Comparative Evaluation of the Effectiveness of a High-Performance, Multiposition, Bumper-Mounted Turret to the Performance of a P-19 Roof-Mounted Turret

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16. Abstract

Advances in firefighting research have brought forth new concepts that have the potential for greatly enhancing firefighting capabilities of airport fire fighters. One such concept is the high-performance, multiposition, bumper-mounted turret. The research described in this report evaluated various operating characteristics of the high-performance, multiposition, bumper-mounted turret and compared those characteristics to the roof-mounted turret. Specific items addressed included extinguishment times for various types of fires, amount of agent required for extinguishment, throw ranges, and overall performance. To investigate these items, a high-performance, multiposition, bumper-mounted turret was mounted on the Federal Aviation Administration high-performance research vehicle. This vehicle was brought to the Air Force Research Laboratory at Tyndall Air Force Base, Florida, for the comparative evaluation. Testing involved three-dimensional engine nacelle and high engine nacelle tail fires, two-dimensional pool fires, water and agent throw range tests, and turret operations.

The evaluation concluded that the high-performance, multiposition, bumper-mounted turret was superior in performance to that of the roof-mounted turret. In all aspects of the evaluation, the data for throw ranges, extinguishment times, the amount of agent dispersed, and overall performance of the high-performance, multiposition, bumper-mounted turret far exceeded those from the roof-mounted turret. The high-performance, multiposition, bumper-mounted turret enabled the driver/operator to extinguish the test fires in less time and with less agent consumption than with the roof-mounted turret.

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LIST OF ACRONYMS AND SYMBOLS

2-D	Two-dimensional
3-D	Three-dimensional
AFB	Air Force Base
AFFF	Aqueous film-forming foam
ARFF	Aircraft Rescue and Firefighting
DEVS	Driver's Enhanced Vision System
DIF	Down-in-front
DNE	Did not extinguish
FAA	Federal Aviation Administration
FFOD	Firefighting operational distance
gpm	Gallons per minute
gps	Gallons per second
HPRV	High-performance research vehicle
HRET	High-reach extendable turret
mph	Miles per hour
NFPA	National Fire Protection Association
PCA	Practical critical area
PKP	Potassium bicarbonate
psi	Per square inch
rpm	Revolutions per minute
USAF	United States Air Force

EXECUTIVE SUMMARY

Advances in firefighting research have brought forth new concepts that have the potential for greatly enhancing firefighting capabilities of airport fire fighters. One such concept is the high-performance, multiposition, bumper-mounted turret. The research described in this report evaluated various operating characteristics of the high-performance, multiposition, bumper-mounted turret and compared those characteristics to the roof-mounted turret. Specific items addressed included extinguishment times for various types of fires, amount of agent required for extinguishment throw ranges, and overall performance. To investigate these items, a high-performance, multiposition, bumper-mounted turret was mounted on the Federal Aviation Administration high-performance research vehicle and was transferred to the Air Force Research Laboratory at Tyndall Air Force Base, Florida, for the comparative evaluation. Testing involved three-dimensional engine nacelle and high engine nacelle tail fires, two-dimensional pool fires, water and agent throw range tests, and turret operations.

The evaluation concluded that the high-performance, multiposition, bumper-mounted turret was superior in performance compared to the roof-mounted turret. In all aspects of the evaluation, the data for throw ranges, extinguishment times, the amount of agent dispersed, and overall performance of the high-performance, multiposition, bumper-mounted turret far exceeded those of the roof-mounted turret. The high-performance, multiposition, bumper-mounted turret enabled the driver/operator to extinguish the test fires in less time and with less agent consumption than with the roof-mounted turret.

INTRODUCTION

PURPOSE.

The test series compared the effectiveness and flow performance of a high-performance, multiposition, bumper-mounted turret (National Fire Protection Association (NFPA) 402 defines a turret as a vehicle-mounted master stream appliance) mounted on the Federal Aviation Administration (FAA) high-performance research vehicle (HPRV) to the flow performance and known operational capability of a United States Air Force (USAF) P-19 roof-mounted turret. The HPRV, with the bumper-mounted turret, is shown in figure 1, and the USAF P-19 with the roof-mounted turret, is shown in figure 2.

FIGURE 1. HIGH-PERFORMANCE RESEARCH VEHICLE WITH BUMPER-MOUNTED TURRET

FIGURE 2. UNITED STATES AIR FORCE P-19 WITH ROOF-MOUNTED TURRET

OBJECTIVES.

The objectives of the test series were to evaluate the performance and effectiveness of the HPRV high-performance, multiposition, bumper-mounted turret and compare it to the performance of a P-19 roof-mounted turret. To document these objectives, the following test criteria were established:

- Compare both turrets in extinguishment and agent used during F-100 engine nacelle test fires.

- Compare both turrets in extinguishment and agent used during tail-mounted, high engine nacelle fires.

- Compare both turrets in extinguishment and agent used during large-scale, two-dimensional (2-D) pool fires.

- Evaluate the performance of each turret in simulated aircraft crash firefighting situations using a large-scale aircraft mockup.

- Evaluate the water stream throw range performance of the high-performance, multiposition, bumper-mounted turret at various boom and turret elevations, and the P-19 roof-mounted turret at various elevations.

- Evaluate the aqueous film-forming foam (AFFF) throw range and pattern width of the high-performance, multiposition, bumper-mounted turret at various boom and turret elevations, and the P-19 roof-mounted turret at various elevations.

- Evaluate and compare the driver/operator performance using the high-performance, multiposition, bumper-mounted turret and the P-19 roof-mounted turret while driving and operating the vehicles under test conditions.

BACKGROUND.

The HPRV is a test platform for new and innovative concepts of interest to civil and military aviation fire protection. In the past, a high-reach extendable turret (HRET) was mounted and tested on the HPRV. Similarly, an all-weather Driver's Enhanced Vision System (DEVS) was developed and tested on the HPRV. These state-of-the-art devices provide significant advantages to responding aircraft rescue and firefighting (ARFF) personnel and are now commonly specified for new vehicle purchases or for retrofitting existing vehicles. The HPRV was equipped with a high-performance, multiposition, bumper-mounted turret developed by Crash Rescue System, Inc., Dallas, Texas, which was given the trade name Rhino™. The Rhino is an innovative product design that could significantly advance commercially available bumper-mounted turret designs and firefighting concepts. It has not been tested or evaluated in large-scale, 1000-gallon, open-air fossil fuel fires to determine its effectiveness or its limitations, nor has it been compared to the proven performance of a roof-mounted turret mounted on an ARFF vehicle. To date, the only manufacturer information or performance data related to the bumper-mounted turret is in the form of an owner's manual and operating instructions. Information obtained from the tests and evaluations of the high-performance, multiposition, bumper-mounted turret can be transitioned to the U.S. military. This device, or a similar concept, could enhance the firefighting capability of current ARFF vehicles and serve as a low-cost alternative to an elevated platform or HRET for airport operators. The Air Force Research Laboratory's 100-ft-diameter, open-air burn facility (located at Tyndall Air Force Base (AFB), Florida), which contains a large-scale aircraft mock-up with test engine nacelles, is designed and instrumented to collect and validate aircraft crash parameters and to document the actual firefighting performance of new aviation industry devices such as the Rhino. The P-19 provides an accessible and realistic platform to perform comparison tests in a large-scale, live fire test environment.

METHODS AND PROCEDURES

All live fire and agent throw range tests were conducted in a controlled, outside 100-ft-diameter fire burn area. Every effort was made to simulate the same firefighting environment that might be encountered at actual aircraft crash fire incidents or accidents. Each test was replicated to ensure the accuracy of the data being collected. Multiple test fires i.e., simulated crash firefighting with a large-scale aircraft mock-up; large-scale, 2-D pool fires; F-100 engine nacelle test fires; and high engine nacelle tail-mounted fires were conducted in the presence of a variety of hot metal surfaces. Reignition sources, such as cascading over heated surfaces, fuel collecting in small pools, debris piles adjacent to the large-scale aircraft mockup, or fire within the engine nacelles, were also present.

A series of three tests of each turret type were conducted, and the results were averaged to achieve the final test results. If one of the test results varied by more than 25%, the tests were repeated and that average was used to establish the final test results. Extinguishment time, defined as the time required to completely extinguish all visible fire on or within the contained area or test apparatus, takes into consideration all the time needed to extinguish all visible fire, including the time to reposition around the periphery of the fire area. Fires occurring outside the test area, including those that might occur in the large-scale aircraft mockup, were not considered as part of the test.

Discharge time, defined as the recorded time of an actual discharge, was also recorded as a means to determine the actual amount of agent used during each live fire test. This data was compared to the amount of agent each vehicle needed to extinguish the same amount of fire in a given test situation following a predetermined test matrix.

In addition to an extensive number of live fire tests, throw range tests were also conducted. A comparison of the throw performance of the high-performance, multiposition, bumper-mounted turret on the HPRV and the roof-mounted turret on the P-19 was performed. Both turrets delivered 500 gpm of water or foam solution at 210 and 225 pounds per square inch (psi), respectively. Each head-to-head test series established the means to compare and evaluate the performance of the turrets during a range of operational tests. Throw range tests were conducted in calm wind conditions of 3 to 5 miles per hour, with the vehicle facing downwind.

TEST EQUIPMENT.

Data collection for the high-performance, multiposition, bumper-mounted turret and the P-19 roof-mounted turret was accomplished by using.

- Stopwatches to record fire extinguishment and preburn.
- A 250-foot measuring tape was used to measure throw distance and pattern widths.
- An inclinometer to measure elevation settings.
- Precut blocks of wood were used to ensure the stability of the P-19 roof-mounted turret during testing.
- Video was taken to record the fire tests and to verify all times.

TEST VEHICLES, TEST DEVICES, AND AGENTS.

THE FAA HPRV. Figure 1 shows that the HPRV is equipped with an HRET device (used to extinguish fires on the interior of aircraft), and a DEVS device to aid the ARFF (used at night and during adverse weather), which are mounted on the top of the vehicle. The HPRV is also equipped with the high-performance, multiposition, bumper-mounted turret (in the full-up home position), which is mounted on the front bumper. The HPRV engine provides pump and roll capabilities to the transmission and simultaneously provides power to the fire pump. When the HRPV is not involved in fire experiments, it is assigned to the Atlantic City International Airport Fire Department.

The HPRV was configured with the high-performance, multiposition, bumper-mounted turret shown in figure 3. The high-performance, multiposition, bumper-mounted turret, normally set to deliver 750 gallons per minute (gpm) at a high-flow setting and 375 gpm at a low-flow setting, was preset to discharge 500 gpm of AFFF solution at a rate of 8.3 gallons per second (gps). The 500-gpm discharge rate equals the discharge rate of the P-19 roof-mounted turret, thus making the two vehicles have comparable performance qualities. The high-performance, multiposition, bumper-mounted turret operates within a wide range of vertical and horizontal elevations. Joystick controls very similar to the controls found on other fixed roof-mounted turrets and deck guns control the dual agent extinguishing capability of the high-performance, multiposition, bumper-mounted turret.

THE P-19 TRUCK. A P-19 aircraft crash and structural firefighting truck, without the structural firefighting kit, was used in the comparison tests. Similar to the HPRV, the P-19 engine provides pump and roll capabilities to the transmission and simultaneously provides power to the fire pump. The P-19 shown in figure 4, with a roof-mounted, 500-gpm turret, was one of two P-19s used in the comparison tests.

The P-19's firefighting system is driven by a single-stage centrifugal water pump. The variable-stream, roof-mounted turret is made by Akron Brass and is rated at 500 gpm with a discharge pressure of 225 psi at the turret, delivering 8.3 gps. The P-19 roof-mounted turret is manually

FIGURE 3. THE HPRV WITH 500-gpm HIGH-PERFORMANCE, MULTIPOSITION, BUMPER-MOUNTED TURRET

FIGURE 4. THE P-19 WITH A STANDARD 500-gpm ROOF-MOUNTED TURRET

operated, aimed, and controlled by the driver/operator inside the cab. Directional control is maintained by a single handle, which moves the turret in both the horizontal and vertical planes. The position of the handle corresponds to the position of the turret. The turret discharge valve is activated by pressing the button on the grip-end of the turret's directional control handle once, and pressing the button again stops the discharge.

EXTINGUISHING AGENTS. Most aircraft incidents and accidents involve some type of three-dimensional (3-D) flowing fuel fires. The potential for igniting flowing fuel that comes in contact with hot metal surfaces is present in virtually every aircraft fire situation. Three-dimensional fires occur when fuel or hydraulic fluid from damaged lines and equipment on the aircraft continuously drain into normally dry bay compartments or external openings. The 2-D pool fire is constantly resupplied by a 3-D flowing fuel column and generally requires constant aggressive agent application for control. These factors make control and extinguishment of the combination 2-D and 3-D fires difficult when only a foam agent is applied. Three-dimensional agents are highly effective knockdown agents but do not possess adequate cooling and burn-back resistance to prevent reignition, and they are limited in their ability to be thrown (discharged) over long distances. The Mil Spec 3% AFFF concentrate used in this test is the most widely used foam agent in the world for extinguishing 2-D ground or surface pool Class B fires. Military and civil aviation crash fire trucks are equipped with foam/water pumps designed specifically for discharging AFFF. The AFFF has superior burn-back resistance to impinging fire by creating foam that quickly spreads across the surface of burning fuel and sealing flammable vapors.

The dry chemical chosen for the test was potassium bicarbonate (PKP). PKP has a good knockdown capability and is effective against pressurized 3-D fires, such as those occurring on oil wellhead fires. In commercial use, a purple dye is added to the dry chemical to visually aid fire fighters in discharging the agent into the fire. Similarly, the purple dye aided in determining how the agent interacted with the AFFF when it was discharged into the dual agent stream. When discharged by itself, slight breezes can easily influence the direction of the dry chemical. A gust of wind could diffuse the agent rendering it ineffective. A downwind approach was necessary to prevent the agent from being carried away in the wind.

TEST DESCRIPTION.

F-100 ENGINE NACELLE AND 30-ft-DIAMETER RING TEST DEVICE. The F-100 engine nacelle and 30-ft-diameter ring, shown in figure 5, were used to compare the ability of the turrets to extinguish flowing fuel fires from fixed ground-level fire threats that might occur from fires under wing engines.

The test configuration established a medium-scale 2-D and 3-D test apparatus for the initial comparison and evaluation of the turrets. The fire area in this test corresponds to the practical critical area (PCA) of a category 1 airport based on the NFPA 403 document titled "Standard for Aircraft Rescue and Firefighting Services at Airports." A category 1 airport, as described in NFPA 403, would include aircraft such as the Cessna 206 or Beech Bonanza 35. A 6-inch-high steel ring was placed on a level concrete slab to form a 30-ft diameter ring to contain the fuel within the ring and create the kind of fire scenario most likely to occur on a tarmac or other aircraft parking area. The hot metal surfaces on the F-100 engine nacelle and the 30-ft-diameter metal ring were sufficient to keep the JP-8 fuel vaporizing until the foam extinguished the fire and cooled the hot metal. Approximately 3 inches of water was put into the ring to establish a smooth, level surface for the 100 gallons of JP-8 jet fuel. The ring contained the fuel and prevented the fire from propagating outside the ring. Fuel spilling from the F-100 engine nacelle was ignited and allowed to flow into the 30-ft ring. The fuel was allowed to flow continuously throughout the test at a rate of 5 gpm. The fuel within the 30-ft ring was ignited immediately following ignition of the engine nacelle and allowed to preburn for 30 seconds to ensure a steady burn rate. Prior to the tests, each vehicle was placed in a stationary position 50 ft upwind of the engine nacelle and the 30-ft ring, as shown in figure 6. In this figure, the P-19 is shown attacking the fire from its prepositioned location upwind of the engine nacelle. To ensure a similarity in attack procedures, the high-performance, multiposition, bumper-mounted turret remained stationary in the fully extended position with articulation occurring at the turret. The driver/operator was permitted to move the nozzle as needed to extinguish the fire. This closely duplicated the action of the P-19 roof-mounted turret, resulting in a better comparison of the two devices. Once the optimum attack position was assumed, the fire vehicles were not allowed to reposition, but the driver/operator could move the turrets as necessary to extinguish the fire. The driver/operator was instructed to attack the fire as aggressively as possible and complete the extinguishment as quickly as possible. At the conclusion of each test, all water, foam, and fuel were removed from the ring and test fixture. Three tests of each agent or combination of agents were conducted to determine the unique suppression capability of each turret and the agent application technique. The test matrices shown in tables 1 and 2 were used as a guide for conducting the F-100 engine nacelle and 30-ft-diameter ring fire tests.

FIGURE 5. F-100 ENGINE NACELLE AND 30-ft-DIAMETER RING TEST DEVICE

FIGURE 6. TYPICAL VEHICLE POSITIONING FOR THE F-100 ENGINE NACELLE AND 30-ft RING FIRE TESTS

TABLE 1. THE HIGH-PERFORMANCE, MULTIPOSITION, BUMPER-MOUNTED TURRET F-100 ENGINE NACELLE FIRE TEST MATRICES

Test No.	Agent	No. of Fires
1-1A through 1-1C	3% AFFF (Mil Spec)	3
1-2A and 1-2B	Dry Chemical	2
1-3A through 1-3C	Combination Agent	3

TABLE 2. THE P-19 ROOF-MOUNTED TURRET F-100 ENGINE NACELLE FIRE TEST MATRICES

Test No.	Agent	No. of Fires
2-1A through 2-1C	3% AFFF (Mil Spec)	3

TAIL-MOUNTED, HIGH ENGINE NACELLE TEST DEVICE. The high engine nacelle test device shown in figure 7 was used to establish a baseline of performance for the high-performance, multiposition, bumper-mounted turret. The high engine nacelle is tail-mounted on the aircraft mockup approximately 25 ft above ground level and is equipped with high-pressure fuel spray nozzles similar to those used in the F-100 engine nacelle. In this fire scenario, fuel is sprayed from two orifices within the engine nacelle at a rate of 5 gpm. Initially, the fuel pools in the engine nacelle and then cascades downward over the simulated aircraft frame into a pool on each side of the aircraft. Fires occurred within the engine nacelle, on the aircraft surface, and in the pool formed by the flowing fuel. The pool fire is approximately 30 ft in diameter, contains 100 gallons of JP-8 on ignition, and generally corresponds to the PCA of a category 1 airport, based on NFPA 403. The degree of difficulty in extinguishing the fire was a test parameter. To ensure a similarity in attack procedures, the high-performance, multiposition, bumper-mounted turret remained stationary in the full-up position, with articulation occurring at the turret. This closely duplicated the action of the P-19 roof-mounted turret, resulting in a better comparison of the technologies used. Once the optimum attack position was assumed, the fire vehicles were not allowed to reposition, but the drivers/operators were free to move the turrets as necessary extinguish to the fire.

FIGURE 7. TAIL-MOUNTED, HIGH ENGINE NACELLE FIRE TEST DEVICE

The fire was attacked from an upwind stationary position approximately 50 ft from the engine nacelle. The driver/operator was instructed to attack the fire aggressively and complete the extinguishment as quickly as possible. At the conclusion of each test, all water, foam, and fuel were removed from the engine nacelle, aircraft, and pool fire area.

The matrices shown in tables 3 and 4 were used to establish the minimum number of fires needed to determine a baseline of performance for evaluating turret performance when combating a fire in high engine nacelles. At the discretion of the test director, additional fires could be conducted as necessary to ensure that the data collected was accurate and to determine if the vehicle's fire suppression system was performing normally.

TABLE 3. THE HIGH-PERFORMANCE, MULTIPOSITION, BUMPER-MOUNTED TURRET HIGH ENGINE NACELLE FIRE TEST MATRICES

Test No.	Agent	No. of Fires
3-1A through 3-1C	3% AFFF (Mil Spec)	3
3-2A through 3-2C	Dry Chemical	3
3-3A through 3-3C	Combination Agent	3

TABLE 4. THE P-19 ROOF-MOUNTED TURRET HIGH ENGINE NACELLE FIRE TEST MATRICES

Test No.	Agent	No. of Fires
4-1A through 4-1C	3% AFFF (Mil Spec)	3

LARGE DIAMETER FIRE BURN AREA. The 100-ft-diameter (7854-square-foot) fire burn area shown in figure 8 was used to compare and evaluate the firefighting performance of the two turrets in a large-scale test environment.

FIGURE 8. LARGE DIAMETER FIRE BURN AREA

The fire area in this test corresponds to the PCA of a category 6 airport, based on NFPA 403. This is equivalent to the FAA Index B under Title 14 Code of Federal Aviation Regulations Part 139. A British Aerospace 146-200 is a representative aircraft to this FAA Index or NFPA category 6.

Approximately 2 inches of water was put into the 100-ft-diameter burn area to establish a smooth, level surface on which the 1000 gallons of JP-8 jet fuel floated. This open-air fire environment allowed the fuel to pool or flow as surface winds dictated. Similarly, turret streams moved the fuel across the surface of water in the same manner that occurs on wide-open tarmacs or runways. The intent of the spill was to ensure that sufficient fuel flowed into the fire burn area, requiring the fire fighters to maneuver the test vehicles around the 100-ft-diameter fire burn area. A 1000-gallon fuel spill covered over 90% of the fire burn area's surface. The existing aircraft mock-up, including supports, helped maintain a heat sink sufficient to keep the JP-8 fuel vaporizing until the firefighting agents, or combination of agents, extinguished the fire and cooled the hot metal below its reignition temperature. In these tests, only one driver/operator was selected to perform all large-scale tests. The driver/operator was instructed to preposition the vehicles upwind, select an optimum approach path, approach the fire from upwind, and apply the agent or combination of agents uniformly to the fire surface while in a pump and roll operation rather than from a stationary position. The HPRV driver/operator was also instructed to position the high-performance, multiposition, bumper-mounted turret in a downward, out in front position to expedite the extinguishment of the fire. This position maximized the likelihood that the agent(s) was being applied uniformly to the fire surface at a sufficient depth to reduce burn-back. Additionally, the driver/operator was instructed to extinguish the fire as rapidly and as safely as possible. The actual duration of the extinguishment effort was determined to be the length of time it took the driver/operator to fully extinguish the fire. Extinguishment time began when the agent was first applied to the fire and continued until the fire was fully extinguished. Extinguishment time did not include discharge time, as a function of extinguishment. The amount of agent used in the fire is related to actual nozzle discharge time, as discussed in appendix A. The fire test matrices shown in tables 5 and 6 were used to conduct the large-scale fire test experiments.

TABLE 5. THE HIGH-PERFORMANCE, MULTIPOSITION, BUMPER-MOUNTED TURRET LARGE-SCALE FIRE TEST MATRICES

Test No.	Agent	No. of Fires
5-1A through 5-1E	3% AFFF (Mil Spec)	5
5-2A through 5-2D	Combination Agent	4

TABLE 6. THE P-19 ROOF-MOUNTED TURRET LARGE-SCALE FIRE TEST MATRICES

Test No.	Agent	No. of Fires
6-1A through 6-1C	3% AFFF (Mil Spec)	3

<u>WATER STREAM THROW RANGE TESTS</u>. The test matrices shown in tables 7 and 8 show the number and types of tests conducted to measure the water stream throw range distances produced by the high-performance, multiposition, bumper-mounted turret and the P-19 roof-mounted turret. In these tests, the high-performance, multiposition, bumper-mounted turret was placed in three firefighting positions: full-up, fully extended, and down-in-front (DIF). Likewise, the P-19 roof-mounted turret was positioned at 0°, 10°, 20°, and 30°, respectively, to obtain maximum reach. Figure 9 shows a technician using an inclinometer to position the high-performance, multiposition, bumper-mounted turret to the desired elevation prior to the test. The

inclinometer was used at the end of the test to ensure that the turret did not move, and that it remained steady under pressure and during discharge. Each vehicle was prepositioned in a downwind position. In a near calm wind condition, water was discharged from the turret to ascertain the longest possible throw distance at the preset elevation. Following an agent discharge, the distance from the turret to the end point of the agent pattern that best established, the furthest point the agent had reached was measured. This measurement did not include any forward movement of the agent as it flowed forward of the agent stream. During the flow, the effective mass was established, that is, the point at which the agent begins to fall out of the agent stream and become an effective firefighting operational distance (FFOD). The width of the agent was measured and the water stream patterns were documented and are tabulated in table A-1 of appendix A.

TABLE 7. THE HIGH-PERFORMANCE, MULTIPOSITION, BUMPER-MOUNTED TURRET WATER STREAM THROW RANGE TEST MATRICES

Test No.	Boom Position	Turret Position 0°	Turret Position 10°	Turret Position 20°	Turret Position 30°
7-1A through 7-1C	Full-up	3			
7-2A through 7-2C	Full-up		3		
7-3A through 7-3C	Full-up			3	
7-4A through 7-4C	Fully extended		3		
7-5A through 7-5C	Fully extended			3	
7-6A through 7-6C	DIF	3			
7-7A through 7-7C	DIF		3		
7-8A through 7-8C	DIF			3	
7-9A through 7-9C	DIF				3
7-10A through 7-10C	Full-up				3
7-11A through 7-11C	Fully extended	3			
7-12A through 7-12C	Fully extended				3

TABLE 8. THE P-19 ROOF-MOUNTED TURRET WATER STREAM THROW RANGE TEST MATRICES

Test No.	Turret Position	0°	10°	20°	30°
8-1A through 8-1C	N/A	3			
8-2A through 8-2C	N/A		3		
8-3A through 8-3C	N/A			3	
8-4A through 8-4C	N/A				3

FIGURE 9. THE HIGH-PERFORMANCE, MULTIPOSITION, BUMPER-MOUNTED TURRET FULL-UP POSITION WITH THE TURRET AT 30°

The high-performance, multiposition, bumper-mounted turret was placed in position by using the control system joystick shown in figure 10.

FIGURE 10. THE HIGH-PERFORMANCE, MULTIPOSITION, BUMPER-MOUNTED TURRET NOZZLE JOYSTICK CONTROL

Because the P-19 roof-mounted turret is bolted to the top of the vehicle's roof, it cannot be evaluated in the same manner as the high-performance, multiposition, bumper-mounted turret. Therefore, a jig was fabricated to allow the turret to be elevated to the desired test positions of 0°, 10°, 20°, and 30°, respectively. A common rooftop tie-down strap was used to hold the jig securely in place while the fire pump was engaged, as shown in figure 11. Water was then discharged from each of these positions.

FIGURE 11. THE P-19 ROOF-MOUNTED TURRET JIG SET AT 20°

<u>AGENT STREAM THROW RANGE TESTS</u>. The test matrices shown in tables 9 and 10 show the number and types of tests conducted to measure the agent stream throw range distances. These tests were conducted to compare the ability of the high-performance, multiposition, bumper-mounted turret and the P-19 roof-mounted turret to discharge AFFF at the distances previously measured during the water stream throw range tests. The high-performance, multiposition, bumper-mounted turret was placed in its three normal firefighting positions, full-up, fully extended, and DIF. The turret was placed at 0°, 10°, 20°, and 30°, respectively, to obtain the maximum reach at those elevations. The P-19 roof-mounted turret was placed at a 0°, 10°, 20°, and 30° elevation using the jig and tie down strap shown in figure 11. Each vehicle was prepositioned in a stationary position facing downwind. In a calm wind condition, AFFF was then discharged from each of the turret positions to ascertain the longest possible throw distance at the preset elevation. In this series of tests, laboratory personnel evaluated the performance of the high-performance, multiposition, bumper-mounted turret to discharge agents, maintain a coherent dry chemical agent pattern, and measure the results of the discharge. In each test, the distance from the turret to the point in the agent pattern that best established the effective FFOD was measured. The width of the agent pattern was measured and an outline of the water stream pattern was drawn on a data collection sheet.

TABLE 9. THE HIGH-PERFORMANCE, MULTIPOSITION, BUMPER-MOUNTED TURRET AGENT STREAM THROW RANGE TEST MATRICES

Test No.	Agent	Turret Position	Elevation (degrees)	No. of Tests
9-1A through 9-1C	AFFF	DIF	10	3
9-2A through 9-2C	AFFF	Fully extended	10	3
9-3A and 9-3B	AFFF	Full-up	10	3
9-4A and 9-4B	PKP	DIF	10	2
9-5A	PKP	Full-up	10	1
9-6A through 9-6C	AFFF	Full-up	30	3
9-7A through 9-7C	AFFF	Full-up	30	3

TABLE 10. THE P-19 ROOF-MOUNTED TURRET AGENT STREAM THROW RANGE TEST MATRICES

Test No.	Agent	Turret Position	Elevation (degrees)	No. of Tests
10-1A through 10-1C	AFFF	N/A	0	3
10-2A through 10-2C	AFFF	N/A	10	3
10-3A through 10-3C	AFFF	N/A	20	3
10-4A through 10-4C	AFFF	N/A	30	3

RESULTS AND DISCUSSION

RESULTS OF THE F-100 ENGINE NACELLE FIRE TESTS.

The results of the high-performance, multiposition, bumper-mounted turret F-100 engine nacelle fire tests are shown in figure 12 and in tables A-1 and A-2 of appendix A.

The timed differential between tests 1-1A and 1-1B in table A-1 was substantial and misleading; therefore, it could not be used to establish a baseline of performance for fires of this type. Due to a lack of driver/operator proficiency and knowledge of the high-performance, multiposition, bumper-mounted turret, test 1-1A did not extinguish (DNE). The results of test 1-1B, on the other hand, were significantly lower due to insufficient heat sync in the F-100 engine cavity, which was not representative of an aircraft engine in a fire condition. Thus, three more tests were conducted to attain more accurate data.

Tests 1-1C through 1-1E, as shown in table A-1 and summarized in figure 12, show that the high-performance, multiposition, bumper-mounted turret successfully extinguished the F-100 engine nacelle fires. Averaging 32 seconds for extinguishment in the latter three fires, the high-performance, multiposition, bumper-mounted turret used an average of slightly over 265 gallons of AFFF solution to completely extinguish the F-100 engine nacelle fires.

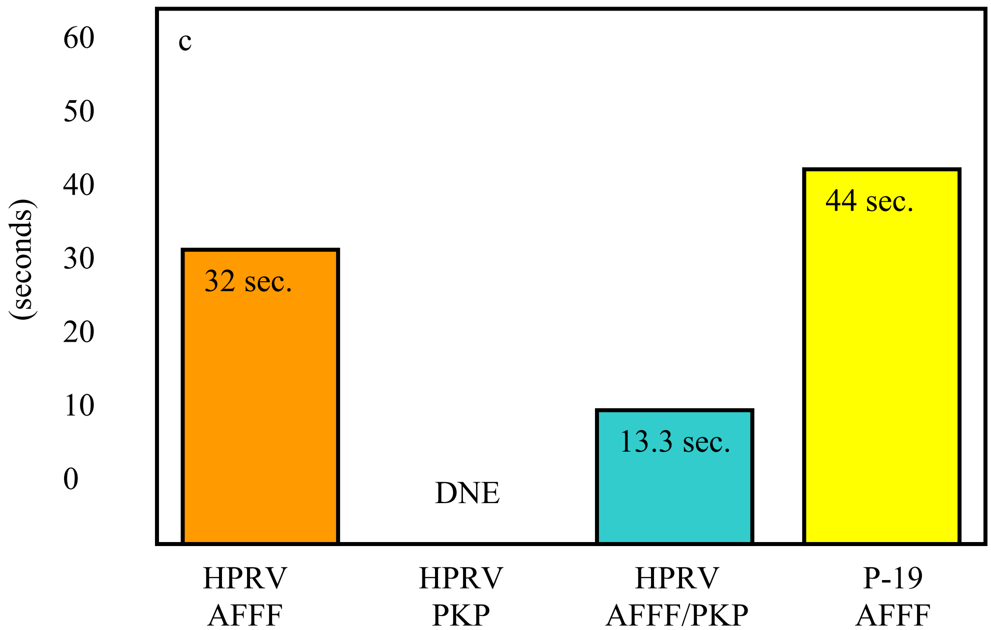

FIGURE 12. AVERAGE RESULTS OF THE F-100 ENGINE NACELLE FIRE TESTS

In test 1-2A, the PKP failed to extinguish the fire, even though a full load (500 pounds) of PKP was expended. It was determined that further attempts to combat fires of this magnitude without benefit of a supplemental AFFF solution cooling agent would achieve similar results.

In tests 1-3A through 1-3D in table A-1, the combination of AFFF and PKP delivered from the high-performance, multiposition, bumper-mounted turret extinguished the F-100 engine nacelle fires in an average of 13.3 seconds. Slightly over 117 gallons of AFFF solution and 284 pounds of PKP were used in the suppression effort. An analysis of this data, based on the average extinguishment time, showed that the high-performance, multiposition, bumper-mounted turret, when used in the dual agent mode, extinguished the F-100 engine nacelle fires agent in 42% of the time that it took when using AFFF alone. In addition, the high-performance, multiposition, bumper-mounted turret took 30% of the time the P-19 roof-mounted turret took using AFFF solution alone. The efficiency of the HPRV's dual agent turret to attack and extinguish 3-D fires resulted in a 58% savings in AFFF solution compared to using only AFFF, and nearly a 70% savings in AFFF compared to the P-19 roof-mounted turret.

The results of the P-19 roof-mounted turret F-100 engine nacelle fire tests are also shown in figure 12 and in table A-2. In tests 2-1A through 2-1C in table A-2, the P-19 roof-mounted turret extinguished the F-100 engine nacelle fires in an average of 44 seconds, using approximately 365 gallons of AFFF solution to completely extinguish the fire.

An important issue to observe is the view from the P-19's cab during fire suppression, as shown in figure 13. This figure shows the difficulty the P-19 driver/operator has in viewing the fire scene and in locating the fire. Given the limited view of the fire scene and virtually no view of the test device from the vehicle's stationary position, the driver/operator occasionally stops the flow of agent to determine whether or not the fire has been extinguished. This operation resulted in increased firefighting time and increased the amount of agent needed to suppress the fire.

FIGURE 13. VIEW OF THE F-100 FIRE SCENE FROM THE P-19 CAB

RESULTS OF THE TAIL-MOUNTED, HIGH ENGINE NACELLE FIRE TESTS.

The results of the high-performance, multiposition, bumper-mounted turret high engine nacelle fire tests are shown in figure 14 and table A-3 of appendix A. In tests 3-1A through 3-1C in table A-3 using AFFF only, the high-performance, multiposition, bumper-mounted turret extinguished the fires in an average of 43.6 seconds, and used an average of 361.8 gallons of agent. Figure 15 shows the high-performance, multiposition, bumper-mounted turret's attack on the high engine nacelle fire using AFFF only. In test 3-2A in table A-3 using PKP only, the high-performance, multiposition, bumper-mounted turret failed to extinguish the fire, even though the full load (500 pounds) of PKP was expended. Therefore, no other fire tests were attempted because it was determined the outcome would be the same. The P-19 roof-mounted turret did not contain PKP, therefore a performance comparison could not be made. In tests 3-3A through 3-3E in table A-3, covering a 2-day period, the dual agent capability of the high-performance, multiposition, bumper-mounted turret was evaluated.

In tests 3-3A and 3-3B in table A-3, the timed difference was significant, and the results were determined to be misleading in terms of establishing a baseline of performance. Consequently, three additional tests were initiated to establish the high-performance, multiposition, bumper-mounted turret's baseline performance. In tests 3-3C through test 3-3E in table A-3, the high engine nacelle flowing fuel fires were extinguished in an average of 36.3 seconds. Slightly over 301 gallons of AFFF solution was continuously discharged on the pool fire and into the high engine nacelle. The PKP dry chemical agent was used to combat the high engine nacelle fire only. The PKP was discharged for an average of 11 seconds per fire and an average of 220 pounds of PKP was used to suppress this fire.

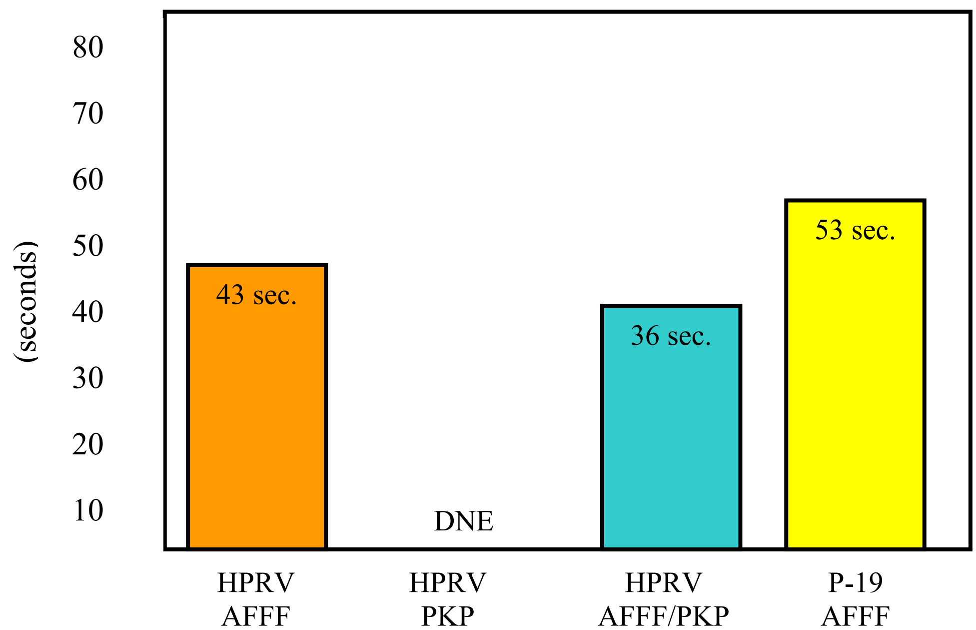

FIGURE 14. AVERAGE RESULTS OF THE TAIL-MOUNTED, HIGH ENGINE NACELLE FIRE TESTS

Figures 15 and 16 show the high-performance, multiposition, bumper-mounted turret attack on the 25-ft-high engine nacelle using only AFFF in tests 3-1A through 3-1C in table A-3 and AFFF and PKP in tests 3-3A through 3-3E in table A-3. The purple dye in the PKP allows the driver/operator to see exactly where the agent is being placed. Because the turret is mounted on the bumper, the driver/operator has a clear view of the fire scene. Figure 15 shows the turret in the low position. Figure 16 shows the turret in the full-up position.

The results of the P-19 roof-mounted turret high engine nacelle fire tests are also shown in figure 14 and in table A-4 of appendix A. The results of the four test fires were mixed, but these results did reveal the difficulty AFFF had in extinguishing 3-D flowing fuel fires. In test 4-1A in table A-4, an insufficient heat sync at the outset of the fire test resulted in a unrealistic extinguishment of the fire, therefore, the fire test was discounted. In test 4-1B in table A-4, the P-19 roof-mounted turret failed to extinguish the fire, resulting in a DNE. This fire was not measurable and was also discounted. The P-19's full load of 1000 gallons of water and

FIGURE 15. THE HIGH-PERFORMANCE, MULTIPOSITION, BUMPER-MOUNTED TURRET USING AFFF ON A 2-D POOL FIRE

FIGURE 16. THE HIGH-PERFORMANCE, MULTIPOSITION, BUMPER-MOUNTED TURRET USING BOTH AFFF AND PKP ON A 3-D FLOWING FUEL FIRE

30 gallons of AFFF were discharged onto the fire without effect. The two test fires (4-1C and 4-10D) that were measured resulted in an average extinguishment time of 53 seconds. On average, nearly 440 gallons of AFFF solution was needed to extinguish test fires 4-1C and 4-1D.

The P-19 roof-mounted turret attack on the high engine nacelle fire is shown in figure 17. Note the obscured view from the driver/operator's perspective.

FIGURE 17. THE P-19 ROOF-MOUNTED TURRET USING AFFF

A comparison of the results of the high-performance, multiposition, bumper-mounted turret and the P-19 roof-mounted turret during high engine nacelle fire tests, based upon the performance average of that turret, is shown in appendix A. An analysis of this data, based on the average time to complete extinguishments, shows that the dual agent, high-performance, multiposition, bumper-mounted turret extinguished the high engine nacelle fires 15 times faster than AFFF alone, and 19 times faster than AFFF discharged from the P-19 roof-mounted turret. Further, the efficiency of the dual agent, high-performance, multiposition, bumper turret to attack and extinguish 3-D flowing fuel fires resulted in a nearly 11% savings in AFFF compared to the same turret delivering AFFF alone, and a 13% savings in AFFF compared to the P-19 roof-mounted turret. An important issue to compare is the view from the HPRV cab during fire suppression, as shown in figures 15 and 16. These figures show that the driver/operator of the HPRV has a clear view of the fire scene, while the driver/operator of the P-19, as shown in figure 17, has a limited view of the fire scene and virtually no view of the test device from the vehicle's stationary position.

RESULTS OF THE LARGE-SCALE (100-ft-DIAMETER) POOL FIRE TESTS.

The results of the high-performance, multiposition, bumper-mounted turret large-scale (100-ft-diameter) JP-8 pool fire tests are shown in figure 18. In tests 5-1A through 5-1C in table A-5 of appendix A, AFFF was used exclusively for fire suppression. In tests 5-1A through 5-1C in table A-5, the high-performance, multiposition, bumper-mounted turret suppressed the large-scale pool fires in an average of 1 minute and 8 seconds (68 seconds), inclusive of the time needed to modulate to a better position of attack. The average actual agent discharge time was 50 seconds, indicating the HPRV used 415 gallons of AFFF solution to extinguish the large-scale pool fires.

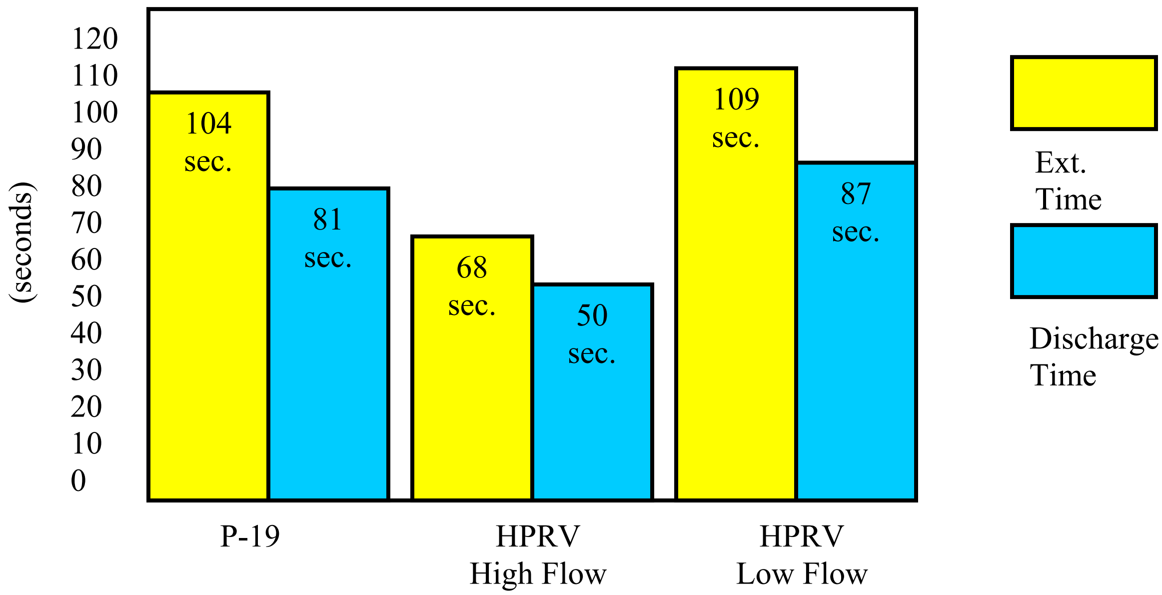

FIGURE 18. AVERAGE RESULTS OF THE LARGE-SCALE POOL FIRE TESTS

A comparison of the high- and low-flow capability of the high-performance, multiposition, bumper-mounted turret is also depicted in figure 18. The low-flow results shown in figure 18 were used in the comparison merely to document the capability of the turret to extinguish fire in a low-flow condition. In tests 5-1D and 5-1E in table A-5, the low-flow discharge setting on the remote control was selected in an effort to compare the high- and low-flow performance of the high-performance, multiposition, bumper-mounted turret in a large fire situation. In a low-flow setting, the HPRV dispenses AFFF solution at 250 gpm at 160 psi at approximately 1250 revolutions per minute (rpm). This compares to the higher-flow setting of 500 gpm at 210 psi at 1500 rpm. In tests 5-1D and 5-1E in table A-5, the high-performance, multiposition, bumper-mounted turret extinguished the test fires in an average of 1 minute and 49 seconds (109 seconds). The actual discharge time averaged 1 minute and 27 seconds (87 seconds). The HPRV is estimated to have used approximately 722 gallons of AFFF solution at the lower setting.

In tests 6-1A through 6-1C shown in table A-6 and summarized in figure 18, AFFF was used exclusively for fire suppression. In these three tests, the P-19 roof-mounted turret suppressed the 100-ft-diameter pool fires in an average of 1 minute and 44 seconds (104 seconds). This is inclusive of the time needed to reposition to the next firefighting position for the best angle of attack on the fire. The average discharge time of the three tests was 1 minute and 21 seconds (81 seconds). At 8.3 gps, the average amount of agent discharged to extinguish the fully involved 100-ft-diameter pool fire was 672 gallons.

A comparison of the high-performance, multiposition, bumper-mounted turret in a high-flow setting and the P-19 roof-mounted turret at an equivalent flow shows that the high-performance, multiposition, bumper-mounted turret suppressed the large-scale pool fire in 62% of the time it took the roof-mounted turret, thus using 38% less AFFF solution than the P-19 roof-mounted turret.

RESULTS OF THE WATER STREAM THROW RANGE TESTS.

Many throw tests were conducted to document the performance of the high-performance, multiposition, bumper-mounted turret at various nozzle and turret elevations. These nonfire tests were conducted and recorded to compare the high-performance, multiposition, bumper-mounted turret's performance to itself and to record these results in a report containing similar background information. These results, shown in table A-7 of appendix A, form an essential part of the report, but were not used in comparing high-performance, multiposition, bumper-mounted turret and nozzle performance at lesser elevations to the fixed elevations on the P-19. For example, in tests 7-1A through 7-1C in table A-7, the high-performance, multiposition, bumper-mounted turret produced an average throw distance of 121 ft 6 in. with the boom in the full-up position and the turret level at 0°. In tests 7-2A through 7-2C in table A-7, with the boom raised to the full-up position and the turret set at 10°, the high-performance, multiposition, bumper-mounted turret produced an average water stream measuring nearly 147 ft, an increase of nearly 26 ft. In tests 7-3A through 7-3C in table A-7, with the boom full-up and the turret elevated to 20°, throw distance was measured at an average of 164 ft 5 in., an increase of nearly 43 ft over the level setting and 17 ft over the 10° setting. In tests 7-10A through 7-10C in table A-7, the boom remained in the full-up position and the turret was elevated to 30°. In this configuration, the high-performance, multiposition, bumper-mounted turret produced an average throw distance of 200 ft 2 in., nearly 79 ft further than the level turret settings recorded in tests 7-1A through 7-1C in table A-7.

The performance of the high-performance, multiposition, bumper-mounted turret, when placed in the DIF position with the turret positioned at 0°, 10°, 20°, and 30° of elevation during water stream throw range tests, is shown in figure 19a and in table A-7. This data is an average of the three tests conducted for each turret setting. Each turret position setting and turret elevation is compared to the other to determine the performance of the high-performance, multiposition, bumper-mounted turret at the respective turret setting indicated. The most important data to be observed are the increasing distances achieved by elevating the turret from a DIF level position to a full-up 30° position.

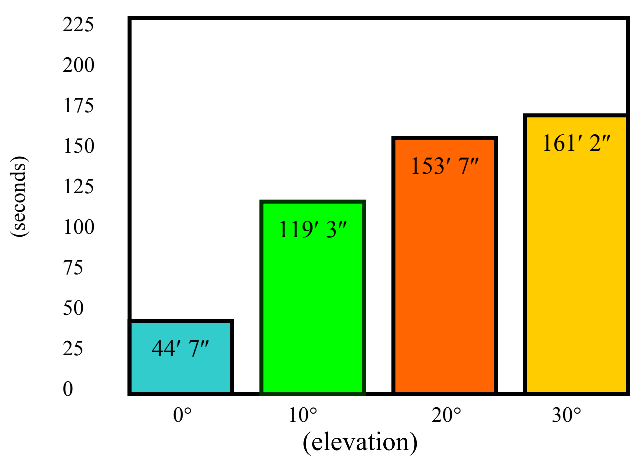

FIGURE 19a. THE HIGH-PERFORMANCE, MULTIPOSITION, BUMPER-MOUNTED TURRET WATER STREAM THROW RANGE TESTS, SET TO DIF POSITION AT VARIOUS DEGREES OF ELEVATION

The performance of the high-performance, multiposition, bumper-mounted turret when placed in the fully extended position with the turret positioned at 0°, 10°, 20°, and 30° of elevation during water stream throw range tests is shown in figure 19b and in table A-7. This data is an average of the three tests conducted for each turret setting. Each turret position setting and turret elevation is compared to the other to determine the performance of the high-performance, multiposition, bumper-mounted turret at the respective turret setting indicated.

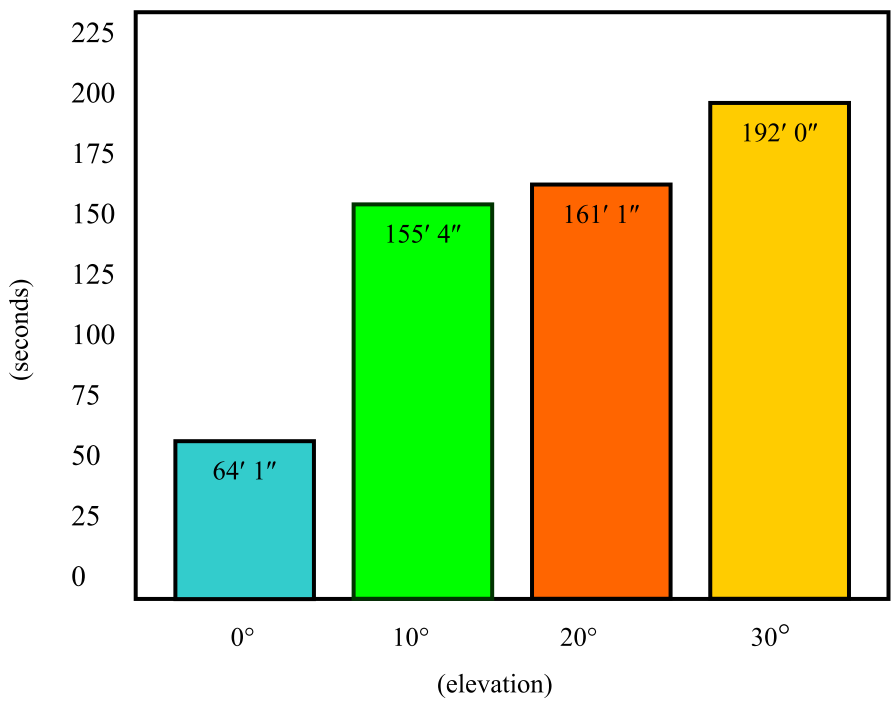

FIGURE 19b. THE HIGH-PERFORMANCE, MULTIPOSITION, BUMPER-MOUNTED TURRET WATER STREAM THROW RANGE TESTS, SET TO FULLY EXTENDED POSITION AT VARIOUS DEGREES OF ELEVATION

The performance of the high-performance, multiposition, bumper-mounted turret, when placed in the full-up position with the turret positioned at 0°, 10°, 20°, and 30° of elevation during water stream throw range tests, is shown in figure 19c and in table A-7. This data is an average of the three tests conducted for each turret setting. Each turret position setting and turret elevation is compared to the other to determine the performance of the high-performance, multiposition, bumper-mounted turret at the respective turret setting indicated.

The results of the P-19 roof-mounted turret water stream throw range tests are shown in figure 20 and in table A-8 in appendix A. The data are an average of the three tests conducted for each preselected turret setting. Each turret elevation was compared to the other to determine the performance of the P-19 roof-mounted turret at the turret setting indicated and comparing that performance to an equivalent high-performance, multiposition, bumper-mounted turret setting.

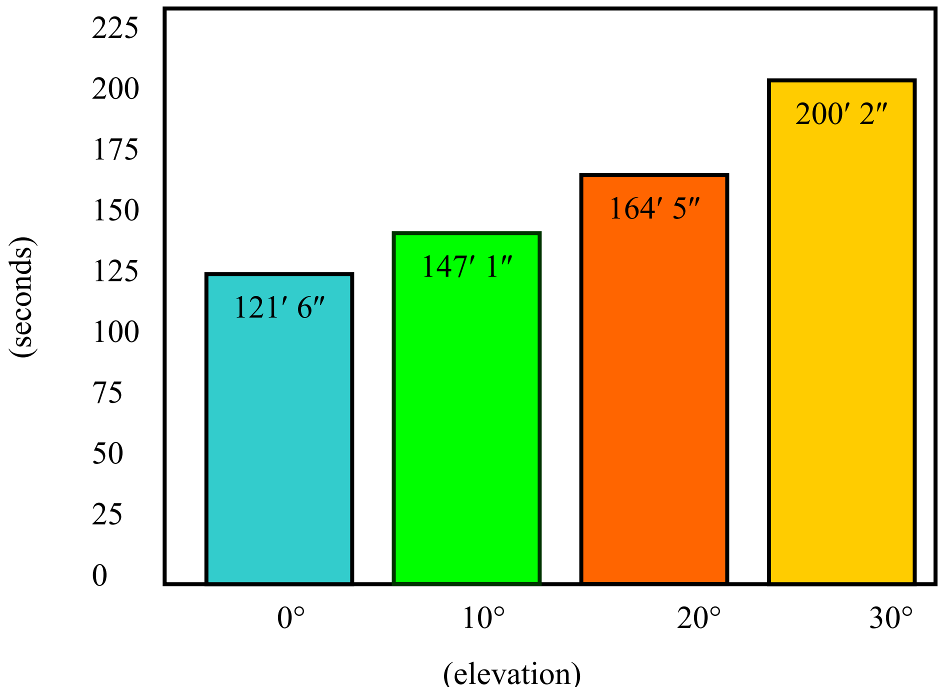

FIGURE 19c. THE HIGH-PERFORMANCE, MULTIPOSITION, BUMPER-MOUNTED TURRET WATER STREAM THROW RANGE TESTS, SET TO FULL-UP POSITION AT VARIOUS DEGREES OF ELEVATION

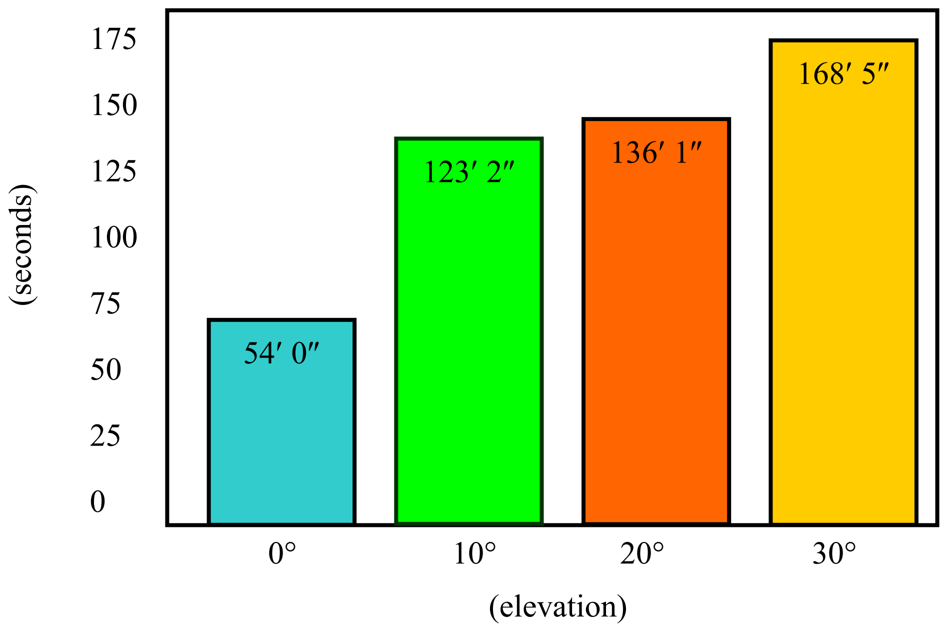

FIGURE 20. THE P-19 ROOF-MOUNTED TURRET WATER STREAM THROW RANGE TESTS AT VARIOUS DEGREES OF ELEVATION

A comparison of the HPRV and P-19 turrets water stream throw range test results at an elevation of 30° are shown in figure 21.

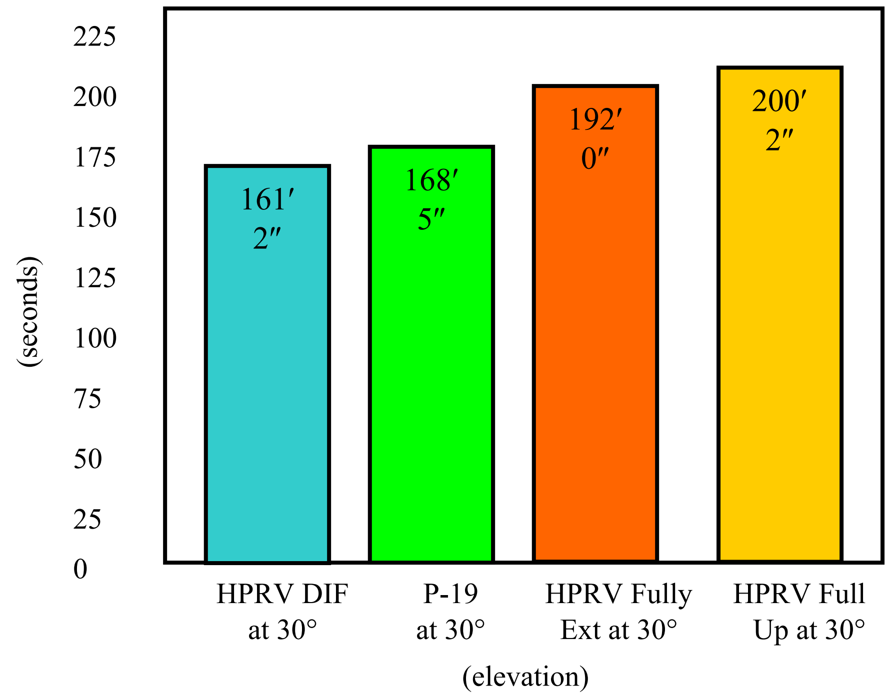

FIGURE 21. COMPARISON OF THE HIGH-PERFORMANCE, MULTIPOSITION, BUMPER-MOUNTED TURRET AND THE P-19 ROOF-MOUNTED TURRET WATER STREAM THROW RANGE TESTS AT A 30° ELEVATION

RESULTS OF THE AGENT STREAM THROW RANGE TESTS.

The results of the high-performance, multiposition, bumper-mounted turret agent stream throw range tests are shown in figure 22 and in table A-9 of appendix A. In this series of tests, laboratory personnel conducted a series of tests designed not only to measure agent throw, but to compare the throw distances to the various turret positions at the same level produced by the same vehicle. The one common factor in this series of tests was the 10° and 30° elevation in each test. Incrementally, as the turret was raised from the DIF position to the full-up position, the throw distances increased. In tests 9-1A though 9-1C in table A-9, a 10° setting on the DIF turret attained an average reach of 144 ft 9 in. with an effective mass of 84 ft 4 in. At the fully extended position, tests 9-2A through 9-2C in table A-9, the agent throw stream measured 149 ft 3 in. with an effective mass measured at 85 ft 6 in. In tests 9-3A through 9-3C in table A-9, with the turret in the full-up position and the turret set to a 10° of elevation, agent throw was measured at 157 ft 4 in. with an average effective mass of 96 ft 3 in. The pattern widths in tests 9-2A and 9-3A in table A-9 were very similar, showing the higher elevations on the turret did not affect pattern widths. In tests 9-4A and 9-4B in table A-9, laboratory personnel measured the throw distance of the PKP dry chemical agent. In a DIF position at a 10° elevation, the agent was discharged at an average of 140 ft 2 in. with an average effective mass of 104 ft. It is important to point out that the slightest gust of wind affects both throw and effective mass. In test 9-5A, the slight wind at 4 mph affected the agent throw stream resulting in a pattern width of 54 ft 8 in. As a result, no other attempts to discharge PKP in the full-up position at a 10° elevation were attempted. In tests 9-6A through 9-6C in table A-9, with the turret in the full-up position and the turret set at a 30° elevation, the high-performance, multiposition, bumper-mounted turret produced an average agent throw stream of 168 ft 8 in. in length. The effective mass averaged 96 ft 4 in. in length and an average agent pattern width of 16 ft 1 in. In tests 9-7A through 9-7C in table A-9, with the turret in the DIF position and the turret set at a 30° elevation, the HPRV produced an average agent throw stream of 164 ft 1 in. in length. The effective mass averaged 105 ft 4 in. in length and an average agent pattern width of 13 ft. In tests 9-8A through 9-8C in table A-9, with the turret in the fully extended position and the turret set at a 30° elevation, the high-performance, multiposition, bumper-mounted turret produced an average agent throw stream of 166 ft in length. The effective mass averaged 99 ft 4 in. in length and an average agent pattern width of 14 ft 1 in.

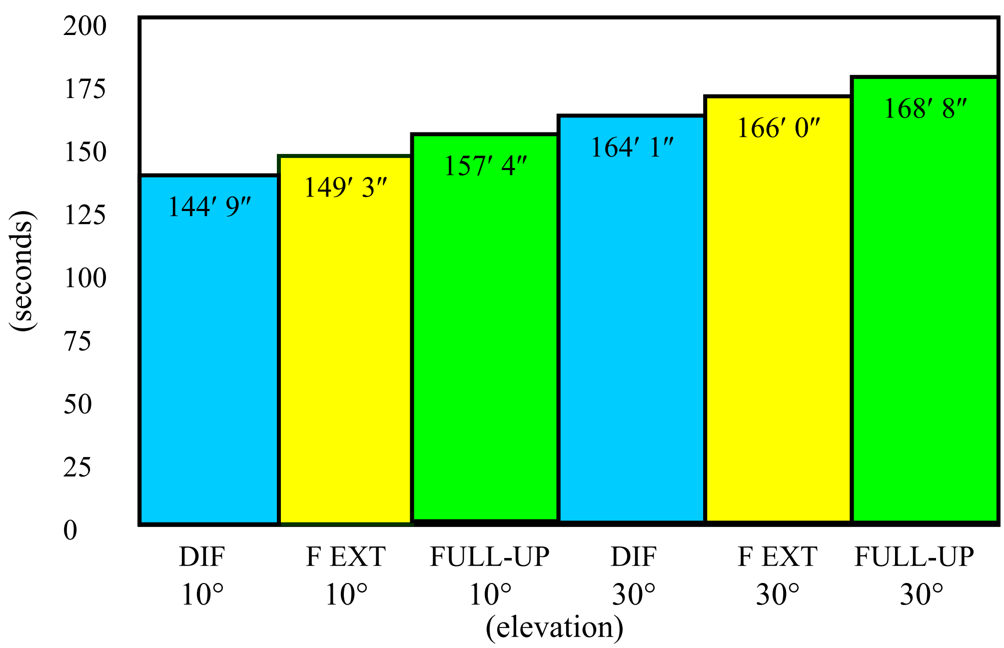

FIGURE 22. COMPARISON OF THE HIGH-PERFORMANCE, MULTIPOSITION, BUMPER-MOUNTED TURRET AGENT STREAM THROW RANGE TEST RESULTS WITH THE P-19 ROOF-MOUNTED TURRET SET AT VARIOUS POSITIONS AND DEGREES OF ELEVATION

The results of the P-19 roof-mounted turret agent stream throw range tests are shown in figure 23 and in table A-10 of appendix A. In tests 10-1A through 10-1C in table A-10, with the turret in a level position, the P-19 roof-mounted turret produced an average agent throw distance of 62 ft 2 in. with an effective mass of 37 ft 8 in. Agent pattern width averaged 8 ft 2 in. in a level turret configuration. Tests 10-2A through 10-2C in table A-10, with the turret set at a 10° elevation, the agent throw stream measured 123 ft 5 in. in length, an effective mass measuring 81 ft 9 in., and an agent pattern width averaging 8 ft 8 in. in width. At 20° of elevation in tests 10-3A through 10-3C in table A-10, the P-19 discharged AFFF an average of 134 ft 8 in. in length, producing an effective mass of 93 ft 7 in. and an average agent pattern width of 7 ft 9 in. Test

10-4A in table A-10 was discounted due to mechanical problems attributed to the P-19's fire pump. Tests 10-4B through 10-4D in table A-10 produced an average agent stream reaching 156 ft, an average effective mass measuring 96 ft 5 in. length, and an agent pattern width of 5 ft 8 in. Taken from atop a P-19, figure 24 shows the measurable results of a typical agent stream throw range test and the narrow width of agent pattern stream inherent to the P-19 roof-mounted turret.

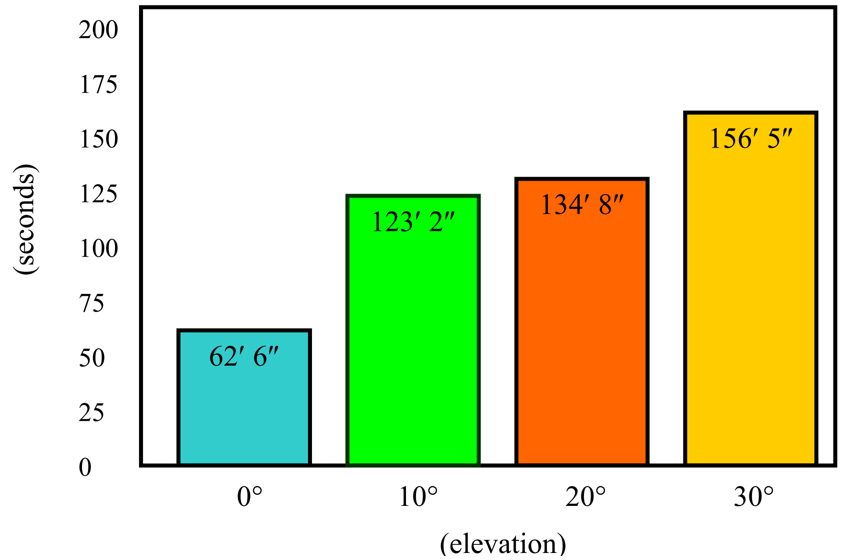

FIGURE 23. THE P-19 ROOF-MOUNTED TURRET AGENT STREAM THROW RANGE TESTS AT VARIOUS DEGREES OF ELEVATION

FIGURE 24. TYPICAL AGENT PATTERN RESULTS USING AFFF

A comparison of the results of the high-performance, multiposition, bumper-mounted turret and the P-19 roof-mounted turret agent stream throw range tests at a maximum elevation of 30° are shown in figure 25. The data showed that the high-performance, multiposition, bumper-mounted turret set at 30° surpassed the throw distance of the P-19 roof-mounted turret. With the high-performance, multiposition, bumper-mounted turret set to its full-up position, the turret projected an agent stream 12 ft 8 in. further than the P-19 roof-mounted turret at the same setting. Each turret produced an effective coverage area of 96 ft long, but the agent pattern width was significantly different. The pattern widths of the high-performance, multiposition, bumper-mounted turret was much greater than the pattern widths of the P-19 roof-mounted turret. The high-performance, multiposition, bumper-mounted turret produced an agent pattern width of 16 ft at 30°, while at the same elevation, the P-19 roof-mounted turret produced an agent pattern width of 6 to 8 ft.

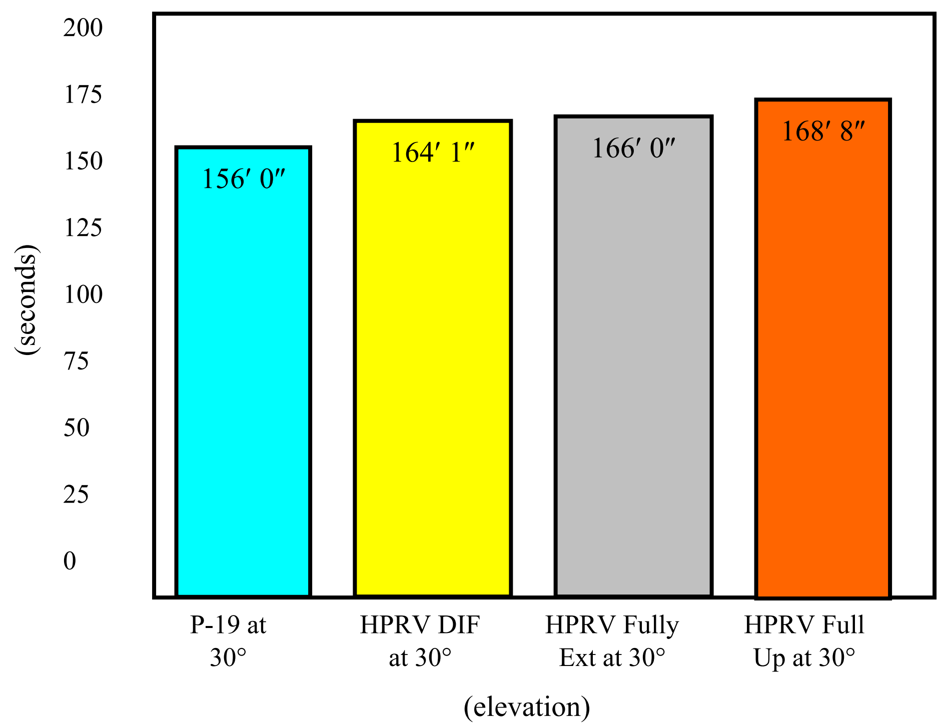

FIGURE 25. COMPARISON OF THE TURRETS AT AN ELEVATION OF 30°

SUMMARY OF RESULTS

The high-performance, multiposition, bumper-mounted turret was found to be superior in performance compared to the P-19 roof-mounted turret. In all aspects of the comparison and evaluation, the data for extinguishment times, total agent used, throw ranges, and overall performance during the evaluation far exceeded those values collected from the P-19 roof-mounted turret.

In comparing the performance of both turrets during the F-100 engine nacelle test fires, the high-performance, multiposition, bumper-mounted turret was faster during extinguishment and less water was used. The high-performance, multiposition, bumper-mounted turret averaged a

12-second faster extinguishment time using, on average, less than 100 gallons of aqueous film-forming foam (AFFF) than the P-19 roof-mounted turret. The tests of the high-performance, multiposition, bumper-mounted turret, using a combination of AFFF and dry chemicals, averaged 31 seconds faster than the tests of the P-19 roof-mounted turret.

In comparing the performance of both turrets during the high engine nacelle tail test fires, the high-performance, multiposition, bumper-mounted turret was faster during extinguishment and less water was used. The extinguishment time of the high-performance, multiposition, bumper-mounted turret averaged 10 seconds faster using AFFF, and 17 seconds faster using a combination of AFFF and dry chemicals. The high-performance, multiposition, bumper-mounted turret used on average, 79 gallons less of AFFF compared to the P-19 roof-mounted turret.

In comparing the performance of the both turrets during large-scale, two-dimensional pool fires, the high-performance, multiposition, bumper-mounted turret was faster than the roof-mounted turret in all aspects of the evaluation. The high-performance, multiposition, bumper-mounted turret averaged a 36-second faster extinguishment time and a 31-second faster agent discharge time. The high-performance, multiposition, bumper-mounted turret was also able to extinguish fire more effectively at greater distances than the P-19 roof-mounted turret.

In evaluating the performance of both turrets in simulated aircraft crash firefighting situations in the presence of a large-scale aircraft mock-up, the results of the evaluation showed that extinguishment times were reduced, and the distance needed between the vehicle and the fire to produce an effective extinguishing agent stream was also increased. This distance reduces the ARFF vehicle and driver/operator's exposure to the fire. It was also determined that the high-performance, multiposition, bumper-mounted turret provided the driver/operator with an improved view of the fire. The high-performance, multiposition, bumper-mounted turret's wide range of movement provides an increased ability to place an agent stream in hard to get locations, particularly under an aircraft, in a wheel well, or into engines nacelles. The ability of the driver/operator to select any elevation while positioning around the fire area gives the high-performance, multiposition, bumper-mounted turret an advantage over the P-19 roof-mounted turret. It also was accurate and able to deliver a consistent stream of AFFF or a combination of AFFF and dry chemicals into engine nacelles, resulting in a quicker extinguishment.

In evaluating the water stream throw range performance, the high-performance, multiposition, bumper-mounted turret produced its longest throw range distance in every boom position with the nozzle elevated at 30°. The P-19 roof-mounted turret using water also produced its longest throw range distance at 30°. The high-performance, multiposition, bumper-mounted turret's range with water was greater in two of the three boom positions at 30° than the P-19 roof-mounted turret at 30°. When the high-performance, multiposition, bumper-mounted turret was in the full-up position at 30°, it had a longer throw range by 31′9″ compared to the P-19 roof-mounted turret. When the high-performance, multiposition, bumper-mounted turret was in the fully extended position at 30°, it had a longer throw range by 23′7″.

In evaluating the AFFF throw range performance, the high-performance, multiposition, bumper-mounted turret produced its longest throw range distance in every boom position at 30°. The

P-19 roof-mounted turret using AFFF also produced its greatest throw range distance at 30°. The high-performance, multiposition, bumper-mounted turret's range with AFFF was longer in all three boom positions with the nozzle at 30° than the roof-mounted turret at 30°. When the high-performance, multiposition, bumper-mounted turret was in the down-in-front position with the nozzle at 30° with AFFF, it had a longer throw range by 8′1″ compared to the P-19 roof-mounted turret. When the high-performance, multiposition, bumper-mounted turret was in the full-extended position with the nozzle at 30° with AFFF, it had a greater throw range by 10 ft. When the high-performance, multiposition, bumper-mounted turret was in the full-up position with the nozzle at 30°, it had a longer throw range by 12′8″. The high-performance, multiposition, bumper-mounted turret also produced a maximum wider agent pattern by 7′5″ compared to the maximum wide pattern of the P-19 roof-mounted turret. An increase in pattern width of the high-performance, multiposition, bumper-mounted turret creates a large effective mass of agent resulting in a faster extinguishing time, particularly in two-dimensional pool fires.

The high-performance research vehicle driver/operator had no difficulty seeing the high-performance, multiposition, bumper-mounted turret and selecting the boom and nozzle settings desired during testing. Conversely, the P-19 driver/operator occasionally had to shut down pumping operations to determine if the fire had been extinguished. By shutting down the pump during the fire test, the extinguishment time was significantly increased.

APPENDIX A—TEST RESULTS

Tables A-1 through A-10 contain the field data collected from this evaluation.

TABLE A-1. RESULTS OF THE HIGH-PERFORMANCE, MULTIPOSITION, BUMPER-MOUNTED TURRET F-100 ENGINE NACELLE FIRE TESTS

Test No.	Date	Agent	Boom Position	Turret Position (degrees)	Extinguish Time (sec)	Wind (direction/ mph)	Temp. (°F)
*1-1A	16/07/01	AFFF	Fully extended	0	DNE	080 at 5	74
*1-1B	16/07/01	AFFF	Fully extended	0	13	084 at 6	74
1-1C	16/07/01	AFFF	Fully extended	0	31	088 at 6	76
1-1D	24/07/01	AFFF	Fully extended	0	25	090 at 4	80
1-1E	24/07/01	AFFF	Fully extended	0	40	090 at 4	80
Average					32		
1-2A	17/07/01	PKP	Fully extended	0	DNE	060 at 5	82
*1-3A	17/07/01	AFFF/PKP	Fully extended	0	17	060 at 5	84
1-3B	17/07/01	AFFF/PKP	Fully extended	0	13	060 at 5	84
1-3C	17/07/01	AFFF/PKP	Fully extended	0	12	060 at 5	85
1-3D	24/07/01	AFFF/PKP	Fully extended	0	15	070 at 5	84
Average					13.3		

*Discounted
DNE = Did not extinguish

TABLE A-2. RESULTS OF THE P-19 ROOF-MOUNTED TURRET F-100 ENGINE NACELLE FIRE TESTS

Test No.	Date	Agent	Extinguish Time (sec)	Wind (direction/mph)	Temp. (°F)
2-1A	14/08/01	AFFF	45	020 at 5	85
2-1B	14/08/01	AFFF	44	020 at 5	85
2-1C	15/08/01	AFFF	43	360 at 6	80
Average			44		

TABLE A-3. RESULTS OF THE HIGH-PERFORMANCE, MULTIPOSITION, BUMPER-MOUNTED TURRET HIGH ENGINE NACELLE FIRE TESTS

Test No.	Date	Agent	Extinguish Time (sec)	Wind (direction/mph)	Temp. (°F)
3-1A	14/08/01	AFFF	45	030 at 5	80
3-1B	14/08/01	AFFF	44	030 at 5	80
3-1C	15/08/01	AFFF	42	010 at 3	81
Average			43.6		
3-2A	15/08/01	PKP	DNE	050 at 4	82
Average			DNE		
*3-3A	14/08/01	AFFF/PKP	46	050 at 4	83
*3-3B	14/08/01	AFFF/PKP	18	050 at 4	83
3-3C	15/08/01	AFFF/PKP	35	030 at 3	84
3-3D	15/08/01	AFFF/PKP	40	360 at 5	85
3-3E	15/08/01	AFFF/PKP	34	360 at 5	85
Average			36.3		

*Discounted
DNE = Did not extinguish

TABLE A-4. RESULTS OF THE P-19 ROOF-MOUNTED TURRET HIGH ENGINE NACELLE FIRE TESTS

Test No.	Date	Agent	Extinguish Time (sec)	Wind (direction/ mph)	Temp. (°F)
*4-1A	14/08/01	AFFF	20	050 at 4	80
*4-1B	20/11/01	AFFF	DNE	070 at 7	75
4-1C	20/11/01	AFFF	40	080 at 7	78
4-1D	20/11/01	AFFF	1 min 6 sec.	080 at 7	78
Average			53 sec.		

*Discounted
DNE = Did not extinguish

TABLE A-5. RESULTS OF THE HIGH-PERFORMANCE, MULTIPOSITION, BUMPER-MOUNTED TURRET LARGE-SCALE (100-ft DIAMETER) POOL FIRE TESTS

Test No.	Date	Agent	Extinguish Time	Discharge Time	Wind (direction/ mph)	Temp. (°F)
5-1A	23/06/01	AFFF	1 min 8 sec.	43 sec.	360 at 2	78
5-1B	23/06/01	AFFF	1 min 18 sec.	54 sec.	360 at 4	80
5-1C	23/06/01	AFFF	58 sec.	53 sec.	010 at 4	81
Average			1 min 8 sec.	50 sec.		
5-1D	23/07/01	AFFF	1 min 39 sec.	1 min 19 sec.	060 at 5	85
5-1E	23/07/01	AFFF	1 min 59 sec.	1 min 36 sec.	060 at 6	85
Average			1 min 49 sec.	1 min 27 sec.		

TABLE A-6. RESULTS OF THE P-19 ROOF-MOUNTED TURRET LARGE-SCALE (100-ft DIAMETER) POOL FIRE TESTS

Test No.	Date	Agent	Extinguish Time	Discharge Time	Wind (direction/ mph)	Temp. (°F)
6-1A	05/06/03	AFFF	1 min 38 sec.	1 min 15 sec.	150 at 3	79
6-1B	05/03/03	AFFF	1 min 46 sec.	1 min 23 sec.	150 at 4	80
6-1C	05/06/03	AFFF	1 min 48 sec.	1 min 26 sec.	150 at 4	80
Average			1 min 44 sec.	1 min 21 sec.		

TABLE A-7. RESULTS OF THE HIGH-PERFORMANCE, MULTIPOSITION, BUMPER-MOUNTED TURRET WATER STREAM THROW RANGE

Test No.	Date	Agent	Boom Position	Turret Position (degrees)	Distance (ft)	Effective Mass (ft)	Width (ft)
7-1A	21/06/01	Water	Full-up	0	121′ 7″	83′ 9″	10′ 9″
7-1B	21/06/01	Water	Full-up	0	119′ 2″	79′ 3″	9′ 9″
7-1C	21/06/01	Water	Full-up	0	123′ 9″	82′ 6″	10′ 5″
Average					121′ 6″		
7-2A	21/06/01	Water	Full-up	10	144′ 8″	88′ 7″	12′ 2″
7-2B	21/06/01	Water	Full-up	10	149′ 0″	86′ 11″	11′ 8″
7-2C	21/06/01	Water	Full-up	10	147′ 5″	88′ 10″	12′ 6″
Average					147′ 1″		

TABLE A-7. RESULTS OF THE HIGH-PERFORMANCE, MULTIPOSITION, BUMPER-MOUNTED TURRET WATER STREAM THROW RANGE (Continued)

Test No.	Date	Agent	Boom Position	Turret Position (degrees)	Distance (ft)	Effective Mass (ft)	Width (ft)
7-3A	21/06/01	Water	Full-up	20	165′ 2″	91′ 0″	10′ 11″
7-3B	21/06/01	Water	Full-up	20	162′ 4″	97′ 2″	13′ 4″
7-3C	21/06/01	Water	Full-up	20	166′ 1″	96′ 1″	12′ 3″
Average					164′ 5″		
7-4A	21/06/01	Water	Fully extended	10	156′ 0″	95′ 11″	13′ 6″
7-4B	21/06/01	Water	Fully extended	10	156′ 11″	96′ 6″	14′ 5″
7-4C	21/06/01	Water	Fully extended	10	154′ 10″	92′ 7″	14′ 1″
Average					155′ 4″		
7-5A	21/06/01	Water	Fully extended	20	160′ 10″	90′ 2″	13′ 6″
7-5B	21/06/01	Water	Fully extended	20	165′ 4″	88′ 4″	12′ 3″
7-5C	21/06/01	Water	Fully extended	20	158′ 0″	92′ 7″	13′ 0″
Average					161′ 1″		
7-6A	21/06/01	Water	DIF	0	44′ 2″	22′ 2″	6′ 3″
7-6B	21/06/01	Water	DIF	0	43′ 0″	21′ 0″	6′ 10″
7-6C	21/06/01	Water	DIF	0	47′ 10″	22′ 7″	6′ 4″
Average					44′ 7″		
7-7A	21/06/01	Water	DIF	10	119′ 6″	56′ 6″	9′ 0″
7-7B	21/06/01	Water	DIF	10	117′ 10″	58′ 2″	10′ 11″
7-7C	21/06/01	Water	DIF	10	121′ 2″	53′ 7″	9′ 0″
Average					119′ 3″		
7-8A	22/06/01	Water	DIF	20	155′ 0″	78′ 4″	13′ 0″
7-8B	22/06/01	Water	DIF	20	152′ 10″	72′ 8″	11′ 6″
7-8C	22/06/01	Water	DIF	20	154′ 0″	76′ 9″	11′ 4″
Average					153′ 7″		
7-9A	12/06/03	Water	DIF	30	161′ 3″	91′ 4″	17′ 1″
7-9B	12/06/03	Water	DIF	30	159′ 8″	89′ 7″	18′ 2″
7-9C	12/06/03	Water	DIF	30	162′ 7″	88′ 5″	16′ 9″
Average					161′ 2″		

TABLE A-7. RESULTS OF THE HIGH-PERFORMANCE, MULTIPOSITION, BUMPER-MOUNTED TURRET WATER STREAM THROW RANGE (Continued)

Test No.	Date	Agent	Boom Position	Turret Position (degrees)	Distance (ft)	Effective Mass (ft)	Width (ft)
7-10A	12/06/03	Water	Full-up	30	202′ 6″	120′ 9″	17′ 6″
7-10B	12/06/03	Water	Full-up	30	197′ 3″	124′ 6″	18′ 2″
7-10C	12/06/03	Water	Full-up	30	200′ 6″	121′ 1″	17′ 1″
Average					200′ 2″		
7-11A	13/06/03	Water	Fully extended	0	62′ 6″	33′ 8″	8′ 6″
7-11B	13/06/03	Water	Fully extended	0	65′ 7″	41′ 0″	7′ 9″
7-11C	13/06/03	Water	Fully extended	0	60′ 1″	42′ 8″	7′ 4″
Average					64′ 1″	39′ 2″	7′ 9″
7-12A	13/06/03	Water	Fully extended	30	192′ 3″	111′ 4″	13′ 6″
7-12B	13/06/03	Water	Fully extended	30	186′ 7″	99′ 9″	14′ 1″
7-12C	13/06/03	Water	Fully extended	30	194′ 0″	103′ 10″	12′ 11″
Average					192′ 0″	104′ 8″	13′ 2″

TABLE A-8. RESULTS OF THE P-19 ROOF-MOUNTED TURRET WATER STREAM THROW RANGE TESTS

Test No.	Date	Agent	Boom Position	Turret Position (degrees)	Distance (ft)	Effective Mass (ft)	Width (ft)
8-1A	07/24/03	Water	N/A	0	54′ 9″	23′ 3″	8′ 9″
8-1B	07/24/03	Water	N/A	0	53′ 5″	24′ 0″	8′ 7″
8-1C	07/24/03	Water	N/A	0	53′ 8″	24′ 3″	8′ 9″
Average					54′ 0″	23′ 8″	8′ 8″
8-2A	07/24/03	Water	N/A	10	112′10″	35′ 4″	11′ 0″
8-2B	07/24/03	Water	N/A	10	122′ 6″	35′ 11″	10′ 7″
8-2C	07/24/03	Water	N/A	10	129′ 6″	33′ 9″	9′ 4″
Average					123′ 2″	34′ 8″	10′ 3″
8-3A	07/24/03	Water	N/A	20	135′ 8″	43′ 8″	11′ 0″
8-3B	07/24/03	Water	N/A	20	133′ 5″	52′ 5″	10′ 5″
8-3C	07/24/03	Water	N/A	20	139′ 3″	51′ 6″	11′ 6″
Average					136′ 1″	49′ 3″	11′ 0″
8-4A	06/30/03	Water	N/A	30	174′ 6″	87′ 0″	7′ 9″
8-4B	06/30/03	Water	N/A	30	164′ 3″	94′ 5″	7′ 1″
8-4C	06/30/03	Water	N/A	30	166′ 8″	95′ 9″	6′ 2″
Average					168’ 5″	89′ 1″	7′ 0″

TABLE A-9. RESULTS OF THE HIGH-PERFORMANCE, MULTIPOSITION, BUMPER-MOUNTED TURRET AGENT STREAM THROW RANGE TESTS

Test No.	Date	Agent	Boom Position	Turret Position (degrees)	Distance (ft)	Effective Mass (ft)	Width (ft)
9-1A	20/06/01	AFFF	DIF	10	149′ 4″	86′ 4″	9′ 0″
9-1B	20/06/01	AFFF	DIF	10	146′ 3″	82′ 5″	8′ 4″
9-1C	20/06/01	AFFF	DIF	10	139′ 11″	85′ 6″	8′ 6″
Average					144′ 9″	84′ 8″	8′ 6″
9-2A	20/06/01	AFFF	Fully extended	10	144′ 10″	84′ 5″	10′ 1″
9-2B	20/06/01	AFFF	Fully extended	10	155′ 0″	84′ 2″	12′ 9″
9-2C	20/06/01	AFFF	Fully extended	10	148′ 9″	88′ 2″	11′ 6″
Average					149′ 3″	85′ 6″	11′ 5″
9-3A	20/06/01	AFFF	Full-up	10	157′ 0″	94′ 7″	13′ 2″
9-3B	20/06/01	AFFF	Full-up	10	157′ 8″	98′ 11″	11′ 8″
9-3C	20/06/01	AFFF	Full-up	10	157′ 5″	96′ 10″	12′ 6″
Average					157′ 4″	96′ 3″	12′ 5″
9-4A	24/07/01	PKP	DIF	10	138′ 0″	100′ 0″	41′ 4″
9-4B	24/07/01	PKP	DIF	10	142′ 4″	108′ 0″	42′ 8″
Average					140′ 2″	104′ 0″	42′ 1″
9-5A	24/07/01	PKP	Full-up	10	131′ 0″	103′ 0″	54′ 8″
Average					131′ 0″	103′ 0″	54′ 8″
9-6A	13/06/03	AFFF	Full-up	30	169′ 2″	96′ 7″	16′ 7″
9-6B	13/06/03	AFFF	Full-up	30	170′ 0″	98′ 4″	16′ 2″
9-6C	13/06/03	AFFF	Full-up	30	167′ 3″	94′ 10″	15′ 5″
Average					168′ 8″	96′ 4″	16′ 1″
9-7A	13/06/03	AFFF	DIF	30	164′ 3″	103′ 4″	12′ 11″
9-7B	14/06/03	AFFF	DIF	30	165′ 9″	103′ 3″	14′ 1″
9-7C	14/06/03	AFFF	DIF	30	162′ 3″	109′ 6″	12′ 8″
Average					164′ 1″	105′ 4″	13′ 0″
9-8A	17/06/03	AFFF	Fully extended	30	167′ 9″	96′ 5″	14′ 9″
9-8B	17/06/03	AFFF	Fully extended	30	164′ 0″	99′ 8″	13′ 6″
9-8C	17/06/03	AFFF	Fully extended	30	166′ 10″	101′ 9″	14′ 0″
Average					166′ 0″	99′ 4″	14′ 1″

TABLE A-10. RESULTS OF THE P-19 ROOF-MOUNTED TURRET AGENT STREAM THROW RANGE TESTS

Test No.	Date	Agent	Boom Position	Turret Position (degrees)	Distance (ft)	Effective Mass (ft)	Width (ft)
10-1A	02/01/03	AFFF	N/A	0	6′ 2″	39′ 0″	8′ 2″
10-1B	02/01/03	AFFF	N/A	0	62′ 3″	38′ 0″	8′ 0″
10-1C	02/01/03	AFFF	N/A	0	55′ 3″	36′ 6″	8′ 4″
Average					62′ 6″	37′ 8″	8′ 2″
10-2A	30/12/02	AFFF	N/A	10	125′ 6″	81′ 3″	8′ 2″
10-2B	30/12/02	AFFF	N/A	10	124′ 8″	83′ 3″	9′ 4″
10-2C	30/12/02	AFFF	N/A	10	120′ 2″	81′ 2″	8′ 8″
Average					123′ 5″	81′ 9″	8′ 8″
10-3A	02/01/03	AFFF	N/A	20	135′ 5″	93′ 3″	7′ 9″
10-3B	02/01/03	AFFF	N/A	20	134′ 9″	92′ 2″	8′ 0″
10-3C	02/01/03	AFFF	N/A	20	134′ 0″	95′ 7″	7′ 8″
Average					134′ 8″	93′ 7″	7′ 9″
*10-4A	02/01/03	AFFF	N/A	30	114′ 3″	48′ 3″	9′ 3″
10-4B	02/01/03	AFFF	N/A	30	157′ 2″	96′ 6″	5′ 9″
10-4C	02/01/03	AFFF	N/A	30	154′ 9″	95′ 7″	6′ 3″
10-4D	02/01/03	AFFF	N/A	30	156′ 0″	97′ 4″	5′ 2″
Average					156′ 0″	96′ 5″	5′ 8″

*Discounted