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DEVELOPMENT OF SMOKE ABATED AIRCRAFT CRASH/RESCUE FIRE FIGHTING TRAINER

IIT Research Institute
10 West 35th Street
Chicago, Illinois
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It was shown previously that liquid petroleum fuels can be burned from a free surface without smoke generation by injecting a water spray near the surface of the burning fuel. This program concerned the extension of this smoke abatement method to aircraft crash/rescue trainers involving fire areas to about 3000 sq ft.

Smoke abated fires of realistic severity for training purposes were obtained using either JP-4 or automotive gasoline, while JP-5 and No. 2 diesel oil—▽ next page (contd)

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20. ABSTRACT

were found ineffective for this purpose. Field experiments proved the compatibility of smoke-abated JP-4 fires with fire extinguishment using aqueous film-forming foam.

A detailed design is presented for a 50-ft diameter smoke abated fire area for fire-fighting training together with step-by-step procedures for its operation.

FOREWORD

The effort described in this report was performed in response to a joint agreement between the Navy and Air Force to develop a smokeless fire fighting facility for air crash/rescue training. The agreement provided that the Navy would further develop, optimize, and produce final design criteria for the smoke abated system using a test-bed facility at Chanute Air Force Base, Illinois. Upon completion of this development effort by the Navy, the Air Force was tasked to conduct a training effectiveness evaluation using actual students and school personnel. The results of the Air Force study can be found in Report # AFHRL-TR-76-60 entitled "Effectiveness of Smoke Abated Training in Simulated Crash Fire Fighting," August 1976, written by the Technical Training Division, Lowry Air Force Base, Colorado. These two reports together provide a coordinated input into the design and operation of a Smoke Abated Fire Fighting Facility for air crash/rescue training.

Alfred H. Rodemann.

ALFRED H. RODEMANN

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SECTION I

INTRODUCTION

An aircraft crash accident fortunately is not a frequent occurrence; but when such an event does occur, the saving of lives and valuable property may depend on the speed of response, skills and judgment of the crash/rescue fire-fighters. These skills much be maintained at a high level during long periods of inactivity by periodic training exercises, and it is generally agreed that live fires are necessary for these exercises. Therefore the training of fire-fighters at Air Force Bases and Naval Air Stations includes the extinguishment of large fires simulating aircraft crash situations.

A training simulator consists of a full scale mock-up of an airplane in the center of an area where fuel is spilled and ignited. The trainees are instructed in the extinguishment of the fire and in the rescue of personnel from the aircraft. Such fires generate huge clouds of black smoke and it is therefore essential to develop simulators that can provide adequate training without air pollution. The air pollution problem has been a deterrent to live fire exercises even at typical air bases where burns occur only on one or two days per month. The problem is especially severe at fire-fighting schools near population centers where such burns occur daily.

In previous research programs at IITRI (Ref. 1-6) sponsored largely by the Naval Training Equipment Center, it was found that the injection of a fine water spray at the surface of liquid petroleum fuel is an effective method for smoke abatement. After the initial laboratory development, the method was progressively improved until it is currently operational at some Navy fire-fighting schools. The emphasis at these schools is on shipboard configurations where, for training purposes, diesel oil is floated atop a water layer. The present program concerned the further development of this smoke abatement method for use at both Air Force and Naval Air Station training facilities where the emphasis is on handling aircraft crash situations. These involve ground spills of more volatile fuels covering much greater areas, and also significantly different methods of attacking a fire.

The following sections of this report describe the results of both laboratory experiments at IITRI and field burns conducted at the Fire Protection Training School, Chanute Air Force Base, Ill. Based on these results and the experience gained during the earlier programs, a design is presented for a prototype smoke abated fire facility for aircraft crash/rescue training.

SECTION II

STATEMENT OF PROBLEMS AND OBJECTIVES

In the training of fire-fighting personnel for aircraft crash/rescue missions, there is much similarity between Air Force and Navy practices regarding both the training simulators and the extinguishment procedures. Both use simulators that consist of a full scale mock-up of an aircraft, and trainees are taught to extinguish fuel spill fires such as may occur in a crash situation. The major difference between Air Force and Navy practice, with respect to the spray water smoke abatement method, concerns the type of fuel. The Air Force uses JP-4 exclusively for training purposes, while the Navy uses both JP-4 and JP-5. The former is a relatively wide boiling range volatile fuel, while the latter is a high flash-point fuel of the kerosine type which is more difficult to ignite. JP-5 is used by carrier based aircraft and is therefore more prevalent at coastal air stations. In the presence of the water spray for smoke abatement, JP-5 cannot be ignited by ordinary means.

With respect to the smoke abatement method, there are significant differences between aircraft crash simulators and the shipboard configurations that were the subject of the earlier work. The major differences are:

a. The fuels are different (shipboard simulators use diesel oil)

b. Aircraft trainers are much larger in fire area

c. There is a need for men to be able to walk through the fire area

d. The extinguishing agents are different

A problem that becomes more pronounced with increasing fire area is the effect of wind. A thin layer of fuel cannot be maintained in a uniform thickness when floating atop a water sublayer in an outdoor environment. Wind drag forces tend to move the fuel downwind so that the upwind portion of the trainer is left without fuel and without fire. In an experimental facility designed and built by the Air Force at Hill AFB, Utah, it was found that the wind drag effect can be effectively reduced by depressing the fuel surface in a bed of crushed stone. The crushed stone also provides a surface on which men can walk. However, as the level of the fuel is depressed, there is less exposed fuel surface available for combustion, resulting in reduced flame heights and longer burning times. The overall effect is a less severe and

unrealistic fire environment. Thus there is a trade-off between fire severity and adverse wind effects, and consequently a need to maintain the surface level of the fuel within narrow bounds.

The objective of this program was to further develop, evaluate, improve and adapt the water-spray smoke abatement method for application to aircraft training simulators. The result of this effort was to be a definitive design in sufficient detail to permit making detail drawings for installation of the smoke abatement system at Navy or Air Force training facilities. More specifically, the initial objectives of the program were to arrive at design information for the following:

a. Size of fire facility

b. Ignition method for JP-5 fuel

c. Means for maintaining a constant surface level in the trainer

d. Method of distributing fuel in the trainer

e. Choice of a water spray nozzle

f. Spacing of spray nozzles in the trainer

g. Choice of crushed stone for trainer

SECTION III

LABORATORY INVESTIGATIONS

1. EXPERIMENTAL SETUP

The laboratory model used for the experiments described in this report consisted of a 4 by 4 ft tank located near floor level below an 8 by 8 ft stack. The stack was in the center of a long building with a width of 25 ft and a roof height of 18 ft. The stack extended through the roof to a height of 22 ft, but its lowest point was 8 ft above floor level. Thus the model tank was not greatly affected by chimney draft.

A 4 by 4 ft fire area is sufficiently large to provide fully developed turbulent burning (Ref. 7), and therefore the fire behavior is representative of much larger fires. The model tank offered considerable versatility for controlling elevation of the water table, and the location of spray nozzles. It is shown schematically in Fig. 1. Control of the elevation of the water table was achieved by rotating the overflow pipe to the proper height, and the elevation was observed on a sight glass 10 ft from the tank.

The model tank incorporated the following systems:

a. A water spray system for smoke abatement.

b. A fuel supply system for either JP-4 or JP-5.

c. A gasoline supply system.

d. An electrical spark igniter system.

Water to the nozzles was supplied through a booster pump capable of discharge pressures up to 125 psi. The water was fed through a regulating valve and a variable area flowmeter (Rotameter). Pressure gages were provided in each of the liquid supply systems.

The fuel and gasoline systems included an individual accumulator in each system. To deliver a given amount of liquid to the burn tank, the accumulator was filled with the desired quantity and pressurized with nitrogen. Actual delivery was initiated by opening a solenoid valve in the accumulator discharge line. The fuel outlet was located below the water surface in one corner of the tank.

An electric spark plug for ignition was activated through an oil-burner type transformer with an output of 10,000 volts.

The model tank was filled with crushed stone of the same size gradation as specified for the trainer at Chanute AFB (Size CA-7; see Table 4). The tank was then filled with water, the "surface" of the stones was made as flat as possible relative to the free water surface, and fuel for a burn was floated atop the water. Zero level (or elevation) of the fuel surface relative to the surface of the bed of stones was initially defined arbitrarily as the condition when, looking down at the tank, the surface seemed half liquid and half stone. Zero level was later redefined as the condition when the surface is all liquid except for isolated projections. By repeated trials it was found that this condition was reproducible by visual observation within 3 to 4 mm (approximately 1/8 in.) of the actual level as read on a gage glass. This latter definition is used consistently in this report whenever reference is made to the level of the fuel surface. For all burn experiments described in this report, the layer of fuel was floating atop a sublayer of water.

Flame heights were estimated visually by comparison with a vertical post marked at 1-ft intervals and located near a corner of the model tank. Since flame heights are never steady, the range of the flame heights was estimated at discrete time intervals, usually every 30 sec.

2. EXPERIMENTS WITH DIESEL OIL

Since a delay was encountered in acquiring military type jet fuels for the laboratory experiments, several burns were made with diesel oil to get an indication of the burning characteristics of a relatively nonvolatile fuel in a bed of crushed stone. The burns were made with 5 to 10 gal of fuel for each burn, representing a free fuel thickness of about 0.5 to 1.0 in. Such thicknesses are greater than would normally be used for field exercises.

The results are summarized in Table 1. It was found that acceptable flame heights were produced only when the fuel surface was less than 3/4 in. below the surface of the stones. At levels deeper than 1½ in., flame heights were insignificant and combustion was barely maintained even without use of the water spray system. For the smoke abated experiments with the diesel oil, the fire was first allowed to develop to maximum flame heights before the spray water was turned on. After the spray was activated, flame heights decreased as the previously heated stones were cooled by the water. The conclusion drawn from these experiments was that diesel oil would not be a desirable fuel for smoke abated fires if the fuel surface were depressed in a bed of stones.

TABLE 1. FLAME HEIGHTS OF DIESEL OIL BURNING IN BED OF CRUSHED STONE

Fuel Surface Level, in.*	Maximum Flame Heights, ft	
	Natural Fire	Smoke Abated Fire
-0.6*	12-15	12-14
-0.85	6-8	4-5
-1.1	5-7	3-4
-1.6	1-2	---

* Depth of fuel surface below surface of bed of stones. At a level of -0.6 in., the burn area visually seemed about 50 percent liquid surface.

3. BURNING CHARACTERISTICS OF JP-4

3.1 INITIAL EXPERIMENTS WITH JP-4. The following series of experiments was carried out to gain a preliminary indication of the burning characteristics of relatively volatile fuels in a bed of crushed stone. These experiments were natural burns (without smoke abatement) and involved measuring flame heights and burning times. In the model tank, one gal of fuel corresponded approximately to 0.1 in. of free thickness; i.e. the thickness of the fuel layer if there were no stones.

a. One gal JP-4 at -0.6 in.

b. One gal JP-4 at -0.85 in.

c. One gal JP-4 at -1.1 in.

d. One gal JP-4 at -1.35 in.

e. Two gal JP-4 at -1.35 in.

The results were plotted as flame height versus time for each burn, and the following conclusions were drawn:

a. Flame heights decrease markedly with lower elevations of fuel (14 ft at -0.6 in. elev; 2 ft at -1.35 in.)

b. Burning times increase with lower elevations of fuel (3 min at -0.6 in. elev; 14 min at -1.35 in.)

c. Peak flame heights occur later with lower elevations of fuel (0.5 min for -0.6 in.; 6 min for -1.35 in.)

d. Flame heights increase with initial fuel thickness (2 ft for 1 gal; 7 ft for 2 gal at -1.35 in.)

It was evident from the above results that realistic fires would be obtained only at a fuel level such that at least half the burn area would be a free surface of fuel. In view of the effect of fuel layer thickness, nearly all subsequent experiments involved 2 gal of fuel per burn. Fuel loadings greater than 2 gal had no major effect on maximum flame heights.

3.2 FLAME HEIGHTS AND BURNING TIMES OF SMOKE ABATED JP-4 FIRES. Experiments were carried out to determine the effect of fuel surface level on the flame heights and burning times of JP-4 in the smoke abated mode. Two gal of fuel were used for each burn. Smoke abatement to a level of about No. 1 on the Ringelmann scale was attained by manually controlling the water supply to four spray nozzles located immediately outside the tank, one nozzle at each corner. The nozzles were DeflectoJet* No. 0.75, the same as those installed in the full-size facility at Chanute AFB on 4-ft centers.

The results of these experiments are shown in Fig. 2 to 4. These plots indicate that flame heights are reduced and burning times increase as the fuel level is progressively depressed into the bed of stones. The major conclusion to be drawn from these results is that the fuel surface of JP-4 cannot be depressed much more than 1/2 in. below the surface of the stones without losing the fire severity associated with realistic flame heights.

4. BURNING CHARACTERISTICS OF JP-5

4.1 FLAME SPREAD CHARACTERISTICS OF JP-5. Several burns were made to observe natural flame spread (no smoke abatement) across a surface of JP-5 at different levels of the water table in a bed of stones. Two gal of JP-5 were used for each burn, and ignition was accomplished using several cc of gasoline in a corner of the tank. The results obtained are shown in Table 2. It is evident that the rate of flame spread is very sensitive to the level of the water table. At the -0.5 in. level, it took 1½ to 2½ min

* Spraying Systems Co., North Avenue at Schmale Road, Wheaton, Illinois 60187. Nozzle type 8686 with 180° spray angle.

for flames to extend over half the fuel surface, and 2½ to 4 min to cover the entire surface. Maximum flame heights developed only when the entire area was in flame.

TABLE 2. TIME FOR FLAME TO SPREAD ON SURFACE OF JP-5 IN BED OF CRUSHED STONE (2 gal JP-5 in 4 by 4 ft tank)

Experiment Number	Surface Level = 0	Surface Level = -0.5 in.			Surface Level = -0.75 in.
	29	26	27	28	30
Flame spread to center of tank	0:15 sec	1:30	2:30	2:00	14:00
Flame spread over full surface	0:27 sec	2:30	4:00	3:00	20:00
Maximum flame height	14-18 ft	10-12	--	9-12	4-6
Time of maximum flame height	0:45 to 1:30 sec	2:30	--	3:00	16:00 to 18:00
Total time of burn	3:00	8:00	--	--	23:00

At the -0.75 in. level, flame heights or intensities were never uniform across the tank. By the time the flame front reached the middle of the tank, about 14 min after ignition, flame heights were already decreasing at the ignition corner. Most intense burning occurred just behind the advancing flame front, but flame heights never exceeded 4 to 6 ft. It took 23 min for flames to reach the far corner of the tank. By this time, the fuel at the ignition corner had burned off.

4.2 FLAME HEIGHTS AND BURNING TIMES OF JP-5 FIRES. An objective in using JP-5 for fire-fighting training is to achieve a smoke-abated fire comparable to an untreated fire burning from a free surface. The variation of flame height with time for such an untreated (natural) fire, using 2 gal of JP-5 in the 4 by 4 ft tank is shown in Fig. 5. A similar burn was carried out after

the fuel surface was lowered to a level of -0.5 in. and the results are shown in Fig. 6. It should be noted that for the burn at -0.5 in., about 2½ min were required for flame to spread over the entire tank, and it was only then that peak flame heights were attained.

A similar burn was carried out at a level of -0.75 in. The results are not plotted because the graph would tend to be misleading. At no time during the burn was the entire surface involved in flame. Peak flames of 4 to 6 ft were attained only after flame had spread over more than 3/4 of the tank, about 17 min after ignition. These flames were only local, immediately behind the flame front. Flame heights farther behind the flame front were much lower.

Trials with the water spray for smoke abatement, with the fuel level at -0.5 in., caused a further reduction in flame heights below those shown in Fig. 6. For these trials, the fire was allowed to develop naturally before the water spray was started.

From a comparison of Fig. 6 with Fig. 5 and from the other results described above it was concluded that JP-5 is not an acceptable fuel for this application.

5. BURNING CHARACTERISTICS OF JP-5 AND GASOLINE MIXTURES

Since flame will not propagate on a surface of JP-5 in the presence of a water spray, attempts at "clean" ignition were made by sprinkling gasoline over the JP-5 prior to ignition. This ignition approach was effective for diesel oil fires (Ref. 4,5,8). The addition of gasoline also would cause a rapid flame spread over the entire surface and would alter the burning characteristics, particularly in the presence of a water spray. A number of experiments were conducted, varying the amounts of fuel and the surface level, and the more significant results are described here.

The surface level for these experiments was maintained at 0.5 in. below the surface of the crushed stone. At this level, more than half the surface is liquid, and it is a realistic level for avoiding wind drag effects in the field. To eliminate fuel-layer thickness as a variable, the total amount of fuel including the gasoline was kept constant at 2 gal. The spray water was controlled from the time of ignition at rates needed to provide good smoke abatement.

The results are shown in Fig. 7 and 8. Flames spread over the entire surface of the tank almost instantly and peak flame heights were attained in 1/2 to 1 min after ignition. However, these fires of JP-5 and gasoline in the smoke abated mode provided lower flame heights and longer burning times than untreated fires

of JP-5 alone. Even the mixture containing 33 per cent gasoline provided unrealistically low flame heights compared with those shown in Fig. 5; and with such a concentration of gasoline the fuel cannot be considered JP-5.

These results were confirmed by additional burns in which the percentages of gasoline were the same as those shown on Fig. 7 and 8, but the total amount of fuel was increased to 2½ and to 3 gal. The effect was to lengthen the burn time, but fire severity as indicated by flame height was not increased sufficiently. These experiments substantiated the previous conclusion that JP-5 cannot be considered a candidate fuel for this application.

6. BURNING CHARACTERISTICS OF GASOLINE

It is a fact that the water spray used for smoke abatement reduces flame heights and burning rates from those produced by untreated fires, and the difference is more pronounced for fuels of low volatility (e.g. JP-5) than for volatile fuels (e.g. gasoline). Therefore a volatile fuel in the smoke abated mode would more closely simulate the severity of an untreated fire of a less volatile fuel. Such a trade-off is not feasible for simulators of shipboard configurations because gasoline fires cannot be extinguished using water hoses alone. But the use of gasoline can be considered for aircraft trainers because the Aqueous Film Forming Foam (AFFF) extinguishing agent used exclusively for these fires is effective for all the common petroleum fuels.

A series of experiments were carried out using the 4 by 4 ft model tank to determine flame heights and burning times for various amounts of automotive gasoline when the fuel surface was 0.5 in. below the surface of the crushed stone. The spray water was controlled from the time of ignition to provide optimum smoke abatement (equal to or less than no. 1 on the Ringelmann scale) throughout the burn. The results of the individual experiments are shown in Fig. 9 to 13.

Very clean burning was obtained during all these fires. A comparison of Fig. 9 and 10 shows a marked increase in flame heights as the amount of fuel was increased from 1 gal to 2 gal (approx. 0.1 in. to 0.2 in. free fuel thickness). Fuel quantities greater than 2 gal, however, simply lengthened the burning times without any significant differences in flame heights, as shown in Fig. 10 to 13. This fact is further illustrated in Fig. 14 which shows that burning time increases linearly with fuel quantity for quantities greater than 2 gal, which indicates a uniform burning rate.

Similar burns with gasoline were carried out to check the effect of lowering the fuel surface to -0.75 in., and the results are shown in Fig. 15 and 16. A comparison of Fig. 10 and 11 with Fig. 15 and 16 respectively shows that lowering the fuel surface causes lower flame heights and longer burning times. But the difference for gasoline (Fig. 10 and 15) is not as great as it was for JP-4 (Fig. 3 and 4). Furthermore, a comparison of Fig. 5 with Fig. 10 shows that a smoke abated fire of gasoline at a level of -0.5 in. is very similar to an untreated fire of JP-5 burning from a free surface. Gasoline is therefore a suitable candidate fuel for producing clean fires whose severity is comparable to untreated fires of the jet fuels.

7. RATE OF FUEL SPREAD ON WATER IN BED OF STONES

It is desirable to attain a fully developed fire over the entire trainer area rapidly so the training exercise can begin promptly with the least waste of fuel. On the other hand, ignition should not be delayed for long after fuel delivery begins, or until it is uniformly distributed over the entire surface, because hydrocarbon vapors would be released to the atmosphere. The rate of fuel spread over a water surface in a bed of crushed stone was therefore studied experimentally.

The laboratory setup for evaluating fuel spread provided for loading an accumulator with a known quantity of fuel, pressurizing the accumulator with nitrogen, and then ejecting the fuel into the 4 by 4 ft model tank by opening a solenoid valve. The fuel outlet in the tank was located in a corner so the model represented one quadrant of an area four times its actual size. The fuel outlet was below the water surface, about 2 in. below the surface of the stone, and consisted of two facing flanges as shown in Fig. 17. The lower flange was screwed onto the pipe, while the upper one was a blind flange held loosely in place by bolts. It was free to be raised by the fuel which emerged horizontally.

Initial experiments were carried out to determine the time to eject 2 gal of liquid at several different initial gas pressures in the accumulator. The following data were obtained:

Initial Pressure in Accumulator	Time to Eject 2 Gal
25 psig	14 seconds
50 psig	7-9 seconds
100 psig	5 seconds

Later experiments concerned the time it takes the fuel to distribute itself over the water sublayer for different initial levels of the water surface. These experiments involved 2 gal of fuel (equal to 0.2 in. free thickness in a 4 by 4 ft tank) and a constant initial pressure in the accumulator of 50 psig. The flow of fuel across the tank could be followed visually. Such data were obtained for many of the burns and the results are summarized in Table 3.

TABLE 3. RATE OF FUEL SPREAD ACROSS WATER SURFACE IN BED OF STONES
(2 gal Fuel Ejected in Corner of 4 by 4 ft Tank; Initial Accumulator Pressure = 50 psi)

Extent of Fuel Spread	Elevation of Water Surface, in.					
	0		-0.5		-0.75	
	JP-4	JP-5	JP-4	JP-5	JP-4	JP-5
Fuel reaches center of tank, sec.	6	5-6	7-9	7-10	9-11	10
Fuel reaches 3/4 way across tank, sec.	10	7-10	13-16	15-20	18-20	16-28
Fuel covers total surface, sec.	11-15	12-21	31-36	43-50	51-53	60-79

It can be seen that the JP-4 fuel covers most of the surface in less than 20 sec because the rapid local deposit of fuel creates a substantial head for flow. The relatively long times shown for total coverage are not as significant as may seem becasue it took the fuel much time to cover the far corner of the tank which represents but a small fraction of the total surface.

8. EFFECT OF SIZE OF CRUSHED STONE ON BURNING CHARACTERISTICS OF FUEL

A bed of crushed stone offers a resistance to the flow of water and therefore hinders the maintenance of a constant surface level over a large trainer area when water is deposited by the spray nozzles. The permeability of the bed of stones is affected by the size and uniformity of size of the individual stones. Larger stones of uniform size offer less flow resistance than a graded mixture of smaller sized stones.

Laboratory experiments using the 4 by 4 model tank were carried out to determine the effects of changing the stone size on fire characteristics and on the rate of fuel spread on a water surface below the surface of the stones. The crushed stone used in previous laboratory experiments as the upper layer in the model tank was Grade CA7, which is the same as that in the trainer at Chanute AFB. For these experiments, the upper layer was replaced with Grade CA5, which consists of larger stones. The comparative size distributions are shown in Table 4.

TABLE 4. COARSE AGGREGATE GRADATIONS
(Numbers give per cent passing indicated sieve size)

Grade ↓ \ Sieve Size →	1½ in.	1 in.	½ in.	No. 4
CA5*	97±3	40±25	5±5	3±3
CA7	100	95±5	45±15	5±5

* Designations of the Illinois Division of Highways

The experiments consisted of measuring the time for fuel to spread over the surface of the water sublayer, and of flame heights versus time of burning. Experiments were conducted at initial liquid surface levels of -0.5 in. and -0.75 in. relative to the surface of the crushed stone, using 2 gal of JP-4 for each burn. The fuel was injected from an accumulator with an initial nitrogen pressure of 50 psig, through a single outlet in the corner of the tank. These test conditions allowed a direct comparison with previous data under the same conditions with Grade CA7 stones.

With respect to the rate of fuel spread, the results of these experiments indicated no significant difference between the two gradations, and the data in Table 3 cover both sizes.

The effect of the different stone size on flame heights and burning times is shown in Figs. 18 and 19, where the current data are plotted on the corresponding curves, from previous experiments, for the smaller stone size. Again, the differences are not significant.

An attempt also was made to judge the response of the two sizes of crushed stone to personnel walking -- insofar as this could be done within the confines of the model tank. Both grades of stone behaved spongy, or somewhat springy. The stone sank under foot and then recovered partially when the load was removed. After repeated walking over the same area, there were visible depressions in the layer of crushed stone. A heavy step with the

heel left a cavity, but subsequent walking over the same area caused some recovery. The stone was not raised so much as to intercept the water spray. Similar behavior of the crushed stone was observed in the trainer at Chanute AFB.

Overall, the results of the experiments described above showed little or no difference between the two sizes of crushed stone with respect to either the rate of fuel spread over the surface or the fire characteristics.

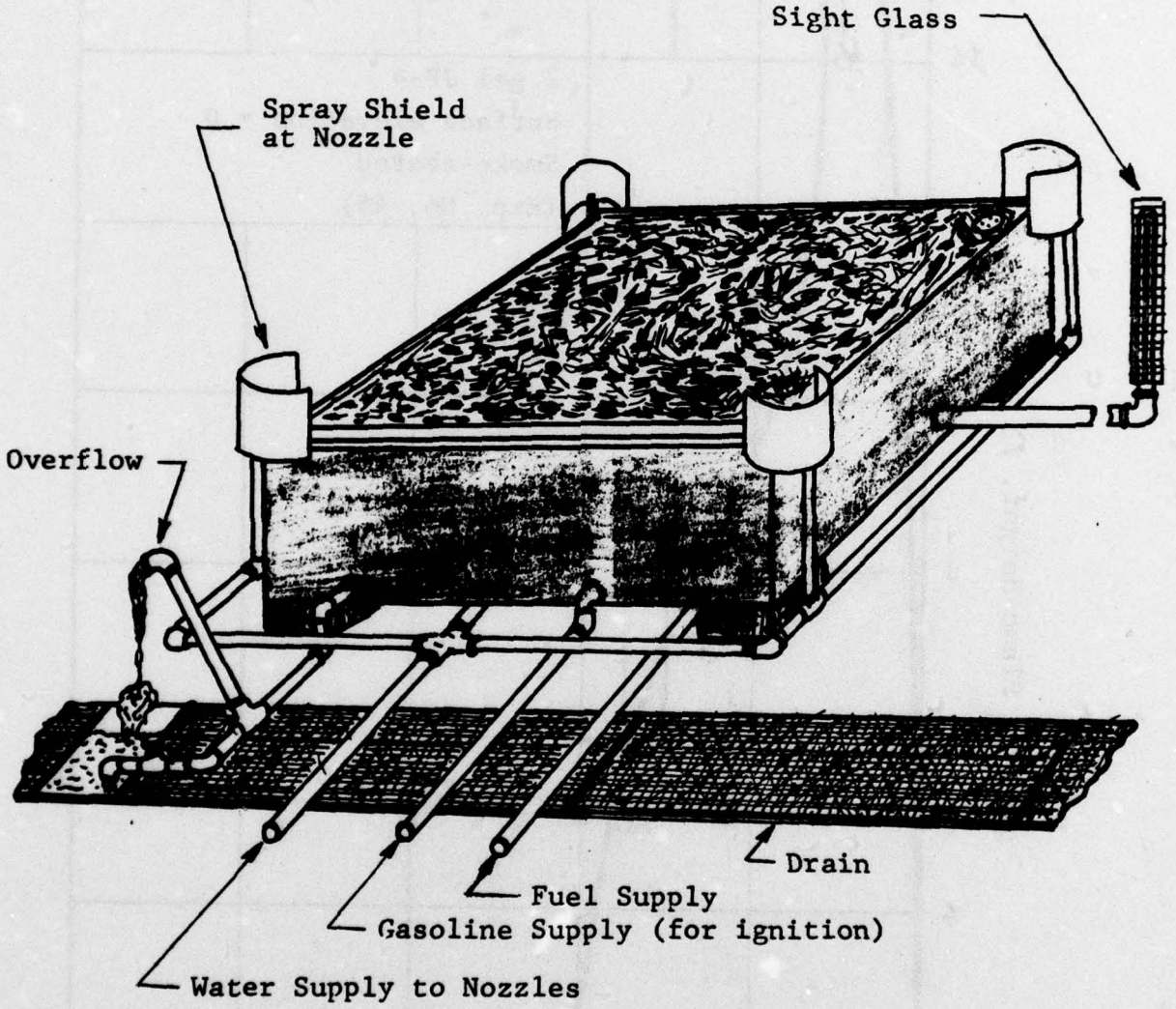


Figure 1. Schematic Diagram of Model Tank

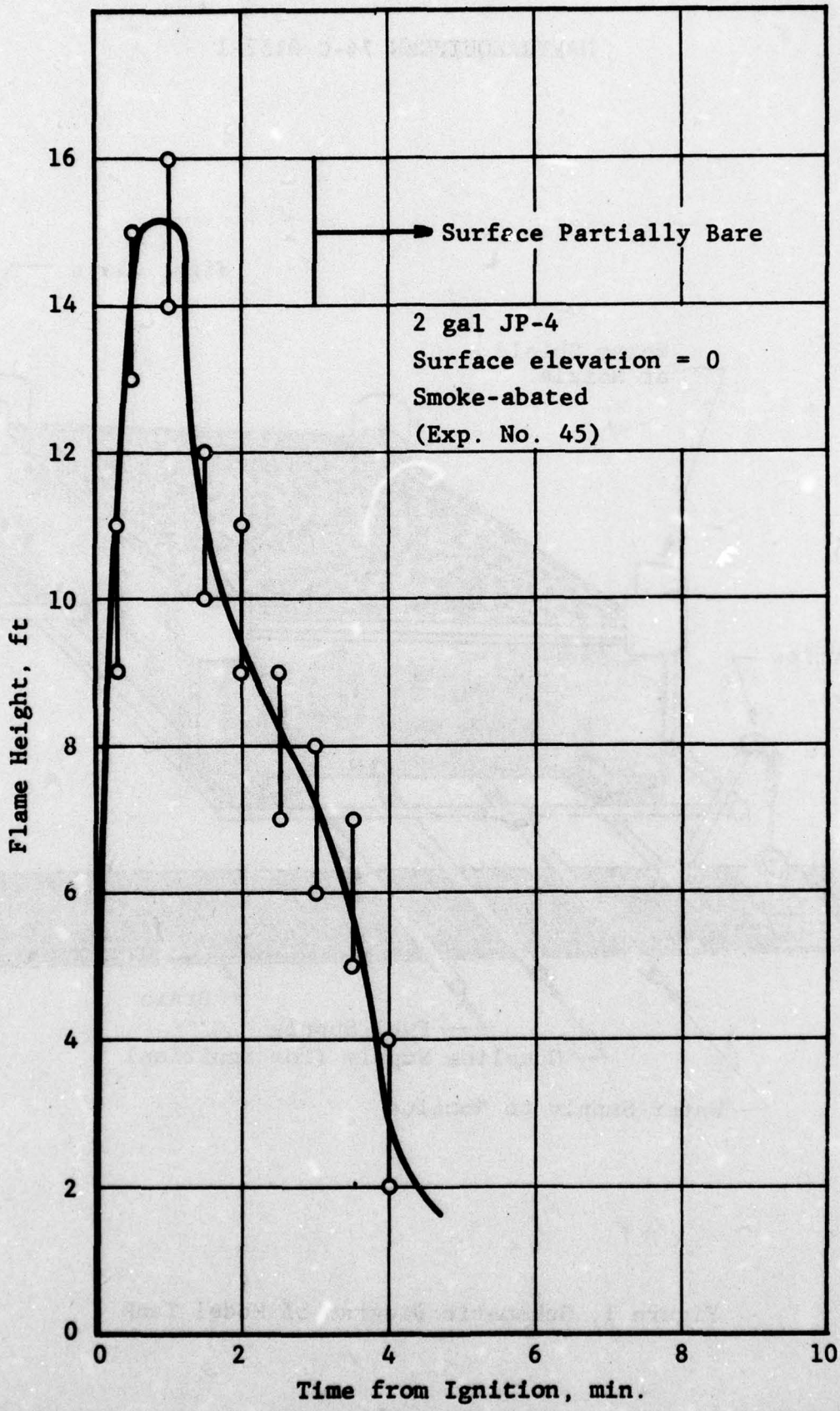


Figure 2. Variation of Flame Height with Time in 4- by 4-foot Tank

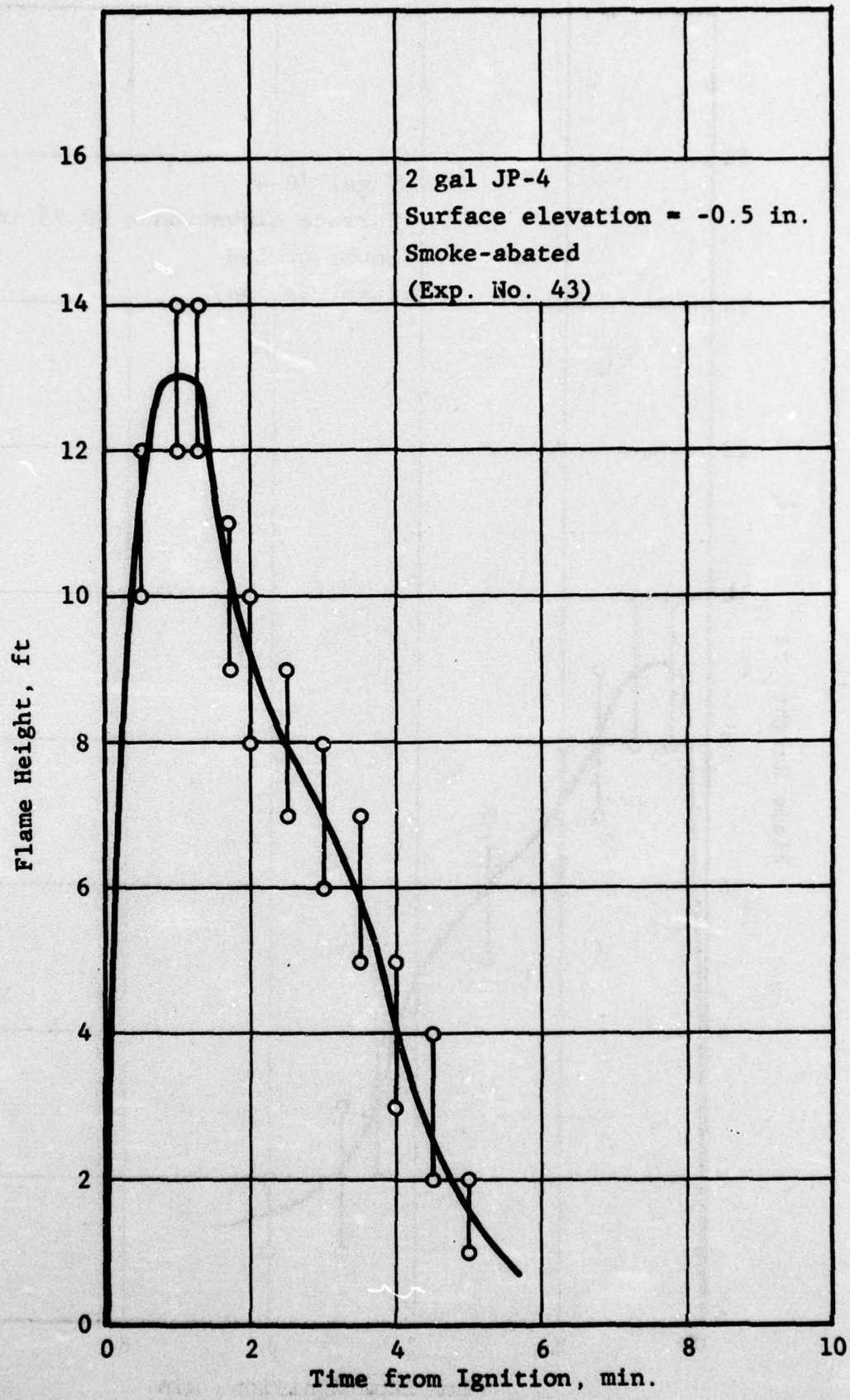


Figure 3. Variation of Flame Height with Time in 4- by 4-foot Tank

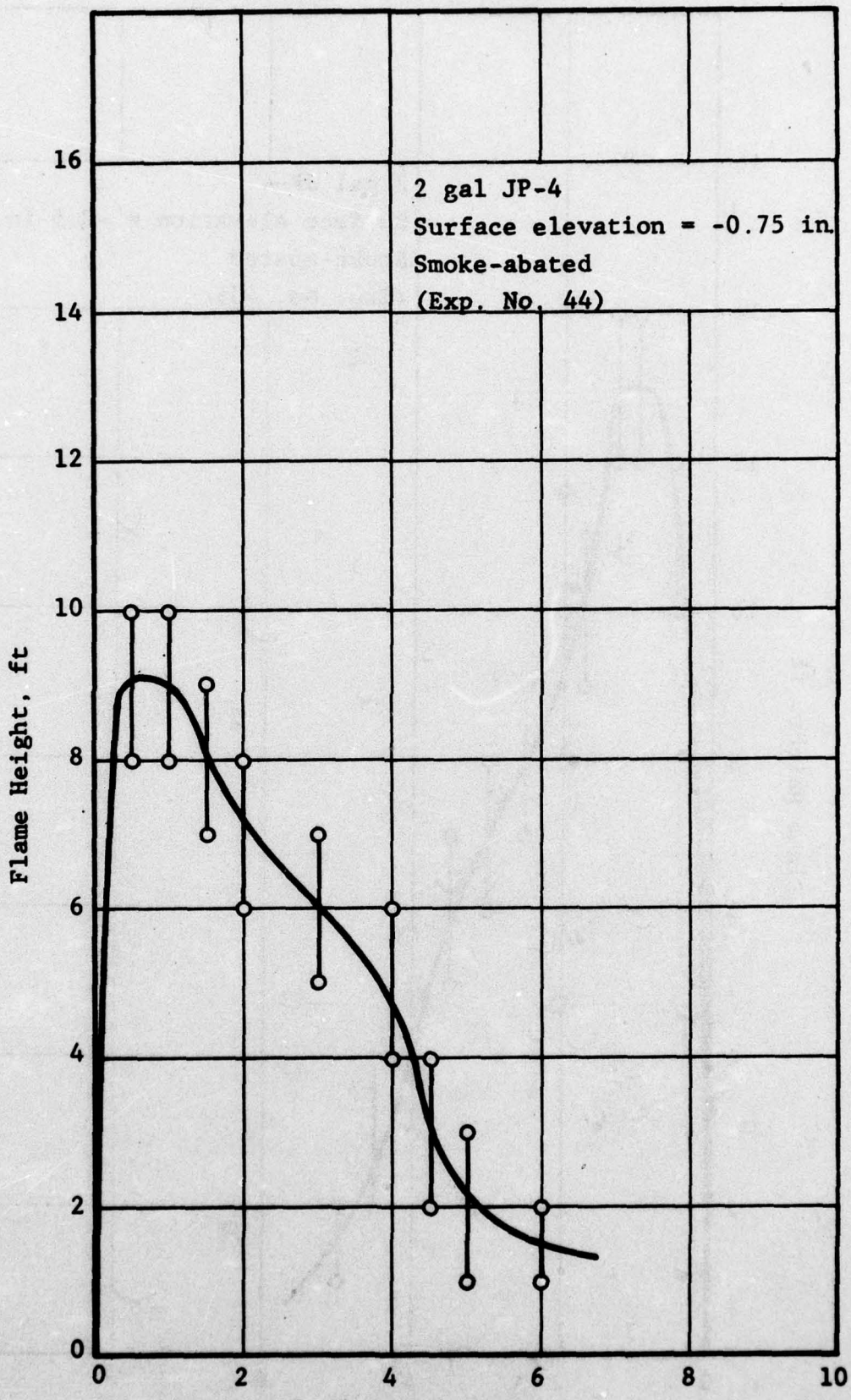


Figure 4. Variation of Flame Height with Time in 4- by 4-foot Tank

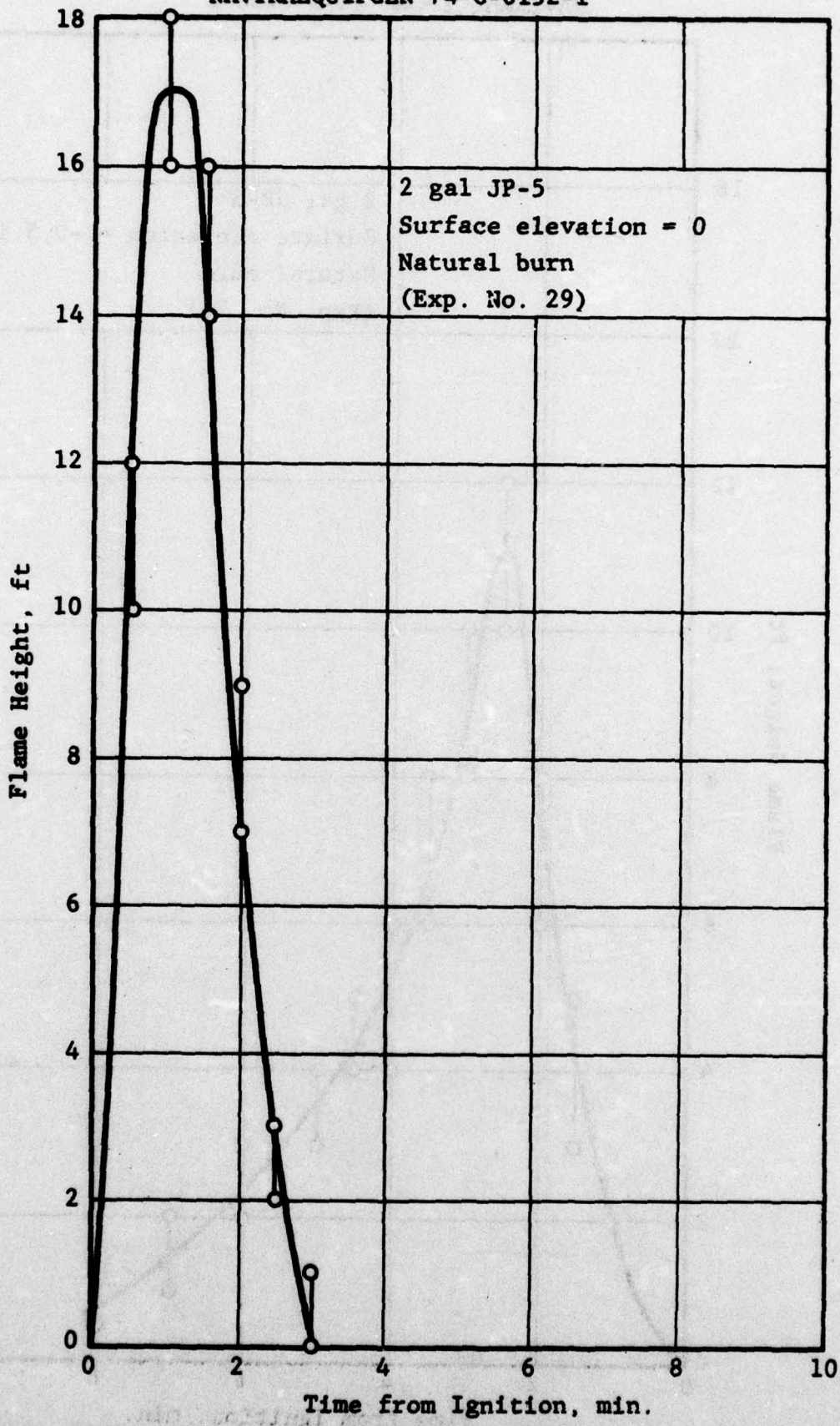


Figure 5. Variation of Flame Height with Time in 4- by 4-foot Tank

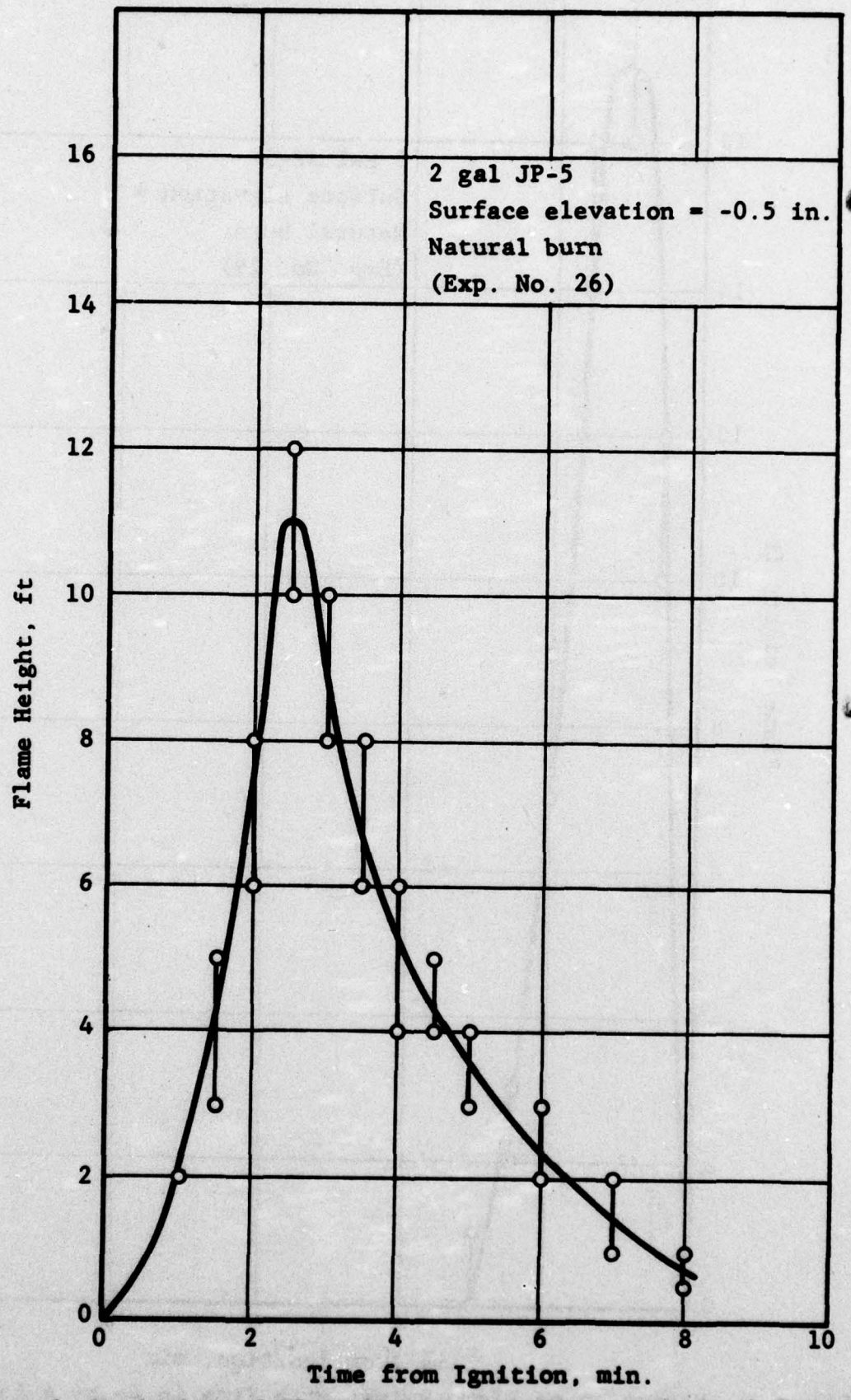


Figure 6. Variation of Flame Height with Time in 4- by 4-foot Tank

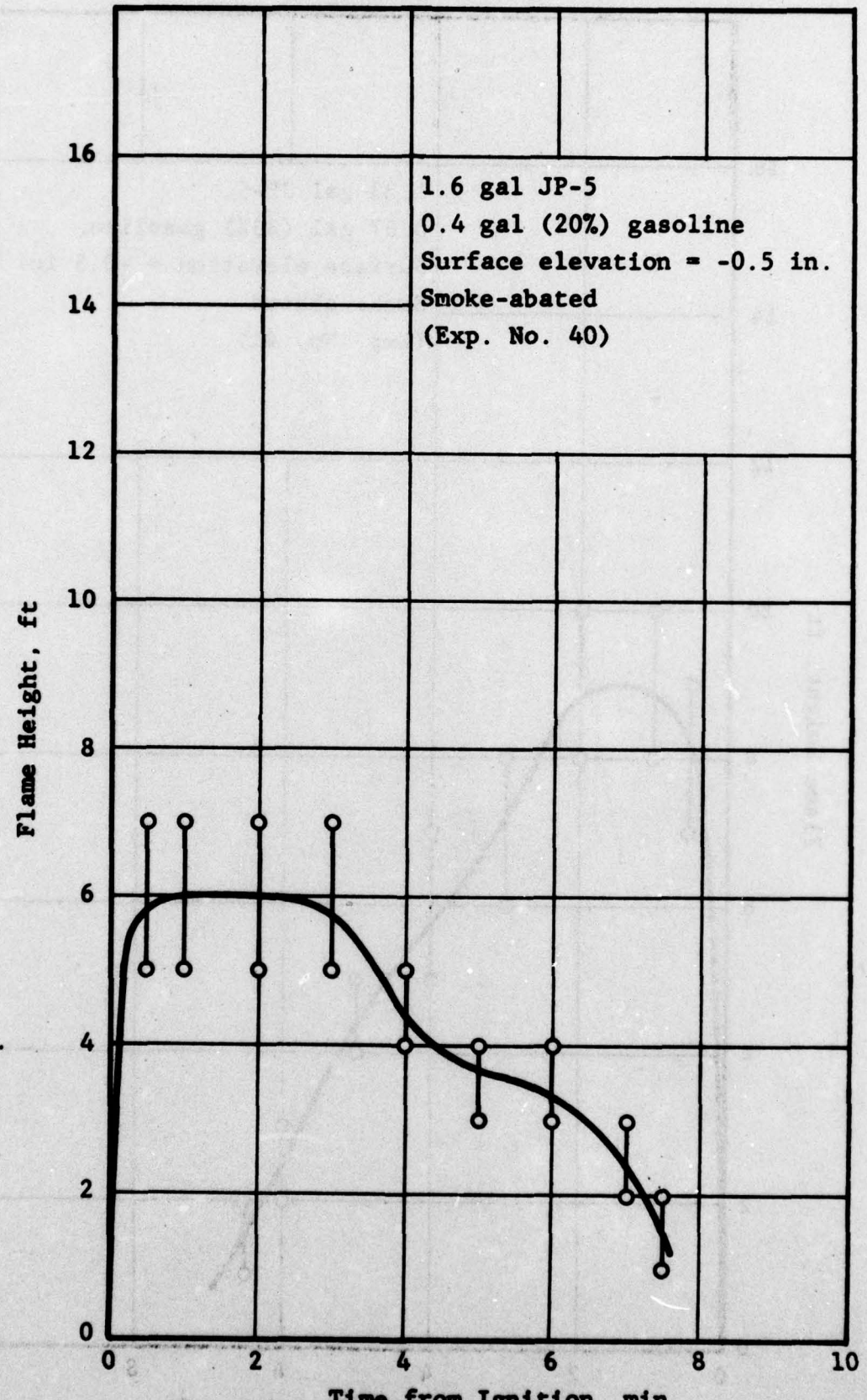


Figure 7. Variation of Flame Height with Time in 4- by 4-foot Tank

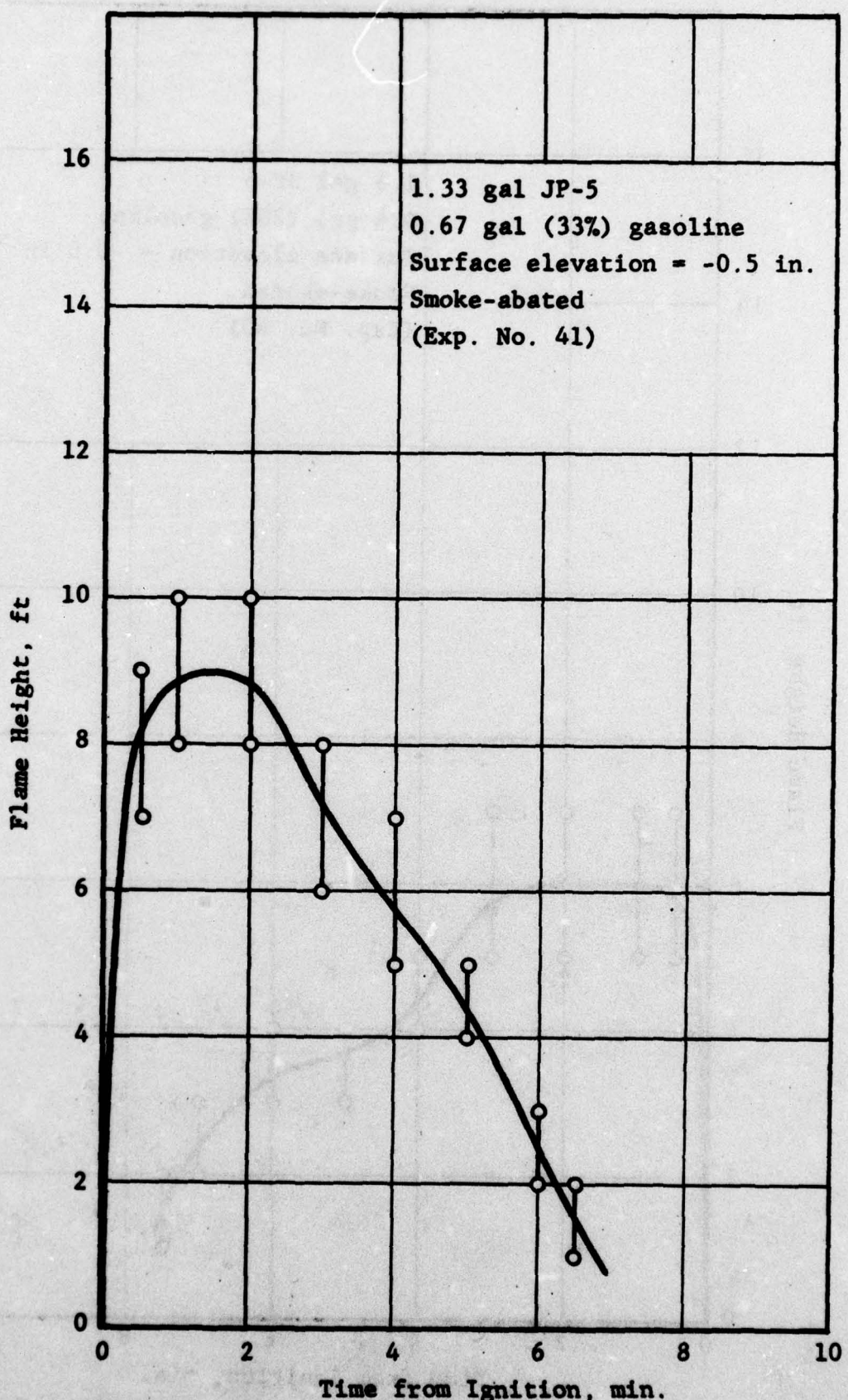


Figure 8. Variation of Flame Height with Time in 4- by 4-foot Tank

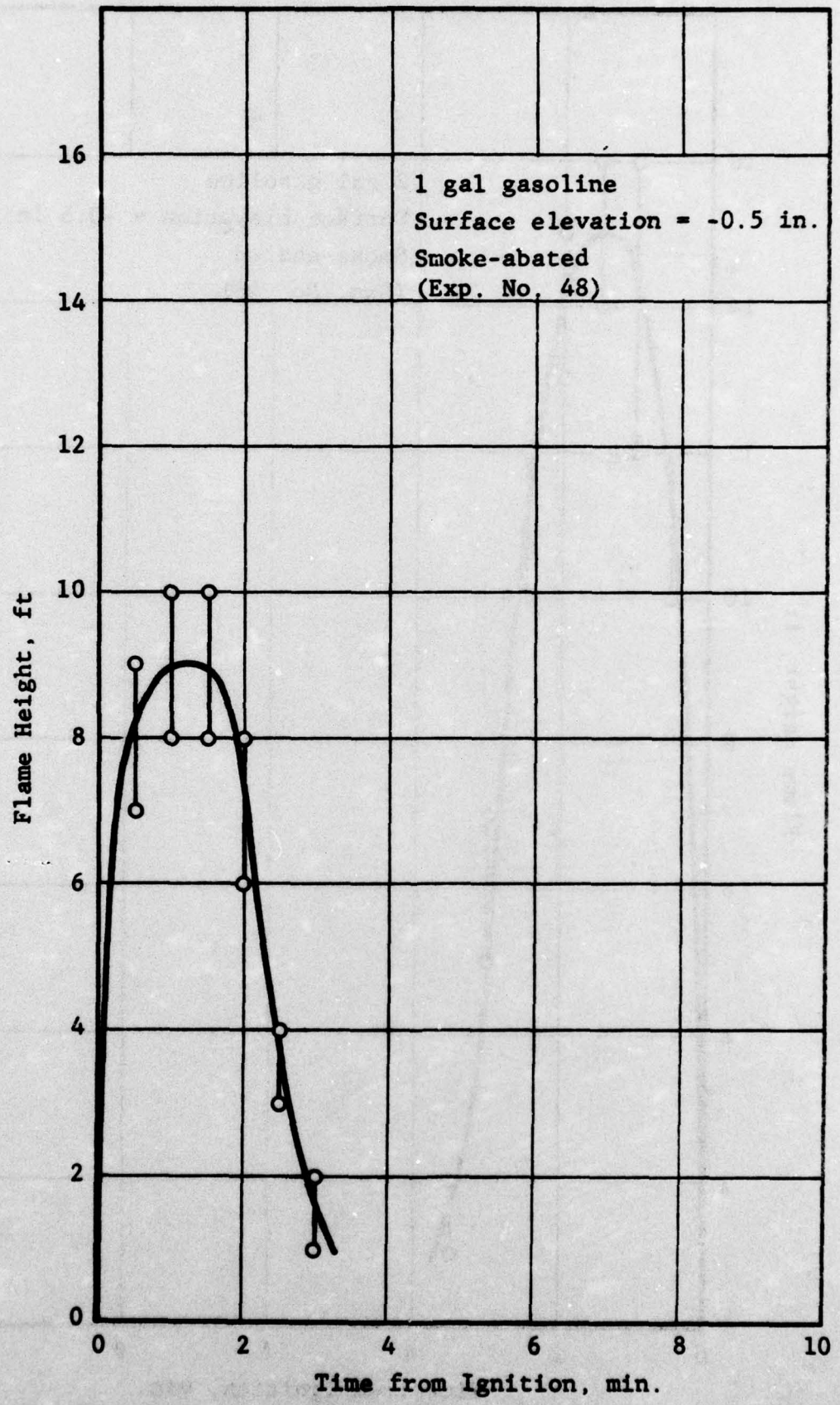


Figure 9. Variation of Flame Height with Time in 4- by 4-foot Tank

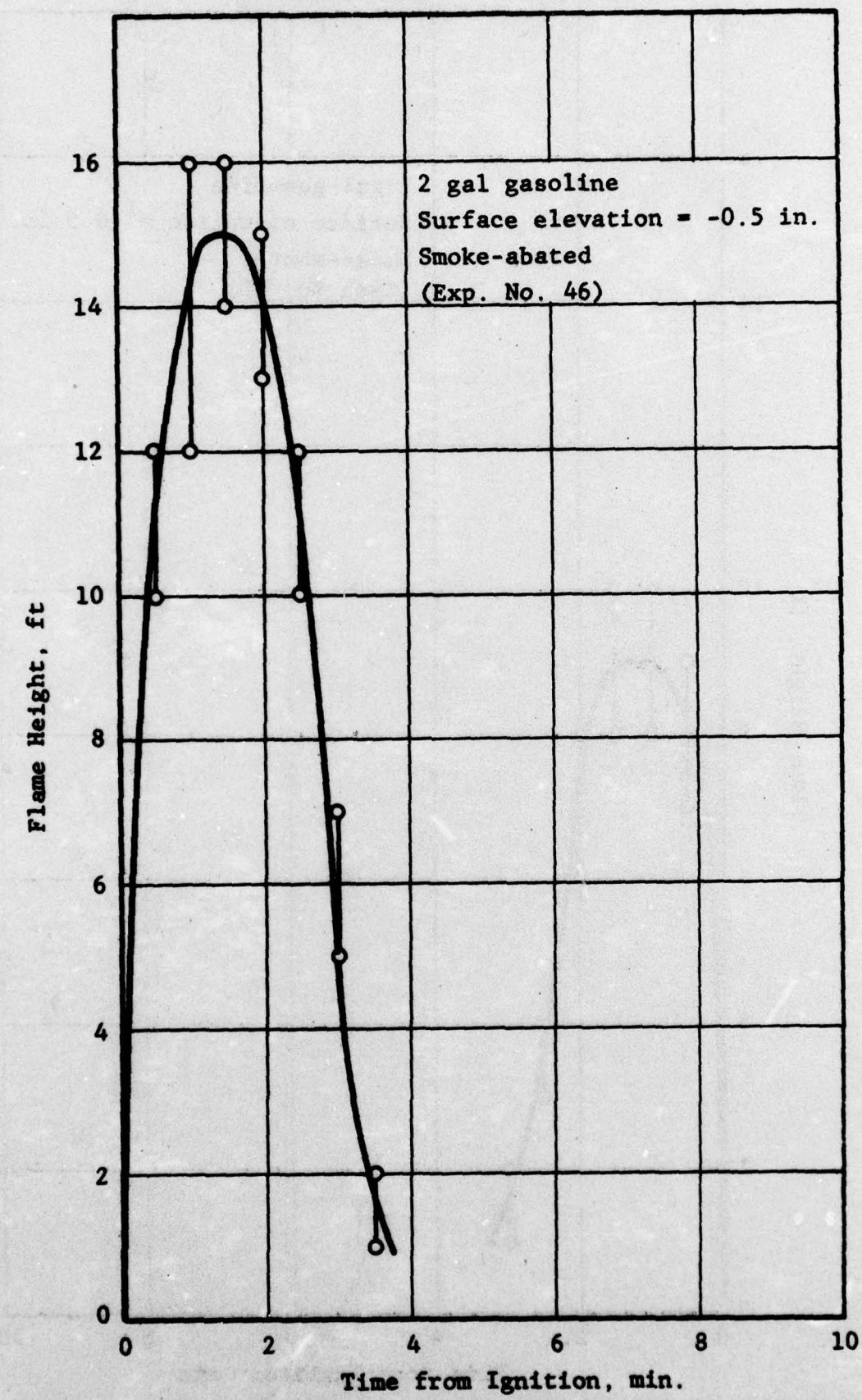


Figure 10. Variation of Flame Height with Time in 4- by 4-foot Tank

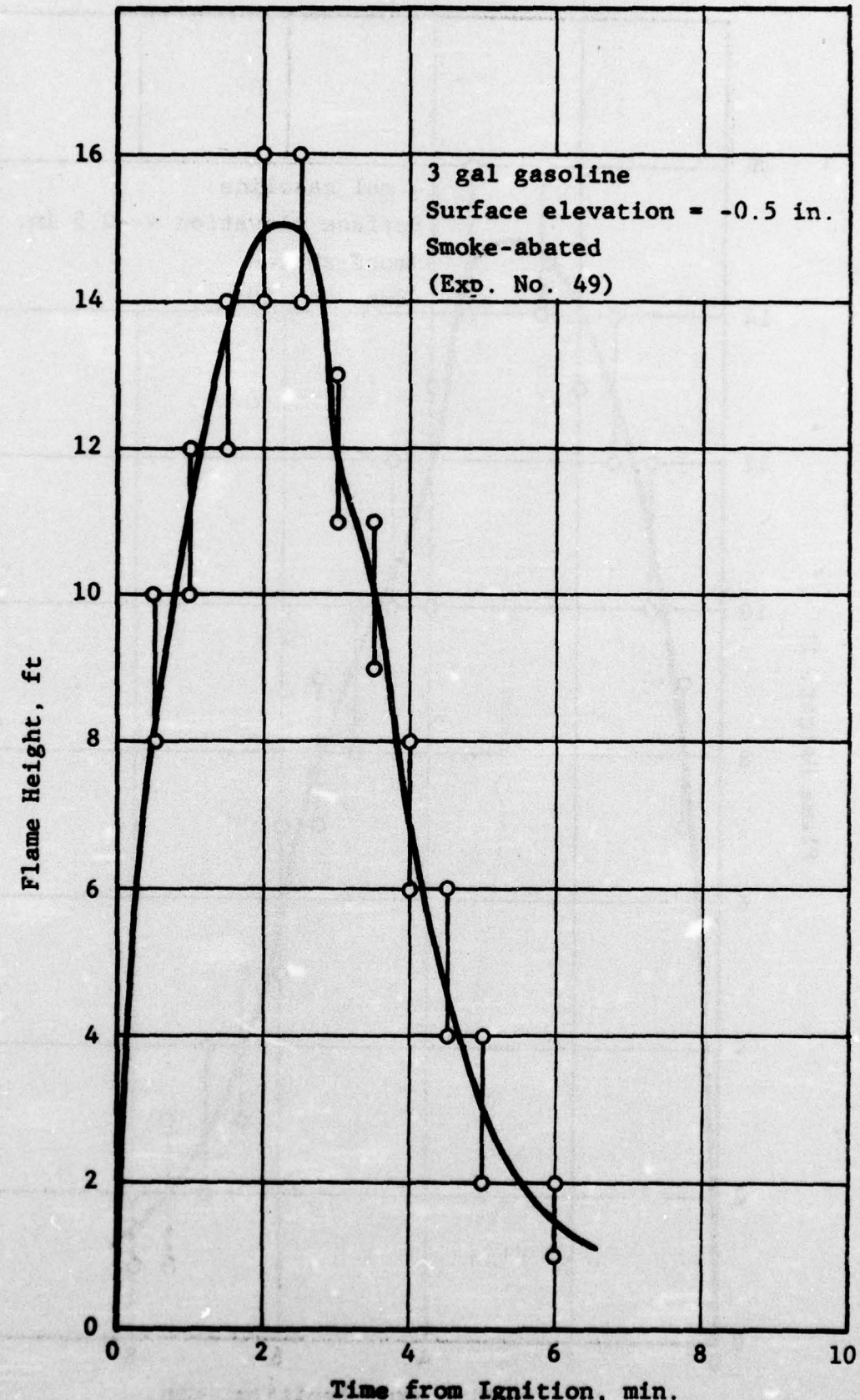


Figure 11. Variation of Flame Height with Time in 4- by 4-foot Tank

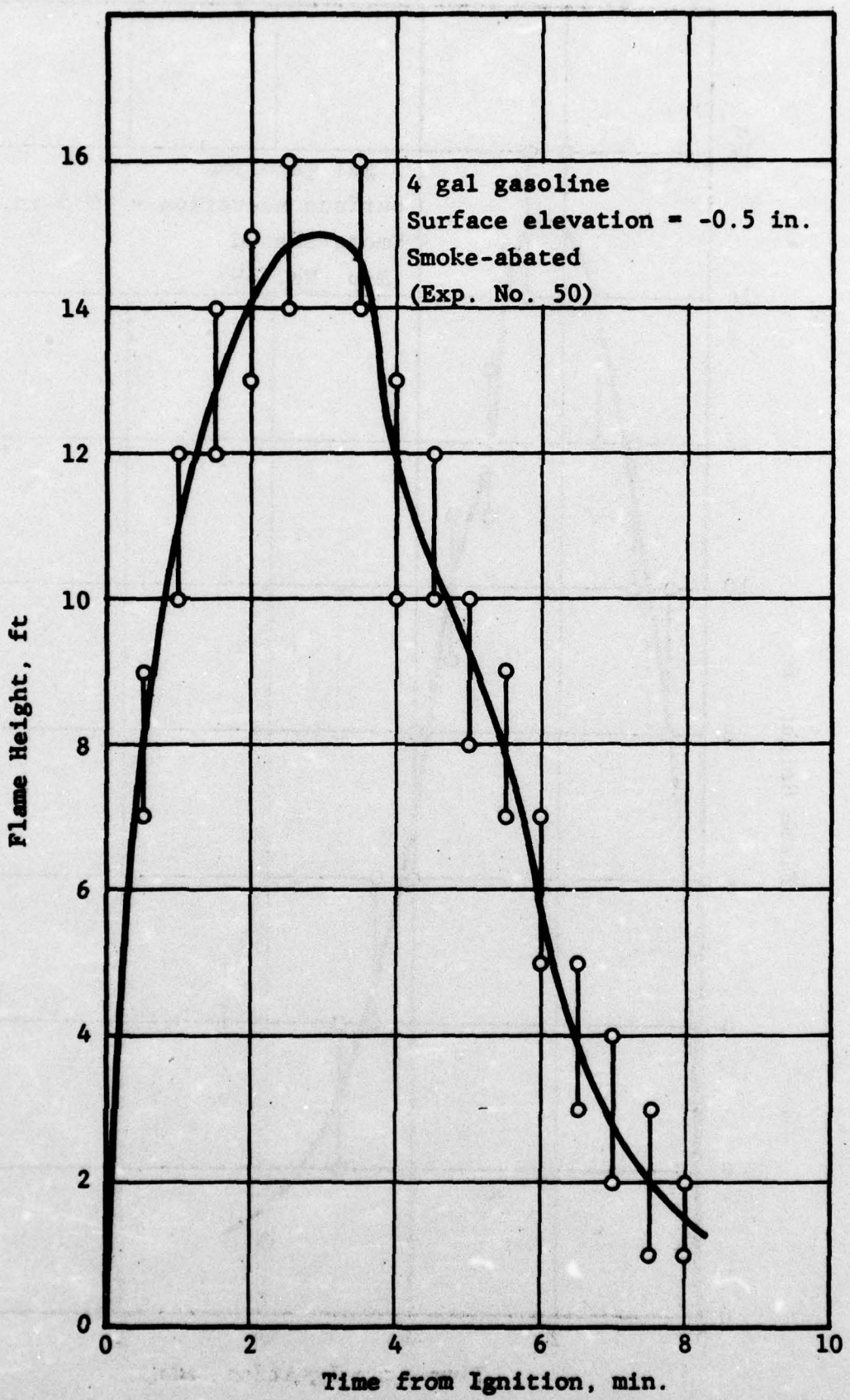


Figure 12. Variation of Flame Height with Time in 4- by 4-foot Tank

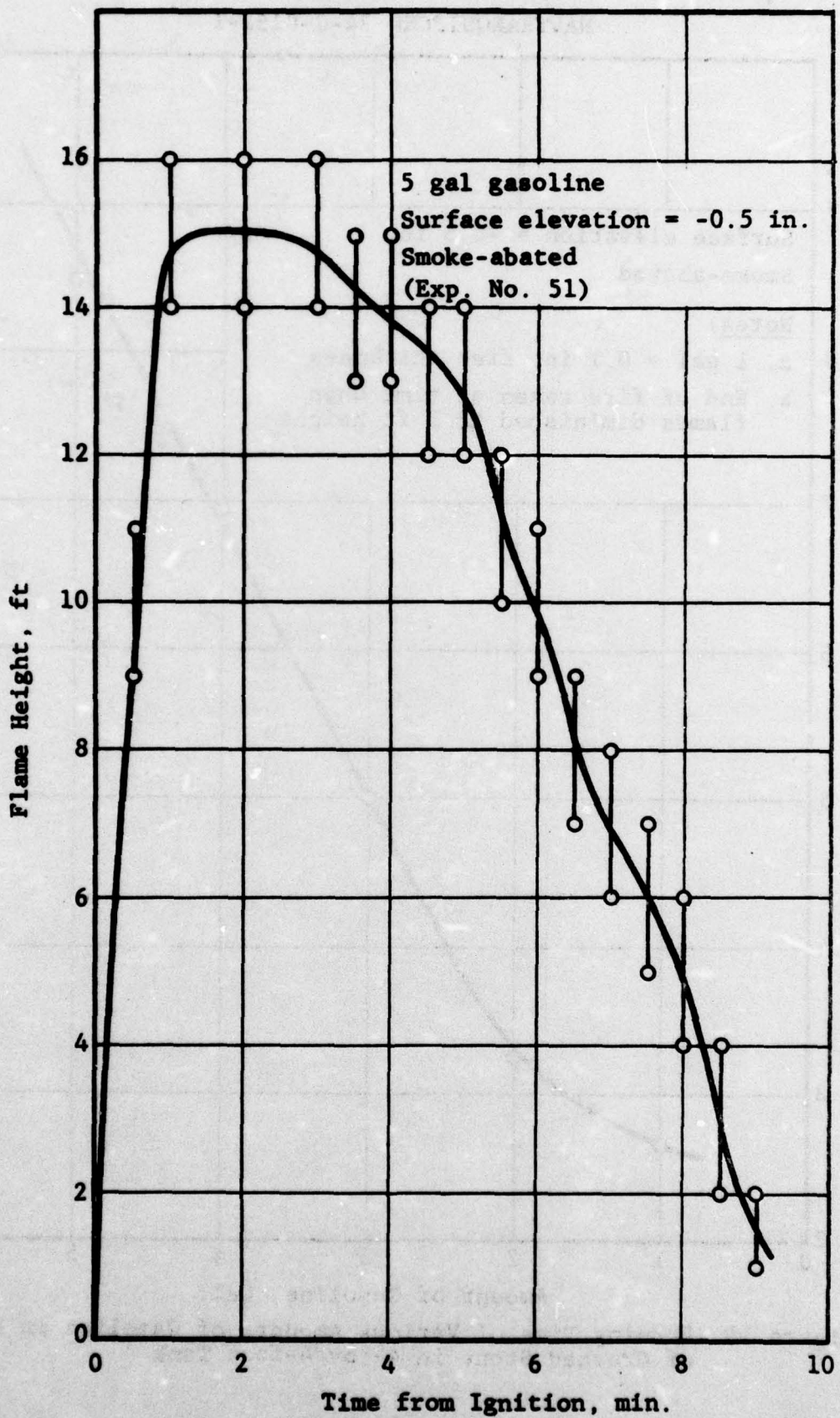


Figure 13. Variation of Flame Height with Time in 4- by 4-foot Tank

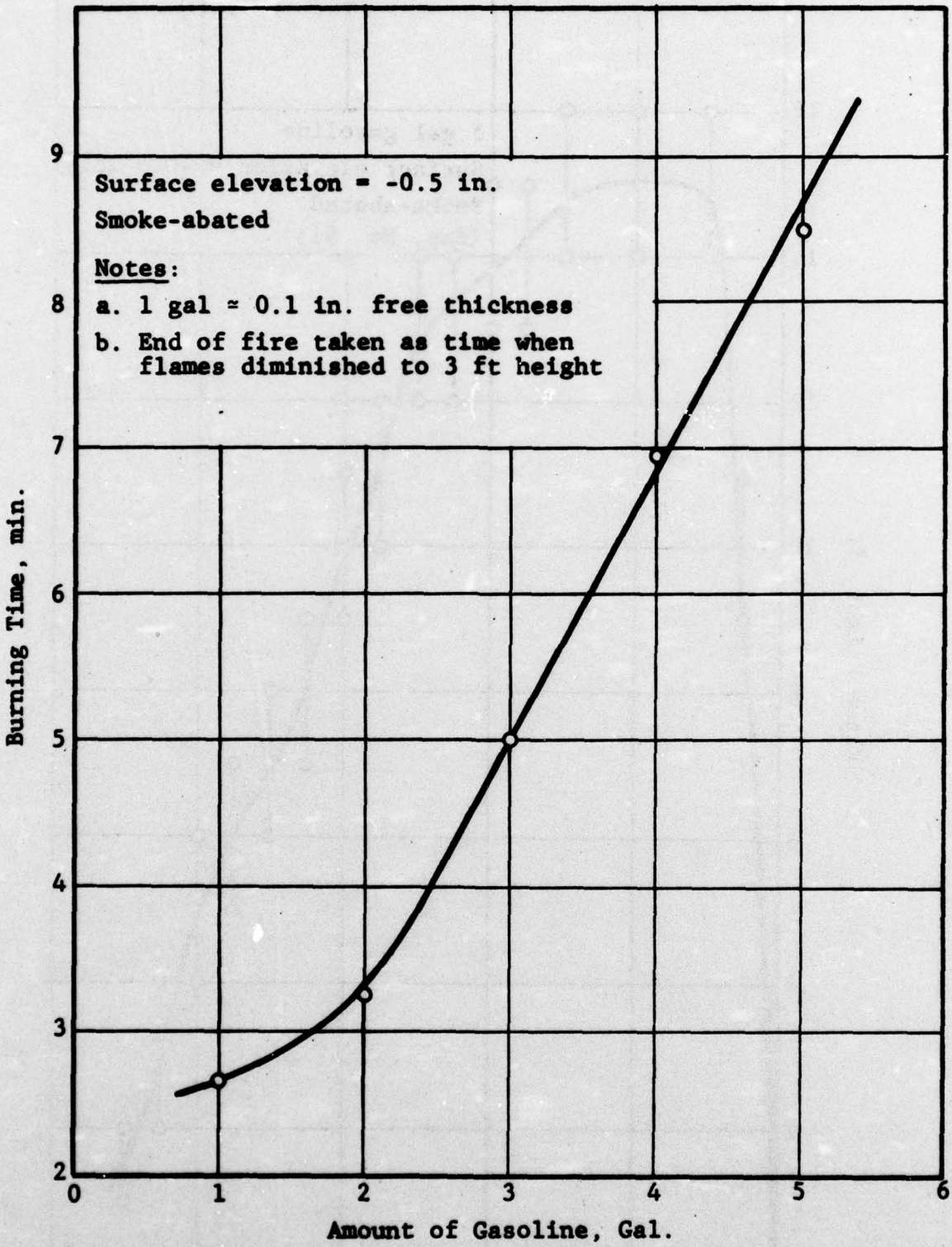


Figure 14. Burning Time of Various Amounts of Gasoline in Layer of Crushed Stone in 4- by 4-foot Tank

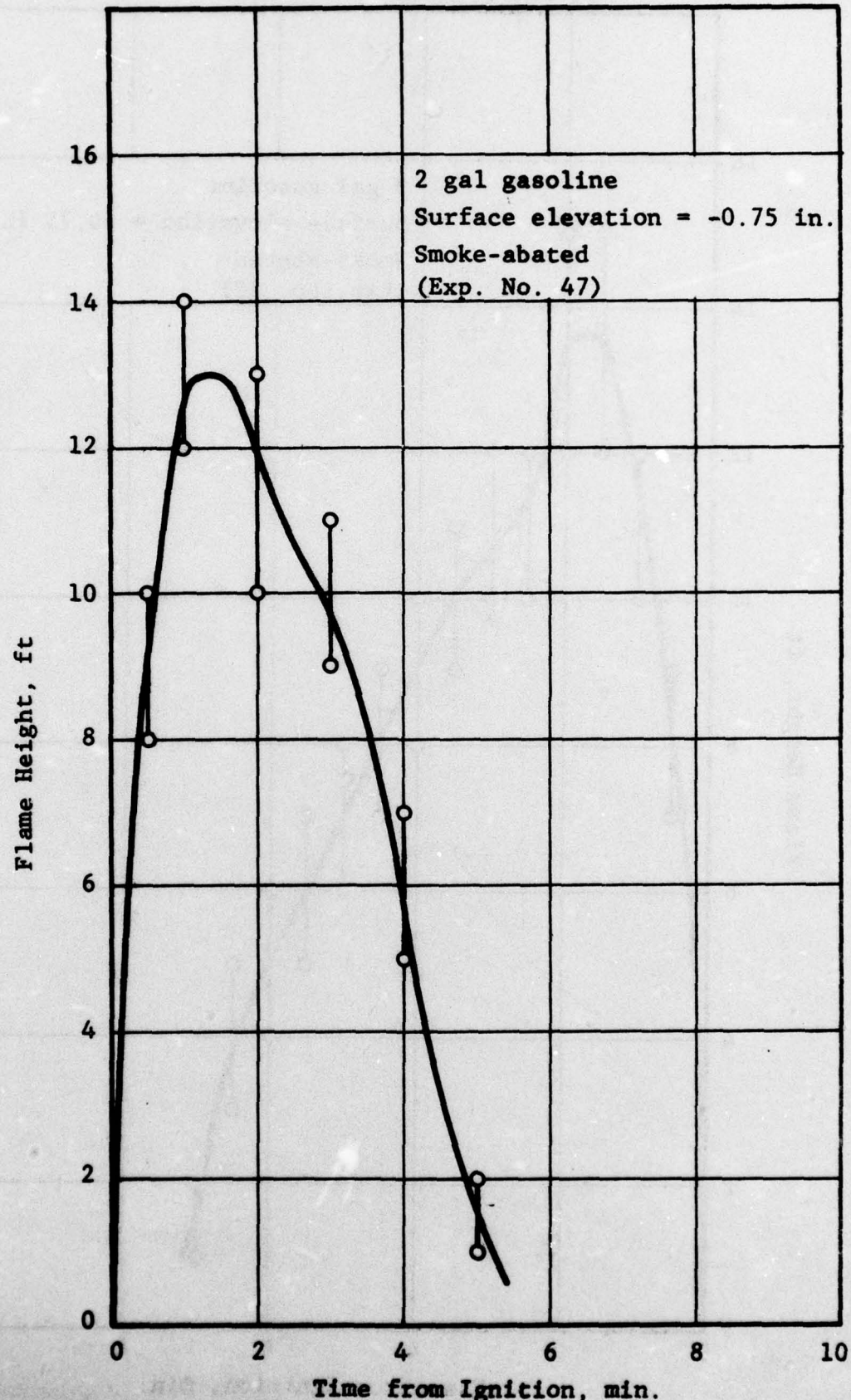


Figure 15. Variation of Flame Height with Time in 4- by 4-foot Tank

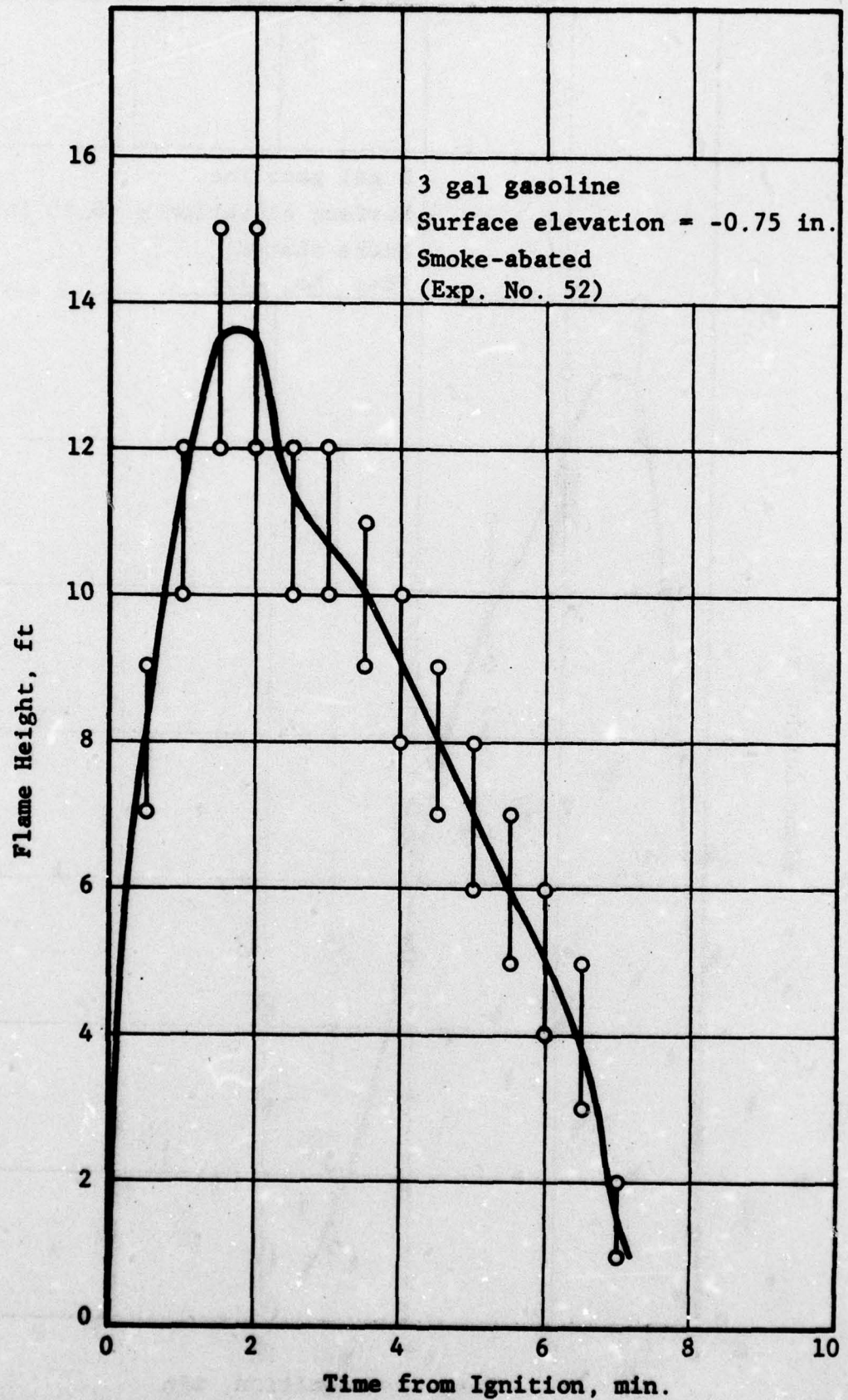


Figure 16. Variation of Flame Height with Time in 4- by 4-foot Tank

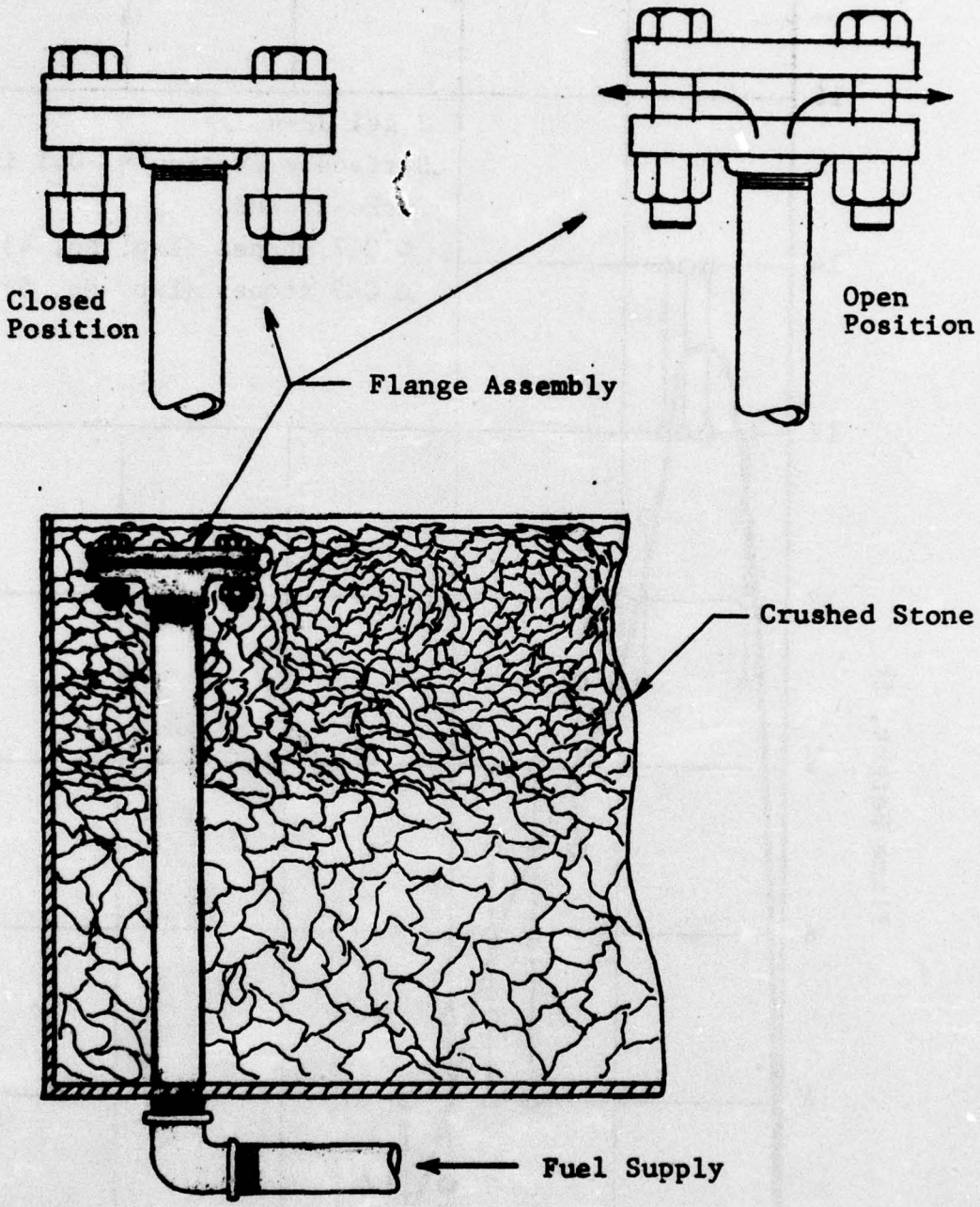


Figure 17. Schematic Diagram of Fuel Outlet in Model Tank

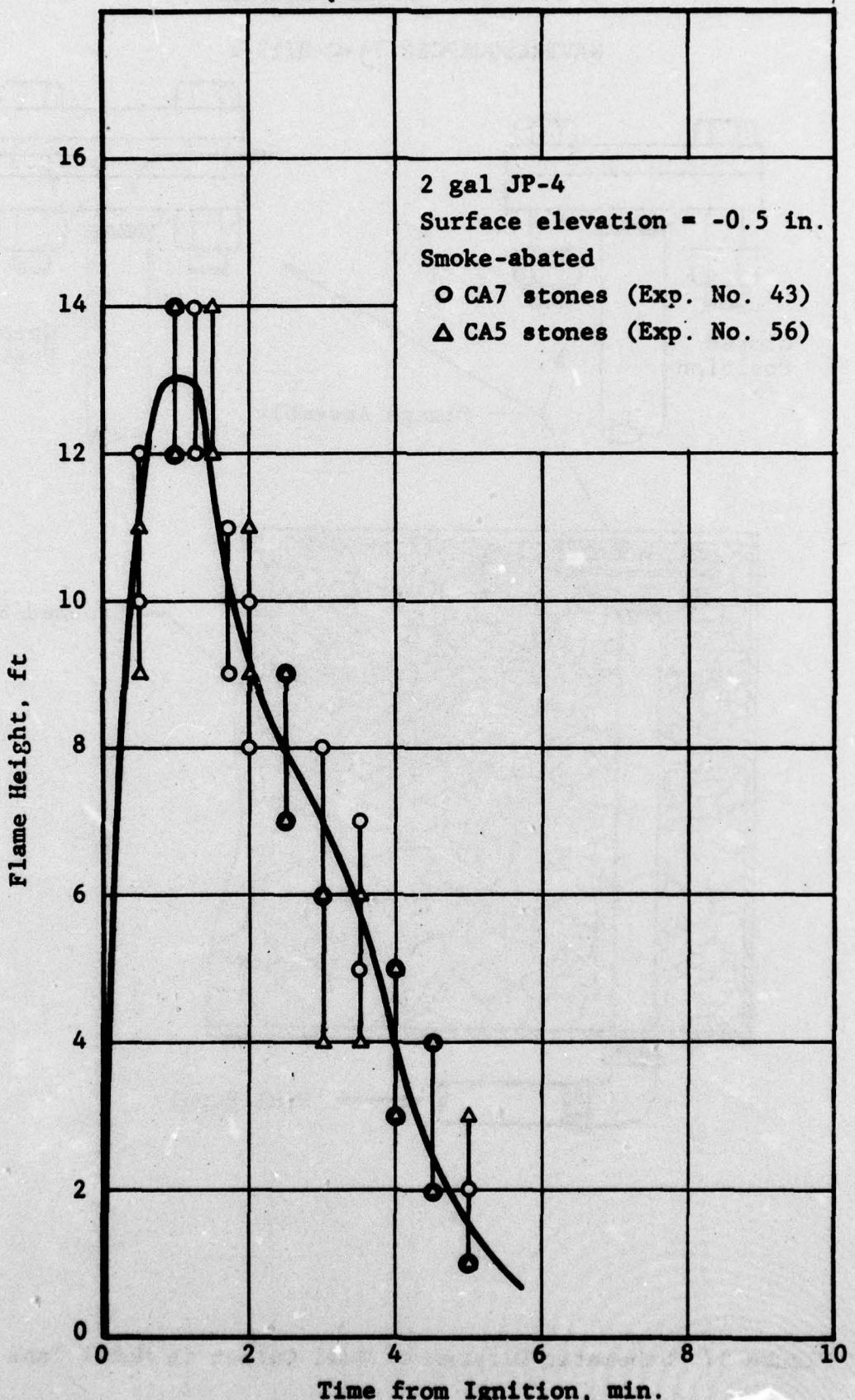


Figure 18. Effect of Stone Size on Flame Heights and Burning Time

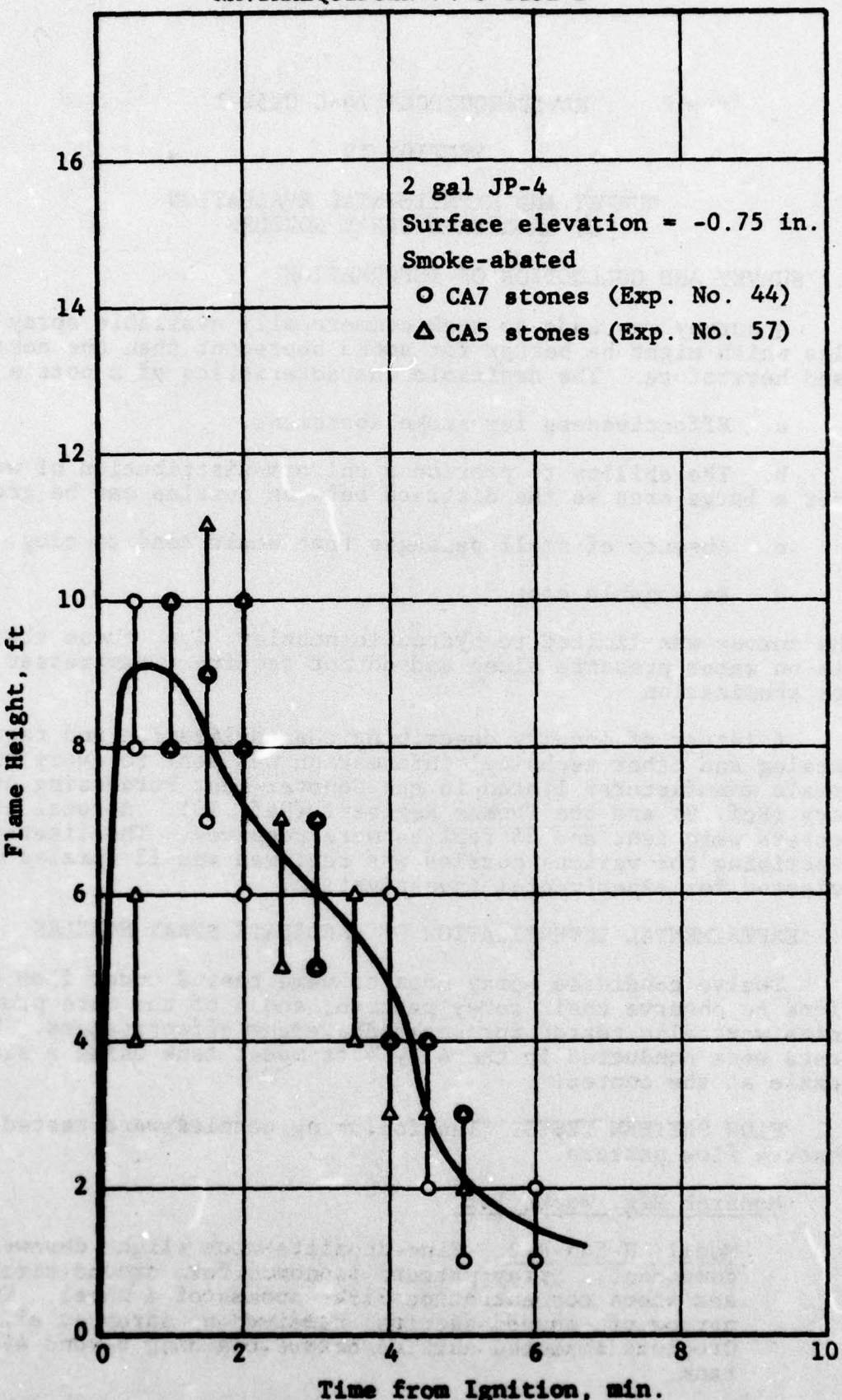


Figure 19. Effect of Stone Size on Flame Heights and Burning Time

SECTION IV

SURVEY AND EXPERIMENTAL EVALUATION OF CANDIDATE SPRAY NOZZLES

1. SURVEY AND COLLECTION OF INFORMATION

A survey was made to seek commercially available spray nozzles which might be better for smoke abatement than the nozzles used heretofore. The desirable characteristics of a nozzle are:

a. Effectiveness for smoke abatement.

b. The ability to provide a uniform distribution of water over a large area so the distance between nozzles can be great.

c. Absence of small passages that would tend to clog.

d. Reasonable cost.

The survey was limited to hydraulic nozzles; i.e. those that operate on water pressure alone and do not require a compressed gas for atomization.

A letter of inquiry describing the application and requesting catalog and other technical information was sent to every spray nozzle manufacturer listed in the Conover-Mast Purchasing Directory (Ref. 9) and the Thomas Register (Ref. 10). A total of 96 letters were sent and 44 replies were received. The literature describing the various nozzles was reviewed and 12 nozzles were selected for experimental investigation.

2. EXPERIMENTAL INVESTIGATION OF CANDIDATE SPRAY NOZZLES

Twelve candidate spray nozzles were tested under flow conditions to observe their spray pattern, and 4 of the more promising units were also tested for smoke abatement effectiveness. The tests were conducted in the 4 by 4 ft model tank using a single nozzle at the center.

2.1 FLOW PATTERN TESTS. The following nozzles were tested to observe flow pattern.

Monarch Mfg. Works Inc.

Model: H-545-R-2. Fine droplets with slight downward component. Spray pattern is nonuniform around circle and shows concentrations like spokes of a wheel. Two narrow pie-shaped sections received no spray at all. Droplets impacted surface before reaching beyond 4-ft tank.

Model: "Non-Clog" 1/4 in. orifice, 160°. (Catalog Fig. 629) Fine droplets with considerable lift above horizontal. Nonuniform distribution around circle.

Wm Steinen Mfg. Co., Industrial Nozzle Division

Model: "Span-jet" No. P151 180°. Spray with slight downward component. Pattern shows concentrations like spokes of wheel that seems to rotate.

Model: "Span-jet" No. P202 180°. Horizontal spray with uniformly distributed droplets. Nozzle imposes high pressure drop but offers good pattern.

Rain Jet Corp.

Model: 59C. Pop-up nozzle that rotates, has high water output with large droplets and some lift above horizontal. Spray pattern has very long reach.

Schnitzer Alloy Products Co., (Bete Fog Nozzles)

Model: Bete AA6W, 180°. Fine droplets with considerable lift. Nonuniform pattern around circle with nonuniform radial distances. Nozzle is tall and pointed and would constitute a hazard to personnel. Nozzle offers little pressure drop and is inherently nonclogging.

Model: Bete TF8XW. Horizontal spray with uniformly distributed fine droplets but nonuniform radial distance of droplet reach. Spray layer has thickness in vertical plane. Nozzle offers little pressure drop and is inherently nonclogging.

Model: Bete TF8W, 180°. Similar to TF8XW above, but spray pattern showed some lift above horizontal with finer droplets and uniform distribution.

Spraying Systems Co.

Model: "Parasol" E-2. Fine uniform droplets with some lift above horizontal. Short radial reach of spray.

Model: "Parasol" E-5. Fine droplets with mist. Lift above horizontal greater than for Model E-2 above. Relatively short radial reach of spray with nonuniform distances around circle.

Model: "Parasol" E-8. Similar to E-5 above, but with greater flow and lower lift above horizontal.

Model: "Stream Jet" 7421-1/2T-1210. A number of individual jets distributed around circle and ejecting water at large angle above horizontal. Long reach of jets but with very little surface coverage.

2.2 SMOKE ABATEMENT TESTS. The following nozzles were tested to observe their smoke abatement effectiveness. A single nozzle was mounted in the center of the 4 by 4 ft model tank and was used to abate smoke from a JP-4 fire. Two gallons of fuel were used for each burn, with the fuel surface above the surface of the crushed stone in the tank.

Wm Steinen Mfg. Co., Industrial Nozzle Division

Model: "Span-Jet" No. P202, 180°. Insufficient smoke abatement in 4 ft tank even at high water pressures (about 100 psi). Flow resistance of nozzle is too great.

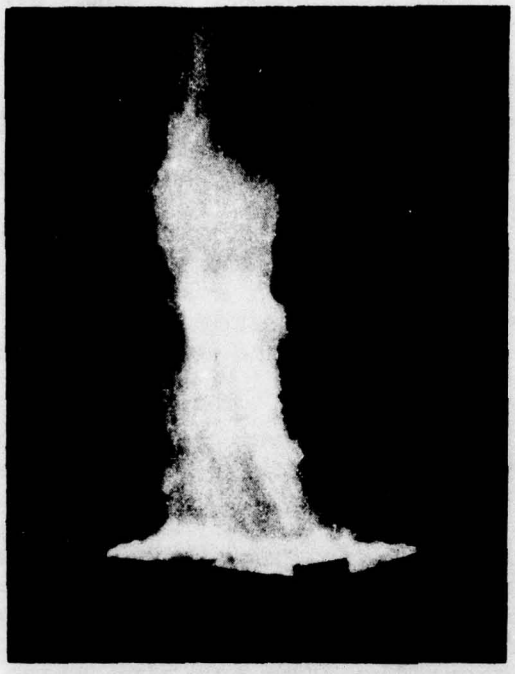
Schnitzer Alloy Products Co. (Bete Fog Nozzles)

Model: Bete AA6W, 180°. Excellent smoke abatement. Nozzle causes necking of fire so cross-section of fire is much smaller than area of fuel tank (Fig. 20a). Flame heights are comparable to natural fire.

Model: Bete TF8W, 180°. Effective smoke abatement. Necking effect is less severe than with Model AA6W above, but still very pronounced. Flame heights are comparable to natural fire. Generates a noticeable whooshing noise.

Model: Bete TF8XW. Effective smoke abatement. This nozzle has unique characteristics in comparison with others tested to date. It causes an intense fire covering the entire tank and increases the heating sensed by an observer. Overall, it seemed to create the most ferocious fire seen to date in the smoke abated mode (Fig. 20b).

The Bete nozzles were attractive from a viewpoint of smoke abatement, and because they have the added advantages of operating at relatively lower head pressures and having no obstructions or fine passages that could cause clogging. The results of field experiments with Bete nozzles are described in Section V-4.1.2.



a. Bete Nozzle Model AA6W



b. Bete Nozzle Model TF8XW

Figure 20. Effect of Nozzle Type on Smoke Abated Fires

SECTION V

FIELD INVESTIGATIONS

1. DESCRIPTION OF FIRE-FIGHTING TRAINING AREA AT CHANUTE AIR FORCE BASE

The aircraft crash/rescue fire training area at Chanute AFB contains several full-scale aircraft mock-ups in sizes ranging from fighter aircraft to a large bomber. Their layout is shown in Fig. 21. These are located in an area surrounded on three sides by an open drainage ditch leading to a sump which also serves as a gravity-type fuel-water separator. The fuel is skimmed off the surface, and the water from the sump is pumped to a sewage plant.

The fire area surrounding each mock-up is provided with fuel outlets that spray JP-4 over the ground. A torch is then used for ignition. The fuel outlets consist of drilled pipe fittings mounted on pipe stubs projecting about 2 to 3 ft above ground. Fuel is supplied through a common underground supply pipe and can be directed to any one of the several trainers by opening an underground valve to the desired trainer. A fuel meter and on-off valve are mounted in the supply line. The fuel storage tank and pump are located beyond the fire training area.

A typical training exercise involves the following sequence of events:

a. Delivery of measured amount of fuel to fire area

b. Ignition (by torch)

c. Short delay for fire spread and development

d. Injection of additional measured amount of fuel

e. Extinguishment by trainees guided by instructors

2. DESCRIPTION OF SMOKE-ABATED TRAINER

A prototype smoke-abated trainer utilizing the water spray method was designed by Air Force personnel and installed by a local construction firm under AF contract on the site of one of the smaller trainers at the Chanute fire training area. Construction of the trainer was nearly complete at the time this program began. The trainer included a mock-up of the F-102 fighter, and is located nearest to the existing open ditch. In addition to the prototype trainer, a pump house facility was built at a central location with respect to the several trainers with the expectation that the other trainers will be upgraded to the smoke-abated mode in the future. Sufficient pumping capacity was

installed to serve the largest trainer in the area. These facilities, as originally built, are described in the following subsections 2.1 to 2.3. The size of the smoke-abated trainer and its location relative to the pump house and the drainage ditch are shown in Fig. 22.

2.1 FIRE AREA. The trainer area has the general shape of a delta wing aircraft and is of a size that allows an open fire area all around the aircraft mock-up (not shown in Fig. 22). The fire area is surrounded by a concrete curb, and water drains are located on opposite sides of the trainer, just outside the curb, as shown in Fig. 22.

2.1.1 Soil Base. The soil base of the trainer consists of the following three layers, from the surface downward:

a. A layer of CA7 crushed stone (see Table 4, p. 13)

b. A 3-in. layer of bituminous concrete (minimum 8% asphalt)

c. A sublayer of pit run gravel

The bituminous layer was intended as a water barrier and is pitched toward the drains. Thus the top layer of crushed stone is only 6 in. thick along the longitudinal centerline of the trainer and near the curbs at the nose and tail, and about 14 in. thick at the drain.

2.1.2 Piping Systems and Zone Arrangement. The trainer is equipped with two piping systems--one for delivering fuel and the other for delivering water to the spray nozzles.

2.1.2.1 Fuel Piping. Fuel is supplied to the trainer through a piping network with outlets in the trainer area located in a square array on 8-ft centers. When a fuel valve to a given trainer is opened, all the fuel pumped and passing the meter is delivered to the given trainer. All the fuel distribution piping within the trainer, except the main supply pipe, was installed above the bituminous layer and was therefore accessible. The outlets were below the surface of the crushed stone and consisted of drilled pipe caps mounted on vertical pipe nipples. There were no fuel outlets in the area normally occupied by the fuselage of the mock-up.

2.1.2.2 Water Piping. The water distribution piping supplying the spray nozzles in the trainer was divided into 8 separately controlled systems, each delivering water to a single zone in the trainer. The zone layout is shown in Fig. 23. The water was supplied from the pump house, which contained both the pumps and the control valves.

Water spray nozzles in the trainer area were located in a square array on 4-ft centers, with the nozzles protruding above the surface of the crushed stone. There were no spray nozzles in the area normally occupied by the fuselage of the mock-up. All water distribution lines were beneath the bituminous layer and therefore inaccessible. The risers feeding individual nozzles consisted of standard 1/2-in. pipes reduced to 1/8-in. female pipe thread to fit the nozzles. These risers, including the reducing fittings, were encased in 5-in. dia. concrete jackets extending more than 2 ft downward to below the bituminous layer. Each concrete jacket terminated in a 1-ft dia. pedestal. All water piping from the pump house to the trainer, except the risers just described, consisted of plastic pipe.

2.1.3 Drainage. Water deposited in the trainer area by the spray nozzles and fire extinguishing agents was removed by two drains located symmetrically on opposite sides of the trainer, outside the curb, as shown in Fig. 22. Thus all water in the trainer had to flow horizontally through the bed of crushed stone to reach a drain. The drain on the north side of the trainer was connected to the one nearer the open ditch by an underground pipe of 6-in. diameter. Separate provision was made for complete drainage of the trainer and weir cavity as freeze protection via a 2-in. dia. pipe.

The drains also were intended to serve as passive controls for maintaining a constant surface level in the trainer by means of adjustable weir plates. This arrangement is shown in Fig. 24. Flow from the trainer to the weir was via 5 holes through the curb, and the weir itself was approximately 4 ft long. The weir plate could be raised or lowered manually over a range of 4 in. This level control system did not function as intended and had to be modified as described in subsection 3.3 below.

2.2 PUMP HOUSE AND MECHANICAL EQUIPMENT. The pump house is a 3-story structure with basement located in the middle of the fire trainer area as shown in Fig. 21, and containing a water reservoir, pumps, and the control system for the smoke-abated trainer. The lower 2 stories are of concrete block walls and the third story is a glass-enclosed control tower which had previously served at the base airstrip. The basement is divided into 2 compartments, one being the water reservoir and the other a dry pit. The latter provides depth below grade so all water piping outside the pump house could be pitched towards this pit for freeze protection drainage. Water thus drained is pumped back into the reservoir.

On the first floor, immediately above the water reservoir, are two centrifugal pumps arranged in parallel to supply water at 150 psi (350 ft head) to an 8-in. supply header. These are shown in Fig. 25. Eight separate pipes extend from the header

to the individual zones in the trainer. The 1500 gpm rated capacity of the two pumps and the size of the supply header evidently were designed to provide smoke abatement for the largest trainer in the fire area.

The second floor of the pump house contains electric panels and a compressed air supply system for the pneumatic controls. The third floor control tower contains the operator's station and controls.

2.3 CONTROL STATION. The primary function of the control system is to permit the operator to vary the amount of water supplied to the spray nozzles so as to produce a fire of realistic severity without generating smoke. He observes the fire conditions and regulates the water flow accordingly. Additional controls are necessary for the water supply, pumps, and drainage.

A pneumatic control system was used, with two panels located in the control tower--one for activating the compressed air system and controlling pump pressure, and the other concerning the water flow to the 8 zones in the trainer. The latter panel had a scaled layout of the 8 zones, with a flow indicator and a flow control knob in each zone, so the operator could readily associate these items with the respective areas of the trainer that they affected.

A piping detail of a typical zone supply line is given in Fig. 26. The valves shown in this figure were located in the dry pit of the pump house, at an elevation about 5 ft below the surface of the fire area. With the air supply off--which is the normal state when the trainer is not used--the zone control valve is normally closed and the zone drain valve is open. Thus the piping system from the pump house to the nozzles is drained when not in use. When the control air is turned on, the drain valve closes, and the zone control valve responds to the manually operated flow control knob at the operator's panel in the control tower.

As originally installed, a large control valve just upstream of the 8-in. supply header (Fig. 25) served to maintain a constant pressure in the header, at a level set in the control tower. A valve that controlled the water supply to the reservoir, and a sump pump that transferred drain water from the dry pit to the reservoir were activated by floats.

3. MODIFICATIONS OF FIELD INSTALLATION

A number of changes were made in the facility at Chanute AFB either to correct original shortcomings or to facilitate performing the necessary experiments. These changes, which are described below, also were necessary to make the entire trainer

operational in the smoke abated mode so a team from the AF Human Resources Laboratory could make an evaluation of the fire-fighting training effectiveness of smoke-abated fires in comparison with natural fires.

3.1 CHANGES IN TRAINER AREA.

3.1.1 Removal of Mock-Up and Addition of Water and Fuel Outlets. The aircraft mock-up was removed from the trainer to provide a larger unobstructed fire area for the experiments. Since the region covered by the fuselage was not originally equipped with water spray nozzles and fuel outlets, these were added. The plumbing was complicated by the fact that the water supply pipes were inaccessible and the added nozzles had to be fed from restricted existing units.

3.1.2 Modification of All Fuel Outlets in Trainer. The originally installed fuel outlets consisting of a small hole drilled in a pipe cap could not deliver the required amount of fuel in a reasonable time. Therefore all 41 fuel outlets in the trainer were replaced with double flange assemblies as shown in Fig. 17.

3.1.3 Isolation of Zone No. 5. To reduce fuel consumption during the fire experiments and the effort to make plumbing changes from one experiment to the next, a single zone of the trainer was isolated for test purposes. Zone No. 5, shown in Fig. 27 with the original nozzle layout on 4-ft centers, was selected for this purpose. The zone was isolated by installing a continuous baffle around its perimeter. This was essentially a short fence of sheet metal to contain fuel within the given area. The ends were fastened to the curb, and the baffle extended several inches below the surface of the crushed stone. The fuel supply was confined to this zone by capping all other fuel outlets in the trainer.

3.2 MODIFICATIONS OF WATER SUPPLY SYSTEM.

3.2.1 Main Control Valve. The original installation did not include a flow control valve upstream of the 8 individual zone valves. To change the total flow to the trainer, it was necessary to manipulate all 8 valves, and it was not possible to preset these valves prior to ignition. To provide such a main control of the total flow to the trainer, the constant pressure regulating valve in the 8-in. line upstream of the header (Fig. 25) was modified to respond to a flow control device set by the operator at the panel in the control tower.

3.2.2 Pump Bypass Valve. As fuel is consumed in the trainer during a training fire, the amount of water necessary for smoke abatement is reduced to low flow rates, and finally zero flow.

Operation of the centrifugal pumps at very low or zero flow causes instabilities and vibrations that can damage the equipment. The original installation permitted pump operation at zero flow, and in fact this would occur at the beginning and end of every fire. Therefore a bypass valve was installed to divert water from the pump discharge back to the reservoir. The bypass valve opened whenever head pressure exceeded a preset value. Since the maximum water requirement of this relatively small trainer was only about half the rated output of one pump, there would be some flow through the bypass most of the time during operation.

3.3 EVALUATION AND MODIFICATION OF LEVEL CONTROL SYSTEM. The originally installed system intended for maintaining a constant surface level in the trainer area had two major shortcomings -- one concerned the operation of the overflow weirs described earlier in Section 2.1.3 and Fig. 24; the other concerned the flow resistance of the bed of crushed stone. The former problem was eliminated during this program while the latter was not. In spite of it, however, it was possible to carry out successful smoke abated burns in the entire trainer.

3.3.1 Original System. To be effective as a level control device for this application, a weir-type overflow would be required to handle up to 375 gpm (the maximum water supply to the nozzles) with a head difference of about 1/4 in. The low permissible head stems from two reasons: first, the surface level of the fuel is a critical dimension for obtaining realistic flame heights while counteracting the effects of wind drag. Second, the water input rate is highly variable during a fire. To meet such requirements, the length of the weir would have to be many times greater than the 4-ft lengths provided on each side of the trainer.

In addition, it was found that under maximum flow conditions, with the weir plate completely removed, the five screened 3-in. dia. holes through the curb (Fig. 24) imposed a head loss of nearly 2 in. Water accumulated in the trainer until this pressure difference was reached, at which time the crushed stone was submerged.

3.3.2 Modification of Level Control System. Since weir length could not be increased within the existing concrete enclosures, an alternative level control system was installed. This consisted of a control valve mounted at the end of the discharge pipe from the trainer, where the pipe emerges into the open ditch (see Fig. 22). The opening of this valve was controlled by a bubbler-type level sensor located in the concrete (weir) enclosure nearest the ditch. A rise in the surface level opened the valve and a drop closed it. The flow resistance of the screened holes through the curb and of the weir itself was reduced by breaking of concrete to remove the obstructions, as shown in Fig. 28.

With the outflow resistance removed, it was possible to measure the surface gradient in the trainer caused by the flow resistance of the bed of stones. With the drain valve closed, the trainer was first filled to make a common reference elevation for a uniform free surface at the nose and tail of the trainer (points farthest from the weirs) and at points inside the curb adjacent to the weirs. Then the drain valve was opened and a high flow rate of water was supplied to the spray nozzles. For this flow condition, in the steady state, the surface level near the drains was more than 4 in. lower than the level at the nose or tail of the trainer. In all subsequent work it was also observed that whenever the drain valve opened, even partially, there was a free surface in areas of the trainer away from the drains, while regions in the vicinity of the drains seemed dry, with the liquid surface invisible within the bed of stones.

The above condition was not corrected. Instead, a burn was begun with the surface level somewhat below the desired elevation, and water was allowed to accumulate in the trainer while the drain valve was opened only a limited amount so the surface level would not be dropped excessively.

4. FIRE EXPERIMENTS

Most of the fire experiments at Chanute AFB were aimed at determining design criteria for nozzle spacing and were limited to zone No. 5 of the trainer (Fig. 27). In some experiments it was necessary to activate several additional spray nozzles located in the adjacent zones No. 3 and 7, but the fuel was still confined to zone No. 5. With the spray water supply to only one zone, drainage through the bed of stones could take place without an excessive surface gradient. The level control was set so the surface in the test zone was about half free liquid surface when the rate of spray water was about average for the time of a burn. This was a compromise setting; with higher rates of spray water the surface in the zone rose a little, and with lower rates it fell.

Burns involving the entire trainer were made in conjunction with the AF studies on the training effectiveness of smoke abated fires.

4.1 EVALUATION OF CANDIDATE SPRAY NOZZLES AND NOZZLE SPACING.

4.1.1 Experiments with DeflectoJet* Nozzles.

4.1.1.1 DeflectoJet No. 0.75 on 4-ft Centers. The original installation at Chanute AFB involved DeflectoJet No. 0.75 nozzles spaced on 4-ft centers, as shown by the small circles on Fig. 29.

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* See footnote, p. 7

Good smoke abatement was attained with this array, and there was the usual trade-off possibility between fire severity and flame cleanliness. A level of about Ringelmann No. 1 was attainable with good fire quality. The maximum rate of water flow to the test zone was 50 gpm which, with 28 nozzles in the zone, corresponds to 0.93 lb per min per sq ft of fire area.

4.1.1.2 DeflectoJet No. 5 on 12-ft Centers. Nozzle No. 5 is the largest available of this type. Six of these nozzles were spaced on 12-ft centers, as shown by the large circles in Fig. 29, using existing outlets. All other nozzle outlets in the zone were plugged. The maximum attainable water flow rate was 70 gpm which, for the given layout, corresponds to 0.67 lb per min per sq ft. This was not sufficient for smoke abatement. Facility limitations at the time of these experiments prevented the placement of nozzles in an adjacent zone to increase the water spray rate capability.

4.1.1.3 DeflectoJet No. 5 on 8½-ft Centers. Piping was extended from existing outlets to permit placing two additional nozzles at the centers of the nominal 12-ft squares, as shown by the triangle symbols in Fig. 29. Actual distances between nozzles ranged from 8 ft to 8 ft 9.5 in. The maximum attainable water flow to the zone with this array was 85 gpm, corresponding to 1.23 lb per min per sq ft. This also was not sufficient for smoke abatement.

4.1.2 Experiments with Bete TFXW* Nozzles.

4.1.2.1 TFXW No. 12 on 8½-ft Centers. Bete Series TFXW extra wide angle nozzles of size No. 12 were placed on nominal 8½-ft centers in the same outlets described above (Fig. 29). In this position the tops of the nozzles were approximately 2½ in. above the stones. These nozzles generate much mist and provided good smoke abatement together with good fire quality. The maximum water flow requirement for good smoke abatement (Ringelmann No. 1 or less) was 60 gpm, corresponding to 0.87 lb per min per sq ft for this array.

Visually, some of the direct spray from the nozzles (as distinguished from the mist) had a downward component and seemed to impinge on the stones. The nozzles were therefore raised to determine if equal smoke abatement could be attained with a lesser water deposit. A lift of 1½ in., so the tops of the nozzles were 4 in. above the stones, showed no significant difference.

4.1.2.2 Other Experiments with Type TFXW Nozzles. The favorable results obtained with the No. 12 nozzles on 8½-ft centers led to a series of fire experiments to determine the maximum practical

* Schnitzer Alloy Products Co., 325 Pine St., Elizabeth, N.J. 07206

nozzle spacing for Bete type TFXW extra wide angle nozzles. The fuel area for these fires was confined to zone No. 5, but nozzles were placed not only in zone 5, but also in one or both of the adjacent zones 3 and 7. This was necessary either to achieve the desired nozzle spacing configuration or to limit the number of nozzles being fed by a single zone supply pipe to obtain a sufficient rate of water flow. Other existing outlets, not used for the TFXW nozzles, were plugged.

Seven experiments were conducted using 70 gal of JP-4 for each burn. This number of burns was essentially prescribed by the fuel allocation for this purpose. Experiments were conducted with nozzles spaced on centerline distances of 12 ft, 11.3 ft ($=8\sqrt{2}$), and 10 ft utilizing TFXW nozzles in sizes No. 20, 16, 14, and 12, as appropriate. In order to achieve the 10-ft spacing, which does not correspond to the existing piping grid on 4-ft centers, it was necessary to provide extension piping from existing outlets to 7 new locations. The specific test conditions are shown in Table 5.

TABLE 5. NOZZLE SPACING EXPERIMENTS
(Bete Type TFXW Nozzles)

Nozzle Spacing (ft)	Nozzle Number (indicates relative size)	Height of Nozzle Tops Above Stones
12	20	4½ to 5
12	20	2½ to 3
11.3 ($=8\sqrt{2}$)	20	2½ to 3
11.3	16	2½ to 3
10	16	2½ to 3
10	14	2½ to 3
10	12	2½ to 3

All the experiments were carried out under windy conditions. With the tops of the nozzles at 4½ to 5 in. above the stones, the effect of wind was to lift or bend up the "sheet" of water spray on the upwind side and thus shorten the reach of the droplets. This effect was reduced by lowering the nozzles to a level of 2½ to 3 in.

Best results in this series were obtained with No. 12 nozzles on 10-ft centers. This combination provided realistic fire severity and good smoke abatement to levels below No. 1 on the Ringelmann scale. This experiment was conducted under wind conditions of 14 knots with gusts to 21 knots. Maximum water consumption during the burn was around 0.8 lb per min per sq ft.

4.1.2.3 Effectiveness of TFXW Nozzles on Diesel Oil Fires. Type TFXW nozzles had not been used previously for smoke abatement, and it was therefore of interest also to evaluate their effectiveness in abating smoke from diesel oil fires since this fuel is used in shipboard simulators at all Navy fire-fighting schools. Experiments for this purpose were conducted in a 15-ft outdoor tank at the Great Lakes Naval Training Center. The experiments involved both a single nozzle located in the center of the tank, and 5 nozzles controlled by individual zone valves. The experiments were conducted under high wind conditions.

Sufficient smoke abatement could not be obtained with a single nozzle in the tank, whether a TFXW No. 14 or a No. 20. This most likely was due to an insufficient water supply because the existing small-diameter supply piping was intended for much smaller nozzles. It was evident, however, that with a single nozzle in the tank it would be impossible to maintain fire over the entire fuel surface under the existing wind conditions. Even without acceptable smoke abatement, there was no visible fire in the upwind section of the tank.

Excellent results were obtained with 5 TFXW No. 8 nozzles in the tank, utilizing the existing zone control valves to regulate the flow to the individual nozzles. This arrangement provided very good smoke abatement together with a realistic fire and good control. The school staff indicated that the overall effect was better than their previous experience.

The primary conclusion to be drawn from these tank experiments is that zone control is essential for the outdoor tanks under wind conditions, so the question of whether or not a single nozzle would suffice under no wind conditions is of little consequence.

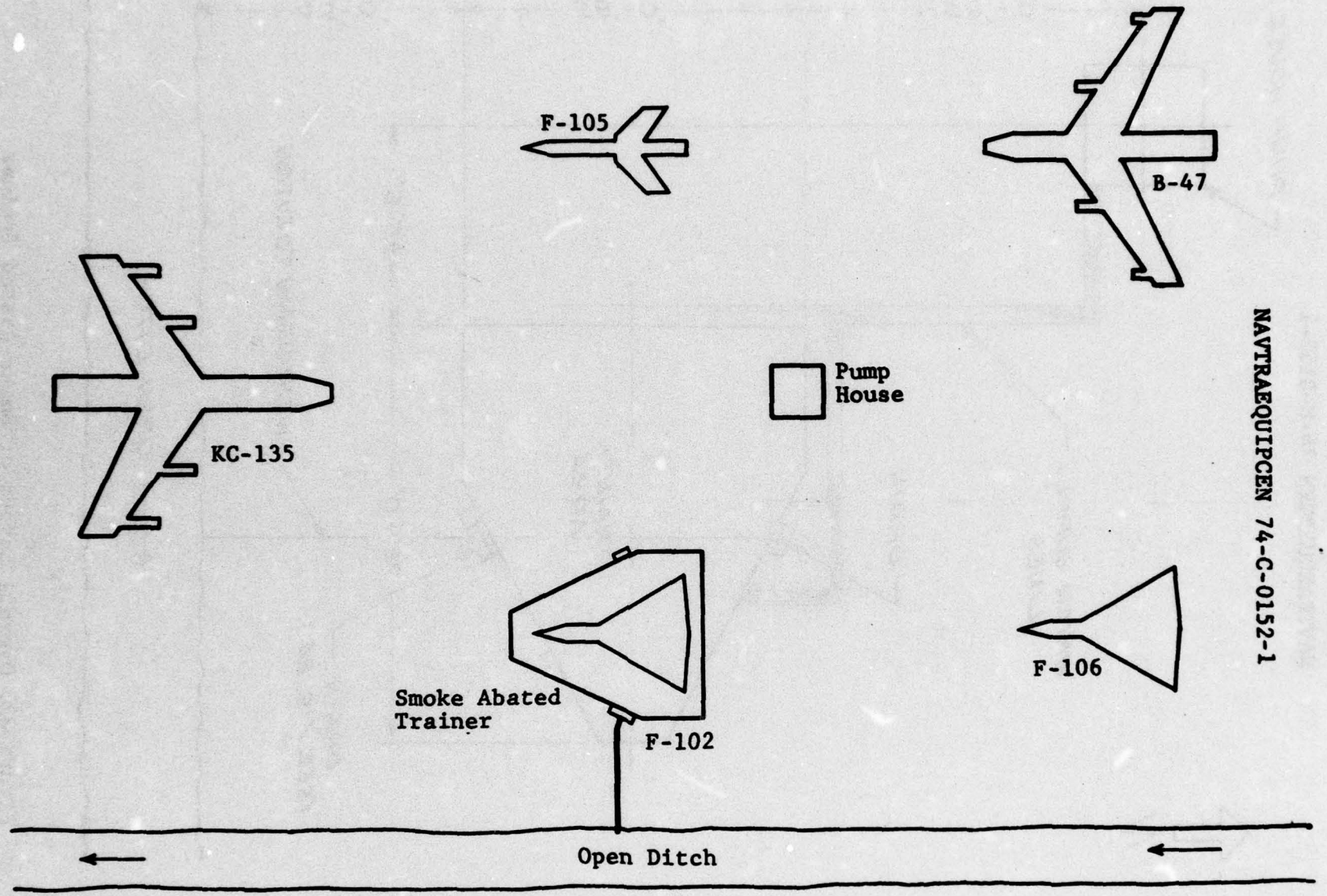
4.1.2.4 Overall Assessment of TFXW Nozzles. From the laboratory and field experiments described above it can be concluded that the Bete Type TFXW nozzles are preferable for this application. In addition to smoke abatement effectiveness, they have the further advantages of being more rugged -- consisting of a single piece of metal rather than an assembly -- and of having no small passages subject to clogging. Their disadvantages are a taller profile, offering a greater tripping hazard, and greater unit cost.

It was noted on two occasions during the training effectiveness evaluations at Chanute AFB that TFXW nozzles were bent by fire hoses being dragged over the nozzles. This occurred after a fire was extinguished, when a hose was turned into a U-shape while being dragged from the fire area.

Inquiry was made of the nozzle manufacturer to determine if the TFXW can be made as a pop-up for operation in a high-temperature environment. A pop-up nozzle would extend to full height when water pressure is applied, but would recede into a housing when pressure is removed. The answer was affirmative, but unfortunately there was no opportunity to experiment with this modification.

4.2 FULL TRAINER BURNS. A series of burns were carried out in conjunction with an AF human factors study to evaluate the suitability of smoke-abated fires for training fire-fighting personnel. The wings of the aircraft mock-up were replaced on their pedestal supports for these burns, and the entire trainer area was used for both natural and smoke-abated fires. Trainee performance data were collected by a team of AF psychologists. The smoke-abatement system, when used during these burns, was operated by personnel from the Chanute fire-fighting school. Seven of the zones in the trainer contained the original DeflectoJet No. 0.75 nozzles on 4-ft centers, while zone No. 5 contained Bete TFXW No. 12 nozzles on 8½-ft centers. These burns were carried out during three consecutive weeks, with two days of burns each week. The final series also served as a demonstration of both natural and smoke abated fires to a group of visitors invited by the AF to Chanute AFB for this purpose.

Good smoke abatement was attained during these burns together with realistic fire conditions. Views of typical fires are shown in Fig. 30. The training effectiveness of the smoke abated fires was illustrated by the occurrence of flashbacks, which were to a great extent at the control of the operator. Extinguishment times were generally longer for the treated fires than for the natural fires, and the adverse flashback consequences of "digging" with a foam jet were evident.



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Figure 21. Layout of Training Simulators at Chanute AFB

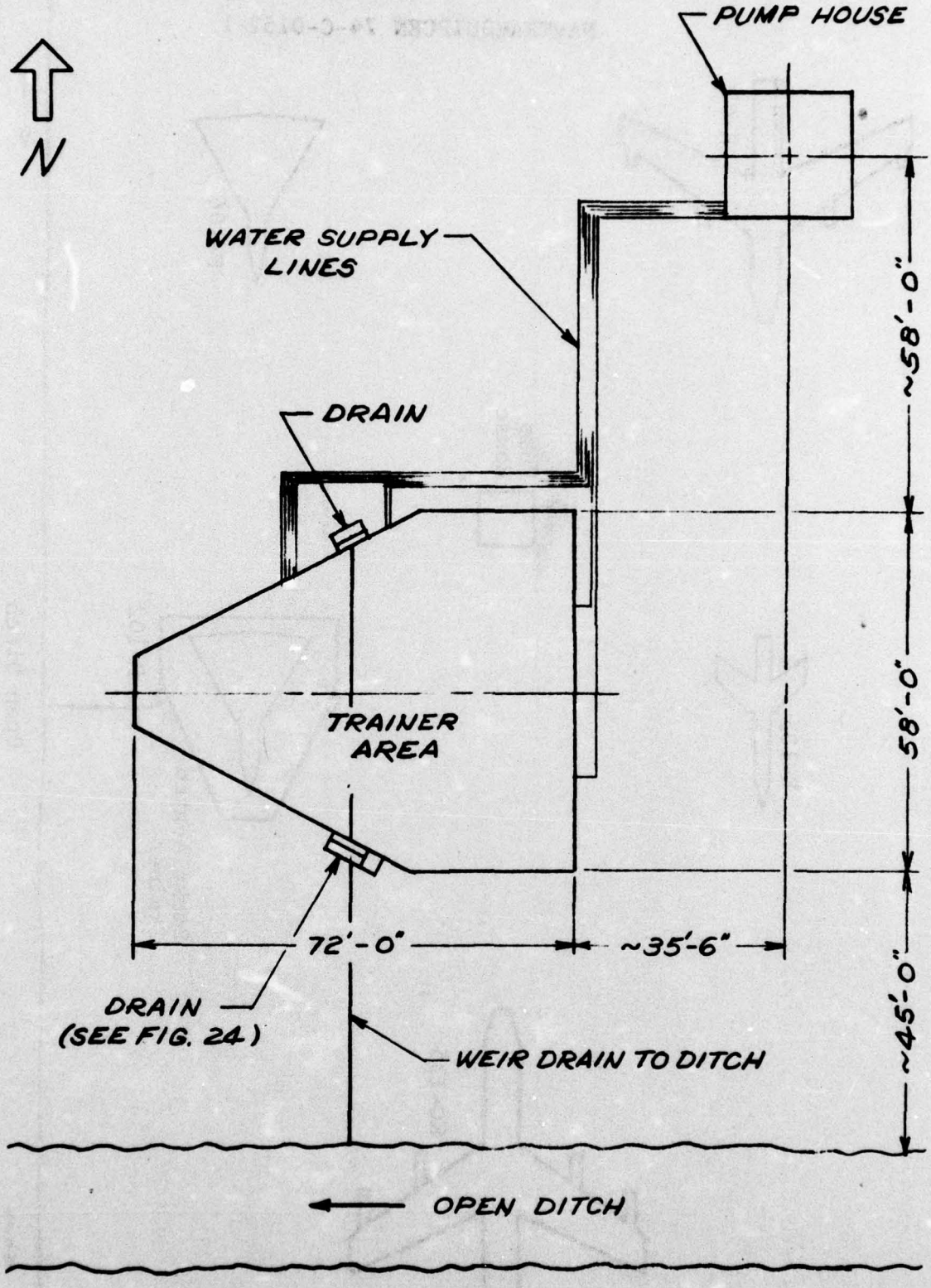


Figure 22. Overall Layout of Smoke-Abated Trainer

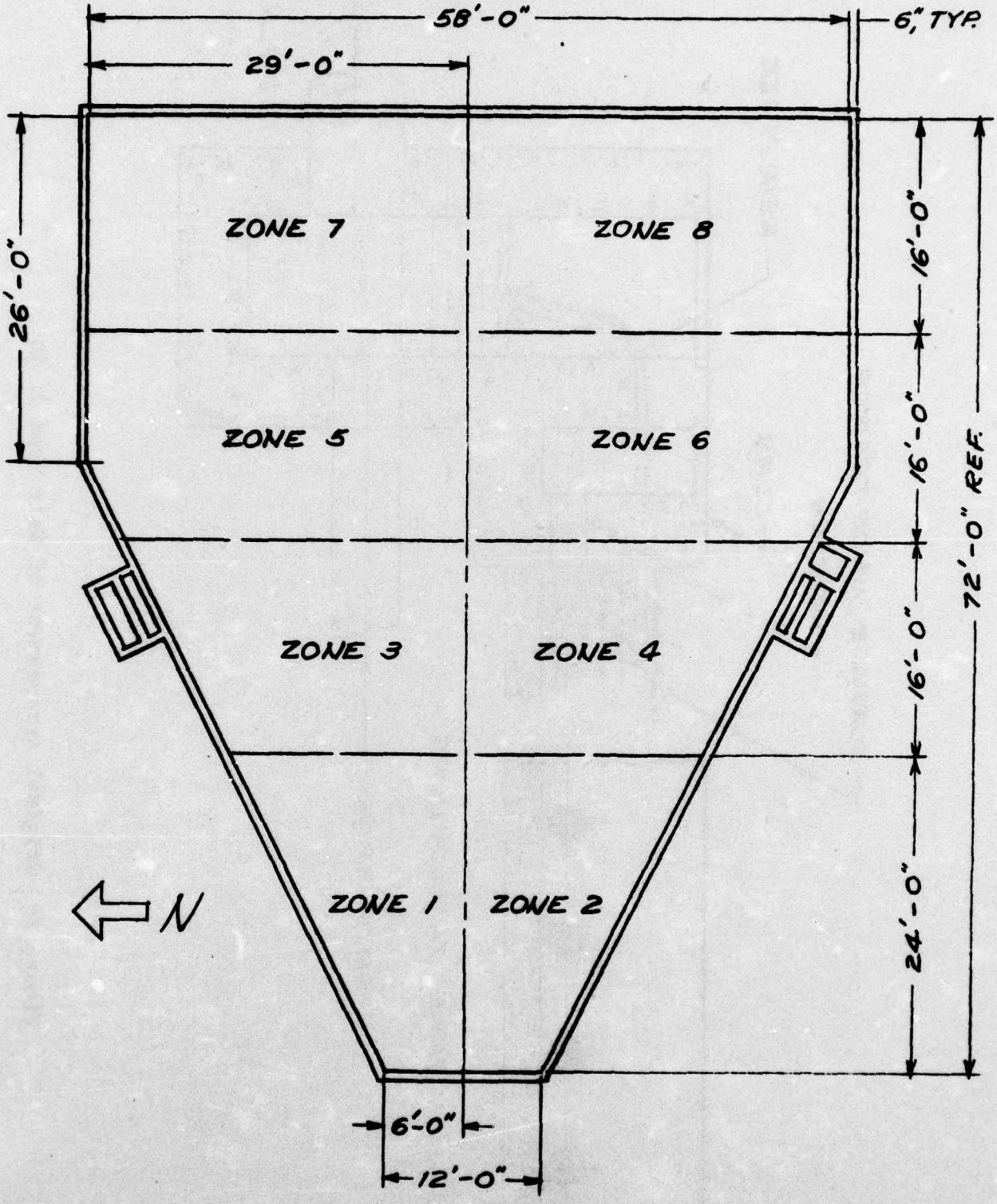


Figure 23. Layout of Zones in Trainer

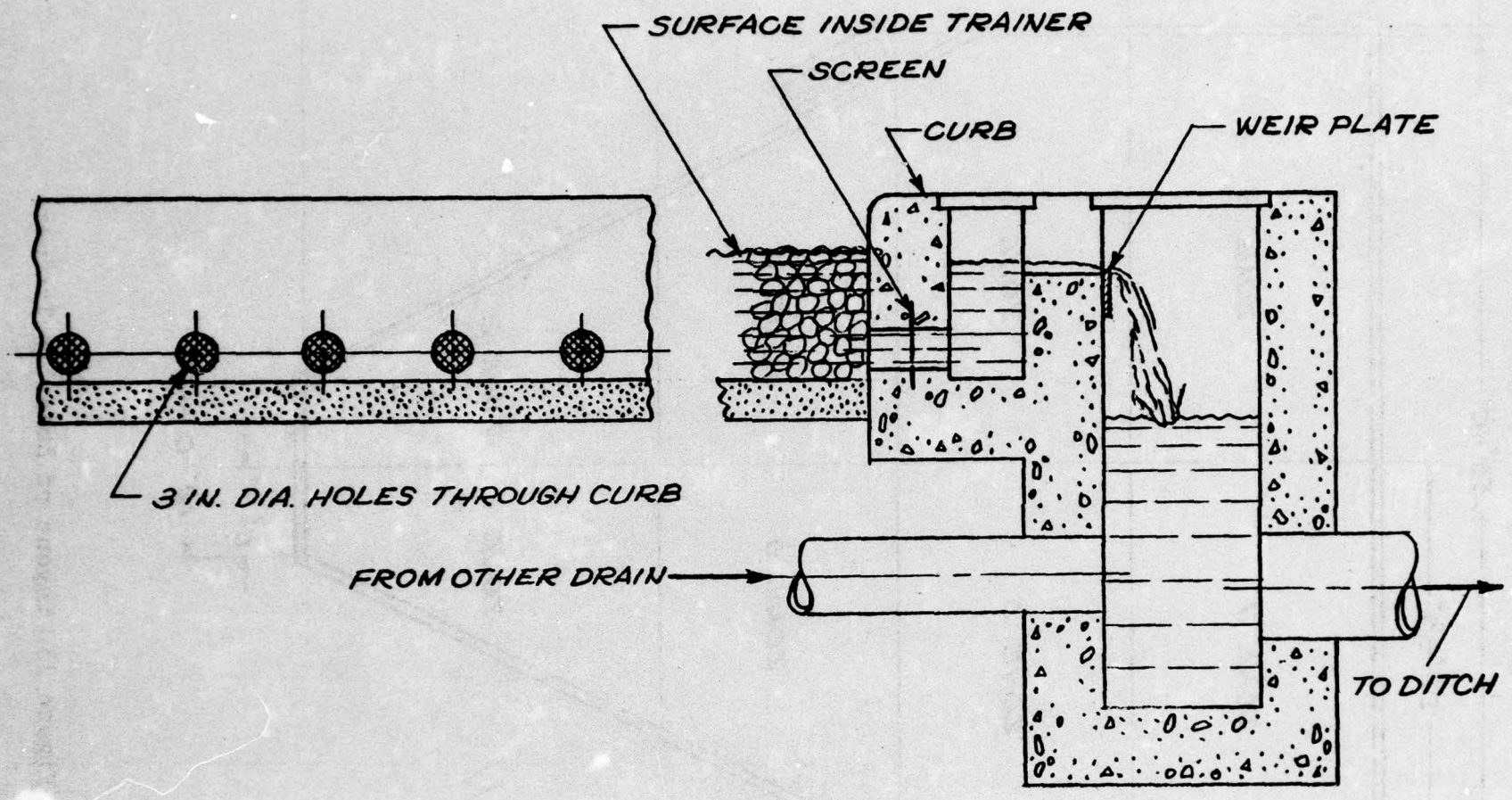


Figure 24. Original Arrangement of Weir Type Drain

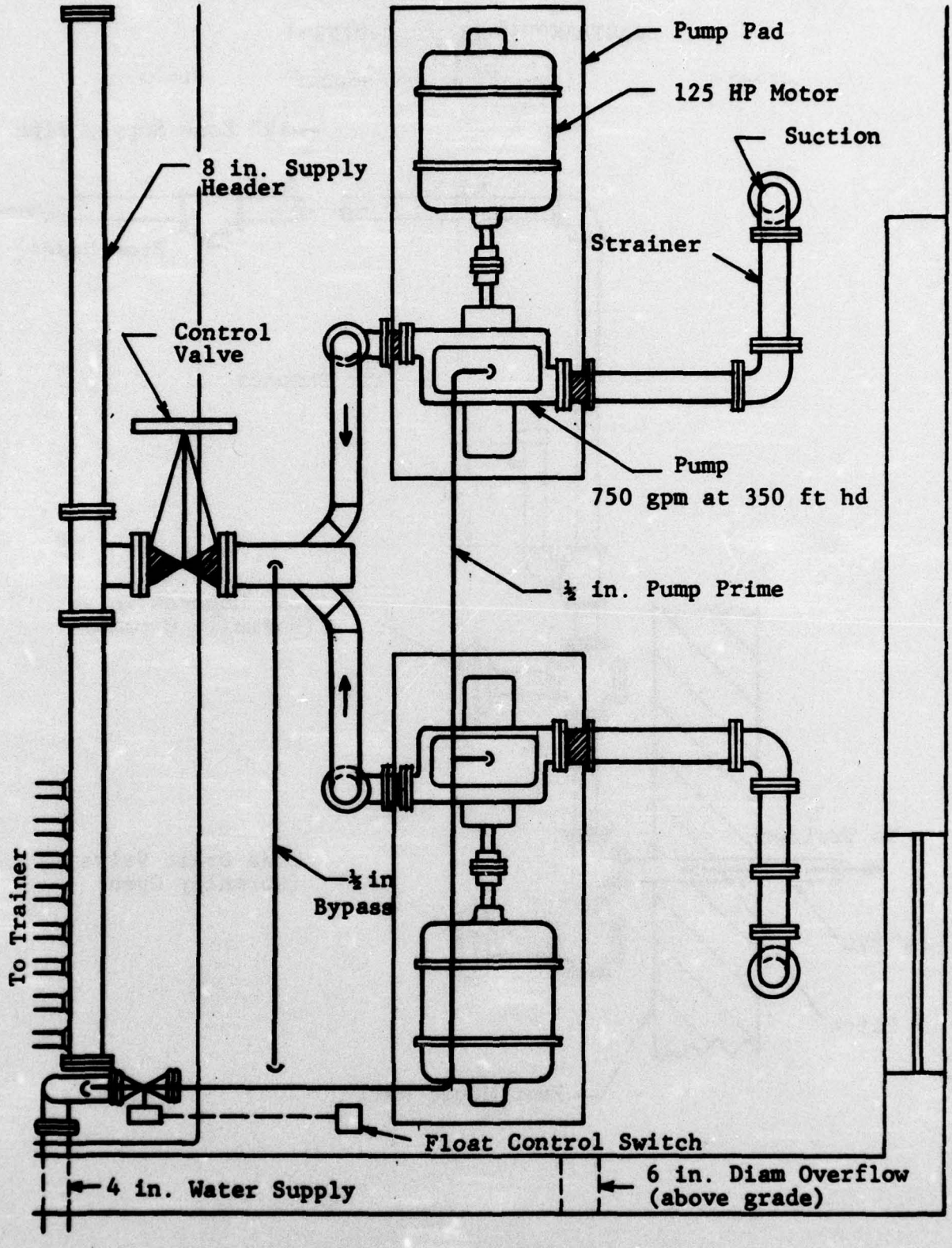


Figure 25. Water Pumping System

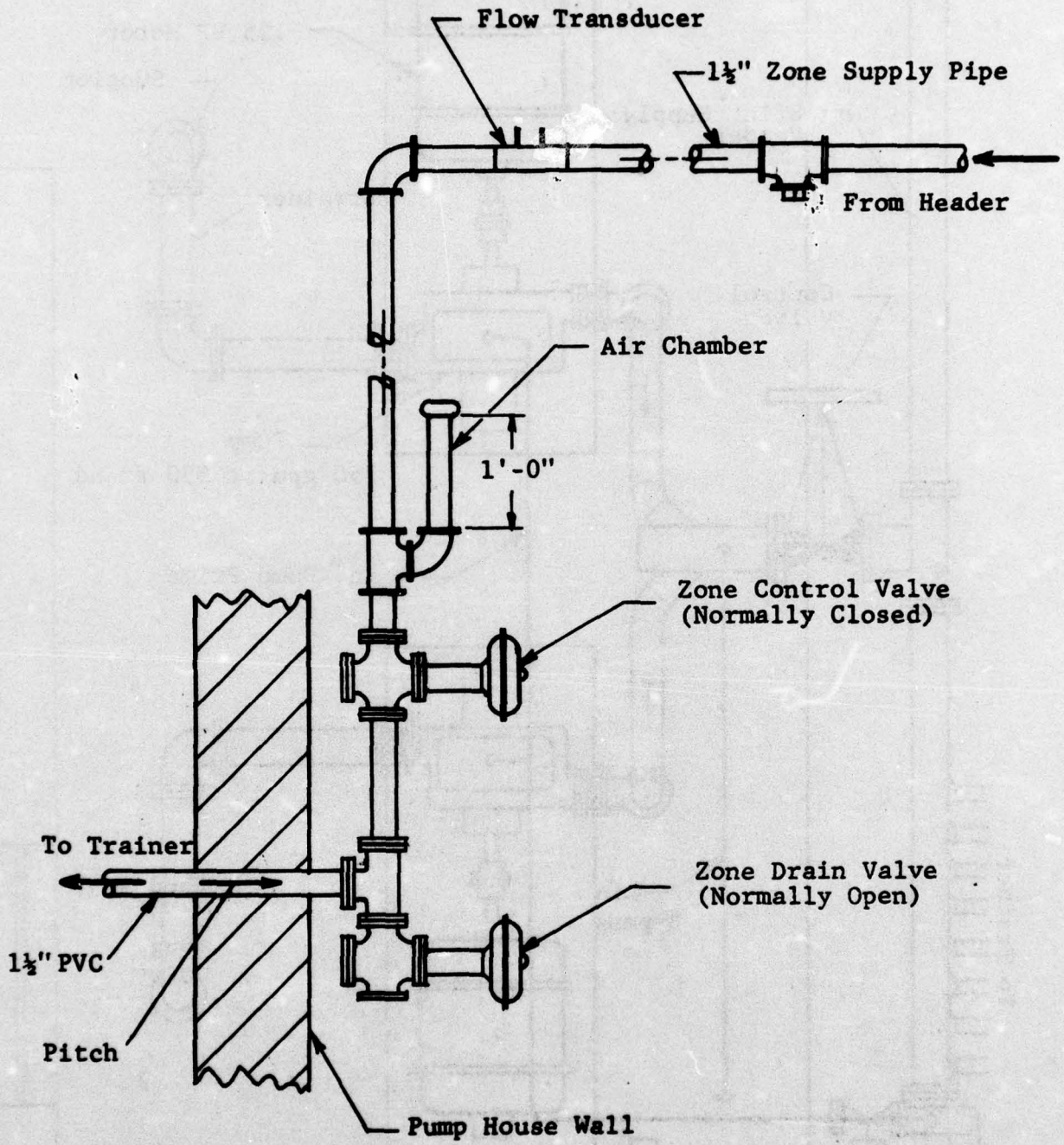


Figure 26. Piping Detail of Typical Zone Supply Line

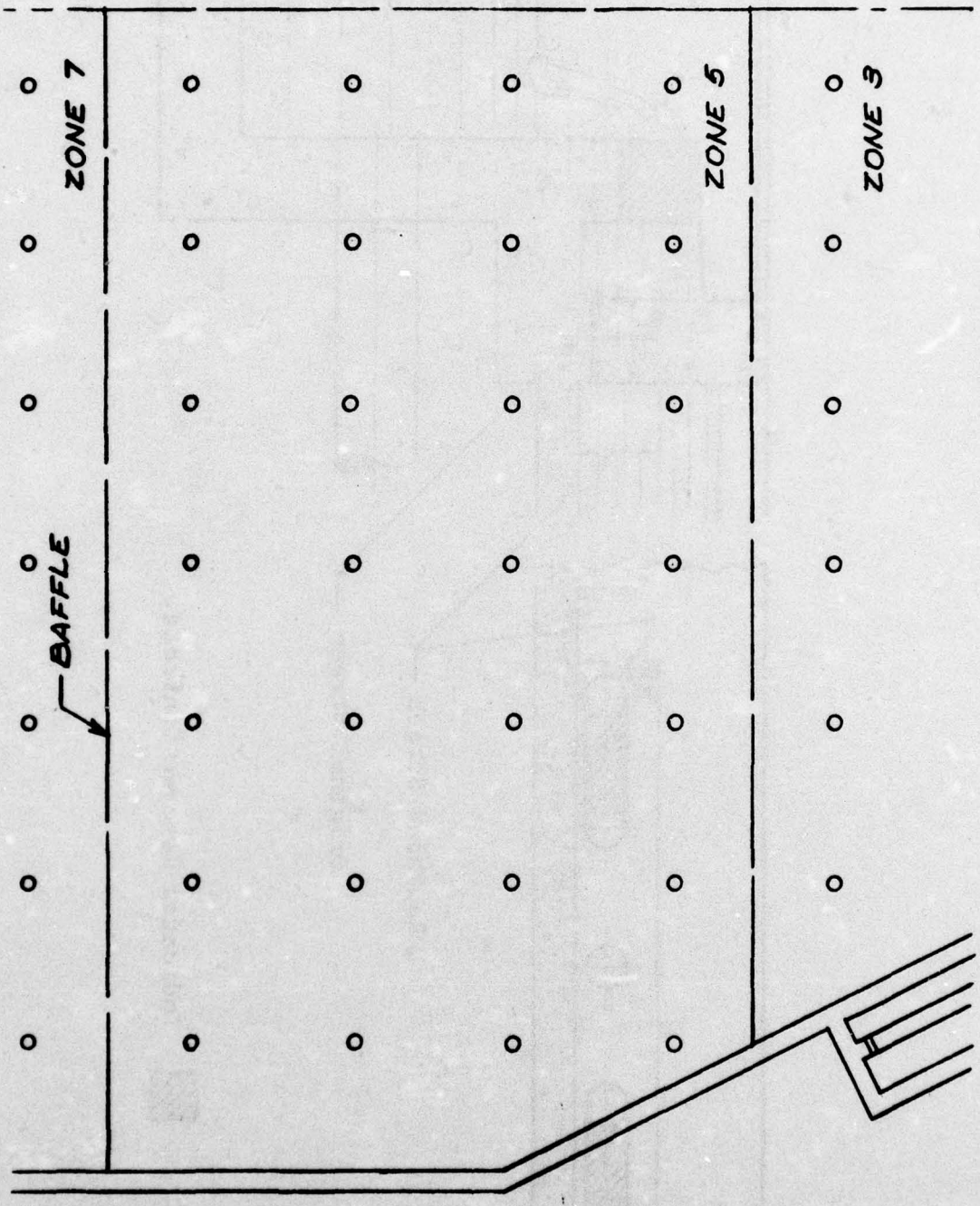


Figure 27. Original Nozzle Layout in Zone No. 5

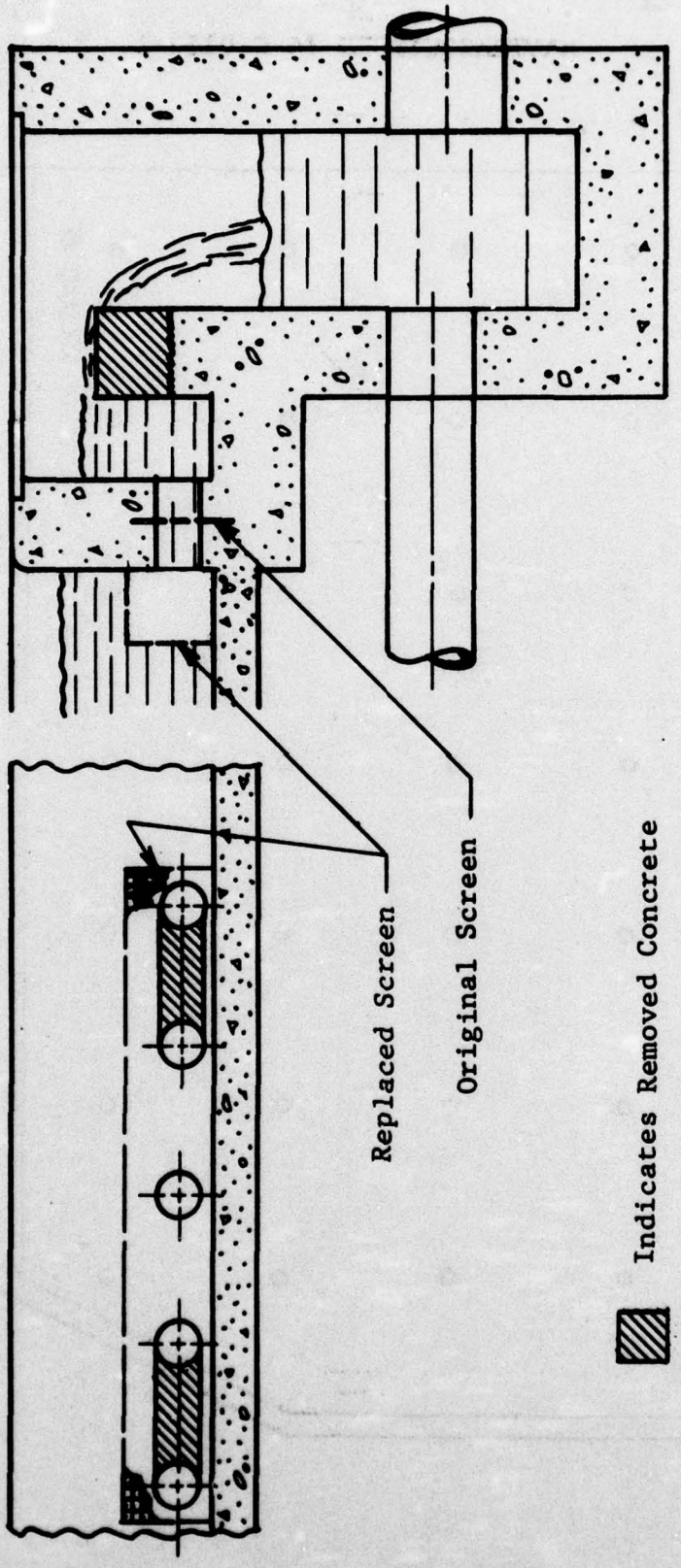


Figure 28. Weir Modifications

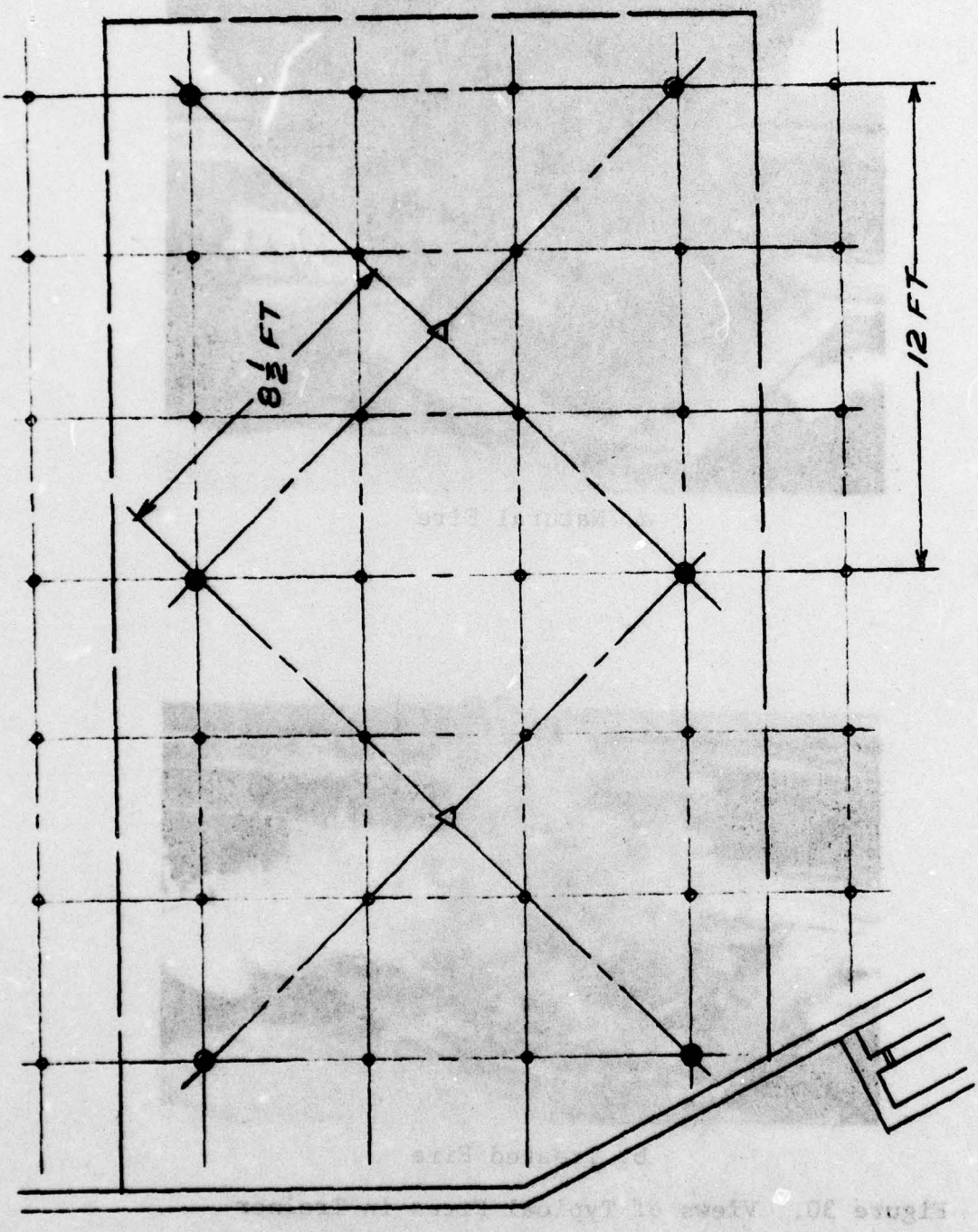
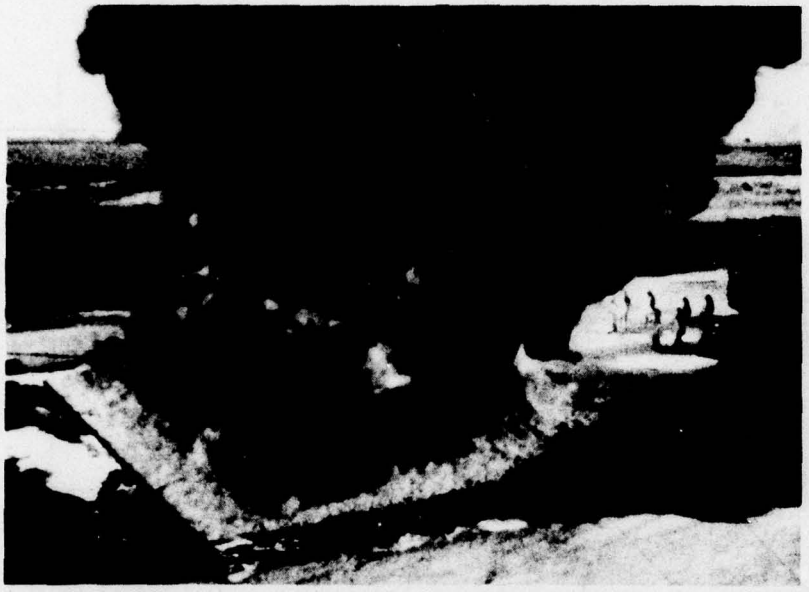
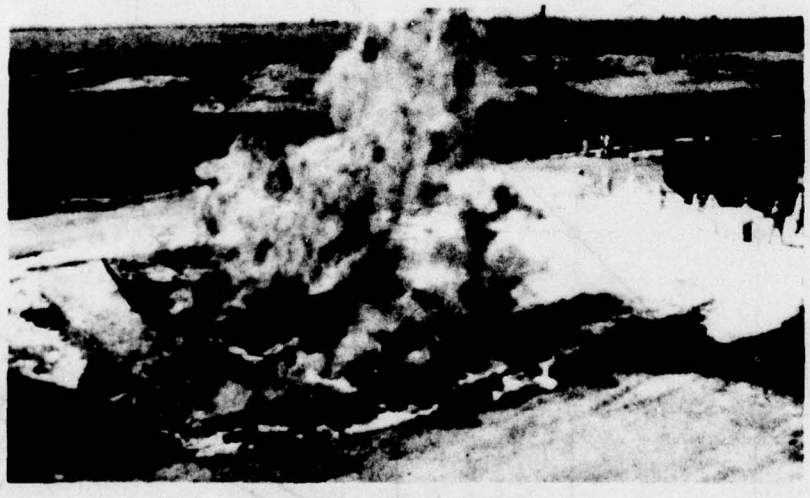


Figure 29. Layout of Nozzles in Zone No. 5



a. Natural Fire



b. Treated Fire

Figure 30. Views of Typical Fires in Trainer

SECTION VI

DESIGN OF AIRCRAFT CRASH/RESCUE TRAINER

A smoke abated fire facility for aircraft crash/rescue fire-fighting training was designed during this program and the results were submitted previously as a self-contained design report. That report is included here in its entirety as Appendix A. The design presented in Appendix A is carried to a level where the next step would be the preparation of detail drawings and specifications for construction of a prototype trainer. Since it was intended for this purpose, few design options are given there. Instead, the rationale for the design and a discussion of some alternative approaches is given in the following paragraphs. The design is based on previous laboratory experiments, previous experience with full-size training simulators of shipboard configurations, and the results of the current program. A facility built according to this design should perform satisfactorily from a viewpoint of both smoke abatement and training effectiveness.

1. TRAINER SIZE

1.1 FUNCTIONS OF PART-TASK SIMULATORS. In defining the size of an aircraft crash/rescue training simulator it may be useful to restate some of the reasons for using part-task simulators altogether.

Safety is obviously first, since personnel can be trained to perform new tasks, or work with new equipment, with the least possible hazard. If errors are committed they are not likely to be catastrophic, and reasonable alternative exit patterns are available. For example, the lack of people or ordnance items aboard an aircraft mockup permits the fire fighters to back off, change approach, or change operating procedures without appreciable hazard. This is most important during the early phases of actual equipment use when errors are committed most frequently.

A simulator also may be adjusted to various levels of difficulty, thus providing a means to measure if performance meets acceptable levels of proficiency. Within this area, specific tasks may be constructed, or decision alternatives provided, which require selecting the method of attack and/or equipment.

Simulators can be varied in design so new tasks can be inserted. Examples are protection of or from explosive devices or other special-purpose hardware.

Simulators are very effective as time compressors. Only the desired task elements are inserted in the procedure; therefore time for intervening tasks and much setup and cleanup time is saved. This also may be a hindrance if the effects of stress and fatigue on performance also are to be identified.

Obviously a simulator does not provide many of the variables normally encountered in field operations. This is a disadvantage when unexpectedness and stress are significant factors in performance degradation, but an advantage when the purpose is to impart simple skills and information. It should be noted here that performance-degrading factors against which no suitable defenses can be learned or developed have no place in most simulator designs. Such factors only impede the acquisition of the skills which can be learned.

1.2 CONSIDERATIONS IN SELECTING TRAINER SIZE. On a practical basis, it has been shown that previous team practice results in more rapid extinguishment of fires of a given size. For shipboard configurations, for example, it is known that prior experience with open tank fires, developing tool handling and communication skills, improves subsequent performance on fires within closed fire-room and engine-room simulators.

Substantiation of these early studies performed by IITRI was provided by Manned Systems Sciences Inc. (Ref. 11). Repeated trials with test fires showed continued improvement as measured by a performance check list.

The simulator dimensions and fire-fighting tools used in these tests differed from those used for aircraft fire fighting, but the concept is similar. For shipboard configurations, training begins with dry runs on a simulator which is ignited after a given level of team proficiency in tool handling is reached. After fire-fighting skills are acquired on the open pan fire, the team advances to a more sophisticated simulator representing a shipboard engine or fire room. Similarly, aircraft crash/rescue training proceeds from dry runs to exercises with mockups. The criteria for satisfactory team performance vary but are frequently based on time from attack through path establishment and retrieval of a dummy. NAVPERS 92175B (p. 37) specifies four grades of profiency with 4 to 8 sec execution time classed as excellent, and over 15 sec unsatisfactory. These times are based on use of a given facility and specified gear. These specifications contrast with FAA recommendations.

A recent FAA publication (Ref. 12) identifies approximately 20 relevant advisory circulars and technical reports. Appendix 2 of this reference, in discussing sizes of training fires, recommends a minimum size of 1000 sq ft with a 90 sq ft fire controlled within 60 sec. Time to extinguishment is obviously much greater than that permitted by the U.S. Navy and emphasis is on fire extinguishing.

The difference between these two recommendations is largely due to differences in manning and fire fighting equipment used with the simulator. The Navy standards are based on teams with hand-held nozzles approximately 30 ft from the flame center making a path to the cockpit and retrieving a dummy. All fire is not extinguished at the end of the timing.

If vehicle-mounted foam units are used, attack is likely to start at some greater distance from the fire, and before hand lines are rigged. The larger capacity of these units requires a more extensive fire, particularly if both turret and hand lines are to be used in a given drill.

The Navy standards also assume extensive supplementary drills while the FAA standards are for periodic refresher training. As directed in NAVAIR 00-80R-14, an MB type fire-fighting vehicle commences attack on the fire as soon as within range, which may be up to 150 ft when a solid stream is used.

A more desirable pattern utilizes spray, which decreases the range for attack to approximately 45 ft with a 25 ft spray width.

Hand-held units may require much shorter attack distances and, because of spray width and capacity, much smaller fires can be fought successfully. The vehicle-mounted twinned agent unit, as an example, is capable of controlling only a 2400 sq ft fire. Similarly, practice with CO_2 or PKP is likely to be effective only on equipment fires which are an order of magnitude smaller, possibly even 10 to 100 sq ft.

The size of a fire required for effective training should be such that the fire would react differently to extinguishment by trained and untrained fire fighting teams. If uniform extinction rates occur regardless of the manner of application, the team will not be able to discriminate between efficient and wasteful practices. Although some skills obviously would still be acquired, more skill acquisition is likely to accrue with fires which show a definite change in response to different tactics. At the opposite extreme, fires which cannot be contained effectively by the available tools present a hazard to trainees and do not permit practice of the entire series of tasks required for complete extinction and flashback prevention.

Larger training fires also consume proportionately greater amounts of fuel and extinguishing agent.

Based on the available information and current practices, it appears that a fire of about 2000 sq ft is the minimum practicable for training purposes with MB units. A fire of this

size could be attacked with a turret foam applicator system. Attack could be initiated at distances of 50 to 150 ft, depending on the foam pattern used. Attack could continue while the vehicle progressed to the fire perimeter, which would place the aircraft mock-up target up to 30 ft from the turret. The width of the foam pattern could still be limited enough to require clearing a path through the fire.

If full use is to be made of a twin-turret foam system, a fire of at least 5000 sq ft is more appropriate, For a fire of this size both turrets could be used to cover the entire fire front. The combined use of turret and hand lines would require similarly large fires.

The twinned agent, CO_2 or PKP extinguishing units generally are applicable to smaller fires. Such units may have a discharge range of 5 to 20 ft, and a useful life of 15 to 30 seconds. Obviously the fires must be sized accordingly.

1.3 SELECTION OF TRAINER SIZE. Available information on sizing of training fires indicates that a size of about 2000 sq ft would be satisfactory for hand-held foam lines or fire trucks using a single turret. This size was therefore selected for the present design. If training with mobile units having twin turret applicators is desired, a 5000 sq ft fire is probably the minimum for a wide range of applications.

If fire sizes were reduced to 1000 sq ft, the training versatility definitely would be limited with the possibility of unsatisfactory hand line training effectiveness.

These sizes are based largely on existing practice and are necessarily approximations. A lack of explicit descriptions of validated fire-fighting requirements prevents more reliable statements of optimum fire sizes and other training parameters. A more precise specification of fire areas requires a systematic analysis of the criteria for fire-fighting effectiveness, the optimum fire-fighting behavior for meeting these criteria, and the hazards and benefits of various fires used in teaching these behaviors.

2. DESIGN ALTERNATIVES

2.1 GEOMETRY OF FIRE AREA. The more likely shapes that might be considered for the fire area are a square, a circle, or a configuration resembling the shape of an aircraft, as was used at Chanute AFB. A circular area was selected for the following reasons: First, since a training schedule is set normally without regard to wind conditions, a symmetric arrangement is desirable. Second, a circle is economical in providing the largest useful fire area.

The maximum length of fire path that a trainee would have to cross is comparable to that of a square (with side length equal to diameter) but the fire area is about 25 per cent less.

2.2 ZONE LAYOUT. A division of the circular fire area into 5 independent zones for spray water control was based on experience. With more than 5 zones in a circular area, operation of the controls by a single person becomes difficult (Ref. 5, p. 35). The proposed 5 zones consist of a large circular zone in the middle, with the surrounding annular area divided into 4 equal sections by radial lines. This arrangement should provide adequate compensation for wind effects.

2.3 BASE OF FIRE AREA. The base of the fire area must meet the following requirements: It must contain water so a thin layer of fuel will cover the entire area uniformly. It must be highly permeable to water flow so a constant surface level can be maintained while water is deposited by the spray nozzles. And it must be suitable for men to walk on. These requirements can be satisfied by containing the water in a concrete enclosure consisting of a slab surrounded by a curb. The following alternatives were considered for providing a low flow resistance together with a walking surface:

a. A layer of crushed stone, as a walking surface, could be placed atop a steel grating. The grating would be just below the water surface, supported by short columns, and the space between the grating and the concrete floor below would be unobstructed except by the piping network.

b. The entire concrete enclosure could be filled with crushed stone selected for relatively high permeability, and flow channels could be provided within the bed of stones to reduce its flow resistance.

Alternative 'a' would provide a more stable walking surface and easy access to the piping; alternative 'b', which was selected for the proposed design, would be less costly but would require periodic raking to maintain the surface relatively flat.

2.4 MAINTENANCE OF CONSTANT SURFACE LEVEL. The basic choice of a method for maintaining a constant surface level is between a passive system and an active system. Once this choice is made, there are alternative approaches in each category.

A passive system must provide a weir of sufficient edge length to overflow the required amount of water with the small available head, and provision must be made for trapping the fuel within the fire area. The overflow weir might be installed over all or part

of the fire area perimeter, or sufficient weir length might be enclosed within a separate compartment designed for this purpose.

An active system would involve either a valve or a pump in the discharge line, responding to a transducer sensing surface level. The valve could be either modulating or full open-full closed, while a pump could be either of variable speed or on-off. There is also a variety of devices for sensing surface level based on different operating principles.

2.5 CONTROL SYSTEMS.

2.5.1 Spray Water Controls. Controls are required to regulate the total rate of water flow to the spray nozzles in the trainer, and the flow to each zone independently. The flows are controlled by the operator in response to his visual observation of fire and smoke conditions.

The basic choice is between directly operated manual valves and remotely controlled valves. With the latter, a single pipe could carry water to a header close to the trainer, and individual pipes from there would lead to the zones in the trainer. A control valve would be mounted in each of these pipes operated remotely through either a pneumatic or electric system by the operator at the control station. Since fire phenomena change rapidly, the control system would need to have a fast response time.

Directly operated manual valves are much simpler, but the supply piping to all zones must be routed through the operator's control station. If a manual system is selected, there is a further choice between control valves having specified flow characteristics (e.g. equal percentage flow), or ordinary plug-type globe valves which are much less expensive.

2.5.2 Fuel System Controls. The complexity of the fuel supply system can range from the direct pouring of fuel into the trainer area from the hose of a delivery truck, to a completely automated pumped system that would distribute a preset amount of fuel uniformly in the trainer at the press of a single button and then shut itself off.

In conjunction with a fuel pump, a bypass valve should be provided so the pump will not operate at zero flow. The bypass can be accomplished by an automatic pressure regulating valve; by a fixed orifice in a bypass line; by physically joining the handles of the fuel supply valve and the bypass valve so the bypass would open when the supply is closed; or by using a three-way valve to serve the same purpose.

For ignition, pilot ignition sources can be placed in the trainer prior to fuel delivery, provided the fuel is delivered rapidly. If a remotely controlled ignition system is desired, electric spark plugs can be used as described in Ref. 5 or 8.

2.6 FUEL OUTLETS. The fuel outlets in the trainer should be below the walking surface so they do not present a tripping hazard. If they remained open in that location, however, water would displace all the fuel in the fuel supply piping, since the fuel is of lower density and would float up. This is undesirable for two reasons: First, fuel reaching the surface in this manner would create a fire hazard when the trainer is not in use, or would pollute the air with unburned hydrocarbons. Second, water entering the fuel piping could cause freeze damage or drain back into the fuel tank. Therefore water should be prevented from entering the fuel outlets when they are not discharging fuel. This can be done either mechanically by a gasket or check valve, or by a U-bend trap.

SECTION VII

SUMMARY AND CONCLUSIONS

The laboratory and field experiments carried out during this program have demonstrated the applicability of the water spray smoke abatement method to large aircraft crash/rescue fire trainers. Smoke generation was reduced to levels of No. 1 or less on the Ringelmann scale for JP-4 fires covering an area greater than 3000 sq ft. The smoke abated fires were of realistic severity and responded properly to extinguishment by aqueous film-forming foam (AFFF). The fire area was involved in flame more uniformly than normally encountered with a ground spill of fuel, and men were able to walk through the area while extinguishing the fire. Flashback occurrences were noted numerous times when improper extinguishment techniques were used, and the operator of the water spray system could, to some extent, control the difficulty of extinguishing a flashback fire.

A superior commercial spray nozzle was tested and proven effective. Field experiments with this nozzle have shown effective smoke abatement with nozzles spaced up to 10 ft apart. Further increases in nozzle spacing would be of little benefit and are no longer a consideration because of the need to control the spray water flow to different areas of the trainer for wind compensation. Nozzles of the same type also were proven effective for diesel oil fires in a 15-ft dia outdoor tank, and it was shown that zone control of the spray nozzles is desirable even for a relatively small fire area of this size.

In addition to the above, a number of conclusions were reached largely on the basis of laboratory experiments using a 4 by 4 ft fire area.

a. High flash-point fuels such as JP-5 or diesel oil are not suitable for aircraft trainers where the fuel surface is partially submerged in a bed of stones. These fuels cannot provide realistic fires under such conditions.

b. JP-4 can provide realistic fires in the smoke abated mode provided at least about half the burn area consists of a free surface of fuel. This conditions is obtained when the surface of the fuel is approximately 1/2 in. below the surface of the stones. Flame heights are reduced as the surface level is depressed. This conclusion was confirmed by field experiments.

To obtain realistic flame heights, the initial fuel layer should be at least 0.2 in. thick (free fuel thickness as if stones were not present). Greater thicknesses have little effect in producing greater flame heights.

c. The most realistic smoke-abated fires, comparable to natural fires, were obtained with automotive gasoline.

d. A change in the size of the crushed stone produced no significant differences either in the rate of fuel spread over the water surface, or in the fire characteristics.

e. Spacing of fuel outlets on 8-ft centers seems reasonable on the basis of laboratory experiments. The limited capability of the fuel supply at Chanute AFB prevented investigation of this variable in the field.

SECTION VIII

RECOMMENDATIONS

Either JP-4 or gasoline are acceptable fuels for smoke-abated aircraft trainers. Gasoline is preferred from a viewpoint of achieving the most realistic fires in the smoke abated mode, but its use would require more rigorous safety precautions. Because of the greater volatility of gasoline, it would be essential for pilot ignition sources to be present in the fire area before fuel delivery begins. Otherwise much hydrocarbon vapor would be released to the atmosphere and a flammable mixture might extend downwind beyond the trainer area.

Much difficulty was experienced with the original control system at Chanute AFB, where control valves were operated remotely by a pneumatic system. It is believed that the difficulties stemmed from a poor choice of components and a poor installation rather than from being inherent in the method. If remote controls are to be used, particular attention should be given to response time. Since fire conditions change rapidly, a water spray control valve should be able to go from full-open to full-closed (or vice versa) in about 5 sec.

Submerged pumps should be used to avoid the problem of pump priming after a period of idleness.

The water spray nozzles should extend above the elevation of the curb enclosing the fire area so there will be no possiblity of fuel entering the water supply system via the spray nozzles.

Fuel remains in the fire area after a fire is extinguished. Provision should be made in the fuel-water separators for reclaiming this fuel for reuse.

The recommended Type TFXW spray nozzle can be manufactured as a pop-up version, and also with a modification to restrict the spray coverage to an arc of a circle rather than a full circle. The pop-up version would tend to reduce nozzle damage and tripping hazard, while the limited coverage modification could reduce the spray water deposit outside the trainer area and reduce somewhat the total water consumption. Field experiments should be carried out to evaluate these changes.

All the development work and applications of this smoke abatement method to date have been on fires burning from a horizontal free surface. Fire-fighting exercises also should include fires of running and spraying fuels. The application of the water spray method to such fires will require further investigation and development.

A smoke abatement installation includes pumps, valves, and other equipment requiring periodic maintenance. The operation of the smoke abatement system requires not only certain skills that can be acquired by practice, but also certain operating procedures and safety practices. Therefore an operation and maintenance manual should be prepared to assure uniform, correct, and safe practices; and responsibility for the trainer should be clearly defined. This would be particularly important at installations having a substantial turnover of personnel, and in freezing climates where an oversight might cause costly damage.

It is strongly recommended that the design presented in Appendix A of this report be applied first to a single installation which should be evaluated in actual practice before additional trainers are built.

Finally, it should be pointed out that the basic mechanism whereby a water spray is so effective for smoke abatement is not understood at this time, although several hypotheses have been advanced and the method has been applied successfully in various installations. Specific experiments should be designed to prove or disprove the several hypotheses, and to aid in understanding the phenomena that occur. An understanding of the basic mechanism might lead to other worthwhile applications.

REFERENCES

1. Goldsmith, A. and H. G. Wakeley, Fire Simulation Concepts, Tech. Report NAVTRADEVCEN 69-C-0181, Feb. 1970, Naval Training Device Center, Orlando, Fla.

2. Waterman, T. E., Analysis of Stack Gases for Natural and Treated Fuel-Oil Fires, Tech. Report NAVTRADEVCEN 69-C-0181, P0001, June 1970, Naval Training Device Center, Orlando, Fla.

3. Goldsmith, A. and H. G. Wakeley, Demonstrations of Full-Scale Simulators for Fire-Fighting Training, Tech. Report NAVTRADEVCEN 71-C-0272-1, Sept. 1970, Naval Training Device Center, Orlando, Fla.

4. Goldsmith, A. and T. Waterman, Development of Zone Control and Ignition Systems for Smoke-Abated Fire-Fighting Simulators, Tech. Report NAVTRADEVCEN 70-C-0272-2, Jan. 1971, Naval Training Device Center, Orlando, Fla.

5. Goldsmith, A., Development of Spray-Water Smoke Abatement Systems, Tech. Report NAVTRADEVCEN 71-C-0083-4, Nov. 1971, Naval Training Device Center, Orlando, Fla.

6. Goldsmith, A., Development of Smoke Abatement System for Air Force Fire-Fighting School, Contract No. F11602-71-C-0165, July 12, 1971, IIT Research Institute, Chicago, Ill.

7. Hottel, H. C., Review of Certain Laws Governing Diffusive Burning of Liquids, Fire Research Abstracts and Reviews, Jan. 1959, p. 41.

8. Hazard, H. R., R. D. Giammar, and D. C. Caudy, Smokeless Ignition of Oil Fires in Ship-Space Simulators for U.S. Navy Fire-Fighting Schools, Contract No. N62470-72-C-1260, Sept. 15, 1972, Battelle Columbus Laboratories, Columbus, Ohio.

9. Conover-Mast Purchasing Directory, Stamford, Ct., Cahners Publication, 1974.

10. Thomas Register of American Manufacturers, 64th Ed., New York, N.Y., Thomas Publ. Co., 1974.

11. Semple, C. A. Jr., Training Effectiveness Evaluation of a Prototype Water-Spray Smoke Abatement System for Fire-Fighting Training, NAVTRAEQUIPCEN Tech. Report 72-C-0209-1, Nov. 1973, Manned Systems Sciences, Inc.

12. Programs for Training of Fire-Fighting and Rescue Personnel, Advisory Circular, AC No. 139.49-1, Nov. 12, 1974, Dept. of Transportation, Fed. Aviation Admin.

APPENDIX A

DESIGN OF SMOKE ABATED FIRE FACILITY FOR AIRCRAFT CRASH/RESCUE TRAINING

SECTION I

INTRODUCTION

The training of fire fighters for aircraft crash/rescue work includes extinguishment exercises of large fuel spill fires that simulate aircraft crash situations. A trainer consists of an outdoor fire area containing a mockup of an aircraft at its center. The area is covered with fuel which is ignited, and trainees are instructed in the extinguishment of the fire and in the rescue of personnel from the aircraft.

The huge clouds of black smoke that are normally present when burning liquid petroleum fuels can be eliminated by injecting a fine water spray over the surface of the burning fuel. The need to provide and control this water spray imposes other requirements and restrictions on the training facility. This document provides the design of a smoke-abated fire facility to a level where the next step would be the preparation of detail drawings for construction. Some of these details would be affected by the geographic area and actual field site of a given facility. For the design presented here, it is assumed that the facility is located in a freezing climate and that it should be able to function in the winter. More detailed information regarding the basis for this design is presented in the final report on the subject contract, and this document is an appendix to that report. A training facility built according to this design should perform satisfactorily from a viewpoint of both smoke abatement and training effectiveness.

The design presented here concerns only the smoke-abated fire area and the equipment necessary for its operation and control. Additional facilities necessary for a complete operational system, not considered in this design, include the aircraft mockup and its supports, fuel-water separators, and wastewater treatment.

The next section outlines the requirements of a smoke-abated fire facility, and the following section provides a detailed description of the design that was developed to meet these requirements and the manner in which the system operates. Later sections outline performance requirements of major equipment items, and provide detailed operating procedures for both nonfreezing and freezing environments. Design drawings, to which reference is made in later sections of this report, are a part of this report.

SECTION II

REQUIREMENTS FOR SMOKE-ABATED FIRE FACILITY

1. LOCALE

The fire facility should be located at a remote area of a base, but preferably with access to a water supply, electric power (for pumps), and adequate drainage for water disposal.

2. FIRE AREA

a. Need for Water Sublayer

To distribute fuel uniformly over a large fire area, and to prevent the spray water from washing away the fuel, it was found effective and convenient to float the fuel atop a water sublayer.

b. Need for Crushed Stone

When a thin layer of fuel floats on water, wind forces tend to drag the fuel downwind. To reduce this effect, and to provide an area in which persons can walk, the trainer area is in the form of a shallow pool filled with crushed stone until the stones protrude partially above the surface of the liquid and thus reduce the wind drag effect.

c. Need for Constant Level Control

The fuel surface must be below the surface of the crushed stone as explained in Paragraph b. On the other hand, it cannot be deep in the crushed stone because burning rates, flame heights, and fire severity would be reduced and the fire would not be realistic. A depth of about 1/2 in. is a workable compromise. Since water is added to the fire area during a fire, means must be provided to maintain a constant level.

d. Need for Removing Fire-Extinguishing Agent

When the extinguishing agent is deposited during a training exercise, the foam remains in the fire area and inhibits the flame spread and rapid fire development of a subsequent fire. For repetitive fires with a rapid turnaround time, the foam should be removed after each fire.

e. Need for Total Drainage

If the trainer is in a region subject to freezing, the fire [illegible] must be capable of being drained to prevent freeze damage.

3. SPRAY WATER SYSTEM

a. Water Requirements

Effective smoke abatement can be attained with a spray water deposit of 1 lb per min per sq ft of fire area during the peak of a fire. To determine the necessary flow rate, allowance must be made for the fact that the spray from nozzles located near the periphery of the trainer extends outside the trainer.

The rate of spray water discharge during a fire is variable. For estimating water consumption, it may be assumed that the average flow during a fire is about 2/3 of the maximum flow, or 2/3 lb per min per sq ft for the duration of a fire.

b. Spray Water Distribution

For effective smoke abatement, it is necessary to deposit the spray water on the burning fuel in a uniform manner. Experiments have shown that the specified spray nozzles are effective when spaced in a square array on 8 to 9 ft centers. The nozzles are supplied from pipes beneath the surface, and the tops of the nozzles extend about 3 in. above the surface of the fuel.

c. Need for Zone Control of Spray Water

Wind affects the character of an outdoor fire, causing greater flame heights and more smoke generation on the downwind side. If the water spray were distributed uniformly over the entire trainer, and at a rate sufficient to abate smoke on the downwind side, the flow would be excessive for the upwind side and would cause fire of insufficient severity in that region. To compensate for this wind effect, it is necessary to divide the fire area into several zones and to provide independent control of the spray water flow to each zone.

d. Need for Pipe Drainage

If the trainer is in a region subject to freezing, the water piping system must be capable of being drained to prevent freeze damage.

4. FUEL SYSTEM

a. Need for Rapid Delivery of Fuel

Candidate fuels for crash/rescue trainers are gasoline or JP-4, both of which are volatile fuels. If ignition were delayed until after all the fuel is delivered, unburned hydrocarbons would be released to the atmosphere; and if gasoline were used,

there might be a flammable atmosphere outside the trainer area. On the other hand, if ignition occurred on first fuel entry, and much time elapsed for complete delivery and distribution, the fuel consumed during this interval would be wasted. Therefore it is desirable to cause ignition on first fuel entry and to complete delivery as rapidly as practicable.

b. Fuel Distribution

If fuel were supplied through one or even several outlets, the time necessary for the fuel to spread over the entire trainer area would be excessive. Therefore the fuel is supplied through many outlets uniformly distributed through the trainer area. The outlets are below the water surface so they are not a tripping hazard.

c. Need for Drainage of Fuel Piping System

Provision for draining the fuel piping system is to be provided for two reasons. First, there is a possibility of water entering the fuel piping and causing damage in a freezing environment. Second, if the need should arise to enter the fuel piping for whatever reason, it is preferable to have the piping empty.

5. AIRCRAFT MOCK-UP

A mock-up of an aircraft in the fire area is deemed necessary for training purposes. The design of the mock-up is not covered in this report, but the following recommendations are made regarding the integration of the mock-up in the fire facility.

The mock-up should be located in the middle of the trainer area with the fuselage parallel to the direction of locally prevailing winds (in line with the direction from control building to fire area). From a viewpoint of smoke abatement, the entire mock-up should be supported by columns about 2 ft above the fuel surface. No gap should be allowed between the wings and the fuselage. Support columns for the mock-up may be placed directly on the concrete floor of the trainer if they are well distributed and provide adequate bearing area to carry the load. The columns should be placed to offer the least interference with the spray water patterns.

The life of a steel mock-up probably could be extended by providing nozzles inside the mock-up to spray water on the back of the steel plates for cooling purposes. If this is done, drain holes should be provided at the low points and, more important, adequate vents should be provided at the top for discharging generated steam.

SECTION III

DESIGN BASIS

For the design presented below, it is assumed that the trainer is located in a freezing climate and provision is made for system drainage. Storage tanks are provided for both fuel and water, so the system could operate even if it were necessary to bring water by tank truck.

The design is neither the most sophisticated and costly, nor is it the cheapest one. Certain of the requirements -- as the size of the water storage tank or the relative orientation of the water discharge system, for example -- are site dependent. However, it is recommended that no changes be made in the proposed design without due consideration for all the possible consequences.

SECTION IV

DESCRIPTION OF FIRE FACILITY AND ITS OPERATION

1. OVERALL LAYOUT OF FIRE FACILITY (SEE DRG NO. 9)

The fire area is a 50-ft dia. circle surrounded by a short curb and a 5-ft-wide apron extending around the periphery beyond the curb. This circular area contains a bed of crushed stone, a layer of water, and piping systems for the distribution of fuel and spray water as described below. A concrete tank containing a weir assembly for constant level control is located immediately outside the curb of the fire area.

A control building is located 75 ft from the curb of the fire area, in a direction such that local prevailing winds will be from behind the building towards the trainer. From this building, an operator will supply fuel and will control manually the rate of spray water discharged in the 5 zones of the trainer during a fire. The floor of the control building is elevated 10 ft above ground to provide the operator good visibility of the fire area.

Storage tanks for fuel and water, together with their respective pumps and auxiliary equipment, are located near the control building.

2. FUEL SYSTEM

a. Storage Tank and Pump

The fuel storage tank is located below grade near the control building, and it is assumed that the tank will be refilled periodically from a tanker truck. The fuel level in the tank is to be determined by a dip stick, and sufficient void space is to be allowed for draining the fuel piping when necessary.

A layout of the fuel tank and associated piping is shown on Drg No. 9. A turbine-type pump is submerged in the tank, with the pump suction at the bottom of the tank. The pump is driven by a directly coupled electric motor located on a pad at ground level directly above the pump. The discharge from the pump leads to the control building, and from there to fuel outlets in the trainer area. Auxiliary equipment and features associated with the storage tank include the following:

- A pressure relief valve that will bypass flow back to the tank whenever the main supply valve is closed or flow is otherwise restricted with the pump running.

- A strainer in the pump discharge line upstream of the valves and fuel meter. (Strainer may be omitted if fuel meter does not require protection)
- A vent pipe extending to the roof of the control building
- An auxiliary fuel outlet (shown plugged) at the pump discharge
- Ports in the tank for filling, and for draining fuel from the piping.

b. Fuel Metering and Control

The supply of fuel to the trainer is controlled by a manually operated ball-type valve located in the control building. A 90-degree turn of the valve handle will move the valve from full-open to full-closed and vice versa. An accumulator is located immediately upstream of the supply valve, and its purpose is to avoid shock on sudden closure of the valve.

A fuel meter to indicate total flow (not rate of flow) is located adjacent to the supply valve in the control building. The operator would open the supply valve just long enough to deliver the desired amount of fuel. Therefore the amount of fuel delivered must be clearly visible on the meter; or else the meter must provide a signal when a preset specified amount has been delivered.

c. Fuel Piping (Drgs. No. 9 and 10)

The fuel pump and piping system are sized to deliver 300 gal to the burn area in 30 sec or less. It is estimated that this amount will provide for a preburn of 30 sec to achieve a well developed fire, plus at least 2 min for the extinguishment exercise.

After leaving the control building, downstream of the supply valve and meter, the fuel supply is divided into two parallel pipes leading to the trainer area (drg. No. 10). There they feed branch pipes leading to individual fuel outlets. The parallel supply pipes are joined at the far end of the fire area to equalize pressure in the system.

The fuel pipes are below grade and are pitched over their entire length so they can drain naturally back into the supply tank. A drain valve is provided for this purpose as shown on Drg. No. 9. This valve is operated manually.

d. Fuel Outlets

There are 28 fuel outlets in the trainer area spaced in a square array on 8½-ft centers (with 2 exceptions) as shown on Drg. No. 10. Each outlet consists of an inverted U-shaped assembly. The inverted U serves as a trap to prevent the entry of water into the fuel system. Fuel is discharged into the trainer as horizontal jets from a railing pipe fitting (side outlet cross) located below the water surface as shown on Drg. No. 10.

e. Means of Ignition

The fuel is ignited by providing pilot ignition sources before the fuel is delivered. The pilots may be small containers of fuel (e.g. beer-can size) set out at several locations in the trainer near fuel outlets. These pilots are lit before fuel delivery begins, and flames would propagate rapidly across the entire surface on the arrival of fuel.

3. WATER SUPPLY SYSTEM

a. Storage Tank and Pump

In the design of the water supply it is assumed that there is no access to a water main and that water is brought in by tanker truck. If a water source should be available locally, the size of the storage tank could be reduced after due consideration of the rates of usage and the available supply.

The water storage tank is located below grade near the control building. A layout of the tank and associated piping is shown on Drg. No. 9. For this drawing it is assumed that a water supply is available but can deliver water at a low rate, so the water level in the storage tank is controlled by a float valve. The level of this valve is set to leave sufficient void space at the top of the tank for draining the water piping when necessary.

The arrangement of the water tank and its piping is similar to that of the fuel tank. A multistage turbine pump driven by a directly coupled motor is submerged in the tank with the pump suction at the bottom of the tank. The motor is on a pad above grade. The discharge from the pump leads to the control building where the flow is divided into 5 separately controlled paths leading to the zones in the trainer. Auxiliary equipment and features associated with the water tank are similar to those listed at the end of Section IV-2a for the fuel tank, except that the vent pipe need not extend to the top of the control building.

b. Control of Spray Water Supply

The rate of spray water delivery and its distribution over the trainer area are controlled manually by six valves located in the control building. During a fire exercise, an operator adjusts these valves in response to his visual observation of the fire to limit smoke generation and yet maintain a realistic fire.

The discharge pipe from the pump contains a main control valve which controls the flow to a manifold or header feeding 5 separate pipes leading to the zones in the trainer (Drg. No. 11). This main control valve also serves as a shutoff valve for the water supply to the trainer. Each of the 5 zone pipes contains a similar control valve used to regulate the rate of spray water delivered to the individual zones in the trainer.

c. Water Supply Piping

The water supply system is designed to provide a spray water rate of 1 lb per min per sq ft of fire area with a margin of safety. To maintain the safety margin, the pressure loss in the piping system from the pump to the spray nozzles should not exceed 20 psi.

Downstream of the zone control valves, the water supply pipes run below grade to the individual zones in the trainer area (Drg. No. 3). They enter the trainer at 3 slightly different elevations to permit pipe cross-overs within the trainer. All water supply pipes are pitched over their entire length to drain naturally back into the supply tank. Since the 5 supply pipes must be independent downstream of their respective control valves, it is necessary to provide an individual drain valve for each zone as shown on Drg. No. 9. Downstream of these drain valves, a common drain pipe leads back to the tank.

e. Zone Layout

The distribution of spray water within the trainer area is divided into 5 zones, with the flow to each zone independently controlled by the operator in the control building. The layout of the zones is shown on Drg. No. 3. Zone No. 1 covers a large central area in the trainer, while the other 4 zones are symmetrically spaced around the periphery. The water spray nozzles are uniformly arranged in a square array on 8½-ft centers.

The piping arrangement for each of the 5 zones is shown separately on Drg. No. 4 through 8. These drawings also show a detail of the riser and spray nozzle combination, and their relative elevations. It is important that the riser pipe to the nozzle be plumb; otherwise the spray from a nozzle would not be horizontal and would not cover the intended fire area. The specified spray nozzles are commercially available (See Section V-1-h).

4. LEVEL CONTROL AND DRAIN SYSTEM

Water in the trainer area is maintained at a constant level by a passive system consisting of an adjustable weir-type overflow arrangement. The water level can be held constant within a fraction of an inch regardless of variations in the rate of water inflow from the spray nozzles or the extinguishing agents.

a. Trainer Area

To facilitate the outflow of water from the trainer area without suffering excessive head loss caused by the bed of stones, the trainer area contains several protected flow channels, or trenches, as shown on Drgs. No. 13 and 14. These trenches are covered by metal screens to keep out the stones and are otherwise unobstructed. Water deposited in the trainer area flows a short distance through the bed of stones to the nearest trench, and from there to the weir overflow assembly located immediately outside the curb of the trainer (Drgs. No. 9 and 12).

The flow resistance of the bed of crushed stone can be kept low by using relatively large stones of uniform size. It is recommended that the crushed stone consist of gap graded aggregate with 100 percent passing a 3-in. sieve and zero percent passing a 2-in. sieve (or as close to zero as can be obtained commercially).

b. Weir Assembly

The weir assembly for constant level control is simply a means of providing sufficient edge length in a compact configuration so water can overflow the edge at the required rate with little available head. The operation of the level control system is illustrated schematically on Drg. No. 12. Water from the trainer enters the weir tank via the trench that runs along a diameter of the fire area and penetrates through the curb. (The function of the sluice gate at the curb is explained in Section IV-5.) Within the weir tank, the water rises until the level reaches the tops of the U-shaped channels, or troughs. Any additional water inflow spills over the edges into the troughs, and from the troughs to the surrounding drain tank. The elevation at which the edges of the troughs are set can be adjusted by jackscrews at the corners of the weir assembly. The discharge from the drain tank should be directed to a fuel-water separation facility from which the remaining fuel can be reclaimed for reuse. This, however, is outside the scope of the present design.

c. Draining of Trainer

Provision is made for draining the entire fire facility, including the weir tank, through a manual gate valve located at the bottom of the weir tank (Drg. No. 12). In a freezing climate, it would be necessary to open this valve at the end of each day's use.

5. FOAM SKIMMING SYSTEM

Extinguishing foam that remains floating in the fire area after an exercise can be removed easily by closing the water exit from the trainer and then adding water until it overflows the curb surrounding the fire area.

The water exit from the trainer can be blocked by a sluice gate located where the main trench from the trainer passes through the curb (Drg. No. 12). This gate is normally out, but can be inserted manually when necessary. With the sluice gate in place, water is added to the trainer by opening all water control valves until the trainer is full. Once full, the spray nozzles discharging at maximum flow aid to flush the foam over the curb.

The sluice gate need not make an absolute watertight seal. However, any substantial leakage would be a waste of water and would increase the time required to overflow the curb. In the detail design of the gate, care should be taken that the gate be easily removable by one man. If necessary, the gate can be made in two vertical halves, with a vertical bracket in the middle, so each half can be lifted out separately.

A trench covered by a grating surrounds the entire trainer area immediately outside the curb, and leads to the drain outside the weir tank (Drg. No. 13). The overflow from the trainer -- consisting of foam, unburned fuel, and water -- flows under gravity into this trench and to the drain.

SECTION V

PERFORMANCE REQUIREMENTS OF MAJOR EQUIPMENT ITEMS

The performance requirements of major items of equipment in the water and fuel systems are listed in the following paragraphs. Items not specifically identified should be commercial grades suitable for use with water or petroleum fuels as applicable.

1. WATER SYSTEM

Water used for the smoke abatement system is untreated tap water.

a. Water Piping

All piping is standard weight (Schedule 40) pipe, wrapped and coated for corrosion protection.

b. Supply Valve

Nominal 100 psi gate valve; brass; screwed. Size: 2 in. preferred; otherwise to fit water supply line. For below ground installation with extended handle.

c. Float Valve

Nominal 100 psi globe or angle valve; brass; screwed. Float up to close. Size to fit water supply line.

d. Pump

Multistage turbine pump with suction at bottom of water storage tank and motor on pad above ground. Capacity 300 gpm at discharge head of 350 ft water.

e. Strainer

4-in., Y-pattern, sediment separator with 20-mesh screen.

f. Pump Bypass Valve

To be selected in conjunction with characteristic curve of water pump. Valve is to begin opening at a pressure greater than rated pump pressure and is to pass a minimum of 20 percent of the rated pump discharge when the main control valve is fully closed.

g. Control Valves

Manually operated valve with equal percentage flow characteristic; 150 psi maximum inlet pressure. Pressure loss not to exceed 2.5 psi at 90 percent of the following nominal flow rates:

Main control valve	280 gpm; size: 4 in.
Control valve for zone no. 1	105 gpm; size: 2½ in.
Control valves for zones 2,3,4,5	45 gpm each; size: 2 in.

h. Water Spray Nozzles

The spray nozzles are identified as follows:

Extra wide angle, series TFXW

Nozzle Number: TF12XW

Material: Brass

Manufacturer: Bete Fog Nozzle, Inc.
305 Wells St.
Greenfield, Mass. 01301

Distributor: Schnitzer Alloy Products Co.
325 Pine St.
Elizabeth, N.J. 07206

i. Drain Valves (5)

Nominal 100 psi gate valve; brass; screwed. Size: 1 in.; for below ground installation with extended handles.

2. FUEL SYSTEM

All components of the fuel supply system must be compatible with liquid petroleum fuels such as gasoline or jet fuels.

a. Piping

All piping is standard weight (Schedule 40) pipe, wrapped and coated for corrosion protection.

b. Pump

Multistage turbine pump with suction at bottom of fuel storage tank, and motor on pad above ground. Capacity: 600 gpm at a discharge head of 50 ft water.

c. Pump Bypass Valve

To be selected in conjunction with characteristic curve of fuel pump. Valve is to begin opening at a pressure greater than rated pump pressure and is to pass a minimum of 20 percent of rated pump discharge when the fuel control valve is fully closed.

d. Fuel Control Valve

Manually operated ball-type valve to pass 600 gpm with pressure loss not to exceed 2 psi.

e. Fuel Meter

Meter to indicate total fuel delivery in gal; flow rate to 1000 gpm minimum; nominal line pressure of 100 psi. Register resetable to zero after each use, with alarm or visual indication at conclusion of flow. Caution: meter should be filled with fuel prior to full opening of fuel control valve.

f. Drain Valve

Nominal 100 psi gate valve; brass; screwed. Size: 1 in.; for below ground installation with extended handle.

SECTION IV

OPERATING PROCEDURE - FREEZING ENVIRONMENT

1. STEADY STATE CONDITION DURING PERIOD OF IDLENESS

   a. No water in trainer

   b. No water in water piping system

   c. No fuel in fuel piping system

   d. Main water control valve and all zone control valves are open

   e. Water piping drain valves are open

   f. Fuel piping drain valve is open

   g. Trench discharge at curb is open

   h. Drain valve from weir tank is open

   i. Water supply valve to storage tank is closed

   j. Fuel supply valve is open

2. FIRST BURN

   a. Open water supply valve to storage tank

   b. Check operation of float valve and water level in water storage tank

   c. Close water piping drain valves

   d. Close fuel piping drain valve

   e. Close fuel supply valve

   f. Close drain valve from weir tank

   g. Trench discharge at curb remains open

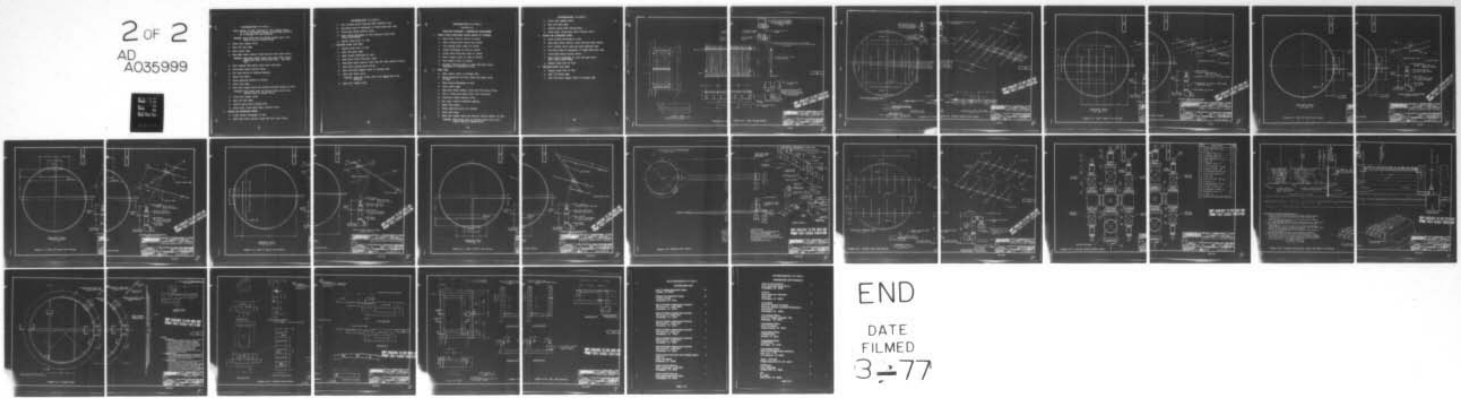
   h. Close main water control valve

   i. Start fuel pump

   j. Open fuel supply valve and fill fuel piping system until fuel just begins to enter trainer

AD-A035 999 IIT RESEARCH INST CHICAGO ILL F/G 6/7
DEVELOPMENT OF SMOKE AB[illegible] AIRCRAFT CRASH/RESCUE FIRE FIGHTING--ETC(U)
MAY 76 A GOLDSMITH N61339-74-C-0152
UNCLASSIFIED IITRI-J6339 NAVTRAEQUIPC-74-C-0152-1 NL

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3-77

Note: Amount of fuel required to fill piping system is to be determined during construction and will be a constant for the facility.

CAUTION: Fuel meter must be filled slowly until full before valve is opened fully.

k. Close fuel supply valve

l. Shut off fuel pump

m. Start water pump

n. Open main water control valve and all five zone valves

CAUTION: Open main water valve only after fuel piping system has been filled with fuel. See Step 2(j).

o. Fill trainer with water until weir overflows

p. Close main water control valve

q. Set zone valves to desired opening

r. Reset fuel meter

s. Place ignition pilots in trainer

t. Start fuel pump

u. Open fuel supply valve and deliver desired amount of fuel

CAUTION: Fuel meter must be filled slowly until full before valve is opened fully

v. Close fuel supply valve

w. Shut off fuel pump

x. Control spray water during burn

y. After burn, close main water control valve

3. SECOND AND SUBSEQUENT BURNS

a. Close trench discharge at curb

b. Open main water control valve and five zone valves

c. Fill trainer until foam and fuel overflow curb

d. Use water hose if necessary to flush foam over curb

e. Close main water control valve

f. Open trench discharge at curb and wait until weir stops overflowing

g. Repeat steps 2(q) to 2(y)

4. SHUTDOWN AFTER LAST BURN

a. Repeat steps 3(a) to 3(d)

b. Shut off water pump

c. Open trench discharge at curb

d. Open drain valve from weir tank

e. Open main water control valve and all zone control valves

f. Open water piping drain valves

g. Shut off water supply valve to storage tank

h. Open fuel drain valve

CAUTION: Open fuel drain valve only <u>after</u> water has drained.

i. Open fuel supply valve

SECTION VII

OPERATING PROCEDURE - NONFREEZING ENVIRONMENT

1. STEADY STATE CONDITIONS DURING PERIOD OF IDLENESS

   a. Main water 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

   e. Drain valve from weir tank is closed

   f. Water supply valve to tank is closed

   g. Fuel supply valve is closed

   h. Trainer contains water to some arbitrary level depending on evaporation loss

2. FIRST BURN

   a. Open supply valve to storage tank

   b. Check operation of float valve and water level in tank

   c. Open trench discharge at curb

   d. Start water pump

   e. Open main water control valve and five zone valves

   f. Fill trainer with water until weir overflows

   g. Close main water control valve

   h. Set zone valves to desired opening

   i. Reset fuel meter

   j. Place ignition pilots in trainer

   l. Start fuel pump

   m. Open fuel supply valve and deliver desired amount of fuel

      CAUTION: Fuel meter must be filled slowly until full before valve is opened fully

n. Close fuel supply valve

o. Shut off fuel pump

p. Control spray water during burn

q. After burn, close main water control valve

3. SECOND AND SUBSEQUENT BURNS

a. Close trench discharge at curb

b. Open main water control valve and five zone valves

c. Fill trainer until foam and fuel overflow curb

d. Use water hose if necessary to flush foam over curb

e. Close main water control valve

f. Open trench discharge at curb and wait until weir stops overflowing

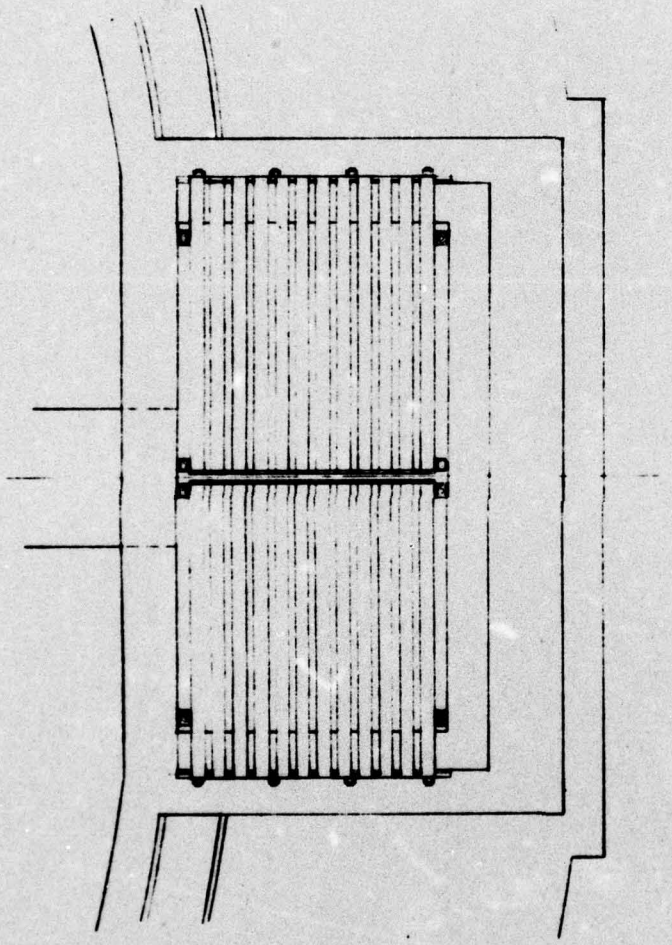
g. Repeat steps 2(h) to 2(q)

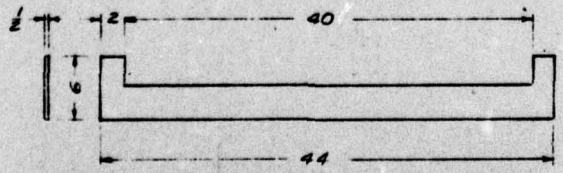
4. SHUTDOWN AFTER LAST BURN

a. Repeat steps 3(a) to 3(e)

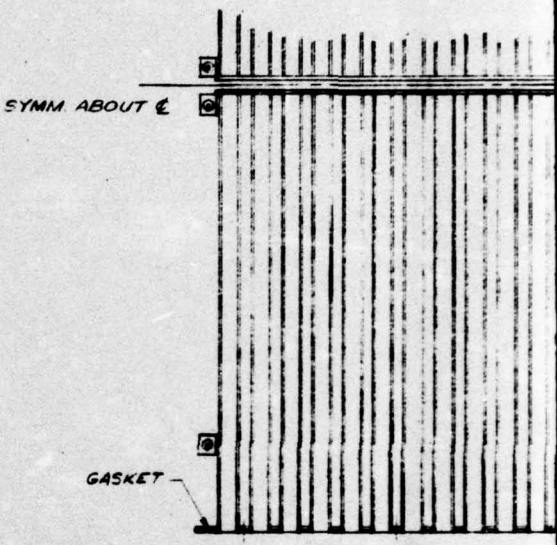
b. Shut off water pump

c. Shut off water supply valve to storage tank





GASKET 2 REQ'D
SPONGE RUBBER, MED. DENSITY, 45 DURO
ADHERE TO INSIDE OF PLATE



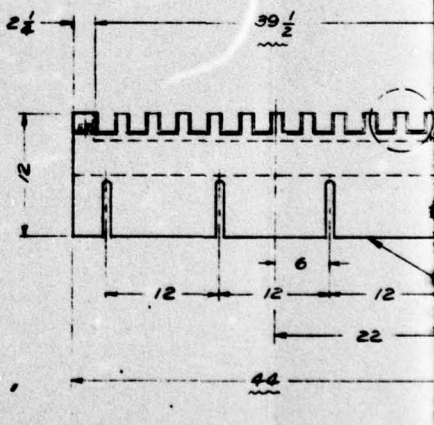


Figure A-1. W

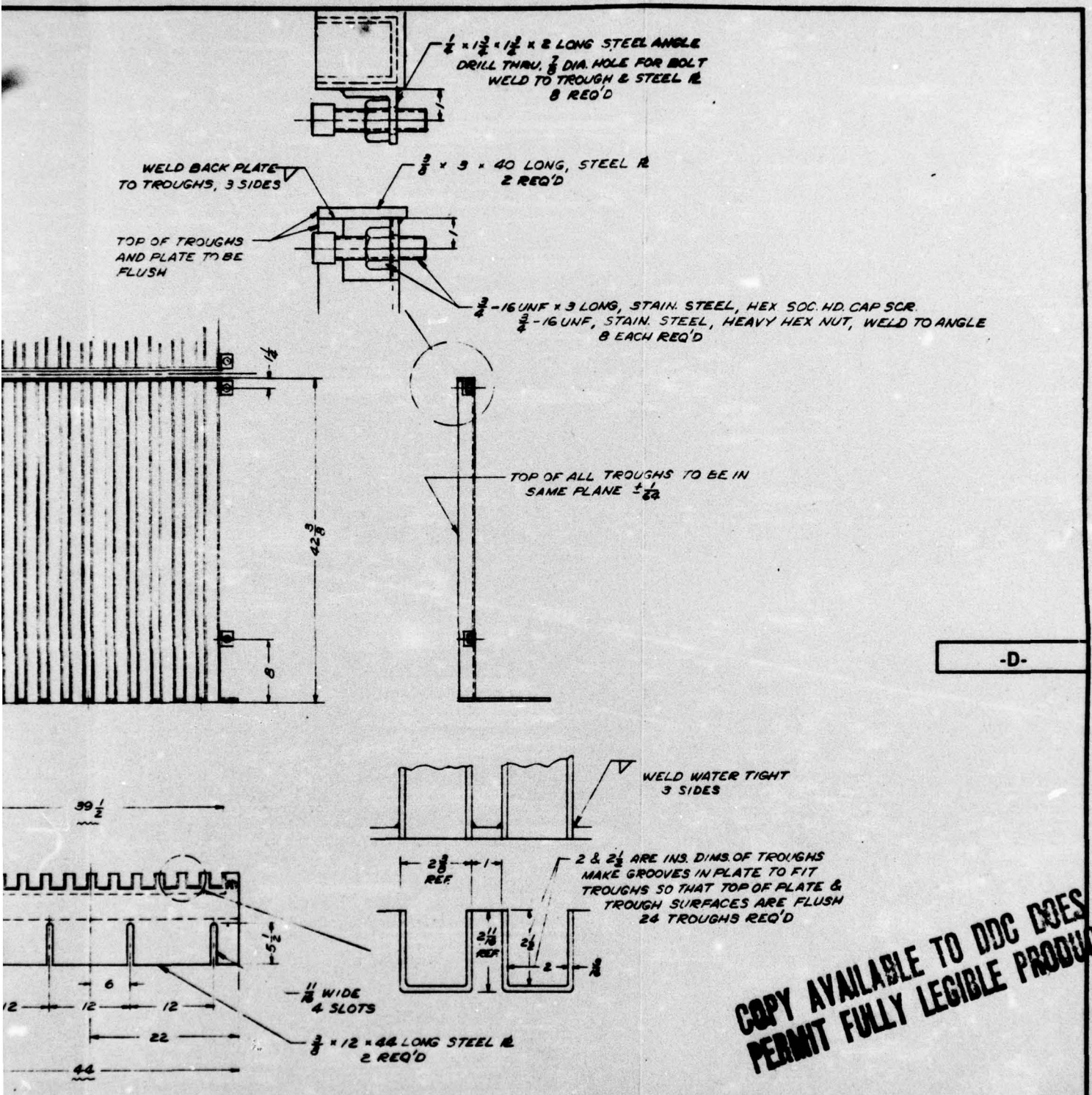


Figure A-1. Weir Trough Detail

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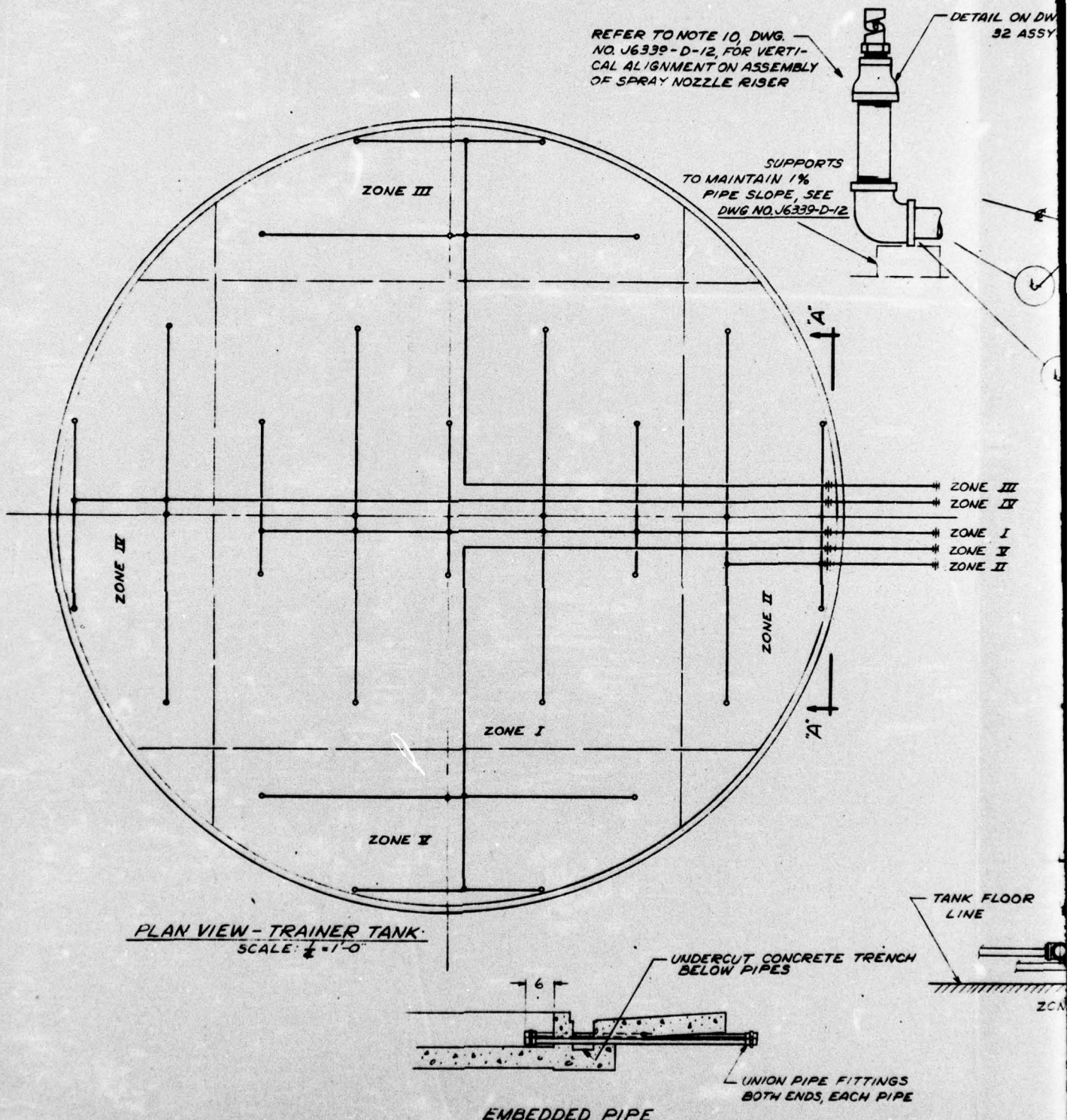
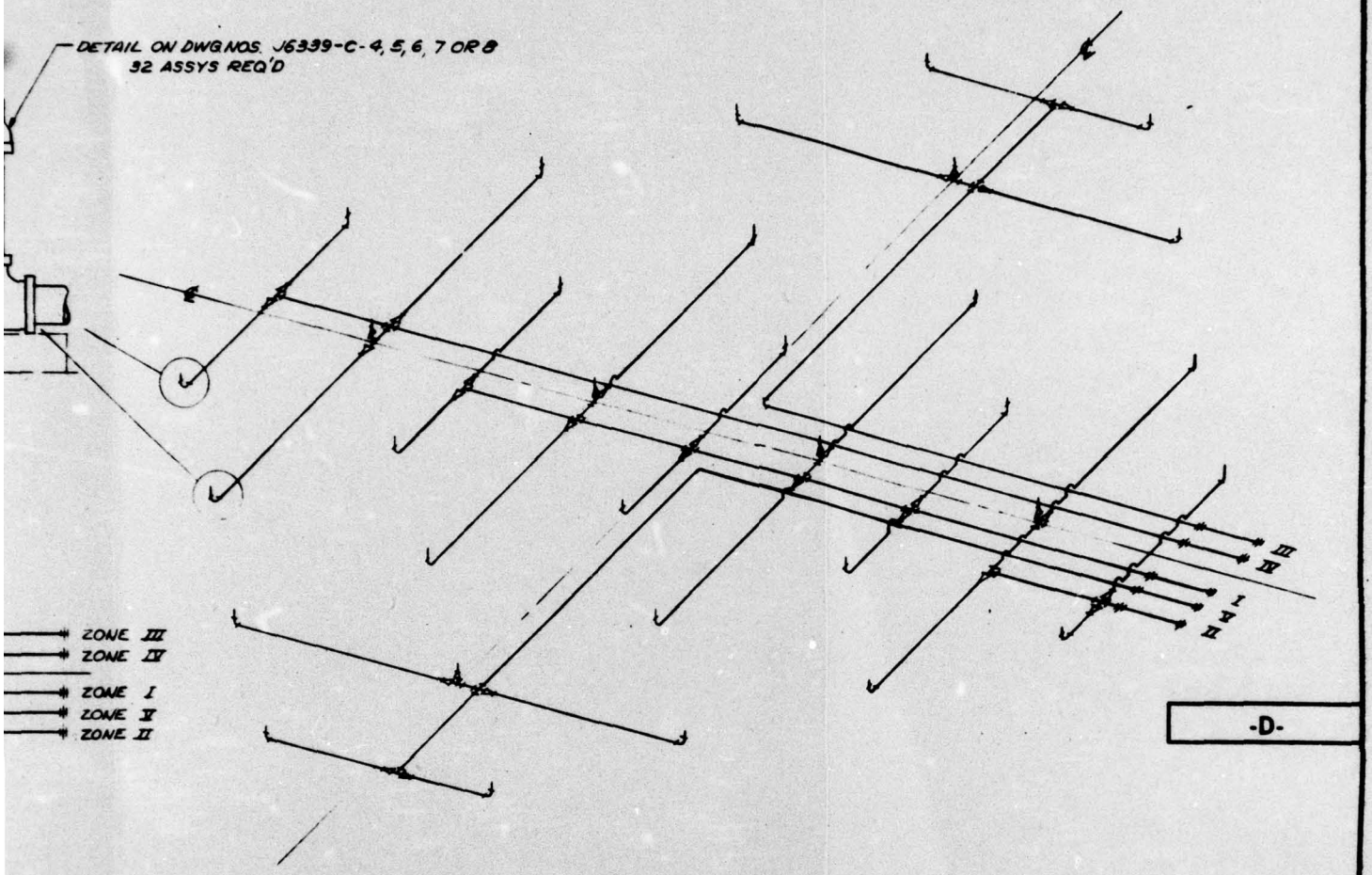
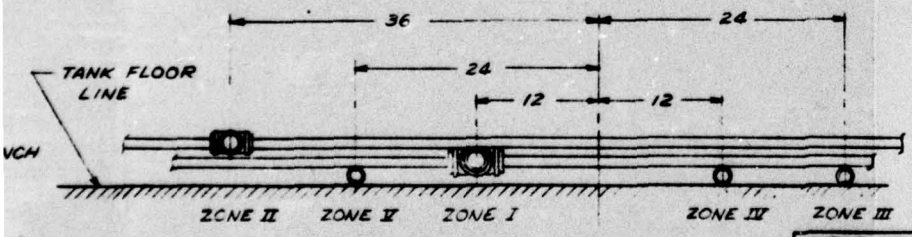


Figure A-2. Trai



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VIEW A'-A' – WATER PIPE STACK
SCALE: 1/2 = 1'-0"

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TRAINER WATER PIPE SYSTEM

J6339 -D- 3

ure A-2. Trainer Water Pipe System

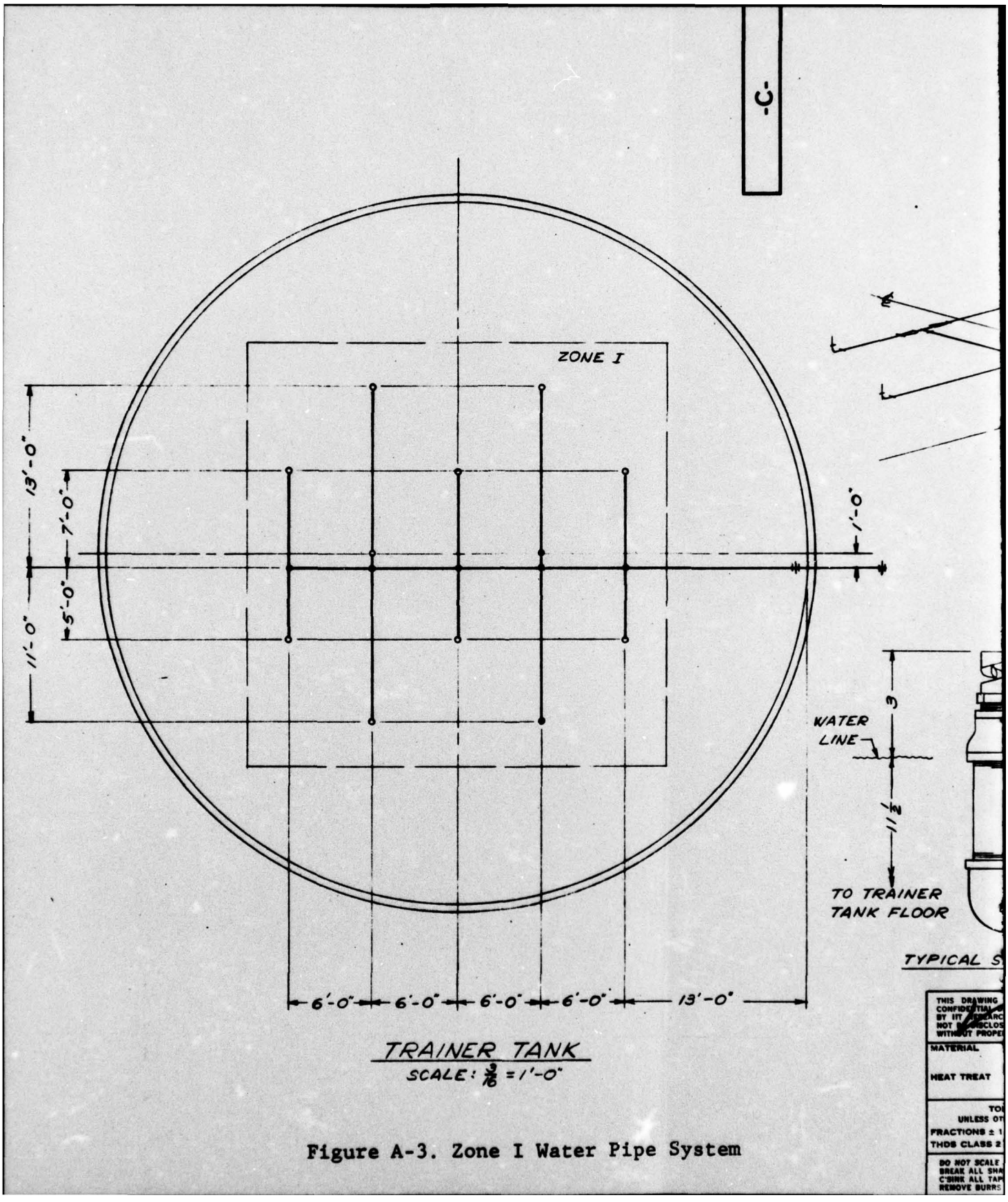


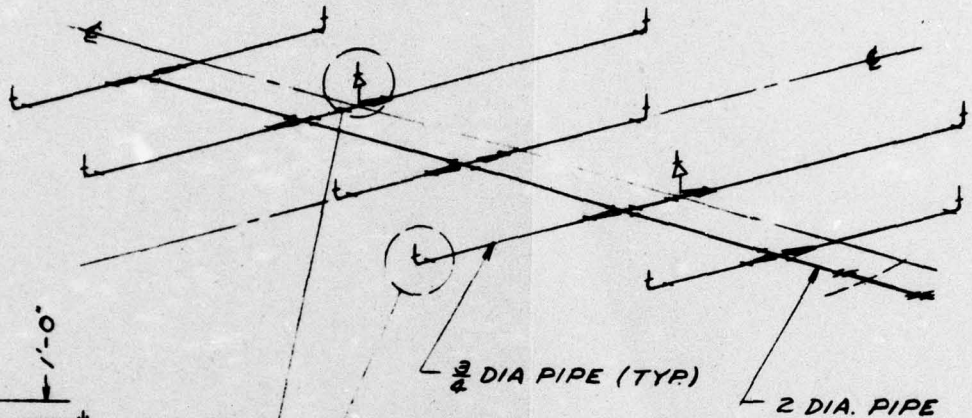
Figure A-3. Zone I Water Pipe System

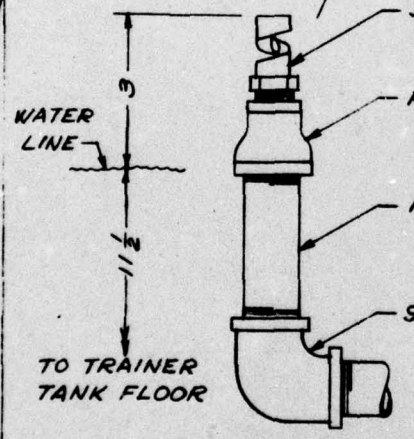
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IE I

1'-0"

13'-0"





TYPICAL SPRAY NOZZLE DETAIL
SCALE: 6" = 1'-0"

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SYM.	DATE	DESCRIPTION OF REVISION	NAME

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TECHNOLOGY CENTER CHICAGO, ILLINOIS 60616

MATERIAL
HEAT TREAT

ZONE I WATER PIPE SYSTEM

TOLERANCES
UNLESS OTHERWISE SPECIFIED
FRACTIONS ± 1/64 DECIMALS ± .005
THDS CLASS 2 FIT ANGULAR ± 1°

FINISH

QUANTITY PER
SUB-ASSEMBLY

	DESIGNED	DRAWN	CHECKED	APPROVED
NAME		J.N.	J.J.S.	A.G.
DATE		2/10/76	3/10/76	3/15/76

DO NOT SCALE - REPORT ERRORS
BREAK ALL SHARP CORNERS
C'SINK ALL TAPPED HOLES 1/32 x 45°
REMOVE BURRS

UNLESS OTHERWISE NOTED

SCALE NOTED
NEXT ASSEMBLY NO.
PROJECT DRAWING NO. J6339 -C- 4

Pipe System

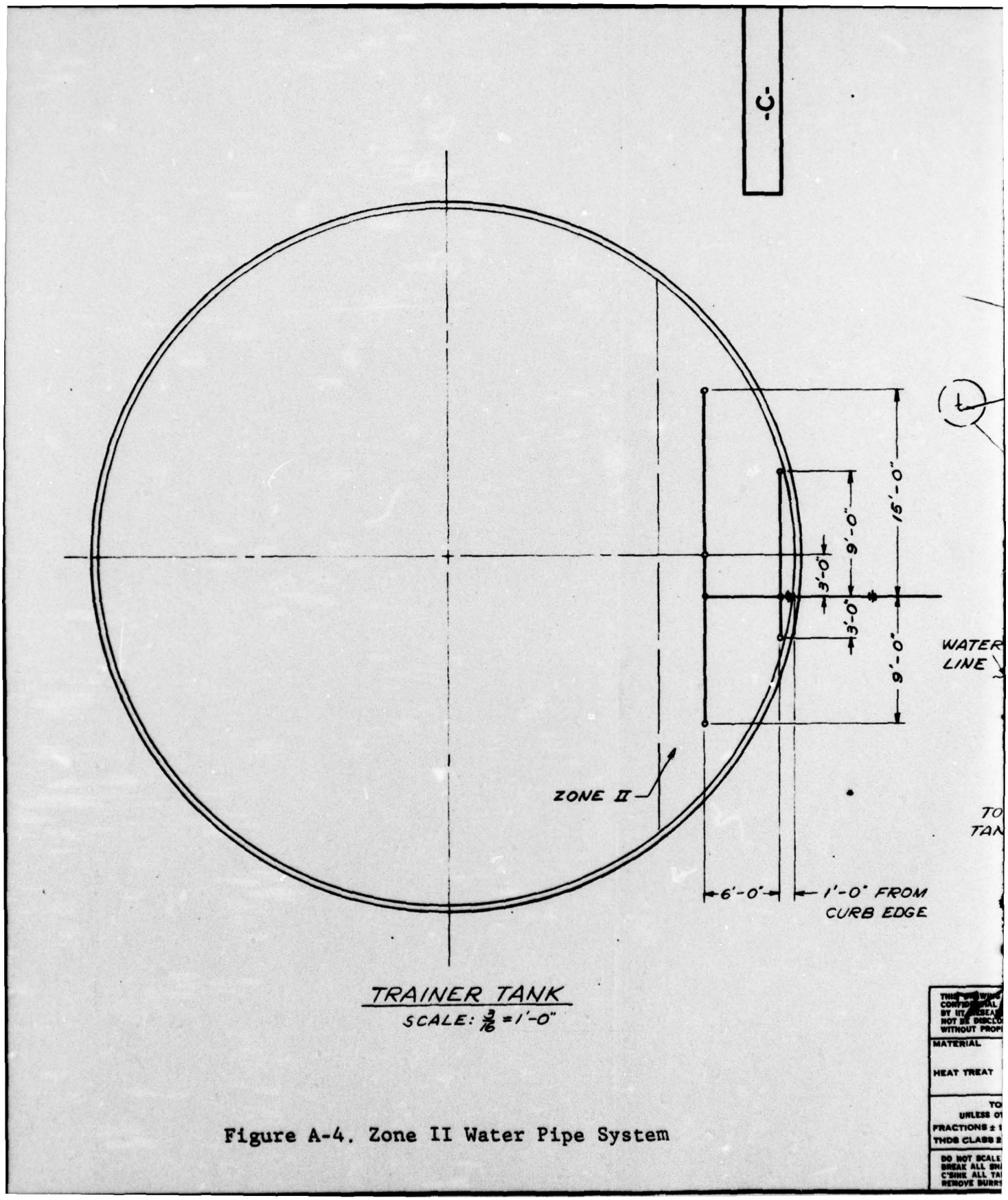
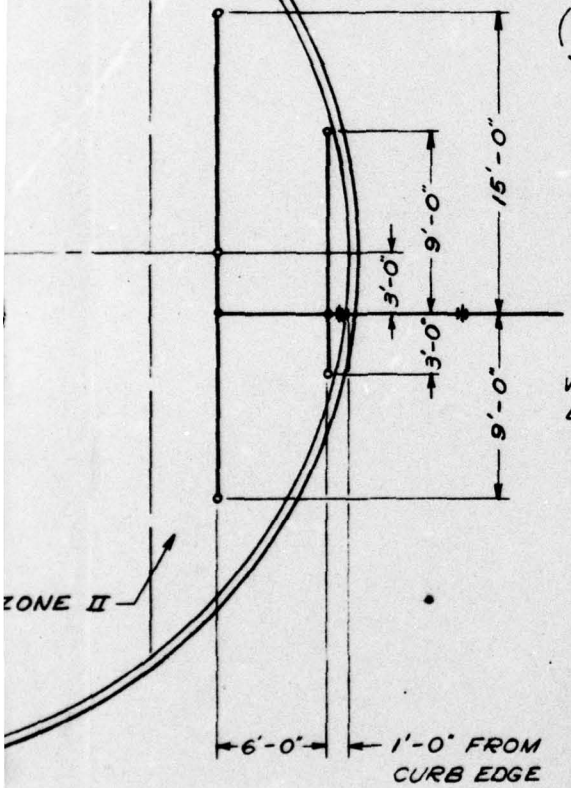
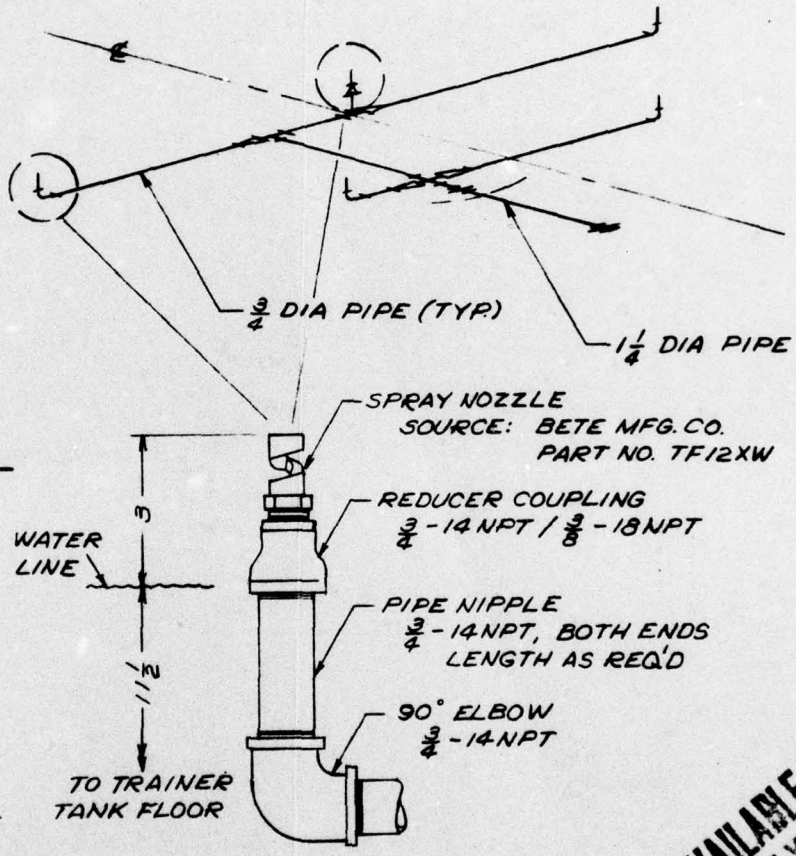


Figure A-4. Zone II Water Pipe System

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TYPICAL SPRAY NOZZLE DETAIL
SCALE: 6" = 1'-0"

COPY AVAILABLE TO
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pe System

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MATERIAL

HEAT TREAT

ZONE II WATER PIPE SYSTEM

TOLERANCES UNLESS OTHERWISE SPECIFIED
FRACTIONS ± 1/64 DECIMALS ± .005
THDS CLASS 2 FIT ANGULAR ± 1°

DO NOT SCALE - REPORT ERRORS
BREAK ALL SHARP CORNERS
C'BORE ALL TAPPED HOLES 1/32 x 45°
REMOVE BURRS

FINISH √ UNLESS OTHERWISE NOTED

QUANTITY PER SUB-ASSEMBLY

	DESIGNED	DRAWN	CHECKED	APPROVED
NAME		J.N.	J.J.S.	
DATE		2/18/76	3/11/76	3/15/76

SCALE NOTED

NEXT ASSEMBLY NO.

PROJECT DRAWING NO. J6339-C-5

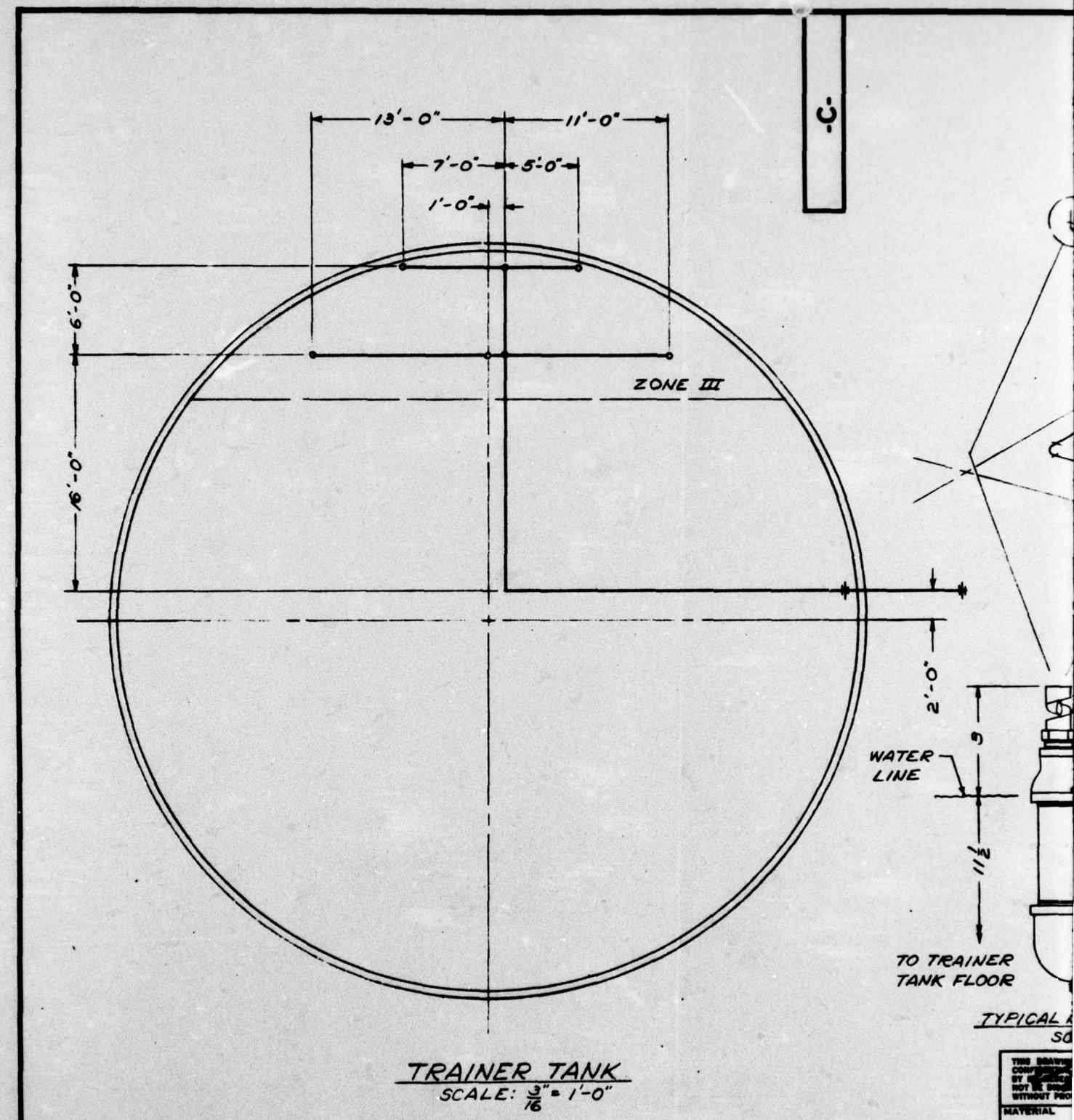
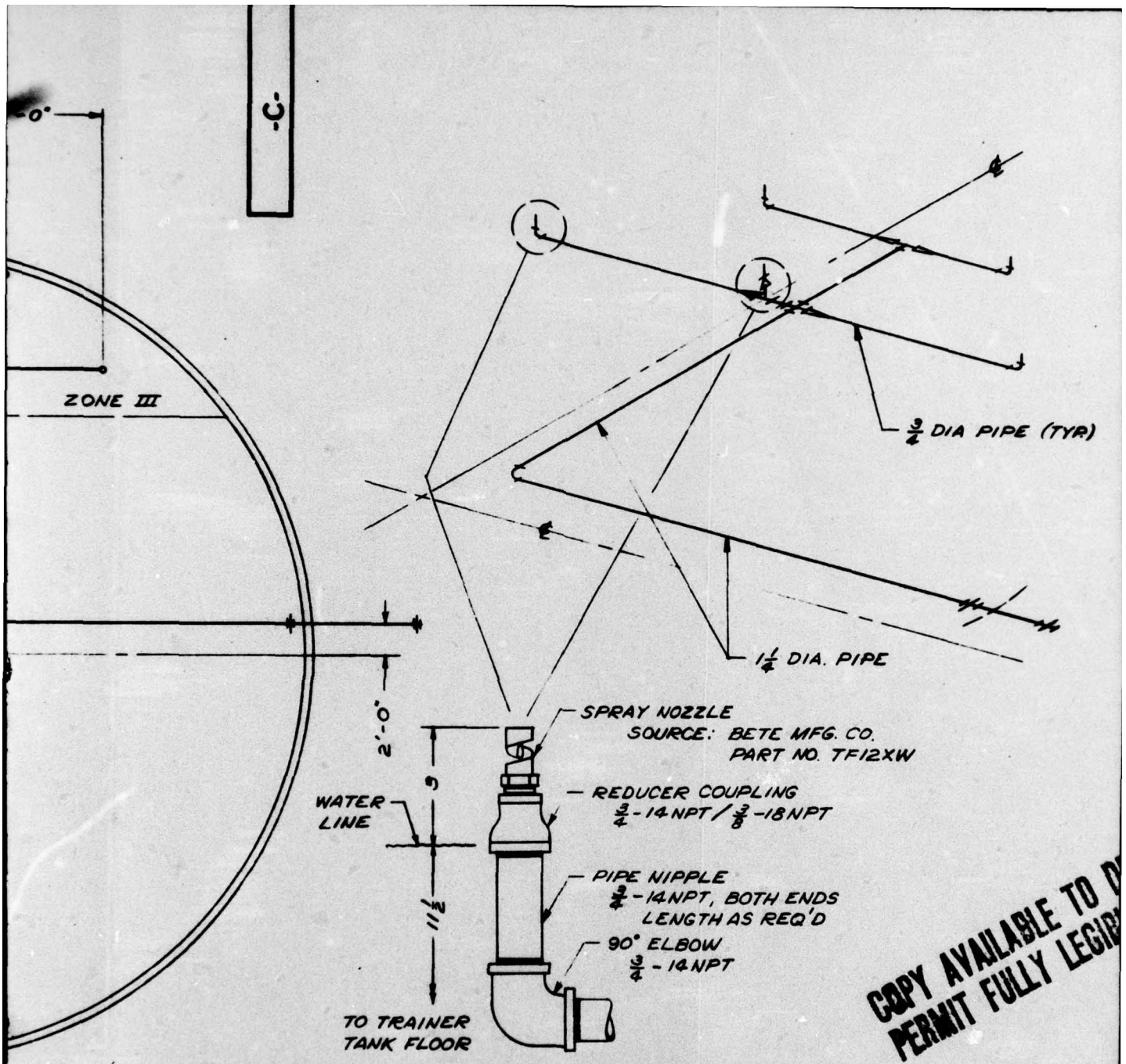


Figure A-5. Zone III Water Pipe System



TYPICAL NOZZLE SPRAY DETAIL
SCALE: 6" = 1'-0"

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Pipe System

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TECHNOLOGY CENTER CHICAGO, ILLINOIS 60616

MATERIAL

HEAT TREAT

ZONE III WATER PIPE SYSTEM

TOLERANCES
UNLESS OTHERWISE SPECIFIED
FRACTIONS ± 1/64 DECIMALS ± .005
THDS CLASS 2 FIT ANGULAR ± 1°

FINISH

QUANTITY PER
SUB-ASSEMBLY

	DESIGNED	DRAWN	CHECKED	APPROVED
NAME		J N	J.J.S.	CLS
DATE		2/10/76	3/11/76	3/15/76

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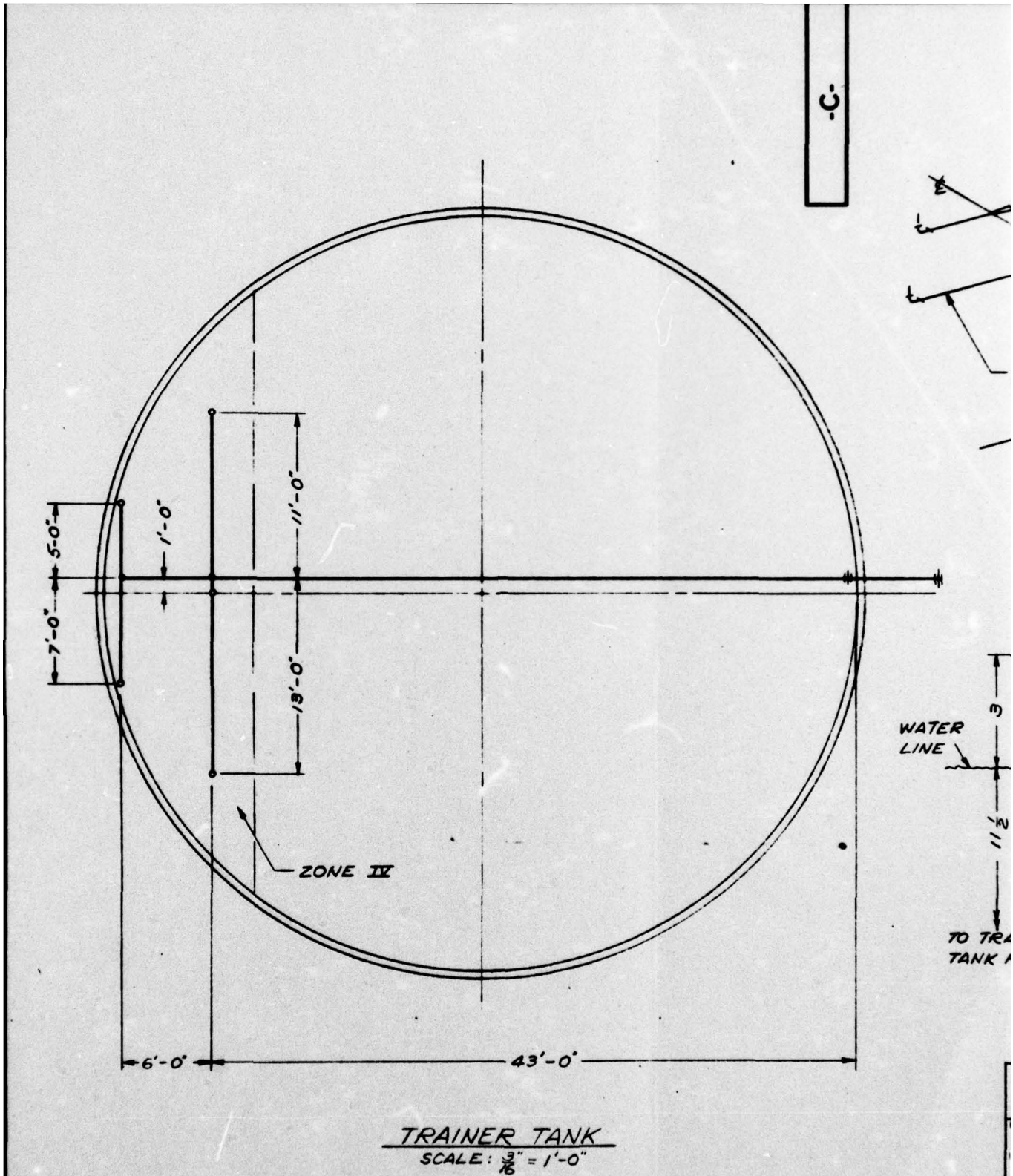
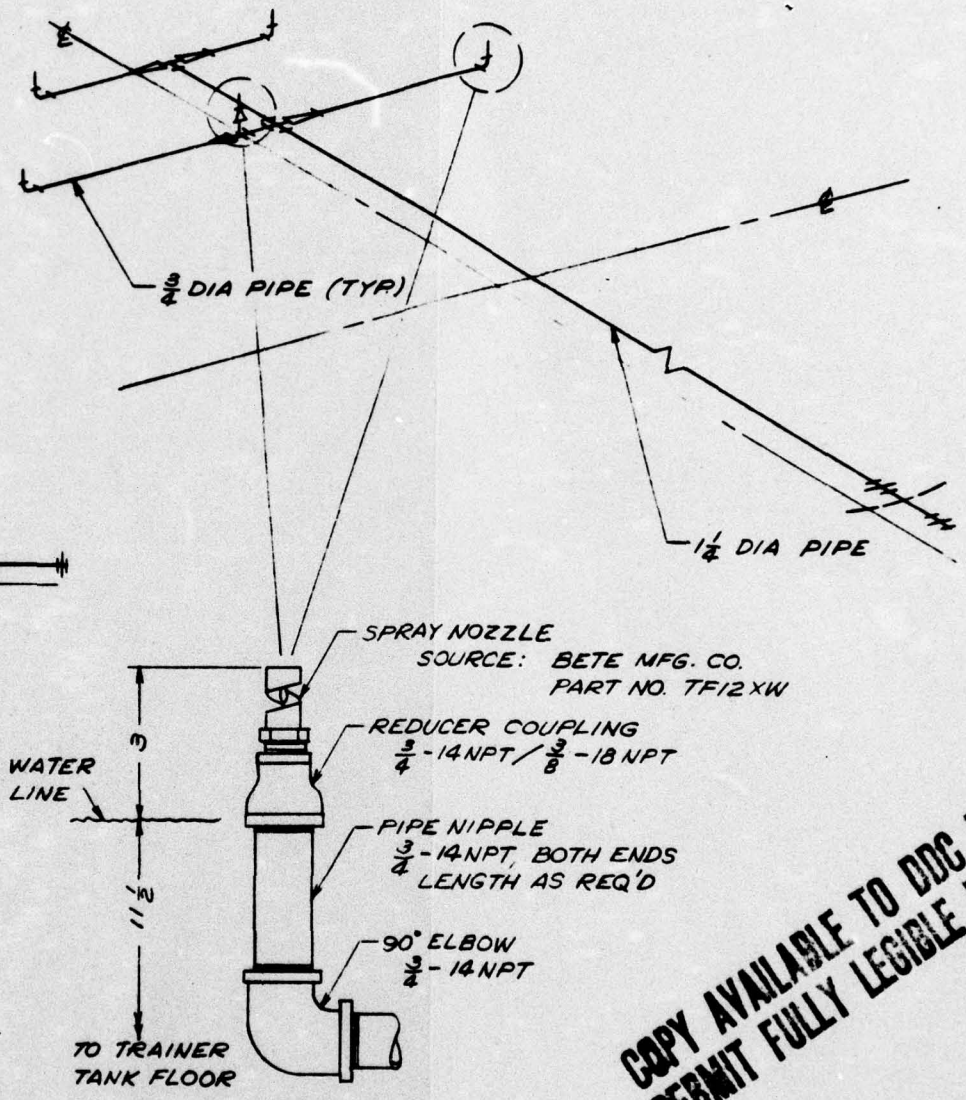


Figure A-6. Zone IV Water Pipe System

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TYPICAL SPRAY NOZZLE DETAIL
SCALE: 6" = 1'-0"

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Pipe System

SYM.	DATE	DESCRIPTION OF REVISION	NAME

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MATERIAL

HEAT TREAT

ZONE IV WATER PIPE SYSTEM

TOLERANCES
UNLESS OTHERWISE SPECIFIED
FRACTIONS ± 1/64 DECIMALS ± .005
THDS CLASS 2 FIT ANGULAR ± 1°

DO NOT SCALE - REPORT ERRORS
BREAK ALL SHARP CORNERS
C'SINK ALL TAPPED HOLES 1/32 x 60°
REMOVE BURRS

FINISH

UNLESS OTHERWISE NOTED

QUANTITY PER

SUB-ASSEMBLY

	DESIGNED	DRAWN	CHECKED	APPROVED
NAME		J N	J.J.S	
DATE		2/18/76	3/11/76	3/14/76

SCALE NOTED

NEXT ASSEMBLY NO.

PROJECT DRAWING NO. J6339 -C- 7

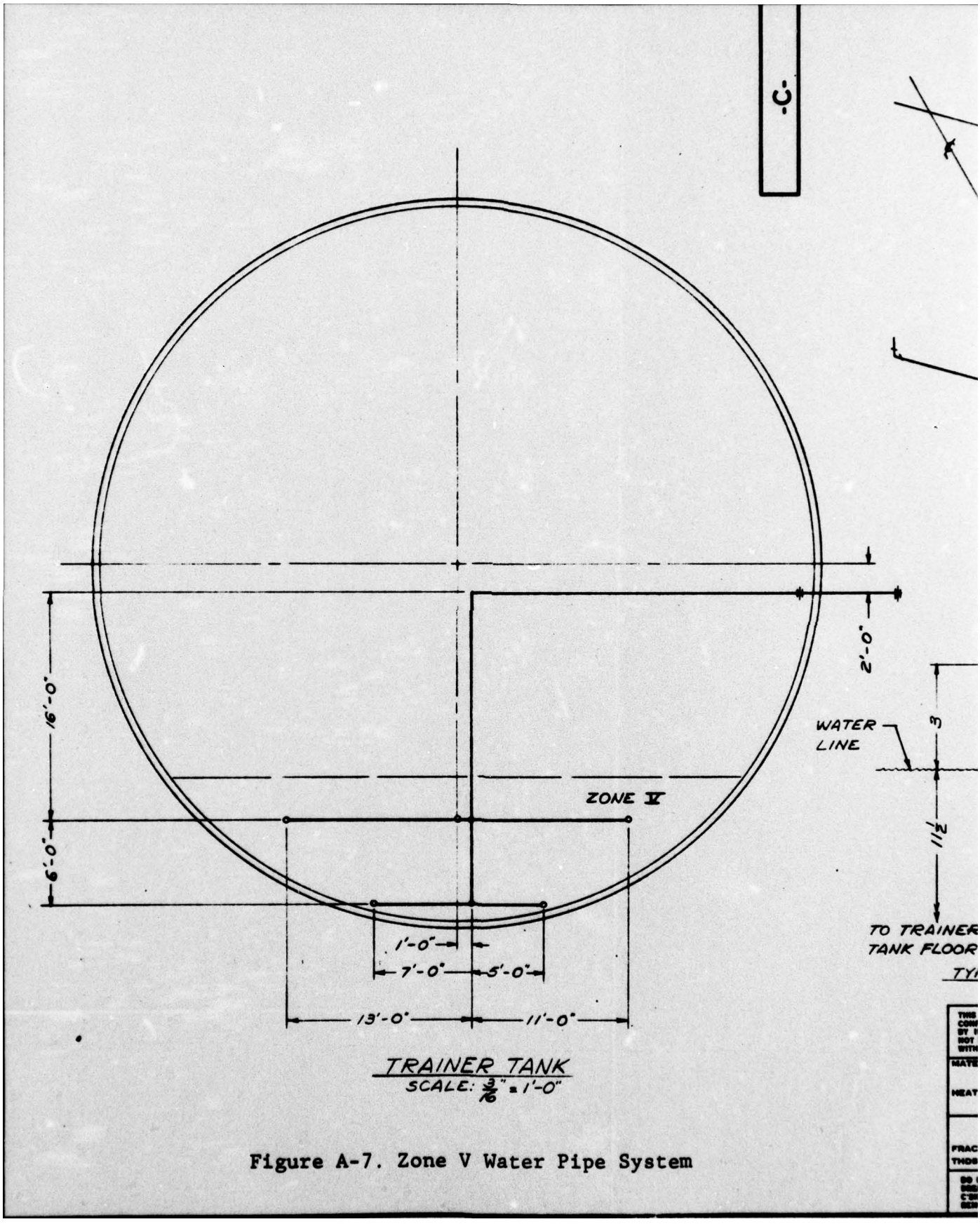
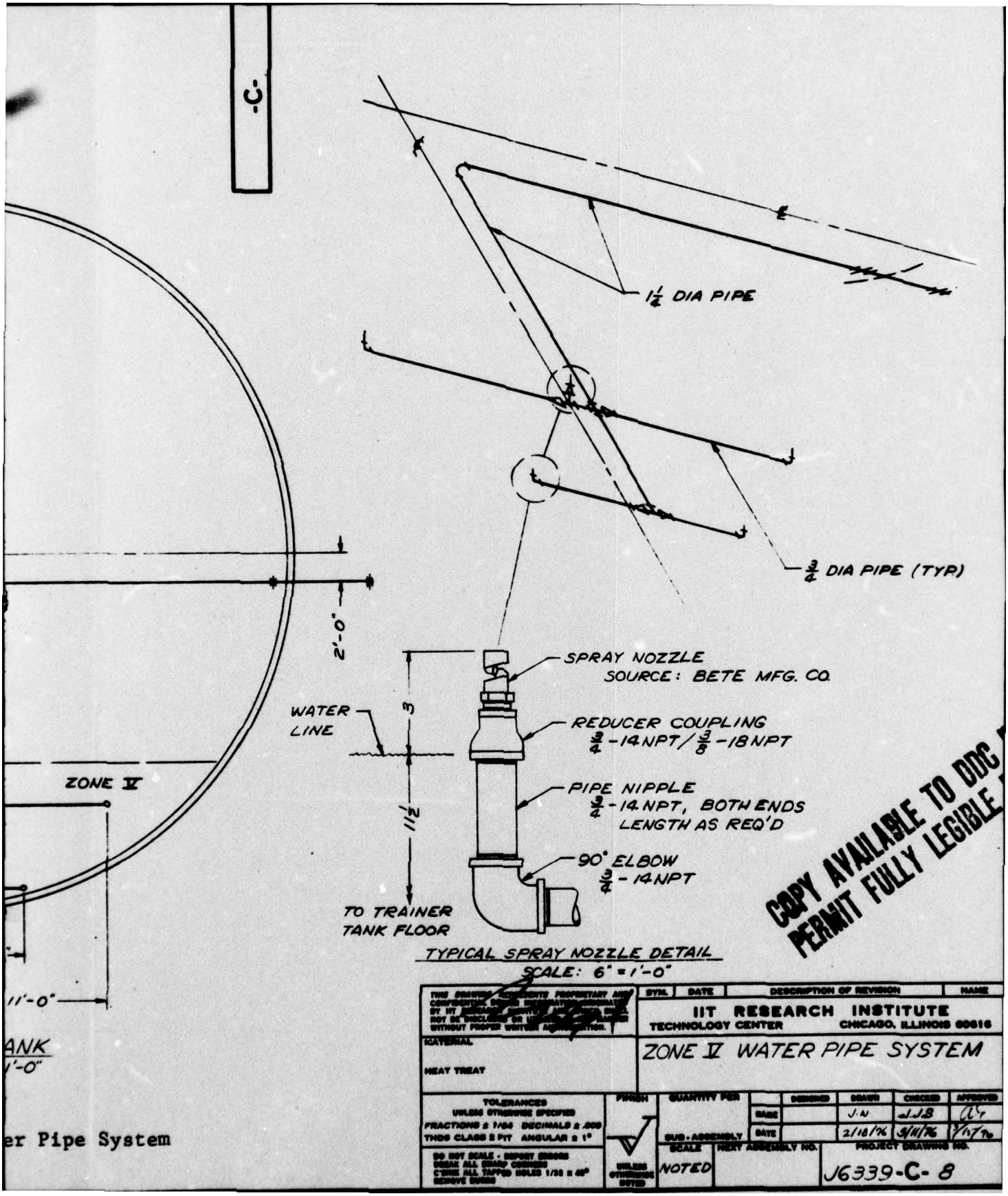


Figure A-7. Zone V Water Pipe System



TYPICAL SPRAY NOZZLE DETAIL
SCALE: 6" = 1'-0"

COPY AVAILABLE TO DDC
PERMIT FULLY LEGIBLE

ANK
1'-0"

er Pipe System

SYM.	DATE	DESCRIPTION OF REVISION	NAME

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MATERIAL
HEAT TREAT

ZONE V WATER PIPE SYSTEM

TOLERANCES
UNLESS OTHERWISE SPECIFIED
FRACTIONS ± 1/64 DECIMALS ± .005
THDS CLASS 2 FIT ANGULAR ± 1°

DO NOT SCALE - REPORT ERRORS
DEBUR ALL SHARP CORNERS
C'SINK ALL TAPPED HOLES 1/32 x 82°
REMOVE BURRS

FINISH
UNLESS OTHERWISE NOTED

QUANTITY PER
SUB-ASSEMBLY

	DESIGNED	DRAWN	CHECKED	APPROVED
BASE		J.N	J.J.S	
DATE		2/18/76	3/11/76	

SCALE NOTED
NEXT ASSEMBLY NO.
PROJECT DRAWING NO. J6339-C-8

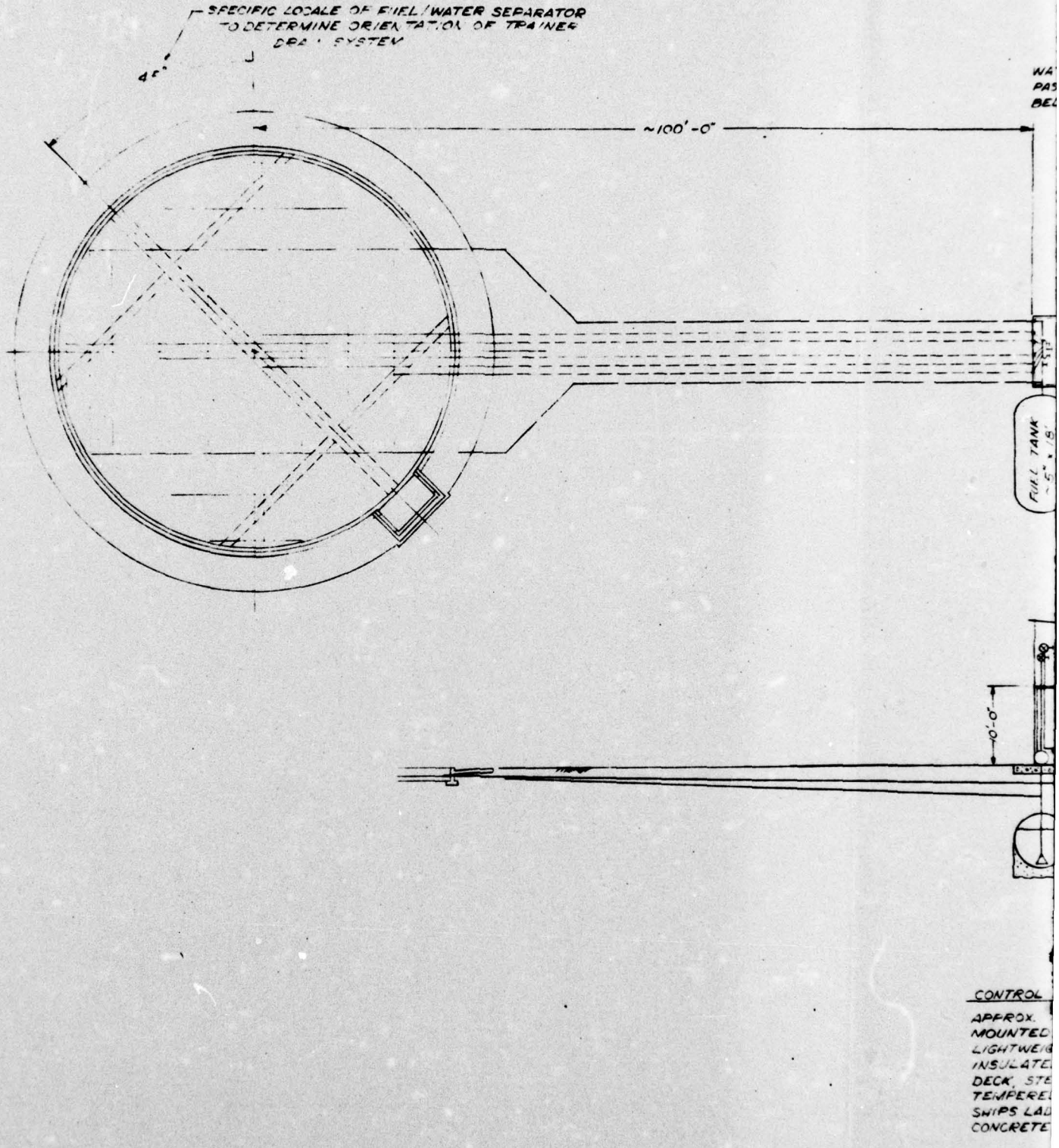
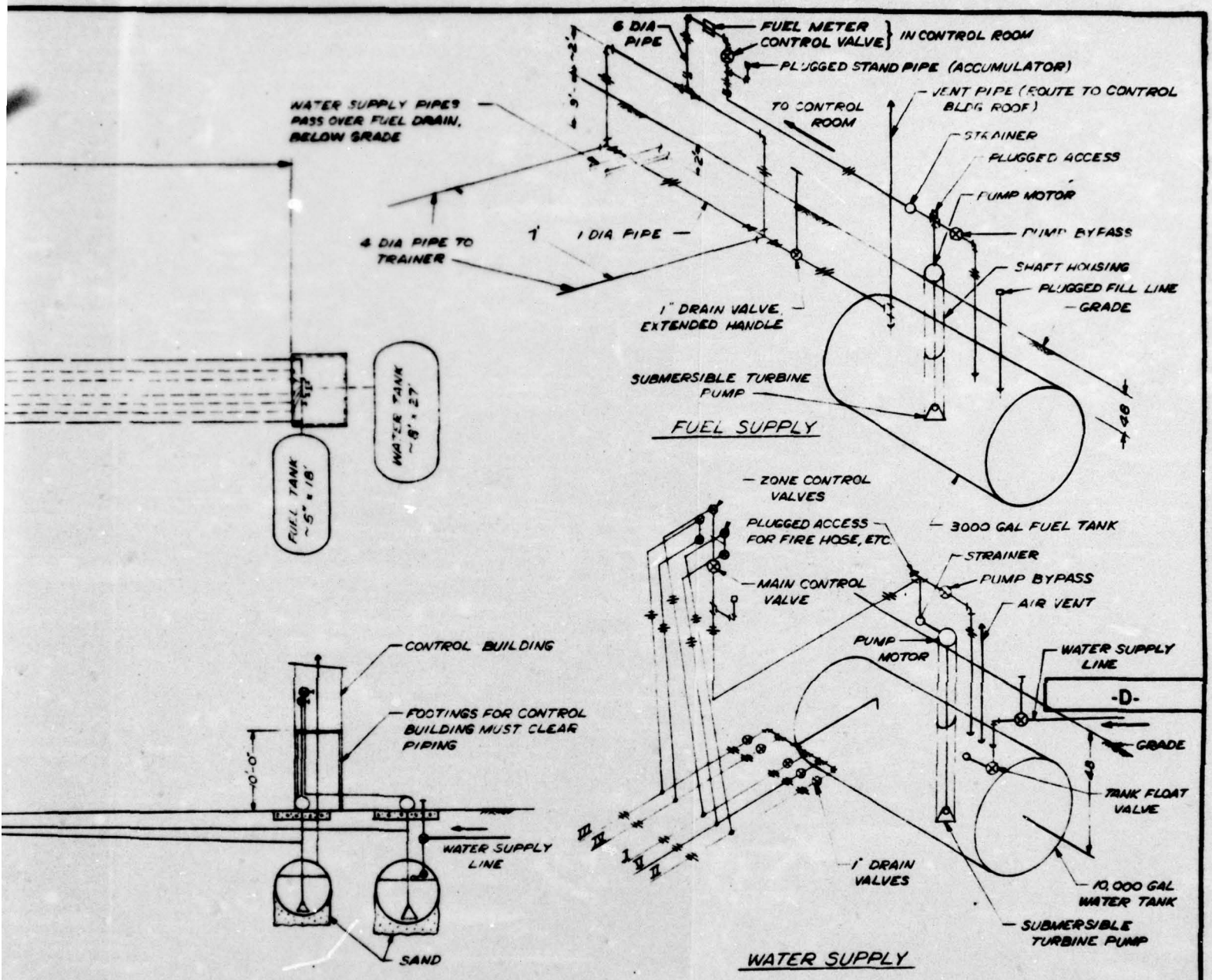


Figure A-8. Trainer Site Layout



CONTROL BUILDING

APPROX. 7'-0" WIDE × 8'-0" LONG × 8'-0" HIGH
MOUNTED 10'-0" ABOVE TRAINER GRADE
LIGHTWEIGHT STEEL MEMBERS
INSULATED METAL WALL PANELS, METAL ROOF DECK, STEEL FLOOR PLATE, SERVICE DOOR, TEMPERED GLASS OBSERVATION WINDOW, STEEL SHIPS LADDER
CONCRETE FOOTINGS FOR POSTS

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TRAINER SITE LAYOUT

J6339-D-9

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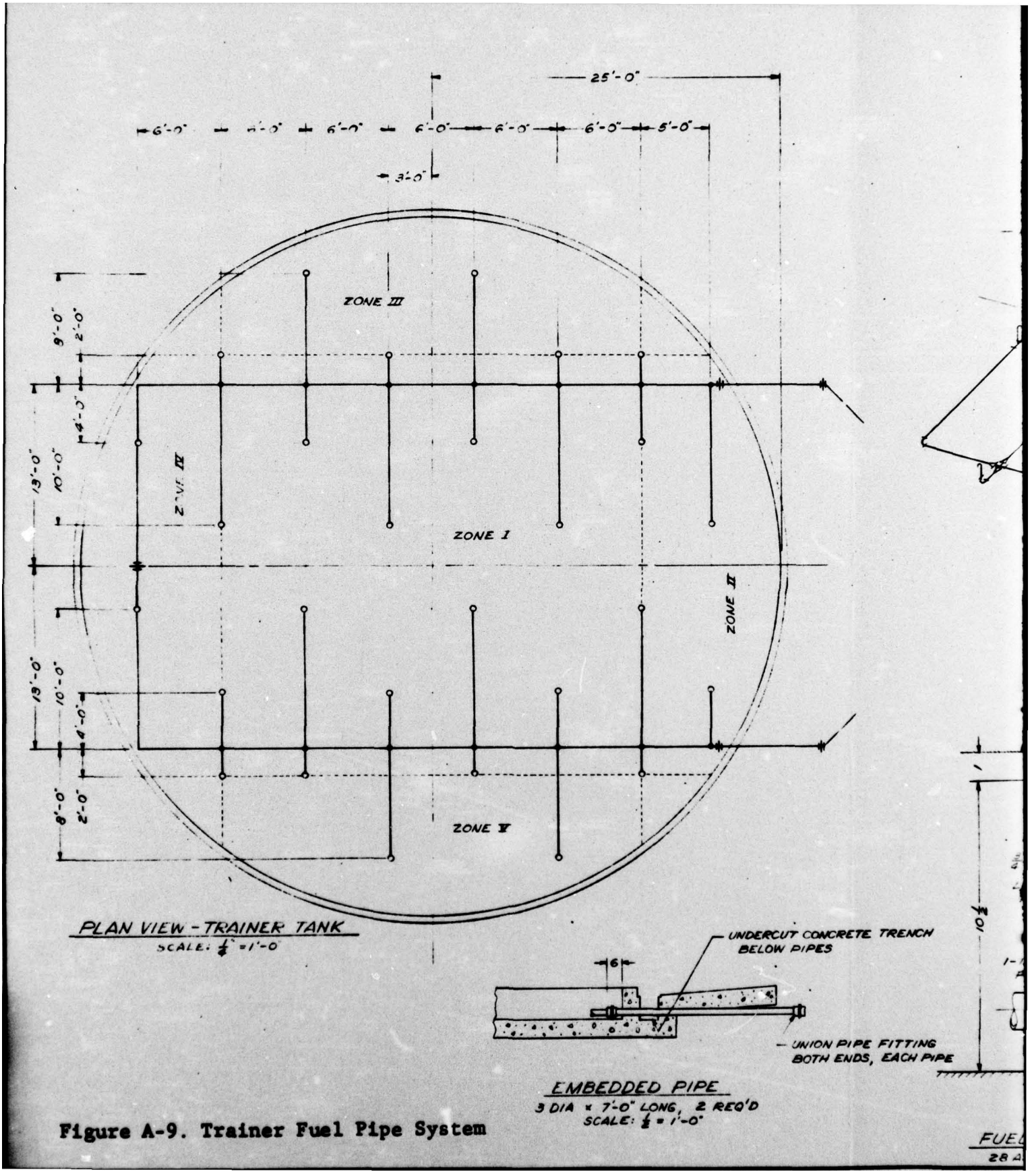
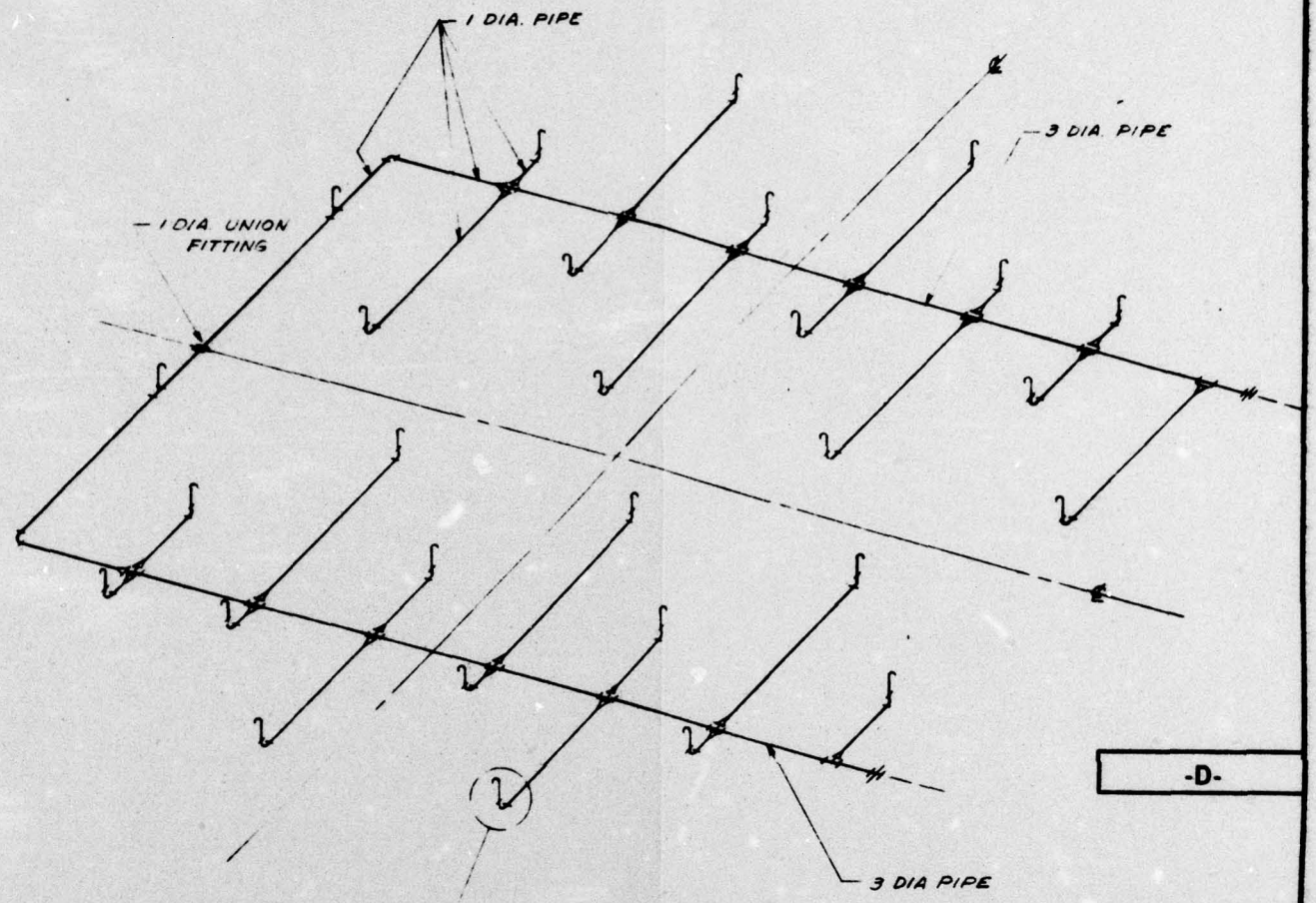
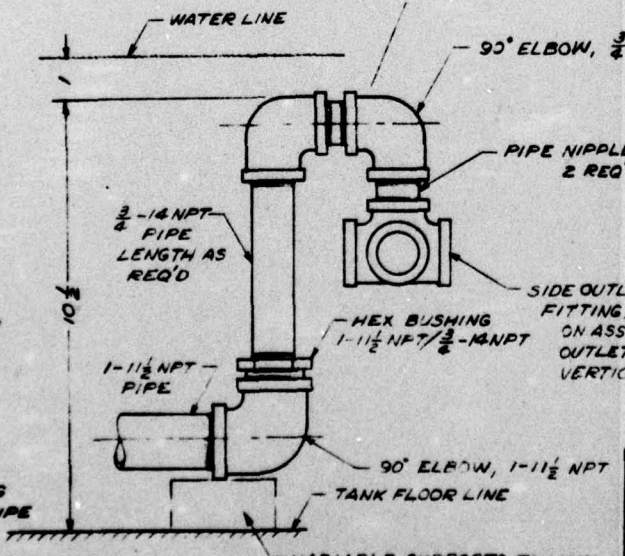


Figure A-9. Trainer Fuel Pipe System



-D-



UT CONCRETE TRENCH
V PIPES

UNION PIPE FITTING BOTH ENDS, EACH PIPE

FUEL PIPE OUTLET DETAIL

28 ASSYS REQ'D SCALE: 6"=1'-0"

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SYM.	DATE	DESCRIPTION OF REVISION	NAME

IIT RESEARCH INSTITUTE
TECHNOLOGY CENTER CHICAGO, ILLINOIS 60616

TRAINER FUEL PIPE SYSTEM

MATERIAL
HEAT TREAT
TOLERANCES UNLESS OTHERWISE SPECIFIED FRACTIONS ± 1/64 DECIMALS ± .005 TYPE CLASS 2 FIT ANGULAR ± 1°
FINISH
QUANTITY PER
SUB-ASSEMBLY
DO NOT SCALE - DEPOSIT DRAWING BREAK ALL SHARP EDGES (TYPE) ALL TAPPED HOLES 1/32 x 45° REMOVE BURRS
SCALE NOTED
UNLESS OTHERWISE NOTED

	DRAWN	CHECKED	APPROVED
ORIG	J.H	J.J.S.	(V)
DATE	2/26/70	4/6/70	4/7/70

NEXT ASSEMBLY NO.
PROJECT DRAWING NO. J6339-D-10

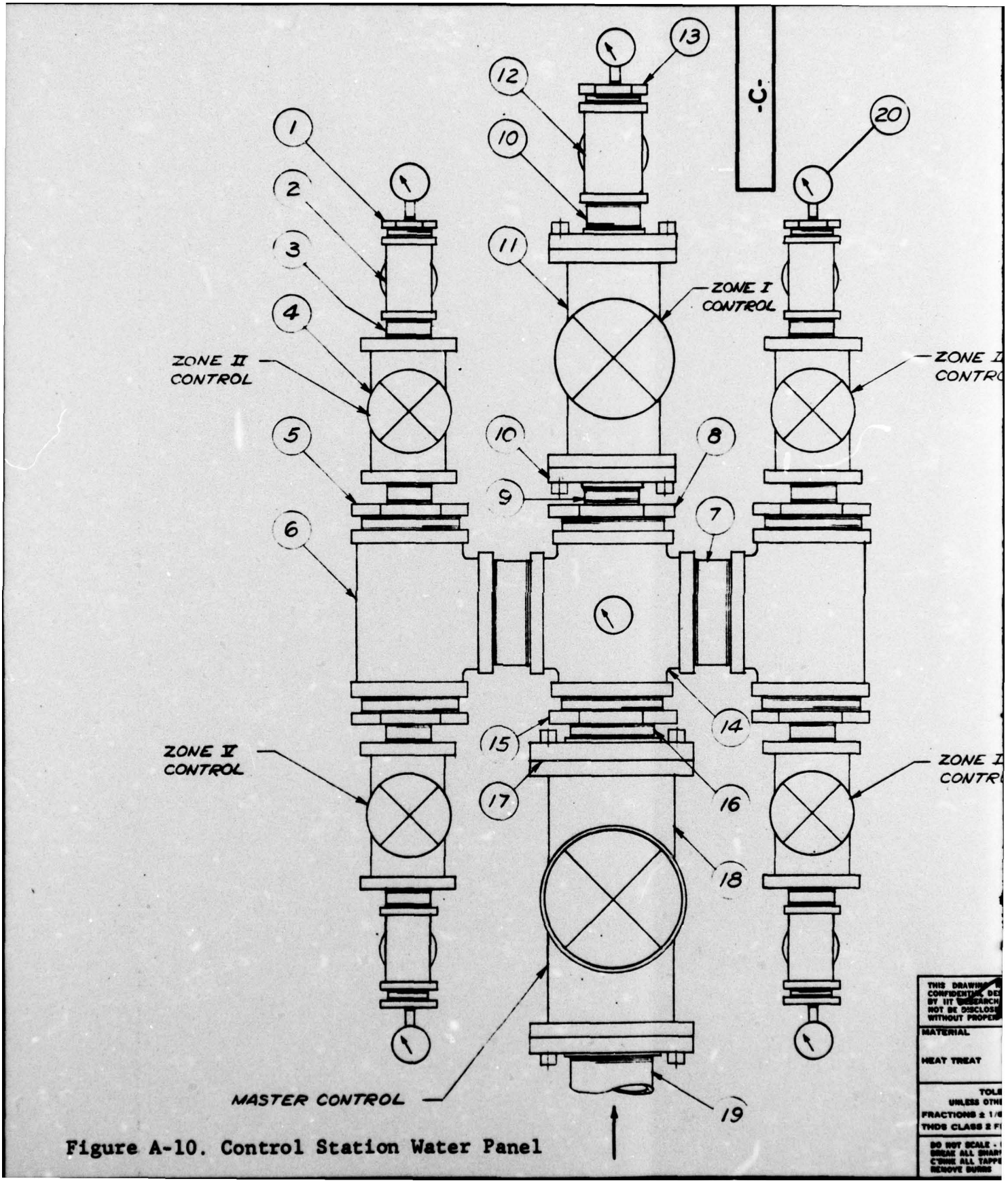
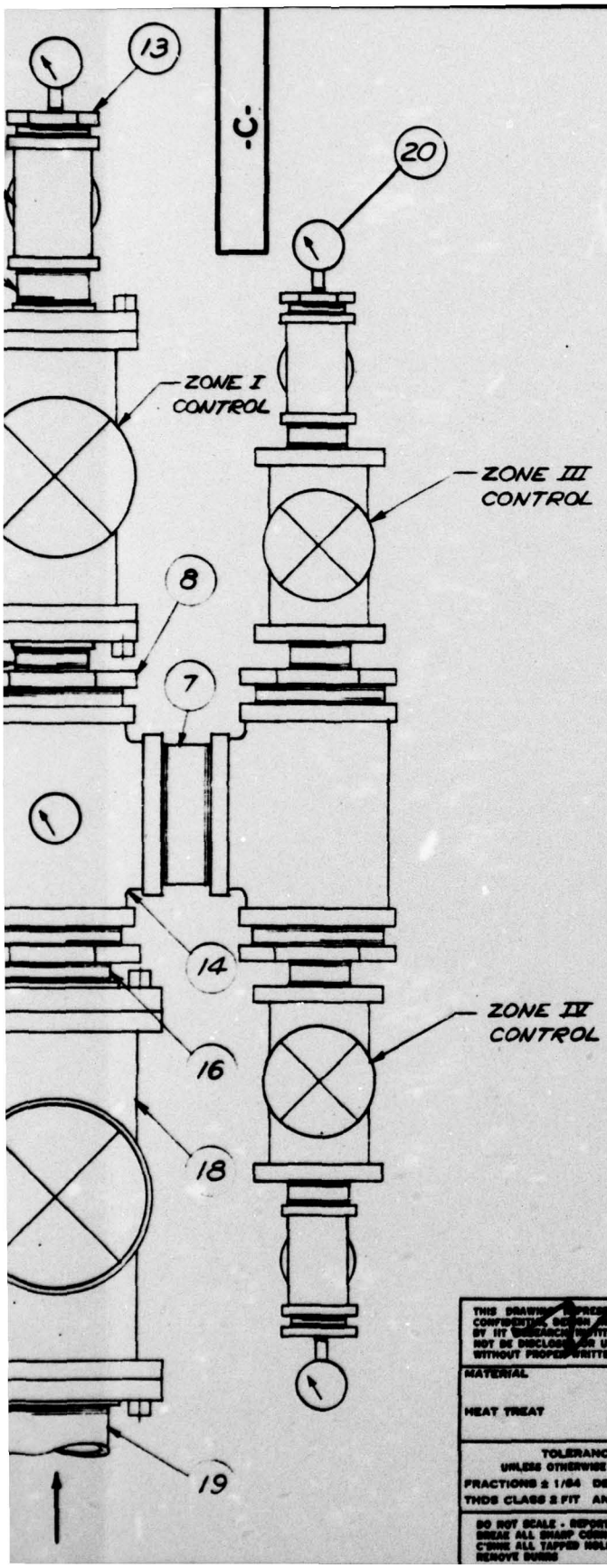


Figure A-10. Control Station Water Panel



PART NO.	DESCRIPTION	REQ'D
1	HEX. BUSHING, 2" × 1"	4
2	TEE, 2"	4
3	SHORT NIPPLE, 2"	8
4	CONTROL VALVE, 2"	4
5	HEX. BUSHING, 5" × 2"	4
6	TEE, 5"	2
7	SHORT NIPPLE, 5"	2
8	HEX. BUSHING, 5" × 2½"	1
9	SHORT NIPPLE, 2½"	1
10	THREADED FLANGE, 2½"	2
11	CONTROL VALVE, 2½"	1
12	TEE, 2½"	1
13	HEX. BUSHING, 2½" × 1"	1
14	CROSS, 5"	1
15	HEX. BUSHING, 5" × 4"	1
16	SHORT NIPPLE, 4"	1
17	THREADED FLANGE, 4"	2
18	CONTROL VALVE, 4"	1
19	PIPE, 4"	
20	PRESSURE REGULATOR GAUGE	6

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SYM.	DATE	DESCRIPTION OF REVISION	NAME

IIT RESEARCH INSTITUTE
TECHNOLOGY CENTER CHICAGO, ILLINOIS 60616

MATERIAL

HEAT TREAT

CONTROL STATION WATER PANEL

TOLERANCES
UNLESS OTHERWISE SPECIFIED
FRACTIONS ± 1/64 DECIMALS ± .005
THDS CLASS 2 FIT ANGULAR ± 1°

DO NOT SCALE - REPORT ERRORS
BREAK ALL SHARP CORNERS
C'SINK ALL TAPPED HOLES 1/32 × 45°
REMOVE BURRS

FINISH

UNLESS OTHERWISE SPECIFIED

QUANTITY PER

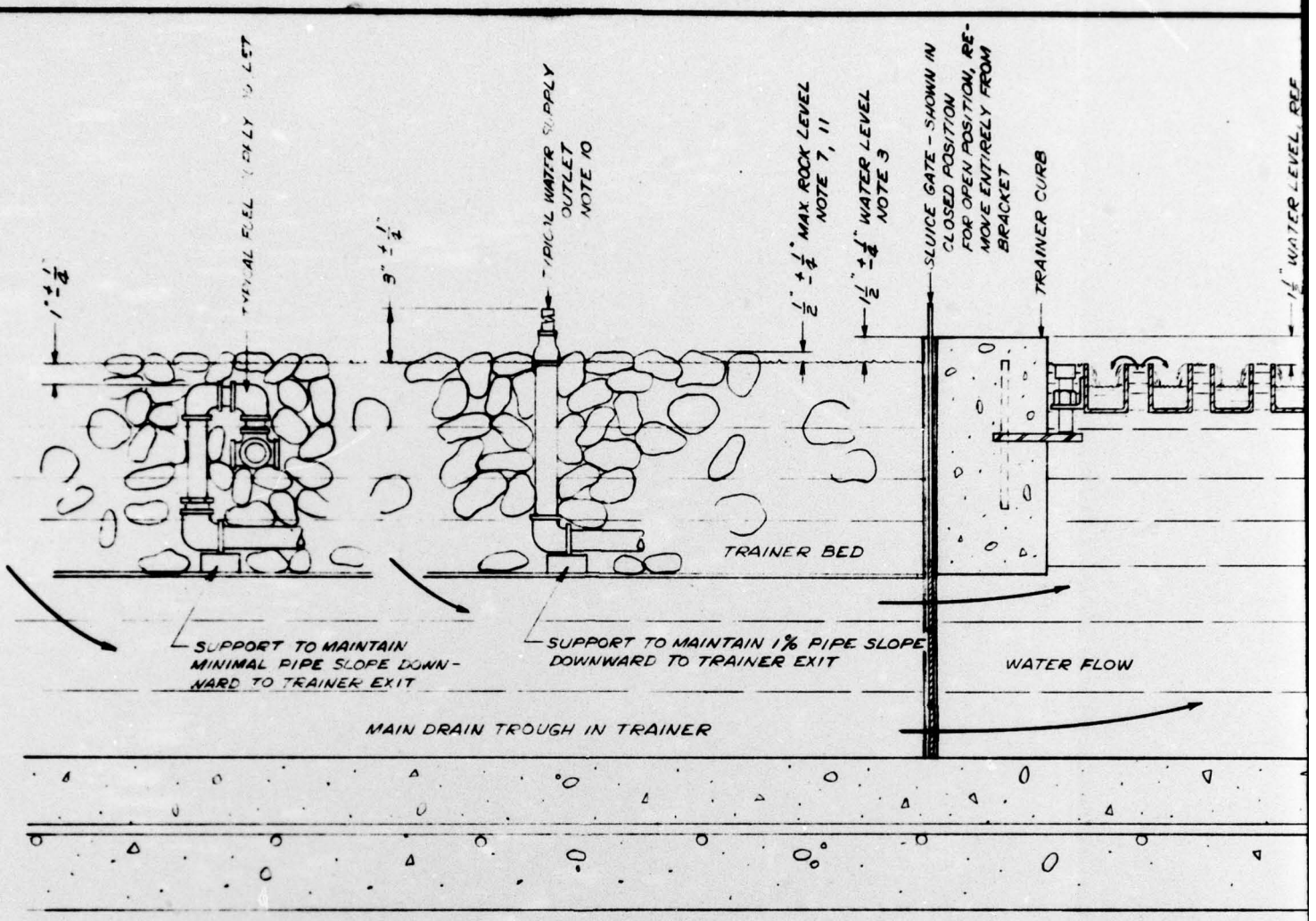
SUB-ASSEMBLY

	NAME	DESIGNED	DRAWN	CHECKED	APPROVED
			J.N	J.J.S.	
DATE			2/24/76	3/11/76	3/15/76

SCALE NONE

NEXT ASSEMBLY NO.

PROJECT DRAWING NO. J6339-C-11



PIPE SIZING AND ASSEMBLY PROCEDURAL NOTES:

1. LOCATE AND PLACE ALL HORIZONTAL PIPING IN TRAINER FOR WATER AND FUEL SYSTEMS, INCLUDING 90° ELBOWS FOR WATER SPRAY NOZZLE AND FUEL OUTLETS
2. PLUG OR CAP FUEL SUPPLY LINES AT UNIONS LOCATED OUTSIDE OF TRAINER AND CLOSE WEIR TANK DRAIN VALVE
3. FILL TRAINER AND WEIR TANK WITH WATER TO SPECIFIED DEPTH AS SHOWN ABOVE
4. ADJUST WEIR TROUGH ASSEMBLY AS REQUIRED TO MAINTAIN SPECIFIED WATER LEVEL
5. MEASURE REQUIRED RISER PIPE NIPPLE LENGTHS TO OBTAIN WATER SPRAY NOZZLE AND FUEL OUTLET DIMENSIONS AT SPECIFIED LEVELS AS SHOWN ABOVE
6. ASSEMBLE WATER SPRAY NOZZLES AND FUEL OUTLETS
7. FILL TRAINER WITH CRUSHED STONE OF SPECIFIED SIZE TO REQUIRED LEVEL AS SHOWN ON DRAWING
8. OPEN DRAIN VALVE FROM WEIR TANK AND DRAIN WATER FROM TRAINER
9. REMOVE PLUGS OR CAPS FROM FUEL SUPPLY LINES AND RECONNECT UNIONS
10. SPRAY NOZZLE RISER SHALL BE PLUMBED TO WITHIN ± 2° IN ALL DIRECTIONS. NOZZLE RISER VERTICALNESS CAN BE INSPECTED BY THREADING A 3/8" x 36" MIN LENGTH ROD INTO THE 3/4" x 3/8" REDUCER COUPLING AND MEASURING.
11. CRUSHED STONE SIZING: GAP GRADED AGGREGATE
    100% PASSING — 3 IN. SIEVE
    0% PASSING — 2 IN. SIEVE

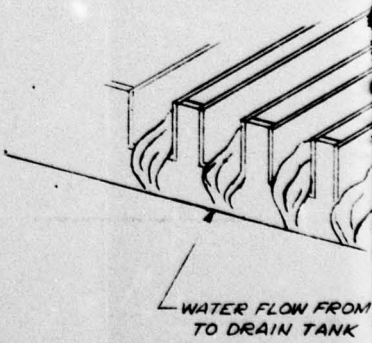
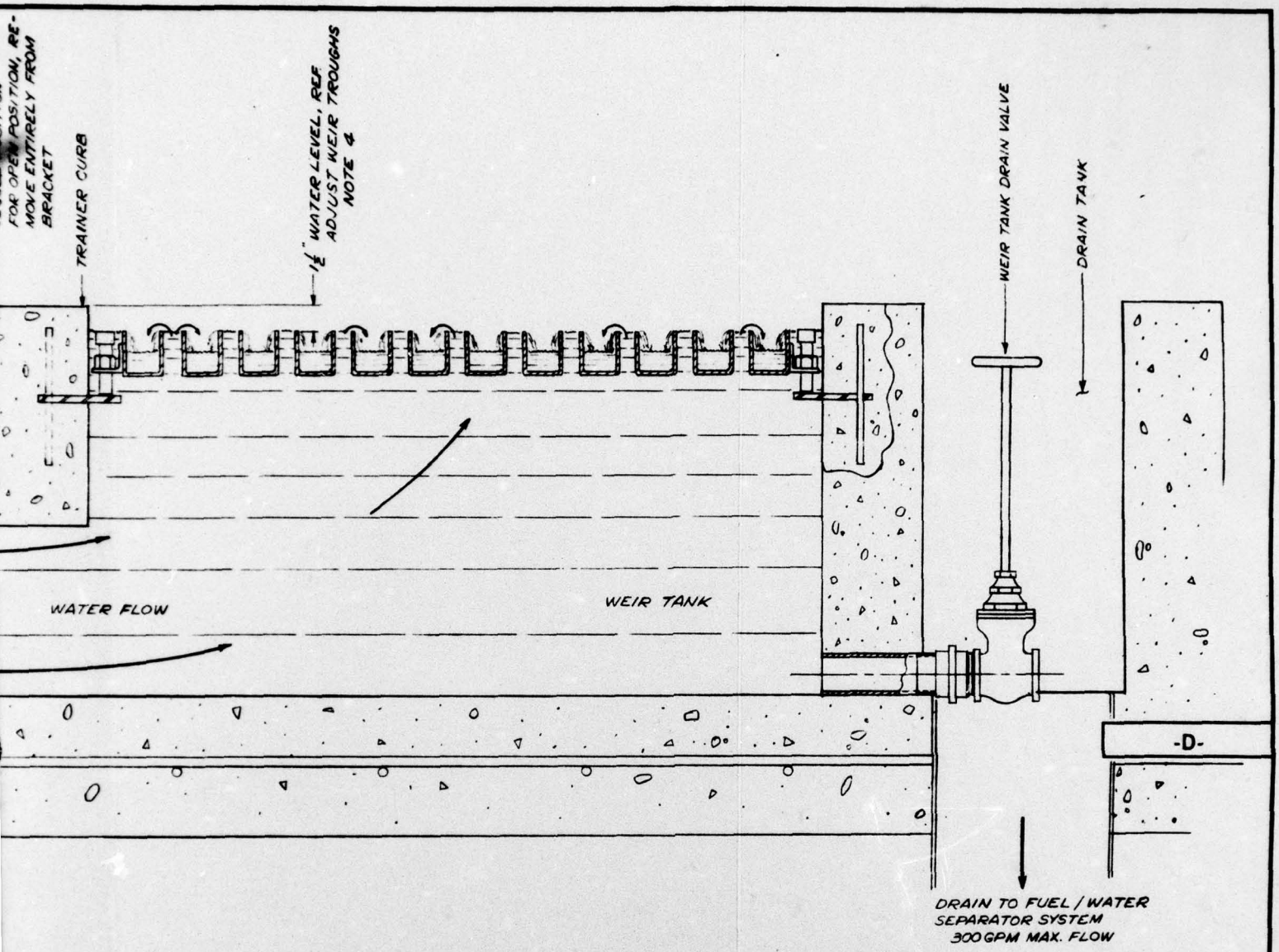
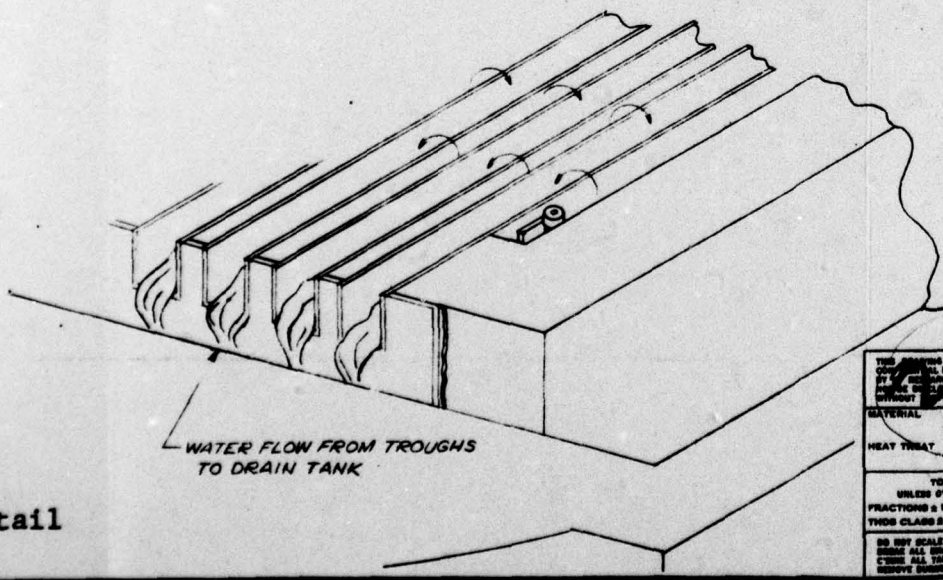


Figure A-11. Trainer Pipe Outlet, Rock and Water Fill Detail





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SYM.	DATE	DESCRIPTION OF REVISION	NAME

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TECHNOLOGY CENTER CHICAGO, ILLINOIS 60616

MATERIAL
HEAT TREAT

TRAINER PIPE OUTLET, ROCK AND WATER FILL DETAIL

TOLERANCES UNLESS OTHERWISE SPECIFIED
FRACTIONS ± 1/64 DECIMALS ± .005
TWOS CLASS 2 FIT ANGULAR ± 1°

FINISH

QUANTITY PER

	DESIGNED	DRAWN	CHECKED	APPROVED
NAME		J.N	J.J.S	CCT
DATE		3/1/74	3/8/74	3/8/74

DO NOT SCALE - REPORT ERRORS
DRILL ALL BOLT HOLES
C'SINK ALL TAPPED HOLES 1/32 x 60°
REMOVE BURRS

UNLESS OTHERWISE NOTED

SCALE 3"-1'-0"

SUB-ASSEMBLY

NEXT ASSEMBLY NO.

PROJECT DRAWING NO. J6339 -D- 12

etail

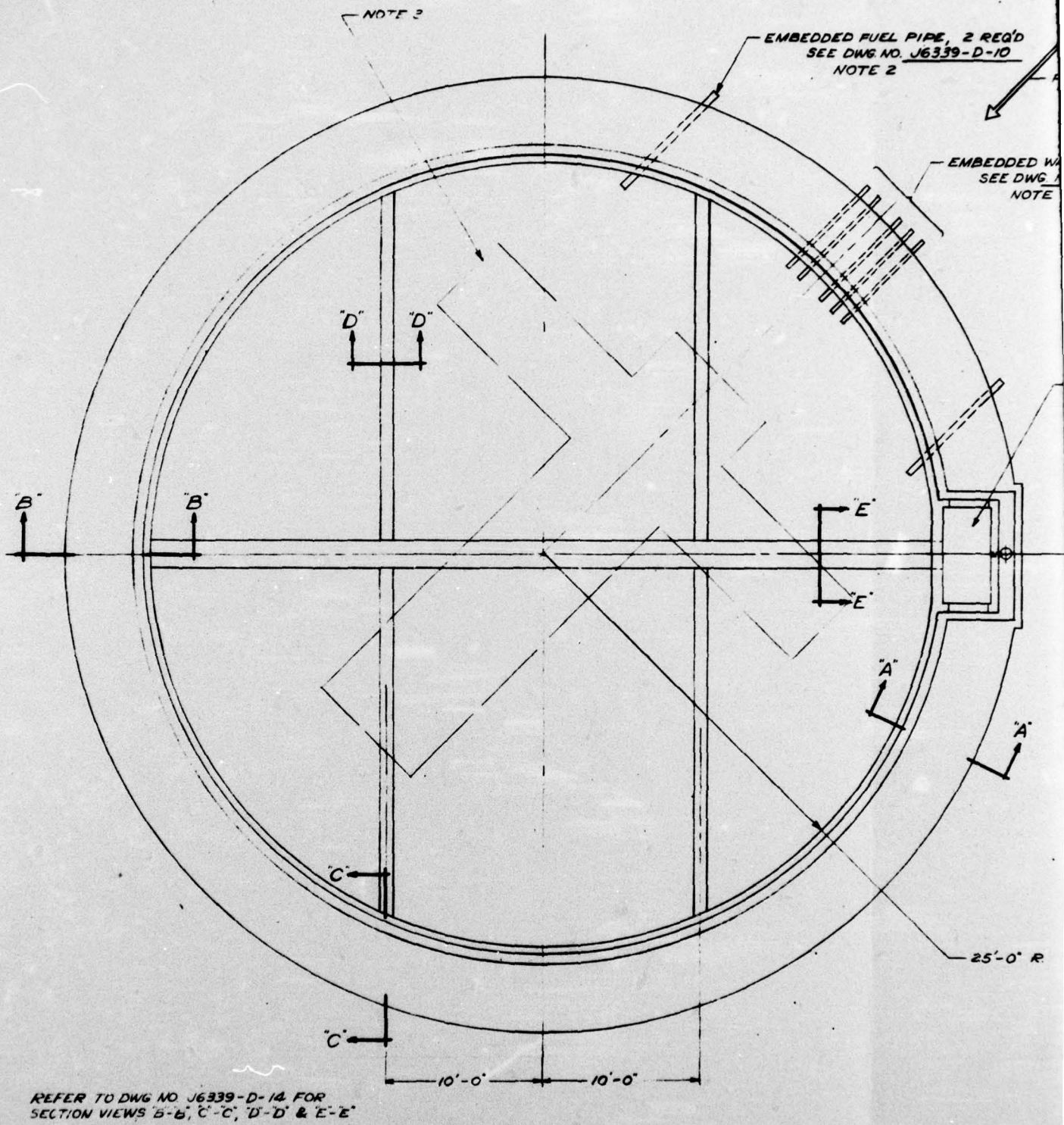
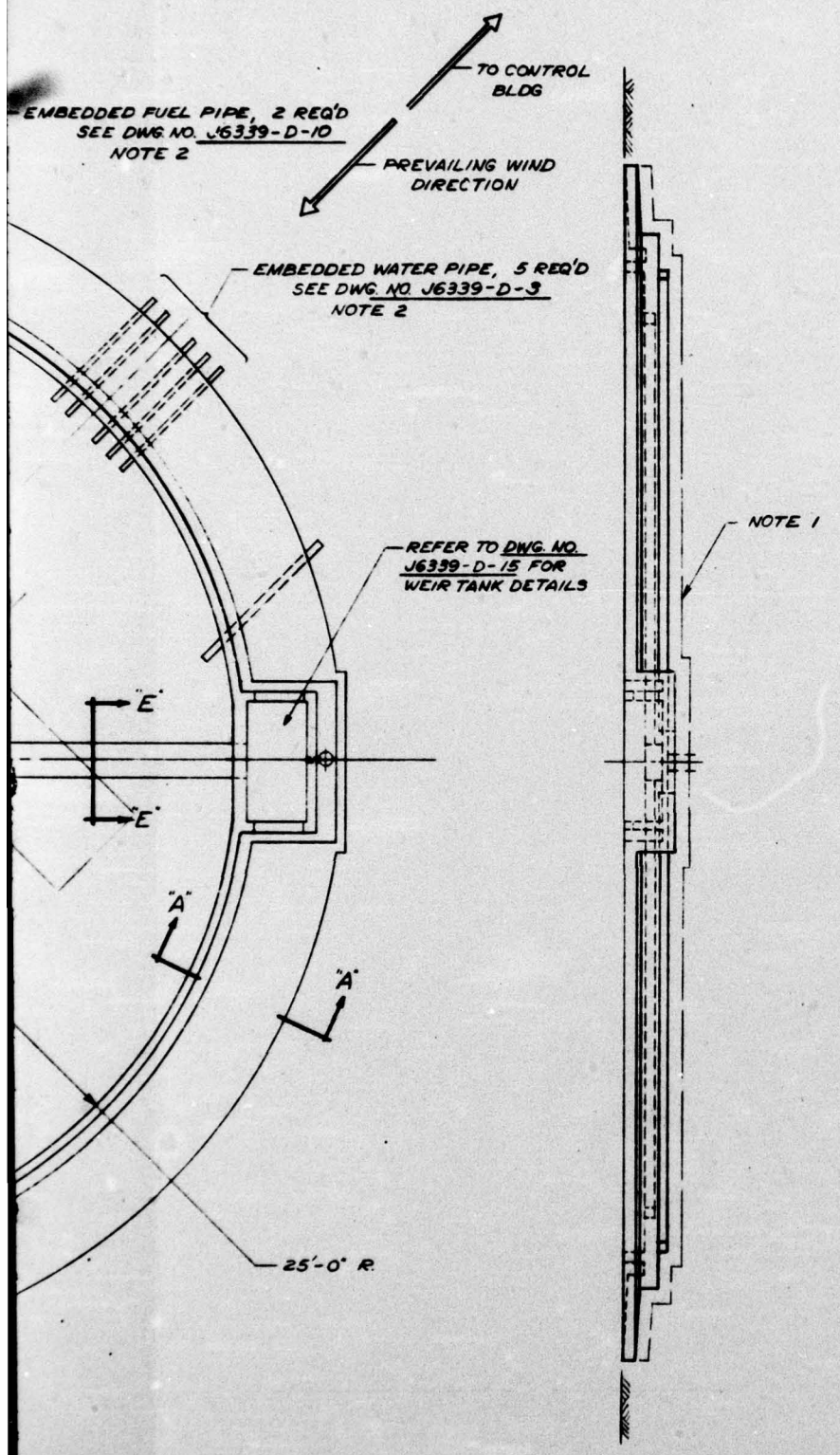
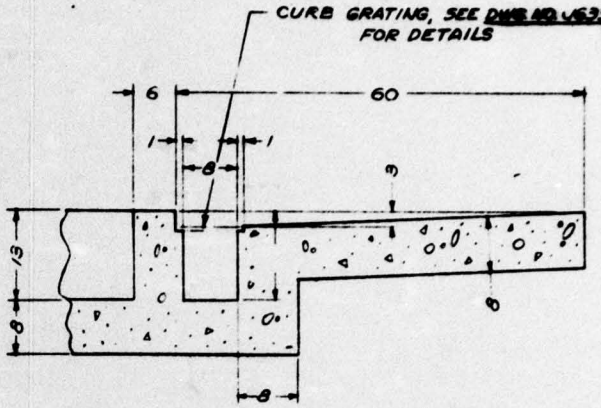


Figure A-12. Trainer Tank





SECTION "A"-"A"
SCALE: 1"=1'-0"

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-D-

NOTES:

1. EXCAVATION:
   REMOVE GROUND MATERIAL FOR 8 IN. THICK LAYER OF SAND OR GRAVEL UNDER AND AROUND TROUGHS
   REMOVE GROUND MATERIAL IN CIRCULAR TRAINER AREA, 55'-6" DIAMETER, TO A LEVEL DEPTH OF 29 IN.
   REMOVE GROUND MATERIAL FOR 60 IN. WIDE APRON AROUND TRAINER AREA TO A DEPTH OF 16 IN.
   BOTTOM OF EXCAVATION TO BE A 3000 P.S.F. BEARING SOIL MINIMUM, OR EQUIVALENT
   INSTALL AND COMPACT (90% DENSITY) 8 IN. THICK LAYER OF SAND OR GRAVEL
2. EMBEDDED PIPE:
   RELATIVE POSITIONING OF EMBEDDED PIPES AND WEIR TANK TO BE DETERMINED FROM AT SITE CONSIDERATIONS. (LOCATION OF DRAINAGE, WATER SUPPLY, PREVAILING WIND DIRECTION, ETC.)
3. TRAINER MOCKUP:
   TRAINER MOCKUP TO BE LOCATED IN CENTER OF TRAINER FACING CONTROL BUILDING SO OPERATOR HAS MAXIMUM VISIBILITY TO WATER SPRAY ZONES. MOCKUP RAISED MINIMUM 24 IN. ABOVE ROCK BED. DISTRIBUTION OF PIPE PEDESTALS ABOVE ROCK BED AND CONCRETE BLOCKS IN ROCK BED ON TRAINER FLOOR TO BE CONSISTENT WITH MOCKUP WEIGHT. CONCRETE BLOCKS IN ROCK BED SIZED TO DISTRIBUTE LOAD ON TRAINER FLOOR

			IIT RESEARCH INSTITUTE TECHNOLOGY CENTER CHICAGO, ILLINOIS 60616		
MATERIAL			TRAINER TANK		
HEAT TREAT					
				DRAWN	J.N
				TRACED	
				CHECKED	
				APPROVED	
				DATE	3/1/74
			NOTED		J6339 -D- 13

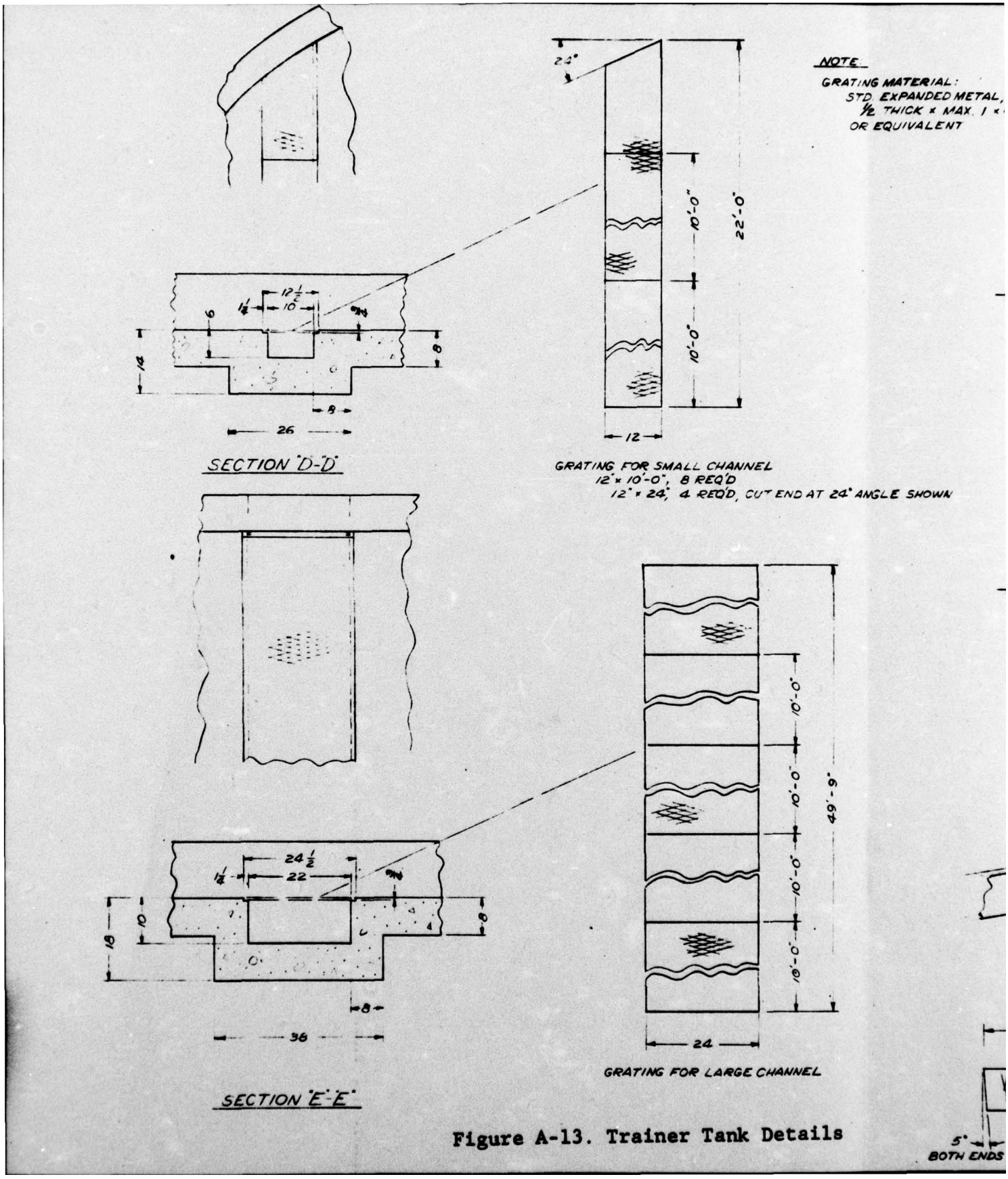
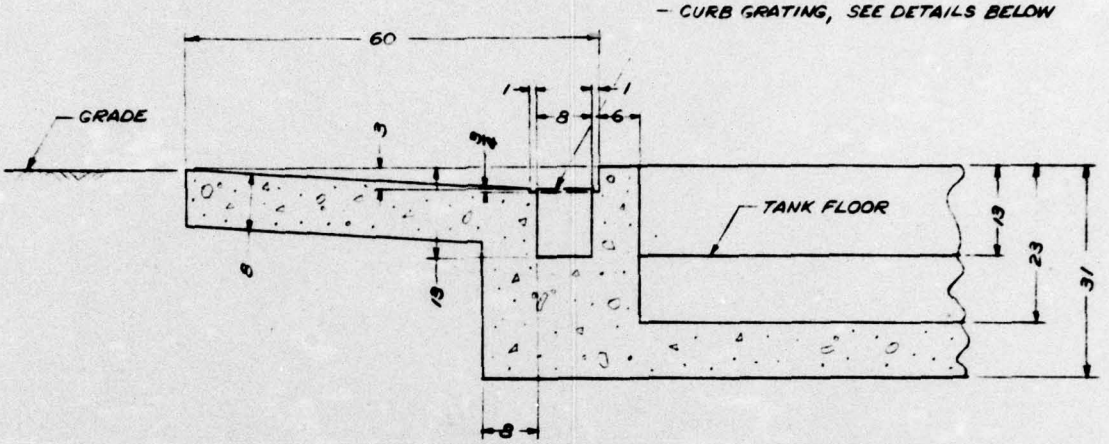


Figure A-13. Trainer Tank Details

NOTE

GRATING MATERIAL:
STD EXPANDED METAL, CARBON STEEL
½ THICK x MAX. 1 x 4 OPENINGS
OR EQUIVALENT

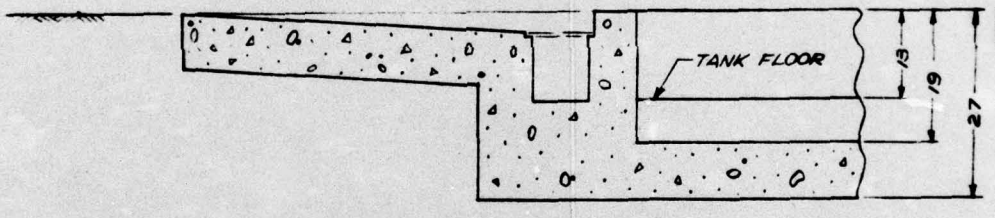
– CURB GRATING, SEE DETAILS BELOW



SECTION "B-B"

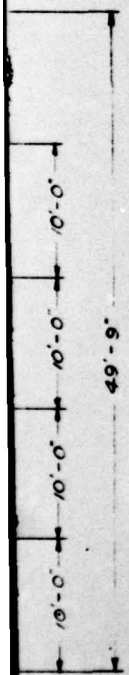
T END AT 24° ANGLE SHOWN

DETAILS SAME AS ABOVE

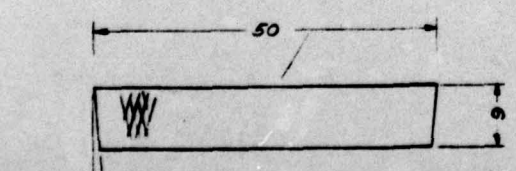


SECTION "C-C"

-D-







CURB GRATING, 40 REQ'D

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NO.	DATE	DESCRIPTION OF REVISION	NAME

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MATERIAL
HEAT TREAT

TRAINER TANK DETAILS

TOLERANCES
UNLESS OTHERWISE SPECIFIED
FRACTIONS ± 1/64 DECIMALS ± .005
THIRD CLASS ± FIT ANGULAR ± 1°
DO NOT SCALE - DEPART DRAWN
REMOVE ALL BURRS AND SHARP CORNERS
FINISH ALL TAPPED HOLES 1/32 x 45°

FINISH
UNLESS OTHERWISE SPECIFIED

QUANTITY PER

	DRAWN	CHKD	CHKD	APPROVED
NAME		J.A.	J.J.S	
DATE		3/9/76	3/9/76	3/9/76

SIZE A
SCALE 1"=1'-0"
DRAWING NO. J6339-D-14

ANNEL

etails

2

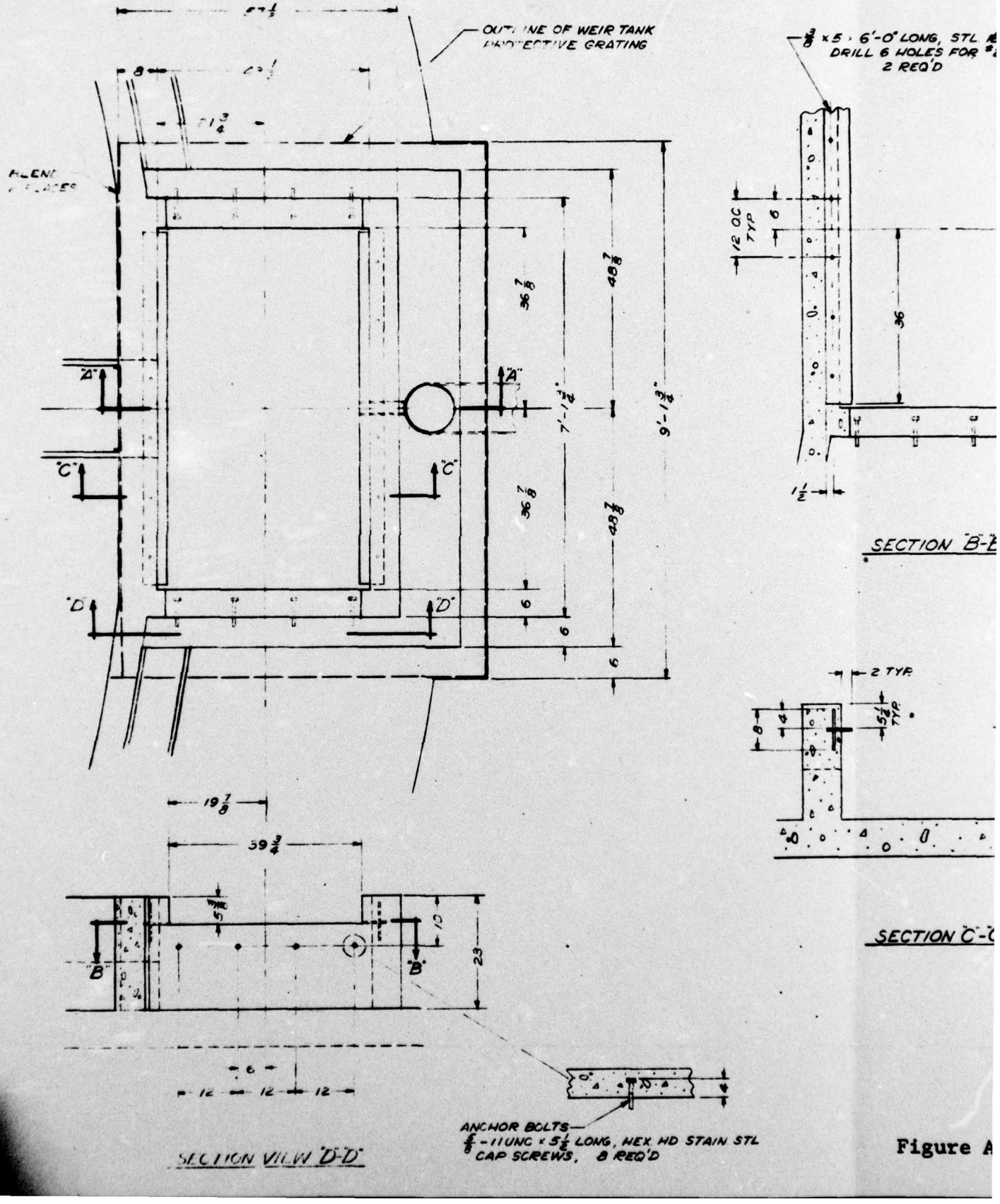
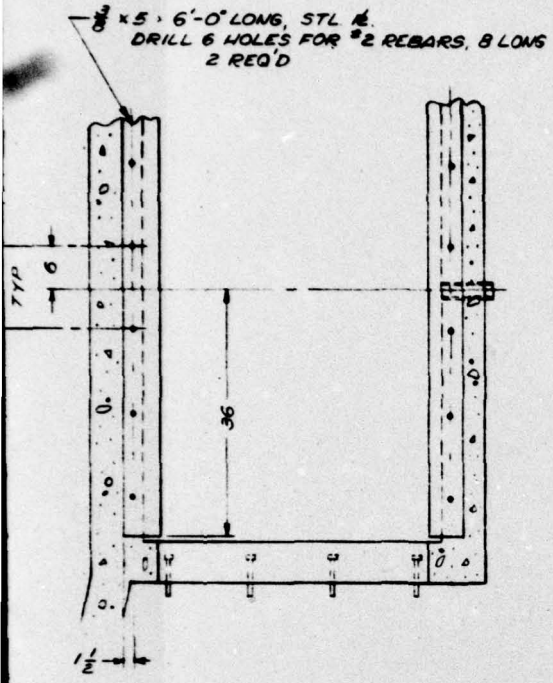
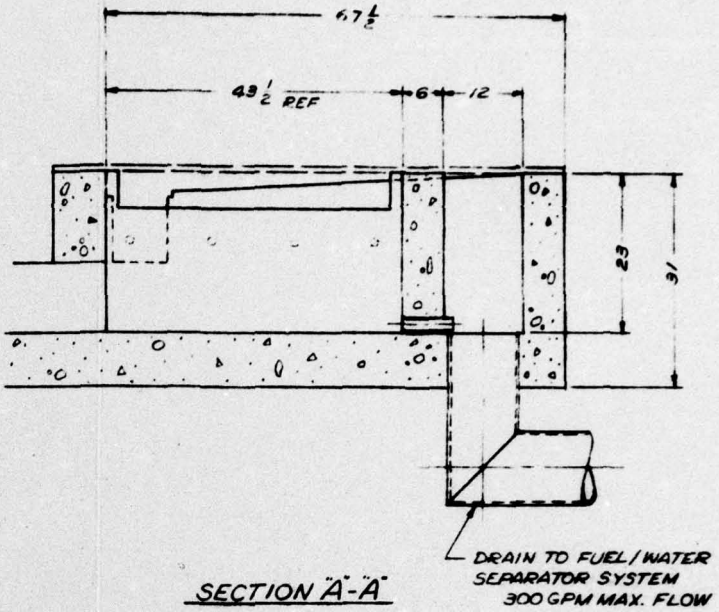

OUTLINE OF WEIR TANK
PROTECTIVE GRATING
ALENI
PLACES
"A"
"B"
"C"
"D"
36 7/8
48 7/8
7'-1 1/2"
9'-1 3/4"
6
19 7/8
39 3/4
5 1/2 TYP
10
23
12
12
12
SECTION VIEW "D-D"
ANCHOR BOLTS—
5/8-11UNC x 5 1/2 LONG, HEX HD STAIN STL
CAP SCREWS, 8 REQ'D
12 OC TYP
36
1 1/2
SECTION "B-B
2 TYP
SECTION "C-C

Figure A

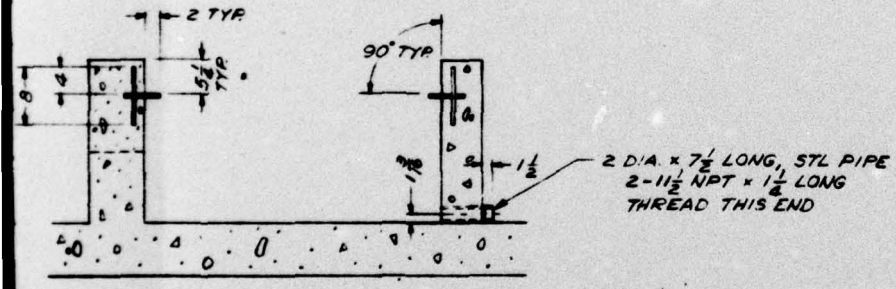


SECTION "B-B"



SECTION "A-A"

-D-



SECTION "C-C"

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MATERIAL: HEAT TREAT		WEIR TANK DETAIL	
TOLERANCES UNLESS OTHERWISE SPECIFIED: FRACTIONS ± 1/64 DECIMALS ± .010 THIRD CLASS ± FIT ANGULAR ± 1° DO NOT SCALE - REMOVE BURRS AND SHARP EDGES	FINISH	QUANTITY PER	DRAWN: J.K. 1-15 CHKD: 3/7/86 APPD:
	SCALE: 1"=1'-0"		U6339-D-15

Figure A-14. Weir Tank Details

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