Aircraft Rescue and Fire Fighting Efficiency Relates to the Use of New Technology

Is it Time to Recalculate ARFF Index Requirements?

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Introduction: ARFF issues are important to airports everywhere. The cost of providing fire protection at airports can be the largest portion of an airport's operating budget and can impact an airline's decision to serve a community. In 2000, the FAA issued a Notice of Proposed Rulemaking that would add ARFF requirements at the smallest of airports. The Final Rule for this will likely be released in 2004. Additionally, the FAA's Aviation Rulemaking Advisory Committee on Airport Certification Issues has been researching existing ARFF regulatory requirements to make recommendations for specific changes.

Is it time to recalculate ARFF index requirements? Should airports that invest in rescue vehicles with increased efficiency be given credit for this efficiency? When is enough really enough and when is too little too little? It sounds like a riddle but its every airport administrator's nightmare. The decision of how many fire trucks, what size trucks and essentially how much manpower and extinguishing agent to carry is acceptable, all from an economic and ethical standpoint to meet their fire rescue mission requirements. Never mind that the FAA FAR Part 139 specifically states what agent requirements are necessary to meet the airport's index certification requirements. Is the airport administrator compelled to go beyond the FAA certification requirement? A lot of organizations and people think so. When a major transport accident occurs on a commercial airport, the Federal Aviation Administration (FAA), the National Transportation Safety Board (NTSB), the fire fighting unions, pilot's organizations, news media, and the public all examine the airport emergency response with a microscope seeking flaws or weaknesses in the airport's emergency response plan.

The Theoretical and Practical Critical Fire Area (TCA/PCA) methodology published in the FAA's ARFF Facilities and Agents Advisory Circular 150/5210-6C is used to establish Airport Rescue and Fire Fighting (ARFF) fire suppression agent and vehicle requirements. The Congress of the United States has authorized the FAA to participate in sharing the cost or offsetting the burden of providing the aircraft rescue and fire fighting response mission at commercial airports within the United States. This has been done to assure that a minimum level of fire protection is provided to all airports providing commercial passenger operations. The FAA determines Aircraft Rescue and Fire Fighting (ARFF) requirements and its index classification against data and technology, which were developed over 30 years ago. The airport administrator's dilemma is, are these formulas still valid today with aircraft now capable of fuel loads in excess of 40,000 gallons and passenger loads of 450 people and 600 passenger double deck aircraft on the horizon? Is just building bigger aircraft the only measure for the need for more agents? Does the airport administrator need to respond to each new model and generation of larger aircraft by expanding their rescue and fire fighting services? Or is there some finite point when enough is enough?

The TCA/PCA methodology evolved in the 1960's and 1970's. It was based on experimental fire suppression tests that did not replicate actual crash site conditions. They were developed based on design fires. Design fires are large pooled fires in which fuel is floated across the surface of water to reduce burning fuel loads. The question still begs to be answered: were these the correct fires that replicated real accident post crash fuel fires? More importantly, the architects of the TCA/PCA methodology did not have the past 30 years of Large Frame Aircraft (LFA) crash fire fighting experience and statistics to baseline their decision making processes. Statistics today support the fact that accidents in the last 30 years rarely involved a large post crash fuel fire, pooled on water. Accidents today, are more likely to have an associated running fuel fire known in the industry as a three-dimensional fuel fire. Specialized nozzles have recently been developed which excel in extinguishing these types of fires. In addition, interior fire suppression has been a particular problem in several historic accidents in both passenger aircraft as well as cargo aircraft. When an aircraft burns to the ground due to an uncontrolled interior fire, it can take several days to a week to remove it from an active runway. The loss revenue to an airport can be in the millions of dollars. Finally, the improved ARFF vehicle and agent technologies and capabilities that are available today were never considered or influenced the methodology structure for calculating fire protection requirements at today's airports. Below is a table of FAA certification requirements for FAA indexed airports.

FAA
Fire Truck and Fire Extinguishment Quantities

FAA AIRPORT	**A**	**B**	**C**	**D**	**E**
Length of Aircraft (ft.)	<90	90<126	126<159	159<200	>200
ARFF Vehicles Required	1	1 or 2	2 or 3	3	3
Total Fire Fighting Agent Required	500 lb. DC*/Halon 1,211 or 450 lb. DC and 100 gal. of H^2O	Same as A and 1,500 gal. of H^2O	Same as A and 3,000 gal. of H^2O	Same as A and 4,000 gal. of H^2O	Same as A and 6,000 gal. of H^2O

****DC= Dry Chemical***

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It is time to recalculate ARFF Index Requirements? The FAA assists commercial airports in obtaining these technologies through its well-known Airports Improvement (AIP) grants program. The AIP is designed to offset the high cost of providing quality fire fighting services at commercial airports in the United States. The FAA advisory circulars are used to develop guidelines on the types of equipment and technology that fire services should use on civil airports. The FAA works in cooperation with the National Fire Protection Association (NFPA) to the mutual benefit of both organizations. The FAA truck advisory circulars 150-5220-10C and the NFPA 414 Heavy Fire Rescue Truck Standard have similar performance requirements.

Truck manufacturers and the ARFF equipment industries have developed technologies, which can enhance efficiency and improve the fire fighting capabilities of ARFF services at airports around the world. Examples of some of the technologies developed in the last decade to improve fire fighting services response are as follows:

Infra Red Cameras systems are now required on all FAA funded heavy rescue vehicles and are designed to improve the response and operation of ARFF crews in low-visibility conditions. They will also provide a substantial increase in the ability to locate people, other aircraft, vehicles, and debris at the emergency site. Its ability to see through flames, smoke, and fog in daytime and nighttime conditions will give ARFF vehicles a increase in effectiveness in every phase of the emergency operations.

Extendable Reach Booms: The analysis of aircraft accidents involving external fuel fires has shown that, although external fires are often effectively extinguished, secondary fires within the fuselage are difficult to control with existing equipment and procedures. *In particular, there is a need to improve post crash interior fire survivability by developing better post crash cabin interior fire suppression techniques***.** Large amounts of smoke-laden toxic gases and high temperatures in the passenger cabin can cause delays in evacuation and pose a severe safety hazard to the fleeing passengers. The fire fighters put themselves at great personal risk when attacking any interior fire with hand lines. Historically, there has been no proven method to get early water intervention into the cabin interior within a few minutes of arrival of fire fighting crews. Dedicated rescue crews with specialized mobile stairways or lifting truck platforms for emergency egress into the cabin takes time to get in place and have not proven to be effective.

There is a need to improve post crash interior fire survivability through better cabin interior fire suppression techniques. The FAA, along with the United States Air Force (USAF) and the San Antonio (Texas) Fire Department have successfully tested an elevated waterway system with a boom-mounted cabin skin penetration system. At present, more than 250 airports in the United States and worldwide have upgraded their fleets with elevated boom-type devices. Fire services responding with vehicles equipped with elevated boom devices could make a significant early contribution to controlling any interior fires. ARFF responders can use elevated boom devices with their high reach and low ground attack agent distribution to gain quicker control of post crash external pool fires. Earlier control of external fires can provide additional valuable minutes of evacuation time for passengers. Strategically positioned to make a cabin skin penetration, these devices have the potential to extend survivability for passengers who cannot themselves self-evacuate and provide a safer situation for fire fighters to enter the aircraft after the evacuation of passengers has been accomplished. The French Department of Aviation at Charles DeGaul International Airport performed a similar large-scale evaluation of a elevated boom and cabin skin penetrator on a Sides manufactured rescue vehicle. Their were similar to the FAA test. Fire services responding with vehicles equipped with elevated boom devices could make a significant early contribution to controlling any interior fires.

The effective use of a boom-mounted cabin skin penetration system and its role in combating a post crash interior fire will be written by future results as many more airports deploy this technology. As the aviation industry moves toward development of the next generation of New Large Aircraft (NLA), which will include second level passenger seating on double-decked aircraft, this technology will be further explored to meet any fire protection requirements of this next generation of aircraft.

The unique advantage of elevated or extendable booms pointed the way to a whole new approach on how to fight aircraft post crash fires. It became evident in early testing of the elevated devices that the lower to the ground agent was applied to the surface of the fuel, the more rapidly the fuel vapor could be suppressed. Thus the fire could be extinguished with considerably smaller quantities of extinguishing agent and in much less time then had previous been possible.

Low ground attack.

High angle application.

Extension into harms way.

Agent Application: For many years fire fighters were taught to apply extinguishing agent in a wasteful manner. The procedure was called the raindrop method. It was found to be ineffective and very inefficient. Fifty per cent of agent applied to the fire never reached the fuel surface. It was carried up vertically into the thermal heated smoke. The FAA/USAF jointly participated in a large-scale fire test program to evaluate new fire fighting technologies. One specific area of research related to the most efficient angle of application for fire fighting extinguishing agents. Data produced from the comprehensive testing indicated that the raindrop method of application was not the most effective method for applying extinguishing agent to a large post crash fuel fire.

In the *Series 1 Tests*, only the agent angle of attack was changed in the fire fighting event. In the large scale fire tests results below, note that as the angle of agent application was raised, the time of fire control increased.

Approach Mode	Large Scale AFFF Delivery Tests Fire Surface –3, 850 SF Average 90% Fire Extinguishment Time (Sec) Nozzle Elevation		
	45^o	30^o	0^o
Frontal @0.07 GPM/SF	56	43	31
Side @ 0.07 GPM/SF	67	63	68
Frontal 0.13 GPM/SF	50	42	22

Table 1, Test Series 1
Roof Turret Elevation Angle

In large pool fires the rescue trucks must be repositioned or elevated turret angles must be used to deliver agent to the far side of the fuselage. Elevating the turret delivery system angles is very inefficient and can increase extinguishment times by 100% or more. Agent directed down onto the fuel surface tended to splash and disturb the film forming over the fuel surface. Total extinguishment of far side fire areas is not possible without application of inordinately large agent quantities. Vehicle repositioning interrupts agent flow, which can permit burn-back and immediate loss of fire control.

Summary and Conclusions of Test Series 1 - Optimum rescue vehicle approach mode conditions that should be considered: Frontal and tail approach; 0.13 GPM/SF AFFF (Aqueous Film Forming Foam) application rate; 0^o, seat of the fire, agent delivery angle parallel to the ground.

The side attack of a Large Frame Aircraft Fire is extremely inefficient and should not be conducted, unless it the only choice for setup. Nose to tail setup allows agent to be applied to protect the fuselage and evacuation slides and allows fire to be swept away from the evacuation corridors.

Approach Mode	Large Scale AFFF Delivery Tests Fire Surface –3, 850 SF Average 90% Fire Extinguishment Time (Sec) Delivery Method			
	Raindrop 45° (Roof Turret)	Raindrop 30° (Roof Turret)	Raindrop Average	Seat of The Fire 0° (Bumper Turret)
Frontal@ 0.07 GPM/SF	56	43	50	31
Frontal @0.13 GPM/SF	50	42	46	27
Total Extinguishment Times	116	85	96	53

Table 2, Test Series 2
Raindrop vs. Seat Of Fire Evaluation Tests

Series 2 Tests - A second series of tests was developed to examine Raindrop vs. Seat of Fire AFFF delivery methods using the following test parameters: 3,927 square foot fire area; water fire surface; 1,000 gallon JP-8 pre-charge; AFFF delivered from a Crash Fire Rescue (CFR) roof turret at a rate of 0.13 GPM/SF; AFFF delivered from a CFR bumper turret at a rate of 0.07 GPM/SF; 0^o, 30^o, and 45^o nozzle delivery elevations at each AFFF delivery rate; and frontal attack ARFF vehicle fire scene approach.

Three tests were conducted for each approach mode, each flow rate, and each nozzle delivery angle with the following results: 0^o, seat of the fire agent delivery angle is shown to be clearly superior to raised turret elevations or the raindrop delivery technique. For 0.07 GPM/SF, increasing the turret elevation to 45^o increased extinguishment time by 81%. For 0.13 GPM/SF, increasing the turret elevation to 45^o increased extinguishment time by 127%. The average extinguishment time for 45^o and 30^o elevation raindrop agent delivery approaches is 81% higher than for the seat of the fire technique. The average extinguishment times of these tests are summarized at Table 2.

Another test consideration was the vehicle driver-operator visibility. Roof turret applications at 30^o and 45^o elevations caused considerable windshield obstruction. Poor visibility caused the target to be directly obscured by the agent plume and by agent blow-back that was deposited on the vehicle windshield. Fire fighters could neither see how effective they were, nor where the agent was going. Visibility improved at a 0^o delivery angle, but some target obscuration and agent blow-back and deposited on the windscreen still occurred. Maximum driver-operator visibility occurred when the bumper turret was used in a 0^o, seat of the fire, agent delivery mode.

Forty-five degree application results in the greatest reach for roof turrets but agent loss occurs in the fire plume and disrupts the surface of the fuel by splashing the film surface buildup process.

Point of attack application from roof turrets accelerates agent but leads to over spray on windshield, which causes waste of agent. Because of obscured vision, fire fighters could not see what effect the agent was having on the fire.

Parallel to ground application accelerates agent across the fuel surface. This type of low ground attack allows a 10 degree power cone spray effect that disperses agent more rapidly.

Test summary and conclusions: Optimum LFA crash vehicle approach mode conditions are frontal and tail approach, 0.13 GPM/SF AFFF application rate, 0^{o}, seat of the fire, agent delivery angle. Bumper turret delivery provides optimum visibility. This approach mode can be executed only if a 250 GPM/SF flow rate is sufficient for the crash-fire scenario. The raindrop agent delivery approach is extremely ineffective and wastes significant quantities of AFFF. Low parallel ground agent application (extendable boom) accelerates the flow of aqueous film across the fuel surface. Technologies, which deliver low ground agent application, are the most effective, as the agent doesn't get lost in the rising heat and smoke plume. Visibility is not lost or interrupted by agent over spray on the windshield. The elevated boom in the ground attack mode places the agent at or near ground level. This technology will be the most effective in initial fire knockdown.

Note – Document source, in part, is an unpublished report "Large Frame Aircraft (LFA) Fire Fighting Validation" dated 1996 which was generated by the USAF Large Frame Aircraft Fire Fighting Research Program. Information was condensed and edited for this publication. The USAF, Tyndall AFB and the FAA jointly funded the testing program.

High-capacity extendable bumper turret systems: FAA/USAF large-pool fire fighting research has shown that low ground application of extinguishing agents produces better results than the raindrop method that was used for many years in AFFF applications. A more direct method where the agent is applied from a low ground position based on a high-capacity extendable bumper turret location reduces agent loss or waste due to window over-spray conditions from high-capacity roof turret application methods. In addition to the window over-spray problem, there is a significant improvement in fire knockdown and control applications when the agent is precisely supplied using low, parallel-to-the-ground application sweeps. Tests results validated a 38% improvement in fire extinguishing when bumper turrets were used at same rate as roof turrets. Thus, the FAA has modified its advisory circular series for large rescue vehicles to allow fire services to include these types of high-capacity extendable bumper turret systems.

Low ground attack ***Good visibility*** ***More agent on fuel surface***

Dual Agent Application: A new method has been developed to provide primary agent and secondary dry chemical applications simultaneously. Developed to address the oil well fire crises in the Middle East in the mid-nineties, the new nozzle system entrains the dry chemical powder into the master stream delivery system. This has resulted in better performance in combating three-dimensional running fuel fires. Measured results have shown the ability to deliver dry chemical precisely at distances of as much as 200 feet in USAF/FAA joint tests. This is a 100% improvement over present dual-agent application nozzles. Extinguishing three-dimensional running fuel fires has always been an extremely difficult task for ARFF fire fighters.

Spraying dry chemical into the master stream allows quick knockdown of large fires.

High-Pressure Compressed Air Foam: Several new devices, which can produce high-expansion foam applications, have been introduced to the ARFF community. The delivery systems being produced use both AFFF and various types of high-expansion, protein-based form derivatives. They expand the foam to approximately a 20 to 1 foam expansion rate. Thus, they typically produce about four times the foam product as normal AFFF systems. The initial interest in these types of applications was driven by a desire to develop a small compact system to provide quick knockdown and suppression of smaller type fires in which a full ARFF type vehicle might not be available on site. This equipment has now been modified to supply both small Rapid Intervention Vehicle (RIV) applications as well as installation on major rescue vehicles. High-pressure compressed air foam systems are just one example of ARFF fire protection proposals being considered as authorities look at pending regulations planned for the smaller commuter markets. Compact systems could be deployed on site, which would provide some level of fire protection at airports that do not presently have such protection, yet may be operated by airline personnel if needed. Additionally these High Energy Cold Foam devices have proven to be very effective in combating running fuel fires or three-dimensional fires. They have shown to far exceed the results obtained using traditional dry chemical powder extinguishing agents currently in rescue service inventories at airports.


Small systems can produce large quantities of finish foam product.

Conclusion: The TCA/PCA methodology evolved three decades ago. It was based on experimental fire suppression tests that did not replicate actual crash site conditions. More importantly, the architects of the TCA/PCA methodology did not have the past 30 years of LFA crash fire fighting experience and statistics to baseline their decision making processes. Research established that agent applied at low ground to near ground application reduced or cut extinguishment times by 100% over older raindrop traditional methods of application.

The improved ARFF vehicles and agent technologies and capacity that are available today were never considered in these early methodology calculations. Neither FAA FAR Part 139, nor ARFF Facilities and Agents Advisory Circular 150/5210-6C, have been upgraded in the last 20 years to reflect changes in the industry. Airports that purchase newer vehicles with improved efficienc***y*** are not given any credit for these technologies**.** As aircraft get larger, a technology offset should be calculated into any new index requirements. ***It is time to recalculate ARFF index requirements. Airports that invest in rescue vehicles with increased efficiency should be given credit for this efficiency***!

Thirty years of technology and accident response experience show that it may be time to review the TCA/PCA methodology developed over three decades ago. As mentioned earlier, it was based on experimental fire suppression tests that did not replicate actual crash site conditions. In the 1960's and 1970's the perceived threat to aircraft was a large post crash pool fire. The improved ARFF vehicles and agent technologies and capacity that are available today were never considered in these early methodology calculations. Today, statistics show that accidents more frequently have the aircraft intact with three-dimensional running fuel fires or interior fires that require specialized equipment and tactics. Additionally, research established that agent applied at low ground to near ground application reduced or cut extinguishment times by 100% over older raindrop traditional methods of application.

Technology that provides for this low ground application should be encouraged by providing airports with index incentives for their use. Airports that purchase newer vehicles with improved efficiency are not given any credit for these technologies. Could it be time for the FAA to provide a technology offset when calculating new index requirements. ***Is it time to recalculate ARFF index requirements to accommodate these new technologies and lessons learned? Time will tell as the FAA and others look at ARFF requirements within Part 139.***