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MASTER

PERFORMANCE OF SMOKELESS GASOLINE FIRE TEST FACILITY

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INTRODUCTION

The DOE Manual Chapter 0529 requires packaging for radioactive materials to perform satisfactorily when subjected to a series of four tests simulating accident conditions. Escape of radioactive materials and reduction of shielding 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 reported in this paper has evolved as a result of requirements for the thermal test. These requirements include exposing the package for 30 min to heat which is not less than that which would result from exposure of the whole package to a radiation environment of 1475°F (800°C) with an emissivity of 0.9, assuming the surface of the package to have an absorption coefficient of 0.8. It is further required 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.

Several techniques can be used to provide this thermal test environment. These techniques can be based on the use of electric or gas fired ovens, or open gasoline fires. We prefer the open gasoline fire since it more closely simulates transportation accident conditions, which form the basis for the thermal test requirements. In addition to providing the necessary thermal radiation temperature and heat flux, the open fire is characterized by strong convection currents and a generous air supply. These latter characteristics produce a degree of realism which cannot be achieved in an oven or other apparatus which has no open flame and a limited air supply.

However, 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, by present environmental standards, are completely unacceptable. In 1972, an effort was initiated at Mound Facility to develop techniques for reduction of such smoke. The techniques included limited fuel distribution and forced air supply. The result was a substantial, but insufficient, reduction of smoke. Figure 1 shows such a test. This work was described in a paper presented at the 4th International Symposium which dealt with the development of the design of the thermal test facility. [1]

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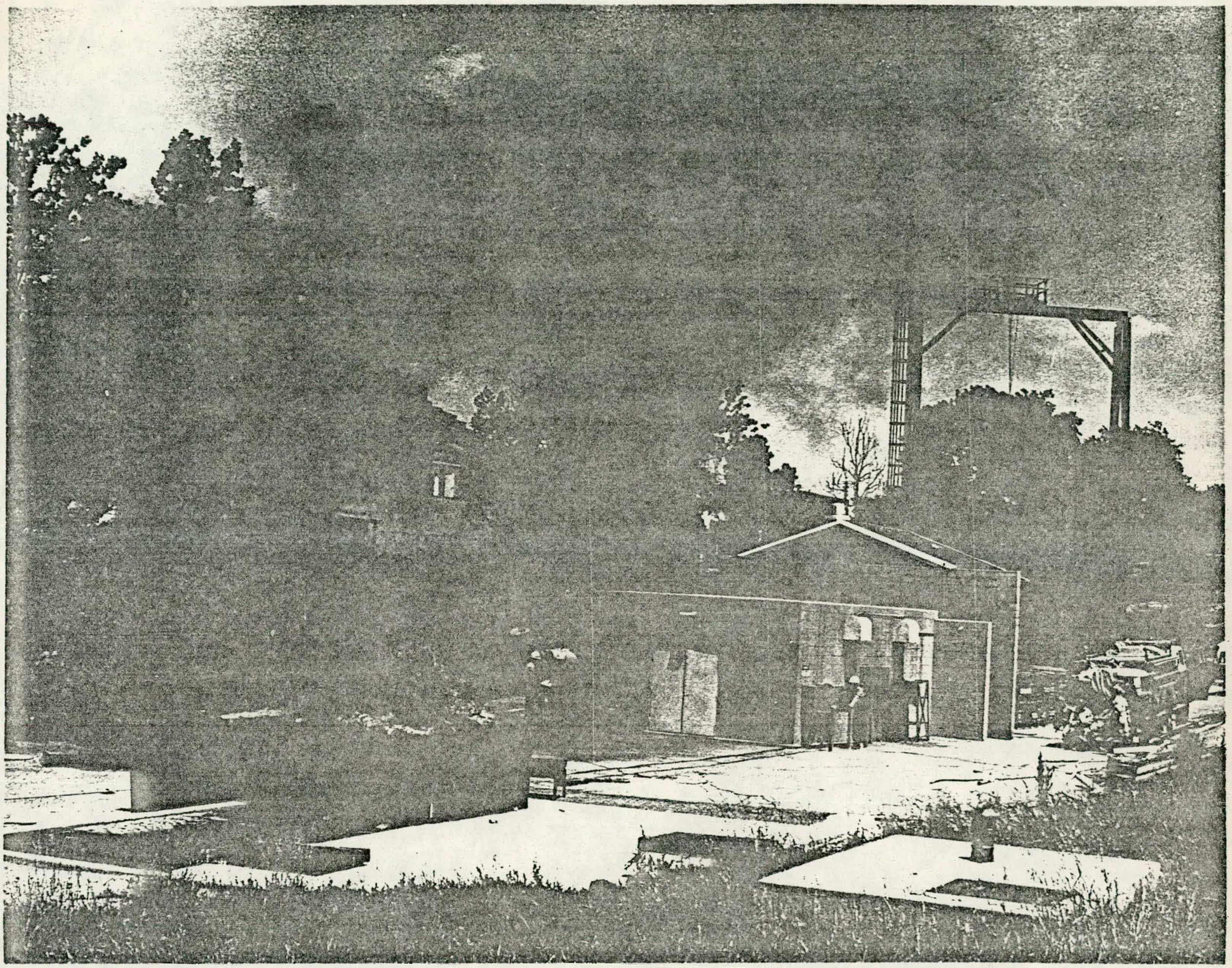

FIGURE 1 - Partial smoke reduction in developmental test prior to permanent thermal fire test facility.

This is a follow-up to the previous paper and describes the final design and actual performance of the facility. Techniques were developed and implemented in the new test facility for an open gasoline fire which does not produce smoke in any significant quantities. This paper reports the successful results of these techniques in eliminating the smoke plume as well as in providing a controllable fire which meets the requirements of the thermal test.

THE THERMAL TEST FACILITY

In the testing facility now used, two techniques are applied to abate smoke. These techniques are the addition of excess air to the fire and the spraying of a water mist at the base of the fire. An excess air technique had been used successfully to reduce smoke in the experimental thermal tests prior to construction of the present facility. The water spray technique, however, is the concept on which the design of the new facility was primarily based. It had been successfully used by others in similar applications. They had demonstrated the effectiveness of the system, and we had studied the "NAVTRADEVCEN 71-C-0083-4" report after meeting and discussing the system with key people in their program. The water is believed to interact in the combustion reaction to provide more complete combustion.

The fire test facility which was completed in 1974 is seen in Figures 2, 3, and 4. It consists of the following major features:

1. Combination wind and heat shield enclosure
2. Fire pit containing water
3. Water spray system
4. Forced air delivery system
5. Fuel delivery and distribution system
6. Hoist.

The combination wind and heat shield is a concrete block enclosure lined with firebrick and located over a 6 in. deep pit. The base of this fire pit is poured concrete measuring 10 ft x 10 ft x 0.5 ft deep. Three sides of the enclosure are 8 ft high, and the remaining side is 4 ft high for observation and ease of handling the shipping container. The enclosure prevents the flame from being blown away from the container and also serves as a shield to protect surrounding equipment from heat.

Figure 5 schematically illustrates the water spray, air supply, fuel feed and the water in the pit. These are the primary features related to elimination of the smoke plume.

The water spray system consists of seven spray nozzles uniformly distributed in the pit and located approximately 4 in. above the surface of the pool of water, which is 5 in. deep. This system provides a fine mist of water approximately 4 in. above the base of the fire. The nozzle spray is directed horizontally and provides complete coverage of the burning fuel surface.

A 5-horsepower fan and air ducts provide approximately 8,000 ft^3/min of air to the enclosure from two opposing sides of the enclosure just above the fire pit.

The fuel delivery and distribution system continuously delivers 100-octane aviation gasoline to the pit from a 5000-gal storage tank buried approximately 100 ft from the fire pit. The fuel is gravity-fed to the pit and released below the water level in a well distributed pattern. The gasoline floats to the surface of the water and burns.

TEST PROCEDURE

In preparation for the thermal test, a hoist is used to place the package on a stand within the enclosure approximately 2 ft above the water surface. Fifty-five gal drum packages are centered within the enclosure approximately 3 ft from the sides. Thermocouples are attached to the package at the required locations and leads are run to a recorder located approximately 30 ft from the fire test enclosure. Approximately 300 gal of water is then fed into the 6 in.

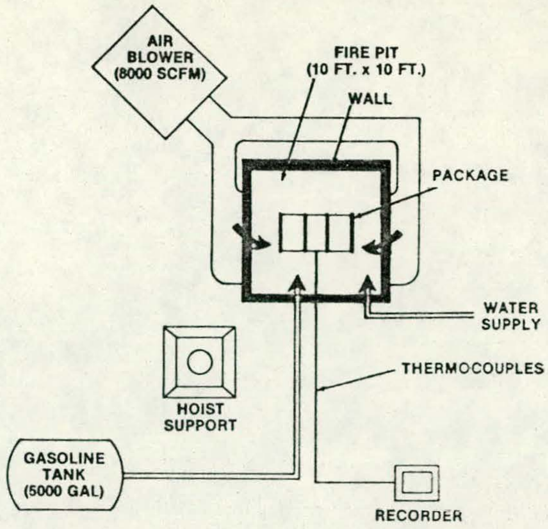

FIGURE 2 - Major features of fire test facility.

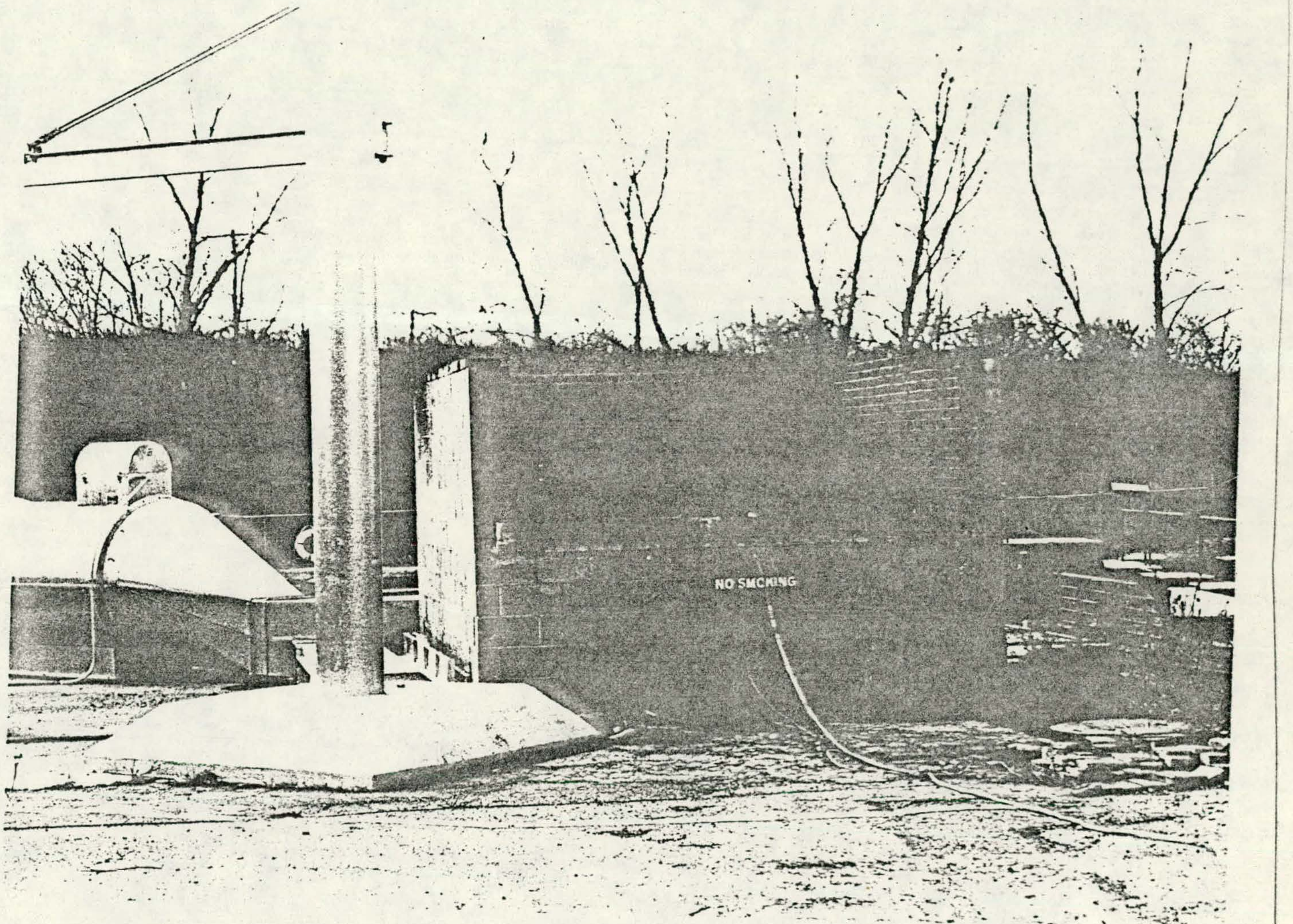

FIGURE 3 - Fire test facility showing air blower, package hoist, fire pit enclosure, and water pipes.

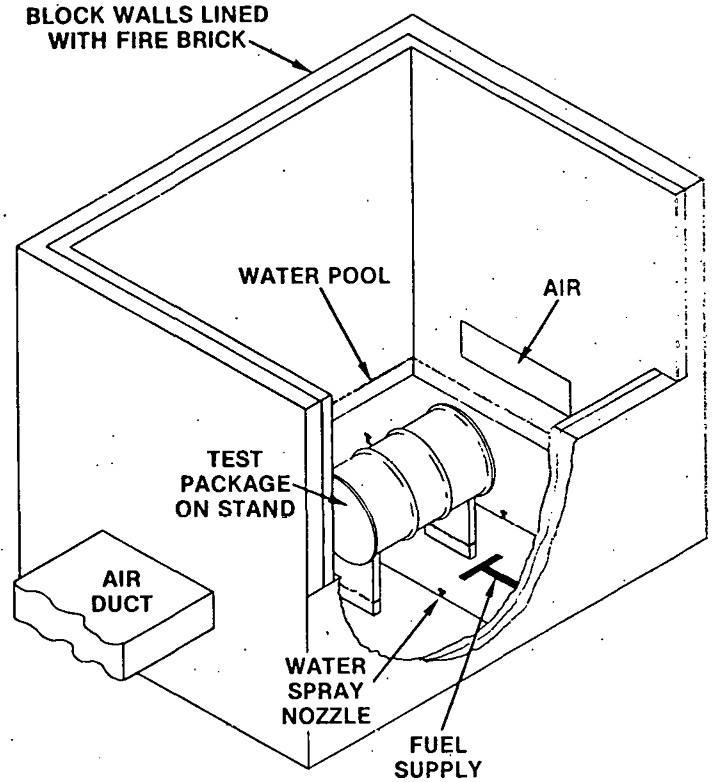

FIGURE 4 - Fire test facility schematic.

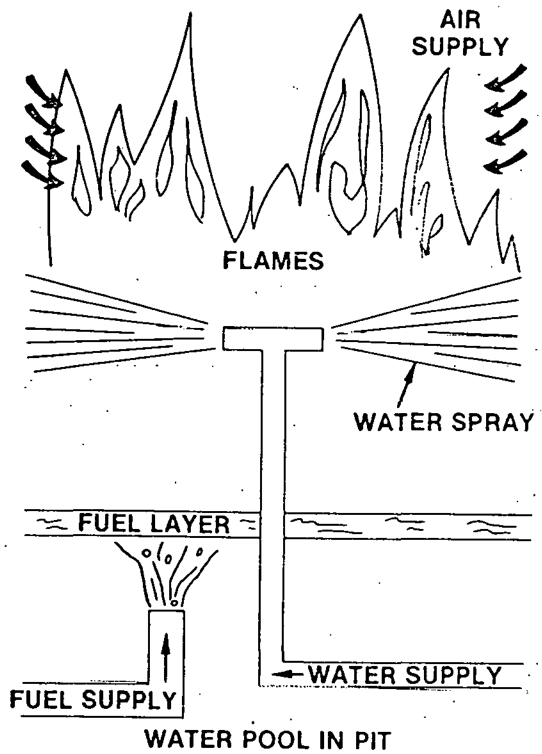

FIGURE 5 - Schematic showing water spray and air techniques for elimination of smoke.

deep pit, resulting in a water level of 5 in. Gasoline is then fed into the pit to form a layer of fuel on top of the water surface. The spark ignition system is used to start the fire remotely.

After ignition of the fire, the water spray and air supply systems are turned on. The water and air supply adjustments are preset, whereas manual adjustments are made to the fuel flow as required. The temperature measured on the surface of the test container is increased to 1475°F. (This is equivalent to conservatively assuming emissivity and absorption coefficients of 1.) The test is run for 1/2 hr. During that time period, approximately 200 gal of fuel is consumed and approximately 700 gal of water is used. The 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.

RESULTS OF TESTS

To date, 16 tests have been performed in the facility. Figure 6 shows one such test. The results of some of these tests are documented in three SARP's. [2,3,4] Usually, during the course of the 30-min tests, the smoke is virtually eliminated. It is estimated that air accounts for approximately 30% of the smoke reduction, and the water spray, for the remaining 70%. Periodically, under the worst conditions, the smoke may approach the upper limit of a Ringelmann number of 1 (20% opacity), which is still below the maximum allowable.

A thick, continuous wall of flame envelops the container to maintain sufficiently high temperatures for successful testing. Most of the time the exterior surface temperature of the shipping container is controlled within +150°F and -50°F of the desired 1475°F temperature. The temperatures obtained throughout one of the tests are plotted as a function of time in Figure 7. The drum skin temperatures were measured at the side of the package. Chromel/alumel thermocouples and a multipoint recorder were used to monitor the test. The drum surface reached the required 1475°F less than 5 min after ignition. Throughout the course of the test, it was necessary to closely monitor the temperature and manually adjust the fuel flow rates. The fire burned out within a few seconds after the fuel flow was stopped.

CONCLUSIONS

The new thermal test facility has proved to be a reliable method for satisfactorily performing the required test. The flame provides sufficient heat to assure that the test is valid, and the temperature can be controlled satisfactorily. Also, the air and water mist systems virtually eliminate any smoke and thereby exceed the local EPA requirements. The combination of the two systems provides an inexpensive, low maintenance technique for elimination of the smoke plume.

REFERENCES

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2. J. F. Griffin, R. E. Bertram, R. K. Blauvelt, D. A. Edling, T. M. Flanagan, J. B. Peterson and D. L. Prosser, Safety Analysis Report for Packaging (SARP): USA/5790/BLF(ERDA-AL) and USA/5791/BLF(ERDA-AL), MLM-2242 (April 30, 1976), 89 pp.

3. R. A. Watkins, R. E. Bertram, R. K. Blauvelt, D. A. Edling, T. M. Flanagan, J. F. Griffin, and T. B. Rhinehammer, Safety Analysis Report for Packaging (SARP): USA/9507/ BLF(ERDA-AL), Model AL-M1, MLM-2447, September 30, 1977.

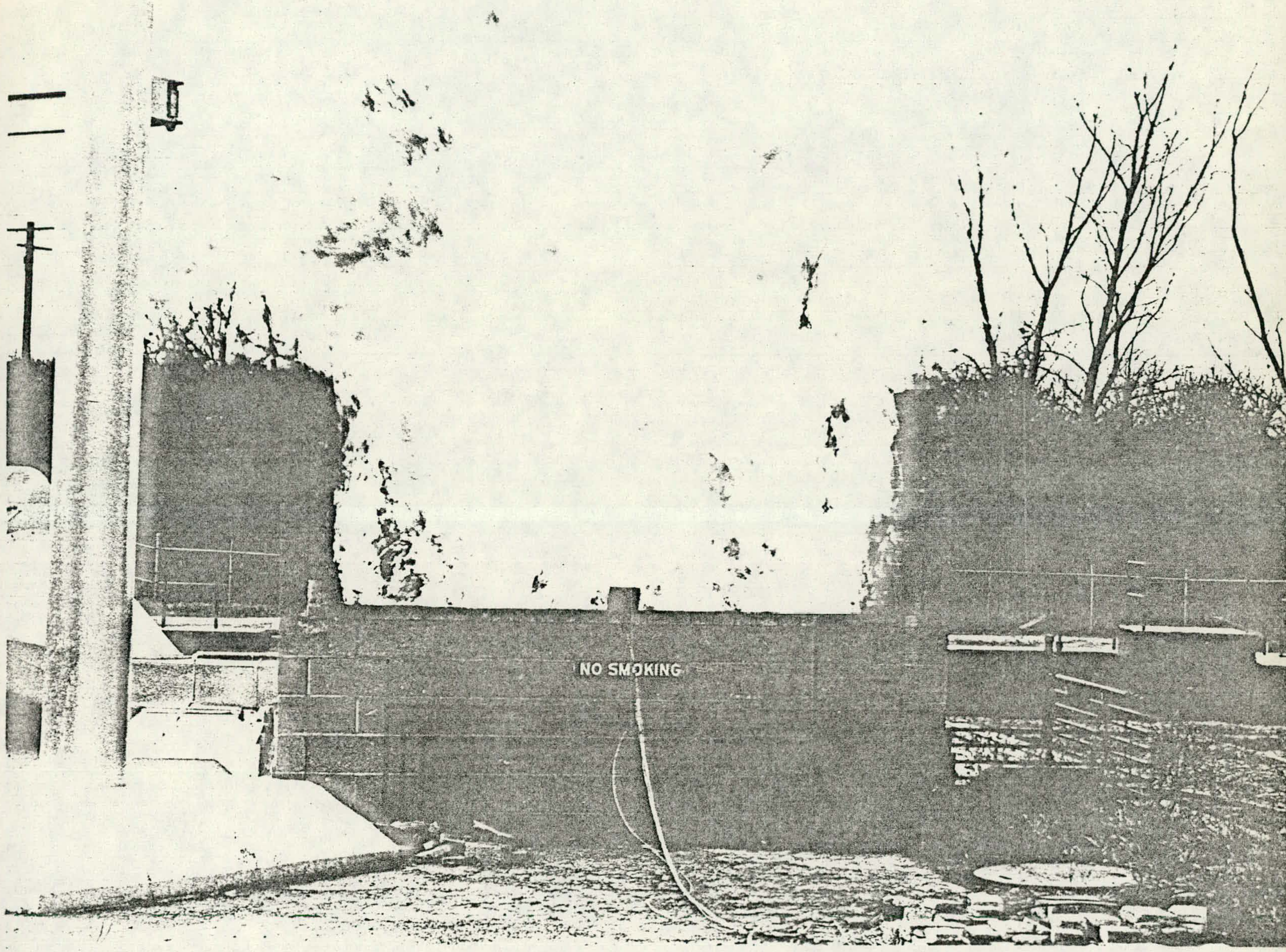

FIGURE 6 - Smokeless fire test in progress.

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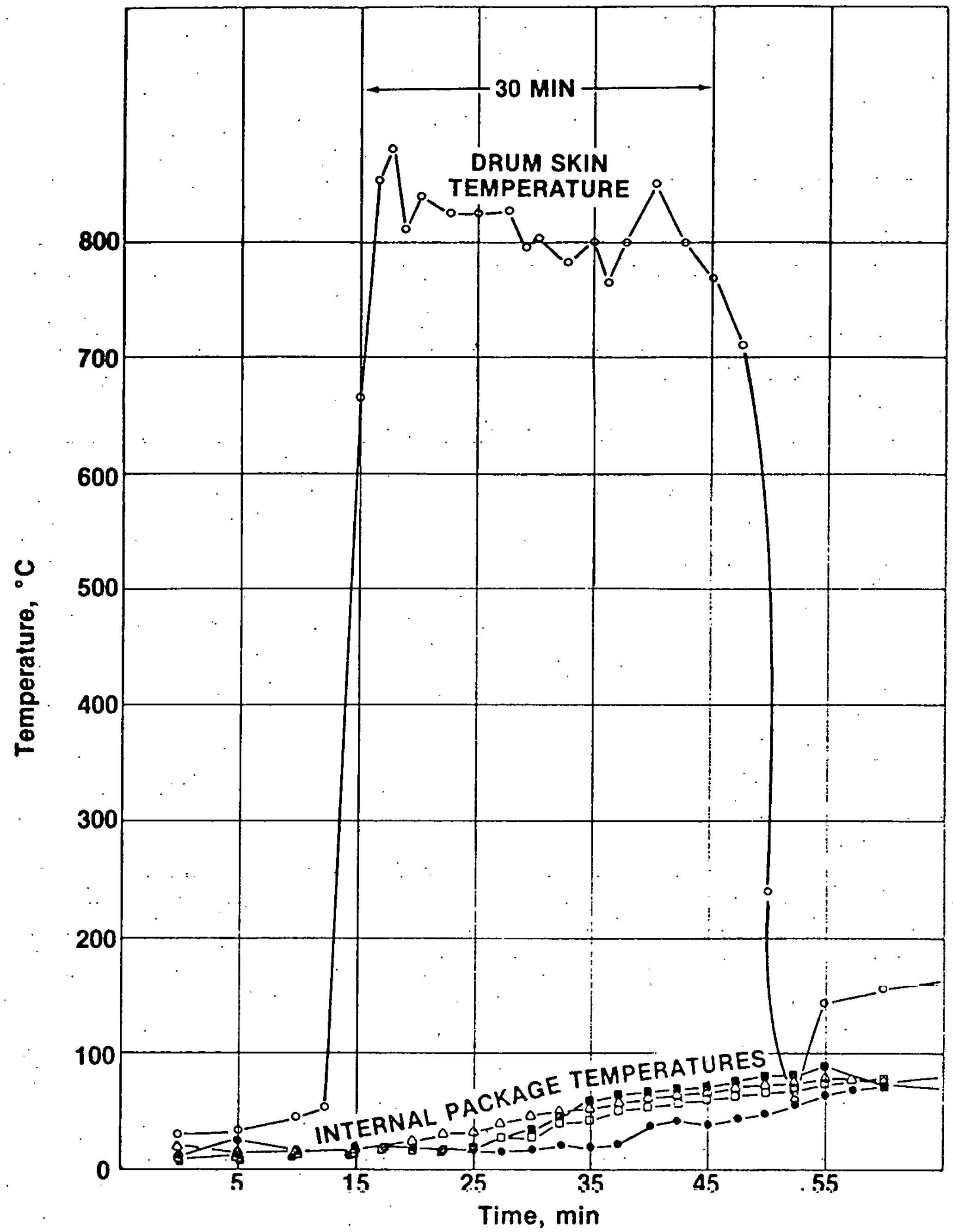

FIGURE 7 - Package temperatures as a function of time in fire test.