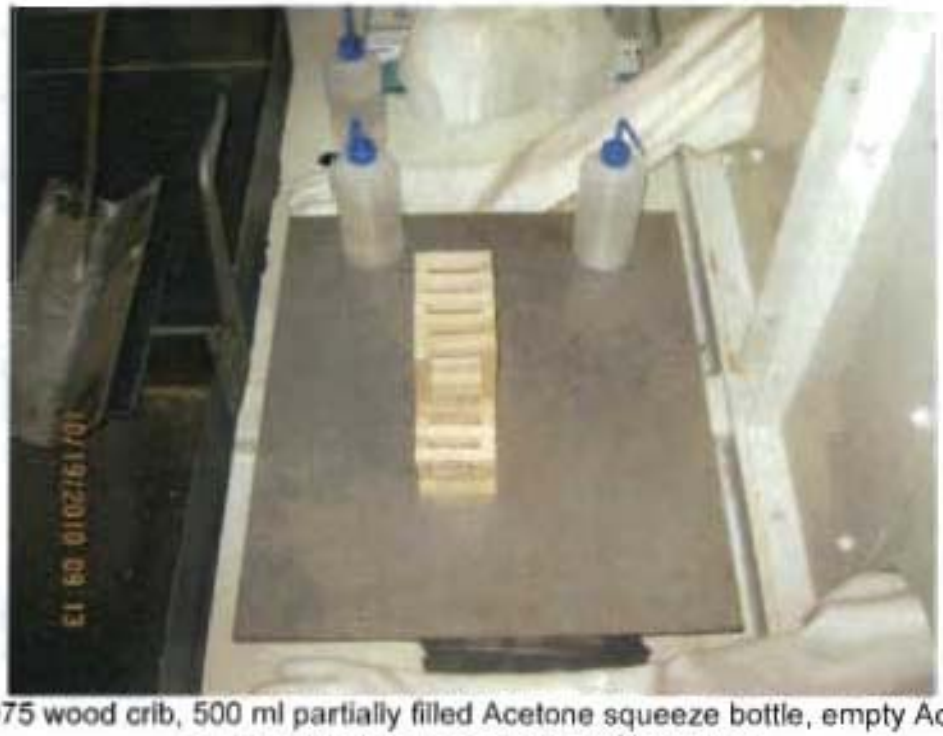
Wood excelsior

Completed UL 1975 wood crib assembly

Nalgene squeeze bottle with 500 ml of Acetone

Consumable material setup prior to test

Unopened box of Kimwipes and partially filled Acetone squeeze bottle



UL 1975 wood crib, 500 ml partially filled Acetone squeeze bottle, empty Acetone squeeze bottle, and open box of Kimwipes

Tygon tubing

Addition of Tygon tubing to consumable material setup prior to test

Suspended wire bundle

Stainless steel pot and natural gas burner for pre-heating cutting oil

Fire Foe™ tube installed with brackets (rear half)

Fire Foe™ tube installed with brackets (front half)

Intertek calibrated digital manometer

Pre-heated cutting oil poured into pre-fill reservoir

Cutting oil thermometer

Acetone poured into pre-fill reservoir

Test #1

Test #1 interior of glove box – post fire

Test #1 interior of glove box – post fire

Test #1 interior of glove box – post fire

Test #1 damage to gloves impinged by flames

Test #1 Fire Foe™ tube discharge point

Test #1 500 ml Nalgene squeeze bottle

Test 2 – QuickFire Experiment #18

Test #2 wood crib

Test #2 pre-fire

Test #2 filter replacement

Test #2 pre-heated cutting oil

Test #2 Fire Foe™ tube location beneath ceiling

Test #2 Fire Foe™ tube location from wall

Test #2 pre-fire

Test #2 pre-heated cutting oil

Test #2 pre-ignition

Test #2 post fire

Test #2 post fire

Test #2 post fire

Test #2 post fire

Test #2 un-activated Fire Foe™ tube

Test #2 un-activated Fire Foe™ tube

Test #2 un-activated Fire Foe™ tube

Test 3 – QuickFire Experiment #19

Test #3 pre-fire

Test #3 pre-fire

Test #3 wood crib

Test #3 wire bundle

Test #3 pre-heated cutting oil

Test #3 pre-heated cutting oil

Test #3 pre-ignition

Test #3 Fire Foe™ tube damaged support brackets

Test #3 post fire

Test #3 post fire

Test #3 post fire

Test #3 post fire

Test #3 activated Fire Foe™ tube

Test #3 activated Fire Foe™ tube

Test #3 activated Fire Foe™ tube

Test 4 – QuickFire Experiment #20

Test #4 wood crib

Test #4 pre-fire

Test #4 pre-fire

Test #4 pre-fire

Test #4 pre-fire

Test #4 pre-fire

Test #4 pre-fire

Test #4 post-fire

Test #4 post-fire

Test #4 post-fire

Test #4 post-fire

Test #4 post-fire

Test #4 post fire

Test #4 HEPA filter post fire

Test 5 – QuickFire Experiment #21

Test #5 wood crib

Test #5 pre-fire

Test #5 pre-fire

Test #5 pre-fire

Test #5 pre-fire

Test #5 pre-fire

Test #5 pre-fire

Test #5 post-fire

Test #5 post-fire

Test #5 post fire

Test #5 post-fire

Test #5 post-fire

Test #5 post-fire

Test #5 damage to glove impinged by flame

Test #5 flame damage to wire bundle

Test #5 flame damage to Tygon tubing

Test #5 HEPA filter post fire

Test #5 Fire Foe™ tube activation section, post-fire

Test 6 – QuickFire Experiment #22

Test #6 wood crib

Test #6 pre-fire

Test #6 pre-fire

Test #6 pre-fire

Test #6 pre-fire

Test #6 pre-fire

Test #6 pre-fire

Test #6 pre-fire

Test #6 post-fire

Test #6 post-fire

Test #6 post-fire

Test #6 post-fire

Test #6 post-fire

Test #6 post-fire

Test #6 post-fire

Test #6 post-fire

Test #6 activated Fire Foe™ tube, post-fire

Test #6 activated Fire Foe™ tube, post-fire

Test #6 HEPA filter post-fire

APPENDIX C

Los Alamos National Laboratory (LANL) Test Protocol

(RECEIVED ON 9-16-10, 6:51 AM, AS FINAL TEST PROCEDURE. TEST SECTION HIGHLIGHTED IN YELLOW)

LANL Test Protocol: Fire Foe Standard Tube in 250 cubic foot glove-box

Glove box design and manufacture:

1. Design a glove box with dimensions 8' X 5' X 6' (l X b X h) with 250 cubic feet volume of frame and panel construction. Box to be constructed in 14 gauge mild steel and to be as air-tight as practicable but to include one doorway or hatch for easy access. Box to incorporate 2 off ¾" full length hanging rails approx 1" below ceiling. Box to incorporate glove ports and glove fixings, glass window panels. Box to incorporate fixed negative pressure differential of ½" or ¼"water and fixed air flow of one air change (250 cubic feet) per minute by means of 8" diameter inlet/exhaust pipes centered 8" below ceiling height on side panels. Exhaust will be through 8" flanged spool piece (provided by LANL) which will house an inline HEPA air filter, with pressure measurement transducers mounted below and above the HEPA filter in existing ¾" N.P.T ports (female thread).

2. Design a rack with dimensions 4' X 2' constructed of a 2" X 2" angle steel frame with number 8 expanded metal grid standing 20" inches off the floor of the box.

3. Windows, gloves and/or glove aperture blanking plates to be affixed to the box per fittings supplied.

4. Install multiple pressure transducers in the box. One transducer will be placed between the glove ports at the lowest level and thereafter one transducer will be placed every 18" to give a total of 4 transducers stacked vertically. These transducers are in addition to the 2 pressure transducers as specified in Line Item No 1 above. Thus the box will contain a total of 6 pressure transducers.

5. Install one glass observation window with removable internal blanking plate (soot and residue protection) to enable clear vision of box interior and contents status post fire and tube activation.

6. Install one copper Acetone filling pipe extending through front panel extending to position in centre of box floor and approx 5" above floor, complete with external shut-off valve and 1 pint measuring reservoir

7. Install one off 1" diameter "keyhole" with external closing plate in front panel of the box at suitable height above the floor.

8. Affix Fire Foe tube fixings at one position in the box

9. Submit drawing of proposed glove box and incorporated rack to LANL for their approval. LANL to countersign drawing to record such approval.

10. Manufacture glove box to such approved specification and drawing. Gloves, glove fixing assemblies and/or glove aperture blanking plates and window panels complete with sealing arrangements to be free-issue supply from LANL and to be incorporated into the glove box manufacture.

11. Install thermocouples on the top panel, bottom panel, side panels and end panels of the box to measure the temperature profile within the box in these positions before, during and after activation.

12. Final glove box assembly to be photographed and photos submitted to LANL prior to use.

Proof of concept fire testing:

The following fire test program will be carried out. In each test one off Fire Foe tube will be mounted in the tube fixings within the box. Each test will be timed from ignition of material to flame extinguishment. All times to be recorded. In Test Protocol 3 plus two further tests under Test Protocol 8 conditions shall be pressure monitored before, during and after tube discharge. Such pressure monitoring shall be automatically recorded in real time. Prior to each test the airflow will be verified and recorded. Each test will be videoed from outside the box. After each test the box will remain closed and stable for 5 minutes.

Tests:

1. Place 1 pint of Acetone in a pan of dimensions 19.5" X 19.5" X 4". Place the pan on the floor of the box. Close hatch/door. Set and verify the required pressure differential and air flow. Ignite Acetone using hand held taper or lance manipulated through the key hole. Observe, videotape and record. *Object: Prove Fire Foe extinguishes acetone fire in isolation in the 250 cu ft glove box.*

2. Place 2 gallons of specified (pre-heated) cutting oil in a pan of dimensions 19.5" X 19.5" X 4". Place the pan on the floor of the box. Close the hatch/door. Set and verify pressure differential and air flow. Ignite cutting oil using hand held taper or lance manipulated through the key hole. Observe, videotape and record. *Object: Prove Fire Foe extinguishes cutting oil fire in isolation in the 250 cu ft glove box.*

3. Place 1 pint of Acetone in the external reservoir. Place an empty pan of dimensions 19.5" X 19.5" X 4" in the centre of the box floor under the copper filling pipe. Place 2 gallons of specified (pre-heated) cutting oil in a pan of dimensions 19.5" X 19.5" X 4" on the floor of the box. Place one wood-crib UL Standard 1975 measuring 10" X 3" X 6" on the floor of the box. Place one wood crib UL Standard 1975 measuring 10" X 3" X 6" on the rack. Close hatch/door. Set and verify the required pressure differential and air flow. (A) Ignite both wood cribs using hand held taper or lance manipulated through the key hole. Allow both cribs to burn for 60 seconds then open the external valve and drain the Acetone held in the external reservoir into the empty pan and if applicable, (B) ignite acetone and cutting oil using hand held taper of lance manipulated through the keyhole. Observe, videotape and record A/B. Record pressure variance before, during, after tube activation in real time. *Object: Prove Fire Foe extinguishes Class A UL specified crib in the presence of accelerants at two levels in the250 cu ft glove box.*

4. Place 1 pint of Acetone in a pan of dimensions 19.5" X 19.5" X 4". Place 2 gallons of specified (pre-heated) cutting oil in a pan of dimensions 19.5" X 19.5" X 4". Place both pans on the floor of the box. Place 5 off 500ml plastic squirt-bottles (two of which shall be empty and three of which shall be partly filled with specified combustible liquid e.g. alcohol) on the floor of the box. Place 5 off 500ml plastic squirt-bottles (two of which shall be empty and three of which shall be partly filled with specified combustible liquid

e.g. alcohol) on the rack. Close hatch/door. Set and verify required pressure differential and air flow. Ignite the acetone and the cutting oil using a hand held taper or lance manipulated through the key hole. Observe, videotape and record. *Object: Prove that Fire Foe extinguishes Class A fire in empty and partially filled squirt bottles at two levels in the250 cu ft glove box.*

5. Place 1 pint of Acetone in a pan of dimensions 19.5" X 19.5" X 4". Place 2 gallons of specified (pre-heated) cutting oil in a pan of dimensions 19.5" X 19.5" X 4". Place both pans on the floor of the box. Place 2 off boxes of chem-wipes (one of which shall be open with a number of chem-wipes removed the other shall be un-opened) on the floor of the box. Place 2 off boxes of chem-wipes (one of which shall be open with a number of chem-wipes removed the other shall be un-opened) on the rack. Close hatch/door. Set and verify the required pressure differential and air flow. Ignite the Acetone and the cutting oil using a hand held taper or lance manipulated through the key hole. Observe, videotape and record. *Object: Prove that Fire Foe extinguishes Class A fire in partially filled and un-broached boxes of chem-wipes at two levels in the 250 cu ft glove box.*

6. Place 1 pint of Acetone in a pan of dimensions 19.5" X 19.5" X 4". Place 2 gallons of specified (pre-heated) cutting oil in a pan of dimensions 19.5" X 19.5" X 4". Place both pans on the floor of the box. Place 3 meters of Tygon tubing on the floor of the box. Place 3 meters of Tygon tubing on the rack. Close hatch/door. Set and verify required pressure differential and air flow. Ignite the Acetone and cutting oil using a hand held taper or lance manipulated through the key hole. Observe, videotape and record. *Object. Prove that Fire Foe extinguishes Class A fire in Tygon tubing at multiple levels in the250 cb ft glove box.*

7. Place 1 pint of Acetone in a pan of dimensions 19.5" X 19.5" X 4". Place 2 gallons of specified (pre-heated) cutting oil in a pan of dimensions 19.5" X 19.5" X 4". Place both pans on the floor of the box. Suspend vertically 5 off wire bundles of #16THHN wires from the ceiling mounted rails. Suspend vertically 2 off wire bundles of #18THHN wires from the ceiling mounted rails. Suspend vertically 2 off bundles of 2 coaxial cables from the ceiling mounted rails. All wires to be bound together with plastic twist ties in a single 9-bundle group. Vertical bundles shall be suspended at varying heights above the Acetone/cutting oil. Close hatch/door. Set and verify the required pressure differential and air flow. Ignite the Acetone and cutting oil using a hand held taper or lance manipulated through the key hole. Observe, videotape and record. . *Object: Prove that Fire Foe extinguishes Class A & C fires in vertically suspended cable bundles at multiple levels in the 250 cu ft glove box.*

8. **Place 1 pint of Acetone in the external measuring reservoir. Place an empty pan of dimensions 19.5" X 19.5" X 4" in the centre of the box floor under the copper filling pipe. Place 2 gallons of specified (pre-heated) cutting oil in a pan of dimensions 19.5" X 19.5" X 4" and place on the floor of the box. Place one wood crib UL Standard 1976 measuring 10" X 3" X 6" on the floor of the box. Place 5 off 500ml plastic squirt-bottles (two of which shall be empty and three of which shall be partly filled with acetone) on the floor of the box. Place 2 off boxes of chem-wipes (one of which shall be open with a number of chem-wipes removed the other shall be un-opened) on the floor of the box. Place 3 meters of Tygon tubing on the floor of the box. Suspend vertically 5 off wire bundles of #16THHN wires from the ceiling mounted rails. Suspend vertically 2 off wire bundles of #18THHN**

wires from the ceiling mounted rails. Suspend vertically 2 off bundles of 2 coaxial cables from the ceiling mounted rails. All wires to be bound together with plastic twist ties in a single 9 bundle group. Vertical bundles shall be suspended at varying heights above the Acetone/cutting oil. Close hatch/door. Set and verify the required pressure differential and air flow. (A) Ignite wood crib using hand held taper or lance manipulated through the key hole. Allow wood crib to burn for 60 seconds then open the external valve and drain the Acetone in the external reservoir into the empty pan and if applicable, (B) ignite Acetone and cutting oil using hand held taper of lance manipulated through the keyhole. Observe, videotape and record A/B. *Object: prove that Fire Foe extinguishes the full range of Class A/B/C fires of varying types of specified materials at varying levels in the250 cu ft glove box.*

9. Repeat the above specified test 8 four further times in succession in the presence of designated personnel from LANL. In 2 consecutive tests record pressure variance before, during, after tube activation in real time. Observe, videotape and record.

Independent verification by NRTL (Intertek)

NRTL to conduct above specified Test 8 five times in succession at the NRTL and verify according to results.

The above specified glove box design and manufacture together with a drawing or photograph signed by the Contractor and countersigned by the Sub-contractor, the above specified proof of concept fire testing and the above specified independent verification by the NRTL constitutes the complete Test Protocol per Subcontract number 86203-001-10 dated August 5th 2010.

For the Contractor:	For the Subcontractor:
Name:	Name:
Title:	Title:
Date:	Date:

APPENDIX D

Envirogel® MSDS

MATERIAL SAFETY DATA SHEET

1. Identification of the substance/preparation and of the company/ undertaking

1.1 Identification of the preparation

Product Name "ENVIROGEL 5634"

1.2 Use of the preparation

The intended or recommended use of this preparation is as a FIRE EXTINGUISHING AGENT

1.3 Company Identification

Supplier	QuickFire
Address	1909 West Main Street, Fort Wayne, IN 46808
Phone	260-440-3089
Web Address	www.quick-fire.com
Date of Issue	03/01/2008

1.4 Emergency telephone

FOR CHEMICAL EMERGENCY, SPILL, LEAK, FIRE, EXPOSURE, OR ACCIDENT or additional non-emergency information, CALL +1-260-440-3089

2. Composition/ Information on Ingredients

2.1 Ingredient Names 1,1,1,3,3,3 - Hexafluoropropane
Chemical Formula $C_3H_2F_6$
CAS No: 690-39-1
EINECS Number 429-320-8
Concentration, Wt %: 70%

Ingredient Names Sodium Bicarbonate
Chemical Formula $NaHCO_3$
CAS No. 144-55-8
EINECS Number 205-633-8
Concentration, Wt %: 30%

Hazard Identification See Heading 3

2.2 General Product Information
This material has been evaluated using the criteria specified in European Union Directives 67/548/EEC, 99/45/EC and 2001/58/EC

3. Hazards Identification

Emergency Overview

Appearance and Odor: white opaque gel with faint ethereal odor.

Potential Health Effects of acute exposure

Eye Contact: "Frostbite-like" effects may occur if escaping vapors contact the eyes.
Skin Contact: Frostbite can occur if escaping vapors contact the skin.
Inhalation: Based on animal data, this material may cause suffocation (if air is displaced by vapors), irregular heartbeat with a strange sensation in the chest, "heart thumping", apprehension, light-headedness, feeling of fainting, dizziness, weakness, sometimes progressing to loss of consciousness and death. The powder may cause mild irritation of the breathing passages.
Ingestion: Not a likely route of entry.

Medical Conditions generally aggravated by exposure: This material may make the heart more susceptible to arrhythmias.

4. First Aid Measures

Eye Contact: Immediately flush eyes with water for at least 15 minutes while holding eyelids open. Seek immediate medical attention.
Skin Contact: Wash areas with lukewarm water. If frostbite has occurred do not use hot water and get medical attention.
Inhalation: Immediately remove affected person to fresh air. If not breathing give artificial respiration and get medical attention.
Ingestion: Not applicable.

NOTE TO PHYSICIANS: Do not give epinephrine or similar drugs. This material may make the heart more susceptible to arrhythmias.

5. Fire-Fighting Measures

Substance is a fire extinguishing media.
There are no fire extinguishing media which must not be used for safety reasons.
If container is exposed to high temperature or flame keep cool with water spray.
Cylinders may rupture under fire conditions.
When combined with burning material substance may generate toxic fumes.
Fire fighters should wear self-contained breathing apparatus.
Ventilate area where substance has been released to remove products of combustion/ decomposition.

6. **Accidental Release Measures**

Evacuate area **and** ventilate. **Do not** enter area where high concentration may exist without protective equipment including **self**-contained **breathing** apparatus. **Allow** vapor to evaporate and **brush** or vacuum residual powder and remove. Flush **spill area** with water.

7. **Handling and Storage:**

Handle in **accordance** with good industrial **safety** and hygiene practice. Do not breathe in vapors. Do not get into contact with eyes or **skin**. Use with **sufficient ventilation** to keep employee exposure below recommended limits. **Store** in a cool, dry, well ventilated area. When used as a fire fighting **agent** in fixed or portable extinguishing systems, follow manufacturer's instructions for inspection, maintenance and operation.
Specific Use: **FIRE EXTINGUISHING AGENT**.

8. **Exposure Controls/ Personal Protection**

8.1 **Exposure Limit Values**

ACGIH, OSHA, NIOSH, The EU, Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Netherlands, Portugal, Spain, United Kingdom have not developed occupational exposure limit **values** for any of the substances in this preparation.
ACGIH and OSHA have established limits for Particulates Not Otherwise Regulated (PNOR). The OSHA PEL/TWA for PNOR is 15mg/m³ total dust and 5 mg/ m³ respirable fraction.
ACGIH has established limits for Particulates **Not** Otherwise Classified (PNOC). **The** ACGIH **TLV/TWA** for PNOC is 10 mg/ m³ total dust and 3 mg/ m³ respirable fraction.

8.2 Exposure **Controls**

8.2.1 **Occupational** exposure
Use local ventilation to minimize exposure to substance.
Use mechanical ventilation for general area control.

8.2.1.1 **Protective Equipment – Respiratory**
Use approved self contained breathing apparatus (NIOSH/ MSHA or MSA) if airborne exposure limits are exceeded or in emergency situations.

8.2.1.2 **Protective Equipment – Eyes/ Face**
Wear chemical goggles.

8.2.1.3 **Protective Equipment – Skin**
Use polyvinyl chloride (PVC) or polyvinyl alcohol (PVA) gloves.

9. **Physical and Chemical Properties**

Appearance: White opaque gel Vapor Density: >1 (Air=1)

Odor:	Faint ethereal	Boiling point:	-1.4°C
pH:	Not Available	Solubility @ H_2O:	Negligible
Vapor Pressure:	272.4 kPa at 25°C	Flammability:	Not flammable
Explosive Properties:	Not explosive	Oxidizing properties:	Not an oxidizer

10. Stability and Reactivity

Chemical Stability: Stable under normal temperature and pressure. Protect container from heat and physical damage.

Materials to Avoid: Incompatible with alkali or alkaline earth metals (powdered aluminum, zinc, beryllium, etc).

Hazardous Decomposition/ Hazardous Polymerization: Combustion or decomposition products include hydrogen fluoride, carbon monoxide and carbon dioxide.

Will not polymerize.

11. Toxicological Information

QuickFire has not conducted health effects studies with the material and information concerning the potential health effects of this material was not found in an abbreviated search of the open scientific literature. Toxicity studies have been conducted with specific components in this product. Information from these studies and from the scientific literature on the components is provided below.

11.1 1,1,1,2,3,3,3 – Heptafluoropropane (CF_3CHFCF_3)

Toxicity Data: Inhalation (rat) 4 hr LC50: > 412,000 ppm.
Direct contact with eyes or skin by liquid can cause frostbite.
Single exposure content: Narcosis, Cardiac sensitization, a potentially fatal disturbance of heart rhythm associated with a body/tissues sensitivity to the action of epinephrine (NOAEL, 10%; LOAEL 15%)
Repeated exposure caused: No significant toxicological effects (NOAEL 25,000 ppm).
Carcinogenicity: No carcinogenicity data available for this product.
Reproductive toxicity: No reproductive toxicity data available for this product.

11.3 Sodium Bicarbonate

Toxicity Data: Oral LD50 Rat: 4220 mg/ kg; Oral LD50 Mouse: 3359 mg/ kg
Product is slightly irritating to the skin, eyes and respiratory system.
Carcinogenicity: No carcinogenicity data available for this product.

12. Ecological Information

Ecotoxicity: Not determined
Mobility: Not determined
Persistence and degradability: Not determined
Bioaccumulative potential: Not determined
Other Adverse Effects: No information available for the product.

13. **Disposal Considerations**

Non-contaminated product is recyclable.
Dispose of waste in an approved chemical incinerator equipped with a scrubber in compliance with national, regional and local provisions that may be in force.
This material when discarded is not a hazardous waste as that term is defined by the US Resource, Conservation and Recovery Act (RCRA), 40 CFR 261.

14. **Transport Information**

Proper Shipping Name:	Liquified Gas n.o.s. (1,1,1,2,3,3,3-Heptafluoropropane)
Hazard Class or Division:	2.2
UN ID Number:	UN3163
Label:	Nonflammable gas.

When shipped in the FireFox™ Automatic Fire Extinguisher

Proper Shipping Name:	Fire Extinguisher containing compressed or liquefied gas
Hazard Class or Division:	2.2
UN ID Number:	UN1044
Label:	Nonflammable gas.

Data provided for information only. Please apply the appropriate regulations to properly classify an individual shipment.

15. **Regulatory Information**

EU Classification:	Nonflammable Gas
R Phrase(s):	None
S Phrase(s):	S Keep container in a well ventilated space.
Limit Values for Exposure:	None Established

EINECS Status:	All components are included in EINECS inventories or are exempt from listing.
EPA TSCA Status:	All components are included in TSCA inventories or are exempt from listing.
Canadian DSL:	All components are included in the DSL or are exempt from listing.
Canadian WHMIS:	Class A - Compressed Gas
SARA, CERCLA Status:	No components are listed under SARA section 302 (40 CFR 355 appendix A), SARA section 313 (40 CFR 372.65), or CERCLA (40 CFR 302.4)

16. Other Information

The information herein is presented in good faith and believed to be correct but does not purport to be all-inclusive and shall be used only as a guide. No warranty, expressed or implied, is given. QuickFire shall not be held liable for any damage resulting from handling or from contact with the above product. It is the buyer's responsibility to ensure that it's activities comply with Federal, State or national, provincial and local laws.

MSDS History: New MSDS 02/01/2009.

Notes

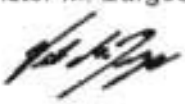
List of Calibrated Instrumentation Used for Testing

Description	Serial No.	Calibration Due Date
Thermo/Hygrometer	101324765	12-30-11
Stopwatch/Timer	91260650	11-24-11
Pressure Transducer	411870	10-12-11
Pressure Transducer	411910	10-11-11
Digital Manometer	08LE004	7-28-11

REFERENCES

1) QuickFire Fire Suppression Technology product brochure, Product Description
2) Fire Foe Automatic Fire Extinguisher with Envirogel, Owners Manual & Installation Instructions, Rev. 04/05

REVISION SUMMARY

DATE	SUMMARY
October 25, 2010	Original Issue Date
November 16, 2010 Victor M. Burgos  Mike Dey 	Revised report as per client's request with the following changes. 1) Added revision number and date throughout report 2) Section 3.2 – Added additional sample assembly descriptions to FT250 tube and installation 3) Section 4 – Added steel glove box panel designation numbers and transducer locations 4) Section 5 – Added additional post test notes 5) Section 6 – Conclusion – Added table displaying tube activation times, individual temperatures, and temperature average for each event 6) Appendix A, Test Data – Added Acetone Ignition and Tube Activation to graphs; Extended temperature and pressure transducer test data to include more data points at the actual +/- pressure events 7) Appendix B, Test Photographs – Added additional sample assembly photos, inserted descriptions to all photos

Appendix E: Technical Bulletins for FE-25™ and FE-36™

(See attached document.)

For further information regarding DuPont Fire Extinguishing Agents, contact:

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Compatibility

DuPont experience with FE-36™ indicates no compatibility problems with common metals during storage as long as moisture is excluded.

In tests performed by the National Institute of Standards and Technology (NIST), certain types of steel, stainless steel, and aluminum in contact with FE-36™ for 28 days at 149°C (300°F) showed no change in appearance.

DuPont two-week tests at room temperature indicate that most common elastomers have negligible swelling, weight gain, and hardness change when exposed to FE-36™, as shown in Table 2.

Availability

FE-36™ is available worldwide in 145-lb and 1,200-lb net weight packages as well as tank trucks or ISO-tank containers

Table 2
Common Elastomers Exposed to DuPont™ FE-36™

	Linear Swell, %	Weight Gain, %	Hardness Change, Units
Butyl Rubber	0	1	0
Nordel® EPDM	1	2	-2
Neoprene	-1	1	3
NBR (Buna-N)	1	3	-4
Hypalon®	-1	1	-1
Viton® A	15	51	-13
Epichlorohydrin Homopolymer	-1	1	0
Polysulfide	-1	1	-1
Hytrel® TPE	2	7	1
Teflon®	—	2	—

Recognition

As a streaming agent, FE-36™ is listed as acceptable for non-residential use under the EPA's Significant New Alternatives Policy (SNAP) program. Also, it is acceptable, without use limits, as a replacement for Halon 1301 in explosion suppression and explosion inertion applications. For total flooding applications FE-36™ may be used where other agents are not technically feasible due to their physical, chemical, or safety properties.

The EPA specifically accepts the FE-36™ system for use inside textile process machinery.

Underwriters Laboratories lists FE-36™ as a recognized component in portable fire extinguishers. Acceptance by Factory Mutual is pending.

The U.S. Coast Guard has granted FE-36™ approval for marine applications.

FE-36™ is included in National Fire Protection Association (NFPA) Standard 2001 and in draft versions of Standard 14520, Gaseous Fire Extinguishing Systems, being developed by the International Organization for Standardization (ISO).

FE-36™ is listed under the Toxic Substance Control Act (TSCA) and the European List of New Chemical Substances (EC-nr.475-320-1).

Table 1
Properties of DuPont™ FE-36™ Fire Extinguishing Agent

Formula	1,1,1,3,3,3-hexafluoropropane
Molecular Weight	152
Boiling Point, °C	-1.4
°F	29.5
Ozone Depletion Potential (ODP)	0
Global Warming Potential (GWP)*	6,300
Atmospheric Lifetime (yrs)	209
Liquid Density at 25°C (kg/m³)	1,360
77°F (lb/ft³)	84.89
Vapor Pressure at 25°C (kPa)	272.4
77°F (psia)	39.5
Heat of Vaporization at B.P. (cal/g)	38.21
(Btu/lb)	68.77
Approximate Lethal Concentration (ALC)**, ppm	>189,000
Cup Burner (in heptane), %	6.3
Cardiac Sensitization	
No Observed Adverse Effect Level (NOAEL), %	10
Lowest Observed Adverse Effect Level (LOAEL), %	15
Allowable Exposure Limit (AEL)***, ppm	1,000

*100-year time horizon.

**Rats, 4 hr.

***Continuous exposure, 8- to 12-hr day.

DuPont™ FE-36™

FIRE EXTINGUISHING AGENT

Technical Bulletin

Description

DuPont™ FE-36™ (HFC-236fa) is a new fire extinguishing agent that is replacing Halon 1211 in portable extinguishers and other streaming applications. FE-36™ is noncorrosive, electrically nonconductive, free of residue, and has zero ozone-depletion potential (ODP). Its boiling point and vapor pressure (see **Figure 1**) are nearly the same as Halon 1211. DuPont's tests, and those sponsored by the U.S. Navy and the Environmental Protection Agency (EPA), indicate a very low level of toxicity.

Applications and Performance

FE-36™ is ideally suited for use in portable fire extinguishers for high-value applications, such as in computer areas, telecommunication facilities, process control rooms, and commercial/military aviation. Extinguishers containing FE-36™ have been rated as 5-B, 1-A:10-BC, and 2-A:10-BC in tests performed to Underwriters Laboratories Standard 711 using agent quantities comparable to that of Halon 1211. In Europe, FE-36™ extinguishers have been tested to Standard BS EN3 and achieved 5A 55B C and 8A 70B C ratings.

Apart from portables, FE-36™ may be used as a streaming agent in fixed systems where the discharge is aimed at the likely source of the fire. Automotive engine compartments are an example of this use.

At room temperatures FE-36™ functions well as a total flooding agent. Its low toxicity and high efficiency make it particularly attractive for use in normally occupied spaces.

Toxicity

Toxicity tests show no remarkable clinical signs in 90-day inhalation studies. All genotoxicity tests were negative. Developmental toxicity studies are favorable. Tests for cardiac sensitization show a 10% No Adverse Effect Level (NOAEL) and a 15% Lowest Adverse Effect Level (LOAEL). Comparable values for Halon 1211 are 0.5% NOAEL and 1.0% LOAEL.

Figure 1. Saturated Vapor Pressure of DuPont™ FE-36™

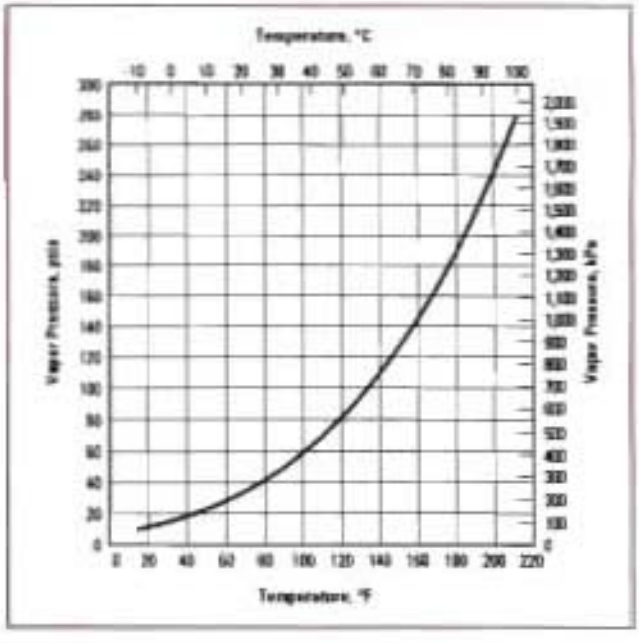

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Table 2
Elastomer Compatibility

	Linear Swell, %	Hardness Change
Adiprene® U	2	-2
Nitrile Rubber NBR	**1*	-6
Butyl Rubber	-1	2
Hypalon® CSM	1	-1
Natural Rubber	-1	1
Neoprene CR	3	-5
Nordel® EPDM	-1	-2
Silicone	4	-5
FA® Polysulfide	-1	2
Viton® A	** 9**	-10

*Sample lost elasticity, did not return to original shape when deformed

**Sample blistered

Specifications

FE-25™ is of high organic purity and essentially residue-free, meeting the following quality specifications:

Purity, % by weight, minimum	99.0
Moisture, ppm by weight, maximum	10
Acidity, ppm by weight, expressed as HCl, max	0.1
Residue, % by volume, maximum	0.01

For further information regarding DuPont Fire Extinguishing Agents, contact:

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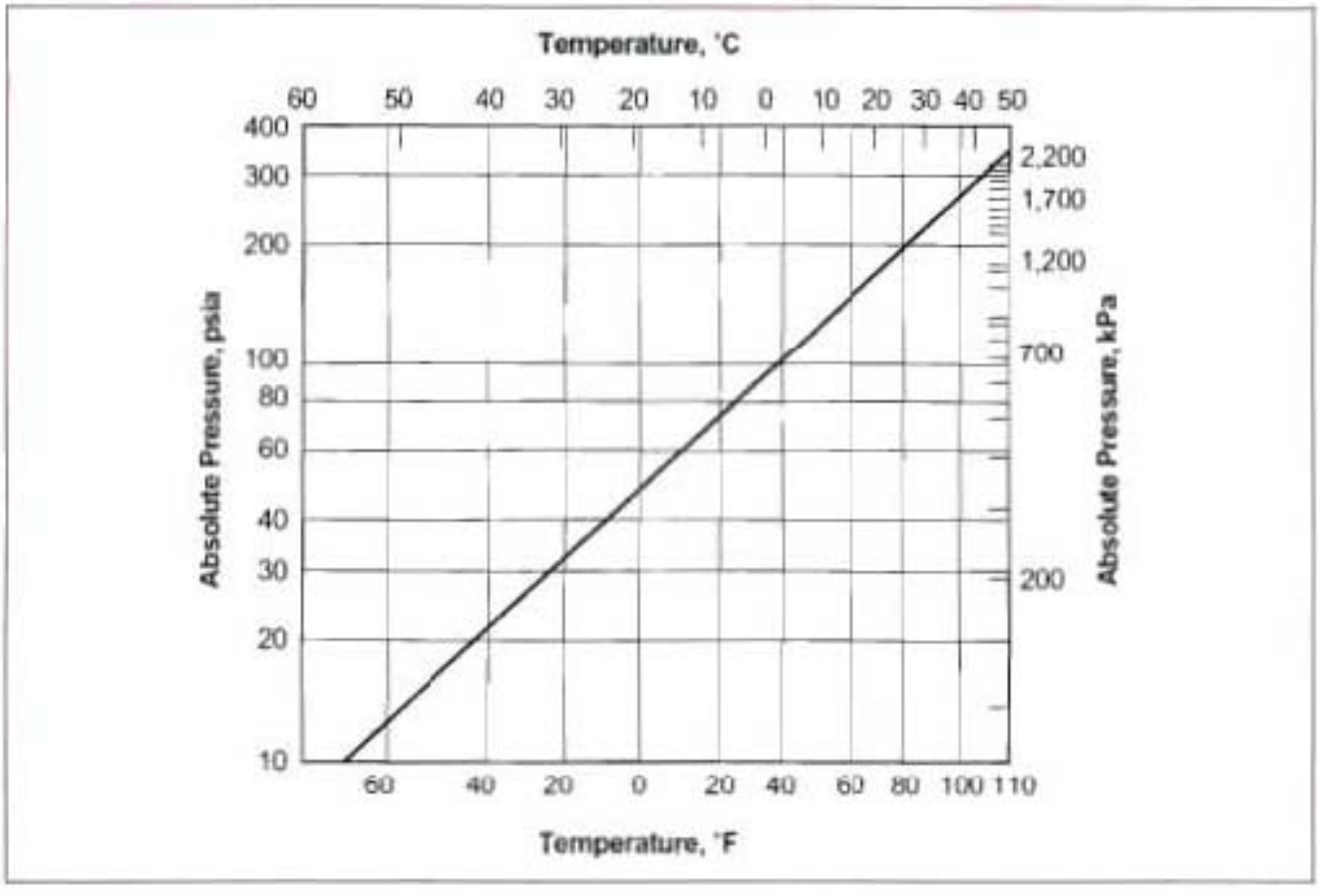
Figure 1. Saturated Vapor Pressure of DuPont™ FE-25™



Environmental

FE-25™ is an environmentally preferred alternative to Halon 1301. Unlike Halon, FE-25™ does not contain chlorine or bromine and therefore has zero ozone-depletion potential (ODP). Like many fluorine-based gases, FE-25™ has some global warming potential. The global warming potential for FE-25™ is 2,800, based on a 100-year time horizon relative to CO_2. This is one of the lowest for the chemical agents commercially available. The overall environmental impact is minimized by improved detection technology to eliminate unwanted emissions into the environment.

Compatibility

NIST tests concluded that FE-25™ showed no decomposition at 150°C (302°F) in the presence of eight commonly used metals for one-month exposure tests. FE-25™ exhibited good compatibility with a spectrum of cross-linked elastomers. The data in Table 2 are based on DuPont tests of each elastomer subjected to aging at room temperature for two weeks in FE-25™.

Availability

FE-25™ is in commercial production and ready to serve the fire protection industry. It is available in tank trucks, ton tanks (1,200 lbs net), and cylinders (90-lbs net).

The concentration of FE-25™ required to inert an atmosphere containing a flammable concentration of methane has been measured as 14.7%. The inerting concentration is defined as the percentage of agent in air that inhibits the propagation of a flame. It is typically measured using the specific fuel and an ignition spark energy of 68 Joules. The inerting concentration is always greater than an agent's extinguishing concentration.

Application

Total Flooding of Class-A Hazards

FE-25™ is an ideal replacement for Halon 1301 for the total flooding of enclosures. It can be used in applications where people are normally present (normally occupied spaces) for Class-A fire assets. Class-A fire assets represent greater than 90% of all commercial protection scenarios. Examples of applications where FE-25™ would be an excellent choice for a total flood fire suppression system where people are present are: computer rooms, telecommunication switch stations and facilities, semi-conductor manufacturing facilities, data processing centers, clean rooms, industrial process control rooms, museums, libraries and historical sites.

Total Flooding of Class-B Hazards

FE-25™ can also be used to suppress Class-B fire hazards. Examples of these applications would include: engine compartments, petrochemical facilities, chemical storage rooms, paint lockers and other areas where hydrocarbon-based materials are stored or handled.

Protection of Aircraft Engine Nacelles

FE-25™ was selected by the U.S. Department of Defense to undergo full-scale testing for engine nacelle applications as a replacement for Halon 1301 in new aircraft designs. This selection follows a comprehensive 17-month study at Wright-Patterson Air Force Base coordinated by National Institute of Standards and Technology (NIST) involving 12 candidate agents. NIST evaluated performance of the candidate agents over the flight envelope noting agent discharge characteristics, toxicity, and agent compatibility. As a result, the Navy has specified FE-25™ for the engine nacelles of aircraft such as the F/A-18 E/F and V-22.

Flow Simulant

HFC-125 (FE-25™) demonstrates the closest match to the flow characteristics of Halon 1301. As a result, FE-25™ is used for system flow verification, eliminating the use and discharge of Halon 1301, an ozone-depleting substance, into the atmosphere. The pressure traces, vaporization, and spray patterns for HFC-125 nearly duplicate that of Halon 1301.

Explosion Suppression

FE-25™ is currently used commercially in the area of explosion suppression. The primary application for FE-25™ in explosion suppression is to stop grain elevator explosions by stopping flame propagations in a fraction of a second.

Toxicity

HFC-125 (FE-25™) is one of a series of fluorocarbon alternatives that was tested by the Program for Alternative Fluorocarbon Toxicity Testing (PAFT). It has very low acute toxicity by inhalation. As with most other halocarbons, HFC-125 produces a cardiac sensitization response in experimental screening studies.

NFPA 2001 Standard provides guidance for human exposure limits for various clean agent alternatives. The Standard lists HFC-125 acceptable for use in normally occupied spaces. For design concentrations up to 11.5%, the EPA recommended, Physiologically-Based Pharmacokinetic (PBPK) method allows an exposure time limited to a duration of five minutes. Typical design concentrations used for Class-A hazards are 8.0% (NFPA) or 8.7% (ISO).

It was also determined that HFC-125 does not cause developmental toxicity and is not mutagenic. The DuPont Acceptable Exposure Limit (AEL) for HFC-125 is 1,000 ppm by volume for an 8- to 12-hr time weighted average. This chronic exposure limit of 1,000 ppm in air, corresponds to the highest value conventionally used for an organic material. The AEL provides limits for long-term exposure in manufacturing operations.

During application as a fire suppressant, HFC-125 has the potential to form acid by-products, as is the case with all other halogenated agents. Rapid fire detection combined with short discharge times will minimize the formation of by-products.

DuPont™ FE-25™

FIRE EXTINGUISHING AGENT

Technical Bulletin

Description

DuPont has developed a Halon 1301 alternative fire extinguishing agent, called FE-25™, for use in a wide range of total flooding and inerting applications. DuPont™ FE-25™, pentafluoroethane or HFC-125, is a safe, clean, and electrically non-conductive agent that is intended to protect people, high value assets and the continuity of business. FE-25™ demonstrates the closest physical property match to Halon 1301 in terms of both flow characteristics and vapor pressure.

FE-25™ has been validated by independent agencies and received component approval from Factory Mutual Research Corporation (FM). It is listed as an acceptable replacement for Halon 1301 in the United States Environmental Protection Agency's Significant New Alternative Policy (SNAP) program for fixed fire extinguishing systems. FE-25™ has zero ozone depletion potential and is an environmentally preferred alternative to Halon. It is also listed in the National Fire Protection Association (NFPA) 2001 Clean Agent Standard and the International Standards Organization (ISO) 14520 Standard.

Performance

The accepted Minimum Extinguishing Concentration (MEC) for FE-25™ for Class-A fires is 6.7% based on the Class-A fire test requirements found in the Underwriters Laboratories' (UL) Standard 2166. For Class-B fires, the MEC is 8.7% based on cup-burner tests with n-heptane fuel. Minimum Design Concentrations (MDC) should be based on the specific hardware manufacturer's MEC plus a safety factor of 20% -30% depending on the requirements of the local Authority Having Jurisdiction (AHJ).

Testing has demonstrated that FE-25™ closely matches the flow characteristics of Halon 1301. This feature may allow FE-25™ to be used in Halon 1301 piping networks when retrofitting existing systems.

Properties of FE-25™ are compared with Halon 1301 in **Table 1**.

Table 1
Typical Properties of DuPont™ FE-25™

	Halon 1301	FE-25™
Chemical Formula	CF_3Br	CF_3CH_2F
Ozone Depletion Potential	16	0
Molecular Weight	148.9	120.02
Boiling Point, °C (°F)	-57.7 (-72.0)	-48.3 (-55)
Critical Temperature, °C (°F)	152.6	66.3 (151.3)
Liquid Density at 77°F, lb/ft³	96.01	74.27
Vapor Pressure at 77°F, psia	234.8	200.4
Heat of Vaporization at Boiling Point, Btu/lb	51	71
Extinguishing Concentration, Heptane, Cup Burner, vol %	3.5	8.7
Acute Toxicity, ALC or LC50 Rats, 4 hr-ppm	400,000-800,000*	>700,000

*Estimated values

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