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EVALUATION OF THE NORTH ISLAND A/C CRASH/RESCUE TRAINING FACILI--ETC(U)
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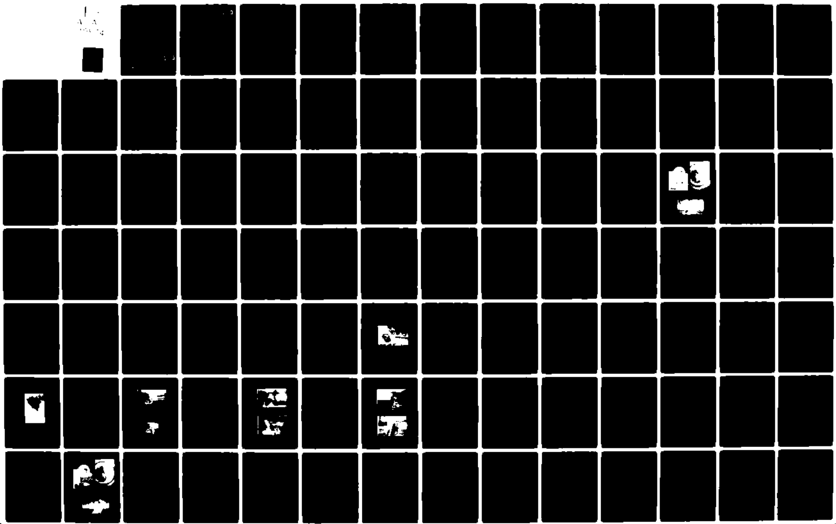

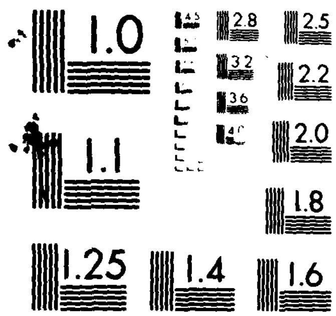

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EVALUATION OF THE NORTH ISLAND A/C CRASH/RESCUE TRAINING FACILITY

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1.0 INTRODUCTION

The Clean Air Act of 1963 suddenly replaced the firefighter's good image with a picture of polluters and despoilers of the environment Although training fires are generally exempt from the no burning regulations the public outcry at the sight of black smoke clouds was effective in curtailing many training programs. Because the large fires traditional in aircraft crash and rescue training are particularly conspicuous, the smoke problem became acute at many air stations. Consequently, under executive order 11752 the Navy and the Airforce began a cooperative effort to develop training facilities that could provide more training with less smoke and water pollution. Soon the central issue of pollution control was surrounded by a series of satellite questions that had to be answered before training facilities could be designed, e.g., what type of training is required; how much training should be provided; where should firemen train; and how much departure from the real emergency situation is permissible. Various public and private groups contributed answers and the Naval Air Station, North Island, San Diego, California Aircraft/Crash Fire Rescue Training Facility is the first Navy facility constructed as an outgrowth of this effort to improve training while reducing the environmental impact to an acceptable level.

This report evaluates the performance of the North Island facility in a series of environmental and training tests. The scope includes: (1) a brief review of the training philosophy and developmental effort behind the design, (2) the evaluation procedure and results, (3) a comparison to other training options and (4) recommendations for future training activity.

2.0 BACKGROUND

2.1 Traditional Aircraft Crash and Rescue Training

2.1.1 Focus on the Crash and Rescue Vehicle

These vehicles are designed primarily to cope with the large fuel spill fires anticipated in the event of a major accident. Initially the fuel was gasoline, and the agent was protean foam or protean foam and potassium bicarbonate. The principal goal was to rescue the flyers and the technique was to form a rescue path through the fuel burning around the plane. A blast of foam from the truck turret formed the initial path and hand linesmen in proximity suits maintained the path and pushed back the flames while the rescue crew in "hot suits" retrieved the flyers. Fire fighting training centered on this evolution and asbestos clad dummies were routinely rescued from boilerplate aircraft surrounded by waste hydrocarbon fires.

Over the years, technology has changed both the challenge and the required response. Four significant developments were:

- The advant of jet engines and the accompanying change in fuel to mostly JP4 and JP5
- Larger aircraft which have larger fuel capacities
- The ejection seat, and
- Aqueous film forming foam.

Larger quantities of fuel increased the challenge which was met with larger crash trucks and higher foam discharge rates. However, the low volatility of JP5 reduced the burnback threat and the high efficiency of AFFF reduced the time and amount of agent required to extinguish a fire. Finally the ejection seat greatly reduced the number of flyers that needed to be rescued. These developments introduced some changes in fire fighting techniques and the associated training requirements. For example, less emphasis was placed on the rescue path because of the ejection seat and more attention was directed to extinguishing the whole fire with AFFF. This shift reduced the hand line requirements and increased the reliance on the turret operator. Simultaneously, economic pressures called for manpower reductions; consequently, trucks and firefighting techniques were arranged for smaller crews; e.g., the original five man crews for MB5 and MB1 have been reduced to three men. Again the change places more of the fire suppression effort on the turret. Finally, it should be noted that big trucks and the emphasis on high discharge rate turrets require large training fires if the operators are to be challenged and these large fires are very conspicuous in a clean air environment. Therefore, the large pool fire was an obvious starting point for the air pollution abatement program.

2.1.2 Division of Responsibility for Training and Facilities

Within the Navy, fire protection and the associated training are complicated by the fragmentation of responsibilities. Consequently, a coordinated action requires an effective cooperative effort across command boundaries. For example:

- NAVFAC designs and supplies the crash rescue vehicles
- NAVAIR provides the U.S. Navy aircraft fire fighting and rescue manual "NAVAIR 00-80R-14"
- NAVMAT has selected the agents; e.g., the switch from protean foam to AFFF and the current introduction of Halon 1211
- The National and Regional Fire Marshals are located in NAVFAC
- NAVFAC is responsible for pollution mitigation research and development
- Training funds come out of the local station budget which is under control of the commanding officer.

In the past the responsibility for specifying the type and amount of training required has not been well defined and there were no provisions to insure availability of the necessary training funds. A revised NAVMAT Instruction "11320XX authority and responsibility for aircraft rescue and firefighting ashore" is designed to alleviate some of this undertainty by specifying that NAVAIR will be responsible for the type and amount of training along with research and development of training tactics and systems. Other responsibilities will remain in their historical locations as listed above.

2.1.3 Training and Training Facilities. What is specified and what is available?

Existing directives are quite general and do not specify the training curriculum or how the trainee is to be evaluated. For example, the current NAVAIR manual 00-80R-14 specifies the need for hot training and a training area at each station located so as not to interfere with flight operations. An earlier version of the manual emphasized the desired results namely successful firemen are well trained, highly skilled, and motivated individuals. Implementing these instructions is a local matter constrained by the station budget. In the usual budget, training funds are included with the other fire department supplies, e.g., agents, turnout gear. Consequently, training frequently ends up with a low priority. When the local chief advocates a rigorous training program, it is usually carried out with homemade test equipment and discarded fuel.

Most stations have provisions for a pool fire where the crash trucks can be exercised on aircraft mockups that may range in sophistication from a few 55 gal barrels to fuselages from discarded aircraft. The fuel is whatever hydrocarbons are surplus and free. Although there tends to be considerable JP5 at stations where this is the principal aircraft fuel, the mixture frequently contains lubricating oil, diesel, hydraulic fluid etc. so there is considerable variation from one fire to another. Another economy practiced until a few years ago involved training with surplus outdated protean foam to save the costs of the more expensive AFFF. This practice was discontinued when it became apparent that the most efficient techniques for applying AFFF were substantially different than the method used with protean foam. The rescue path evolution is commonly practiced at these pool fire pits equipped with a mockup. Other facilities present at some stations but not as universal as the pool fire pit include areas where the turret can be exercised with plane water, old aircraft fuselages for forceable entry practice and structures to simulate fires inside a large aircraft where the fire must be attacked from inside the fuselage.

2.2 Development of Smokeless Training Fires

2.2.1 The Hot Fire Pit

About 10 years ago a program was initiated to abate the smoke from large pool fires. This effort culminated in the IITRI water spray technique described in reference 1. By 1974 a full scale prototype of the water spray pool fire system was under construction at Chanute AFB. In 1975 a series of tests jointly sponsored by the Airforce and the Navy evaluated the system both for its ability to control air pollution and as a training device.[1,2] Based on these results, the system was approved as the principal training device to be installed at AF Bases and naval air stations where smoke abatement was a problem. However, several aspects of the system continue to cause confusion and differences of opinion. First there is the question of mechanism, i.e., how does the water spray abate the smoke? The initial discovery was fortuitous and the Chanute design was based on empirical tests because support was never provided to discern the physics and chemistry of the process. This uncertainty in the relative importance of the various system parameters makes it difficult to evaluate the effects of changes that creep in during other site adaptations of the design or during construction. Second and most important, the training performance tests at Chanute failed to convince most of the professional firemen that the abated fire was an adequate simultion of aircraft crash fires. Consequently there was no clamor from local commands to have the systems installed at their stations. Initially two features were responsible for this reticence regarding smoke and heat. More recently, cost has become a major deterrent. Because the clean air objective was to abate smoke the debate hinged on how smoke impacted on crash and rescue training. Two aspects are visability and the psychological influence of large billowing black clouds of smoke that add a sense of greater size and ferocity to the appearance of the fire. The Chanute tests seemingly answered the psychological questions because they involved inexperienced new recruits entering the fire area with hand lines. No statistically significant difference was observed between teams that trained on abated or unabated fires when the final tests were performed on unabated fires. Unfortunately the visibility question was left in doubt. The crash truck drivers were fire school instructors who knew the test area intimately and could lay out the rescue path without having to see the mockup. In retrospect it appears that inexperienced drivers and monitor operators would have made the Chanute tests more convincing.

The water spray substantially decreases the burning rate and the radiant heat experienced by the firefighters in their proximity suits; however, the Chanute tests would indicate that this factor did not seriously influence the training results. Normally this reduction in burning rate would be expected to reduce the amount of foam required to cool the fuel bed and extinguish the fire but the Chanute tests did not indicate a significant difference in extinguishment requirement. Apparently the foam breakage and washing caused by the sprays counteracted the cooler fire advantage.

A final concern was the limited flexibility of the abated fire for problem solving types of extinguishment exercises, i.e., the fire area and intensity are rather stringently established by the spray field design. Actually the conventional training pool fire is similarly fixed so flexibility is introduced in the mockup through location, other types of fuels e.g., tires, and spraying or flowing fuel leaks in the aircraft. Similar options are available to the abated pool fire.

To date including the original Chanute prototype, five water spray pit fires have been constructed in general agreement with the IITRI Specifications, i.e., Chanute, Heckham, Hill, Tyndal and North Island. The experience of these Air Force facilities will be considered along with the North Island results in the discussion section 6.0 and recommendations 8.0.

2.2.2 Auxiliary Fire Training Devices

In 1975, a project was initiated at NSWC-SRI to examine the questions of type and amount of training required. Reference 3 presents the results of this study. On the basis of historical evidence, i.e., the incidence of Air Force, Navy and commercial aircraft fires during the previous five years the report suggested the following classes of aircraft fires for a comprehensive training program:

- Class A and Class C compartment fires
- Class B (1) large pool open pit fires, (2) semienclosed engine and nacelle fires, and (3) spraying or cascading fires in the open
- Class A and D fires involving wheels, tires and brakes.

"Two factors were reflected in this selection: (1) the frequency of the prototype accident and (2) the consequences, i.e., the potential for loss of life and property in each category. For example, crash fires involving large quantities of burning fuel are rather rare. Many air stations fortunately operate for years without such an occurrence. Nevertheless, the consequences of such potential major accidents are the principal raison d' etre of airport crash/rescue services and a major factor in the design and selection of fire fighting vehicles. Their low frequency of occurrence, however, means that firemen cannot depend on real emergencies to maintain their proficiency; therefore, training exercises become a vital factor in preparing for the rare but serious emergency. Similarly, Class A compartment fires were included in the list because of the potential for large loss of life and equipment, but the rest are present because of their high occurrence frequency." Based on these conclusions NSWC/SRI designed the smoke abated cascade fire, engine and nacelle fires, and compartment fire simulators described in Appendices A, B, and C respectively. The cascade fire simulator was first demonstrated to a group of DOD fire chiefs and officers at the C5A test sight in China Lake where they were assembled to observe a series of crash vehicle tests. In 1977 the engine and nacelle fire simulator was also demonstrated at China Lake under simular circumstances. There is no electric power at the C5A test sight and it was not convenient to use the units there for routine training. Consequently the simulator sat unused in the desert for about 5 years. Shortly before the simulators were moved to North Island, the NWC firemen moved the units to their training area and exercised them both with PKP and Halon 1211. No training deficiencies were encountered during the brief periods of use at China Lake.

2.3 Training Philosophy

Besides preparing the fireman to meet a particular type of emergency, training aids should reflect the philosophy behind the training program. The philosophy behind the simulators prescribed for North Island is described in reference 3. Three elements of this philosophy are:

- Self-evaluation of performance
- Uniform certification throughout the Navy
- Motivation - training should be enjoyable, rewarding, and not monotonous.

Both self-evaluation and uniform certification of performance involve quantitative measurements of suppression proficiency. Reproducible challenges are an indispensable requirement for training programs in which standardized yardsticks of performance are employed. Obviously, it is impossible to compare hot-fire suppression results from one man to another, one day to the next, or between different stations until we can insure reproducible fire characteristics and an equal level of suppression difficulty. In the cascade and engine fire simulators, the fire size and intensity are controlled by the rate of fuel and air supply which can be adjusted to provide various levels of challenge. The amount of agent required to extinguish each fire provides the yardstick to measure performance. A fireman can keep track of his own performance by comparing the amount of agent he uses from one time to another and a target valve similar to PAR in Gulf can be used to indicate acceptable levels of performance. Such quantitative results can be used to insure a uniform certification of performance throughout the land. Motivation comes through competition and reward. Most sports involve very repetitive processes that would soon become boring if it were not for the competition either with ourselves or against others. Quantitative training devices provide a scoring method that can be used as a basis for competition. Problem solving exercises are not only essential but they are probably more stimulating than the standard repetitive fires. The mockup in the hot pit and the fuselage fire trainer provide the flexibility for this type of exercise. Finally financial awards through promotions, merit increases, or accomplishment awards can be tied in part to quantitative indications of performance. One goal of the North Island tests was to evaluate this quantitative aspect of the training aids and accummulate some data that can be used to establish yardsticks.

This quantitative approach also provides an answer to the question "how much training is required?" Once minimum levels of performance are established for each fire, the minimum amount of training is that required to equal the minimum score. All people do not learn (or forget) at the same rate. Consequently different firemen will require different amounts of training. Appropriate intervals between performance checks will materialize for each fireman from his accummulative scorecard record.

2.4 Integrated Training Facility

Reference 3 integrated five training devices into an environmentally compatible facility designed to satisfy the training requirements and philosophy outlined above. Appendix A reproduces the field layout for this facility adjusted to meet various training loads. All three modifications contain the same training devices but the auxiliary equipment, i.e., to handle fuel, water, and contaminants, varies to meet the training loads. The hot fire pit dominates both the cost and training schedule so the different facilities are rated according to the number of hot pit fires that can be accommodated per week, e.g., up to 5 for Spartan, 5 to 20 for Modest, and 20 to 60 for Sophisticated. In addition to the hot fire pit, fuselage fire trainer, cascade fire, and engine fire trainer, the facility contains a cold fire pad where the crash vehicle and turret can be exercised virtually continuously at very little cost because the agent is recovered and reused. Reference 3 describes the construction and approach to quantitative measurements for the cold foam pad. Again the philosophy is to achieve a suitable level of performance on the cold foam pad before the fireman is allowed to move on to the hot fire pit where the cost of operation and pollution control are prohibitive if used as the only source of training in truck and turret control.

2.5 Economic Analyses of Various Options Involving Location and Frequency of Training

The questions of when and where to train were addressed in an economic analysis reported in reference 4. Initial acquisition costs plus the maintenance and operating costs for an estimated 25 year life of the facility were compared for the following options:

- Training goes to the firemen
  - Option 1. Each station has its own training facility (44 facilities)
  - Option 2. A mobile training facility visits each station once a quarter (8 units required)
- Firemen go to the training
  - Option 3. Neighboring Navy stations, e.g., within a 100 N mile radius share a facility (23 facilities required)
  - Option 4. Neighboring Navy and Air Force stations within 100 mile radius share a facility (15 facilities required)
  - Option 5. Regional training centers train and certify all firemen on an individual basis (two regional centers)
  - Option 6. Three regional centers
  - Option 7. Four regional centers
- Combinations where cold pad training is performed locally but firemen go to hot fire training
  - Option 8. Combination of Options 1 and 3
  - Option 9. Combination of Options 1 and 4
  - Option 10. Combination of Options 1 and 5
  - Option 11. Combination of Options 1 and 6
  - Option 12. Combination of Options 1 and 7

Because of the large reoccurring costs of firemen's wages while they were away from the station for training, Option 1 was the most economical as well as least disruptive to the station schedule. Consequently reference 4 recommended the adoption of Option 1 with a selection of Spartan or Modest facilities based on the station fire department size. No single stations were large enough to require the Sophisticated design.

Reference 4 concludes with recommendations and specific site considerations for proposed training facilities at NAS China Lake and North Island. Both of these stations are large enough to require a Modest facility.

3.0 DESCRIPTION OF THE NORTH ISLAND FACILITY

Figure 3.1 shows the location of the North Island training facility with respect to the taxi ways. Figure 3.2 is an enlarged view of the training area. As noted on the drawing, a location has been established for all five of the training devices discussed in section 2.2; however, only the hot fire pit was included in the construction contract.

3.1 The North Island Hot Fire Pit

In general the unit follows the IITRI design set forth in reference 1 and specified in more detail in reference 5; however, there are some departures that significantly influenced the performance. Figure 3.2 shows the three main features of the design: (1) the fir pit $\frac{CS}{1A}$, (2) the control tower $\frac{B}{1}$, and (3) the fuel and water handling equipment namely pumps $\frac{P}{1}$ through $\frac{P}{6}$, sumps $\frac{CS}{2}$ and $\frac{CS}{3}$ and storage tanks $\frac{T}{1}$ through $\frac{T}{4}$.

According to the sizes and capacities of the fuel and water handling equipment summarized in table (3.1), this trainer qualifies as a high capacity modest unit. The design departures from reference 1 include:

- The continuous metal cover over the curb $\frac{CS}{1D}$
- Surface mounted pumps instead of submersible self-priming pumps in the fuel and water tanks
- No pressure gauges on the spray water zone lines

The operating procedure specified in reference 1 is as follows:

(1) Fill the pool to the water level controlled by the weir. Either fresh water from $\frac{T}{1}$ or waste water from $\frac{T}{4}$ can be used for this purpose.

(2) Start the smoke abatement sprays in the 5 zones. Pump $\frac{P}{1}$ supplies this water from the fresh water tank $\frac{T}{1}$. Set the zone control valves near their optimum openings.

(3) Start the fuel delivery and ignite immediately to prevent the escape of hydrocarbon vapors. $\frac{P}{2}$ will supply 300 gal of fuel from Tank $\frac{T}{2}$ in about 30 sec.

(4) During this 30 sec Preburn, adjust the zone control valves to optimize the fire size and smoke level.

(5) After the preburn initiate fire suppression with trucks maneuvering in the 300 dia clear area.

(6) After extinguishment, close the wier gate, flood the pool with water (waste or fresh) and flush foam and unburned fuel over the curb into the drainage gutter and thence to the drainage sump $\frac{CS}{10}$ and the fuel water separator $\frac{CS}{2}$. Waste fuel drains by gravity into the waste fuel tank $\frac{T}{3}$ and waste water goes to the waste water storage tank $\frac{T}{4}$ by way of sump $\frac{CS}{3}$.

(7) After the pool is cleared of foam and fuel, open the weir gate, reestablish the pool water level and the system is ready for the next training exercise.

When the equipment performs as intended, the first 5 steps go very quickly, e.g., several minutes at the most, therefore the cleanup steps 6 and 7 make the major contribution to the turn around time.

3.2 Cold Fire Pit

Figure 3.2 shows an existing concrete pad in the southeast corner of the training area. A 50' dia. simulation of the hot fire pit was laid out in the northwest corner of the pad and sampling pans were located to monitor approximately equal areas of the circle as illustrated in Figure 3.3. Because the P4 and MB1 turrets are equipped with water nozzles, these trucks can be exercised with water and the flow pattern will be essentially the same as with AFFF. Therefore there is no foam to be recovered. In operation the vehicle driver and monitor operator maneuver as they would at the hot fire pit. The monitor is turned on only long enough to deliver the amount of water equivalent to PAR for the hot fire, e.g., 10 to 15 seconds. After the discharge, the water collected in each 2' x 2' pan is measured with a graduate. This process is repeated until the desired degree of uniformity is achieved before moving on to the hot fir pit. Water from this pad drains into an existing holding tank and then is trucked to the sewer plant. In this exercise the sampling pans were not attached to the pad, an arrangement suitable for foam or nozzles set in the semi-fog position but incompatible with straight stream application. This restriction was accepted for this exercise because straight stream could not be used on the hot pit without knocking rocks out of the pit. For straight stream exercises the sampling pans would have to be attached to the pad.

3.3 Cascade and Engine Fire Simulators

The two units described in Appendices A and B were moved to North Island from China Lake and located approximately at the locations shown in Figure 3.2. No 230 volt power was available in the test area so a mobile electrical generator was used to drive the air compressor and fuel pump. JP4 fuel was supplied from 55 gal drums. These trainers were operated according to the directions included in Appendices A and B.

3.4 Fuselage Fire Trainer

This unit was deleted from the North Island installation and will probably not be included in any future Navy modest training facility. Many fire departments have structures where interior fires can be attacked to gain experience in a hot smokey environment. A long quanset type structure served this purpose at North Island, but this unit was not included in the tests.

4.0 TEST AND EVALUATION PLAN, GOALS, AND PROCEDURES

Appendix E contains: (1) the original test plan outline, (2) the division of responsibility among the four participants, and (3) calibration and operational procedures for the hot fire pit.

4.1 Objectives

The test goal was to answer the following questions:

- Is the atmospheric and water pollution abatement adequate and what limits environmental considerations would place on the number of training exercises?
- Are the smoke abated fires adequate simulations of the anticipated accidental fires?
- Do the fires present an adequate challenge to the firemen and their equipment?
- Are the fires reproducible enough for quantitative training, i.e., would yardsticks to measure fireman proficiency have validity?

4.2 Division of Responsibility

Responsibility for the various aspects of the tests was divided among the participants as follows:

- NAS-North Island Fire Department: (1) procure the test materials, i.e., fuel, agents, vehicles and other suppression apparatus (2) schedule the tests, (3) operate the training facility and (4) provide the trainees. This initial assignment assumed the facility was operational and ready to commence the test. Actually the hot pit could not be operated according to the design specifications until considerable modifications and repairs were made. This additional time consuming effort fell to the fire department.
- SRI International: (1) prepared the test plans, (2) installed the cascade and engine fire simulators, (3) instructed the firemen in the use of the auxiliary training devices including the cold pad, (4) arranged for the procurement of test data, (5) analyze the results, and (6) prepare the final report.
- NCEL Code L54: (1) monitor the waste water handling facilities and procedures to determine their adequacy for disposing of the AFFF and unburned fuel, (2) Recommend procedures for improving the disposal or recovery of AFFF.

- NAS N.I. Code 183: Monitor the air pollution created by the fires and recommend operational restrictions if any to make the training procedures compatible with the clean air requirements.

4.3 Test Procedure and Scheduling

The procedure and schedule outlined in Appendix E was divided into three segments based on the hot fire pit requirements. During an initial week of joint SRI-F.D. activity on the training facility the objectives were to: (1) establish the spray water rates for optimum fire intensity and smoke control of AV gasoline and JP4 fires, (2) monitor and evaluate the atmospheric pollution, (3) select the fuel to be used in the training exercises, (4) establish the data to be collected during training, and (5) obtain some baseline suppression data, i.e., fireman performance at the beginning of the training experiments. The second segment involved a period of about a month devoted to three different training routines. Third, during another week of joint SRI-F.D. effort at North Island, efforts would be made to establish yardsticks for performance and to detect effects of the various training rituals.

The actual procedure departed substantially from this schedule primarily because of the problems with the hot fire pit. Appendix F outlines these problems and the corrective action taken or required. Consequently the initial week (i.e., January 4, 1981) of joint SRI-F.D., exercise on the facility was devoted largely to debugging and repairing the hot pool fire trainer or exercising the auxiliary training devices. These repairs and efforts to obtain challenging reproducible fires were continued by the North Island fire department. AV gasoline was selected as the preferred fuel because the fire was more challenging than the JP4 fires. Unfortunately, much of the fuel originally allotted for suppression exercises was consumed in the struggle to produce suitable test fires. Consequently the training schedule which started May 28th had to be substantially curtailed, but there were sufficient fires to address all of the questions in the list of objectives. T : test program was completed on June 7th.

5.0 TEST RESULTS

In this section, the performance of each training device is presented in the order of the questions raised in Section 4.1. In addition to these four questions, some attention will be directed to questions of reliability. We will commence with the good news, namely the successful performance of the auxiliary equipment. Both the cascade fire simulator and the engine fire simulator had been used in demonstrations at China Lake; therefore, the successful performance was to be expected.

5.1 Cascade and Engine Fire Simulators

5.1.1 Air and Water Pollution

In the previous demonstrations at China Lake, only the smoke produced by the fires was monitored and the air to fuel settings in the operating instructions were selected to produce smokeless fires. At North Island smoke density observations were recorded throughout entire training exercises so that all the associated sources of pollution were included such as clouds of extinguishing powder. Copies of the original data are included in Appendix G. Some of the observations are in Ringelmann numbers which increase in 20% density steps so that 5 corresponds to 100% density. Observations were recorded at 15 second intervals and each value corresponds to the densest region of smoke visable at that time. In some cases this densest region was produced by a bucket of burning fuel used to ignite the ignitor torch and not the training fire. In interpreting the results it is necessary to understand the nature of the observations. For example, pollution should relate to the amount of smoke produced which in turn is a function of the density and the size of the cloud. The size depends on the rate of emission and the duration but only the duration was observed. Also, the Ringelmann system was developed for fairly uniform density smoke plumes such as those from smoke stacks. Consequently, the very nonuniform clouds produced in the training exercises require further interpretation. For example with Halon 1211, tests #46, 47, 48, the readings are near zero throughout the 30 second preburn time.

Then a high reading occurs when the Halon is applied and reacts with the fuel to generate a white or black cloud of very short duration. The white cloud of PKP was recorded in test #51. Fortunately these clouds produced by the agents and their interactions were short lived and did not impose a limitation on the number of exercises that could be conducted in a day. Only the CO_2 produced no visable pollution at any stage of the extinguishment, e.g. see tests #43, 44 and 45. As CO_2 was applied, the size and intensity of the flames decreased until they disappeared completely.

Unfortunately the North Island air pollution observations were conducted only during fires with fuel burning rates of 1 and 2 GPM so no confirmation of the China Lake test blessing at 3 GPM was obtained. Water pollution is no problem with the cascade and engine fire simulators because the water is not contaminated, and it escapes only by evaporation.

5.1.2 Adequacy of the Simulation

Both the cascade and the engine fires are real spray fires so the only simulation involves the structures that play haste to the flames. Because of the more complete combustion these fires generate slightly more heat than their smokey counterparts; therefore, in the cascade fire, the trainee is exposed to the full thermal insult. The lack of smoke should not be a problem with these small sized fires because visual obscuration does not interfere with suppression. For example, Reference 6 describes a series of tests performed with unabated cascade fires. In all cases the smoke plume left the extinguishment zone clear and visable for the attack. Obviously more involved structures could be provided particularly in the engine and nacelle simulators where a real jet engine turbine may create more impedance than the vanes in the trainer. If some real jet engines are available for a comparison test the need for more or less impedance could soon be established. In all cases the firemen's response to the existing design was favorable.

5.1.3 Adequacy of the Challenge

As described in Appendices A and B, the challenge is adjustable to accommodate the Type of agent and size of extinguisher. Furthermore, the cascade unit is modular so the size can be expanded in increments of four feet. The single units were quite adequate for the extinghishers tested, i.e. 30# PKP, 30# Halon 1211, 15# and 50# CO_2.

It should be emphasized that in the quantitative type exercises employed here, the fires should be extinguishable with the agent available in the extinguisher so the expended agent can be used as a measure of proficiency. In this respect, one 4' x 8' cascade fire module appears to be about the right size for the 30# PKP extinguishers. Table 5.1 shows that most firemen can extinguish the cascade fires at burning rates of 1 and 2 GPM; however, at 2½ and 3 GPM over half of the attempts failed. Also the two exploratory attacks with Halon 1211 failed to extinguish 2½ GPM fires. Table 5.2 summarizes the tests results for the engine and nacelle fire extinguishments. At burning rates above 1 GPM the challenge was too much for both the 15 and 50 lb. CO_2 extinguishers. Fires in the range of ½ to 1 GPM are about the limit for these CO_2 units. Most of the Halon 1211 extinguishments were successful on all the fire sizes; therefore, the challenge appears to be appropriate for these extinguishers.

5.1.4 Reproducibility and Quantitative Evaluation

In both simulators, the burning rates are reproducible because the fuel flows are established by the flowmeter. However, the wind is a variable that can influence the flame shape and the agent pattern particularly with the cascade unit where the fire is exposed. In the engine fire simulator the fires are enclosed thereby reducing wind effect. The flame geometry was recorded for each test fire and all of the engine and nacelle fires were described as symmetrical. Table 5.1 lists the assymetries observed in the cascade fires. The flame assymetry did not appear to influence the amount of agent required to extinguish the fire; however, the exercises were not designed to study wind effects so the results are not statistically significant on this point. If the wind becomes troublesome, the cascade unit can be rotated to provide a uniform angle of attack.

Table 5.3 lists some tentative yardsticks for evaluating performance on the cascade and engine fire simulators. As additional results are accumulated, these numbers can be refined. Hopefully every fireman would be able to achieve the minimum performance value. A few firemen are already operating more effectively than the achievable performance levels. The existing data does not permit a more detailed breakdown, e.g. for 1½ and 2½ GPM.

In an enclosed space, the extinguishment concentrations with agents such as Halon 1211 and CO_2 are relatively insensitive to the size of the fire. Although the engine and nacelle fires are not completely enclosed, the amount of Halon 1211 required is essentially the same at fuel burning rates of 1 and 3 GPM. Only one fire was successfully extinguished with CO_2, and it was for a fuel burning rate of ½ GPM. Either larger discharge rates or smaller fires appear desirable for the CO_2.

5.2 Cold Fire Pad

The tests performed on the cold fire pad were free of pollution problems because fresh water was used for all the exercises. This device is designed to develop dexterity and proficiency in manipulating the turret under circumstances where the agent application density and pattern can be measured, i.e. without a fire. Consequently, the question of simulation adequacy must be answered first by stating what is being simulated. Normally the cold fire pad would simulate the hot fire area, and the various obstacles such as the mockup that interfere with the application of the agent. As previously mentioned, the size of the test area and the layout of the sampling pans was the same as used in the hot fire pit. However, there was no mockup or other obstruction so this aspect was deficient.

The challenge was to apply a uniform density of water over the training area in a time commensurate with the expected discharge time for a fire, i.e. about 10 to 15 seconds for the MB1 vehicle. Because the water stream blocks the operator's view, the turretman cannot see where the water lands, and it is a fair challenge to provide a uniform deposit even without obstacles. Both new recruits and experienced journeymen showed improved control after several exercises. Figure 5.1 shows a series of cold fire pad exercises for a turret operator with one year of experience. Ideally these plots would be horizontal lines with the same displacement for both sets of sampling pans. Initially some of the outer pans were missed almost completely, but with practice the application density became more uniform. A similar improvement was also noted for the journeyman. If the first attempts had been on real fires, they would have been expensive lessons in turret control. Wind and vehicle position are the principal sources of nonreproducibility from one test to the next. In the exercises reported here, the truck was stationary so that only the wind was a variable.

The fireman response to this exercise was favorable and the training officers felt the quantitative measurements were a definite improvement over the fresh water turret drills conventionally practiced.

5.3 The Hot Fire Pit

5.3.1 Does the Facility Satisfy the Clean Air and Water Requirements?

In general the answer appears to be yes for the gasoline tests; however, there are explanations and qualifications that should be given by the environmentalists. Appendix G contains observations made on two days encompassing five tests and six extinguishments, i.e. one reignition completely involved the pool. These fires covered a full range of equipment failures that contributed to the production of smoke. For example, in Test 1 on May 27 the electrical igniters failed and the gasoline had to be ignited with a hand torch. Then the circuit breaker opened on the water spray pump so a large black cloud developed before the water spray could be restarted. When the water came on again, it stopped the smoke and almost put out the fire. About 13 min later a reflash covered the entire pool while the control tower was unoccupied and therefore no water spray was immediately available to control the smoke. Manual ignition was also required in Tests 2 and 3. Consequently, hydrocarbon vapors escaped into the air during the filling time and the abortive attempt to ignite the fuel with the electrical ignitor. A brief puff of smoke accompanied each of these manual ignitions because the water sprays were off during the ignition. After the first test, another source of smoke was the fuel burning outside the pit in foam washed overboard with fire hoses during the skimming operation. This errant fuel produced small clouds, but they were the blackest ones in the field of view and therefore the ones that controlled the Ringelmann reading. When the equipment functioned as designed, the smoke levels were quite modest; therefore, these failures dramatically demonstrated the effectiveness of the spray system for smoke control. The maximum number of tests conducted in one day was six and at this rate, air pollution was no problem when the equipment performed as intended. Even with marginal ignition performance, the smoke clouds were of brief duration and could be tolerated for all the fires the station could afford.

Appendix H discusses the water pollution question and possibilities for minimizing the problem. The evaluation of the waste water handling equipment for the hot pit depends both on the rate of testing and the schedule for trucking the waste water to the disposal plant. The following capacities and rates of flow were used in this evaluation:

- Waste water storage - 30,000 gal
- Station industrial waste disposal capacity - 3/4 million gal day^{-1}
- Total station sewer discharge rate - 2½ million gal day^{-1}
- San Diego discharge rate at Point Loma - 120 million gal day^{-1}

For example, if the allowable AFFF concentration is limited to 20 ppm and the training waste is diluted successively by addition to the industrial waste, the station sewer discharge and the Point Loma discharge, 30,000 gal of .2% AFFF solution could be dumped every 36 min. However, the total station discharge would exceed the 20 ppm unless the waste AFFF solution was dumped over 1.2 days. The cost of transporting the waste water to the disposal plant can become a significant item in the training budget unless the water is conserved. Consequently, 30,000 to 40,000 gal of waste per month would appear to be more reasonable. Of course this reuse of the water increases the AFFF concentration and therefore the burden on the sewer system when a disposal occurs; however, the average burden will remain far below the 20 ppm.

5.3.2 Is the Simulated Fire Adequate?

The firemen who participated or observed the hot fire pit tests and training exercises were uniformly negative in response to this question. The reasons for these judgments can be grouped under several headings.

- Appearance of the fire and the fire characteristics. The smoke abated fire appears much less threatening than the unabated counterpart. Black smoke adds to the visual image of size and the unabated flames are at least 3 times higher than the best flames with the spray nozzles in operation. Also, the flame intensity was substantially reduced by the spray nozzles. Consequently, the radiant heat was reduced in the abated mode of operation. Finally the hang fires under the metal curb were not characteristic of the usual aircraft spill fires.
- Limitations on the types of training exercises that can be conducted. "The firefighters at North Island have been trained to use straight stream to provide maximum range on the approach to a crash. The pit fire will not allow this technique and for this reason leaves much to be desired." (See Appendix I), i.e. the straight stream knocks rocks out of the pit. It is not practical to train in one pattern and then expect the firemen to use another in the real emergency.
- Differences of opinion about what should be included in the training program. The pit was designed primarily to provide training for the turret operator; consequently, there is no adequate provision for the rescue path type of exercise. Features such as AV Gas for the fuel, poor footing on the rocks, and protruding nozzles constitute hazards to handline operators who enter the pit.
- Without a mockup that can be adjusted both in orientation and the types of secondary fires, there is no provision to vary the training exercise. The unrealistic fire environment and the lack of flexibility were disappointments to some of the firemen.

It should be emphasized that the test program was not designed to answer this question in a quantitative manner as was attempted at Chanute, i.e. there were no planned extinguishments with unabated fires. The emphasis was on maintaining and improving firefighting skills rather than the initial training of completely inexperienced personnel. Quantitative measurements were reserved for the next question which covers an important aspect of a satisfactory simulation.

5.3.3 Is the Hot Pit Fire an Adequate Challenge?

Based on comments heard during the tests, the first impression was that the smoke abatement sprinklers extinguished so much of the fire that the challenge was reduced below a practical level. However, the amount of agent required to control and extinguish the test fires was usually as much as required for unabated fires of comparable area particularly for JP4 and JP5 fires. For example, the critical application density to extinguish JP4 with 6% AFFF is about 1½ gal per 100 ft^2 which corresponds to 30 gal of agent for a 50' dia pool. The critical application density is close to the theoretical limit and is not normally observed outside the laboratory; however, it serves as a useful guide to indicate one's departure from perfection. In the aircraft ground fire suppression and rescue tests at China Lake with P-4 trucks and the Cat-Klein vehicle the better extinguishments on JP4 fires required AFFF application densities of about 7 to 9 gal per 100 ft^2. For the hot training pit fires such application densities would require 140 to 180 gal. In the initial plan, the AFFF procurement was based on an average allowance of 200 gal of agent per test. Table 5.4 summarizes the test data from the last 16 tests when the facility was operating at its best. As expected, all of the values are well above the critical application density; however, five tests with application densities of about 5.3 indicate either proficient turret operation or weak fires. Half of the tests were above the average allowance thereby indicating a challenging fire. In two of the MB-1 tests, the water tanks were completely emptied without controlling the fire because the truck was not making respectable foam although the concentration was at 6%. One factor clouds this quantitative evidence of a challenging fire, and that is the role played by the warped metal curb cover. It appeared that a disproportionate amount of agent was expended suppressing these curbside fires.

5.3.4 Reproducibility and Suitability for Quantitative Evaluation of Turret Operator Performance

First we must define what we mean by reproducible fires; then perhaps it will be possible to evaluate the hot pit fires. Identical fires would be desirable for suppression performance evaluations but large turbulent pool fires are never identical in all their characteristics; therefore, the question is what departure from identical fires is acceptable. In the past, fires have been judged by their burning rate and the general size and shape of the flames. Typically the measured parameters are burning rate, flame height, angle of tilt and the radiant energy emitted by the fire. Figure 5.2 shows typical flame heights and burning rates for a number fires as a function of the pan diameter. Fifty feet equal 1524 cms; therefore, the unabated AV Gas fires should burn with a rate of about 6 mm min^{-1}, and the flame heights would be about 100 ft. In the figure, the scattering of points and the bars indicate that variations of 25% in burning rate are not unusual. For example, wind and the associated flame tilt readily reduce the burning rate and augment extinguishment. There is no specification for the abated fire to be more reproducible than the corresponding smokey fire; consequently, 25% variations in burning rate would appear normal. Because the water spray reduces the burning rate it might be possible to reduce all fires to the same burning rate but in practice such control is not mentioned in References 1 and 2 and it would be very difficult to achieve with only visual images as guidance. At one time, a flame height measuring pole was incorporated in the Chanute smoke abated fire pit, but it probably was not intended as a guide for controlling the fire reproducibility.

In the North Island smoke abated tests, there were no provisions for physical measurements so the judgments about reproducibility are based on visual observations and photographs of the flames. Reproducibility was a problem particularly when trying to reproduce the best fire. For example, one particular fire that had the best balance between large flames and smoke was used by the operators to judge other fires. Some fires approached but none equaled the superior fire. The footnotes for Table 5.4 indicate some of the variations in flame size and uniformity experienced in this test series. Most of these variations involved the areas extinguished or almost extinguished by the water spray. From the pictures, the burning rates for these fires appeared to vary much more than the 25% associated with freely burning pools. This lack of control scuttled the plan to establish yardsticks that could be used to quantitatively evaluate fireman performance. Unfortunately, our knowledge of critical application densities for extinguishing fires of various intensities and burning rates ranges from meager for conventional pool fires to nonexistent for these water spray smoke abated systems. Reference 6 reports some laboratory tests in which the burning rate was intentionally changed by modifying the fuel substrate. In this case the variations in the critical application density were in the range of 15 to 25%. It would appear that the variations were much larger than this in the North Island tests. For example, in Table 5.4 the tests with "Big Fires", i.e. 9 and 11 required 4.5 and 2.4 times as much agent respectively, as lesser fires extinguished by the same firemen.

This lack of reproducibility also obscured efforts to evaluate the effect of cold pit training on extinguishment proficiency. The application concentrations listed in Table 5.4 for tests 12 through 17 are quite respectable and could serve as temporary yardsticks except for the uncertainties about the fire intensities.

5.4 Reliability and Ease of Operation

A satisfactory facility should be reliable both in the performance of the components and in the product resulting from the man machine interaction. The North Island hot pit fire trainer failed on both of these counts. Normally, station training facilities are operated intermittently at intervals of a week or more; consequently the equipment should start up and function properly after long periods of idelness. As previously mentioned, the departure from the IITRI pump design left the system with pumps that lose their prime. With the fuel pump this situation was usually discovered after the exercise had started and no fuel appeared in response to the operator. Failure of the ignition system was so common that a pot of burning fuel and a torch were held ready for a manual ignition. Also failure of the water spray circuit was relatively routine. Appendix I reflects these component reliability frustrations along with the more severe problem of operational ease and understanding i.e., when does the operator know he has produced the best fire possible with the device. There is no specification for the fire only the absence of smoke. Considerable time and fuel was expended in trial and error training of the control tower operator and the training officer. Unfortunately the operation and maintainance manual recommended by Reference 1 never materialized so all the pitfalls of operation had to be rediscovered. The absence of pressure gages or flow meters in the water spray zone circuits contributed additional uncertainty. There was a provision in the original test plan (Appendix I) to calibrate the zone control valves by sampling the water delivered to 2' by 2' pans arranged as in the cold pad array. After a couple of sprays, it became apparent that a reliable water pattern could not be obtained until the racks were adjusted to the proper level and the weir modified for proper control of the water. During the subsequent week of repair activities the calibraton plan was sidetracked and never recovered, so efforts to control the sprays continued without any application density information, e.g., Reference 1 found about 0.8 lbs of water per ft^2 min. about optimum for maximum fire intensity with minimum smoke.

6.0 DISCUSSION OF THE HOT FIRE PIT PROBLEMS

This evaluation of the hot fire pit has revealed three classes of problems.

- The firemen are not satisfied that the system is a satisfactory training device.
- Money problems, the device is too expensive to build and too expensive to operate.
- Operational problems which include training operators, maintainance and repairs.

The lack of firemen acceptance is the most damaging of the three problems because without enthusiastic support by the firemen there is no chance of or point in solving the monetary and operational problems. This dissatisfaction extends beyond the Navy firemen involved in the North Island facility test where the equipment failures certainly could generate a negative bias. The Air Force has constructed four of the smoke abated pool fire simulators but their firemen are not enthusiastic about using the devices. For example, the original unit at Chanute was never used consistently and the current instructors are not familiar with its operation and cannot remember when it was used. The most positive response came from Hickam field where a 50 ft dia trainer is exercised about 12 to 14 times per year. The training officer commented that the device was okay for small plane training exercises but it was not suitable for their larger aircraft. Also with new men, they need the heat and smoke until they know what to expect from a real fire. He also mentioned the high cost of fuel as an important factor in operating the device. Consequently the Hickam mode of operation has been modified somewhat to permit rapid turnaround times and a minimum loss of fuel. If I understand the procedure correctly, the smoke abatement feature is used only during part of the burn. After the first igniton, the JP4 is allowed to burn unabated for 15 to 20 seconds before the water spray nozzles are activated and suppression begins. Initially there are lots of black smoke and flames that reach 100 to 150 ft in the air. When the water sprays are turned on the flame heights drop to about 50 to 75 ft for the suppression exercise. They do not completely extinguish the fire but leave some flames to reestablish the unabated fire for the next exercise. Foam is washed away with hand lines and additional fuel is added as required to produce a fire that completely covers the pit. With this procedure they can go through 6 or 7 training evolutions in about 40 min.

The unit at Tyndal Air Force Base is an experimental facility designed to demonstrate that an economical unit can be constructed for less than 100K as compared to 1/2 million for their other systems. Despite this effort to reduce the financial problems, the main effort at Tyndal is to develop a better simulator of the electronic type.

The high initial cost of construction and the high cost of operation contribute to the firemens sense of disillusionment and frustration. So much money should provide superior training. To illustrate this point of view one must realize that the initial construction costs for the hot pit trainer was equal to 34 years of the North Island budget for all crash and rescue supplies plus training. Realistic operating costs are not available for the test period because of all the emergency repairs and maintanence but if the bare minimum for fuel, agent, and waste disposal is considered, the price for one fire is about $655. Again in terms of the station budget, the allotment for all crash and rescue supplies and training would cover about 22 fires. The department contains about 90 firemen and the turnover rate is about 30 per year so the current budget would not even supply a fire for each new man. To justify such expense, the system should provide training that is much superior to what is currently available. Unfortunatley the hot pit fire does not come up to these expectations.

Although the operational problems were very frustrating during the tests at North Island, such problems are much easier to solve than the other types. Experience has taught much that should have been supplied in a manual of operation and maintainance. The idiosyncrasies of the equipment and the symptoms of failure were abundantly displayed during the test period. Also, operational procedures were developed to circumvent some of the design and construction deficiencies. These errors should not be repeated if another hot fire pit is to be constructed. Unfortunately much of the wisdom in reference 1 regarding pumps, gages, operations, and maintanence was lost somewhere between Chanute and North Island.

7.0 COMPARISON OF OPTIONS

The original intent for this section was to update the economic analysis of reference 4 by allowing for the high costs of constructing and operating the North Island hot fire pit. This intent was based on the assumption that the North Island unit would be declared satisfactory and the next step would be to decide on the location for future units.

Unfortunately the results from North Island make this analysis appear to be an exercise in futility and I suspect we would be hard pressed to give such units away irrespective of the location. This lack of a suitable hot pit trainer leaves us with a comparison of alternatives to overcome this deficiency in the principal component of the training facility. Advantages and disadvantages of the various options will be discussed but it appears to be a bit premature to try an economic analysis until it is apparent which options are satisfactory to the firemen.

7.1 Port Authority of NY and NJ Miniaturized Turret Operator Trainer

The port authority approach was to scale down the fire and suppression system by a factor of about one hundred. Figure 7.1 shows an aircraft mockup in a 60 ft^2 pan where about 5 gal of contaminated fuels provide the training fire. A regular turret is mounted on a pickup truck as shown in Figure 7.2. A small nozzle mounted inside the turret supplies the agent at a rate of about 14 GPM. Both the polution and training costs are substantially reduced and the firemen who receive their training on this device have consistently performed as well as their colleagues who trained exclusively with full scale fires and trucks. The FAA airport certification team has approved use of the simulator method to conduct basic and semi-annual refresher training. Besides reducing pollution and cost, the simulator also reduces wear and maintanance on the full size pathfinder trucks. This unit appears to solve the money and operational problems. It remains to be seen if the firemen will be satisfied with this training approach. The small fire may be an adequate solution to the pollution problem; however, the Port Authority is considering the possibility of using this trainer in a hanger or other large building where the smoke could be collected and scrubbed . Other ideas in the concept stage include an optical system to make the aircraft mockup and fire more realistic. Additional information about the port authority system can be obtained from Joseph W. Haman, Police Lieutenant, Emergency Services, Port Authority NY and NJ, Journal Squad Transportation Center, One Path Plaza, Jersey City, NJ 07306.

7.2 Air Force Fire Fighting Simulator

Training with simulators has proven to be cost effective in many applications ranging from the simple automated driver trainers to the sophisticated NASA trainers for space flight and moon landings. Almost any operation can be simulated but the costs frequently are high so that the art tends to be reserved for expensive operations or situations where the real event cannot be used for training. e.g., trainers for aircraft pilots can easily cost 3 or 4 million dollars and the complexity of the system requires highly trained operators and technicians to keep the equipment performing. However, recent development in electronics, i.e., microprocessers, video recording and mixing equipment, and audio visual display are reducing costs and expanding opportunities for certain types of simulation as witnessed by the electronic television games. The Air Force Engineering Systems Command at Tyndal Air Force Base has sponsored a design contract to provide an electronic simulator suitable for firemen turret training. One concept of the device employed three superimposed images (1) the airfield background, (2) a view of the crashed air craft that deteriorates with time in the fire and (3) the fire that has to interact with the turret. A library of video tapes of each of the components would allow tremendous flexability, i.e., any type of aircraft could crash and burn under a variety of fire conditions at any airport or other location. The first two images are straight forward but the proper interaction between the fire image and the turret operation is the crucial step. The principle advantages envisioned for this approach are (1) a complete solution to the pollution problem, (2) a large number of firemen could be trained with one device, (3) the flexability in scenarios should maintain interest and motivate the fireman, and (4) the possibilities for quantitative evaluation of performance appear even better than with a real fire. Uncertainties and potential disadvantages are cost, adequacy of the simulation and fireman acceptance. It should be noted that the Air Force crash vehicle configuration may be easy to simulate realistically because the turrets are operated remotely from inside the cab consequently the visual display can occupy the window space as is customary in simulating an aircraft cockpit. The navy fireman protruding through the roof hatch to manually operate his turret would require a different display.

7.3 Real Fires Either in Situ or at a Remote Site

The in situ option maintains the status quo and admits that pollution control is either impractical or too costly. In such an event, a good public relations job may minimize the complications with the environmentalists and neighbors. The remote site fire avoids the consequences of pollution by moving both the polluters and the pollution away from those who object to dirty air. This is the approach used by the students of the Texas A&M fire training school or the DoD proposal to make Chanute the principal DoD fireman training school. In their present size, such schools can handle only a small fraction of the total firemen. For example, Texas A&M is already booked solid through 1985. Even if space were available, Reference 4 demonstrated that it becomes a very costly and disruptive procedure to ship all the fire fighting firemen away from the station for yearly training. Such schools are good training grounds for new recruits but hard to justify for training to maintain proficiency. In considering the costs, it should be recalled that free contaminated fuel at the local station is a decided advantage favoring the status quo. At a large school, the fuel has to be purchased and it costs as much for a big fire there as in the abated smoke pit; consequently, none of the existing station budgets can afford to send a majority of their firemen to such training. These options do have the advantage that firemen accept the real fires as suitable training aids and there are no operational problems.

8.0 RECOMMENDATIONS

Two types of recommendations are in order (1) in general, what to do about training the turret operators for aircraft crash and rescue vehicles, and (2) specifically what to do with the hot fire pit at North Island.

8.1 General Proposals

1. Defer construction of additional water spray smoke abated pool fire trainers and see if one of the other simulation options will be more acceptable to the firemen and affordable to the Navy.

2. Continue training in situ with more emphasis on cold pad exercises in which sampling pans are employed to provide quantitative measurements. Add realistic mockups and obstructions to the cold pad training.

3. Examine the Port Authority modeling approach to see if it will meet Navy needs either as a temporary or permanent solution. Send some training officers who can speak for the fire service to use the unit and render an opinion. If the unit appears to be a successful training aid a simplified version could be supplied to every Navy air station for about the price of another hot fire pit.

   Because the Navy turrets are manually operated, a simple module consisting of the turret mockup, a small foam nozzle, pump and tank could be assembled in a frame suitable for hauling in existing pickup trucks. I feel the electronic simulators will ultimately take over most of the turret training so such arrangements as the Post Authority model would serve as a very useful interim system.

4. Follow the Air Force Crash and Rescue Vehicle simulator developments through the design and prototype development. consider what modifications would be required to adapt this approach to Navy needs e.g., because of differences in vehicle design and operation.

5. Establish the fire fighting procedures to be taught and practiced with the crash and rescue vehicles so the developers of training aids and simulators will know what evolutions are required. For example, how pertinent are the rescue and rescue path proceedures coordinating hand lines and turret operations. If these are of high priority, the Port Authority simulator and the electronic simulators will not satisfy such rescue requirements involving coordination between rescue people on foot and turret operators in the simulator.

6. Initiate use of the cascade fire and engine fire simulators in the regular training program if such training is deemed pertinent under recommendation (5). The drawings and specifications included in appendices A and B should provide sufficient information.for their construction and operation.

8.2 Specific Recommendations Regarding the North Island Facility

Here we are on the horns of a dilemma. On the one hand, performance of the hot fire pit is unsatisfactory and the costs are exorbitant but on the other hand there is no proven alternative to replace this pivotal component in the training facility. Under this circumstance, the following options are available:

- Abandonment, i.e., salvage the usable ports and camouflage the rest to blend in with the sandy environment.
- Wait and see, i.e., put the unit in mothballs until the outcome of the general recommendations becomes available and it is apparent whether a more satisfactory solution can be obtained.
- Limited modification and exercise, i.e., see if the training objections given in Appendix I can be ameliorated by modest changes in the fire pit and modifications in the operation procedure.

  The North Island fire department would probably use the hot fire pit if (1) they could train in their usual manner using the straight stream approach and the rescue technique, and (2) the fuel was provided.

I feel that in our dilemma, a small effort should be applied to the third option. For example, the pool could probably be made suitable for a straight stream attack by replacing the top layers of rocks with concrete turf blocks resting on a sheet of expanded metal. Such an arrangement would provide a stable footing that would not be displaced by the straight stream and still control the fuel motion and water drainage as well or better than the rocks. Operationally, a little compromise between a hotter fire and more smoke might improve the challenge while maintaining the air pollution well below the unabated level. Both the physical and operational modifications could be carried out by the firemen at very little additional expense.

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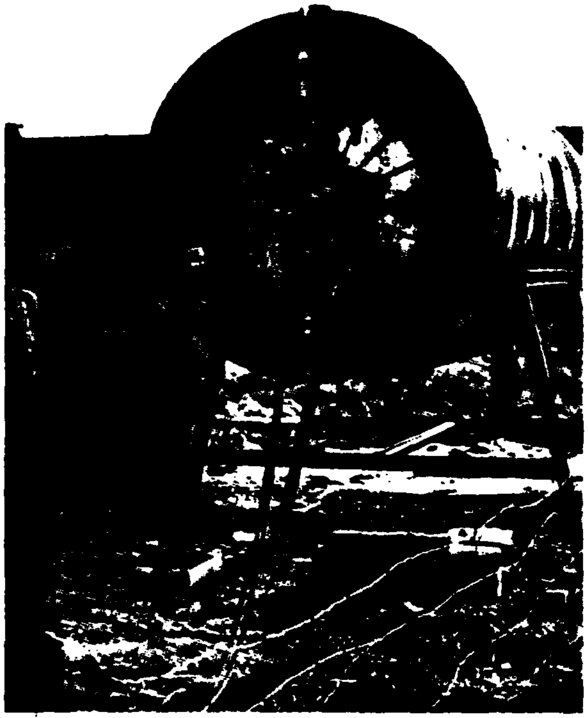

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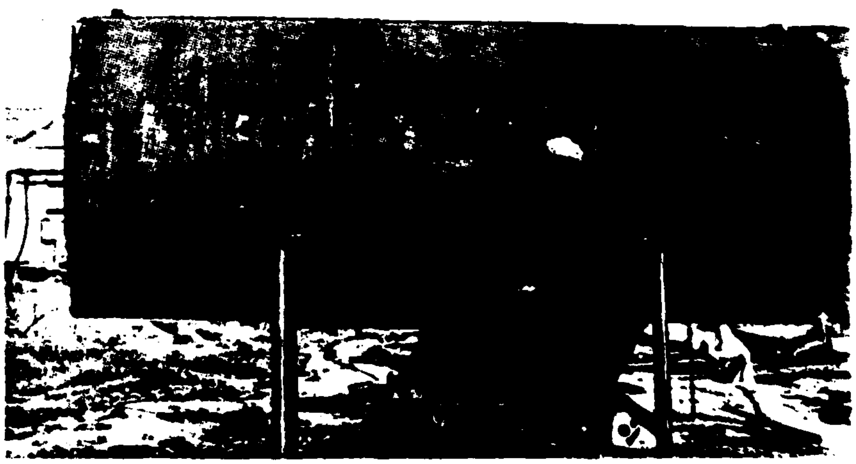

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Table 3.1

FUEL AND WATER HANDLING EQUIPMENT FOR
THE HOT FIRE TRAINING TANK

CS/1A	50' dia. rock filled trainer tank with 32, Bete No. TF 12 XW type sprinkler grouped in 5 zones, 28 fuel outlets, and 4 electrical igniters.
CS/1B	IITRI designed water level control weir and tank.
CS/1C	Drain tank connected to 6" drain line.
CS/1D	Peripheral basin to drain tank, 6" curb, and 5' apron, the curb had been modified to include a continuous metal cover to protect the concrete from spalling.
B/1	6' x 6' control tower 10' high encloses the fuel metering valve, the 5 zone water spray control valves and the activation buttons for the ignitors and and the major pumps.
T/1	10,000 gal fresh water storage tank, buried below ground.
T/2	4,00 gal fuel storage tank, buried below ground.
T/3	1,000 gal reclaimed fuel storage tank, buried below ground.
T/5	37,800 gal reclaimed waste water holding tank, above ground.
P/1	Fresh water pump 60 H.P., 300 GPM, 350 ft HD, above ground.
P/2	Fresh fuel pump 20 H.P., 600 GPM, 50 ft. HD. above ground.
P/3	Reclaimed fuel pump 1/2 H.P., 7 GPM, 15 ft. HD, above ground.
P/4	Reclaimed waste water sump pump 4 H.P., 300 GPM, 30 ft. HD. CS/1C to T/4.
P/5	Reclaimed waste water pump 5 H.P., 300 GPM, 50 ft. HD. T/4 to CS/1A.
P/6	Hand operated water separator pump in T/3 cap = 10 GPM max.

Table 5.1

RESULTS OF EXTINGUISHMENT TESTS WITH CASCADE FIRES

Test No.	Fireman Status[a]	Fuel GPM	Agent Type	Amount of Agent Used Lbs/Oz.	Did Fire Go Out	Smoke Visable	Flame to Left	Flame Symmetrical	Flame to Right
7	J	1	PKP	2/ 3	Yes	Yes		x	
8	J,T	1	PKP	3/12	Yes	No		x	
29	T	1	PKP	2/ 5	Yes	Yes		x	
28	J	1	PKP	5/11	Yes	—	x		
30	J	1	PKP	5/15[b]	Yes	No		x	
31	J	1	PKP	1/ 9	Yes	No		x	
51	J	1	PKP	18/ 4	No	Yes	x		
52	T	1	PKP	5/ 5	Yes	No	x		
53	J	1	PKP	6/ 5	Yes	Yes	x		
54	T	1	PKP	15/10	No	Yes	x		
33	T	1-1/2	PKP	2	Yes	No		x	
32	J	1-1/2	PKP	3/10	Yes	No		x	
34	J	1-1/2	PKP	3/14	Yes	No	x		
68	T	1-1/2	PKP	9/12	Yes	No		x	
1	J	2	PKP	5/10-3/4	Yes	No		x	
2	T	2	PKP	20/ 6	Yes	No		x	
24	J	2	PKP	15/ 4	Yes	No		x	
25	T	2	PKP	10/ 3	Yes	Yes			x
27	T	2	PKP	19/10	No	—			x
37	T	2	PKP	6/ 7	Yes	No		x	
36	J	2	PKP	5/ 8	Yes	Yes		x	
38	J	2	PKP	1/ 4	Yes	Yes		x	
35	J	2	PKP	4/ 7	Yes	No		x	
73	T	2	PKP	5. 5	Yes	No			x
74	-	2	PKP	3. 7	Yes	No			x
75	T	2	PKP	3. 7	Yes	No			x
76	-	2	PKP	7. 5	Yes	No			x
78	-	2	PKP		No	No			x
83	-	2	PKP	10. 5	Yes	Yes			x
84	J	2	PKP	2. 6	Yes	No	x		
85	J	2-1/2	PKP	-	—[c]	-	x		
86	J	2-1/2	PKP	10. 9	Yes	No	x		
87	J	2-1/2	PKP	17. 3	No	No	x		
88	J	2-1/2	Halon 1211	9. 1	No	No	x		
89	J	2-1/2	Halon 1211	7. 9	No	Yes	x		
94	J	2-1/2	PKP	8. 98	Yes	No	x		
95	J	2-1/2	PKP	17. 12	No	No	x		
6	J	3	PKP	21/ 8	No	Yes		x	
5	T	3	PKP	10/14	Yes	No		x	
3	J	3	PKP	27/	Yes	No		x	
4	J,T	3	PKP	6/ 8	Yes	Yes		x	
26	J	3	PKP	9/13	Yes	Yes			x
41	T	3	PKP	9/13	No	Yes		x	
40	J	3	PKP	7/ 4	Yes	Yes		x	
42	J	3	PKP	4/ 6	Yes	Yes		x	
39	J	3	PKP	13/	No	Yes		x	
55	J	3	PKP	26/ 5	No	Yes	x		
56	T	3	PKP	25/ 7	No	Yes	x		
57	J	3	PKP	27/15	No	Yes		x	
58	T	3	PKP	27/ 3	No	Yes		x	
65	T	3	PKP	20/ 4	No	No			x
66	J	3	PKP	25/ 0	No	Yes		x	
67	T	3	PKP	23/ 4	No	No		x	
77	-	3	PKP	16. 2	Yes	No			x
78	-	3							

[a]J = Journeyman, T = Trainee

[b]Discharge valve stuck open.

[c]Electrical problem forced to terminate test.

Table 5.2

RESULTS OF EXTINGUISHMENT TESTS WITH ENGINE AND NACELLE FIRES

Test No.	Fireman Status	Fuel GPM	Agent Type	Amount of Agent Used Lbs/Oz.	Did Fire Go Out	Type of Fire
13	J	1	1211	2/ 6	Yes	Engine
14	T	1	1211	14/10	Yes	Engine
16	T	1	1211	2/ 1	Yes	Engine
46	J	1	1211	4/ 3	Yes	Engine
47	T	1	1211	2/14	Yes	Engine
48	J	1	1211	4/ 2	Yes	Engine
49	J	1	1211	4/14	Yes	Engine
15	J	2	1211	9/ 4	No	Engine
17	J	2	1211	11/ 9	No	Engine
60	T	2	1211	2/ 4	Yes	Engine
82	J	2	1211	2. 5	Yes	Engine
91	J	2	1211	3. 1	Yes	Engine
69	T	3	1211	8/ 0	Yes	Engine
61	J	3	1211	3/ 8	Yes	Engine
93	J	3	1211	2.17	Yes	Engine
10	J	1/2	CO_2	7/ 9	Yes	Engine
11	T	1/2	CO_2	13/ 1	No	Engine
9	J	1	CO_2	22/ 6	No	Engine
22	T	1	CO_2	10/ 7	No	Engine
23	T	1	CO_2	11/13	No	Engine
43	J	1	CO_2	11/11	No	Engine
44	T	1	CO_2	12/ 5	No	Engine
45	J	1	CO_2	9/15	No	Engine
80	T	1-1/2	CO_2	11.14	No	Engine
50	J,T	2	CO_2	27/ 0	No	Engine
59	J	2	CO_2	13/ 0	No	Engine
90	J	2	CO_2	12. 9	No	Engine
69	-	3	CO_2	9/ 2	No	
92	-	3	CO_2	13/ 0	No	
18	J	1	1211	1/11	Yes	Nacell
19	T	1	1211	7/ 8	No	Nacell
20	J	1	1211	0/ 8	Yes	Nacell
21	T	1	1211	0/ 8	Yes	Nacell
63	J	2	1211	2/ 0	Yes	Nacell
81	T	2	1211	4/ 9	Yes	Nacell
12	J	1	CO_2	12/10	No	Nacell
62		2	CO_2	14/ 8	No	Nacell
79		2	$)_2$	7. 9	No	Nacell

TABLE 5.3

TENATIVE YARDSTICKS TO EVALUATE FIRE FIGHTING PERFORMANCE ON CASCADE AND ENGINE FIRES

1. 30 lb PKP Extinguisher on Cascade Fire

Fuel Flow Rate GPM	Agent for Minimum Performance lbs	Agent for Achievable Performance lbs
1	5	2½
2	7	4
3	10	7

2. 30 lb 1211 Extinguisher on Engine Fire

Fuel Flow Rate GPM	Agent for Minimum Performance lbs	Agent for Achievable Performance lbs
1 to 2	5	3
3	8	4

TABLE 5.4

AFFF EXTINGUISHMENTS OF SMOKE ABATED

POOL FIRES

Test No.	Date	Turret Man	Experience Years	Preburn Time Sec.	90% Cont. Sec.	Concetrate Gal.	Water Gal.	Aug. Application Density Gal./100ft^2	Wind Velocity MPH	Wind Direction	Temp. ^oF
No Cold Pad Work											
1	5-28	Bower	T			15	300	16.0	10	250	70
2	5-28	Bower	T		60	30	400	21.9	10	250	70
3	5-28	Bower	T	5	~60	15	300	16.0	10	250	70
4	5-28	Garcia		3		65	950	51.7	6	240	66
5	5-28	Wilken-son		4		60	1000	54.0	6	240	66
6	6-6	Lopex	1	10	60	30	500	27.0	7	120	66
7	6-6	Lopez	1	25	60	30	450	24.4	7	120	66
8	6-6	Collins	5	30	15	6	110	5.9	9	120	68
9	6-6	Collins	5	60	60	32	500	27.1	9	120	68
10	6-6	Shore	12	20	15	6	100	5.4	12	120	68
11	6-6	Shore	12	30	28	20	240	13.2	12	120	68
After Cold Pad Work											
12	6-7	Tijerina	1	10	15	10	150	8.1	6	300	67
13	6-7	Tijerina	1	20	20	13	200	10.8	6	300	67
14	6-7	Saine	12	20	8	5	100	5.3	6	300	67
15	6-7	Saine	12	15	10	5	100	5.3	6	300	67
16	6-7	Quillan	5½	10	10	5	100	5.3	6	300	67
17	6-7	Quillan	5½	10	15	9	140	7.6	6	300	67

FOOTNOTES

Test 1 Flame height about 8 to 10' Zone 1 lower in Zones 2 and 5. Coverage fairly uniform but holes in flames around each water spray.

Test 2 Water spray essentially extinguished fire in pit, flames only several feet high, most of the fire was in foam outside the pit.

Test 3 Very nonuniform fire, few flames in Zones 2, 5 and 1. Apparently no spray in Zone 3 and perhaps 4, so flames were 25 to 30 feet high with black smoke.

Test 4 A respectable fire, flames 20 to 25 feet high, fairly uniform over pit although flame density low on upwind side.

Test 5 Water spray extinguished center of fire - flames mostly in foam outside the pit.

Test 7 Test 7 about 20% less fire than Test 6.

Test 8 Sprinkler system failed during preburn

Test 9 Big fire

Test 11 Big fire

Test 16 Good application.

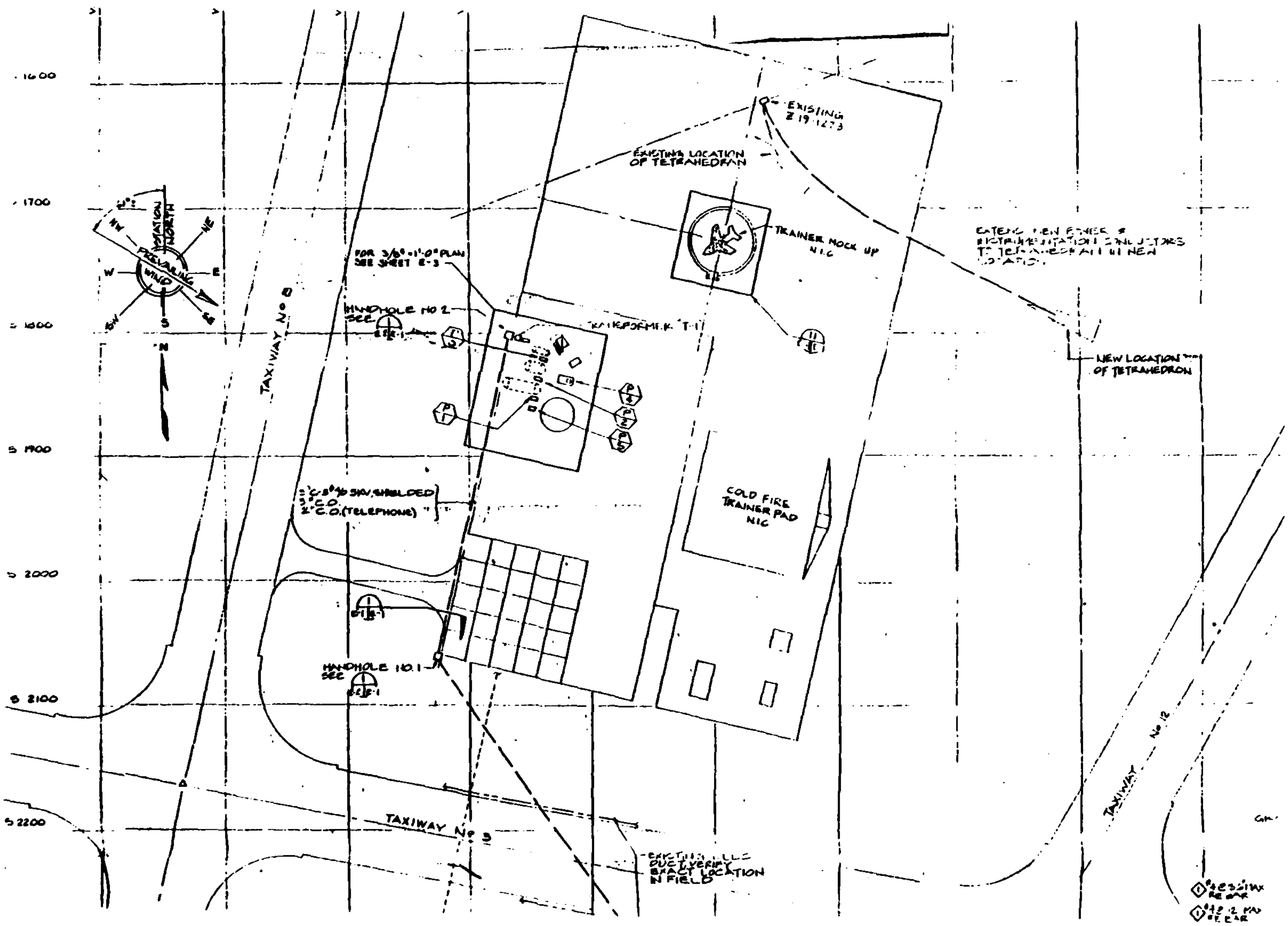


FIGURE 3.1 LOCATION OF THE NORTH ISLAND TRAINING FACILITY

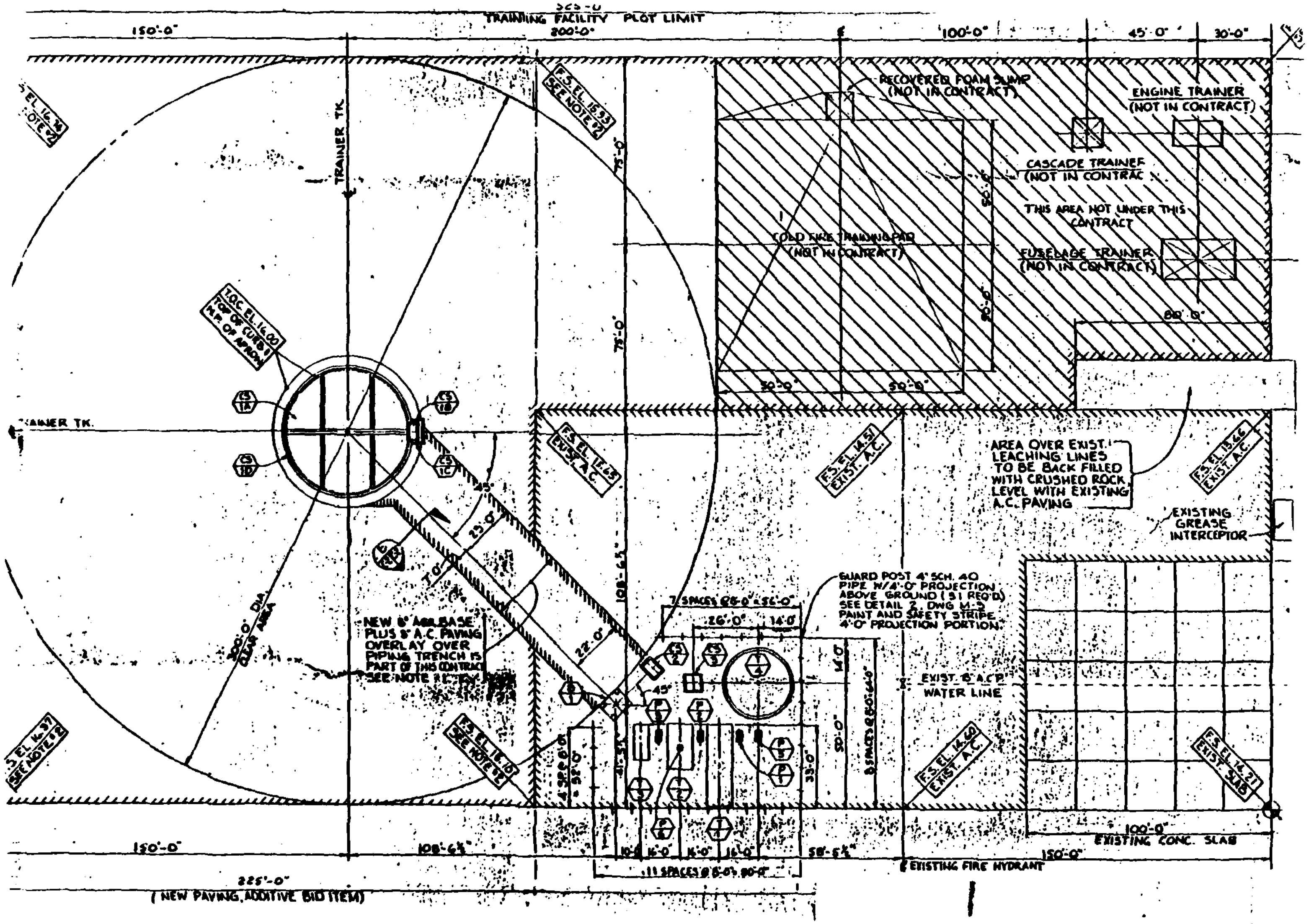


FIGURE 3.2 ARRANGEMENT OF UNITS IN THE TRAINING FACILITY

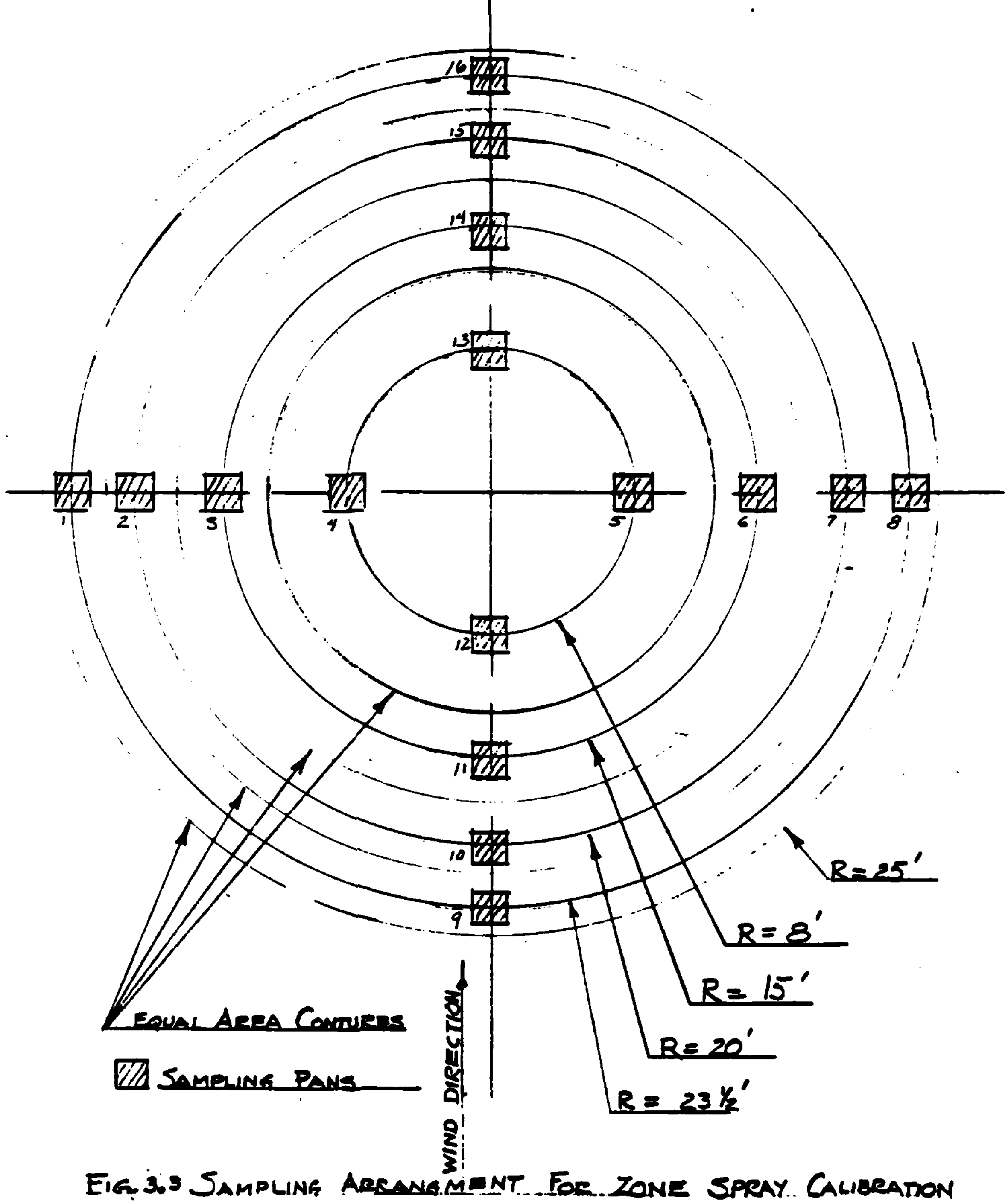


FIG. 3.3 SAMPLING ARRANGEMENT FOR ZONE SPRAY CALIBRATION

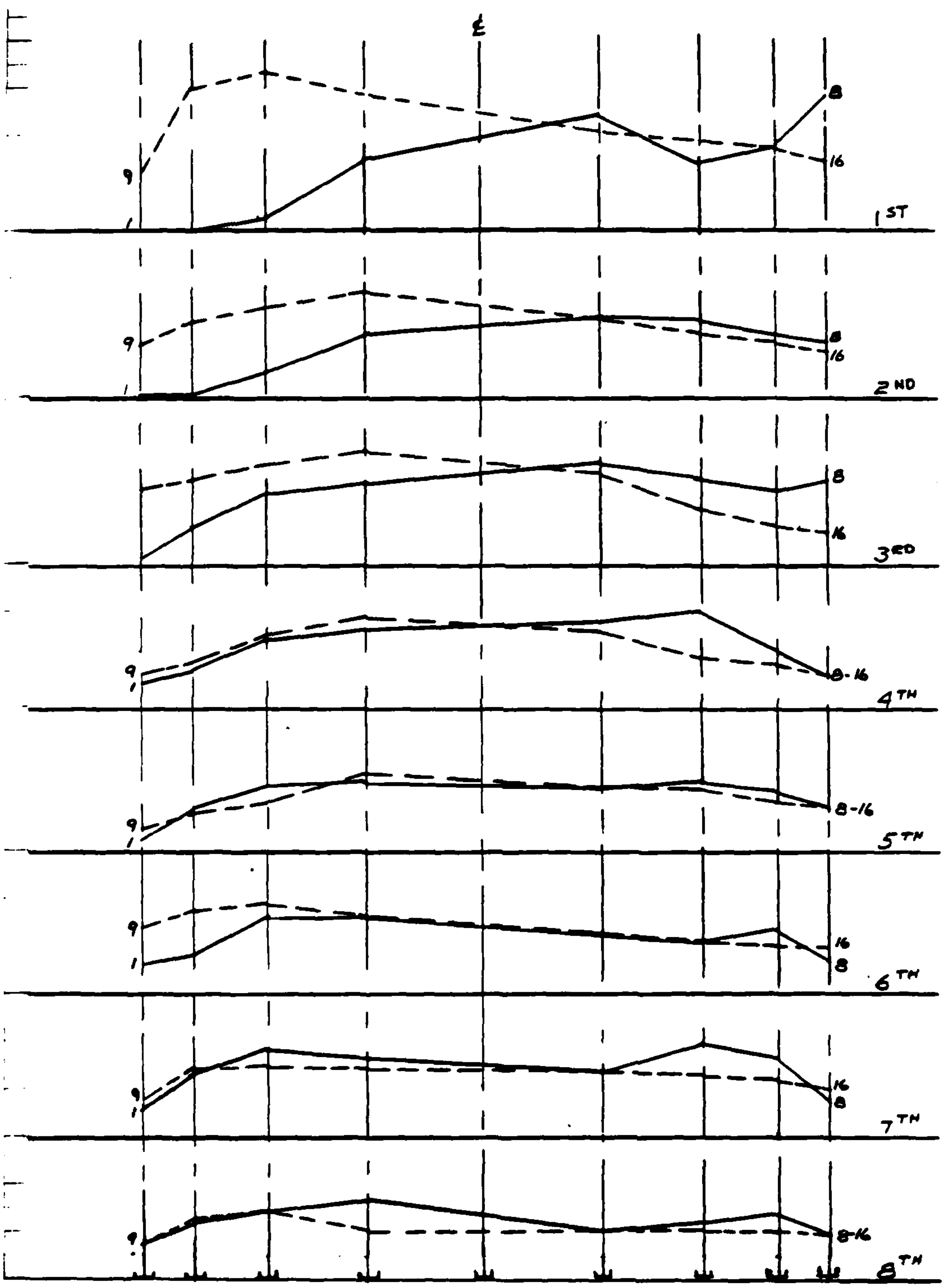


FIGURE 5.1 APPLICATION DENSITIES FOR SERIES OF COLD FIRE EXERCISES

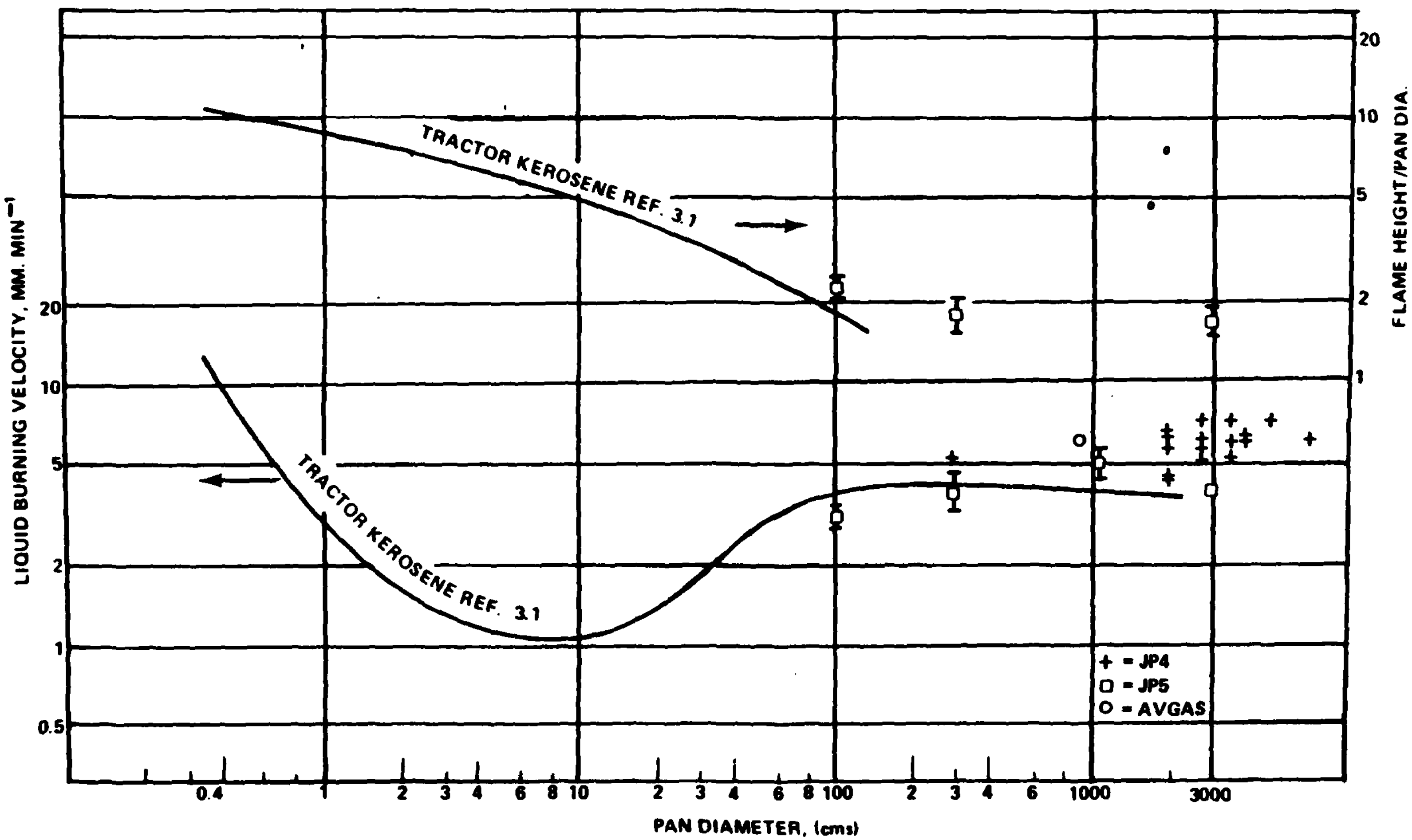
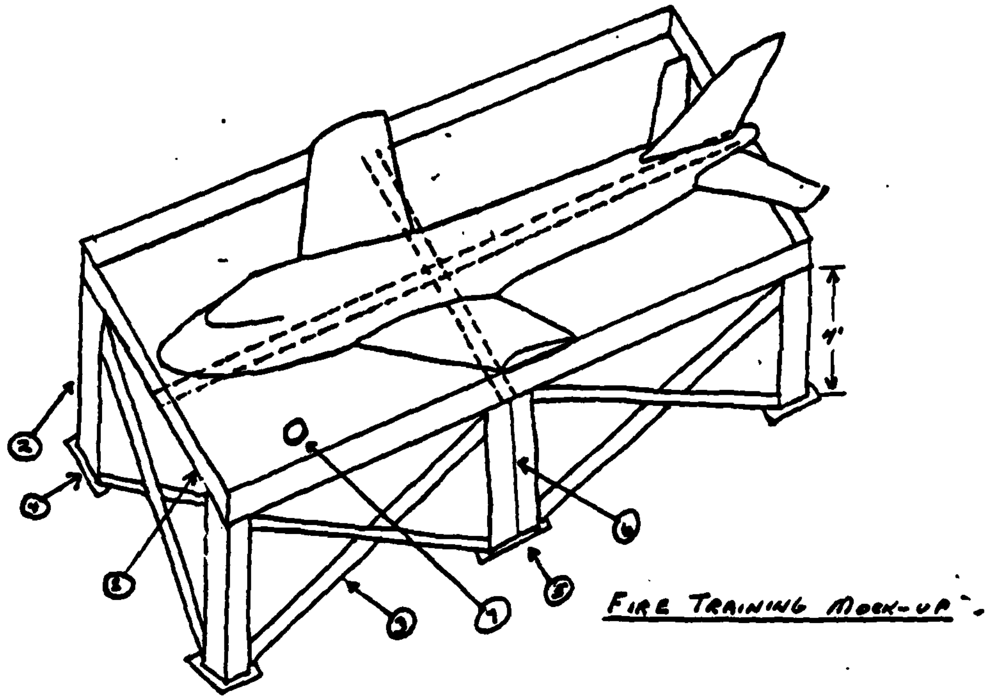


FIG 5.2 PEAK FLAME HEIGHTS AND BURNING RATE FOR JET FUELS

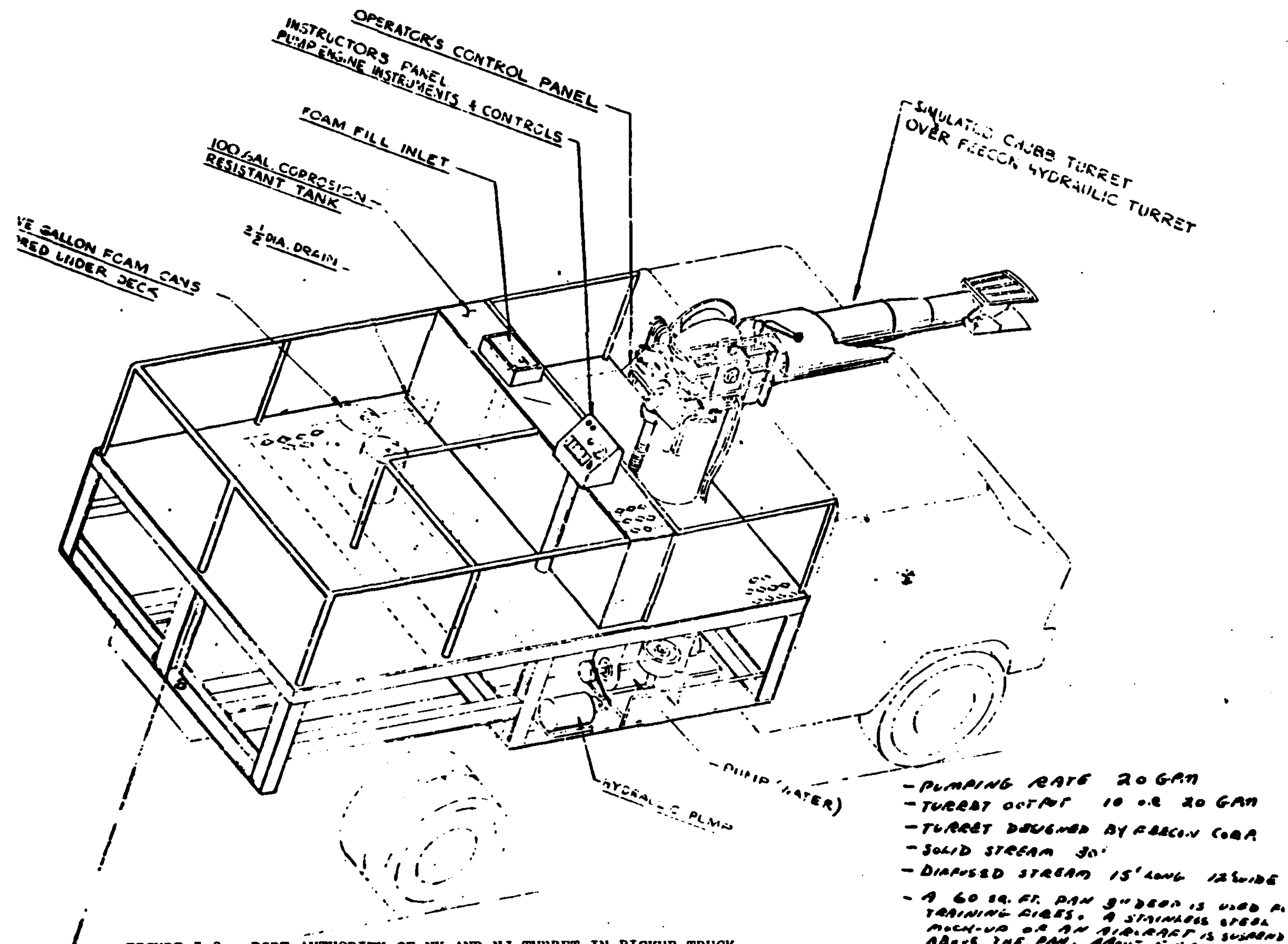


1. PAN 12' LONG 5' WIDE 3" DEEP - MADE OF 3/16" MILD STEEL - MUST BE WATER TIGHT.
2. CORNER LEGS MADE OF 3" X 3" X 1/4" ANGLE IRON
3. LEG SUPPORTS MADE OF 1 1/4" X 1 1/4" X 1/8" ANGLE IRON
4. CORNER LEGS TO REST ON 5" X 5" X 1/4" MILD STEEL PADS
5. CENTER LEGS TO REST ON 6" X 8" X 1/4" MILD STEEL PADS
6. CENTER LEGS TO COMPRISE 2 - 3" X 3" X 1/4" ANGLE IRON - BACK TO BAC
7. 2" DRAIN EQUIPPED WITH SUITABLE VALVE

NOTE 1: SIMULATED AIRCRAFT TO BE MADE OF 12 GAUGE STAINLESS STEEL

NOTE 2: BOTTOM OF PAN MUST BE SUPPORTED BY 1 1/4" X 1 1/4" X 1/8" ANGLE IRON AS INDICATED BY DOTTED LINES

FIGURE 7.1 PORT AUTHORITY OF NY AND NJ AIRCRAFT MOCKUP



- PUMPING RATE 20 GPM
- TURRET OUTPUT 10 OR 20 GPM
- TURRET DESIGNED BY FEECON CORP.
- SOLID STREAM 30'
- DIFFUSED STREAM 15' LONG 12' WIDE
- A 60 SQ. FT. PAN 3" DEEP IS USED FOR TRAINING FIRES. A STAINLESS STEEL MOCK-UP OF AN AIRCRAFT IS SUSPENDED ABOVE THE PAN. ABOUT 5 GALLONS OF CONTAMINATED JET A FUEL ARE USED ON EACH TRAINING FIRE.

FIGURE 7.2 PORT AUTHORITY OF NY AND NJ TURRET IN PICKUP TRUCK

Appendix A

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September 30, 1976

R & D CONTRACT STATUS REPORT ON ENVIRONMENTALLY COMPATIBLE AIRCRAFT CRASH AND RESCUE TRAINING FACILITIES

1. Title: Smokeless Cascade Fire Device and Demonstration at NWC China Lake
2. Contract No. N60921-75-C-0184
3. Agency: SRI Report No. 1
4. Summary

Reference 1 identified the requirement for an open cascade fire or spray fire to provide fire suppression training and fireman certification in the use of powder and vapor auxiliary agents. Reference 2 discussed these requirements in more detail, provided a schematic design for the cascade fire test device, and outlined the auxiliary equipment for controlling the fuel, air, and cooling water required by the "cascade fire" and the "JET Engine Fire" devices. The Reference 2 cascade fire has been modified slightly, constructed, and demonstrated to Navy and Air Force firemen during the "P-4A Airfield Firefighting Vehicle Indoctrination" program at NWC China Lake. This summary presents the construction details and the demonstration results along with a few observations pertaining to the P-4A.

4.1 Design Objectives

- A reproducible three-dimensional fire such as would be expected from fuels flowing or spilling over predominantly vertical surfaces.
- Minimum disturbance of the flames under moderate wind conditions.
- An adjustable fire intensity, i.e., burning rate, so that the test severity can be matched to the ability of the firemen and the capacity of the application equipment.

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- An adjustable fire size to provide for variation in extinguisher capacity.

- Compatibility with clean air and water regulations.

Figure 1 shows a cascade fire developed under the AGFSRS Program, Reference 3, that meets the first four objectives; however, with free-flowing fuel, the fire is obviously very smokey. Fire reproducibility and intensity are controlled by the fuel spray rate. Wind effects are ameliorated by the solid back panel and the modular construction permits the fire area to be increased in increments of 4 x 8 ft. Two modules are operating in Figure 1, i.e., a 64-ft^2 fire.

4.2 Description of the Smokeless Cascade Fire Test Device

Figure 2 shows the construction of the smokeless device demonstrated at NWC China Lake. The modular geometry is the same as in Figure 1; however, the construction details have been modified to make more effective use of the construction materials, to provide a relatively smokeless fire and to conserve the cooling water in a recirculation system. In the assembly drawing of Figure 2, some of the shingles have been removed and other members have been cut away to show the pipe framework, the water-cooled back plate, and the cooling water circulation system. The submerged centrifugal pump sends water from the reservoir into the lower header and up through the four shingle support pipes to the upper header where the water sprays onto the back plate and flows down to the reservoir. These structural members are shielded from the flames by the sheet metal shingles that heat up and warp individually without distorting the entire structure. A smokeless fire can be achieved with furnace burners designed for complete combustion. Two flat-flame air-atomizing burners spray the finely divided JP4 over the shingles as indicated in Figure 2. One of the pipe braces carries fuel to the top burner and the other supplies the air. Fuel and air for the bottom burner pass through the pallet-type base and under the water reservoir. Valves in each line permit the fuel and air to be divided equally or in any other desired proportions between the two nozzles. During the extinguishment exercise, some unburned fuel will flow down the shingles between the time when the flames are out and when the fuel pump is turned off. This fuel flows into the forward section of the water reservoir where a dam lets the water pass into the main tank but keeps the fuel in the fire area. Figures 3, 4, and 5 show the pertinent dimensions and details of the pipe framework, the water tank, the shingles, and the base.

4.3 The Control Panel

Air, fuel, and electric lines run from the cascade fire unit for a distance of about 50 ft to the control panel shown in Figure 6. In addition to the electrical switches and regulator valves mounted on the panel, the station will ultimately contain an air compressor and the fuel pump. In the tests at Camp Parks compressed air was supplied by cylinders coupled into the control panel, while at China Lake a separate trailer-mounted compressor supplied the air. The air pressure regulator was adjusted according to the fuel flow until smokeless conditions prevailed. Typical values were 34 and 60 psi for fuel rates of 2 and 3 gpm, respectively. The fuel pump received JP4 from a 55-gal drum mounted in an adjoining barrel rack and pumped the fuel through regulator valves and a flow meter and the interconnecting tubing to the burners. In the flow diagram of Figure 7, the selection valves and parallel outlets in the air and fuel lines provide for burner control in the aircraft engine simulator which remains to be constructed. Figure 7 also shows the electrical circuit for the control panel, i.e., the control circuit breaker and the motor starting switches for the fuel pump, water pump, and air compressor.

4.4 Demonstrations at NWC China Lake

Figure 8 shows the location of the cascade fire system with respect to the China Lake C5-A test area and the viewing stands set up for the visiting firemen. Cascade fire extinguishment tests were conducted when pauses in the P-4A program and the availability of 30-lb PKP extinguishers would permit. The extinguishers were the limiting factor in the number of tests performed. Most of the extinguishers had been in storage for a long time without maintenance; consequently, about half the units failed to operate, much to the inconvenience of the firemen. All tests were conducted with volunteers solicited from the P-4A observers. The general procedure was to commence with a fuel flow rate of 2 gpm, which can be readily extinguished with a 30-lb extinguisher, and in subsequent tests with the same fireman increase the burning rate until he could not extinguish the fire. Table 1 lists the China Lake demonstrations and the operating conditions for the control panel. Fires were initiated according to the following procedure.

- Turn on the cooling H_2O circulation pump.
- Turn on the air and adjust to approximate pressure.
- Apply burning torch (10' handle) to the nozzle area.
- Turn on fuel pump and adjust flow to desired value.
- Adjust air pressure to provide smokeless condition with minimum air flow.
- Commence extinguishment after 30-sec preburn.
- Shut off fuel after fire is extinguished and adjust air flow for next test.

Figure 9 shows a typical 3-gpm fire against the desert evening sky and Figure 10 provides two views of a 2-gpm fire during a successful extinguishment with PKP. When the available NWC supply of powder extinguishers was exhausted several demonstrations were conducted with water and AFFF. Figure 11 shows an unsuccessful attack on a 3-gpm fire with a fog nozzle spraying at about 60 gpm. Three hundred gallons of water were applied during tests 19 through 22. AFFF from the P4-A handline at 100-gpm was more successful, as shown in Figure 12. The P4-A had successfully extinguished fires with fuel flows up to 5 gpm when the tests were terminated because the truck was required elsewhere. With such large foam application rates, a multipanel test would provide more of a challenge.

4.5 Fireman Reaction to the Cascade Fire Device and Other Training Questions

After the cascade fires had been demonstrated for two days, questionnaires were circulated among the observers to obtain their opinions regarding the device and its usefulness. Table II summarizes their responses which were generally quite favorable. Conversations with the firemen who exercised the cascade fire unit indicated that they felt the fire was very challenging and useful for training. The variable intensity was appreciated.

The comments on the aircraft engine fire simulator were based on the sketch in Figure 13. In the absence of a demonstration it was difficult to evaluate this device; consequently, the response to the associated portion of the questionnaire was not as definite.

Sixteen mm motion pictures of the NWC tests have been processed and as soon as titles can be inserted, a copy will be prepared for NavFac.

4.6 Miscellaneous Comments on the P4-A Demonstration

The announced purpose for the P4-A demonstrations was to acquaint the firemen with the new vehicle and not to test its efficiency for applying the agent. Consequently, no comparison of performance with the C5A AGFSRS tests was attempted. Qualitatively, however, some rather inefficient applications were observed, mostly due to difficulty in controlling the bumper nozzle. This remotely controlled device will require extensive practice by the operator before it can be used efficiently. The cold fire trainer described in Reference 1 offers an excellent opportunity for this type of practice. Actually, a little human engineering applied to the hydraulic control system would greatly simplify the operation, but in the present form practice and more practice will be required. Less difficulty was experienced with the roof top nozzle; however, cold fire pit practice with this nozzle would also provide considerably more experience for a given amount of agent. If future demonstrations of the P4-A, either at a conclave or at individual stations, are planned, the inclusion of considerable cold pit practice should be considered.

5.0 Plans for the Next Period

Construct the aircraft engine fire simulator and test it in conjunction with the NWC fire department. Develop plans for the fuselage enclosed fire trainer described in References 1 and 2.

REFERENCES

1. NSWC/WOL/TR 75-205, Environmentally Compatible Aircraft Crash and Rescue Training Facilities, R. S. Alger, NSWC; S. B. Martin and A. E. Lipska, SRI, October 24, 1975

2. R. Alger and S. Martin, "Preliminary Economic Analysis of Various Options for Environmentally Compatible Aircraft Crash and Reserve Training Facilities," SRI, April 20, 1976

3. DOD-AGFSRS-76-7, Aircraft Ground Fire Suppression and Rescue Systems Design of a Cascade Fire Apparatus for Testing Countermeasure Effectiveness, NSWC and SRI, S. J. Wiersma, R. S. Alger, R. G. McKee, and W. H. Johnson, June 1976

Table I

CASCADE FIRE EXTINGUISHMENT TESTS

Test No.	Air Pressure Tank PSI	Air Pressure Burner PSI	Fuel Flow GPM	Fire Characteristics Visible Smoke	Fire Characteristics Symmetrical	Suppression Agent	Suppression Amount lbs	Extinguished	Fireman
1	130	58	2	No	to Left	PKP	6.6	Easily	A+
2	125	62	3	No	Yes	PKP	16.7	No	A
3	130	64	2	No	Yes	PKP	6.9	Easily	A
4	125	60	3	No	to Left	PKP	4.7	Easily	A
5	140	80	4	Slight	to Left	PKP	11.1	Yes	A
6	120	60	3	No	Yes	PKP	26	No	B
7	120	40	2	No	Yes	PKP		Easily	C
8	120	60	3	No	Yes	PKP		No	C
9	120	42	2.5	No	Yes	PKP		No	D
10	120	34	2	No	to Left	PKP		Yes	E
11	120	55	2.4	No	to Left	PKP		Yes	E
12	120	60	3	No	to Left	PKP		Yes	E
13	120	34	2	No	Yes	PKP		Easily	F
14	120	55	2.4	No	Yes	PKP		Yes	F
15	120	60	3	No	Yes	PKP		Yes	F
16	120	34	2	No	Yes	PKP		Easily	G
17								*	G
18	120	42	2.5	No	Yes	PKP		No #	G
19	120	34	2	No	Yes	H_2O		Yes	G
20	120	55	2.5	No	Yes	H_2O		Yes	G
21	120	60	3	No	Yes	H_2O		No	G
22	120	60	3	No	Yes	H_2O		No	H
23	120	34	2	No	Yes	AFFF		Yes	I
24	120	55	2.5	No	Yes	AFFF		Yes	I
25	120	60	3	No	Yes	AFFF		Yes	I
26	120	62	4	Slight	Yes	AFFF		Yes	I
27	120	62	5	Medium	Yes	AFFF		Yes	I

*Extinguished fire before fuel was adjusted
#Extinguisher trouble and this was the last extinguisher
+Tests 1 through 5 were conducted at Camp Parks, 6 through 27 at NWC China Lake

Table II

RESPONSE OF FIREMEN TO QUESTIONNAIRE REGARDING TRAINING AND TRAINING DEVICES

1. What Type of Hot Fire Training is Desired

	No. of Votes			
	Essential	Desirable+	Convenient#	Not Necessary‡
• Large Class B Pool Fires - Emphasis on Efficient Use of Crash Vehicles	20	3	1	1
• Fuselage Class A and C Fires - Emphasis on Entry, Breathing Apparatus, Safetying, Rescue, Extinguishment	16	5	3	0
• Open Cascading or Spraying Fuel Fires	6	11	5	2
• Semi-Enclosed Class B Fires, e.g. Engine Fires	6	14	4	0
• Class A and D Wheel Fires	7	10	6	2

• Other Fires Recommended
  Chemical
  Electrical
  Magnesium

Foot Notes

+Would use if I had to pay operating costs
#Would use if others pay operating costs
‡Would not use.

2. Comments on the Cascade-Spray Fire Trainer

	Yes	No
• Does this Fire Appear to Meet the Cascade Fire Requirement	18	1
• Is the Challenge Adequate	19	0
• Is the Reduction in Smoke Adequate for Your Needs	23	0
• Would you Expend the PKP and Fuel to Use This Trainer	20	0

• What Improvements or Modifications Would you Desire in the Cascade-Spray Fire Trainer
  - Larger area of fire, e.g., twice the size
  - Add wind direction feature
  - Ability to use JP-5
  - Provide a rolling fire where flames and heat extend above and beyond the firefighter
  - Improve ease of setting up and operation

3. Comments on Engine Fire Simulator, i.e., Figure 13.
  - Length 9, 18, 20 ft.
  - Diameter 6 ft
  - Height 3, 5, 6, 8 ft
  - Suggested changes
    - Provide an adjustable elevation
    - Provide a mobil simulator
    - Provide different sizes to meet the needs of specific airfields.

Fig. 1. Two Module Cascade Fire Developed Under the AGFSRS Program

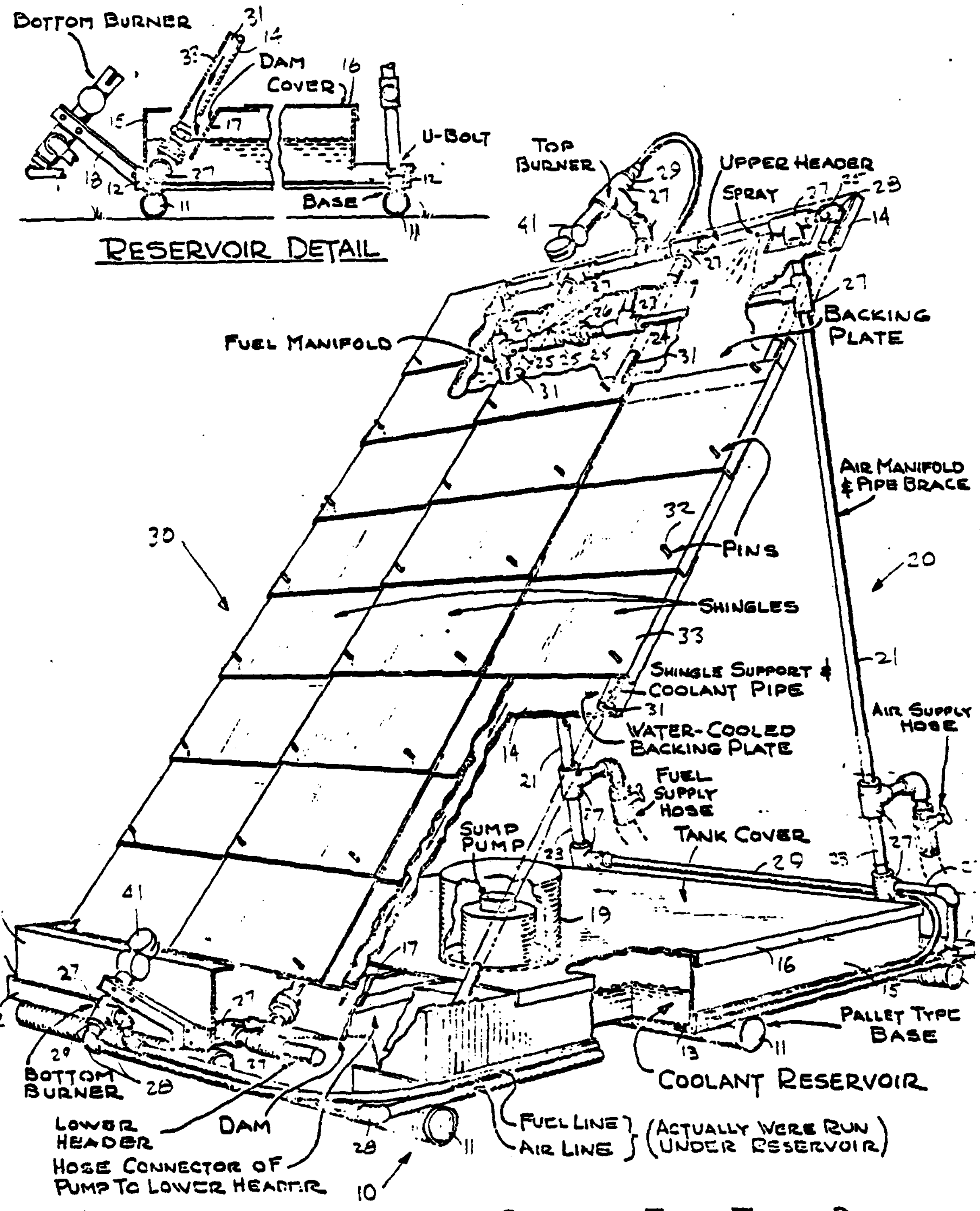
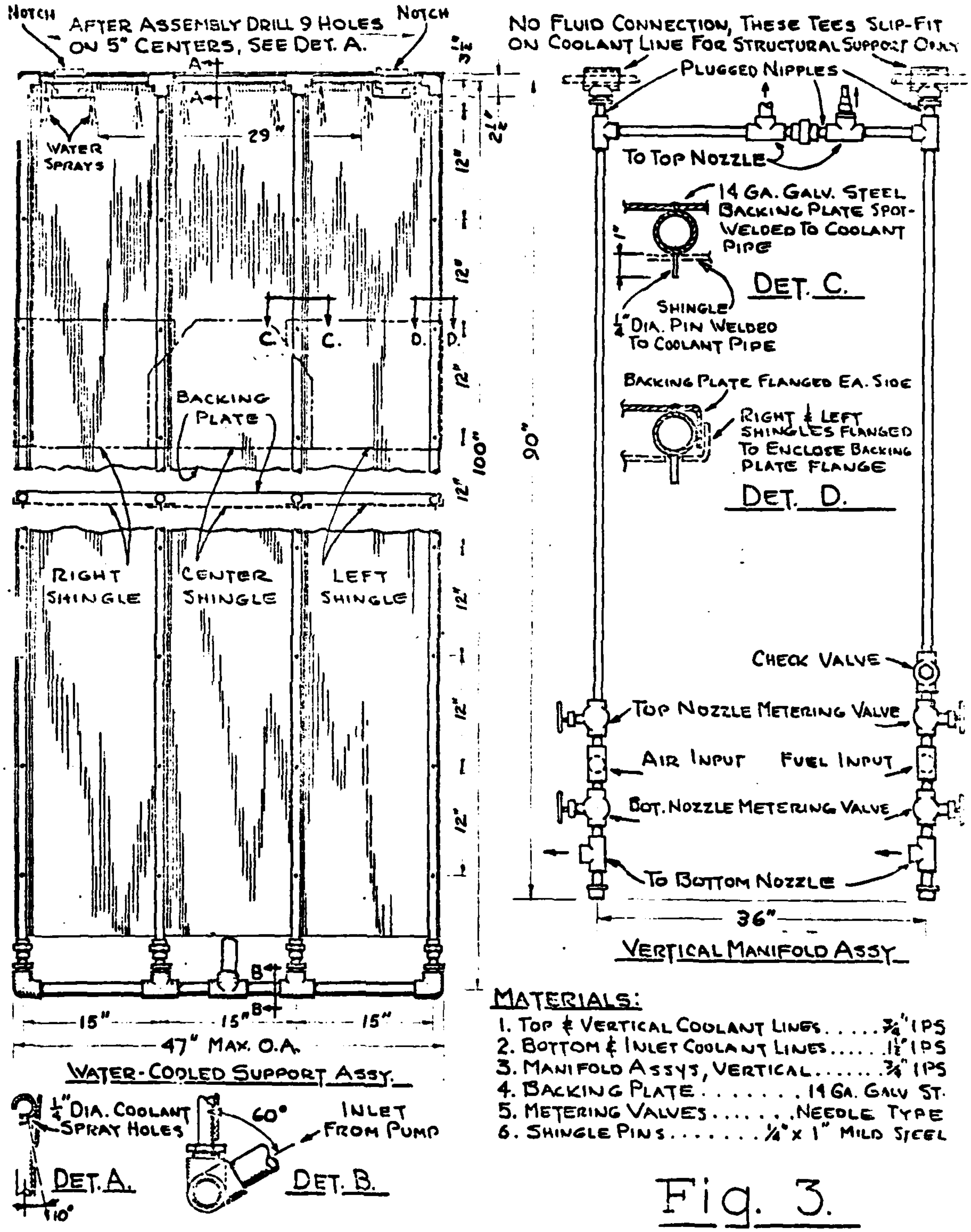


Fig. 2 - Smokeless Cascade Fire Test Device



NOTCH
AFTER ASSEMBLY DRILL 9 HOLES ON 5" CENTERS, SEE DET. A.
NOTCH
29"
WATER SPRAYS
C.
C.
D.
D.
BACKING PLATE
RIGHT SHINGLE
CENTER SHINGLE
LEFT SHINGLE
100"
90"
15"
15"
15"
47" MAX. O.A.
WATER-COOLED SUPPORT ASSY.
1/4" DIA. COOLANT SPRAY HOLES
DET. A.
10°
60°
INLET FROM PUMP
DET. B.
NO FLUID CONNECTION, THESE TEES SLIP-FIT ON COOLANT LINE FOR STRUCTURAL SUPPORT ONLY
PLUGGED NIPPLES
TO TOP NOZZLE
14 GA. GALV. STEEL BACKING PLATE SPOT-WELDED TO COOLANT PIPE
SHINGLE
1/4" DIA. PIN WELDED TO COOLANT PIPE
DET. C.
BACKING PLATE FLANGED EA. SIDE
RIGHT & LEFT SHINGLES FLANGED TO ENCLOSE BACKING PLATE FLANGE
DET. D.
CHECK VALVE
TOP NOZZLE METERING VALVE
AIR INPUT
FUEL INPUT
BOT. NOZZLE METERING VALVE
TO BOTTOM NOZZLE
36"
VERTICAL MANIFOLD ASSY
MATERIALS:
1. TOP & VERTICAL COOLANT LINES.....3/4" IPS
2. BOTTOM & INLET COOLANT LINES.....1 1/2" IPS
3. MANIFOLD ASSYS, VERTICAL.....3/4" IPS
4. BACKING PLATE.......14 GA. GALV ST.
5. METERING VALVES.......NEEDLE TYPE
6. SHINGLE PINS.......1/4" x 1" MILD STEEL

Fig. 3.

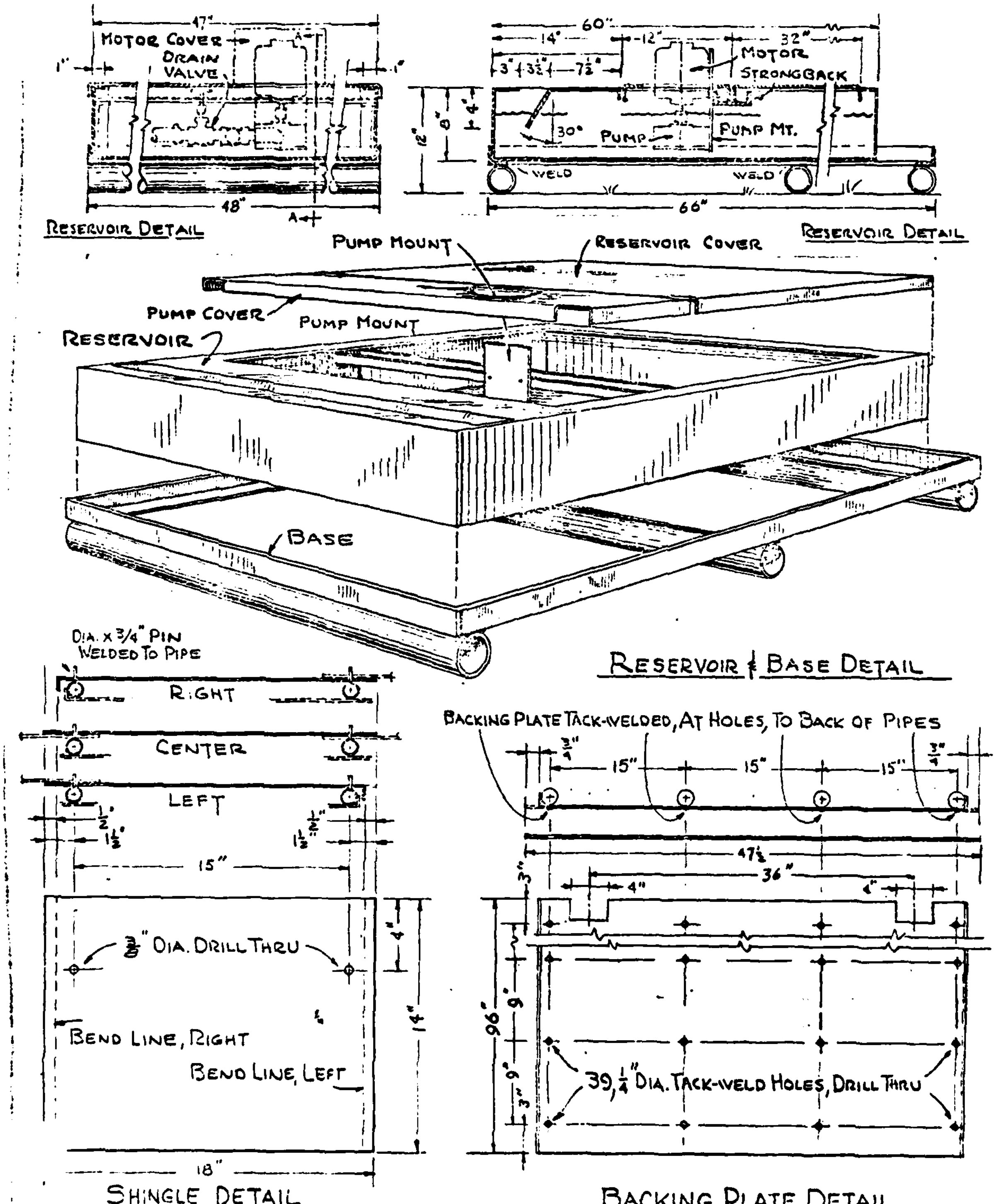
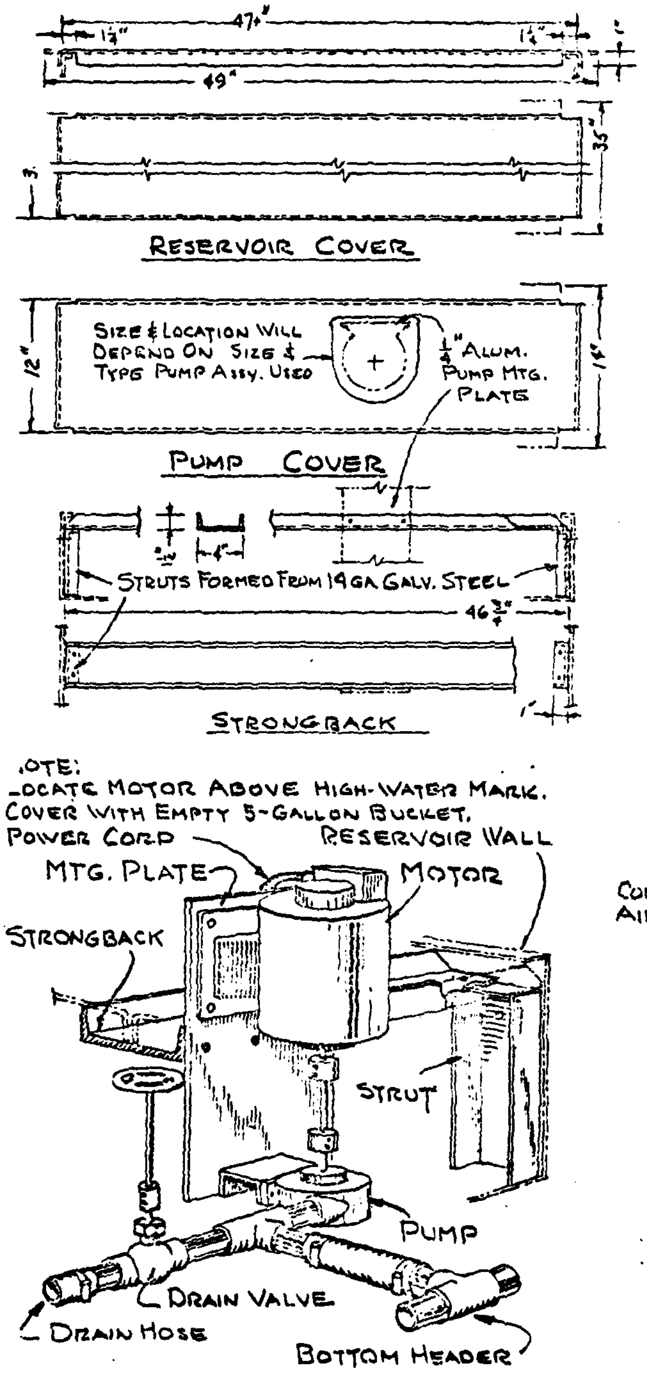

47"
Motor Cover
Drain Valve
1"
48"
Reservoir Detail
60"
14"
12"
32"
Motor
Strongback
3"
7½"
12"
8"
4"
30°
Pump
Pump Mt.
Weld
66"
Reservoir Detail
Pump Mount
Reservoir Cover
Pump Cover
Pump Mount
Reservoir
Base
Dia. x 3/4" Pin
Welded To Pipe
Right
Center
Left
15"
3/8" Dia. Drill Thru
Bend Line, Right
Bend Line, Left
4"
14"
18"
Shingle Detail
Reservoir & Base Detail
Backing Plate Tack-welded, At Holes, To Back of Pipes
15"
47½
36"
4"
96"
9"
3"
39, 1/4" Dia. Tack-weld Holes, Drill Thru
Backing Plate Detail

Fig. 4.



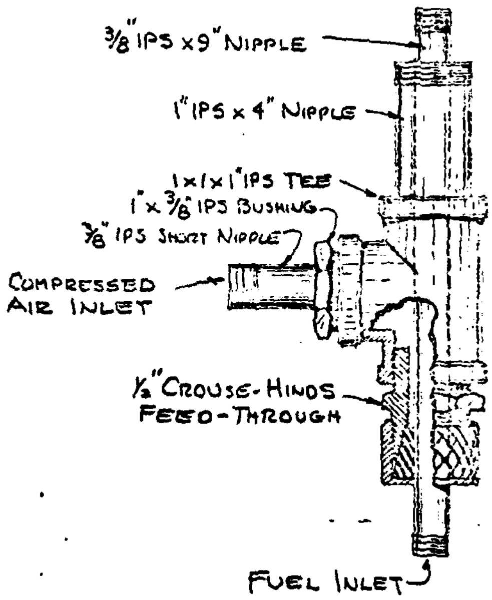
RESERVOIR COVER

PUMP COVER

STRONGBACK

TYPICAL COOLANT PUMP ARRANGEMENT.

CHANGE AS REQ. TO ACCOMODATE SIZE & TYPE COMPONENTS AVAILABLE



BURNER ADAPTOR

Fig. 5.

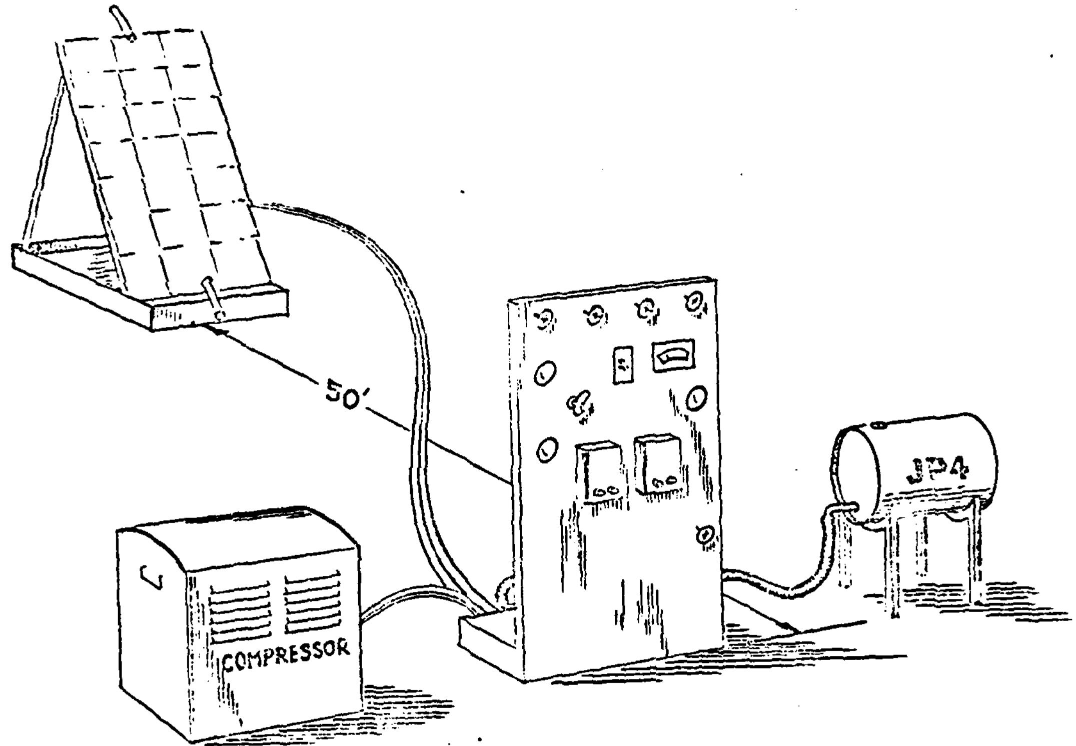

50'
JP4
COMPRESSOR

Fig. 6.

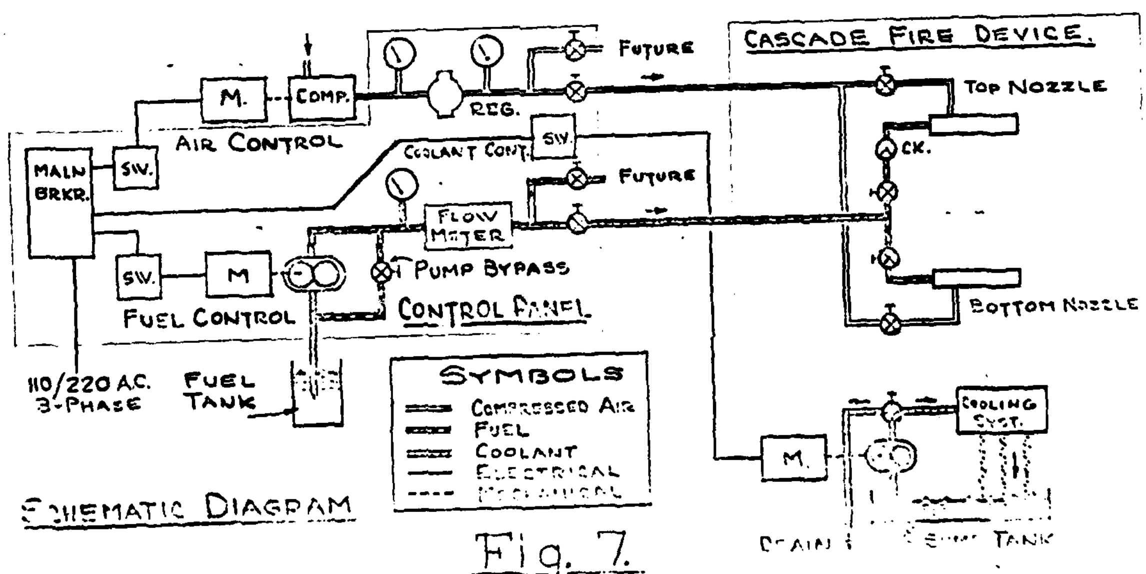
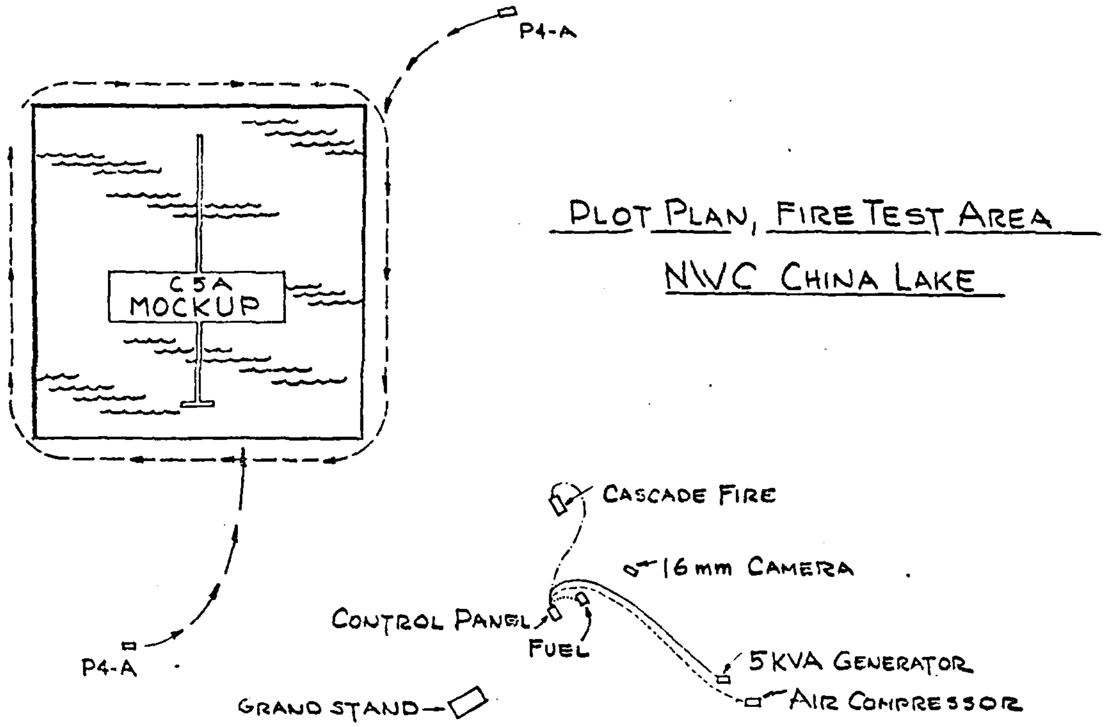

FUTURE
CASCADE FIRE DEVICE.
M.
COMP.
REG.
TOP NOZZLE
AIR CONTROL
SW.
COOLANT CONT.
CK.
MAIN BRKR.
SW.
FUTURE
FLOW METER
SW.
M
PUMP BYPASS
BOTTOM NOZZLE
FUEL CONTROL
CONTROL PANEL
110/220 A.C. 3-PHASE
FUEL TANK
SYMBOLS
COMPRESSED AIR
FUEL
COOLANT
COOLING SYST.
M.
TANK

Fig. 7.

PLOT PLAN, FIRE TEST AREA
NWC CHINA LAKE



SUGGESTED COMPONENTS & MATERIALS:

1. SUMP PUMP:	TEEL, CENTRIFUGAL, MOD. 1P798, 16 gpm
2 FUEL PUMP:	TEEL, GEAR, MOD. 1P769, 12 gpm. 80 psi WITH 2 HP MOTOR.
3. FLOWMETER:	FISHER-PRICE, IN-LINE, DIRECT-READING, 0-15 gpm, MOD. YN5671.
4. AIR COMPRESSOR:	SPEEDAIRE MOD 1Z936, 7½ HP MOTOR, 230/460 V. 2 EA, 120 GAL. (AN ADDITIONAL 120 GAL. TANK SHOULD BE INSTALLED)

TO MAXIMIZE THE SERVICABLE LIFE OF THIS UNIT, USE CORROSION-RESISTANT MATERIALS OR MATERIALS COATED, PLATED OR GALVANIZED WHEREVER PRACTCABLE. HINGLES MUST BE REPLACED WHENEVER CORROSION OR DISTORTION AFFECT USE OF THE UNIT.

Fig. 8.

Fig. 9. Photo. Typical 3 GPM Fire

Fig. 10. Photo. Two Stages in the Successful Extinguishment of 2 GPM Fire with PKP.

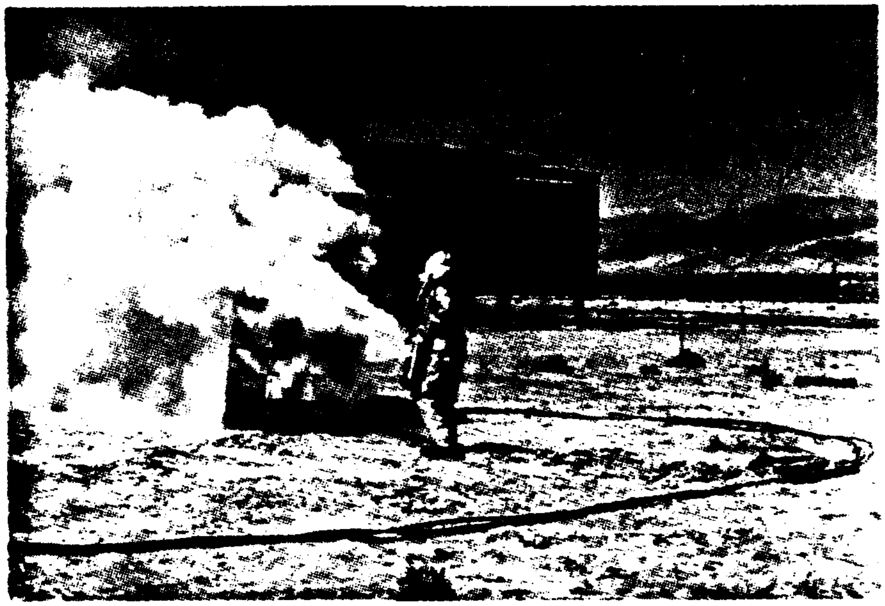
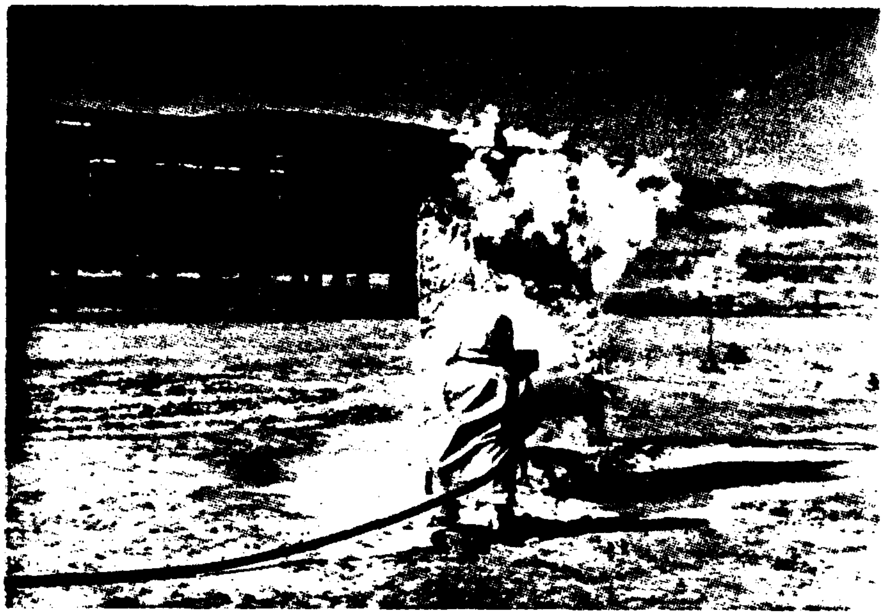


Fig. 11. Two Views of Unsuccessful Attack on 3 GPM Fire with Water. Application Rate approx 60 GPM.

Fig. 12. Two Views of Successful Extinguishment of 5 GPM Fire with AFFF, Application Rate approx. 100 GPM.



Appendix B

STANFORD RESEARCH INSTITUTE
MENLO PARK, CALIFORNIA 94025
(415) 326-6200

R & D CONTRACT STATUS REPORT
ON ENVIRONMENTALLY COMPATIBLE AIRCRAFT CRASH
AND RESCUE TRAINING FACILITIES

1. Title: Smokeless Aircraft Engine Fire Simulator and Demonstration at NWC China Lake
2. Contract No. N60921-75-C-0184
3. Agency: SRI Final Report on this Contract
4. Summary

Reference 1 identified the requirements for environmentally compatible training fires to provide firemen with practice and certification in the use of powder and vapor auxiliary agents. Reference 2 discussed these requirements in more detail and provided schematic designs for a cascading fuel fire and an engine fire simulator. These two devices are only part of the overall training facility described in References 1 and 2; however, they are considered together here because they share a common control panel. Reference 3 described the construction and evaluation of the cascade device and part of the control panel. This summary provides the construction details and the demonstration results for the engine fire simulator, a description of the completed control panel, and comments on the air pollution evaluation.

4.1 Aircraft Engine Fire Simulator Design and Construction

The design objectives were threefold:

- To simulate two types of turbojet engine fires i.e., a fuel spill burning inside the engine and a fire in the nacelle.
- To provide a range of fire intensities so that the challenge can be adjusted to the ability of the firemen and the capacity of the application equipment.
- Compatibility with the clean air and water regulations.

Figure 1 shows a fore, aft, and side view of the engine fire simulator. Construction details are shown in Figures 2 through 6. In essence the device consists of two double walled cylinders aligned coaxially to represent the engine proper and the nacelle. Baffles

CABLE: STANRES, MENLO PARK / TWX 910-373-1246

in the form of the annular ring and slotted disks visible in Figure 1A restrict access to the fire zones in a very crude simulation of the restrictions caused by the ventilation control vanes and the comprisor stages of a real engine. Smokeless fires are provided by the two air atomizing furnace burners located about midway fore and aft. This simulator is not modeled after a particular aircraft engine but the size and configuration provide a rough approximation to several engines in current use where access is primarily available through the compressor stage or inspection plates opening into the annular space. Figure 1C shows a typical sized inspection opening in the nacelle. The simulator is designed primarily for training with agents such as CO_2 and the Halons, that can penetrate the obstructions in the forward end. Powders such as PKP become trapped between the slotted discs much as they would in the compressor stage of a real engine; however, the powder can be successfully applied through the inspection port or in the open aft end of the simulator. Of course, firemen are reluctant to apply powder to a real engine because the abrasive powder introduces an expensive engine removal and cleaning operation.

As indicated in Figures 2 and 3, the simulator is cooled by about 185 gal of water that fill the double walled cylinders; i.e., 117 gal and 68 gal r spectively for the 5' and 3' dia tanks. The inner cylinder rests in two water cooled Y-supports formed out of 2½" pipe as indicated in Figure 3. This support allows the tanks to expand and contract without straining each other except for the slight impediment imposed by the interconnecting plumbing fore and aft. Figure 4 shows details of the Y-supports and the provisions for transmitting the load to the support stand without shutting off water circulation. Two 3" pipe nipples welded in the top of the outer cylinder serve as filling ports and vents. A drainage line at the bottom allows the water to be removed in cold weather to avoid freezing. Because of the relatively thin sheet metal it was necessary to tie the outer and inner walls together on the 5' dia tank to prevent the inner tube from buckling under hydrostatic compression. The uniformly spaced tie-bolts are visible in Figures 1C and 2. Each bolt head and nut was welded in place to prevent a water leak. Three circular ribs were inserted in the 3' dia tank as shown in Figures 1B and 3 to provide additional strength to support the hydrostatic load. As indicated, these ribs are positioned by three channels equally spaced around their circumference. This construction leads to a relatively light unit i.e., about 1,700 lbs. Obviously the same results could be obtained by using thicker material for the inner walls e.g., 1/8" for the 34" and about 3/16" for 58" dia. tubes.

An appropriate height for the simulator was one of the questions posed by the questionnaire discussed in Reference 3. Suggested values range from 3 to 8 ft with no particular height prevailing; therefore, the support stand was built to provide a 5½' center line height in accordance with the desires at NWC. This height permits all operations to be performed from the ground; however, it would be a relatively simple matter to construct a taller stand if training from a ladder were required. In positioning the stand, the aft end was always at a slightly lower elevation so that spilled fuel or water would drain out.

Figure 5 shows details of the simulated turbin blades and their method of support on the coaxial air fuel pipes. The V trough in the southwest quadrant just below the burner pipes serves as a guide and support for the asbestos cloth wick ignition torch. Details of the coaxial air fuel line and burner are included in Figure 6. Each burner head consists of three parts (1) a mechanical fuel tip body to spray and partially atomize the fuel, (2) the mixing chamber where the compressed air mixes with the partially atomized fuel, and (3) the flame tip which determines the pattern of the fuel as it leaves the burner. Parts 1 and 2 are the same in both burners but flame tips were selected to match the geometry of the combustion space i.e., a cone flame tip for the engine and a flat flame tip in the nacelle space. The flat flame burner and the ignitor V trough are supported by a clamp on the Y support bracket. In order to make the extinguishment a bit more challenging, the flat flame burner is mounted on the opposite side of the 3' tube from the access port. Figure 6 also shows the external connections for the air fuel and water. Each burner nozzle is separately controlled from the control panel; therefore, two air and two fuel lines (all ½" cu tubing) connect the engine simulator to the controller.

4.2 Modifications to the Control Panel

In the arrangement described in Reference 3 one fuel line and one air line spplied both burners on the cascade fire trainer. Valves in the trainer plumbing system were used to balance the flows equally between the two burners; however, this process was a bit tedious and subject to some uncertainty about how well the burners were remaining balanced. A little dirt in one of the burners could change the relative flow without appreciably effecting the total controlled by the throttling valve and flow meter. This problem was eliminated by introducing the 4 pipe system and separate fuel flow meters for each burner as indicated in Figures 7 and 8. The flow meters are of the purge meter type and come with a calibration constant for water stamped on the dial. Figure 9 shows a calibration curve for JP-4 drawn along the average for both meters.

The other significant addition to the control panel was the air-compressor to provide air for the burners. Air atomizing fuel systems consume substantial quantities of air and therefore require a large compressor for continuous operation. However, for short burns such as are anticipated in training exercises there is another alternative i.e., a modest sized compressor can be equipped with storage tanks that can provide a substantial fraction of the air. The control panel was equipped with a

$7\frac{1}{2}$ hp compressor and two 180 gal tanks. Provisions were made in the design for a third tank but two appeared to have sufficient capacity for the immediate needs. Starting at atmospheric pressure the compressor takes about 10 min to raise both tanks to the 180 PSI cut off pressure. Since the rate of air consumption required to maintain a smokeless flame depends on the fuel burning rate, the allowable running time is different for each burning rate. Figure 10 shows a family of tank air pressure versus time curves for various burner air pressures, i.e., various setting of the pressure regulator. Initially, there is a rapid drop in the tank pressure until the compressor starts and begins to supply part of the load. Typical times are about 5, 3, 1.5 min for 1, 2, and 3 GPM, respectively. If the fireman is ready to commence when the fire is fully developed, the 1.5 min provides sufficient time to discharge the types of fire extinguishers envisioned for use with this trainer. The attached operating instructions tabulate fuel flow rates and smokeless times for both the cascade fires and the engine simulator.

4.3 Demonstration of Engine Fire Simulator at NWC China Lake

After a few preliminary tests at Camp Parks the simulator and control panel were shipped to NWC China Lake for a demonstration during the week of January 17 while the P-4 and P-4A Tests were in progress at the C5A test site. Figure 11 shows the arrangement of the training devices, the controller, and the electrical supply as installed on the east side of the main test area. The prevailing wind strikes the front of the engine simulator and the operator at the controls is down wind where he can observe the flames, determine when extinguishment has been achieved, and shut off the fuel. Figure 12 shows aft views of the engine fire (A) and the nacelle fire (B) when operating at about 1 GPM during the Camp Parks start up. Although the burner is at about four o'clock in the annular space, the flames fill the entire space. Figure 13 shows perspective views of the two fire types during the China Lake demonstrations. For a burning rate of about 3 GPM, the central flames extend well beyond the engine compartment. The nacelle fire was burning at about $1\frac{1}{2}$ GPM. When operated according to the air pressures tabulated in the operating instructions, the fires were essentially smokeless. In Figure 13 the black streak in the sky behind the simulator is the distant remains of a smoke cloud sent up during a preceding fire in the C5A pool. Figure 14 shows several extinguishment exercises with CO_2. In (A) the fireman is applying the CO_2 through the simulated fan blades with little noticeable effect on the fire. In (B) another CO_2 extinguisher is being applied through the aft opening. While the flames are drastically reduced, the CO_2 was not capable of extinguishing a $1\frac{1}{2}$ GPM fire from any position. Table 2 summarizes the extinguishment efforts. CO_2 could extinguish a $\frac{1}{2}$ GPM fire from the aft position but was unseccessful at $1\frac{1}{2}$ GPM and above. PKP was ineffective when applied through the fan blades but successfully extinguished 3 GPM fires through the inspection opening and from the aft position. The PKP was very effective when it could reach the burners. If the engine simulator is to be used for general training with PKP, it may be desirable to incorporate a few additional obstructions in the aft section to make the extinguishment more challenging. The challenge appears to be more than adequate for the small (50 lb) CO_2 extinguishers. A larger CO_2 extinguisher would probably be successful. The system was left in operating condition at NWC so the firemen can practice training with both the engine fire simulator and the cascade fire.

4.4 Compatibility with Clean Air and Water Regulations

Arrangements were made through the NAVFAC San Bruno office for a calibrated eye to observe and evaluate the smoke produced by both the cascade fire and engine fire simulators during the NWC demonstrations. Mr. T. Dodson of NWC coordinated the inspection and Mr. P. E. Ross, an air pollution engineering inspector for the Southern California air Pollution Control District performed the evaluation which will be reported directly to NAVFAC. As long as the units are operated according to the air flow rates specified in the "operators instructions", there appears to be no air pollution problem. If fuel flows are pushed above the air flow capability of the present air supply, the fire begins to produce smoke and pollution becomes a problem, e.g., when the cascade fire was operated at 5.2 GPM, the available air could not eliminate all of the smoke.

REFERENCES

1. NSWC/WOL/TR 75-205, "Environmentally Compatible Aircraft Crash and Rescue Training Facilities," R.S. Alger, NSWC; S.B. Martin and A.E. Lipska, SRI, October 24, 1075.
2. R. Alger and S. Martin, "Preliminary Economic Analysis of Various Options for Environmentally Compatible Aircraft Crash and Reserve Training Facilities," SRI, April 20, 1976.
3. Smokeless Cascade Fire Device and Demonstration at NWC China Lake, Contract No. N60921-75-C-0184, SRI Report No. 1.

Tables 1 and 2

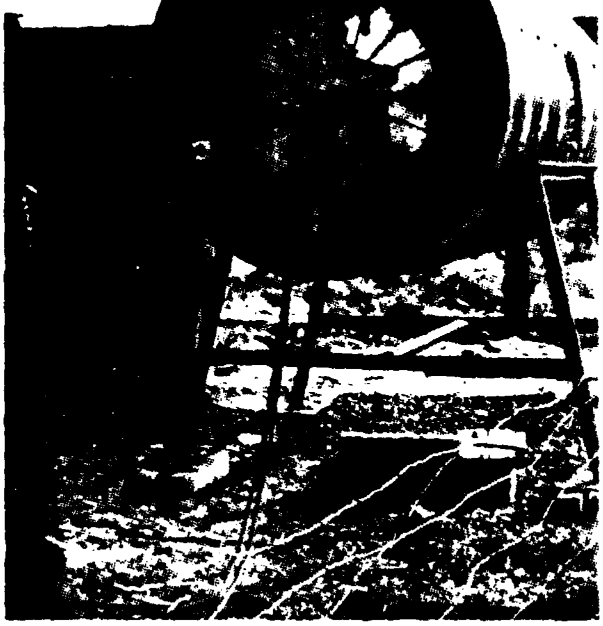
ENGINE FIRE SIMULATOR EXTINGUISHMENT TESTS

Run No	Burner	Fuel Flow GPM	Flowmeter Reading	Air Pressure PSI	Burn Time Min	Agent Type	Fire Extinguished	Agent Consumed lbs
Camp Parks 5 Jan.								
1	center	1.9	13	30	4	PKP	yes	
2	annulus	1.4	13	34	1	PKP	yes	
3	annulus	2.3	26	62	1.6	none		
4	center	2.3	20	70	2.3	PKP	yes	
5	annulus	3.1	39	95	1.8	none		
6	annulus	3.1	39	95	.8	PKP	no	
7	center	2.9	30	95	1.7	none		
China Lake 17 Jan.								
1	center	1	11	35	2.5	CO_2	no	30
2	center	.5	6.5	35	.8	CO_2	yes	1
3	center	1	11	35	1.4	CO_2	no	29.7
4	annulus	1	11	35	1.5	CO_2	no	30
5	annulus	1.5	16	40		CO_2	no	15
	annulus	1.5	16	40	.7	PKP	yes	2
6	annulus	2.5	26.5	70	.2	PKP	yes	6
7	annulus	3	33	95	.3	PKP	yes	8
8	center	3	32	95	.3	PKP	yes	3

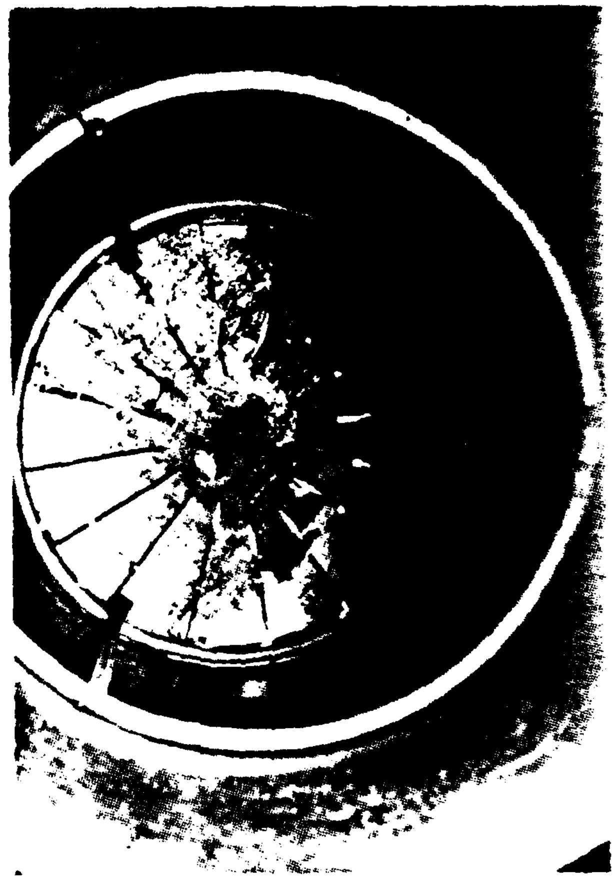
Figure 1. Three Views of Aircraft Engine Simulator

(a) Front End Showing Simulated Turbine Stage

(b) Aft End Showing Engine Compartment and Center Burner



A



B

C

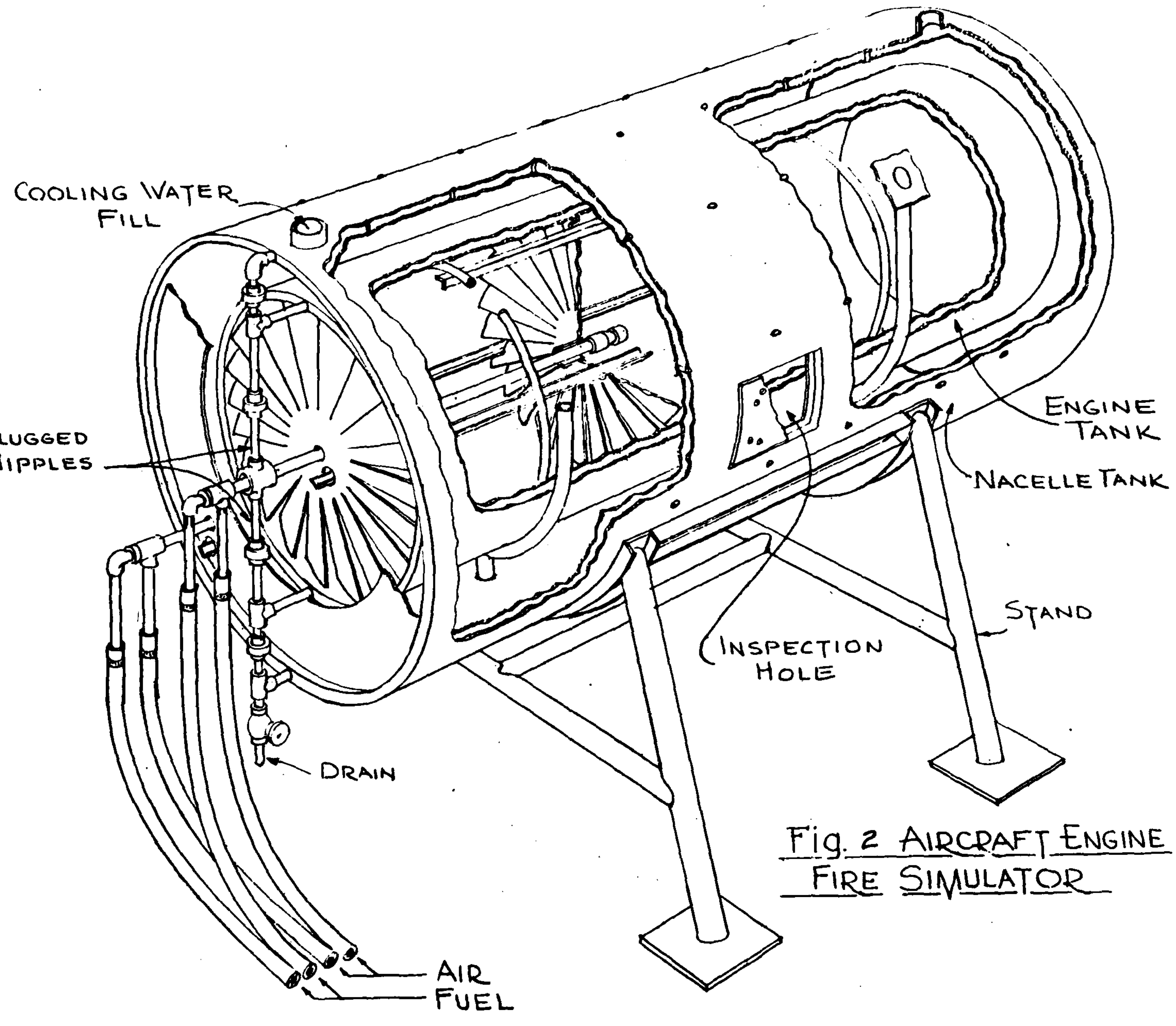


Fig. 2 AIRCRAFT ENGINE FIRE SIMULATOR

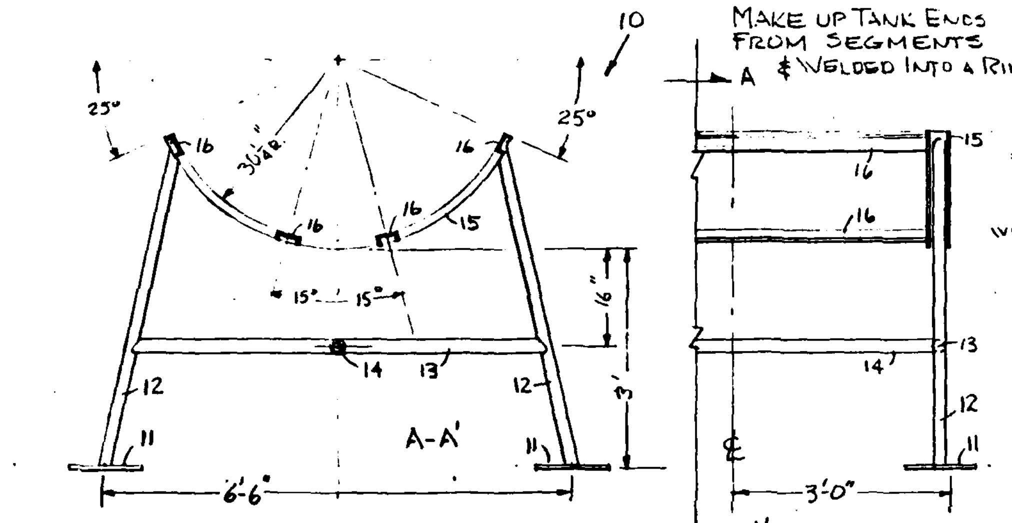
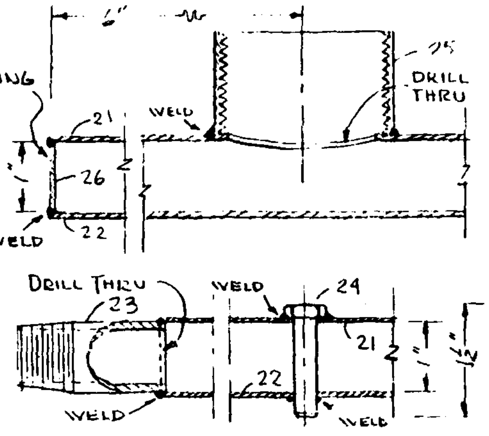


Fig. STAND
1/2" = 1'-0"



NACELLE TANK DETAILS
1/2" = 1"

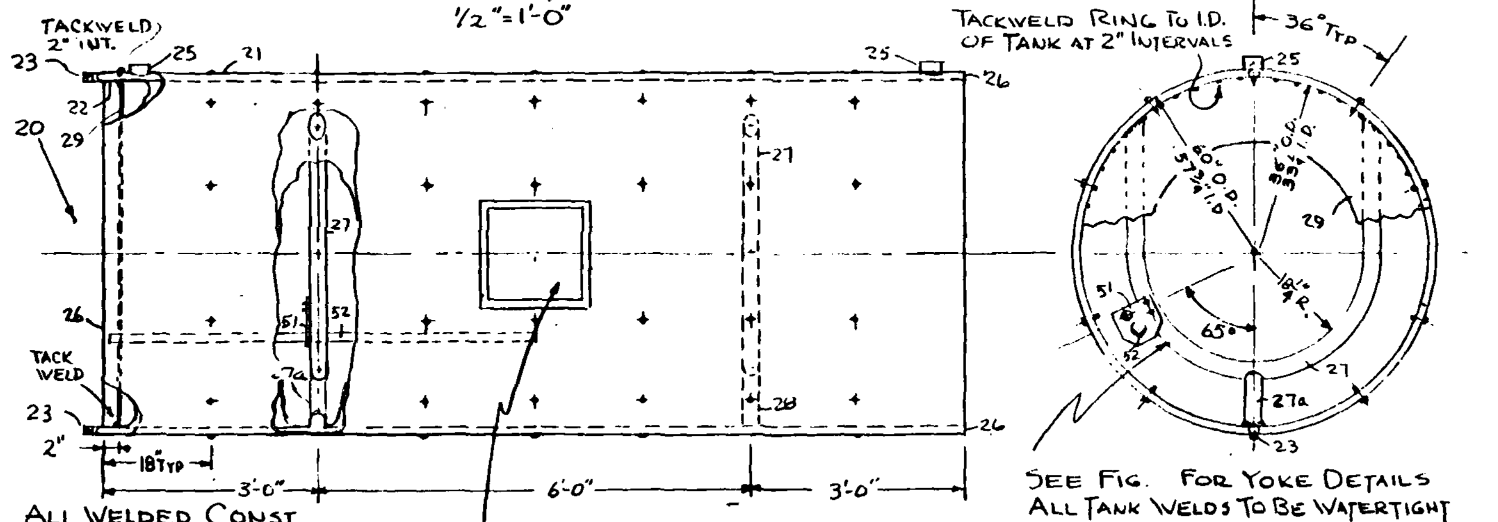


Fig. 3 NACELLE TANK
1/2" = 1'-0"

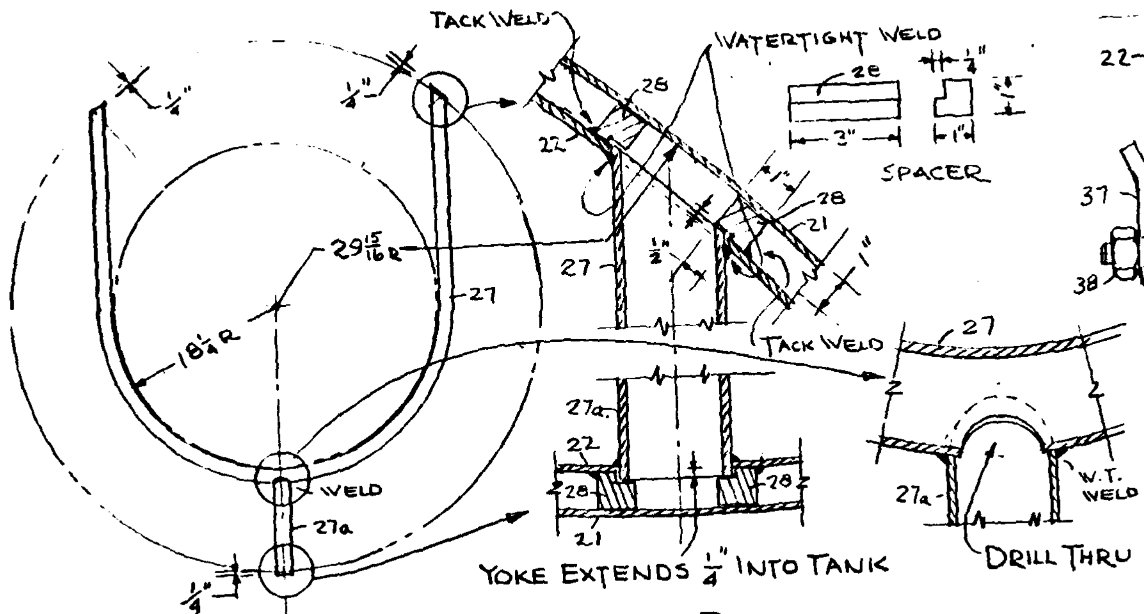
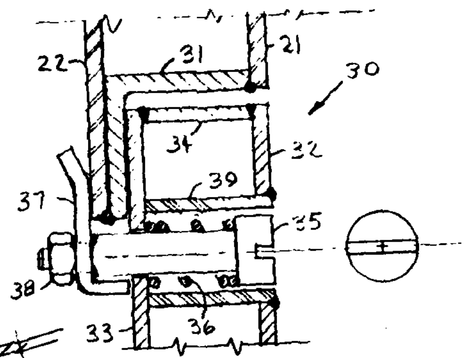
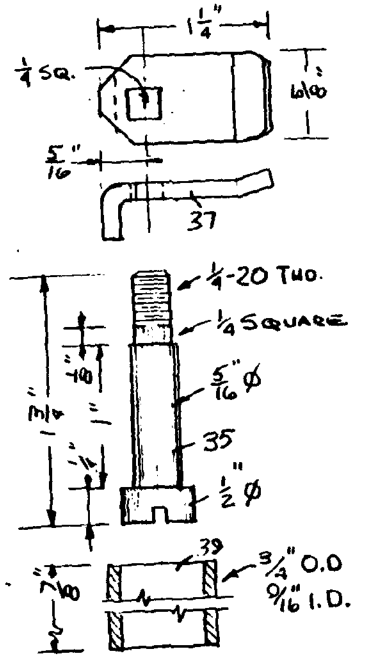


Fig. YOKE DETAILS
1/4" = 1"



LATCH ASSY SECT
FULL SCALE



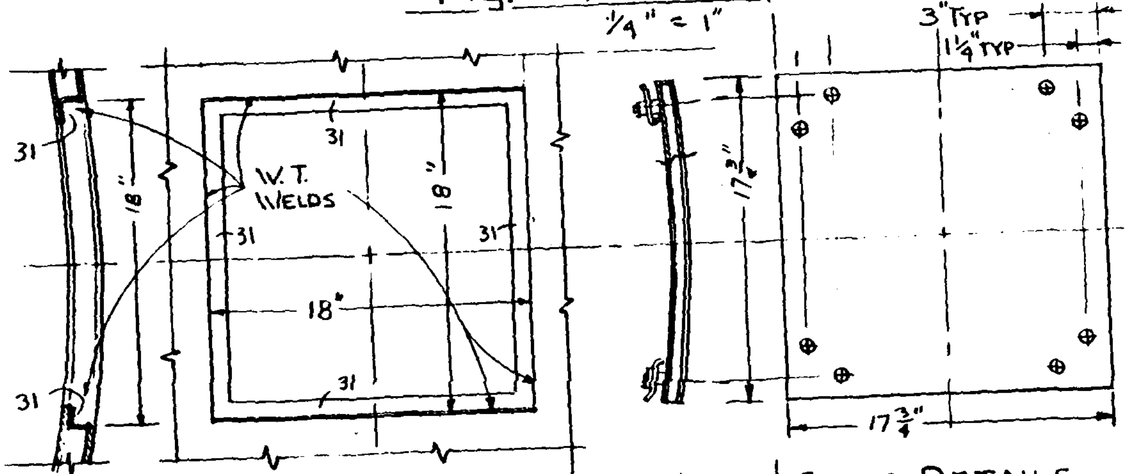


Fig. 4 INSPECTION HOLE & COVER DETAILS

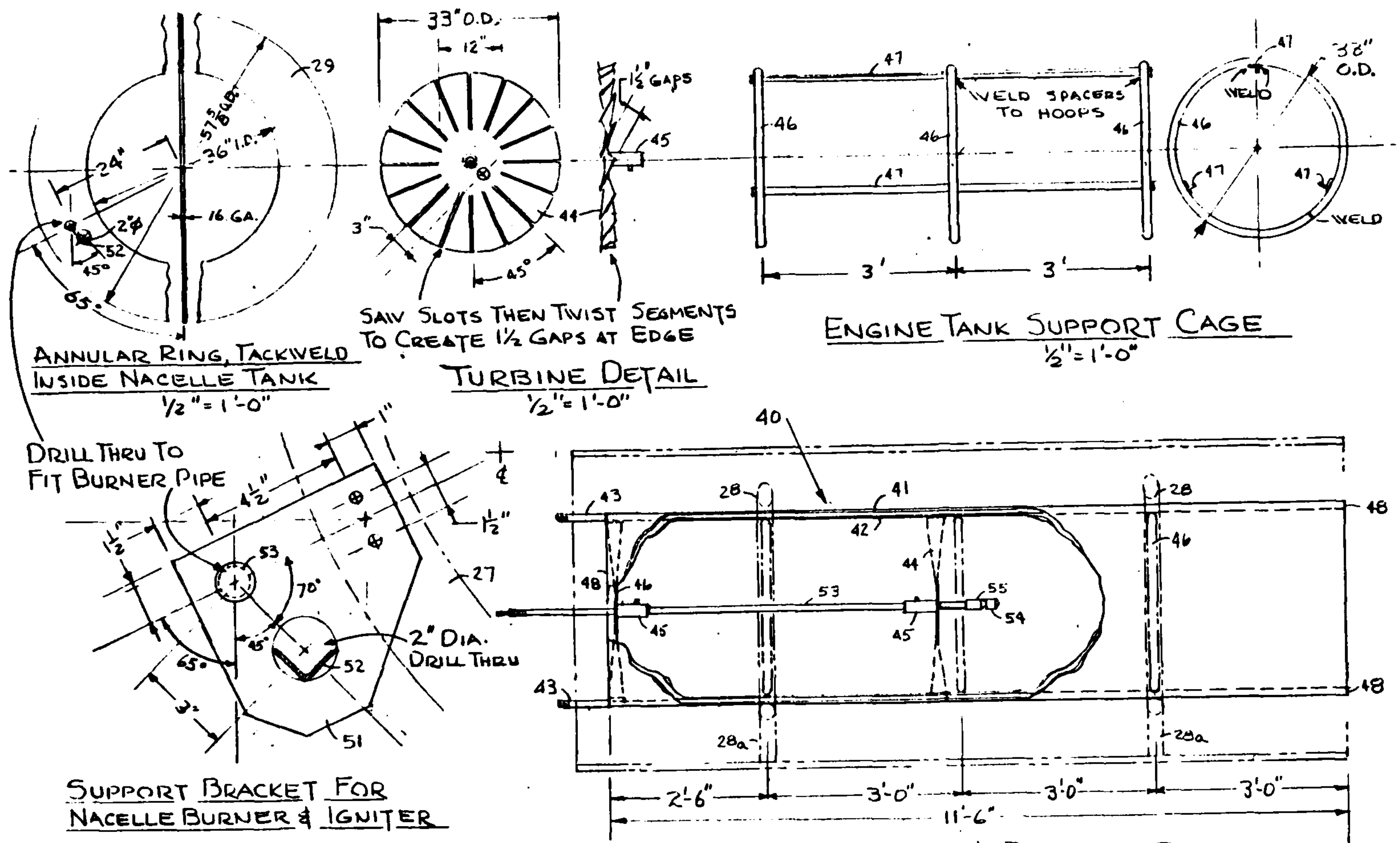
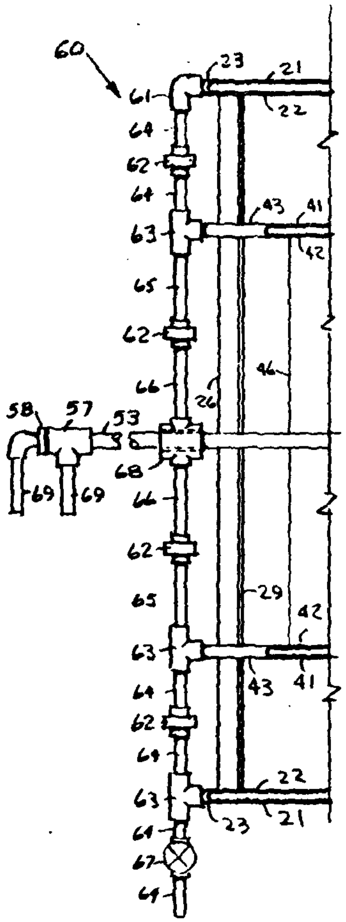


Fig. 5 ENGINE TANK & RELATED DETAILS



TANK MANIFOLD ASSY.
1" = 1'-0"

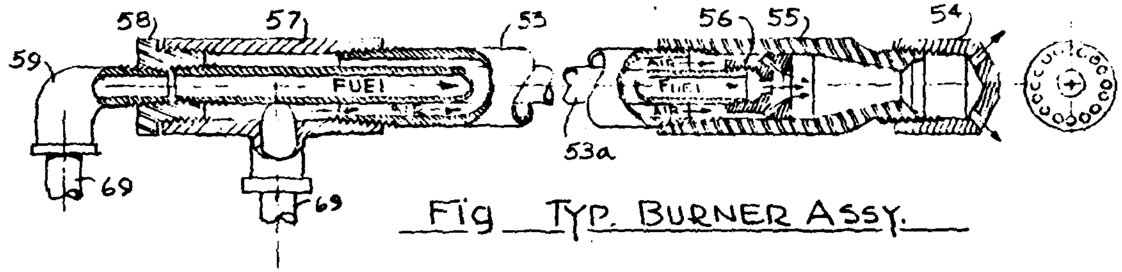


Fig TYP. BURNER ASSY.

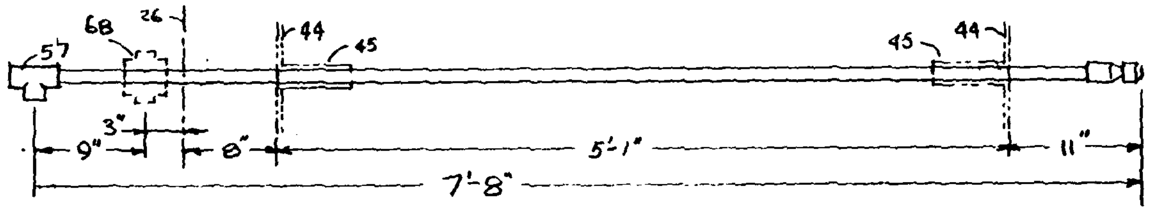


Fig ENGINE BURNER

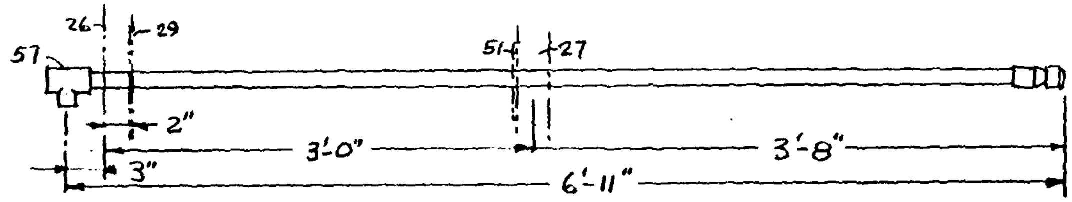


Fig 6 NACELLE BURNER

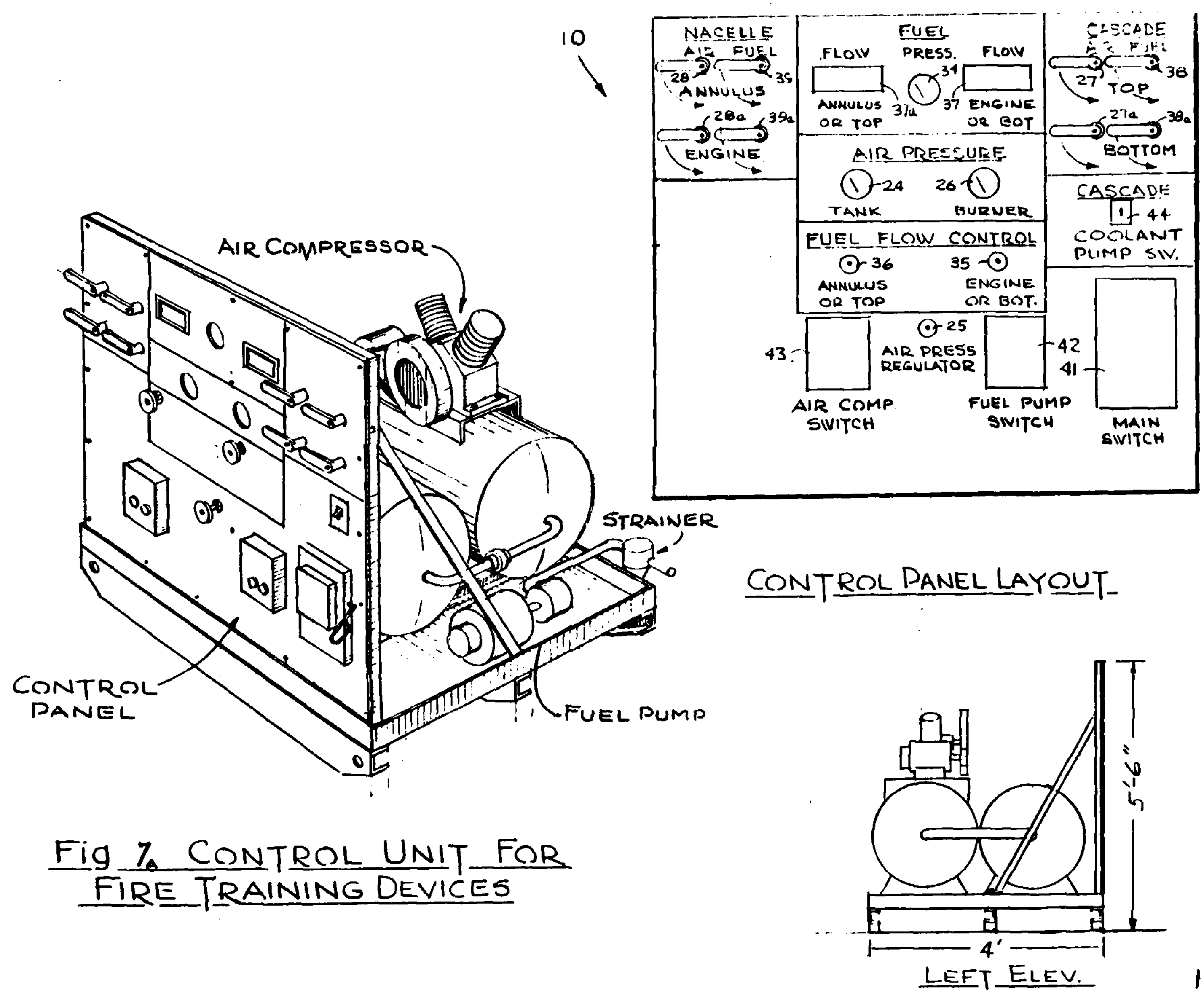


Fig 7. CONTROL UNIT FOR FIRE TRAINING DEVICES

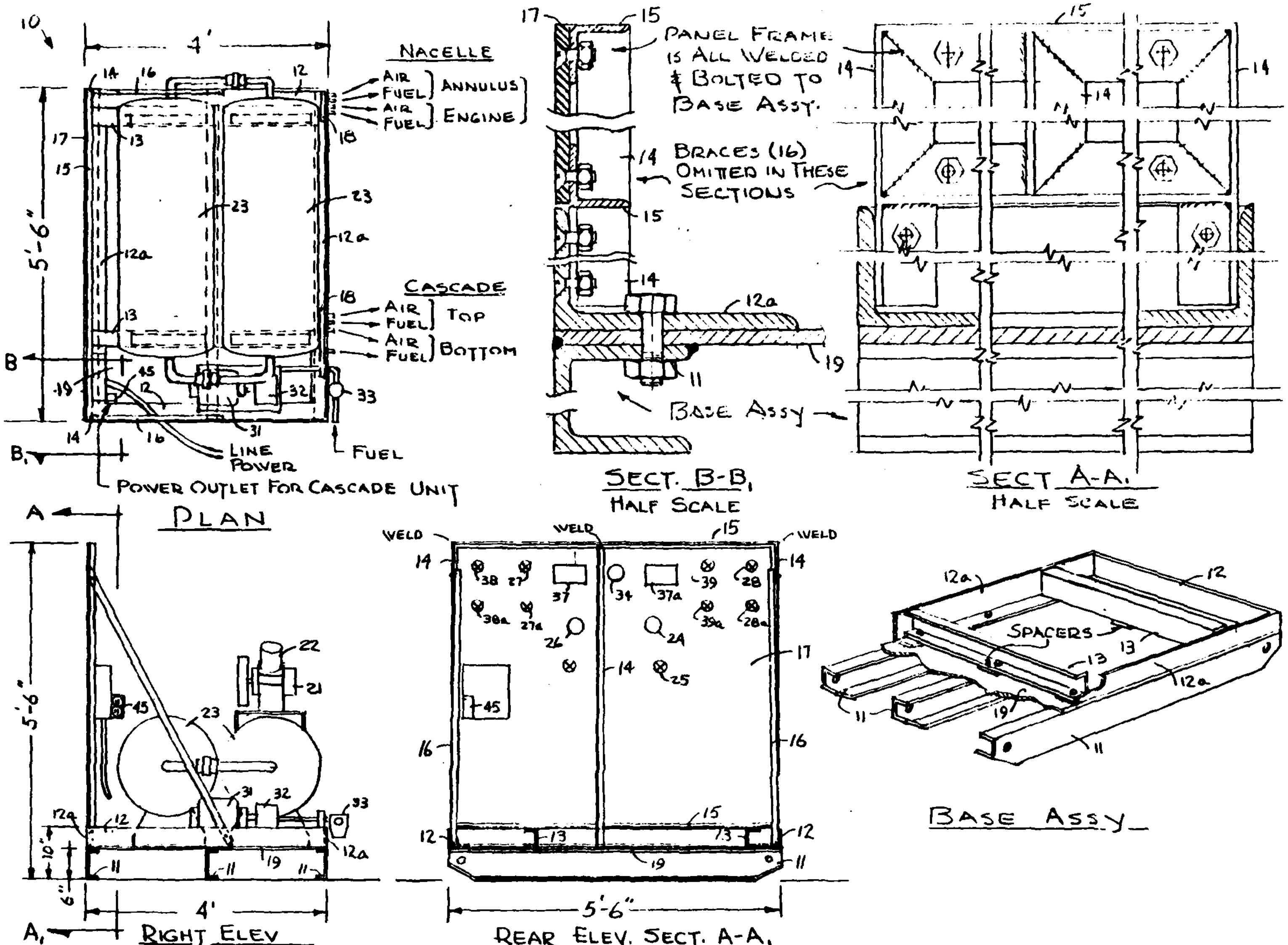


Fig 7. GENERAL ARRGT., CONTROL UNIT STRUCTURE
1/2" = 1'-0"

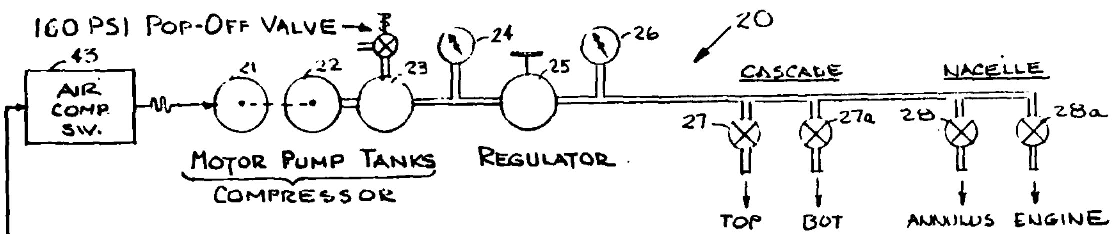


Fig Compressed Air System

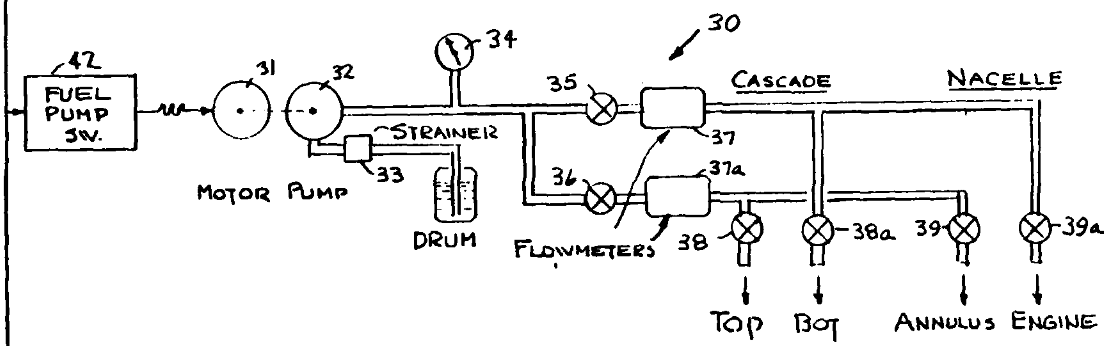


Fig Burner Fuel System

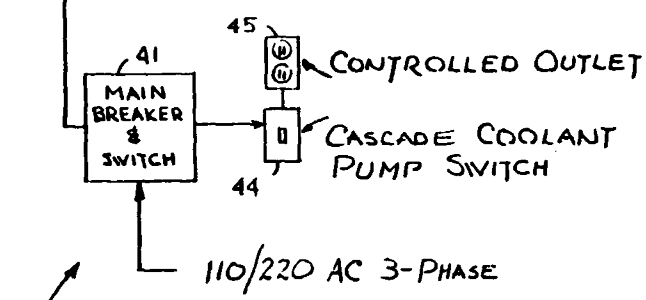


Fig 8 Electric System

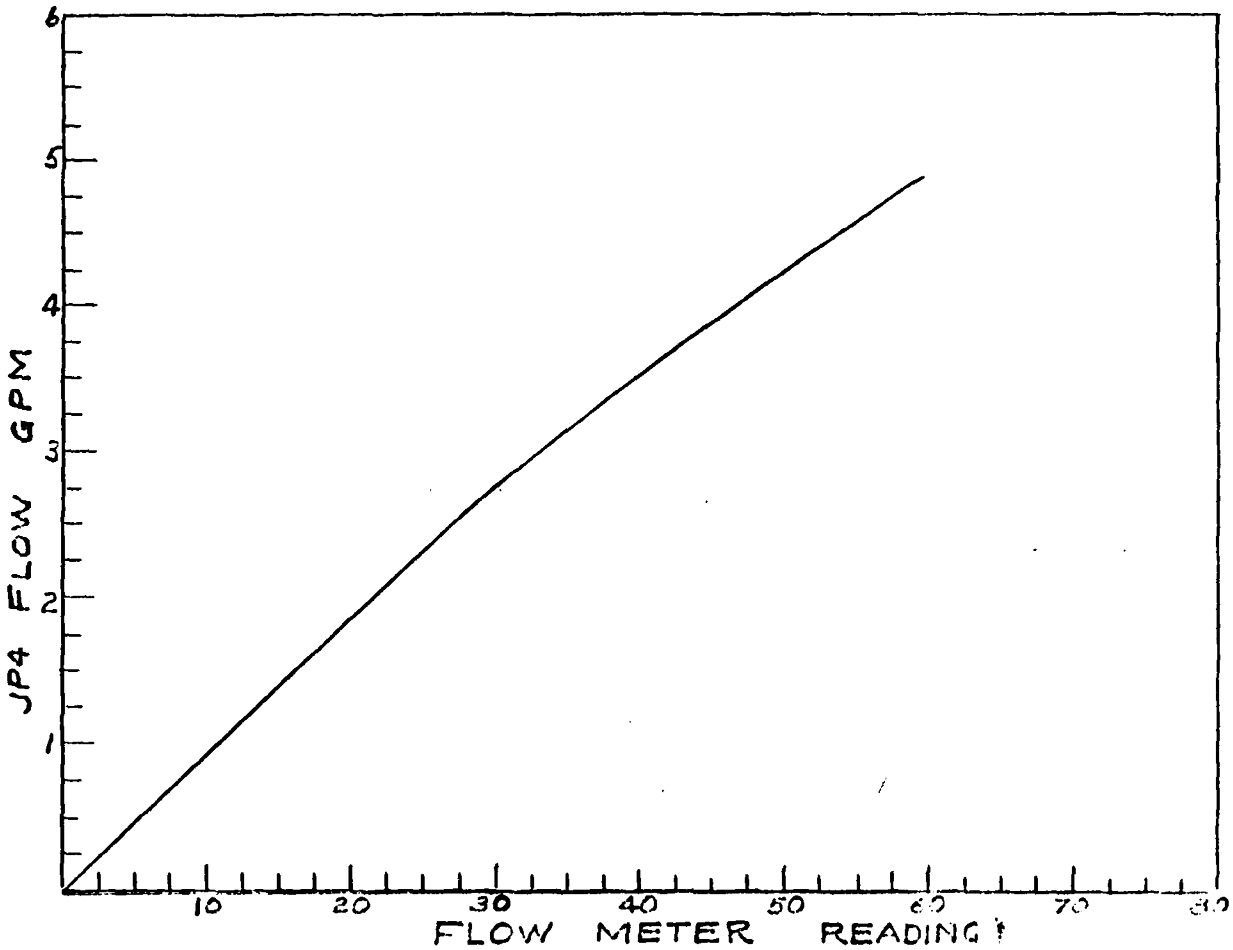


FIG. 9 CALIBRATION CURVE FOR FLOW METERS

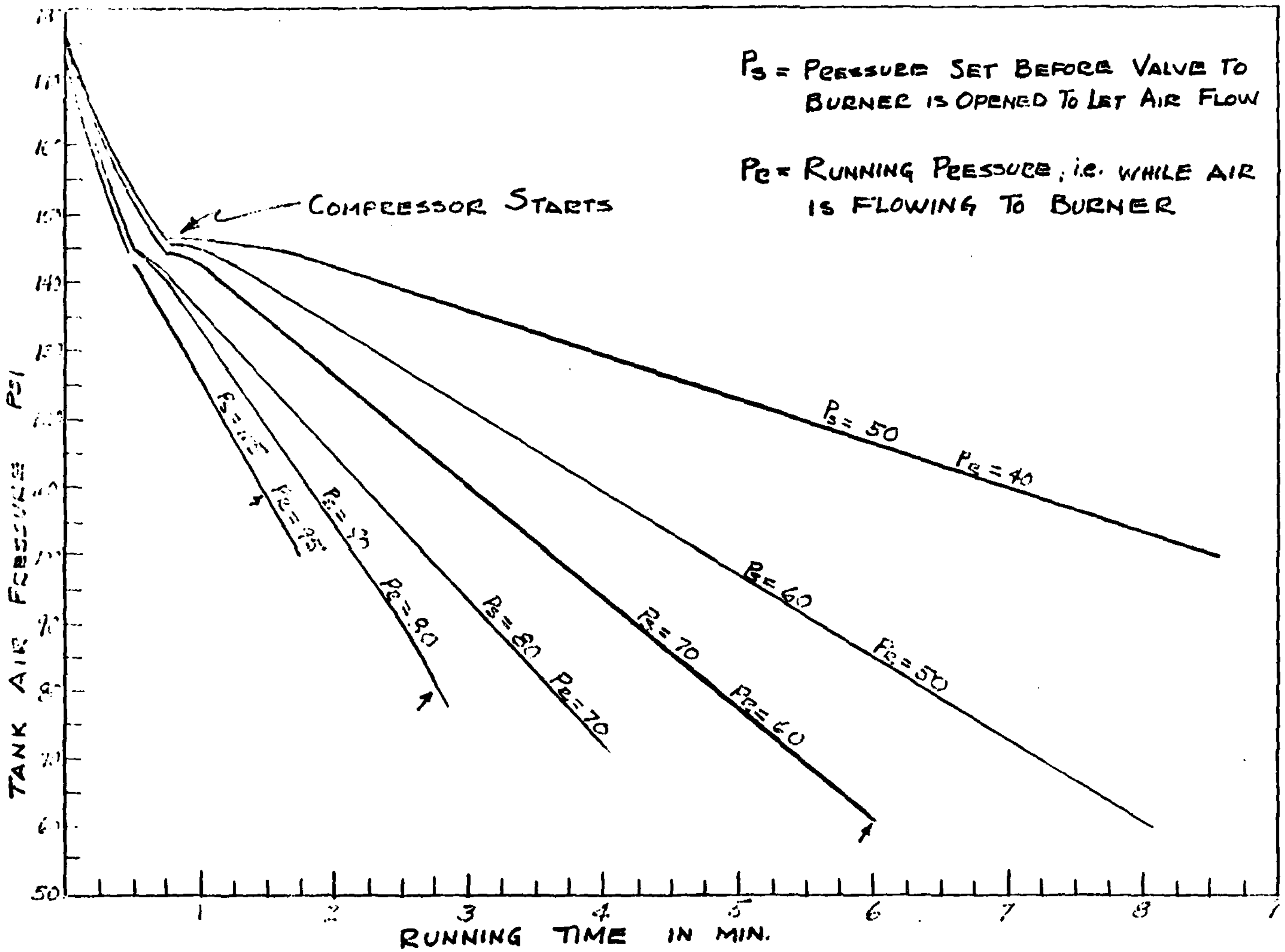


FIG. 10 Tank Air Pressure VS Running Time For Various Burner Air Pressure Settings

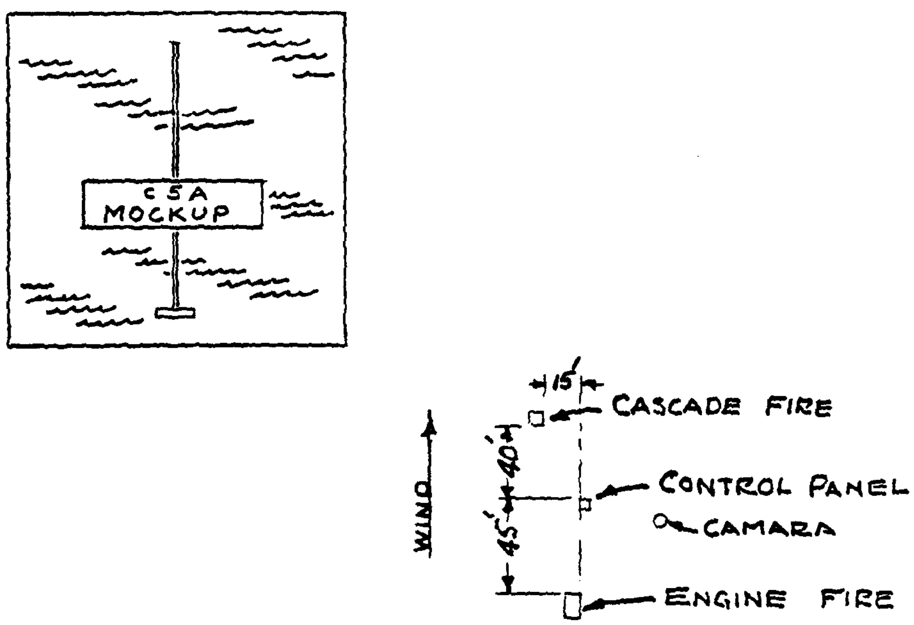


FIG. 11 ARRANGMENT AT NWC CHINA LAKE

Figure 12. Aft View of Low Intensity Engine and Nacelle Fires

(a) Engine Fire at about 1 GPM JP-4

(b) Nacelle Fire at about 1 GPM JP-4.

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EVALUATION OF THE NORTH ISLAND A/C CRASH/RESCUE TRAINING FACILI--ETC(U)
AUG 81 R S ALGER, W H JOHNSON   N00014-80-C-0696
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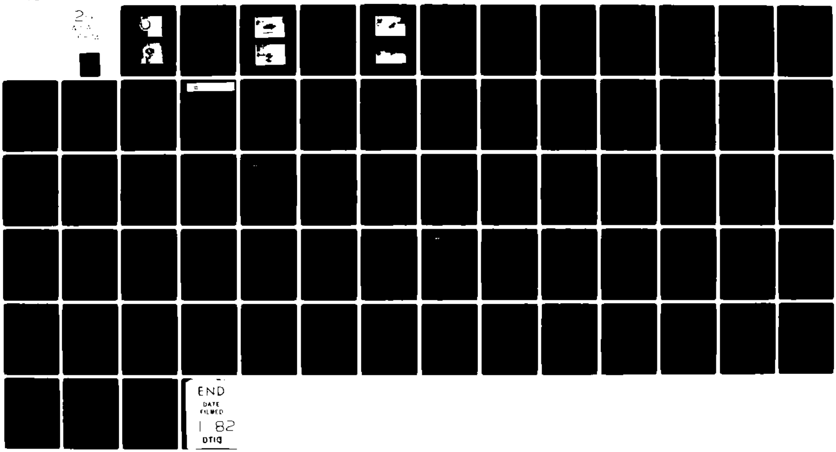

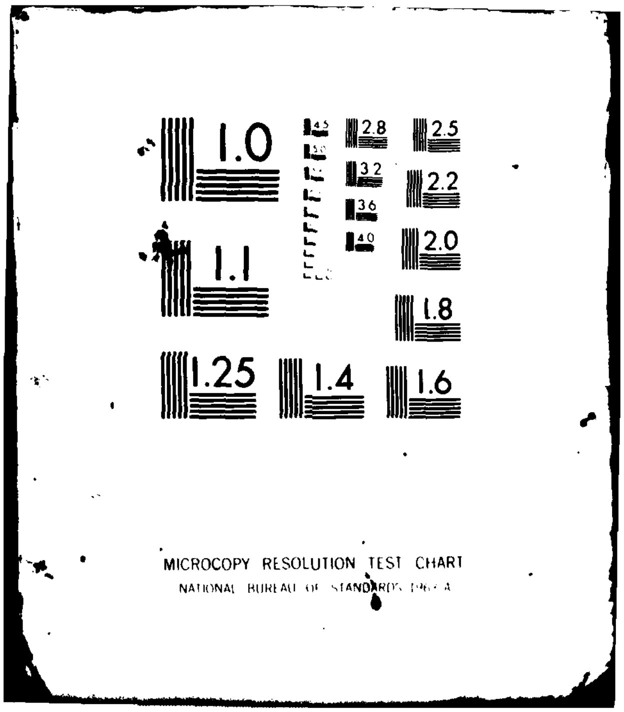
1.0
1.1
1.25
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2.0
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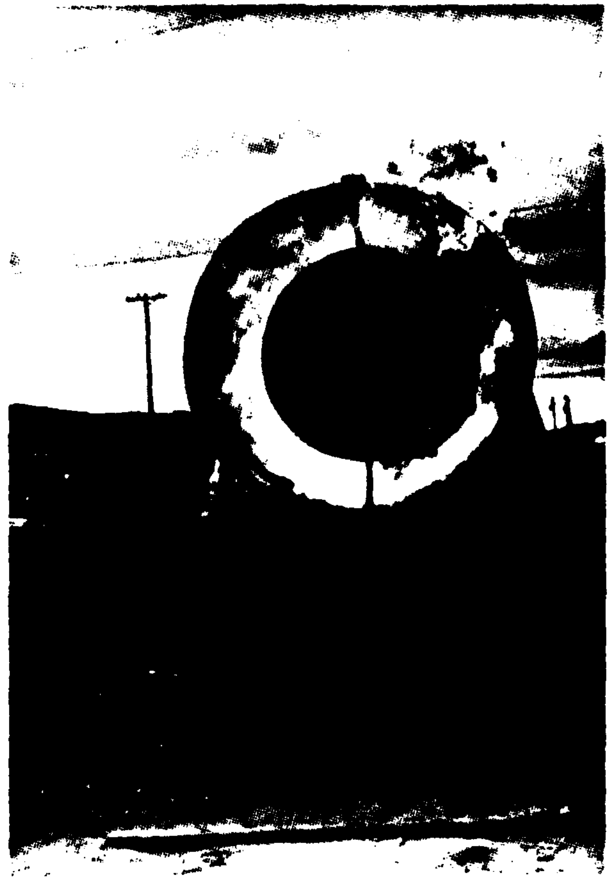
MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963 A

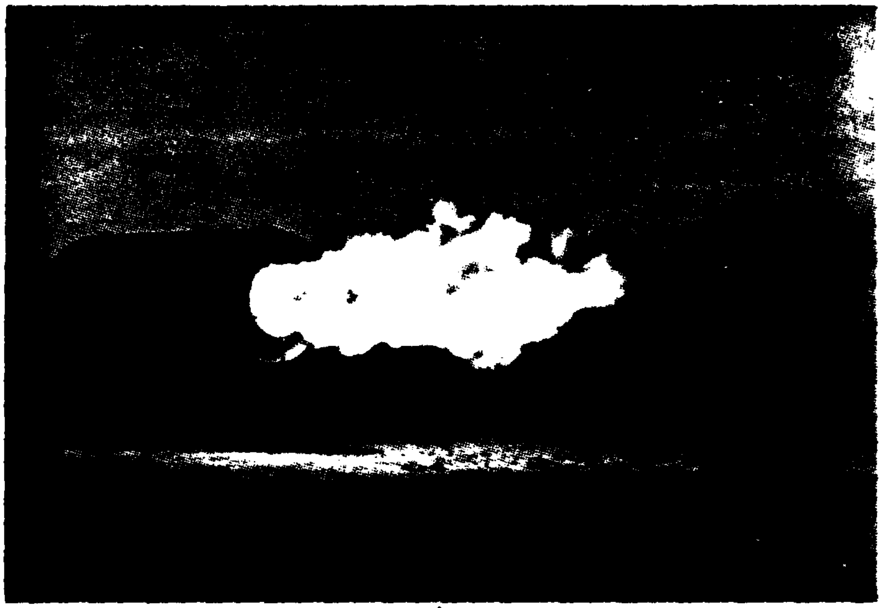
A



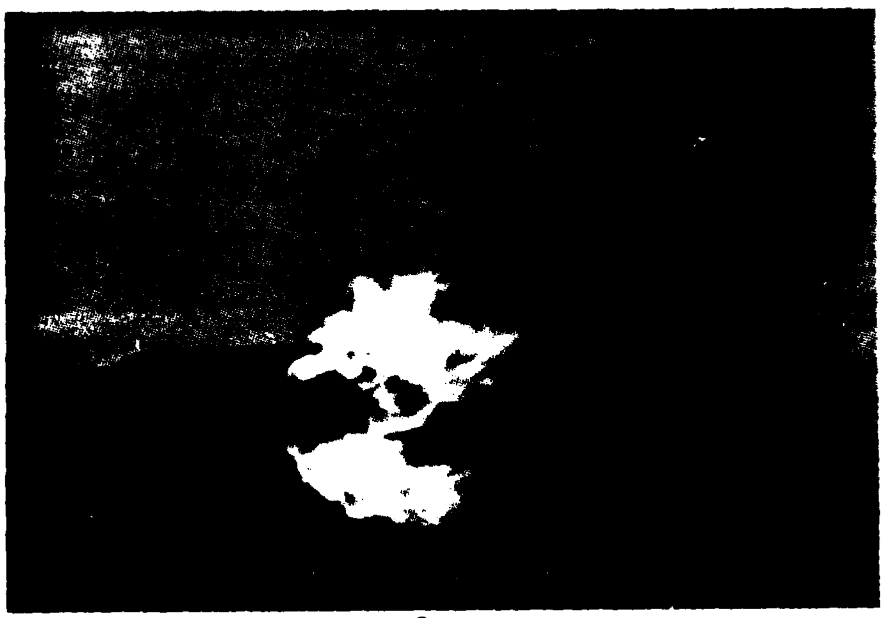
B

Figure 13. View of Simulator Fires from Vicinity of the Control Panel

(a) Engine Fire at about 3 GPM JP-4
(b) Nacelle Fire at about 1½ GPM JP-4



A

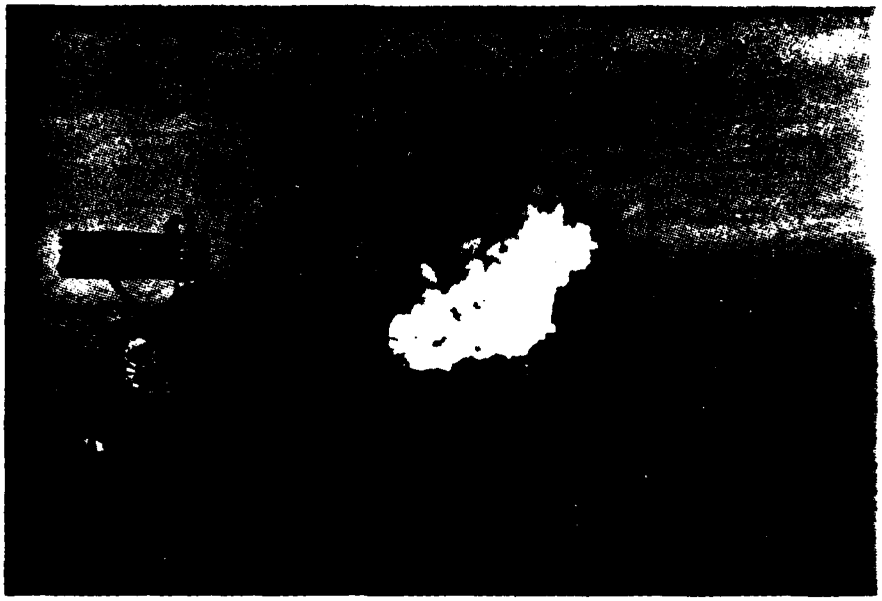


B

Figure 14. Extinguishment Exercises

(a) Firemen Applying CO_2 to Front of Engine with Little Effect on 1 GPM Fire

(b) Fireman Applying CO_2 from Aft End of Engine. The 1 GPM Fire is Suppressed but not Extinguished.



A

B

Operating Instructions for Cascading Fuel Fire and Aircraft Engine Fire Simulators

A. General Principles

These training devices are designed to provide several levels of fire intensity i.e., challenge to the firemen, without appreciable pollution of the atmosphere by the smoke. Fairly complete combustion of the JP4 fuel is achieved through the use of atomizing burners. Atomization is achieved with jets of compressed air; therefore, for every fuel flow rate there is a minimum air flow rate for satisfactory smokeless operation. All of the controls to regulate the air, fuel, and cooling water are mounted in the control panel shown schematically in Figure 1. The air compressor and fuel pump are on the baseplate behind the control panel. Since the air flow rates exceed the continuous operating capacity of the air compressor, two storage tanks are included in the circuit to provide sufficient air for a training exercise. When the air supply is depleted and the regulated pressure (P_r) begins to drop, the fire will become smokey; consequently, the training exercise should be completed while the tank pressure is adequate to maintain P_r at the desired level. Table 1 indicates the approximate operating times available for the various fuel flow rates and their required air pressures.

The two burners in the aircraft engine simulator and two burners on the cascade fuel panel are all separately activated by the four red fuel valves and the four black air valves grouped according to burner designation on the top left and right areas of the control panel. Normally both burners on the cascade panel are operated simultaneously at the same fuel flow rate as indicated in table 1 where the maximum combined fuel flow for smokeless fires is about 3 GPM i.e., 1.5 GPM per nozzel. In the engine simulator each nozzel has a capacity of 3 GPM because it was assumed that most of the training would involve either a central fire or a nacelle fire. If both burners are to be operated simultaneously, the total fuel flow should be limited to about 3 GPM. Fuel flow rates are indicated by the two flow meters and regulated by the needle valves mounted directly below the meters. The left line supplies either the top cascade burner or the engine annulus and the right line supplies either the bottom cascade burner or the central burner in the engine. It is assumed that equal fuel flow rates will be employed when two burners are operating simultaneously; therefore, only one air pressure regulator

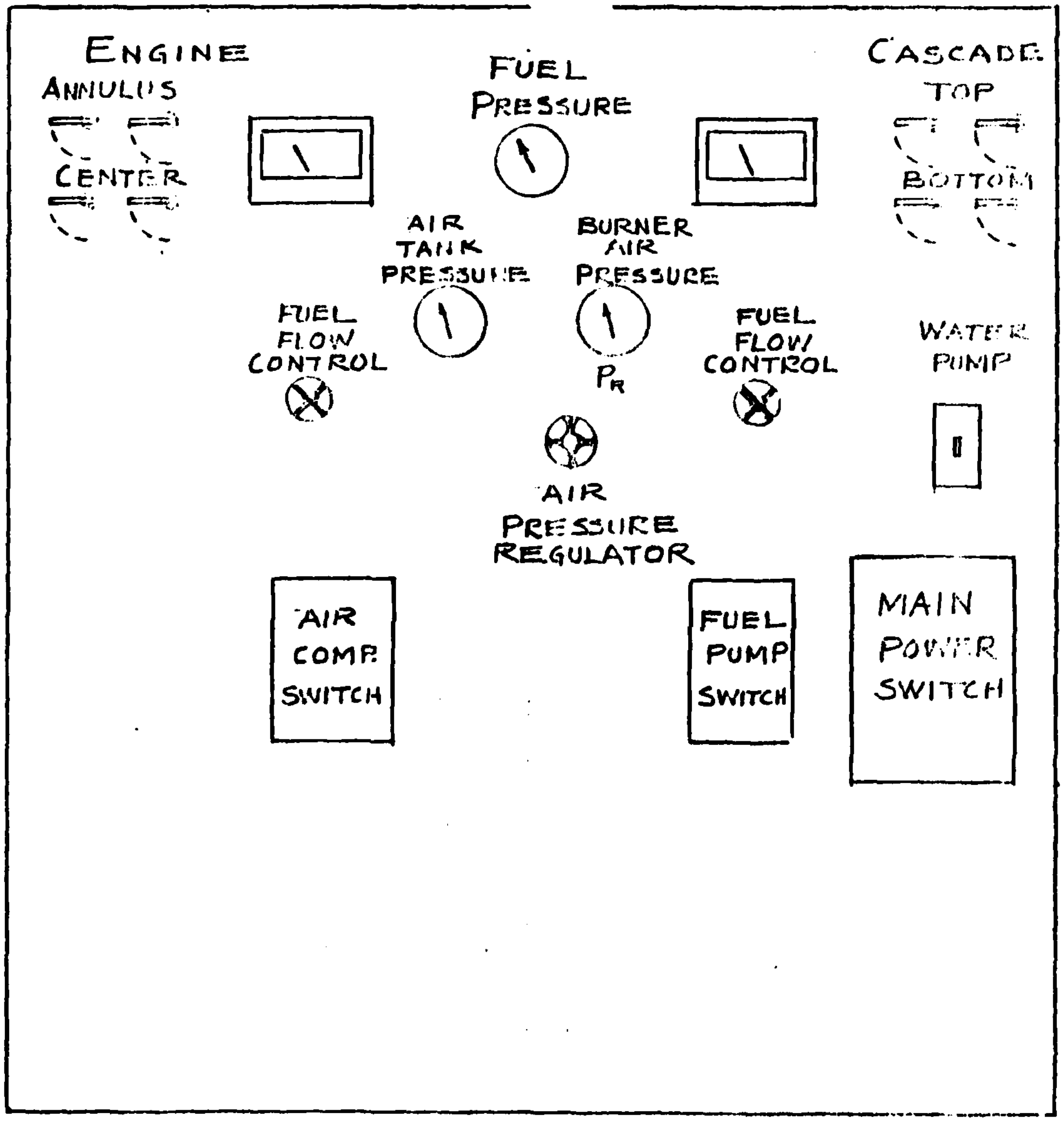


FIG. 1 CONTROL PANEL

Table I

AIR PRESSURES AND OPERATING TIMES
FOR VARIOUS FUEL FLOW RATES

CASCADE FIRE SIMULATOR

Fuel Flow Rate					Burner		Operating Time
Bottom Nozzle		Top Nozzle		Total	Air Pressure		
Meter Reading	GPM	Meter Reading	GPM	GPM	(P_r) PSI	P_r + 10	Min
6.5	1/2	6.5	1/2	1	35	45	> 10
8	3/4	8	3/4	1 1/2	40	50	8
11	1	11	1	2	45	55	5
13 1/2	1 1/4	13 1/3	1 1/4	2 1/2	55	65	2
16	1 1/2	16	1 1/2	3	65	75	1 3/4

ENGINE FIRE SIMULATOR

(Either Annulus or Center Burner)

Fuel Flow Rate		Burner		Operating Time
Meter Reading	GPM	Air Pressure (P_r) PSI	P_r + 10	Min
11	1	35	45	> 10
16	1 1/2	40	50	> 10
21	2	60	70	6
26 1/2	2 1/2	70	80	3 1/2
33	3	95	115	1 3/4

valve is provided. If unequal fuel flows are employed, the regulator should be set to provide a (P_r) appropriate to the larger flow. Two pressure gauges in the center of the panel indicate the tank air pressure (P_t) and the regulated or burner air pressure (P_r) respectively.

Finally the control panel contains four electrical switches i.e., (1) the main power disconnect switch on the fuse box, (2) a starter switch for the fuel pump, (3) a starter switch for the air compressor and (4) a switch for the cooling water circulation pump on the cascade panel.

B. Initial Start up for the Cascade Fire

1. Fill the tank on the base of the cascade panel with cooling water
2. Bleed water from compressed air tanks according to instructions on air compressor.
3. Connect 50 gal drum of JP4 to the control panel fuel inlet. Open valve at drum end of hose and crack drum air vent to allow fuel to flow.
4. Draw off sufficient JP4 to wet ignition torch. For example, use side spigot on hose line.
5. Turn main power switch On.
6. Start cooling water pump and check to insure that water is flowing
7. Start air compressor and run until the compressor shuts itself off at 180 PSI.
8. Ignite ignition torch and hold near bottom burner.
9. Adjust air regulator to a pressure about 10 PSI above the (P_r) listed in Table 1 for the desired fuel flow rate.
10. Open air valve to bottom burner.
11. Start fuel pump.
12. Open fuel valve to bottom burner
13. Adjust fuel flow to desired rate with the needle valve.
14. Remove ignition torch when fuel is burning regularly.
15. Open air valve to top burner.
16. Open fuel valve to top burner.
17. Adjust fuel flow to desired rate.
18. Make minor adjustments in air pressure to maintain P_r throughout run.

C. Temporary Shut Down after Fire is Extinguished or Whenever Desired

1. Close fuel valves to burners
2. Stop fuel pump
3. Close air valves to burners

D. Start up after Temporary Shut Down

1. Follow steps 8 through 18 of initial start up procedure.
2. Note: when successive runs are to be made at the same fuel flow rate, no air regulator or needle valve adjustments are necessary i.e., follow steps 8, 10, 11, 12, 14, 15, 16, and 18.

E. Permanent Shut Down

1. Close both fuel valves to burners
2. Stop fuel pump
3. Close both air valves to burners
4. Stop air compressor
5. Stop cooling water pump
6. Close valve on JP4 tank and set tank upright.
7. Shut off main power.

F. Engine Fire Simulation

1. Fill both tanks of the simulator with water.
2. Bleed water from compressed air tanks according to instructions on air compressor.
3. Connect 50 gal drum of JP4 to the control panel fuel inlet. Open valve at drum end of hose and crack drum air vent to allow fuel to flow.
4. Draw off sufficient JP4 to wet ignition torch, e.g., use side spigot on hose line.
5. Turn main power switch on.
6. Start air compressor and run until the compressor shuts itself off at 180 PSI.
7. Ignite ignition torch and place in the Vee trough next to the burner to be ignited.
   Note: the distances to be inserted are different for the two burners as indicated on the handle.
8. Adjust air regulator to a pressure about 10 PSI above the (P_r) listed in Table 1 in the desired fuel flow rate.
9. Open air valve to burner.
10. Start fuel pump
11. Open fuel valve to burner.
12. Adjust fuel flow to desired rate.
13. Make minor adjustments in air pressure to maintain (P_r) throughout run.

G. Temporary Engine Shutdown same as for cascade i.e., "C".

H. Starting Engine Simulator after Temporary Shut Down

1. Add water to fill tanks
2. Follow steps 6 through 13 under "F."
   Note: When successive runs are to be made of the same fuel flow rate, no air regulator or needle valve adjustments are required.

I. Permanent Engine Simulator Shut Down.

1. Same as for cascade i.e., "E".
2. Drain water jackets in cold weather to prevent damage due to frozen water.

NOMENCLATURE, FIRE TRAINING DEVICES & CONTROLS

	Number Req.	Material	Size	Notes or mfg. identification
I. Control Unit				
10 Control panel assy.				
11 Base skids	3	STEEL	6" x 2"	CHANNELS 5'-6" LONG 1/4" THICK
12 Base sides	2	"	4" x 3"	ANGLES 4' LONG 1/4" THICK
12a Base front and rear	2	"	4" x 3"	" 5'-6" " " "
13 Compressor supports	2	"	4" x 1 3/4"	CHANNELS 3'-11½" " " "
14 Panel frame sides & center	3	"	2" x 2"	ANGLES 5' LONG 1/4" THICK
15 Panel frame top & bottom	2	"	2" x 2"	" 5'-6" LONG " "
16 Frame braces	2	"	2" x 2"	"
17 Panel plate	1	AL	4'-8" x 5'-6"	1/8" PLATE
18 Pipe supports	2	STEEL	4" x 1 3/4"	CHANNELS 16" LONG
19 Base plate	1	"	4' x 5'-6"	1/8" PLATE
20 Compressed air system				
21 Compressor motor	1		7½ h.P.	
22 Compressor	1		16 CFM	SPEEDAIR 37497, DAYTON ELECT CO
23 Compressor tanks	2	STEEL	80 GAL	
24 Tank gauge	1		2 1/2"	0 to 300 PSI
25 Regulator	1	BRONZE	20 to 60 PSI	BAILEY NO 30A
26 Line gauge	1		2 1/2"	0 to 300 PSI
27 Valve to cascade top	1	BRASS	1/2" SPT	BALL VALVE
27a Valve to cascade bot	1	"	1/2" "	" "
28 Valve to nacelle annulus	1	"	1/2" "	" "
28a Valve to nacelle engine	1	"	1/2" "	" "
30 Burner fuel system				
31 Pump motor	1		1 1/2 h.P.	1725 RPM
32 Fuel pump	1			1P781 TEEL
33 Fuel strainer	1	BL. IRON	3/4"	Y-PATTERN SEDIMENT SEPERATOR (CRANE)
34 Line gauge	1		100 PSI	
35 Fuel flow control to 38a & 39a	1	BRASS	3/4" IPS	NEEDLE VALVE
36 Fuel flow control to 38 & 39	1	"	3/4 "	" "
37 Flowmeter to 38a & 39a	1	"		FISCHER & PORTER MODEL 10A2227
37a Flowmeter to 38 & 39	1	"		" " " "
38 Valve to cascade top	1	"	1/2" IPS	BALL VALVE
38a Valve to cascade bot	1	"	" "	" "
39 Valve to nacelle annulus	1	"	" "	" "
39a Valve to nacelle engine	1	"	" "	" "
40 Electric system				
41 Main breaker & switch	1			
42 Fuel pump switch	1		NEMA SIZE 1	CUTTER HAMMER A10CR0B W/
43 Compressor switch	1		" "	" " " W/H10 44
44 Cascade coolant pump switch	1		20 AMP	CIRCUIT BREAKER SWITCH

NOMENCLATURE, FIRE TRAINING DEVICES & CONTROLS

I I	Number Req	Material	Size	Notes or mfg. I.D.
II. Aircraft Engine Fire Simulator				
10. Stand				
11. Bases	4	STEEL	1/2" x 1' x 1'	
12. Legs	4	BL IRON	2 1/2"	STD BLK. IRON PIPE
13. Lateral brace	2	" "	"	" " " "
14. Longitudinal brace	1	" "	"	" " " "
15. Cradle	2	" "	3"	STD. CHANNEL
16. Battens	4	" "	"	" "
20. Nacelle tank assy				
21. Outer tube	1	1/16" STEEL	60" OD	1" WATER SPACE BETWEEN WALLS
22. Inner tube	1	1/16 "	57 3/4 I.D	1" " " " "
23. Coolant pipe nipple	4	BL. IRON	3/4 NPT	
24.				
25. Filler pipe	2	BL. IRON	3" NPT	
26. Tank ends	2	1/16 STEEL	59 7/8 OD	57 [illegible]" I.D.
27. Yoke	2	BL. IRON	2 1/2	STD PIPE
27a Yoke stem	2	" "	"	" "
28. Spacers	6	" "		
29. Annular ring	1	1/16 IRON	57 3/8" OD	36" I.D. 1/16 THICK
30. Inspection hole assy				
31. Frame	1	STEEL	1" x 1"	ANGLES 1/8" THICK
32. Outer cover plate	1	1/16 STEEL	17 3/4 x 17 3/4	1/16 THICK
33. Inner cover plate	1	1/16 "	" "	
34. Cover edges	4	1/16 "	13/16 WIDE	
35. Dog bolt	4	STEEL		
36. Dog bolt spring	4	SPRING STEEL		
37. Dog	4	STEEL		
38. Dog bolt nut	4	"	1/4-20	
39. Dog bolt sleeve	4	"	3/4 O.D 9/16 I.D.	
40. Engine tank assy.				
41. Outer tube	1	1/16 STEEL	36" O.D.	
42. Inner tube	1	1/16 "	33 3/4 O.D.	
43. Coolant pipe nipples	4	BL. IRON	3/4 NPT	
44. Turbine blades	2	1/16 AL	33 5/8 O.D.	16 SLOTS 10" DIA HUB
45. Tubine sleeve	2	AL		
46. Support cage hoop	3	3/4 PIPE	33 5/8 O.D.	
47. Support cage stringers	3	STEEL	1" x 1"	ANGLE 1/8" THICK
48. Engine tank ends	2	1/16 STEEL	35 [illegible] I.D.	33 [illegible]" I.D.
49.				
50. Burner assys	NATIONAL AIROIL BURNER PARTS FOR 2-4 GPM JP4 AT 60 PSI			
51. Support plate, annulus	1	1/8 STEEL		
52. Igniter guide trough	1	1/16 "	1 1/2 x 1 1/2	ANGLE
53. Burner pipes, coaxial			1" & 3/8"	
54. Burner tip, CONE FLAME TIP	1	STEEL	NO 3	#226-3 CONE FLAME TIP 14 HOLES AT 40°
55. Burner body	4	"	" "	2110-3 OUTER TIP
56. Burner core	4	"	" "	2051-3A CORE 5/16 ORIFICE
57. Burner tee	2	"		
58. Burner tee bushing	2	"		
59. Burner street ell	2	"		
54 B Burner tip, FLAT FLAME TIP	1	"	NO 3	224-3 L-3

NOMENCLATURE, FIRE TRAINING DEVICES & CONTROLS

	Number Req.	Material	Size	Notes or Mfg. I.D.
II. Aircraft Engine Fire Simulator, cont.				
60. Tank Manifold Assy.				
61. Elbow		Galv. Iron	3/4	
62. Union		" "	"	
63. Tee		" "	"	
64. Nipple		" "	"	
65. Plugged nipple		" "	"	
66. Nipple		" "	"	
67. Drain valve		" "	"	
68. False Cross		" "	1"	
69. Hose nipples		" "	1/2"	To Cu Tubing.
III. Cascade Unit				
10. Structure				
11. Base skids	3	Bl. Iron	3" NPT	
12. Frame sides	2	Steel	1½ x 1½	Angle 1/4" thick 60" long
13. Frame front & back	2	"	" "	" " " 48" "
14. Backing plate	1	Galv. Steel	4' x 8'	14 Ga.
15. Coolant reservoir	1	" "		14 "
16. Reservoir cover	1	" "	4' x 5'	14 "
17. dam				
18. Bottom burner bracket				
19. Sump pump cover				
20. Coolant/fuel plumbing assy				
21. Brace pipe	2	Galv Iron	3/4	
22. Pipe nipples		" "	3/4	
23. Brace nipples		" "	3/4	
24. Long nipples		" "	3/4	
25. Short nipples		" "	3/4	Blocked
26. Unions		" "	3/4	
27. Tees		" "	3/4	Thds. Bored Out in St. Sec.
28. Elbows		" "	3/4	
29. Reducers		" "	1" to 1/2"	Cu Tubing
30. Cascade assy				
31. Pin pipes	4	Galv Iron	3/4"	
32. pins	28	CR Rod	1/4"	
33. Shingles	8	Bl. Iron	14" x 18"	Left
34. "	8	" "	19" x 18"	Center
35. "	8	" "	14" x 18"	Right
40. Burner Assys				
41. Burner	2	Steel	No 3	224-3 W
42.				
43.				
44.				
45.				
50. Electric System				
51. Sump pump	1	Bronze		Model 1P798A Teel
52. Power cord				

Appendix C

STANFORD RESEARCH INSTITUTE
Menlo Park, California 94025 · U.S.A.

Enclosure 1

Title: FUSELAGE FIRE TRAINER FOR ENVIRONMENTALLY COMPATIBLE AIRCRAFT CRASH AND RESCUE TRAINING FACILITY

I OBJECTIVES: (1) To evaluate alternative approaches to fuselage fire training; e.g.,

- Real fires in a real aircraft fuselage
- Real fires in a simulated aircraft environment
- Simulated fires in a real aircraft fuselage
- Simulated fires in a simulated aircraft environment.

(2) Develop yardsticks and procedures for measuring fireman performance and proficiency in fuselage fire training.

(3) Develop specifications and construction plans for a training device that is environmentally compatible and suitable for the following training activities.

- Regular and forcible entry practice
- Exercise in the use of protective clothing and OBAs or air packs during rescue and firefighting operations.
- Practice in safetying the various aircraft systems, e.g., engines, O_2, electrical, etc.
- Extinguishing practice on class A fires from inside and outside the compartment.
- Rescue operations involving people and equipment

III BACKGROUND INFORMATION: Figure 1 from Reference 1 illustrates the modest aircraft fire training facility currently under consideration for installation where the smoke from traditional training fires is incompatible with clean air requirements. The proposed facility contains fire training devices, (1) a water spray pool fire, (2) a cold fire pit, (3) a cascade fire simulator, (4) an engine fire simulator, and (5) a fuselage fire trainer. Prototypes of (1), (3), and (4) have been constructed and examined for effectiveness as training devices operating under conditions where the levels of atmospheric pollution are acceptable. Since the cold fire pit does not generate pollution and the principle has been practiced in simplified form, a prototype is probably not necessary. However, several basic questions remain to be answered regarding the fuselage fire trainer before specifications and design drawings can be prepared. These questions deal with the importance of realism in fireman training and the resulting impact on performance. At one extreme, real fires would be initiated in a real aircraft fuselage and at the other, both the aircraft and the fire would be simulated. Several factors make it desirable to determine whether an adequate proficiency can be developed under complete or partial simulation. First, the procurement and delivery of aircraft fuselages to all training sites promises to be an expensive operation. Second, only antiquated aircraft are available; consequently, considerable departure from modern aircraft realism is inherent, particularly, with respect to shutdown and safetying procedures. Third, considerable modification and insulation of the aluminum fuselage will be required to prevent damage and destruction under real test fires.

Finally, the fully simulated system would have a shorter turn around time than real fires; consequently, the opportunity for more evolutions and practice time may compensate for the loss of realism. Since opinion is divided on the reliability of simulation, a test is in order to establish the merits of simulation versus the real fires. Such tests should be performed at a station such as China Lake where smoke can be tolerated and the training devices can be evaluated without the additional cost and complication of incorporating a complete smoke abatement system in the test set up.

IV PLANS:

Phase 1. Design of test procedures and apparatus. As indicated in the approach, this phase embraces three steps:

- Establish the training evolutions required to insure an adequate proficiency in all of the categories listed under objective 3. Assuming the B-29 fuselage shown in Figure 2 is employed, safetying practice would be conducted in the forward pressurized cabin (41), rescue operations and extinguishment practice could take place in both the forward and aft cabins (41 and 44A), and forcible entry could be practiced either in these spaces or in the non-pressurized adjoining areas e.g., 42 and 44B. Various approaches will be considered ranging from simple one step operations, i.e., practicing one activity at a time, to the more problem orientated exercises where all 5 activities are combined in a single evolution. In all cases, the procedures will be compatible with the new NATOPS manual for fire training.
- Develop procedures and yardsticks to evaluate the performance and proficiency of the trainees. Ideally, these yardsticks should be self evident and objective so that a fireman could evaluate his own performance. Parameters such as the time to perform the various steps in an evolution and the amount of agent expended are likely candidates for yardsticks.

- Design the test apparatus. Figure 3 shows the schematic concept of the fuselage fire trainer as described in Reference 1. Normal entry procedures use the regular aircraft opening (Item 1). Forcible entry with cutting tools is practiced on replaceable panels (2) bolted onto the fuselage at prescribed entry points. These panels can be sections cut from other salvage aircraft parts or sheets of metal. Additional experience and agility with the cutting tools can be obtained by using the tools to prepare the supply of panels. Similarly replaceable patches (3) are available for practice with penetrating applicators. Smoke abatement and air control during the ventilated burns depend on the exhaust fan (4) the air inlet damper (5) and the chevron baffeled scrubber (6). Also, the fan can be used at reduced speed in the sealed aircraft exercise after entry has been achieved to provide a slight inflow through the opening to carry the smoke to the scrubber. A supply of movable obstacles, i.e., passengers (simulated with mannequins) in seats (7) or cargo (8) permit rescue training and fire fighting with impediments in the way. Empty O_2 bottles (9) and electrical batteries (10) are included for safetying practice. Finally comes the fire (11) and its products, heat (12) and smoke (13). Several locations in the fuselage are selected as burn areas (11) and a good insulation such as Kaowool, Fiberflax or possibly mineral wool is applied to the adjacent interior regions of the fuselage to prevent damage to the aluminum. A thin steel or stainless steel covering over the insulation prevents mechanical and H_2O damage. Water sprinklers (15) at each burn site provide control of the burning rate in order to force the heat buildup to approach the planned heating curve. When necessary the sprinklers can also control or extinguish the fire. After each training exercise, the hot, smokey air exhausts through the scrubber (14) to remove smoke and pyrolysis products.

When the fire environment is simulated, the flames for suppression are provided by a NTEC type computer controlled burner (16). Smoke could be provided either with a smoke bomb (17) or a neutral density filter in the firefighter's face mask. If additional heat is required to simulate the thermal insult, it could be provided by a regulated gas burner (18).

The equipment envisioned for the China Lake tests would include the features outlined above except for the scrubber. As indicated previously, the scrubber question would be deferred until the optimum degree of simulation had been determined. Figures 1 and 5 show layouts of the B-29 forward and aft cabins to be modified for the tests. Both the real and simulated fire pits would be movable modulus that could be relocated either in the B-29 or in the fireproof simulated fuselage. The choice of materials for the simulated fuselage will be based primarily on the relative costs of metal versus concrete block construction.

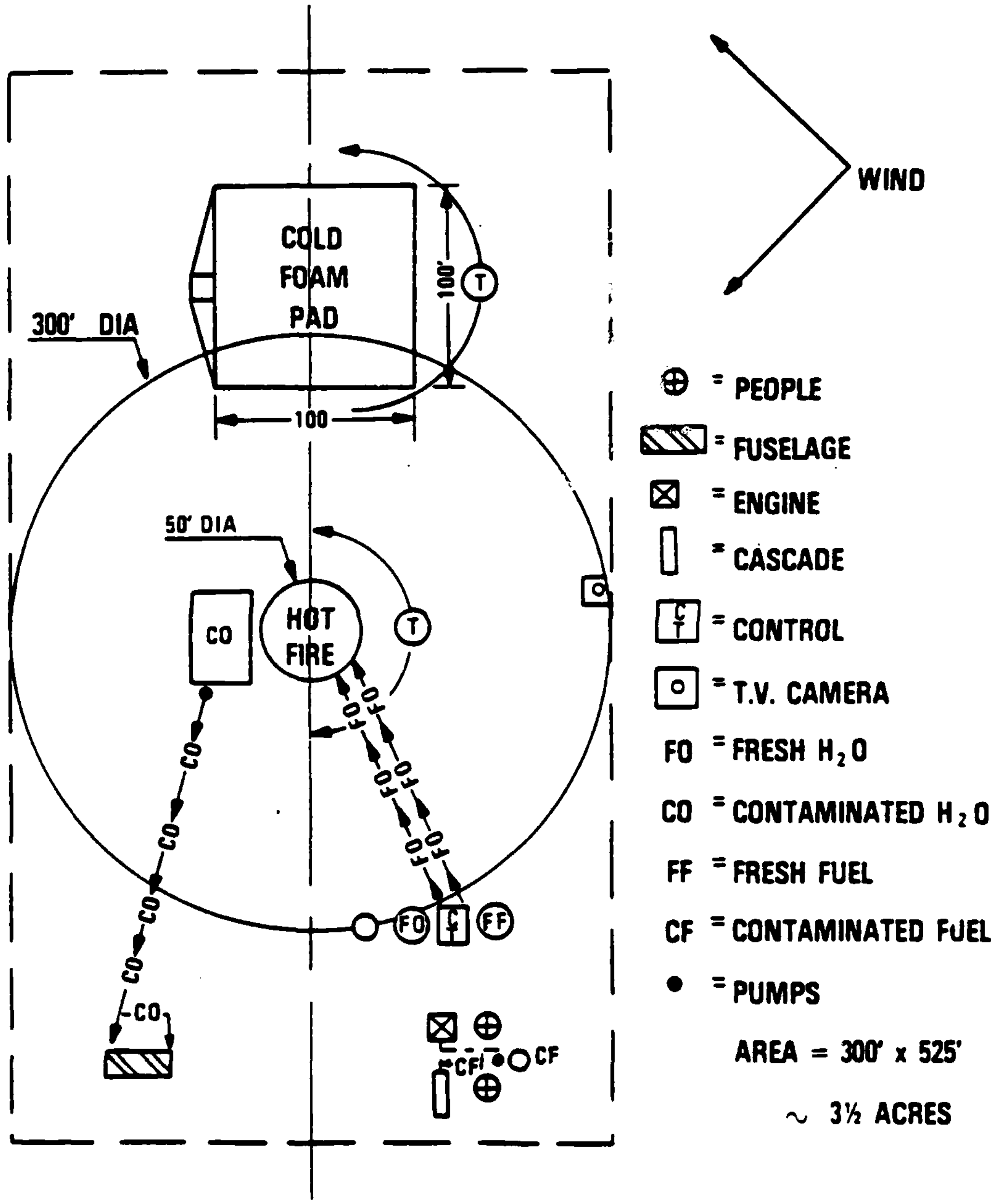
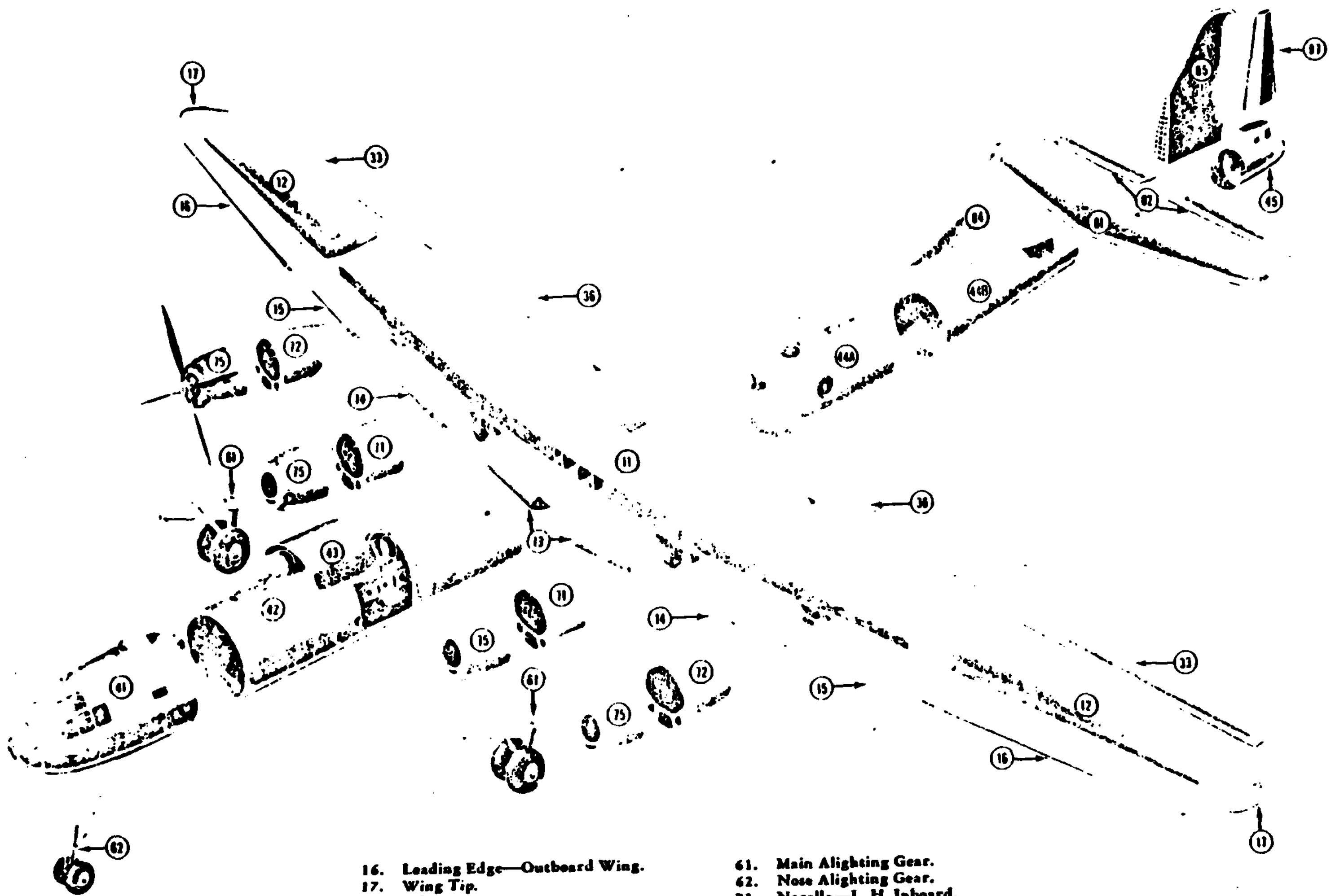


FIG. 1 MODEST FACILITY



11. Inboard Wing.
12. Outboard Wing.
13. Leading Edge—Inboard Wing.
14. Leading Edge—Inboard Wing.
15. Leading Edge—Inboard Wing.
16. Leading Edge—Outboard Wing.
17. Wing Tip.
33. Aileron.
36. Flap.
41. Fuselage—Forward Pressurized Cabin.
42. Fuselage—Bomb Bay.
43. Fuselage—Wing Gap Enclosure.
44A. Fuselage—Aft Pressurized Cabin.
44B. Fuselage—Non-Pressurized.
45. Fuselage—Tail Gunner's Enclosure.
61. Main Alighting Gear.
62. Nose Alighting Gear.
71. Nacelle—L. H. Inboard.
71. Nacelle—R. H. Inboard.
72. Nacelle—L. H. Outboard.
72. Nacelle—R. H. Outboard.
75. Engine—L. H. Inboard.
75. Engine—R. H. Inboard.
75. Engine—L. H. Outboard.
75. Engine—R. H. Outboard.
81. Stabilizer.
82. Elevator.
84. Dorsal Fin.
85. Vertical Fin.
87. Rudder.

Figure 2 -Major Assembly Breakdown (Exploded View)

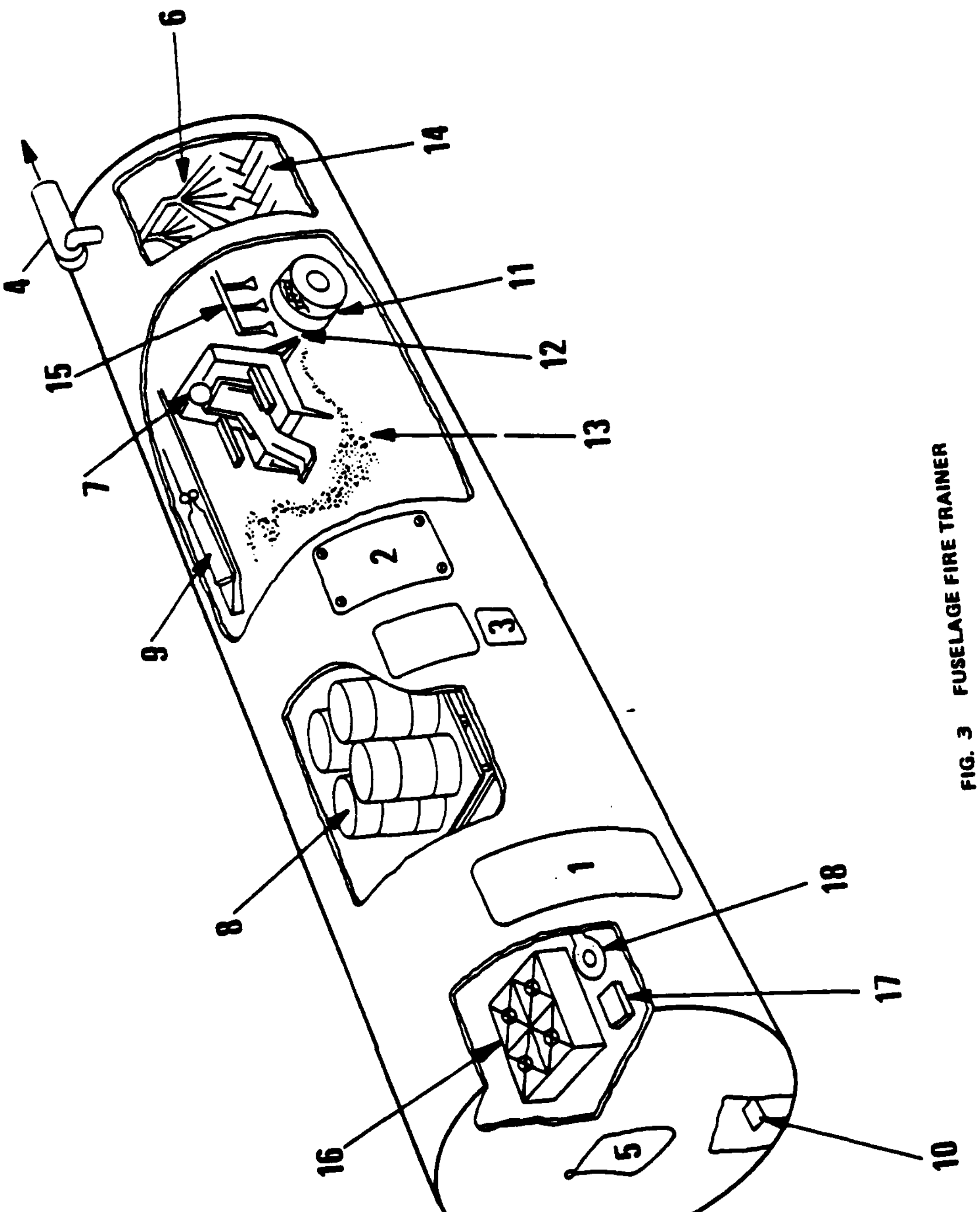
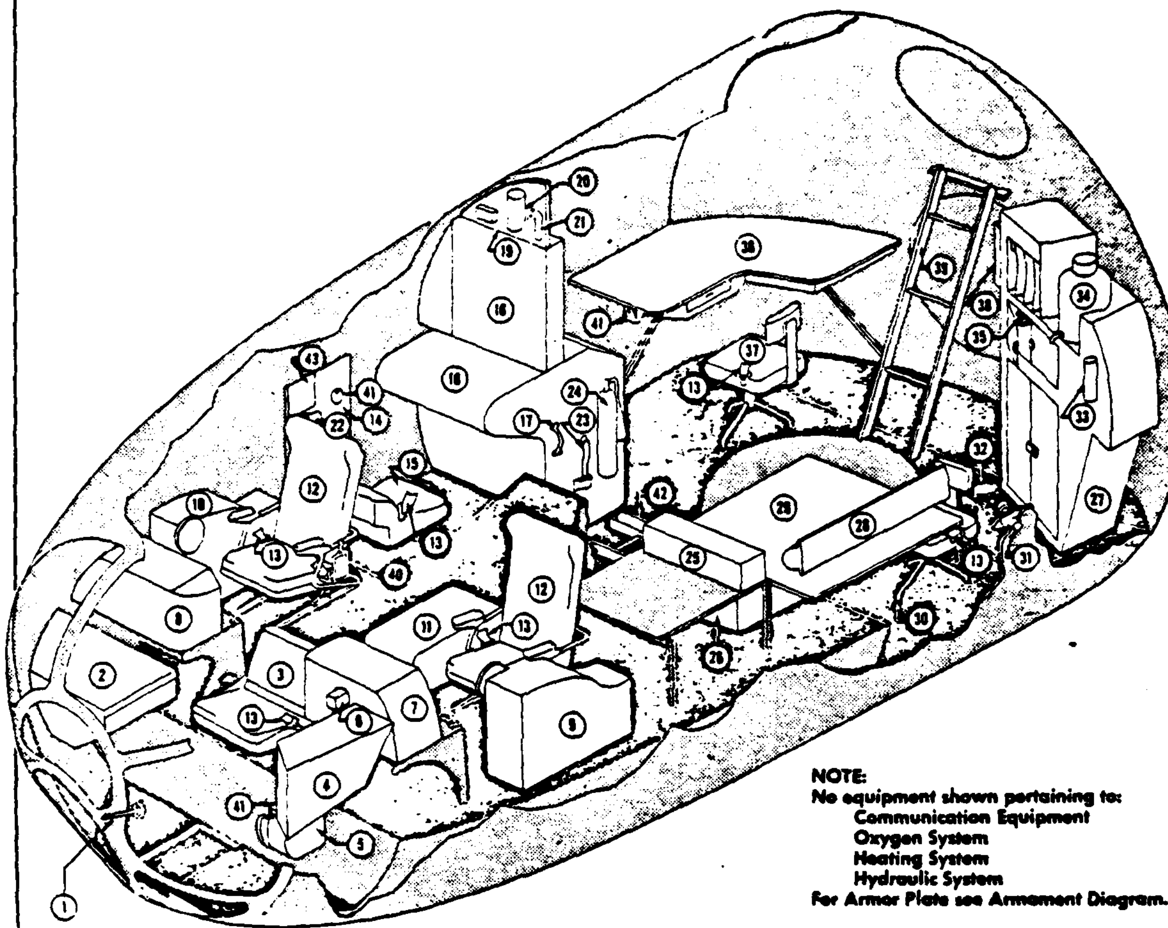


FIG. 3 FUSELAGE FIRE TRAINER



LEGEND

1. Bombardier's Thermometer Inst.
2. Bombardier's Panel Inst.
3. Bombardier's Seat Inst.
4. Bombardier's [illegible] Inst.
5. Bombardier's Control Stand
6. Intervalometer
7. Pilot's Instrument Panel Assy.
8. Copilot's Instrument Panel Assy.
9. Pilot's Stand Assy.
10. Copilot's Stand Assy.
11. Pilots' Aisle Stand
12. Pilot's and Copilot's Seat Assy.
13. Safety Belt (Type B-11)
14. Engineer's Equip. Panel Inst.
15. Engineer's Seat Assy.
16. Engineer's Instr. Board Inst.
17. Engineer's Stand Assist Handle
18. Engineer's Control Stand
19. Auxiliary Equip. Panel Assy.
20. First Aid Kit Assy.
21. Flashlight (Eveready)
22. Clip Board
23. Hand Axe
24. Fire Extinguisher
25. Navigator's Panel Inst.
26. Drift Signal Cabinet Inst.
27. Navigator's Cabinet Inst.
28. Navigator's Map Case
29. Navigator's Table Inst.
30. Navigator's Seat Assy.
31. Drift Recorder Inst.
32. Drift Signal Chute Inst.
33. Paper Cup Dispenser
34. Water Jug (Type III)
35. Sextant
36. Radio Operator's Table Inst.
37. Radio Operator's Seat Inst.
38. Waste Cup Receptacle
39. Front Tunnel Ladder Inst.
40. Check List and Holder
41. Ash Tray
42. Forward Entrance Ladder (Stowed)
43. Fuel System Diagram

Figure 4 -Fuselage Furnishings Diagrams

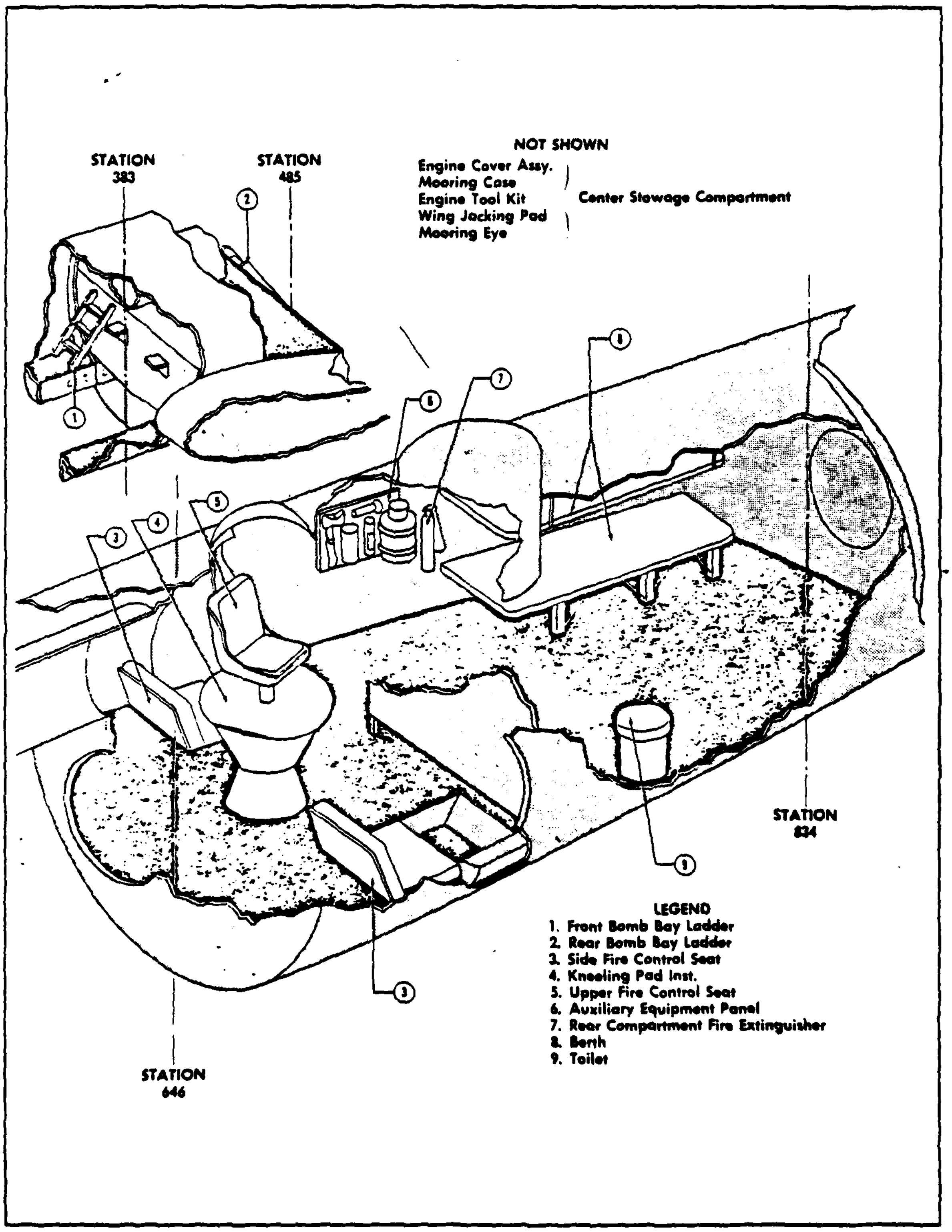


Figure 5 -Fuselage Furnishings Diagrams

Appendix D

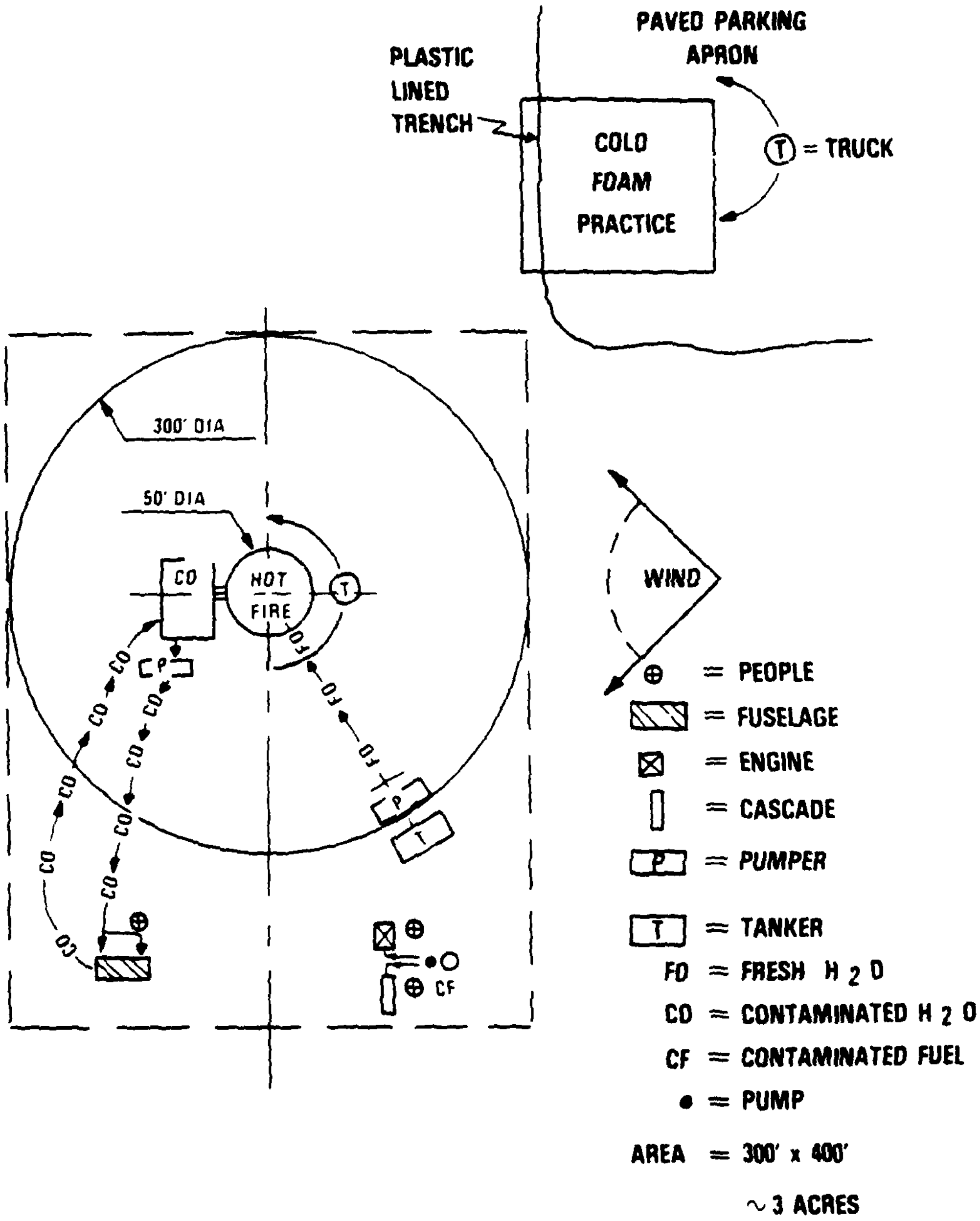


FIG. 7.1 SPARTAN FACILITY

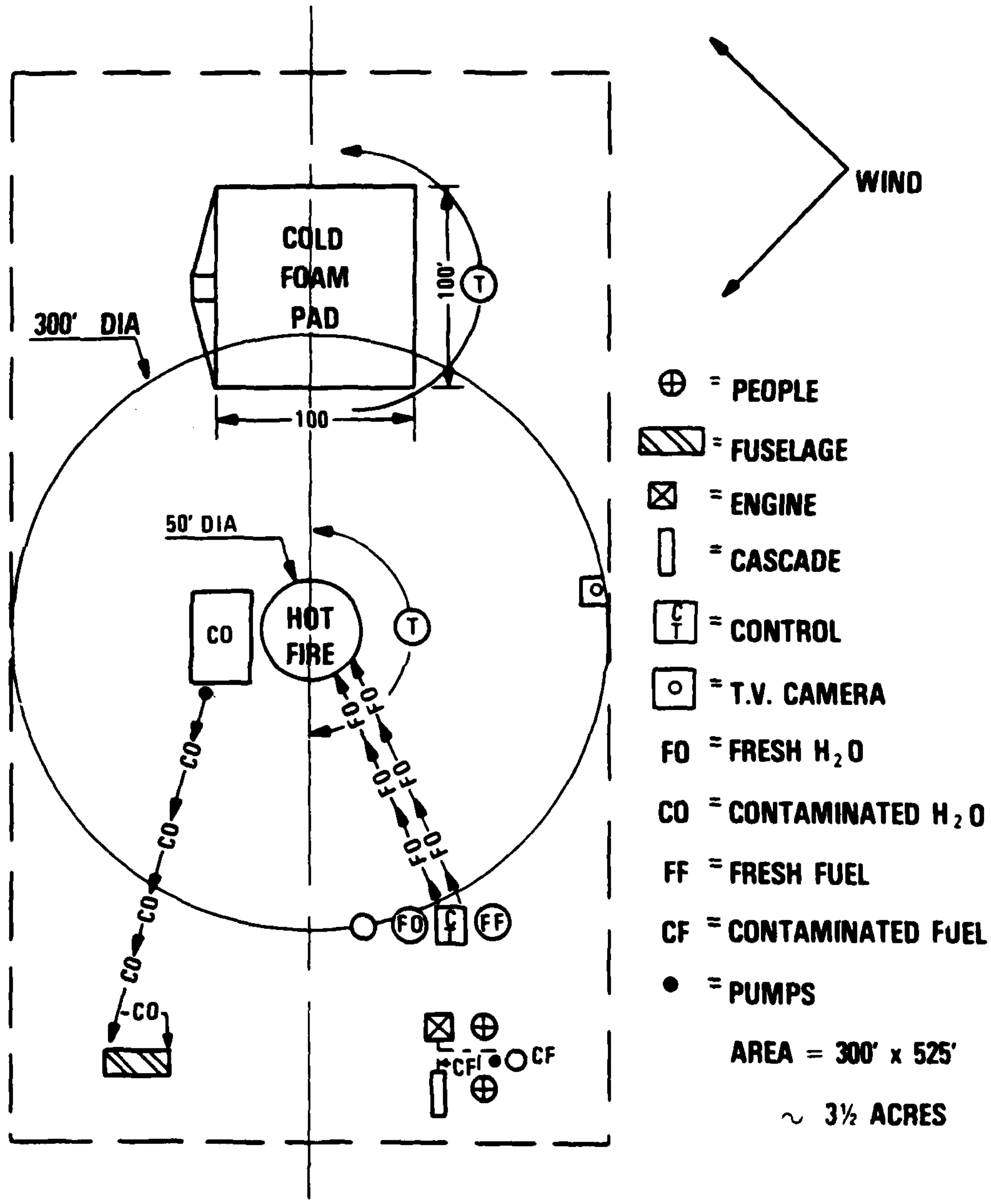


FIG. 7.2 MODEST FACILITY

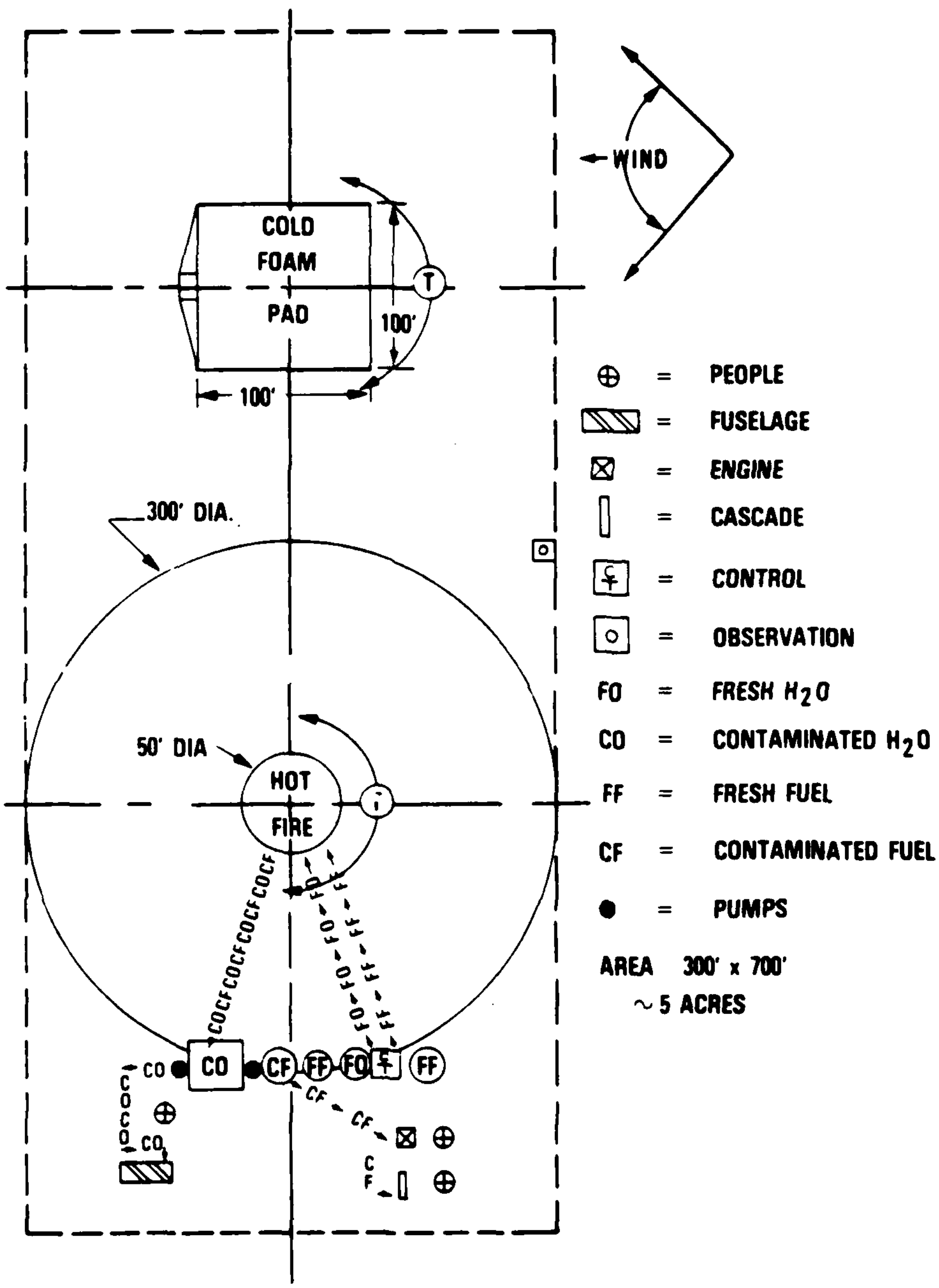


FIG. 7.3 SOPHISTICATED FACILITY

Appendix E

SRI International

MEMO

TO	Steve Hurley NAVFAC Code 032	DATE	August 22, 1980
FROM	R. S. Alger	LOCATION	108
SUBJECT	Proposed Test Plan for Evaluation of North Island A/C Crash/Rescue Training Facility	CC	

Ref. 1. Technical Report NAUTRAFQUIPEN 74-C-0152-1
2. NAVFAC Memo 10F/JMM 27 Feb. 1980

1.0 OBJECTIVES

1.1 Determine Facility Performance (Primary Objectives)

- Does the facility satisfy the clean air and water requirements?
  - with gasoline fires
  - with JP-4 fires
- Is the fire real enough? i.e., is the simulation of an unabated fire adequate?
- Is the fire big enough? Does the fire provide sufficient challenge for the new generation of fire trucks with their higher pumping rates or is the fire overwhelmed so that differences in operator proficiency cannot be detected?
- Is the fire reproducible enough? i.e., can the fire be used for quantitative measurements of fireman performance?

1.2 Secondary Objectives

- Develop some training recommendations for use of the facility, e.g., training procedures and frequency.
- If the answers to the questions in 1.1 are affirmative, determine some yardsticks for evaluating firemen performance.

2.0 APPROACH

2.1 Test Variables

- Parameters that control the test fire characteristics
  - Fuel
  - Operation of the smoke abatement water spray system
  - Mockup

SRI 2903 2/78

- Suppression equipment, i.e.,
  - Type of crash and rescue vehicle
  - Pumping rate
- Firemen experience
  - New recruits
  - Journeymen
- Training ritual
  - Initial base performance fire . . . . final test fire

    Initial base performance fire + cold pit training + final test fire

    Cold pit training . . . . + final test fire

2.2 Choice of Fuel and Smoke Abatement Procedure

Some of the competing factors in the choice of fuel for the fire in the A/C crash/rescue training facility are

- Ability to meet the environmental constraints
- Adequate simulation of anticipated fires
- Cost
- Availability

In the laboratory tests at IITRI (see Reference 1) flame heights and burning times were measured for automative gasoline (MoGas) JP-4, JP-5, and mixtures of JP-5 + gasoline. The results indicated that gasoline and JP-4 were suitable candidate fuels for fuel levels within ½ of the top of the rock substrate; how ever, the water spray reduced the JP-5 and JP-5 + gasoline flame heights to unacceptable levels. An abated gasoline fire had flame heights comparable to a natural JP-5 fire; therefore, gasoline was the preferred fuel with JP-4 second. It should be noted that extinguishment behavior was not included in this recommendation.

JP-4 was used for the prototype work at Chanute AFB. These tests involved extinguishment with AFFF applied primarily with hand lines. Some flashbacks occurred and to a great extent, these occurrences depended on the operator of the water sprays. Apparently such spray fires can be more difficult to extinguish than the corresponding natural fire; however, agent application densities were not reported in Reference 1.

In the initial tests of the North Island facility, aviation gasoline was used as the fuel because JP-4 is no longer stocked at the stations. Flashbacks were so severe, the fires could not be extinguished when the smoke abatement sprays were operating, i.e., the water was secured and some smoke occurred during the final stages of extinguishment. Since only a few tests were performed and the operators did not become familiar with the flexibility provided by the spray water zone control system, Avgas cannot be excluded as a suitable fuel but additional tests will be required to settle the fuel question. The fuel or fuels selected should be extinguishable with the facility operating in the smoke abatement mode. In the proposed test schedule, first priority is given to facility operation and fuel selection.

Figures 1, 2, and 3 indicate several decision tree variations of the tests required to answer the fuel questions. Figure 1 for gasoline starts with all the fire suppression variables optimized for extinguishment, i.e., journeymen firemen maximum application rate for the AFFF and securing the spray water zones as extinguishment progresses. Only the presence of the mockup raises this test above the minimum challenge. If this fire cannot be extinguished with a reasonable amount of AFFF (e.g., twice the AFFF required for an unabated fire) the simulation is not realistic and another fuel should be tried. If extinguishment is successful testing should proceed along the indicated paths until the possibilities with mogas as the fuel have been determined. Based on the limited experience with Avgas at North Island, it is expected that paths a, b, or c will materialize so 6 to 9 tests are anticipated; nevertheless, we should be prepared with enough fuel and agent for 12 tests.

Figure 2 shows the same tree for JP-4; however, the Chanute tests suggest path (d) could develop. Therefore, Figure 3 shows the tree rearranged to reach the decision point sooner if path (d) is correct. Probably 6 tests will be sufficient to answer the fuel question for JP-4. Altogether, 12 to 24 fires are anticipated to answer the first and second objectives as well as shed some light on whether the fire is big enough.

Fuel cost and availability are secondary concerns. JP-4 and Mogas are comparable in price while Avgas is a bit more expensive. e.g., according to the Defense-Fuel regions on August 19, JP-4 was $1.18 per gal versus Avgas at $1.40 per gal in tank truck lots. JP-4 is available in Norwalk.

2.3 Fire Reproducibility and Secondary Objectives. The questions of reproducibility and quantitative yardsticks to measure fireman performance are intimately linked together because the yardsticks have no meaning unless the fires are essentially identical. A very important uncertainty is the effect of the spray water zone control operator on the fire characteristics and the effectiveness of the foam application. Presumably the operator influence can be minimized if the water spray zone controls can be held constant throughout the burn, otherwise, we must strive for a very uniform pattern for adjusting these controls during suppression. The following set of tests should satisfy the reproducibility and secondary objective tests.

No. of Teams	Types of Teams	Routine	Fires/Team Assuming 2 Application Rates	Number of Fires
4	2 Journeymen 2 Recruits	Base Fire . . . . . . Test Fire	4	16
4	2 Journeymen 2 Recruits	Base Fire . Cold pit . Test Fire	4	16
4	2 Journeymen 2 Recruits	Cold pit . . . . . . Test	2	8
				40

A minimum of 40 tests or 2 tanks of JP-4 (or mogas if it is acceptable) would be required in addition to the tests in Section 2.2 i.e., about 3 tanks for JP-4. Additional information about training recommendations and procedures could be compiled with additional tests. If fuel is acquired by the tank i.e., 3000 gal, about 15 tests could be run per tank assuming 200 gal of fuel per test.

2.4 Engine Fire Simulator and Cascade Fire Tests

Two considerations make it desirable to conduct these tests at North Island. First, these training devices are supposed to burn the waste fuel from the pool fire simulator. The fuel water separator, waste fuel storage tank and fuel pump to supply the fuel to these devices are in place. Also, electricity is available at the test site although not at the proper voltage. Of course, the reclaimed fuel can be returned to the pool fire simulator so exercising the periferal training devices according to the original design mode is not an overriding consideration, however, the waste fuel system should be tested and made to work. In the preliminary efforts to date, satisfactory fuel separation was not achieved and the waste fuel tank filled with water.

Second, the SRI International contract includes only two weeks of testing in the field; therefore, it would be most efficient to conduct the engine and cascade fire tests concurrently with the pool fire tests. The inital proposal assumed consultation and some observation of the pool fire tests, now more active participation appears desirable; therefore, the necessity for concentrating the tests even at the expense of some inconvenience to NWC China Lake.

Since the engine fire simulator was developed, the Navy has become interested in the use of Halon 1211 for extinguishing such fires. After consultations with NAVMAT Code 00F1. it appears desirable to include some Halon 1211 tests in this series; therefore, about half of the extinguishments planned For CO_2 will be converted to Halon 1211, i.e., about 54 tests.

2.5 Utilization of the P-17 CFR/Vehicle

Reference 2 states that the P-17 should be used in evaluating the pool fire facility. If the P-17 trucks become available in time, they can be used for the higher pumping rate extinguishments; however, the tests should not be delayed appreciably for lack of a P-17.

2.6 Test Schedule

Initiation of the test program depends on the availability of fuel and extinguishing agents to be supplied by NAVFAC Code 032 directly to North Island. Since FY 81 funds will be used for this purpose, the tests cannot begin before October. A tentative suggestion is as follows:

- Week of October 19th conduct the burns outlined in Figures 1, 2, 3 and commence the baseline fire tests of Section 2.3.
- October 26 through November 29 complete baseline fuel tests and cold pit training.
- Week of November 30 commence post training fire tests.

3.0 *EVALUATION*

3.1 Evaluate environmental impact of facility operation for both gasoline and JP-4 fires.

- The air and environmental support office will monitor and evaluate the air pollution performance of each training device.
- NAVFAC Port Hueneme will monitor and evaluate the waste water handling operation.

3.2 Evaluate the fire challenge and reproducibility by comparison with agent application concentrations required in past tests with unabated fires.

3.3 Evaluate potential to quantitatively measure firemen proficiency.

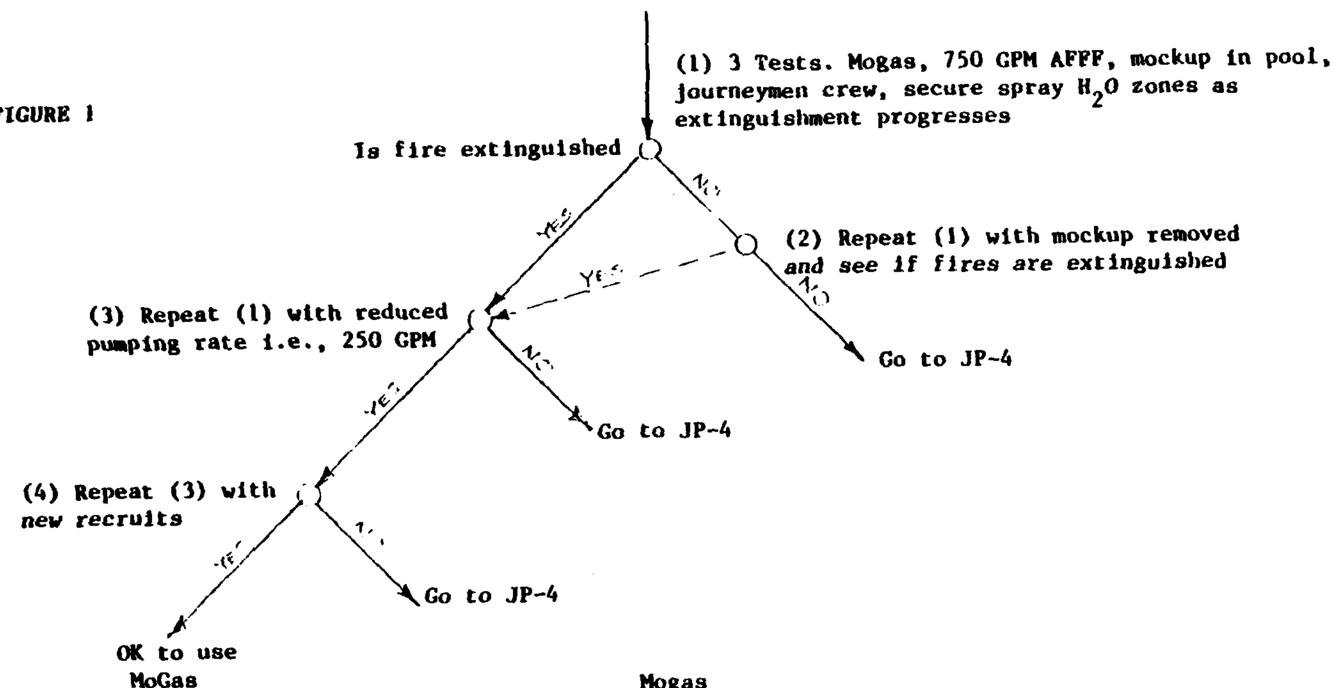
- Compare initial and final performance of individual teams for improvement due to training.
- Compare new recruits and journeymen for yardsticks.
- Look for effects of pumping rate on the challenge presented by the fire and the potential for measuring proficiency.
- Look at effect of training ritual.

3.4 Comments on this proposed test plan are solicited.

Copies to:

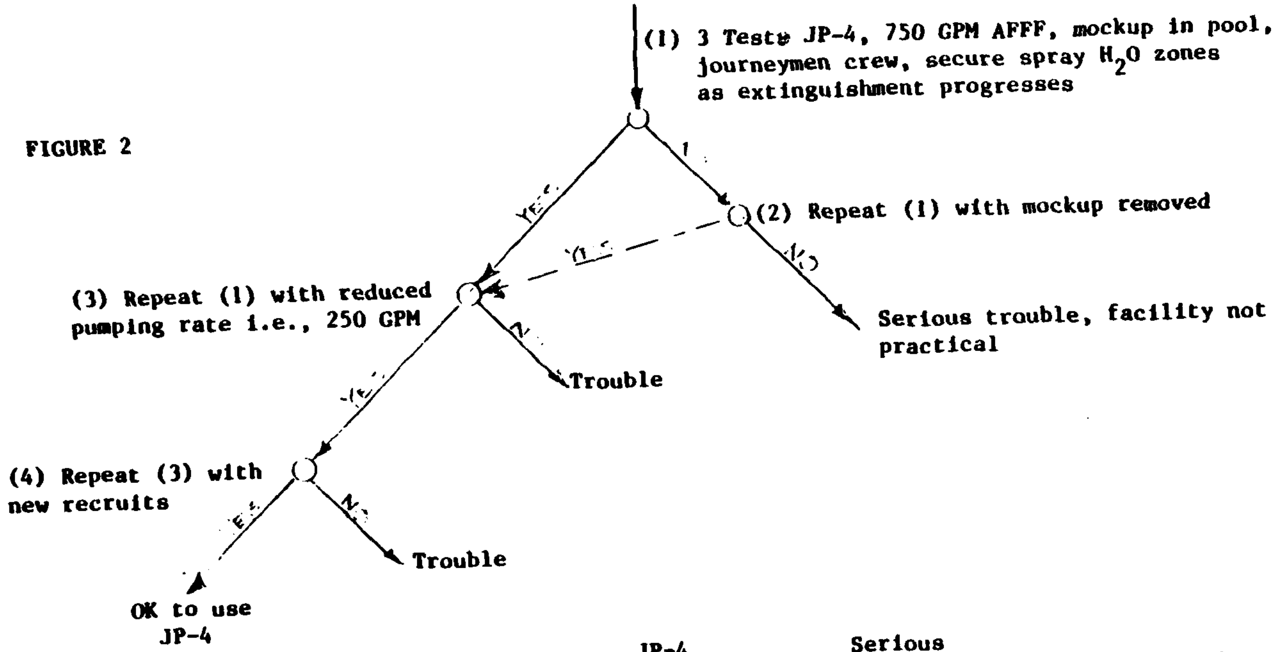
Bob Darwin NAVMAT 00F1
Fire Chief Winters NAS North Island
Fire Chief O'Lauglin NWC China Lake Code 242
John Krimmel AESO North Island
Charley Imel CEL Port Hueneme

FIGURE 1



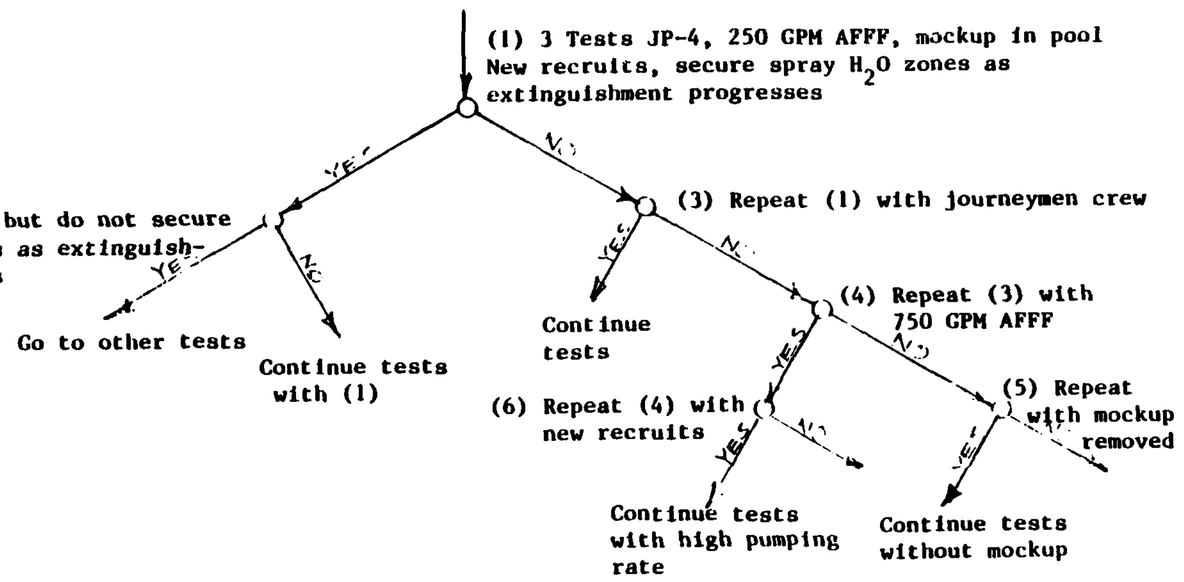
Possible Paths	Mogas OK	Go to JP-4	No of Fires	
(a)....(1) No to (2) No		x	(6)	1200 gal
(b)....(1) Yes to (3) No		x	(6)	1200 gal
(c)....(1) Yes to (3) Yes to (4) No		x	(9)	1800 gal
(d)....(1) Yes to (3) Yes to (4) Yes	x		(9)	1800 gal
(e)....(1) No to (2) Yes to (3') No		x	(9)	1800 gal
(f)....(1) No to (2) Yes to (3') Yes to (4') No		x	(12)	2400 gal
(g)....(1) No to (2) Yes to (3') Yes to (4') Yes	x		(12)	2400 gal

FIGURE 2



Possible Paths	JP-4 OK	Serious Trouble	No of Fires
(a)....(1) No to (2) No		x	6
(b)....(1) Yes to (3) No		x	6
(c)....(1) Yes to (3) Yes to (4) No		x	9
(d)....(1) Yes to (3) Yes to (4) Yes	x		9
(e)....(1) No to (2) Yes to (3') No		x	9
(f)....(1) No to (2) Yes to (3') Yes to (4) No		x	12
(g)....(1) No to (2) Yes to (3') Yes to (4) Yes	x		12

FIGURE 3



Possible Paths	JP-4 OK for Tests	JP-4 Marginally Successful	Serious Trouble	No. of Fires
(a)....(1) Yes to (2) Yes	x			6
(b)....(1) Yes to (2) No	x			6
(c)....(1) No to (3) Yes		x		6
(d)....(1) No to (3) No to (4) Yes		x		
(e)....(1) No to (3) No to (4) No to (5) Yes		x		
(f)....(1) No to (3) No to (4) No to (5) No			x	
(g)....(1) No to (3) No to (4) Yes to (6) Yes		x		
(h)....(1) No to (3) No to (4) Yes to (6) No			x	

MEMO

TO Steve Hurley
Via Fire Chief Kenneth Winters NAS North Island

DATE 10-10-80

FROM R. S. Alger

LOCATION 108

SUBJECT Division of Responsibilities for the North Island A/C Crash/Rescue Training Facility Tests

CC

Ref: A. SRI Memo of 22 August 1980 to Steve Hurley NAVFAC Code 032
B. October 2, 1980 Phone Call NFAC 032 to SRI

1. Reference (A) sets forth a proposed test plan to evaluate the North Island A/C Crash/Rescue Training facility. Reference (B) explained plans to implement the tests and requested a memorandum of understanding to establish responsibilities for the various aspects of the test program. The following paragraphs set forth these responsibilities.

2. SRI International R. S. Alger (415) 326-6200 X 2827

- Pre test planning
  - Provide descriptions of the number and types of tests
  - Develop operating procedures to insure the required data is obtained.
  - Provide measuring equipment and data sheets.
- Test activities
  - Instruct firemen in the operation of the training facility particularly the engine fire and cascade fire simulators.
  - Oversee data aquisition including both measured quantities and photography
  - Analyze test results and modify procedures where necessary.
- Post test
  - Complete the analysis of the test results
  - Prepare the final report.

NAS-North Island Fire Chief Kenneth Winters (714) 437-5600

- Pre test preparation
  - Procure fire suppression agents, i.e., AFFF, CO_2, PKP, and Halon 1211
  - Procure fuel both gasoline and JP-4
  - Procure application equipment i.e., foam trucks and portable extinquishers.

- Move engine fire, and cascade fire simulators from China Lake to North Island and provide electrical power to these simulators.
- Select fire fighting teams and facility operators
- Set the test schedule
- Authorize observers or visitors to the tests.

- Test activities
  - Take command of the tests, all tests are performed by firemen operating within the normal chain of command.
  - Regulate the operation of the facility to insure the safety of both personnel and equipment.

3. Participants or activities that should be kept informed of the test plans and progress.

• Steve Hurley NFAC Code 032	(202) 325-9044
• Bob Darwin N MAT Code 00F1	(202) 692-9130
• Larry Michalec NAS N.I Code 64240	(714) 437-6564
• Charley Imel NAVFAC Port Hueneme	(805) 982-4173
• Donald Lydy NASN.I. Code 183	(714) 437-7716
• Chief O'Laughlin NWC	(714) 939-2146
• Chief Andy Wise Miramar	(714) 271-3114
• E. J. Jablonski NRL Code 6180	(202) 767-2262
• Hank Kimbel A&E	(714) 638-7901

OPERATING PROCEDURE - NONFREEZING ENVIRONMENT

1. Steady State Conditions During Period of Idleness

   (a) Main H_2O control valve is closed

   (b) Water piping drain valves are closed

   (c) Fuel piping drain valve is closed

   (d) Trench discharge at curb is closed (sluice gate)

   (e) Drain valve from weir tank is closed

   (f) Water supply valve to fresh H_2O storage tank is closed

   (g) Fuel supply valve is closed

   (h) Trainer contains water to some artitrary level depending on evaporation loss.

2. Preparation for First Test of the Day

   (a) Check fuel supply to insure a minimum of 200 gal for each test contemplated that day

   (b) Check water levels

      - Open supply valve to fresh H_2O storage tank and check operation of float valve

      - Water level in trainer should be up to the weir - if not, add water from waste water tank if available or fresh water if necessary

      - Measure water level in truck

   (c) Measure AFFF in truck

   (d) Check fuel ignitor system

   (e) Instruct test team i.e., truck operators, trainer operator, data takers, etc.

      - Truck operators - when to start attack and when to stop, i.e., from trial runs establish when truck should start moving in so agent can be applied at end of 30 sec preburn. Limit concentrate to 10 gal per test.

      - Trainer operator - spray zone ritual

      - Data takers - timing and recording.

3. The First Test

   (a) Open trench discharge at curb (sluice gate)

   (b) Start water pump

   (c) Open main water control valve

   (d) Adjust zone valves to desired pressures

   (e) Set fuel monitor to deliver fuel e.g., 200 gal

   (f) Turn on fuel ignitor

   (g) Start fuel pump

   (h) Open fuel supply valve and deliver the fuel

   (i) Shut off ignitor

   (j) Close fuel supply valve

   (k) Shut off fuel pump

   (l) Allow 30 sec preburn - adjust spray nozzles, if necessary for smoke control

   (m) Attack fire with truck in accordance with 2e

   (n) Terminate attack when allotted agent is consumed or fire is extinguished - if not extinguished let fuel burn itself out while minimizing spray water.

   (o) After burn close main H_2O control valve and shut off water pump.

   (p) Fill in data sheet

4. Second and Subsequent Burns

   (a) Close trench discharge at curb. (sluice gate)

   (b) Apply water to trainer from waste watertank until fuel and foam overflow curb

   (c) Use water hose if necessary to flush foam over curb

   (d) Shut waste water supply valve

   (e) Open trench discharge at curb and wait until weir stops overflowing

   (f) Repeat steps in 3.

5. Shut Down after Last Burn

   (a) Repeat steps 4a through 4e.

A/C FIRE RESCUE TRAINING FACILITY
DATA SHEET

Test No. ______________

Date ______________

Team

- Driver ______________
- Monitor ______________
- Hand lines ______________

Facility Operators

- Training Officer ______________
- Zone Control ______________

Fuel

- Type ______________
- Amount ______________

Fire

- Ignition time ______________
- Preburn time ________ sec
- 90% control time ________ sec
- Extinguishment time ____ sec

Agent

- Type ______________
- Amount in tank at start ______ gal
- Amount in tank at finish ______ gal
- Water in tank at start ______ gal
- Water in tank at finish ______ gal
- Nominal concentration ______ %

Remarks:

Weather

- Wind velocity ______________
- Wind direction ______________
- Temperature ______________

Application equipment

- Vehicle ______________
- Monitor type ______________
- Pumping rate ____________ GPM
- Application time ______ sec
- Application pattern

Zone Control Pressure Settings

Time Sec	Zone 1 PSI	Zone 2 PSI	Zone 3 PSI	Zone 4 PSI	Zone 5 PSI

INITIAL CALIBRATION OF SPRAY WATER CONTROL SYSTEM

OBJECTIVES

- Determine valve and pressure settings for uniform spray pattern
- Calibrate spray rate versus pressure readings and valve settings
- Establish operating procedures e.g., when to use the main control valve and when to use the five zone control valves.

PROCEDURES to be performed during initial fill of training pit.

A. Check spray valve performance

(1) Open fresh water supply valve and fill fresh water storage tank.

(2) Close weir tank drain valve, water piping drain valves, and fuel piping drain valves.

(3) Start water pump

(4) Completely open main control valve and five zone control valves.

(5) Adjust the zone control valves to make all five pressures equal.

(6) Reduce water flow with master valve and record the zone pressures as a function of master valve position

(7) Stop water pump

(8) Compare readings and decide if pressure control is adequate or if trimming with zone control valves is required.

B. Calibrate spray rate and determine spray pattern uniformity.

(1) Position sampling pans as shown in Figure 1

(2) Set zone control valves at position found in A5

(3) Close master valve and start water pump

(4) Open master valve for one minute, check and record pressure readings for the five zones; then stop water pump

(5) Measure water collected in sampling pans = W lb/ft^2

(6) Compare for uniformity - allowing for any wind effects.

(7) Estimate required pressure to get average rate of 2/3 lb/ft^2 i.e., $P = \frac{P_o \times 2/3}{W}$

(8) Set desired pressures for uniformity and rate by repeating part of A4, A5, A6, adjust individual zones if necessary for uniformity.

(9) Measure new pattern and rate by repeating B1, through B5.

(10) Continue B6, B7, B8, B9 until have curves for rate versus pressure.

C. Check H_2O Level, Rock Level and Weir Level

(1) Fill with spray nozzel unti weir sets level of H_2O

(2) Check H_2O level below trainer curb 1½' ± ¼, 3" ± ¼" below spray nozzles

(3) Adjust weir if necessary to get 3"

(4) Check rock level ½ ± ¼" above water level.

(5) Check fuel inlet levels to make sure they are below rocks.

Appendix F

R & D CONTRACT STATUS REPORT

1. Scientific Officer: Steve Hurley, NFAC Code 032
200 Stovall Street, Alexandria, VA. 22332
2. Title: Environmentally Compatible and Cost Effective Facilities for Aircraft Ground Fire Suppression Training
3. Contract No.: N00014-80-C-0696 (SRI PYU-1943)
4. Agency: SRI Report No. 1
5. Performance Period: Week of January 4, 1981
6. Summary:

6.1 Cascade-Fire and Engine-Fire Trainers

The good news is that these trainers have been installed and are operating quite satisfactorily at NAS North Island. During December, Fire Chiefs O'Laughlin (NWC) and Winters (N.I.) transfered these units from China Lake to North Island where they were located according to the Site Plan for the North Island A/C Fire Rescue Training Facility. The trainers survived the move with only minor damage: e.g., a broken water pipe both on the cascade unit and the engine simulator, missing mounting bolts from the A/C compresser, and a short in the water pump motor electrical cord. After repairs including the installation of new air and fuel lines, these trainers were placed in operation and exercised according to the test schedule. Twenty firemen, 11 journeymen, 8 trainees and one intermediate participated in 69 fires during three days of testing. Several pertinent observations during these exercises are as follows:

- Regarding air pollution: Larry Michalec made observations and will prepare his own evaluation; however, his comments during the tests indicate there should be no problem with smoke from these fires in range of burning rates used in the tests: i.e., up to 3 gpm. The observations also include pollution from the agents during suppression and this factor may limit the number of exercises that could be conducted per hour. There is no problem with CO_2, it is completely clean; however, PKP and Halon 1211 generate clouds. PKP is white and Halon 1211 produces a very black cloud of reaction products. Fortunately, both of these generation times are short and the clouds soon dissipate.

- Relative effectiveness of agents: Carbon Dioxide and Halon 1211 were compared on engine simulation fires. With CO_2, some firemen could extinguish a ½ gpm engine fire and two firemen operating two extinguishers simultaniously extinguished a 1 gpm fire but CO_2 from a 50 lb extinguisher could not extinguish a 2 or 3 gpm fire. Halon 1211 readily extinguished the 1, 2, and 3 gpm fires and three or four extinguishes could be obtained with one filling of the extinguisher.

SRI International

333 Ravenswood Ave. • Menlo Park, CA 94025 • (415) 326-6200 • Cable: SRI INTL MNP • TWX: 910-373-1246

- Effect of technique on extinguishment effectiveness. Both trainers demonstrated the importance of technique both in ability to extinguish the fire and in the amount of agent required. Measurements of the agent required put the observations on a quantitative basis, and we are accumulating data that will be used to establish par for the various exercises.

6.2 Cold-Fire Trainer Pad

As indicated in the site plan, North Island has a large concrete covered area that can be used as a Cold-Fire Trainer Pad. A 50-ft diameter circle to simulate the Hot-Fire Trainer was laid out on one corner of the pad and equipped with 16 sampling pans to measure the agent application uniformity. The pans were spaced to sample equal areas of the circle. Several observations during the exercises on this trainer are pertinent to operation of the turret in general and to tests on the Hot-Fire Trainers in particular.

- Straight Stream versus Fog Operation
  At North Island, most of the ground is covered with concrete or black top; therefore, the firemen have been trained to approach a crash scene with the turret operating on straight stream to provide the maximum range and to sweep fuel away from the aircraft. At close range, they switch to fog and extinguish the fuel remaining near the aircraft. The exercises on the Cold-Fire Training Pad were conducted with a P-4 truck pumping 750 gpm; consequently on streight stream with water, the sampling pans were washed away. Subsequently, it was observed that the straight stream also knocked the rocks out of the Hot-Fire Trainer. Obviously the pans can be anchored to stay put during the water discharge, but we will have to see if the rock displacement is a problem with foam.

- Visibility of the test area:
  In the fog and semi-fog positions, the cone of water from the turret obscures most of the target area; therefore, the operator cannot see where the water is landing and he must manipulate the turret mostly by instinct. This obscuration provides all the more need for exercise with the turret.

- Room for improvement
  During these exercises with the turret in a semi-fog position, the firemen experienced difficulty in covering the complete test area and in obtaining fairly uniform coverage when limited to a 10-second operation at 750 gpm: i.e., a time of 10 to 15 seconds is considered the limit for the amount of agent that can be expended in the hot-fire trainer exercise with the P-4.

6.3 The Hot-Fire Trainer Tank

The bad news is that numerous problems were encountered with this facility and a satisfactory training fire was not produced during the week: i.e., when smokeless, the fire was too small to challenge the P-4, and with a large fire there was too much smoke. Presumably the main problem centers on our ability to control the critical water level during a test. The system is infested with water gremlins which must be dispelled before the necessary level of control can be achieved. However, one benefit from such problems is that the firemen become intimately familiar with the unit during trouble shooting. All types of problems were encountered: design, construction, and operation.

- Design Deficiencies

  1. Most of the time was lost because the 4-inch pipe to fill the trainer overwhelmed the main fresh water pump, produced cavitation, and overheated the 60 HP motor in less that a minute. The lack of a functioning pressure gage contributed to the difficulty in diagnosing the problem; but this is construction deficiency, i.e.30 psi gages were installed on the 150 psi line, consequently they had ceased functioning long before we arrived.

  2. No positive control of the drainage rate from the trainer to the the waste fuel water separator existed. The separator is rated at 500 gpm, consequently it is easily overwhelmed when about 300 gpm are coming from the spray nozzles and 750 gpm is coming from the fire truck. Consequently, water transferred into the waste fuel tank.

  3. There is no provision for drainage water control when a critical pump fails. When the 300gpm sump pump ceased to operate while flushing the foam from the trainer, the fuel-water separator, waste fuel tank, and sump tanks all filled up and overflowed, depositing gasoline and water around the pumping station.

  4. Location of the trainer fill line discharge.
     This line terminates just inside the trainer wall: consequently during the foam flushing operation, the incoming water flows over the adjacent section of the wall and little foam is swept away from the main area of the pool.

  5. Departed Pressure gages:
     The original ITTRI drawings show pressure gages following the zone control valves to give some indication of what is happening in each line. These gages were left out of the North Island design, so the only water pressure gage in the control tower is in the relatively useless position before the main shutoff valve.

  6. Fuel line filter
     This filter plugged after very little use; therefore, provisions should be incorporated to expedite filter changes: e.g., put a spigot in the filter flange so the fuel can be drained out of the filter without generating a fuel spill.

- Construction Deficiencies

  1. Problems associated with the weir

     The location of the clamp down bolts in the weir tank prevented lowering the weir to the proper level. Also, there were no gaskets between the weir and the concrete and the associated leak precluded maintaining the water at a fixed level. The weir has been modified to accommodate the misplaced bolts, but the gaskets remain to be provided.

2. Spray nozzle elevations
   The spray nozzles were not at the same elevation and at the proper elevation with respect to the tank curb. These were adjusted to about the proper level.

3. Too many rocks in the tank.
   Rocks were removed to comply with the dimensions specified: i.e., ± ½" with respect to the water line which should be 1½ ± ¼" below the tank curb and 3" below the spray nozzles. Some adjustment of the rocks is probably still necessary after the weir leaks are stopped.

4. Uneven metal cap on the tank curb.
   This uneveness causes most of the water used to flush away the used fuel and foam to escape to the peripheral basin in a few spots; consequently the foam sweeping action is impaired.

5. Sluice gate
   There is no provision to keep rocks from getting under the sluice gate. Consequently, it is difficult to shut off this water path which contributes to the overloading of the fuel water separator.

6. Pump failures
   The reasons for the failure of the P-4 (Reclaimed Waste Water Submersible Pump) and P-5 (Reclaimed Waste Water Pump) have not been determined, but the system obviously is not adequate with respect to these pumps and their controls.

7. Ignitor failure
   One out of four of the ignitors failed to act; the cause was not determined.

- Operational questions and problems

  First, the system has to be repaired so that the water control both in and out of the training tank is reliable. Also, provisions to allow for equipment failure at crucial points in the exercise should be incorporated either in the operational plan or in the equipment: e.g., a shut-off valve (sluice gate) in the 6" waste water drain line Directions and suggestions for trouble shooting should be prepaid for any new system. Finally, a good description or picture of the fire under satisfactory operating conditions would let the operator know what he is aiming for.

7 Plans for the Next Period:

Correct the essential equipment failures: i.e., pumps P-4 and P-5, eleminate the weir tank leaks, prepare a control and shut-off weir for the 6" waste water drain, check the rock levels, and modify the operation procedure to optimize the fire and prevent flooding of the fuel water separator.

Appendix G

VISIBLE EMISSIONS–FIELD EVALUATION RECORD
(ND-NAVAIREWORKFAC-4000 1 (3-78))

COMPANY: U.S. NAVY Firefighting Test Area
DATE: 8 JAN 80
LOCATION: PRACTICE FIRE FIGHTING AREA
OBSERVER: L.E. MICHALEC
TIME START: 1016
SKY CONDITION: Clear
TIME STOP: 1018
WIND SPEED:
DIRECTION:
AIR TEMPERATURE:
RELATIVE HUMIDITY:
PLUME CHARACTERISTICS (Color, etc.):
STACK HEIGHT: ____ FEET
OBSERVER LOCATION: 100 FEET SE OF STACK

MINUTE	0	1/4	1/2	3/4	REMARKS	MINUTE	0	1/4	1/2	3/4	REMARKS
0 (1016)	0	0	0	0	Test #43 Engine	30 (1057)	0	0	0	0	CASCADE FIRE
1 (1017)	0	0	0	0	CO_2 1GPM JP4	31 (1058)	0	1	2	1/4	TEST
2						32 (1059)	1/4	1/2	1/2		PKP 1GPM
3 (1021)	0	0	0	0	Test #44 Engine	33					TEST #51
4 (1022)	0	0	0	0	CO_2 1GPM JP4	34					
5						35					
6 (1025)	0	0	0	0	TEST #45 Engine 1GPM JP4	36					
7					CO_2	37					
8 (1031)	0	1/4	1/4	1/4	TEST #46 Engine	38					
9 (1035)	100	20	1/4	0	white smoke due to fire agent.	39					
10					1211 1gpm	40					
11						41					
12 (1038)	0	1/2	1/2	1/4	TEST #47 Engine	42					
13 (1039)	1/4	3	100	1/4	1211 1gpm	43					
14						44					
15 (1042)	0	1/2	2	1/4	Engine TEST #48	45					
16 (1043)	1/4	100	20	0	1211 1gpm	46					
17						47					
18 (1046)	0	1/4	1/4	1/4	Engine TEST #49	48					
19 (1047)	4	20	0	—	1211 1gpm	49					
20						50					
21 (1051)	0	1/2	3/4	1/4	Engine TEST #50	51					
22 (1052)	1/4	1/2	3 1/2	2 1/2	CO_2 2gpm	52					
23 (1053)	2 1/2	2 1/2	2 1/2	2 1/2		53					
24 (1054)	2	2	2	1/4		54					
25						55					
26						56					
27						57					
28						58					
29						59					

VISIBLE EMISSIONS–FIELD EVALUATION RECORD
11ND-NAVAIREWORKFAC-6000 1 (3-78)

COMPANY	DATE
LOCATION ~~[illegible]~~ - NAS NI R&D Firefighting Pit	
OBSERVER EJK + JFN	TIME START 28 May 81
SKY CONDITION Clear, some white clouds	TIME STOP

WIND SPEED	DIRECTION	AIR TEMPERATURE	RELATIVE HUMIDITY
10 Knots	West	70°	65%

PLUME CHARACTERISTICS (Color, etc.)

STACK HEIGHT ______ FEET — OBSERVER LOCATION 150 FEET West OF STACK

Test 1

MINUTE	0	¼	½	¾	REMARKS	MINUTE	0	¼	½	¾	REMARKS
0	5	1	3/4	1/4	1349 hrs	30					
1						31					
2					Total Time	32					
3					2 mins -	33					
4					No smoke	34					
5					during [illegible]	35					
6					white	36					
7					Sun slightly	37					
8					to our backs	38					
9						39					
10						40					15 June
11					Wind Thermo	41					Washington
12					[illegible] Turret!	42					Wedding
13						43					
14						44					
15					AFFF	45					
16						46					
17						47					
18					15 gal	48					
19					AF^3	49					
20						50					
21					35 gal	51					
22					H_2O	52					
23						53					
24						54					
25					MB-5 Truck	55					
26						56					
27						57					
28						58					
29						59					

VISIBLE EMISSIONS–FIELD EVALUATION RECORD
11ND-NAVAIREWORKFAC-6000 1 (3-78)

COMPANY:

DATE:

LOCATION:

OBSERVER: R+D FF Pit

TIME START: 28 May 81

SKY CONDITION:

TIME STOP:

WIND SPEED: ~~[illegible]~~ DIRECTION: AIR TEMPERATURE: RELATIVE HUMIDITY:

PLUME CHARACTERISTICS (Color, etc.): accidental reignition (ref'ash fire)

STACK HEIGHT ______ FEET OBSERVER LOCATION ______ FEET ______ OF STACK

MINUTE	0	1/4	1/2	3/4	REMARKS	MINUTE	0	1/4	1/2	3/4	REMARKS
0	2	2 1/4	5	5	140 2 hrs	30					
1	5	5	4	0		31					
2					~~[illegible]~~	32					
3						33					
4					Chief	34					
5					writes	35					
6					on	36					
7					Turret	37					
8					foam	38					
9					~~[illegible]~~	39					
10						40					
11					AFFF	41					
12						42					
13					reason –	43					
14						44					
15					metal ring	45					
16					buckling	46					
17						47					
18					caused	48					
19						49					
20					reflash	50					
21						51					
22					15 gals AF³	52					
23					300 gal H_2O	53					
24						54					
25						55					
26					MB-5 truck	56					
27						57					
28						58					
29						59					

VISIBLE EMISSIONS–FIELD EVALUATION RECORD
11ND-NAVAIREWORKFAC-6000/1 (3-78)

COMPANY	DATE
LOCATION: R&D FF Pit	
OBSERVER	TIME START: 28 May 81
SKY CONDITION	TIME STOP

WIND SPEED	DIRECTION	AIR TEMPERATURE	RELATIVE HUMIDITY
Test #2			

PLUME CHARACTERISTICS (Color, etc.)

STACK HEIGHT ______ FEET | OBSERVER LOCATION ______ FEET ______ OF STACK

MINUTE	0	1/4	1/2	3/4	REMARKS	MINUTE	0	1/4	1/2	3/4	REMARKS
0	0	0	0	0	1440	30					6% [illegible]
1	0	1G	5	1		31					15 gal AF^3
2	1/4	2	1 3/4	3	→ reflash	32					from 2nd
3	3		1/2	1/4	starting	33					Truck
4	1/2	1/4	0	0		34					
5	out				2nd Truck	35					300 gal H_2O
6					also H_2O	36					
7					dry ext.	37					H_2O hand
8					used also	38					line used
9						39					+
10						40					
11						41					
12					AF^3	42					PK Powder
13						43					[illegible]
14					30 gal AF^3	44					used
15					400 gal H_2O	45					
16						46					
17						47					
18					MB-5 Truck	48					
19						49					
20						50					
21					Water	51					check
22					T. [illegible]	52					Weather Bureau
23						53					
24						54					
25						55					
26						56					
27						57					
28						58					
29						59					

VISIBLE EMISSIONS–FIELD EVALUATION RECORD
1IND-NAVAIREWORKFAC-6000 1 (3-78)

COMPANY

DATE

LOCATION R&D FF Pit

OBSERVER

TIME START 28 May 81

SKY CONDITION

TIME STOP

WIND SPEED Test #3

DIRECTION

AIR TEMPERATURE

RELATIVE HUMIDITY

PLUME CHARACTERISTICS (Color, etc.)

STACK HEIGHT ______ FEET

OBSERVER LOCATION ______ FEET ______ OF STACK

MINUTE	0	1/4	1/2	3/4	REMARKS	MINUTE	0	1/4	1/2	3/4	REMARKS
0	0	0	0	0	1508	30					
1	7G	5	2 1/2	3c		31					
2	control	1	1/4	0	→ 1st Truck	32					
3	[illegible]	0	0	0		33					
4					→ 99% out	34					
5					ring portion	35					
6					lit.	36					
7						37					
8					→ ring	38					
9					portion	39					
10					lit	40					
11					Cloud dissipates	41					
12						42					
13					Quickly	43					
14						44					
15						45					
16						46					
17						47					
18					177 gal fuel	48					
19					used	49					
20						50					
21						51					
22						52					
23						53					
24						54					
25						55					
26					MB-5 truck	56					
27						57					
28						58					
29						59					

VISIBLE EMISSIONS–FIELD EVALUATION RECORD
11ND-NAVAIREWORKFAC-6000/1 (3-78)

COMPANY: NAS NI	DATE: 29 May 81
LOCATION: NAS R&D FIRE PIT	
OBSERVER: J.P. Nalevanko	TIME START: 1147
SKY CONDITION: OVER CAST	TIME STOP: 1156

WIND SPEED	DIRECTION	AIR TEMPERATURE	RELATIVE HUMIDITY
0-5	South	65	65

PLUME CHARACTERISTICS (Color, etc.)

STACK HEIGHT Ø NA FEET OBSERVER LOCATION 150 W FEET SW OF STACK

MINUTE	0	1/4	1/2	3/4	REMARKS	MINUTE	0	1/4	1/2	3/4	REMARKS
0	Ø	Ø	Ø	Ø	1147	30					
1	Ø	Ø	Ø	Ø		31					
2	Ø	Ø	Ø	Ø		32					
3	Ø	Ø	1½	3	IGNITION	33					
4	5	5	2½	½		34					
5	½	1	¼	¼		35					
6	¼	¼	4	3		36					
7	3	9	4½	Ø	← FIRE OUT	37					
8	Ø	Ø	Ø	Ø	1156	38					
9						39					
10						40					
11						41					
12						42					
13						43					
14						44					
15						45					
16						46					
17						47					
18						48					
19						49					
20						50					
21						51					
22						52					
23						53					
24						54					
25						55					
26						56					
27						57					
28						58					
29						59					

VISIBLE EMISSIONS–FIELD EVALUATION RECORD
11ND-NAVAIREWORKFAC-6000/1 (3-78)

COMPANY: [illegible]S NI	DATE: [illegible] May 19[illegible]
LOCATION: NAS R&D FIRE PIT	
OBSERVER: J.P. [illegible]	TIME START:
SKY CONDITION: OVERCAST	TIME STOP:
WIND SPEED: 0-5	DIRECTION: South
AIR TEMPERATURE: 65	RELATIVE HUMIDITY: 65
PLUME CHARACTERISTICS (Color, etc.): black	
STACK HEIGHT: Ø NA FEET	OBSERVER LOCATION: 150 W FEET 5[illegible] OF STACK

MINUTE	0	1/4	1/2	3/4	REMARKS	MINUTE	0	1/4	1/2	3/4	REMARKS
0	Ø	Ø	Ø	Ø	1050 HR	30					
1	Ø	Ø	Ø	Ø		31					
2	Ø	Ø	Ø	Ø		32					
3	Ø	Ø	Ø	Ø		33					
4	Ø	Ø	Ø	Ø		34					
5		Ø	Ø	Ø		35					
6	Ø	Ø	Ø	Ø		36					
7	Ø	Ø	Ø	Ø		37					
8	Ø	Ø	Ø	Ø		38					
9	Ø	Ø	Ø	Ø		39					
10	Ø	Ø	Ø	Ø	1106	40					
11	Ø	Ø	Ø	Ø		41					
12	Ø	Ø	✓	5	✓ IGNITION	42					
13	5	2 1/2	1	1/2		43					
14	1/4	5	1 1/2	1 1/2		44					
15	4	1 1/2	1 1/2	1 1/2		45					
16	Ø	Ø	Ø	Ø	FIRE OUT	46					
17					1200 GAL water	47					
18					65 Gal AFFF	48					
19						49					
20					[illegible] Gal [illegible] ?	50					
21						51					
22						52					
23						53					
24						54					
25						55					
26						56					
27						57					
28						58					
29						59					

Appendix H

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INTRODUCTION

Naval Facilities Engineering Command (NAVFAC) Code 03 has tasked the Civil Engineering Laboratory (CEL) to review the Navy's crash/rescue training activity as represented by Naval Air Station, North Island (NAS NORIS) and identify disposal options for the wastewaters being generated.

The Navy has two functional facility category codes (CCNs), 141-20 and 141-25, which are part of the aircraft crash/rescue firefighting capability. Based on the Navy Real Property Inventory (RPI), there are 123 installed facilities under these two CCNs. The Air Force also has about 100 bases where aircraft crash/rescue firefighting training exercises are routinely practiced. The Army has about 30.

Wastewater generated from such firefighting exercises contains Aqueous Film Forming Foam (AFFF), residual fuel/oil, and combustion products. The wastewater, which ranges from 500 to 3,000 gallons for each training exercise, has been found to be toxic to the receiving streams/environments (Ref 1). Cost-effective treatment and disposal options must be developed for these wastes to preserve the continuous use of the fuel fire extinguishing agent, AFFF. This compound is uniquely effective in suppressing fuel oil fires. The upcoming environmental regulations are expected to be significantly more stringent on Navy options than the available training facilities are capable of handling. In response to this need, NAVFAC has tasked CEL to develop cost-effective treatment and disposal options. The Air Force (HQ, AFESC, Tyndall AFB, Fla.), responding to similar needs, has joined the Navy in undertaking the RDT&E effort for such technology development.

NAS NORIS has recently constructed one of the largest and most complex crash/rescue firefighting training facilities. Along with other test objectives of the facility (Ref 2), CEL has been tasked to evaluate the AFFF-containing wastewater and its treatment and disposal options. Results obtained from preliminary tests of the North Island facility and CEL recommendations are reported hereafter.

BACKGROUND

NAS NORIS has constructed a complete aircraft crash/rescue fire trainer, the pool fire training device. This device consists of: (1) a 50-foot-diam trainer tank (pool) filled with 2 to 3 inches of rock, (2) thirty-two water spray nozzles (300-gpm capacity) near the surface of the trainer tank, (3) a weir tank, (4) a 500-gpm-capacity fuel-water separator, (5) a 900-gpm-capacity wet well with a sump pump, (6) a 37,800-gallon-capacity wastewater storage tank, (7) a facility operation control tower, (8) a 10,000-gallon-capacity freshwater storage tank, (9) a 4,000-gallon fuel storage tank, and (10) a 1,000-gallon reclaimed fuel tank.

In operation, the pool fire, simulating real aircraft fire emergencies, is extinguished with a fire engine that delivers AFFF foam. The delivery rate can range from 250 to 750 gpm, depending on the type of fire engine used (i.e., P-17 or P-4). The fire should be extinguished within 1 minute. The fire smoke is controlled with the water spray to meet air quality regulation standards.

Two objectives were set for the test and evaluation of the North Island aircraft crash/rescue training facility (Ref 2):

1. Primary Objective - Determination of Facility Performance

- Does the facility satisfy the clean air and water requirements with gasoline and JP-4 fires?
- Is the fire real enough (i.e., is the simulation of an unabated fire adequate)?
- Is the fire big enough? Does the fire provide sufficient challenge for the new generation of fire trucks with their higher pumping rates, or is the fire overwhelmed so that differences in operator proficiency cannot be detected?
- Is the fire reproducible enough (i.e., can the fire be used for quantitative measurements of fireman performance)?

2. Secondary Objective - Determination of Training Requirements

- Develop training requirements (e.g., training procedures and frequency).
- Develop fireman performance evaluation criteria.

These two objectives are to be jointly accomplished by Stanford Research Institute (SRI) and NAS NORIS. CEL will assist in accomplishing part of the objective, in terms of wastewater reuse potential, treatment requirements, disposal options evaluation, and environmental impact assessment.

The test plan prepared by SRI and approved by NAVFAC called for a total of 40 fire tests. However, due to numerous design and construction deficiencies of the firefighting training facility at NAS NORIS (Ref 3), the test plan execution was delayed for 5 months, and the number of fires tested was reduced by 50%. The limited wastewater collected from the firefighting exercises has been analyzed for its AFFF content (see the Appendix). Based on these analytical results and on the test results of the effect of AFFF in water on its ability to ignite fuel, some feasible disposal options are discussed and presented.

DISCUSSION

Two approaches were employed for evaluation of wastewater reuse potential.

1. Wastewater generation rates from each firefighting training exercise were estimated and the AFFF content in the wastewater was analyzed.

2. The maximum allowable AFFF concentration in the wastewater that would not affect fuel ignition was determined.

The experimental results of these two approaches are presented in the following section.

<u>Wastewater Analysis</u>

<u>Estimation of Wastewater Flow</u>. The water reused in each pool firefighting exercise is estimated at about 3,065 gallons, as described below:

1. About 300 gallons of water was used for smoke control when the water spray nozzles were delivering full capacity at an average rate of 300 gpm for a total of one minute.

2. Approximately 2,000 gallons of water was used to flood the pool after the fire was extinguished to wash off all the foam and residual fuel in the pool.

3. About 500 gallons (variable) of water was used to manually wash off the unremoved foam on the surface of the pool.

4. About 250 gallons of water was used to mix the AFFF concentrate for fire extinguishment.

5. About 15 gallons of AFFF concentrate was used.

Some of the AFFF and wastewater was inevitably lost during pool surface washoff. If the facility were designed and constructed correctly, this type of loss could be minimized and/or the washoff could be totally eliminated.

<u>Estimation of AFFF Content in the Wastewater</u>.

1. The AFFF content in the wastewater is estimated at 15/3,065 or 0.49% v/v (volume by volume).

2. The wastewater containing 0.49% v/v from each cycle of use should be stored for reuse in flooding the pool (2,000 gallons per exercise).

3. Assuming that there is no AFFF removal process to be provided, except that supernatant and sludge are constantly removed from the storage tank (the flow amounts to 35% of the total flow), then the following equation can be used to estimate the AFFF concentration in the wastewater when a steady state is reached.

$$C_s = \frac{C_1}{1 - R}$$

where C_s = AFFF concentration at the steady state

C_1 = AFFF concentration added in each cycle

R = recycle ratio

$$C_s = \frac{0.49\%}{1 - 0.65} = \bar{1}.40\% \text{ v/v}$$

Wastewater Sampling and Analysis. Due to the irregular/intermittent fire tests performed, only 10 wastewater samples were collected. They were by no means a continuous operation sampling, nor was a steady state reached.

The wastewater samples were analyzed for their AFFF content (in terms of volume-by-volume ratio) by a foamability test (shake test). The AFFF analytical procedure and the analytical results of field wastewater samples are presented in the Appendix. The AFFF concentration measured in the wastewater appeared to be very low (an average of 0.25% v/v). This was about one-half of the calculated value of the AFFF content in the wastewater. During exercises, it was observed that a significant amount of AFFF was lost in the washoff and flooding operations (e.g., foam flowed over the pool rim to the ground rather than being collected into the weir tank and wastewater transport pipelines).

Maximum Allowable AFFF Concentration in Recycling Wastewater

The results of the equipment/procedures tests (conducted by SRI for CEL) are as follows. A 6-inch-diam stainless steel pan was used for the fuel ignition tests.

Test 1. A mixture of 400 ml of AFFF concentrate and 200 ml of gasoline was added carefully to the pan surface so that no foam bubbles were generated. The mixture ignited readily and burned as if no AFFF was present.

Test 2. AFFF concentrate (400 ml) was mixed with 200 ml of gasoline in the pan and stirred vigorously. The mixture ignited readily and burned. It was stirred during the fire, but could not extinguish the fire until the gasoline was exhausted. This process did not make a good foam.

Test 3. In a 400-ml 6% AFFF solution, 200 ml of gasoline was poured in vigorously so that it plunged beneath the AFFF. It was a little more difficult to ignite (three matches were required), but it burned readily once ignited. It was stirred vigorously during the burn, but could not extinguish the fire. Foam formed over much of the surface, but would not seal off the oxygen.

Test 4. A 400-ml 6% AFFF solution was mixed with 200 ml of gasoline, shaken well to form an emulsion, and poured into the pan. A single match caused transient ignition, but a taper was required to generate sustained ignition. The fire burned at a reduced rate until all the fuel was consumed.

The test results indicated that the AFFF concentration in the water did not appear to affect the gasoline fuel ignition. The original test plan called for JP-4 to be compared with gasoline. However, due to the fuel availability on the base, gasoline was selected for the fire tests. The effect of mixing the AFFF concentration into the water when JP-4 is used as a fire fuel and/or when the wastewater contains other contaminants, such as combustion products, is unknown. More fire tests and field sample analyses will be required to define the effects.

Wastewater Treatment/Disposal Options

The concentration of AFFF in the water did not appear to affect the ignition of the gasoline. This indicates that the wastewater can be recycled and reused. However, many factors must be considered and monitored to assure continuous use of the wastewater. These include wastewater storage time (may become septic in a week) and effectiveness of gravity separation in the oil/water separator and/or storage tank.

Based on the previous calculation, when the wastewater in the storage tank maintains a 35% blowdown rate, the AFFF concentration in the wastewater will contain 1.4% v/v AFFF at the steady state. A lower blowdown rate will provide a higher AFFF concentration in the wastewater. However, a much larger wastewater storage tank will be required.

Treatment technology currently under development in this Laboratory includes the following processes: membrane AFFF recovery, soil treatment, rotating biological contactor treatment, and anaerobic carbon bed treatment. These processes, except for the membrane process (due to the low AFFF concentration in the wastewater), appear to be applicable for treating wastewater at North Island. Design criteria for these identified processes could become available towards the end of FY82.

At the present time, the supernatant in the storage tank can be skimmed off and combined with the recovered waste fuel from an oil/water separator. This is being used for cascade fire training exercises. The sludge drawn from the bottom of the wastewater storage tank can be dried at the industrial treatment plant sludge bed.

More wastewater samples must be collected for determination of the validity of the preliminary results. In the meantime, the effect of using JP-4 as a fire fuel, the waste sludge disposal impact on the environment, and the actual wastewater characterization after 5, 10, and 20 continuous recirculations must be investigated.

REFERENCES

1. Civil Engineering Laboratory. Technical Memorandum M-54-78-06: Disposal of wastewater containing aqueous film forming foam (AFFF), by D. B. Chan. Port Hueneme, Calif., Apr 1979.

2. Stanford Research Institute. SRI Memo with a Test Plan: Proposed test plan for evaluation of North Island A/C Crash/Rescue Training Facility, by R. S. Alger. Menlo Park, Calif., Aug 22, 1980. (to S. Hurley, NAVFAC Code 034P)

3. __________. SRI R&D Contract Status Report. Menlo Park, Calif., Jan 1981. (Contract no. N00014-80-C-0696)

Appendix

AFFF ANALYTICAL PROCEDURE AND ANALYTICAL RESULTS OF FIELD WASTEWATER SAMPLES

FOAMABILITY TEST (SHAKE TEST) PROCEDURE FOR AFFF CONCENTRATION

This determination consists of placing 100 ml of wastewater in a 250-ml graduated cylinder with a secure fitting glass stopper. The sample is then shaken vigorously for 30 seconds and allowed to settle for 5 minutes. Toward the end of 5 minutes, the foam volume in milliliters (ml) is recorded. The results of this method can be represented by the volume of the foam alone or calibrated against a pure AFFF standard sample to obtain the concentration (volume by volume) of AFFF. The foamability of 3M FC-780 and ANSUL AFFF after 1 to 500 dilutions of the AFFF concentrate is 85 and 130 ml, respectively.

ANALYTICAL RESULTS OF FIELD WASTEWATER SAMPLES

Sampling Date	Sampling No.	AFFF Concentration (% v/v)
9 Apr 81	1	0.12
10 Apr 81	2	0.15
20 Apr 81	3	0.23
21 Apr 81	4	0.25
27-29 May 81	5	0.21
	6	0.24
	7	0.25
	8	0.23
	9	0.31
	10	0.26
	11	0.27

Appendix I

309/KJW:ld
9 June 1981

From: Operations Department/Fire Division
To: Mr. Ray Alger, SRI International

Subj: Test and Evaluation of Crash Training Facility

Encl: (1) Test Data and Comments

1. On 8 June 1981, the North Island Fire Department concluded our test and evaluation of the Crash Training Facility.

2. At this time we are forwarding the results of the test along with our comments and opinions as per our phone conversation on Tuesday, 9 June 1981.

a. The cascade fire and engine fire trainers were installed and tested and demonstrated to me that they can be a valuable firefighting training aid. I think we can teach technique and come up with a program that will establish the amount of agent required to maintain the level of training required.

b. The cold fire trainer PAD using the sampling pans method to measure the uniformity of application of agent is, in my opinion, very useful. We can provide cost effective turret training, "No fuel or AFFF." and reduce the amount of fires needed to maintain a trained crash crew.

c. The hot fire trainer tank was used and the following observations are submitted for your review:

(1) First of all there were many design and construction deficiencies, many system failures, and a total lack of knowledge on our part as to the operation of this unit which consequently made it very difficult for us to conduct the tests. Many fires had to be held so we could find out how to operate the unit, more fires I am sure then were held testing the firefighters. You have noted the deficiencies in your status report of 4 January 1981. We found it very hard to control the amount of fuel and water on each fire and had to estimate on the data sheets.

(2) The firefighters, at North Island, have been trained to use straight stream to provide maximum range on the approach to a crash. The pit fire will not allow this technique and for this reason leaves much to be desired in providing a realistic crash situation.

(3) We wanted to try and establish the cost factor and compaire this unit with our present method. We could not accomplish this because of all the inconsistencies and failures of the unit.

Subj: Test and Evaluation of Crash Training Facility

3. In conclusion, in my opinion, this unit will not provide a satisfactory training program that is cost effective and pollution free. We can have fires that challenge the firefighter but have smoke. When we eliminate the smoke we do not have a challenging fire. I hope we have been able to provide you with the information you require and on behalf of the North Island Fire Department I would like to thank you for the opportunity to work with you. Without your patience and guidance the task would have been impossible.

K. J. WINTERS
Fire Chief

Copy to:
Operations Officer