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Effectiveness of Water Spray Within the Cabin Overhead Area

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16. Abstract

Four full-scale postcrash fire tests were conducted in a modified DC-10 fuselage to investigate the benefits, if any, of spraying water in the area above the cabin ceiling, known as the overhead. The tests were part of a 28-test series using a wide body fuselage to study the performance of an on-board cabin water spray system. The spray system uses low flow rate nozzles which produce a fine mist consisting of a range of water droplet diameters. The system being tested was a "breadboard" design for the purpose of demonstrating concept feasibility only. In order to better quantify the overhead spray performance, two areas of the cabin ceiling were removed: the area directly adjacent to the fire door, and an area in the forward section of the fuselage near the gas sampling stations. Temperature, smoke, heat, and gas concentrations were monitored at various locations throughout the fuselage. Test results showed little or no improvement in cabin conditions due to the overhead spray.

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EXECUTIVE SUMMARY

Several important regulatory changes have been implemented in the last 5 years aimed at reducing the spread of postcrash fire throughout the cabin. From a materials standpoint, fire blocked seats and low heat release interior panels are very effective in impeding the progress of cabin fires. An alternative to fire hardening of cabin interiors through materials technology is a low flow rate cabin water spray system. Developed by Safety Aircraft and Vehicles Equipment (SAVE) Limited, the system consists of an array of spray nozzles installed in the cabin and above the ceiling, filling these areas with a heavy water mist. Twenty-eight full-scale tests have been conducted in a modified DC-10 fuselage to study the performance of such a system. Four of these tests studied the effects of spraying water in the area above the ceiling, known as the overhead. The overhead spray had very little impact on reducing heat and washing acid gases in the cabin area when compared to the overall ability of the system to perform these functions.

INTRODUCTION

PURPOSE.

The purpose of this report is to present the results of four water spray tests (identified as tests 19, 20, 21, and 22) conducted in a modified DC-10 fuselage to determine the importance of spraying water in the area above the ceiling.

BACKGROUND.

The onboard cabin water spray program is composed of several phases aimed at developing a safe and effective system to be installed in commercial transport aircraft. To evaluate the ability of the Safety Aircraft and Vehicles Equipment (SAVE) Limited system in providing additional escape time during a postcrash fire scenario, full-scale tests are being conducted in both narrow body and wide body configurations. Concurrently, a study is being undertaken to address the various service considerations associated with an inadvertent discharge of water spray while the aircraft is in flight or on the ground. The results of these initial studies will be factored into a benefit analysis to determine the potential for lives saved. If the benefits of such a system outweigh the disbenefits, the next phase will be to optimize the system and to develop design requirements and specifications. The initial full-scale tests in both the narrow body and wide body configurations are complete and the results are favorable. Although the service considerations and benefit analysis studies are not complete, preliminary indications are positive. In anticipation of this, a series of tests was run to determine the ability of the water spray system with less water and/or less nozzles (i.e., less weight) to provide escape times comparable to those previously achieved. The simplest way of reducing the amount of nozzles is to eliminate those in the overhead portion of the fuselage. During the initial wide body tests, there were 324 total nozzles, with 28 (or 8.6 percent) of those located in the overhead. There was much concern over the usefulness of installing the nozzles in this area, so several tests were conducted to investigate the impact.

DISCUSSION

TEST DESCRIPTION.

As shown in figure 1, two sections of the cabin ceiling were removed for the tests, allowing the heat and smoke to propagate into the overhead area. The section removed near the fire door was directly over the seat area and measured approximately 10 by 12 feet. A 4- by 8-foot section was also removed near the forward gas sampling stations. During each of the four tests, four non-fire blocked double seats were positioned as shown. No other combustible materials were included in the tests. Water was sprayed throughout the cabin during tests 19 and 20, and additionally in the overhead for test 19 (figures 2 and 3). Test 21 provided water spray coverage in areas forward and aft of the fire door and in the overhead of these areas (figure 4). During test 22, water was sprayed forward and aft of the fire door, in the cabin area only (figure 5). A schematic of the nozzle configuration is shown in figure 6.

The water spray in all tests lasted approximately 3 minutes, followed by a mixture of fine droplets and air for an additional 30 seconds. All tests were 5 minutes in duration, with water spray activation simultaneous to fire ignition. The four scenarios used a standard 8- by 10-foot pan fire adjacent to a type A door opening; 55 gallons of JP-4 fuel were used to create the pan fire. The fire was drawn into the fuselage with the aid of a fan mounted at the forward bulkhead (nose). The fan exhausted at a rate no greater than 5000 cubic feet per minute. The TC-10 test article was fully fire hardened and instrumented with thermocouple trees, smoke meters, gas sampling stations/gas analyzers, calorimeters, and photographic and video coverage (figure 1). A description of the instrumentation follows:

THERMOCOUPLE TREES. Seven thermocouple trees continuously measured the temperature throughout the cabin. The trees were located at 40, 220, 400, 590, 750, 940, and 1180 inches from the forward most point of the test article, or nose. Each tree consisted of eight thermocouple probes positioned from 1 foot above the floor to 8 feet above the floor. The 8-foot location was just under the ceiling level. In addition to the seven trees, eight individual thermocouples were positioned in the overhead area, 16 inches above the ceiling level on the fuselage centerline. These were located at 72, 168, 264, 384, 480, 576, 672, and 768 inches from the nose of the fuselage.

SMOKE METERS. Smoke meter stations were located at 80, 340, 570, and 1320 inches from the nose. Each station contained three smoke meters positioned at 18, 42, and 66 inches from the floor level. The smoke meters consisted of a columnated light source and photocell separated by 1 foot.

GAS ANALYSIS. Continuous gas sampling stations used to measure carbon monoxide, carbon dioxide, and oxygen were located at 60 and 530 inches from the nose. Each station had two intakes at heights of 42 and 66 inches from the floor. In addition to the continuous gas sampling, "grab" sampling stations were located at 60 and 530 inches from the nose, at heights of 66 and 42 inches, respectively. These stations measured the acid gas production of hydrogen bromide, hydrogen chloride, and hydrogen fluoride for 30-second intervals from 90 to 120, 150 to 180, 210 to 240, and 270 to 300 seconds from the test start.

Hydrogen cyanide was measured by two methods, amperometric analysis and gas chromatography. The amperometric analysis was performed by a Kin-tech™ analyzer which sampled at 60 and 530 inches from the nose, both locations at a height of 66 inches. In addition, hydrogen cyanide concentration was determined by the gas chromatography method at station 60, 66 inches from floor level.

CALORIMETERS. Calorimeters were used to measure the heat flux at four locations: 80, 590, 940, and 1320 inches. The transducers were all mounted at a height of 42 inches. At stations 80 and 590, the transducers were facing aft; at station 1320, the transducer was facing forward. The transducer located at station 940 was facing directly toward the fire door.

TEST RESULTS.

As shown in the test description, tests 19 and 20 are identical with the exception of water being sprayed in the overhead during test 19. Likewise, test 21 and 22 are identical with the exception of water being sprayed in the overhead during test 21. Therefore, a simplified test analysis follows, comparing test 19 to 20, and 21 to 22.

TESTS 19 AND 20. The temperature profiles of the thermocouple tree at station 40 indicate that the temperature at 4 feet is slightly higher with no overhead spray (test 20) as compared to the test in which water is being sprayed (test 19). The temperatures at station 40 in the lower portion of the cabin are very similar in each of these tests (figure 7). (The temperatures in the upper portion of the cabin at station 40 could not be recorded during any of these four tests due to an inoperative data collection device.) By examining the temperature at station 220, we find that the temperatures are nearly identical between the 1- and 6-feet levels (figure 8), but above 6 feet the temperatures are higher in test 20 (figure 9). Station 220 is located aft of the section of ceiling that was removed. This also holds true for the temperatures at station 590 (figure 10). Due to difficulties encountered in reading some overhead thermocouples during test 19, it was necessary to estimate a portion of the temperature profile (figure 11). As expected, the temperatures are much lower in the overhead when spraying water.

The comparisons of smoke levels at stations 80, 340, 570, and 1320 indicate no significant change in visibility within the cabin when spraying water in the overhead.

Results of these two tests did show that there was a lowered burning rate of the seats during test 19 as compared to test 20. This determination was based on the comparison of temperature profiles and gas analysis. As mentioned above, the temperatures were consistently higher from approximately 6 feet and above throughout the cabin during test 20, but remained nearly identical at the lower levels. The gas analysis indicates that there was a reduced carbon dioxide production and oxygen depletion during test 19, indicative of a reduced burning rate (figure 12). It could not be determined whether this decreased burning rate could be attributed to the overhead spray suppressing the seat fire by directly spraying on it (since there was no ceiling in this area) or whether there was a greater "washing" of the cabin atmosphere due to the additional spray. Because this effect needed to be studied further, two additional tests (21 and 22) were run in which there was no water sprayed in the area of the seats (either in the cabin or overhead) allowing the seats to become equally involved in the fire (figures 4 and 5).

TESTS 21 AND 22. The temperatures at station 40 (figure 13) and station 400 (figure 14) are nearly the same when comparing these two tests. As expected, a comparison of the overhead temperature at station 72 shows a lower temperature when spraying water up to the point at which the water expires (210 seconds). After this point, the temperature climbs to the level attained in the non-spray case (figure 15).

Comparisons of smoke levels at various stations indicate very little disparity of smoke generation between the two tests (figure 16). Similarly, the generation of hydrogen chloride (figure 17) and hydrogen cyanide during the two tests are very close.

The initial temperatures within the cabin also varyed by as much as 20 degrees Fahrenheit from test to test (figures 7,8,10,13,14).

SUMMARY

Based on the results of the temperatures, smoke levels, and gas analysis there was insignificant difference in cabin environmental conditions when spraying water in the overhead versus not spraying in the overhead. The only notable change was the burning rate of the seats, which was slightly lower with overhead water spray (test 19) than without overhead spray (test 20). That was attributed to the fact that additional water in the overhead nozzles was sprayed directly on the seats (since there was no ceiling in this area), thus slowing the burning process. Differences in both the initial temperature of the water spray and of the air also affected the test results.

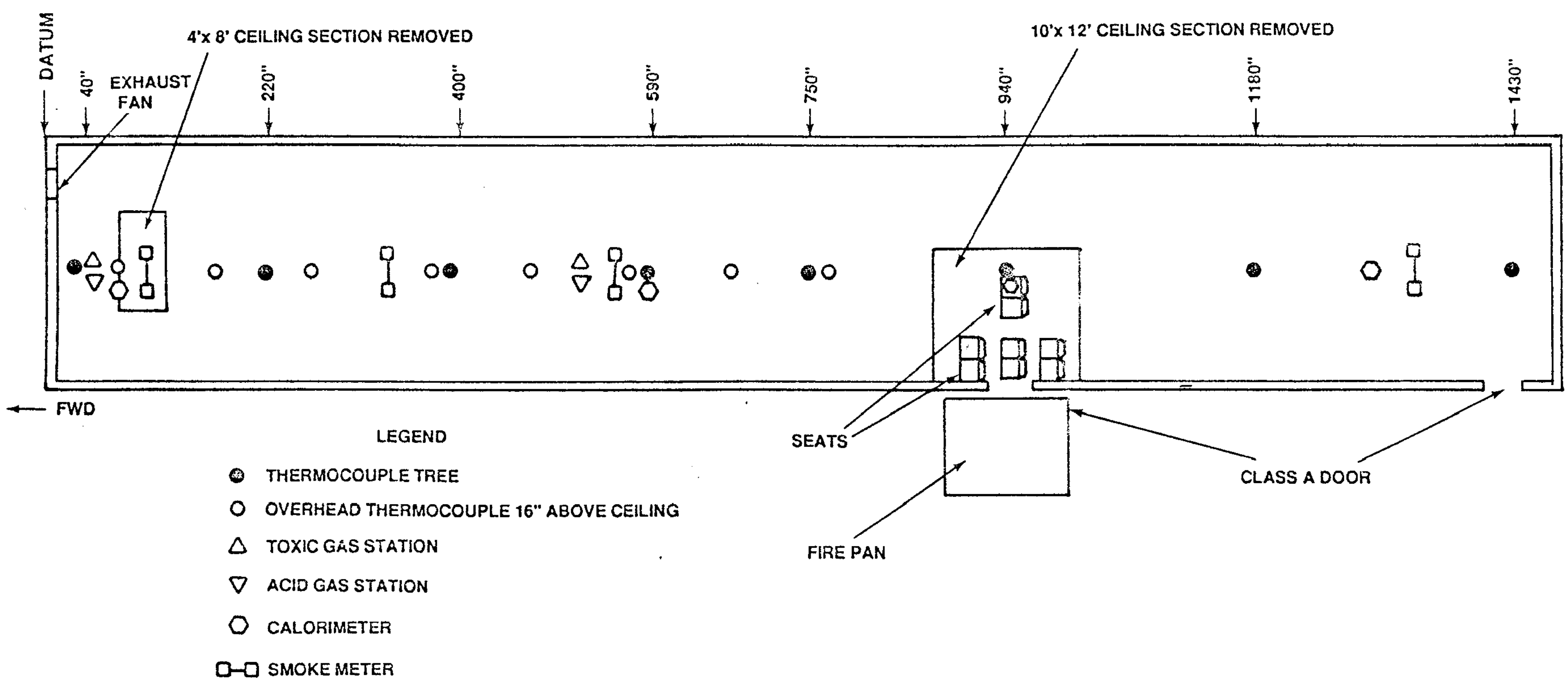

FIGURE 1. TC-10 CONFIGURATION FOR OVERHEAD WATER SPRAY TESTS

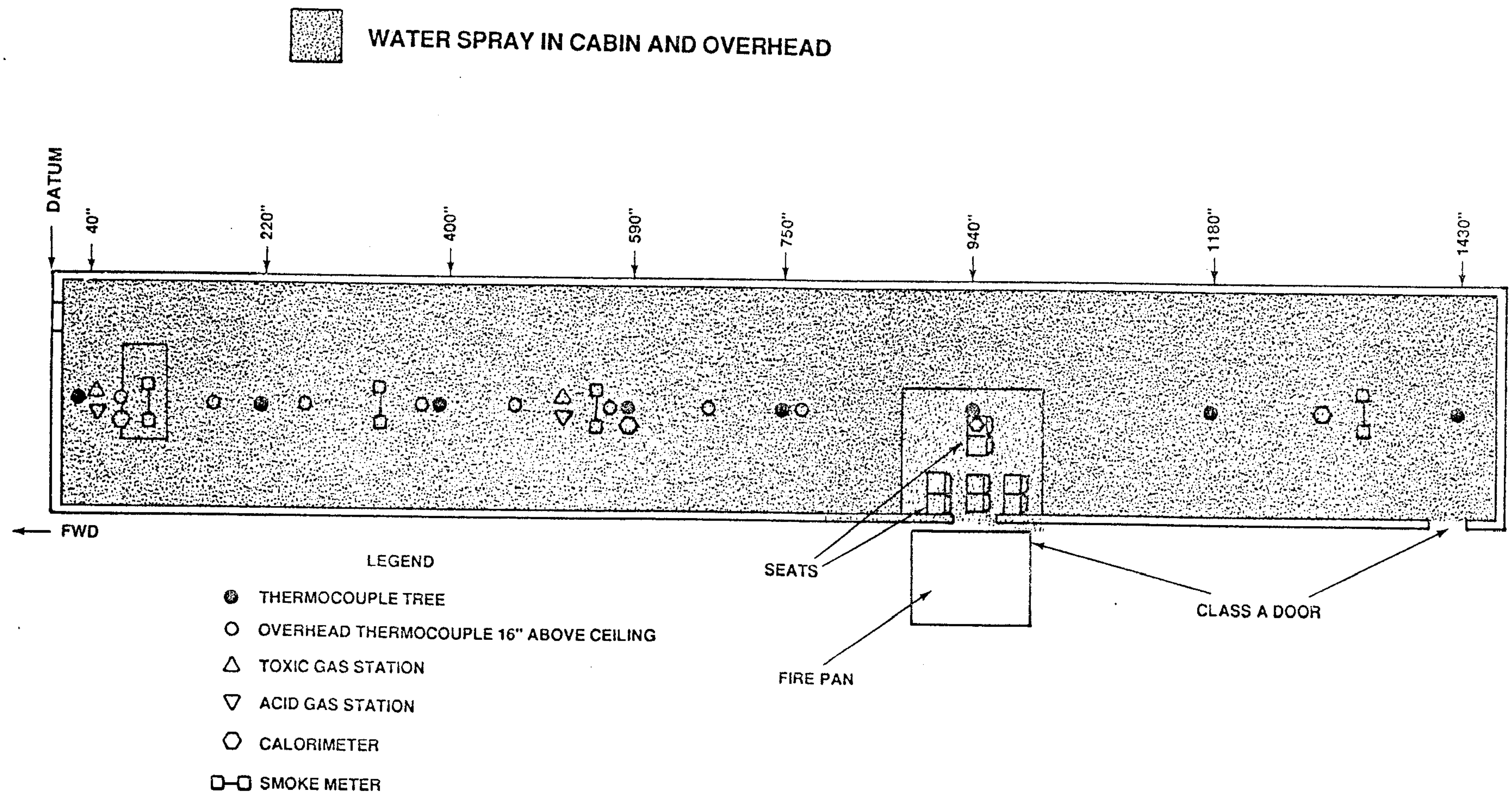

FIGURE 2. TEST 19 WATER SPRAY IN CABIN AND OVERHEAD

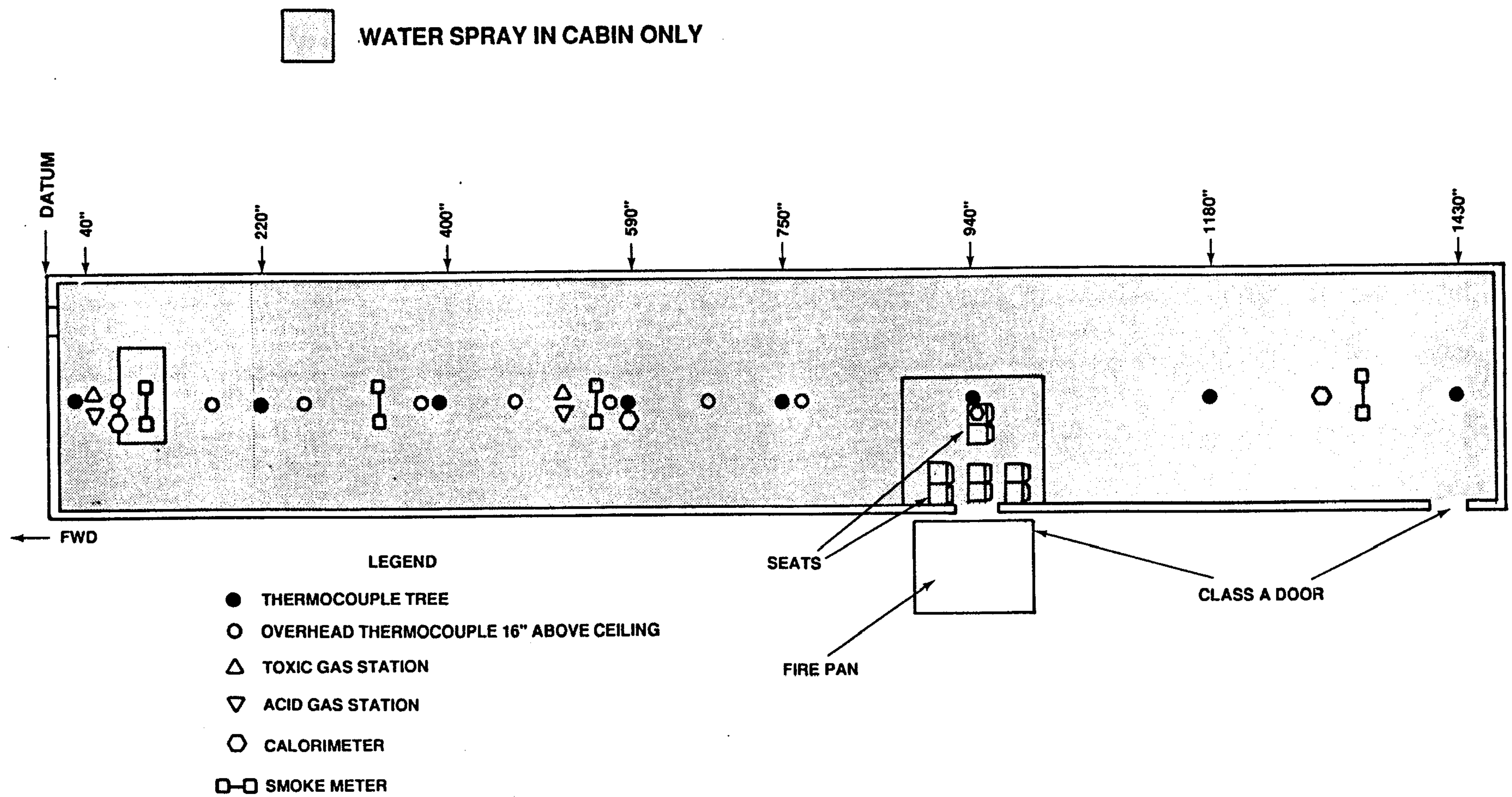

FIGURE 3. TEST 20 WATER SPRAY IN CABIN ONLY

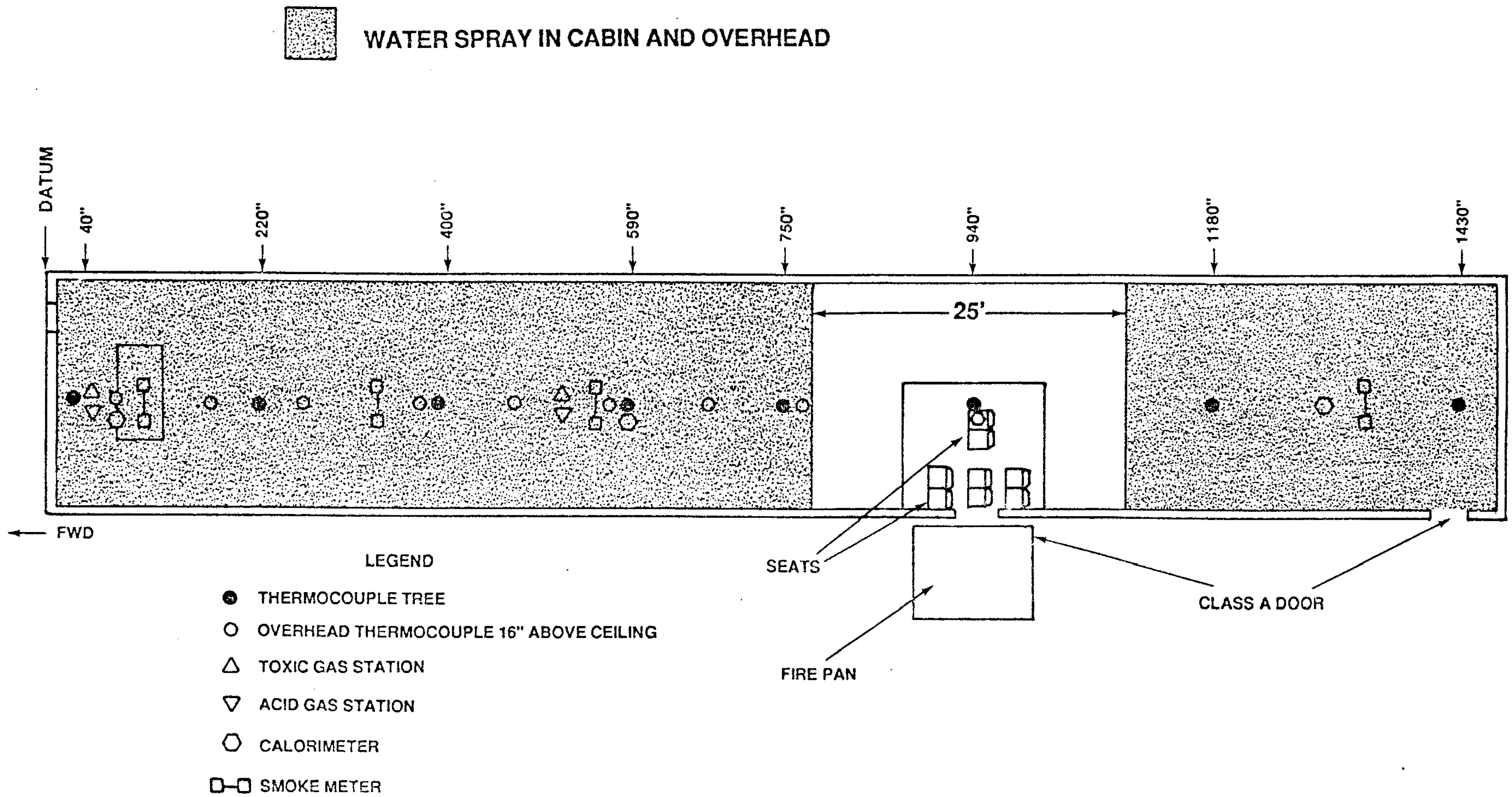

FIGURE 4. TEST 21 WATER SPRAY IN CABIN AND OVERHEAD

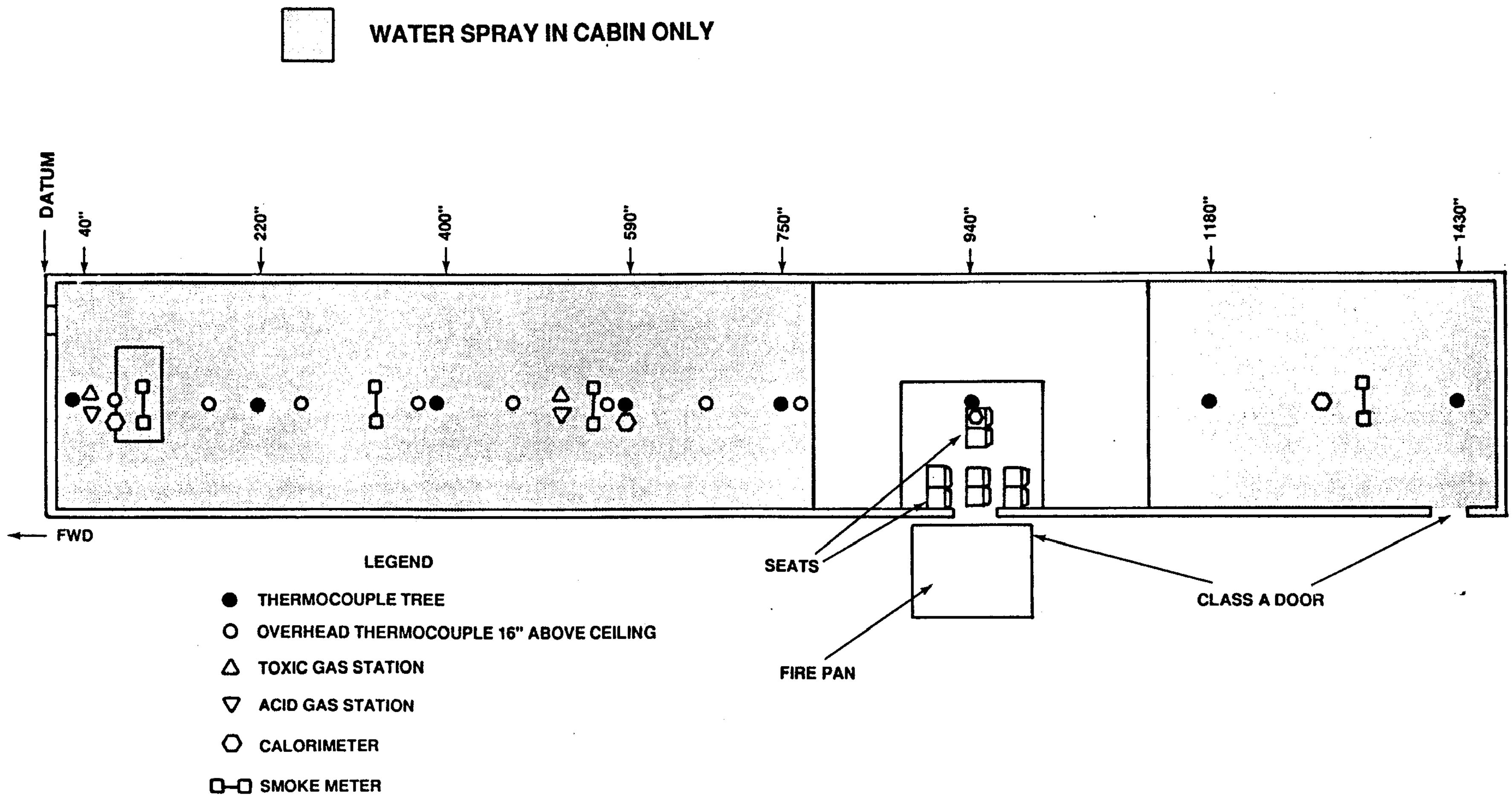

FIGURE 5. TEST 22 WATER SPRAY IN CABIN ONLY

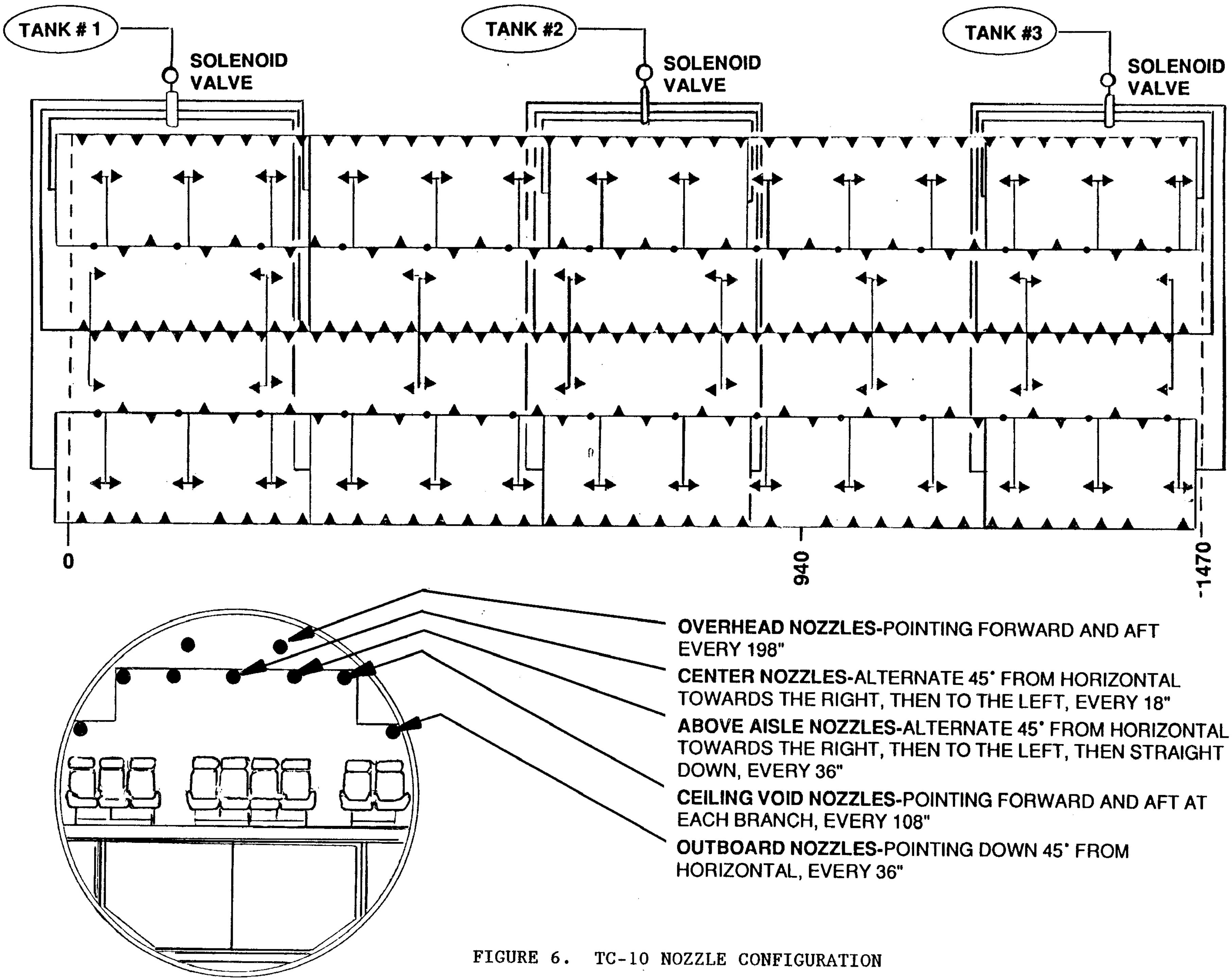

FIGURE 6. TC-10 NOZZLE CONFIGURATION

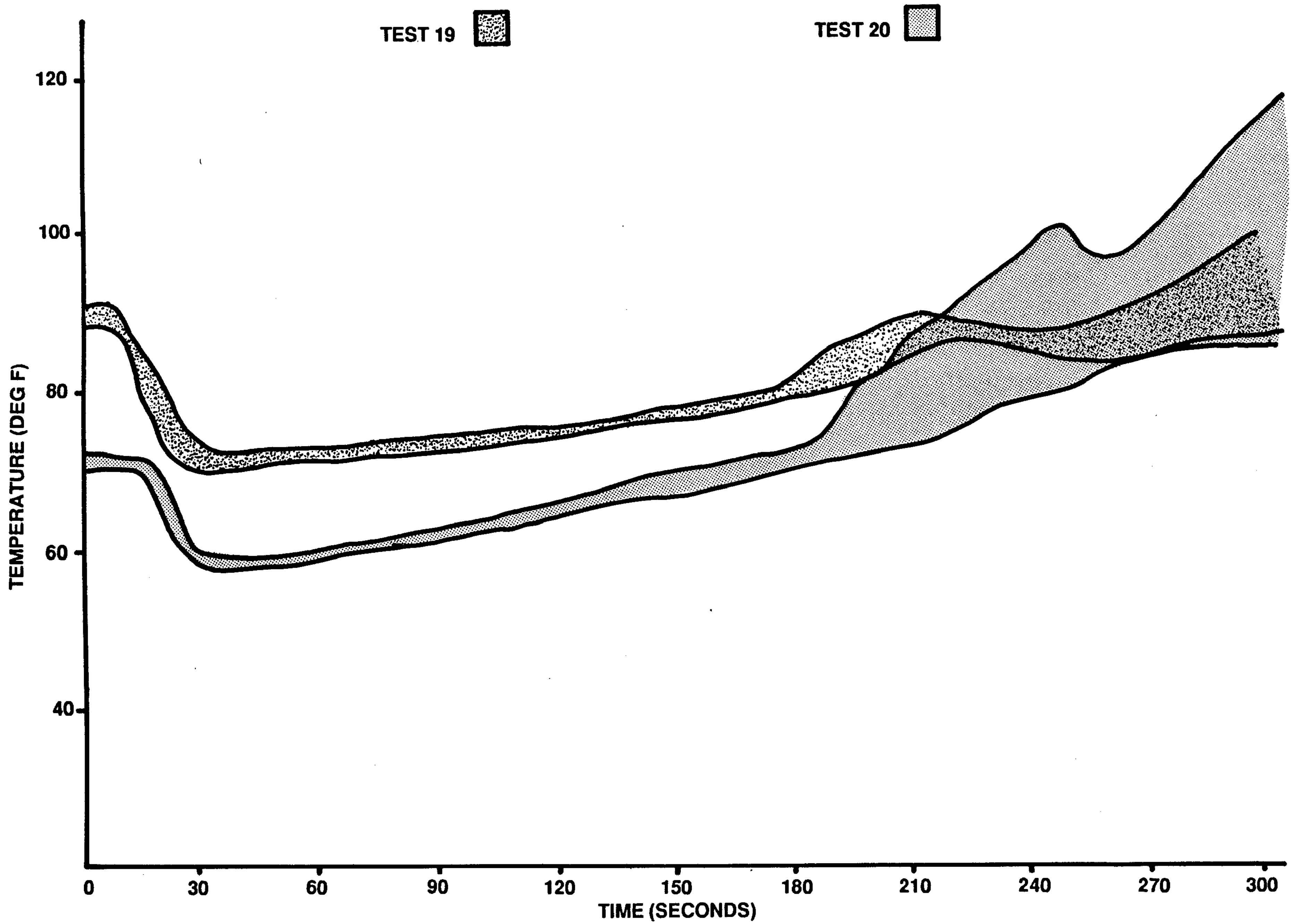

FIGURE 7. TEMPERATURE STATION 40 -- 1 TO 4 FEET

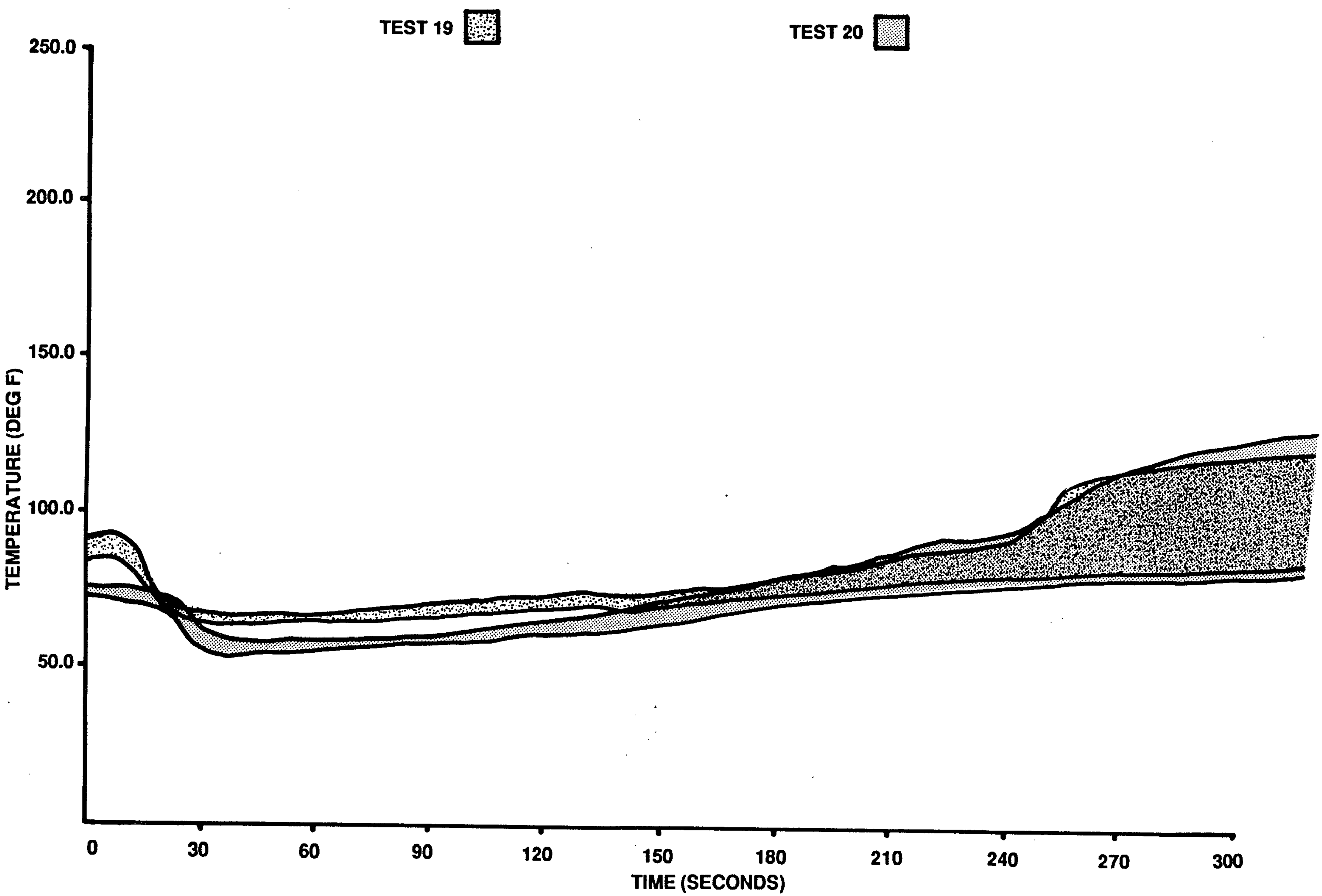

FIGURE 8. TEMPERATURE STATION 220 -- 1 TO 6 FEET

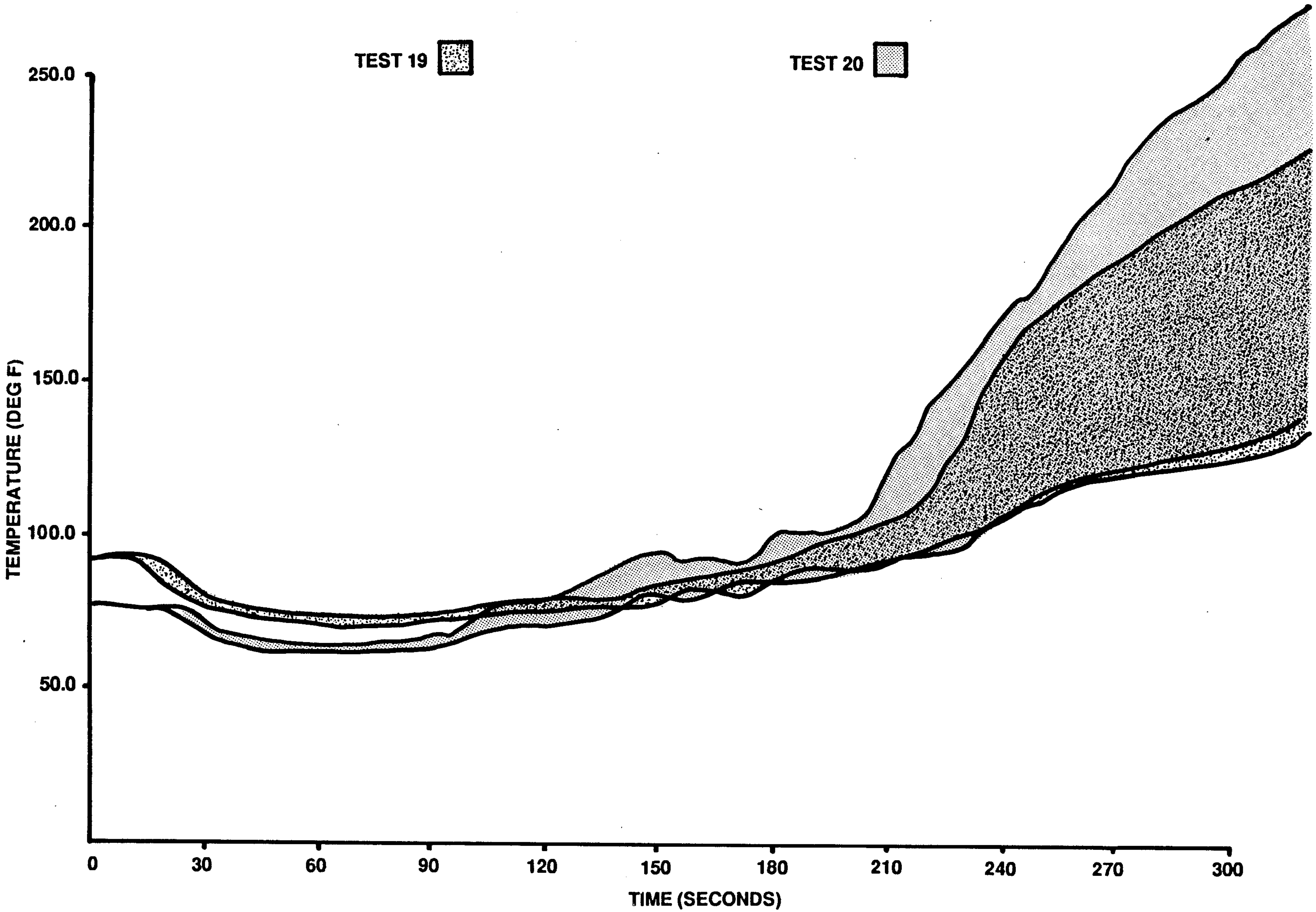

FIGURE 9. TEMPERATURE STATION 220 -- 7 TO 8 FEET

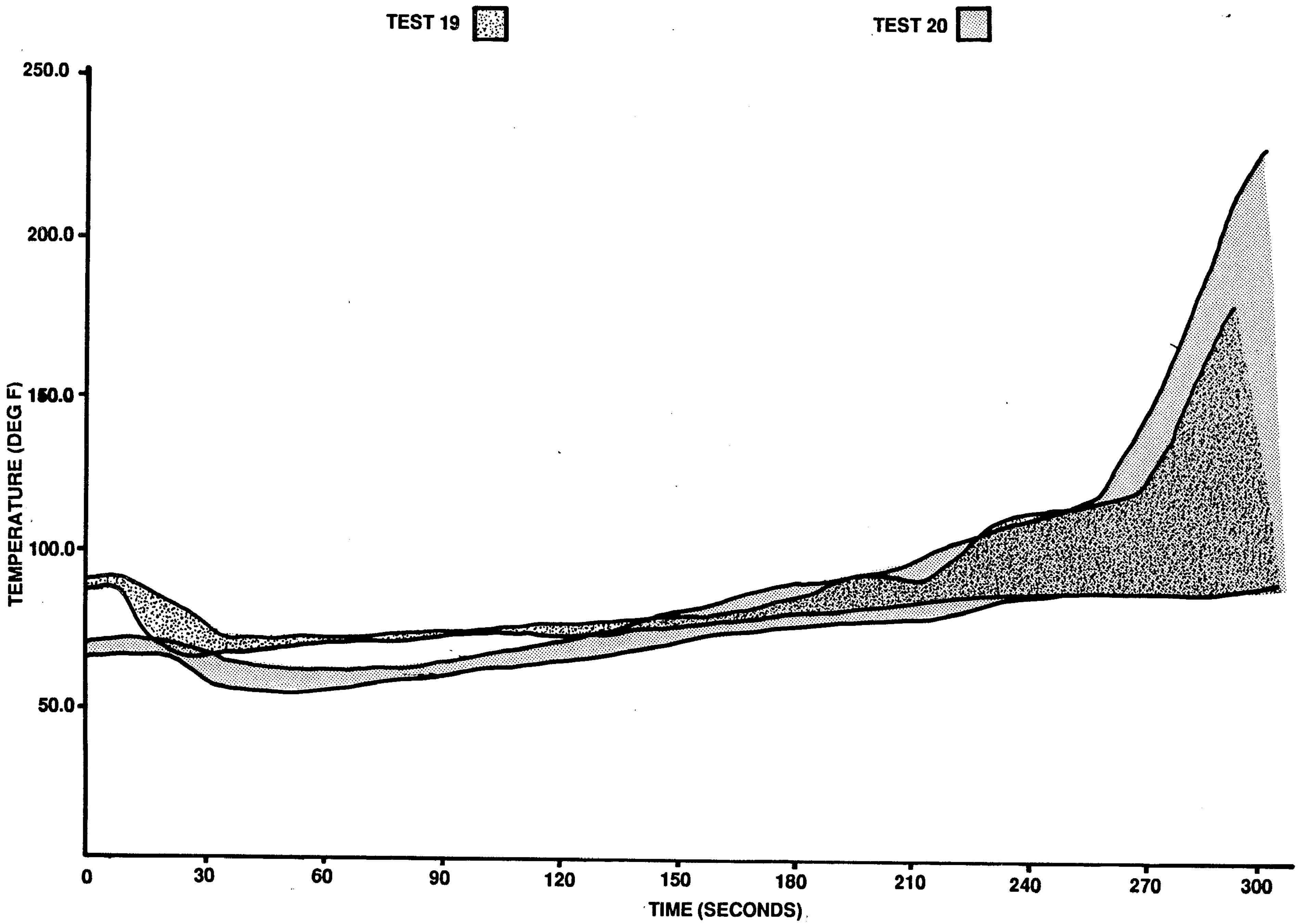

FIGURE 10. TEMPERATURE STATION 590 -- 1 TO 8 FEET

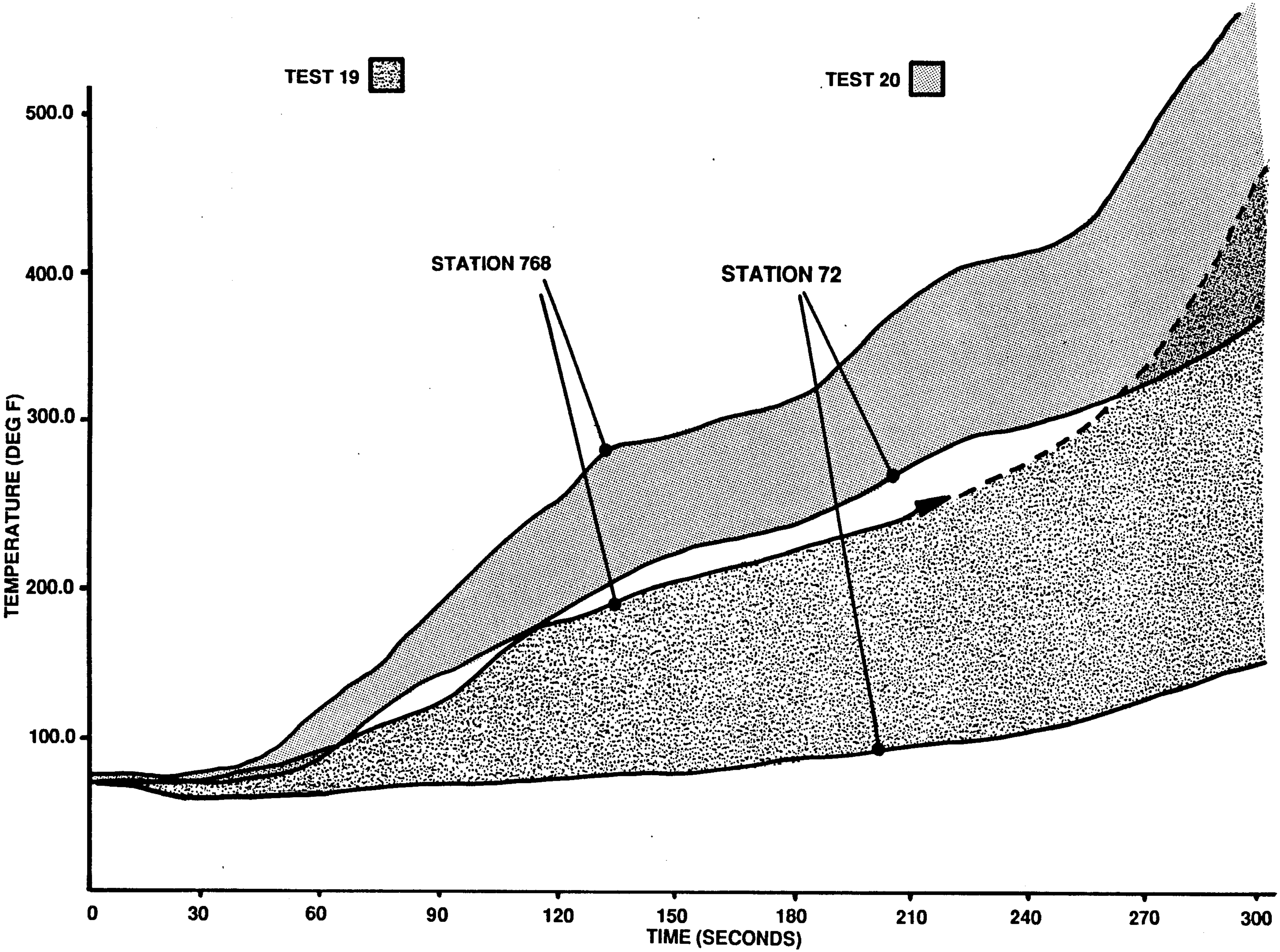

FIGURE 11. OVERHEAD TEMPERATURES ESTIMATED

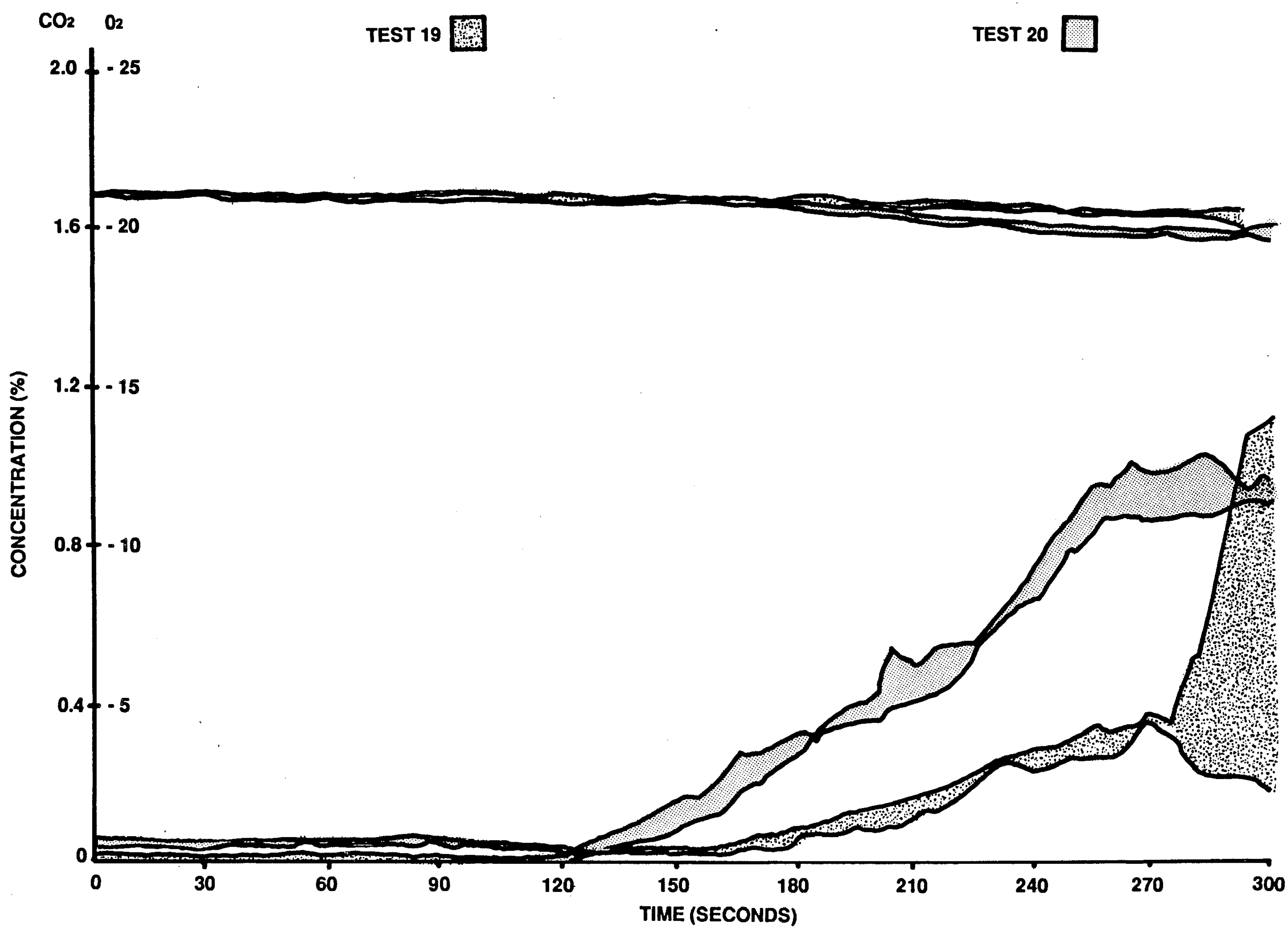

FIGURE 12. CARBON DIOXIDE AND OXYGEN CONCENTRATION STATION 530 --
3 FEET 6 INCHES TO 5 FEET 6 INCHES

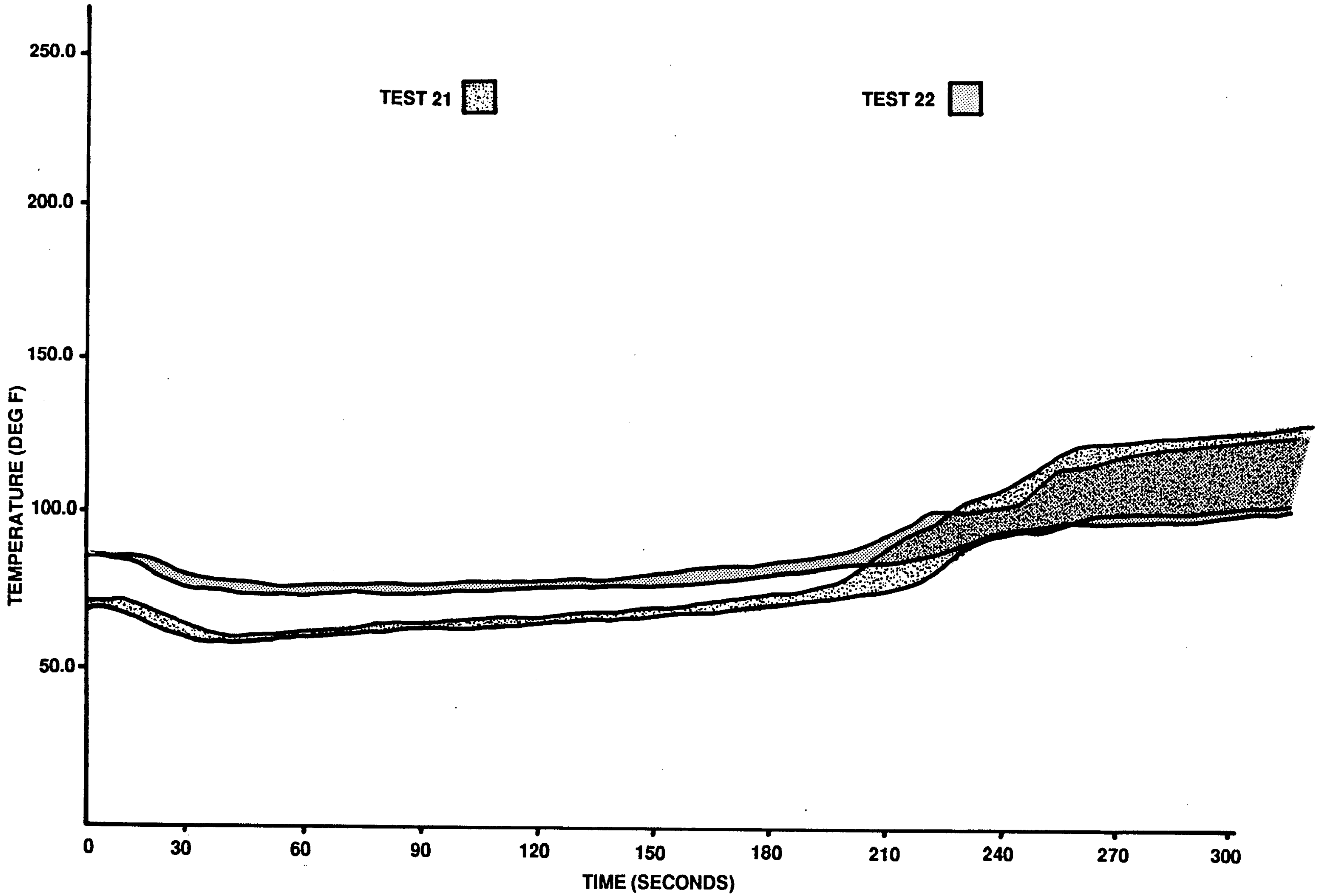

FIGURE 13. TEMPERATURE STATION 40 -- 1 TO 4 FEET

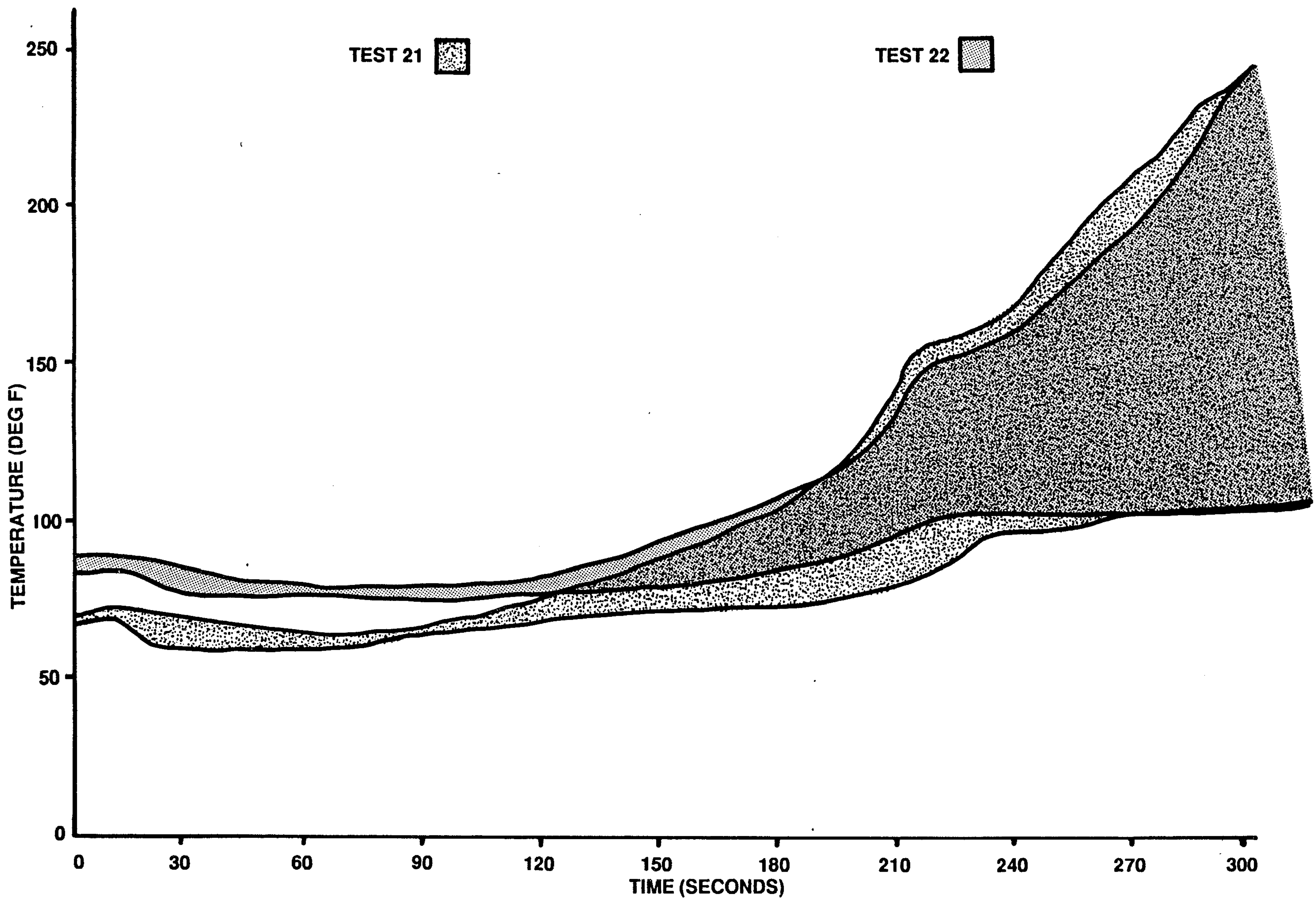

FIGURE 14. TEMPERATURE STATION 400 -- 1 TO 8 FEET

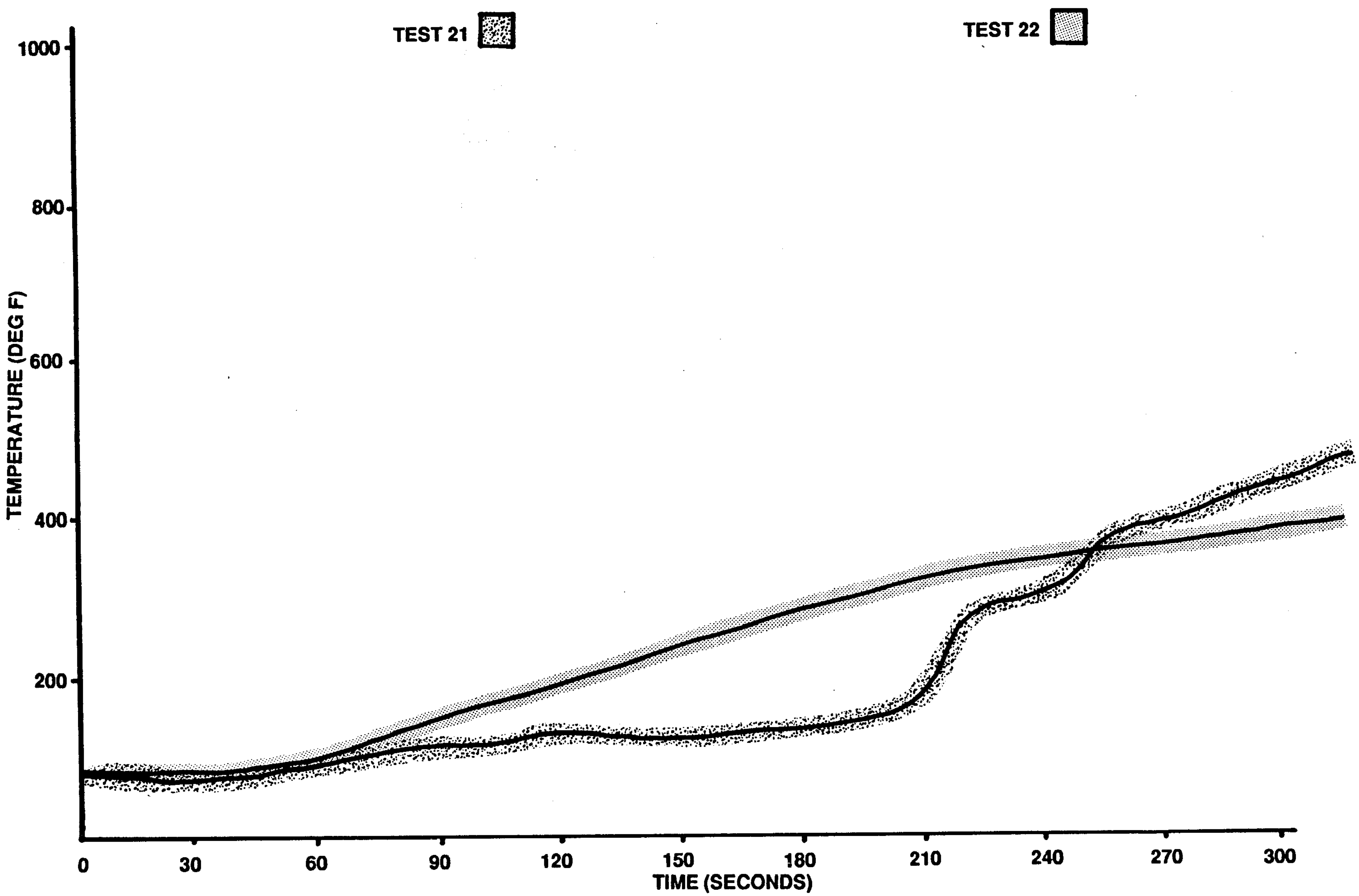

FIGURE 15. OVERHEAD TEMPERATURE STATION 72

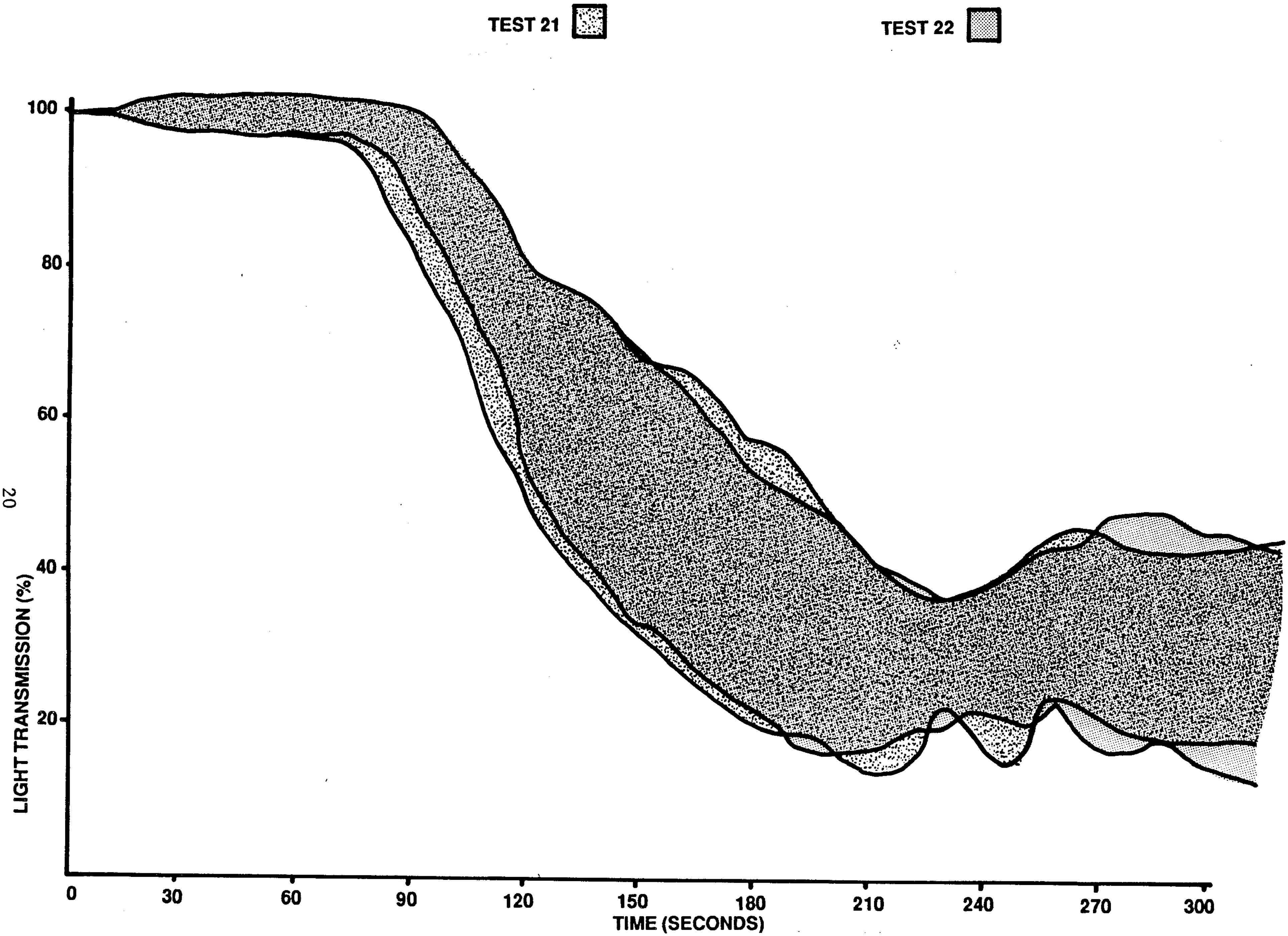

FIGURE 16. SMOKE STATION 340 -- 1 FEET 6 INCHES TO 5 FEET 6 INCHES

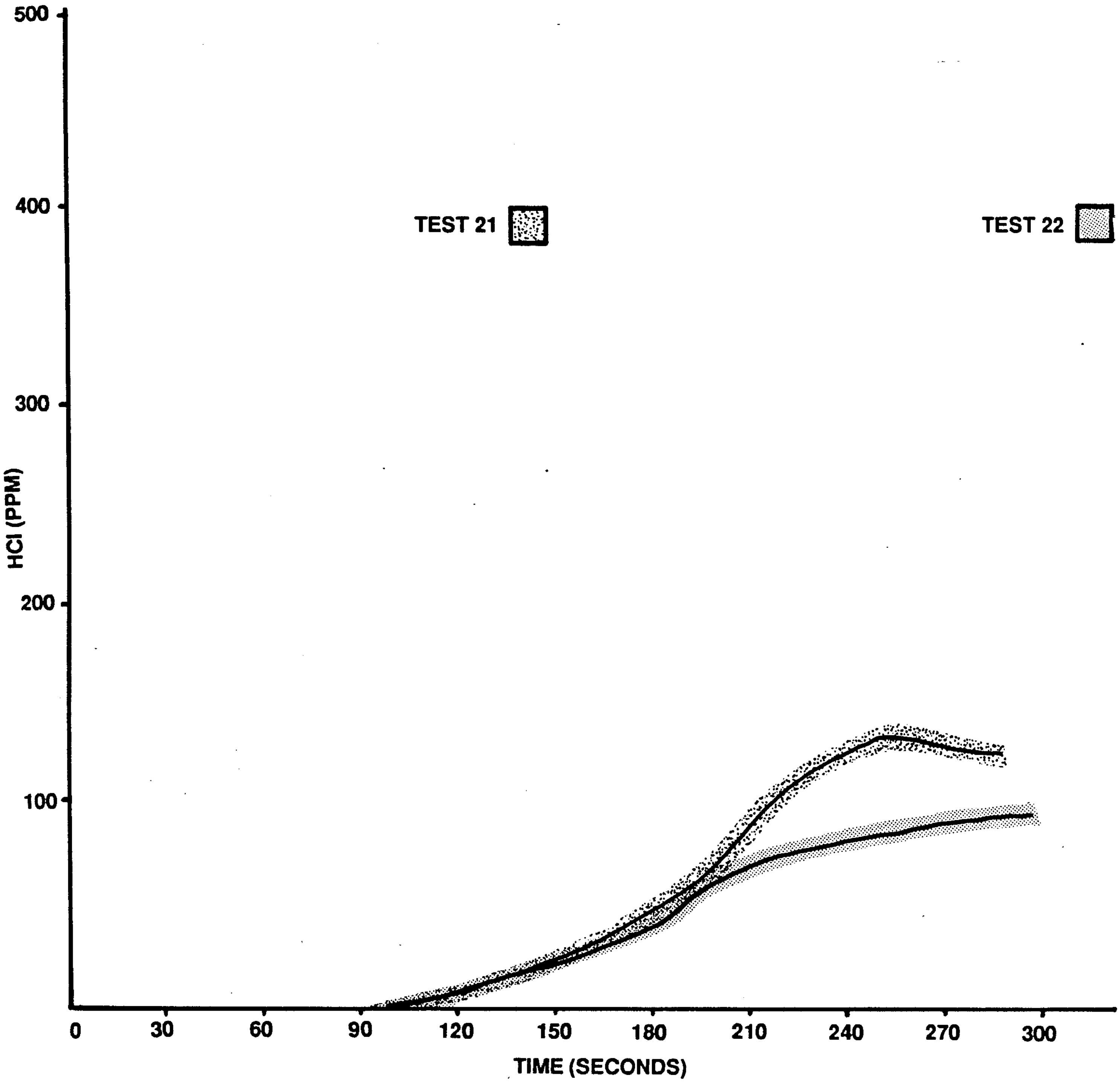

FIGURE 17. HCl CONCENTRATION STATION 530 -- 3 FEET 6 INCHES