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SMOKELESS GASOLINE FIRE TEST

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ABSTRACT

As a result of the recent concern by environmentalists, the hypothetical accident thermal test can no longer be performed by simply burning gasoline in an open pit. The uncontrolled open pit technique creates thick, dense, black clouds of smoke which are not permitted by local authorities. This paper deals with the design of the fire test facility and the techniques used to eliminate the smoke plume. The techniques include the addition of excess air to the fire in combination with a spray of water mist near the fuel surface. The excess air technique has been used successfully in an experimental setup; it was found that the temperature could be controlled in the neighborhood of the required 1475°F environment and the smoke could be reduced to very low levels. The water spray technique has been successfully used by others in similar applications and, on completion of a permanent fire test facility at Mound Laboratory (anticipated July, 1974), test results will be available. The water is believed to interact with the combustion reaction to provide more complete combustion. The permanent facility will be a 10 x 10 ft cement block enclosure lined with firebrick. It will be 8 ft high on three sides and 4 ft high on one side to provide for observation of the test. A 5000-gal underground tank provides storage for the aviation gasoline which is gravity fed to the fire.

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SMOKELESS GASOLINE FIRE TEST

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The AEC Manual Chapter 0529 requires satisfactory performance of packaging for radioactive materials when the package is subjected to a series of four tests simulating accident conditions. Escape of radioactive materials must be below defined limits and the package must remain subcritical. The free drop, puncture, thermal, and water immersion tests must be performed in the listed sequence.

Work in this paper has evolved as a result of requirements for the thermal test. This test requires exposure to a heat input to the package which is not less than that which would result from exposure of the whole package to a radiation environment of 1475°F (800°C) for 30 min with an emissivity of 0.9, assuming the surface of the package to have an absorption coefficient of 0.8. The test further requires that the package be naturally cooled for 3 hr after the test period, unless it can be shown that the temperature on the inside of the package has begun to fall in less than 3 hr.

Although these requirements are difficult to obtain, the most difficult problem is not in producing the environment but in producing a realistic test with a minimum smoke generation. The hypothetical accident thermal test can no longer be performed by simply burning gasoline in an open pit as a result of the recent concern by environmentalists. The uncontrolled open pit technique creates thick, dense, black clouds of smoke which are not permitted by local authorities. Since an actual gasoline fire provides a considerably more realistic test than an electric oven or similar methods which limit the available air supply, techniques were developed for an open gasoline fire which does not produce excessive quantities of smoke. This paper deals with the design of the fire test facility and the techniques used to eliminate the smoke plume, as well as some of the experimental work leading to the design.

Figure 1 shows the aviation gasoline test setup which was designed in earlier development work to minimize the smoke plume resulting from the 30-min fire test at 1475°F. The container is shown prior to the test mounted on a stand 2 ft above the water surface. It was centered in the burning area approximately 3 ft from the sides since a 2- to 3-ft flame thickness is equivalent to an infinitely thick wall. The sheetmetal burning pan, measuring 8 x 10 x 0.5 ft deep, was filled to a depth of 5 in. with water for the aviation gasoline to float on and thereby avoid excessively heating the burning pan. Sheetmetal "blockout boxes" measuring 48 x 6 x 6 in. high were placed within the burning pan to decrease fuel consumption and smoke. The exposed surface

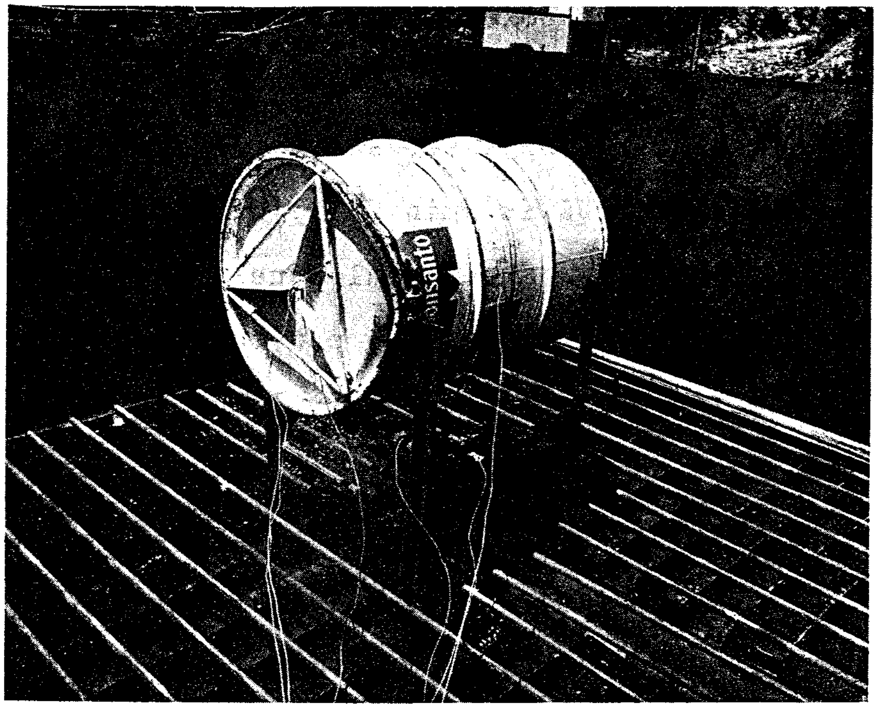

Figure 1 - Thermal Test Setup, early prototype test. This test setup, with the air manifold and 16 sheet metal block-out boxes, was used to abate the smoke in the aviation gasoline fire to the levels demonstrated in figures 2 and 3.

area of the aviation gasoline floating on the water was reduced to 60% of the total area within the burning pan by using 16 blockout boxes. Additional air for more efficient combustion provided additional smoke abatement. The portable diesel air compressor shown in Figure 2 supplied approximately 1000 ft^3/min (STP) of air to the fire through the air manifold. Sheetmetal panels 4 ft high surrounded the perimeter of the burning pan to reduce wind effects. Additional panels were added in later tests to provide an 8-ft high wind screen on the west side of the enclosure to reduce wind effects. The combined effects of the reduction in fuel consumption, the addition of air, and the wind shield reduced the smoke from the black plume, typically produced during open tests, to the gray plume as seen in Figures 2 and 3.

In later tests three portable compressors were used to supply approximately 5000 ft^3/min (STP) of air to a trilevel air manifold system. Results of these tests are shown in Figures 4 and 5. The lower manifold assembly was approximately 2 in. above the water level as in earlier tests, the middle manifold assembly was approximately 4 ft above the water level, and the upper manifold system was approximately 5 ft above the water level. Each of the three manifold systems were turned off in turn while the other two systems were kept running to determine quantitatively the effect of

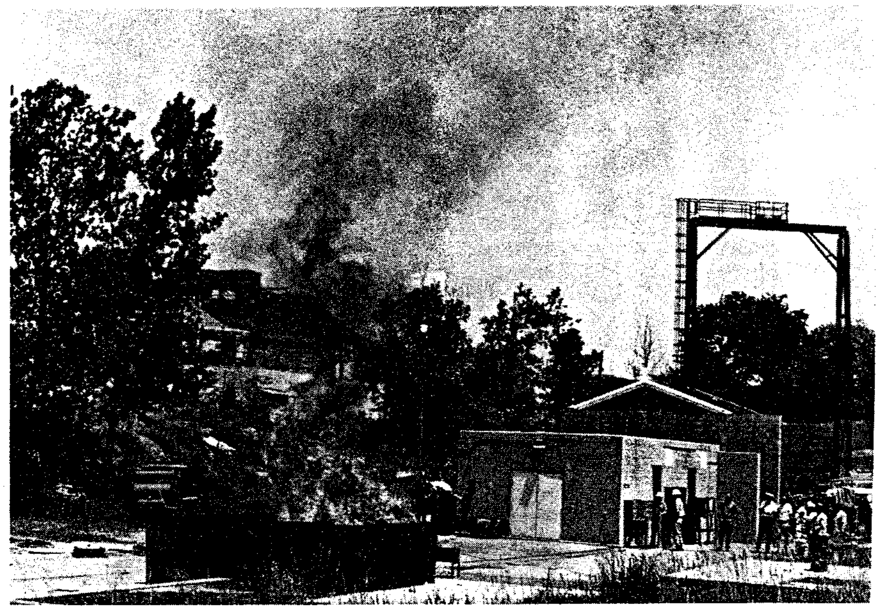

Figure 2 - Thermal Test Area, early prototype test. This view shows the results of early fire tests with 1000 ft^3/min (STP) of air added to the fire.

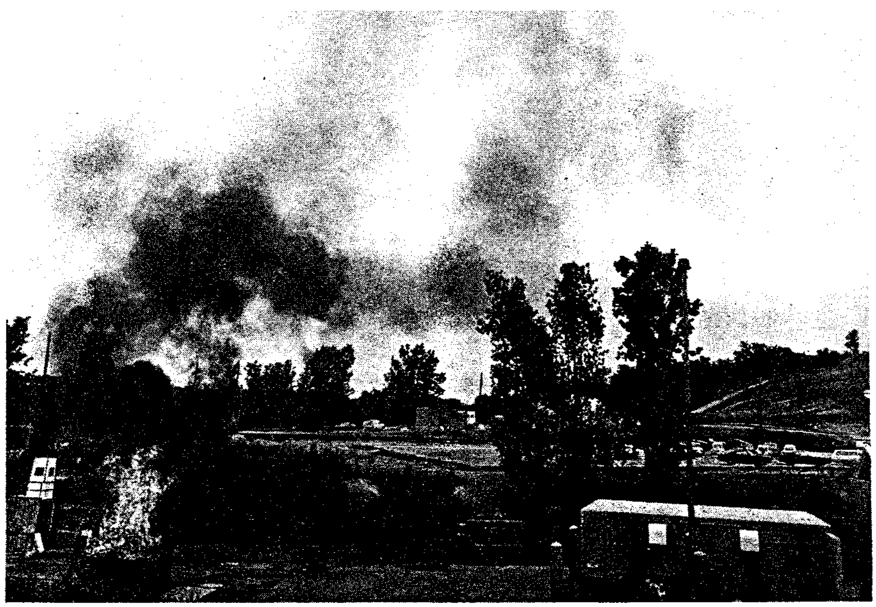

Figure 3 - Thermal Test, early prototype test. This distant view shows the thick continuous wall of flame enveloping the container.

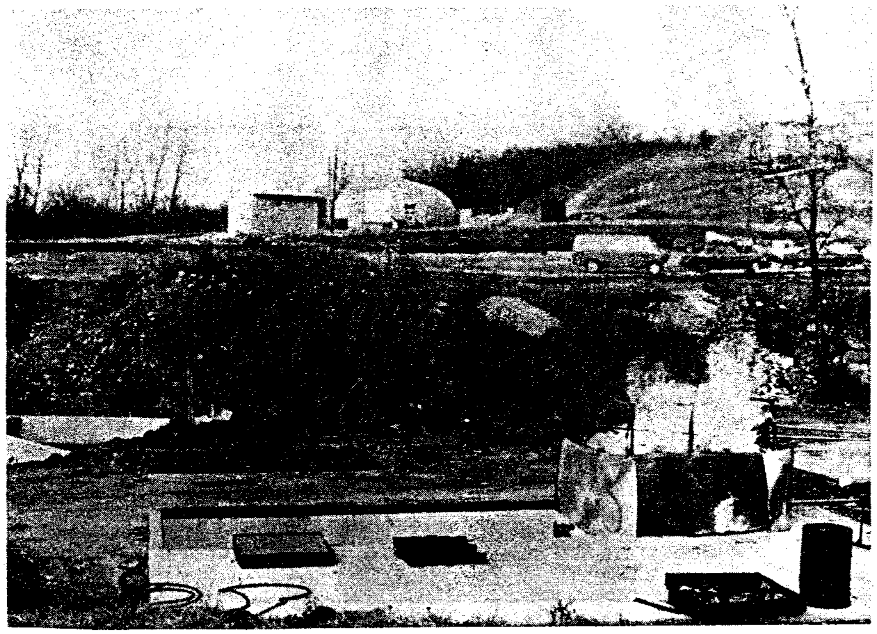

Figure 4 - Thermal Test, later prototype test. This test shows the results of a fire test with three layers of air manifolds with approximately 5000 ft^3/min (STP) of air added to the fire.

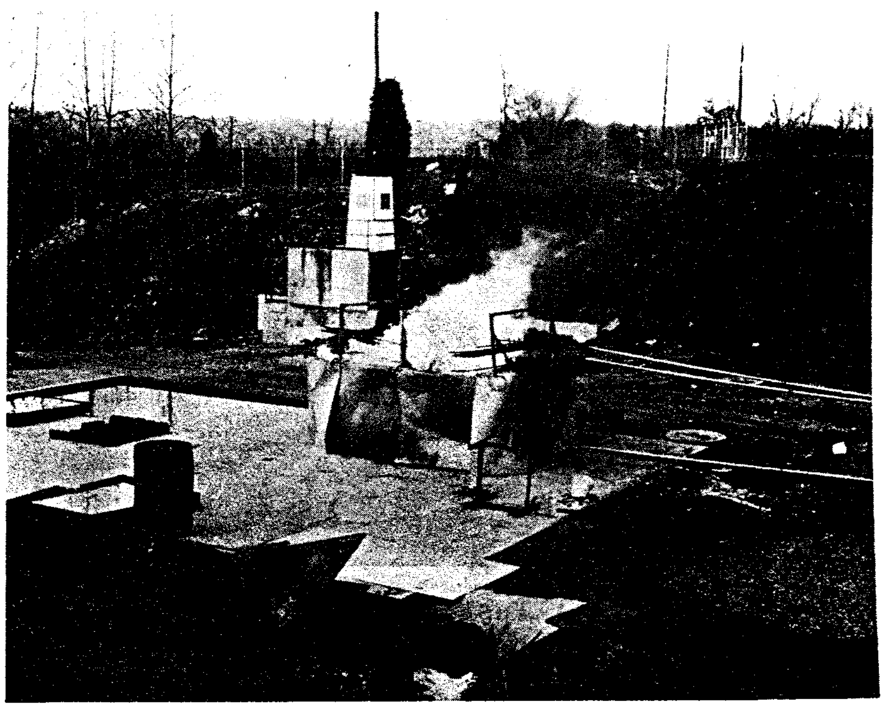

Figure 5 - Thermal Test, later prototype test. This test shows a different view of the same fire shown in figure 4.

both total air supplied and application point. Results indicated that application of air near the base of the fire had the most significant effect on the reduction of smoke, and that the addition of air at higher points along the flame profile yielded less significant results per unit of air supplied. However, it appeared that less smoke was generated in the fire with more air than in earlier fires with less air.

Another concept on which research was done, but no experimental work performed at Mound Laboratory, was the water spray smoke abatement system. Demonstration of the effectiveness of the system, performed by others, was observed, and the "NAVTRADEVCEN 71-C-0083-4" report was studied after meeting and discussing the system with key people in their program. No photos of a water spray fire have been included in the paper but photos were published in the above-mentioned report.

The fire test facility seen in Figure 6 consists basically of the following key items:

1. Combination wind and heat shield
2. Water spray system
3. Fuel delivery and distribution system
4. Fan and air delivery system

The combination wind and heat shield is a 10 x 10 ft concrete block enclosure lined with firebrick and located

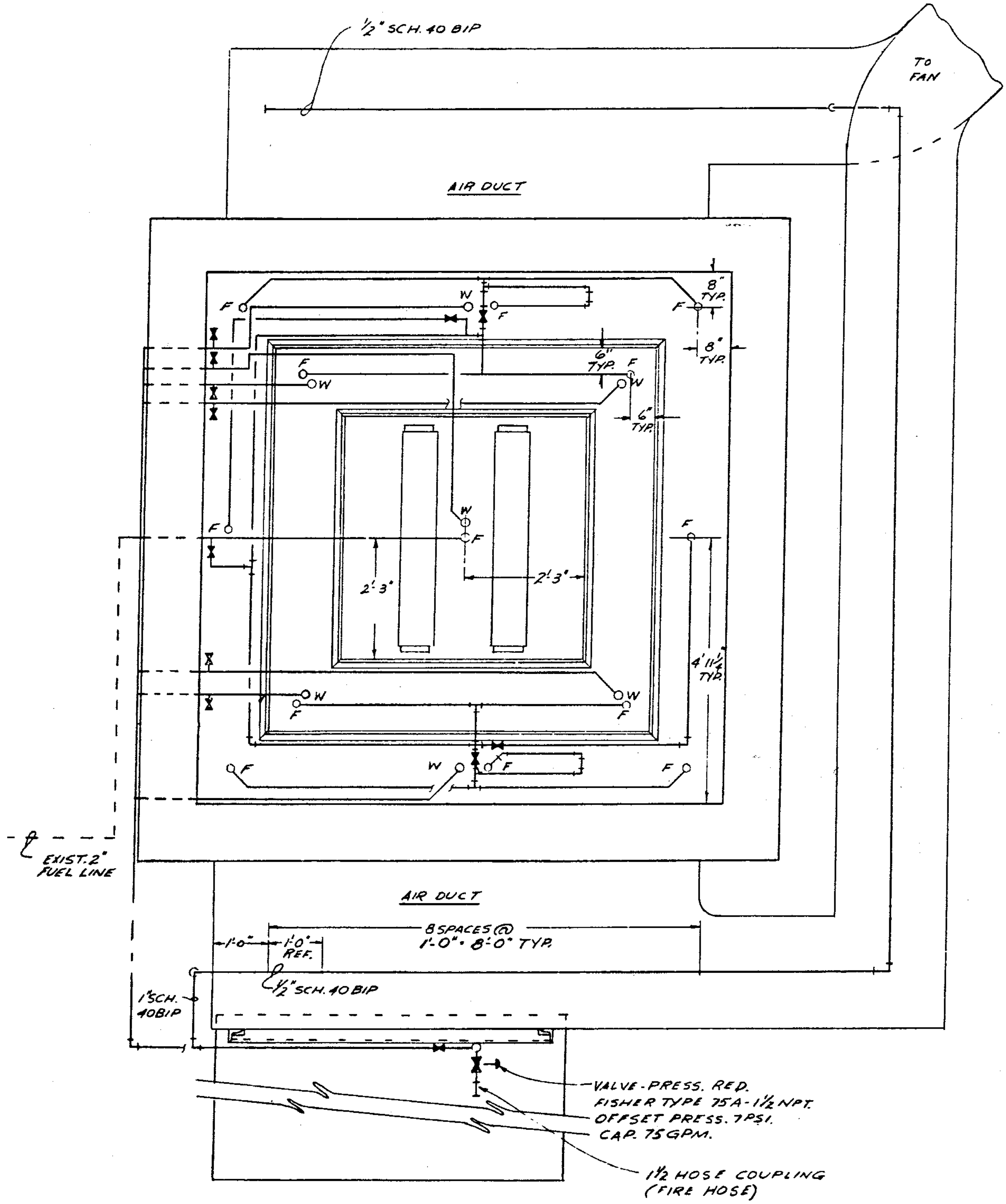

Figure 6 - Thermal Test Facility - Plan view.

over a 6-in. deep pit. Three sides of this enclosure are 8 ft high, and the remaining side is 4 ft high for observation. The shield serves both to protect surrounding equipment from heat as well as to prevent the flame from blowing away from the container.

The water spray system consists of five spray nozzles uniformly distributed about the pit and located approximately 6 in. from the bottom of the pit. This system provides a fine mist of water at the base of the fire.

The fuel delivery and distribution system delivers 100 octane aviation gasoline to the pit from a 5000-gal underground storage tank. Fuel is gravity fed to the pit and released below the water level in a well distributed pattern.

The fan and air delivery system provides approximately 8,000 ft^3/min of air to the enclosure from two opposing sides of the enclosure.

The thermal test is started by inserting the test container in the enclosure and attaching temperature sensing devices at various locations as required. Approximately 260 gal of water is fed into the 6 in. pit to make a 4-1/2 in. water level; gasoline is fed into the pit to form a layer of fuel on top of the water surface. The spark ignition system is ignited, and the fire is started.

After the start of the fire, the water spray and air supply systems are activated and adjustments are made as required. The temperature of the test container is raised to 1475°F and the test is run for one-half hour; during that time period fuel is consumed at the approximate rate of 450 gal/hr. Excess water generated by the water spray system is drained from the bottom of the pit via an overflow system to maintain a constant water level.

After the test, all excess fuel is burned off the water surface; and excess water and carbon particles are removed by a drainage system to a separate area for removal.

In the test just described, two techniques will be used to abate smoke, these techniques being the addition of excess air and a water spray mist to the fire. The excess air technique has been used successfully in an experimental setup; it was found that the temperature could be controlled in the neighborhood of the required 1475°F environment and the smoke could be reduced to very low levels. The water spray technique has been successfully used by others in similar applications and, on completion of a permanent fire test facility at Mound Laboratory (anticipated July 1974), test results will be available. The water is believed to interact with the combustion reaction to provide more complete combustion.

The two independent techniques appear to provide approximately equal smoke reduction capabilities when both are operating under optimum conditions. However, to accomplish low smoke levels, with the water spray system the quantity of water supplied to the fire must be increased and as a result the temperature of the fire drops off. At the time of this writing no data are available on the profile of "Temperature" as a function of "Water Input to Fire"; however, experience from the "water only fire" suggests the temperature is less than the "air only fire". The "NAVTRADEVCEN 71-C-0083-4" report showed the smoke emissions from a water spray fire to be between 0.5 to 1 on the Ringelmann scale.

Experience at Mound Laboratory indicates that the smoke level generated from an "air-only fire" is approximately a Ringelmann number of 1. However, it should be noted that the "water spray" results are for optimum conditions and the air results are for a special case that is not necessarily the optimum.

In conclusion, the objective in the combined test will be to adjust the water spray system for low water input (higher temperature and higher smoke content) and to reduce the smoke level to an even lower value by the injection of air.