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AIRCRAFT SEAT CUSHION MATERIALS TESTS

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AIRCRAFT SEAT CUSHION MATERIALS TESTS

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SUMMARY

Five component level flammability tests were conducted in a 400 cubic foot chamber to determine the products of combustion and relative destruction of coated (with fire-retardants) and uncoated polyurethane foams during exposure of the foams to a large flaming ignition source for five minutes. The test results indicate that the improved state-of-the-art polyurethane foams without the added fire retardant and coating treatments were not significantly better than untreated older less fire-resistant polyurethane foams. However, by treating and coating the state-of-the-art foams, the production of toxic gases was delayed and the destruction of the foam limited.

INTRODUCTION

During the past several years the Johnson Space Center has been involved in the development and evaluation of improved fire resistant materials for spacecraft and, to a lesser extent, passenger aircraft. One aspect of this program has been to install some of the more promising materials in four NASA executive aircraft for in-use evaluation.

Polyurethane foam, treated with a fire retardant to reduce burning and coated with a plastic material to provide a barrier, was used for the seat cushions and backs. Because the use of such large quantities of foam constitutes a significant fuel source in passenger aircraft, full-scale flammability tests were conducted in a 737 fuselage (ref. 1) which included treated seat cushions and backs. However, the presence of other materials affected the products of combustion, material destruction, and temperature effects to such an extent that the gaseous products produced by the foam alone could not be determined. In these full-scale tests, interpretation of the results was further complicated by the fact that gas analysis for hydrogen cyanide by infrared spectrometer gave appreciably higher results than analysis for hydrolyzable cyanides determined using a specific ion electrode, even though pretest calibrations using known gas concentrations indicated close correlation between the results. Thus, to investigate the aforementioned discrepancies, five component level flammability tests were conducted of coated and uncoated polyurethane foams.

The component flammability tests were conducted in a 400 cubic foot steel chamber. A preliminary test, which consisted of burning the ignition fuel only, was conducted to provide background information concerning smoke and toxic gas production by the fuel only. Two tests (1 and 2) involved foam seat cushion materials treated and coated with fire-resistant materials. Two additional tests (3 and 4) utilized improved state-of-the-art seat cushion materials without additional treatment, and the fifth test employed seat cushion material installed in aircraft before the 1968 issuance of Federal Air Regulations (which were more stringent regarding flammability of materials than previous regulations).

EXPERIMENTAL PROGRAM

Test Objectives

The overall objectives of this test series were to compare data concerning the products of combustion and relative destruction of the five seat cushion foams (two treated and coated with fire retardants and three not) during exposure of the foams to a relatively large flaming ignition source for five minutes.

Specific test objectives were as follows:

1. Identification and quantification of the major products of combustion and the onset rate occurring as a result of each test.

2. Determination of the extent to which the polyurethane seat cushions contributed to the high levels of hydrogen cyanide detected in full-scale tests.

3. Determination of the degree of destruction of the various materials when exposed to a relatively large ignition source and determination of the protection provided by fire retardant treated and coated foams.

4. Determination of the upper seat back temperature during each test.

5. Determination of the degradation in visibility because of smoke.

Test Setup

A boilerplate Apollo Command Module of 400-cubic-foot volume was used as a chamber for conducting the tests (fig. 1). A simplified seat frame (fig. 2) was fabricated out of lightweight steel structure with an expanded metal bottom to support the bottom and back seat cushions used in each test. Upholstery or other materials typical of aircraft seat configurations were not included in these tests in order to simplify the gas analysis.

The seat cushion foam used in test 1 was Scott high resilient foam impregnated with ammonium dihydrogen phosphate (ADP) and then coated with Fluorel. The material was the same as had been installed in the four NASA executive aircraft and tested in full-scale flammability tests conducted in 1973 (ref. 1). In test 2, Mobay foam treated with ADP and coated with Fluorel was used; this configuration was representative of the seat cushion materials utilized in two full-scale flammability tests conducted in July 1974. In test 3, the polyurethane seat cushion foam was representative of the current state-of-the-art material installed in the latest generation commercial wide-bodied jet aircraft. For test 4, the untreated and uncoated Mobay foam was used to evaluate the virgin foam. Test 5 utilized the foam in use in commercial aircraft prior to the passing of more stringent Federal Air Regulations in 1968 concerning the degree of flammability permitted for cabin interior materials including seat cushion foams. The foam samples used in each test measured 3 inches by 17 inches by 17 inches for the seat cushion, and 3 inches by 17 inches by 34 inches for the seat back, for a total volume of 2600 cubic inches. The foam descriptions, densities, and weights of foam tested are given in table I.

The ignition source for each of these tests was one quart of JP-4 fuel (which burns for approximately 5 minutes) in a metal pan 12 inches by 12 inches placed under the mockup seat. A baseline test was conducted using the fuel alone and data from this test are also included. During each test a ventilation system flowed approximately 300 cfm of air through the test chamber.

Each test was allowed to continue for five minutes, after which the fire was extinguished with carbon dioxide. Material residues were removed after each test and weighed, and a calibration test using the JP-4 fuel alone was run to verify that residues from previous tests were not affecting subsequent tests.

Gas Sampling an Analysis

The sampling sequence consisted of evacuating the gas collection vessels to a pressure of 5 torr or less, and then taking a background sample just before ignition. After ignition, five other samples were taken at one minute intervals. The samples were removed through a sampling port located as shown in figure 1 and approximately fifteen seconds was required for each sample bottle to fill. The contents of each vessel were then analyzed using a mass spectrometer, gas chromatograph, and an infrared spectrophotometer, primarily to detect the quantities of oxygen, carbon dioxide, carbon monoxide, and hydrogen cyanide. After this portion of the analysis was completed, each gas collection vessel was connected to an additional vessel which had been evacuated to about 25 torr and which contained 200 milliliters of 0.05 molar sodium hydroxide solution. The gas sample in the collection vessel was allowed to pressure equilibrate with the second vessel, and the resultant solution was analyzed for hydrolyzable fluorides and cyanides using specific ion electrodes.

Instrumentation

Instrumentation was provided to measure flame and material temperatures, chamber pressure, and smoke density. Test specimens were weighed before and after each test. Still photographs were taken before and after selected tests.

RESULTS AND DISCUSSION

During each test after ignition, flame impingement occurred over most of the seat cushion bottom with additional envelopment of the sides and backs of the cushions. Damage to two of the untreated foams, as shown in figures 3 and 4 (tests 3 and 4), was significantly greater than to the treated foams (tests 1 and 2), one of which, the Mobay foam, is shown in figure 5. Figure 6 shows the back of the same foam cushion and demonstrates the barrier effect of the Fluorel coating.

The pretest and post-test weights and percentage of weight loss for the foam used in each test are shown in table I. The initial weights show considerable variation because of the different foam densities and the weight added due to treatment with ADP and Fluorel coating (for the foams in tests 1 and 2). The percentage weight loss for the treated and coated foams (tests 1 and 2) was significantly less than for the uncoated foams (tests 3, 4, and 5). The temperatures measured on the upper front side of the seat back (fig. 2) were considerably higher for the untreated foams than for the treated foams (fig. 7). The rapid rise in temperature of the untreated foams to almost 1500° F, in approximately one minute, is indicative of a flash fire or direct flame impingement on the upper region of the seat. These initial rises are coincident with rapid oxygen depletion (fig. 11), the probable cause of the sudden drop in temperature.

The maximum toxic gas concentrations by volume of the major products of combustion did not vary considerably with type of foam. The maximum concentrations of hydrogen cyanide (fig. 8), with one exception, varied from 778 to 1603 ppm, carbon monoxide concentrations (fig. 9) varied from 420 to 664 ppm, and carbon dioxide concentrations (fig. 10) from 0.22 to 0.36 percent. The minimum oxygen concentrations (fig. 11), with one exception, varied from 15.2 to 16.4 percent.

The significant difference between the samples treated with ADP and coated with Fluorel (tests 1 and 2) and the other samples was the relatively slower buildup of toxic products (figs. 8 thru 10) during the first two minutes of the tests. The foams used in tests 3, 4, and 5 apparently burned faster and more completely and therefore produced higher concentrations of combustion products early in the tests (one to two minutes). Toxic gas production rates for the treated foams used in tests 1 and 2 were relatively lower during the early portion of the tests (three to four minutes) and increased as the tests progressed. Oxygen depletion (fig. 11) was also slower during the early part of the tests. The difference in smoke density for each of the tests was not very noticeable; however, the smoke contributed by the JP-4 fuel alone was quite high, as shown in figure 12.

The fluorine content of some of the Fluorel coating used in tests 1 and 2 suggests that fluorine containing compounds should be detected in the gas phase as hydrolyzable components. The absence of any fluoride (as measured by specific ion electrode) does not necessarily verify that fluoride compounds were not produced. The infrared spectra of the combustion products from these four tests show indications of carbonyl fluoride bonds in the gas phase products. If the only significant hydrolyzable fluorine containing product was hydrogen fluoride rather than carbonyl fluoride, then it is reasonable to expect that fluorides might not be detected in the specific ion analysis because of their reactivity with the walls of the collection vessels.

Again, in this test series - as in previous full-scale flammability tests - the hydrolyzable cyanide concentrations as measured by a specific ion electrode were considerably lower than the HCN concentration obtained by infrared spectroscopy (table II). The levels detected using the infrared spectrometer were 4.7 to 8.7 times the levels detected using the specific ion electrode. Although no specific interferences to the ion electrode could be detected by the various analyses performed, an interfering ion must exist. Furthermore, the interfering species must be produced during the combustion of JP-4, since the same effect was seen with JP-4 alone. Additional work is being done in an attempt to identify the interfering species.

The JP-4 fuel also had significant effects on all of the measured test parameters, as indicated by the data obtained from the baseline test for toxic gases, oxygen depletion, and smoke production (figs. 8 through 11).

CONCLUSIONS

The following conclusions are made with respect to the results of this test program.

1. All of the foams tested produced similar maximum concentrations of hydrogen cyanide, carbon monoxide, carbon dioxide, and smoke; however, the onset rates for the gases produced by the treated and coated foams were significantly retarded during the first one to two minutes of the test as compared to the untreated foams. The JP-4 fuel also contributed to the gas production.

2. Relatively high levels of hydrogen cyanide (over that produced by the JP-4 fuel) were detected in each test, indicating that the polyurethane foam may be the major contributor to similar high levels found in the full-scale tests.

3. The hydrogen cyanide levels detected by infrared spectroscopy were approximately five to nine times the hydrolyzable cyanides measured by a specific ion electrode, indicating that an interfering species affected the specific ion electrode technique.

4. The lack of any measured fluoride for the Fluorel coated foams may have been due to differences in the collection techniques used in these tests in comparison with the techniques used in the full-scale tests and does not necessarily indicate the absence of fluoride compounds.

5. Total destruction for the two treated and coated foams was much less than for the three untreated foams, one of which was of the same material as the protected foam.

6. Temperatures measured on the upper portion of the front side of the seat back were significantly lower during the tests for the protected foams when compared to the unprotected foams.

7. Loss of visibility due to smoke production did not vary significantly between tests. This could partially be due to the large quantity of smoke produced by the JP-4 ignition source.

To summarize the above conclusions, the results indicate that under the conditions tested, the improved state-of-the-art polyurethane foams without the added fire retardant and coating treatments were not significantly better than untreated older less fire-resistant polyurethane foams. However, by treating and coating the state-of-the-art foams, the production of toxic gases was delayed and the destruction of the foam limited.

REFERENCES

1. Stuckey, Robert N.; Supkis, Daniel E.; and Price, L. James: Full-Scale Aircraft Cabin Flammability Tests of Improved Fire-Resistant Materials. Rep. TMX-58141, National Aeronautics and Space Administration, June 1974.

TABLE I. - PRETEST AND POST-TEST WEIGHTS

Test	Foam material	Treated and coated	Density, lbs/ft^3	Pretest weight, gms	Post-test weight, gms	Weight loss, gms	Weight loss, percent
1	Scott	Yes	3.3	2260	1050	1210	54
2	Mobay	Yes	5.3	3620	2015	1605	44
3	Upjohn CPR 9700	No	2.5	1710	430	1280	75
4	Mobay	No	2.9	1947	495	1452	75
5	Pre-1968	No	1.8	1220	0	1220	100

TABLE II. - HYDROGEN CYANIDE AND HYDROLYZABLE CYANIDES

Test	Foam material	Treated and coated	Maximum hydrogen cyanide measured by infrared spectrometer, ppm	Maximum hydrolyzable cyanides measured by specific ion electrode, ppm	Ratio of IR measured HCN to hydrolyzable cyanides
1	Scott	Yes	778	129	6
2	Mobay	Yes	986	113	8.7
3	Upjohn CPR 9700	No	1603	338	4.7
4	Mobay	No	1084	160	6.7
5	Pre-1968	No	1408	271	5.2

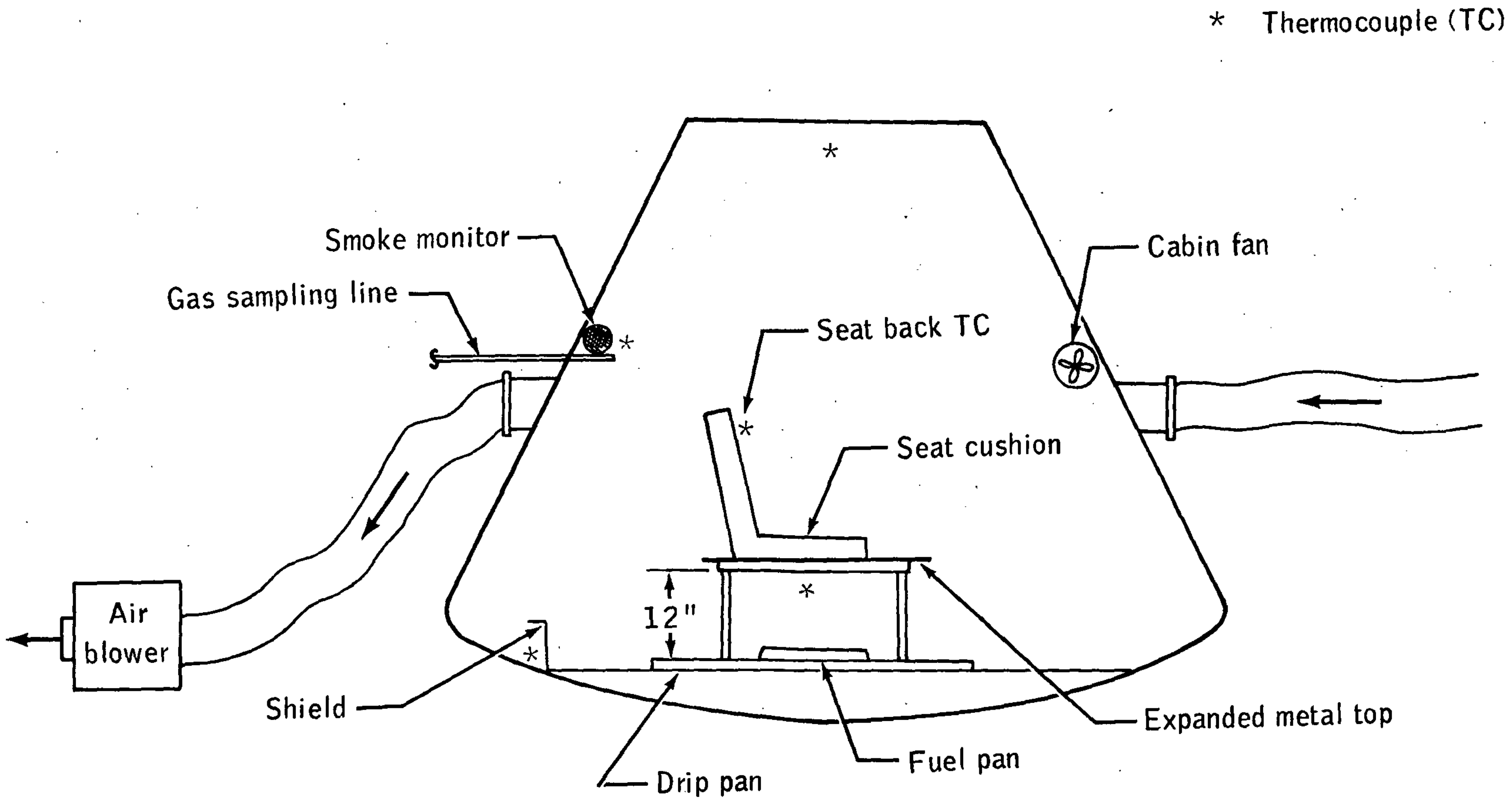

Figure 1.-Test setup

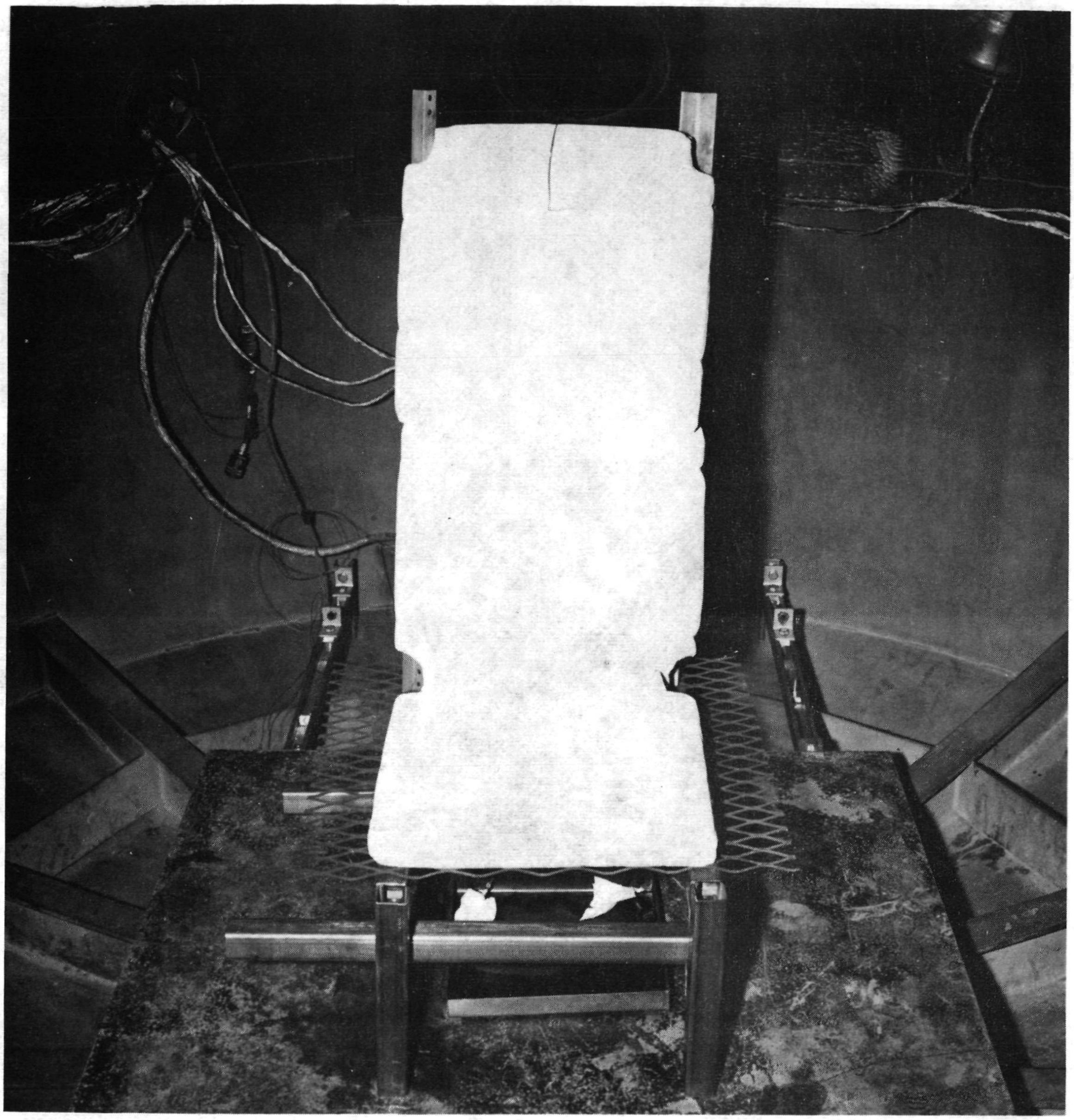

Figure 2.- Typical pretest seat mockup.

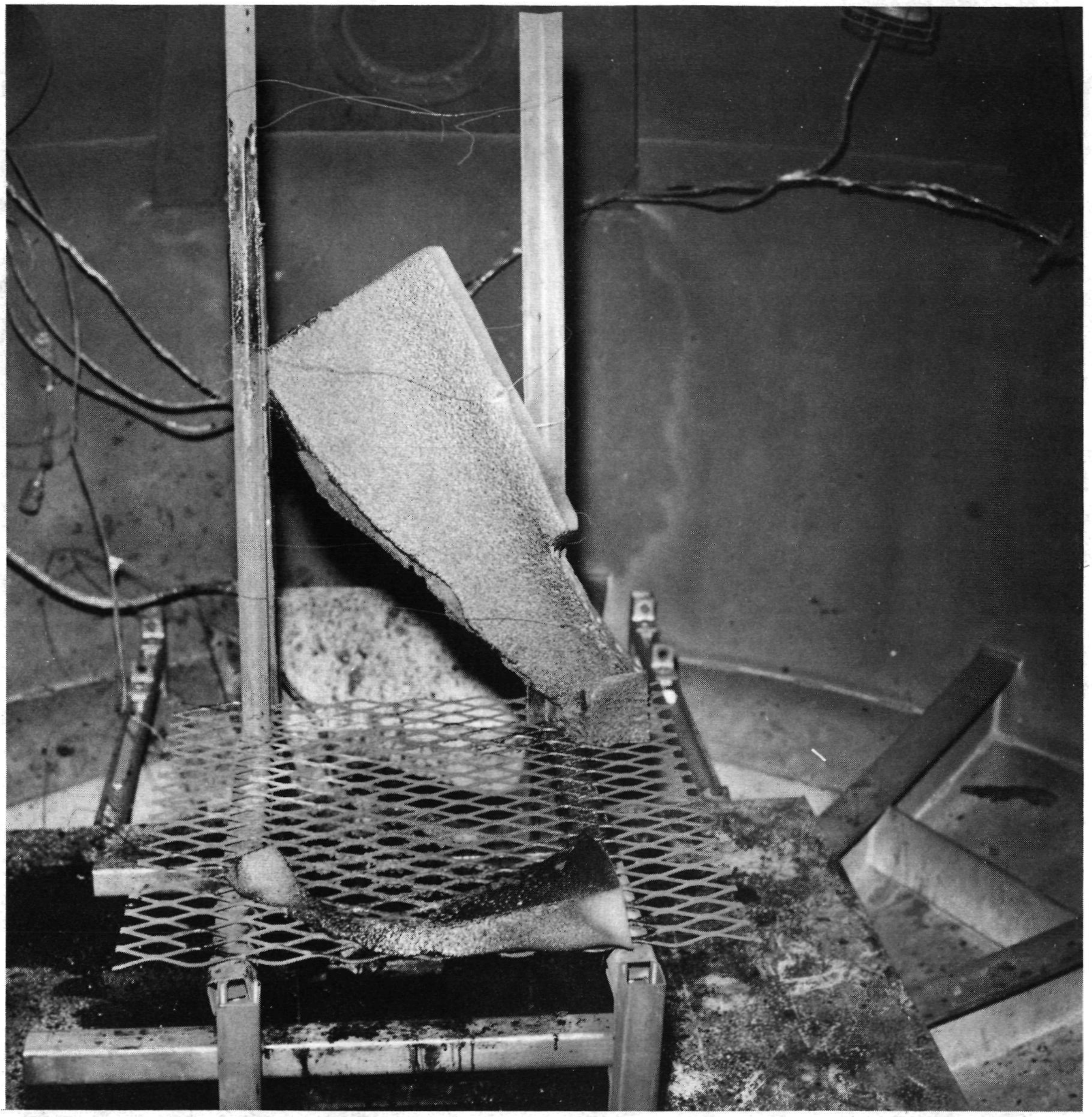

Figure 3.- Test damage to Upjohn CPR 9700 foam.

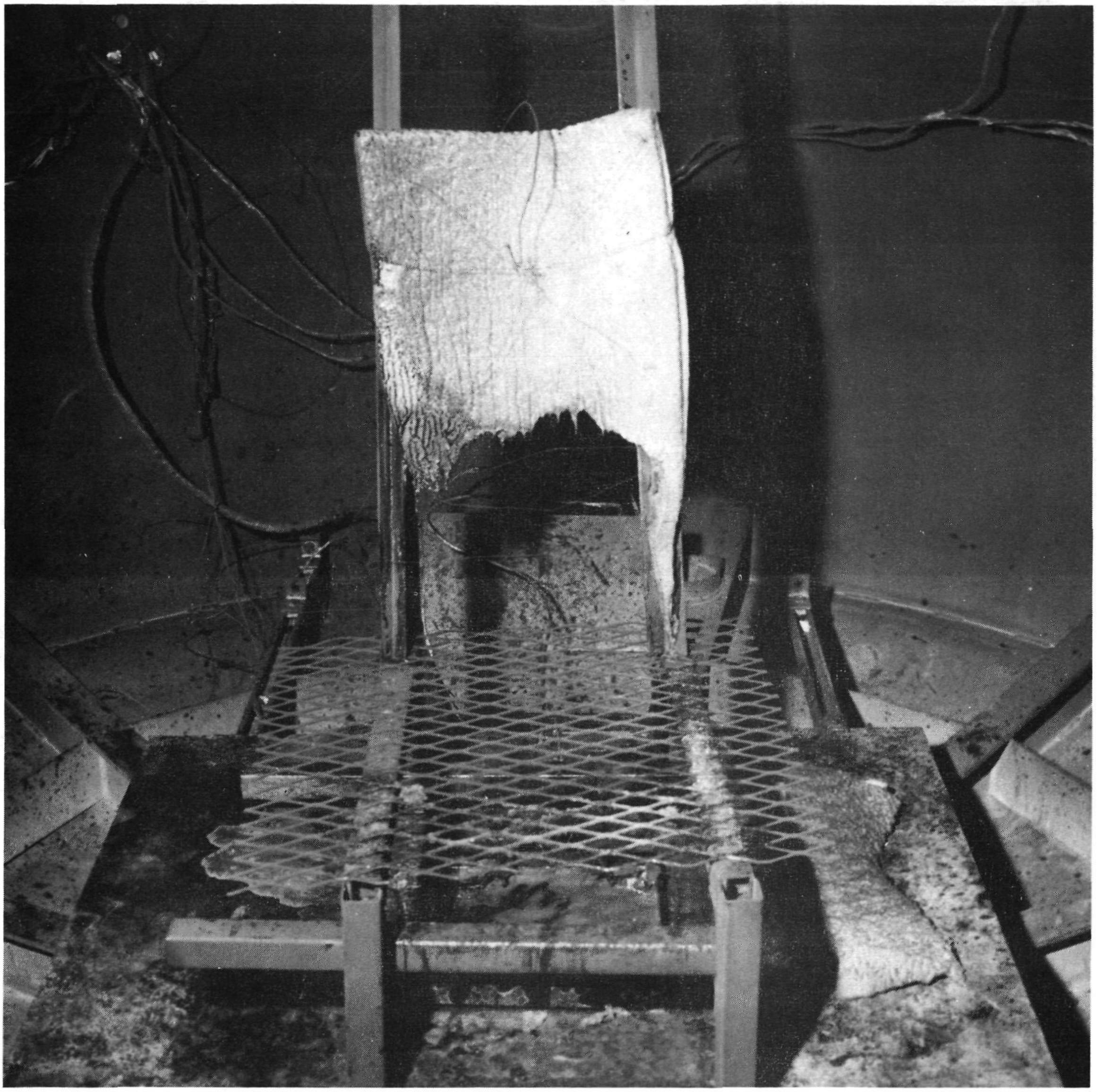

Figure 4.- Test damage to untreated and uncoated Mobay foam.

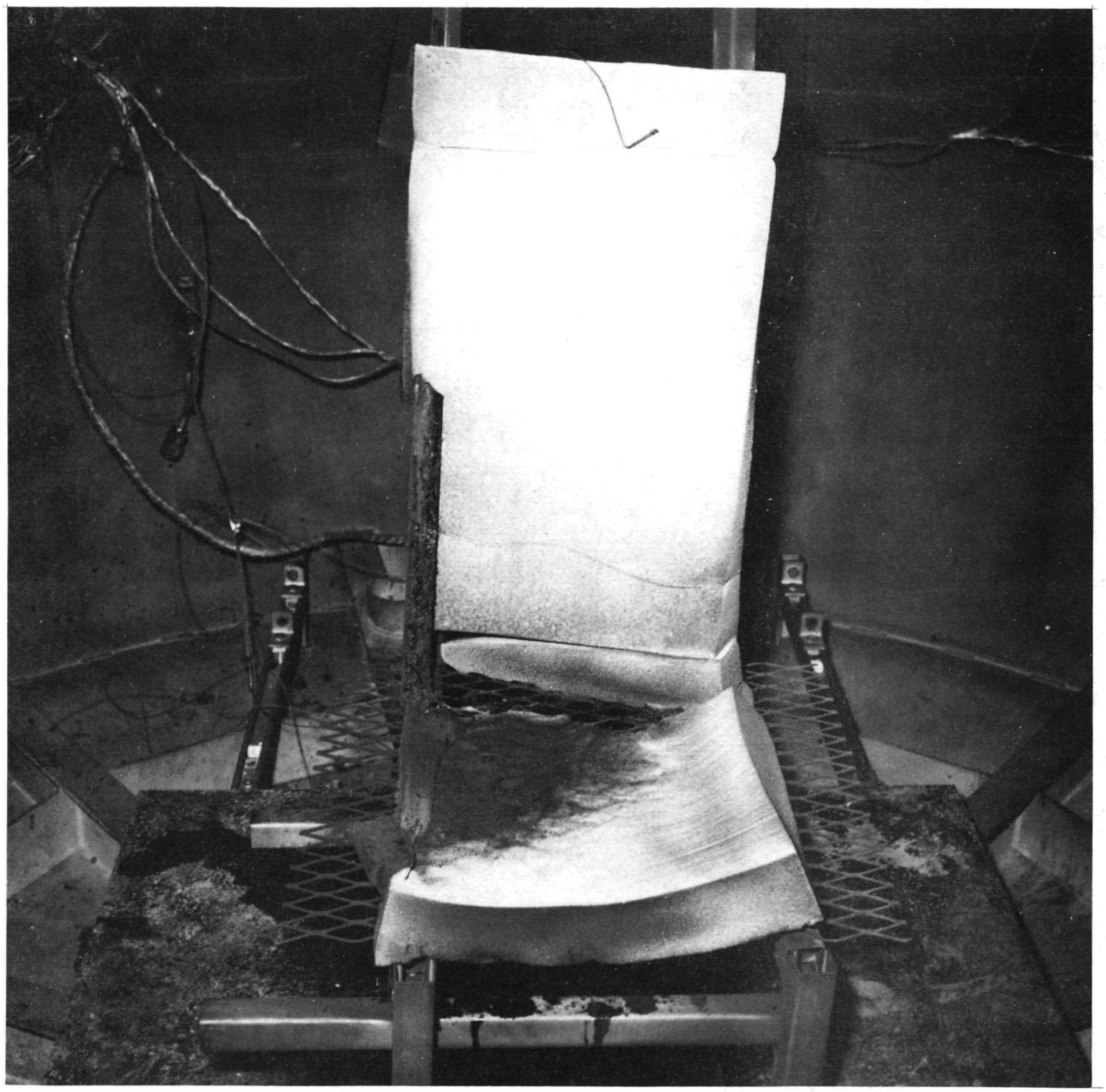

Figure 5.- Test damage to treated and coated Mobay foam.

Figure 6.- Test damage to back of treated and coated Mobay foam.

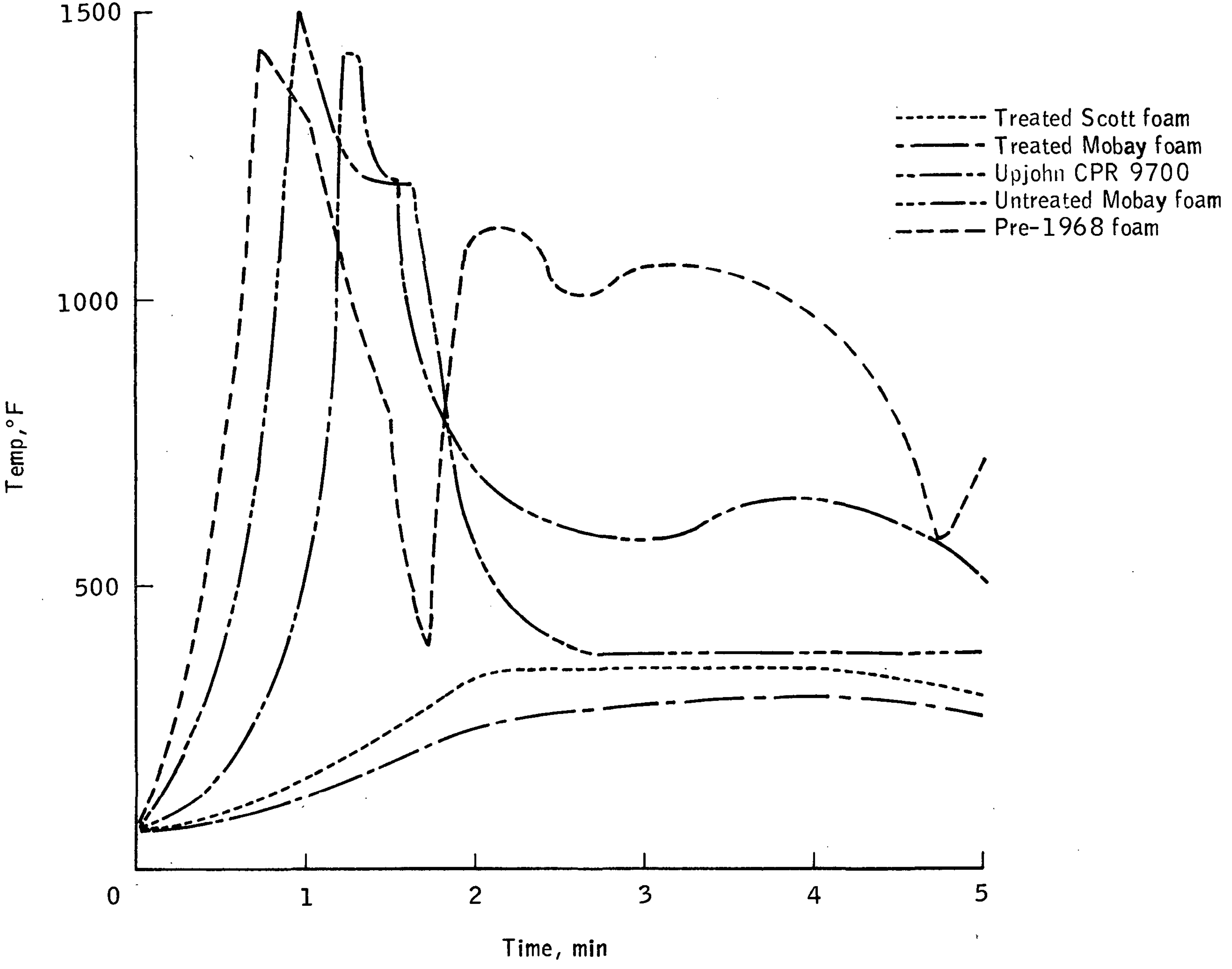

Figure 7.- Temperature at top of seat back.

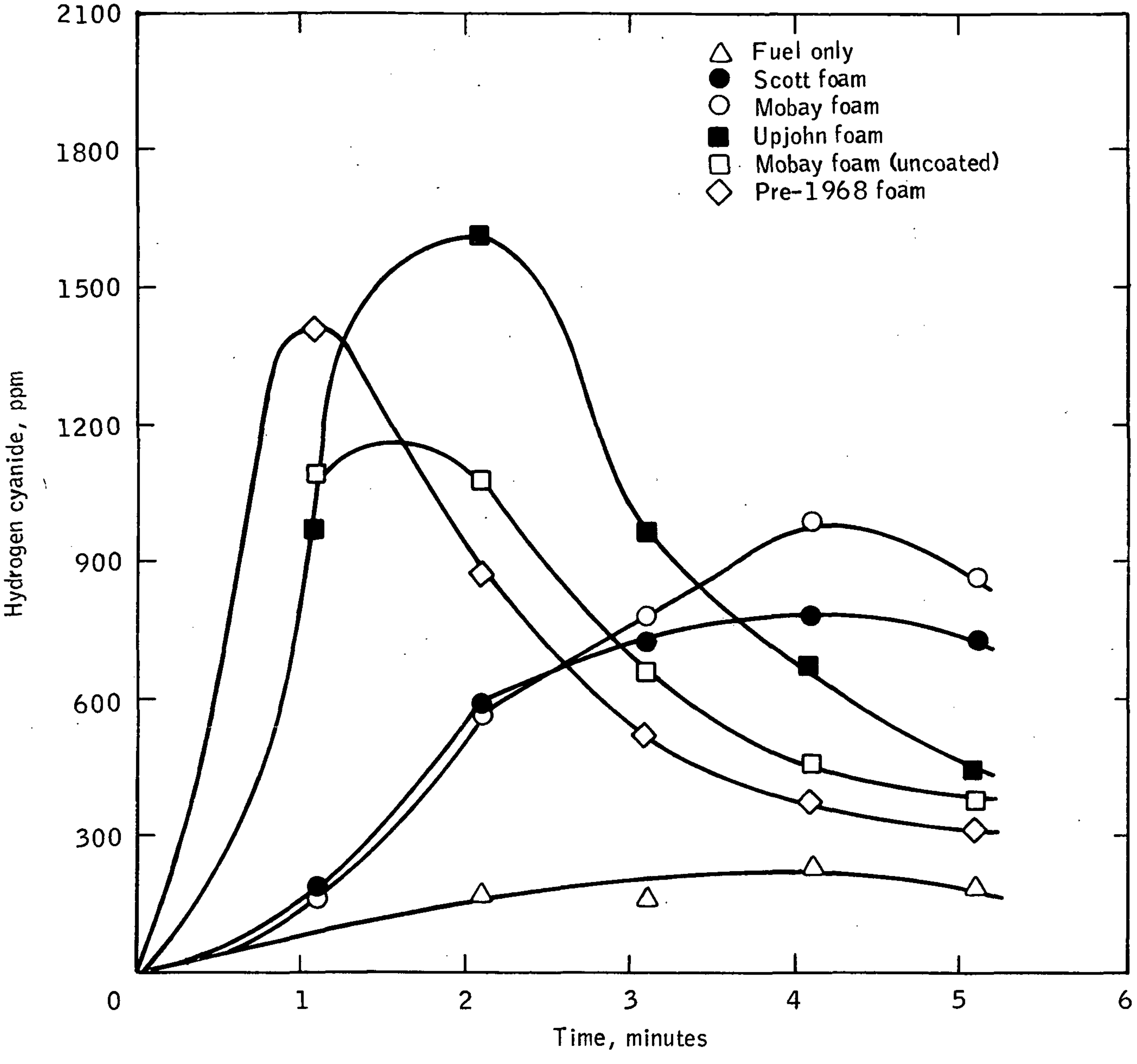

Figure 8. - Hydrogen cyanide concentrations.

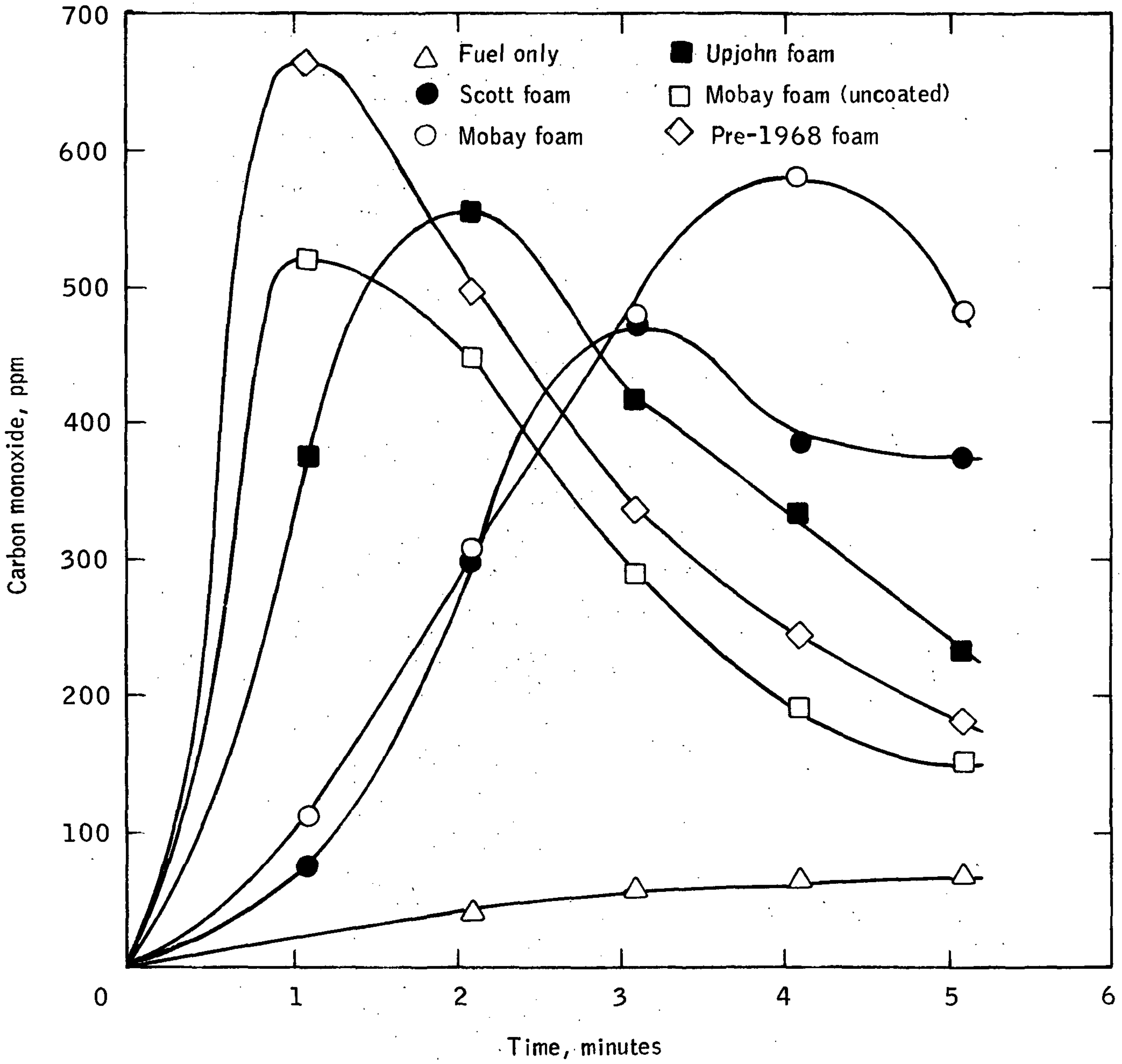

Figure 9.- Carbon monoxide concentrations.

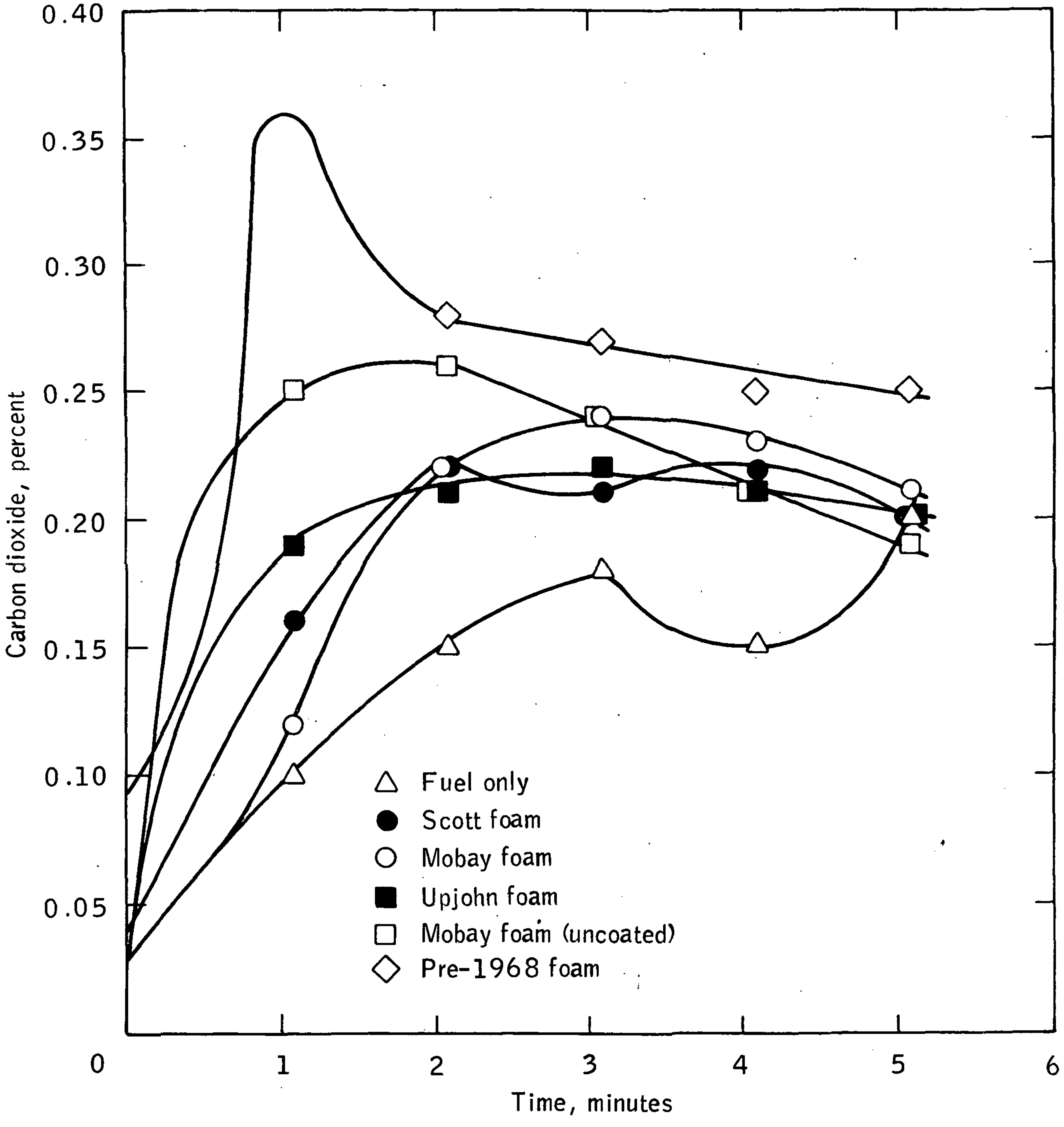

Figure 10.- Carbon dioxide concentrations.

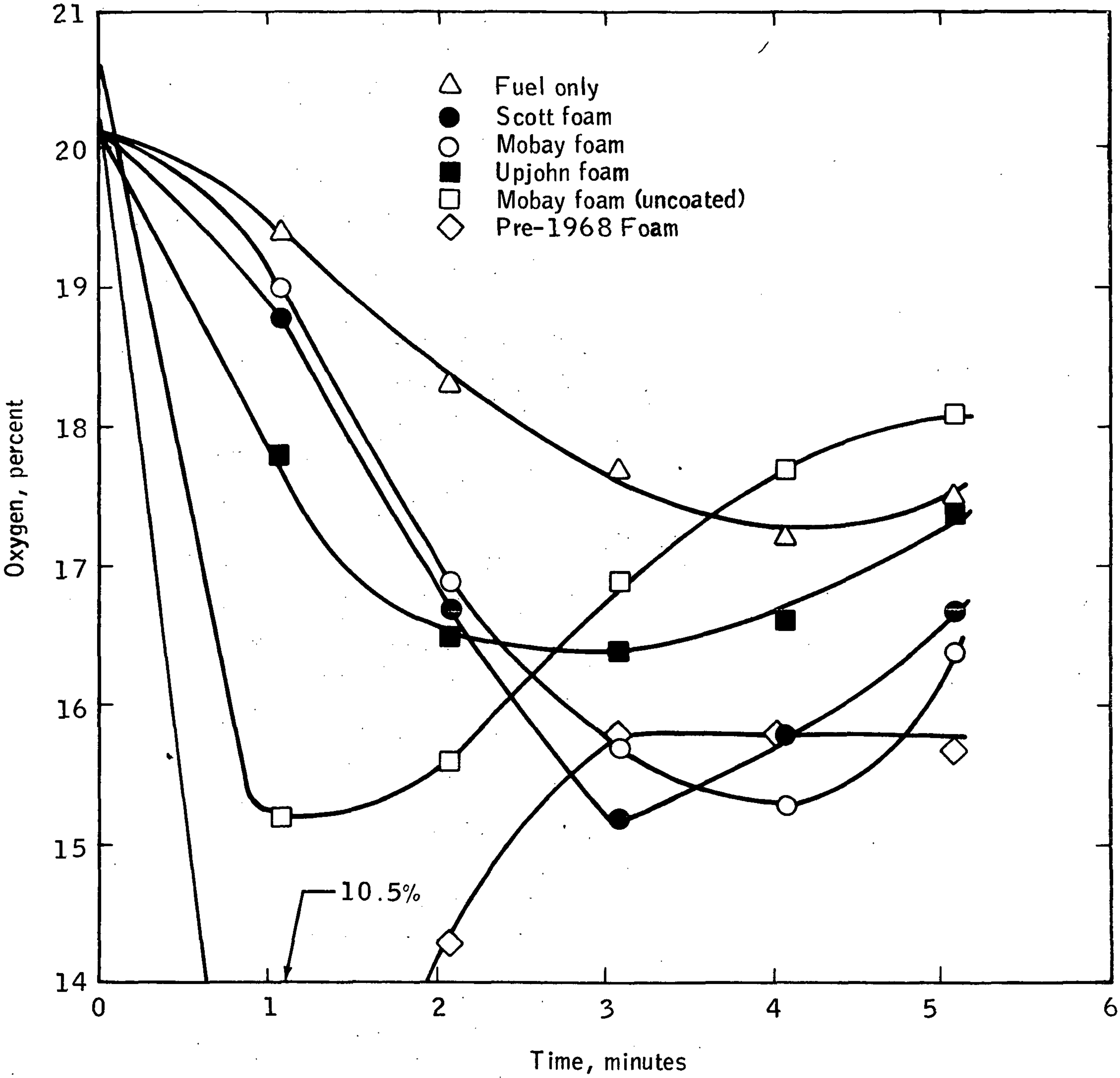

Figure 11.- Oxygen concentrations.

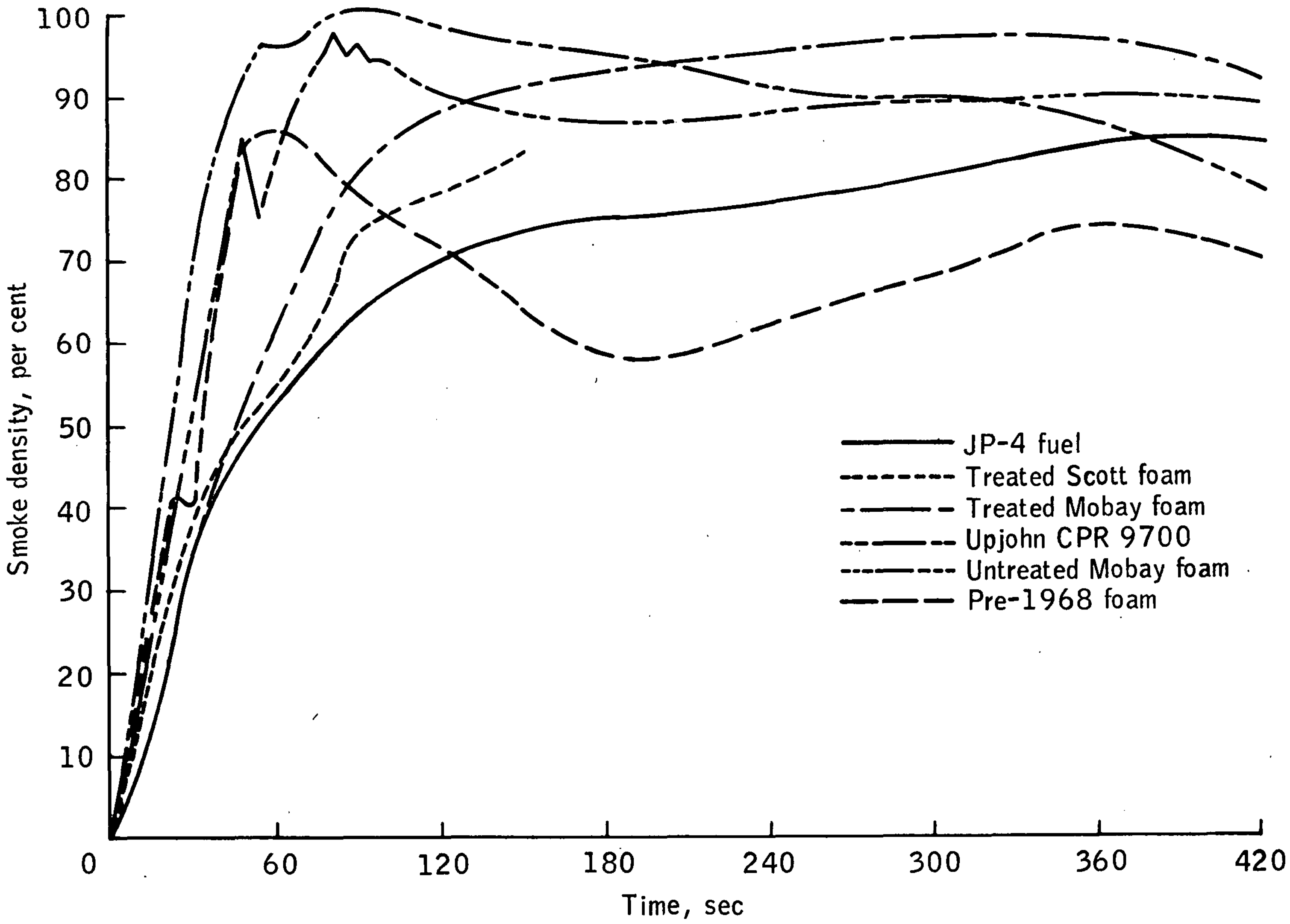

Figure 12. - Smoke density levels.