Full Scale Test Evaluations of Halon 1211 Replacement Agents for Airport Fire Fighting

Joseph A. Wright FAA
Charles Risinger WL/FIVCF

INTRODUCTION

A. OBJECTIVE

The object of this test program was to evaluate extinguishing agents which are candidates for replacement of Halon **1211** to be used for airport fire fighting and airport flight line fire fighting use. The test protocols were based on past full-scale fire test evaluations conducted by the Federal Aviation Administration (FAA) (AGFSRS **71-1,1972**, & DOT/FAA **82/109, 1982)** to determine the acceptability of using Halon **1211** as a clean fire extinguishing agent at commercial airports. Specifically, a comparison was made of the fire performance of Perflurohexane (3-M Corporation) and Halotron I (American Pacific Corporation), relative to Halon **1211**, for the extinguishment of small pool fires, three-dimensional flowing engine fuel fires and inclined plane running fuel fires.

The tests were conducted by the Wright Laboratory Air Base Fire Protection and Crash Rescue Systems Section, Tyndall, AFB, Florida.

B. BACKGROUND

Halon **1211** is a very effective "clean" fire extinguishing agent. This product was approved as an extinguishing agent for flight line equipment and crash fire vehicles by the FAA Administrator in about **1972**. The National Fire Protection Association (NFPA) defines a "clean agent" as an electrically nonconductive, volatile or gaseous fire fighting agent that does not leave residue upon evaporation. For many years Halon 1211 has been relied upon as the first line of defense for aircraft maintenance and flight line operational personnel for fighting small engine and nacelle fires.

Halon **1211** has been identified as a stratospheric ozone depleter. Its production was banned in January **1, 1994**, as specified by the November **1992** Copenhagen Amendments to the Montreal Protocol. The

FAA negotiated with the U.S. Environmental Protection Agency's (EPA) Significant New Alternatives Policy (SNAP) program administrator for the continued use of Halon 1211 until a suitable substitute could be found. The following restriction were agreed upon for civil fire fighting use: 1) Only critical fire fighter training would be accomplished. 2) All trucks may be reserviced with recycled Halon 1211 if existing contents are used. 3) Trucks left in service would be fitted with leak-proof safety valve devices. 4) A research and development program would be under taken to look at the performance of replacement candidate agents.

Perflurohexane and Halotron I are two clean streaming extinguishing agents which are candidate replacements for Halon 1211. Only Halotron I was approved by EPA as a streaming agent candidate for civil flight line and fire vehicle use under the SNAP program. Perflurohexane was initially approved as a military application, flight line clean candidate agent. The FAA research program evaluated both of these agents as possible candidates for fire fighting use from the beginning of this research program. Specific properties of these products are contain in table 1 page 8.

C. Scope

This test program quantifies the fire extinguishment performance of Perflurohexane and Halotron I. In addition it reestablished the test articles and test protocols by which any future candidate agent could be evaluated. The following tests were conducted: agent throw-range, dry-pool fire extinguishment, three-dimensional inclined-plane running fuel fire, simulated engine-nacelle running-fuel fire, and simulated wheel-well fires involving hydraulic fluid. All tests except the wheel-well fire used JP-4 as the fuel.

Initially, all three agents were dispensed using a standard Amerex Model 600 extinguisher. However, it became apparent early in the testing that the standard Amerex extinguisher was not the optimum system for dispensing Halotron I. Despite following precise extinguisher loading procedures, a smooth, continuous flow of agent could not be achieved throughout the entire duration of discharge. It was concluded that the pulsating flow or "chugging" was due mainly to a drop in extinguisher pressure during discharge.

Based on the hypothesis that Halotron I performance would be improved if a constant agent discharge rate could be achieved, American Pacific Corporation (AMPAC) developed a modification to the 150 pound capacity standard Amerex Model 600 extinguisher. The modification basically consisted of the addition of a booster cylinder filled with Halotron I expander gas. The purpose of the expander gas was to maintain a constant extinguisher operating pressure. At the request of the FAA, additional Halotron I testing (using modified extinguishers) was conducted.

Through a contract with the Amerex Corporation, AMPAC further optimized their modified extinguisher design. At the request of the FAA, this extinguisher configuration was also tested.

Test Protocol

A. INTRODUCTION

It has been over twenty years since Halon **1211** was evaluated under full-scale aircraft ground fire conditions. The FAA Technical Center's Fire Safety Branch has taken the position that any test protocols developed for evaluation of replacement candidates clean extinguishing agent should duplicate as much as possible the original test scenarios for quantifying Halon 1211 as a flight line stand-by bottle and fire vehicle auxiliary extinguishing agent.

The five unique fire extinguishing tests utilized in this evaluation program are below.

B. AGENT THROW-RANGE TESTS

The agent-specific, effective throw-range of the Amerex Model 600 (150-pound) extinguisher was assessed by discharging Halon **1211**, Perflurohexane, and Halotron I over a linear array of fire pans. The eleven, 11-inch diameter pans were spaced 36 inches from center-to-center. Each pan contained 1/4 inch of fuel floating on 3 inches of water. At thirty seconds after the last pan was ignited, the agent was discharged from the fixed nozzle located 21 feet from the first pan. The nozzle was positioned 32 inches above and parallel to the ground. The extinguishers were allowed to fully discharge. The test objective was to establish the maximum effective throw range for each candidate agent.

C. DRY-POOL FIRE EXTINGUISHMENT TESTS

pool fire extinguishment tests are usually conducted by floating the fuel on a "pool" of water. These tests are not representative of most small fuel spills. A common scenario is the spillage of fuel on a dry, level concrete surface. To simulate this event, JP-4 fuel was poured onto a flat level concrete surface, and ignited (dry-pool fire test). Fuel spill area was varied between 250 and 800 square feet. The approximate quantity of fuel required to cover a given area of concrete surface is shown in Table 2 . As soon as the entire spill area was involved in fire, the fire was extinguished by an experienced fire fighter using the 150-pound Amerex extinguisher. The objective of the dry-pool fire test was to extinguish the fire' as quickly as possible.

D. THREE-DIMENSIONAL INCLINED-PLANE TESTS

A fire scenario common to many aircraft accidents involves the flow of fuel from ruptured fuel tanks over sloping terrain. The tests apparatus constructed to simulate this condition was a 20-feet long, 5-foot wide steel ramp with a catch basin at the base which measured 4 feet by 8 feet (figure 1). The ramp had a slope of 1 inch per foot. To more accurately represent actual field conditions, the steel ramp was over laid with 1.5 inches of concrete. JP-4 was discharged at the rate of 3 gpm (gallons per minute) through five holes in the horizontal pipe positioned across the top of the incline (fuel feed). After 1/4 inch (5 gallons) of fuel accumulation in the catch pan, the fire was ignited. Following a 30 second preburn, the fire was extinguished using the 150 pound Amerex extinguisher. The fire fighting approach employed in these tests was to initially extinguish the catch basin, and drive the fire up the ramp toward the fuel spray bar. The fire fighter was positioned on the windward side of the ramp. The test objective was to extinguish the fire as rapidly as possible.

E. SIMULATED ENGINE-NACELLE RUNNING-FUEL FIRE TESTS

This test article was designed to evaluate agent penetration and extinguishment capability for a full-size F-100 jet engine mockup apparatus (figure 5 & 6) with fuel flow externally from the engine nacelle cavity onto the concrete pavement below. The slightly lower afterburner end of the engine-nacelle test apparatus (figure 5) was unblocked to permit fuel flow out of this end of the nacelle and onto the concrete pavement. A 5-gpm fuel flow rate was initiated from the nacelle afterburner fuel nozzle. Twenty-four gallons of JP-4 was allowed to flow onto the concrete test pad before ignition. Following a 15 second preburn, the fire was attacked using the 150 pound Amerex extinguisher. The test objective was to extinguish the fire as rapidly as possible. A less severe nacelle test with 15 gallons of fuel on the concrete pad was also conducted.

F. SIMULATED WHEEL-WELL FIRE INVOLVING HYDRAULIC FLUID

This test apparatus was designed to simulate a wheel-well hydraulic fluid fire ignited by a hot brake. The apparatus consisted of an F-4 aircraft tire and magnesium rim mounted on a stand inside a 4 foot by 4 foot steel pan. A 2 gallon discharge of hydraulic fluid was placed inside the pan. After an additional 1 gallon of hydraulic fluid was poured on the tire itself, the fire was ignited. The most flammable MILSPEC hydraulic fluid specified for aircraft systems was used (MIL-H-5606F). Following a 90 second preburn, the fire was attacked using the 150-pound Amerex extinguisher. Using the proper technique for this situation, the fire fighter approached the wheel from a direction perpendicular to the axle. As an additional safety precaution, the aircraft tire was deflated prior to testing. The test objective was to extinguish the fire as rapidly as possible.

G. DATA COLLECTION

Two video cameras were used to record all test activities. Dozens of still photographs were taken to record significant events. All pertinent test data was recorded. Standard weather data including wind direction and velocity, temperature, and relative humidity were recorded for each test.

H. TEST RESULTS

Preliminary test results are contain in tables 3,4,5, and 6. Test results are published in report WL-TR-93-3520 Halon 1211 Replacement Agent Evaluation available through Wrights Laboratory, Tyndall A.F.B.

I. CONCLUSIONS

When using the standard Amerex Model 600 extinguishers to dispense each agent, neither Perflurohexane or Halotron I exhibits the extinguishing performance of Halon 1211 under all of the fire scenarios tested for equivalent weights of agents (only under one inclined plane test condition was any of the replacement agents in this case Halotron I, superior to Halon 1211). Comparing the replacement agents, Halotron I proved to be slightly more effective than perflurohexane for extinguishing the five fire scenarios tested during this project. Halotron I was nearly twice as effective as perflurohexane for extinguishing the inclined-plane running-fuel fires. and 33 percent more effective than perflurohexane for extinguishing the wheel-well hydraulic fluid fires. Both agents exhibited equal performance on the dry-pool fires and the engine-nacelle running-fuel fires. Perflurohexane outperformed Halotron I in the effective throw-range testing.

Performance of the Halotron I system was improved by optimizing the Amerex extinguisher with an expander gas booster cylinder. The magnitude of the improvement was not quantified since the optimized extinguisher was not tested against the original fire test scenarios. Using the optimized extinguisher, the "chugging" problem was eliminated, and the agent discharge rate was increased by 36 percent. Additionally, the throw-range was improved (based on visual observations), and the agent capacity of the extinguisher was increased from 130 pounds to 180 pounds. With the booster installed the first two incline-plane fires were not extinguished. The third and forth test were extinguished successfully.

J. FUTURE TESTS

Additional test will be accomplished to evaluate the performance of the candidate agents using a large capacity twin agent fire extinguishing unit. Test videos and test observation showed that in many of the fires the fire fighters were close to controlling the fire when all available agent had been exhausted. The assumption is that if a larger capacity appliance had been available, total extinguishment could have occurred in many of the first round tests.

It should be understood that this is a continuing program and further work is contemplated in the near future. Each agent will benefit from further optimization of the delivery systems which are used to expel the agent. When reviewing the tables of test results, one can easily arrive at a conclusion that these agents will not work as a clean extinguishing agent from the large number of failed extinguishments. These tests are designed as the worst case situations for which an gaseous agent can be expected to perform. Clean auxiliary agents are considered an economic option to dry powder and AFFF. If performance is the only issue to consider dry chemical powders can be expected to exhibit equivalent performance to Halon **1211.**

References:

Geyer.G B., Evaluation of Aircraft Ground Fe Techniques, FAA-RD-71-57, AGFSRS 71-1, **1972**

Geyer, G. B. Equivalency Evaluation of Firefighting Agents and Minimum Requirements At U.S. Air Force Airfields, DOT/FAA **82/109,1982**

Rocheford M. A., Dees B. R., Risinger C. W., Halon 1211 Replacement Agent Evaluation= Perflurohexane and Halotron I, WL-**TR-93-3520**

TABLE 1. FIRE-EXTINGUISHING AGENT PROPERTY COMPARISON

Property	Halon 1211	perfluorohexane	Halotron I
Chemical Formula	CF_2ClBr	C_6F_{14}	$C_2HCl_2F_3$ + (exp)
Molecular Weight	165.4	338	150.7
Boiling Point	-4°C	56°C	27°C *
Liquid Density at 25°C	1.79 kg/l	1.68 kg/l	1.48 kg/l
Vapor Pressure at 25°C	2.67 bar	0.31 bar	15.49 bar **
Atmospheric Lifetime ***	12.5 - 25 yrs.	500 - 1000 yrs.	3.5 - 11 yrs.
Ozone Depletion Potential (ODP)	4	0	0.014
Acute Toxicity, ALC, LC_{50} (4 hrs.)	3.1 - 10%	> 30%	> 3%

* For blend at 1 atm., 70% filling ratio, 1 kg/l filling density
** Vapor pressure for blend and expander gas
*** Depending on model used for calculation

Table 2

"Fuel Spill" Area Sq. Ft.	Fuel Required (gallons)
250	7
400	11
800	15

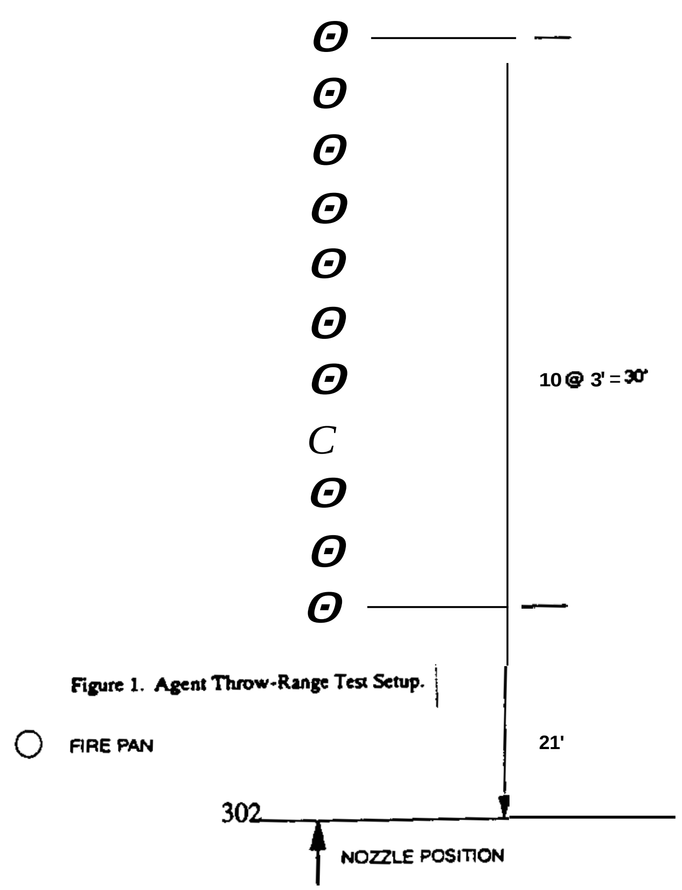

Figure 1. Agent Throw-Range Test Setup.

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FIRE RAMP

(WITH SPILL PAN)

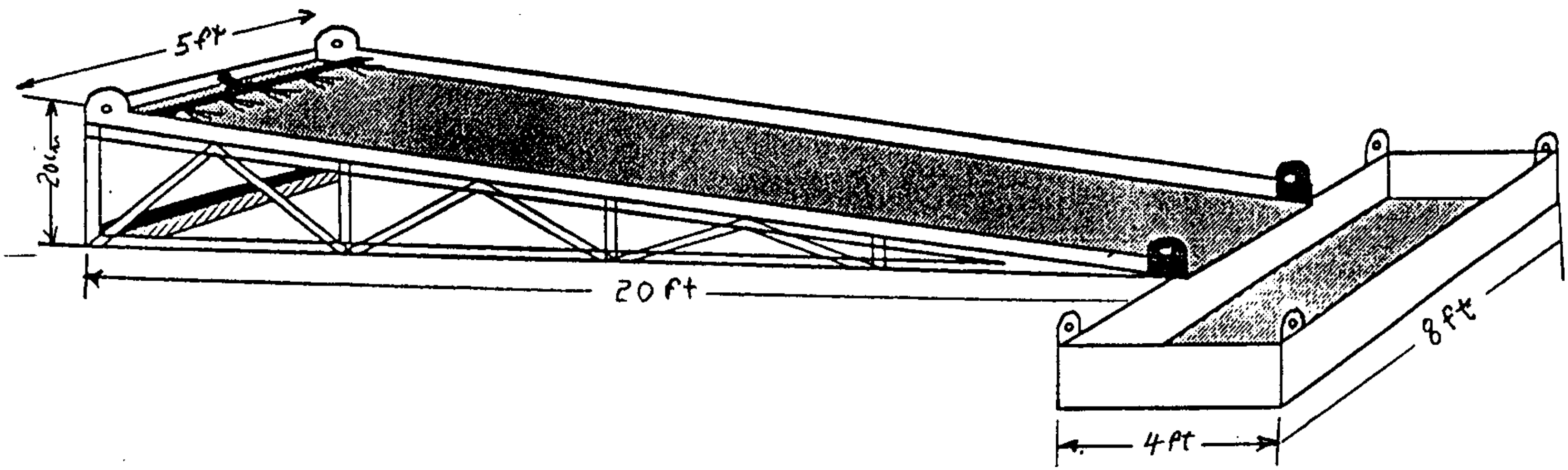

Figure 2

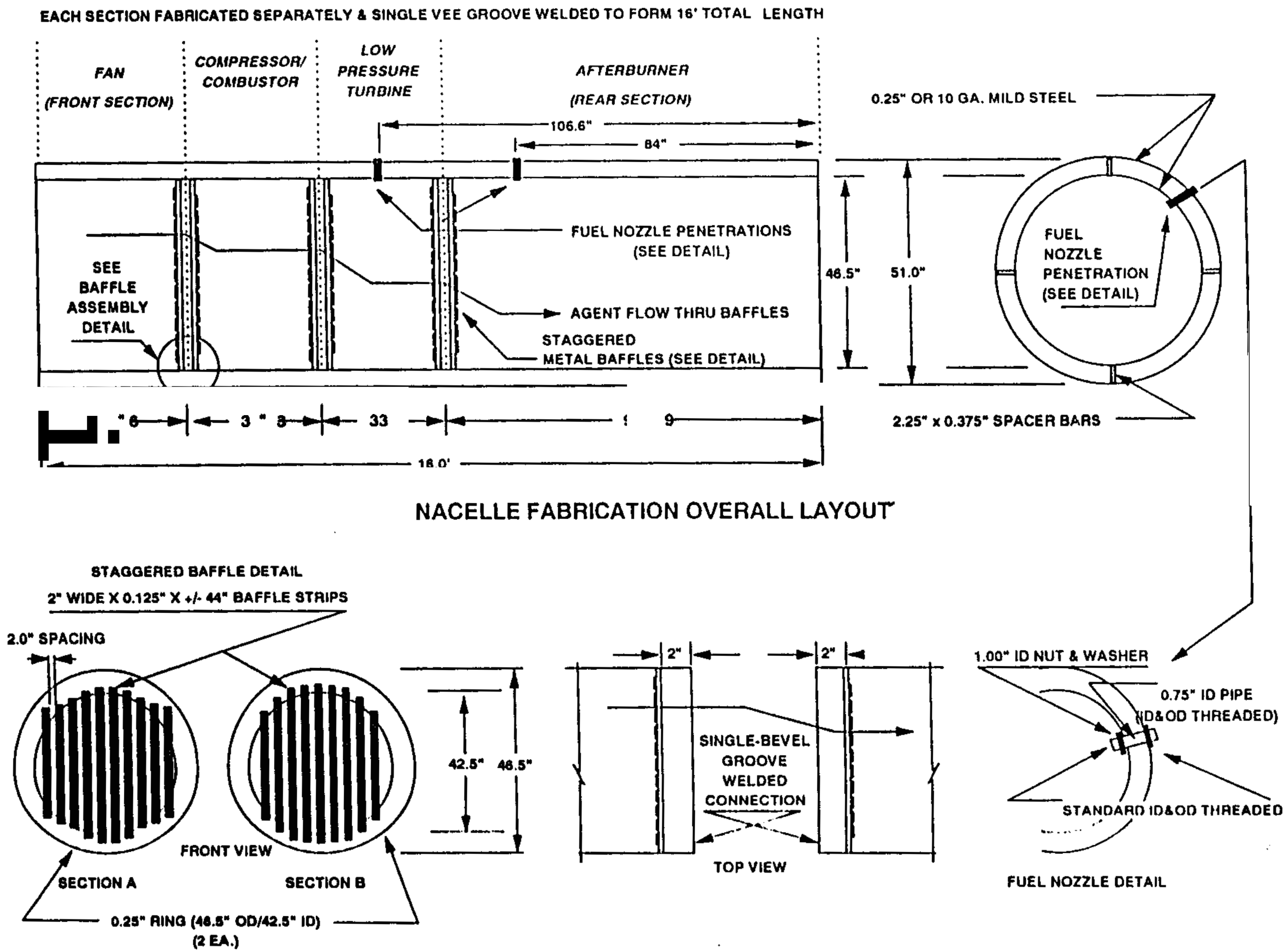

Figure 5. F-100 Engine-Nacelle Test Apparatus; Fabrication Drawing, Page 1.

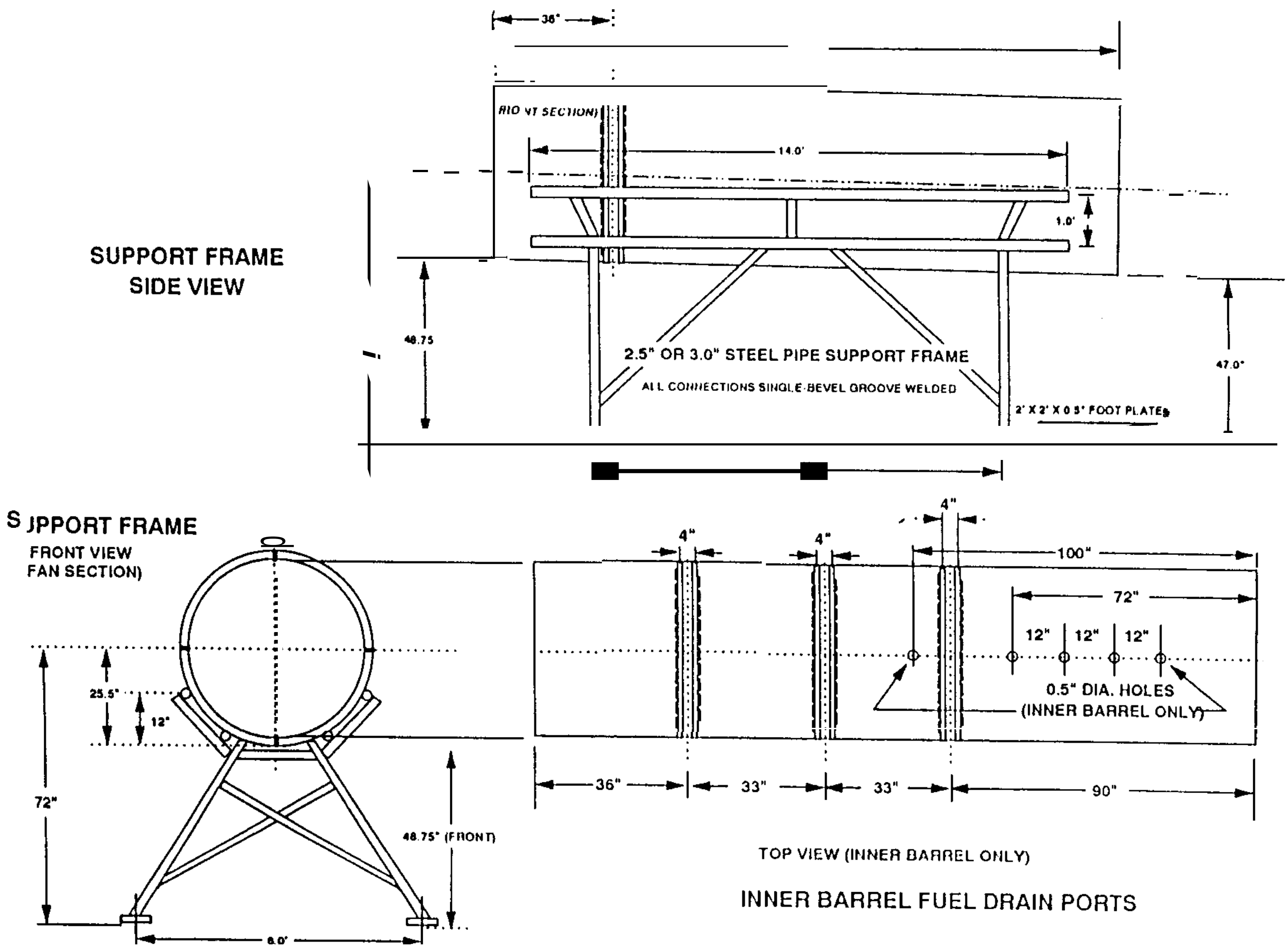

Figure 6. F-100 Engine-Nacelle Test Apparatus; Fabrication Drawing, Page 2.

TABLE 3. DRY-POOL FIRE RESULTS

Agent	"Fuel Spill" (ft^2)	Extinguishment Time (sec)
Halon 1211	250	4
	800	13
perfluorohexane	250	5.5
	400	13
	800	18
Halotron I [a]	250	6.5
	400	8
	800	22
Halotron I [b]	25 gal	DNE
	25 gal	DNE
Halotron I [c]	10 gal	27
	15 gal	DNE
	20 gal	30
	20 gal	20

[a] standard Amerex Model 600
[b] Amerex Model 600 with 1200 psi booster
[c] Amerex Model 600 with 2000 psi booster

DNE: *Did not extinguish*

SIMULATED ENGINE-NACELLE RUNNING-FUEL FIRE TESTS

TABLE 5. ENGINE-NACELLE RUNNING-FUEL TEST RESULTS (5 gpm flow rate)

Agent	Extinguishment Time (sec)
24 gallons JP-4 on pad	
Halon 1211	15
perfluorohexane	DNE
	DNE
Halotron I [a]	DNE
	DNE
15 gallons JP-4 on pad	
perfluorohexane	DNE
Halotron I [a]	DNE
Halotron I [b]	DNE
	DNE
10 gallons JP-4 on pad	
Halotron I [b]	DNE
	DNE
	26
Halotron I [c]	DNE
	DNE
	29
5 gallons JP-4 on pad	
Halotron I [b]	26
	37
Halotron I [c]	27

[a] standard Amerex Model 600
[b] Amerex Model 600 with 1200 psi booster
[c] Amerex Model 600 with 2000 psi booster

DNE: Did not extinguish

TABLE 4. THREE-DIMENSIONAL INCLINED-PLANE TEST RESULTS

Agent	Extinguishment Time (sec)
Halon 1211	23
perfluorohexane	28
	36
	40
Halotron I [a]	17
	13
	23
Halotron I [b]	DNE
	DNE
	17
	28

[a] standard Amerex Model 600
[b] Amerex Model 600 with 1200 psi booster

DNE: Did not extinguish

TABLE 6. WHEEL-WELL FIRE TEST RESULTS

Agent	Extinguishment Time (sec)
Halon 1211	5
perfluorohexane	18
Halotron I [a]	12

[a] standard Amerex Model 600