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Uranium Oxide—Iron Oxide Mixed Aerosol Experiments in Steam—Air Atmospheres: NSPP Tests 611, 612, 613, and 631, Data Record Report

M. L. Tobias
R. E. Adams

Prepared for the
U.S. Nuclear Regulatory Commission
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SUMMARY

This data record report summarizes the results from four tests in which the behavior of mixed aerosols of uranium oxide and iron oxide in steam-air atmospheres was studied. The tests were conducted in the Nuclear Safety Pilot Plant, which is part of the LWR Aerosol Release and Transport Program at the Oak Ridge National Laboratory. This research is sponsored by the Division of Reactor System Safety, Office of Nuclear Regulatory Research, U.S. Nuclear Regulatory Commission and the purpose is to provide a data base on the behavior of aerosols in containment under conditions assumed to occur in postulated LWR accident sequences. These data are to provide experimental validation of aerosol behavioral codes under development elsewhere.

In three of the tests described, the test aerosols were generated and introduced into a quasi-steady-state steam-air environment. The fourth test was in a dry air environment to provide data for comparison with the other experiments. The primary experimental observation was aerosol mass concentration as a function of time. Maximum solid aerosol mass concentrations in these four tests ranged from 0.82 to 2.9 g/m^3.

The data contained in this report should be utilized in preference to data contained in previous progress reports of the program. In particular, the aerosol mass concentration data contained in this report have been revised and are lower than those reported previously as the result of the correction of an error made in the method of calculating aerosol sample volumes.

In this report, a brief description is given of each test together with the results in the form of tables and graphs. Included are data on aerosol mass concentration, aerosol fallout and plateout rates, total mass fallout and plateout, aerosol particle size, vessel atmosphere pressure, vessel atmosphere temperatures at various locations, temperature gradients near the vessel wall, and steam condensation rates on the vessel wall.

URANIUM OXIDE—IRON OXIDE MIXED AEROSOL EXPERIMENTS IN STEAM—AIR ATMOSPHERES: NSPP TESTS 611, 612, 613, AND 631, DATA RECORD REPORT

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ABSTRACT

This data record report summarizes the results from three tests involving mixed aerosols of uranium oxide and iron oxide in a steam-air environment and one test in a dry environment. This research, sponsored by the U.S. Nuclear Regulatory Commission, was conducted in the Nuclear Safety Pilot Plant at the Oak Ridge National Laboratory. The purpose of this project is to provide a data base on the behavior of aerosols in containment under conditions assumed to occur in postulated LWR accident sequences; this data base will provide experimental validation of aerosol behavioral codes under development. In the report, a brief description is given of each test together with the results in the form of tables and graphs. Included are data on aerosol mass concentration, aerosol fallout and plateout rates, total mass fallout and plateout, aerosol particle size, vessel atmosphere pressure, vessel atmosphere temperatures, temperature gradients near the vessel wall, and steam condensation rates on the vessel wall.

1. INTRODUCTION

The Nuclear Safety Pilot Plant (NSPP) project is part of the LWR Aerosol Release and Transport (ART) Program at the Oak Ridge National Laboratory, sponsored by the Division of Reactor System Safety, Office of Nuclear Regulatory Research, U.S. Nuclear Regulatory Commission. The purpose of the project is to provide a data base on the behavior of aerosols in containment under conditions assumed to occur in postulated LWR accident sequences. These data are intended to provide experimental validation of aerosol behavior codes under development elsewhere.

The test program provided for the study of the behavior, within containment, of simulated LWR accident aerosols emanating from fuel, reactor core structural materials, and from concrete-molten core materials interactions. Aerosols of U_3O_8 (fuel), Fe_2O_3 (core structure), and concrete were studied individually to establish the characteristics of their aerodynamic behavior. Various mixtures were then studied to establish their interactive and collective behavior. Tests were conducted in an environment of either dry air [relative humidity (RH) less than 20%] or steam-air [relative humidity (RH) ~100%] with aerosol mass concentration as a function of time being the primary observation. This report covers three tests in a steam-air environment and one test in a dry atmosphere with mixed aerosols of uranium oxide and iron oxide.

The data contained in this report should be utilized in preference to data contained in previous progress reports of the program. In particular, the aerosol mass concentration data contained herein have been revised and are lower in magnitude than those reported previously as the result of the correction of an error made in the method of calculating aerosol sample volumes.

2. NUCLEAR SAFETY PILOT PLANT (NSPP)

2.1 NSPP System

The NSPP is composed of a test vessel, aerosol generating equipment, analytical sampling equipment, and system parameter measuring equipment. A schematic representation of the system is given in Fig. 1. The NSPP vessel is a stainless steel cylinder with dished ends having a diameter of 3.05 m, a total height of 5.49 m, and a volume of 38.3 m^3. The wall thickness of the vessel is 9.53 mm, the floor area is 7.7 m^2, and the internal surface area (including top and floor) is 68.9 m^2. For calculation of fallout values, the total area of upward-facing horizontal surfaces is 10.3 m^2 and the total surface area for plateout within the vessel, including both vertical and horizontal internal structural surfaces, is 75.3 m^2. The vessel outer surface (with the exception of two 0.91 m diam flanges — one on the top and one on the sidewall of the vessel) is covered with insulation consisting of 13 mm of fiberglass and 76 mm of calcium silicate. The thermal conductivity values are 43.3 (at 294 K) and 60.6 (at 311 K) mW/(m K), respectively. The design temperature limitation is 423 K, and the design pressure limitation is 0.41 MPa gauge pressure.

Originally, aerosol studies in the NSPP were related to the behavior of Na_2O_x and U_3O_8 aerosols released under assumed LMFBR accident conditions into dry secondary containment. To enable aerosol tests to be conducted in steam-air environments, as would be expected to occur in LWR accident situations, certain modifications of and additions to the facility were required. These modifications were completed before conduct of the U_3O_8 aerosol tests, the Fe_2O_3 aerosol tests, and the limestone concrete aerosol tests, which were reported previously (1,2,3).

Most of the major components of the NSPP system were retained for application in the LWR aerosol studies. The only components removed were the sodium injection system and the sodium burn pan. The U_3O_8 aerosol generator, used previously, was retained. Steam is supplied to the NSPP by the ORNL plant supply system and is introduced into the vessel at a point ~0.6 m above the low point of the vessel floor. Instrumentation is included to measure the temperature and pressure of the steam at the steam injection nozzle.

In tests where steam injection continued over a number of hours, a significant amount of steam condensate was collected on the bottom of the vessel. The system has been arranged so that this condensate can be transferred from the vessel to the weighing tank without significant loss of vessel pressure.

A small fan was mounted near the bottom of the vessel to aid in uniformly dispersing the test aerosol in the vessel atmosphere.

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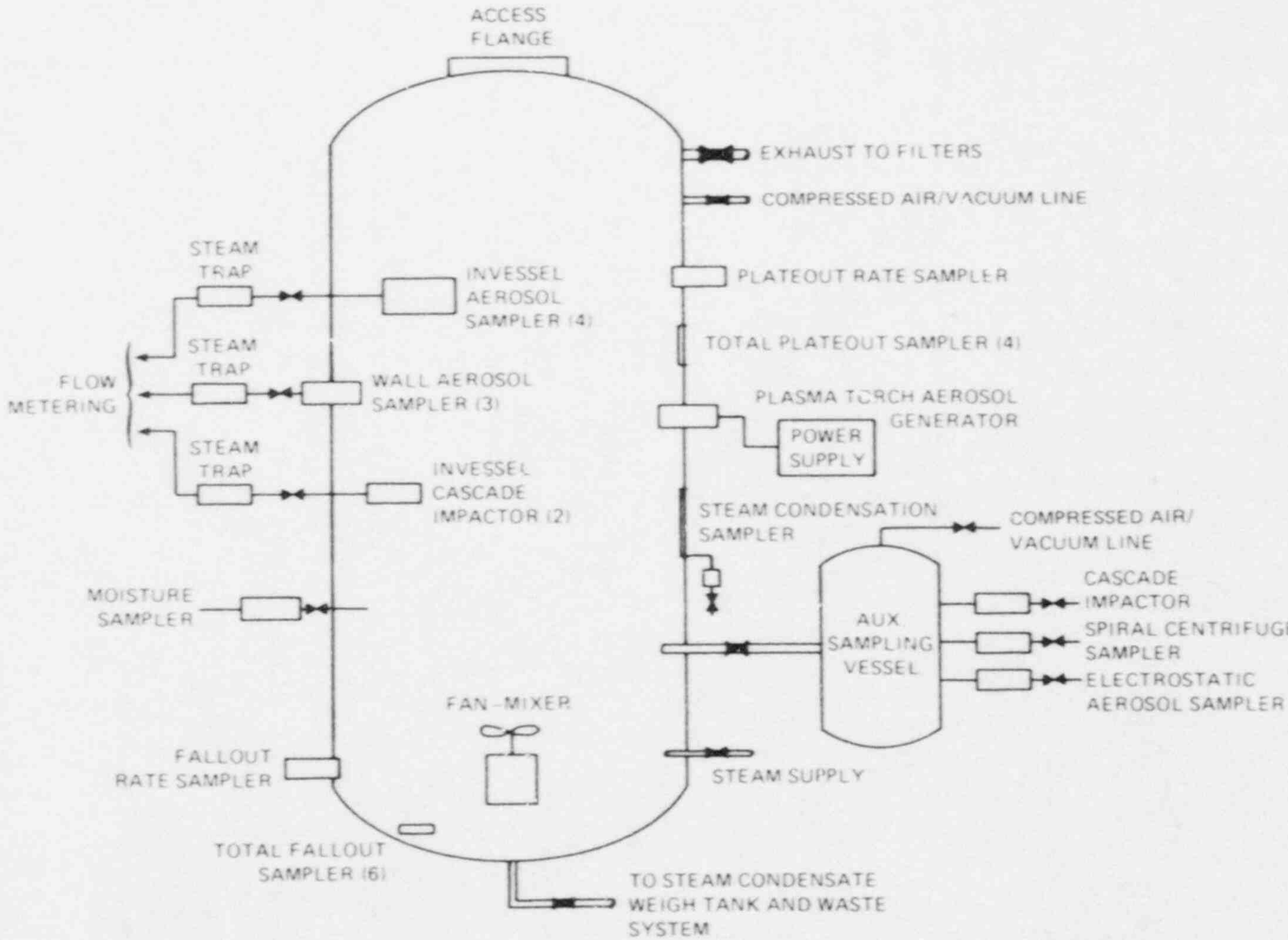

Fig. 1. Schematic of Nuclear Safety Pilot Plant (NSPP) Facility.

2.1.1 Equipment for measurement of aerosol parameters

All of the aerosol sampling systems in the NSPP were originally designed for operation in a low humidity environment. For successful application in a steam-air environment some modifications were required, either in the system or in the method of operation; the primary problem in all the samplers was control of the steam condensate.

Aerosol mass concentration. Aerosol mass concentrations are obtained with two types of filter samplers. The in-vessel sampler is a self-contained unit with 12 filter tubes, a sequential valve, and a stepping motor; it is remotely operated from the control room. The wall aerosol sampler penetrates the vessel wall through a ball valve and flange arrangement; it is inserted and retrieved manually. These systems were modified by the addition of water traps and water adsorption tubes to prevent moisture from reaching the pressure- and flow-measuring devices. In addition, to prevent steam from penetrating the in-vessel sampling canisters, an externally controlled, pressurized air system keeps the interior of the canisters at a pressure slightly higher than the vessel atmosphere so that any leakage is outward from the canister. This feature protects the contact points of the small stepping motor which are very susceptible to moisture.

The sampling procedure for either type of sampler requires drawing a measured volume of containment vessel atmosphere through a sampling pack that contains four membrane filters in series. All aerosol mass concentration values are reported under the test conditions that existed within the vessel at the time that the sample was taken. The filter material is Millipore Fluoropore with a 0.5 m-pore size.

The locations of the four in-vessel samplers and the three wall aerosol samplers are noted in Table 1.

Table 1. Locations of aerosol mass concentration samplers

Sampler name	Radial position	Elevation from lowest point (m)	Radial distance from centerline (m)
In-vessel 151	East	4.15	0.58
In-vessel 152	Southeast	4.15	1.06
In-vessel 153	East	2.80	1.09
In-vessel 154	Southeast	1.34	1.11
Wall 155	South	4.15	0.61
Wall 156	Southeast	2.80	(25 mm from wall)
Wall 157	Southwest	2.80	1.06

Aerosol fallout rate. Aerosol fallout rate is measured with an incremental, retrievable coupon sampler. This system also penetrates the vessel wall through a ball valve and flange arrangement. The sampler is located in the southwest quadrant at 51 mm from the vessel wall and is ~0.56 m above the low point of the vessel floor.

Aerosol plateout rate. Aerosol plateout rate is measured with an incremental, retrievable coupon sampler; the coupon is in the form of a disk and fits flush with the vessel wall. This system penetrates the vessel wall through a ball valve and flange arrangement and is located in the northeast quadrant ~2.92 m above the low point of the vessel floor.

Total fallout (TFO) collectors. Total fallout is determined with six shallow dishes, 65-mm in diameter, placed along a vessel radius near the bottom of the vessel within the northwest quadrant. The dishes are placed ~30 mm apart; the edge of the first dish (TFO-1) is 13 mm from the wall. The exposed collectors are retrieved with remote tools at the end of test operations and before liquid spray decontamination of the interior of the vessel.

Total plateout (TPO) collectors. Total plateout is determined with four flat disks, 61-mm diam, mounted flat on the vessel wall. One disk (TPO-BE) is mounted on the east side of the vessel at an elevation of 0.76 m from the low point of the vessel bottom. Two disks (TPO-BW and TPO-TW) are mounted on the west side of the vessel, 0.76 m and 2.67 m, respectively, from the bottom of the vessel. The remaining disk (TPO-TN) is mounted on the north side of the vessel 2.67 m from the bottom of the vessel. These plateout disks are also retrieved with remote tools along with the total fallout collectors.

Aerosol particle size. Aerodynamic aerosol particle size is measured with two different instruments. One instrument used was a cascade impactor (Andersen Mark III Particle Sizing Stack Sampler). This eight-stage impactor operates at a gas flow rate of 236 mL/s and covers the aerodynamic mass median diameter (AMMD) range from 0.54 to 13.6 μm. The other instrument used was a modified version of the Stöber Spiral Duct Centrifuge by Research Developments, Los Alamos, NM, and designated as a Spiral Centrifuge Aerosol Spectrometer (4,5). This instrument was applied at a rotor speed of 3000 rpm with a gas sample flow rate of 8.5×10^{-6} m^3/s; useful range in this application was 0.2 to 6 μm aerodynamic mass median diameter.

Neither instrument can tolerate condensation of a vapor during measurement of the aerosol size distribution. One method by which a gas-aerosol sample (containing water vapor) can be processed external to the vessel is to dilute and "dry" the aerosol sample with instrument air before introduction into the sizing instrument. A small auxiliary sampling vessel (0.18 m^3 in volume) was installed for this purpose next to the NSPP vessel at an elevation of 2.9 m. The external impactors and the centrifuge draw samples from this auxiliary tank.

It is recognized that the AMMD of the "dried" aerosol is not necessarily the same as that of the aerosol existing within the vessel during the test. Operation of a cascade impactor within a steam-air environment is not a standard application and calibration data are not available. However, to be able to pursue an approximate measurement of AMMD within the vessel, a calibration curve was calculated using accepted mathematical relationships relating to impactor stage constants with corrections made for viscosity and slip factors (6). Gas flow rates were chosen so that the velocity of gas through the holes of the impactor plates of the internal impactors under test conditions would be approximately the same as that of the external impactors.

Two impactors were mounted within the vessel at elevations of 0.56 m (southwest quadrant) and 2.8 m (southeast quadrant). The impactors were installed before the start of the test and allowed to heat up and thermally equilibrate as the vessel was heated during the preliminary steam injection period.

Samples of aerosol for electron microscopy are also taken from the auxiliary sampling vessel. The aerosol is deposited onto carbon-coated copper grids using a Model 3100 Electrostatic Aerosol Sampler (Thermo-System, Inc.).

2.1.2 Equipment for measurement of system parameters

Temperature of the vessel atmosphere. Twelve thermocouples (3.2-mm-diam sheathed Chromel-Alumel) are used for the measurement of the vessel atmospheric temperatures. At each of three elevations in the vessel, there are four thermocouples (one placed in each quadrant). The elevations are 1.22 m, 2.74 m, and 4.27 m. Table 2 identifies and locates each thermocouple. Thermocouple responses are recorded with strip-chart recorders and with a Digitrend data logger.

Wall temperature gradients. Two thermocouple arrays, each having five thermocouples (1.6-mm-diam sheathed Chromel-Alumel) are mounted near the wall, one at 2.7 m elevation on the east radius and the other at 1.2 m elevation on the north radius. The tips of the thermocouples in each array are located at 10 mm, 5 mm, 2.5 mm, and 1.25 mm distance

Table 2. Location of thermocouples for measurement of temperature of vessel atmosphere

Thermocouple No.	Elevation (m)	Quadrant	Radial distance (m)
4-1	4.27	N	0.48
4-2	4.27	W	1.07
4-3	2.74	N	0.48
4-4	2.74	S	0.97
4-5	2.74	W	1.22
4-6	1.22	W	1.07
4-7	4.27	S	0.97
4-20	1.22	S	0.61
4-21	4.27	E	0.48
4-22	1.22	E	0.81
4-23	2.74	E	0.99
4-24	1.22	N	1.37

from the wall and on the wall surface; a sixth thermocouple is located on the outer surface of the vessel at approximately the same location. Thermocouple responses are recorded with strip-chart recorders and with the Digitrend data logger.

Vessel gas pressure. Vessel gas pressure is measured with a pressure cell, and the pneumatic signal is converted to an equivalent electrical signal and recorded on a strip-chart recorder and with the Digitrend data logger.

Vessel atmosphere moisture sampler. The mass of steam per unit volume within the vessel was determined by removing a measured volume of gas through a treatment train where the steam was condensed and trapped in an absorbent column. The mass of steam was then determined by weighing.

This system produced rather imprecise data with a large spread in calculated values of relative humidity. Values for the various tests ranged in a random fashion from around 90% to about 110%. For this reason the values are not included in this report.

Steam condensation rate samples. The rate at which steam condensed on the vessel walls was measured by defining an area of the wall with perimeter seals. After steam condensed on this defined area the water flowed downward until it reached a funneling trough at the lower edge where it drained into a collecting tank outside the test vessel for subsequent volume measurement. The defined area was hexagonal in shape, covered 0.324 m^2, and was located at an approximate elevation of 2.7 m.

2.1.3 Aerosol generating equipment

The mixture of test aerosols was generated using two plasma torch (PT) generators (7). Each consists of a commercial plasma metalizing torch assembly (METCO 7M System) and a special high-temperature reaction chamber into which the iron or uranium metal powder was injected together with argon and oxygen gases. Each of the test aerosols was formed by vaporization and oxidation of the powder in the argon plasma flame. Introduction of the Fe_2O_3 aerosol was by way of a flange on top of the vessel. The U_3O_8 aerosol was introduced by way of a flange on the side of the vessel (see Fig. 1).

2.2 NSPP LWR Aerosol Test Procedures

Experiments 611, 612, and 613 were in a steam-air environment and experiment 631 was performed in dry air (RH <20%) at ambient conditions. The basic steps in the steam-air aerosol tests were essentially the same. The vessel initially contained air significantly below ambient pressure. The vessel, and the captive air atmosphere, were heated by injecting steam into the vessel; after about 1 h the temperature of the vessel atmosphere reached the desired value. At this point the rate of steam injection was reduced to a level to match steam losses to the vessel wall. After a period of temperature equilibration, the steam condensate (produced during vessel heatup) was drained from the vessel and moved to the weigh tank. Aerosol generation commenced after this point with introduction into the semi-steady-state steam-air environment for a brief period. The two torches were started separately and operating times were generally different. A small fan-mixer located near the bottom of the vessel was employed to augment thermal convection forces and aid in mixing. Steam injection at the low rate continued for 6 h after start of aerosol generation in these three tests. Total test duration was 24 h in all cases. The small fan-mixer operated for the first 10 h of each test.

At termination of test operations the steam condensate was removed from the vessel, weighed and transferred to the liquid waste system. The vessel was then opened and the various samplers were removed; decontamination of the vessel interior by liquid sprays completed the test procedures.

Test 631 was conducted to obtain data on the behavior of mixed aerosols under dry conditions for use in estimating the extent of influence of steam on the aerosol behavior. All steps, with the exception of steam injection, were the same as for the steam-air tests.

All of the sampling devices (filter packs, impactors, coupons, etc.) were disassembled, packaged, and submitted to the ORNL analytical laboratory for determination of the aerosol content. The physical characteristics of the aerosol were studied by use of electron microscopy.

3. DESCRIPTION OF INDIVIDUAL AEROSOL TESTS

3.1 LWR Aerosol Test 611

Experiment 611 was the first test involving a mixed aerosol of Fe_2O_3 and U_3O_8. To prepare the test atmosphere, steam was introduced into the vessel, which was initially at 36 kPa,* to bring the vessel atmosphere (air) to an average temperature of 382 K and a pressure of 183 kPa. This step required about 1.3 h; at this point, the rate of steam injection was reduced, and the accumulated steam condensate was removed to a holding vessel. The two aerosols were then produced with separate PT generators and mixed within the vessel. The Fe_2O_3 aerosol was generated for a period of 11.5 min starting at time 0; the U_3O_8 aerosol generator was operated for a period of 8 min starting at an elapsed time of 2 min, and ending at 10 min, but it appears that all of the uranium metal powder was probably injected into the generator over the first 4 min of operation. Steam injection at the low rate was maintained for ~6 h to balance steam losses caused by wall condensation. Over this period, the temperature and pressure slowly increased until, at 6 h, the average temperature was 383 K and the pressure was 203 kPa. The vessel was allowed to cool for 18 h after termination of the steam injection.

The two aerosols were injected into the vessel in the upper quadrant at two different locations, and the steam was introduced near the bottom of the vessel. To facilitate mixing, a small fan-mixer was operated in the center of the vessel near the bottom. This fan-mixer produced a fairly homogeneous mixture of aerosol and steam as indicated by results from the four in-vessel filter samplers installed at four different locations within the vessel.

The first set of aerosol mass concentration samples was taken at 4 min after termination of Fe_2O_3 aerosol generation. At this time the average mass concentrations of Fe_2O_3 and U_3O_8 aerosol were 0.88 and 0.55 g/m^3, respectively. Extrapolation of these data to the time of Fe_2O_3 aerosol generation cutoff (11.5 min) yields values of 1.4 and 0.9 g/m^3 for Fe_2O_3 and U_3O_8 aerosol, respectively. These ratios of Fe_2O_3 and U_3O_8 are about 1.6, satisfactorily close to a desired equal concentration ratio.

The aerodynamic mass median diameter (AMMD) of the aerosol was measured by both the spiral centrifuge sampler and the cascade impactor (Andersen Mark III). The "wet" aerosol was dried by dilution with clean air before introduction into the samplers. At 18 min after termination of the Fe_2O_3 aerosol generation, an AMMD of about 1 μm (standard deviation, σ_g = 1.5) for the mixed aerosol was determined by the centrifuge sampler; at 38.7 min, an impactor sample indicated an AMMD of 1.7 μm (σ_g = 1.9) for the aerosol mixture. Determination of the AMMD by using

*Unless otherwise specified, all pressures cited are absolute.

only the Fe_2O_3 mass fraction or the U_3O_8 mass fraction yielded equivalent values to those determined using the total mass of aerosol; this behavior suggests that the two aerosols may be coagglomerating. The rate of disappearance of the two aerosols from the vessel atmosphere was about the same, also suggesting coagglomeration (8).

At the termination of the test (24 h), the approximate distribution of the mixed aerosol (Fe_2O_3 + U_3O_8), as determined by the total fallout samplers, the total plateout samplers, and the final filter samples, was as follows: aerosol settled onto the floor of vessel, 83%; aerosol plated onto internal surfaces, 17%; and aerosol still suspended in the vessel atmosphere, nil.

3.2 LWR Aerosol Experiment 612

Experiment 612 was the second test involving a mixed aerosol of Fe_2O_3 and U_3O_8. To prepare the test atmosphere, steam was introduced into the vessel, which was initially at 36 kPa, to bring the vessel atmosphere (air) to an average temperature of 385 K and a pressure of 218 kPa. This step required about 1.3 h; at this point the rate of steam injection was reduced, and the accumulated steam condensate was removed to a holding vessel. As before, the two aerosols were produced with separate plasma torch aerosol generators and mixed within the vessel. The Fe_2O_3 aerosol was generated for a period of 25.5 min starting at time 0; the U_3O_8 aerosol generator was started at an elapsed time of 20 min and operated for 5 min, ending at an elapsed time of 25 min. Steam injection at the low level was maintained for 6 h to balance steam losses to vessel walls. Over this period, the temperature and pressure increased until, at 6 h, the average temperature was 388 K and the pressure was 234 kPa. The vessel was allowed to cool for 18 h after termination of steam injection.

The two aerosols and the steam were fairly well mixed by the fan-mixer as indicated by results for U_3O_8 aerosol from the four in-vessel filter samplers installed at four different locations within the vessel (8).

The first set of aerosol mass concentration samples was taken at 2.8 min after termination of Fe_2O_3 aerosol generation. At this time the average mass concentrations of Fe_2O_3 and U_3O_8 were 0.14 and 0.41 g/m^3, respectively. Extrapolation of these data to the time of Fe_2O_3 aerosol generator cutoff (25.5 min) yields values of 0.22 and 0.6 g/m^3 for Fe_2O_3 and U_3O_8 aerosol, respectively. These ratios of Fe_2O_3 to U_3O_8 are about 0.3 to 1; similar ratios for Run 611 were about 1.6 to 1. The rate of disappearance of the two aerosol components from the vessel atmosphere is approximately the same, suggesting that the two aerosol components were coagglomerated.

The AMMD of the aerosol was measured by a cascade impactor (Andersen Mark III). Other samples of the aerosol were taken with the spiral centrifuge sampler, but insufficient material was obtained for chemical analysis. The wet aerosol was dried by dilution with clean air before introduction to the cascade impactor. At 4.5 min after termination of the Fe_2O_3 aerosol generator, an AMMD of about 1.5μm (σ_g = 2.1) was determined for the mixed aerosol. Determination of the AMMD by using only the Fe_2O_3 mass fraction produced a value of 1.2 μm (σ_g = 2.3); by using the U_3O_8 mass fraction, an AMMD of 1.8 μm (σ_g = 1.9) was obtained. This similarity in the AMMD's and σ_g's provides some support for the observation that the two aerosols are possibly coagglomerated.

At the termination of the test (24 h), the approximate distribution of the mixed aerosol (Fe_2O_3 + U_3O_8), as determined by the total fallout samplers, the total plateout samplers, and the final filter samples, was as follows: aerosol settled onto the floor of the vessel, 76%; aerosol plated onto internal surfaces, 24%; and aerosol still suspended in the vessel atmosphere, nil.

3.3 LWR Aerosol Experiment 613

Experiment 613 was the third in a series involving a mixed aerosol of Fe_2O_3 and U_3O_8. To prepare the test atmosphere, steam was introduced into the vessel, which was initially at 37 kPa and ambient temperature, to bring the vessel atmosphere (air) to an average temperature of 381 K and an absolute pressure of 178 kPa. This heating step required about 1.2 h; at this point, the rate of steam injection was reduced and the accumulated steam condensate in the bottom of the NSPP vessel was removed to a holding vessel. The two test aerosols were then produced with separate plasma torch aerosol generators and mixed within the vessel. Fe_2O_3 aerosol was generated for a period of 26 min starting at time 0; the U_3O_8 aerosol generator was operated for 3 min starting at 13 min and ending at 16 min (measured from time 0). Steam injection at the low rate was maintained for ~6 h to balance steam losses at the vessel wall. Over this period, the temperature and pressure slowly increased until, at 6 h, the average temperature was 386 K and the pressure was 220 kPa. The vessel was allowed to cool for 18 h after termination of steam injection.

The two aerosols were injected into the vessel in the upper quadrant at two different locations, and the steam was introduced near the bottom of the vessel. To facilitate mixing of the two aerosols and the steam, a small fan-mixer was installed in the center of the vessel near the bottom. Operation of the fan-mixer produced a fairly homogeneous mixture of aerosol and steam as indicated by the results for Fe_2O_3 aerosol from the four in-vessel filter samplers installed at four different locations within the vessel (9).

The first set of aerosol mass concentration samples was taken at 24 min (2 min before termination of aerosol generation), and the aerosol mass concentration values were scattered indicating nonhomogeneous conditions. The second set of samples was taken at 34.4 min (8.4 min after termination of aerosol generation), and the values were comparable, indicating more complete mixing of the aerosol within the vessel. At this time, the average mass concentrations of Fe_2O_3 and U_3O_8 aerosol were 0.58 and 0.072 g/m^3, respectively. Extrapolation of these data to the time of Fe_2O_3 aerosol generator cutoff (26 min) yields values of 0.80 and 0.13 g/m^3 for Fe_2O_3 and U_3O_8 aerosol, respectively. The ratio of Fe_2O_3 to U_3O_8 was, therefore, 6.2 to 1, which is reasonably close to the target ratio of 10 to 1. The rate of disappearance of the two aerosols from the vessel environment was approximately the same, suggesting that the two aerosols were coagglomerated (9).

The aerodynamic mass median diameter (AMMD) of the aerosol was measured by both the spiral centrifuge sampler and the cascade impactor (Andersen Mark III). The "wet" aerosol was dried by dilution with clean air before introduction into the samplers. At 29.3 min after start of Fe_2O_3 aerosol generation, an AMMD of about 1.7 μm (σ_g = 1.7) for the mixed aerosol was determined by the spiral centrifuge sampler; at 138 min, an impactor sample indicated an AMMD of 1.0 μm (σ_g = 2.1) for the aerosol mixture. Determination of the AMMD by using only the Fe_2O_3 mass fraction or the U_3O_8 mass fraction yielded nearly equivalent values for the AMMD in the previous two mixed aerosol experiments (Nos. 611 and 612). The same behavior was true in this experiment for the early centrifuge sample; in the later impactor sample, the U_3O_8 mass fraction produced an AMMD of 1.1 μm (σ_g = 3.3), however. In this later sample (138 min), the mass of sample taken was low, and this could account for the large difference in the value of σ_g. On the whole, the sizing data suggest coagglomeration of the two aerosols.

At the termination of the experiment (24 h), the approximate distribution of the mixed aerosol (Fe_2O_3 + U_3O_8), as determined by the total fallout samplers, the total plateout samplers, and the final filter samples was as follows: aerosol settled onto floor of vessel, 65%; aerosol plated onto internal surfaces, 35%; and aerosol still suspended in the vessel atmosphere, nil.

3.4 LWR Aerosol Experiment 631

This experiment involved study of the behavior of U_3O_8 and Fe_2O_3 mixed aerosol in a dry air environment. Results from this test serve to illustrate the magnitude of the influence of steam on mixed aerosol behavior as studied in Tests 611, 612, and 613.

The two aerosols were generated simultaneously with separate PT aerosol generators and mixed within the vessel. The initial test atmosphere was dry air at ambient temperature and pressure; the relative humidity was <20%. Fe_2O_3 aerosol was generated for a period of 16.2 min starting at time 0; the U_3O_8 aerosol was generated for a period of 4.3 min starting at elapsed time 11 min and ending at 15.3 min.

Although this experiment did not involve steam, the small fan-mixer was operated in the same manner as in Tests 611–613 to promote mixing of the two aerosols. The mixing was fairly complete as indicated by the results for the U_3O_8 aerosol component from three of the four in-vessel filter samplers; sampler 152 did not operate satisfactorily after the first sample was taken.

The first set of aerosol mass concentration samples was taken at 22.3 min (~6 min after termination of Fe_2O_3 aerosol generation). At this time, the average mass concentrations of Fe_2O_3 and U_3O_8 were 0.87 and 1.17 g/m^3, respectively. Extrapolation of these data to the time of Fe_2O_3 aerosol generator cutoff (16.2 min) yields values of 1.2 and 1.7 g/m^3 for Fe_2O_3 and U_3O_8 aerosol, respectively. The rate of disappearance of the two aerosols from the vessel environment was approximately the same, suggesting that the two aerosols were coagglomerated.

The aerodynamic mass median diameter (AMMD) of the aerosol was measured by both the spiral centrifuge sampler and the cascade impactor (Andersen Mark III). Although the vessel did not contain steam, sampling procedures identical to those used in steam, were followed. Six samples as a function of elapsed time were taken for size analysis: four were taken from the auxiliary sampling tank external to the NSPP vessel, and two were taken inside the NSPP vessel. Determination of the AMMD was made in three ways, one using the U_3O_8 fractional mass, one using the Fe_2O_3 fractional mass, and one using the total aerosol mass, $Fe_2O_3 + U_3O_8$. For the most part, equivalent values were calculated, lending support to the contention that the two aerosols were coagglomerated (9).

At the termination of the experiment (24 h), the approximate distribution of the mixed aerosol ($Fe_2O_3 + U_3O_8$), as determined by the total fallout samplers, the total plateout samplers, and the final filter samples was as follows: aerosol settled onto the floor of the vessel, 52%; aerosol plated onto internal surfaces, 48%; and aerosol still suspended in the vessel atmosphere, nil.

4. RESULTS FROM INDIVIDUAL AEROSOL TESTS

The results from each test are summarized in this section in the form of tables and graphs. At the beginning of each subsection a summary sheet is presented listing information on aerosol source, vessel test atmosphere, aerosol parameters and system parameters for each test. Following this summary sheet are graphs and tables reporting aerosol mass concentrations, fallout and plateout rates, total fallout and plateout masses, aerosol particle sizes, absolute vessel pressure, vessel atmosphere temperatures, temperature gradients near the vessel wall, and steam condensation rates on the vessel walls. Time is measured from start of aerosol generation. To aid in the interpretation of these graphs and tables, the following comments are offered.

Mass concentration. Results from the seven mass concentration filter samplers are presented in two forms; a table lists the values obtained from each individual sampler, and a graph presents the numerical average value obtained by computation from the values from individual samplers operated at the same time period. Values of mass concentrations are for the Fe_2O_3 aerosol component and the U_3O_8 aerosol component within the vessel atmosphere computed under vessel atmospheric conditions existing at the time of the sample. The location of each sampler may be found in Table 1.

Aerosol fallout and plateout rates; cumulative values for fallout and plateout mass. The data reported in these tables were obtained from the coupon samplers. An average fallout or plateout rate was computed from the mass of aerosol deposited on the coupon over the time interval of exposure. The average elapsed time from the start of aerosol generation is taken as one-half of the time interval of exposure added to the elapsed time at the start of the coupon exposure.

Values for cumulative mass fallout or plateout were computed by summing the values obtained by multiplying the fallout and plateout rate by the appropriate time period for exposure of the coupon and the appropriate area within the vessel.

Total aerosol fallout and plateout. Fallout cups placed near the bottom of the vessel and plateout coupons mounted on the vessel wall were exposed over the full term of each experiment. The mass of aerosol collected by these samplers is used to estimate the total fallout and plateout of aerosol within the vessel. Values determined in this manner should be comparable with the total values computed from results obtained from the rate samplers, but this is not true in every case. Difficulty in obtaining representative samples may be the cause of these inconsistent data.

Aerosol particle size. The data presented were derived with an Andersen Mark III Particle Sizing Stack Sampler (cascade impactor) and a Spiral Centrifuge Aerosol Spectrometer. The raw data were processed to the extent necessary to produce the tables in this report. An aerodynamic mass median diameter (AMMD) may be determined by plotting on log probability paper the "percent smaller than" values against the calibrated aerodynamic diameter value for each stage and reading the AMMD value at 50%.

Vessel atmosphere pressure. For all tests, the vessel initially contained a captive volume of air at ambient pressure, or below. The increase in vessel pressure resulted from the steam injection and the hot gases introduced by the plasma torch aerosol generator. The graph depicts the absolute pressure as a function of time after start of aerosol generation.

Vessel atmosphere temperatures. Three graphs are presented displaying the temperatures within each of the four quadrants at three elevations. The elevations are 1.22 m, 2.74 m, and 4.27 m from the low point on the vessel floor; radial distance of each thermocouple from the vessel centerline is given on each graph. Some of the thermocouples at the 4.27 m level can sense the heat of the plasma torch generator and may temporarily indicate a temperature higher than others at this level during aerosol generation.

Temperature profile near vessel wall. Two tables are presented indicating the temperature profiles near the vessel wall on the north radius at an elevation of 1.22 m and on the east radius at an elevation of 2.74 m. One thermocouple is attached to the inner wall surface and five others are located at varying distances from the vessel wall. Sets of data are listed for various times after start of aerosol generation.

4.1 Summary and Data Listings for Test 611

Aerosol source

Mass of uranium metal powder into generator	0.2 kg
Mass of iron metal powder into generator	0.5 kg
Duration of aerosol generation	11.5 min
Maximum measured Fe_2O_3 aerosol concentration (at 4 min after end of aerosol generation)	0.88 g/m^3
Maximum measured U_3O_8 aerosol concentration (at 4 min after end of aerosol generation)	0.55 g/m^3
Estimated average Fe_2O_3 aerosol concentration at end of aerosol generation (under test conditions)	1.4 g/m^3
Estimated average U_3O_8 aerosol concentration at end of aerosol generation (under test conditions)	0.9 g/m^3

Vessel atmosphere

Vessel air pressure before steam injection	36 kPa
Relative humidity at start of aerosol generation	~100%
Duration of steam injection after start of aerosol generation	6 h
Mass of steam condensate collected after start of aerosol generation	237 kg

Aerosol parameters measured

Aerosol mass concentration (average)	Fig. 2
Aerosol mass concentration (individual samplers)	Tables 3-4

Aerosol fallout and plateout rates; cumulative fallout and plateout mass	Table 5
Aerosol integral fallout and plateout mass	Table 6
Andersen impactor data	Tables 7-8
Spiral centrifuge aerosol sample data	Table 9

System parameters measured

Vessel atmosphere pressure	Fig. 3
Vessel atmosphere temperature	Figs. 4-6
Temperature gradient near wall	Tables 10-11
Steam condensation rate	Table 12

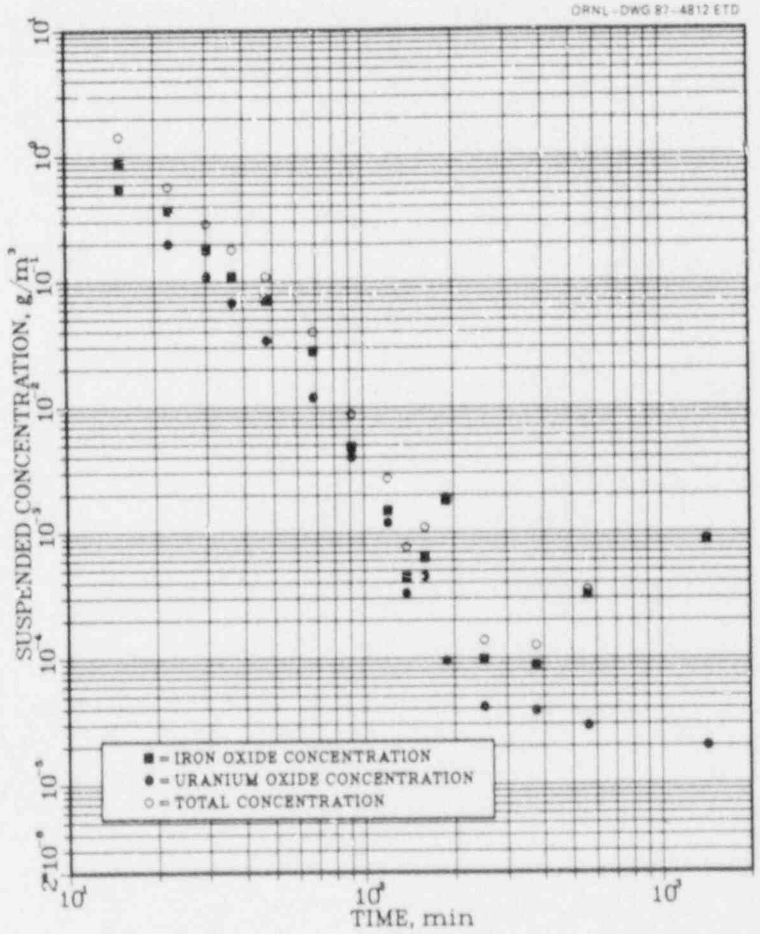

Fig. 2. Average aerosol mass concentration — NSPP Test 611.

Table 3. Aerosol mass concentration as determined with individual in-vessel samplers - Test 611

Sampler — Sampler No.	Time[a] (min)	Mass[b] concentration, Fe_2O_3 (g/m^3)	Mass[b] concentration, U_3O_8 (g/m^3)
151-1	14.1	1.14	0.51
152-1	14.4	1.17	0.60
153-1	16.3	0.53	0.43
154-1	16.5	0.68	0.64
151-2	21.0	0.49	0.25
152-2	21.3	0.37	0.13
153-2	23.2	0.35	0.24
154-2	23.5	0.28	0.16
151-3	28.9	0.24	0.13
152-3	29.2	0.17	0.13
153-3	30.9	0.18	0.083
154-3	31.2	0.14	0.086
151-4	36.4	0.10	0.070
152-4	36.6	0.12	0.078
153-4	36.8	0.11	0.060
154-4	37.1	0.097	0.064
151-5	47.1	0.051	0.039
152-5	47.4	0.049	0.037
153-5	47.7	0.041	0.029
154-5	47.9	0.044	0.030
151-6	67.9	0.065	0.081[c]
152-6	68.2	0.013	0.013
153-6	68.4	0.013	0.0091
154-6	68.7	0.021	0.014
151-7	90.7	0.0062	0.0059
152-7	91.0	0.0021	0.0030
153-7	91.3	0.0042	0.0030
154-7	91.5	0.0065	0.0040
151-8	119.5	0.0011	0.0017
152-8	119.7	0.00066	0.0010
153-8	119.9	0.0017	0.0013
154-8	120.1	0.0024	0.00091
151-9	159.4	0.00028	0.00079
152-9	--	--	--
153-9	159.9	0.00031	0.00030
154-9	160.2	0.0013	0.00030

[a]Time measured from start of aerosol generation.

[b]Aerosol mass concentration in the vessel under test conditions that existed at time the sample was taken.

[c]Doubtful value omitted from calculation of average concentration.

Table 4. Aerosol mass concentration as determined with individual wall filter samplers - Test 611

Sampler — Sampler No.	Time[a] (min)	Mass concentration,[b] Fe_2O_3 ($\mu g/m^3$)	Mass concentration,[b] U_3O_8 ($\mu g/m^3$)
155-1	138.1	190[c]	610[c]
156-1	138.1	380	220
157-1	138.6	760	170
155-2	188.1	2400[d]	150
156-2	188.4	--	70
157-2	188.8	1100	64
155-3	250.1	25	--
156-3	250.3	--	42
157-3	250.8	170	39
155-4	376.0	120	--
156-4	376.0	110	41
157-4	376.0	32	28
155-5	561.0	--	30
156-5	561.0	320	28
157-5	561.0	--	29
155-6	1413.0	1300[d]	23
156-6	1426.0	--	21
157-6	1426.0	410	15

[a]Time measured from start of aerosol generation.

[b]Aerosol mass concentration in the vessel under test conditions that existed at time the sample was taken.

[c]Note units. These entries are 0.00019 g/m^3 and 0.00061 g/m^3, respectively.

[d]Doubtful value omitted from calculation of average concentration

Table 5. Fallout and plateout data for aerosol components; rate and cumulative mass vs time — NSPP Test 611

Sampler name	Midpoint of sampling time[a] (s)	Duration of sample[a] (s)	Fallout, Fe_2O_3 Rate [μg/(m^2·s)]	Fallout, Fe_2O_3 Cumulative (g)	Plateout, Fe_2O_3 Rate [μg/(m^2·s)]	Plateout, Fe_2O_3 Cumulative (g)	Fallout, U_3O_8 Rate [μg/(m^2·s)]	Fallout, U_3O_8 Cumulative (g)	Plateout, U_3O_8 Rate [μg/(m^2·s)]	Plateout, U_3O_8 Cumulative (g)
FO-1	1,033	2,065	347.6	5.2			177.6	2.7		
PO-1	820	1,640			628.7	71.0			712.9	80.6
FO-2	3,057	1,496	128.7	6.6			59.8	3.4		
PO-2	2,612	1,537			136.1	85.4			20.9	82.8
FO-3	4,960	1,848	25.6	6.9			67.2	4.3		
PO-3	4,545	1,896			52.8	92.3			3.5	83.3
FO-4	8,024	3,842	8.67	7.1			4.5	4.4		
PO-4	7,620	3,897			35.3	101.8			1.1	83.6
FO-5	12,697	5,118	6.51	7.3			3.1	4.5		
PO-5	12,308	5,088			123.4	145.1			0.35	83.7
FO-6	25,034	19,116	0.85	7.4			0.52	4.6		
PO-6	24,629	19,228			14.0	163.6			0.17	83.9
FO-7	60,642	51,545	0.10	7.4			0.26	4.7		
PO-7	60,156	51,469			2.15	171.2			0.03	84.0

[a]Uncertainty in sampling times, ~5 s.

Table 6. Aerosol fallout and plateout data: integral samples — NSPP Test 611

Fallout			Plateout		
Sampler name	Sample mass, Fe_2O_3 (mg)	Sample mass, U_3O_8 (mg)	Sampler name	Sample mass, Fe_2O_3 (mg)	Sample mass, U_3O_8 (mg)
TFO-1	37.18	33.01	FPO-BW	0.26	1.23
TFO-2	25.74	31.83	TPO-BE	0.14	1.00
TFO-3	31.46	36.55	TPO-TW	0.13	1.20
TFO-4	28.60	36.55	TPO-TN	0.12	1.19
TFO-5	47.19	--			
TFO-6	34.32	36.55			
Average	34.08	34.90	Average	0.16	1.16
Estimated[a] total fallout	74.7 g	76.5 g	Estimated[a] total plateout	3.9 g	27.9 g

[a]Calculated from vessel-to-sample area ratios.

Table 7. Internal Andersen impactor data — Test 611

Sample No.	Component	Time (min)	Percent of total sampled aerosol mass made up of particles smaller than the aerodynamic diameter listed							
			Aerodynamic diameter (μm)							
			14.2	8.9	6.0	4.1	2.6	1.3	0.82	0.61
1[a]	Fe_2O_3	45.3	94.7	90.5	82.8	71.3	53.7	20.7	5.8	1.2
1	U_3O_8	45.3	97.8	95.2	88.6	83.4	70.8	26.1	8.2	2.1
1	Total	45.3	96.2	92.9	85.7	77.3	62.2	23.4	7.0	1.7

[a]Impactor at 2.8 m elevation.

Table 8. External Andersen impactor data — Test 611

Sample No.	Component	Time (min)	Percent of total sampled aerosol mass made up of particles smaller than the aerodynamic diameter listed: Aerodynamic diameter (μm)							
			13.7	8.5	5.8	4.0	2.5	1.3	0.78	0.53
1[a]	Fe_2O_3	38.7	97.2	94.1	90.7	85.9	73.8	34.3	10.0	1.8
1	U_3O_8	38.7	99.5	99.1	98.1	94.9	81.7	38.8	12.6	4.2
1	Total	38.7	97.9	95.5	92.8	88.5	76.0	35.6	10.8	2.5

[a]Impactor at 2.8 m elevation.

Table 9. Spiral centrifuge aerosol sampler data — Test 611

Sample No.	Component	Time (min)	Percent of total sampled aerosol mass made up of particles smaller than the aerodynamic diameter listed: Aerodynamic diameter (μm)						
			4.4	2.2	1.5	1.2	1.0	0.91	0.70
1	Fe_2O_3	17.9	95.5	90.0	81.3	64.7	46.1	39.6	13.1
1	U_3O_8	17.9	98.3	90.4	77.7	63.3	50.7	39.4	18.0
1	Total	17.9	97.0	90.2	79.3	64.0	48.6	39.5	15.8

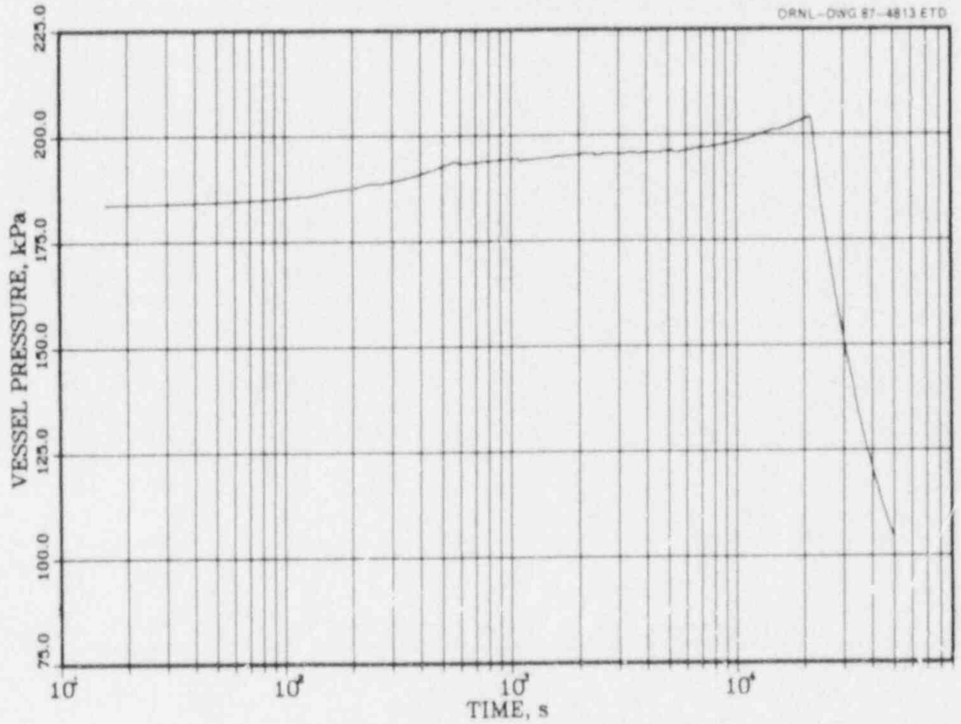

Fig. 3. Vessel atmosphere absolute pressure — NSPP Test 611.

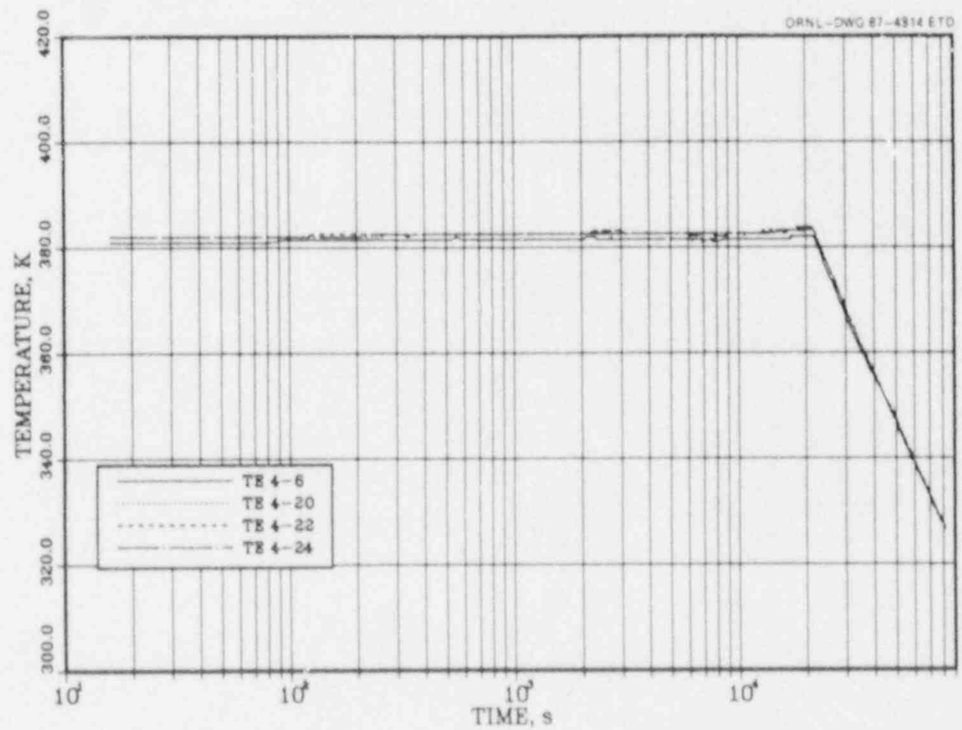

Fig. 4. Vessel atmosphere temperature at 1.22 m elevation — NSPP test 611.

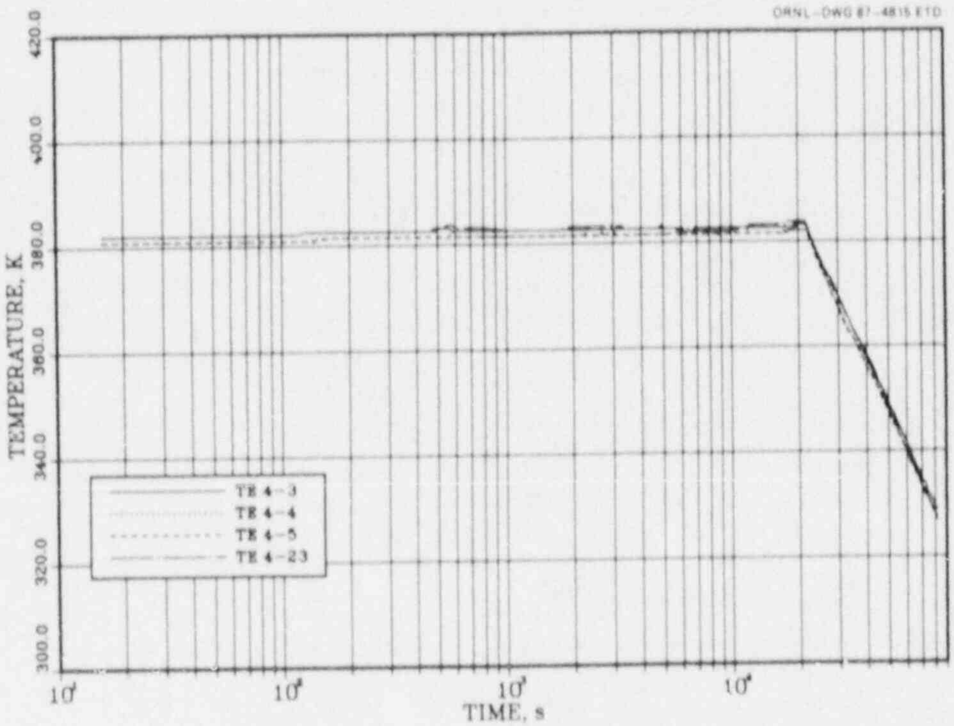

Fig. 5. Vessel atmosphere temperature at 2.74 m elevation — NSPP test 611.

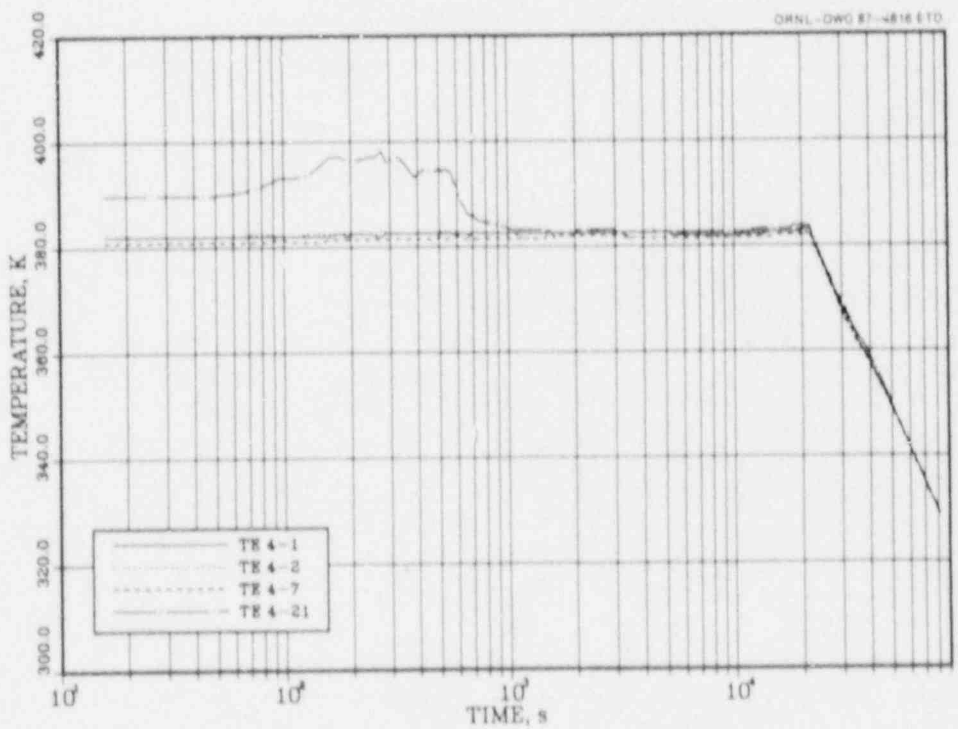

Fig. 6. Vessel atmosphere temperature at 4.27 m elevation — NSPP test 611.

Table 10. Temperature profile at 1.22 m elevation for various times after start of aerosol generation — NSPP Test 611

Time (s)	Temperature readings (K)					
	Thermocouple locations — distance from vessel wall					
	On wall	1.25 mm	2.5 mm	5 mm	10 mm	255 mm
80	382	382	382	382	382	382
1,074	382	383	383	383	383	383
16,022	382	383	383	383	383	383
18,122	382	383	383	383	383	383
21,422	382	383	383	383	383	383
31,073	366	366	366	366	367	366
87,190	324	324	324	324	324	325

Table 11. Temperature profile at 2.74 m elevation for various times after start of aerosol generation — NSPP Test 611

Time (s)	Temperature readings (K)					
	Thermocouple locations — distance from vessel wall					
	On wall	1.25 mm	2.5 mm	5 mm	10 mm	533 mm
80	381	381	381	381	381	382
1,074	382	382	382	382	382	383
16,022	382	382	382	382	382	383
18,122	382	382	382	382	382	384
21,422	382	382	383	382	383	384
31,073	365	366	366	366	367	368
87,190	324	325	325	325	325	325

Table 12. Steam condensation rates on vessel wall — Test 611

Sample No.	Sampling start time (min)	Sample duration (min)	Volume of condensate (cm^3)	Rate [$cm^3/(min\ m^2)$]
1	0.0	32.3	37	3.5
2	32.8	28.0	29	3.2
3	61.4	33.6	22	2.0
4	95.6	67.5	37	1.7
5	163.7	87.3	54	1.9
6	252.1	115.6	44	1.2
7	368.3	206.0	14.5	0.22
8	574.7	859.2	5	0.02

NOTE: Area of sampler = 0.324 m^2.

4.2 Summary and Data Listings for Test 612

Aerosol source

Mass of uranium metal powder into generator	0.1 kg
Mass of iron metal powder into generator	0.9 kg
Duration of aerosol generation	25.5 min
Maximum measured Fe_2O_3 aerosol concentration (at 2.8 min after end of aerosol generation)	0.14 g/m^3
Maximum measured U_3O_8 aerosol concentration (at 2.8 min after end of aerosol generation)	0.47 g/m^3
Estimated Fe_2O_3 concentration at end of aerosol generation (under test conditions)	0.22 g/m^3
Estimated U_3O_8 concentration at end of aerosol generation (under test conditions)	0.60 g/m^3

Vessel atmosphere

Vessel air pressure before steam injection	36 kPa
Relative humidity at start of aerosol generation	~100%
Duration of steam injection after start of aerosol generation	6 h
Mass of steam condensate collected after start of aerosol generation	314 kg

Aerosol parameters measured

Aerosol mass concentration (average)	Fig. 7
Aerosol mass concentration (individual samplers)	Tables 13-14
Aerosol fallout and plateout rates; cumulative fallout and plateout mass	Table 15
Aerosol integral fallout and plateout mass	Table 16
Andersen impactor data	Tables 17-18

System parameters measured

Vessel atmosphere pressure	Fig. 8
Vessel atmosphere temperature	Figs. 9-11
Temperature gradient near wall	Tables 19-20
Steam condensation rate	Table 21

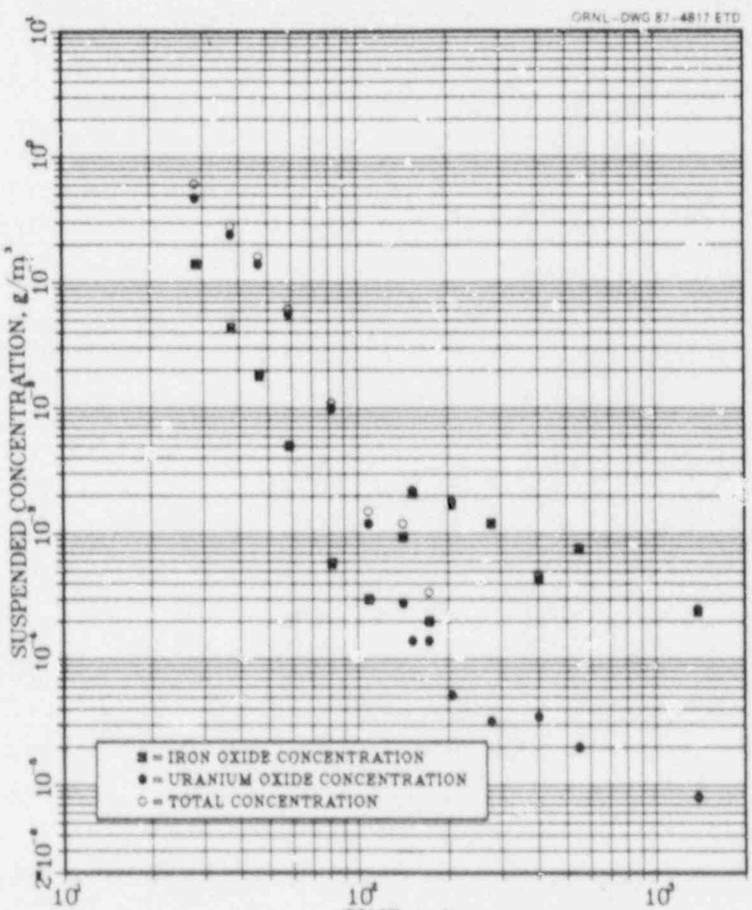

Fig. 7. Average aerosol mass concentration — NSPP Test 612.

Table 13. Aerosol mass concentration as determined with individual in-vessel samplers - Test 612

Sampler — Sampler No.	Time[a] (min)	Mass[b] concentration, Fe_2O_3 (g/m^3)	Mass[b] concentration, U_3O_8 (g/m^3)
151-1	26.7	0.17	0.49
152-1	27.3	0.17	0.56
153-1	29.[illegible]	0.10	0.37
154-1	29.7	0.13	0.47
151-2	35.8	0.061	0.30
152-2	36.3	0.036	0.25
153-2	38.6	0.044	0.21
154-2	38.9	0.029	0.20
151-3	45.1	0.017	0.15
152-3	45.5	0.023	0.14
153-3	47.8	0.011	0.14
154-3	48.1	0.020	0.12
151-4	56.7	0.0087	0.058
152-4	57.4	0.0065	0.057
153-4	60.0	0.0043	0.054
154-4	60.3	0.0026	0.054
151-5	81.1	0.00030	0.013
152-5	81.5	0.0010	0.0079
153-5	81.7	--	--
154-5	82.0	0.00043	0.010
151-6	107.7	0.0038[c]	0.0014
152-6	108.0	0.00022	0.0013
153-6	108.3	0.00035	0.00095
154-6	108.4	0.00032	0.0012
151-7	140.2	0.0014	0.00023
152-7	140.5	0.00076	0.00019
153-7	140.8	0.00065	0.00048
154-7	141.1	0.0021[c]	0.00023
151-8	171.6	0.0063[c]	0.00010
152-8	172.1	0.00034	0.00018
153-8	172.5	0.00013	0.00013
154-8	172.9	0.00013	0.00013

[a]Time measured from start of aerosol generation.

[b]Aerosol mass concentration in the vessel under test conditions that existed at time the sample was taken.

[c]Doubtful value omitted from calculation of average concentration.

Table 14. Aerosol mass concentration as determined with individual wall filter samplers - Test 612

Sampler — Sampler No.	Time[a] (min)	Mass[b] concentration, Fe_2O_3 ($\mu g/m^3$)	Mass[b] concentration, U_3O_8 ($\mu g/m^3$)
155-1	151.1	1,700[c]	250[c]
156-1	151.5	2,900	69
157-1	151.9	1,800	91
155-2	205.4	13,000[d]	100
156-2	205.6	1,600	37
157-2	205.8	1,800	110
155-3	277.0	2,100	40
156-3	278.0	860	28
157-3	278.0	510	27
155-4	401.0	320	82
156-4	401.0	410	9
157-4	401.0	560	14
155-5	550.0	1,200	33
156-5	550.0	850	11
157-5	550.0	210	16
155-6	1384.0	170	9
156-6	1384.0	410	6
157-6	1384.0	150	10

[a]Time measured from start of aerosol generation.

[b]Aerosol mass concentration in the vessel under test conditions that existed at time the sample was taken.

[c]Note units. These entries are 0.0017 and 0.00025 g/m^3, respectively.

[d]Doubtful value omitted from calculation of average concentration.

Table 15. Fallout and plateout data for aerosol components; rate and cumulative mass vs time — NSPP Test 612

Sampler name	Midpoint of sampling time[a] (s)	Duration of sample[a] (s)	Fallout, Fe_2O_3 Rate [μg/(m²·s)]	Fallout, Fe_2O_3 Cumulative (g)	Plateout, Fe_2O_3 Rate [μg/(m²·s)]	Plateout, Fe_2O_3 Cumulative (g)	Fallout, U_3O_8 Rate [μg/(m²·s)]	Fallout, U_3O_8 Cumulative (g)	Plateout, U_3O_8 Rate [μg/(m²·s)]	Plateout, U_3O_8 Cumulative (g)
FO-1	1,396	2,792	100.3	2.04			36.7	0.7		
PO-1	1,254	2,508			125.1	21.6			26.0	4.5
FO-2	3,708	1,272	No sample				No sample			
PO-2	3,263	1,135			158.0	34.0			529.7	45.9
FO-3	5,730	2,351	9.0				12.9			
PO-3	5,273	2,425			30.2	39.0			25.9	50.2
FO-4	9,179	4,147	4.2				3.0			
PO-4	8,820	4,203			120.9	74.0			4.4	51.5
FO-5	14,299	5,658	2.2				1.5			
PO-5	13,907	5,645			22.8	82.9			3.1	52.7
FO-6	25,236	16,004	0.8				0.3			
PO-6	24,955	15,980			3.5	86.8			1.0	53.8
FO-7	58,101	49,076	0.2				0.2			
PO-7	57,756	49,188			1.5	91.9			0.1	54.1

[a]Uncertainty in sampling times, ~5 s.

Table 16. Aerosol fallout and plateout data: integral samples — NSPP Test 612

Fallout			Plateout		
Sampler name	Sample mass, Fe_2O_3 (mg)	Sample mass, U_3O_8 (mg)	Sampler name	Sample mass Fe_2O_3 (mg)	Sample mass, U_3O_8 (mg)
TFO-1	24.31	11.28	TPO-BW	0.744	0.324
TFO-2	27.17	14.38	TPO-BE	0.586	0.134
TFO-3	24.31	13.79	TPO-TW	1.273	0.377
TFO-4	32.89	17.33	TPO-TN	0.972	0.369
TFO-5	28.60	12.26			
TFO-6	30.03	19.69			
Average	27.88	14.79	Average	0.894	0.301
Estimated[a] total fallout	61.1 g	32.4 g	Estimated[a] total plateout	21.6 g	7.26 g

[a]Calculated from vessel-to-sample area ratios.

Table 17. Internal Andersen impactor data — Test 612

Sample No.	Component	Time (min)	Percent of total sampled aerosol mass made up of particles smaller than the aerodynamic diameter listed: Aerodynamic diameter (μm) 14.2	8.9	6.0	4.1	2.6	1.3	0.82	0.61
8[a]	Fe_2O_3	77.8	82.0	78.9	75.7	70.1	67.0	63.6	35.8	16.2
8	U_3O_8	77.8	95.4	92.5	80.6	73.2	63.6	48.0	17.9	4.6
8	Total	77.8	89.0	86.0	78.2	71.7	65.2	55.4	26.5	10.2
9[b]	Fe_2O_3	120.5	87.2	78.0	69.9	57.4	41.5	33.7	9.0	2.6
9	U_3O_8	120.5	— Insufficient sample							
9	Total	120.5	86.3	77.8	70.0	58.4	43.6	36.0	11.5	3.8

[a]Impactor at 2.8 m elevation.

[b]Impactor at 0.56 m elevation.

Table 18. External Andersen impactor data — Test 612

Sample No.	Component	Time (min)	Percent of total sampled aerosol mass made up of particles smaller than the aerodynamic diameter listed: Aerodynamic diameter (μm)							
			13.7	8.5	5.8	4.0	2.5	1.3	0.78	0.53
1	Fe_2O_3	30.0	99.8	99.2	95.6	91.4	79.9	62.2	50.7	11.6
1	U_3O_8	30.0	99.2	99.1	95.5	88.1	69.8	32.7	11.5	7.9
1	Total	30.0	99.4	99.1	95.5	88.9	72.2	39.9	21.1	8.8

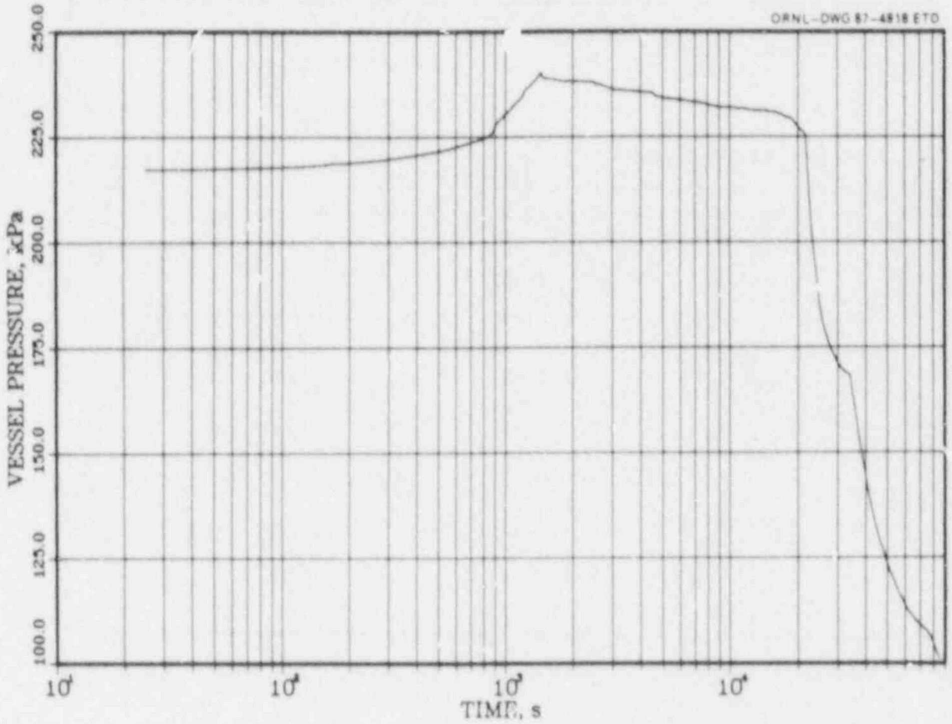

Fig. 8. Vessel atmosphere absolute pressure — NSPP Test 612.

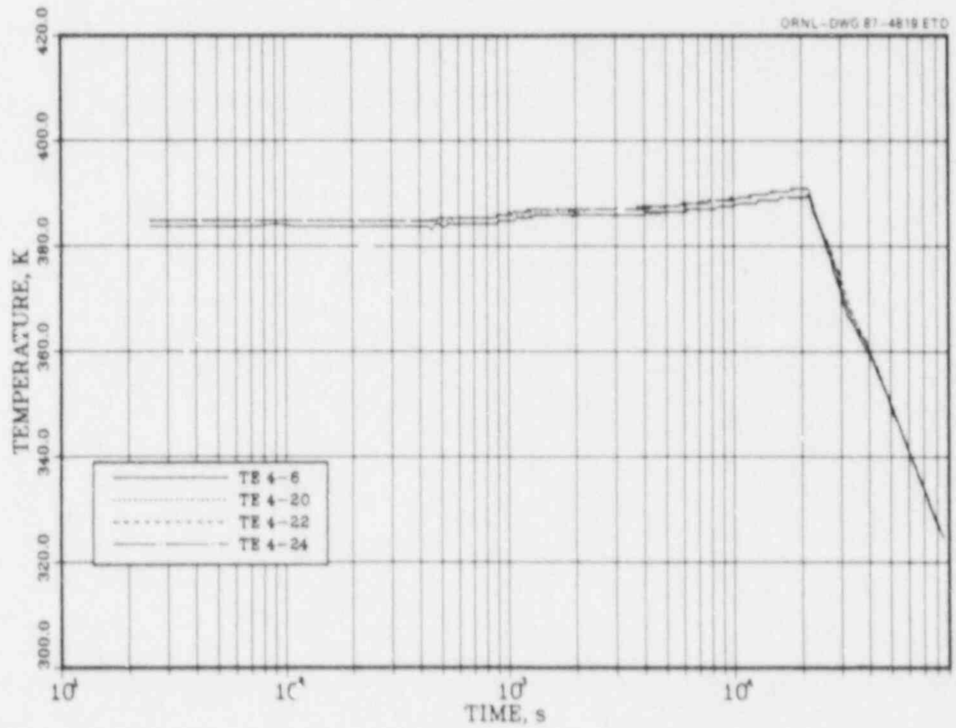

Fig. 9. Vessel atmosphere temperature at 1.22 m elevation — NSPP test 612.

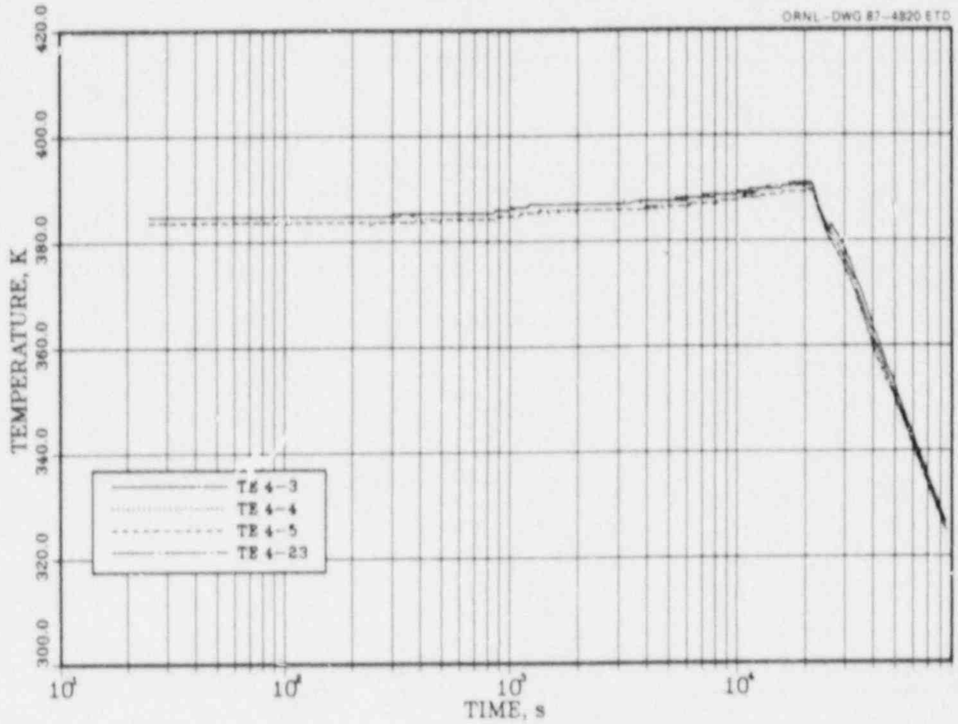

Fig. 10. Vessel atmosphere temperature at 2.74 m elevation — NSPP test 612.

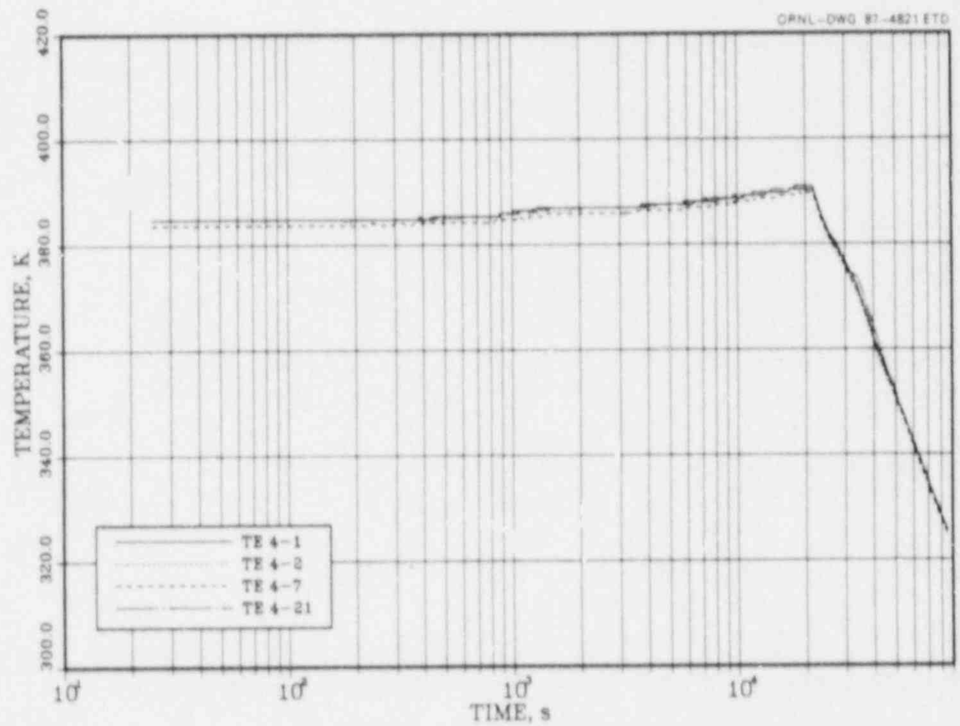

Fig. 11. Vessel atmosphere temperature at 4.27 m elevation — NSPP test 612.

Table 19. Temperature profile at 1.22 m elevation for various times after start of aerosol generation — NSPP Test 612

Time (s)	Temperature readings (K)					
	Thermocouple locations — distance from vessel wall					
	On wall	1.25 mm	2.5 mm	5 mm	10 mm	255 mm
91	384	385	385	385	385	385
1,081	385	386	386	386	386	386
4,450	387	388	388	388	388	388
8,138	389	388	389	389	389	389
24,875	383	383	383	383	383	383
30,875	370	370	370	370	370	370
57,194	343	343	343	343	343	343
84,989	324	324	324	324	324	325

Table 20. Temperature profile at 2.74 m elevation for various times after start of aerosol generation — NSPP Test 612

Time (s)	Temperature readings (K)					
	Thermocouple locations — distance from vessel wall					
	On wall	1.25 mm	2.5 mm	5 mm	10 mm	533 mm
91	384	384	384	384	384	385
1,081	385	385	385	385	385	386
4,450	386	386	386	386	386	388
8,138	388	388	388	388	388	389
24,875	382	382	382	382	382	383
30,875	374	374	374	374	374	375
57,194	343	343	343	343	343	344
84,989	324	325	325	325	325	325

Table 21. Steam condensation rates on vessel wall — Test 612

Sample No.	Sampling start time (min)	Sample duration (min)	Volume of condensate (cm^3)	Rate [$cm^3/(min\ m^2)$]
1	0.0	52.9	190	11.1
2	53.5	15.0	7	1.4
3	70.3	42.4	16	1.2
4	113.6	71.6	29	1.3
5	185.8	97.2	54	1.7
6	283.9	256.4	10	0.12
7	553.8	820.2	16	0.06

NOTE: Area of sampler = $0.324\ m^2$.

4.3 Summary and Data Listings for Test 613

Aerosol source

Mass of uranium metal powder into generator	0.1 kg
Mass of iron metal powder into generator	0.9 kg
Duration of aerosol generation	26 min
Maximum measured Fe_2O_3 concentration (at 8.4 min after end of aerosol generation)	$0.58\ g/m^3$
Maximum measured U_3O_8 concentration (at 8.4 min after end of aerosol generation)	$0.072\ g/m^3$
Estimated Fe_2O_3 concentration at end of aerosol generation (under test conditions)	$0.80\ g/m^3$
Estimated U_3O_8 concentration at end of aerosol generation (under test conditions)	$0.13\ g/m^3$

Vessel atmosphere

Vessel air pressure at start of aerosol generation	37 kPa
Relative humidity at start of aerosol generation	~100%
Duration of steam injection after start of aerosol generation	6 h
Mass of steam condensate collected after start of aerosol generation	221 kg

Aerosol parameters measured

Aerosol mass concentration (average)	Fig. 12
Aerosol mass concentration (individual samplers)	Tables 22-23
Aerosol fallout and plateout rates; cumulative fallout and plateout mass	Table 24
Aerosol integral fallout and plateout mass	Table 25
Andersen impactor data	Tables 26-27
Spiral centrifuge aerosol sample data	Table 28

System parameters measured

Vessel atmosphere pressure	Fig. 13
Vessel atmosphere temperature	Figs. 14-16
Temperature gradient near wall	Tables 29-30
Steam condensation rate	Table 31

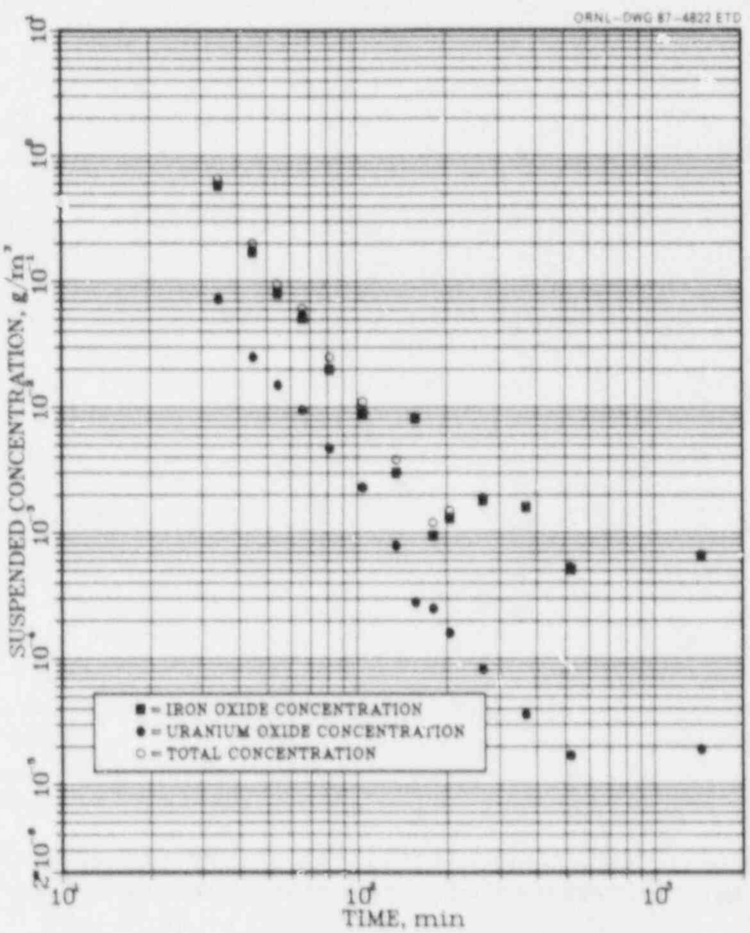

Fig. 12. Average aerosol mass concentration — NSPP Test 613.

Table 22. Aerosol mass concentration as determined with individual in-vessel samplers - Test 613

Sampler — Sampler No.	Time[a] (min)	Mass[b] concentration, Fe_2O_3 (g/m^3)	Mass[b] concentration, U_3O_8 (g/m^3)
151-1	22.5	4.92	0.61
152-1	22.9	1.41	0.19
153-1	25.8	0.95	--
154-1	26.1	--	0.092
151-2	32.6	0.60	0.076
152-2	32.9	0.64	0.077
153-2	35.9	0.50	0.062
154-2	36.2	--	--
151-3	43.5	0.18	0.028
152-3	43.8	0.20	0.16[c]
153-3	47.2	0.13	0.021
154-3	--	--	--
151-4	53.9	0.077	0.014
152-4	54.1	0.082	0.015
153-4	54.3	0.090	0.017
154-4	54.7	0.072	0.013
151-5	65.6	0.052	0.011
152-5	65.8	0.041	0.0081
153-5	66.0	0.045	0.0093
154-5	66.2	0.065	0.0095
151-6	80.8	0.023	0.0056
152-6	81.1	0.020	0.0047
153-6	81.3	0.020	0.0049
154-6	81.5	0.015	0.0037
151-7	104.2	0.0090	0.0026
152-7	104.4	0.0094	0.002
153-7	104.6	0.0076	0.0024
154-7	104.8	0.0093	0.0023
151-8	134.6	0.0041	0.0011
152-8	134.8	0.0025	0.00065
153-8	135.0	0.0028	0.00076
154-8	135.2	0.0024	0.00064
151-9	179.9	0.00092	0.00033
152-9	180.1	0.00064	0.00013
153-9	180.5	0.00093	0.00021
154-9	180.8	0.0011	0.00034

[a]Time measured from start of aerosol generation.

[b]Aerosol mass concentration in the vessel under test conditions that existed at time the sample was taken.

[c]Doubtful value omitted from calculation of average concentration.

Table 23. Aerosol mass concentration as determined with individual wall filter samplers - Test 613

Sampler — Sampler No.	Time[a] (min)	Mass[b] concentration, Fe_2O_3 ($\mu g/m^3$)	Mass[b] concentration, U_3O_8 ($\mu g/m^3$)
155-1	156.7	16,000[c]	380[c]
156-1	157.1	6,300	150
157-1	157.4	2,100	320
155-2	204.4	1,500	200
156-2	204.7	--	--
157-2	205.1	1,000	120
155-3	263.3	1,300	100
156-3	263.6	1,400	110
157-3	263.9	2,600	35
155-4	367.6	3,800	47
156-4	367.7	550	34
157-4	367.9	520	26
155-5	521.0	790	450[d]
156-5	521.0	460	15
157-5	521.0	290	19
155-6	1438.0	690	23
156-6	2438.0	820	16
157-6	1438.0	430	19

[a]Time measured from start of aerosol generation.

[b]Aerosol mass concentration in the vessel under test conditions that existed at time the sample was taken.

[c]Note units. These entries are 0.016 g/m^3 and 0.00038 g/m^3, respectively.

[d]Doubtful value omitted from calculation of average concentration.

Table 24. Fallout and plateout data for aerosol components; rate and cumulative mass vs time — NSPP Test 613

Sampler name	Midpoint of sampling time[a] (s)	Duration of sample[a] (s)	Fallout, Fe_2O_3 Rate [μg/(m²·s)]	Fallout, Fe_2O_3 Cumulative (g)	Plateout, Fe_2O_3 Rate [μg/(m²·s)]	Plateout, Fe_2O_3 Cumulative (g)	Fallout, U_3O_8 Rate [μg/(m²·s)]	Fallout, U_3O_8 Cumulative (g)	Plateout, U_3O_8 Rate [μg/(m²·s)]	Plateout, U_3O_8 Cumulative (g)
FO-1	1,488	2,975	882.7	19.2			274.1	5.9		
PO-1	1,244	2,488			150.2	25.7			11.9	2.0
FO-2	3,562	1 [illegible]74	102.9	20.1			36.9	6.2		
PO-2	3,135	1,294			75.1	32.4			6.2	2.6
FO-3	5,772	2,513	31.4	20.7			10.9	6.4		
PO-3	5,381	2,487			25.8	36.8			1.9	2.9
FO-4	9,180	3.907	22.0	21.3			4.8	6.5		
PO-4	8,796	4,001			6.7	38.6			0.97	3.2
FO-5	13,854	5,030	5.6	21.5			1.8	6.6		
PO-5	13,494	5,009			6.6	40.9			0.56	3.4
FO-6	24,114	15,132	3.1	21.8			0.74	6.6		
PO-6	23,722	15,108			0.46	41.4			0.12	3.5
FO-7	58,693	53,674	0.52	22.0			0.11	6.7		
PO-7	58,264	53,512			0.36	42.8			0.03	3.6

[a]Uncertainty in sampling times, ~5 s.

Table 25. Aerosol fallout and plateout data: integral samples — NSPP Test 613

Fallout			Plateout		
Sampler name	Sample mass, Fe_2O_3 (mg)	Sample mass, U_3O_8 (mg)	Sampler name	Sample mass Fe_2O_3 (mg)	Sample mass, U_3O_8 (mg)
TFO-1	57.2	9.38	TPO-BW	3.86	0.60
TFO-2	54.3	12.85	TPO-BE	4.43	0.48
TFO-3	65.8	25.35	TPO-TW	4.29	0.71
TFO-4	80.1	28.30	TPO-TN	3.86	0.54
TFO-5	97.2	25.58			
TFO-6	107.3	20.75			
Average	77.08	20.4	Average	4.11	0.58
Estimated[a] total fallout	168.8 g	44.7 g	Estimated[a] total plateout	99.1 g	14.1 g

[a]Calculated from vessel-to-sample area ratios.

Table 26. Internal Andersen impactor data — Test 613

Sample No.	Component	Time (min)	Percent of total sampled aerosol mass made up of particles smaller than the aerodynamic diameter listed							
			Aerodynamic diameter (μm)							
			14.2	8.9	6.0	4.1	2.6	1.3	0.82	0.61
8[a]	Fe_2O_3	54.6	96.2	91.0	79.5	72.4	53.3	20.4	5.1	1.0
8	U_3O_8	54.6	98.2	94.8	87.2	82.6	68.5	36.6	12.8	3.3
8	Total	54.6	96.5	91.5	80.6	73.8	55.4	22.6	6.2	1.3
9[b]	Fe_2O_3	95.7	90.8	83.7	74.9	67.6	57.6	31.8	10.1	2.4
9	U_3O_8	95.7	95.9	94.0	88.9	85.2	77.3	54.9	25.2	9.4
9	Total	95.7	91.5	85.2	76.9	70.2	60.4	35.1	12.3	3.4

[a]Impactor at 2.8 m elevation.

[b]Impactor at 0.56 m elevation.

Table 27. External Andersen impactor data — Test 613

Sample No.	Component	Time (min)	Aerodynamic diameter (μm)							
			13.7	8.5	5.8	4.0	2.5	1.3	0.78	0.53
2	Fe_2O_3	137.6	98.4	98.1	96.5	93.8	91.3	66.8	36.4	15.6
2	U_3O_8	137.6	97.5	95.2	91.4	85.7	78.6	57.9	39.4	24.5
2	Total	137.6	98.2	97.5	95.5	92.2	88.8	65.0	37.0	17.4

Percent of total sampled aerosol mass made up of particles smaller than the aerodynamic diameter listed

Table 28. Spiral centrifuge aerosol sampler data — Test 613

Sample No.	Component	Time (min)	Aerodynamic diameter (μm)						
			4.4	2.2	1.5	1.2	1.0	0.91	0.70
1	Fe_2O_3	29.3	93.7	69.7	40.0	26.0	19.9	14.3	6.0
1	U_3O_8	29.3	98.1	73.9	38.7	23.3	15.5	10.9	4.5
1	Total	17.9	29.3	70.0	39.9	25.8	19.5	14.0	5.8
2	Fe_2O_3	71.8	96.7	92.4	75.1	63.7	56.0	32.5	24.5
2	U_3O_8	71.8	97.1	92.3	79.3	60.1	45.7	35.6	20.2
2	Total	45.3	71.8	92.4	78.2	63.5	55.4	32.8	24.2

Percent of total sampled aerosol mass made up of particles smaller than the aerodynamic diameter listed

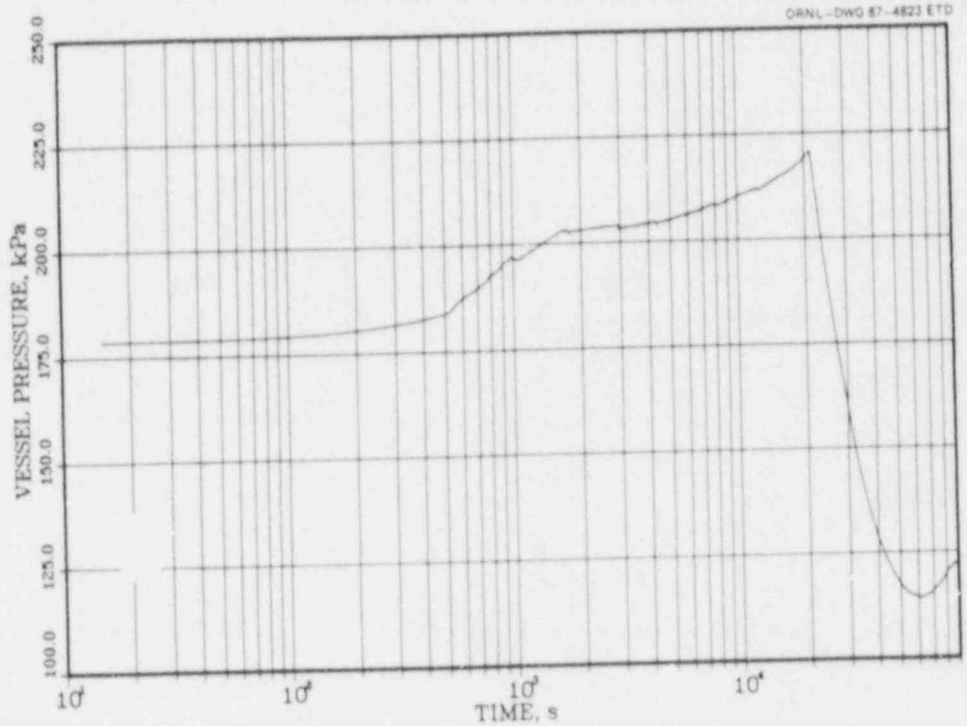

Fig. 13. Vessel atmosphere absolute pressure — NSPP Test 613.

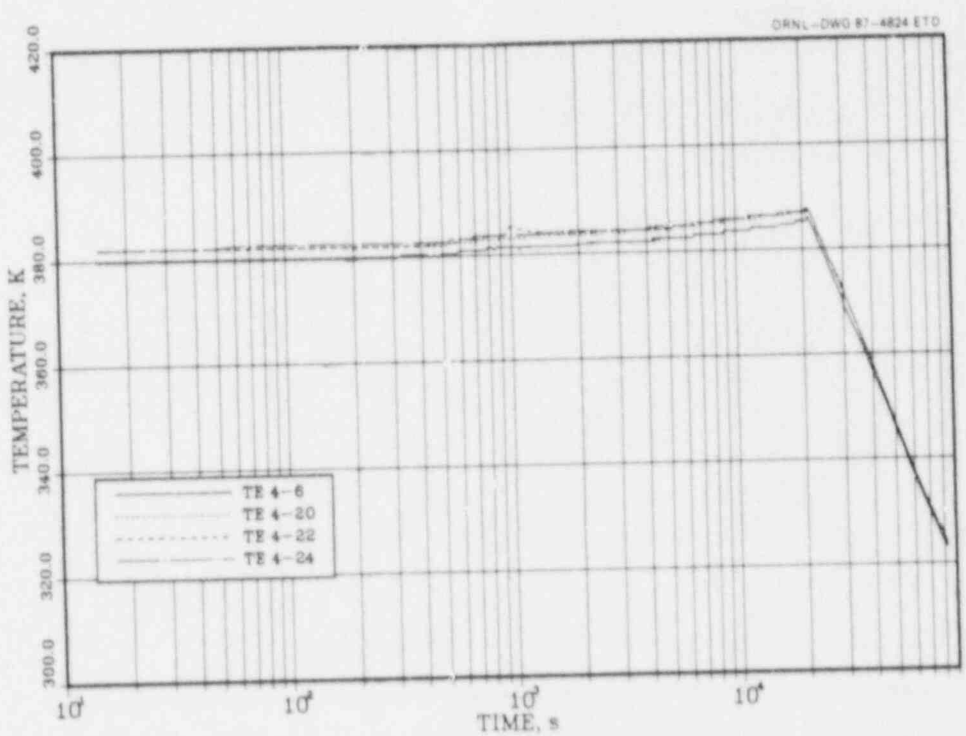

Fig. 14. Vessel atmosphere temperature at 1.22 m elevation — NSPP test 613.

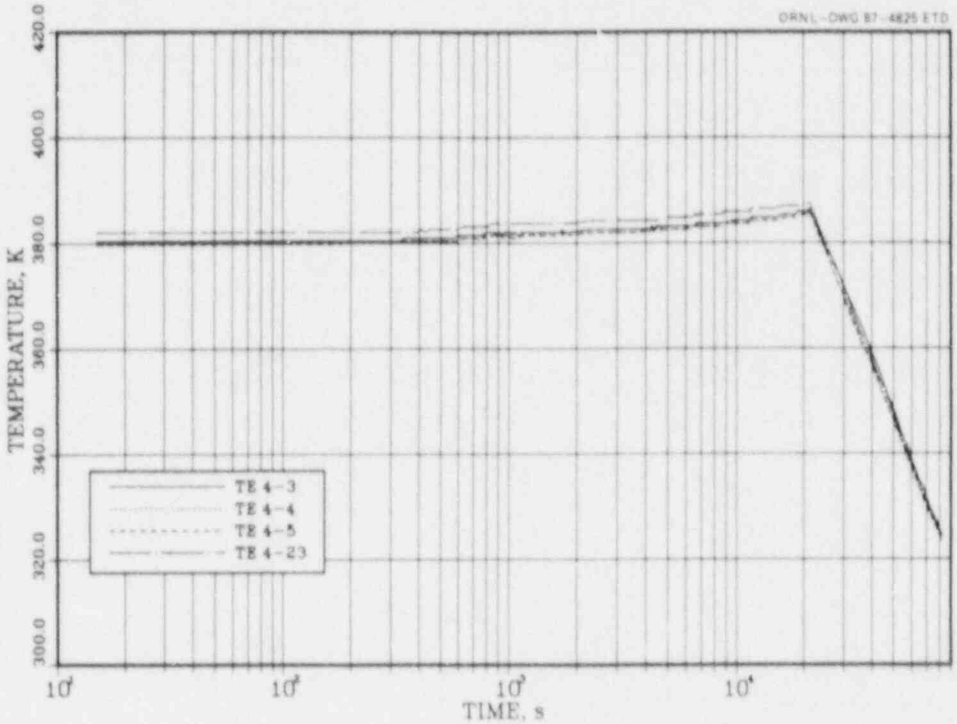

Fig. 15. Vessel atmosphere temperature at 2.74 m elevation — NSPP test 613.

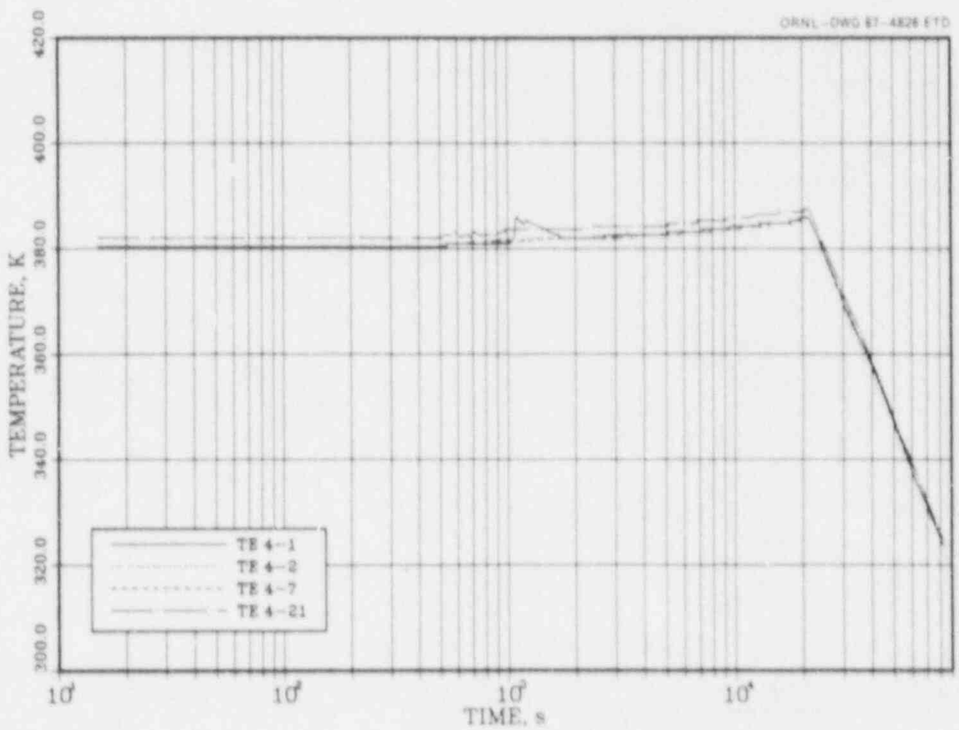

Fig. 16. Vessel atmosphere temperature at 4.27 m elevation — NSPP test 613.

Table 29. Temperature profile at 1.22 m elevation for various times after start of aerosol generation — NSPP Test 613

Time (s)	Temperature readings (K)					
	Thermocouple locations — distance from vessel wall					
	On wall	1.25 mm	2.5 mm	5 mm	10 mm	255 mm
15	380	382	382	382	382	382
758	381	382	383	383	383	384
3,603	383	384	384	384	384	384
11,438	384	385	385	385	386	386
20,349	386	386	387	387	387	387
28,742	372	373	373	374	374	374
71,878	329	329	329	329	329	330

Table 30. Temperature profile at 2.74 m elevation for various times after start of aerosol generation — NSPP Test 613

Time (s)	Temperature readings (K)					
	Thermocouple locations — distance from vessel wall					
	On wall	1.25 mm	2.5 mm	5 mm	10 mm	533 mm
15	380	380	380	380	380	382
758	382	382	382	382	382	383
3,603	383	383	383	383	383	384
11,438	384	384	384	384	384	386
20,349	386	386	386	386	386	388
28,742	372	372	372	372	372	374
71,878	329	329	329	329	329	330

Table 31. Steam condensation rates on vessel wall — Test 613

Sample No.	Sampling start time (min)	Sample duration (min)	Volume of condensate (cm^3)	Rate [$cm^3/(min\ m^2)$]
1	0.0	47.0	94.0	6.2
2	47.2	22.9	10.5	1.4
3	71.2	43.2	13.0	0.93
4	114.7	69.3	26.0	1.2
5	184.3	86.3	42.0	1.5
6	271.6	103.2	44.0	1.3
7	375.4	150.2	1.55	0.03
8	526.0	895.2	1.0	0.003

NOTE: Area of sampler = 0.324 m^2.

4.4 Summary and Data Listings for Test 631

(Dry Atmosphere)

Aerosol source

Mass of uranium metal powder into generator	0.19 kg
Mass of iron metal powder into generator	0.50 kg
Duration of aerosol generation	16.2 min
Maximum measured Fe_2O_3 concentration at 6 min after end of aerosol generation)	0.87 g/m^3
Maximum measured U_3O_8 concentration (at 6 min after end of aerosol generation)	1.17 g/m^3
Estimated Fe_2O_3 concentration at end of aerosol generation (under test conditions)	1.2 g/m^3
Estimated U_3O_8 concentration at end of aerosol generation (under test conditions)	1.7 g/m^3

Vessel atmosphere

Vessel air pressure at start of aerosol generation	Ambient
Relative humidity at start of aerosol generation	<20%

Aerosol parameters measured

Aerosol mass concentration (average)	Fig. 17
Aerosol mass concentration (individual samplers)	Tables 32-33
Aerosol fallout and plateout rates; cumulative fallout and plateout mass	Table 34
Aerosol integral fallout and plateout mass	Table 35
Andersen impactor data	Tables 36-37
Spiral centrifuge aerosol sample data	Table 38

System parameters measured

Vessel atmosphere pressure	Fig. 18
Vessel atmosphere temperature	Figs. 19-21
Temperature gradient near wall	Tables 39-40

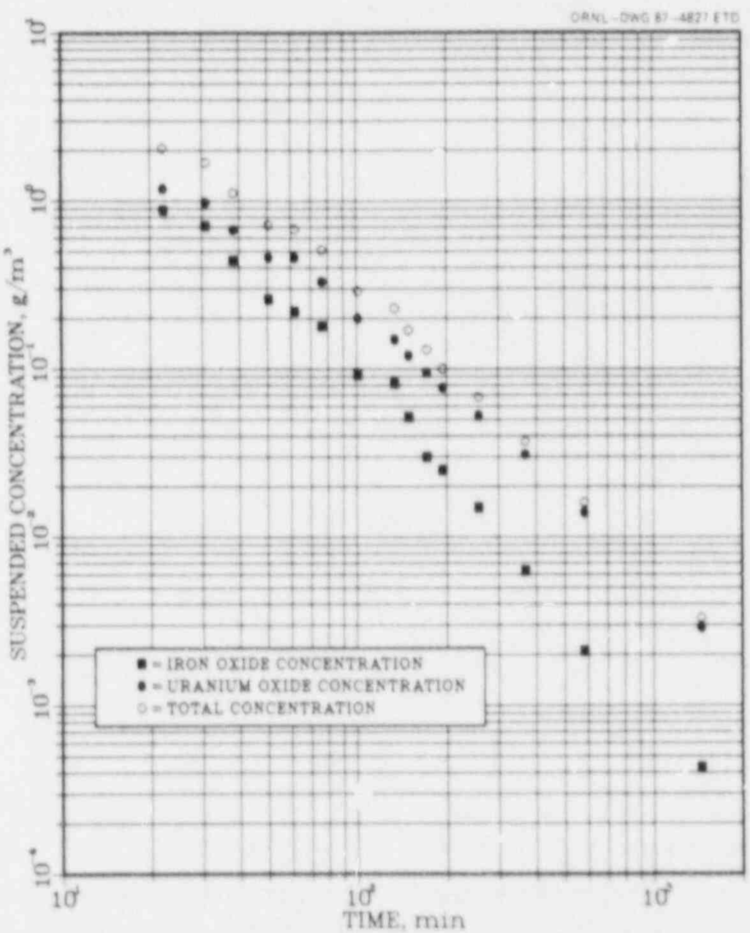

Fig. 17. Average aerosol mass concentration — NSPP Test 631.

Table 32. Aerosol mass concentration as determined with individual in-vessel samplers - Test 631

Sampler — Sampler No.	Time[a] (min)	Mass[b] concentration, Fe_2O_3 (g/m^3)	Mass[b] concentration, U_3O_8 (g/m^3)
151-1	20.8	1.22	1.46
152-1[c]	--	--	--
153-1	23.4	0.64	0.88
154-1	23.6	0.63	1.02
151-2	30.4	0.89	1.22
152-2	--	--	--
153-2	30.9	0.63	0.89
154-2	31.1	0.62	0.84
151-3	37.9	0.60	0.78
152-3	--	--	--
153-3	38.2	0.40	0.60
154-3	38.4	0.33	0.62
151-4	50.3	0.30	0.45
152-4	--	--	--
153-4	50.5	0.24	0.42
154-4	50.7	0.24	0.50
151-5	61.6	0.29	0.49
152-5	--	--	--
153-5	61.8	0.22	0.39
154-5	62.2	0.24	0.49
151-6	76.0	0.19	0.31
152-6	--	--	--
153-6	76.3	0.17	0.32
154-6	76.6	0.19	0.36
151-7	100.8	0.12	0.20
152-7	--	--	--
153-7	101.0	0.075	0.18
154-7	101.2	0.081	0.21
151-8	134.1	0.090	0.16
152-8	--	--	--
153-8	134.4	0.11	0.14
154-8	134.6	0.046	0.15
151-9	171.4	0.036	0.10
152-9	--	--	--
153-9	171.7	0.028	0.085
154-9	172.0	0.027	0.10

[a]Time measured from start of aerosol generation.

[b]Aerosol mass concentration in the vessel under test conditions that existed at time the sample was taken.

[c]Sampler 152 did not operate satisfactorily.

Table 33. Aerosol mass concentration as determined with individual wall filter samplers - Test 631

Sampler — Sampler No.	Time (min)	Mass concentration, Fe_2O_3 (g/m^3)	Mass concentration, U_3O_8 (g/m^3)
155-1	148.6	0 063	0.13
156-1	199.4	0.056	0.13
157-1	[illegible]	0.038	0.098
155-2	193.8	0.028	0.080
156-2	194.0	0.028	0.072
157-2	194.6	0.019	0.080
155-3	256.4	0.016	0.053
156-3	256.7	0.014	0.049
157-3	257.0	0.015	0.057
155-4	368.0	0.0068	0.030
156-4	368.0	0.0058	0.031
157-4	368.0	0.0063	0.032
155-5	584.0	0.0023	0.013
156-5	584.0	0.0020	0.015
157-5	584.0	0.0019	0.014
155-6	1,451.0	0.00072	0.0028
156-6	1,451.0	0.00028	0.0030
157-6	1,451.0	0.00030	0.0028

Table 34. Aerosol fallout and plateout data for aerosol components; rate and cumulative mass vs time — NSPP Test 631

Sampler name	Midpoint of sampling time[a] (s)	Duration of sample[a] (s)	Fallout, Fe_2O_3 Rate [μg/(m²·s)]	Fallout, Fe_2O_3 Cumulative (g)	Plateout, Fe_2O_3 Rate [μg/(m²·s)]	Plateout, Fe_2O_3 Cumulative (g)	Fallout, U_3O_8 Rate [μg/(m²·s)]	Fallout, U_3O_8 Cumulative (g)	Plateout, U_3O_8 Rate [μg/(m²·s)]	Plateout, U_3O_8 Cumulative (g)
FO-1	1,054	2,107	515.2	7.9			703.6	10.8		
PO-1	892	1,783			21.0	2.6			11.7	1.4
FO-2	2,824	1,434	293.0	11.0			423.8	15.2		
PO-2	2,522	1,477			11.1	3.7			9.2	2.3
FO-3	5,189	2,534	24.2	11.4			165.2	18.3		
PO-3	4,939	2,614			29.1	8.9			5.2	3.2
FO-4	8,547	3,804	18.9	11.9			55.8	19.8		
PO-4	8,293	3,815			3.2	9.7			1.8	3.7
FO-5	12,994	4,789	6.2	12.1			20.2	20.5		
PO-5	12,801	4,811			3.1	10.7			1.3	4.1
FO-6	25,028	19,004	1.0	12.2			5.8	21.3		
PO-6	24,815	18,958			0.04	10.8			0.23	4.4
FO-7	60,554	51,723	0.33	12.3			1.6	21.9		
PO-7	60,225	51,530			0.44	12.4			0.07	4.6

[a]Uncertainty in sampling times, ~5 s.

Table 35. Aerosol fallout and plateout data: integral samples — NSPP Test 631

Fallout			Plateout		
Sampler name	Sample mass, Fe_2O_3 (mg)	Sample mass, U_3O_8 (mg)	Sampler name	Sample mass, Fe_2O_3 (mg)	Sample mass, U_3O_8 (mg)
TFO-1	31.46	36.20	FPO-BW	3.15	4.15
TFO-2	32.89	35.84	TPO-BE	2.29	3.15
TFO-3	32.89	37.02	TPO-TW	2.15	3.51
TFO-4	34.32	39.85	TPO-TN	2.43	3.33
TFO-5	34.32	37.26			
TFO-6	34.32	38.02			
Average	33.37	37.36	Average	2.50	3.54
Estimated[a] total fallout	73.14 g	81.9 g	Estimated[a] total plateout	60.4 g	85.3 g

[a]Calculated from vessel-to-sample area ratios.

Table 36. Internal Andersen impactor data — Test 631

Sample No.	Component	Time (min)	Percent of total sampled aerosol mass made up of particles smaller than the aerodynamic diameter listed: Aerodynamic diameter (μm)							
			13.7	8.5	5.8	4.0	2.5	1.3	0.78	0.53
8[a]	Fe_2O_3	40.2	98.1	94.8	85.8	74.2	51.9	29.6	14.0	7.0
8	U_3O_8	40.2	98.7	96.4	91.1	83.2	63.4	40.2	21.0	11.4
8	Total	40.2	98.5	95.8	89.0	79.7	59.0	36.1	18.3	9.7
9[b]	Fe_2O_3	111.9	99.9	99.8	99.7	99.6	84.4	44.6	23.6	12.9
9	U_3O_8	111.9	99.5	99.0	98.0	96.4	85.6	52.3	35.1	23.1
9	Total	111.9	99.6	99.2	98.4	97.3	85.2	50.1	31.9	20.2

[a]Impactor at 2.8 m elevation.

[b]Impactor at 0.56 m elevation.

Table 37. External Andersen impactor data — Test 631

Sample No.	Component	Time (min)	Percent of total sampled aerosol mass made up of particles smaller than the aerodynamic diameter listed — Aerodynamic diameter (μm)							
			13.7	8.5	5.8	4.0	2.5	1.3	0.78	0.53
1	Fe_2O_3	19.6	99.4	98.2	92.2	78.1	53.9	20.6	3.9	1.3
1	U_3O_8	19.6	99.6	98.8	94.8	86.4	63.2	23.2	4.5	1.5
1	Total	19.6	99.5	98.6	93.6	82.6	59.0	22.0	4.29	1.39

Table 38. Spiral centrifuge aerosol sampler data — Test 631

Sample No.	Component	Time (min)	Percent of total sampled aerosol mass made up of particles smaller than the aerodynamic diameter listed — Aerodynamic diameter (μm)						
			4.4	3.0	2.2	1.8	1.5	1.31	1.0
1	Fe_2O_3	26.0	90.3	81.2	61.1	42.6	31.4	23.4	14.8
1	U_3O_8	26.0	97.3	89.3	62.4	37.4	20.7	12.6	4.5
1	Total	26.0	93.7	85.2	61.7	40.0	26.1	18.0	9.7
2	Fe_2O_3	73.5	92.7	73.1	51.4	38.1	29.2	23.5	18.3
2	U_3O_8	73.5	72.1	48.6	23.9	11.8	6.68	4.5	2.1
2	Total	73.5	80.4	58.5	35.0	22.4	15.7	12.2	8.6

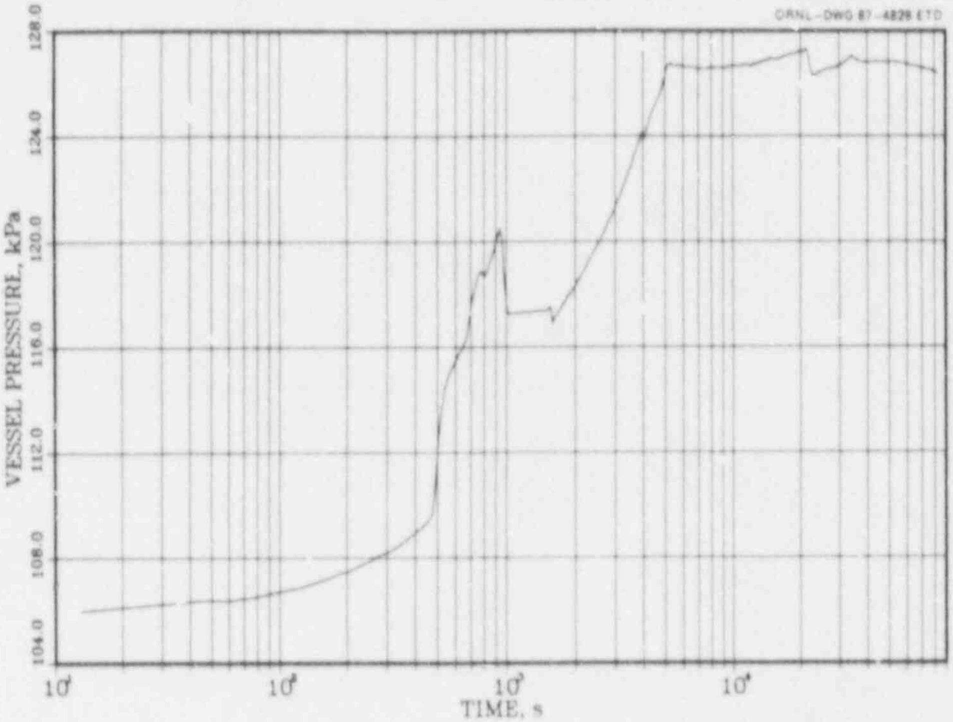

Fig. 18. Vessel atmosphere absolute pressure — NSPP Test 631.

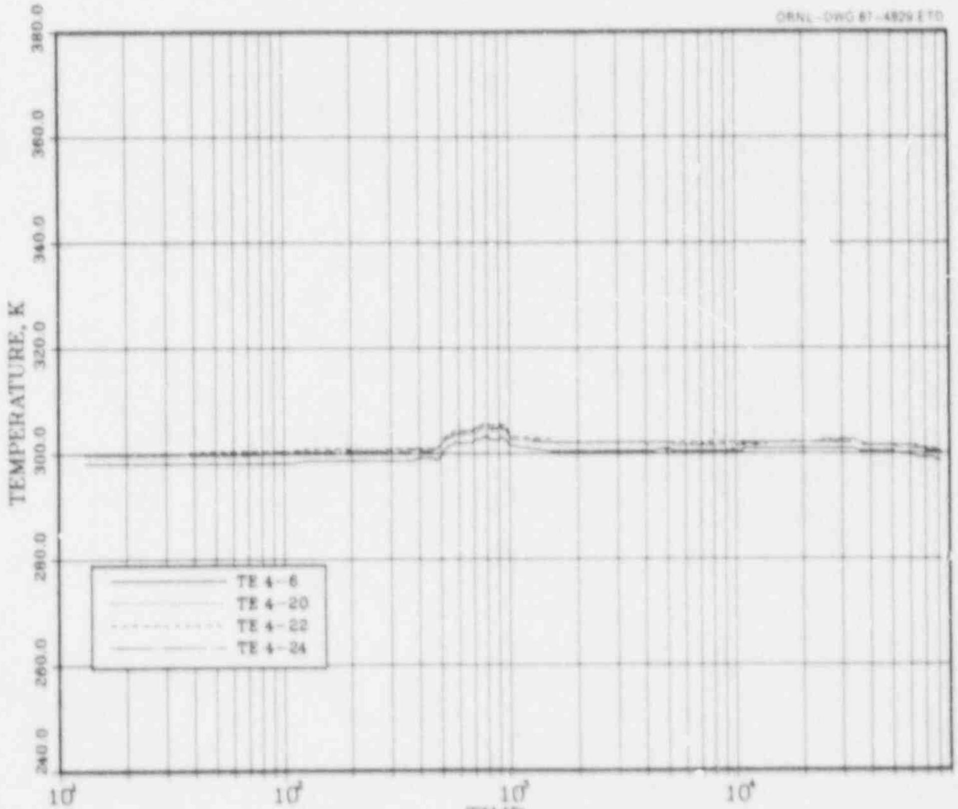

Fig. 19. Vessel atmosphere temperature at 1.22 m elevation — NSPP test 631.

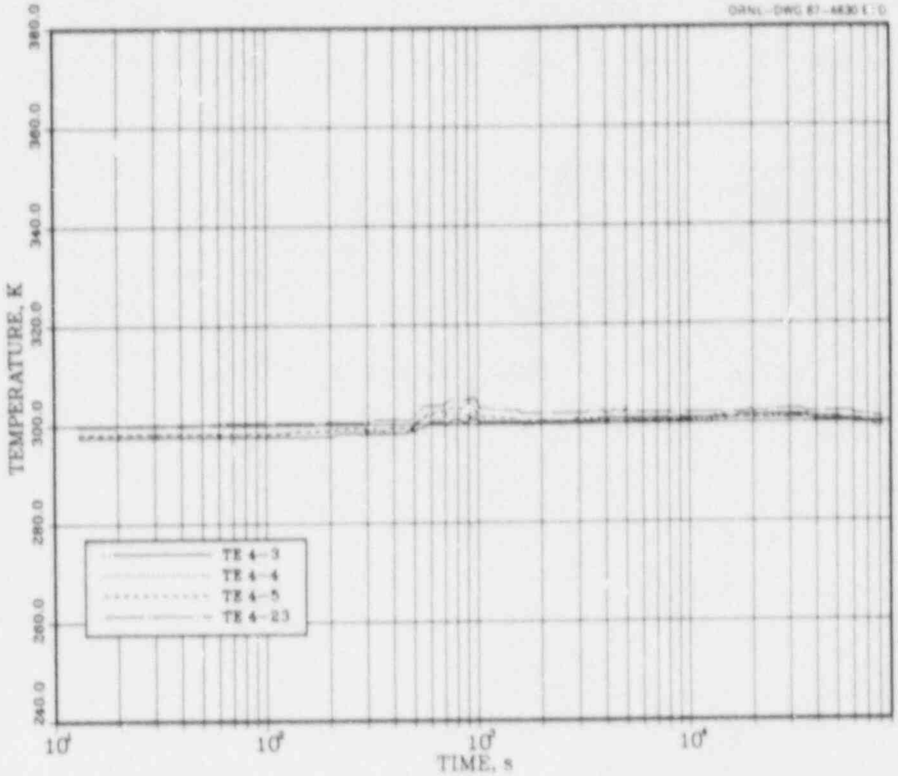

Fig. 20. Vessel atmosphere temperature at 2.74 m elevation — NSPP test 631.

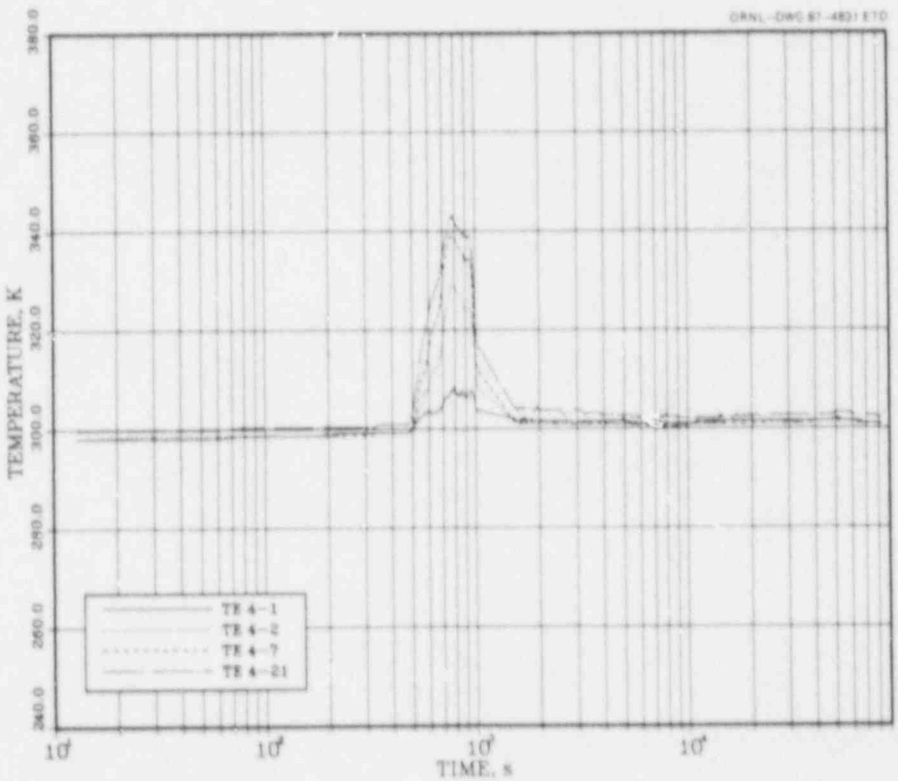

Fig. 21. Vessel atmosphere temperature at 4.27 m elevation — NSPP test 631.

Table 39. Temperature profile at 1.22 m elevation for various times after start of aerosol generation — NSPP Test 631

Time (s)	Temperature readings (K)					
	Thermocouple locations — distance from vessel wall					
	On wall	1.25 mm	2.5 mm	5 mm	10 mm	255 mm
93	298	298	298	298	298	300
13,014	299	300	301	301	301	302
26,854	298	302	302	302	302	302
89,406	298	299	299	299	299	300

Table 40. Temperature profile at 2.74 m elevation for various times after start of aerosol generation — NSPP Test 631

Time (s)	Temperature readings (K)					
	Thermocouple locations — distance from vessel wall					
	On wall	1.25 mm	2.5 mm	5 mm	10 mm	255 mm
93	298	298	298	298	298	300
13,014	300	301	301	301	301	302
26,854	301	301	301	301	301	303
89,406	299	299	299	299	299	300

5. REFERENCES

1. R. E. Adams and M. L. Tobias, *Uranium Oxide Aerosol Experiments in Steam-Air Atmospheres: NSPP Tests 401-407, Data Record Report*, NUREG/CR-4716 (ORNL/TM-10165) (September 1986).
2. R. E. Adams and M. L. Tobias, *Iron Oxide Aerosol Experiments in Steam-Air Atmospheres: NSPP Tests 501-505 and 511, Data Record Report*, NUREG/CR-4798 (ORNL/TM-10301) (February 1987).
3. M. L. Tobias and R. E. Adams, *Limestone Concrete Aerosol Experiments in Steam-Air Atmospheres: NSPP Tests 521, 522, and 531, Data Record Report*, NUREG/CR-5017 (ORNL/TM-10587) (October 1987).
4. T. S. Kress and M. L. Tobias, *LMFBR Aerosol Release and Transport Program Quarterly Progress Report for April–June 1980*, NUREG/CR-1791 (ORNL/NUREG/TM-417) (December 1980).
5. T. S. Kress and M. L. Tobias, *LMFBR Aerosol Release and Transport Program Quarterly Progress Report for July–September 1980*, NUREG/CR-2117 (ORNL/TM-7806) (June 1981).
6. R. E. Adams and M. L. Tobias, *Aerosol Release and Transport Program Semiannual Progress Report for April–September 1984*, NUREG/CR-3830 Vol. 2 (ORNL/TM-9217/V2) (December 1984).
7. T. S. Kress and A. L. Wright, *LMFBR Aerosol Release and Transport Program Quarterly Progress Report for July–September 1978*, ORNL/NUREG/TM-276) (January 1979).
8. R. E. Adams and M. L. Tobias, *Aerosol Release and Transport Program Quarterly Progress Report for July–September 1983*, NUREG/CR-3422 Vol. 3 (ORNL/TM-8849/V3) (April 1984).
9. R. E. Adams and M. L. Tobias, *Aerosol Release and Transport Program Semiannual Progress Report for October 1983–March 1984*, NUREG/CR-3830, Vol. 1 (ORNL/TM-9217/V1) (August 1984).

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This data record report summarizes the results from three tests involving mixed aerosols of uranium oxide and iron oxide in a steam-air environment and one test in a dry air environment. This research spons[illegible] by the U.S. Nuclear Regulatory Commission was conducted in the Nuclear Safety [illegible]ot Plant at the Oak Ridge National Laboratory. The purpose of this project is to provide a data base on the behavior of aerosols in containment under conditions assumed to occur in postulated LWR accident sequences; this data base will provide experimental validation of aerosol behavioral codes under development. In the report a brief description is given of each test together with the results in the form of tables and graphs. Included are data on aerosol mass concentration, aerosol fallout and plateout rates, total mass fallout and plateout, aerosol particle size, vessel atmosphere pressure, vessel atmosphere temperatures, temperature gradients near the vessel wall, and steam condensation rates on the vessel wall.

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