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Storage of LWR Spent Fuel in Air

Volume 3: Results from Exposure of Spent Fuel to Fluorine Contaminated Air

M. E. Cunningham
L. E. Thomas

June 1995

**Prepared for the U.S. Department of Energy
under Contract DE-AC06-76RLO 1830**

**Pacific Northwest Laboratory
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STORAGE OF LWR SPENT FUEL IN AIR
VOLUME 3 - RESULTS FROM EXPOSURE OF
SPENT FUEL TO FLUORINE-CONTAMINATED
AIR

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MASTER

PREFACE

The Behavior of Spent Fuel in Storage Project has conducted tests on the behavior of spent commercial nuclear fuel exposed to air. These tests were conducted for the U.S. Department of Energy, Office of Civilian Radioactive Waste Management.

Presented in this report are the collected data for Test Series B, the microstructural characterization data obtained since PNL-6640, Volume 2, was published, and a discussion of the impact of the fluorine contamination that was discovered after the oven exposures were completed. Two test series, Scoping and Test Series A, preceded Test Series B; the results from those two preceding test series were published by Campbell et al. (1987).

A series of reports had been planned to present the BSFS results; for example, in the prefaces to PNL-6640, Volumes 1 and 2,^(a) reference is made to a four-volume and five-volume report series, respectively. Only the first two volumes in the series have been published to date. This report is a companion report to the first two volumes of PNL-6640. A third and concluding volume of PNL-6640 may be prepared by the U.S. Department of Energy at a later date.

(a) Volume 1 - Design and Operation of an Experimental Facility for Conducting Spent Fuel Oxidation Tests (PNL-6640, Vol. 1).

Volume 2 - Microstructural Characterization of Low-Temperature Oxidized LWR Spent Fuel (PNL-6640, Vol. 2).

EXECUTIVE SUMMARY

The Behavior of Spent Fuel in Storage (BSFS) Project has conducted research to develop data on spent nuclear fuel (irradiated UO_2) that could be used to support design, licensing, and operation of dry storage installations. Test Series B conducted by the BSFS Project was designed as a long-term study of the oxidation of spent fuel exposed to air. It was discovered after the exposures were completed in September 1990 that the test specimens had been exposed to an atmosphere of bottled air contaminated with an unknown quantity of fluorine. This exposure resulted in the test specimens reacting with both the oxygen and the fluorine in the oven atmospheres. The apparent source of the fluorine was gamma radiation-induced chemical decomposition of the fluoro-elastomer gaskets used to seal the oven doors. This chemical decomposition apparently released hydrofluoric acid (HF) vapor into the oven atmospheres. **Because the Test Series B specimens were exposed to a fluorine-contaminated oven atmosphere and reacted with the fluorine, it is recommended that the Test Series B data not be used to develop time-temperature limits for exposure of spent nuclear fuel to air.** This report has been prepared to document Test Series B and present the collected data and observations.

The work conducted by the BSFS Project was performed for the U.S. Department of Energy's (DOE) Office of Civilian Radioactive Waste Management (OCRWM). The BSFS Project conducted Test Series B for research into the behavior of spent light-water reactor fuel under dry air storage conditions. The degradation mechanism of particular concern during dry air storage is oxidation of irradiated (spent) UO_2 in spent fuel rods having cladding breaches. Oxidation of the spent UO_2 can result in the development of lower density, higher volume phases. These high volume phases, in turn, can split the cladding resulting in a possible release of radioactive particles into the storage container.

Test Series B was conducted from December 1985 through September 1990, and the data from Test Series B are provided in this report. Test specimens were of two types: bare fragments of spent UO_2 and short segments of spent fuel rods. The rod segments were intended to simulate spent fuel rods with cladding breaches. The test matrix for Test Series B employed twelve sealed

ovens with the specimens exposed at one of six different temperatures (135°, 150°, 170°, 190°, 210°, and 230°C) and one of three initial atmospheric moisture levels (0°, 20°, and 40°C dew point); the test matrix with cumulative exposure periods is provided as Figure i. Gamma radiation sources (CsCl in stainless steel containers) were placed outside of the ovens to impose a gamma field of approximately 1×10^5 R/h on the specimens to simulate the self-imposed gamma field inside a dry storage cask. The bare fragment specimens were exposed for periods up to ~38,000 h (4.3 yr) while the rod segment specimens were exposed for periods up to ~26,000 h (3.0 yr). Rod segments, upon being observed to have split, were permanently removed from the test ovens.

During the course of the exposures, the ovens were periodically shut down and cooled to room temperature, the specimens removed, and visual examination, photography, and weighing of the specimens performed; profilometry of the rod segments was also performed. After these interim examinations, the specimens were returned to the ovens and brought back to the specified exposure conditions. Based on interim examination results, the following observations were made (see Section 3.0) of the specimens exposed to fluorine-contaminated air. First, there was no significant dependence of spent fuel weight gain upon the moisture level in the ovens. Second, there was an apparent effect of burnup on weight gain of the spent fuel. Low burnup (0 to 10 MWd/kgM) specimens exposed at temperatures of 210° and 230°C gained more weight than higher burnup spent fuel specimens. Third, there was a significant difference in the weight gain of the spent fuel specimens relative to that of the nonirradiated UO_2 specimens. The nonirradiated UO_2 gained weight more slowly at 135° to 150°C than the spent fuel, but more quickly for temperatures exceeding 150°C. The nonirradiated UO_2 specimens also formed powder at lower weight gain levels than the spent fuel specimens.

To supplement the interim examination data, samples were obtained from the specimens for analytical examination by x-ray diffraction, electron microscopy, or other techniques (see Section 4.0). These analyses identified the principal phase as hyperstoichiometric U_4O_9 ; $\text{UO}_2\text{F}_2 \cdot 1.5\text{H}_2\text{O}$ was also observed in some specimens. Phases identified in exceptionally high weight gain specimens exposed at 230°C were U_3O_8 and U-O hydrate phases such as schoepite and dehydrated schoepite. U-O hydrates in nonirradiated UO_2 specimens at

230°C were also found. Because in some cases only U_4O_9 was detected in powders, powder formation was determined to be a poor indicator of U_3O_8 formation (it had been expected that powder formation would be an indicator of U_3O_8 formation).

Analysis of phases present in samples of exposed spent fuel taken from split rod segments showed only small amounts of U_3O_8 present. The small amounts of U_3O_8 , although not quantified, are not believed to have been sufficient to have produced the necessary volume expansion of the spent fuel required to split the rod segments. A suggested alternative mechanism for the cladding splitting is delayed hydrogen cracking due to the HF vapor interaction with the Zircaloy.

It should be noted that there was no precedent found for the observed fluoridation of spent fuel and nonirradiated UO_2 under the temperature and probable atmospheric conditions that existed in the ovens during Test Series B. It is apparent, therefore, that a previously unrecognized regime of low-temperature interaction of fluorine with irradiated UO_2 and Zircaloy was encountered during the test series. This unexpected reaction of the spent fuel to a fluorine-contaminated atmosphere highlights a need to be concerned with contaminants during storage of spent fuel.

		Temperature, °C					
		135	150	170	190	210	230
Dew Point, °C	0	<u>Oven 10</u> Fragments (a) 36,134 h exposure No rod segments	<u>Oven 7</u> Fragments 37,002 h exposure 1 rod segment 23,114 h exposure ^(b) 1 split segment		<u>Oven 8</u> Fragments 33,170 h exposure 4 rod segments 19,137 h exposure 1 split segment		
	20		<u>Oven 1</u> Fragments 38,071 h exposure 2 rod segments 26,575 h exposure No split segments	<u>Oven 3</u> Fragments 36,260 h exposure 3 rod segments 24,192 h exposure 1 split segment <u>Oven 11</u> Fragments 35,338 h exposure 6 rod segments 18,653 h No split segments	<u>Oven 4</u> Fragments 36,122 h exposure 3 rod segments 18,997 h exposure 1 split segment	<u>Oven 9</u> Fragments 32,422 h exposure 2 rod segments 17,776 h exposure 1 split segment 1 pulled segment	<u>Oven 12</u> Fragments 31,661 h exposure 4 rod segments 18,064 h exposure 4 split segments
	40	<u>Oven 6</u> Fragments 36,371 h exposure 1 rod segment 23,554 h exposure No split segments	<u>Oven 2</u> Fragments 33,578 h exposure 2 rod segments 19,398 h exposure No split segments				

(a) All ovens had twelve boats of bare fragments; eleven with spent fuel fragments and one with nonirradiated UO₂ pellets.

(b) Listed exposure for rod segments is maximum for any segment in that oven.

FIGURE i. Summary of As-Completed Test Series B Matrix (Exposures to Fluorine-Contaminated Atmosphere)

ACKNOWLEDGMENTS

The Behavior of Spent Fuel in Storage (BSFS) Project was supported by the U.S. Department of Energy, Office of Civilian Radioactive Waste Management through the U.S. Department of Energy, Richland Operations Office. This work was begun under the Commercial Spent Fuel Management (CSFM) Program and was completed subsequent to the completion of the CSFM Program.

Although the authors have compiled the data and analyses presented herein, this report would not have been possible without the efforts of many other persons. Among those who have played key roles in the BSFS Project and need to be acknowledged are:

- Dr. E. R. Gilbert, the original BSFS Project Manager, who was assigned to another program in October 1989.^(a)
- Mr. T. K. Campbell (currently with Boeing Aircraft), who was responsible for designing the oxidation tests, developing the procedures, and managing the data collection and analyses through September 1989.
- Professor D. M. Barnhart (retired from Eastern Montana University) who, working through the Northwest College and University Association of Science (NORCUS) Program, assisted with the data analysis from 1987 through 1989.
- Professor K. M. Maloney (Southern University) who, working through the Northwest College and University Association of Science (NORCUS) Program, assisted with the data collection and analysis during 1990.
- Ms. C. K. Thornhill, who was the Task Leader responsible for hot cell operations throughout the BSFS Project.
- Mr. R. E. Holeman, who was the principal technician involved in daily operation of the ovens and data collection throughout the BSFS Project.
- Ms. N. J. Wildung, who was responsible for data base entry and data plotting.

(a) M. E. Cunningham was the succeeding, and completing, Project Manager.

ACRONYMS AND ABBREVIATIONS

AES	Auger electron spectrometry
BSFS	Behavior of Spent Fuel in Storage
BWR	boiling-water reactor
CSFM	Commercial Spent Fuel Management
DSC	differential scanning calorimetry
DOE	U.S. Department of Energy
EDS	energy-dispersive x-ray spectrometry
GE-VNC	General Electric Company - Vallecitos Nuclear Center
h	hour
HAZ	heat-affected-zone
HBR	H. B. Robinson (PWR)
HF	hydrofluoric (acid)
ISW	initial starting weight
JCPDS-ICDD	Joint Center for Powder Diffraction--International Crystallographic Diffraction Data
LWR	light-water reactor
M	Monticello (BWR)
NI	nonirradiated
O/M	oxygen-to-metal atom ratio; derived from weight gain data by assuming that all weight gain is due to uptake of oxygen only
OCRWM	Office of Civilian Radioactive Waste Management
PEELS	parallel-detection electron energy loss spectrometer
PB	Point Beach (PWR)
PNL	Pacific Northwest Laboratory
PWR	pressurized-water reactor
QC	Quad Cities-1 (BWR)
REW	run end weight
RSW	run start weight
SEM	scanning electron microscopy
SP	Shippingport (PWR)
S/V	surface-to-volume ratio
TEM	transmission electron microscopy
TGA	thermogravimetry analysis

t_p	time-to-powder formation
t_s	time-to-cladding split
XRD	x-ray diffraction
Zry	Zircaloy

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1.0 INTRODUCTION

Spent (used) nuclear fuel assemblies are placed into interim storage after their discharge from light-water reactors (LWRs). This interim storage begins with "wet" storage in a water pool at the reactor site. However, wet storage capacities at reactor sites are becoming exhausted (Department of Energy 1986) and some spent nuclear fuel is being placed in dry storage. Dry storage of spent nuclear fuel is currently licensable using inert cover gases (Gilbert et al. 1990) and dry storage using an oxidizing cover gas (air) is being investigated because it may be a simpler and less expensive option than inerted dry storage.

The behavior of spent nuclear fuel stored dry has been investigated by the Behavior of Spent Fuel in Storage (BSFS) Project conducted at Pacific Northwest Laboratory (PNL)^(a) for the U.S. Department of Energy's (DOE) Office of Civilian Radioactive Waste Management (OCRWM). The BSFS Project work on dry storage using air had the objective of providing data that could be used to set temperature and time limits for the exposure of spent fuel to air during storage.

Test Series B was the third^(b) test series conducted by the BSFS Project wherein spent fuel specimens were exposed to air atmospheres. This test series began in December 1985 and was concluded in September 1990. During the examination of samples collected after the exposures were completed, it was discovered that the test specimens had become contaminated with fluorine. As will be discussed in the body of this report, the source of the fluorine was apparently the gamma radiation-induced chemical decomposition of fluoro-elastomer gaskets used to seal the test ovens. The chemical decomposition

(a) Pacific Northwest Laboratory is operated by Battelle Memorial Institute for the U.S. Department of Energy under Contract DE-AC06-76RLO 1830.

(b) The first test series was a "scoping" test series employing two ventilated ovens. The Scoping Test Series was conducted during 1983 and 1984. The second test series was "Test Series A." This test series employed five of the twelve sealed ovens that were used in Test Series B. Test Series A ran during the period April through December 1985. The data from the Scoping and Test Series A tests are provided in Campbell et al. (1987).

apparently released hydrofluoric (HF) vapor into the oven atmospheres; the HF then reacted with the spent fuel specimens.

The exposure of specimens in Test Series B was completed in September 1990. Analytical examination work continued in FY-1991 on samples taken from the specimens after the completion of the test series. In March 1991, fluorine was detected during examination of a corrosion product sample taken from the surface of a rod segment end cap. Subsequent examinations of other samples, including those taken earlier in the test series, revealed widespread fluorine contamination of the specimens.

In Test Series B, spent fuel specimens from five different LWR sources were exposed to oven atmospheres at six temperatures from 135 to 230°C and one of three initial partial pressures of moisture. Another feature was the use of an imposed gamma field of approximately 1×10^5 R/h, using $^{137}\text{CsCl}$ clad with stainless steel, to simulate the self gamma field generated by spent fuel in dry storage. Some of the Test Series B specimens were exposed for periods up to ~38,000 hours (4.3 years). The specimens consisted of bare fragments of irradiated UO_2 (contained within open-top aluminum boats), short segments of spent fuel rods (UO_2 and Zircaloy), and non-irradiated UO_2 fuel pellets (also in open-top aluminum boats).

Test Series B specimens were characterized on both macro and micro scales. Visual examination, weight, and rod segment diameter data were taken during interim examinations of the specimens. Also, selected samples were taken from the specimens and subjected to analytical examination including optical microscopy, x-ray diffraction (XRD), and electron microscopy.

This report has been prepared to document Test Series B and present the data and observations, and is organized as follows. First, a general description of the experiment, along with the as-collected operating history data, is presented in Section 2. Next, the as-collected interim examination data (visual, weight gain, cladding profilometry) are presented in Section 3. Third, results of the analytical examinations (XRD, optical and electron microscopy, and other examinations) are presented in Section 4. Summary and concluding remarks are provided in Section 5. Most of the data and analyses are included in the appendices rather than within the body of the report.

It should be kept in mind when using this report that the data and analyses presented are for spent fuel exposed to an oven atmosphere consisting of bottled air contaminated with unknown amounts of fluorine. Because of significant, unquantified uncertainties associated with the data, for example, the quantity of fluorine in the oven atmospheres, the inter-reaction of fluorine and oxygen in the spent fuel specimens, etc., it is recommended that the Test Series B data not be used to develop time-temperature limits for exposure of spent nuclear fuel to air. In addition, the unexpected interaction of fluorine with the spent fuel under the test conditions highlights the need to understand the potential impact of possible contaminants in cover gases used during dry storage of spent fuel.

2.0 TEST SERIES B EXPERIMENT DESCRIPTION

For Test Series B, two spent fuel specimen-types (bare irradiated UO_2 fragments and short irradiated fuel rod segments) were exposed to oven atmospheres^(a) in a twelve-oven matrix. Provided in the following sections are summary descriptions of the Test Series B specimens, the experimental equipment and procedures, and the experiment operating history. Additional details on specimen preparation and the experimental equipment and procedures are provided in Thornhill, Campbell, and Thornhill (1988).

2.1 TEST SPECIMENS

Two types of spent fuel specimens were prepared. The first were bare fragments of irradiated UO_2 pellets removed from the spent fuel rods and placed in open-top aluminum trays (boats) for confinement during Test Series B. The surfaces of the bare fragments were completely exposed to the oven atmospheres. The second set of specimens were rod segments, short sections of fuel rods with end caps to confine the fragmented irradiated UO_2 within the cladding and a drilled hole in the fuel rod Zircaloy (Zry) cladding to allow air to contact the irradiated UO_2 . The specimens were prepared from spent fuel rods obtained from five commercial LWRs: Shippingport (SP),^(b) Point Beach (PB), and H. B. Robinson (HBR) pressurized-water reactors (PWRs); and Quad Cities-1 (QC) and Monticello (M) boiling-water reactors (BWRs).

The available pre-test characterization data varied from fuel to fuel. A summary of the spent fuel sources and the characterization data available when the fuel was obtained by the BSFS Project is provided in Table 2.1. Except for the M and QC spent fuel, the BSFS Project used spent fuel that had been originally acquired for other programs. The BSFS Project did not perform

-
- (a) The term "oven atmosphere" will be used rather than "air" because of the fluorine contamination. Oven atmosphere will refer to the atmosphere in the oven after backfilling with bottled air and being contaminated with an unknown amount of fluorine.
- (b) The acronyms for the reactor names will be used in some tables and figures in this report.

additional pre-test characterizations. A summary of preirradiation design characteristics is provided in Table 2.2.

Based on the limited irradiation history and postirradiation examination data, it may be concluded that the irradiations of the fuels were relatively benign. That is, the fuels were operated at low to moderate powers, and thus low to moderate temperatures, and had minimal microstructural changes during irradiation. For the HBR and SP fuels, fission gas release values were low (less than 0.5%) and optical ceramography revealed little microstructural change, i.e., grain growth or porosity redistribution, relative to the as-fabricated microstructures. Based on the power history data for the M and QC fuels (maximum linear heat generation rates of 22 kW/m with usual rod peak linear heat generation rates less than 16 kW/m), it may be conjectured that these fuels also had low fission gas release and minimal irradiation-induced changes to the as-fabricated microstructure. Non-exposed M and HBR spent fuel samples have been examined by the BSFS Project; this was discussed in Thomas et al. (1989). XRD analysis detected only UO_2 in the as-irradiated, non-exposed spent fuel samples.

Specific rods and rod-average burnup values from which the specimens were obtained are listed in Table 2.3. Also provided in the table are the number of specimens obtained from each spent fuel rod.

2.1.1 Bare Fragments

The bare fragment specimens were obtained from 3.8 to 4.4-cm long (1.5 to 1.75 in.) sections cut from designated locations of the spent fuel rods using either a diamond wafering or aluminum oxide saw blade.^(a) The irradiated UO_2 was removed from the cladding by striking the cladding with a hammer and allowing the fragments to fall into a stainless steel collection pan. The fragments were then sieved to remove fines less than No. 16 Tyler mesh (~1.2 mm) to obtain ~18 to 46 grams of fragments per specimen. The fragments were then placed into aluminum weigh boats that had been weighed to

(a) If the cut rod section was not going to be immediately prepared as a test specimen and inserted into an oven, the rod section was stored by placing it into a nitrogen-filled, labelled vial with a vented top; this was done within five days after cutting.

± 0.001 g. One boat of PNL-produced, nonirradiated UO_2 pellets (White et al. 1983; White and Gilbert 1986) was also included at each test temperature as a reference for comparison with previous work. The initial weights of the nonirradiated UO_2 pellets averaged ~ 16 grams per weight boat.

A total of 132 spent fuel bare fragment specimens (11 specimens per oven) and twelve nonirradiated UO_2 pellet specimens (1 specimen per oven) were prepared and tested. An example of spent fuel bare fuel fragments in a weigh boat is provided in Figure 2.1. A listing of the bare fragment specimens placed in each oven is provided in Appendix A.

An estimate of average fragment weight and volume was made for each bare fragment specimen. This was done to help characterize the bare fragment specimens. Polaroid photographs taken of each weigh boat at the end of an oven run were used to count the number of fragments in each weigh boat.^(a) Because not all fragments in a weigh boat could be easily discerned and counted, the estimated number of fragments is considered a minimum for each weigh boat. Average fragment weight in each weigh boat was determined from the estimated number of fragments per weigh boat and the measured total weight of UO_2 per weigh boat. Average fragment volume was determined from the average fragment weight and an assumed UO_2 density of 10.41 g/cm^3 . Measured UO_2 weight, estimated number of fragments, and calculated average fragment weight and volume are listed in Appendix A. Average fragment volume was found to generally decrease with increasing burnup; this is illustrated in Figure 2.2. In general, the spent fuel fragments from the BWR sources (QC and M) were larger than the spent fuel fragments from the PWR sources (SP, PB, and HBR).

2.1.2 Rod Segments

Specimens for the spent fuel rod segment tests were obtained from the same spent fuel rods as the bare fragment specimens (see Table 2.3). The rod segments were prepared for the purpose of simulating a defected spent fuel rod in dry air storage. To begin, segments were cut from selected spent fuel rod

(a) Photographs were not taken for the first few oven runs; therefore, the earliest photograph of each weight boat was used for the analysis.

locations. The cut fuel rod segments were then stored in stainless steel tubes until they could be prepared for testing.

The cut rod segments were typically 14.0 to 16.5-cm long (5.5 to 6.6 in.). To prepare each rod segment for testing, end caps of nonirradiated Zry-4 were welded onto the rod segment, the rod segment was leak tested, and then a single hole 0.76 mm in diameter (0.030 in.) was drilled at the axial midplane of the segment. This drilled hole constituted an artificially induced breach for oven atmosphere access to the irradiated UO_2 , and with the use of the welded end caps, was the only point of atmosphere access to the irradiated UO_2 .

A total of 35 spent fuel rod segments with artificially induced breaches were prepared, of which 33 were eventually placed in an oven and exposed. A list of the rod segment specimens is provided in Appendix B. An example of a prepared rod segment is provided in Figure 2.3.

2.2 TEST EQUIPMENT AND PROCEDURE

A detailed description of the test equipment and design methodology has been presented elsewhere (Thornhill, Campbell, and Thornhill 1988). Therefore, only aspects of the equipment relevant to the test procedure are repeated here.

The 132 spent fuel bare fragment, 12 nonirradiated UO_2 pellet, and 33 artificially breached rod segment specimens were allocated among the 12 ovens. The tests were conducted in a static atmosphere at nominal test temperatures of 135°, 150°, 170°, 190°, 210°, or 230°C. The oven atmospheres were initiated at dew point levels of 0°, 20°, or 40°C. Temperature control was specified to be $\pm 4^\circ\text{C}$ (Thornhill, Campbell, and Thornhill 1988); no dew point control was specified. To simulate the self-imposed gamma field of spent fuel under dry air storage conditions, Test Series B was conducted in the presence of a gamma radiation ($^{137}\text{CsCl}$ source) field of approximately 1×10^5 R/h. The entire oven system was installed in a radiochemical hot cell (Figure 2.4). The test matrix for the ovens (temperature and dew point) is provided in Figure 2.5.

Before the start of a run, weigh boats containing the bare fragment specimens were carefully set onto the oven shelves. There were three shelves

per oven and four weigh boats per shelf. The shelves were mounted on sliders to allow for ease of manipulator access. Next, diameter measurements on the rod segments were made^(a) and then the rod segment specimens were placed on the oven shelves between the bare fragment specimens; an illustration of an oven and the location of specimens is provided as Figure 2.6. Once positioned, the shelf position of each bare fragment specimen was maintained throughout the course of Test Series B (shelf positions are provided in Appendix A and B). The oven door was then sealed, the oven evacuated to -3.4 kPa, and back filled with bottled air. To obtain a given initial dew point in an oven, bottled air with the specified dew point was passed through the oven, equilibrated, and then the oven was sealed.

The duration of a test run was dependent upon the test temperature, with the higher temperature ovens being shut down and the specimens examined more frequently. Before the shut down of an oven, an aliquot of the oven atmosphere was removed for analysis. The specimens were allowed to cool before being carefully removed from the oven shelves and weighed twice (to within ± 0.001 g for the bare fragments and ± 0.01 g for the rod segments). The specimens were visually examined through a wall-mounted periscope system in the hot cell test facility. Also using the periscope system, instant black and white photographs at magnifications of 2X or 4X were taken of both the bare fragment and rod segment specimens. Photographs were taken along the length of a rod segment to form a composite photograph of the entire segment. The bare fragment specimens were visually examined for the presence of powders, crack formation, and color change. The rod segments were visually examined for the presence of strain, breaches in the cladding, and surface oxidation of the cladding. After each interim examination, the specimens were returned to their shelf positions and the oven restarted. The as-performed oven test schedule is provided in Appendix C and a schematic of the schedule is provided as Figure 2.7.

(a) Initially, rod segment diameter measurements were performed both manually with vernier calipers as well as with a laser micrometer. Unfortunately, the laser scanning component of the laser micrometer failed due to radiation damage. As a result, most of the measurements were made mechanically.

Oven door sealing gaskets were changed before to the start of every oven run. Silicone gaskets were initially used, but because of performance difficulties a switch was made to fluoro-elastomer Viton™ gaskets beginning in April 1986. The dates and oven runs when the gasket switch was made are identified in Table 2.4 and in Appendix C. It is after April 1986 that the specimens became exposed to an oven atmosphere of bottled air with an unknown quantity of fluorine.

2.3 OVEN OPERATION HISTORIES

Because the individual oven run times and overall duration of Test Series B were of long intervals, the oven operating conditions, temperature and pressure, were monitored on an approximately daily basis.^(a) Daily monitoring of the oven operating conditions was important to ensure run-to-run consistency, meaningful correlation, and evaluation and analysis of the experimental data. The as-collected oven temperature and cover gas pressure data are provided in Appendix D. Approximate average temperatures for each oven shelf are provided in Table 2.5. These shelf-average temperatures were calculated from the data provided in Appendix D by using a linear time-weighted assumption. The shelf-average temperatures are considered approximate because daily temperature data are not available and oven heating and cooling periods are not included; other approaches to estimating average temperatures could result in different values.^(b)

Oven atmosphere gas samples were collected and analyzed at the end of every run. The initial oven atmosphere was assumed to be equal to the atmosphere of the bottle from which the oven was filled. The atmosphere of each gas bottle was sampled and analyzed before to its initial use to fill any ovens. Results of gas analyses for new bottles and end-of-run oven atmo-

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- (a) Temperature and pressure were recorded approximately daily except during the shut down of an oven, a scheduled non-monitoring period, or weekends.
- (b) In particular, temperatures might be weighted on an exponential basis because oxidation is exponentially dependent on temperature. However, such a weighting scheme is difficult to implement because it requires assuming a value for the activation energy and the temperature data fluctuate over a wide range.

spheres are provided in Appendix E. Evaluation of the gas sample results led to two primary conclusions. First, significant quantities of carbon dioxide were present in the oven atmosphere at the end of a run; the source of the carbon dioxide was not identified. Second, no meaningful correlation between oxygen loss from the oven atmosphere and UO_2 weight gain, or other factors, could be made because of the presence of the carbon dioxide and the mass imbalances.

A final point to note, no fluorine was found in the oven atmosphere samples removed at the end of the oven runs. Although the mass spectrometer equipment would have detected fluorine if it was present in the sample at the time of analysis, the reactive nature of fluorine probably assured that it had reacted and been removed from the oven atmosphere sample before mass spectrometry analysis.

TABLE 2.1. Pre-Test Characterization of Spent Fuel

<u>Spent Fuel</u>	<u>Design</u>	<u>Irradiation History</u>	<u>Characterization Reason</u>	<u>Reference</u>
Monticello	yes	yes	for BSFS	(a)
Quad Cities	yes	yes	for BSFS	(a)
H.B. Robinson	yes	yes	ATM-101	Barner (1985)
Point Beach	yes	burnup only	waste vitrification	Wheelwright et al. (1979)
Shippingport	yes	yes	storage evaluation	Bradley et al. (1981)

-
- (a) A characterization data package was prepared by General Electric Company, Vallecitos Nuclear Center (GE-VNC) for Pacific Northwest Laboratory. The package was "Data Package for Fuel Segments," by D. M. Hoyt, dated July 1985, under Special Agreement M-5314-A-F.

TABLE 2.2. Preirradiation Characterization Parameters of Spent Fuel

<u>Parameter</u>	<u>Monticello</u>	<u>Quad Cities</u>	<u>H.B. Robinson</u>	<u>Point Beach</u>	<u>Shippingport</u>
Cladding outer diameter, mm	14.30	12.52	10.69	NA ^(a)	10.44
Cladding inner diameter, mm	12.42	10.80	9.45	NA	9.17
Cladding	Zry-2	Zry-2	Zry-4	Zry-4	Zry-4
Fuel diameter, mm	12.12	10.69	9.30	NA	9.08
Fuel enrichment, % ²³⁵ U	2.56	2.87	2.55	3.04	0.25 (depleted)
Fuel density, %TD	96.40	95.40	92.00	NA	NA
Fuel grain size, μm ^(b)	15.00	18.00	6-9.00 ^(c)	~10.00	~7.00

(a) NA = information not available.

(b) True grain size; as-observed*1.56.

(c) Postirradiation, fuel edge to centerline, at peak heat rate location.

TABLE 2.3. Sources for Test Specimens

<u>Specimen Source Reactor</u>	<u>Rod Identification</u>	<u>Rod-Average Burnup, MWd/kgM</u>	<u>Number of Bare Fragment Specimens</u>	<u>Number of Rod Segment Specimens</u>
Shippingport (PWR)	SP-D	23.7	4	0
	SP-E	23.7	4	0
	SP-F	23.7	4	0
Point Beach (PWR)	PB-B	29.5	17	6
H.B. Robinson (PWR)	G9C	28.4 ^(a)	0	8
	G9T	28.4 ^(a)	24	0
Quad Cities-1 (BWR)	1A01-1	22.6	8	2
	1A01-2	7.5	6	3
	1A03-3	12.0	10	2
	1B02-4	7.5	6	3
	1C02-1	15.9	14	1
	1C02-4	22.6	6	2
	DTA0103	16.6	9	2
Monticello (BWR)	0A03-4	28.7	7	2
	0A08-4	28.7	6	2
	5D18-3	28.7	7	2

Rod-average burnup values determined by:

SP: derived from power history

PB: derived from power history

HBR: gamma activity data used to determine burnup values by assuming a linear relationship between ¹³⁷Cs counts and burnup (Barner 1985; Guenther et al., 1988).

QC: supplied by GE-VNC

M: supplied by GE-VNC

Specimen burnup values determined by:

SP: same as rod-average burnup because no gamma profile available.

PB: same as rod-average burnup because no gamma profile available.

HBR: derived from rod-average burnup and axial gamma activity profile.

QC: derived from rod-average burnup and axial gamma activity profile.

M: derived from rod-average burnup and axial gamma activity profile.

(a) Derived from rod section G9, not rod sections G9C or G9T specifically.

TABLE 2.4. Starting Oven Runs and Dates for Use of Viton™ Gaskets
First Use of Viton™ Gaskets

<u>Oven Number</u>	<u>Run Number</u>	<u>Run Start Date</u>
1	3	May 5, 1986
2	4	August 8, 1986
3	3	May 7, 1986
4	4	May 16, 1986
5	4	May 19, 1986
6	2	August 12, 1986
7	3	July 24, 1986
8	4	May 6, 1986
9	3	April 16, 1986
10	3	April 29, 1986
11	3	April 24, 1986
12	4	May 21, 1986

TABLE 2.5. Shelf-Average Temperatures from Linear Time-Weighting

<u>Oven No. (nominal°C)</u>	<u>Shelf-Average Temperature (°C)/σ(°C)</u>		
	<u>Top</u>	<u>Middle</u>	<u>Bottom</u>
1 (150)	154.6/4.4	148.1/4.1	145.1/4.4
2 (150)	151.0/3.2	147.6/3.2	145.0/3.2
3 (170)	175.8/3.2	167.1/3.6	164.4/3.6
4 (190)	194.1/2.1	185.1/2.1	184.7/2.2
5 (190)	184.6/3.7	186.9/3.8	192.2/4.3
6 (135)	136.8/3.7	130.7/3.0	did not operate
7 (150)	151.1/3.9	145.9/4.4	144.5/7.7
8 (190)	195.7/2.8	188.0/2.4	186.3/2.6
9 (210)	213.9/3.2	206.6/2.8	205.4/3.3
10 (135)	136.1/7.7	131.6/6.8	130.1/7.1
11 (170)	176.4/3.9	171.3/4.2	169.7/4.0
12 (230)	233.5/2.1	224.5/2.4	228.6/2.2

Specimen 6B-8 (Monticello), 5347 h at 135°C

Specimen 6B-12 (Monticello), 5347 h at 135°C

FIGURE 2.1. Examples of Bare Fragment Spent UO_2 Specimens

39208015.5

FIGURE 2.2. Average Bare Fragment Size as a Function of Specimen Burnup

FIGURE 2.3. Example of Rod Segment Spent Fuel Specimen Prior to Oven Exposure (5B-c1)

FIGURE 2.4. Oven Rack, Containing Ovens 7 through 12, Installed in D-Cell of 324 Building.
A CsCl Capsule Holder is Positioned in Front of Ovens 7, 9, and 11

		Temperature, °C					
		135	150	170	190	210	230
Dew Point, °C	0	<u>Oven 10</u> Fragments (a) No rod segments	<u>Oven 7</u> Fragments 1 rod segment		<u>Oven 8</u> Fragments 4 rod segments		
	20		<u>Oven 1</u> Fragments 2 rod segments	<u>Oven 3</u> Fragments 3 rod segments <u>Oven 11</u> Fragments 6 rod segments	<u>Oven 4</u> Fragments 3 rod segments	<u>Oven 9</u> Fragments 2 rod segments	<u>Oven 12</u> Fragments 4 rod segments
	40	<u>Oven 6</u> Fragments 1 rod segment	<u>Oven 2</u> Fragments 2 rod segments				

(a) All ovens had twelve boats of bare fragments; eleven with spent fuel fragments and one with nonirradiated UO_2 pellets.

FIGURE 2.5. Test Series B Test Matrix

FIGURE 2.6. Oxidation Test Oven Interior

Oven

V = Switch to Viton™ Gasket
 R = Rod Segments Started
 S(x) = Split Rod Segment Observed (how many observed)

FIGURE 2.7. Schematic of Oven Schedule Showing Oven Run Start/Stop Dates, Viton™ Start Dates, Rod Segment Start Dates, and Rod Segment Split Dates

3.0 INTERIM EXAMINATION DATA

Presented within this section are the data, observations, and analyses on spent fuel bare fragment and rod segment specimens for Test Series B with a fluorine-contaminated air atmosphere. For the bare fragment specimens, visual, weight gain, and time-to-powder data and analyses are presented and discussed. For the rod segments, selected visual observations, weight gain, time-to-cladding split, and cladding profilometry data are presented and discussed. Finally, basic analyses of the reaction kinetics will be presented. Data and analyses will be presented as a function of nominal oven temperature.

Reference may occasionally be made to differences in reaction behavior between spent fuel specimens from BWR fuels versus those from PWR fuels. Nominally, the fuel from both reactor types was the same; i.e., low-enriched (-3% ^{235}U) UO_2 of $\sim 95\%$ theoretical density. Differences in reaction behavior that will be noted between specimens from PWRs and BWRs (for example, see Section 3.1.1) were most likely, but were not determined to be, due to differences in fuel postirradiation condition arising from different irradiation histories, rather than strictly because the fuel was irradiated in a BWR or PWR. For example, differences in fragment size, grain condition due to fission gas release (e.g., bubbles, interlinkage), etc., are possible because of different irradiation histories (power levels and burnups). In general, PWR fuels operate at higher power levels and to higher burnup levels than do BWR fuels. Increased power levels can lead to higher fuel temperatures, greater pellet fragmentation, more fission gas bubbles on grain boundaries (Lanning 1986; Barner et al. 1990) and other factors that might influence the rate and/or progression of spent fuel reaction to the oven atmosphere.

A summary of the as-completed Test Series B test matrix is presented as Figure 3.1. In this figure the number of bare fragment and rod segment specimens is provided, along with the maximum cumulative exposure time for each specimen type, and the number of rod segments that were observed to have split.

3.1 BARE FRAGMENTS

The spent fuel bare fragment specimens were the simplest to prepare and examine. This sample configuration, i.e., bare fragments in an open weigh boat, was expected to respond with the greatest reaction rate because of maximum exposure of the spent fuel to the oven atmosphere. In addition, because of ease of access to the irradiated UO_2 , this configuration facilitated the interim examinations and selection of samples for detailed characterization. Results of the interim examinations (weight gain and visual--time-to-powder) are presented in the following; results of the detailed characterizations are presented in Section 4.

3.1.1 Weight Gain Behavior

The complete as-measured bare fragment weight gain data set for Test Series B is provided in Appendix F. Cumulative exposure periods for the bare fragment specimens ranged from 31661 to 38071 hours (approximately 3.6 to 4.3 years). Observed weight gains ranged from nearly zero for nonirradiated UO_2 pellets at 135°C to 6% for spent fuel and 15% for nonirradiated pellets at 230°C. A wide range of weight gain behavior within an oven was generally observed. This is illustrated by Figures F.1 through F.12 (Appendix F) where the measured weight gain of each bare fragment specimen in each oven is presented.^(a)

Differences in weight gain behavior for the bare fragment specimens were observed between the specimens from different spent fuel sources. This is illustrated in Figures 3.2 through 3.8, which present average weight gain^(b) as a function of cumulative exposure time at each of the six test temperatures. In general, the bare fragment specimens from the SP and PB PWR spent

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- (a) To determine if reaction of the aluminum weigh boats contributed to the overall weight gain, empty weigh boats were added to all ovens. The highest temperature tests at 210° and 230°C indicated negligible contributions to the total weight gain of the bare fragment specimens. A summary of the weight gain of the empty weigh boats is provided in Appendix H. Degradation of the empty weigh boats was not observed during interim examinations.
- (b) Average weight gain within an oven for bare fragment specimens from a single spent fuel source.

fuel sources demonstrated the highest initial rates of weight gain at all the test temperatures. In addition, the SP and PB bare fragment specimens had the highest end-of-test weight gains at the lower temperatures of 135°, 150°, and 170°C. Because the bare fragment specimens from the SP and PB spent fuel sources also tended to have the smallest fragment size, the observed weight gain behavior indicates that fragment size may have affected the reaction behavior. That is, smaller fragments, with larger surface-to-volume ratios, had larger initial rates of weight gain than larger fragments. In addition, smaller fragment specimens obtained higher end-of-test weight gains than larger fragment specimens at temperatures of 135°, 150°, and 170°C. However, at the higher temperatures, specimens from all the spent fuel sources obtained similar end-of-test weight gains. Therefore, although fragment size apparently impacted the initial rate of weight gain, it is also apparent that, exposed to a high enough temperature, all spent fuel specimens did obtain the same level of weight gain.

The observed weight gain behavior of the nonirradiated UO_2 pellet specimens (one specimen per oven) differed from that of the spent fuel bare fragment specimens. Observed weight gains for the nonirradiated UO_2 pellets were very low at 135° and 150°C, and much lower than for the spent fuel bare fragment specimens. At the higher temperatures (170° to 230°C) the nonirradiated UO_2 pellets were observed to still have initial rates of weight gain less than the spent fuel bare fragment specimens. However, this period of low weight gain for the nonirradiated UO_2 pellets was then followed by a period of rapid weight gain to weight gain levels exceeding those observed for the spent fuel bare fragment specimens. The length of the period between exposure start and rapid weight gain decreased as exposure temperature increased. This weight gain behavior of the nonirradiated UO_2 pellets is illustrated as a function of time and temperature in Figure 3.9.

Effect of Burnup

It was reported by Campbell et al. (1987) that the level of weight gain for the bare fragment specimens from the BWR (QC and M) sources was independent of burnup at 230°C through an exposure period of 4000 hours. Examination of the complete data set, however, does reveal some apparent dependency of weight gain upon burnup level for the BWR-source bare fragment specimens at

the higher temperatures. This is illustrated in Figure 3.10 where weight gain at 230°C is presented as a function of specimen burnup after various exposure periods. Bare fragment specimens with lower burnup levels were observed to have greater weight gains after exposure exceeded 2000 hours and weight gains exceeded 3 to 4%. Similarly, at 210°C (Figure 3.11), a burnup dependency is revealed for specimens with weight gains greater than 4%; again, with the lower burnup specimens having the greater weight gain. There were not enough PWR bare fragment specimens at these temperatures to determine if there was also a burnup dependency for those fuel types.

A burnup dependency of weight gain behavior, if present, at temperatures below 210°C was much less distinct. No burnup dependency was observed for BWR-source bare fragment specimens at 135° or 170°C, or for the HBR (PWR) bare fragment specimens at 150°C.

Effect of Moisture Level

Data on the possible effect of oven atmosphere moisture level upon spent fuel behavior was obtained at dew points of 0°, 20°, and 40°C for the temperatures 135°, 150°, and 190°C. Observed weight gain data as a function of temperature and moisture level is presented in Table 3.1. In Table 3.1a, end-of-test average weight gains are listed for the varying exposure temperatures and dew points. In Table 3.1b, instantaneous rates of weight gain at 0.6% weight gain (see Section 3.3.1 for why 0.6% weight gain was selected) are listed for the varying exposure temperatures and dew points. There is no apparent consistent trend of weight gain behavior as a function of moisture level. For example, end-of-test weight gains at 150°C are higher at 20°C dew point than for either 0°C or 40°C dew point (Table 3.1a). Similarly, the spent fuel bare fragment specimens from BWR sources apparently had higher weight gains at 40°C dew point than at 0°C dew point while the bare fragment specimens from PWR sources displayed the opposite behavior (Table 3.1a). Finally, initial weight gain rates for the bare fragment sources also showed inconsistent trends as a function of moisture level (Table 3.1b).

Duplicative Specimens

Two ovens (3 and 11) were both operated at the nominal conditions of 170° and 20°C dew point to provide duplicative conditions for evaluating variations in reaction behavior among nominally identical material. Even for nominally identical spent fuel specimens exposed under nominally identical conditions, variations in end-of-test weight gains were observed.^(a) For example, end-of-test weight gains for QC (BWR) bare fragment specimens with a burnup of 24 MWd/kgM varied from 2.9 to 4.2%. In general, all spent fuel specimens in Oven 3 had higher end-of-test weight gains than the spent fuel specimens in Oven 11; examples of this are provided in Figure 3.12.^(b)

Observed variations in weight gain at the end of the exposure period for similar specimens (i.e., same source and burnup level), as presented in Figure 3.13, were 0.15% for the PB specimens in either oven and 0.25% for the QC specimens in Oven 3. Maximum variation for these specimens, including both ovens, were 0.57% for the M specimens, 0.83% for the PB specimens, and 1.22% for the QC specimens.

Various factors were considered that might have contributed to the specimens in Oven 3 having greater end-of-test weight gain than for specimens in Oven 11. Among these considered were: a) Viton™ use: use of Viton™ gaskets was initiated with run 3, at approximately the same date, for both ovens. Therefore, the period of operation with Viton™ gaskets was approximately the same for both ovens and not an apparent contributing factor. b) Fragment size: fragments from the same sources were approximately the same size in each oven; e.g., PB fragments were approximately 0.030 cm³ and QC fragments were approximately 0.100 cm³. The M fragments in Oven 3 were smaller (0.023 cm³) than those in Oven 11 (0.044 cm³). Therefore, it is not readily apparent that fragment size impacted weight gain differences between the two ovens, although the M specimen in Oven 3 had greater weight gain and

(a) Observed weight gains and differences among specimens are noted in this section. Possible reasons for observed variations are presented in Section 4.0, with characterization results presented in Section 4.2.3.1.

(b) In general, Oven 3 operated at a slightly lower temperature than Oven 11; see Table 2.5.

smaller fragment sizes. c) Oven temperature: although both ovens were nominally at the same temperature (170°C), there were differences in the temperature histories as detailed in Appendix D. However, if the average histories of the ovens are compared (Figures D.3 and D.11), it is apparent that Oven 11 had the higher average temperature (see Table 2.5). Therefore, oven temperature differences apparently do not account for the apparent weight gain bias between specimens exposed in the two ovens.

3.1.2 Powder Formation Times

The visual examination portion of the interim examinations was used to note changes in the appearance of the bare fragment specimens. One change of assumed importance was the period of time until powder formation was noted. The formation of powder has been assumed to correspond with the formation of U_3O_8 , time-to-split of breached fuel rods, and the formation of respirable particles (Einziger and Strain 1986).

The visual examinations were conducted by viewing the bare fragment specimens through the periscope system. During the viewing the boats were tilted to approximately a 45-degree angle that would result in fragment movement and reveal powder adhered to the boat's inner surface. The boats were then returned to a level position, rotated 180° and again tilted to 45° for a second observation. Based on the relative volumes of fragments and exposed powder, crude qualitative estimates of the volume percentage of powder were made. Although reasonably accurate estimates of small differences in powder formation were not possible, the onset of powder formation was relatively easy to observe. A qualitative estimate of the amount of powder for each bare fragment specimen at the end of each oven run is summarized in tables provided in Appendix G; other visual observations are also included with the tables. A summary of the bare fragment specimens observed to have formed powder is provided as Table 3.2. Included in this table are time-to-powder (t_p), observed weight gain at t_p , and specimen burnup.

Before the formation of powder, several observations were usually noted. The most prevalent observation was the formation of cracks in the fragments as illustrated in Figure 3.13. In general, the first indications of crack formation were the formation of "hairline" cracks in some fragments (Fig-

ure 3.13b). With increased exposure the number of cracks and the gap width increased (Figure 3.13c). In addition, the fragment surfaces usually changed from a semi-glossy luster to a dulled appearance.

Noticeable amounts of powder for the spent fuel bare fragment specimens were observed only at 230 and 210°C. At 230°C, an apparent burnup dependence for powder formation was observed. The low burnup specimens (8 to 12 MWd/kgM) formed powder first and eventually developed substantial volumes of powder. Two specimens with burnups of 17 and 24 MWd/kgM, respectively, eventually developed a noticeable amount of powder while the remaining specimens (17 to 34 MWd/kgM) developed only trace amounts of powder. No definite burnup dependence of powder formation was observed for the bare fragment specimens at 210°C. Noticeable amounts of powder were observed for specimens having burnups of 17, 24, and 33 MWd/kgM while only trace amounts were observed for the other specimens (burnups ranging from 8 to 30 MWd/kgM).

Bare fragment specimens exposed at 135 to 190°C generally developed only trace amounts of powder; no definite dependence of initial powder formation with burnup was observed. Two specimens demonstrated a different behavior. The first was specimen 1B-4 (150°C, 20°C dew point), which exhibited trace amounts of powder after 5105 hours and had noticeable powder after 38071 hours. The second exception was specimen 10B-11 (135°C, 0°C dew point), which developed trace powder after 4604 hours of exposure but then did not develop further, noticeable amounts of additional powder with additional exposure.^(a)

The nonirradiated UO₂ fuel pellets were observed to form powder after shorter exposure periods and lower weight gain than the spent fuel specimens at 170°C and above. The pellets were reacted totally, or nearly totally, to powder in less than 3500 hours at temperatures of 190 to 230°C.^(b) At 170°C, powder was first observed at 3500 hours with substantial powder

(a) The examination of powder samples from these two specimens was reported by Thomas et al. (1989).

(b) Note that at 190°, 210°, and 230°C, initial powder formation on non-irradiated UO₂ pellets occurred before the introduction of Viton™ gaskets.

formation by 10,000 hours. At 150°C, formation of powder was not observed until greater than 20,000 hours. Reaction phases present in these powders were not determined.

Trends of powder formation are illustrated in Figures 3.14 through 3.17. Time-to-powder data for the spent fuel bare fragment specimens, as a function of exposure temperature, are presented in Figure 3.14. The line in the figure is a lower bound for the data and the equation of the line is:

$$\log_e (t_p) = -8.53 + 7729 \left(\frac{1}{T} \right)$$

where t_p is in hours and T is in K. The two points at 135° and 150°C below the bounding line, and discussed above, have been excluded on the assumption that they are atypical of the powder formation observed in Test Series B. As presented by Thomas et al. (1989), these early-formed powders at 135° and 150°C did not have the same structure as powders formed at higher temperatures.

Time-to-powder as a function of specimen burnup is presented in Figure 3.15; lines are again provided to delineate the lower bound of t_p for each temperature. It appears that t_p is largely independent of specimen burnup except for the much shorter t_p periods for the nonirradiated UO_2 pellets. Also, there is little variation in minimum t_p for the temperature range 190° to 230°C.

Specimen weight gain at powder formation is presented as a function of t_p and specimen burnup in Figures 3.16 and 3.17, respectively. For each figure, a line is provided delineating the lower bound of weight gain at powder formation at each temperature. From the data presented in Figure 3.16, it is observed that for any temperature, the minimum weight gain at powder formation increases with increasing t_p . From the data presented in Figure 3.17, it is observed that, excluding the nonirradiated UO_2 pellets, minimum weight gain at powder formation is approximately constant as a function of burnup. In addition, from both figures, it may be observed that the minimum weight gain at powder formation apparently increases with increasing temperature.

3.2 ROD SEGMENTS

The artificially defected rod segment specimens were intended to be the most directly representative of spent fuel rods in dry air storage. Of particular interest was the observed period required before the cladding would split due to the stress/strain imposed by the increased specific volume of the reacted spent fuel. This time-to-split (t_s) is considered an important parameter in defining limiting conditions for storing spent fuel in air. Analyses of rod segment weight gain, t_s (visual), and cladding strain (profilometry) are presented in the following.^(a)

3.2.1 Weight Gain

The weight gain data set for the spent fuel rod segments is provided in Appendix I. The listed UO_2 weight gains are segment-average values and assume all weight gain may be attributed to the irradiated UO_2 . The weight gain increased with increasing temperature and, at comparable times and temperatures, the levels of weight gain for the rod segments were less than for comparable spent fuel bare fragments, as illustrated in Figure 3.18.

The difference in weight gain between the rod segments and the bare fragments is assumed to be due to limited access of the oven atmosphere through the artificially induced 0.76 mm breaches in the rod segments as compared to the unlimited accessibility of the oven atmosphere to the exposed bare fragments. This assumption is also made by other researchers, e.g., Einziger and Strain (1986).

The possible effect of oven atmosphere moisture level upon the weight gain behavior of the rod segments was evaluated. Only at 190°C were enough rod segments exposed to allow an evaluation: One QC rod segment was exposed at each of the three dew point levels; all three rod segments had end-of-test weight gains of approximately 2%. One PB rod segment was exposed at each of the three dew point levels; all three rod segments split with end-of-test weight gains ranging from 2.54% to 3.10%. One M rod segment was at 0° and 20°C dew point and two rod segments were at 40°C dew point; the highest weight

(a) Note: all rod segments were introduced into the ovens after the use of Viton™ gaskets was begun.

gain was 3% at 20°C dew point and one rod segment split at 40°C dew point with a weight gain of 2.37%. Based on these observations, it appears that oven atmosphere moisture level did not affect the reaction behavior of the rod segments.

3.2.2 Time-to-Split

The visual examination portion of the interim examinations for the rod segments was used to, first, identify if cladding splitting had begun and, second, to note any other changes in the visual appearance of the rod segments. T_s is defined as the elapsed time to the end of the run for which splitting was observed to have occurred. In actuality, the splitting could have occurred at any time during the oven run.

The t_s data for the rod segments that split are summarized in Table 3.3 and presented as a function of temperature in Figure 3.19. It may be seen from the data presented in Figure 3.19 that, as would be expected, t_s increases with decreasing temperature. The line in the figure roughly defines the lower bound of the data and may be expressed as

$$\log_e (t_s) = 0.29 + 4129 \left(\frac{1}{T} \right)$$

where t_s is in hours and T is in K. T_s as a function of rod segment burnup is presented in Figure 3.20. It would appear that there might be a slight increase with burnup for the lower bound of t_s , but that would be based principally on the rod segments exposed at 230°C.

Weight gain data for the split rod segments at the end of the oven runs when splitting was observed are presented as a function of t_s in Figure 3.21. Weight gain at split was greater than 2% for all rod segments except for the segment that split at 150°C. It should also be noted that the rod segment that split at 170°C had the second lowest weight gain at split. A possible trend to lower weight gain at splitting for rod segments exposed at lower temperatures is indicated by these data, but cannot be substantiated because of the limited quantity of data.

All cladding splits for the rod segments were observed to initiate from the original defect site. In most cases, a relatively straight longitudinal split developed. However, in a couple of cases, the split began to spiral around the cladding. End-of-test photographs of the split rod segments are provided in Section 4; comments on the appearance of the splits for those rod segments are provided in Table 3.3.

A principal visual observation of the rod segments that became apparent near the end of the exposures was the development of a reaction product on the surface of the rod segments and the nonirradiated endcaps.^(a) An example of this is shown in Figure 3.22; presented is the progressive development of the reaction product. As the reaction progressed, nodules became more apparent on the surface of the rod segment^(b) whereas the reaction product on the endcap was more uniformly distributed. The reaction at the defect site appeared to spread symmetrically about the defect. At rupture, the extent of the reaction appears to have progressed well beyond the initial diameter of the defect. It is important to point out that not all of the rod segments showed significant reaction of the cladding before rupture (see Figure 3.23, rod segment 9B-c5).

3.2.3 Cladding Strain

The cladding profilometry data are provided in Appendix J. Based on the profilometry data, there were negligible changes in rod segment diameter during the oven runs, except for the run in which cladding splitting was observed. In essence, any specific volume change of the irradiated UO_2 due to the reaction did not manifest itself as a gradual change in the diameter of the surrounding Zry before splitting. Typical local diameter variations along the length of a rod segment were approximately 0.002 and 0.003 inches ($\pm 0.35\%$ and $\pm 0.71\%$) for the BWR and PWR rod segments, respectively. All measurements on rod segments that had not split were within these bounding values.

-
- (a) Any weight gain that occurred in connection with this observed reaction is included in the total rod segment weight gain.
 - (b) Nodules were present on the cladding prior to oven exposure due to in-reactor corrosion; however, the presence of the nodules became more visually apparent with increasing exposure period in the ovens.

3.3 REACTION KINETICS

A basic kinetic parameter is the activation energy, which defines the temperature dependence of a reaction. Assuming that a reaction is exponentially dependent on temperature, the Arrhenius equation states:

$$K = A \cdot e^{-(Q/RT)}$$

where K is the reaction rate of interest, A is a constant, Q is the activation energy, R is the gas constant, and T is the absolute temperature. The activation energy may be derived from experimental data by recognizing that $-Q/R$ is the slope of $\log_e(K)$ versus $1/T$ from the following equation:

$$\log_e (K) = A' - \frac{Q}{RT}$$

Then,

$$Q = -R \cdot \text{slope}$$

where K is the rate (1/time), $A' = \log_e(A)$, $R = 8.314 \text{ kJ/mol}$, and T is in K.

Data from three different observed processes during Test Series B are used to derive activation energies: the rate of weight gain for the spent fuel bare fragments; the t_p formation for the spent fuel bare fragments; and the t_s for the spent fuel rod segments.

3.3.1 Bare Fragment Weight Gain

The weight gain rate for the bare fragment specimens can be defined in a variety of ways, for example: weight gain during a specific period, the maximum weight gain rate whenever it should occur, etc. Woodley, Einziger, and Buchanan (1989) have evaluated activation energy from rates determined at differing instantaneous values of weight gain. They concluded that oxidation must proceed to a weight gain of 0.6% (oxygen-to-metal ratio (O/M)^(a) increase of 0.1) before a steady-state rate constant could be determined.

Activation energy based on weight gain data has been determined for the Test Series B bare fragment specimens by applying the conclusion of Woodley, Einziger, and Buchanan (1989) that rates determined at an instantaneous weight gain of 0.6% are most applicable. Ideally, the weight gain rate at 0.6% weight gain is determined by the tangent to the weight gain curve; i.e., rate = dW/dt where W is weight gain and t is time. Practically, however, the instantaneous weight gain rate for each bare fragment specimen was determined from the slope of the line connecting the two data points bracketing 0.6% weight gain; i.e., rate = $(W_{+0.6\%} - W_{-0.6\%}) / (t_{+0.6\%} - t_{-0.6\%})$ where "+0.6%" and "-0.6%" indicate the data points post- and pre-0.6% weight gain, respectively. The resulting rate data are presented in Figure 3.24 as a function of inverse nominal oven temperature. The rate data in Figure 3.24 exclude data from the SP specimens and data from specimens exposed in the 135°C ovens. The SP data are excluded because there was only one specimen per oven and initial weight gain rates were significantly greater than for the other spent fuels. The 135°C data are excluded because of great variability.

A linear least-squares analysis was applied to the $\log_e(\text{rate})$ versus $1/T$ data presented in Figure 3.24 to determine the slope of the best fit line and, thus, the activation energy. This analysis was done for the complete data set plus for the bare fragment specimens from each reactor source. The following list includes the resulting activation energy values.

(a) Quoted values of O/M ratios for the test specimens are defined from the measured weight gain by assuming all weight gain is due only to oxygen uptake and assuming pre-exposure O/M of 2.00.

<u>Fuel Source</u>	<u>Activation Energy, kJ/mol</u>
All (except SP)	80.6
Quad Cities	67.8
Monticello	75.6
H.B. Robinson	93.9
Point Beach	99.7

NOTE: depending on the specimen and oven, 0.6% weight gain may have occurred before or after introduction of the Viton™ oven door seals.

3.3.2 Bare Fragment Time-to-Powder

The applicable bare fragment time-to-powder (t_p) data are provided in Table 3.2. The rate for t_p was defined as the inverse t_p , i.e., $1/t_p$; therefore, activation energy for powder formation may be determined from the slope of $\log_e(1/t_p)$ versus $1/T$. The rate data are presented in Figure 3.25 and the result of the linear least-squares analysis for activation energy is 49.5 kJ/mol. An analysis based on the specimens having burnup greater than 10 MWd/kgM also resulted in an activation energy of 49.5 kJ/mol. **NOTE:** all powder was observed to form after the introduction of the Viton™ oven door seals.

3.3.3 Rod Segment Cladding T_s

The applicable rod segment cladding t_s data are provided in Table 3.3. The rate for cladding t_s was defined as the inverse t_s ($1/t_s$); therefore, activation energy for cladding split may be determined from the slope of $\log_e(1/t_s)$ versus $1/T$. The rate data are presented in Figure 3.26 and the result of the linear least-squares analysis for activation energy is 24.8 kJ/mol. An analysis based on the least t_s at each temperature resulted in an activation energy of 34.6 kJ/mol.

NOTE: all cladding splitting was observed to occur after the introduction of the Viton™ oven door seals.

TABLE 3.1. Bare Fragment Specimen Weight Gain Trends as a Function of Moisture Level

(a) Average End-of-Test Weight Gain, %

Spent Fuel Source	Dew Point at 135°C			Dew Point at 150°C			Dew Point at 190°C						
	0°C		40°C	0°C		20°C	40°C	0°C		20°C		40°C	
QC	0.17	<	0.38	2.11	<	3.06	>	2.54	4.66	>	4.32	<	4.46
M	0.36	<	0.56	-		-	1.92	-		4.11	≡		4.18
HBR	1.05	-	-	1.93	<	2.64	>	2.25	-		-		-
SP	3.26	≡	3.40	4.04	<	7.31	>	5.47	4.66	>	4.13	>	3.32
PB	2.75	>	2.23	4.23	<	4.10	>	2.30	3.33	≡	3.36	<	3.50

(b) Average Weight Gain Rate at 0.6% Weight Gain, %/hr

Spent Fuel Source	<u>Dew Point at 150°C</u>					<u>Dew Point at 190°C</u>				
	<u>0°C</u>		<u>20°C</u>		<u>40°C</u>	<u>0°C</u>		<u>20°C</u>		<u>40°C</u>
QC	9.16x10 ⁻⁵	<	2.42x10 ⁻⁴	>	6.31x10 ⁻⁵	7.69x10 ⁻⁴	>	5.17x10 ⁻⁴	>	4.33x10 ⁻⁴
M	-		-		9.06x10 ⁻⁵	-		7.38x10 ⁻⁴	>	6.52x10 ⁻⁴
HBR	5.74x10 ⁻⁵	>	4.44x10 ⁻⁵	<	5.53x10 ⁻⁵	-		-		-
PB	-		2.13x10 ⁻⁴	>	1.15x10 ⁻⁵	1.29x10 ⁻³	>	7.93x10 ⁻⁴	<	1.02x10 ⁻³

TABLE 3.2. Summary of Observed Powder Formation Data

<u>Temperature, °C</u>	<u>Specimen</u>	<u>Time-to-Powder, hr^b</u>	<u>Weight Gain at Powder, %^b</u>	<u>Specimen Burnup, MWd/kgM</u>
230	12B-12	<1679 ^a	<3.55	0
	12B-6	<1679 ^a	<3.66	8.0
	12B-7	<1679 ^a	<3.53	8.0
	12B-4	1679	3.68	12.0
	12B-8	2517	3.71	17.2
	12B-5	5430	4.44	17.7
	12B-1	5430	5.12	23.7
	12B-9	5430	4.00	24.2
	12B-2	5430	4.47	29.5
	12B-11	5430	3.7	33.9
	12B-10	5430	4.46	34.4
	12B-3	14751	5.50	26.8
210	9B-12	<2362 ^a	<2.12	0
	9B-8	6145	3.92	7.7
	9B-9	6145	3.89	17.2
	9B-10	6145	3.84	23.8
	9B-7	6145	3.65	32.6
	9B-11	9325	4.02	23.7
	9B-5	25391	5.53	12.5
	9B-1	25391	4.48	23.7
	9B-4	25391	4.38	27.6
	9B-2	25391	4.07	29.5
190	5B-12	<2831 ^a	<1.49	0
	8B-12	<3517 ^a	<1.15	0
	4B-12	<3716 ^a	<1.46	0
	8B-11	3517	1.77	16.8
	8B-10	3517	2.06	18.7
	5B-7	6644	2.06	10.1
	5B-9	6644	3.48	22.4
	8B-9	10019	3.80	19.8
	8B-6	10010	3.83	23.5
	8B-5	10019	3.82	23.7
	8B-4	10019	1.18	33.5
	4B-4	17130	3.55	7.9
	4B-8	17130	2.83	12.5
	4B-11	17130	2.70	17.5
	4B-9	17130	3.15	19.1
	4B-10	17130	3.15	19.6
	4B-7	17130	3.21	23.5
	5B-10	17590	3.73	27.5
	4B-6	30556	4.20	23.3
	4B-5	30556	3.98	32.4
	5B-5	35347	4.53	12.5
	5B-8	35347	4.31	16.0
	5B-6	35347	4.13	18.0

TABLE 3.2. (contd)

Temperature, °C	Specimen	Time-to-Powder, hr ^b	Weight Gain at Powder, % ^b	Specimen Burnup, MWd/kgM
190	5B-3	35347	4.05	22.6
	5B-4	35347	4.15	23.0
	5B-11	35347	3.80	34.4
170	3B-12	3578	0.21	0
	11B-12	7633	0.26	0
	11B-8	24918	3.39	8.0
	11B-9	24918	1.98	17.2
	11B-10	24918	1.96	17.2
	11B-11	24918	2.19	24.2
150 ^c	1B-4	7217	0.88	7.7
	7B-12	20436	0.49	0
135	10B-11	4600	0.04	24.2
	6B-9	33380	0.62	21.5

-
- (a) Significant amounts of powder were observed at first recorded visual examination (see Appendix G), therefore indicating powder formation had occurred during previous oven runs.
- (b) Time and weight gain at conclusion of oven run where powder was first observed.
- (c) All spent fuel bare fragment specimens in Ovens 1 and 2 showed traces of powder formation at the final examination, 35221 and 33578 hours, respectively.

TABLE 3.3. Summary of Observed Time-to-Split Data

<u>Temperature, °C</u>	<u>Rod Segment</u>	<u>Time-to-Split, hr</u>	<u>Weight Gain, %</u>	<u>Burnup, MWd/kgM</u>	<u>Comments</u>
230	10B-c2	4894	2.66	7.0	wide split; spirals in one direction from breach and opposite end cap fell off; full-length
	10B-c3	7196	2.85	23.4	straight split; extends about 2 cm to each side of breach
	11B-c3	9406	3.03	33.3	straight split; extends almost to cladding heat affected zones ^(a)
	11B-c2	18064	3.78	23.0	split is straight in one direction from breach and spirals in the other direction; full-length
210	9B-c5	6458	3.09	28.4	straight split; full-length
	8B-c4	17776	3.40	13.0	removed prior to splitting for examination; assume 17776 h for t_s
190	8B-c1	8574	2.85	29.5	wavy split; extends into cladding heat affected zones
	1B-c2	17757	2.54	29.5	small, tight split; extends about 0.5 cm to each side of breach
	9B-c2	17757	2.37	33.7	small, tight split; extends about 0.5 cm to each side of breach
	4B-c2	18997	3.10	29.5	straight split; extends greater than 2 cm to each side of breach
170	3B-c3	24192	2.24	28.4	straight split; extends about 2 cm to each side of breach
150	7B-c2	23114	1.16	29.5	straight split; extends about 3 cm to each side of breach

(a) Heat affected zones are at end of cladding sections and are due to welding on of nonirradiated Zircaloy endcaps.

DEW POINT (°C)	TEMPERATURE (°C)					
	135	150	170	190	210	230
0	<u>Oven 10</u> F(12) 36134 h	<u>Oven 7</u> F(12) 37002 h R(1) 23114 h 0 split		<u>Oven 8</u> F(12) 33170 R(4) 19137 h 1 split		
20		<u>Oven 1</u> F(12) 38071 h R(2) 26575 h 0 split	<u>Oven 3</u> F(12) 36260 h R(3) 24192 h 0 split ----- <u>Oven 11</u> F(12) 35338 h R(6) 18653 h 0 split	<u>Oven 4</u> F(12) 36122 h R(3) 18997 h 1 split	<u>Oven 9</u> F(12) 32422 h R(2) 17776 h 1 split 1 pulled	<u>Oven 12</u> F(12) 31661 h R(4) 18064 h 4 split
40	<u>Oven 6</u> F(12) 36731 h R(1) 23554 h 0 split	<u>Oven 2</u> F(12) 33578 h R(2) 19398 h 0 split		<u>Oven 5</u> F(12) 35346 h R(5) 17757 h 2 split		

F = Bare fuel test fragments (number of samples in parenthesis).
R = Rod segments (number of segments in parenthesis).

FIGURE 3.1. Summary of As-Completed Test Series B Test Matrix

FIGURE 3.2. Average Weight Gain for Bare Fragment Specimens at 135°C (Viton™ seal use begun with Run 2, 3192 h for Oven 6 and Run 3, 4604 h for Oven 10)

FIGURE 3.3. Average Weight Gain for Bare Fragment Specimens at 150°C (Viton™ seal use begun with Run 3, 2849 h for Oven 1; Run 4, 4335 h for Oven 2; and Run 3, 3387 h for Oven 7)

FIGURE 3.4. Average Weight Gain for Bare Fragment Specimens at 170°C (Viton™ seal use begun with Run 3, 1704 h for Oven 3 and Run 3, 1492 h for Oven 11)

39208015.35

FIGURE 3.5. Average Weight Gain for Spent Fuel Bare Fragment Specimens at 190°C (Viton™ seal use begun with Run 4, 1544 h for Oven 4; Run 4, 1384 h for Oven 5; and Run 4, 1360 h for Oven 8)

FIGURE 3.6. Comparison of Average Nonirradiated and Spent Fuel Bare Fragment Weight Gains at 190°C (Viton™ seal use begun with Run 4, 1544 h for Oven 4; Run 4, 1384 h for Oven 5; and Run 4, 1360 h for Oven 8)

FIGURE 3.7. Average Weight Gain for Bare Fragment Specimens at 210°C (Viton™ seal use begun with Run 3, 348 h)

39208015.37

FIGURE 3.8. Average Weight Gain for Bare Fragment Specimens at 230°C (Viton seal use begun with Run 4, 775 h)

39208015.30

FIGURE 3.9. Average Weight Gain for Nonirradiated UO_2 Pellet Specimens

FIGURE 3.10. Burnup Dependence of Weight Gain at 230°C

39208015.3

FIGURE 3.11. Burnup Dependence of Weight Gain at 210°C

39208015.23

FIGURE 3.12. Comparison of Weight Gain Data from Replicate Ovens 3 and 11 (170°C, 20°C Dew Point) (Viton™ seal use begun with Run 3, 1704 h for Oven 3 and Run 3, 1492 h for Oven 11)

a) No observable cracking (end of Run 5, 2362 h)

b) Some cracks
(end of Run 7, 4350 h)

c) Extensive cracking
(end of Run 9, 5401 h)

FIGURE 3.13. Example of Development of Cracks in Bare Fragment Specimens (Specimens 9B-9, Quad Cities, 210°C)

39208015.11

FIGURE 3.14. Time-to-Powder for Spent Fuel Bare Fragment Specimens as a Function of Temperature

39208015.12

FIGURE 3.15. Time-to-Powder for Spent Fuel Bare Fragment Specimens as a Function of Specimen Burnup

39208015.14

FIGURE 3.16. Weight Gain at Powder Formation for Spent Fuel Bare Fragment Specimens as a Function of Time-to-Powder

39208015.13

FIGURE 3.17. Weight Gain at Powder Formation for Spent Fuel Bare Fragment Specimens as a Function of Specimen Burnup

39208015.22

FIGURE 3.18. Comparison of Weight Gain for Bare Fragments and Rod Segments (Viton™ seal use begun with Run 4, 1384 h for Oven 5; Run 3, 1492 h for Oven 11; and Run 4, 775 h for Oven 12. Viton™ seals in use for entire rod segment exposures.)

39208015.7

FIGURE 3.19. Time-to-Split for Spent Fuel Rod Segments as a Function of Temperature

39208015.6

FIGURE 3.20. Time-to-Split for Spent Fuel Rod Segments as a Function of Rod Segment Burnup

39208015.8

FIGURE 3.21. Rod Segment Weight Gain at t_s as a Function of Time-to-Split

FIGURE 3.22. Example of Reaction Product on Zircaloy Cladding of Rod Segment 11B-c2

Spent Fuel Rodlet Failures During Air Oxidation

B-C5, 210°C, 6458 h

11B-C3, 230°C, 9406 h

10B-C2, 230°C, 4894 h

11C-C2, 230°C, 18064 h

10B-C3, 230°C, 7196 h

3.41

FIGURE 3.23. Examples of Cladding Reaction Product Near Defect Site

39208015.19

FIGURE 3.24. Rate Data for Determining Activation Energy for Weight Gain of Spent Fuel Bare Fragments

FIGURE 3.25. Rate Data for Determining Activation Energy for Powder Formation on Spent Fuel Bare Fragments

39208015.17

FIGURE 3.26. Rate Data for Determining Activation Energy for Cladding Splitting of Spent Fuel Bare Fragments

4.0 ANALYTICAL EXAMINATIONS

Characterization of bare fragment and rod segment specimens from Test Series B covered a wide range of sample conditions and analytical methods. The purpose of these analyses was to provide a physical basis for understanding the reaction behavior indicated by the weight gains, and the reasons for failure and reaction of the rod segments. Spent fuel fragments sampled at intermediate exposure times were also examined to determine the cause of powder formation in instances where U_3O_8 was not expected based on the weight gains or test temperatures.

Previous analyses of fuel fragments sampled at intermediate exposure times of 4600 to 16,600 h were reported in Thomas et al. (1989). The fluorine contamination was not recognized when this interim report was prepared and the contamination may have affected the reported results. The methods used in these analyses were scanning electron microscopy (SEM), x-ray powder diffractometry (XRD), Auger electron spectrometry (AES), and transmission electron microscopy (TEM). The SEM was used mainly to examine the intergranular fracture surfaces of the fuel to observe the effects of the reaction along the grain boundaries. XRD was used to identify the crystalline phases in bulk samples, and AES provided information on the local reaction state of the grain boundary fracture surfaces. TEM was used to examine details of the microstructures and to identify reaction products by electron diffraction. For completeness, the sample conditions, analyses, and results given in Tables 4.1 and 4.2 of Thomas et al. (1989), are reproduced in Appendix K of this report.

The main results from the interim analyses of bare fragment specimens (Thomas et al. 1989) are summarized as follows:

- Reaction of spent fuel at 135 to 190°C to weight gains as high as 3.25% (average O/M of 2.55) produced U_4O_9 or $\alpha-U_3O_7$ (in one low-burnup fuel) but no other products detectable by XRD. Although vein-like structures containing very fine-grained UO_2 and U_3O_8 were observed by TEM in some of the more highly reacted samples, the amounts of this product were considered too small to account for the weight gains. These results indicated a high degree of hyperstoichiometry in the U_4O_9 formed.
- The reaction behavior of LWR spent fuel in the oven atmospheres differed significantly from that of nonirradiated UO_2 . The differences included

the tendency of spent fuel to react primarily along grain boundaries rather than from external surfaces, initial formation of U_4O_9 , and apparently greater resistance of the fuel to formation of U_3O_8 . This result is consistent with recently reported results of independent studies on the low-temperature air oxidation of LWR spent fuel in which no fluorine contamination occurred (Thomas, Einziger, and Buchanan 1993; Thomas, Slagle, and Einziger 1991).

- The reaction of spent fuel and nonirradiated UO_2 to O/Ms of 2.73 and higher at 230°C produced U_3O_8 and U-O hydrates (schoepite and dehydrated schoepite). A weight gain of over 10% in one sample of nonirradiated UO_2 (equivalent O/M of 3.78) resulted from formation of U-O-hydrates, primarily schoepite ($UO_3 \cdot 2H_2O$).
- Powder formation during the tests was an unreliable indicator of U_3O_8 formation. In some samples, powder formed with no detectable U_3O_8 ; in other samples, U_3O_8 formed without producing powder.
- In agreement with other characterization studies of LWR spent fuel (e.g., Thomas and Guenther 1989; Thomas, Beyer, and Charlot 1992), the spent fuels used in this work showed only minor precipitation of fission products. The only fission-product precipitates observed in low (<0.5%) gas release fuels, such as used in Test Series B, are small bubbles containing the fission gases Xe and Kr and metallic particles of the solid-solution alloy ϵ -ruthenium (Mo-Ru-Pd,-Tc-Ru alloy). All other fission products, including the cesium, remained in solution in the UO_2 matrix of these fuels.
- The most useful analyses in these interim examinations proved to be XRD and TEM. Sample charging under the electron beam and beam-induced sample degradation prevented useful distinction of different U-O oxidation states by AES. Consequently, AES analyses were not continued in this work.

Subsequent analyses of the reacted spent fuel, described in this report, used several additional analysis methods as well as variations or extensions of the XRD, TEM, and SEM methods. The samples examined and analyses performed since the work reported by Thomas et al. (1989), are listed in Table 4.1. These analyses were tailored to answer specific questions regarding the fuel reaction behavior. In particular, the questions were: 1) What caused the defected rod segments to split open at relatively short times and low test temperatures? 2) Did the reaction cause fuel swelling by formation of difficult-to-detect amorphous phases or other nonconventional effects? 3) What caused the accelerated (and unexpected) reaction of the rod segment cladding and nonirradiated endcaps in some tests?, and 4) After fluorine contamination

was detected in the rod segment reaction product and in reacted fuel, how extensive was the contamination and when was it first detectable?

The additional analyses used to address these questions included the following:

- Immersion density (ρ_i) measurements of the reacted spent fuel.
- "Reverse" O/M determinations $(O/M)^{-1}$ of reacted spent fuel by measuring sample weight losses upon reduction to $UO_{2.00}$ in an equilibrated reducing gas mixture.
- Thermal analysis by dynamic thermogravimetry analysis (TGA) and differential scanning calorimetry (DSC).
- Ceramographic examination of sections from rod segments.
- Micro-area compositional analysis by energy-dispersive x-ray spectrometry (EDS) in the SEM. This method served mainly to detect the presence of fluorine in the reacted fuel cladding and spent fuel samples.
- Cold stage (-170°C) examination of reacted spent fuel specimens in a TEM, used to identify phases that decomposed rapidly under the electron beam at normal observation temperatures near 25°C .

This section will begin with a short summary of the analysis methods used in examining samples from the specimens. The results of the analyses will then be presented. Finally, a discussion on the significance of the results will be provided.

4.1 ANALYSES METHODS

The analysis equipment and methods used in examining samples from the spent fuel specimens are provided in the following.

X-ray Diffraction (XRD) The XRD analyses were performed with a computer-controlled diffractometer (Scintag PAD V) equipped with a thermoelectrically cooled Si(Li) x-ray detector. Samples containing 1 to 3 mg of spent fuel (to limit the sample radioactivity) were prepared by grinding of material with a few drops of collodion/amyl acetate solution and pipetting the resulting slurry onto a glass slide. The collodion served as a binder for the sample on

the mounting slide, and produced minimal background interference with the diffraction pattern from the sample. For special analyses, the amorphous background from the mounting slide was avoided by use of a low-background quartz holder, and the quantities of sample and collodion were controlled by weighing. Samples were run with a copper x-ray tube operated at 50 kV, 40 mA (2 kW power). Typical run conditions were 0.02° 2θ per step with a 0.3° final detector slit. Run times of 15 to 20 h were generally used to obtain satisfactory counting statistics from the limited-quantity samples. The range of diffraction angles was usually 3 to 80° 2θ for general phase identification, or 46 to 60° 2θ to distinguish the various UO_2 -structure phases (UO_2 , U_4O_9 , and U_3O_7).

Background subtraction and $\text{K}\alpha$ peak stripping from the diffraction patterns were performed using a Scintag-supplied computer program. Correct operation of this program was verified by visually examining the results of the processing operations. Most of the UO_2 reaction products were identified by visually comparing the diffraction patterns with standard patterns from the Joint Centre for Powder Diffraction-International Crystallographic Diffraction Data (JCPDS-ICDD) database. The database was current through Set No. 37 at the time the analyses was performed. Unidentified phases were also automatically searched against the database, but final identifications were always verified by direct visual comparisons of unknown and standard patterns.

Transmission Electron Microscopy (TEM) TEM examinations of the fuel samples were performed in either a 120 or a 200 kV transmission/scanning transmission electron microscope (TEM/STEM) equipped with a LaB_6 electron source, an EDS detector for x-rays, and a parallel-detection electron energy loss spectrometer (PEELS). The sample preparation (McCarthy and Thomas 1985) involved embedding, sectioning, and ion micromilling a 200 to 400 μm fuel particle to a thickness suitable for TEM examination and analysis. Most of the TEM analyses involved conventional TEM imaging and selected-area diffraction analysis. Examinations were also performed with an x-y tilting, liquid-nitrogen-cooled sample holder.

Scanning Electron Microscopy (SEM) SEM examinations were done at 15 to 35 keV using both secondary and backscattered electrons. The image contrast from backscattered electrons is sensitive to average atomic number of the sample, and was particularly useful for distinguishing phases according to their light-element content. A Si(Li) x-ray detector with selectable windows for enhanced detection of light elements such as oxygen and fluorine also proved useful for this work.

Immersion Density Measurements Densities of reacted and non-exposed spent fuel samples were determined by the Archimedian method of weighing in media of different densities (air and kerosene at 20°C). The densities were checked by comparison with Invar standards ($\rho_i = 8.8$, near that of U_3O_8). The reported density values and standard deviations are averages of five determinations for each sample.

Reverse O/M The oxygen to metal (assumed to be uranium) ratios of selected fuel samples were determined from measured weight losses upon reducing the samples to $UO_{2.00}$. Samples of approximately 250 mg were weighed to ± 0.1 mg using a calibrated balance before and after reduction with an equilibrated H-CO gas mixture at 900°C.

Ceramography Transverse and longitudinal sections from the rod segments were prepared by standard ceramographic methods in a hot cell. After final polishing with 0.05 μm alumina, the samples were etched with 90% H_2O_2 -10% H_2SO_4 to show the structure. A brief dip in the etchant (or a swipe with an etchant-saturated cloth) followed by an immediate rinse with water produced extensive grain boundary attack on the reacted sample regions. Cooling the etchant helped to retard the grain boundary attack and minimize grain fallout from the reacted areas. The optical examinations were conducted with a shielded metallograph at magnifications up to 750X. Following examination, samples for XRD or TEM analysis were obtained by chipping small fragments from selected areas of the ceramographic mounts.

Thermal Analysis Four samples from bare fragment specimens (including one nonirradiated sample) collected at termination of the exposures were analyzed

by TGA and DSC using a computer-controlled Perkin-Elmer DSC-2 analyzer. The DSC and TGA runs in this analyzer are done separately, with different analysis chambers, and required calibrations of the thermocouples, the thermobalance, and the calorimeter apparatus. The calorimeter was calibrated by measuring the reaction heat of perkallloy standard. In both types of analysis, finely ground samples weighing 10 to 30 mg were placed in clean gold sample holders and heated in air at a rate of 10°C/min. The TGA runs were made by heating the samples from 40 to 650°C. For DSC, the samples were run at two temperature ranges to improve the baseline correction. These were 40 to 550°C, and 500 to 750°C. Some of the TGA samples were recovered after analysis and analyzed by XRD to determine the final product.

4.2 ANALYSIS RESULTS

Presentation of the characterization results is broken into five areas based on sample type: 1) spent fuel from split and nonsplit rod segments; 2) bare fragments collected at intermediate exposures; 3) bare fragments collected after the conclusion of exposures; 4) reaction products taken from rod segment cladding and endcaps; and 5) other samples tested for fluorine contamination.

4.2.1 Fuel From Rod Segments

Observation of cladding splitting after unexpectedly short periods for some of the rod segments prompted characterization of those segments to determine the cause of splitting. Because it was suspected that the rod segments would split due to U_3O_8 formation, the initial characterization focused on the oxidation state of the fuel. Photographs of the split rod segments are provided in Figure 4.1, and the appearance of the fuel in two of the split rod segments is shown in Figure 4.2. Visual observations of the split rod segments were summarized in Table 3.3 and Appendix I.

Although the first split segments showed weight gains that were consistent with U_3O_8 formation, initial XRD analysis of the fuel from one of the rod segments (9B-c5, split after 6458 h at 210°C) showed only phases with the UO_2

structure type (i.e., UO_2 , U_4O_9 , or U_3O_7). No U_3O_8 or other higher oxide/hydrate phases were detected. However, these results were not considered definitive because the x-ray patterns from the limited-quantity samples used for analysis were too noisy (poor counting statistics) to detect low concentrations of U_3O_8 or to distinguish the various UO_2 -structure phases.

Subsequent analyses involved detailed examination of the fuel from three split rod segments (8B-c1; 9B-c5, and 10B-c2), and one non-split rod segment (8B-c4). The analyses included ceramography, XRD, immersion density, reverse O/M, and TEM.

Cutting diagrams showing the sample section locations in the three rod segments and the analyses performed at these locations are provided in Figure 4.3; the results from these analyses are summarized in Table 4.2 and discussed below.

4.2.1.1 Rod Segment 8B-c1 (8574 h at 190°C, average O/M = 2.48)

Ceramography of the transversely sectioned fuel near the defect site is presented in Figure 4.4. The cladding split appears at the left side of the figure. Reacted regions of the fuel are revealed by the strong etching attack on reacted grain boundaries, and part of the fuel has fallen out due to weakening of the attacked grain boundaries. The dark regions on the photos correspond to the lost fuel; light areas at the centers of the large fuel fragments are non-reacted UO_2 . The reaction has progressed around the entire fuel pellet periphery and extended into the pellet interior along cracks that existed in the as-irradiated fuel. Large fuel fragments at the pellet interior show incomplete reaction of the UO_2 . A narrow gap appears between the fuel and cladding in this section. Due to the relaxation of the cladding after splitting occurred, however, it was not possible to tell from this examination whether the fuel and cladding were in contact before the cladding split open. A longitudinal section (not shown) exhibited similar incomplete reaction of the fuel.

XRD analysis of the fuel from six axial locations in the sectioned rod segment indicated that the spent fuel was predominantly U_4O_9 plus non-reacted UO_2 . Minor $\alpha\text{-U}_3\text{O}_7$ was also detected in some of these samples as indicated by

splitting of some of the UO_2 peaks, but was not a major reaction product in these samples. These samples came from random axial locations in the transverse fuel sections. U_3O_8 was also detected in three of the samples, usually just above the detection limit of ~1%, but near an estimated 10% for one sample. The U_3O_8 was also a minor constituent and was not found in most of the samples. No uranium oxide hydrates or unidentified phases were detected. The x-ray diffraction pattern obtained from the sample that shows the greatest amount of U_3O_8 is presented in Figure 4.5. The relative amounts of UO_2 , U_4O_9 , and U_3O_8 , estimated from x-ray peak intensities, at different axial locations in the rod segment are plotted in Figure 4.6. The degree of reaction in the rod segment, indicated by the ratio of U_4O_9 to UO_2 , decreased with increasing distance from the defect. Although U_3O_8 was found in the rod segment, the amount appeared insufficient to account for the rod segment splitting.

Additional XRD analyses were performed on fuel sampled from five different radial locations on the transverse ceramographic section. The sampling locations are indicated in Figure 4.4. These samples contained mainly U_4O_9 , minor UO_2 , and minor $\alpha\text{-U}_3\text{O}_7$. An x-ray pattern from one of these samples, showing broad peaks from the U_4O_9 and the absence of U_3O_8 peaks is given in Figure 4.7. No U_3O_8 or U-O-hydrates were found in any of these samples including a sample taken next to the cladding split. The lack of detectable U_3O_8 in the fuel section at the defect where the cladding split apparently initiated further indicated that U_3O_8 formation was not the cause of the rod segment splitting.

Further analyses of the fuel from this rod segment included an immersion density measurement from one section, and reverse O/M determinations from several section locations. Results of these analyses are given in Table 4.2a. The measured immersion density of fuel sampled 2.5 to 3.8 cm (1 to 1.5 in.) from the defect was 10.26 g/cm^3 , slightly below the measured density of the non-exposed archive fuel (see O/M measurements in Table 4.3). Note the density of the fuel is lower than the theoretical density of UO_2 ($\sim 10.96 \text{ g/cm}^3$) due to the presence of closed porosity (gas bubbles, cracks, etc.) in the actual material. Measured O/M ratios of the fuel varied from 2.28 at a distance of about 6.6 cm (2.6 in.) from the defect to 2.67 about 1.5 cm (0.6 in.) from the defect. The highest measured O/M value of 2.86 in sample 89-17

appears anomalous, and may have resulted from the presence of adsorbed water in the sample. Overall results of these local O/M analysis were consistent with the fuel average O/M of 2.48 determined from the measured weight gain in the test.

TEM examination of a reacted fuel sample from this rod segment further confirmed the conversion of original UO_2 grains to U_4O_9 . The U_4O_9 in the reacted fuel is the partially disordered γ form of the phase reported in other spent fuel oxidation studies (Thomas, Einziger, and Buchanan 1993). However, the TEM examination also showed the presence of another reaction product along grain boundaries in the fuel. The reacted fuel microstructure is shown in Figure 4.8. A reaction layer ~40 nm in width has formed along the grain boundary in the area shown. Particles of metallic ϵ -phase, which are normally formed along the grain boundaries during irradiation of the fuel, appear unaffected by the grain boundary reaction. However, the particles indicate the original grain boundary position, and thereby show that the reaction occurred at the expense of material in the adjacent U_4O_9 grains.

Electron diffraction analysis of these grain-boundary reaction layers in the TEM indicated that they contained fine-grained polycrystalline UO_2 . The original layers apparently contained a phase which decomposed under the electron beam during TEM observation. Examination at -170°C of a freshly prepared sample, in a liquid-nitrogen cooled sample holder, slowed the decomposition reaction sufficiently to observe the process. Electron diffraction patterns taken from the grain-boundary phase in the first few seconds of observation showed what appeared to be a noncrystalline (amorphous) phase decomposing rapidly to the very fine-grained UO_2 or U_4O_9 . Cracking and bubble formation occurred in the layer during the decomposition reaction. Even at -170°C , however, the reaction was too fast to be certain of the original phase identity. Attempts to analyze the layers by PEELS showed only oxygen and uranium. This method would not detect water, or any volatile products such as fluorine that might escape from the sample during the beam-induced decomposition.

4.2.1.2 Rod Segment 9B-c5 (6458 h at 210°C, average O/M = 2.52)

The analyses performed on this rod segment are summarized in Table 4.2b. Transverse ceramography at the rod segment defect (Figure 4.9) indicated complete reaction of the original UO_2 at this location. Unlike what was observed for rod segment 8B-c1 (Section 4.2.1.1), none of the UO_2 appeared to remain unreacted. Optical examination of this sample at higher magnification additionally indicated formation of reaction layers about $0.8 \mu\text{m}$ in thickness at the grain boundaries; these grain boundary layers are shown in Figure 4.10.

XRD analysis of samples from different axial locations of rod segment 9B-c5 showed predominantly U_4O_9 plus $\alpha\text{-U}_3\text{O}_7$ and traces (1-2%) of U_3O_8 . None of these phases would explain the observed splitting of the rod segment. An immersion density result of 10.31 g/cm^3 from one of the sections also indicated no significant swelling of the fuel, although the density appears slightly lower than that of the non-reacted fuel (see Table 4.3). Measured O/M values of -2.5 to 2.7 for the fuel near the defect were consistent with the average O/M indicated by weight gain for the total fuel in the rod segment.

The XRD analyses from rod segment 9B-c5 generally indicated a higher proportion of U_3O_7 than was found in lower temperature rod segment 8B-c1. The XRD pattern obtained from a sample taken from rod segment 9B-c5, after removal of the U_4O_9 pattern, is presented in Figure 4.11. This x-ray pattern is characteristic of a tetragonal phase based on the cubic UO_2 structure, but having a c/a ratio of -0.99 or 1.01 and, thus, is consistent with $\alpha\text{-U}_3\text{O}_7$ (c/a = 0.986).

TEM examination of fuel near the defect also showed conversion of the UO_2 grains to U_4O_9 , and formation of a beam-sensitive reaction product at the grain boundaries. The microstructure of this sample showed extensive reaction-induced cracking of the U_4O_9 grains, but otherwise resembled the fuel from rod segment 8B-c1. Cold stage observations of beam-induced decomposition of the grain boundary reaction product in this sample also indicated that the original product could have been amorphous.

4.2.1.3 Rod Segment 10B-c2 (4894 h at 230°C, average O/M = 2.45)

No ceramography was performed on this rod segment; the analyses that were performed are listed in Table 4.2c. The XRD results from several samples from different axial locations indicated no remaining unreacted UO_2 . These samples contained mostly $\alpha\text{-U}_3\text{O}_7$ and U_4O_9 , plus minor amounts (3 to 6%) of U_3O_8 . As in the rod segments exposed at lower temperatures, no hydrates or other phases were detected. The measured local O/Ms of ~ 2.44 to 2.56 were consistent with the rod segment average of 2.45 indicated by the total weight gain. The only apparent difference between the reacted fuel in this split rod segment and that in the lower temperature rod segments was a noticeably larger proportion of $\alpha\text{-U}_3\text{O}_7$ oxidation product.

4.2.1.4 Rod Segment 8B-c4 (Nonsplit after 17756 h at 210°C, average O/M = 2.57)

Ceramographic examination of the fuel near the defect in this rod segment showed apparently uniform reaction. The ceramographic photo montage of the entire transverse section is shown in Figure 4.12. Part of the original aim was to determine if reacted fuel in an intact rod segment had swelled into contact with the cladding. Loss of fuel from the section precluded making this observation. Observations of the fuel at higher magnification (not shown) indicated a structure similar to that in Figure 4.10, from the rod segment that split during exposure at the same temperature. XRD analysis of fuel from three locations in this section indicated complete conversion to U_4O_9 , with no detectable U_3O_8 or higher products, and little or no U_3O_7 . The XRD patterns from these samples (not provided here) were similar in appearance to the XRD pattern of Figure 4.7. One possible interpretation of this observation is that the U_3O_7 and U_3O_8 observed in other rod segments formed after rod segment splitting occurred and during continued reaction of the fuel in the ovens.

4.2.2 Bare Fragments at Intermediate Exposures

Immersion density and XRD analyses were performed on bare fuel samples reacted to O/Ms of 2.73 and 2.78 at 210°C. The aim of these analyses was to determine if the fuel had swelled and if an amorphous reaction product had formed. The immersion density results of 8.63 to 8.75 g/cm³ for four samples (see Table 4.3) indicated considerable swelling of the fuel. For example, the density change from 10.41 g/cm³ for archive H.B. Robinson fuel to 8.74 g/cm³ corresponds to 16% swelling.

Although the measured densities in this case approached the theoretical density of 8.39 g/cm³ for U₃O₈ (Loopstra 1964), XRD analysis of the reacted fuel indicated no detectable U₃O₈. The XRD analysis showed U₄O₉ plus a minor phase which was then unidentified. Subsequently, additional analysis was performed to determine if the low density of the reacted fuel could be due to an amorphous phase that would be hard to detect by XRD in samples mounted on glass slides.

For this analysis, the fuel was mounted on an oriented quartz mount that contributed a greatly reduced background to the x-ray pattern. Following XRD data acquisition, the background contribution from the collodion binder used in sample preparation, as well as that from the quartz mount, was removed by data processing. A "background" pattern obtained from the same (weighed) amount of collodion on the quartz mount without the fuel sample was subtracted (stripped) from fuel/collodion/mount pattern. The resulting pattern after background removal (Figure 4.13) indicates that an amorphous phase existed in the reacted fuel.

The X-ray pattern from this reacted fuel sample also contains small peaks from a minor phase that was initially unidentified. Subsequent analysis, discussed in a later section, identified the minor phase as UO₂F₂·1.5H₂O (JCPDS No. 24-1151). An XRD pattern from non-reacted UO₂ (dots) is shown in Figure 4.13 for comparison with the U₄O₉ pattern.

4.2.3 End-of-Exposure Spent Fuel Bare Fragments and Nonirradiated UO₂ Fragments

Following completion of the oven exposures, examination of the weight gains produced in bare fragment specimens exposed for 30,000 to 38,000 h indicated large differences in behavior between the spent fuel and nonirradiated UO₂. As shown for representative samples in Figure 4.14, the differences varied with the test temperature. At 135° and 150°C, the spent fuel gained weight more rapidly than nonirradiated UO₂; in fact, the non-irradiated UO₂ gained very little weight at these temperatures while some spent fuel specimens exposed at 135°C attained O/M ratios as high as 2.5.

In contrast, the nonirradiated UO₂ at 190°C and higher temperatures showed weight gains of 15% and more, much greater than the spent fuel at these temperatures. The transition between these "low" and "high" temperature behaviors occurred at exposure temperatures between 150 and 170°C. These effects are also seen in the variation in final weight gains between the spent fuel and nonirradiated UO₂ specimens, shown in Figure 4.15.

4.2.3.1 XRD Analysis of Samples Collected Post-Exposure

Twelve end-of-exposure samples of spent fuel and nonirradiated UO₂ bare fragments were analyzed by XRD. These samples included several different fuels with different weight gain responses at the same test temperatures. This group of samples was also selected to show the behavior of each fuel as a function of test temperature. During this analysis, fluorine compounds were identified in some of these samples by XRD. Fluorine was also detected in the samples by EDS analysis in a scanning electron microscope. Sample identifications, sample characteristics, and result summaries are presented in Table 4.4.

XRD analyses of the end-of-test spent fuel samples having average O/Ms from 2.03 to 2.78 generally indicated UO₂, U₄O₉, and minor α -U₃O₇ but no U₃O₈. The patterns from U₄O₉ were similar to those found in the rod segment samples (e.g., Figure 4.7). In addition to the uranium oxide phases, however, minor peaks from the reacted spent fuel samples matched a uranyl fluoride hydrate UO₂F₂·1.5H₂O (JCPDS No. 24-1151).

In contrast to the spent fuel, the nonirradiated UO_2 remained essentially non-reacted at 135-150°C, or converted to entirely $\text{UO}_2\text{F}_2 \cdot 1.5\text{H}_2\text{O}$ above 170°C. The x-ray pattern shown in Figure 4.16 from a nonirradiated UO_2 sample exposed at 170°C indicates complete conversion to the fluoride phase. The relatively low measured weight gain of this sample was not consistent with 100% conversion, and indicates either sample inhomogeneity or material losses. $\text{UO}_2\text{F}_2 \cdot 1.5\text{H}_2\text{O}$ has a density of 4.600 g/cm³, and its formation from UO_2 involves a swelling of 58%. Such large expansion of the sample could cause particles to be ejected from the open weigh boats used in Test Series B. The possible ejection of specimen material from some of the weigh boats during the tests might also account for anomalous weight gains for other boats. Even a small fragment added in this manner could produce a significant weight gain compared to reaction weight gains.

An XRD pattern from reacted spent fuel is also included in Figure 4.16. The XRD pattern is expanded vertically to show the uranyl fluoride hydrate peaks.

4.2.3.2 Fluorine Analysis by SEM/EDS

After the initial discovery of fluorine in the exposed materials, most of the end-of-exposure fragment samples were examined for the presence of fluorine by using a "thin-window" EDS detector in the scanning electron microscope. As indicated in Table 4.18, fluorine was detected in surface deposits on all the end-of-exposure spent fuel samples that were analyzed by this method. Fluorine was also detected on post-test grain-boundary fracture surfaces on several of the spent fuel samples. This observation indicates that the fluorine probably penetrated the samples along grain boundaries, and that the spent fuel was internally fluorided.

Photographs of two surfaces of a spent fuel particle (sample 91-06) after a weight gain of 2.7% (average O/M of 2.46) at 150°C, are presented in Figure 4.17. The original (as-exposed) particle surface (Figure 4.17a) had a reaction layer coating in which fluorine was detected. A post-exposure fracture surface of the fuel particle, shown in Figure 4.17b, also showed concentrations of fluorine. An EDS spectrum from this surface, shown with the

horizontal scale expanded in the light-element region, indicates nearly as much fluorine as oxygen. Fluorine signals from the samples tended to decrease during SEM examination, indicating that the fluoride phase was decomposed by the electron beam.

The appearance of the uranyl fluoride product from nonirradiated UO_2 , and a corresponding EDS spectrum is presented in Figure 4.18. A small aluminum peak in the EDS spectrum is probably an artifact of sample preparation. The sample was extremely friable and tended to break into particles having the shape and approximate size of the original UO_2 grains. No fluorine was detected on the surfaces of nonirradiated UO_2 exposed at 135° and 150°C .

4.2.3.3 Thermal Analysis

Before the fluorine discovery, several end-of-exposure fragment samples including the high weight gain (14.7%) nonirradiated material, were analyzed by TGA and DSC to determine if the samples contained hydrated products. Upon heating in air, U-O hydrates undergo decomposition reactions involving release of water and subsequent reduction of the anhydrous phases to U_3O_8 . The endothermic dehydration reactions can be identified from the reaction heats measured by DSC, and the amount of water released can be determined from the corresponding weight loss measured by TGA.

The TGA results from the spent fuel and nonirradiated samples are presented in Figure 4.19. The nonirradiated sample, 91-12, identified by XRD analysis as being $\text{UO}_2\text{F}_2 \cdot 1.5\text{H}_2\text{O}$ or a similar compound, decomposed in two main reactions. The first reaction, between 100 and 150°C produced a large endothermic peak in the DSC and resulted in an 8% weight loss. The second reaction, between 500 and 600°C , resulted in an additional 7% weight loss with no definitive corresponding DSC result. XRD analysis of the final product after heating to 670°C indicated 100% conversion of the material to U_3O_8 .

A simple calculation indicates that the reactions observed by TGA of the nonirradiated sample material are consistent with a sample composition close to $\text{UO}_2\text{F}_2 \cdot 1.5\text{H}_2\text{O}$. These assumed reactions are as follows:

The final TGA product, U_3O_8 , is assumed to be $\text{UO}_{2.667}$ (mole wt = 280.0 g). A 15% total weight loss to form this product implies an initial mole wt of 330.2 g; this compares well with the molar wt of 335.0 g for $\text{UO}_2\text{F}_2 \cdot 1.5\text{H}_2\text{O}$. Further, the 8% weight loss observed in the first decomposition reaction corresponds to a molar weight loss of 26.41 g; which compares well with 27.0 g for 1.5 H_2O . Adjusting the fluorine to match the weight change in the second reaction gives a revised composition of the initial fluoride phase as $\text{UO}_2\text{F}_{1.78} \cdot 1.5\text{H}_2\text{O}$.

In fact, other decomposition reactions of $\text{UO}_2\text{F}_2 \cdot 1.5\text{H}_2\text{O}$ may be possible. A study of the decomposition of anhydrous UO_2F_2 at 700 to 900°C (Ferris and Baird 1960), for example, indicated the following reaction:

In the reacted spent fuel, the reactions during thermal analysis in air are more complex. XRD analyses of these samples showed mostly U_4O_9 , non-reacted UO_2 , and $\text{UO}_2\text{F}_2 \cdot 1.5\text{H}_2\text{O}$. Based on the XRD analysis of other highly reacted bare fragment samples, in Section 4.2.2, the end-of-exposure fuel samples probably also contained an x-ray amorphous reaction product. As shown by the XRD pattern in Figure 4.20, heating these materials to 675°C in air in the TGA yielded a final product of U_3O_8 . The intermediate reactions probably included conversion of the UO_2 to U_4O_9 and decomposition of the $\text{UO}_2\text{F}_2 \cdot 1.5\text{H}_2\text{O}$ and amorphous phase of unknown composition.

4.2.4 Corrosion Product from Rod Segment Cladding and Endcap Hardware

The presence of fluorine in Test Series B specimens was initially detected by analyzing the corrosion scale from a rod segment. An example of the cladding corrosion that occurred during the rod segment tests was shown in Figure 3.23. The figure illustrates the progressive growth of corrosion nodules on the irradiated cladding of rod segment 11B-c2 and formation of white scale on the nonirradiated Zircaloy endcap. Nodular corrosion of this

BWR rod segment (both ends) occurred predominantly in the heat-affected zones near the endcap welds. Other rod segments showed different degrees and types of corrosion scale formation during the tests at 150 to 230°C. Normally, no significant oxidation of Zry is expected at these temperatures. Samples collected by scraping the rod segments were examined by SEM/EDS and XRD. As shown by the SEM/EDS analysis in Figure 4.21, the corrosion scale from the endcap contained considerable fluorine. Similar results were obtained from the nodular product on the cladding.

XRD analysis results from a sample of the endcap corrosion scale is shown in Figure 4.24. The corrosion scales and nodules from both the endcap and heat-affected-zone (HAZ) samples consisted of monoclinic ZrO_2 and a second phase that roughly matched $\text{Zr}_7\text{O}_9\text{F}_{10}$ (JCPDS No. 27-998) (Figure 4.22). The approximate match for $\text{Zr}_7\text{O}_9\text{F}_{10}$ indicated a structurally similar phase. Thus, the rapid and unexpected corrosion of the Zry rod segment metal resulted from formation of a zirconium oxide fluoride. This observation gave the first indication that the specimens were exposed to a source of fluorine during the Test Series B.

4.2.5 Other Samples Tested for the Presence of Fluorine

To help determine the onset and extent of fluorine contamination in the exposed specimens, additional SEM/EDS analyses were performed on fuel samples from two defected rod segments, on archive (non-exposed) fuel, and on an oxidized fuel sample from Test Series A. Results of these analyses are included in Table 4.4. Fluorine contamination was found in the samples taken from the rod segment specimens. The fracture surface of fuel from rod segment 8B-c1, and a corresponding EDS spectrum in which fluorine is easily detectable, are presented in Figure 4.23. The archive spent fuel and oxidized fuel samples from Test Series A contained no detectable fluorine.

In addition, XRD and AES results described by Thomas et al. (1989), from Test Series B bare fragment exposed for 3400 to 16,600 h, were reviewed to determine if fluorine could be found in these earlier samples. No fluorine or fluorides were detectable in these analyses, although some of the AES results were ambiguous. An AES spectrum from a 7174 h fuel sample (no. 86-28), that

had an average O/M of 2.42, is presented in Figure 4.24; no statistically significant fluorine peak is present.

4.3 DISCUSSION

The analysis of samples taken from the Test Series B specimens was discussed in Section 4.2, including the detection of fluorine compounds. In the following, a discussion of the fluorine contamination is presented. This discussion will begin with the probable source of the fluorine, continue with how the fluorine might have been incorporated in the spent fuel, and conclude with how the fluorine might have impacted the cladding splitting of the rod segments.

4.3.1 Fluorine Contamination Source

Analyses described in the preceding sections revealed the presence of reaction products containing fluorine in many of the test samples. The fluorine contamination affected both the spent fuel and cladding in the rod segments, as well as the bare fragments of spent fuel and nonirradiated UO_2 that were sampled near the end of Test Series B. Earlier analyses of bare UO_2 and fuel pellet fragments after exposure for 3000 to 16,600 h did not reveal the fluorine contamination; a review of those earlier results gave no positive indication for fluorine. The earliest positive identification of fluorine in the bare fragment specimens was after 19,000 h at 210°C.^(a) However, these results cannot exclude the possibility that fluorine contamination began earlier in Test Series B. Rod segments, some of which showed fluorine contamination after their first examination,^(b) were added relatively late in Test Series B.

A search for the source of the fluorine in Test Series B revealed only one likely candidate--the Viton™ o-rings used to seal the oven doors. Examinations of the non-exposed archive spent fuel and other materials used in the

(a) Samples were collected from specimens 9B-6 and 9B-10 after Run 14 concluded in November 1988.

(b) Samples were collected from rod segment 9B-c5 after Run 13 concluded in March 1988.

tests revealed no other fluorine-containing materials in the ovens. Viton™, although its exact composition is proprietary, is a copolymer of vinylidene fluoride and hexafluoropropylene (Dixon, Rexford, and Rugg 1957); the structure is shown schematically in Figure 4.25. According to information given in the manufacturers' brochure,^(a) total combustion of this product in excess oxygen gives 251 mg of HF and 1836 mg of CO₂. Thus, Viton™ is ~24% fluorine by weight. The Viton™ may have also been the source of CO₂ gas that was detected in end-of-run samples of the oven atmospheres.

The formation of fluoride products in both the Zircaloy cladding and the spent fuel (as well as in nonirradiated UO₂) samples from Test Series B suggests the presence of a powerful reaction agent, such as HF, in the oven atmosphere. This observation, plus the well-known tendency of fluoroelastomers to release HF vapor when exposed to ionizing radiation, indicates that fluorine contamination of fuel and cladding materials in the Test Series B occurred by HF attack.

Although thermal degradation during curing of Viton™ releases a small amount of HF (Wall 1972), the amount appears far too small to account for the contamination observed. However, the seals in the ovens were directly exposed to a high gamma-radiation field (10⁵ R/h) produced by ¹³⁷Cs. Like other fluoroelastomeric materials, Viton™ in the presence of ionizing radiation is known to degrade rapidly at room temperature and to release HF. Detailed information on the halogen release from irradiated Viton™ was not available, but halide releases of up to 1.5 millimoles per gram of a closely related elastomer fluorothene were measured in samples exposed to doses of 10⁹ R at room temperature (Byrne et al. 1953). Halogen release data for irradiated fluorothene are shown in Figure 4.26; the release effect accelerates with increasing dose.

Although these release data are inexact for Viton™, they allow an estimate of the possible HF release in Test Series B. The oven door seals, each weighing ~100 g, degraded visibly during the oven runs and were replaced

(a) Dupont product information: VT-515.1, E37758, "Radiation Resistance of Viton," p. 5; "Viton," Table 1, p. 7.

at each specimen weighing interval. The actual exposure for each seal varied as shown by the example in Figure 4.27; initial weighing intervals were relatively short in order to follow the rapid initial weight gains of the specimens. Although the gamma radiation exposures of the seals were thus limited early in Test Series B, there is, as shown by the data in Figure 4.26, no apparent threshold dose for the halogen release.

Toward the end of Test Series B, after the weight gain rate slowed, the door seals received doses as high 10^9 R, and thus were subject to severe degradation. The calculated cumulative release of HF in Oven 8, based on the release data for fluorothene and the oven history, is presented in Figure 4.28. The total fluorine release indicated by this approximate calculation, if fully incorporated into the specimens, would be sufficient to account for half the total measured weight gain for the specimens in this oven.

4.3.2 Interaction of Fluorine With Nonirradiated UO_2 and Spent Fuel

UO_2 is known to interact rapidly with halogens such as HF, and the volatile fluoride compounds produced by this reaction at high temperatures form the basis for production of UO_2 fuel. However, the fluoridation of LWR spent fuel at 135 to 230°C in air appears unprecedented. A review of published literature on UO_2 oxyfluorides yielded no information on fluoridation of the fuel at these temperatures. There is also an absence of literature on the amorphous uranium oxyfluoride that appeared to be the main product of the fluoride reaction with spent fuel. Based on its rapid decomposition during observation in a TEM, the amorphous fluoride found mainly along the grain boundaries appears to be a metastable phase.

The strong fluoridation response of the nonirradiated UO_2 specimens indicates that the fluoridation was not limited to spent fuel. Further, the reaction behavior of the nonirradiated UO_2 in Test Series B suggests that concurrent oxidation of the UO_2 played a role in the fluorine reactions. In nonirradiated UO_2 at low temperatures without fluorine, oxidation apparently proceeds by surface-controlled reactions involving initial formation of thin ($\sim 1 \mu\text{m}$), protective U_3O_7 layers, which are subsequently broken by the formation of U_3O_8 powder (Taylor, Burgess, and Owen 1980). In Test Series B,

the tendency observed early in the tests (Thomas et al. 1989) was for nonirradiated UO_2 to form U_3O_8 and U-O-hydrates followed by rapid, complete conversion of the oxidized, nonirradiated UO_2 to $\text{UO}_2\text{F}_2 \cdot 1.5\text{H}_2\text{O}$. The nonirradiated UO_2 specimens exposed at 135° and 150°C had no detectable fluoridation and low levels of weight gain while the specimens exposed at 230°C converted to hydrates within 6000 to 9000 h; this behavior might be attributed to oxidation alone. However, the nonirradiated UO_2 specimens exposed at 170° and 190°C had rapid rates of weight gain and high levels of weight gain when formation of U_3O_8 would not be expected. This behavior indicates a process of oxidation coupled with extensive fluoridation for these specimens.

Under similar conditions, spent fuel not exposed to fluorine apparently oxidizes through the grain boundaries, and completely converts to hyperstoichiometric $\gamma\text{-U}_4\text{O}_9$ that resists forming U_3O_8 (Thomas, Einziger, and Buchanan 1993; Einziger et al. 1992). In the spent fuel exposed to fluorine, initial reaction to relatively stable U_4O_9 (with little or no U_3O_8 formation) proceeded to apparent formation of an amorphous fluoride and only minor amounts of $\text{UO}_2\text{F}_2 \cdot 1.5\text{H}_2\text{O}$.

The presence of a hydrated oxyfluoride product in nonirradiated UO_2 and spent fuel specimens suggests that the presence of water vapor might have been an important factor in the fluoridation reactions. Although the test conditions included three different air moisture levels (0°, 20°, and 40°C dew points), test results indicated no apparent relation of fluoridation behavior with air moisture. For example, XRD analyses of end-of-test nonirradiated UO_2 specimens tested at 170° and 190°C indicated total conversion of these specimens to $\text{UO}_2\text{F}_2 \cdot 1.5\text{H}_2\text{O}$. Judging from the corresponding weight gains and otherwise similar behavior of the nonirradiated specimens in tests at different air moisture levels, hydrated fluorides were produced at all moisture levels. An alternative interpretation of the results is that the original oxyfluoride product might have been an anhydrous phase that became hydrated after the ovens were opened and the specimens were exposed to hot cell air.

The HF might be expected to react strongly with some of the fission products (e.g., cesium) if these products were concentrated along grain boundaries in the fuel. However, Auger and TEM indicated no significant

segregation of cesium to the grain boundaries. Consequently, the fission products at grain boundaries (apart from the gas bubbles) in these spent fuels do not appear to directly influence fuel fluoridation behavior.

Based on the behavior of the bare fuel fragments, the formation of minor U_3O_8 in the spent fuel from the rod segments appears anomalous. One possible explanation for the relatively low temperature formation of U_3O_8 in the rod segments is that the U_3O_8 could have been formed indirectly by reduction of a higher oxide or fluoride hydrate product. However, there is insufficient information about the amorphous fluoride to predict its behavior.

Because additional information on the actual reaction productions would be necessary, thermodynamic analysis of the oxygen-fluorine-spent fuel interaction cannot be verified at this time.

4.3.3 Relation of Fuel Reaction to Rod Segment Splitting

It was initially assumed that oxidation of spent fuel in the rod segments would convert the UO_2 fuel to U_3O_8 and cause the cladding to split due to the resultant fuel swelling. However, analyses of the fuel from several rod segments that split during Test Series B indicated a lack of sufficient U_3O_8 formation to explain the rod segment splitting. The U_3O_8 was a minor phase in the rod segment samples, generally amounting to only a few percent of the fuel even in the most highly reacted sections near the defect. The amount of fuel swelling from this U_3O_8 would be insufficient to swell the fuel into contact with the cladding (i.e., to close the physical gap that exists between the fuel pellets and the cladding at the exposure temperatures), let alone to exert stresses on the cladding.

Because of the cladding relaxation that occurred after cladding failure, ceramographic observations of the rod segment sections did not reveal whether the fuel was in contact with the cladding. One attempt to observe the cladding in an nonsplit rod segment also failed due to fuel losses during the sample preparation. However, no bulging or swelling of the cladding was observed for any of the rod segments before splitting occurred. Also, splitting occurred in some rod segments that showed relatively low weight gain (e.g., in rod segment 7B-c5, that failed at 150°C.). From the observations of

the reaction phases and the rod segment behavior, it appeared that the failures were not caused by swelling of the fuel.

An alternative explanation of the cladding splitting involves splitting of the cladding by the hydrogen generated by a Zry-HF reaction, i.e., a delayed hydrogen cracking mechanism. In this proposed mechanism, reaction of the Zry with HF would produce atomic hydrogen in the Zry. The hydrogen produced at a crack initiated at the defect in the residually stressed cladding could propagate and split the cladding. Such a mechanism could explain why the rod segments split without apparent swelling of the fuel, why splitting always appeared to initiate at the defect, and why a wide range of split lengths appeared in different rod segments. Metallographic examination of the cladding to observe the distribution of hydrides near the crack tip, although not done, might have confirmed whether hydrogen-induced cracking was responsible for the cladding splitting.

TABLE 4.1. Summary of Samples and Analyses of Exposed Spent Fuel

Sample ID	Material	Condition	Analysis
88-40	fuel from failed rodlet 9BC2	powder from defect region	XRD: Initial attempt to determine cause of rodlet splitting. All samples showed UO_2 -structure phases with no U_3O_8 . Limited interpretability of data due to poor counting statistics.
88-42		fragment from rodlet segment	
88-43		powder from rodlet segment	
88-45		fragment from defect region	
88-115	fuel fragments, 19493hr at 210°C	HBR fuel, fine cracks	immersion density, XRD
88-116		HBR fuel, open cracks	immersion density, XRD (special, for amorphous phases)
88-117		QC fuel, fine cracks	immersion density, XRD (special, for amorphous phases)
88-118		QC fuel, open cracks	immersion density, XRD
89-16	fuel from failed rodlet 8BC1; 8574hr. at 190°C	Sect. A	XRD, O/M
89-17		Sect. B	XRD, O/M
89-18		Sect. C	XRD (each end), O/M
89-19		Sect. D	Immersion density
89-20		Sect. E	XRD (each end), O/M (each end), TEM, SEM/EDS
89-21		Sect. F (at defect)	transverse ceramography, XRD of 4 locations from section
89-22		Sect. G	longitudinal ceramography
89-24	fuel from failed rodlet 9BC5; 6458hr. at 210°C	sect. D (at defect)	transverse ceramography, XRD of 4 locations from section)
89-25		sect. C	XRD (each end), O/M (each end), TEM, SEM/EDS
89-26		sect. B	immersion density
89-27		sect. A	O/M XRD
89-28	fuel from failed rodlet 10BC2; 4894hr, 230°C	Sect. A (Sect. B unused)	XRD, O/M
89-30		Sect. C (at defect)	XRD (each end), O/M (each end)

TABLE 4.1. (Contd)

89-32	archive HBR fuel,	unoxidized	immersion density
89-33	archive QC fuel	unoxidized	immersion density
89-77	archive PB fuel	unoxidized	immersion density
90-01	fuel from unfailed rodlet 8BC4; 17756 hr at 210°C	defect section	transverse ceramography, post ceram. XRD (3 locations)
91-01	End-of-Test Fuel Fragment Samples (33 to 35Khrs) QC, 135°C,	0.174% wt gain	XRD, SEM/EDS
91-02	PB, 135°C,	2.75% wt gain	XRD, SEM/EDS, TGA/DSC
91-03	HBR, 135°C,	2.18 % wt gain	XRD, SEM/EDS
91-04	nonirradiated, 135°C	0.019% wt gain	XRD, SEM/EDS
91-05	QC, 150°C	2.52% wt gain	XRD
91-06	HBR, 150°C	2.46 % wt gain	XRD, SEM/EDS, TGA/DSC
91-07	nonirradiated, 150°C	0.124 % wt gain	XRD, SEM/EDS
91-08	QC, 170°C	3.03% wt gain	XRD
91-09	HBR 170°C	4.06% wt gain	XRD
91-10	nonirradiated, 170°C	5.56% wt gain	XRD
91-11	QC, 190°C	4.61% wt gain	XRD, SEM/EDS, TGA/DSC
91-12	nonirradiated, 190°C	14.7% wt gain	XRD, SEM/EDS, TGA/DSC
91-24	failed rodlet 7BC2 (23114 hr at 150°C)	section 1A	not analyzed
91-25		section 1B	not analyzed
91-26		section 1C	not analyzed
91-27	failed rodlet 4BC2 (18997 hr at 190°C)	defect section	not analyzed

TABLE 4.1. (Contd)

91-28	rodlet 11BC2 cladding corrosion product	scraping from endcap	XRD, SEM/EDS
91-29		scraping from heat-affected zone	XRD, SEM/EDS
91-UO-1	archive HBR fuel	unoxidized	SEM/EDS
91-UO-2	HBR fuel, Test Series A	5070 hr at 200°C (2.28% wt gain)	SEM/EDS

TABLE 4.2a. Summary of Results from Analytical Examinations of Split Rod Segments; 8b-c5 (190°)

Sample	Distance from defect, in.	Analysis	Result
89-21	0-0.5	transverse ceramography XRD of selected regions on ceramo. section	non-uniform fuel oxidation from pellet and pellet fragment edges inward. Enhanced oxidation near pellet edges. Fragments near pellet center have nonoxidized UO_2 cores. Predominantly U_4O_9 in oxidized regions; $\text{U}_4\text{O}_9/\text{UO}_2$ mixture in partially oxidized regions. No U_3O_8 detected.
89-22	0-0.75	longitudinal ceramography	Oxidized material (U_4O_9) at pellet edges and enclosing nonoxidized centers of fuel fragments. No distinct variation along rodlet length.
89-20b	0.6	XRD* reverse O/M TEM*	U_4O_9 plus ~15% UO_2 and 10% U_3O_8 . O/M = 2.670 U_4O_9 grains. Unidentified electron beam sensitive phase along grain boundaries.
89-20a	0.9	XRD* reverse O/M	U_4O_9 plus ~40% UO_2 , 1-2% (trace) U_3O_8 . O/M = 2.453
89-19	1.0-1.5	immersion density	$\rho = 10.26 \text{ g/cm}^3$
89-18b	1.6	XRD*	
89-18a	1.9	XRD* reverse O/M	U_4O_9 plus traces of UO_2 and $\alpha\text{-U}_3\text{O}_7$; no U_3O_8 . O/M = 2.423
89-17b	2.1	XRD* reverse O/M	U_4O_9 plus minor $\alpha\text{-U}_3\text{O}_7$; no U_3O_8 . O/M = 2.864
89-16b	2.6	XRD* reverse O/M	U_4O_9 only; no U_3O_8 . O/M = 2.283

* XRD Samples from random radial locations of transverse fuel sections

TABLE 4.2b. Summary of Results from Analytical Examinations of Split Rod Segments; 9b-c5 (210°)

Sample	Distance from defect, in.	Analysis	Result
89-24	0-0.5	transverse ceramography XRD of selected regions on ceramo. section	Uniform fuel oxidation across pellet. Apparent second phase filling grain boundaries. U ₄ O ₉ plus possible trace α -U ₃ O ₇ ; no U ₃ O ₈ .
89-25b	0.6	XRD* reverse O/M TEM	U ₄ O ₉ plus trace α -U ₃ O ₇ ; ~1% U ₃ O ₈ . No UO ₂ . O/M = 2.639 add description
89-25a	0.9	XRD* reverse O/M	U ₄ O ₉ plus minor α -U ₃ O ₇ ; ~2% U ₃ O ₈ . Possible trace UO ₂ . O/M = 2.675
89-26	1.0-1.5	immersion density	$r = 10.314 \text{ g/cm}^3$
89-27a	2.0-2.5	XRD* reverse O/M	U ₄ O ₉ plus trace α -U ₃ O ₇ ; no U ₃ O ₈ . Possible trace UO ₂ . O/M = 2.561

TABLE 4.2c. Summary of Results from Analytical Examinations of Split Rod Segments; 10b-c5 (230°)

Sample	Distance from defect, in.	Analysis	Result
89-30b	0.1	XRD* reverse O/M	α -U ₃ O ₇ plus 30-40% U ₄ O ₉ ; ~6% U ₃ O ₈ . No UO ₂ . O/M = 2.559
89-30a	0.4	XRD* reverse O/M	α -U ₃ O ₇ plus 30-40% U ₄ O ₉ ; 2-3% U ₃ O ₈ . No UO ₂ . O/M = 2.481
89-28a	2.0	XRD* reverse O/M	α -U ₃ O ₇ plus 40-50% U ₄ O ₉ ; ~4% U ₃ O ₈ . No UO ₂ . O/M = 2.442

- XRD Samples from random radial locations of fuel sections

TABLE 4.3. Immersion Density Results for Exposed and Non-exposed (Archive) Spent Fuel

Sample ID	Fuel	Condition	Wt gain, %	O/M	Density, g/cm ³ (***)
89-32	H. B. Robinson	as irradiated	0	2.01*	10.4131±0.0220
89-33	Quad Cities	as irradiated	0	2.01*	10.4031±0.0028
89-77	Point Beach	as irradiated	0	2.01*	10.4188±0.0055
88-115 (9B6)	H. B. Robinson	bare fuel,oxidized 19493 h at 210°C. Fine cracks	4.30	2.73	8.0915±0.0119
88-116 (9B6)	H. B. Robinson	bare fuel,oxidized 19493 h at 210°C. Open cracks	4.30	2.73	8.7529±0.0056
88-117 (9B10)	Quad Cities 23.8 MWd/kgM	bare fuel,oxidized 19493 h at 210°C. Fine cracks	4.60	2.78	8.6441±0.0062
88-118 (9B10)	Quad Cities 23.8 MWd/kgM	bare fuel,oxidized 19493 h at 210°C. Open cracks	4.60	2.78	8.6348±0.0049
89-19	Point Beach	rodlet 8B-c1, 190°C	not measured	2.42-2.45 **	10.2737±0.0125
89-26	H. B. Robinson	rodlet 9B-c5, 210°C	not measured-	2.56-2.67 **	10.3141±0.0090

*estimated; typical O/M for irradiated LWR spent fuel

**measured O/M values from adjacent rodlet segments

***average of 5 determinations at 20 ± 0.2°C

TABLE 4.4. Fluoride Analysis Results From Exposed Spent UO_2 Fuel and Nonirradiated UO_2

Specimen	Sample #	Source ¹	Burnup, Mwd/kgM	Temp., °C	Time, h	Weight Gain, %	Oxygen-to- Metal Ratio	XRD Date	Examination Results
Spent Fuel Fragments: Test Series B									
10B-11	91-1	QC	24.2	135	36134	0.174	2.03	1/18/91	UO_2 with trace of $\text{U}_4\text{O}_9/\text{U}_3\text{O}_7$ (high angle shoulder on UO_2 peaks). No detectable uranyl fluoride. Fluorine detected in fuel surface deposits by EDS.
10B-2	91-2	PB	29.5	135	36134	2.75	2.46	1/19/91	U_4O_9 with minor $\text{UO}_2\text{F}_2 \cdot 1.5\text{H}_2\text{O}$ (PDF-1151). SEM/EDS detected fluorine.
10B-3	91-3	HBR	27.6	135	36134	1.05	2.18	1/21/91	$\text{UO}_2/\text{U}_4\text{O}_9$ mixture. No detectable uranyl fluoride. Fluorine detected in fuel surface deposits by EDS.
10B-12	91-4	NI	0	135	36134	0.019	2.003	1/17/91	UO_2 (no detectable oxidation); no fluorine detected by EDS.
1B-4	91-5	QC	7.7	150	38071	3.07	2.52	1/22/91	complex mixture of UO_2 , U_4O_9 , U_3O_7 plus minor $\text{UO}_2\text{F}_2 \cdot 1.5\text{H}_2\text{O}$ (PDF-1151). No EDS done.
1B-7	91-6	HBR	28.4	150	38071	2.70	2.46	1/23/91	U_4O_9 with minor UO_2 plus minor $\text{UO}_2\text{F}_2 \cdot 1.5\text{H}_2\text{O}$ (PDF-1151). SEM/EDS detected fluorine at fracture surfaces.
1B-12	91-7	NI	0	150	38071	0.124	2.02	1/31/91	UO_2 plus trace U_3O_7 (closer to $\alpha\text{-U}_3\text{O}_7$ than β). No uranyl fluoride detected by XRD; no fluorine detected by EDS.
11B-6	91-8	QC	19.4	170	35338	3.03	2.51	1/24/91	U_4O_9 plus minor $\text{UO}_2\text{F}_2 \cdot 1.5\text{H}_2\text{O}$ (PDF-1151). No EDS done.
11B-4	91-9	HBR	27.6	170	35338	4.06	2.67	1/25/91	U_4O_9 plus minor $\text{UO}_2\text{F}_2 \cdot 1.5\text{H}_2\text{O}$ (PDF-1151). Note U_4O_9 broadening. No EDS done.
11B-12	91-10	NI	0	170	35338	5.56	2.94	1/31/91	complete conversion to $\text{UO}_2\text{F}_2 \cdot 1.5\text{H}_2\text{O}$ (PDF-1151). No EDS done.
8B-5	91-11	QC	23.7	190	33170	4.61	2.78	1/29/91	U_4O_9 plus minor $\text{UO}_2\text{F}_2 \cdot 1.5\text{H}_2\text{O}$ (PDF-1151). Note U_4O_9 broadening. SEM/EDS detected fluorine.
8B-12	91-12	NI	0	190	33170	14.7	4.48	2/1/91	complete conversion to $\text{UO}_2\text{F}_2 \cdot 1.5\text{H}_2\text{O}$ (PDF-1151). SEM/EDS detected fluorine.
9B-6	88-116	HBR	24.4	210	19493	4.30	2.73	10/2/90	U_4O_9 plus minor $\text{UO}_2\text{F}_2 \cdot 1.5\text{H}_2\text{O}$ (PDF-1151). Note U_4O_9 broadening. No EDS done.
9B-10	88-117	QC	23.8	210	19493	4.60	2.78	11/1/90	U_4O_9 plus minor $\text{UO}_2\text{F}_2 \cdot 1.5\text{H}_2\text{O}$ (PDF-1151). Note U_4O_9 broadening. No EDS done.
8B-c1 ²	89-20	PB	29.5	190	8574	2.85	2.48	9/7/89	XRD detected no fluorides. SEM/EDS detected fluorine.

TABLE 4.4. (Contd)

<u>Specimen</u>	<u>Sample #</u>	<u>Source</u> ¹	<u>Burnup, Mwd/kgM</u>	<u>Temp., °C</u>	<u>Time, h</u>	<u>Weight Gain, %</u>	<u>Oxygen-to- Metal Ratio</u>	<u>XRD Date</u>	<u>Examination Results</u>
98-c5 ²	89-25	HBR	29.5	210	6458	3.09	2.66	8/3/89	XRD detected no fluorides. SEM/EDS detected fluorine.
Spent Fuel Cladding: Test Series B									
11B-c2 ³	11-28	QC	23.0	230	18064	3.78 ⁴	2.64	3/15/91	ZrO ₂ plus ZrO ₂ F ₂ . SEM/EDS detected fluorine.
11B-c2 ⁵	11-29	QC	23.0	230	18064	3.78 ⁴	2.64	3/14/91	ZrO ₂ plus ZrO ₂ F ₂ . SEM/EDS detected fluorine.
Spent Fuel Fragments: non-Test Series B									
Archive	91-U01	HBR	22.0	N/A	0	0	2.	4/18/91 ⁶	SEM/EDS detected no fluorine. No XRD done.
Series A ⁷	91-U02	HBR	22.0	200	5070	2.28	2.38	4/18/91 ⁶	SEM/EDS detected no fluorine. No XRD done.
105P2 ⁸	011A	ATM-105		175	19598	2.25	2.38	4/26/91	XRD detected no fluorides. EDS detected no fluorine.
TPP2 ⁸	004A	TP		175	29124	2.13	2.36	4/30/91	XRD detected no fluorides. EDS detected no fluorine.

1. QC = Quad Cities BWR; PB = Point Beach PWR; HBR = HB Robinson PWR; NI = nonirradiated; TP = Turkey Point PWR; ATM-105 = Materials Characterization Center Approved Testing Material-105 (Cooper BWR).
2. Spent fuel taken from within the split rod segment.
3. Scale taken from the cladding heat-affected zone.
4. Assumes all weight gain is in UO₂.
5. Scale taken from the rodlet nonirradiated endcap.
6. Date of SEM/EDS examination.
7. Spent fuel fragment oxidized in BSFS Test Series A (low gamma, silicon seals).
8. Sample cut in D-cell then oxidized by another program in another facility.

Spent Fuel Rodlet Failures During Air Oxidation

FIGURE 4.1. Photographs of Split Rod Segments Illustrating Initial Defect Locations and Splitting Behavior

Spent Fuel Rodlet Failures During Air Oxidation

B-C5, 210°C, 6458 h

11B-C3, 230°C, 9406 h

10B-C2, 230°C, 4894 h

11C-C2, 230°C, 18064 h

10B-C3, 230°C, 7196 h

FIGURE 4.1. (Contd)

a) 9B-c5 Defect Region
as cut surface

b) 9B-c5 Defect Region
Fuel Vibrated from
Cladding

c) 10B-c2 Defect Region
View from End of Rod Where Endcap Split 360°

FIGURE 4.2. Fuel Condition in Split Rod Segments

FIGURE 4.3. Cutting Diagrams for Fuel Rodlets, Showing Analysis Locations

b) Rodlet 9B-c5 (210°C)

c) Rodlet 10B-c2 (230°C)

FIGURE 4.3. (Contd)

FIGURE 4.4. Transverse Ceramographic Section from Split Rod Segment 8B-cl. Light areas of fuel fragments are unoxidized UO_2 . Part of fuel fell out due to etching attack on oxidized grain boundaries. Sketch indicates location where XRD samples were taken after ceramography was completed.

FIGURE 4.5. X-ray Diffraction Pattern from Oxidized Fuel in Rod Segment 8B-c1 Near Defect Section

FIGURE 4.6. Axial Distribution of Oxidation Products in Split Rod Segment 8B-cl. Relative amounts of UO₂, U₄O₉, and U₃O₈ in the oxidized fuel were determined from X-ray peak intensities.

FIGURE 4.7. X-ray Diffraction Pattern from Oxidized Fuel in Transverse Section from Rod Section 8B-cl. No U_3O_8 detected.

Transmission Electron Micrograph of Oxidized Fuel from Rod Segment 8B-c1, showing grain unidentitied oxidation product along boundary between U_3O_8 grains. Grain-boundary particles of metallic fission product phase (ϵ) appear unaltered by oxidation.

FIGURE 4.8.

FIGURE 4.9 Optical Ceramograph of Transverse Section from Split Rod Segment 9B-c5 (210°C), Showing Complete Oxidation of Section

FIGURE 4.10. Ceramograph of Fuel from Rod Segment 9B-c5, Showing Oxidation Product Along Grain Boundaries

FIGURE 4.11. X-ray Diffraction Pattern from U_3O_7 in Oxidized Fuel from Rod Segment 9B-c5 (210°C oxidation). After removal (stripping) of superimposed U_4O_9 pattern.

FIGURE 4.12 Optical Ceramograph Unsplit Rod Segment 8B-c4 (210°C)
Showing Uniform Oxidation of the Fuel

FIGURE 4.13. XRD Pattern from Bare Spent Fuel Specimen Oxidized as 210°C, Showing U_4O_9 and an Amorphous Phase After Removal of Background Produced by the Holder; Small Peaks in the Background Match $UO_2F_2 \cdot 1.5H_2O$

FIGURE 4.14. Weight Gain Differences Between Spent Fuel and Nonirradiated UO_2 at Different Test Temperatures

FIGURE 4.15. End-of-Test Weight Gain Differences Between Spent Fuel and Nonirradiated UO_2

FIGURE 4.16. XRD Patterns from End-of-Test Nonirradiated UO_2 and Spent Fuel Samples, showing formation of $UO_2F_2 \cdot 1.5H_2O$. Nonirradiated sample was 100% uranyl fluoride hydrate.

a) Surface of As-tested Fuel Particle

b) Post Test Fracture Showing Altered Grain Boundaries

c) EDS Spectrum from Fracture Surface in b). Spectrum is expanded to show fluorine and oxygen peaks.

FIGURE 4.17. SEM/EDS Analysis of End-of-Test Spent Fuel Sample; 38,000 h at 150°C (sample 91-06)

FIGURE 4.18. SEM/EDS of Uanyl Oxide Fluoride Formed from Nonirradiated UO_2 at 190°C (sample 91-12)

FIGURE 4.19. TGA Analysis of Oxidized Spent Fuel and Nonirradiated UO_2

FIGURE 4.20. XRD Pattern from U_3O_8 Formed by Heating Oxidized Spent Fuel (sample 91-11) to 675°C in the TGA

FIGURE 4.21. SEM/EDS Analysis of Corrosion Product from Rod Segment Encap, Showing Presence of Fluorine

FIGURE 4.22. XRD Analysis of Corrosion Product from Rod Segment Endcap. Analysis indicates monoclinic $\text{Zr}_7\text{P}_9\text{F}_{10}$.

FIGURE 4.23. SEM/EDS of Oxidized Spent Fuel from Split Rod Segment 8B-cl (190°C). Corresponding EDS spectrum shows presence of fluorine on sample fracture surface.

FILE: 8628SF12 Fuel Particle Sample 86-28 as sampled

SCALE FACTOR, OFFSET=162.360, 0.000 K COUNTS/SEC

BV=10.00KV BI=0.0000uA

FIGURE 4.24. Auger Electron Spectrum from Interim Bare Fuel Oxidation Sample (86-28: Quad Cities fuel, 7171 h at 190°C). Fluorine not detected.

Viton-A: vinylidene fluoride-hexafluoropropylene copolymer⁽¹⁾

VITON-A

FIGURE 4.25. Schematic Structural Representation for Viton[™] (Dixon, Rexford, and Rugg 1957)

FIGURE 4.26. Halogen Release from Irradiated Fluorothene as a Function of Gamma Dose (Byrne et al. 1953)

FIGURE 4.27. Radiation Periods for Viton™ Door Seals in Oven 8 (190°C)

FIGURE 4.28. Calculated Cumulative HF Release from Oven Door Seals in Oven 8

5.0 SUMMARY AND CONCLUSIONS

Documented in this report has been the conduct and results of Test Series B conducted by the BSFS Project. In Test Series B, the oven atmospheres in which the test specimens were exposed were contaminated with an unknown quantity of fluorine. **Because of the fluorine contamination of the oven atmospheres and test specimens, it is recommended that the Test Series B data not be used to develop time-temperature limits for exposure of spent nuclear fuel to air.**

Data and observations from interim examinations and analytical examinations were presented in Sections 3 and 4, respectively. From the observations and the results of the analyses, it is apparent that a previously unrecognized regime of accelerated corrosion of irradiated UO_2 and Zircaloy cladding at low temperature in the presence of fluorine was encountered during Test Series B. This unexpected reaction of the spent fuel to a fluorine-contaminated air atmosphere highlights the need to be concerned with cover gas contaminants during dry storage of spent nuclear fuel.

As noted, fluorine contamination of the Test Series B specimens was discovered after the exposures were completed. The first specimens in which fluorine was found were samples of cladding corrosion products taken from a rod segment nonirradiated endcap and from the irradiated cladding. Following this discovery, the spent fuel specimens were examined, or re-examined, in light of the fluorine discovery and several were found to contain significant amounts of fluorine. After the presence of the fluorine in the exposed specimens was confirmed, the source, the extent, and the impact of the fluorine contamination were investigated. Provided in the following is a summary of the investigation results.

FLUORINE DISCOVERY

Fluorine contamination was discovered during analysis of corrosion product taken from a nonirradiated Zry endcap and irradiated Zry cladding of a rod segment exposed at 230°C. The corrosion product was examined because the formation of a reaction product was not expected under the test conditions. The fluorine was detected by thin-window EDS analysis and XRD analysis of the

corrosion product identified it as a mixture of ZrO_2 and a zirconium oxide fluoride compound. Thin-window EDS analysis also established the presence of fluorine in samples of exposed nonirradiated UO_2 and spent fuel from Test Series B. XRD analysis identified a uranyl fluoride hydrate phase in both the nonirradiated UO_2 and spent fuel samples.

Fluorine was found only in specimens that had been exposed in ovens sealed with Viton™ gaskets; i.e., only the Test Series B specimens were contaminated with fluorine. However, no fluorine was detected in Test Series B bare fragment specimens that had been exposed for less than 16,000 h. No fluorine was found in samples obtained from materials not exposed in the Test Series B ovens. Those samples included oxidized material from BSFS Test Series A (ovens with silicon gaskets), BSFS Project archive non-exposed spent fuel, and non-BSFS spent fuel samples that were prepared in the radiochemical hot cell used by the BSFS Project and subsequently oxidized in a different facility as part of a different program.

FLUORINE SOURCE

The source of the fluorine is concluded to be gamma radiation-induced chemical decomposition of the Viton™ oven door gaskets. Observations supporting this conclusion include: a) Viton™ contains approximately 25% fluorine, which is more than sufficient to account for the observed levels of contamination; b) there were no other known sources of fluorine in the system; c) the observed physical degradation of the seals; d) investigations (Byrne et al. 1953; Dixon, Rexford, and Rugg 1957; Wall 1972) into the effect of gamma radiation on Viton™ (and halogenated hydrocarbons in general) indicated that chemical decomposition could begin at gamma doses as low 10^5 R with significant halogen releases at $>10^8$ R; e) the fluorine must have been incorporated during the oven exposures because there was insufficient fluorine in the specimens due to fabrication or irradiation^(a) to account for the observed levels of contamination; and f) only the Test Series B specimens were contaminated with fluorine.

^(a) Fluorine does exist as an impurity in the fabricated UO_2 and is formed during irradiation as a fission product.

INTERACTION OF FLUORINE WITH SPENT FUEL AND NONIRRADIATED UO_2

The fluorine contamination of nonirradiated UO_2 and spent fuel specimens in Test Series B apparently resulted from reaction of UO_2 specimens with HF vapor released from the Viton™ seals used in the ovens. Conditions under which the fluoridation of the specimens occurred included a) the presence of moist air containing HF vapor, b) test temperatures ranging from 135° to 230°C, c) the presence of a high gamma radiation field, and d) apparent partial oxidation of the test specimens before any fluoridation was detected.

It is particularly noteworthy that there is no precedent for the fluoridation of spent fuel or nonirradiated UO_2 under the temperature and probable atmospheric conditions that existed in the ovens during Test Series B. Reactions of UO_2 with HF at low temperatures may produce $\text{UF}_4 + \text{H}_2\text{O}$ plus intermediate hydrated fluorides (Weigel 1986). However, none of the fluoride products of those reactions were found in Test Series B specimens. The only known, or suspected, fluoridation products found in the nonirradiated UO_2 and spent fuel specimens were 1) a hydrate, $\text{UO}_2\text{F}_2 \cdot 1.5\text{H}_2\text{O}$, found predominantly in the nonirradiated specimens, but also as a minor constituent of the spent fuel specimens, 2) cubic U_4O_{9+x} , possibly with fluorine incorporated into its structure, and 3) an amorphous phase detected by both XRD and TEM and found as a major constituent in highly fluorided spent fuel specimens. None of these products have been previously identified in fluoridation reactions of UO_2 .

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APPENDIX A

BARE FRAGMENT TEST MATRIX DETAILS

APPENDIX A

BARE FRAGMENT TEST MATRIX DETAILS

Presented in this appendix are twelve tables, one for each oven, providing the matrix of spent fuel bare fragments used in Test Series B. Provided in each table is a listing of the bare fragment specimens (in order of increasing burnup) tested in that oven, the spent fuel source and spent fuel rod from which the specimen was obtained, and the burnup value for the bare fragment specimen.

Presented in Table A.13 are the results of an analysis of average fragment size in each bare fragment specimen. This analysis began by counting the number of fragments in each bare fragment specimen; the counting was done from Polaroid photographs of the specimens. Average fragment weight was then determined by dividing the total specimen weight by the number of fragments in the specimen. Average fragment volume was determined by dividing average fragment weight by an assumed density of $10.41 \text{ cm}^3/\text{g UO}_2$. Because not all fragments in a specimen were necessarily counted, the number of fragments in a specimen should be considered a minimum and, therefore, average fragment weight and volume should be considered a maximum.

TABLE A.1. Oxidation Test Bare Fragment Specimens Used in 150°C Test in a Gamma Field of 1.3×10^5 R/h (20°C dew point)

<u>Specimen ID</u>	<u>Reactor</u> ^(a)	<u>Rod ID</u>	<u>Burnup,</u> <u>(MWd/kgM)</u> ^(b)	<u>Shelf</u>
1B-12	N/A	N/A	0.0	bottom front
1B-4	Quad Cities	1B02-4	0.7	top front
1B-11	H.B. Robinson	G9T	11.7	bottom front
1B-10	H.B. Robinson	G9T	17.1	bottom back
1B-9	H.B. Robinson	G9T	18.5	bottom back
1B-8	H.B. Robinson	G9T	23.0	middle front
1B-1	Shippingport	SP-D	23.7 ^(c)	top back
1B-5	H.B. Robinson	G9T	27.9	middle back
1B-6	H.B. Robinson	G9T	28.4	middle back
1B-7	H.B. Robinson	G9T	28.4	middle front
1B-2	Point Beach	PB-B	29.5 ^(c)	top back
1B-3	Point Beach	PB-B	29.5 ^(c)	top front

(a) PWR Fuel: Point Beach, H.B. Robinson, Shippingport
BWR Fuel: Quad Cities, Monticello

(b) Gamma scan of rod used to determine burnups of specimens. Assumes a linear relation between cesium-137 counts and burnup (Barner 1985).

(c) Specimen assigned the estimated average burnup of the rod since no gamma scan was available.

TABLE A.2.

Oxidation Test Bare Fragment Specimens Used in 150°C Test in a Gamma Field of 1.3×10^5 R/h (40°C dew point)

<u>Specimen ID</u>	<u>Reactor</u> ^(a)	<u>Rod ID</u>	<u>Burnup, (MWd/kgM)</u> ^(b)	<u>Shelf</u>
2B-12	N/A	N/A	0.0	bottom front
2B-3	Quad Cities	1B02-4	7.8	top front
2B-7	H.B. Robinson	G9T	13.4	middle front
2B-8	Monticello	0A03-4	14.6	middle front
2B-9	Monticello	0A03-4	21.4	bottom back
2B-1	Shippingport	SP-D	23.7 ^(c)	top back
2B-6	H.B. Robinson	G9T	24.9	middle back
2B-10	Monticello	0A03-4	28.0	bottom back
2B-4	H.B. Robinson	G9T	28.4	top front
2B-5	H.B. Robinson	G9T	28.4	middle back
2B-2	Point Beach	PB-B	29.5 ^(c)	top back
2B-11	Monticello	0A03-4	34.4	bottom front

(a) PWR Fuel: Point Beach, H.B. Robinson, Shippingport
BWR Fuel: Quad Cities, Monticello

(b) Gamma scan of rod used to determine burnups of specimens. Assumes a linear relation between cesium-137 counts and burnup (Barner 1985).

(c) Specimen assigned the estimated average burnup of the rod since no gamma scan was available.

TABLE A.3. Oxidation Test Bare Fragment Specimens Used in 170°C Test in
a Gamma Field of 1.3x10⁵ R/h (20°C dew point)

<u>Specimen ID</u>	<u>Reactor</u> ^(a)	<u>Rod ID</u>	<u>Burnup, (MWd/kgM)</u> ^(b)	<u>Shelf</u>
3B-12	N/A	N/A	0.0	bottom front
3B-4	Quad Cities	1B02-4	7.9	top front
3B-11	Quad Cities	1C02-1	8.7	bottom front
3B-8	Quad Cities	1A03-3	12.5	middle front
3B-10	Quad Cities	1C02-1	16.0	bottom back
3B-9	Quad Cities	1C02-1	19.6	bottom back
3B-6	Quad Cities	1A01-1	23.5	middle back
3B-7	Quad Cities	1A01-1	23.5	middle front
3B-1	Shippingport	SP-D	23.7 ^(c)	top back
3B-2	Point Beach	PB-B	29.5 ^(c)	top back
3B-3	Point Beach	PB-B	29.5 ^(c)	top front
3B-5	Monticello	0A03-4	34.0	middle back

(a) PWR Fuel: Point Beach, H.B. Robinson, Shippingport
 BWR Fuel: Quad Cities, Monticello

(b) Gamma scan of rod used to determine burnups of specimens. Assumes a
linear relation between cesium-137 counts and burnup (Barner 1985).

(c) Specimen assigned the estimated average burnup of the rod since no gamma
scan was available.

TABLE A.4.

Oxidation Test Bare Fragment Specimens Used in 190°C Test in a Gamma Field of 1.3×10^5 R/h (20°C dew point)

<u>Specimen ID</u>	<u>Reactor</u> ^(a)	<u>Rod ID</u>	<u>Burnup,</u> <u>(MWd/kgM)</u> ^(b)	<u>Shelf</u>
4B-12	N/A	N/A	0.0	bottom front
4B-4	Quad Cities	1B02-4	7.9	top front
4B-8	Quad Cities	1A03-3	12.5	middle front
4B-11	Quad Cities	1C02-1	17.5	bottom front
4B-9	Quad Cities	1C02-1	19.1	bottom back
4B-10	Quad Cities	1C02-1	19.6	bottom back
4B-6	Quad Cities	1A01-1	23.3	middle back
4B-7	Quad Cities	1A01-1	23.5	middle front
4B-1	Shippingport	SP-E	23.7 ^(c)	top back
4B-2	Point Beach	PB-B	29.5 ^(c)	top back
4B-3	Point Beach	PB-B	29.5 ^(c)	top front
4B-5	Monticello	0A03-4	32.4	middle back

(a) PWR Fuel: Point Beach, H.B. Robinson, Shippingport
BWR Fuel: Quad Cities, Monticello

(b) Gamma scan of rod used to determine burnups of specimens. Assumes a linear relation between cesium-137 counts and burnup (Barner 1985).

(c) Specimen assigned the estimated average burnup of the rod since no gamma scan was available.

TABLE A.5. Oxidation Test Bare Fragment Specimens Used in 190°C Test in
a Gamma Field of 1.3x10⁵ R/h (40°C dew point)

<u>Specimen ID</u>	<u>Reactor</u> ^(a)	<u>Rod ID</u>	<u>Burnup, (MWd/kgM)</u> ^(b)	<u>Shelf</u>
5B-12	N/A	N/A	0.0	bottom front
5B-7	Quad Cities	1C02-1	10.1	middle front
5B-5	Quad Cities	1A03-3	12.5	middle back
5B-8	Monticello	5D18-3	16.0	middle front
5B-6	Quad Cities	1C02-1	18.0	middle back
5B-9	Monticello	5D18-3	22.4	bottom back
5B-3	Quad Cities	1A01-1	22.6	top front
5B-4	Quad Cities	1A01-1	23.0	top front
5B-1	Shippingport	SP-E	23.7 ^(c)	top back
5B-10	Monticello	5D18-3	27.5	bottom back
5B-2	Point Beach	PB-B	29.5 ^(c)	top back
5B-11	Monticello	5D18-3	34.4	bottom front

(a) PWR Fuel: Point Beach, H.B. Robinson, Shippingport
BWR Fuel: Quad Cities, Monticello

(b) Gamma scan of rod used to determine burnups of specimens. Assumes a linear relation between cesium-137 counts and burnup (Barner 1985).

(c) Specimen assigned the estimated average burnup of the rod since no gamma scan was available.

TABLE A.6. Oxidation Test Bare Fragment Specimens Used in 135°C Test in
a Gamma Field of 1.3×10^5 R/h (40°C dew point)

<u>Specimen ID</u>	<u>Reactor</u> ^(a)	<u>Rod ID</u>	<u>Burnup,</u> <u>(MWd/kgM)</u> ^(b)	<u>Shelf</u>
6B-12	N/A	N/A	0.0	bottom front
6B-5	Quad Cities	1A01-2	8.0	middle back
6B-3	Quad Cities	1A01-2	12.2	top front
6B-8	Monticello	0A08-4	15.1	middle front
6B-7	Quad Cities	DTA0103	17.0	middle front
6B-6	Quad Cities	DTA0103	17.2	middle back
6B-4	Quad Cities	1C02-1	18.5	top front
6B-9	Monticello	0A08-4	21.5	bottom back
6B-1	Shippingport	SP-F	23.7 ^(c)	top back
6B-10	Monticello	PB-B	28.0	bottom back
6B-2	Point Beach	PB-B	29.5 ^(c)	top back
6B-11	Monticello	0A08-4	34.4	bottom front

(a) PWR Fuel: Point Beach, H.B. Robinson, Shippingport
BWR Fuel: Quad Cities, Monticello

(b) Gamma scan of rod used to determine burnups of specimens. Assumes a linear relation between cesium-137 counts and burnup (Barner 1985).

(c) Specimen assigned the estimated average burnup of the rod since no gamma scan was available.

TABLE A.7. Oxidation Test Bare Fragment Specimens Used in 150°C Test in
a Gamma Field of 1.3×10^5 R/h (0°C dew point)

<u>Specimen ID</u>	<u>Reactor</u> ^(a)	<u>Rod ID</u>	<u>Burnup, (MWd/kgM)</u> ^(b)	<u>Shelf</u>
7B-12	N/A	N/A	0.0	bottom front
7B-3	Quad Cities	1B02-4	7.6	top front
7B-11	H.B. Robinson	G9T	9.9	bottom front
7B-10	H.B. Robinson	G9T	15.3	bottom back
7B-9	H.B. Robinson	G9T	19.6	bottom back
7B-8	H.B. Robinson	G9T	20.8	middle front
7B-1	Shippingport	SP-D	23.7 ^(c)	top back
7B-7	H.B. Robinson	G9T	26.3	middle front
7B-4	H.B. Robinson	G9T	26.4	top front
7B-5	H.B. Robinson	G9T	28.4	middle back
7B-6	H.B. Robinson	G9T	28.4	middle back
7B-2	Point Beach	PB-B	29.5 ^(c)	top back

(a) PWR Fuel: Point Beach, H.B. Robinson, Shippingport
 BWR Fuel: Quad Cities, Monticello

(b) Gamma scan of rod used to determine burnups of specimens. Assumes a
linear relation between cesium-137 counts and burnup (Barner 1985).

(c) Specimen assigned the estimated average burnup of the rod since no gamma
scan was available.

TABLE A.8. Oxidation Test Bare Fragment Specimens Used in 190°C Test in
a Gamma Field of 1.3×10^5 R/h (0°C dew point)

<u>Specimen ID</u>	<u>Reactor</u> ^(a)	<u>Rod ID</u>	<u>Burnup, (MWd/kgM)</u> ^(b)	<u>Shelf</u>
8B-12	N/A	N/A	0.0	bottom front
8B-3	Quad Cities	1B02-4	7.9	top front
8B-7	Quad Cities	1A03-3	12.5	middle front
8B-8	Quad Cities	1A03-3	12.5	middle front
8B-11	Quad Cities	1C02-1	16.8	bottom front
8B-10	Quad Cities	1C02-1	18.7	bottom back
8B-9	Quad Cities	1C02-1	19.8	bottom back
8B-6	Quad Cities	1A01-1	23.5	middle back
8B-1	Shippingport	SP-E	23.7 ^(c)	top back
8B-5	Quad Cities	1A01-1	23.7	middle back
8B-2	Point Beach	PB-B	29.5 ^(c)	top back
8B-4	Monticello	0A03-4	33.5	top front

(a) PWR Fuel: Point Beach, H.B. Robinson, Shippingport
BWR Fuel: Quad Cities, Monticello

(b) Gamma scan of rod used to determine burnups of specimens. Assumes a linear relation between cesium-137 counts and burnup (Barner 1985).

(c) Specimen assigned the estimated average burnup of the rod since no gamma scan was available.

TABLE A.9. Oxidation Test Bare Fragment Specimens Used in 210°C Test in
a Gamma Field of 1.3x10⁵ R/h (20°C dew point)

<u>Specimen ID</u>	<u>Reactor</u> ^(a)	<u>Rod ID</u>	<u>Burnup, (MWd/kgM)</u> ^(b)	<u>Shelf</u>
9B-12	N/A	N/A	0.0	bottom front
9B-8	Quad Cities	1A01-2	7.7	middle front
9B-5	Quad Cities	1A03-3	12.5	middle back
9B-9	Quad Cities	DTA0103	17.2	bottom back
9B-1	Shippingport	SP-E	23.7 ^(c)	top back
9B-11	Quad Cities	1C02-4	23.7	bottom front
9B-10	Quad Cities	1C02-4	23.8	bottom back
9B-6	H.B. Robinson	G9T	24.4	middle back
9B-4	H.B. Robinson	G9T	27.6	top front
9B-2	Point Beach	PB-B	29.5 ^(c)	top back
9B-3	Point Beach	PB-B	29.5 ^(c)	top front
9B-7	Monticello	5D18-3	32.6	middle front

(a) PWR Fuel: Point Beach, H.B. Robinson, Shippingport
BWR Fuel: Quad Cities, Monticello

(b) Gamma scan of rod used to determine burnups of specimens. Assumes a linear relation between cesium-137 counts and burnup (Barner 1985).

(c) Specimen assigned the estimated average burnup of the rod since no gamma scan was available.

TABLE A.10. Oxidation Test Bare Fragment Specimens Used in 135°C Test in a Gamma Field of 1.3×10^5 R/h (0°C dew point)

<u>Specimen ID</u>	<u>Reactor</u> ^(a)	<u>Rod ID</u>	<u>Burnup, (MWd/kgM)</u> ^(b)	<u>Shelf</u>
10B-12	N/A	N/A	0.0	bottom front
10B-6	Quad Cities	1A01-2	7.9	middle back
10B-4	Quad Cities	1A03-3	12.5	top front
10B-7	Quad Cities	DTA0103	16.7	middle front
10B-8	Quad Cities	DTA0103	17.0	middle front
10B-9	Quad Cities	DTA0103	17.2	bottom back
10B-1	Shippingport	SP-F	23.7 ^(c)	top back
10B-10	Quad Cities	1C02-4	24.2	bottom back
10B-11	Quad Cities	1C02-4	24.2	bottom front
10B-3	H.B. Robinson	G9T	27.6	top front
10B-2	Point Beach	PB-B	29.5 ^(c)	top back
10B-5	Monticello	5D18-3	34.1	middle back

(a) PWR Fuel: Point Beach, H.B. Robinson, Shippingport
BWR Fuel: Quad Cities, Monticello

(b) Gamma scan of rod used to determine burnups of specimens. Assumes a linear relation between cesium-137 counts and burnup (Barner 1985).

(c) Specimen assigned the estimated average burnup of the rod since no gamma scan was available.

TABLE A.11. Oxidation Test Bare Fragment Specimens Used in 170°C Test in a Gamma Field of 1.3x10⁵ R/h (20°C dew point)

<u>Specimen ID</u>	<u>Reactor</u> ^(a)	<u>Rod ID</u>	<u>Burnup, (MWd/kgM)</u> ^(b)	<u>Shelf</u>
11B-12	N/A	N/A	0.0	bottom front
11B-8	Quad Cities	1A01-2	8.0	middle front
11B-5	Quad Cities	1A03-3	12.0	middle back
11B-9	Quad Cities	DTA0103	17.2	bottom back
11B-10	Quad Cities	DTA0103	17.2	bottom back
11B-6	Quad Cities	1C02-1	19.4	middle back
11B-1	Shippingport	SP-F	23.7 ^(c)	top back
11B-11	Quad Cities	1C02-4	24.2	bottom front
11B-4	H.B. Robinson	G9T	27.6	top front
11B-2	Point Beach	PB-B	29.5 ^(c)	top back
11B-3	Point Beach	PB-B	29.5 ^(c)	top front
11B-7	Monticello	5D18-3	33.7	middle front

(a) PWR Fuel: Point Beach, H.B. Robinson, Shippingport
BWR Fuel: Quad Cities, Monticello

(b) Gamma scan of rod used to determine burnups of specimens. Assumes a linear relation between cesium-137 counts and burnup (Barner 1985).

(c) Specimen assigned the estimated average burnup of the rod since no gamma scan was available.

TABLE A.12.

Oxidation Test Bare Fragment Specimens Used in 230°C Test in a Gamma Field of 1.3×10^5 R/h (20°C dew point)

<u>Specimen ID</u>	<u>Reactor</u> ^(a)	<u>Rod ID</u>	<u>Burnup, (MWd/kgM)</u> ^(b)	<u>Shelf</u>
12B-12	N/A	N/A	0.0	bottom front
12B-6	Quad Cities	1A01-2	8.0	middle back
12B-7	Quad Cities	1A01-2	8.0	middle front
12B-4	Quad Cities	1A03-3	12.0	top front
12B-8	Quad Cities	DTA0103	17.2	middle front
12B-5	Quad Cities	1C02-1	17.7	middle back
12B-1	Shippingport	SP-F	23.7 ^(c)	top back
12B-9	Quad Cities	1C02-4	24.2	bottom back
12B-3	H.B. Robinson	G9T	26.8	top front
12B-2	Point Beach	PB-B	29.5 ^(c)	top back
12B-11	Monticello	0A08-4	33.9	bottom front
12B-10	Monticello	0A08-4	34.4	bottom back

(a) PWR Fuel: Point Beach, H.B. Robinson, Shippingport
BWR Fuel: Quad Cities, Monticello

(b) Gamma scan of rod used to determine burnups of specimens. Assumes a linear relation between cesium-137 counts and burnup (Barner 1985).

(c) Specimen assigned the estimated average burnup of the rod since no gamma scan was available.

TABLE A.13. Summary of Fragment Analysis for Spent Fuel Samples

<u>Fuel Source</u>	<u>Sample</u>	<u>Burnup, MWd/kgU</u>	<u>Initial Weight, gUO₂</u>	<u>Estimated Number of Fragments</u>	<u>Average gUO₂ per Fragment</u>	<u>Average cm³ per Fragment</u>
SP	1B-1	23.7	22.03	100	0.220	0.021
	2B-1	23.7	17.65	100	0.177	0.017
	3B-1	23.7	20.82	90	0.231	0.022
	4B-1	23.7	27.86	46	0.606	0.058
	5B-1	23.7	23.34	70	0.333	0.032
	6B-1	23.7	27.45	60	0.458	0.044
	7B-1	23.7	21.73	100	0.217	0.021
	8B-1	23.7	26.45	57	0.464	0.045
	9B-1	23.7	24.00	100	0.240	0.023
	10B-1	23.7	26.49	52	0.509	0.049
	11B-1	23.7	24.33	60	0.406	0.039
	12B-1	23.7	25.68	55	0.467	0.045
PB	1B-2	29.5	24.22	80	0.303	0.029
	1B-3	29.5	24.31	106	0.229	0.022
	2B-2	29.5	24.76	65	0.381	0.037
	3B-2	29.5	24.80	70	0.354	0.034
	3B-3	29.5	23.85	90	0.265	0.025
	4B-2	29.5	25.14	90	0.279	0.027
	4B-3	29.5	24.74	65	0.381	0.037
	5B-2	29.5	24.61	80	0.308	0.030
	6B-2	29.5	24.91	84	0.296	0.028
	7B-2	29.5	25.29	90	0.281	0.027
	8B-2	29.5	23.64	106	0.223	0.021
	9B-2	29.5	23.99	70	0.343	0.033
	9B-3	29.5	23.75	100	0.238	0.023
	10B-2	29.5	22.86	100	0.229	0.022
	11B-2	29.5	23.85	77	0.310	0.030
	11B-3	29.5	23.31	73	0.319	0.031
	12B-2	29.5	23.74	110	0.216	0.021
QC	1B-4	7.7	45.11	70	0.644	0.062
	2B-3	7.8	43.91	45	0.976	0.094
	3B-4	7.9	43.99	35	1.257	0.121
	3B-6	23.5	44.79	40	1.120	0.108
	3B-7	23.5	45.14	43	1.050	0.101
	3B-8	12.5	46.50	71	0.655	0.063
	3B-9	19.6	44.35	33	1.344	0.129
	3B-10	16.0	44.71	24	1.863	0.179
	3B-11	8.7	43.90	12	3.658	0.351
	4B-4	7.9	44.68	34	1.314	0.126
	4B-6	23.3	44.72	46	0.972	0.093
	4B-7	23.5	44.76	45	0.995	0.096
	4B-8	12.5	43.81	70	0.626	0.060
	4B-9	19.1	44.40	38	1.168	0.112
	4B-10	19.6	44.43	27	1.646	0.158

TABLE A.13. Continued

<u>Fuel Source</u>	<u>Sample</u>	<u>Burnup, MWd/kgU</u>	<u>Initial Weight, gUO₂</u>	<u>Estimated Number of Fragments</u>	<u>Average gUO₂ per Fragment</u>	<u>Average cm³ per Fragment</u>
QC	4B-11	17.5	48.17	37	1.302	0.125
	5B-3	22.6	44.90	34	1.321	0.127
	5B-4	23.0	45.11	47	0.960	0.092
	5B-5	12.5	45.66	80	0.571	0.055
	5B-6	18.0	43.79	37	1.184	0.114
	5B-7	10.1	44.63	7	6.376	0.612
	6B-3	12.2	43.83	47	0.933	0.090
	6B-4	18.5	44.61	34	1.312	0.126
	6B-5	8.0	46.59	50	0.932	0.090
	6B-6	17.2	45.12	25	1.805	0.173
	6B-7	17.0	44.82	38	1.318	0.127
	7B-3	7.6	44.96	38	1.183	0.114
	8B-3	7.9	40.43	37	1.093	0.105
	8B-5	23.7	45.30	48	0.944	0.091
	8B-6	23.5	44.89	38	1.181	0.113
	8B-7	12.5	45.64	64	0.713	0.069
	8B-8	12.5	44.03	60	0.734	0.070
	8B-9	19.8	44.48	33	1.348	0.129
	8B-10	18.7	44.69	31	1.442	0.138
	8B-11	16.8	46.77	32	1.462	0.140
	9B-5	12.5	44.88	48	0.935	0.090
	9B-8	7.7	45.67	53	0.862	0.083
	9B-9	17.2	46.24	42	1.101	0.106
	9B-10	23.8	45.61	47	0.970	0.093
	9B-11	23.7	46.28	39	1.187	0.114
	10B-4	12.5	44.66	50	0.893	0.086
	10B-6	7.9	46.40	57	0.814	0.078
	10B-7	16.7	46.00	35	1.314	0.126
	10B-8	17.0	46.52	32	1.454	0.140
	10B-9	17.2	43.27	26	1.664	0.160
	10B-10	24.2	45.93	56	0.820	0.079
	10B-11	24.2	45.87	60	0.765	0.073
	11B-5	12.0	44.24	50	0.885	0.085
	11B-6	19.4	44.56	35	1.273	0.122
	11B-8	8.0	46.15	47	0.982	0.094
	11B-9	17.2	44.49	26	1.711	0.164
	11B-10	17.2	43.27	27	1.603	0.154
	11B-11	24.2	46.16	45	1.026	0.099
	12B-4	12.0	44.30	70	0.633	0.061
	12B-5	17.7	36.38	22	1.654	0.159
	12B-6	8.0	46.69	75	0.623	0.060
	12B-7	8.0	45.88	70	0.655	0.063
	12B-8	17.2	45.07	36	1.252	0.120
	12B-9	24.2	46.09	55	0.838	0.080

TABLE A.13. Continued

<u>Fuel Source</u>	<u>Sample</u>	<u>Burnup, MWd/kgU</u>	<u>Initial Weight, gUO₂</u>	<u>Estimated Number of Fragments</u>	<u>Average gUO₂ per Fragment</u>	<u>Average cm³ per Fragment</u>
HBR	1B-5	27.9	23.80	100	0.238	0.023
	1B-6	28.4	7.26	45	0.161	0.015
	1B-7	28.4	23.30	76	0.307	0.029
	1B-8	23.0	24.83	72	0.345	0.033
	1B-9	18.5	25.18	66	0.382	0.037
	1B-10	17.1	20.09	48	0.419	0.040
	1B-11	11.7	23.69	39	0.607	0.058
	2B-4	28.4	24.99	83	0.301	0.029
	2B-5	28.4	24.55	65	0.378	0.036
	2B-6	24.9	21.22	90	0.236	0.023
	2B-7	13.4	24.95	50	0.499	0.048
	7B-4	26.4	24.84	80	0.311	0.030
	7B-5	28.4	22.98	110	0.209	0.020
	7B-6	28.4	25.10	93	0.270	0.026
	7B-7	26.3	24.29	110	0.221	0.021
	7B-8	20.8	25.25	64	0.395	0.038
	7B-9	19.6	24.57	55	0.447	0.043
	7B-10	15.3	22.98	68	0.338	0.032
	7B-11	9.9	23.18	33	0.702	0.067
	9B-4	27.6	23.36	95	0.246	0.024
	9B-6	24.4	25.11	95	0.264	0.025
	10B-3	27.6	23.50	80	0.294	0.028
	11B-4	27.6	22.99	110	0.209	0.020
	12B-3	26.8	24.61	100	0.246	0.024
M	2B-8	14.6	31.62	37	0.855	0.082
	2B-9	21.4	31.59	67	0.471	0.045
	2B-10	28.0	26.86	120	0.224	0.022
	2B-11	34.4	24.81	120	0.207	0.020
	3B-5	34.0	24.17	100	0.242	0.023
	4B-5	32.4	24.62	120	0.205	0.020
	5B-8	16.0	36.73	50	0.735	0.071
	5B-9	22.4	36.88	50	0.738	0.071
	5B-10	27.5	36.46	62	0.588	0.056
	5B-11	34.4	37.14	90	0.413	0.040
	6B-8	15.1	33.83	50	0.677	0.065
	6B-9	21.5	30.80	75	0.411	0.039
	6B-10	28.0	26.26	100	0.263	0.025
	6B-11	34.4	18.56	100	0.186	0.018
	8B-4	33.5	24.36	150	0.162	0.016
	9B-7	32.6	36.67	60	0.611	0.059
	10B-5	34.1	36.80	75	0.491	0.047
	11B-7	33.7	35.17	76	0.463	0.044
	12B-10	34.4	17.39	100	0.174	0.017
	12B-11	33.9	15.91	100	0.159	0.015

APPENDIX B

SPENT FUEL ROD SEGMENT TEST MATRIX DETAILS

APPENDIX B

SPENT FUEL ROD SEGMENT TEST MATRIX DETAILS

Presented in this appendix are two tables providing the matrix of spent fuel rod segments used in Test Series B. The first table, B.1, provides a listing of the rod segments placed in each oven, along with the reactor source for the rod segment and the rod segment burnup value. For ovens having only 1 or 2 rod segments (ovens 1, 2, 6, 7, and 9), the rod segments were always placed on the middle shelf. For ovens having 3 or more rod segments (ovens 3, 4, 5, 8, 11, and 12), there was no consistent placement of the rod segments on the same shelf through the test; the middle and bottom shelves were used for these ovens.

Provided in Table B.2 are the total weight, non-UO₂ weight, and UO₂ weight for each rod segment. The total rod segment weight is a measured value; the non-UO₂ weight is the summation of the calculated weights for the Zircaloy cladding, end caps, and inserts; and the UO₂ weight is the difference between the measured total weight and the calculated non-UO₂ weight. For the cladding, length was determined from cutting diagrams and diameter (and tolerance) was taken from drawings and/or specifications provided by the spent fuel rod suppliers. For the end caps and inserts, dimensions were taken from PNL design drawings. Component volumes were determined from the dimensions, then weight was determined from the volume and Zircaloy density. Also provided in Table B.2 is an estimate of the upper and lower limits for the UO₂ weight. This was calculated by applying tolerances to the component dimensions to provide limits on the weight of non-UO₂ components.

TABLE B.1. Spent Fuel Rod Segment Test Matrix

<u>Rod ID</u>	<u>Oven</u>	<u>Oven Temperature, °C</u>	<u>Dew Point, °C</u>	<u>Reactor</u> ^(a)	<u>Burnup, Mwd/kgM</u>
7B-c3	1	150	20	H.B. Robinson	28.4
4B-c6				Quad Cities	12.0
2B-c1	2	150	40	Point Beach	29.5
2B-c2				H.B. Robinson	28.4
9B-c4	3	170	20	Quad Cities	14.8
3B-c2				H.B. Robinson	28.4
3B-c3				H.B. Robinson	28.4
4B-c2	4	190	20	Point Beach	29.5
4B-c3				Quad Cities	7.3
4B-c4				Monticello	31.3
1B-c2	5	190	40	Point Beach	29.5
3B-c1				Quad Cities	7.7
4B-c7				Monticello	31.5
9B-c2				Monticello	33.7
5B-c1				H.B. Robinson	28.4
6B-c1	6	135	40	H.B. Robinson	28.4
7B-c2	7	150	0	Point Beach	29.5
8B-c1	8	190	0	Point Beach	29.5
1B-c3				Quad Cities	7.7
9B-c1				Monticello	33.5
8B-c5				H.B. Robinson	28.4
9B-c5	9	210	20	H.B. Robinson	28.4
8B-c4				Quad Cities	13.0
10B-c1	11	170	20	Point Beach	29.5
9B-c3				Quad Cities	7.7
11B-c1				Quad Cities	7.7
11B-c4				Quad Cities	16.2
8B-c2				Quad Cities	22.0
10B-c4				Monticello	30.9

TABLE B.1. Continued

<u>Rod ID</u>	<u>Oven</u>	<u>Oven Temperature, °C</u>	<u>Dew Point, °C</u>	<u>Reactor</u> ^(a)	<u>Burnup, MWd/kgM</u>
10B-c2	12	230	20	Quad Cities	7.0
11B-c2				Quad Cities	23.0
10B-c3				Quad Cities	23.4
11B-c3				Monticello	33.3

(a) PWR Fuel: Point Beach, H.B. Robinson
 BWR Fuel: Quad Cities, Monticello

TABLE B.2. Calculated UO_2 Weights for Rod Segment Specimens

Rod Segment	Measured Total Weight, g	Calculated ^(a) Non- UO_2 Weight, g	Calculated ^(b) UO_2 Weight, g	UO_2 Weight Limits, g ^(c)
6B-c1	151.16	63.00	88.16	+4.26/-4.39
7B-c2	146.80	67.46	79.34	+4.36/-4.48
4B-c6	260.51	115.72	144.79	+6.10/-6.25
7B-c3	145.45	62.52	82.93	+4.20/-4.28
2B-c1	144.34	67.46	76.88	+4.20/-4.28
2B-c2	149.14	63.00	86.14	+4.14/-4.22
3B-c2	148.20	67.46	80.74	+4.36/-4.48
3B-c3	150.36	67.46	82.90	+4.36/-4.48
9B-c4	199.82	109.16	90.66	+5.53/-5.67
8B-c2	264.76	115.72	149.04	+6.10/-6.25
9B-c3	234.53	109.16	125.37	+5.53/-5.67
10B-c1	142.58	67.46	75.12	+4.36/-4.48
10B-c4	213.98	90.26	123.72	+5.22/-5.36
11B-c1	220.48	109.16	111.32	+5.53/-5.67
11B-c4	226.34	109.16	117.18	+5.53/-5.67
1B-c3	232.65	109.16	123.49	+5.53/-5.68
8B-c1	143.00	67.46	75.54	+4.36/-4.54
8B-c5	144.97	63.00	81.97	+4.26/-4.39
9B-c1	211.31	90.26	121.05	+5.22/-5.36
4B-c2	130.68	67.46	63.22	+4.36/-4.48
4B-c3	235.37	112.44	122.93	+5.81/-5.96
4B-c4	208.42	90.26	118.16	+5.22/-5.36
1B-c2	145.87	67.46	78.41	+4.36/-4.48
3B-c1	223.53	109.16	114.37	+5.53/-5.67
4B-c7	199.86	86.01	113.85	+5.14/-5.28
5B-c1	140.52	61.40	79.12	+4.06/-4.17
9B-c2	204.76	86.01	118.75	+5.14/-5.28
8B-c4	217.28	115.72	101.56	+6.10/-6.25
9B-c5	128.29	63.00	65.29	+4.26/-4.39
10B-c2	236.69	109.16	127.53	+5.53/-5.67
10B-c3	261.63	115.72	145.91	+6.10/-6.25
11B-c2	259.89	115.72	144.17	+6.10/-6.25
11B-c3	212.82	90.26	122.56	+5.22/-5.36

(a) Calculated from specified dimensions and material density.

(b) Calculated by subtracting calculated non- UO_2 weight from measured total rod segment weight.

(c) Limits based on calculated variance in non- UO_2 weight derived from specified dimensional tolerances of cladding, endcaps, and inserts.

APPENDIX C

OVEN TEST SCHEDULE FOR TEST SERIES B

APPENDIX C

OVEN TEST SCHEDULE FOR TEST SERIES B

The table in this appendix provides a listing, for each oven, of the start and end date for each oven, the elapsed time for the run, and the cumulative at-temperature time. Cumulative times are listed separately for bare fragments and rod segments. Also identified are the oven runs when rod segments were inserted and the oven runs when Viton™ oven gaskets began to be used.

TABLE C.1. As-Operated Oven Test Schedule for Test Series B

Oven No.	Temp.	Dewpoint	Run No.	Actual Start	Actual End	At (hours)	Total t (hours)		
							Fragments	Segments	
1	150	20	1	12/18/85	03/17/88	2129.3	2129.3		
			2	03/20/86	04/19/86	720.0	2849.3		
			Viton TM begun	3	05/05/86	08/07/86	2255.3	5104.6	
			4	08/18/86	11/14/86	2112.4	7217.0		
			5	11/21/86	05/18/87	4278.8	11495.8		
			Rod segments added →	6	07/13/87	11/13/87	2950.9	14446.7	2950.9
			4B-c6 and 7B-c3	7	12/02/87	10/11/88	7533.4	21980.1	10484.3
			8	11/01/88	05/07/90	13241.3	35221.4	23725.6	
			9	05/22/90	09/18/90	2849.8	38071.2	26575.4	
2	150	40	1	01/23/86	04/01/86	1626.2	1626.2		
			2	04/04/86	04/04/86				
			3	04/09/86	07/31/86	2708.2	4334.5		
			Viton TM begun	4	08/08/86	11/10/86	2259.5	6593.9	
			5	11/19/86	02/13/87	2061.5	8655.4		
			6	03/17/87	11/02/87	5524.5	14179.9		
			Rod segments added →	7	11/13/87	09/22/88	7536.4	21716.2	7536.4
			2B-c1 and 2B-c2	8	10/17/88	02/23/90	11861.8	33578.0	19398.2
			3	170	20	1	02/07/86	02/27/86	474.2
2	03/12/86	05/02/86				1229.8	1704.0		
Viton TM begun	3	05/07/86				07/24/86	1874.8	3578.8	
4	08/08/86	10/01/86				1291.9	4870.7		
5	10/08/86	11/24/86				1131.1	6001.8		
6	12/03/86	03/02/87				2133.6	8135.4		
7	03/31/87	09/11/87				3932.8	12068.2		
Rod segments added →	8	09/25/87				06/08/88	6166.8	18234.9	6166.8
9B-c4, 3B-c2, and 3B-c3	9	06/29/88				10/16/89	11371.3	29606.2	17538.1
10	12/04/89	09/07/90				6653.4	36259.6	24191.5	
4	190	20	1	02/21/86	03/05/86	283.1	283.1		
			2	03/13/86	04/02/86	473.2	756.3		
			3	04/04/86	05/07/86	787.8	1544.0		
			Viton TM begun	4	05/16/86	07/08/86	1266.5	2810.5	
			5	07/14/86	08/21/86	905.8	3716.1		
			6	09/02/86	10/23/86	1221.7	4937.8		
			7	10/28/86	01/29/87	2232.7	7170.5		
			8	02/06/87	10/06/87	5804.9	12975.4		
			9	10/30/87	04/20/88	4154.8	17130.2		
			Rod segments added →	10	05/25/88	05/09/89	8379.5	25509.7	8379.5
			4B-c2, 4B-c3, and 4B-c4	11	06/13/89	01/09/90	5045.9	30555.6	13425.4
			12	02/01/90	09/21/90	5566.0	36121.6	18997.2	
5	190	40	1	02/24/86	03/10/86	330.8	330.8		
			2	03/21/86	04/07/86	404.4	735.2		
			3	04/11/86	05/08/86	648.8	1384.0		
			Viton TM begun	4	05/19/86	07/18/86	1446.8	2830.8	
			5	07/29/86	09/18/86	1221.7	4052.5		
			6	09/25/86	11/03/86	938.1	4990.6		
			7	11/05/86	12/02/86	648.8	5639.4		
			8	12/08/86	01/19/87	1004.1	6643.5		
			9	02/05/87	10/06/87	5827.4	12470.9		
			10	10/26/87	05/26/88	5118.8	17589.6		
			Rod segments added →	11	06/16/88	07/21/89	9594.4	27184.0	9594.4
			1B-c2, 3B-c1, 4B-c7	12	08/29/89	11/20/89	2239.2	29423.2	11833.6
			5B-c1, and 9B-c2	13	01/09/90	09/13/90	5922.4	35345.6	17756.7

TABLE C.1. Continued

Oven			Run					Total t (hours)	
No.	Temp.	Dewpoint	No.	Actual Start	Actual End	At (hours)	Fragments	Segments	
6	135	40	1	03/20/86	07/31/86	3191.8	3191.8		
Viton [™] begun			2	08/12/86	11/10/86	2155.4	5347.2		
			3	11/17/86	02/13/87	2120.5	7467.7		
			4	03/09/87	11/02/87	5709.3	13177.0		
			5	11/16/87	08/23/88	6739.2	19916.2	6739.2	
Rod segment added →			6	10/05/88	04/19/90	13459.3	33379.5	20198.5	
6B-c1			7	05/08/90	09/25/90	3355.3	36730.8	23553.8	
7	150	0	1	12/19/85	02/24/86	1594.5	1594.5		
			2	03/05/86	05/19/86	1792.5	3387.0		
Viton [™] begun			3	07/24/86	10/28/86	2299.8	5686.8		
			4	10/30/86	02/05/87	2351.5	8038.3		
			5	02/13/87	10/15/87	5849.4	13888.2		
Rod segment added →			6	11/05/87	08/04/88	6548.0	20436.2	6548.0	
7B-c2			7	08/15/88	11/13/89	10920.3	31356.5	17468.3	
			8	12/22/89	08/14/90	5645.9	37002.4	23114.2	
8	190	0	1	02/13/86	02/24/86	260.4	260.4		
			2	03/11/86	03/27/86	378.5	638.9		
			3	04/01/86	05/01/86	725.5	1360.4		
Viton [™] begun			4	05/06/86	06/16/86	986.9	2347.3		
			5	06/24/86	08/12/86	1170.1	3517.4		
			6	08/22/86	10/03/86	1005.9	4523.3		
			7	10/09/86	11/18/86	964.5	5487.8		
			8	11/25/86	01/06/87	1008.0	6495.8		
			9	01/09/87	06/05/87	3522.9	10018.7		
			10	07/01/87	12/15/87	4014.6	14033.3		
Rod segments added →			11	01/26/88	01/17/89	8573.7	22607.0	8573.7	
8B-c1, 1B-c3, 9B-c1, and 8B-c5			12	03/03/89	05/17/90	10562.8	33169.8	19136.5	
9	210	20	1	02/28/86	03/01/86				
			2	03/27/86	04/09/86	348.8	347.8		
Viton [™] begun			3	04/16/86	05/06/86	478.8	826.6		
			4	05/09/86	06/04/86	619.7	1446.3		
			5	06/10/86	07/18/86	915.8	2362.1		
			6	07/24/86	08/28/86	839.8	3201.9		
			7	09/05/86	10/23/86	1147.8	4349.7		
			8	10/27/86	11/24/86	670.8	5020.5		
			9	12/02/86	12/18/86	380.5	5401.0		
			10	01/05/87	02/05/87	744.4	6145.4		
			11	02/12/87	04/14/87	1470.1	7615.5		
	Rod segments added →		12	05/26/87	08/05/87	1709.6	9325.1	1709.6	
9B-c5 and 8B-c4		13	09/01/87	03/17/88	4748.1	14073.2	6457.7		
		14	04/06/88	11/18/88	5420.0	19493.2	11877.3		
		15	01/26/89	09/29/89	5897.9	25391.1	17775.6		
		16	10/12/89	08/01/90	7030.8	32421.9			
10	135	0	1	02/03/86	02/06/86				
			2	02/10/86	04/20/86	1701.9	1701.9		
Viton [™] begun			3	04/29/86	08/28/86	2901.6	4603.5		
			4	09/04/86	12/02/86	2139.1	6742.6		
			5	12/10/86	03/03/87	1991.3	8733.9		
			6	04/08/87	12/07/87	5832.8	14566.8		
			7	12/15/87	06/15/88	4391.6	18958.4		
			8	07/19/88	01/25/90	13319.1	32277.4		
			9	03/08/90	08/16/90	3856.7	36134.2		

TABLE C.1. Continued

Oven			Run				Total t (hours)	
No.	Temp.	Dewpoint	No.	Actual Start	Actual End	At (hours)	Fragments	Segments
11	170	20	1	02/04/86	02/25/86	491.7	491.7	
			2	03/04/86	04/16/86	999.9	1491.6	
Viton™ begun			3	04/24/86	06/16/86	1279.7	2771.3	
			4	06/24/86	08/21/86	1386.8	4158.1	
			5	08/26/86	10/23/86	1386.7	5545.4	
			6	10/24/86	01/19/87	2087.7	7633.1	
			7	01/28/87	09/01/87	5188.7	12821.8	
			8	09/09/87	02/17/88	3863.6	16685.4	
Rod segments added →			9	04/06/88	03/15/89	8232.8	24918.2	8232.8
10B-c1, 9B-c3, 11B-c1, 11B-c4, 8B-c2, and 10B-c4			10	04/18/89	06/26/90	10419.8	35338.0	18652.6
12	230	20	1	04/01/86	04/04/86	61.5	61.5	
			2	04/09/86	04/14/86	119.8	181.3	
			3	04/17/86	05/12/86	593.5	774.8	
Viton™ begun			4	05/21/86	06/03/86	305.4	1080.2	
			5	06/05/86	06/16/86	264.1	1344.3	
			6	06/24/86	07/08/86	335.1	1679.4	
			7	07/10/86	07/24/86	332.5	2011.9	
			8	07/31/86	08/21/86	504.8	2516.7	
			9	08/25/86	09/24/86	721.2	3237.9	
			10	10/03/86	11/03/86	738.8	3976.7	
			11	11/06/86	12/02/86	630.7	4606.9	
			12	12/10/86	01/13/87	822.8	5429.7	
			13	01/20/87	07/07/87	4037.3	9467.0	
			14	08/06/87	01/25/88	4130.2	13597.2	
Rod segments added →			15	02/17/88	04/05/88	1154.1	14751.3	1154.1
10B-c2, 11B-c2, 10B-c3, and 11B-c3			16	05/11/88	07/15/88	1556.3	16307.7	2710.4
			17	07/29/88	11/01/88	2183.7	18491.4	4894.1
			18	11/17/88	02/21/89	2301.7	20793.1	7195.8
			19	03/19/89	06/19/89	2209.9	23003.0	9405.7
			20	07/18/89	09/05/89	1170.9	24173.9	10576.6
			21	09/28/89	04/30/90	5139.3	29313.2	15715.9
			22	05/16/90	08/22/90	2348.1	31661.3	18064.0

APPENDIX D

OVEN TEMPERATURE AND PRESSURE HISTORIES

APPENDIX D

OVEN TEMPERATURE AND PRESSURE HISTORIES

Each oven was monitored for temperature and cover gas pressure; this monitoring was done approximately daily during each five-day work week. Provided in this appendix are listings of the as-recorded temperatures and pressures.

Three thermocouples that were in each oven were used to monitor the temperature of each (top, middle, and bottom) shelf. The thermocouples were positioned at the back wall of an oven. A fourth thermocouple was used to control oven temperature; data from this thermocouple were not recorded. A chronological listing of the as-recorded temperatures are provided in Table D.1. The oven temperature histories are summarized in Figures D.1 through D.12.

All thermocouples were calibrated before installation. After the ovens were placed in the hot cell, and the thermocouples were no longer reasonably accessible for recalibration, a separate calibrated thermocouple was used periodically to check the oven temperatures and verify that data from the original thermocouples could still be used.

One pressure gage was used for each oven to monitor the cover gas pressure. The as-recorded values are gage pressures (in inches of mercury), therefore the listed pressures are relative to the hot cell air pressure. The hot cell air pressure was normally maintained at a negative pressure of approximately -0.2 inches of water, relative to atmospheric, to ensure that hot cell air leakage was inward and not outward. A chronological listing of the as-recorded pressures are provided in Table D.2. The oven pressure histories are summarized in Figures D.13 through D.24.

The pressure transducers were originally calibrated by a non-QA inspected laboratory. Because facilities were not available to recalibrate the pressure transducers, data from these instruments should be considered "for indication only."

TABLE D.1. Oven Temperature Histories

Date	Oven 1(150°C)			Oven 2(150°C)			Oven 3(170°C)			Oven 4(190°C)			Oven 5(190°C)			Oven 6(135°C)		
	Top	Mid	Bot	Top	Mid	Bot	Top	Mid	Bot	Top	Mid	Bot	Top	Mid	Bot	Top	Mid	Bot
12/23/85	151	145	140	NA	NA	NA	NA	NA	NA	NA	NA	NA	370	382	NA	172	164	NA
12/26/85	151	143	140	NA	NA	NA	NA	NA	NA	NA	NA	NA	372	382	NA	NA	NA	NA
12/27/85	150	144	140	NA	NA	NA	NA	NA	NA	NA	NA	NA	372	382	NA	NA	NA	NA
12/30/85	151	144	140	NA	NA	NA	NA	NA	NA	NA	NA	NA	372	382	NA	NA	NA	NA
12/31/85	150	144	140	NA	NA	NA	NA	NA	NA	NA	NA	NA	371	382	NA	NA	NA	NA
01/02/86	154	146	142	NA	NA	NA	NA	NA	NA	NA	NA	NA	372	382	NA	NA	NA	NA
01/03/86	155	147	143	NA	NA	NA	NA	NA	NA	NA	NA	NA	372	382	NA	NA	NA	NA
01/06/86	154	147	144	NA	NA	NA	NA	NA	NA	NA	NA	NA	372	382	NA	NA	NA	NA
01/07/86	153	146	142	NA	NA	NA	NA	NA	NA	NA	NA	NA	371	382	NA	NA	NA	NA
01/08/86	154	147	143	NA	NA	NA	NA	NA	NA	NA	NA	NA	372	383	NA	NA	NA	NA
01/09/86	155	147	144	NA	NA	NA	NA	NA	NA	NA	NA	NA	372	382	NA	NA	NA	NA
01/10/86	155	147	144	NA	NA	NA	NA	NA	NA	NA	NA	NA	372	383	NA	NA	NA	NA
01/13/86	155	147	144	NA	NA	NA	NA	NA	NA	NA	NA	NA	372	383	NA	NA	NA	NA
01/14/86	153	146	143	NA	NA	NA	NA	NA	NA	NA	NA	NA	372	382	NA	NA	NA	NA
01/15/86	154	147	143	NA	NA	NA	NA	NA	NA	NA	NA	NA	372	382	NA	NA	NA	NA
01/16/86	154	147	144	NA	NA	NA	NA	NA	NA	NA	NA	NA	372	383	NA	NA	NA	NA
01/17/86	155	147	144	NA	NA	NA	NA	NA	NA	NA	NA	NA	372	383	NA	NA	NA	NA
01/20/86	154	147	144	NA	NA	NA	NA	NA	NA	NA	NA	NA	372	382	NA	NA	NA	NA
01/21/86	154	147	144	NA	NA	NA	NA	NA	NA	NA	NA	NA	372	383	NA	NA	NA	NA
01/22/86	154	147	144	NA	NA	NA	NA	NA	NA	NA	NA	NA	372	383	NA	NA	NA	NA
01/23/86	155	148	144	144	141	139	NA	NA	NA	NA	NA	NA	373	383	NA	NA	NA	NA
01/24/86	155	148	144	149	146	144	NA	NA	NA	NA	NA	NA	373	383	NA	NA	NA	NA
01/27/86	155	148	145	150	147	145	NA	NA	NA	NA	NA	NA	372	383	NA	NA	NA	NA
01/28/86	155	147	144	150	149	146	NA	NA	NA	NA	NA	NA	372	383	NA	NA	NA	NA
01/29/86	154	147	144	150	148	145	NA	NA	NA	NA	NA	NA	372	383	NA	NA	NA	NA
01/30/86	155	148	144	150	148	145	NA	NA	NA	NA	NA	NA	372	383	NA	NA	NA	NA
01/31/86	155	148	145	151	148	145	NA	NA	NA	NA	NA	NA	372	383	NA	NA	NA	NA
02/03/86	154	147	144	150	148	145	NA	NA	NA	NA	NA	NA	372	383	NA	NA	NA	NA
02/04/86	154	148	144	150	148	145	NA	NA	NA	NA	NA	NA	371	382	NA	NA	NA	NA
02/05/86	154	147	144	151	148	145	NA	NA	NA	NA	NA	NA	371	382	NA	NA	NA	NA
02/06/86	154	147	144	151	148	145	NA	NA	NA	NA	NA	NA	371	383	NA	NA	NA	NA
02/07/86	154	147	144	150	147	145	154	150	148	NA	NA	NA	371	383	NA	NA	NA	NA
02/10/86	154	147	145	151	148	146	172	162	161	NA	NA	NA	372	383	NA	NA	NA	NA
02/11/86	154	147	144	150	148	146	171	164	162	NA	NA	NA	NA	NA	NA	NA	NA	NA
02/12/86	154	147	144	151	149	146	173	165	162	NA	NA	NA	NA	NA	NA	NA	NA	NA
02/13/86	154	147	144	151	148	145	172	164	161	NA	NA	NA	NA	NA	NA	NA	NA	NA
02/14/86	155	148	145	151	148	145	173	165	163	NA	NA	NA	NA	NA	NA	NA	NA	NA
02/18/86	154	147	145	151	148	145	180	172	169	NA	NA	NA	NA	NA	NA	NA	NA	NA
02/19/86	154	147	144	151	148	145	179	171	168	NA	NA	NA	NA	NA	NA	NA	NA	NA
02/20/86	154	147	144	151	148	145	178	170	167	NA	NA	NA	NA	NA	NA	NA	NA	NA
02/21/86	153	147	144	151	148	146	175	167	165	NA	NA	NA	NA	NA	NA	NA	NA	NA
02/24/86	155	149	146	151	149	147	176	169	167	195	185	184	170	171	175	NA	NA	NA
02/25/86	154	147	144	151	148	146	173	165	163	194	183	182	185	186	192	NA	NA	NA
02/26/86	154	148	145	151	149	146	172	165	162	194	183	182	184	186	191	NA	NA	NA
02/27/86	157	151	148	151	149	146	176	168	166	193	183	182	185	186	192	NA	NA	NA
02/28/86	153	147	144	151	149	147	NA	NA	NA	195	184	183	185	188	193	NA	NA	NA
03/03/86	154	147	144	151	149	146	NA	NA	NA	194	184	183	185	187	193	NA	NA	NA
03/04/86	154	147	144	151	149	146	NA	NA	NA	195	185	183	185	187	192	NA	NA	NA
03/05/86	154	147	144	151	149	146	NA	NA	NA	195	185	184	185	187	192	NA	NA	NA
03/06/86	154	147	144	151	148	146	NA	NA	NA	NA	NA	NA	185	187	192	NA	NA	NA
03/07/86	153	147	144	150	148	145	NA	NA	NA	NA	NA	NA	185	187	193	NA	NA	NA
03/10/86	154	147	144	150	147	144	NA	NA	NA	NA	NA	NA	184	186	192	NA	NA	NA
03/11/86	153	146	143	150	147	145	120	116	113	NA	NA	NA	NA	NA	NA	NA	NA	NA
03/12/86	154	146	143	151	149	146	179	170	168	NA	NA	NA	NA	NA	NA	NA	NA	NA
03/13/86	154	147	145	151	149	146	180	173	170	149	140	139	NA	NA	NA	NA	NA	NA
03/14/86	153	147	144	151	149	147	182	174	172	175	166	165	NA	NA	NA	NA	NA	NA
03/17/86	154	147	144	151	149	147	181	174	171	193	184	182	NA	NA	NA	NA	NA	NA
03/18/86	NA	NA	NA	151	149	147	175	167	165	194	184	182	NA	NA	NA	NA	NA	NA
03/19/86	NA	NA	NA	151	150	147	174	166	164	193	183	182	NA	NA	NA	NA	NA	NA
03/20/86	NA	NA	NA	151	150	147	178	170	166	193	183	182	151	153	156	135	129	NW
03/21/86	153	146	140	151	149	147	178	170	168	193	183	181	181	183	188	135	130	NA
03/24/86	155	147	142	151	150	147	179	171	169	193	184	182	187	190	193	136	130	NW

TABLE D.1. Continued

Date	Oven 1(150°C)			Oven 2(150°C)			Oven 3(170°C)			Oven 4(190°C)			Oven 5(190°C)			Oven 6(135°C)		
	Top	Mid	Bot	Top	Mid	Bot	Top	Mid	Bot	Top	Mid	Bot	Top	Mid	Bot	Top	Mid	Bot
03/26/86	155	147	143	151	149	146	180	172	170	194	183	182	187	189	193	136	130	NW
03/27/86	155	147	143	152	149	146	180	173	170	193	184	182	187	190	192	136	130	NW
03/31/86	155	147	142	151	148	146	178	170	167	192	182	181	187	189	193	137	130	NW
04/01/86	154	147	142	151	149	147	180	172	170	193	183	181	187	189	194	137	130	NW
04/02/86	155	146	142	NA	NA	NA	179	171	168	191	181	180	187	188	193	136	130	NA
04/03/86	154	146	142	NA	NA	NA	182	174	172	NA	NA	NA	186	188	193	136	130	NA
04/04/86	155	147	143	155	149	147	182	175	172	157	148	149	187	189	194	137	130	NW
04/07/86	154	147	142	NA	NA	NA	181	174	171	197	188	186	187	189	193	137	130	NW
04/08/86	154	147	142	NA	NA	NA	177	170	167	196	186	185	NA	NA	NA	136	130	NW
04/09/86	153	146	140	NA	NA	NA	174	165	163	197	187	186	NA	NA	NA	137	130	NW
04/10/86	161	155	150	153	149	147	180	173	170	197	187	186	125	126	128	137	131	NW
04/11/86	160	153	149	152	149	147	180	172	170	196	187	186	152	154	157	137	131	NW
04/14/86	161	155	150	155	150	148	181	174	171	197	187	186	159	160	155	136	131	NW
04/15/86	162	155	150	150	147	145	184	176	175	197	188	186	183	185	190	137	131	NW
04/16/86	162	155	150	151	148	145	182	175	173	197	187	186	183	185	190	137	131	NW
04/17/86	161	154	150	150	147	145	182	175	172	197	188	186	183	185	190	137	131	NW
04/18/86	161	154	150	150	148	146	184	176	174	197	188	186	183	186	191	137	130	NW
04/21/86	NA	NA	NA	152	149	147	182	175	173	197	188	187	184	185	190	136	130	NW
04/22/86	NA	NA	NA	152	149	147	180	173	170	197	188	186	183	185	190	137	131	NW
04/23/86	NA	NA	NA	150	148	146	180	174	171	197	188	186	183	185	190	137	131	NW
04/24/86	NA	NA	NA	151	148	146	179	171	168	197	188	186	182	185	190	137	131	NW
04/25/86	NA	NA	NA	153	150	148	174	166	164	197	188	186	183	185	191	137	131	NW
04/28/86	NA	NA	NA	150	147	146	175	166	164	197	188	186	183	185	191	137	131	NW
04/29/86	NA	NA	NA	150	148	146	175	168	165	197	188	186	183	185	191	137	131	NW
05/01/86	NA	NA	NA	153	150	148	174	166	164	197	188	186	182	185	191	137	131	NW
05/02/86	NA	NA	NA	153	150	148	182	175	172	197	188	187	183	185	191	136	131	NW
05/05/86	105	100	99	154	150	148	NA	NA	NA	196	188	186	183	185	191	137	131	NW
05/06/86	168	160	155	149	145	144	NA	NA	NA	196	186	185	183	185	191	136	131	NW
05/07/86	161	155	151	150	148	146	175	168	165	191	187	186	183	185	191	137	131	NW
05/08/86	163	156	154	150	147	145	174	166	164	NA	NA	NA	183	185	191	136	130	NW
05/09/86	156	149	145	150	147	145	167	159	156	NA	NA	NA	NA	NA	NA	136	130	NW
05/12/86	156	149	145	150	147	145	165	158	155	NA	NA	NA	NA	NA	NA	137	131	NW
05/13/86	164	156	154	150	147	145	173	166	163	NA	NA	NA	NA	NA	NA	136	130	NW
05/14/86	162	155	152	153	149	147	174	166	163	NA	NA	NA	NA	NA	NA	137	130	NW
05/15/86	160	154	150	154	149	148	170	161	159	NA	NA	NA	NA	NA	NA	137	131	NW
05/16/86	161	155	151	154	150	148	172	165	162	156	149	148	141	143	145	137	131	NW
05/19/86	173	166	164	149	146	145	177	170	167	194	185	183	184	186	190	136	130	NW
05/20/86	156	150	147	149	146	145	174	166	164	194	185	182	186	190	194	137	130	NW
05/21/86	160	154	151	150	147	145	177	170	167	194	185	183	187	190	194	137	131	NW
05/23/86	157	150	148	150	147	145	174	166	164	194	185	183	186	190	194	137	130	NW
05/27/86	159	153	150	149	147	145	175	168	165	194	185	183	187	190	194	136	130	NW
05/28/86	157	150	148	150	148	146	174	166	164	195	185	184	186	190	194	135	130	NW
05/29/86	163	156	154	150	148	146	175	168	165	194	185	183	187	190	194	136	130	NW
05/30/86	163	156	154	150	148	146	175	168	166	194	185	183	187	190	194	136	130	NW
06/02/86	164	157	155	152	149	148	181	174	171	194	185	184	187	190	194	136	130	NW
06/03/86	160	155	152	150	148	147	178	170	169	194	185	183	187	190	194	137	131	NW
06/05/86	167	160	158	153	149	148	183	175	173	194	185	183	187	190	195	137	130	NW
06/06/86	166	160	157	152	149	148	181	175	172	194	185	184	187	190	194	138	130	NW
06/09/86	165	158	155	149	146	144	177	170	167	194	184	183	186	190	194	137	131	NW
06/10/86	161	155	152	150	147	145	174	165	163	193	184	183	186	190	194	137	131	NW
06/11/86	160	155	151	151	148	146	175	167	165	194	185	183	185	190	194	137	130	NW
06/12/86	160	154	150	149	146	145	175	167	164	195	185	184	185	190	194	137	130	NW
06/13/86	164	156	154	150	147	145	176	169	165	195	185	184	186	190	194	137	130	NW
06/16/86	163	156	153	150	147	145	173	165	162	194	184	183	185	190	194	136	131	NW
06/17/86	163	156	154	150	147	145	177	169	166	195	185	184	186	190	195	137	130	NW
06/18/86	164	157	155	149	145	145	180	172	170	195	185	184	187	190	195	136	130	NW
06/19/86	165	159	155	150	147	145	181	174	170	193	184	183	186	190	195	136	130	NW
06/20/86	164	157	155	152	148	147	180	173	170	193	184	183	186	190	195	137	130	NW
06/23/86	165	158	155	149	147	145	181	174	170	194	184	183	186	190	195	137	130	NW
06/24/86	160	153	150	152	149	147	174	165	164	193	184	183	186	190	195	136	130	NW
06/25/86	165	158	155	150	147	146	178	170	169	194	185	184	185	190	194	136	130	NW

TABLE D.1. Continued

Date	Oven 1(150°C)			Oven 2(150°C)			Oven 3(170°C)			Oven 4(190°C)			Oven 5(190°C)			Oven 6(135°C)		
	Top	Mid	Bot	Top	Mid	Bot	Top	Mid	Bot	Top	Mid	Bot	Top	Mid	Bot	Top	Mid	Bot
06/26/86	164	157	155	152	148	146	180	174	170	194	184	183	186	190	195	136	130	NW
06/27/86	163	156	154	150	147	145	179	170	169	194	184	183	186	190	195	137	130	NW
07/02/86	160	155	152	153	149	147	178	170	167	194	184	183	185	189	194	135	130	NW
07/09/86	160	155	152	150	147	145	177	170	168	NA	NA	NA	185	188	194	136	131	NW
07/10/86	160	154	150	155	148	146	175	168	165	NA	NA	NA	185	188	194	136	130	NW
07/11/86	160	154	150	149	145	143	174	165	162	NA	NA	NA	185	188	193	135	131	NW
07/14/86	159	152	149	150	148	146	177	170	166	197	185	184	185	189	194	135	130	NW
07/15/86	156	150	147	149	147	145	170	160	156	196	185	183	184	187	192	135	130	NW
07/18/86	160	154	150	154	149	148	178	170	167	192	186	185	185	189	193	135	131	NW
07/21/86	161	155	152	150	147	145	177	170	167	197	186	185	NA	NA	NA	136	131	NW
07/23/86	156	150	148	151	148	146	171	164	160	196	186	185	NA	NA	NA	136	130	NW
07/24/86	156	150	147	150	148	146	172	164	160	196	186	185	NA	NA	NA	136	130	NW
07/28/86	165	159	155	150	147	145	NA	NA	NA	196	186	185	130	130	131	136	131	NW
07/29/86	165	159	155	150	147	146	NA	NA	NA	196	186	185	174	174	179	136	130	NW
07/30/86	164	157	154	151	148	147	NA	NA	NA	197	187	185	186	186	191	136	130	NW
07/31/86	164	157	155	150	148	147	NA	NA	NA	197	187	185	187	187	192	136	130	NW
08/04/86	163	156	154	NA	NA	NA	NA	NA	NA	195	185	184	186	186	192	NA	NA	NA
08/05/86	162	156	154	NA	NA	NA	NA	NA	NA	195	185	184	186	186	191	NA	NA	NA
08/07/86	163	156	154	NA	NA	NA	NA	NA	NA	196	185	185	186	187	192	NA	NA	NA
08/08/86	NA	NA	NA	145	142	140	176	169	166	192	187	186	185	185	191	NA	NA	NA
08/11/86	NA	NA	NA	148	145	143	175	168	165	192	186	185	185	185	191	NA	NA	NA
08/13/86	NA	NA	NA	146	144	141	175	167	165	196	186	185	185	185	191	137	132	NW
08/14/86	NA	NA	NA	147	144	142	174	166	165	196	187	186	185	185	191	137	133	NW
08/20/86	162	151	148	148	145	143	175	168	165	195	187	185	184	185	191	137	132	NW
08/21/86	165	155	152	148	145	143	177	170	169	196	187	186	185	186	192	137	133	NW
08/22/86	160	150	148	147	144	142	170	163	161	NA	NA	NA	184	185	191	137	133	NW
08/25/86	163	154	152	147	145	142	180	173	170	NA	NA	NA	184	185	191	137	133	NW
08/26/86	159	149	147	146	144	140	176	170	167	NA	NA	NA	184	185	191	137	131	NW
08/28/86	161	152	150	147	144	141	179	171	170	NA	NA	NA	185	185	191	137	132	NW
08/29/86	162	153	151	148	146	144	179	172	170	168	160	158	185	186	191	137	132	NW
09/02/86	161	152	150	147	145	142	180	172	170	181	172	171	184	185	190	137	133	NW
09/03/86	164	154	152	148	147	145	183	175	174	195	186	184	185	185	191	137	133	NW
09/04/86	160	151	149	147	145	142	180	172	170	195	185	184	185	185	191	137	133	NW
09/08/86	160	152	149	147	145	142	182	174	172	194	185	184	184	185	191	137	132	NW
09/09/86	160	151	150	146	145	142	181	174	172	194	185	183	184	185	190	136	131	NW
09/10/86	160	152	149	148	146	144	182	175	173	194	185	184	185	186	191	137	132	NW
09/11/86	160	150	149	148	146	144	174	166	165	194	185	184	185	186	192	138	133	NW
09/12/86	161	151	149	148	146	143	179	170	169	194	185	184	185	186	191	137	132	NW
09/15/86	160	150	148	148	145	143	175	169	167	194	185	184	184	185	191	137	132	NW
09/16/86	160	150	149	149	147	144	177	170	168	194	185	184	184	185	191	138	132	NW
09/17/86	160	150	148	148	146	143	176	170	168	195	185	184	184	185	191	137	132	NW
09/18/86	160	151	150	147	145	143	178	170	169	194	185	184	184	185	191	138	132	NW
09/22/86	156	147	145	147	145	142	172	164	161	195	186	184	NA	NA	NA	138	133	NW
09/23/86	154	146	144	148	147	145	170	163	160	195	185	184	NA	NA	NA	137	132	NW
09/26/86	162	153	151	148	146	144	177	170	168	194	186	184	184	187	193	137	132	NW
09/29/86	160	152	150	147	145	143	178	170	168	194	185	184	185	187	194	137	133	NW
10/03/86	153	144	141	147	145	144	NA	NA	NA	195	185	184	184	186	194	137	132	NW
10/06/86	154	145	143	149	147	145	NA	NA	NA	195	188	186	186	189	195	139	134	NW
10/08/86	161	152	150	149	147	145	179	172	169	195	187	186	186	190	195	139	134	NW
10/09/86	161	152	151	149	147	145	180	172	170	195	187	186	186	190	195	140	134	NW
10/14/86	160	152	150	148	146	144	176	170	166	195	187	186	186	190	195	138	133	NW
10/15/86	160	152	150	149	147	145	179	171	169	195	188	186	187	190	195	140	134	NW
10/16/86	160	150	149	148	146	144	177	170	167	195	186	185	186	188	195	138	133	NW
10/17/86	162	153	151	150	148	146	179	172	169	195	187	185	186	190	195	140	134	NW
10/20/86	163	154	152	149	147	145	180	173	170	195	188	185	187	190	195	140	134	NW
10/21/86	162	153	151	149	147	145	179	171	169	195	187	186	186	189	195	139	134	NW
10/22/86	160	152	150	149	147	145	179	171	169	196	188	186	186	190	195	139	134	NW
10/23/86	160	152	150	149	147	145	178	170	167	196	188	187	187	190	195	140	134	NW
10/24/86	160	150	149	152	148	147	177	170	168	NA	NA	NA	186	189	195	139	133	NW
10/27/86	165	155	154	162	160	157	182	175	172	NA	NA	NA	187	189	195	139	134	NW
10/28/86	165	155	154	160	157	155	181	175	172	175	164	166	187	189	195	139	134	NW

TABLE D.1. Continued

Date	Oven 1(150°C)			Oven 2(150°C)			Oven 3(170°C)			Oven 4(190°C)			Oven 5(190°C)			Oven 6(135°C)		
	Top	Mid	Bot	Top	Mid	Bot	Top	Mid	Bot	Top	Mid	Bot	Top	Mid	Bot	Top	Mid	Bot
10/29/86	166	157	155	164	160	159	185	177	175	196	187	186	187	190	195	140	135	NW
10/30/86	167	157	155	161	159	156	184	175	173	196	186	185	186	189	195	140	135	NW
10/31/86	165	155	154	164	160	159	182	175	173	196	187	186	187	189	195	140	135	NW
11/03/86	165	156	155	162	160	157	182	175	172	195	186	186	187	189	195	140	135	NW
11/04/86	160	150	148	160	158	156	176	169	165	195	187	186	NA	NA	NA	139	135	NW
11/05/86	164	155	153	160	157	155	180	173	170	196	186	186	NA	NA	NA	140	135	NW
11/06/86	165	157	155	162	160	158	182	175	173	196	187	186	186	189	192	140	135	NW
11/07/86	164	155	153	160	157	155	180	174	171	196	187	186	186	189	192	140	135	NW
11/10/86	161	152	151	161	159	156	179	172	169	195	187	186	186	188	192	140	134	NW
11/13/86	162	153	152	NA	NA	NA	179	172	169	195	185	185	186	188	193	NA	NA	NA
11/14/86	160	150	149	NA	NA	NA	175	170	167	195	185	185	186	189	193	NA	NA	NA
11/18/86	NA	NA	NA	NA	NA	NA	175	169	165	195	187	186	185	187	192	145	140	NW
11/19/86	NA	NA	NA	NA	NA	NA	174	166	164	195	187	187	185	187	192	NA	NA	NA
11/20/86	137	130	125	153	150	147	180	174	171	196	187	187	185	187	191	135	130	NW
11/21/86	159	152	147	151	149	147	180	174	170	196	187	187	185	187	191	136	132	NW
11/24/86	161	155	149	153	150	147	184	176	174	195	187	186	185	188	192	135	130	NW
12/01/86	159	153	147	148	145	142	NA	NA	NA	195	187	187	185	188	192	140	135	NW
12/02/86	160	154	147	149	147	144	NA	NA	NA	195	186	186	185	187	191	136	132	NW
12/04/86	157	150	145	147	145	142	175	166	160	195	186	186	NA	NA	NA	137	134	NW
12/05/86	164	157	150	150	148	145	175	167	162	195	186	186	NA	NA	NA	140	135	NW
12/08/86	161	155	149	149	147	145	175	167	163	195	186	186	NA	NA	NA	140	135	NW
12/09/86	162	155	149	149	147	145	175	167	163	195	186	186	185	187	193	135	130	NW
12/10/86	160	155	149	149	147	144	175	167	163	195	186	186	185	187	192	140	135	NW
12/11/86	162	155	149	150	147	145	175	167	163	195	186	186	185	187	192	132	130	NW
12/12/86	164	157	150	149	147	145	175	167	163	195	186	186	185	187	193	134	130	NW
12/15/86	163	156	150	149	147	145	175	167	163	195	187	186	185	187	193	156	152	NW
12/16/86	160	155	150	147	145	142	175	167	163	195	186	186	185	187	192	134	130	NW
12/17/86	154	149	144	149	147	145	175	167	162	195	186	186	185	187	192	135	130	NW
12/18/86	152	147	142	149	147	145	175	167	162	195	187	187	185	187	192	132	129	NW
12/19/86	153	147	142	148	147	144	175	167	162	195	186	186	185	186	191	135	130	NW
12/22/86	153	147	142	148	146	144	175	167	162	195	185	186	185	186	191	135	131	NW
12/23/86	155	150	145	149	147	144	175	168	163	195	187	187	185	186	191	135	130	NW
01/05/87	150	147	140	147	145	142	175	165	160	195	186	187	184	185	191	132	129	NW
01/07/87	151	147	141	147	145	141	175	167	162	195	185	185	185	186	192	132	129	NW
01/08/87	154	148	143	148	146	144	175	167	162	195	186	186	185	186	192	135	130	NW
01/09/87	151	147	142	147	145	142	175	167	162	195	185	185	184	186	191	130	127	NW
01/15/87	151	147	142	151	149	147	175	167	163	195	186	186	185	187	192	131	128	NW
01/16/87	152	147	142	154	150	149	175	167	162	195	186	186	185	186	192	130	127	NW
01/20/87	154	148	144	152	149	147	175	167	162	196	187	187	NA	NA	NA	134	130	NW
01/21/87	155	149	145	152	150	147	175	167	161	195	186	186	NA	NA	NA	136	132	NW
01/23/87	153	148	143	150	148	145	175	165	160	195	185	185	NA	NA	NA	135	132	NW
01/28/87	148	144	137	148	147	144	175	166	161	195	186	186	NA	NA	NA	135	131	NW
01/30/87	150	146	140	143	140	135	175	166	161	NA	NA	NA	NA	NA	NA	131	126	NW
02/04/87	147	144	137	142	139	135	175	166	160	NA	NA	NA	NA	NA	NA	130	126	NW
02/05/87	153	147	142	145	141	137	175	166	161	NA	NA	NA	NA	NA	NA	131	127	NW
02/09/87	157	150	146	150	147	145	175	167	162	195	185	184	185	186	192	132	130	NW
02/11/87	160	154	148	153	150	147	175	167	162	195	186	184	185	186	192	134	130	NW
02/13/87	160	154	148	151	149	147	175	167	162	195	186	184	185	186	191	141	137	NW
02/17/87	160	154	148	NA	NA	NA	175	167	162	195	185	184	185	186	191	NA	NA	NA
02/20/87	158	152	147	NA	NA	NA	175	167	162	194	185	183	185	186	191	NA	NA	NA
03/02/87	156	150	146	NA	NA	NA	NA	NA	NA	195	186	184	185	186	191	NA	NA	NA
03/05/87	155	150	145	NA	NA	NA	NA	NA	NA	194	185	184	185	185	191	NA	NA	NA
03/10/87	152	147	140	NA	NA	NA	NA	NA	NA	195	185	185	184	185	192	133	130	NW
03/11/87	158	153	147	NA	NA	NA	NA	NA	NA	194	185	185	185	186	191	132	129	NW
03/13/87	150	146	140	NA	NA	NA	NA	NA	NA	195	186	185	184	185	192	132	130	NW
03/16/87	152	146	140	149	145	142	NA	NA	NA	194	186	185	185	185	192	134	130	NW
03/19/87	150	146	139	154	150	147	NA	NA	NA	194	186	185	184	185	192	134	130	NW
03/23/87	154	147	142	155	150	147	NA	NA	NA	194	186	185	185	186	192	135	131	NW
03/30/87	151	146	140	151	148	145	NA	NA	NA	195	186	185	184	186	192	134	130	NW
04/01/87	160	154	148	157	153	150	175	170	167	195	186	185	185	186	193	135	131	NW
04/06/87	161	156	150	159	155	152	174	170	167	194	186	185	185	186	192	133	130	NW

TABLE D.1. Continued

Date	Oven 1(150°C)			Oven 2(150°C)			Oven 3(170°C)			Oven 4(190°C)			Oven 5(190°C)			Oven 6(135°C)		
	Top	Mid	Bot	Top	Mid	Bot	Top	Mid	Bot	Top	Mid	Bot	Top	Mid	Bot	Top	Mid	Bot
04/14/87	160	154	149	160	156	153	175	170	167	195	187	186	185	186	192	132	130	NW
04/17/87	160	155	149	157	153	150	174	169	165	194	186	185	184	185	192	135	131	NW
04/20/87	158	153	147	155	153	149	174	170	166	194	186	185	184	185	191	135	132	NW
04/23/87	159	154	148	160	156	153	175	170	166	195	186	185	184	186	192	133	130	NW
04/28/87	158	152	147	157	153	149	174	170	166	194	185	185	185	185	192	132	130	NW
05/04/87	160	155	150	158	153	150	174	170	166	195	186	185	185	186	192	137	134	NW
05/08/87	160	155	149	157	153	150	175	170	166	194	185	185	184	185	192	136	133	NW
05/11/87	160	155	150	154	150	147	174	169	165	195	186	185	184	185	192	134	130	NW
05/14/87	160	155	150	155	150	147	174	169	165	195	186	185	185	186	193	135	131	NW
05/18/87	164	159	153	157	154	150	174	170	166	194	185	185	184	185	192	132	130	NW
05/19/87	NA	NA	NA	156	154	150	174	169	166	195	186	185	184	185	192	135	130	NW
05/22/87	NA	NA	NA	155	152	148	173	168	165	194	185	185	184	185	191	134	130	NW
06/02/87	NA	NA	NA	152	149	146	172	167	165	194	185	185	184	185	191	133	130	NW
06/08/87	NA	NA	NA	160	158	155	174	173	165	194	186	185	184	186	192	134	130	NW
06/15/87	NA	NA	NA	154	151	148	174	169	166	195	186	185	184	185	191	135	130	NW
06/22/87	NA	NA	NA	153	150	147	174	169	166	194	186	185	184	185	191	131	129	NW
06/26/87	NA	NA	NA	151	148	146	174	170	166	195	186	185	184	185	192	134	130	NW
07/13/87	149	141	141	150	147	145	174	170	167	195	185	185	184	185	191	134	130	NW
07/14/87	147	140	140	150	147	145	174	170	166	195	186	185	184	185	191	132	129	NW
07/22/87	160	150	150	155	152	150	174	169	166	194	185	184	184	185	191	132	129	NW
07/31/87	151	148	149	153	150	147	174	169	166	194	185	184	183	185	191	132	128	NW
08/04/87	156	147	147	152	150	147	174	170	167	194	185	185	184	185	191	132	129	NW
08/05/87	157	148	148	153	150	147	174	169	167	194	185	184	184	185	191	134	130	NW
08/11/87	158	149	149	151	148	146	174	169	167	194	185	184	184	185	191	131	129	NW
08/17/87	150	142	142	150	147	145	174	169	166	195	185	184	184	185	192	132	129	NW
08/24/87	152	144	145	152	149	147	174	169	167	194	185	184	184	185	191	134	130	NW
08/28/87	156	147	148	151	148	145	174	169	167	194	185	184	183	185	191	132	129	NW
09/02/87	157	148	148	153	150	147	174	170	167	194	185	184	184	185	191	134	130	NW
09/09/87	157	148	148	153	150	147	175	170	168	194	185	185	184	185	191	132	129	NW
09/10/87	155	147	147	157	153	150	175	170	167	195	185	185	184	185	192	132	129	NW
09/14/87	152	144	145	150	147	145	NA	NA	NA	194	185	185	184	185	191	132	129	NW
09/17/87	147	137	138	153	151	148	NA	NA	NA	194	185	185	184	185	192	132	129	NW
09/23/87	147	138	138	156	153	150	NA	NA	NA	194	185	184	184	185	191	141	131	NW
09/28/87	152	143	144	153	150	147	176	168	165	194	185	184	184	185	191	133	129	NW
10/02/87	153	145	145	160	157	154	176	169	165	195	185	185	184	185	192	132	129	NW
10/07/87	161	151	152	151	148	145	176	169	165	NA	NA	NA	NA	NA	NA	132	130	NW
10/12/87	144	135	135	147	145	142	177	168	165	NA	NA	NA	NA	NA	NA	132	129	NW
10/14/87	152	144	145	145	141	138	177	169	165	NA	NA	NA	NA	NA	NA	132	129	NW
10/16/87	160	150	150	148	146	143	178	170	166	NA	NA	NA	NA	NA	NA	132	129	NW
10/21/87	141	134	134	146	142	139	177	169	165	NA	NA	NA	NA	NA	NA	134	130	NW
10/23/87	151	143	143	145	142	138	175	167	164	NA	NA	NA	184	185	189	132	127	NW
10/26/87	151	143	144	144	140	137	175	167	165	NA	NA	NA	185	188	193	130	127	NW
10/27/87	153	145	145	150	146	145	175	166	164	NA	NA	NA	185	187	192	131	127	NW
10/30/87	151	144	144	150	146	145	175	166	164	195	184	183	185	188	193	130	126	NW
11/02/87	150	143	144	150	147	145	175	167	165	194	185	183	185	187	192	130	127	NW
11/03/87	154	145	145	NA	NA	NA	175	165	164	195	184	182	185	187	192	NA	NA	NA
11/06/87	149	140	141	NA	NA	NA	175	165	164	194	184	182	185	188	193	NA	NA	NA
11/10/87	152	144	144	NA	NA	NA	174	165	163	194	182	182	185	188	193	NA	NA	NA
11/16/87	NA	NA	NA	160	157	153	174	165	162	194	184	183	185	186	192	NA	NA	NA
11/17/87	NA	NA	NA	155	151	148	174	165	163	194	184	183	185	186	191	160	157	NW
11/18/87	NA	NA	NA	154	149	146	174	165	162	194	183	182	185	186	192	135	132	NW
11/20/87	NA	NA	NA	150	147	144	174	165	162	195	185	183	185	186	192	136	134	NW
12/02/87	154	146	145	150	146	143	174	165	162	194	185	183	185	186	192	136	133	NW
12/03/87	157	150	147	150	147	144	174	165	162	194	185	184	185	186	192	139	135	NW
12/07/87	152	146	145	147	146	142	174	165	162	194	185	184	185	186	192	130	127	NW
12/08/87	156	149	147	148	146	142	174	165	164	194	183	182	185	186	192	133	129	NW
12/09/87	158	150	147	150	146	144	175	165	163	194	185	184	185	186	192	135	130	NW
12/14/87	158	150	150	152	147	145	174	166	164	194	184	183	185	186	191	135	130	NW
12/15/87	154	148	147	150	146	144	174	166	164	194	184	183	185	186	191	134	130	NW
12/18/87	153	147	146	148	146	142	174	166	164	194	184	183	185	186	191	135	130	NW
12/22/87	152	147	146	149	146	143	174	166	164	194	185	184	185	186	191	135	130	NW

TABLE D.1. Continued

Date	Oven 1(150°C)			Oven 2(150°C)			Oven 3(170°C)			Oven 4(190°C)			Oven 5(190°C)			Oven 6(135°C)		
	Top	Mid	Bot	Top	Mid	Bot	Top	Mid	Bot	Top	Mid	Bot	Top	Mid	Bot	Top	Mid	Bot
12/23/87	152	147	146	150	147	144	174	165	164	194	184	183	185	186	191	134	130	NW
12/30/87	153	147	146	150	147	144	175	166	164	194	184	184	185	186	191	135	130	NW
01/04/88	152	146	146	148	146	142	174	165	164	194	185	184	185	186	191	134	130	NW
01/07/88	150	145	144	149	146	143	175	166	164	195	185	184	185	188	193	135	130	NW
01/08/88	150	145	144	150	146	144	175	166	165	194	185	184	185	186	191	138	134	NW
01/11/88	153	147	146	150	146	145	175	167	165	194	185	184	185	186	191	140	136	NW
01/12/88	150	145	144	147	145	140	175	166	165	194	185	184	185	186	191	137	134	NW
01/13/88	150	145	144	151	147	145	175	166	165	194	185	184	185	187	192	140	135	NW
01/15/88	154	148	147	151	147	145	175	166	164	194	185	184	185	187	192	135	130	NW
01/18/88	154	148	147	154	150	147	175	166	165	194	185	184	185	188	192	135	130	NW
01/19/88	153	147	146	153	150	147	174	166	165	194	185	184	185	187	192	132	130	NW
01/20/88	152	146	146	153	150	147	175	167	165	194	185	184	185	187	192	144	139	NW
01/22/88	155	149	148	153	150	147	175	167	165	195	185	185	185	187	192	135	130	NW
01/25/88	155	149	148	154	150	147	175	167	165	194	185	184	185	186	191	142	137	NW
01/28/88	154	148	147	153	150	146	175	167	165	194	185	185	185	186	191	141	137	NW
01/29/88	154	148	147	153	150	147	175	167	165	194	185	184	185	186	191	144	135	NW
02/01/88	155	149	148	155	150	147	175	167	165	194	185	185	185	186	191	135	132	NW
02/02/88	154	148	147	152	148	146	174	166	165	194	185	183	185	186	191	135	130	NW
02/03/88	155	149	148	158	154	150	175	167	165	194	185	185	185	186	191	135	130	NW
02/05/88	153	148	147	151	147	145	175	166	165	194	185	184	185	186	191	135	130	NW
02/08/88	154	148	147	154	150	147	175	167	165	194	185	185	185	186	191	137	133	NW
02/09/88	156	150	149	155	151	148	175	167	165	194	185	185	185	186	191	136	134	NW
02/10/88	154	149	148	154	150	148	175	167	165	194	185	185	185	186	191	135	132	NW
02/16/88	156	150	149	155	150	147	175	168	165	194	185	184	185	186	191	136	132	NW
02/18/88	155	150	149	155	151	148	175	167	165	194	185	184	185	187	192	135	130	NW
02/19/88	155	150	149	153	150	146	175	167	165	194	185	185	185	186	191	136	132	NW
02/22/88	155	149	148	155	150	147	175	167	165	194	185	184	185	186	191	136	133	NW
02/23/88	154	149	148	153	150	147	175	167	165	194	185	184	185	186	192	135	133	NW
02/25/88	155	149	148	153	150	147	175	168	165	194	185	184	185	186	192	135	133	NW
02/29/88	155	150	148	154	150	147	175	167	165	194	185	185	185	187	192	135	131	NW
03/02/88	155	150	148	153	150	146	175	166	165	194	185	185	185	186	191	135	130	NW
03/04/88	155	149	148	155	150	147	175	167	165	194	185	184	185	187	192	135	132	NW
03/08/88	154	148	147	153	150	146	175	166	165	194	185	185	185	187	191	135	131	NW
03/09/88	155	149	148	153	149	146	175	166	165	194	185	184	185	186	191	135	130	NW
03/10/88	155	150	148	152	149	146	174	166	165	194	185	184	185	187	191	137	131	NW
03/11/88	155	149	147	153	150	147	175	167	165	194	185	184	190	191	195	135	130	NW
03/14/88	155	149	148	153	150	146	175	167	165	194	185	184	190	191	195	135	130	NW
03/15/88	154	148	147	153	150	146	175	167	165	194	185	185	190	191	195	135	131	NW
03/16/88	155	149	148	155	151	148	175	167	165	194	185	185	190	191	195	135	131	NW
03/17/88	153	147	147	153	148	146	175	167	165	194	185	185	190	190	195	135	130	NW
03/21/88	155	149	148	153	150	146	175	167	165	194	185	185	185	190	195	135	130	NW
03/22/88	156	150	150	154	150	146	175	167	165	194	185	184	190	190	195	135	130	NW
03/23/88	157	150	150	155	152	149	175	167	165	195	185	185	190	191	195	135	132	NW
03/24/88	156	150	150	157	153	150	175	167	165	194	185	184	190	190	195	135	130	NW
03/28/88	155	149	148	154	150	147	175	167	165	194	185	185	190	191	195	135	130	NW
03/29/88	159	152	150	155	152	149	175	167	165	194	185	185	190	191	195	135	130	NW
03/30/88	155	149	148	155	150	147	174	166	165	194	185	185	189	190	195	135	130	NW
03/31/88	155	150	149	153	149	146	174	166	165	194	185	185	190	190	195	135	130	NW
04/01/88	154	149	148	153	149	146	175	166	165	194	185	185	190	190	195	135	130	NW
04/04/88	155	149	148	158	153	150	174	166	165	194	185	185	189	190	195	135	130	NW
04/06/88	153	147	147	151	148	146	175	168	165	194	185	185	189	191	195	135	130	NW
04/07/88	153	147	147	153	149	146	175	167	165	194	185	185	190	191	195	135	130	NW
04/08/88	158	150	150	154	150	147	175	167	165	194	185	184	190	192	196	135	130	NW
04/11/88	155	149	148	154	150	146	175	166	165	194	185	185	190	192	196	135	130	NW
04/12/88	154	147	146	155	150	147	175	167	165	194	185	185	190	191	195	135	130	NW
04/13/88	152	146	146	154	150	147	175	167	165	194	185	185	189	190	195	135	131	NW
04/14/88	153	147	147	153	150	147	175	167	165	194	185	185	190	191	195	135	130	NW
04/15/88	154	147	146	154	150	147	175	167	165	194	185	184	190	190	195	135	130	NW
04/18/88	157	155	150	156	152	150	175	167	165	194	185	184	189	190	195	135	130	NW
04/19/88	155	150	149	155	150	147	175	166	165	194	185	185	190	191	195	135	131	NW
04/20/88	154	148	147	153	150	146	175	167	165	195	185	185	190	191	195	135	130	NW

TABLE D.1. Continued

Date	Oven 1(150°C)			Oven 2(150°C)			Oven 3(170°C)			Oven 4(190°C)			Oven 5(190°C)			Oven 6(135°C)		
	Top	Mid	Bot	Top	Mid	Bot	Top	Mid	Bot	Top	Mid	Bot	Top	Mid	Bot	Top	Mid	Bot
04/21/88	156	155	149	154	150	146	175	167	165	NA	NA	NA	190	191	195	136	130	NW
04/26/88	157	150	150	154	150	147	175	167	165	NA	NA	NA	189	190	195	135	130	NW
04/27/88	157	150	150	159	154	150	175	167	165	NA	NA	NA	190	191	195	135	130	NW
04/28/88	157	150	150	158	154	150	175	167	165	NA	NA	NA	190	191	195	135	130	NW
05/02/88	157	150	150	153	149	146	175	166	165	NA	NA	NA	190	191	195	135	130	NW
05/03/88	155	150	149	153	148	146	175	167	165	NA	NA	NA	190	191	195	135	131	NW
05/06/88	157	150	150	158	153	150	175	167	165	NA	NA	NA	190	191	195	135	130	NW
05/09/88	158	150	150	156	152	149	175	167	165	NA	NA	NA	190	191	195	135	131	NW
05/11/88	151	147	146	153	148	146	175	168	166	NA	NA	NA	190	191	196	135	130	NW
05/12/88	152	146	146	150	146	143	175	167	165	NA	NA	NA	190	191	195	135	130	NW
05/13/88	155	149	148	153	148	145	175	167	165	NA	NA	NA	189	191	196	135	130	NW
05/16/88	154	147	152	153	147	145	175	167	165	NA	NA	NA	189	191	196	134	130	NW
05/17/88	156	150	148	152	147	145	175	167	165	NA	NA	NA	190	191	195	135	130	NW
05/18/88	155	148	147	151	146	145	175	167	165	NA	NA	NA	189	191	195	134	130	NW
05/19/88	156	150	149	152	147	145	175	167	165	NA	NA	NA	190	191	195	135	130	NW
05/24/88	155	150	149	155	152	149	175	168	165	NA	NA	NA	190	191	195	135	132	NW
05/25/88	154	149	148	157	153	150	175	169	166	195	185	185	190	190	195	135	133	NW
05/26/88	156	150	149	159	154	150	175	168	165	195	185	185	190	190	195	135	130	NW
05/31/88	154	147	147	161	157	154	175	166	165	195	185	185	NA	NA	NA	135	132	NW
06/02/88	151	145	144	155	150	147	175	166	164	195	185	185	NA	NA	NA	135	132	NW
06/03/88	152	146	145	156	152	150	175	166	164	195	185	185	NA	NA	NA	135	132	NW
06/06/88	151	146	145	158	155	150	175	166	165	194	185	185	NA	NA	NA	135	131	NW
06/09/88	150	144	143	157	153	150	NA	NA	NA	195	185	185	NA	NA	NA	135	132	NW
06/13/88	150	140	138	154	150	147	NA	NA	NA	194	185	185	NA	NA	NA	135	132	NW
06/15/88	150	145	144	154	150	147	NA	NA	NA	195	185	186	NA	NA	NA	135	133	NW
06/16/88	150	145	144	154	150	147	NA	NA	NA	195	185	186	184	189	194	135	134	NW
06/17/88	150	145	143	155	150	147	NA	NA	NA	195	185	186	180	185	190	135	132	NW
06/20/88	150	145	144	156	153	150	NA	NA	NA	195	185	186	183	188	194	135	132	NW
06/22/88	150	145	144	155	150	147	NA	NA	NA	194	185	185	189	195	200	135	134	NW
06/24/88	152	146	145	151	147	145	NA	NA	NA	195	185	186	184	189	195	135	131	NW
06/29/88	155	147	147	155	150	147	NA	NA	NA	195	185	185	190	195	203	135	130	NW
06/30/88	157	151	150	156	154	150	175	166	163	194	185	185	181	186	192	135	132	NW
07/05/88	160	153	152	161	158	155	175	166	164	194	185	185	181	185	192	135	132	NW
07/06/88	154	148	147	150	146	144	175	165	161	194	185	185	185	191	198	134	131	NW
07/07/88	157	150	150	156	152	149	176	166	164	194	185	185	185	190	197	135	130	NW
07/12/88	159	152	152	152	148	146	179	169	165	195	185	185	185	192	198	135	130	NW
07/13/88	156	150	150	156	152	150	175	165	162	194	185	185	185	191	198	135	131	NW
07/15/88	153	147	147	150	146	145	173	163	160	194	185	185	184	189	194	135	131	NW
07/20/88	154	149	148	147	145	143	175	166	164	195	185	186	182	186	194	135	130	NW
07/22/88	155	150	149	155	150	148	175	166	164	195	185	186	185	190	196	135	131	NW
07/26/88	154	148	147	148	146	144	178	169	165	194	185	185	184	189	195	135	131	NW
07/27/88	154	148	147	150	147	145	176	167	165	194	185	185	184	189	195	135	131	NW
07/28/88	158	152	151	146	144	142	179	169	165	194	185	185	179	184	190	135	130	NW
08/01/88	155	150	149	147	145	142	179	169	166	194	185	185	180	185	191	134	130	NW
08/02/88	155	150	148	145	140	138	175	165	163	194	185	185	175	180	186	135	130	NW
08/04/88	155	150	149	146	144	140	175	166	164	195	185	186	175	181	192	135	130	NW
08/09/88	155	150	150	145	142	139	175	165	162	195	185	186	175	180	185	135	130	NW
08/11/88	154	147	147	145	141	138	174	165	162	195	185	186	175	180	185	135	130	NW
08/15/88	150	146	145	147	145	142	175	165	163	194	185	185	180	185	191	135	130	NW
08/18/88	150	146	145	150	146	144	177	169	165	195	185	186	183	189	195	135	130	NW
08/22/88	154	147	147	150	147	145	178	169	165	194	185	185	182	188	194	135	130	NW
08/23/88	150	146	145	149	146	144	179	170	166	194	185	186	184	189	194	135	130	NW
08/24/88	152	146	146	149	145	144	178	169	165	194	185	185	182	186	194	NA	NA	NA
08/25/88	155	150	149	148	145	143	175	167	165	195	185	186	180	185	192	NA	NA	NA
08/30/88	150	145	145	145	141	137	176	166	164	194	184	185	184	188	195	NA	NA	NA
09/01/88	150	145	144	145	142	137	175	165	163	194	184	185	182	186	194	NA	NA	NA
09/02/88	150	145	143	140	135	132	172	162	159	194	183	185	175	181	187	NA	NA	NA
09/06/88	149	144	143	146	142	138	175	165	161	194	185	185	179	184	190	NA	NA	NA
09/07/88	150	146	145	146	144	140	175	165	161	195	185	185	182	185	192	NA	NA	NA
09/08/88	153	147	147	145	141	138	175	165	162	194	184	185	184	188	195	NA	NA	NA
09/09/88	157	151	150	147	143	140	175	166	164	194	184	185	184	187	195	NA	NA	NA

TABLE D.1. Continued

Date	Oven 1(150°C)			Oven 2(150°C)			Oven 3(170°C)			Oven 4(190°C)			Oven 5(190°C)			Oven 6(135°C)		
	Top	Mid	Bot	Top	Mid	Bot	Top	Mid	Bot	Top	Mid	Bot	Top	Mid	Bot	Top	Mid	Bot
09/12/88	154	149	147	146	142	139	175	165	162	194	184	185	182	186	194	NA	NA	NA
09/14/88	154	148	147	145	140	137	174	164	160	194	184	185	180	185	194	NA	NA	NA
09/16/88	150	145	145	146	143	140	175	165	162	194	184	185	180	185	192	NA	NA	NA
09/19/88	155	150	149	144	140	135	178	169	165	194	184	185	185	190	197	NA	NA	NA
09/21/88	154	148	147	150	146	143	178	169	165	194	183	185	185	190	197	NA	NA	NA
09/23/88	155	149	147	NA	NA	NA	175	165	162	194	185	185	186	192	200	NA	NA	NA
09/28/88	150	145	145	NA	NA	NA	175	165	163	194	184	185	180	185	194	NA	NA	NA
09/30/88	154	148	147	NA	NA	NA	181	172	169	194	184	185	185	190	196	NA	NA	NA
10/04/88	150	145	144	NA	NA	NA	175	165	162	194	185	185	180	185	192	NA	NA	NA
10/10/88	155	150	146	NA	NA	NA	177	167	165	193	184	185	185	190	198	135	127	NW
10/11/88	NA	NA	NA	NA	NA	NA	180	170	167	193	184	185	184	189	195	146	139	NW
10/13/88	NA	NA	NA	NA	NA	NA	174	164	160	194	185	186	185	190	199	137	130	NW
10/18/88	NA	NA	NA	150	145	141	174	164	160	194	185	185	180	185	193	140	131	NW
10/20/88	NA	NA	NA	150	146	143	175	165	162	194	185	186	185	190	197	138	130	NW
10/24/88	NA	NA	NA	150	146	144	173	162	160	194	185	185	191	196	205	133	125	NW
10/25/88	NA	NA	NA	150	145	142	175	164	160	194	185	185	186	193	200	140	132	NW
10/31/88	NA	NA	NA	150	145	144	175	165	160	194	185	186	189	194	201	138	130	NW
11/01/88	NA	NA	NA	150	145	143	175	165	162	194	185	186	187	193	200	138	130	NW
11/02/88	152	146	141	150	145	143	174	164	160	194	185	186	185	190	199	134	125	NW
11/07/88	153	146	142	150	145	143	175	165	161	194	185	185	180	185	192	142	134	NW
11/09/88	152	146	142	149	145	143	175	165	162	193	185	185	180	185	192	142	134	NW
11/11/88	151	145	140	149	145	141	174	164	160	194	185	185	184	188	196	130	122	NW
11/14/88	152	146	141	149	145	143	175	165	162	193	185	185	185	190	198	135	130	NW
11/15/88	153	146	142	150	145	143	175	165	162	194	185	186	179	185	191	141	134	NW
11/17/88	153	146	142	150	145	143	175	165	161	194	185	186	180	185	193	141	134	NW
11/18/88	154	146	144	150	145	143	176	165	163	195	185	186	184	188	196	141	134	NW
11/22/88	152	146	142	150	146	144	174	164	160	195	185	186	185	191	199	143	135	NW
11/28/88	152	145	140	150	145	143	174	164	160	194	185	186	185	190	198	135	129	NW
11/30/88	152	145	142	149	145	143	175	165	161	194	185	185	177	182	190	139	130	NW
12/01/88	149	143	138	149	145	143	176	166	164	194	185	185	177	183	190	136	130	NW
12/07/88	149	143	138	149	145	143	177	167	164	194	185	185	180	185	192	135	127	NW
12/08/88	149	143	138	150	145	143	177	166	164	194	185	185	180	185	192	135	129	NW
12/09/88	153	146	142	149	146	143	175	165	162	194	185	185	180	185	192	139	135	NW
12/13/88	154	146	143	150	145	143	175	165	162	194	185	185	187	193	201	130	123	NW
12/14/88	149	143	137	149	145	142	176	166	164	194	185	185	180	185	192	138	130	NW
12/16/88	153	146	142	150	146	143	174	165	161	193	185	185	185	192	200	132	125	NW
12/19/88	153	146	143	150	146	144	175	165	162	194	185	185	186	192	200	131	125	NW
12/21/88	154	146	143	150	145	143	176	165	163	194	185	185	186	193	200	139	131	NW
12/22/88	153	146	144	150	146	144	176	166	164	194	185	186	187	194	200	139	131	NW
12/28/88	153	146	143	150	145	143	175	165	162	193	185	185	185	190	198	143	135	NW
12/30/88	155	148	145	150	146	144	178	167	165	194	185	185	185	190	199	130	122	NW
01/03/89	153	146	144	150	146	144	175	165	163	194	185	185	185	190	198	138	130	NW
01/04/89	153	146	143	150	146	144	175	165	162	194	185	186	185	190	198	138	130	NW
01/06/89	153	146	143	149	145	143	175	165	162	194	185	186	185	190	198	135	129	NW
01/09/89	150	145	140	149	145	142	174	164	160	194	185	185	182	187	195	149	141	NW
01/10/89	153	146	142	149	145	142	175	165	162	193	185	185	185	191	199	135	128	NW
01/11/89	152	145	141	150	145	144	174	164	160	195	185	186	185	190	198	135	129	NW
01/12/89	150	144	138	150	145	142	173	162	160	194	185	185	185	190	198	138	130	NW
01/13/89	153	146	144	150	145	144	177	167	165	194	185	185	189	194	201	142	134	NW
01/16/89	151	145	140	150	145	142	174	164	160	195	185	185	185	190	198	135	127	NW
01/17/89	154	147	144	150	145	144	176	166	164	194	185	185	186	193	200	135	127	NW
01/19/89	154	147	143	150	146	144	175	165	162	193	185	185	180	185	193	142	134	NW
01/24/89	153	147	143	150	146	144	176	167	165	194	185	185	188	193	200	141	134	NW
01/25/89	154	147	144	152	147	146	179	169	166	194	185	186	187	193	200	147	140	NW
01/31/89	155	149	145	150	147	144	178	169	165	194	185	186	185	190	197	145	135	NW
02/01/89	152	146	141	149	146	142	174	164	160	194	185	185	185	191	199	140	131	NW
02/02/89	152	146	142	150	146	143	174	164	160	194	185	186	184	189	195	133	125	NW
02/06/89	149	143	137	150	146	142	170	160	158	193	185	185	179	184	191	134	125	NW
02/07/89	150	144	139	150	146	144	178	167	165	194	185	185	184	188	195	145	136	NW
02/08/89	150	145	140	150	146	144	174	164	160	194	185	186	185	189	197	150	143	NW
02/09/89	150	144	139	150	146	143	180	170	166	194	185	185	185	191	199	135	130	NW

TABLE D.1. Continued

Date	Oven 1(150°C)			Oven 2(150°C)			Oven 3(170°C)			Oven 4(190°C)			Oven 5(190°C)			Oven 6(135°C)		
	Top	Mid	Bot	Top	Mid	Bot	Top	Mid	Bot	Top	Mid	Bot	Top	Mid	Bot	Top	Mid	Bot
02/10/89	150	145	140	150	146	144	177	167	164	194	185	185	184	189	192	137	130	NW
02/13/89	151	146	140	150	146	142	173	162	160	195	185	186	184	188	195	130	122	NW
02/16/89	150	145	139	150	146	143	186	173	171	194	185	186	185	190	197	134	125	NW
02/21/89	153	146	142	150	146	143	174	164	160	194	185	186	185	190	198	134	125	NW
02/22/89	152	146	142	150	146	143	175	165	161	194	185	186	185	190	198	134	120	NW
02/23/89	153	147	143	150	146	144	176	165	163	194	185	186	184	189	196	140	131	NW
02/28/89	153	147	143	150	146	144	175	165	161	194	185	185	185	190	197	137	130	NW
03/02/89	155	149	146	150	146	143	179	168	165	194	185	185	189	194	203	130	124	NW
03/03/89	159	151	147	150	147	144	182	172	170	194	185	186	193	198	205	135	129	NW
03/07/89	157	150	147	150	146	144	180	170	168	194	185	185	180	185	193	139	131	NW
03/08/89	157	150	147	150	146	144	180	170	167	194	185	185	185	189	196	135	128	NW
03/09/89	157	150	147	150	146	144	181	170	168	194	185	186	185	191	199	135	130	NW
03/10/89	157	150	147	150	146	144	180	170	167	195	185	186	185	190	192	131	125	NW
03/13/89	159	152	147	150	147	144	182	172	170	194	185	186	188	193	201	134	126	NW
03/14/89	158	150	147	150	147	144	180	170	169	194	185	185	185	189	196	137	130	NW
03/16/89	155	147	145	149	145	141	175	165	162	194	185	185	178	185	190	140	131	NW
03/20/89	155	150	146	150	146	144	178	169	165	195	185	186	183	187	194	139	131	NW
03/23/89	157	151	147	150	146	144	176	166	165	195	185	186	180	185	193	140	132	NW
03/27/89	155	150	146	150	147	144	175	166	165	194	185	186	185	190	197	130	125	NW
03/29/89	158	151	147	150	147	145	178	169	166	194	185	185	185	190	196	136	130	NW
03/30/89	155	149	146	150	147	145	178	168	165	195	185	186	183	187	195	138	130	NW
03/31/89	157	150	147	150	147	145	178	169	165	195	185	187	182	187	194	135	129	NW
04/03/89	155	150	147	150	147	145	179	170	166	195	185	187	184	189	195	141	134	NW
04/05/89	158	152	147	150	147	145	179	169	167	195	185	187	185	190	196	130	124	NW
04/07/89	156	150	146	150	146	144	176	167	165	195	185	186	183	188	195	140	133	NW
04/10/89	152	146	144	150	146	144	176	166	165	194	185	185	180	185	191	139	130	NW
04/13/89	150	145	140	150	146	144	175	165	163	195	185	186	179	185	190	138	130	NW
04/19/89	157	150	147	150	146	144	177	168	165	194	185	186	185	190	197	135	127	NW
04/20/89	157	150	147	150	146	144	177	167	165	195	185	186	185	190	195	133	125	NW
04/24/89	156	150	146	150	146	144	176	167	165	194	185	186	179	184	190	138	130	NW
04/26/89	157	150	146	150	146	144	177	167	165	195	185	186	180	185	193	140	131	NW
04/28/89	155	150	146	150	146	143	175	165	164	194	185	185	178	185	190	137	130	NW
05/01/89	155	150	146	150	146	144	176	166	165	194	185	185	183	187	194	135	129	NW
05/04/89	155	149	146	150	147	145	175	166	165	194	185	186	182	187	194	140	132	NW
05/05/89	157	150	147	150	147	144	176	167	165	194	185	186	182	188	195	142	133	NW
05/08/89	157	150	147	150	146	144	176	166	165	194	185	186	182	187	194	138	130	NW
05/09/89	155	149	146	150	146	143	175	166	164	194	185	185	182	185	194	136	129	NW
05/12/89	157	150	147	149	145	141	178	169	165	NA	NA	NA	180	185	191	135	127	NW
05/15/89	156	150	146	150	145	142	175	165	164	NA	NA	NA	182	187	194	132	123	NW
05/17/89	158	150	147	149	146	143	178	169	165	195	182	176	183	189	195	135	128	NW
05/18/89	155	149	146	150	146	143	179	169	166	194	185	175	180	185	192	139	130	NW
05/19/89	156	150	146	150	146	142	175	165	164	193	181	178	182	187	194	135	127	NW
05/26/89	158	150	147	150	145	142	177	167	165	NA	NA	NA	182	188	195	135	129	NW
05/31/89	157	150	147	150	146	141	175	166	165	NA	NA	NA	180	185	193	135	129	NW
06/02/89	155	149	146	150	146	142	178	168	165	NA	NA	NA	180	185	193	146	139	NW
06/05/89	155	149	145	150	145	142	175	165	164	NA	NA	NA	180	185	192	135	128	NW
06/07/89	159	151	147	150	146	142	177	168	165	NA	NA	NA	181	185	193	139	130	NW
06/12/89	157	151	147	150	146	142	178	169	165	NA	NA	NA	180	185	193	135	129	NW
06/15/89	159	152	147	150	146	143	179	170	166	193	185	184	179	185	190	138	130	NW
06/16/89	155	149	146	149	146	142	179	170	167	193	185	184	180	185	192	141	134	NW
06/19/89	160	154	150	149	146	143	182	172	170	193	185	184	180	185	193	140	132	NW
06/21/89	159	152	148	150	147	144	180	170	169	194	185	185	181	186	194	146	138	NW
06/23/89	157	150	146	150	146	144	178	169	165	194	185	185	180	185	193	137	130	NW
06/26/89	156	150	146	150	146	144	179	170	167	194	185	185	184	188	194	147	140	NW
06/30/89	157	150	147	150	147	145	180	170	168	194	186	185	185	190	197	150	142	NW
07/07/89	160	153	150	150	147	145	182	173	170	193	185	184	180	185	191	140	132	NW
07/10/89	158	151	147	150	147	145	181	172	170	194	186	185	181	185	192	136	130	NW
07/12/89	155	149	146	150	147	145	180	170	169	194	186	185	180	185	192	132	125	NW
07/13/89	155	149	146	150	147	145	180	170	169	194	186	185	181	185	193	130	124	NW
07/18/89	155	150	146	150	146	145	180	170	169	194	186	185	180	185	192	140	133	NW
07/20/89	160	154	150	150	147	145	185	175	174	194	186	185	184	189	195	144	135	NW

TABLE D.1. Continued

Date	Oven 1(150°C)			Oven 2(150°C)			Oven 3(170°C)			Oven 4(190°C)			Oven 5(190°C)			Oven 6(135°C)		
	Top	Mid	Bot	Top	Mid	Bot	Top	Mid	Bot	Top	Mid	Bot	Top	Mid	Bot	Top	Mid	Bot
07/21/89	150	146	143	150	147	145	179	169	166	194	185	184	NA	NA	NA	144	135	NW
07/25/89	151	146	142	150	146	144	175	165	163	193	185	184	NA	NA	NA	139	130	NW
07/26/89	152	147	144	150	146	145	177	168	165	193	185	184	NA	NA	NA	143	135	NW
07/28/89	150	145	141	150	146	144	179	169	165	194	185	185	NA	NA	NA	139	130	NW
08/01/89	154	148	145	150	146	144	175	166	164	194	185	185	NA	NA	NA	140	131	NW
08/03/89	150	145	141	150	146	144	177	167	165	194	186	185	NA	NA	NA	139	130	NW
08/09/89	151	145	140	150	147	145	174	163	160	194	186	185	185	185	186	135	129	NW
08/10/89	153	147	144	150	146	145	175	165	162	194	185	185	187	190	190	140	133	NW
08/11/89	150	145	140	150	146	144	175	165	162	194	186	185	189	188	192	144	135	NW
08/15/89	150	145	140	150	146	144	173	162	159	194	185	185	NA	NA	NA	141	135	NW
08/18/89	150	145	140	150	147	145	170	160	157	193	185	185	NA	NA	NA	132	125	NW
08/25/89	150	146	141	150	146	144	176	167	165	193	185	185	NA	NA	NA	141	134	NW
08/29/89	152	146	144	150	146	145	175	165	162	194	185	185	185	185	190	140	133	NW
09/05/89	152	147	144	150	146	145	177	167	165	194	186	185	185	185	190	143	135	NW
09/12/89	151	147	143	150	147	144	181	171	169	194	185	185	183	185	188	140	133	NW
09/20/89	150	145	141	150	147	144	180	170	167	194	186	185	185	186	190	142	134	NW
09/22/89	154	147	145	150	146	144	176	166	164	194	185	185	181	183	185	140	133	NW
09/27/89	150	146	141	150	147	144	177	167	165	194	185	185	185	185	190	140	132	NW
09/28/89	150	145	141	150	147	144	179	169	166	194	186	185	185	186	190	141	134	NW
10/04/89	150	146	141	150	146	144	172	162	160	194	185	185	186	189	192	138	130	NW
10/10/89	150	145	140	150	147	144	175	165	164	194	185	185	187	189	194	142	135	NW
10/13/89	150	144	139	150	146	144	175	165	163	194	185	185	187	189	193	142	135	NW
10/20/89	153	147	144	150	147	144	NA	NA	NA	194	186	185	185	185	190	138	130	NW
10/23/89	153	147	142	150	146	144	NA	NA	NA	194	185	185	185	188	192	139	131	NW
10/24/89	149	144	139	150	146	144	NA	NA	NA	194	186	185	186	189	194	138	130	NW
10/27/89	150	144	139	150	146	144	NA	NA	NA	194	186	185	186	189	193	138	130	NW
10/30/89	150	145	140	150	146	144	166	146	122	193	185	185	185	185	190	138	130	NW
10/31/89	150	145	140	150	146	144	160	146	120	194	185	185	185	186	191	138	130	NW
11/01/89	150	145	140	150	146	144	171	150	135	194	185	185	182	185	188	139	130	NW
11/06/89	150	144	139	150	146	144	NA	NA	NA	193	185	185	183	185	190	140	133	NW
11/13/89	153	147	144	150	146	144	NA	NA	NA	194	185	185	204	206	212	139	130	NW
11/17/89	156	150	146	150	146	144	NA	NA	NA	194	185	185	195	198	200	139	130	NW
11/27/89	155	150	146	150	146	144	NA	NA	NA	194	185	185	182	183	185	135	126	NW
11/30/89	158	150	147	150	146	144	NA	NA	NA	194	185	185	185	185	190	132	125	NW
12/01/89	150	145	140	150	146	143	NA	NA	NA	194	185	185	NA	NA	NA	139	130	NW
12/04/89	151	146	141	150	146	144	NA	NA	NA	194	185	185	NA	NA	NA	135	126	NW
12/05/89	150	144	139	150	146	144	176	165	161	194	185	185	NA	NA	NA	137	130	NW
12/12/89	150	144	140	150	146	144	172	160	158	194	185	185	NA	NA	NA	136	130	NW
12/14/89	150	144	140	150	146	144	175	164	160	194	185	185	NA	NA	NA	137	130	NW
12/18/89	150	144	140	150	146	144	180	167	165	193	185	185	NA	NA	NA	139	131	NW
12/20/89	150	144	139	150	146	144	173	160	157	194	185	185	NA	NA	NA	137	130	NW
12/28/89	150	144	139	150	146	143	171	160	158	194	185	185	NA	NA	NA	132	125	NW
01/08/90	153	146	142	150	146	144	175	164	160	193	185	185	NA	NA	NA	141	134	NW
01/10/90	150	144	139	150	146	143	175	164	162	NA	NA	NA	186	187	190	145	137	NW
01/16/90	150	145	141	150	145	141	181	170	168	NA	NA	NA	185	186	189	139	131	NW
01/18/90	150	145	140	149	145	141	179	167	165	NA	NA	NA	185	186	189	140	132	NW
01/24/90	151	145	141	149	145	141	175	164	162	NA	NA	NA	188	189	190	139	130	NW
01/26/90	150	145	140	150	146	141	178	166	165	NA	NA	NA	185	185	188	140	132	NW
01/31/90	150	145	140	149	145	141	177	166	165	NA	NA	NA	185	185	187	136	130	NW
02/02/90	153	147	145	150	145	142	179	167	165	194	185	183	185	185	187	140	132	NW
02/07/90	150	145	140	149	145	142	179	167	165	194	185	183	185	185	188	140	132	NW
02/14/90	159	152	148	150	147	145	181	170	169	195	186	185	193	194	195	147	138	NW
02/20/90	153	147	145	150	147	145	181	170	169	194	185	185	191	192	194	144	135	NW
02/27/90	151	146	143	NA	NA	NA	178	167	165	194	185	185	187	188	190	139	131	NW
03/02/90	150	145	140	NA	NA	NA	180	169	167	194	185	184	185	186	189	140	132	NW
03/06/90	152	146	143	NA	NA	NA	179	168	165	194	185	184	185	185	188	141	134	NW
03/08/90	153	147	145	152	135	114	177	166	165	194	185	184	185	185	188	140	133	NW
03/13/90	150	145	141	149	142	125	178	167	165	194	185	184	185	186	190	141	134	NW
03/15/90	150	145	140	NA	NA	NA	176	165	164	194	185	184	185	186	190	138	130	NW
03/21/90	150	145	140	NA	NA	NA	175	165	162	194	185	183	184	185	186	139	131	NW
03/22/90	150	145	140	NA	NA	NA	177	166	165	194	185	184	185	185	186	139	131	NW

TABLE D.1. Continued

Date	Oven 1(150°C)			Oven 2(150°C)			Oven 3(170°C)			Oven 4(190°C)			Oven 5(190°C)			Oven 6(135°C)		
	Top	Mid	Bot	Top	Mid	Bot	Top	Mid	Bot	Top	Mid	Bot	Top	Mid	Bot	Top	Mid	Bot
03/28/90	150	145	141	NA	NA	NA	176	165	164	194	185	184	183	183	185	140	132	NW
03/30/90	151	146	143	NA	NA	NA	177	166	164	194	185	184	185	186	189	140	131	NW
04/02/90	150	145	142	NA	NA	NA	175	165	164	194	185	184	185	185	188	139	131	NW
04/05/90	150	145	142	NA	NA	NA	177	166	165	194	185	184	185	186	190	139	130	NW
04/09/90	150	145	141	NA	NA	NA	176	165	164	194	185	185	186	187	190	139	130	NW
04/10/90	150	145	141	NA	NA	NA	178	167	165	194	185	185	185	186	190	139	130	NW
04/11/90	153	147	145	NA	NA	NA	177	166	165	194	185	184	185	185	189	140	132	NW
04/17/90	150	145	140	NA	NA	NA	172	160	159	194	185	184	184	185	186	136	129	NW
04/23/90	150	144	140	NA	NA	NA	173	163	160	194	185	183	185	185	187	NA	NA	NA
04/25/90	150	144	140	NA	NA	NA	176	165	163	194	185	184	185	185	188	NA	NA	NA
04/30/90	152	146	142	NA	NA	NA	174	164	161	194	185	184	185	186	190	NA	NA	NA
05/01/90	150	145	140	NA	NA	NA	177	166	164	194	185	184	185	185	189	135	115	NW
05/02/90	150	145	140	NA	NA	NA	173	161	160	194	185	184	185	185	189	130	117	NW
05/07/90	NA	NA	NA	NA	NA	NA	175	164	161	194	185	185	189	190	192	NA	NA	NA
05/15/90	157	149	145	NA	NA	NA	172	160	158	194	185	184	182	182	185	136	127	NW
05/16/90	151	143	131	NA	NA	NA	170	159	156	194	185	184	180	181	184	140	129	NW
05/21/90	NA	NA	NA	NA	NA	NA	174	162	160	194	185	185	182	183	185	140	130	NW
05/22/90	154	146	140	NA	NA	NA	172	160	158	194	185	185	182	183	185	140	130	NW
05/25/90	154	145	138	NA	NA	NA	172	160	158	194	185	185	184	185	186	140	130	NW
05/30/90	153	145	139	NA	NA	NA	172	160	158	194	185	185	184	185	186	140	130	NW
06/04/90	152	144	137	NA	NA	NA	171	160	157	194	185	185	180	180	184	140	130	NW
06/07/90	152	144	137	NA	NA	NA	170	158	156	194	185	184	181	182	185	140	130	NW
06/11/90	155	146	141	NA	NA	NA	173	161	160	194	185	185	185	185	190	140	130	NW
06/14/90	158	149	145	NA	NA	NA	180	170	168	194	186	185	194	194	195	139	130	NW
06/25/90	157	148	145	NA	NA	NA	177	166	164	194	186	185	185	186	189	140	130	NW
06/27/90	159	150	146	NA	NA	NA	179	167	165	194	186	185	189	190	193	143	132	NW
06/29/90	160	150	146	NA	NA	NA	179	168	165	194	186	185	187	188	191	143	132	NW
07/02/90	158	149	146	NA	NA	NA	180	170	167	194	186	185	190	191	194	144	133	NW
07/09/90	157	148	145	NA	NA	NA	177	166	165	194	185	184	185	186	190	141	130	NW
07/12/90	156	147	145	NA	NA	NA	179	168	165	194	186	185	185	186	190	136	126	NW
07/17/90	154	147	143	NA	NA	NA	183	172	170	194	186	185	194	194	197	142	131	NW
07/19/90	154	146	142	NA	NA	NA	179	168	165	194	185	185	187	189	192	143	132	NW
07/24/90	159	150	146	NA	NA	NA	184	172	170	194	185	184	193	194	196	145	135	NW
07/27/90	155	147	144	NA	NA	NA	175	164	162	194	186	185	189	189	192	143	132	NW
08/03/90	155	147	144	NA	NA	NA	174	163	161	194	186	185	185	185	187	143	132	NW
08/07/90	152	145	140	NA	NA	NA	174	164	161	194	185	184	182	183	185	137	128	NW
08/10/90	154	146	142	NA	NA	NA	175	165	164	194	186	185	185	185	189	144	134	NW
08/16/90	154	147	144	NA	NA	NA	172	161	160	194	186	185	182	184	185	144	132	NW
08/20/90	155	147	144	NA	NA	NA	175	165	164	194	186	185	185	185	189	144	134	NW
08/23/90	154	147	143	NA	NA	NA	174	163	161	194	186	185	184	184	185	140	130	NW
08/27/90	153	146	142	NA	NA	NA	175	164	163	194	186	185	185	185	189	142	132	NW
08/29/90	155	147	144	NA	NA	NA	174	163	161	194	187	185	184	185	186	143	132	NW
09/06/90	150	142	136	NA	NA	NA	169	157	155	194	185	185	179	180	183	137	128	NW
09/13/90	153	145	140	NA	NA	NA	NA	NA	NA	194	185	185	181	182	185	137	128	NW
09/18/90	NA	NA	NA	NA	NA	NA	NA	NA	NA	194	185	185	NA	NA	NA	136	126	NW
09/21/90	NA	NA	NA	NA	NA	NA	NA	NA	NA	194	185	184	NA	NA	NA	134	124	NW
09/25/90	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	130	120	NW

NA = Not applicable because oven not operating

NW = Instrument not working

CRB = Chart recorder broken

TABLE D.1. Continued

Date	Oven 7(150°C)			Oven 8(190°C)			Oven 9(210°C)			Oven 10(135°C)			Oven 11(170°C)			Oven 12(230°C)		
	Top	Mid	Bot	Top	Mid	Bot	Top	Mid	Bot	Top	Mid	Bot	Top	Mid	Bot	Top	Mid	Bot
12/23/85	150	150	151	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
12/26/85	150	150	151	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
12/27/85	150	151	152	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
12/30/85	150	150	152	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
12/31/85	151	151	155	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
01/02/86	141	142	146	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
01/03/86	144	145	149	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
01/06/86	145	146	150	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
01/07/86	141	143	146	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
01/08/86	148	149	150	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
01/09/86	141	142	146	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
01/10/86	159	159	161	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
01/13/86	159	159	161	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
01/14/86	140	143	147	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
01/15/86	149	149	151	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
01/16/86	149	150	151	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
01/17/86	159	159	160	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
01/20/86	156	156	159	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
01/21/86	150	151	153	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
01/22/86	154	154	157	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
01/23/86	NA	153	156	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
01/24/86	159	159	161	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
01/27/86	151	152	154	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
01/28/86	152	153	156	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
01/29/86	156	156	159	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
01/30/86	159	159	160	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
01/31/86	150	151	153	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
02/03/86	159	159	161	NA	NA	NA	NA	NA	NA	128	123	121	NA	NA	NA	NA	NA	NA
02/04/86	160	159	162	NA	NA	NA	NA	NA	NA	137	132	130	NA	NA	NA	NA	NA	NA
02/05/86	NW	151	154	NA	NA	NA	NA	NA	NA	136	131	129	170	168	165	NA	NA	NA
02/06/86	NW	151	155	NA	NA	NA	NA	NA	NA	135	130	129	169	167	165	NA	NA	NA
02/07/86	NW	150	154	NA	NA	NA	NA	NA	NA	45	45	45	170	168	166	NA	NA	NA
02/10/86	NW	150	153	NA	NA	NA	NA	NA	NA	45	45	45	171	170	168	NA	NA	NA
02/11/86	NW	150	154	NA	NA	NA	NA	NA	NA	134	129	127	172	170	168	NA	NA	NA
02/12/86	NW	151	155	NA	NA	NA	NA	NA	NA	132	128	127	173	170	169	NA	NA	NA
02/13/86	NW	152	156	180	173	170	NA	NA	NA	135	130	129	174	172	170	NA	NA	NA
02/14/86	NW	151	156	193	185	183	NA	NA	NA	136	131	130	176	174	171	NA	NA	NA
02/18/86	NW	151	156	195	188	183	NA	NA	NA	136	130	129	173	170	169	NA	NA	NA
02/19/86	NW	150	154	195	187	183	NA	NA	NA	133	129	127	171	169	166	NA	NA	NA
02/20/86	NW	150	154	195	187	183	NA	NA	NA	133	129	128	173	170	169	NA	NA	NA
02/21/86	NW	152	157	195	187	183	NA	NA	NA	134	129	128	173	170	169	NA	NA	NA
02/24/86	60	89	87	195	187	184	NA	NA	NA	137	133	131	179	176	175	NA	NA	NA
02/25/86	NA	NA	NA	NA	NA	NA	NA	NA	NA	133	129	128	173	170	169	NA	NA	NA
02/26/86	NA	NA	NA	NA	NA	NA	NA	NA	NA	131	126	125	NA	NA	NA	NA	NA	NA
02/27/86	NA	NA	NA	NA	NA	NA	176	169	165	131	126	125	NA	NA	NA	NA	NA	NA
02/28/86	NA	NA	NA	NA	NA	NA	189	182	179	133	129	128	NA	NA	NA	NA	NA	NA
03/03/86	NA	NA	NA	NA	NA	NA	39	39	39	132	128	126	NA	NA	NA	NA	NA	NA
03/04/86	NA	NA	NA	NA	NA	NA	NA	NA	NA	131	127	125	NA	NA	NA	NA	NA	NA
03/05/86	NA	NA	NA	NA	NA	NA	NA	NA	NA	138	132	131	162	160	159	NA	NA	NA
03/06/86	NW	160	161	NA	NA	NA	NA	NA	NA	139	134	133	173	169	169	NA	NA	NA
03/07/86	NW	152	153	NA	NA	NA	NA	NA	NA	135	130	129	172	169	168	NA	NA	NA
03/10/86	NW	151	152	181	174	173	NA	NA	NA	134	130	129	172	169	168	NA	NA	NA
03/11/86	NW	151	153	188	180	179	NA	NA	NA	135	130	129	173	170	169	NA	NA	NA
03/12/86	NW	151	153	193	185	182	NA	NA	NA	136	131	130	173	170	169	NA	NA	NA
03/13/86	NW	151	152	193	186	183	NA	NA	NA	137	132	131	172	169	169	NA	NA	NA
03/14/86	NW	153	155	192	185	183	NA	NA	NA	129	123	122	168	166	165	NA	NA	NA
03/17/86	NW	153	155	193	185	184	NA	NA	NA	136	130	130	169	166	165	NA	NA	NA
03/18/86	NW	152	153	192	185	184	NA	NA	NA	133	128	127	166	163	163	NA	NA	NA
03/19/86	NW	152	154	193	185	183	NA	NA	NA	133	128	126	167	164	163	NA	NA	NA
03/20/86	NW	152	155	193	186	183	NA	NA	NA	132	127	126	168	165	164	NA	NA	NA
03/21/86	NA	153	153	191	185	181	NA	NA	NA	130	128	125	170	167	165	NA	NA	NA
03/24/86	NW	153	154	193	185	183	NA	NA	NA	132	127	126	167	164	163	NA	NA	NA

TABLE D.1. Continued

Date	Oven 7(150°C)			Oven 8(190°C)			Oven 9(210°C)			Oven 10(135°C)			Oven 11(170°C)			Oven 12(230°C)		
	Top	Mid	Bot	Top	Mid	Bot	Top	Mid	Bot	Top	Mid	Bot	Top	Mid	Bot	Top	Mid	Bot
03/26/86	NW	135	153	193	185	184	208	193	193	131	127	125	166	162	162	NA	NA	NA
03/27/86	NW	134	153	191	184	184	204	195	192	124	119	118	165	161	160	NA	NA	NA
03/31/86	NW	130	153	NA	NA	NA	205	197	196	124	119	118	166	162	161	NA	NA	NA
04/01/86	NW	130	155	198	188	186	206	199	196	132	127	126	167	163	163	NA	NA	NA
04/02/86	NA	130	152	193	185	184	208	200	199	130	125	125	165	163	162	230	220	225
04/03/86	NA	NS	155	194	186	183	207	200	199	133	130	129	167	165	164	234	224	230
04/04/86	NW	NW	155	193	187	184	206	199	198	134	130	129	168	164	164	233	224	229
04/07/86	NW	152	154	194	186	183	209	200	199	123	118	117	167	163	162	NA	NA	NA
04/08/86	NW	153	155	194	186	184	207	199	198	132	128	127	167	163	163	189	179	183
04/09/86	NW	153	155	193	186	183	207	200	198	131	126	125	167	163	162	229	219	224
04/10/86	NW	150	151	193	186	184	NA	NA	NA	132	129	128	164	161	160	235	223	230
04/11/86	NW	150	151	193	187	184	NA	NA	NA	131	126	125	167	161	162	234	223	229
04/14/86	NW	150	151	193	187	184	NA	NA	NA	133	129	128	166	162	161	234	223	229
04/15/86	NW	152	155	193	186	183	146	141	139	125	120	119	179	175	175	NA	NA	NA
04/16/86	NW	153	156	193	186	183	151	147	144	133	128	126	178	174	173	NA	NA	NA
04/17/86	NW	150	151	193	187	184	215	208	204	142	138	138	NA	NA	NA	205	199	201
04/18/86	NW	150	152	194	187	184	213	207	203	142	137	135	NA	NA	NA	239	232	236
04/21/86	NW	148	149	190	183	181	211	203	200	NA	NA	NA	NA	NA	NA	235	229	232
04/22/86	NW	150	151	190	183	180	211	203	201	NA	NA	NA	NA	NA	NA	235	227	231
04/23/86	NW	150	151	190	182	180	210	204	201	NA	NA	NA	129	122	122	235	228	231
04/24/86	NW	151	153	189	182	180	213	207	204	NA	NA	NA	173	170	169	236	228	232
04/25/86	NW	151	154	190	182	180	207	201	199	NA	NA	NA	172	169	169	235	229	232
04/28/86	NW	151	154	190	183	181	207	201	199	127	121	120	172	170	169	235	229	231
04/29/86	NW	151	153	189	183	181	208	201	199	133	129	126	172	170	169	235	228	232
05/01/86	NW	151	153	190	183	181	207	201	199	134	130	127	173	170	169	236	229	232
05/02/86	NW	149	151	NA	NA	NA	209	202	200	125	120	117	173	170	169	235	228	232
05/05/86	NW	150	151	NA	NA	NA	207	201	199	127	121	119	173	170	169	234	226	231
05/06/86	NW	147	150	135	126	126	208	201	199	132	127	124	173	170	169	233	227	231
05/07/86	NW	150	151	196	187	186	NA	NA	NA	136	130	128	173	169	169	233	227	231
05/08/86	NW	150	152	196	187	186	176	169	168	135	130	127	173	169	169	234	227	231
05/09/86	NW	150	152	196	187	186	198	186	185	137	131	129	173	170	169	234	227	231
05/12/86	NW	151	154	196	187	186	211	204	201	138	133	130	173	170	169	233	227	231
05/13/86	NW	148	151	196	187	186	212	204	203	130	126	123	173	170	169	NA	NA	NA
05/14/86	NW	150	152	196	187	186	211	204	202	132	127	124	173	170	169	NA	NA	NA
05/15/86	NW	149	151	196	187	186	211	203	202	132	127	123	173	170	169	NA	NA	NA
05/16/86	NW	149	151	196	187	186	211	204	201	132	128	125	173	169	169	NA	NA	NA
05/19/86	NW	156	160	197	188	187	211	204	203	136	131	129	173	170	169	NA	NA	NA
05/20/86	NA	NA	NA	196	187	186	211	204	202	131	127	123	172	169	169	NA	NA	NA
05/21/86	NA	NA	NA	195	186	186	210	203	201	132	127	124	172	169	168	NA	NA	NA
05/23/86	NA	NA	NA	196	187	186	210	204	202	133	129	127	173	170	169	232	225	231
05/27/86	NA	NA	NA	196	188	187	210	204	203	138	132	130	173	170	169	234	226	232
05/28/86	NA	NA	NA	196	187	186	211	205	203	136	131	129	173	170	169	234	226	231
05/29/86	NA	NA	NA	196	188	187	211	205	203	138	132	130	173	169	169	233	226	231
05/30/86	NA	NA	NA	196	188	187	211	205	203	139	133	131	172	170	169	233	226	232
06/02/86	NA	NA	NA	195	187	186	210	204	203	140	134	131	173	170	169	232	226	231
06/03/86	NA	NA	NA	196	187	186	211	205	204	137	130	129	172	170	169	NA	NA	NA
06/05/86	NA	NA	NA	196	188	187	NA	NA	NA	138	132	129	172	169	168	NA	NA	NA
06/06/86	NA	NA	NA	195	187	186	172	167	162	139	133	130	173	169	169	224	217	221
06/09/86	NA	NA	NA	195	187	186	200	190	186	133	129	127	172	169	168	223	217	221
06/10/86	NA	NA	NA	196	188	186	201	193	189	136	130	129	173	169	168	223	217	221
06/11/86	NA	NA	NA	196	187	187	209	199	194	136	131	129	172	169	169	230	220	226
06/12/86	NA	NA	NA	196	188	188	206	199	194	135	130	128	172	169	169	225	219	222
06/13/86	NA	NA	NA	195	188	187	206	199	194	137	131	129	172	169	168	226	219	222
06/16/86	NA	NA	NA	195	188	188	204	199	194	138	133	131	172	169	169	226	219	222
06/17/86	NA	NA	NA	NA	NA	NA	205	199	193	133	129	126	NA	NA	NA	NA	NA	NA
06/18/86	NA	NA	NA	NA	NA	NA	204	197	192	123	118	115	NA	NA	NA	NA	NA	NA
06/19/86	NA	NA	NA	NA	NA	NA	207	198	193	123	119	115	NA	NA	NA	NA	NA	NA
06/20/86	NA	NA	NA	NA	NA	NA	206	199	193	126	120	118	NA	NA	NA	NA	NA	NA
06/23/86	NA	NA	NA	NA	NA	NA	205	199	194	126	120	118	NA	NA	NA	NA	NA	NA
06/24/86	NA	NA	NA	194	180	182	207	199	194	126	121	119	168	165	162	235	227	231
06/25/86	NA	NA	NA	193	184	184	207	199	196	128	123	121	178	174	172	235	227	232
06/26/86	NA	NA	NA	193	185	186	206	200	195	133	129	128	177	173	171	235	228	231

TABLE D.1. Continued

Date	Oven 7(150°C)			Oven 8(190°C)			Oven 9(210°C)			Oven 10(135°C)			Oven 11(170°C)			Oven 12(230°C)		
	Top	Mid	Bot	Top	Mid	Bot	Top	Mid	Bot	Top	Mid	Bot	Top	Mid	Bot	Top	Mid	Bot
06/27/86	NA	NA	NA	193	185	186	206	199	195	134	129	128	177	173	171	235	228	232
07/02/86	NA	NA	NA	193	186	186	206	200	197	132	129	127	177	173	171	237	228	233
07/09/86	NA	NA	NA	193	183	184	207	200	197	121	116	112	177	172	171	NA	NA	NA
07/10/86	NA	NA	NA	194	186	187	207	200	196	131	127	124	176	172	171	NA	NA	NA
07/11/86	NA	NA	NA	193	186	186	206	200	197	132	128	126	176	172	171	234	222	230
07/14/86	NA	NA	NA	193	186	186	206	200	197	131	126	123	176	172	171	235	223	230
07/15/86	NA	NA	NA	192	185	186	205	200	197	131	126	124	176	172	170	233	223	229
07/18/86	NA	NA	NA	193	186	187	206	200	197	131	126	124	176	172	170	234	223	230
07/21/86	NA	NA	NA	193	186	187	NA	NA	NA	133	129	128	176	172	170	233	224	229
07/23/86	NA	NA	NA	194	186	187	NA	NA	NA	136	131	130	177	173	171	233	225	230
07/24/86	NA	NA	NA	193	186	187	196	189	186	139	133	131	176	172	171	233	224	229
07/28/86	151	152	158	194	185	186	219	213	210	128	123	120	176	173	171	NA	NA	NA
07/29/86	146	147	152	193	185	186	217	211	208	126	120	119	177	172	171	NA	NA	NA
07/30/86	143	144	149	193	185	186	215	209	206	129	123	121	176	172	171	225	218	222
07/31/86	146	146	151	193	185	187	214	209	204	129	123	121	177	172	171	234	225	231
08/04/86	148	148	153	193	186	187	215	210	207	137	132	130	177	173	171	231	224	229
08/05/86	147	148	152	192	186	187	215	210	208	138	132	130	177	172	171	230	223	229
08/07/86	146	147	152	193	186	187	219	212	209	139	132	130	176	173	171	230	223	229
08/08/86	143	145	150	193	185	186	212	207	203	130	125	121	177	173	172	231	222	229
08/11/86	147	147	152	193	185	186	213	208	204	128	123	120	176	172	171	231	222	229
08/13/86	144	145	150	NA	NA	NA	213	208	204	129	123	121	176	172	171	231	222	229
08/14/86	145	147	151	NA	NA	NA	216	210	207	129	124	121	176	172	171	231	222	229
08/20/86	145	146	151	NA	NA	NA	217	211	209	130	126	122	176	172	171	230	222	229
08/21/86	146	147	151	NA	NA	NA	214	209	206	129	124	121	177	172	171	230	222	229
08/22/86	142	144	149	190	182	181	211	206	202	123	119	117	NA	NA	NA	NA	NA	NA
08/25/86	140	140	146	194	187	186	209	203	200	132	129	126	NA	NA	NA	232	220	227
08/26/86	143	144	150	194	187	185	212	207	202	132	129	127	NA	NA	NA	236	229	232
08/28/86	146	147	152	194	188	186	214	209	205	138	132	130	179	175	173	237	229	232
08/29/86	142	142	148	194	186	184	NA	NA	NA	NA	NA	NA	178	175	172	237	229	232
09/02/86	142	141	148	193	185	183	NA	NA	NA	NA	NA	NA	178	174	171	237	228	232
09/03/86	143	143	149	193	187	185	129	117	118	104	98	99	178	175	172	236	228	232
09/04/86	142	143	149	193	186	185	194	189	188	133	127	124	179	174	172	236	229	232
09/08/86	NW	147	151	193	187	185	214	207	206	134	129	128	179	175	173	236	229	232
09/09/86	145	146	150	193	186	185	215	208	206	132	130	129	179	176	174	235	230	231
09/10/86	145	147	151	193	187	185	213	207	206	135	130	129	179	175	173	236	228	232
09/11/86	NW	144	149	193	186	185	213	205	205	133	128	127	178	174	172	236	228	232
09/12/86	143	145	150	193	186	185	214	207	206	132	129	127	178	174	172	235	228	232
09/15/86	NW	146	151	194	187	186	214	208	207	135	130	129	178	175	173	236	229	232
09/16/86	NW	146	151	193	187	186	213	207	208	134	130	129	178	175	172	236	228	232
09/17/86	143	145	150	194	187	186	214	207	208	135	130	129	179	175	173	236	228	232
09/18/86	145	146	151	194	187	186	214	207	207	133	129	128	178	175	172	236	228	232
09/22/86	145	146	151	193	187	187	214	208	208	133	129	128	179	175	173	236	229	232
09/23/86	143	145	150	194	188	187	216	209	209	134	129	129	179	176	174	236	229	232
09/26/86	146	148	151	193	186	185	215	209	209	135	129	129	179	176	173	NA	NA	NA
09/29/86	144	146	150	193	186	185	213	208	208	137	130	129	178	175	173	NA	NA	NA
10/03/86	144	146	150	193	187	187	214	209	208	133	129	128	178	175	172	NA	NA	NA
10/06/86	147	149	152	NA	NA	NA	218	211	211	138	131	131	181	178	176	241	231	237
10/08/86	147	148	153	NA	NA	NA	217	211	211	136	132	131	180	177	176	240	232	236
10/09/86	146	147	152	193	188	184	216	210	210	135	131	130	179	176	174	239	231	234
10/14/86	145	146	151	194	190	185	215	209	210	135	130	130	130	125	125	236	230	233
10/15/86	146	147	151	194	189	186	215	209	209	136	130	130	179	176	174	239	230	234
10/16/86	146	147	152	194	189	186	216	208	209	136	130	130	178	177	175	240	232	235
10/17/86	146	147	152	195	189	186	216	209	209	134	130	129	179	176	174	238	230	234
10/20/86	146	147	151	195	189	186	215	209	209	135	130	130	179	176	174	239	230	234
10/21/86	146	147	151	195	189	187	215	209	209	136	131	130	179	176	174	239	231	234
10/22/86	146	147	151	195	189	187	215	209	209	136	131	130	179	176	174	239	231	234
10/23/86	145	146	151	195	189	187	215	209	210	134	130	129	179	176	174	239	231	235
10/24/86	142	144	149	195	189	187	NA	NA	NA	134	130	129	NA	NA	NA	239	230	233
10/27/86	150	151	157	194	189	187	205	200	199	138	132	132	175	172	171	239	231	235
10/28/86	146	149	153	194	189	186	216	210	209	134	130	129	171	169	168	238	230	233
10/29/86	NA	NA	NA	195	189	187	216	210	209	135	131	130	171	169	168	239	230	233
10/30/86	NA	NA	NA	195	189	187	216	210	209	135	130	129	171	169	168	239	231	233

TABLE D.1. Continued

Date	Oven 7(150°C)			Oven 8(190°C)			Oven 9(210°C)			Oven 10(135°C)			Oven 11(170°C)			Oven 12(230°C)		
	Top	Mid	Bot	Top	Mid	Bot	Top	Mid	Bot	Top	Mid	Bot	Top	Mid	Bot	Top	Mid	Bot
10/31/86	146	145	147	194	189	187	216	210	209	135	130	130	171	169	168	239	230	233
11/03/86	150	149	151	194	189	187	216	210	209	135	131	130	171	169	168	239	230	233
11/04/86	151	152	153	194	189	186	217	211	210	135	129	128	172	169	168	NA	NA	NA
11/05/86	151	152	153	195	189	187	218	210	209	135	130	129	172	169	168	NA	NA	NA
11/06/86	151	152	154	195	189	187	217	211	210	135	131	130	172	169	169	NA	NA	NA
11/07/86	151	152	153	195	189	188	217	210	209	135	130	130	172	169	168	236	228	231
11/10/86	151	152	154	194	189	187	215	209	209	137	131	131	172	169	168	236	228	231
11/13/86	151	152	153	194	189	186	216	210	209	135	131	130	171	168	167	236	228	231
11/14/86	151	151	153	194	189	186	217	211	210	135	130	129	173	170	169	237	228	231
11/18/86	151	152	154	193	189	186	215	210	209	137	131	130	171	169	169	236	228	231
11/19/86	151	152	153	NA	NA	NA	215	209	209	136	131	130	171	169	168	236	228	231
11/20/86	150	151	153	NA	NA	NA	216	210	209	134	129	129	181	178	176	238	227	231
11/21/86	151	152	153	NA	NA	NA	215	209	209	138	131	130	172	169	168	236	227	231
11/24/86	151	152	154	NA	NA	NA	217	211	210	136	131	130	183	181	180	236	228	232
12/01/86	150	148	150	191	183	180	NA	NA	NA	138	131	130	170	167	166	236	227	231
12/02/86	151	151	153	191	183	179	NA	NA	NA	137	131	130	172	168	168	236	227	231
12/04/86	151	151	153	191	183	178	213	207	203	NA	NA	NA	171	169	167	NA	NA	NA
12/05/86	151	152	155	191	183	179	213	208	204	NA	NA	NA	173	170	169	NA	NA	NA
12/08/86	151	152	154	191	182	179	213	209	205	NA	NA	NA	171	169	168	NA	NA	NA
12/09/86	151	151	154	191	182	179	213	209	205	NA	NA	NA	173	170	169	NA	NA	NA
12/10/86	151	152	154	191	183	179	213	208	205	135	131	129	172	169	169	236	227	231
12/11/86	151	151	154	191	183	179	213	209	205	133	129	126	172	170	169	236	226	231
12/12/86	151	152	155	191	184	180	214	209	205	138	131	129	173	170	169	236	226	231
12/15/86	151	151	153	191	184	180	214	209	205	136	131	129	170	168	167	236	227	231
12/16/86	151	151	153	191	183	180	213	209	205	137	131	129	170	168	167	237	227	232
12/17/86	151	152	154	192	184	180	213	209	205	139	132	130	171	169	168	235	227	231
12/18/86	151	152	154	191	183	179	213	209	205	137	131	129	172	169	168	235	226	231
12/19/86	150	149	151	191	183	179	NA	NA	NA	136	131	129	170	168	166	236	226	231
12/22/86	150	149	151	191	183	180	NA	NA	NA	138	131	129	170	167	165	235	226	231
12/23/86	150	149	151	191	184	180	NA	NA	NA	138	132	130	171	168	166	235	227	231
01/05/87	151	150	154	191	184	180	202	196	191	137	131	129	171	168	167	236	227	231
01/07/87	151	150	153	NA	NA	NA	216	209	204	137	131	129	171	168	166	236	226	231
01/08/87	151	151	154	NA	NA	NA	216	209	203	139	131	129	171	168	167	237	226	231
01/09/87	150	151	153	NA	NA	NA	214	207	203	135	129	127	170	168	166	236	226	231
01/15/87	151	151	155	197	188	183	217	209	205	137	130	128	170	168	166	NA	NA	NA
01/16/87	151	151	155	197	188	183	217	209	205	137	130	128	172	169	168	NA	NA	NA
01/20/87	151	150	152	196	189	185	215	207	202	137	131	129	NA	NA	NA	232	224	227
01/21/87	NW	150	152	197	189	185	215	208	203	135	130	129	NA	NA	NA	235	225	229
01/23/87	NW	149	151	197	189	185	215	208	203	135	130	129	NA	NA	NA	235	225	229
01/28/87	150	151	155	196	189	184	215	208	203	137	131	129	NA	NA	NA	235	225	229
01/30/87	150	151	153	196	189	185	215	208	204	138	131	129	175	171	171	235	226	230
02/04/87	151	152	155	197	189	185	216	209	205	138	131	129	176	172	171	237	227	231
02/05/87	NA	NA	NA	197	190	185	NA	NA	NA	137	132	129	177	172	171	238	227	231
02/09/87	NA	NA	NA	196	189	184	NA	NA	NA	136	131	129	175	171	170	237	227	230
02/11/87	NA	NA	NA	196	189	185	NA	NA	NA	136	131	129	175	171	170	235	226	230
02/13/87	NA	NA	NA	197	189	185	218	209	204	137	131	129	176	172	171	235	226	230
02/17/87	149	149	152	197	189	186	219	210	206	139	133	131	177	173	172	236	227	230
02/20/87	149	149	152	197	189	186	219	210	205	140	132	131	177	173	172	236	227	230
03/02/87	149	149	154	197	190	188	219	211	208	138	133	132	181	179	178	237	228	231
03/05/87	148	149	152	198	190	188	220	212	208	NA	NA	NA	182	179	178	238	228	231
03/10/87	145	147	150	197	189	186	218	210	205	NA	NA	NA	176	172	171	237	227	231
03/11/87	NW	146	150	197	189	185	218	210	207	NA	NA	NA	176	172	171	237	227	230
03/13/87	145	146	150	196	190	186	219	210	207	NA	NA	NA	176	172	171	235	226	230
03/16/87	145	146	150	196	189	186	219	210	206	NA	NA	NA	176	172	171	235	226	229
03/19/87	NW	143	148	196	189	185	218	210	206	NA	NA	NA	175	172	171	236	227	230
03/23/87	NW	147	151	196	189	185	219	210	208	NA	NA	NA	176	172	172	236	227	230
03/30/87	NW	146	151	196	189	185	219	210	208	NA	NA	NA	176	172	171	237	227	230
04/01/87	NW	147	151	196	189	186	219	211	209	NA	NA	NA	178	174	173	235	227	230
04/06/87	146	146	151	196	189	185	219	210	207	NA	NA	NA	177	173	173	235	226	230
04/14/87	142	142	147	197	190	187	219	211	208	139	133	131	177	173	171	235	228	230
04/17/87	NW	140	143	196	189	186	NA	NA	NA	138	132	130	176	172	170	235	227	230
04/20/87	NW	137	141	197	189	186	NA	NA	NA	137	132	129	175	172	170	235	227	230

TABLE D.1. Continued

Date	Oven 7(150°C)			Oven 8(190°C)			Oven 9(210°C)			Oven 10(135°C)			Oven 11(170°C)			Oven 12(230°C)		
	Top	Mid	Bot	Top	Mid	Bot	Top	Mid	Bot	Top	Mid	Bot	Top	Mid	Bot	Top	Mid	Bot
04/23/87	NW	140	143	197	189	186	NA	NA	NA	137	132	130	176	172	171	235	226	230
04/28/87	139	138	142	197	189	186	NA	NA	NA	138	132	130	175	171	170	235	228	230
05/04/87	149	148	151	196	190	186	NA	NA	NA	138	133	130	175	171	170	235	227	230
05/08/87	NW	148	151	197	189	187	NA	NA	NA	137	132	130	175	172	170	236	228	231
05/11/87	149	148	151	196	189	186	NA	NA	NA	135	130	129	175	172	170	236	228	231
05/14/87	148	147	151	196	189	186	NA	NA	NA	138	132	130	175	172	170	236	228	230
05/18/87	151	150	154	195	189	186	NA	NA	NA	137	132	130	178	174	173	234	227	230
05/19/87	150	149	152	195	189	185	NA	NA	NA	135	131	129	177	173	172	235	226	230
05/22/87	152	152	156	195	189	185	217	211	205	136	131	129	180	176	174	235	228	231
06/02/87	153	153	157	194	188	185	217	210	208	137	132	130	175	171	170	235	227	230
06/08/87	158	160	163	NA	NA	NA	215	210	210	135	132	130	180	180	178	235	228	230
06/15/87	155	154	159	NA	NA	NA	218	210	209	135	130	129	180	178	176	235	228	NW
06/22/87	156	156	160	NA	NA	NA	216	209	209	134	129	127	180	177	175	234	226	230
06/26/87	152	152	156	NA	NA	NA	217	210	209	137	130	129	180	177	174	235	227	NW
07/13/87	NW	154	159	197	190	189	218	211	211	138	131	130	182	179	178	NA	NA	NA
07/14/87	NW	156	160	200	193	190	220	213	213	140	132	131	185	182	180	NA	NA	NA
07/22/87	163	163	CRB	CRB	CRB	CRB	CRB	CRB	CRB	CRB	CRB	CRB	CRB	CRB	CRB	NA	NA	NA
07/31/87	NW	148	151	192	186	183	213	208	209	139	132	130	170	168	166	NA	NA	NA
08/04/87	149	149	153	193	187	184	214	209	209	133	129	125	175	171	170	NA	NA	NA
08/05/87	150	150	154	192	187	184	NA	NA	NA	135	129	127	175	171	170	NA	NA	NA
08/11/87	141	140	144	193	188	186	NA	NA	NA	133	130	128	170	167	165	235	225	230
08/17/87	142	141	146	193	188	186	NA	NA	NA	136	131	129	170	167	165	233	225	229
08/24/87	NW	140	142	193	188	186	NA	NA	NA	137	132	130	170	167	165	235	225	230
08/28/87	141	139	143	193	188	186	NA	NA	NA	136	131	129	172	168	167	234	225	230
09/02/87	147	146	150	193	188	187	217	208	204	135	130	129	NA	NA	NA	233	225	230
09/09/87	145	144	149	193	188	186	218	208	205	134	129	128	178	172	171	234	225	230
09/10/87	147	146	150	193	188	186	218	207	205	134	129	128	179	178	175	233	225	230
09/14/87	147	147	151	193	188	186	218	208	204	136	131	130	179	177	175	234	225	230
09/17/87	153	154	159	193	188	186	218	208	206	136	132	130	179	177	174	233	224	229
09/23/87	153	153	157	193	188	186	218	209	207	137	131	129	179	177	175	233	225	229
09/28/87	153	153	158	193	189	186	218	209	207	137	131	129	179	176	175	233	225	229
10/02/87	154	155	159	193	188	186	218	209	207	134	130	129	179	176	174	233	225	229
10/07/87	157	157	162	193	188	186	218	209	207	135	131	129	179	177	174	233	225	229
10/12/87	153	153	159	192	188	187	218	209	208	136	132	130	179	177	175	233	225	229
10/14/87	153	153	158	193	188	185	218	208	206	135	130	129	178	177	175	233	226	230
10/16/87	NA	NA	NA	193	188	187	218	209	208	135	130	130	179	178	175	232	225	229
10/21/87	NA	NA	NA	193	188	186	217	208	207	135	131	129	179	176	174	233	224	229
10/23/87	NA	NA	NA	192	188	185	217	208	206	133	129	128	178	176	174	232	224	229
10/26/87	NA	NA	NA	192	187	185	218	208	207	132	129	127	178	175	174	232	224	229
10/27/87	NA	NA	NA	192	187	185	217	208	206	134	130	129	178	175	173	232	224	228
10/30/87	NA	NA	NA	192	188	185	218	208	206	133	129	128	178	175	173	232	225	229
11/02/87	NA	NA	NA	192	187	185	217	207	206	134	130	128	178	175	173	233	225	229
11/03/87	NA	NA	NA	192	186	184	216	207	205	132	128	127	177	174	173	232	224	229
11/06/87	151	153	155	192	187	184	217	207	205	133	128	126	177	175	174	233	225	228
11/10/87	150	152	155	192	186	184	216	207	206	133	129	128	177	175	173	233	224	NW
11/16/87	149	151	153	192	186	184	217	207	206	132	128	126	177	175	173	232	224	228
11/17/87	150	151	153	192	186	184	217	207	205	133	130	128	177	175	173	233	225	NW
11/18/87	150	152	155	192	187	185	217	208	206	135	130	129	178	176	174	232	224	NW
11/20/87	149	151	154	192	187	185	217	208	206	135	130	129	178	175	173	232	224	NW
12/02/87	150	151	153	192	187	185	217	208	205	133	128	127	178	176	174	232	225	229
12/03/87	151	152	155	192	187	185	217	207	205	134	129	128	178	175	174	233	225	230
12/07/87	146	150	152	192	187	185	217	207	205	134	130	128	178	175	174	232	224	230
12/08/87	152	154	156	192	187	185	217	208	205	NA	NA	NA	178	175	173	233	225	230
12/09/87	NW	153	156	192	187	184	217	207	205	NA	NA	NA	178	175	174	232	225	230
12/14/87	148	150	152	192	185	182	217	207	205	NA	NA	NA	178	175	173	233	225	230
12/15/87	NW	150	152	NA	NA	NA	217	207	205	139	132	131	178	175	173	232	224	229
12/18/87	147	150	151	NA	NA	NA	217	207	205	138	132	131	178	175	174	233	225	230
12/22/87	145	147	150	NA	NA	NA	217	206	205	138	132	130	178	175	173	233	224	230
12/23/87	147	149	151	NA	NA	NA	217	207	205	138	132	130	178	175	174	232	224	229
12/30/87	145	147	150	NA	NA	NA	216	207	205	137	131	129	178	175	173	233	224	230
01/04/88	146	149	150	NA	NA	NA	216	206	205	137	132	130	177	175	173	234	224	230
01/07/88	NW	133	129	NA	NA	NA	217	207	205	138	132	129	178	175	173	232	223	230

TABLE D.1. Continued

Date	Oven 7(150°C)			Oven 8(190°C)			Oven 9(210°C)			Oven 10(135°C)			Oven 11(170°C)			Oven 12(230°C)		
	Top	Mid	Bot	Top	Mid	Bot	Top	Mid	Bot	Top	Mid	Bot	Top	Mid	Bot	Top	Mid	Bot
01/08/88	155	140	137	NA	NA	NA	217	208	205	138	132	130	178	175	173	234	225	230
01/11/88	NW	141	137	NA	NA	NA	217	207	206	139	133	131	178	175	173	232	225	230
01/12/88	149	141	136	NA	NA	NA	217	208	206	145	140	138	178	176	174	232	225	229
01/13/88	152	142	137	NA	NA	NA	217	207	206	143	139	137	178	175	173	233	225	230
01/15/88	152	142	137	NA	NA	NA	217	207	205	137	132	130	177	175	173	232	224	229
01/18/88	150	141	136	NA	NA	NA	217	207	206	137	132	130	178	175	173	232	225	229
01/19/88	150	142	136	NA	NA	NA	217	207	206	137	132	130	178	175	173	233	225	230
01/20/88	149	140	135	NA	NA	NA	217	208	206	137	131	130	178	175	173	232	225	230
01/22/88	149	141	135	NA	NA	NA	217	208	206	135	130	129	178	175	173	233	225	230
01/25/88	151	141	137	162	150	149	218	208	207	136	131	129	178	175	173	NA	NA	NA
01/28/88	149	141	137	199	189	187	218	208	206	135	130	128	178	176	174	NA	NA	NA
01/29/88	152	142	138	199	189	187	217	208	207	137	132	130	178	175	174	NA	NA	NA
02/01/88	149	141	136	198	189	187	217	208	207	137	130	129	178	176	174	NA	NA	NA
02/02/88	149	141	135	198	189	186	217	207	206	137	131	129	178	175	174	NA	NA	NA
02/03/88	151	142	137	199	189	187	218	209	207	137	131	130	178	175	174	NA	NA	NA
02/05/88	151	142	138	198	190	188	218	208	206	138	132	130	178	176	174	NA	NA	NA
02/08/88	150	142	137	198	189	188	217	208	207	137	132	130	179	176	175	NA	NA	NA
02/09/88	152	142	138	199	190	187	218	209	207	136	131	129	178	176	175	NA	NA	NA
02/10/88	152	142	137	198	189	187	217	208	207	137	132	130	178	175	174	NA	NA	NA
02/16/88	149	141	136	198	189	187	218	208	206	135	131	129	178	175	174	NA	NA	NA
02/18/88	152	142	137	199	189	188	218	208	207	136	131	130	NA	NA	NA	234	224	229
02/19/88	152	141	136	199	190	188	218	208	207	137	132	130	NA	NA	NA	235	225	229
02/22/88	152	140	135	199	190	189	217	208	207	138	134	132	NA	NA	NA	235	225	228
02/23/88	152	141	136	198	191	189	218	208	207	136	132	130	NA	NA	NA	235	225	228
02/25/88	NW	140	134	198	190	189	218	208	208	138	133	132	NA	NA	NA	235	225	228
02/29/88	NW	141	135	199	190	189	218	208	207	138	133	132	NA	NA	NA	234	225	229
03/02/88	150	140	134	198	190	188	217	208	207	137	133	132	NA	NA	NA	234	224	228
03/04/88	150	140	134	198	190	189	217	208	207	139	135	133	NA	NA	NA	235	226	230
03/08/88	150	140	133	198	189	188	217	207	206	136	132	131	NA	NA	NA	235	225	230
03/09/88	149	140	134	198	190	189	217	207	206	135	132	130	NA	NA	NA	235	225	229
03/10/88	151	140	135	198	190	189	217	207	206	135	132	130	NA	NA	NA	235	225	229
03/11/88	148	140	133	198	190	189	218	207	206	136	132	130	NA	NA	NA	235	225	230
03/14/88	150	140	133	198	190	189	217	208	207	136	132	131	NA	NA	NA	234	225	229
03/15/88	152	140	135	198	190	188	217	208	207	137	132	131	NA	NA	NA	235	225	230
03/16/88	148	139	133	198	190	188	217	206	206	136	132	130	NA	NA	NA	235	225	230
03/17/88	150	140	134	198	189	188	218	208	207	136	132	130	NA	NA	NA	235	225	229
03/21/88	149	140	133	198	190	189	NA	NA	NA	138	134	133	NA	NA	NA	235	225	230
03/22/88	150	140	134	198	190	189	NA	NA	NA	146	142	140	NA	NA	NA	235	225	229
03/23/88	149	140	133	198	190	189	NA	NA	NA	147	139	138	NA	NA	NA	235	226	230
03/24/88	149	139	133	198	190	189	NA	NA	NA	135	132	131	NA	NA	NA	235	226	229
03/28/88	NW	139	132	198	190	188	NA	NA	NA	136	132	131	NA	NA	NA	235	225	230
03/29/88	NW	140	134	198	190	189	NA	NA	NA	137	133	132	NA	NA	NA	235	225	230
03/30/88	149	139	133	198	189	188	NA	NA	NA	133	128	127	NA	NA	NA	234	225	229
03/31/88	152	140	134	198	189	188	NA	NA	NA	133	130	128	NA	NA	NA	235	225	229
04/01/88	NW	139	133	198	189	188	NA	NA	NA	133	129	127	NA	NA	NA	235	225	229
04/04/88	NW	139	133	198	190	188	NA	NA	NA	135	130	129	NA	NA	NA	235	225	229
04/06/88	152	141	135	199	190	189	NA	NA	NA	144	138	138	181	173	174	NA	NA	NA
04/07/88	152	140	135	198	190	189	215	206	205	133	128	127	177	169	170	NA	NA	NA
04/08/88	151	143	138	198	189	187	215	207	207	143	138	135	177	168	170	NA	NA	NA
04/11/88	150	143	138	198	188	187	215	206	206	137	132	130	178	169	172	NA	NA	NA
04/12/88	150	142	137	198	189	188	215	207	207	132	127	125	178	170	172	NA	NA	NA
04/13/88	152	143	138	198	189	187	215	208	208	133	128	127	178	169	171	NA	NA	NA
04/14/88	150	142	137	198	189	187	215	207	207	132	127	125	178	170	172	NA	NA	NA
04/15/88	149	142	137	198	189	187	215	207	207	132	128	125	178	170	172	NA	NA	NA
04/18/88	149	142	137	197	189	187	216	207	208	137	132	129	178	170	171	NA	NA	NA
04/19/88	149	142	137	198	189	187	216	207	208	142	134	133	178	169	171	NA	NA	NA
04/20/88	151	142	138	198	189	188	215	207	208	138	134	133	178	169	172	NA	NA	NA
04/21/88	151	142	138	198	189	188	216	208	208	140	134	133	177	169	170	NA	NA	NA
04/26/88	NW	143	138	198	189	187	217	208	209	142	135	133	178	169	171	NA	NA	NA
04/27/88	NW	142	138	198	189	188	215	208	208	142	135	133	178	169	172	NA	NA	NA
04/28/88	NW	142	137	198	189	187	215	208	208	138	133	132	178	170	172	NA	NA	NA
05/02/88	NW	142	137	197	188	187	214	207	208	136	132	129	178	169	171	NA	NA	NA

TABLE D.1. Continued

Date	Oven 7(150°C)			Oven 8(190°C)			Oven 9(210°C)			Oven 10(135°C)			Oven 11(170°C)			Oven 12(230°C)		
	Top	Mid	Bot	Top	Mid	Bot	Top	Mid	Bot	Top	Mid	Bot	Top	Mid	Bot	Top	Mid	Bot
05/03/88	148	142	136	198	189	187	215	207	208	134	131	128	178	169	171	NA	NA	NA
05/06/88	152	143	138	198	189	187	215	207	208	137	133	132	178	170	172	NA	NA	NA
05/09/88	149	143	137	198	189	187	215	208	209	134	135	132	178	169	171	NA	NA	NA
05/11/88	150	143	138	199	190	189	215	208	209	143	138	137	178	169	172	237	227	232
05/12/88	152	143	139	198	190	189	216	208	209	141	137	135	178	169	171	235	225	230
05/13/88	151	143	138	198	190	189	215	208	209	141	137	134	178	169	172	235	225	229
05/16/88	153	143	138	198	190	188	215	207	208	141	136	135	178	169	171	235	225	230
05/17/88	152	143	138	198	189	188	215	206	207	140	136	134	178	168	172	235	225	230
05/18/88	150	143	137	198	190	188	215	207	208	170	164	163	178	168	171	233	224	228
05/19/88	152	143	138	198	190	188	215	207	208	139	135	133	178	169	172	234	224	229
05/24/88	152	143	139	198	190	188	215	208	209	142	137	135	178	170	172	235	225	230
05/25/88	150	143	138	199	190	189	215	208	209	150	145	143	178	169	171	233	224	229
05/26/88	152	143	138	198	190	188	215	208	208	140	135	133	178	169	171	235	225	229
05/31/88	151	143	138	198	190	189	NW	207	208	170	165	163	178	169	172	235	225	229
06/02/88	NW	143	137	198	190	189	NW	207	208	168	162	160	178	169	172	235	225	229
06/03/88	NW	143	139	198	190	189	215	208	208	133	128	127	178	169	172	235	225	230
06/06/88	NW	143	139	198	190	188	215	207	208	137	132	131	178	169	172	233	224	228
06/09/88	NW	143	138	198	190	188	215	208	209	137	133	132	178	169	172	234	225	229
06/13/88	NW	143	138	198	190	189	215	208	209	135	132	130	178	170	172	235	225	230
06/15/88	NW	145	140	198	190	189	215	208	209	NA	NA	NA	178	169	172	233	225	229
06/16/88	NW	145	141	198	191	189	215	208	209	NA	NA	NA	178	169	172	235	225	230
06/17/88	NW	143	139	198	190	188	215	208	209	NA	NA	NA	178	169	171	234	225	229
06/20/88	NW	145	141	198	190	189	215	208	209	NA	NA	NA	178	169	171	233	225	229
06/22/88	NW	144	140	198	190	189	215	208	209	NA	NA	NA	178	168	171	235	225	230
06/24/88	NW	145	141	198	190	189	215	208	209	NA	NA	NA	178	169	171	235	225	230
06/29/88	NW	144	140	198	190	189	215	208	209	NA	NA	NA	178	169	171	235	225	230
06/30/88	NW	143	140	198	190	188	216	208	210	NA	NA	NA	179	169	172	233	225	230
07/05/88	NW	142	138	198	189	187	215	208	209	NA	NA	NA	178	168	171	236	225	230
07/06/88	NW	143	138	198	189	188	215	208	209	NA	NA	NA	178	169	171	233	224	229
07/07/88	NW	142	138	197	189	187	214	207	208	NA	NA	NA	178	169	171	234	225	229
07/12/88	NW	142	137	198	189	187	214	207	208	NA	NA	NA	177	168	170	235	225	229
07/13/88	NW	142	138	198	189	188	214	208	209	NA	NA	NA	178	169	171	233	224	228
07/15/88	150	142	137	198	189	188	214	207	208	NA	NA	NA	178	169	172	NA	NA	NA
07/20/88	148	142	137	198	189	188	214	207	208	140	133	130	178	169	171	NA	NA	NA
07/22/88	152	143	138	198	189	188	214	208	209	141	134	132	178	169	172	NA	NA	NA
07/26/88	149	143	137	197	189	188	215	208	208	158	143	143	178	169	172	NA	NA	NA
07/27/88	150	143	138	198	189	188	215	207	208	153	146	143	177	168	172	NA	NA	NA
07/28/88	152	143	138	197	189	187	215	207	208	140	133	131	177	168	171	NA	NA	NA
08/01/88	151	143	137	197	189	187	214	207	208	148	142	138	178	169	171	NA	NA	NA
08/02/88	148	142	137	197	188	187	214	208	209	138	133	130	178	169	171	NA	NA	NA
08/04/88	NA	NA	NA	198	190	188	214	207	208	137	132	129	177	168	170	233	223	228
08/09/88	NA	NA	NA	198	190	189	214	207	208	137	133	130	178	168	170	233	223	228
08/11/88	NA	NA	NA	198	190	189	214	207	208	139	133	132	178	168	170	234	224	228
08/15/88	153	140	132	198	189	189	213	206	208	138	133	132	178	168	170	233	223	227
08/18/88	153	143	137	197	190	189	214	207	208	146	141	139	177	168	170	233	223	228
08/22/88	154	143	137	197	190	188	214	207	208	143	138	136	177	168	170	233	223	228
08/23/88	154	143	137	197	189	188	214	207	208	142	137	134	177	168	170	233	223	227
08/24/88	153	143	136	198	189	188	214	207	208	133	129	128	177	168	170	233	224	227
08/25/88	154	143	137	198	190	189	214	207	209	134	130	129	177	168	170	233	224	228
08/30/88	154	145	139	197	190	188	214	207	209	142	137	135	177	168	170	233	224	228
09/01/88	153	145	139	197	189	188	214	207	208	138	133	132	177	168	170	233	223	227
09/02/88	NW	145	139	198	190	189	215	208	209	130	126	124	177	168	170	233	224	228
09/06/88	NW	144	139	197	189	188	213	208	209	135	130	129	177	168	169	233	223	227
09/07/88	NW	145	139	197	190	188	214	208	209	133	129	127	177	168	170	233	224	228
09/08/88	NW	145	140	198	190	188	215	208	210	131	127	125	178	169	171	233	223	228
09/09/88	NW	145	140	197	190	189	215	208	210	163	150	151	178	169	171	233	223	228
09/12/88	NW	145	140	197	190	188	214	207	209	145	142	139	177	168	170	233	224	228
09/14/88	NW	145	140	198	190	189	215	208	210	133	129	128	178	169	171	233	224	228
09/16/88	NW	145	140	197	189	188	213	207	208	142	137	135	177	168	169	232	223	227
09/19/88	NW	145	140	198	190	188	215	208	209	145	141	138	177	168	170	233	224	228
09/21/88	NW	145	140	197	190	188	215	208	210	133	128	127	178	168	171	234	225	229
09/23/88	153	145	140	197	190	188	215	209	210	132	128	127	177	168	170	233	224	228

TABLE D.1. Continued

Date	Oven 7(150°C)			Oven 8(190°C)			Oven 9(210°C)			Oven 10(135°C)			Oven 11(170°C)			Oven 12(230°C)		
	Top	Mid	Bot	Top	Mid	Bot	Top	Mid	Bot	Top	Mid	Bot	Top	Mid	Bot	Top	Mid	Bot
09/28/88	NW	145	140	197	190	189	215	208	209	138	134	133	178	168	171	233	223	228
09/30/88	NW	145	140	198	189	188	214	208	209	133	129	127	177	168	170	233	224	228
10/04/88	155	145	140	197	190	188	215	208	209	137	132	132	177	168	170	233	223	228
10/10/88	154	145	139	197	190	189	214	208	209	133	129	128	177	168	170	233	223	227
10/11/88	153	145	140	197	190	188	215	208	209	136	132	130	177	168	170	233	225	228
10/13/88	154	145	140	198	190	188	214	208	210	133	129	128	177	168	170	233	223	227
10/18/88	NW	144	140	197	189	188	214	208	209	140	135	133	177	168	169	233	223	227
10/20/88	154	145	140	196	190	188	213	207	209	142	138	137	177	168	170	233	224	228
10/24/88	NW	145	140	197	190	189	215	208	210	133	129	127	178	169	170	233	224	228
10/25/88	NW	145	140	198	190	189	214	208	209	142	137	135	177	168	170	234	224	228
10/31/88	154	145	140	198	190	189	215	209	210	129	125	124	178	169	170	233	224	228
11/01/88	154	146	140	198	190	189	215	209	210	135	133	131	178	169	172	234	225	229
11/02/88	NW	145	140	198	191	189	215	209	210	142	139	137	178	169	171	NA	NA	NA
11/07/88	NW	145	140	197	190	188	214	208	209	161	150	151	177	168	169	NA	NA	NA
11/09/88	NW	145	139	197	190	189	214	208	209	157	152	151	178	168	170	NA	NA	NA
11/11/88	NW	145	140	197	190	189	215	208	210	132	128	127	178	168	171	NA	NA	NA
11/14/88	153	145	140	197	190	188	214	208	209	135	132	130	178	169	170	NA	NA	NA
11/15/88	NW	144	140	197	189	188	214	208	209	136	132	131	177	168	170	NA	NA	NA
11/17/88	NW	145	140	197	190	188	214	208	210	141	138	137	178	168	170	NA	NA	NA
11/18/88	154	143	138	197	190	189	NA	NA	NA	132	130	129	177	167	170	233	225	228
11/22/88	155	143	137	198	190	189	NA	NA	NA	140	138	136	177	168	170	233	226	227
11/28/88	155	144	138	198	190	189	NA	NA	NA	138	135	134	176	168	170	234	225	228
11/30/88	154	143	137	197	189	188	NA	NA	NA	147	144	143	177	168	170	233	225	227
12/01/88	153	143	138	197	190	188	NA	NA	NA	142	140	139	176	166	169	232	225	227
12/07/88	NW	143	138	198	189	188	NA	NA	NA	137	133	133	177	167	169	233	225	227
12/08/88	NW	143	137	197	190	189	NA	NA	NA	148	145	143	176	168	170	233	225	228
12/09/88	NW	143	137	198	190	188	NA	NA	NA	139	136	135	177	168	170	232	226	228
12/13/88	NW	143	138	197	190	189	NA	NA	NA	132	128	128	177	167	170	233	225	227
12/14/88	158	143	137	197	189	188	NA	NA	NA	136	133	132	177	167	170	233	226	228
12/16/88	NW	143	138	197	190	188	NA	NA	NA	134	132	132	176	167	169	233	225	227
12/19/88	NW	143	137	197	190	188	NA	NA	NA	140	137	137	177	168	171	233	225	228
12/21/88	NW	143	138	197	190	189	NA	NA	NA	147	145	142	176	167	170	233	226	227
12/22/88	NW	143	138	197	190	188	NA	NA	NA	138	135	135	177	168	170	233	225	227
12/28/88	NW	142	138	197	189	188	NA	NA	NA	135	132	132	177	169	171	233	225	227
12/30/88	NW	143	138	198	190	189	NA	NA	NA	152	150	148	177	168	170	232	225	227
01/03/89	NW	143	138	197	189	188	NA	NA	NA	132	128	128	176	168	170	233	226	228
01/04/89	NW	143	137	197	190	188	NA	NA	NA	133	130	130	176	167	170	233	225	227
01/06/89	NW	143	137	197	189	188	NA	NA	NA	141	138	137	176	167	169	233	225	227
01/09/89	NW	142	137	197	190	189	NA	NA	NA	132	128	128	177	167	170	232	225	227
01/10/89	153	143	137	197	190	188	NA	NA	NA	156	152	151	176	167	170	233	225	227
01/11/89	154	144	139	197	189	188	213	206	184	150	147	146	177	167	170	233	225	226
01/12/89	153	143	138	197	189	188	220	200	183	133	130	130	177	168	170	233	225	227
01/13/89	153	143	137	197	190	188	NA	NA	NA	133	129	128	177	169	171	233	225	227
01/16/89	153	143	137	197	190	189	NA	NA	NA	142	138	137	177	168	171	233	225	227
01/17/89	NW	145	140	197	188	187	NA	NA	NA	161	151	152	177	168	171	233	225	227
01/19/89	152	145	140	NA	NA	NA	NA	NA	NA	128	124	123	178	169	172	232	225	227
01/24/89	153	145	140	NA	NA	NA	NA	NA	NA	127	123	123	177	168	170	233	225	227
01/25/89	NW	145	140	NA	NA	NA	NA	NA	NA	128	125	124	176	168	170	233	225	227
01/31/89	153	146	141	NA	NA	NA	215	207	205	146	143	142	176	168	170	235	227	229
02/01/89	153	145	140	NA	NA	NA	215	207	205	132	128	128	178	169	172	233	225	227
02/02/89	153	145	140	190	187	183	215	207	205	133	131	130	178	169	172	233	225	227
02/06/89	153	145	140	194	186	185	215	207	205	129	127	127	177	168	170	233	225	227
02/07/89	153	146	140	193	186	184	216	208	205	127	124	124	177	168	170	233	225	228
02/08/89	153	145	140	193	185	184	216	208	205	160	152	152	177	169	171	233	225	227
02/09/89	153	145	140	193	189	185	216	208	205	130	127	126	177	169	171	233	225	227
02/10/89	153	145	140	192	189	185	216	207	205	153	150	148	178	169	171	233	225	227
02/13/89	154	146	140	192	184	188	215	206	205	160	151	152	177	167	170	232	225	227
02/16/89	153	145	140	NA	NA	NA	215	207	205	152	148	147	177	168	171	233	225	227
02/21/89	153	146	140	NA	NA	NA	215	207	205	148	145	143	177	168	170	233	225	227
02/22/89	154	146	141	NA	NA	NA	215	207	205	158	150	150	176	168	170	NA	NA	NA
02/23/89	154	146	141	193	184	183	215	208	205	137	133	132	176	168	170	NA	NA	NA
02/28/89	NW	145	140	NA	NA	NA	216	207	205	131	127	125	177	167	171	NA	NA	NA

TABLE D.1. Continued

Date	Oven 7(150°C)			Oven 8(190°C)			Oven 9(210°C)			Oven 10(135°C)			Oven 11(170°C)			Oven 12(230°C)		
	Top	Mid	Bot	Top	Mid	Bot	Top	Mid	Bot	Top	Mid	Bot	Top	Mid	Bot	Top	Mid	Bot
03/02/89	NW	146	142	NA	NA	NA	215	207	205	124	120	119	177	168	170	NA	NA	NA
03/03/89	154	146	140	197	187	183	215	208	205	142	138	136	177	167	170	NA	NA	NA
03/07/89	154	146	140	196	187	183	215	207	205	129	127	126	176	167	170	233	204	197
03/08/89	155	147	141	197	187	183	215	208	205	143	141	140	177	168	171	NA	NA	NA
03/09/89	NW	146	141	197	187	183	215	207	205	128	127	125	177	168	170	233	211	200
03/10/89	NW	146	142	197	188	184	216	208	205	142	140	138	177	168	170	NA	NA	NA
03/13/89	NW	145	141	197	188	184	215	207	205	142	140	139	177	168	170	NA	NA	NA
03/14/89	NW	146	141	197	188	183	215	207	206	140	137	136	177	168	170	232	207	195
03/16/89	153	144	138	197	188	185	215	207	205	147	142	141	NA	NA	NA	NA	NA	NA
03/20/89	153	144	138	197	188	185	216	207	205	138	136	135	NA	NA	NA	233	223	227
03/23/89	154	145	139	197	188	186	216	207	205	130	127	125	NA	NA	NA	232	223	226
03/27/89	NW	144	140	197	189	187	215	207	205	151	141	142	NA	NA	NA	233	223	227
03/29/89	NW	145	140	197	188	186	215	207	205	148	137	139	177	167	162	233	223	227
03/30/89	153	145	140	197	188	186	215	207	205	137	135	133	173	170	160	232	223	227
03/31/89	NW	138	133	197	188	186	215	207	205	150	142	143	173	165	163	233	223	227
04/03/89	NW	143	138	197	188	185	215	207	204	128	127	125	NA	NA	NA	232	223	227
04/05/89	NW	143	139	196	188	186	215	207	205	152	141	143	NA	NA	NA	233	223	227
04/07/89	153	145	139	197	189	187	215	207	204	148	143	143	NA	NA	NA	233	223	227
04/10/89	154	145	139	197	188	187	215	206	204	152	142	143	NA	NA	NA	233	223	227
04/13/89	153	143	138	197	188	186	215	207	205	145	140	139	NA	NA	NA	232	222	226
04/19/89	153	144	139	197	188	187	214	207	205	123	121	120	177	172	167	233	223	227
04/20/89	152	144	138	197	189	187	214	207	204	127	123	122	177	172	167	232	223	227
04/24/89	153	144	138	197	189	187	215	207	204	135	133	132	178	172	167	233	223	226
04/26/89	153	146	141	197	189	187	215	207	205	143	141	139	178	172	168	233	223	227
04/28/89	NW	145	141	197	189	187	215	207	204	153	148	147	177	172	167	233	223	226
05/01/89	NW	145	141	198	189	187	215	207	205	123	120	119	177	172	168	233	223	226
05/04/89	NW	146	141	198	190	187	215	208	206	145	143	141	177	172	168	233	223	227
05/05/89	NW	146	142	198	190	188	215	208	205	123	121	120	178	172	168	233	223	227
05/08/89	NW	145	141	198	190	187	215	207	205	149	146	143	178	172	168	233	223	227
05/09/89	154	146	142	197	189	187	214	207	204	128	126	125	177	172	168	233	223	227
05/12/89	NW	146	141	197	189	187	215	207	205	128	125	123	177	172	168	233	223	227
05/15/89	153	146	141	197	189	187	214	207	205	128	127	125	177	172	168	232	223	227
05/17/89	154	146	142	197	188	187	214	207	205	155	149	149	177	172	167	233	223	226
05/18/89	154	146	142	197	188	186	214	207	204	128	125	124	177	172	168	233	223	227
05/19/89	NW	146	142	197	189	187	214	207	205	138	137	134	177	172	167	233	223	226
05/26/89	NW	146	142	198	190	187	215	208	206	128	124	123	178	173	167	233	223	227
05/31/89	NW	146	141	197	188	187	215	207	205	143	142	139	177	172	168	232	223	227
06/02/89	NW	147	143	198	189	187	215	207	206	157	140	148	177	172	168	233	223	227
06/05/89	NW	145	141	197	188	187	214	207	205	123	122	120	177	172	167	233	223	227
06/07/89	NW	147	142	197	188	187	213	207	205	157	143	147	177	172	167	234	224	228
06/12/89	NW	147	142	197	189	187	214	207	205	158	143	148	177	172	167	233	223	227
06/15/89	NW	146	142	197	188	186	214	207	204	123	121	119	178	172	168	233	224	227
06/16/89	NW	146	142	197	188	186	214	206	204	133	130	128	177	172	167	232	223	227
06/19/89	NW	146	142	197	188	187	215	207	205	134	132	130	178	172	167	237	228	232
06/21/89	NW	147	142	196	187	185	214	207	205	140	137	133	177	172	167	NA	NA	NA
06/23/89	NW	146	141	196	187	185	214	207	205	157	145	146	177	172	167	NA	NA	NA
06/26/89	NW	146	142	197	188	185	215	208	206	153	146	145	178	172	168	NA	NA	NA
06/30/89	NW	146	142	197	188	186	215	208	206	158	147	149	177	173	168	NA	NA	NA
07/07/89	NW	145	142	196	187	185	214	207	205	125	123	120	178	172	168	NA	NA	NA
07/10/89	NW	146	142	197	188	185	214	207	205	153	148	145	177	172	168	NA	NA	NA
07/12/89	NW	146	141	196	187	185	214	207	205	128	126	124	178	172	168	NA	NA	NA
07/13/89	NW	146	141	197	188	186	215	208	205	158	144	146	178	173	168	NA	NA	NA
07/18/89	NW	146	141	197	188	186	215	207	205	134	133	129	178	172	168	NA	NA	NA
07/20/89	NW	147	143	197	188	186	215	207	205	159	146	147	177	172	168	233	223	228
07/21/89	153	146	141	197	189	187	214	207	204	121	118	117	177	172	167	233	224	228
07/25/89	NW	147	142	197	188	187	213	207	203	137	135	132	177	172	167	232	223	227
07/26/89	NW	147	143	197	189	187	213	207	205	123	122	120	177	173	168	233	223	227
07/28/89	NW	145	141	197	188	187	213	207	205	143	141	138	177	172	167	233	223	227
08/01/89	NW	145	141	197	188	187	213	207	205	139	136	133	177	172	167	232	223	227
08/03/89	NW	145	142	197	189	187	214	207	205	127	125	123	177	172	168	232	223	227
08/09/89	NW	145	141	197	189	187	214	207	205	NW	132	129	177	172	168	236	227	231
08/10/89	NW	145	141	197	189	187	213	207	205	NW	143	141	177	172	167	232	223	227

TABLE D.1. Continued

Date	Oven 7(150°C)			Oven 8(190°C)			Oven 9(210°C)			Oven 10(135°C)			Oven 11(170°C)			Oven 12(230°C)		
	Top	Mid	Bot	Top	Mid	Bot	Top	Mid	Bot	Top	Mid	Bot	Top	Mid	Bot	Top	Mid	Bot
08/11/89	NW	145	141	197	190	187	214	207	205	NW	123	122	177	172	168	233	223	227
08/15/89	NW	145	141	197	188	187	214	207	205	NW	126	124	178	172	167	233	223	227
08/18/89	NW	145	140	197	189	187	215	208	206	NW	118	116	177	173	168	232	223	227
08/25/89	NW	144	140	197	189	187	214	207	205	NW	132	129	178	173	168	233	224	228
08/29/89	NW	145	140	196	188	187	214	207	205	NW	127	125	177	172	167	232	223	227
09/05/89	NW	144	140	197	188	187	213	207	205	NW	120	118	177	172	167	NA	NA	NA
09/12/89	NW	144	141	196	187	185	213	206	203	NW	125	123	177	172	167	NA	NA	NA
09/20/89	NW	145	141	197	187	185	213	207	205	NW	126	123	177	172	167	NA	NA	NA
09/22/89	153	145	140	197	187	185	213	207	205	NW	128	126	177	172	167	NA	NA	NA
09/27/89	NW	144	140	197	187	184	213	207	205	NW	132	129	177	172	167	NA	NA	NA
09/28/89	NW	143	139	197	187	185	214	207	204	NW	119	116	178	172	167	233	222	226
10/04/89	153	144	137	197	188	186	NA	NA	NA	NW	127	125	177	171	167	233	222	227
10/10/89	153	145	139	197	188	187	NA	NA	NA	NW	148	148	177	172	167	233	223	227
10/13/89	153	145	140	198	188	187	212	203	203	NW	143	141	177	173	167	233	223	227
10/20/89	153	145	140	197	188	187	212	204	203	NW	143	140	178	173	167	233	223	227
10/23/89	NW	144	140	197	189	187	211	203	203	NW	138	137	177	172	167	233	223	227
10/24/89	NW	145	141	197	188	187	211	203	203	NW	129	127	177	172	167	232	223	227
10/27/89	NW	145	140	197	188	187	211	203	203	NW	130	127	177	172	167	233	223	227
10/30/89	NW	146	141	197	188	186	210	203	202	NW	143	140	177	172	167	232	223	227
10/31/89	NW	146	141	197	187	186	211	203	202	132	127	126	178	173	168	232	222	226
11/01/89	NW	147	142	197	188	187	211	204	203	135	132	130	178	173	168	232	223	227
11/06/89	NW	146	142	197	188	187	210	204	203	NW	138	136	178	173	169	232	223	226
11/13/89	NW	144	140	197	188	187	210	203	202	NW	129	129	177	172	167	232	223	227
11/17/89	NA	NA	NA	197	188	187	210	203	202	NW	134	132	177	172	167	232	222	226
11/27/89	NA	NA	NA	197	187	186	210	203	202	NW	143	140	178	173	167	232	223	227
11/30/89	NA	NA	NA	197	187	186	209	203	202	NW	148	148	177	172	167	232	223	227
12/01/89	NW	137	131	197	187	186	210	203	202	NW	132	130	177	172	167	232	223	226
12/04/89	NW	137	132	197	187	186	210	203	203	NW	127	126	177	172	167	232	222	226
12/05/89	NW	137	133	196	188	187	210	203	203	NW	131	130	177	171	167	232	223	226
12/12/89	NA	NA	NA	197	187	186	210	203	202	NW	124	123	178	172	167	231	222	226
12/14/89	NA	NA	NA	197	187	186	210	203	202	NW	130	127	177	172	167	232	222	226
12/18/89	NA	NA	NA	197	188	187	210	203	203	NW	130	129	180	173	169	232	223	227
12/20/89	NA	NA	NA	197	188	187	210	203	202	NW	129	127	178	172	168	232	223	227
12/28/89	153	143	137	196	188	187	211	204	203	NW	133	130	177	172	167	231	223	226
01/08/90	153	143	138	196	188	188	210	204	203	NW	140	137	177	172	167	232	223	227
01/10/90	153	143	138	196	188	187	211	204	204	NW	129	127	177	172	167	232	223	227
01/16/90	153	143	138	196	188	187	211	204	203	NW	127	124	177	173	167	232	223	227
01/18/90	153	143	138	196	188	187	210	203	203	NW	132	129	177	172	167	232	223	227
01/24/90	153	143	138	196	188	187	211	204	203	NW	132	129	178	173	167	232	223	227
01/26/90	153	143	138	196	188	187	210	203	203	NA	NA	NA	179	173	168	232	223	227
01/31/90	153	147	138	196	188	187	210	203	202	NA	NA	NA	178	173	167	233	223	227
02/02/90	153	143	138	196	188	187	210	204	203	NA	NA	NA	178	173	168	233	223	227
02/07/90	153	143	138	197	188	187	210	204	203	NA	NA	NA	177	172	167	232	223	227
02/14/90	153	143	138	196	187	186	211	204	203	NA	NA	NA	182	174	172	233	223	227
02/20/90	153	143	138	196	188	187	212	205	204	NA	NA	NA	178	173	167	232	223	227
02/27/90	153	143	138	197	188	187	212	205	204	NA	NA	NA	179	173	168	233	224	227
03/02/90	154	143	138	197	188	187	211	205	204	NA	NA	NA	178	172	168	232	223	227
03/06/90	153	143	138	197	188	187	212	205	204	NA	NA	NA	178	173	168	232	223	227
03/08/90	153	143	138	197	188	187	212	205	205	NW	135	133	178	172	168	233	223	227
03/13/90	153	143	138	197	188	188	212	205	204	NW	127	125	178	172	167	232	223	227
03/15/90	153	143	139	197	188	187	212	205	204	136	132	129	178	172	168	233	223	227
03/21/90	153	143	138	196	188	187	212	205	204	NW	131	128	179	173	169	233	223	228
03/22/90	153	143	138	197	188	187	211	204	203	NW	125	123	178	173	168	232	223	228
03/28/90	153	143	138	197	188	187	212	205	204	NW	129	127	177	172	167	233	223	227
03/30/90	153	143	138	197	189	188	212	205	204	NW	147	145	177	172	167	233	223	228
04/02/90	153	143	138	197	188	187	213	206	205	NW	120	119	178	173	168	233	224	229
04/05/90	153	143	138	196	188	187	212	205	204	NW	127	125	177	172	167	233	224	228
04/09/90	153	143	138	197	188	187	211	204	203	NW	129	128	177	172	167	233	223	228
04/10/90	153	143	138	197	188	187	212	204	203	NW	134	133	178	172	167	232	223	227
04/11/90	153	143	138	196	188	187	211	204	203	NW	122	120	177	173	167	232	223	227
04/17/90	154	143	138	196	188	187	211	204	203	153	132	139	178	173	168	232	223	228
04/23/90	154	143	138	197	188	187	210	204	203	NW	119	117	180	173	169	233	224	228

TABLE D.1. Continued

Date	Oven 7(150°C)			Oven 8(190°C)			Oven 9(210°C)			Oven 10(135°C)			Oven 11(170°C)			Oven 12(230°C)		
	Top	Mid	Bot	Top	Mid	Bot	Top	Mid	Bot	Top	Mid	Bot	Top	Mid	Bot	Top	Mid	Bot
08/11/89	NW	145	141	197	190	187	214	207	205	NW	123	122	177	172	168	233	223	227
08/15/89	NW	145	141	197	188	187	214	207	205	NW	126	124	178	172	167	233	223	227
08/18/89	NW	145	140	197	189	187	215	208	206	NW	118	116	177	173	168	232	223	227
08/25/89	NW	144	140	197	189	187	214	207	205	NW	132	129	178	173	168	233	224	228
08/29/89	NW	145	140	196	188	187	214	207	205	NW	127	125	177	172	167	232	223	227
09/05/89	NW	144	140	197	188	187	213	207	205	NW	120	118	177	172	167	NA	NA	NA
09/12/89	NW	144	141	196	187	185	213	206	203	NW	125	123	177	172	167	NA	NA	NA
09/20/89	NW	145	141	197	187	185	213	207	205	NW	126	123	177	172	167	NA	NA	NA
09/22/89	153	145	140	197	187	185	213	207	205	NW	128	126	177	172	167	NA	NA	NA
09/27/89	NW	144	140	197	187	184	213	207	205	NW	132	129	177	172	167	NA	NA	NA
09/28/89	NW	143	139	197	187	185	214	207	204	NW	119	116	178	172	167	233	222	226
10/04/89	153	144	137	197	188	186	NA	NA	NA	NW	127	125	177	171	167	233	222	227
10/10/89	153	145	139	197	188	187	NA	NA	NA	NW	148	148	177	172	167	233	223	227
10/13/89	153	145	140	198	188	187	212	203	203	NW	143	141	177	173	167	233	223	227
10/20/89	153	145	140	197	188	187	212	204	203	NW	143	140	178	173	167	233	223	227
10/23/89	NW	144	140	197	189	187	211	203	203	NW	138	137	177	172	167	233	223	227
10/24/89	NW	145	141	197	188	187	211	203	203	NW	129	127	177	172	167	232	223	227
10/27/89	NW	145	140	197	188	187	211	203	203	NW	130	127	177	172	167	233	223	227
10/30/89	NW	146	141	197	188	186	210	203	202	NW	143	140	177	172	167	232	223	227
10/31/89	NW	146	141	197	187	186	211	203	202	132	127	126	178	173	168	232	222	226
11/01/89	NW	147	142	197	188	187	211	204	203	135	132	130	178	173	168	232	223	227
11/06/89	NW	146	142	197	188	187	210	204	203	NW	158	156	178	173	169	232	223	226
11/13/89	NW	144	140	197	188	187	210	203	202	NW	129	129	177	172	167	232	223	227
11/17/89	NA	NA	NA	197	188	187	210	203	202	NW	134	132	177	172	167	232	222	226
11/27/89	NA	NA	NA	197	187	186	210	203	202	NW	143	140	178	173	167	232	223	227
11/30/89	NA	NA	NA	197	187	186	209	203	202	NW	148	148	177	172	167	232	223	227
12/01/89	NW	137	131	197	187	186	210	203	202	NW	132	130	177	172	167	232	223	226
12/04/89	NW	137	132	197	187	186	210	203	203	NW	127	126	177	172	167	232	222	226
12/05/89	NW	137	133	196	188	187	210	203	203	NW	131	130	177	171	167	232	223	226
12/12/89	NA	NA	NA	197	187	186	210	203	202	NW	124	123	178	172	167	231	222	226
12/14/89	NA	NA	NA	197	187	186	210	203	202	NW	130	127	177	172	167	232	222	226
12/18/89	NA	NA	NA	197	188	187	210	203	203	NW	130	129	180	173	169	232	223	227
12/20/89	NA	NA	NA	197	188	187	210	203	202	NW	129	127	178	172	168	232	223	227
12/28/89	153	143	137	196	188	187	211	204	203	NW	133	130	177	172	167	231	223	226
01/08/90	153	143	138	196	188	188	210	204	203	NW	140	137	177	172	167	232	223	227
01/10/90	153	143	138	196	188	187	211	204	204	NW	129	127	177	172	167	232	223	227
01/16/90	153	143	138	196	188	187	211	204	203	NW	127	124	177	173	167	232	223	227
01/18/90	153	143	138	196	188	187	210	203	203	NW	132	129	177	172	167	232	223	227
01/24/90	153	143	138	196	188	187	211	204	203	NW	132	129	178	173	167	232	223	227
01/26/90	153	143	138	196	188	187	210	203	203	NA	NA	NA	179	173	168	232	223	227
01/31/90	153	147	138	196	188	187	210	203	202	NA	NA	NA	178	173	167	233	223	227
02/02/90	153	143	138	196	188	187	210	204	203	NA	NA	NA	178	173	168	233	223	227
02/07/90	153	143	138	197	188	187	210	204	203	NA	NA	NA	177	172	167	232	223	227
02/14/90	153	143	138	196	187	186	211	204	203	NA	NA	NA	182	174	172	233	223	227
02/20/90	153	143	138	196	188	187	212	205	204	NA	NA	NA	178	173	167	232	223	227
02/27/90	153	143	138	197	188	187	212	205	204	NA	NA	NA	179	173	168	233	224	227
03/02/90	154	143	138	197	188	187	211	205	204	NA	NA	NA	178	172	168	232	223	227
03/06/90	153	143	138	197	188	187	212	205	204	NA	NA	NA	178	173	168	232	223	227
03/08/90	153	143	138	197	188	187	212	205	205	NW	135	133	178	172	168	233	223	227
03/13/90	153	143	138	197	188	188	212	205	204	NW	127	125	178	172	167	232	223	227
03/15/90	153	143	139	197	188	187	212	205	204	136	132	129	178	172	168	233	223	227
03/21/90	153	143	138	196	188	187	212	205	204	NW	131	128	179	173	169	233	223	228
03/22/90	153	143	138	197	188	187	211	204	203	NW	125	123	178	173	168	232	223	228
03/28/90	153	143	138	197	188	187	212	205	204	NW	129	127	177	172	167	233	223	227
03/30/90	153	143	138	197	189	188	212	205	204	NW	147	145	177	172	167	233	223	228
04/02/90	153	143	138	197	188	187	213	206	205	NW	120	119	178	173	168	233	224	229
04/05/90	153	143	138	196	188	187	212	205	204	NW	127	125	177	172	167	233	224	228
04/09/90	153	143	138	197	188	187	211	204	203	NW	129	128	177	172	167	233	223	228
04/10/90	153	143	138	197	188	187	212	204	203	NW	134	133	178	172	167	232	223	227
04/11/90	153	143	138	196	188	187	211	204	203	NW	122	120	177	173	167	232	223	227
04/17/90	154	143	138	196	188	187	211	204	203	153	132	139	178	173	168	232	223	228
04/23/90	154	143	138	197	188	187	210	204	203	NW	119	117	180	173	169	233	224	228

TABLE D.1.. Continued

Date	Oven 7(150°C)			Oven 8(190°C)			Oven 9(210°C)			Oven 10(135°C)			Oven 11(170°C)			Oven 12(230°C)		
	Top	Mid	Bot	Top	Mid	Bot	Top	Mid	Bot	Top	Mid	Bot	Top	Mid	Bot	Top	Mid	Bot
04/25/90	153	143	138	197	188	188	210	203	203	NW	128	126	178	172	167	233	223	228
04/30/90	155	144	139	196	188	187	211	204	203	NW	133	131	181	173	171	232	223	228
05/01/90	155	144	140	196	188	187	211	204	203	NW	130	128	178	173	168	NA	NA	NA
05/02/90	154	143	139	197	188	187	211	204	203	NW	126	124	178	173	168	NA	NA	NA
05/07/90	153	143	138	197	187	187	210	203	202	NW	115	113	177	172	167	NA	NA	NA
05/15/90	NW	143	137	196	187	187	210	203	203	NW	140	140	178	173	167	NA	NA	NA
05/16/90	NW	143	137	195	187	187	210	204	203	NW	123	122	178	173	167	NA	NA	NA
05/21/90	NW	143	139	NA	NA	NA	210	204	203	NW	141	138	177	172	166	233	223	227
05/22/90	NW	143	137	NA	NA	NA	210	204	203	NW	120	118	178	172	167	231	222	226
05/25/90	153	143	138	NA	NA	NA	211	204	204	NW	125	123	178	172	168	232	221	226
05/30/90	153	143	138	NA	NA	NA	211	205	204	NW	128	126	178	172	167	232	222	226
06/04/90	153	143	139	NA	NA	NA	210	205	204	NW	125	123	177	172	166	233	222	227
06/07/90	154	143	139	NA	NA	NA	211	205	205	NW	128	126	177	172	167	233	222	227
06/11/90	153	143	138	NA	NA	NA	211	205	204	NW	130	128	177	172	167	232	220	225
06/14/90	154	143	138	NA	NA	NA	212	205	205	NW	128	125	178	172	167	232	220	226
06/25/90	156	145	140	NA	NA	NA	210	205	205	NW	119	117	177	172	167	232	220	226
06/27/90	154	143	139	NA	NA	NA	210	205	205	NW	120	119	NA	NA	NA	231	219	225
06/29/90	NW	144	139	192	176	177	211	205	205	NW	123	120	NA	NA	NA	231	220	226
07/02/90	NW	143	138	188	179	173	210	205	205	NW	127	125	NA	NA	NA	231	220	225
07/09/90	153	142	137	NA	NA	NA	210	204	204	NW	123	122	NA	NA	NA	232	220	226
07/12/90	154	143	137	NA	NA	NA	211	205	204	NW	117	115	NA	NA	NA	233	223	227
07/17/90	NW	142	137	NA	NA	NA	210	203	203	NW	130	128	NA	NA	NA	231	220	226
07/19/90	NW	142	137	NA	NA	NA	210	203	203	NW	121	120	NA	NA	NA	231	220	226
07/24/90	NW	142	137	NA	NA	NA	210	203	203	NW	125	123	NA	NA	NA	231	221	227
07/27/90	NW	142	137	NA	NA	NA	210	203	202	NW	120	119	NA	NA	NA	231	220	226
08/03/90	153	143	137	NA	NA	NA	NA	NA	NA	NW	133	132	NA	NA	NA	231	220	226
08/07/90	153	141	135	NA	NA	NA	NA	NA	NA	NW	133	131	NA	NA	NA	231	220	225
08/10/90	153	142	136	NA	NA	NA	NA	NA	NA	NW	153	154	NA	NA	NA	231	220	226
08/16/90	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	231	220	225
08/20/90	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	230	220	226
08/23/90	NA	NA	NA	NA	NA	NA	NA	NA	NA	NW	129	126	NA	NA	NA	NA	NA	NA
08/27/90	NA	NA	NA	NA	NA	NA	NA	NA	NA	NW	124	122	NA	NA	NA	NA	NA	NA
08/29/90	NA	NA	NA	NA	NA	NA	NA	NA	NA	NW	124	117	NA	NA	NA	NA	NA	NA
09/06/90	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
09/13/90	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
09/18/90	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
09/21/90	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
09/25/90	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

NA = Not applicable because oven not operating

NW = Instrument not working

CRB = Chart recorder broken

TABLE D.2. Oven Pressure Histories

Date	Oven Gage Pressure, inches of Mercury											
	Oven 1	Oven 2	Oven 3	Oven 4	Oven 5	Oven 6	Oven 7	Oven 8	Oven 9	Oven 10	Oven 11	Oven 12
12/23/85	2.6	NA	NA	NA	0.9	-1.5	2.0	NA	NA	NA	NA	NA
12/26/85	2.4	NA	NA	NA	1.0	NA	2.1	NA	NA	NA	NA	NA
12/27/85	2.4	NA	NA	NA	1.0	NA	2.3	NA	NA	NA	NA	NA
12/30/85	2.3	NA	NA	NA	1.0	NA	2.2	NA	NA	NA	NA	NA
12/31/85	2.3	NA	NA	NA	1.1	NA	2.5	NA	NA	NA	NA	NA
01/02/86	2.5	NA	NA	NA	1.4	NA	2.1	NA	NA	NA	NA	NA
01/03/86	2.2	NA	NA	NA	1.1	NA	1.9	NA	NA	NA	NA	NA
01/06/86	1.9	NA	NA	NA	1.0	NA	1.9	NA	NA	NA	NA	NA
01/07/86	1.7	NA	NA	NA	0.9	NA	1.6	NA	NA	NA	NA	NA
01/08/86	1.9	NA	NA	NA	1.1	NA	2.1	NA	NA	NA	NA	NA
01/09/86	1.7	NA	NA	NA	1.0	NA	1.6	NA	NA	NA	NA	NA
01/10/86	1.8	NA	NA	NA	1.1	NA	2.8	NA	NA	NA	NA	NA
01/13/86	1.6	NA	NA	NA	1.1	NA	2.8	NA	NA	NA	NA	NA
01/14/86	1.7	NA	NA	NA	1.3	NA	1.8	NA	NA	NA	NA	NA
01/15/86	1.8	NA	NA	NA	1.4	NA	2.4	NA	NA	NA	NA	NA
01/16/86	1.7	NA	NA	NA	1.0	NA	2.3	NA	NA	NA	NA	NA
01/17/86	1.5	NA	NA	NA	0.5	NA	2.7	NA	NA	NA	NA	NA
01/20/86	1.4	NA	NA	NA	0.1	NA	2.5	NA	NA	NA	NA	NA
01/21/86	1.1	NA	NA	NA	-0.1	NA	2.0	NA	NA	NA	NA	NA
01/22/86	1.3	NA	NA	NA	0.0	NA	2.4	NA	NA	NA	NA	NA
01/23/86	1.3	2.3	NA	NA	-0.1	NA	2.3	NA	NA	NA	NA	NA
01/24/86	0.9	2.1	NA	NA	-0.2	NA	2.2	NA	NA	NA	NA	NA
01/27/86	1.0	2.3	NA	NA	-0.1	NA	2.0	NA	NA	NA	NA	NA
01/28/86	1.0	2.2	NA	NA	-0.1	NA	2.0	NA	NA	NA	NA	NA
01/29/86	1.1	2.5	NA	NA	-0.1	NA	2.5	NA	NA	NA	NA	NA
01/30/86	1.2	2.5	NA	NA	-0.1	NA	2.7	NA	NA	NA	NA	NA
01/31/86	1.1	2.5	NA	NA	-0.1	NA	2.0	NA	NA	NA	NA	NA
02/03/86	0.6	2.3	NA	NA	-0.1	NA	2.0	NA	NA	NA	NA	NA
02/04/86	0.2	2.1	NA	NA	-0.1	NA	1.7	NA	NA	NA	NA	NA
02/05/86	0.1	2.2	NA	NA	-0.1	NA	1.1	NA	NA	3.1	2.2	NA
02/06/86	-0.1	2.0	NA	NA	-0.1	NA	0.7	NA	NA	2.8	1.9	NA
02/07/86	0.0	2.0	1.0	NA	-0.1	NA	0.7	NA	NA	-3.7	1.4	NA
02/10/86	0.0	2.0	1.9	NA	-0.1	NA	0.3	NA	NA	3.7	1.0	NA
02/11/86	0.0	2.0	1.9	NA	NA	NA	0.3	NA	NA	3.0	0.7	NA
02/12/86	0.0	2.2	2.1	NA	NA	NA	0.5	NA	NA	3.2	0.5	NA
02/13/86	0.0	2.1	2.0	NA	NA	NA	0.3	2.0	NA	3.2	0.3	NA
02/14/86	0.0	2.0	1.9	NA	NA	NA	0.1	2.4	0.2	3.3	0.3	NA
02/18/86	0.0	2.2	2.2	NA	NA	NA	0.1	2.2	NA	3.3	-0.1	NA
02/19/86	0.0	2.0	2.0	NA	NA	NA	0.1	2.0	NA	3.0	-0.4	NA
02/20/86	0.0	1.9	1.7	NA	NA	NA	0.1	1.8	NA	2.9	-0.3	NA
02/21/86	0.0	1.8	1.5	NA	NA	NA	0.1	1.6	NA	2.8	-0.3	NA
02/24/86	0.0	1.9	1.5	2.8	2.6	NA	0.2	1.5	NA	3.0	0.0	NA
02/25/86	0.0	1.8	1.2	2.5	3.2	NA	NA	NA	NA	2.7	-0.2	NA
02/26/86	0.0	1.6	0.9	2.2	2.7	NA	NA	NA	NA	2.3	NA	NA
02/27/86	0.1	1.6	1.1	2.3	2.7	NA	NA	NA	2.1	2.4	NA	NA
02/28/86	0.0	1.7	NA	2.3	2.6	NA	NA	NA	2.8	2.7	NA	NA
03/03/86	0.1	1.4	NA	1.8	1.9	NA	NA	NA	-7.5	2.2	NA	NA
03/04/86	0.0	1.5	NA	1.8	1.9	NA	NA	NA	NA	2.2	NA	NA
03/05/86	0.0	1.5	NA	1.8	1.8	NA	NA	NA	NA	2.7	2.7	NA
03/06/86	0.0	1.6	NA	NA	1.8	NA	4.3	NA	NA	3.0	3.7	NA
03/07/86	0.0	1.9	NA	NA	2.1	NA	4.3	NA	NA	3.2	4.2	NA
03/10/86	0.0	1.8	NA	NA	1.7	NA	4.1	3.8	NA	3.1	4.1	NA
03/11/86	0.0	1.7	1.4	NA	NA	NA	4.0	4.0	NA	2.9	3.9	NA
03/12/86	0.1	1.7	1.6	NA	NA	NA	3.9	3.8	NA	2.9	2.6	NA
03/13/86	0.0	1.7	1.6	1.2	NA	NA	3.9	3.8	NA	3.0	3.8	NA
03/14/86	0.0	1.6	1.5	2.4	NA	NA	3.8	3.4	NA	2.2	3.2	NA
03/17/86	0.0	1.4	1.2	2.8	NA	NA	3.6	3.0	NA	2.5	3.1	NA
03/18/86	NA	1.2	0.6	2.4	NA	NA	3.3	2.6	NA	2.0	2.5	NA
03/19/86	NA	1.2	0.4	2.3	NA	NA	3.2	2.4	NA	2.0	2.5	NA

TABLE D.2. Continued

Oven Gage Pressure, inches of Mercury												
Date	Oven 1	Oven 2	Oven 3	Oven 4	Oven 5	Oven 6	Oven 7	Oven 8	Oven 9	Oven 10	Oven 11	Oven 12
03/20/86	NA	1.2	0.6	2.2	1.4	1.9	3.3	2.3	NA	1.9	2.6	NA
03/21/86	1.3	1.3	0.8	2.2	3.1	2.0	3.2	2.3	NA	2.0	2.9	NA
03/24/86	0.0	1.3	0.9	2.0	3.3	2.1	3.5	2.2	NA	2.1	2.8	NA
03/26/86	0.0	1.0	0.8	1.7	3.1	1.9	3.2	1.9	3.4	1.9	2.5	NA
03/27/86	0.0	1.3	0.9	1.8	3.1	2.0	3.3	0.9	3.3	1.6	2.5	NA
03/31/86	-0.1	-0.1	0.4	1.2	2.6	1.6	3.0	NA	2.2	1.2	2.1	NA
04/01/86	0.1	-0.7	0.9	1.5	2.9	2.0	3.5	3.9	2.5	2.5	2.7	NA
04/02/86	-0.1	NA	0.4	1.0	2.5	1.6	2.9	3.1	1.9	1.7	2.1	1.9
04/03/86	0.0	NA	0.6	NA	2.5	1.7	3.1	3.1	1.9	1.9	2.3	0.9
04/04/86	0.1	1.9	0.8	2.8	2.7	1.9	3.4	3.4	2.0	2.2	2.6	0.4
04/07/86	-0.1	NA	0.6	1.9	2.3	1.7	3.0	2.9	1.5	1.1	2.0	NA
04/08/86	-0.1	NA	0.2	1.6	NA	1.5	3.0	2.8	1.3	1.7	1.7	2.6
04/09/86	0.0	NA	-0.2	1.5	NA	1.8	2.9	2.7	1.0	1.5	1.7	2.1
04/10/86	0.1	1.9	0.0	1.3	0.9	1.8	2.1	2.5	NA	1.5	0.9	2.3
04/11/86	0.1	1.7	0.0	1.4	2.5	2.0	1.7	2.6	NA	1.6	1.0	2.4
04/14/86	-0.1	1.1	-0.2	1.0	1.2	1.8	0.7	2.3	NA	1.3	0.2	2.1
04/15/86	0.0	0.9	0.0	1.2	2.6	2.0	1.1	2.4	1.9	0.8	1.3	NA
04/16/86	-0.1	0.8	-0.1	1.0	2.5	1.9	1.1	2.3	2.4	1.2	1.1	NA
04/17/86	-0.2	0.4	-0.2	0.8	2.2	1.6	0.5	1.9	1.4	0.6	NA	2.5
04/18/86	-0.2	0.1	-0.1	0.5	1.9	1.4	0.2	1.6	0.9	0.2	NA	2.1
04/21/86	NA	0.4	-0.1	0.8	2.0	1.6	0.5	1.9	1.0	NA	NA	2.5
04/22/86	NA	0.4	-0.1	0.8	2.0	1.7	0.7	1.8	1.1	NA	NA	2.6
04/23/86	NA	0.0	-0.1	0.5	1.7	1.5	0.3	1.5	0.7	NA	3.8	2.4
04/24/86	NA	0.1	-0.1	0.6	1.8	1.6	0.6	1.6	0.9	NA	1.6	2.6
04/25/86	NA	0.3	-0.1	0.7	1.8	1.6	0.7	1.7	0.6	NA	1.8	2.5
04/28/86	NA	-0.1	-0.1	0.3	1.5	1.4	0.3	1.3	0.2	2.2	1.5	1.7
04/29/86	NA	0.0	0.0	0.3	1.4	1.4	0.3	1.3	0.2	2.8	1.4	1.5
05/01/86	NA	0.1	0.0	0.3	1.4	1.5	0.3	1.2	0.2	3.0	1.5	1.1
05/02/86	NA	0.1	-0.1	0.3	1.4	0.3	0.1	NA	0.2	2.3	1.5	0.8
05/05/86	3.2	0.1	NA	0.2	1.2	0.0	0.2	NA	0.0	2.5	1.5	0.3
05/06/86	3.4	-0.1	NA	0.1	1.2	0.0	0.1	3.4	0.0	2.9	1.4	0.0
05/07/86	2.8	-0.2	1.1	0.0	1.0	0.0	0.1	2.5	NA	3.0	1.2	-0.3
05/08/86	2.8	-0.3	0.8	NA	0.8	0.0	0.1	2.2	2.1	2.8	1.0	-0.6
05/09/86	2.4	-0.2	0.6	NA	NA	0.1	0.2	2.4	3.1	3.0	1.1	-0.6
05/12/86	2.2	-0.3	0.3	NA	NA	0.0	0.1	2.0	2.5	3.0	-1.4	0.8
05/13/86	2.9	0.0	1.0	NA	NA	0.1	0.2	2.2	2.8	2.8	1.1	NA
05/14/86	2.5	-0.2	0.7	NA	NA	0.0	0.2	1.8	2.3	2.6	0.7	NA
05/15/86	2.3	-0.1	0.5	NA	NA	0.0	0.1	1.8	2.1	2.6	0.7	NA
05/16/86	2.2	-0.3	0.5	3.2	3.1	0.0	0.1	1.5	1.8	2.5	0.5	NA
05/19/86	3.0	-0.2	1.0	2.5	3.2	0.0	0.1	1.6	1.7	3.0	0.8	NA
05/20/86	2.1	-0.1	0.8	2.3	3.3	0.0	NA	1.5	1.7	2.8	0.8	NA
05/21/86	2.4	-0.2	1.1	2.4	3.3	-0.1	NA	1.4	1.5	2.9	0.8	NA
05/23/86	1.8	-0.2	0.6	2.0	3.0	0.0	NA	1.1	1.1	2.8	0.5	1.5
05/27/86	1.9	-0.2	0.8	1.9	2.9	0.0	NA	0.8	0.8	3.2	0.2	0.5
05/28/86	1.7	-0.1	0.6	1.8	2.7	0.0	NA	0.8	0.7	3.1	0.5	-0.1
05/29/86	2.0	-0.2	0.7	1.8	2.8	0.0	NA	0.7	0.6	3.2	0.4	-0.4
05/30/86	2.0	0.1	0.7	1.8	2.7	0.0	NA	0.6	0.5	3.3	0.5	-0.6
06/02/86	2.0	0.0	1.0	1.7	2.7	0.0	NA	0.5	0.4	3.4	0.5	-1.1
06/03/86	1.8	-0.1	0.7	1.5	2.5	0.0	NA	0.3	0.2	3.0	0.3	NA
06/05/86	2.1	-0.1	1.0	1.5	2.4	-0.1	NA	0.0	NA	3.2	0.3	NA
06/06/86	1.9	-0.2	0.8	1.4	2.3	-0.1	NA	0.0	3.0	3.1	0.2	1.6
06/09/86	1.5	-0.5	0.3	0.9	1.9	-0.1	NA	-0.6	2.8	2.6	-0.1	1.1
06/10/86	1.4	-0.4	0.1	1.0	1.9	0.0	NA	-0.6	2.9	2.7	0.0	1.1
06/11/86	1.4	-0.3	0.2	1.0	1.8	0.0	NA	-0.7	3.1	2.8	0.0	1.6
06/12/86	1.3	-0.3	0.2	1.0	1.8	0.0	NA	-0.7	2.8	2.7	0.0	1.2
06/13/86	1.6	-0.2	0.4	1.0	1.8	0.0	NA	-0.7	2.8	3.0	0.0	1.2
06/16/86	1.5	-0.2	0.2	0.9	1.7	0.0	NA	-0.8	2.5	3.1	0.0	1.0
06/17/86	1.4	-0.2	0.3	0.9	1.6	0.0	NA	NA	2.4	2.7	NA	NA
06/18/86	1.3	-0.4	0.4	0.8	1.5	0.0	NA	NA	2.1	1.8	NA	NA

TABLE D.2. Continued

Date	Oven Gage Pressure, inches of Mercury											
	Oven 1	Oven 2	Oven 3	Oven 4	Oven 5	Oven 6	Oven 7	Oven 8	Oven 9	Oven 10	Oven 11	Oven 12
06/19/86	1.2	-0.5	0.3	0.5	1.2	-0.1	NA	NA	1.9	1.6	NA	NA
06/20/86	1.3	-0.2	0.4	0.6	1.2	-0.1	NA	NA	1.8	1.9	NA	NA
06/23/86	1.2	-0.1	0.3	0.6	1.1	-0.1	NA	NA	1.6	1.9	NA	NA
06/24/86	1.0	0.0	0.1	0.7	1.2	-0.1	NA	3.9	1.6	2.1	1.9	2.4
06/25/86	1.3	0.0	0.4	0.7	1.2	-0.1	NA	2.2	1.6	2.3	2.6	2.3
06/26/86	1.3	-0.1	0.5	0.7	1.1	-0.1	NA	2.2	1.4	2.7	2.5	2.3
06/27/86	1.2	-0.1	0.3	0.6	1.0	-0.1	NA	2.1	1.3	2.7	2.5	2.2
07/02/86	0.8	0.0	0.1	0.3	0.7	0.0	NA	1.7	0.7	2.5	2.4	1.6
07/09/86	0.6	0.0	0.0	NA	0.5	-0.1	NA	1.1	0.3	1.5	2.4	NA
07/10/86	0.6	-0.1	0.0	NA	0.4	-0.1	NA	1.0	0.1	2.2	2.4	NA
07/11/86	0.7	-0.1	-0.1	NA	0.3	-0.1	NA	1.0	0.1	2.4	2.4	3.2
07/14/86	0.5	-0.1	0.1	3.2	0.3	0.0	NA	0.7	0.0	2.2	2.4	3.1
07/15/86	0.3	-0.1	-0.5	3.0	0.2	0.0	NA	0.6	-0.2	2.1	2.3	2.9
07/18/86	0.5	0.0	0.0	3.0	0.1	0.0	NA	0.3	-0.4	2.0	2.2	2.8
07/21/86	0.6	-0.1	0.0	2.9	NA	0.0	NA	0.1	NA	2.4	2.4	2.6
07/23/86	0.3	0.0	-0.3	2.8	NA	-0.1	NA	-0.1	NA	2.5	-0.2	2.4
07/24/86	0.2	-0.1	-0.4	2.8	NA	-0.1	NA	-0.3	0.4	2.6	-0.3	2.2
07/28/86	0.7	-0.1	NA	2.6	1.8	-0.1	0.3	-0.6	0.0	1.8	-0.2	NA
07/29/86	0.6	0.0	NA	2.4	2.5	0.0	-0.1	-0.8	-0.4	1.4	-0.4	NA
07/30/86	0.4	0.0	NA	2.2	2.8	-0.1	-0.3	-1.0	-0.6	1.6	-0.6	2.6
07/31/86	0.5	0.0	NA	2.3	2.7	-0.1	-0.1	-1.0	-0.6	1.7	-0.5	3.3
08/04/86	0.4	NA	NA	2.2	1.8	NA	0.1	-1.3	-0.6	2.3	-0.4	2.8
08/05/86	0.5	NA	NA	2.2	1.8	NA	0.1	-1.2	-0.5	2.4	-0.3	2.9
08/07/86	0.5	NA	NA	2.1	1.5	NA	0.1	-1.4	-0.4	2.5	-0.2	2.7
08/08/86	NA	2.7	2.7	2.3	1.4	NA	0.2	-1.3	-0.6	2.1	0.0	2.7
08/11/86	NA	2.3	2.5	1.9	1.0	NA	0.2	-1.6	-0.9	1.7	-0.2	2.3
08/13/86	NA	2.0	2.5	1.9	0.8	3.3	0.1	NA	-0.9	1.8	-0.3	2.1
08/14/86	NA	2.0	2.5	2.0	0.8	3.4	0.3	NA	-0.7	1.9	-0.2	2.2
08/20/86	1.7	1.4	2.3	1.4	0.1	3.2	0.0	NA	-1.2	1.6	-0.5	1.6
08/21/86	1.8	1.5	2.6	1.5	0.2	3.4	0.2	NA	-1.2	1.6	-0.4	1.7
08/22/86	1.5	1.4	2.2		0.1	3.4	0.0	2.8	-1.3	1.3	NA	NA
08/25/86	1.2	1.4	2.7	NA	0.0	3.4	-0.1	3.0	-1.5	1.8	NA	3.0
08/26/86	0.8	1.2	2.5	NA	-0.2	3.3	0.0	2.8	-1.4	1.8	NA	3.2
08/28/86	1.1	1.4	2.7	NA	-0.1	3.5	0.3	2.9	-1.2	2.3	1.6	3.4
08/29/86	1.1	1.5	2.7	2.6	-0.1	3.4	0.0	2.7	NA	NA	1.6	3.3
09/02/86	0.9	1.1	2.6	2.4	-0.4	3.3	-0.1	2.2	NA	NA	1.4	2.8
09/03/86	1.0	1.2	2.8	2.6	-0.4	3.3	-0.1	2.1	1.6	3.1	1.3	2.7
09/04/86	0.8	1.1	2.7	2.3	-0.4	3.4	0.0	2.1	2.1	2.0	1.4	2.8
09/08/86	0.9	1.2	2.9	1.8	-0.3	3.5	0.3	2.0	3.2	2.2	1.6	3.3
09/09/86	0.9	1.2	2.9	1.6	-0.4	3.5	0.2	1.9	3.0	2.1	1.6	3.2
09/10/86	0.7	1.1	0.8	1.4	-0.5	3.2	0.1	1.8	2.8	2.1	1.5	3.0
09/11/86	0.6	0.9	2.2	1.1	-0.7	3.3	-0.2	1.5	2.5	1.8	1.3	2.8
09/12/86	0.8	1.0	2.6	1.2	-0.6	3.5	0.0	1.7	2.6	1.9	1.5	3.0
09/15/86	0.6	1.0	2.4	1.0	-0.6	3.4	0.1	1.5	2.2	2.0	1.5	2.9
09/16/86	0.6	1.0	2.4	0.9	-0.7	3.4	0.0	1.4	2.0	1.9	1.4	2.7
09/17/86	0.6	1.0	2.4	1.1	-0.6	3.5	0.1	1.4	2.0	2.0	1.6	2.8
09/18/86	0.6	0.9	2.4	1.0	-0.7	3.4	0.1	1.3	1.8	1.8	1.5	2.6
09/22/86	0.2	0.7	1.9	0.8	NA	3.3	0.0	0.9	1.3	1.6	1.3	2.4
09/23/86	0.5	1.2	2.3	1.2	NA	3.5	0.3	1.4	1.8	2.1	1.9	2.9
09/26/86	0.8	1.1	2.6	1.0	2.4	2.8	0.4	1.0	1.4	2.0	1.8	NA
09/29/86	0.5	0.7	2.3	0.7	1.8	2.2	0.0	0.4	0.8	1.7	1.5	NA
10/03/86	-0.2	0.6	NA	0.6	1.2	1.7	-0.1	0.1	0.3	1.4	1.3	NA
10/06/86	-0.3	0.7	NA	0.6	1.0	1.6	-0.1	NA	0.2	1.4	1.3	2.5
10/08/86	0.3	0.6	3.5	0.6	0.9	1.6	0.0	NA	0.2	1.4	1.3	2.3
10/09/86	0.3	0.6	3.5	0.6	0.8	1.5	0.0	3.1	0.1	1.4	1.4	2.3
10/14/86	0.1	0.3	3.3	0.3	0.5	0.7	-0.2	1.8	-0.3	1.2	1.1	1.9
10/15/86	0.1	0.4	3.5	0.4	0.5	0.6	-0.1	1.8	-0.2	1.3	1.1	2.0
10/16/86	0.4	0.5	3.6	0.5	0.6	0.7	0.0	1.8	0.0	1.5	1.4	2.2
10/17/86	0.4	0.7	3.7	0.5	0.6	0.6	0.1	1.7	0.0	1.4	1.4	2.2

TABLE D.2. Continued

Oven Gage Pressure, inches of Mercury												
Date	Oven 1	Oven 2	Oven 3	Oven 4	Oven 5	Oven 6	Oven 7	Oven 8	Oven 9	Oven 10	Oven 11	Oven 12
10/20/86	0.3	0.4	3.6	0.4	0.3	0.2	0.0	1.3	-0.3	1.4	1.3	2.0
10/21/86	0.2	0.4	3.5	0.4	0.3	0.1	0.0	1.2	-0.3	1.4	1.2	1.9
10/22/86	0.2	0.4	3.6	0.4	0.3	0.1	0.0	1.2	-0.3	1.4	1.3	1.9
10/23/86	0.2	0.5	3.5	0.4	0.3	0.0	0.0	1.2	-0.3	1.4	1.3	2.0
10/24/86	0.0	0.5	3.5	NA	0.2	0.0	-0.3	0.9	NA	1.2	NA	1.8
10/27/86	0.4	1.2	3.8	NA	0.2	0.0	0.3	0.9	0.8	1.6	2.4	1.9
10/28/86	0.2	0.8	3.6	3.8	0.0	0.0	-0.1	0.6	1.1	1.2	1.8	1.6
10/29/86	0.5	1.2	3.8	3.0	0.1	0.1	NA	0.7	1.3	1.4	2.1	1.8
10/30/86	0.5	1.1	3.8	3.0	0.1	0.0	NA	0.7	1.2	1.4	2.1	1.9
10/31/86	0.2	1.0	3.6	2.8	0.0	0.0	1.7	0.4	0.9	1.2	1.8	1.5
11/03/86	0.1	0.8	3.4	2.4	-0.2	0.0	1.8	0.1	0.6	1.0	1.6	1.3
11/04/86	-0.1	0.8	3.2	2.5	NA	0.0	2.0	0.1	0.7	1.0	1.8	NA
11/05/86	0.3	1.0	3.6	2.6	NA	0.1	2.3	0.4	0.9	1.3	2.1	NA
11/06/86	0.3	0.9	3.6	2.4	2.8	0.0	2.1	0.2	0.7	1.2	1.9	NA
11/07/86	0.3	1.0	3.7	2.6	2.8	0.0	2.4	0.4	0.9	1.4	2.2	3.2
11/10/86	-0.3	0.5	3.0	1.8	1.9	0.1	1.6	-0.3	0.0	0.8	1.4	2.8
11/13/86	0.2	NA	3.4	2.1	2.0	NA	2.1	0.0	0.4	1.3	2.0	3.4
11/14/86	0.1	NA	3.3	2.0	1.9	NA	2.1	0.0	0.5	1.2	2.2	3.5
11/18/86	NA	NA	3.6	2.4	1.9	2.5	2.6	0.4	0.8	1.8	2.7	4.0
11/19/86	NA	NA	3.1	2.0	1.4	NA	2.1	NA	0.2	1.3	2.1	3.4
11/20/86	2.9	2.0	3.8	2.1	1.5	1.5	2.3	NA	0.4	1.5	3.1	3.6
11/21/86	3.1	1.6	3.5	1.8	1.1	1.4	1.9	NA	0.1	1.3	2.1	3.3
11/24/86	3.2	1.9	3.8	2.0	1.2	1.5	2.1	NA	0.3	1.5	3.2	3.5
12/01/86	2.1	1.2	NA	1.5	0.5	1.5	1.4	1.4	NA	1.1	1.8	3.0
12/02/86	2.0	1.1	NA	1.4	0.3	1.2	1.4	1.3	NA	1.0	1.8	2.9
12/04/86	1.8	1.1	1.5	1.4	NA	1.4	1.5	1.2	3.2	NA	1.8	NA
12/05/86	2.4	1.4	1.7	1.6	NA	1.7	1.7	1.4	3.2	NA	2.1	NA
12/08/86	1.8	0.9	1.4	1.1	NA	1.3	1.1	0.8	2.4	NA	1.5	NA
12/09/86	1.7	0.8	1.3	1.0	2.6	0.9	1.0	0.7	2.2	NA	1.5	NA
12/10/86	1.8	0.9	1.5	1.2	2.6	1.4	1.1	0.9	2.3	2.5	1.7	2.7
12/11/86	1.8	1.1	1.6	1.3	2.6	1.0	1.3	1.0	2.3	1.5	1.8	2.9
12/12/86	1.9	1.1	1.7	1.3	2.6	1.1	1.4	1.0	2.3	1.4	1.9	3.0
12/15/86	1.7	1.2	1.7	1.4	2.4	2.3	1.3	1.1	2.1	1.4	1.8	3.1
12/16/86	1.3	0.8	1.5	1.1	2.0	0.7	1.0	0.8	1.8	1.1	1.5	2.8
12/17/86	0.9	1.0	1.6	1.2	2.0	0.8	1.1	0.9	1.8	1.4	1.6	2.9
12/18/86	0.9	1.1	1.7	1.3	2.0	0.8	1.3	1.0	1.8	1.4	1.8	3.0
12/19/86	0.9	1.1	1.7	1.2	2.0	0.9	1.1	0.9	NA	1.4	1.7	3.0
12/22/86	1.0	1.2	1.9	1.4	1.9	1.2	1.3	1.1	NA	1.7	1.9	3.3
12/23/86	0.9	1.1	1.8	1.3	1.7	0.9	1.0	0.9	NA	1.5	1.7	3.0
01/05/87	0.6	1.0	1.8	1.3	1.1	0.9	1.1	0.8	2.5	1.6	1.9	3.1
01/07/87	0.2	0.6	1.5	0.9	0.7	0.6	0.6	NA	2.6	1.1	1.3	2.5
01/08/87	0.3	0.7	1.5	0.9	0.6	0.6	0.6	NA	2.4	1.1	1.3	2.6
01/09/87	0.0	0.4	1.3	0.7	0.4	0.2	0.4	NA	2.1	0.7	1.0	2.4
01/15/87	0.0	0.7	1.4	0.8	0.3	0.3	0.4	1.8	1.6	0.9	1.0	NA
01/16/87	0.1	0.8	1.4	0.8	0.3	0.3	0.5	1.9	1.6	0.9	1.3	NA
01/20/87	0.1	0.8	1.4	0.8	NA	0.6	0.4	1.7	1.2	1.0	NA	3.0
01/21/87	0.2	0.8	1.4	0.7	NA	0.6	0.4	1.7	1.1	0.9	NA	3.1
01/23/87	0.5	1.1	1.8	1.2	NA	1.1	0.8	2.2	1.5	1.4	NA	3.8
01/28/87	0.3	1.1	1.9	1.3	NA	1.2	1.0	2.3	1.4	1.7	NA	3.4
01/30/87	0.3	0.6	1.8	NA	NA	0.8	0.9	2.1	1.2	1.5	2.3	3.2
02/04/87	0.0	0.0	1.4	NA	NA	0.5	0.4	1.5	0.5	1.0	1.6	2.8
02/05/87	0.1	0.1	1.3	NA	NA	0.4	NA	1.3	NA	0.8	1.4	2.7
02/09/87	0.6	0.8	1.6	3.7	2.9	0.7	NA	1.6	NA	1.2	0.5	3.2
02/11/87	0.6	0.9	1.6	3.6	2.7	0.7	NA	1.4	NA	1.2	0.4	3.0
02/13/87	0.8	1.2	1.9	4.0	2.9	1.6	NA	1.8	3.4	1.6	0.9	3.5
02/17/87	0.3	NA	1.4	3.5	2.1	NA	0.3	1.2	2.5	1.1	0.2	2.9
02/20/87	0.1	NA	1.2	3.2	1.8	NA	0.1	0.0	2.1	0.9	0.0	2.7
03/02/87	0.4	NA	NA	3.6	1.6	NA	0.7	0.0	2.1	1.4	0.5	3.6
03/05/87	0.4	NA	NA	3.6	1.0	NA	0.6	0.0	2.0	NA	0.0	3.5

TABLE D.2. Continued

Oven Gage Pressure, inches of Mercury												
Date	Oven 1	Oven 2	Oven 3	Oven 4	Oven 5	Oven 6	Oven 7	Oven 8	Oven 9	Oven 10	Oven 11	Oven 12
03/10/87	0.0	NA	NA	3.2	0.1	0.0	0.2	0.0	1.5	NA	0.0	3.2
03/11/87	0.3	NA	NA	3.2	0.0	-0.1	0.2	0.0	1.4	NA	0.0	3.2
03/13/87	0.0	NA	NA	3.4	0.0	0.0	0.3	0.0	1.5	NA	0.0	3.3
03/16/87	-0.1	2.0	NA	3.2	-0.3	0.0	0.0	0.0	1.1	NA	0.0	3.2
03/19/87	-0.1	2.3	NA	3.3	-0.3	0.0	0.0	0.0	1.1	NA	0.0	3.3
03/23/87	-0.1	2.0	NA	3.0	-0.4	0.0	0.0	0.0	0.9	NA	0.0	3.3
03/30/87	-0.4	1.5	NA	2.6	-0.5	-0.4	0.0	0.0	0.6	NA	0.0	1.8
04/01/87	0.2	1.8	1.8	2.6	-0.4	-0.3	0.0	0.0	0.6	NA	0.0	1.4
04/06/87	0.3	1.9	1.8	0.8	-0.3	-0.4	0.0	0.0	0.6	NA	0.0	0.9
04/14/87	0.2	1.8	1.8	0.1	-0.2	-0.4	0.0	0.0	0.5	3.5	0.0	0.8
04/17/87	0.6	2.0	2.0	0.2	-0.3	0.0	0.0	0.0	NA	3.8	0.0	0.9
04/20/87	-0.1	1.2	1.3	0.1	-0.2	-0.6	0.0	0.0	NA	2.9	0.0	0.9
04/23/87	0.1	1.8	1.6	0.0	-0.3	-0.4	0.0	0.0	NA	3.3	0.0	1.0
04/28/87	0.2	1.7	1.6	0.1	-0.3	-0.5	0.0	0.0	NA	3.3	0.0	0.8
05/04/87	0.0	1.2	1.1	0.0	-0.3	-0.4	0.0	0.0		2.9	0.0	0.6
05/08/87	0.2	1.5	1.4	0.1	-0.3	-0.3	0.0	0.0	NA	3.1	0.0	0.5
05/11/87	0.2	1.2	1.2	0.1	-0.3	-0.5	0.0	0.0	NA	2.9	0.5	0.1
05/14/87	0.1	-0.1	1.1	0.1	-0.3	-0.4	0.0	0.0	NA	2.9	0.1	0.4
05/18/87	0.2	-0.1	1.1	0.1	-0.3	-0.4	0.0	0.0	NA	2.9	0.0	0.4
05/19/87		-0.1	1.0	0.1	-0.3	-0.5	0.0	0.0		2.6	0.0	0.4
05/22/87	NA	0.0	0.9	0.1	-0.3	-0.5	0.0	0.0	2.7	2.6	0.0	0.3
06/02/87	NA	0.0	0.3	0.1	-0.3	-0.7	0.0	0.0	1.0	1.5	0.0	0.1
06/08/87	NA	0.0	0.6	0.1	-0.3	0.0	0.1	NA	0.9	0.5	0.1	-0.1
06/15/87	NA	0.0	0.7	0.1	-0.3	0.0	0.1	NA	0.7	0.2	0.1	-0.2
06/22/87	NA	-0.1	0.2	0.1	-0.3	0.0	0.0	NA	-0.1	0.0	0.0	-0.2
06/26/87	NA	0.0	0.5	0.1	-0.3	0.0	0.0	NA	0.0	0.1	0.1	-0.2
07/13/87	2.9	-0.1	0.1	0.1	-0.3	0.0	0.1	1.6	-0.3	0.1	0.1	NA
07/14/87	2.8	-0.1	0.1	0.1	-0.3	0.0	0.1	1.7	-0.1	0.1	0.1	NA
07/22/87	2.8	-0.1	0.0	0.1	-0.3	0.0	0.0	1.5	-0.3	0.1	0.1	NA
07/31/87	1.5	-0.1	0.0	0.1	-0.3	0.0	0.0	1.2	-0.6	0.1	0.1	NA
08/04/87	2.0	-0.1	0.0	0.1	-0.3	0.0	0.0	1.6	-0.2	0.1	0.1	NA
08/05/87	1.8	-0.1	0.0	0.1	-0.3	0.0	0.0	1.3	NA	0.1	0.1	NA
08/11/87	1.6	-0.1	0.0	0.1	-0.3	0.0	0.0	1.3	NA	0.1	0.0	2.6
08/17/87	0.6	-0.1	0.0	0.1	-0.3	0.0	0.0	1.0	NA	0.1	0.1	2.0
08/24/87	0.8	-0.1	0.0	0.1	-0.3	0.0	0.0	1.2	NA	0.1	0.0	2.0
08/28/87	0.9	-0.1	0.0	0.1	-0.3	0.0	0.0	1.3	NA	0.1	0.1	1.9
09/02/87	0.9	-0.1	0.0	0.1	-0.3	0.0	0.0	1.3	1.9	0.1	NA	2.0
09/09/87	0.7	-0.1	0.0	0.1	-0.3	0.0	0.0	1.2	1.1	0.1	0.3	1.8
09/10/87	0.5	-0.1	0.0	0.1	-0.3	0.0	0.0	1.1	0.9	0.1	0.4	1.7
09/14/87	0.4	-0.1	NA	0.1	-0.3	0.0	0.0	1.3	0.8	0.1	0.5	1.8
09/17/87	-0.2	-0.1	NA	0.0	-0.3	0.1	0.0	1.0	0.3	0.1	0.2	1.4
09/23/87	-0.1	0.0	NA	0.0	-0.3	0.0	0.0	1.1	0.2	0.1	0.3	1.5
09/28/87	0.0	0.0	1.2	0.1	-0.3	0.1	0.0	0.9	-0.1	0.1	0.1	1.2
10/02/87	0.1	0.0	1.3	0.1	-0.3	0.0	0.0	1.0	0.0	0.1	0.2	1.3
10/07/87	0.7	0.0	1.4	NA	NA	0.0	0.0	1.2	0.1	0.0	0.3	1.4
10/12/87	-0.2	0.0	1.4	NA	NA	0.1	0.0	1.1	0.0	0.0	0.3	1.4
10/14/87	0.2	0.0	1.0	NA	NA	0.0	0.0	1.1	-0.1	0.1	0.2	1.2
10/16/87	0.6	0.0	1.3	NA	NA	0.1	NA	0.9	-0.2	0.1	0.1	1.0
10/21/87	-0.4	-0.1	1.2	NA	NA	0.0	NA	0.9	-0.3	0.1	0.0	0.1
10/23/87	0.4	-0.1	1.4	NA	-0.5	0.0	NA	1.0	-0.1	0.0	0.1	0.1
10/26/87	0.0	0.0	1.0	NA	-0.5	0.0	NA	0.5	-0.5	0.0	-0.3	0.0
10/27/87	0.3	0.0	1.2	NA	-0.3	0.0	NA	0.8	-0.3	0.1	-0.1	0.1
10/30/87	0.4	0.0	1.3	2.0	-0.2	0.0	NA	1.0	-0.2	0.1	0.0	0.0
11/02/87	0.1	0.0	1.1	2.0	-0.3	0.0	NA	0.7	-0.4	0.1	-0.1	0.0
11/03/87	0.2	NA	1.0	1.9	-0.4	NA	NA	0.6	-0.5	0.1	-0.2	0.0
11/06/87	0.1	NA	1.1	2.0	-0.3	NA	1.9	0.7	-0.4	0.1	-0.1	0.0
11/10/87	0.0	NA	0.8	1.6	-0.6	NA	1.2	0.3	-0.8	0.1	-0.5	0.0
11/16/87	NA	1.4	1.0	2.0	-0.2	NA	1.3	0.7	-0.2	0.1	-0.1	0.0
11/17/87	NA	0.8	0.7	1.7	-0.6	1.2	0.9	0.3	-0.6	0.0	-0.6	0.1

TABLE D.2. Continued

Oven Gage Pressure, inches of Mercury												
Date	Oven 1	Oven 2	Oven 3	Oven 4	Oven 5	Oven 6	Oven 7	Oven 8	Oven 9	Oven 10	Oven 11	Oven 12
11/18/87	NA	0.6	0.6	1.6	-0.6	-0.2	0.9	0.3	-0.6	0.1	-0.6	0.1
11/20/87	NA	0.8	0.9	2.0	-0.3	0.2	1.2	0.6	-0.2	0.1	-0.1	0.1
12/02/87	2.9	0.9	0.9	2.0	-0.3	0.4	1.3	0.0	0.0	0.1	-0.1	0.0
12/03/87	2.7	0.9	0.8	2.0	-0.4	0.5	1.4	0.0	0.0	0.1	-0.1	0.0
12/07/87	1.4	0.7	0.7	1.9	-0.6	0.0	0.9	-0.2	-0.2	0.1	-0.3	0.1
12/08/87	1.5	0.7	0.7	1.8	-0.5	0.1	1.3	-0.2	-0.2	NA	-0.3	0.1
12/09/87	1.8	1.1	1.0	2.2	-0.2	0.5	1.7	0.1	0.1	NA	0.1	0.1
12/14/87	1.0	0.6	0.4	1.5	-0.5	0.0	0.5	-0.4	-0.4	NA	-0.7	0.3
12/15/87	0.9	0.7	0.5	1.7	-0.3	0.1	0.9	NA	-0.3	1.3	-0.5	0.3
12/18/87	0.7	0.5	0.4	1.6	-0.3	0.1	0.6	NA	-0.3	1.1	-0.6	0.3
12/22/87	0.6	0.5	0.3	1.6	-0.3	0.1	0.5	NA	-0.3	1.0	-0.6	0.3
12/23/87	0.2	0.3	0.0	1.2	-0.3	-0.2	0.2	NA	-0.7	0.7	-1.0	0.3
12/30/87	0.4	0.4	0.1	1.4	-0.3	0.0	0.3	NA	-0.3	0.8	-0.9	0.5
01/04/88	0.2	0.2	-0.1	1.3	-0.3	-0.2	0.2	NA	-0.4	0.7	-1.1	0.6
01/07/88	0.1	0.3	0.0	1.2	-0.3	-0.1	-0.8	NA	-0.3	0.7	-1.0	0.5
01/08/88	0.2	0.5	0.0	1.4	-0.3	0.1	0.1	NA	0.0	0.9	-0.9	0.6
01/11/88	0.8	0.9	0.4	1.8	-0.3	0.7	0.5	NA	0.0	1.5	-0.1	0.6
01/12/88	0.1	0.3	0.0	1.3	-0.3	0.1	-0.1	NA	0.0	1.3	0.0	0.6
01/13/88	0.1	0.6	0.0	1.3	-0.3	0.3	0.0	NA	0.0	1.4	0.0	0.5
01/15/88	0.7	0.9	0.3	1.7	-0.3	0.3	0.3	NA	0.0	1.2	0.0	0.6
01/18/88	0.4	0.9	0.1	1.5	-0.3	0.1	0.0	NA	-0.1	1.1	0.0	0.6
01/19/88	0.0	0.5	-0.3	1.0	-0.3	-0.2	-0.3	NA	0.0	0.6	0.0	0.5
01/20/88	0.1	0.7	-0.1	1.3	-0.3	0.4	-0.2	NA	0.0	0.8	0.0	0.6
01/22/88	0.2	0.6	-0.2	1.2	-0.3	-0.2	-0.3	NA	0.0	0.6	0.0	0.6
01/25/88	0.1	0.6	-0.3	1.0	-0.3	0.1	-0.2	3.0	0.0	0.6	0.0	NA
01/28/88	0.6	0.9	0.1	1.6	-0.3	0.6	0.3	2.7	0.0	1.2	0.0	NA
01/29/88	0.6	1.1	0.2	1.6	-0.3	0.8	0.4	2.7	0.0	1.3	0.0	NA
02/01/88	0.2	0.7	-0.2	1.1	-0.3	0.0	-0.2	2.1	0.0	0.7	0.0	NA
02/02/88	0.1	0.5	-0.3	1.0	-0.3	-0.1	-0.3	2.0	-0.1	0.7	0.0	NA
02/03/88	0.1	0.8	-0.3	1.1	-0.3	-0.2	-0.3	1.9	0.0	0.6	0.0	NA
02/05/88	-0.1	0.2	-0.5	0.9	-0.3	-0.4	-0.5	1.6	0.0	0.4	0.0	NA
02/08/88	0.1	0.7	-0.3	1.2	-0.3	0.0	-0.1	1.8	0.0	0.8	0.0	NA
02/09/88	0.3	0.8	-0.2	1.2	-0.3	0.1	0.0	1.8	0.0	0.8	0.0	NA
02/10/88	0.0	0.5	-0.4	1.1	-0.3	-0.2	-0.3	1.5	0.0	0.6	0.0	NA
02/16/88	0.0	0.6	-0.4	1.0	-0.3	-0.1	-0.4	1.3	0.0	0.5	0.0	NA
02/18/88	-0.1	0.5	-0.6	0.9	-0.3	-0.3	-0.3	1.0	-0.1	0.5	NA	0.0
02/19/88	0.0	0.5	-0.5	0.9	-0.3	-0.2	-0.3	1.0	0.0	0.5	NA	-0.2
02/22/88	0.1	0.7	-0.4	1.0	-0.3	0.0	-0.1	1.2	0.0	0.9	NA	-0.4
02/23/88	0.0	0.5	-0.4	1.0	-0.3	-0.1	-0.3	1.1	0.0	0.6	NA	-0.7
02/25/88	0.0	0.5	-0.4	1.0	-0.3	-0.1	-0.2	1.1	0.0	0.7	NA	-1.1
02/29/88	0.2	0.8	-0.2	1.3	-0.3	0.1	0.0	1.3	0.0	1.1	NA	-1.4
03/02/88	0.1	0.6	-0.4	1.1	-0.3	0.0	-0.2	1.1	0.0	0.9	NA	-1.8
03/04/88	0.2	0.7	-0.3	1.1	-0.3	0.0	-0.1	1.1	0.0	1.1	NA	-2.1
03/08/88	0.0	0.6	-0.4	1.0	-0.3	-0.1	-0.3	0.9	0.0	0.3	NA	-2.7
03/09/88	0.1	0.5	-0.4	1.0	-0.3	0.0	-0.3	0.9	0.0	0.9	NA	-2.8
03/10/88	-0.1	0.3	-0.6	0.8	-0.3	-0.2	-0.4	0.7	0.0	0.6	NA	-3.1
03/11/88	-0.2	0.4	-0.6	0.8	-0.3	-0.2	-0.5	0.6	0.0	0.6	NA	-3.3
03/14/88	0.1	0.6	-0.4	1.0	-0.3	-0.1	-0.2	0.9	0.0	0.9	NA	-3.2
03/15/88	0.0	0.6	-0.4	1.0	-0.3	0.0	-0.2	0.8	0.0	0.9	NA	-3.4
03/16/88	-0.1	0.5	-0.7	0.9	-0.3	-0.2	-0.6	0.6	0.0	0.6	NA	-3.7
03/17/88	-0.3	0.2	-0.8	0.7	-0.3	-0.4	-0.7	0.4	0.0	0.5	NA	-4.0
03/21/88	0.2	0.7	-0.4	1.1	-0.3	0.0	-0.2	0.7	NA	1.1	NA	-3.7
03/22/88	0.3	0.7	-0.4	1.2	-0.4	0.1	-0.1	0.8	NA	1.7	NA	-3.7
03/23/88	0.4	0.9	-0.3	1.2	-0.3	0.0	-0.1	0.8	NA	1.9	NA	-3.7
03/24/88	0.0	0.6	-0.6	0.9	-0.3	0.0	-0.5	0.5	NA	0.7	NA	-4.2
03/28/88	-0.2	0.3	-0.7	0.7	-0.3	0.0	-0.6	0.2	NA	0.4	NA	-4.6
03/29/88	0.3	0.8	-0.4	1.1	-0.3	0.0	-0.2	0.6	NA	1.0	NA	-4.1
03/30/88	-0.1	0.4	-0.7	0.9	-0.3	0.0	-0.5	0.3	NA	0.4	NA	-4.6
03/31/88	0.0	0.3	-0.7	0.8	-0.3	0.0	-0.4	0.3	NA	0.5	NA	-4.6

TABLE D.2. Continued

Oven Gage Pressure, inches of Mercury												
Date	Oven 1	Oven 2	Oven 3	Oven 4	Oven 5	Oven 6	Oven 7	Oven 8	Oven 9	Oven 10	Oven 11	Oven 12
04/01/88	0.0	0.5	-0.5	1.0	-0.3	0.1	-0.3	0.5	NA	0.6	NA	-4.4
04/04/88	0.2	0.9	-0.1	1.1	-0.3	0.0	-0.2	0.5	NA	0.8	NA	-4.3
04/06/88	0.1	0.6	0.0	1.3	-0.3	0.0	0.0	0.5	NA	1.4	0.0	NA
04/07/88	-0.1	0.4	0.0	0.9	-0.3	0.0	-0.3	0.2	3.2	0.5	0.0	NA
04/08/88	-0.1	0.3	0.0	0.7	-0.3	0.1	-0.4	-0.1	2.9	0.8	0.0	NA
04/11/88	0.0	0.5	0.0	1.0	-0.3	0.0	-0.2	0.2	3.1	0.8	0.0	NA
04/12/88	0.1	0.7	0.0	1.1	-0.3	0.0	-0.1	0.3	3.1	0.5	0.0	NA
04/13/88	0.2	0.8	0.0	1.3	-0.3	0.0	0.2	0.4	3.2	0.7	0.0	NA
04/14/88	0.2	0.8	0.0	1.3	-0.3	0.0	0.2	0.4	3.1	0.7	0.1	NA
04/15/88	0.1	0.6	0.0	1.1	-0.3	0.0	0.0	0.3	2.9	0.6	0.1	NA
04/18/88	0.1	0.7	0.0	1.1	-0.3	0.0	-0.1	0.1	2.6	0.9	0.1	NA
04/19/88	0.3	0.8	0.0	1.3	-0.3	0.0	0.0	0.3	2.7	1.3	0.1	NA
04/20/88	0.3	0.8	0.0	1.4	-0.3	0.0	0.4	0.5	2.8	1.2	0.1	NA
04/21/88	0.5	0.9	0.0	NA	-0.4	0.0	0.5	0.5	2.8	1.4	0.1	NA
04/26/88	0.0	0.4	0.0	NA	-0.3	0.0	-0.2	-0.1	1.9	0.8	0.1	NA
04/27/88	0.2	0.8	0.0	NA	-0.3	0.1	0.0	0.1	2.1	1.1	0.0	NA
04/28/88	0.2	0.9	0.0	NA	-0.3	0.1	0.2	0.2	2.2	1.0	0.1	NA
05/02/88	-0.1	0.1	0.0	NA	-0.3	0.0	-0.3	-0.3	1.5	0.4	0.0	NA
05/03/88	0.0	0.3	0.0	NA	-0.3	0.1	-0.1	-0.1	1.7	0.5	0.0	NA
05/06/88	0.2	0.8	0.0	NA	-0.3	0.0	0.1	0.0	1.7	0.8	0.0	NA
05/09/88	0.0	0.5	0.0	NA	-0.3	0.0	-0.2	-0.2	1.4	0.3	0.1	NA
05/11/88	-0.3	0.3	0.0	NA	-0.4	0.0	-0.1	-0.2	1.4	1.0	0.1	2.7
05/12/88	-0.1	0.4	0.0	NA	-0.5	0.0	0.3	0.1	1.6	1.2	0.1	2.5
05/13/88	-0.2	0.3	0.0	NA	-0.5	0.0	0.0	-0.2	1.2	0.9	0.1	2.1
05/16/88	0.1	0.6	0.0	NA	-0.6	0.0	0.3	0.1	1.5	1.2	0.1	1.9
05/17/88	-0.1	0.1	0.0	NA	-0.6	0.0	0.0	-0.2	1.0	0.8	0.1	1.5
05/18/88	-0.2	0.1	0.0	0.0	-0.6	0.1	-0.2	-0.3	1.0	2.8	0.1	1.2
05/19/88	-0.3	0.0	0.0	NA	-0.6	0.1	-0.2	-0.4	0.8	0.5	0.1	0.8
05/24/88	0.0	0.4	0.0	NA	-0.6	0.1	-0.1	-0.2	0.9	0.8	0.1	0.6
05/25/88	0.0	0.6	0.0	3.2	-0.6	0.1	0.0	-0.1	1.0	1.6	0.1	0.5
05/26/88	0.0	0.6	0.0	3.2	-0.6	0.0	0.0	-0.2	0.9	0.8	0.1	0.5
05/31/88	-0.1	0.8	0.0	3.2		0.1	-0.1	-0.2	0.7	2.7	0.1	0.2
06/02/88	-0.4	0.3	0.0	2.9	NA	0.0	-0.2	-0.3	0.5	2.4	0.1	-0.1
06/03/88	-0.3	0.4	0.0	2.9	NA	0.0	-0.1	-0.3	0.5	0.2	0.1	-0.2
06/06/88	-0.3	0.6	0.0	2.9	0.0	0.0	-0.1	-0.2	0.6	0.5	0.1	-0.4
06/09/88	-0.4	0.5	NA	2.8	NA	0.1	-0.2	-0.3	0.5	0.4	0.1	-0.5
06/13/88	-0.4	0.2	NA	2.7	NA	0.1	-0.1	-0.4	0.3	0.2	0.1	-0.8
06/15/88	-0.2	0.3	NA	2.9	NA	0.0	0.0	-0.3	0.5	NA	0.1	-0.8
06/16/88	0.0	0.6	NA	3.0	4.5	0.0	0.3	-0.1	0.7	NA	0.1	-0.5
06/17/88	-0.1	0.5	NA	2.9	4.0	0.0	0.2	-0.2	0.6	NA	0.1	-0.6
06/20/88	-0.1	0.6	NA	2.9	3.8	0.0	0.1	-0.3	0.5	NA	0.1	-0.8
06/22/88	-0.2	0.5	NA	2.8	3.9	0.0	0.2	-0.3	0.4	NA	0.1	-0.8
06/24/88	-0.2	0.1	NA	2.6	3.3	0.1	0.0	-0.4	0.3	NA	0.1	-1.0
06/29/88	-0.2	0.1	NA	2.2	3.1	0.1	-0.2	-0.6	0.0	NA	0.1	-1.4
06/30/88	0.2	0.4	1.4	2.5	2.7	0.0	-0.1	0.4	0.2	NA	0.1	-1.2
07/05/88	0.1	0.7	1.3	2.3	2.4	0.0	-0.2	-0.5	0.1	NA	0.1	-1.3
07/06/88	-0.2	-0.2	1.0	2.0	2.5	0.1	-0.4	-0.7	0.0	NA	0.1	-1.7
07/07/88	0.0	0.2	1.1	2.0	2.4	0.1	-0.4	-0.7	0.0	NA	0.1	-1.7
07/12/88	0.0	0.1	1.2	2.1	2.3	0.1	-0.1	-1.0	0.0	NA	0.1	-1.6
07/13/88	-0.1	0.3	1.0	2.1	2.3	0.0	-0.1	-1.0	0.0	NA	0.1	-1.7
07/15/88	-0.1	0.0	0.8	2.0	1.9	0.0	0.0	-1.2	-0.1	NA	0.1	NA
07/20/88	0.0	-0.3	0.9	1.9	1.6	0.0	-0.1	-1.3	-0.1	3.7	0.1	NA
07/22/88	0.0	0.1	0.8	1.9	1.7	0.0	0.0	-1.3	-0.1	3.7	0.1	NA
07/26/88	0.0	-0.2	0.9	1.8	1.5	0.0	0.0	-1.2	0.0	4.8	0.1	NA
07/27/88	-0.1	0.0	0.9	1.9	1.5	0.0	0.0	-1.1	0.0	4.6	0.2	NA
07/28/88	0.0	-0.4	0.8	1.7	1.1	0.0	-0.1	-1.3	-0.2	3.5	0.1	NA
08/01/88	-0.1	-0.3	0.8	1.8	1.0	0.1	0.0	-1.3	-0.2	4.1	0.1	NA
08/02/88	0.0	-0.5	0.6	1.7	0.7	0.0	-0.1	-1.3	-0.1	3.3	0.1	NA
08/04/88	0.0	-0.3	0.7	1.9	0.8	0.0	NA	-1.2	0.0	3.3	0.1	1.0

TABLE D.2. Continued

Oven Gage Pressure, inches of Mercury												
Date	Oven 1	Oven 2	Oven 3	Oven 4	Oven 5	Oven 6	Oven 7	Oven 8	Oven 9	Oven 10	Oven 11	Oven 12
08/09/88	0.0	-0.4	0.5	1.7	0.6	0.0	NA	-1.2	0.0	3.2	0.1	0.6
08/11/88	0.0	-0.3	0.5	1.8	0.7	0.0	NA	-1.1	0.0	3.5	0.1	0.6
08/15/88	0.0	-0.2	0.5	1.7	0.8	0.0	2.7	-1.1	0.0	3.3	0.2	0.3
08/18/88	0.0	-0.4	0.2	1.4	0.6	0.0	0.0	-1.4	0.0	3.5	0.1	0.0
08/22/88	0.0	-0.4	0.2	1.3	0.4	0.1	-0.1	-1.4	0.0	3.2	0.1	-0.3
08/23/88	0.0	-0.4	0.2	1.3	0.4	0.1	0.0	-1.4	0.0	3.2	0.1	-0.3
08/24/88	0.0	-0.3	0.2	1.5	0.4	NA	0.0	-1.3	0.0	2.7	0.1	-0.2
08/25/88	0.0	-0.3	0.1	1.5	0.3	NA	0.0	-1.1	0.0	2.8	0.2	-0.2
08/30/88	-0.1	-0.6	0.0	1.4	0.2	NA	0.0	-1.2	-0.1	3.2	0.1	-0.6
09/01/88	-0.1	-0.7	-0.1	1.2	0.0	NA	-0.1	-1.3	-0.1	2.9	0.1	-0.7
09/02/88	-0.1	-1.0	-0.3	1.2	-0.4	NA	0.0	-1.2	0.0	2.2	0.1	-0.8
09/06/88	-0.1	-0.4	0.0	1.5	-0.2	NA	0.2	-0.9	-0.1	2.9	0.1	-0.7
09/07/88	-0.1	-0.5	-0.2	1.2	0.0	NA	0.0	-1.1	-0.1	2.5	0.1	-1.0
09/08/88	-0.1	-0.6	-0.2	1.2	-0.1	NA	0.0	-1.1	0.0	2.3	0.1	-0.9
09/09/88	-0.1	-0.4	-0.1	1.3	-0.1	NA	0.2	-1.0	-0.1	4.6	0.1	-0.9
09/12/88	-0.1	-0.8	-0.4	0.9	-0.5	NA	-0.1	-1.2	-0.1	3.0	0.1	-1.3
09/14/88	-0.1	-0.5	-0.3	1.2	-0.4	NA	0.1	-1.0	0.0	2.4	0.1	-1.3
09/16/88	-0.1	-0.5	-0.3	1.0	-0.4	NA	0.1	-1.1	-0.1	2.9	0.1	-1.4
09/19/88	-0.1	-0.4	0.0	1.2	-0.2	NA	0.4	-0.8	-0.1	3.3	0.1	-1.3
09/21/88	-0.1	-0.3	-0.3	1.0	-0.5	NA	0.0	-1.1	-0.1	2.1	0.1	-1.7
09/23/88	-0.1	NA	-0.4	1.1	-0.2	NA	0.2	-1.0	-0.1	2.2	0.1	-1.7
09/28/88	-0.1	NA	-0.9	0.6	-1.2	NA	-0.3	-1.5	-0.1	2.1	0.1	-2.5
09/30/88	-0.1	NA	-0.4	0.8	-0.9	NA	-0.1	-1.3	-0.1	1.9	0.1	-2.3
10/04/88	-0.1	NA	-0.5	1.0	-0.9	NA	0.2	-0.9	-0.1	2.4	0.1	-2.2
10/10/88	-0.1	NA	-0.6	0.9	-0.8	0.0	0.1	-1.0	-0.1	1.9	0.2	-2.5
10/11/88	NA	NA	-0.5	0.8	-0.9	0.6	0.1	-1.0	-0.1	2.2	0.1	-2.4
10/13/88	NA	NA	-0.7	1.1	-0.7	0.3	0.3	-0.8	-0.1	2.1	0.1	-2.2
10/18/88	NA	3.4	-1.0	0.7	-1.3	0.2	0.0	-1.1	-0.1	2.2	0.1	-2.5
10/20/88	NA	3.4	-1.0	0.7	-1.1	0.1	-0.1	-1.2	-0.1	2.2	-0.1	-2.6
10/24/88	NA	3.4	-1.2	0.7	-0.7	-0.2	-0.1	-1.1	-0.1	1.6	0.1	-2.6
10/25/88	NA	3.4	-1.1	0.7	-0.9	0.3	0.0	-1.0	-0.1	2.2	0.1	-2.5
10/31/88	NA	3.6	-0.9	0.9	-0.8	0.3	0.1	-0.7	-0.1	1.3	0.1	-2.4
11/01/88	NA	3.7	-0.7	1.1	-0.6	0.5	0.3	-0.5	-0.1	2.1	0.1	-1.9
11/02/88	2.8	3.9	-0.7	1.2	-0.6	0.3						NA
11/07/88	1.5	3.3	-1.2	0.8	-1.5	0.4	-0.1	-1.0	-0.1	1.4	0.1	NA
11/09/88	1.4	3.4	-1.2	0.7	-1.4	0.5	0.0	-1.0	-0.1	1.3	0.1	NA
11/11/88	1.2	3.4	-1.2	0.7	-1.2	-0.1	0.0	-0.8	-0.1	-0.2	0.1	NA
11/14/88	1.0	3.4	-1.2	0.8	-1.1	0.2	0.0	-0.4	-0.1	-0.2	0.1	NA
11/15/88	0.9	3.3	-1.2	0.7	-1.5	0.4	0.0	-0.2	-0.1	-0.3	0.1	NA
11/17/88	1.0	3.4	-1.2	0.8	-1.3	0.5	0.1	0.0	-0.1	0.1	0.1	NA
11/18/88	0.7	3.1	-1.4	0.6	-1.4	0.3	-0.2	0.0	NA	-0.7	0.1	3.3
11/22/88	1.3	3.9	-0.7	1.4	-0.6	1.1	0.5	0.0	NA	0.4	0.1	4.2
11/28/88	0.3	3.1	-1.6	0.6	-1.4	0.0	-0.3	0.0	NA	-0.7	0.1	3.1
11/30/88	0.0	2.8	-1.8	0.2	-2.0	-0.1	-0.7	0.0	NA	-0.4	0.1	2.7
12/01/88	0.0	3.0	-1.5	0.4	-1.8	0.0	-0.4	0.0	NA	-0.4	0.0	3.0
12/07/88	-0.2	2.7	-1.8	0.1	-1.9	-0.4	-0.7	0.0	NA	-1.1	0.1	2.5
12/08/88	-0.1	2.8	-1.7	0.3	-1.8	-0.2	-0.6	0.0	NA	-0.3	0.1	2.7
12/09/88	0.1	2.9	-1.7	0.4	-1.8	0.0	-0.5	0.0	NA	-0.7	0.1	2.8
12/13/88	0.3	3.0	-1.6	0.4	-1.2	-0.3	-0.3	0.0	NA	-1.1	0.1	2.8
12/14/88	-0.3	2.7	-1.9	0.2	-1.9	-0.1	-0.7	0.0	NA	-1.1	0.0	2.4
12/16/88	-0.1	2.6	-2.1	0.1	-1.7	-0.7	-0.9	0.0	NA	-1.4	0.0	2.3
12/19/88	0.5	3.2	-1.4	0.7	-1.0	0.0	-0.1	0.0	NA	-0.2	0.0	3.2
12/21/88	0.5	3.3	-1.3	0.7	-0.9	0.4	0.0	0.0	NA	0.2	0.1	3.3
12/22/88	0.6	3.4	-1.2	0.9	-0.8	0.5	0.1	0.0	NA	-0.2	0.0	3.4
12/28/88	0.0	2.8	-1.8	0.3	-1.5	0.2	-0.6	0.0	NA	-1.1	0.0	3.4
12/30/88	0.6	3.4	-1.2	0.8	-0.9	0.0	0.1	0.0	NA	0.5	0.0	4.0
01/03/89	0.1	3.0	-1.6	0.6	-1.2	0.1	-0.3	0.0	NA	-1.1	0.1	3.7
01/04/89	0.2	3.1	-1.6	0.6	-1.1	0.2	-0.2	0.0	NA	-0.9	0.0	3.8
01/06/89	0.1	3.0	-1.6	0.6	-1.2	0.1	-0.2	0.0	NA	-0.5	0.0	3.8

TABLE D.2. Continued

Oven Gage Pressure, inches of Mercury												
Date	Oven 1	Oven 2	Oven 3	Oven 4	Oven 5	Oven 6	Oven 7	Oven 8	Oven 9	Oven 10	Oven 11	Oven 12
01/09/89	0.1	3.1	-1.6	0.7	-1.2	0.9	-0.1	0.0	NA	-0.9	0.0	4.3
01/10/89	0.0	2.9	-1.8	0.4	-1.2	0.0	-0.3	0.0	NA	0.2	0.0	3.9
01/11/89	-0.3	2.6	-2.1	0.2	-1.5	-0.3	-0.6	0.0	NA	-0.3	0.0	3.6
01/12/89	-0.4	2.6	-2.2	0.1	-1.6	-0.2	-0.7	0.0	NA	-1.4	0.0	3.5
01/13/89	0.2	3.1	-1.5	0.6	-0.9	0.4	-0.1	0.0	NA	-0.9	0.1	4.2
01/16/89	0.0	3.0	-1.7	0.5	-1.2	-0.1	-0.3	0.0	NA	-0.5	0.1	4.0
01/17/89	0.0	2.8	-1.9	0.3	-1.2	-0.3	-0.4	0.0	NA	0.4	0.1	3.7
01/19/89	-0.1	2.7	-2.0	0.2	-1.7	0.0	-0.5	NA	NA	-1.5	0.1	3.5
01/24/89	-0.1	2.7	-1.9	0.2	-1.3	0.0	-0.5	NA	NA	-1.8	0.1	3.5
01/25/89	-0.2	2.7	-2.0	0.1	-1.5	0.3	-0.6	NA	NA	-1.6	0.0	3.3
01/31/89	0.4	3.1	-1.5	0.6	-1.1	0.5	0.0	NA	0.0	-0.2	0.0	4.0
02/01/89	0.1	2.9	-1.8	0.4	-1.1	0.2	-0.1	NA	0.0	-1.2	0.0	3.8
02/02/89	-0.3	2.5	-2.3	0.1	-1.6	-0.6	-0.6	NA	0.0	-1.6	0.0	3.2
02/06/89	-0.7	2.3	-2.6	-0.2	-2.0	-0.7	-0.8	NA	0.0	-1.5	0.0	2.9
02/07/89	-0.5	2.5	-2.2	-0.1	-1.7	0.0	-0.7	NA	0.0	-1.5	0.0	3.0
02/08/89	-0.6	2.4	-2.5	-0.2	-1.7	0.1	-0.8	NA	0.0	0.3	0.0	2.9
02/09/89	-0.4	2.5	-2.0	0.0	-1.5	-0.5	-0.6	NA	0.0	-1.3	0.0	3.1
02/10/89	-0.4	2.5	-2.2	-0.1	-1.6	-0.3	-0.6	NA	0.0	0.1	0.0	3.0
02/13/89	0.0	2.7	-2.1	0.2	-1.4	-0.1	-0.2	NA	0.0	0.6	0.0	3.3
02/16/89	-0.1	2.7	-1.5	0.2	-1.3	0.0	-0.3	NA	0.0	0.0	0.0	3.3
02/21/89	-0.1	2.5	-2.3	0.0	-1.5	0.0	-0.4	NA	0.0	-0.3	0.1	3.1
02/22/89	0.1	2.8	-2.0	0.3	-1.1	0.2	-0.1	NA	0.0	0.5	0.1	NA
02/23/89	0.1	2.8	-2.0	0.2	-1.3	0.4	-0.1	NA	0.0	-0.8	0.0	NA
02/28/89	0.1	2.8	-2.0	0.2	-1.1	0.2	-0.1	NA	0.0	-1.5	0.0	NA
03/02/89	0.6	3.0	-1.6	0.5	-0.6	0.0	0.2	NA	0.0	-1.9	0.0	NA
03/03/89	0.2	2.6	-1.9	0.1	-0.9	-0.1	-0.3	4.6	0.0	-0.9	0.0	NA
03/07/89	0.4	2.7	-1.8	0.3	-1.3	0.2	-0.1	4.3	0.0	-1.4	0.1	NA
03/08/89	0.5	2.8	-1.8	0.3	-1.0	-0.1	0.0	4.3	0.0	-0.5	0.1	NA
03/09/89	0.6	2.9	-1.5	0.5	-0.8	0.1	0.1	4.4	0.0	-1.4	0.1	NA
03/10/89	0.3	2.7	-1.8	0.3	-1.1	-0.2	-0.1	4.0	0.0	-0.7	0.1	NA
03/13/89	0.5	2.8	-1.7	0.4	-0.8	-0.1	-0.1	3.8	0.0	-0.7	0.1	NA
03/14/89	0.3	2.6	-1.9	0.2	-1.1	0.0	-0.2	3.5	0.0	-0.4	0.1	NA
03/16/89	0.4	2.8	-1.9	0.4	-1.2	0.0	0.0	3.6	0.0	0.0	NA	NA
03/20/89	0.1	2.5	-2.1	0.1	-1.3	0.1	-0.4	2.9	0.0	-0.5	NA	NA
03/23/89	0.3	2.6	-2.0	0.3	-1.2	0.2	-0.2	3.0	0.0	-0.7	NA	NA
03/27/89	0.3	2.7	-1.9	0.4	-0.9	-0.1	-0.1	2.9	0.0	0.2	NA	4.4
03/29/89	0.1	2.5	-2.1	0.0	-1.2	0.0	-0.4	2.5	0.0	0.2	0.0	3.9
03/30/89	0.0	2.5	-2.1	0.1	-1.2	0.0	-0.3	2.6	0.0	-0.6	0.0	3.9
03/31/89	0.2	2.6	-2.0	0.2	-1.2	-0.1	0.0	2.6	0.0	0.1	0.0	3.8
04/03/89	0.0	2.4	-2.1	-0.1	-1.2	0.0	-0.7	2.3	0.0	-1.3	NA	3.5
04/05/89	0.2	2.5	-2.0	0.1	-1.0	0.0	-0.5	2.4	0.1	0.2	NA	3.4
04/07/89	0.0	2.4	-2.2	0.0	-1.1	0.0	-0.6	2.2	0.0	0.0	NA	3.2
04/10/89	0.0	2.4	-2.1	0.0	-1.3	0.1	-0.5	2.2	0.1	0.1	NA	3.2
04/13/89	-0.1	2.5	-2.1	0.1	-1.2	0.0	-0.3	2.3	0.1	0.0	NA	3.2
04/19/89	0.3	2.6	-2.0	0.0	-0.8	0.0	-0.2	2.2	0.1	-1.9	0.1	2.8
04/20/89	0.4	2.7	-1.9	0.1	-0.7	0.0	-0.2	2.3	0.1	-1.5	0.1	2.9
04/24/89	0.3	2.6	-1.9	0.1	-1.0	0.0	-0.2	2.2	0.1	-0.9	0.1	2.6
04/26/89	0.1	2.5	-2.1	0.0	-1.1	0.0	-0.4	1.9	0.0	-0.5	0.1	2.2
04/28/89	-0.1	2.2	-2.3	0.0	-1.3	0.0	-0.5	1.7	0.0	-0.1	0.1	1.9
05/01/89	0.1	2.5	-2.1	0.0	-0.9	0.0	-0.3	1.9	0.0	-0.8	0.1	2.2
05/04/89	0.0	2.4	-2.2	0.1	-0.9	0.2	-0.3	1.8	0.0	-0.5	0.1	2.1
05/05/89	0.1	2.5	-2.1	0.0	-0.9	0.2	-0.3	1.9	0.0	-1.5	0.1	2.2
05/08/89	0.1	2.4	-2.1	0.0	-0.9	0.1	-0.2	1.8	0.0	-0.2	0.1	2.3
05/09/89	0.2	2.6	-2.0	0.1	-0.7	0.0	0.0	2.0	0.0	-1.4	0.1	2.5
05/12/89	0.0	2.2	-2.1	NA	-1.1	0.0	-0.2	1.7	0.0	0.0	0.1	1.9
05/15/89	0.1	2.4	-2.1	0.0	-0.8	0.1	-0.1	1.8	0.0	-0.6	0.1	1.9
05/17/89	0.1	2.5	-1.9	0.0	-0.8	0.0	0.0	1.8	0.0	0.1	0.1	2.0
05/18/89	-0.1	2.3	-2.0	0.0	-1.1	-0.1	-0.2	1.7	0.0	-1.1	0.1	2.3
05/19/89	-0.2	2.1	-2.3	0.0	-1.1	0.0	-0.4	1.5	0.0	-0.8	0.1	2.3

TABLE D.2. Continued

Oven Gage Pressure, inches of Mercury												
Date	Oven 1	Oven 2	Oven 3	Oven 4	Oven 5	Oven 6	Oven 7	Oven 8	Oven 9	Oven 10	Oven 11	Oven 12
05/26/89	NW	NW	NW	NA	NW	NW	-0.2	NA	1.5	0.0	0.1	2.3
05/31/89	NW	NW	NW	NW	NW	NW	-0.3	1.3	0.0	-0.5	0.1	2.0
06/02/89	NW	2.3	-2.1	NA	NW	0.0	-0.1	1.4	0.0	0.1	0.1	2.2
06/05/89	NW	2.4	-2.0	NW	NW	0.0	0.0	1.6	0.0	0.1	0.1	2.4
06/07/89	NW	2.3	-2.0	NW	NW	0.0	0.0	1.4	0.0	0.1	0.1	2.2
06/12/89	NW	2.3	-2.1	NA	NW	0.0	-0.1	1.3	0.0	0.2	0.1	1.7
06/15/89	NW	2.3	-2.0	NW	NW	-0.1	-0.1	1.2	0.0	-0.5	0.1	-0.1
06/16/89	NW	2.1	-2.1	NW	NW	0.0	-0.3	0.8	0.0	-0.8	0.1	-0.6
06/19/89	NW	2.2	-1.9	NW	NW	0.0	-0.2	0.5	0.0	-1.2	0.1	-0.6
06/21/89	NW	2.0	-2.1	NW	NW	0.0						NA
06/23/89	NW	2.2	-2.1	NW	NW	0.0	-0.3	0.2	0.0	0.1	0.1	NA
06/26/89	NW	2.4	-1.9	NW	NW	0.1	0.0	0.4	0.0	0.0	0.1	NA
06/30/89	NW	1.6	-1.9	NW	NW	0.1	-0.1	0.3	0.0	0.0	0.1	NA
07/07/89	NW	0.6	-1.9	NW	NW	0.0	-0.2	0.0	0.0	0.1	0.1	NA
07/10/89	NW	0.5	-1.9	NW	NW	0.0	-0.1	0.1	0.0	-0.1	0.1	NA
07/12/89	NW	0.3	-1.9	NW	NW	0.0	0.0	0.0	0.0	0.0	0.1	NA
07/13/89	NW	0.4	-2.0	NW	NW	0.0	-0.1	0.0	0.0	0.1	0.1	NA
07/18/89	NW	0.2	-2.1	NW	NW	0.0	-0.1	-0.1	0.0	-0.4	0.1	NA
07/20/89	NW	0.3	-1.8	NW	NW	0.0	0.0	0.0	0.0	0.1	0.1	3.0
07/21/89	NW	0.1	-2.1	NW	NW	0.0	0.0	0.0	0.0	0.1	0.1	3.0
07/25/89	NW	0.0	-2.3	NW	NW	0.0	0.0	0.0	0.0	0.0	0.1	2.7
07/26/89	NW	0.1	-2.1	NW	NW	0.0	0.0	0.0	0.0	0.1	0.1	2.9
07/28/89	NW	0.0	-2.1	NW	NW	0.0	0.0	0.0	0.0	0.0	0.1	2.6
08/01/89	NW	0.0	-2.2	NW	NW	0.1	0.0	0.0	0.0	0.0	0.1	2.8
08/03/89	NW	0.0	-2.2	NW	NW	0.1	0.0	0.0	0.0	0.1	0.1	2.7
08/09/89	NW	0.0	0.0	NW	NW	0.0	0.0	0.0	0.0	0.0	0.1	3.1
08/10/89	NW	0.0	0.0	NW	NW	0.0	0.0	0.0	0.0	-0.2	0.1	3.5
08/11/89	NW	-0.1	0.0	NW	NW	0.0	0.0	0.0	0.0	0.1	0.1	3.4
08/15/89	NW	0.0	0.0	NW	NW	0.1	0.0	0.0	0.0	0.1	0.1	3.5
08/18/89	NW	0.0	0.0	NW	NW	0.1	0.0	0.0	0.0	0.1	0.1	3.7
08/25/89	NW	0.0	0.0	NW	NW	0.0	0.0	0.0	0.0	0.1	0.1	3.6
08/29/89	NW	0.0	0.0	NW	NW	0.0	0.0	0.0	0.0	0.1	0.1	3.6
09/05/89	NW	0.0	0.0	NW	NW	0.0	0.0	0.0	0.0	0.1	0.1	NA
09/12/89	NW	0.0	0.0	NW	NW	0.1	0.0	0.0	0.0	0.1	0.1	NA
09/20/89	NW	0.0	0.0	NW	NW	0.1	0.0	0.0	0.0	0.1	0.1	NA
09/22/89	NW	0.0	0.0	NW	NW	0.1	0.0	0.0	0.0	0.1	0.1	NA
09/27/89	NW	0.0	0.0	NW	NW	0.1	0.0	0.0	0.0	0.0	0.1	NA
09/28/89	NW	0.0	0.0	NW	NW	31.0	0.0	0.0	0.0	0.0	0.1	1.3
10/04/89	NW	0.0	0.0	NW	NW	0.1	0.0	0.0	NA	0.1	0.1	1.2
10/10/89	NW	0.0	0.0	NW	NW	0.1	0.0	0.0	NA	0.0	0.1	1.1
10/13/89	NW	0.0	0.0	NW	NW	0.1	0.0	0.0	0.0	0.1	0.1	0.4
10/20/89	NW	0.0	NA	NW	NW	0.0	0.0	0.0	0.3	0.0	0.1	0.4
10/23/89	NW	0.1	NA	NW	NW	0.0	0.0	0.0	0.5	0.1	0.1	0.5
10/24/89	NW	0.0	NA	NW	NW	0.0	-0.3	0.0	0.1	0.1	0.1	0.4
10/27/89	NW	0.0	NA	NW	NW	0.0	-0.3	0.0	0.0	0.1	0.1	0.3
10/30/89	NW	0.0	NA	NW	NW	0.0	-0.5	0.0	-0.1	0.0	0.1	0.2
10/31/89	NW	0.0	NA	NW	NW	0.0	-0.7	0.0	-0.3	0.0	0.1	-0.1
11/01/89	NW	0.0	NA	NW	NW	0.0	-0.7	0.0	-0.2	0.1	0.1	0.0
11/06/89	NW	0.0	NA	NW	NW	0.0	0.0	0.0	0.4	0.0	0.1	0.7
11/13/89	NW	0.0	NA	NW	NW	0.0	-0.3	0.0	0.2	0.0	0.1	0.5
11/17/89	NW	0.0	NA	NW	NW		NA	0.0	0.0	0.0	0.1	0.1
11/27/89	NW	0.0	NA	NW	NW	0.0	NA	0.0	-0.3	0.0	0.1	-0.1
11/30/89	NW	0.0	NA	NW	NW	0.0	NA	0.0	-0.3	0.0	0.1	-0.2
12/01/89	NW	0.0	NA	NW	NW	0.1	NA	0.0	-0.4	0.1	0.1	-0.3
12/04/89	NW	0.1	NA	NW	NW	0.0	NA	0.0	0.3	0.1	0.1	0.4
12/05/89	NW	0.1	4.3	NW	NW	0.0	NA	0.0	0.0	0.1	0.1	0.0
12/12/89	NW	0.1	3.5	NW	NW	0.0	NA	0.0	-0.3	0.0	0.0	-0.2
12/14/89	NW	0.1	3.7	NW	NW	0.0	NA	0.0	-0.1	0.0	0.1	0.0
12/18/89	NW	0.1	4.0	NW	NW	-0.1	NA	0.0	0.0	0.0	0.1	0.1

TABLE D.2. Continued

Oven Gage Pressure, inches of Mercury												
Date	Oven 1	Oven 2	Oven 3	Oven 4	Oven 5	Oven 6	Oven 7	Oven 8	Oven 9	Oven 10	Oven 11	Oven 12
12/20/89	NW	0.1	3.5	NW	NW	-0.1	NA	0.0	0.0	0.0	0.0	-0.1
12/28/89	NW	0.1	3.0	NW	NW	-0.1	0.8	0.0	0.0	0.0	0.1	-0.2
01/08/90	NW	0.2	3.0	NW	NW	-0.2	1.2	0.0	0.3	0.0	0.1	0.0
01/10/90	NW	0.2	2.7	NW	NW	-0.2	0.9	0.0	0.0	0.1	0.1	-0.1
01/16/90	NW	0.2	3.1	NW	NW	-0.2	1.2	0.0	0.2	0.1	0.1	0.1
01/18/90	NW	0.1	2.8	NW	NW	-0.2	1.0	0.0	0.0	0.1	0.1	0.0
01/24/90	NW	0.2	2.4	NW	NW	-0.2	1.0	0.0	0.0	0.1	0.1	0.0
01/26/90	NW	0.1	2.7	NW	NW	-0.2	1.2	0.0	0.2	NA	0.1	0.0
01/31/90	NW	0.2	2.9	NW	NW	-0.2	1.6	0.0	0.4	NA	0.1	0.0
02/02/90	NW	0.2	2.7	NW	NW	-0.2	1.3	0.0	0.2	NA	0.1	0.0
02/07/90	NW	0.1	2.8	NW	NW	-0.2	1.5	0.0	0.3	NA	0.1	0.0
02/14/90	NW	0.1	2.5	NW	NW	-0.2	1.0	0.0	0.0	NA	0.0	0.1
02/20/90	NW	0.1	2.6	NW	NW	-0.1	1.2	0.0	0.1	NA	0.0	0.0
02/27/90	NW	NA	1.8	NW	NW	-0.1	0.7	0.0	-0.4	NA	0.1	0.0
03/02/90	NW	NA	2.1	NW	NW	-0.1	1.1	0.0	0.0	NA	0.0	0.0
03/06/90	NW	NA	3.1	NW	NW	-0.1	1.2	0.0	0.0	NA	0.1	0.0
03/08/90	NW	NA	3.5	NW	NW	-0.1	1.3	0.0	0.2	0.0	0.0	0.0
03/13/90	NW	0.1	2.0	NW	NW	-0.1	1.2	0.0	0.0	0.0	0.0	0.0
03/15/90	NW	NA	1.7	NW	NW	-0.1	1.0	0.0	-0.1	0.0	0.1	0.0
03/21/90	NW	NA	1.8	NW	NW	-0.1	1.2	0.0	0.0	0.1	0.0	0.0
03/22/90	NW	NA	2.0	NW	NW	-0.1	1.2	0.0	0.0	0.0	0.1	0.0
03/28/90	NW	NA	0.8	NW	NW	0.1	1.2	0.0	0.1	0.0	0.1	0.0
03/30/90	NW	NA	0.6	NW	NW	0.1	1.4	0.0	0.2	0.1	0.1	0.0
04/02/90	NW	NA	2.5	NW	NW	0.1	1.2	0.0	0.1	0.1	0.1	0.0
04/05/90	NW	NA	1.7	NW	NW	0.1	1.3	0.0	0.1	0.1	0.1	0.0
04/09/90	NW	NA	NW	NW	NW	NW	1.0	0.0	-0.1	0.1	0.1	0.0
04/10/90	NW	NW	NW	NW	NW	NW	1.0	0.0	-0.1	0.1	0.1	0.0
04/11/90	NW	NW	NW	NW	NW	NW	1.1	0.0	0.0	0.1	0.1	0.0
04/17/90	NW	NW	NW	NW	NW	NW	1.5	0.0	0.0	0.3	0.1	0.0
04/23/90	NW	NW	NW	NW	NW	NW	1.5	0.0	0.0	0.1	0.1	0.0
04/25/90	NW	NW	NW	NW	NW	NW	1.3	0.0	0.0	0.1	0.1	0.0
04/30/90	NW	NW	NW	NW	NW	NW	0.9	0.0	0.0	0.1	0.1	0.0
05/01/90	NW	NW	NW	NW	NW	NW	1.0	0.0	0.0	0.1	0.1	NA
05/02/90	NW	NW	NW	NW	NW	NW	1.2	0.0	0.0	0.0	0.1	NA
05/07/90	NA	NA	NW	NW	NW	NA	1.0	0.0	0.0	0.1	0.1	NA
05/15/90	NA	NA	NW	NW	NW	NW	0.9	0.0	0.0	0.1	0.1	NA
05/16/90	NA	NA	NW	NW	NW	NW	0.9	0.0	0.0	0.1	0.1	NA
05/21/90	NA	NA	NW	NW	NW	NW	0.9	NA	0.0	0.1	0.1	2.5
05/22/90	NW	NA	NW	NW	NW	NW	1.0	NA	0.0	0.1	0.1	2.5
05/25/90	NW	NA	NW	NW	NW	NW	1.0	NA	0.0	0.1	0.1	2.5
05/30/90	NW	NA	NW	NW	NW	NW	1.3	NA	0.0	0.1	0.1	2.6
06/04/90	NW	NA	NW	NW	NW	NW	0.8	NA	0.0	0.1	0.1	2.1
06/07/90	NW	NA	NW	NW	NW	NW	0.9	NA	0.0	0.1	0.1	2.1
06/11/90	NW	NA	NW	NW	NW	NW	0.8	NA	0.0	0.1	0.1	2.0
06/14/90	NW	NA	NW	NW	NW	NW	0.9	NA	0.0	0.1	0.1	2.0
06/25/90	NW	NA	NW	NW	NW	NW	0.9	NA	0.0	0.1	0.1	1.6
06/27/90	NW	NA	NW	NW	NW	NW	0.9	NA	0.0	0.1	NA	1.7
06/29/90	NW	NA	NW	NW	NW	NW	1.1	NA	-0.1	0.1	NA	1.7
07/02/90	NW	NA	NW	NW	NW	NW	0.8	NA	0.0	0.1	NA	1.5
07/09/90	NW	NA	NW	NW	NW	NW	0.6	NA	0.0	0.1	NA	2.9
07/12/90	NW	NA	NW	NW	NW	NW	0.6	NA	0.0	0.1	NA	NW
07/17/90	NW	NA	NW	NW	NW	NW	0.5	NA	0.0	0.1	NA	1.2
07/19/90	NW	NA	NW	NW	NW	NW	0.5	NA	0.0	0.4	NA	1.2
07/24/90	NW	NA	NW	NW	NW	NW	0.6	NA	0.0	0.1	NA	1.4
07/27/90	NW	NA	NW	NW	NW	NW	0.3	NA	0.0	0.1	NA	1.1
08/03/90	NW	NA	NW	NW	NW	NW	0.2	NA	NA	0.1	NA	0.9
08/07/90	NW	NA	NW	NW	NW	NW	0.3	NA	NA	0.1	NA	1.0
08/10/90	NW	NA	NW	NW	NW	NW	0.3	NA	NA	0.1	NA	1.0
08/16/90	NW	NA	NW	NW	NW	NW	NA	NA	NA	NA	NA	1.0

TABLE D.2. Continued

<u>Oven Gage Pressure, inches of Mercury</u>												
<u>Date</u>	<u>Oven 1</u>	<u>Oven 2</u>	<u>Oven 3</u>	<u>Oven 4</u>	<u>Oven 5</u>	<u>Oven 6</u>	<u>Oven 7</u>	<u>Oven 8</u>	<u>Oven 9</u>	<u>Oven 10</u>	<u>Oven 11</u>	<u>Oven 12</u>
08/20/90	NW	NA	NW	NW	NW	NW	NA	NA	NA	NA	NA	1.0
08/23/90	NW	NA	NW	NW	NW	NW	NA	NA	NA	NA	NA	NA
08/27/90	NW	NA	NW	NW	NW	NW	NA	NA	NA	NA	NA	NA
08/29/90	NW	NA	NW	NW	NW	NW	NA	NA	NA	NA	NA	NA
09/06/90	NW	NA	NW	NW	NW	NW	NA	NA	NA	NA	NA	NA
09/13/90	NW	NA	NW	NW	NW	NW	NA	NA	NA	NA	NA	NA
09/18/90	NW	NA	NW	NW	NW	NW	NA	NA		NA	NA	NA
09/21/90	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
09/25/90	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

NA = Not applicable because oven not operating

NW = Instrument not working

Oven 1 (150 C)

FIGURE D.1. Temperature History for Oven 1

FIGURE D.2. Temperature History for Oven 2

FIGURE D.3. Temperature History for Oven 3

Oven 4 (190 C)

FIGURE D.4. Temperature History for Oven 4

FIGURE D.5. Temperature History for Oven 5

FIGURE D.6. Temperature History for Oven 6

Oven 7 (150 C)

FIGURE D.7. Temperature History for Oven 7

FIGURE D.8. Temperature History for Oven 8

Oven 9 (210 C)

FIGURE D.9. Temperature History for Oven 9

FIGURE D.10. Temperature History for Oven 10

Oven 11(170 C)

FIGURE D.11. Temperature History for Oven 11

Oven 12 (230 C)

FIGURE D.12. Temperature History for Oven 12

Oven 1

FIGURE D.13. Oven Pressure History for Oven 1

FIGURE D.14. Oven Pressure History for Oven 2

Oven 3

FIGURE D.15. Oven Pressure History for Oven 3

Oven 4

FIGURE D.16. Oven Pressure History for Oven 4

Oven 5

FIGURE D.17. Oven Pressure History for Oven 5

Oven 6

FIGURE D.18. Oven Pressure History for Oven 6

Oven 7

FIGURE D.19. Oven Pressure History for Oven 7

D.56

Gage Pressure,
in. Hg

Oven 8

FIGURE D.20. Oven Pressure History for Oven 8

Oven 9

FIGURE D.21. Oven Pressure History for Oven 9

Oven 10

FIGURE D.22. Oven Pressure History for Oven 10

Oven 11

FIGURE D.23. Oven Pressure History for Oven 11

Oven 12

FIGURE D.24. Oven Pressure History for Oven 12

APPENDIX E

COVER GAS ANALYSES DATA

APPENDIX E

COVER GAS ANALYSES DATA

Cover gas analyses data are summarized in the attached tables. A gas sample was taken from each new commercial grade dry air bottle to determine the starting composition of the cover gas for each oven run drawn from that bottle. The mass spectrometer results for the bottle analyses are listed in Table E.1. The oven runs drawn from each bottle are presented in Table E.2.

Cover gas analyses were taken just prior to ending each oven run. The results are provided in Table E.3. Isotopic analyses of xenon and krypton fission gases in the end-of-run cover gases are presented in Tables E.4 and E.5, respectively. In some cases, the oven shutdown prematurely after hitting the upper temperature limit switch. The reduced oven pressure (due to cooling) prevented sampling.

The presence of fluorine in the cover gas samples was not reported. This was because no fluorine was detected by the mass spectrometer equipment, not because the equipment was incapable of detecting fluorine. The probable cause of not detecting fluorine is the reactive nature of fluorine, i.e., the fluorine reacted with other materials and, therefore, was removed from the cover gas samples prior to mass spectrometry analysis.

TABLE E.1. Bottle Gas Analyses

<u>Bottle</u>	<u>Date Analyzed</u>	<u>Concentration, Mole%</u>									
		<u>O₂</u>	<u>N₂</u>	<u>CO</u>	<u>CO₂</u>	<u>Ar</u>	<u>He</u>	<u>H₂</u>	<u>CH₄</u>	<u>N₂O</u>	<u>NO_x</u>
G411A	12/18/85	21.1	78.4	<0.1	0.02	0.05	0.36	<0.01	0.01	NA	NA
K527A	01/21/86	18.5	80.7	<0.1	0.03	0.22	0.52	<0.01	<0.01	NA	NA
K527A	02/19/86	20.8	78.4	<0.1	0.02	0.05	0.74	<0.01	<0.01	NA	NA
D512A	03/12/86	20.7	79.0	<0.1	0.03	0.03	0.25	<0.01	<0.01	NA	NA
D512A	04/01/86	20.9	78.3	<0.1	0.02	0.04	0.72	<0.01	<0.01	NA	<0.01
C607A	07/24/86	21.2	78.1	<0.1	0.03	0.22	0.47	<0.01	<0.01	NA	NA
C607A	08/18/86	17.8	82.1	<0.1	0.03	0.06	0.07	<0.01	<0.01	NA	NA
D709A	11/06/87	21.2	78.4	<0.1	0.02	0.22	0.10	<0.01	<0.01	NA	NA
D709A	01/22/88	21.1	78.3	<0.1	0.02	0.06	0.52	<0.01	<0.01	NA	NA
D709A	07/29/88	21.0	78.8	<0.1	0.04	0.13	0.03	<0.01	<0.01	NA	NA
D709A	12/01/89	21.1	78.4	<0.1	0.08	0.42	0.03	<0.01	<0.01	NA	NA
10214590A	05/30/90	20.7	78.7	<0.1	0.04	0.54	0.10	<0.01	<0.01	NA	<0.01
G607A	not in records										
K613A	not in records										
I630A	not in records										

NA = Not Analyzed

TABLE E.2. Oven Runs Initiated from Each Gas Bottle

Bottle	Oven/Run Initiated from Bottle^(a)
G411A	1/1, 1/3, 3/3, 4/4, 5/4, 7/1, 8/4, 9/4, 12/4, 12/5
K527A	2/1, 3/1, 3/2, 4/1, 5/1, 7/2, 8/1, 8/2, 9/1, 10/1, 10/2, 11/1, 11/2
D512A	1/2, 2/2, 2/3, 4/2, 4/3, 5/2, 5/3, 6/1, 8/3, 9/2, 9/3, 10/3, 11/3, 12/1, 12/2, 12/3
C607A	1/4, 2/4, 3/4, 3/5, 4/5, 4/6, 4/7, 5/5, 5/6, 5/7, 6/2, 7/3, 7/4, 8/5, 8/6, 8/7, 9/5, 9/6, 9/7, 9/8, 10/4, 11/4, 11/5, 11/6, 12/6, 12/7, 12/8, 12/9, 12/10, 12/11
D709A	1/6, 1/7, 1/8, 2/7, 2/8, 3/8, 3/9, 3/10, 4/9, 4/10, 4/11, 4/12, 5/10, 5/11, 5/12, 5/13, 6/5, 6/6, 7/6, 7/7, 7/8, 8/10, 8/11, 8/12, 9/13, 9/14, 9/15, 9/16, 10/7, 10/8, 10/9, 11/8, 11/9, ^(b) 11/10, 12/14, 12/15, 12/16, 12/17, 12/18, 12/19, 12/20, 12/21
10214590A	1/9, 6/7, 12/22
G607A	1/5, 2/5, 2/6, 3/6, 4/8, 5/8, 5/9, 6/3, 6/4, 7/5, 8/8, 8/9, 9/9, 9/10, 9/11, 10/5, 11/7, 12/12, 12/13
K613A	3/7
I630A	9/12, 10/6

(a) As specified on oven start-up sheets.

(b) Not specified on start-up sheet, but most likely taken from this bottle.

TABLE E.3. Post Test Cover Gas Analyses

Oven	Run	Concentration, Mole%										Date Analyzed
		O ₂	N ₂	CO	CO ₂	Ar	He	H ₂	CH ₄	N ₂ O	NO _x	
1	1	20.2	78.1	<0.1	0.41	0.90	0.34	<0.01	0.01	NA	0.01	03/19/86
	2	no sample due to premature oven shutdown (overtemperature trip)										
	3	16.5	80.7	<0.1	1.67	0.07	1.02	<0.01	<0.01	NA	0.08	08/11/86
	4	18.9	78.8	<0.1	1.79	0.09	0.26	<0.01	<0.01	NA	0.15	11/17/86
	5	17.5	79.0	<0.1	2.92	0.17	0.14	<0.01	<0.01	NA	0.28	05/19/87
	6	18.2	79.5	<0.1	2.12	0.14	0.04	<0.01	<0.01	NA	0.10	11/16/87
	7	16.9	79.3	<0.1	2.30	0.72	0.12	<0.01	<0.01	0.57	0.08	10/11/88
	8	18.6	78.9	<0.1	1.39	0.92	0.05	<0.01	<0.01	0.09	0.05	05/11/90
	9	17.8	79.3	<0.1	2.45	0.32	0.01	<0.01	<0.01	0.12	0.05	09/19/90
2	1	13.6	84.1	<0.1	1.52	0.30	0.26	0.02	0.12	NA	0.07	04/01/86
	2	20.5	79.0	<0.1	0.14	0.06	0.33	<0.01	<0.01	NA	NA	04/07/86
	3	20.3	78.1	<0.1	0.08	0.94	0.53	<0.01	<0.01	NA	NA	07/31/86
	4	6.61	91.3	<0.1	1.61	0.07	0.20	0.01	<0.01	NA	0.18	11/10/86
	5	19.6	77.6	1.4	0.78	0.08	0.04	0.02	<0.01	0.41	0.06	02/19/87
	6	20.8	78.0	<0.1	0.06	0.94	0.21	<0.01	<0.01	NA	NA	11/02/87
	7	12.5	82.1	<0.1	3.85	0.20	0.06	<0.01	<0.01	1.05	0.23	09/23/88
	8	16.1	80.0	<0.1	2.30	0.91	0.15	0.06	<0.01	0.46	0.01	03/05/90
3	1	16.7	81.6	<0.1	1.08	0.09	0.48	<0.01	0.06	NA	NA	03/04/86
	2	13.4	83.8	<0.1	1.98	0.31	0.38	<0.01	0.09	NA	0.03	05/02/86
	3	13.6	84.1	<0.1	1.63	0.06	0.46	<0.01	<0.01	NA	0.07	07/25/86
	4	18.5	80.2	<0.1	1.10	0.08	0.02	<0.01	0.02	NA	0.08	10/01/86
	5	18.7	79.7	<0.1	1.40	0.05	0.04	<0.01	<0.01	NA	0.09	11/24/86
	6	17.5	80.4	<0.1	1.85	0.08	0.17	<0.01	<0.01	NA	NA	03/03/87
	7	20.6	78.4	<0.1	0.04	0.94	0.06	<0.01	<0.01	NA	NA	09/11/87
	8	15.6	81.1	<0.1	2.49	0.71	0.06	<0.01	<0.01	NA	0.10	06/08/88
	9	20.4	78.2	<0.1	0.37	0.93	0.08	<0.01	0.01	NA	<0.01	10/19/89
	10	11.1	80.8	<0.1	6.24	0.47	0.35	<0.01	<0.01	1.00	0.02	09/11/90
4	1	16.7	82.1	<0.1	0.78	0.08	0.36	<0.01	0.05	NA	NA	03/12/86
	2	16.5	81.9	<0.1	1.11	0.08	0.31	<0.01	0.06	NA	0.04	04/02/86
	3	12.5	84.9	<0.1	2.01	0.09	0.34	<0.01	0.12	NA	0.04	05/07/86
	4	11.2	87.3	<0.1	1.23	0.05	0.08	<0.01	<0.01	NA	0.09	07/08/86
	5	15.2	83.4	<0.1	0.86	0.06	0.49	<0.01	<0.01	NA	NA	08/21/86
	6	16.1	81.5	<0.1	2.04	0.06	0.20	<0.01	<0.01	NA	0.11	10/24/86
	7	13.6	83.3	<0.1	2.55	0.06	0.02	<0.01	<0.01	0.27	0.14	02/02/87
	8	20.5	78.3	<0.1	0.05	0.94	0.16	<0.01	<0.01	NA	NA	10/07/87
	9	12.6	79.8	<0.1	7.32	0.08	0.03	<0.01	<0.01	NA	0.23	04/21/88
	10	9.65	82.1	<0.1	7.58	0.36	0.15	<0.01	<0.01	NA	0.13	05/10/89
	11	17.2	79.3	<0.1	2.65	0.77	0.08	<0.01	<0.01	NA	0.04	01/10/90
	12	9.62	83.6	<0.1	5.46	0.56	0.10	<0.01	<0.01	0.71	<0.01	09/26/90

TABLE E.3. Continued

Oven	Run	Concentration, Mole%										Date Analyzed
		O ₂	N ₂	CO	CO ₂	Ar	He	H ₂	CH ₄	N ₂ O	NO _x	
5	1	16.5	82.2	<0.1	0.80	0.10	0.28	<0.01	0.04	NA	0.02	03/12/86
	2	15.9	82.3	<0.1	0.95	0.15	0.58	<0.01	0.05	NA	NA	04/07/86
	3	15.6	82.8	<0.1	1.11	0.17	0.24	<0.01	0.04	NA	0.02	05/09/86
	4	8.94	89.6	<0.1	1.21	0.07	0.18	<0.01	<0.01	NA	0.04	07/21/86
	5	15.1	83.7	<0.1	0.93	0.08	0.22	<0.01	<0.01	NA	0.02	09/22/86
	6	1.96	96.4	<0.1	1.39	0.07	0.04	<0.01	<0.01	NA	0.09	11/03/86
	7	18.6	80.4	<0.1	0.64	0.07	0.16	<0.01	<0.01	NA	0.06	12/03/86
	8	16.6	82.1	<0.1	1.09	0.08	0.05	<0.01	<0.01	NA	0.10	01/21/87
	9	20.7	78.3	<0.1	0.06	0.95	<0.01	<0.01	<0.01	NA	NA	10/07/87
	10	20.9	77.9	<0.1	0.20	0.93	0.03	<0.01	<0.01	NA	0.02	05/31/88
	11	0.07	95.1	<0.1	4.19	0.46	0.12	<0.01	<0.01	NA	NA	07/25/89
	12	10.2	85.8	<0.1	2.80	1.04	0.11	<0.01	<0.01	NA	NA	12/06/89
	13	4.47	87.1	<0.1	7.17	0.77	0.04	<0.01	<0.01	0.4	0.05	09/19/90
6	1	20.4	78.1	<0.1	0.18	0.94	0.36	<0.01	<0.01	NA	0.01	07/31/86
	2	6.84	91.1	<0.1	1.47	0.14	0.20	0.02	<0.01	NA	0.20	11/10/86
	3	19.7	78.7	<0.1	0.85	0.07	0.29	0.03	<0.01	0.34	0.06	02/19/87
	4	20.8	78.0	<0.1	0.06	0.93	0.20	<0.01	<0.01	NA	NA	11/02/87
	5	21.0	77.1	<0.1	0.41	1.42	<0.01	<0.01	<0.01	NA	0.04	08/24/88
	6	20.9	78.0	<0.1	0.16	0.93	<0.01	<0.01	0.01	NA	<0.01	04/20/90
	7	21.0	78.0	<0.1	0.04	0.94	0.06	<0.01	<0.01	NA	NA	10/01/90
7	1.	no sample due to premature oven shutdown (overtemperature trip)										
	2	15.4	81.9	<0.1	1.89	0.32	0.34	0.01	0.10	NA	0.04	05/20/86
	3	18.1	79.9	<0.1	1.40	0.07	0.16	0.03	<0.01	NA	0.38	10/28/86
	4	19.0	79.1	<0.1	1.43	0.07	0.38	0.02	<0.01	NA	NA	02/09/87
	5	20.3	78.3	<0.1	0.15	0.94	0.30	<0.01	<0.01	NA	NA	10/16/87
	6	14.6	80.7	<0.1	3.24	0.39	0.22	<0.01	<0.01	0.50	0.30	08/04/88
	7	9.16	40.3	<0.1	1.19	0.42	0.21	<0.01	<0.01	<0.1	0.08	11/17/89
	8.	no sample due to failed oven solenoid valve, unable to retrieve sample										
8	1	17.1	81.4	<0.1	1.24	0.08	0.16	<0.01	0.03	NA	NA	03/04/86
	2	16.1	82.0	<0.1	0.89	0.09	0.85	<0.01	0.04	NA	0.03	03/27/86
	3	15.7	82.4	<0.1	1.01	0.08	0.75	<0.01	0.06	NA	0.01	05/02/86
	4	9.42	89.0	<0.1	0.82	0.06	0.67	<0.01	<0.01	NA	NA	06/17/86
	5.	sample lost during gas analysis										
	6	13.7	84.8	<0.1	0.77	0.06	0.59	<0.01	<0.01	NA	0.05	10/09/86
	7	15.1	83.7	<0.1	0.97	0.07	0.06	<0.01	<0.01	NA	0.11	11/19/86
	8	18.2	80.4	<0.1	0.84	0.06	0.45	<0.01	<0.01	<0.01	0.06	01/07/87
	9	21.4	77.4	<0.1	0.10	0.94	0.13	<0.01	0.02	NA	0.02	06/09/87
	10	14.3	80.4	<0.1	4.69	0.46	0.07	<0.01	<0.01	NA	NA	12/17/87
	11	10.8	83.3	<0.1	4.44	0.53	0.57	<0.01	<0.01	0.30	0.04	01/18/89
	12	20.8	77.9	<0.1	0.12	0.93	0.20	<0.01	<0.01	NA	0.01	05/18/90

TABLE E.3. Continued

Oven	Run	Concentration, Mole%									Date Analyzed	
		O ₂	N ₂	CO	CO ₂	Ar	He	H ₂	CH ₄	N ₂ O		NO _x
9	1.	no sample due to oven controller problem and premature shutdown										
	2	13.9	84.4	<0.1	1.12	0.07	0.47	<0.01	0.08	NA	NA	04/09/86
	3	14.8	83.3	<0.1	1.18	0.09	0.49	<0.01	0.06	NA	0.02	05/07/86
	4	12.6	86.1	<0.1	0.72	0.06	0.47	<0.01	<0.01	NA	0.03	06/04/86
	5	12.6	85.8	<0.1	0.76	0.07	0.80	<0.01	<0.01	NA	0.01	08/11/86
	6	13.2	84.6	<0.1	1.18	0.10	0.86	<0.01	<0.01	NA	0.04	08/29/86
	7	12.2	85.4	<0.1	1.74	0.07	0.47	<0.01	<0.01	NA	0.05	10/23/86
	8	17.6	81.2	<0.1	0.85	0.06	0.27	<0.01	<0.01	NA	0.08	11/24/86
	9	19.7	79.3	<0.1	0.53	0.01	0.40	<0.01	<0.01	<0.01	0.06	12/18/86
	10	17.5	80.2	<0.1	1.72	0.17	0.37	<0.01	0.07	NA	NA	02/09/86
	11	17.8	79.3	<0.1	2.22	0.09	0.50	<0.01	0.03	NA	0.08	04/20/87
	12	10.5	86.1	<0.1	2.78	0.16	0.27	0.02	<0.01	0.13	NA	08/06/87
	13	20.8	78.5	<0.1	0.19	0.88	0.03	<0.01	<0.01	NA	NA	03/18/88
	14	16.3	78.4	<0.1	4.12	0.78	0.10	<0.01	<0.01	0.32	<0.01	11/21/88
	15	20.7	77.9	<0.1	0.13	0.92	0.29	<0.01	<0.01	NA	NA	10/04/89
	16	20.5	78.2	<0.1	0.20	0.92	0.19	<0.01	<0.01	NA	NA	08/06/90
10	1.	no sample taken										
	2.	no sample due to premature oven shutdown										
	3	19.2	79.0	<0.1	1.12	0.05	0.40	0.05	<0.01	NA	0.20	08/29/86
	4	19.8	78.3	<0.1	1.13	0.06	0.43	0.07	<0.01	NA	0.19	12/03/86
	5	19.9	78.6	<0.1	1.03	0.07	0.30	0.05	<0.01	NA	NA	03/06/87
	6	21.0	78.1	<0.1	0.05	0.89	<0.01	<0.01	<0.01	NA	NA	12/08/87
	7	18.8	78.9	<0.1	1.37	0.12	0.33	<0.01	<0.01	0.23	0.22	06/16/88
	8.	no sample due to failed oven solenoid valve, unable to retrieve sample										
	9.	no sample due to failed oven solenoid valve, unable to retrieve sample										
11	1	17.0	80.5	<0.1	0.83	0.16	1.45	<0.01	0.04	NA	NA	03/04/86
	2	15.4	82.0	<0.1	1.38	0.12	1.10	<0.01	0.06	NA	NA	04/16/86
	3	13.6	84.6	<0.1	0.88	0.07	0.80	<0.01	<0.01	NA	NA	06/17/86
	4	18.4	79.7	<0.1	0.92	0.07	0.86	<0.01	<0.01	NA	NA	08/21/86
	5	21.1	76.7	<0.1	1.39	0.07	0.63	<0.01	<0.01	NA	0.13	10/24/86
	6	18.6	79.4	<0.1	1.30	0.06	0.47	<0.01	<0.01	NA	0.22	01/21/87
	7	20.8	78.0	2.1	0.03	0.94	0.20	<0.01	<0.01	NA	NA	09/08/87
	8	16.3	80.9	<0.1	2.04	0.63	0.07	<0.01	<0.01	NA	0.10	02/17/88
	9	20.6	78.2	<0.1	0.12	0.96	0.11	<0.01	<0.01	NA	0.01	03/21/89
	10	20.6	78.2	<0.1	0.18	0.93	0.05	<0.01	<0.01	NA	0.02	06/27/90

TABLE E.3. Continued

Oven	Run	Concentration, Mole%										Date Analyzed
		O ₂	N ₂	CO	CO ₂	Ar	He	H ₂	CH ₄	N ₂ O	NO _x	
12	1	15.1	83.0	<0.1	1.00	0.05	0.88	<0.01	0.01	NA	0.01	04/04/86
	2	17.6	81.4	<0.1	0.80	0.05	0.14	<0.01	0.04	NA	NA	04/15/86
	3	4.92	91.8	<0.1	1.81	0.13	1.24	<0.01	0.06	NA	NA	05/12/86
	4	8.56	90.3	<0.1	0.55	0.08	0.47	<0.01	<0.01	NA	0.05	06/03/86
	5	18.7	80.1	<0.1	0.30	0.06	0.82	<0.01	<0.01	NA	NA	06/17/86
	6	16.7	81.7	<0.1	0.32	0.08	1.16	<0.01	<0.01	NA	0.03	07/08/86
	7	17.7	81.0	<0.1	0.39	0.06	0.81	<0.01	<0.01	NA	0.02	07/25/86
	8	17.0	82.3	<0.1	0.33	0.07	0.27	<0.01	<0.01	NA	NA	08/21/86
	9	15.6	82.4	<0.1	1.02	0.06	0.80	<0.01	<0.01	NA	0.05	09/25/86
	10	17.4	80.6	<0.1	1.30	0.06	0.62	<0.01	<0.01	NA	0.08	11/03/86
	11	19.1	79.5	<0.1	0.97	0.07	0.24	<0.01	<0.01	NA	0.11	12/03/86
	12	18.7	79.6	<0.1	1.18	0.07	0.27	<0.01	<0.01	0.10	NA	01/19/87
	13	21.4	77.0	<0.1	0.24	0.91	0.30	<0.01	<0.01	0.07	0.01	07/09/87
	14	20.5	78.3	<0.1	0.22	0.93	0.01	<0.01	<0.01	NA	NA	01/26/88
	15	2.55	94.9	<0.1	1.88	0.35	0.30	<0.01	<0.01	NA	NA	04/06/88
	16	5.80	92.2	<0.1	1.61	0.17	0.04	<0.01	<0.01	0.09	0.07	07/15/88
	17	6.27	90.5	<0.1	2.61	0.18	0.14	<0.01	<0.01	0.34	<0.01	11/02/88
	18	13.0	83.5	<0.1	2.86	0.25	0.28	<0.01	<0.01	NA	0.07	02/23/89
	19	14.1	82.1	<0.1	3.22	0.32	0.01	<0.01	<0.01	0.18	0.06	06/21/89
	20	19.0	78.6	<0.1	1.54	0.56	0.21	<0.01	<0.01	0.13	0.01	09/11/89
	21	20.2	78.5	<0.1	0.42	0.92	0.02	<0.01	<0.01	NA	<0.01	05/03/90
	22	14.1	80.5	<0.1	3.89	0.19	1.16	<0.01	<0.01	0.18	0.02	08/23/90

NA = Not analyzed

TABLE E.4. Post Test Cover Gas Analyses for Xenon

<u>Oven</u>	<u>Run</u>	<u>Concentration of Each Xenon Isotope, ppm</u>									
		<u>124</u>	<u>126</u>	<u>128</u>	<u>129</u>	<u>130</u>	<u>131</u>	<u>132</u>	<u>133</u>	<u>134</u>	<u>136</u>
1	1										
	2										
	3						0.7	1.7		2	3
	4						0.2	0.4		0.5	0.7
	5				0.4		1.7	4		5	7
	6						4	10		13	19
	7	<0.1	<0.1	<0.1	0.2	0.1	4	9		12	47
	8	<0.1	<0.1	0.2	1.3	0.2	3	6		8	11
	9	0.03	0.03	0.06	0.3	0.1	3	8		11	16
2	1										
	2										
	3.	≤ 0.06 ppm total Xenon, natural distribution									
	4						-0.1	-0.3		-0.4	-0.5
	5						0.9	1.4		1.6	2.1
	6.	$C_2H_2 + Xe = 0.6$ ppm									
	7	<0.1	0.1	0.3	0.4	0.2	9	23		30	45
	8	0.1	0.003	0.2	1	0.2	5	12		15	22
3	1										
	2										
	3						-0.5	-1.2		-1.6	-2.1
	4						-0.14	-0.3		-0.4	-0.5
	5						0.2	0.4		0.5	0.7
	6						1.0	2.4		2.7	3.5
	7.	≤ 1 ppm total Xenon									
	8			0.2	0.1	0.2	10	24		32	47
	9	<0.1	<0.05	0.1	0.5	0.07	1.0	2.0		2.5	3.5
	10	0.03	0.03	0.1	0.5	0.2	16	35		50	68
4	1										
	2										
	3										
	4						-0.9	-1.9		-2.7	-9
	5						-0.9	-1.2		-1.5	-2
	6						-0.15	-0.38		-0.43	-0.54
	7						0.1	0.2		0.26	0.3
	8.	$C_2H_2 + Xe = 1.8$ ppm, natural distribution									
	9	<0.1	<0.1	0.1	0.05	0.1	4	10		13	18
	10			≤ 0.3	1	≤ 0.3	19	41		58	79
	11	<0.1	<0.1	0.2	0.9	0.1	4	8		11	15
	12	0.03	0.03	0.06	0.3	0.1	7.5	16		23	31

TABLE E.4. Continued

Oven	Run	Concentration of Each Xenon Isotope, ppm									
		124	126	128	129	130	131	132	133	134	136
5	1										
	2										
	3				0.5	0.2	0.9	1.4		1.5	2
	4						0.6	1.3		1.7	2.3
	5						-0.2	-0.4		-0.5	-0.7
	6						0.1	0.3		0.4	0.5
	7						0.3	0.7		0.8	1.0
	8						0.1	0.3		0.4	0.5
	9.	≤0.8 ppm total Xenon, natural distribution									
	10						0.5	1.1		1.3	1.5
	11				0.6	0.4	22	53		73	104
	12	<0.1	<0.1	0.3	1.1	0.2	9	17		23	32
	13	0.03	0.03	0.08	0.4	0.2	11	24		35	47
6	1.	≤0.2 ppm total Xenon, natural distribution									
	2						-0.1	-0.2		-0.2	-0.3
	3						0.6	0.8		1.1	1.4
	4.	$C_xH_y + Xe = 0.2$ ppm									
	5						≤0.2	0.5		0.5	0.5
	6.	1.8 ppm total Xenon									
	7	≤0.03	≤0.03	≤0.03	0.2	≤0.03	0.1	0.2		0.08	0.08
7	1.	no sample due to premature oven shutdown (overtemperature trip)									
	2						0.8	1.5		1.8	2.5
	3						0.4	0.8		1.0	1.4
	4							0.1		0.1	0.13
	5						0.3	0.4		0.4	0.5
	6	<1	<1	<1	<1	<1	3.2	8		10	15
	7	<0.1	<0.1	0.2	1.0	0.1	2.5	5.6		7	10
	8.	no sample due to failed oven solenoid valve, unable to retrieve sample									
8	1										
	2										
	3										
	4						-0.7	-1.6		-2.3	-3.2
	5.	sample lost during gas analysis									
	6				1.2		1.4	2.2		1.9	2.3
	7						0.6	1.3		1.8	2.3
	8						0.03	0.05		0.07	0.09
	9.	$C_xH_y + Xe ≤ 0.5$ ppm, natural distribution									
	10				0.3	<0.1	0.5	1.4		1.1	1
	11	<0.1	<0.1	0.1	0.4	0.2	10	29		33	48
	12.	-2.6 ppm total Xenon									

TABLE E.4. Continued

		Concentration of Each Xenon Isotope, ppm									
Oven	Run	124	126	128	129	130	131	132	133	134	136
9	1.	no sample due to oven controller problem and premature shutdown									
	2										
	3										
	4										
	5										
	6										
	7										
	8.	$C_xH_y + Xe \leq 0.2$ ppm									
	9.	$C_xH_y + Xe \leq 0.4$ ppm									
	10.	≤ 0.05 ppm total Xenon									
	11.	≤ 1 ppm total Xenon									
	12										
	13.	$C_xH_y + Xe \leq 1.4$ ppm									
	14	<0.1	<0.1	<0.1	0.2	<0.1	2.9	6.2		8.4	11
	15.	1.8 ppm total Xenon, natural distribution									
	16	<0.1	<0.1	0.1	0.8	0.1	0.9	1.3		1.4	1.8
10	1.	no sample taken									
	2.	no sample due to premature oven shutdown									
	3										
	4.	≤ 0.5 ppm total Xenon									
	5										
	6.	$C_xH_y + Xe \leq 2$ ppm									
	7	<0.1	<0.1	<0.1	<0.1	<0.1	1	2		3	4
	8.	no sample due to failed oven solenoid valve, unable to retrieve sample									
	9.	no sample due to failed oven solenoid valve, unable to retrieve sample									
11	1										
	2										
	3.	$C_xH_y + Xe \leq 1$ ppm									
	4										
	5.	$C_xH_y + Xe \leq 0.2$ ppm, natural distribution									
	6										
	7.	$C_xH_y + Xe \leq 1.6$ ppm, natural distribution									
	8										
	9										
	10	<0.1	<0.1	0.2	1.9	0.3	1.7	2.3		1.4	1.6

TABLE E.4. Continued

Oven	Run	Concentration of Each Xenon Isotope, ppm									
		124	126	128	129	130	131	132	133	134	136
12	1										
	2										
	3.	<0.005 mole% total Xenon									
	4.	0.9 ppm total Xenon, natural plus trace fission product									
	5					1.0		2.4		3.2	4.5
	6.	~0.9 ppm total Xenon									
	7.	≤0.2 ppm total Xenon									
	8.	C _x H _y + Xe ≤0.2 ppm									
	9.	≤0.1 ppm total Xenon									
	10.	≤0.2 ppm total Xenon									
	11.	<0.5 ppm total Xenon									
	12.	≤0.01 ppm total Xenon									
	13							~0.3		~0.3	~0.4
	14.	C _x H _y + Xe ≤0.6 ppm									
	15			≤0.1	≤0.1	0.2	14	32		46	62
	16	<0.1	<0.1	<0.1	<0.1	<0.1	7	15		21	29
	17	<0.1	<0.1	<0.1	<0.1	0.1	0.1	4		13	17
	18		<0.1	<0.1	<0.1	0.3	<0.1	0.6	1.2	1.4	1.9
	19				0.4	≤0.05	1.0	2.0		2.4	3.3
	20	<0.1	<0.1	<0.1	1.0	<0.1	0.7	1		1	2
	21.	2.3 ppm total Xenon, natural distribution									
	22	0.03	0.03	0.06	0.4	0.06	1.2	2.0		2.8	3.7

NA = Not analyzed

TABLE E.5. Post Test Cover Gas Analyses for Krypton

		Concentration of Each Krypton Isotope, ppm						
Oven	Run	78	80	82	83	84	85	86
1	1							
	2							
	3.	$C_xH_y + Kr \sim 2$ ppm						
	4.	$C_xH_y + Kr \leq 1$ ppm						
	5.	$C_xH_y + Kr \leq 7$ ppm						
	6.	$C_xH_y + Kr \sim 14$ ppm						
	7	<0.5	<0.5	0.8	1.4	2.6	≤ 0.3	2.6
	8	0.2	0.3	0.5	0.9	2	0.2	1.7
	9	0.1	0.1	0.3	0.9	1.2	0.2	1.3
2	1							
	2							
	3.	~ 0.3 ppm total Krypton, natural distribution						
	4.	no Krypton detected due to C_xH_y interference						
	5.	$C_xH_y + Kr \leq 8$ ppm						
	6.	$C_xH_y + Kr \sim 2.4$ ppm						
	7					≤ 5		≤ 9
	8	0.6	1	2	4	10	1	12
3	1							
	2							
	3.	C_xH_y interference						
	4					~ 0.1		~ 0.1
	5.	$C_xH_y + Kr \leq 1.2$ ppm						
	6.	$C_xH_y + Kr \leq 7$ ppm						
	7.	≤ 1 ppm total Krypton						
	8			1	2.5	5	3	7
	9	0.2	0.3	0.3	0.4	1.15	<0.1	0.7
	10	0.1	0.2	0.5	4	8	0.9	12
4	1							
	2							
	3							
	4.	$C_xH_y + Kr < 0.3$ ppm						
	5.	$C_xH_y + Kr \leq 1$ ppm						
	6					~ 0.18	~ 0.17	~ 0.16
	7.	$C_xH_y + Kr \leq 0.7$ ppm						
	8.	$C_xH_y + Kr = 3$ ppm, natural distribution						
	9			2	4			7. C_xH_y interference
	10			0.8	5	12	1.8	17
	11	<0.2	<0.2	0.4	1	3	0.5	3
	12	0.2	0.1	0.5	2.1	3.4	1.3	4.1

TABLE E.5. Continued

Concentration of each Iodine Isotope, ppm								
<u>Oven</u>	<u>Run</u>	<u>78</u>	<u>80</u>	<u>82</u>	<u>83</u>	<u>84</u>	<u>85</u>	<u>86</u>
5	1							
	2							
	3.	~1 ppm total Krypton						
	4.	~1 ppm total Krypton, natural distribution						
	5					~0.2		~0.2
	6.	~0.6 ppm total Krypton						
	7.	$C_{H_y} + Kr = 1.8$ ppm						
	8.	$C_{H_y} + Kr \leq 0.7$ ppm						
	9.	$C_{H_y} + Kr \sim 2$ ppm, natural distribution						
	10.	$C_{H_y} + Kr \leq 2$ ppm						
	11			0.5	4	10	0.9	14
	12	0.2	0.2	0.5	1	3	≤ 0.6	3
	13	0.2	0.2	0.5	3	6	1.5	21
6	1.	~0.8 ppm total Krypton, natural distribution						
	2.	C_{H_y} interference						
	3.	$C_{H_y} + Kr \leq 0.4$ ppm						
	4.	$C_{H_y} + Kr = 1.7$ ppm						
	5.	$C_{H_y} + Kr \leq 3$ ppm						
	6.	2.7 ppm total Krypton						
	7	≤ 0.2	≤ 0.2	≤ 0.2	≤ 0.2	0.6	≤ 0.05	≤ 0.2
7	1.	no sample due to premature oven shutdown (overtemperature trip)						
	2.	~1 ppm total Krypton						
	3.	C_{H_y} interference						
	4.	$C_{H_y} + Kr \leq 0.2$ ppm						
	5.	$C_{H_y} + Kr \leq 1$ ppm						
	6	<1	<1	<1	<1	3		5
	7.	3 ppm total Krypton, natural distribution						
	8.	no sample due to failed oven solenoid valve, unable to retrieve sample						
8	1							
	2							
	3							
	4.	$C_{H_y} + Kr \leq 1$ ppm						
	5.	sample lost during gas analysis						
	6.	3.7 ppm total Krypton, natural distribution						
	7			0.1	0.45	0.1		0.35
	8.	≤ 0.1 ppm total Krypton						
	9.	$C_{H_y} + Kr \leq 2$ ppm, natural distribution						
	10.	≤ 1.8 ppm total Krypton						
	11	0.1	0.1	0.5	2	5		7
	12.	~2 ppm total Krypton						

TABLE E.5. Continued

Concentration of Each Iodine Isotope, ppm								
<u>Oven</u>	<u>Run</u>	<u>78</u>	<u>80</u>	<u>82</u>	<u>83</u>	<u>84</u>	<u>85</u>	<u>86</u>
9	1.	no sample due to oven controller problem and premature shutdown						
	2							
	3							
	4.	1 ppm total Krypton						
	5.	~1 ppm total Krypton						
	6.	$C_xH_y + Kr \leq 0.9$ ppm						
	7.	$C_xH_y + Kr \leq 0.4$ ppm, natural distribution						
	8.	$C_xH_y + Kr \leq 0.3$ ppm						
	9.	$C_xH_y + Kr \leq 1.3$ ppm						
	10.	$C_xH_y + Kr \leq 0.2$ ppm						
	11.	≤ 1 ppm total Krypton						
	12		≤ 2	3	6	3	9	
	13.	$C_xH_y + Kr \leq 3$ ppm						
	14	<0.2	<0.2	1.0	1.9	3.0		3.6
	15.	2.3 ppm total Krypton, natural distribution						
	16	≤ 0.3	≤ 0.3	0.6	0.6	2.2		1.1
10	1.	no sample taken						
	2.	no sample due to premature oven shutdown						
	3.	$C_xH_y + Kr \leq 0.9$ ppm						
	4.	$C_xH_y + Kr \leq 2.3$ ppm						
	5.	$C_xH_y + Kr \leq 3$ ppm						
	6.	$C_xH_y + Kr \leq 5$ ppm						
	7			≤ 1		≤ 3		
	8.	no sample due to failed oven solenoid valve, unable to retrieve sample						
	9.	no sample due to failed oven solenoid valve, unable to retrieve sample						
11	1							
	2							
	3.	$C_xH_y + Kr \leq 0.5$ ppm						
	4.	$C_xH_y + Kr \leq 1$ ppm						
	5.	$C_xH_y + Kr \leq 0.9$ ppm, natural distribution						
	6.	$C_xH_y + Kr \leq 0.7$ ppm						
	7.	$C_xH_y + Kr \leq 1.6$ ppm, natural distribution						
	8.	$C_xH_y + Kr \leq 8$ ppm						
	9.	$C_xH_y + Kr \leq 5$ ppm						
	10	0.2	0.2	0.4	0.4	1.7	<0.1	0.6

TABLE E.5. Continued

Concentration of Each Iodine Isotope, ppm									
Oven	Run	78	80	82	83	84	85	86	
12	1								
	2								
	3.	<0.005 mole% total Krypton							
	4.	0.6 ppm total Krypton, natural distribution							
	5.	$C_xH_y + Kr \leq 1$ ppm							
	6.	$C_xH_y + Kr \leq 0.5$ ppm							
	7.	≤ 0.2 ppm total Krypton							
	8.	$C_xH_y + Kr \leq 0.2$ ppm							
	9.	≤ 0.2 ppm total Krypton, natural distribution							
	10.	≤ 0.6 ppm total Krypton							
	11.	$C_xH_y + Kr \leq 1$ ppm							
	12.	≤ 0.1 ppm total Krypton							
	13.	$C_xH_y + Kr \leq 1.5$ ppm							
	14.	$C_xH_y + Kr \leq 2$ ppm							
	15			0.3	2.4	6.4	0.8	9.7	
	16	<0.1	<0.1	<0.1	1.7	3.4		3.5	
	17		0.1	0.2	0.4	1.9		2.3	
	18.	≤ 2 ppm total Krypton							
	19.	$C_xH_y + Kr \leq 2.6$ ppm							
	20.	2.5 ppm total Krypton, natural distribution							
	21.	2.2 ppm total Krypton, natural distribution							
	22	≤ 0.3	0.1	0.1	0.8	1.2	≤ 0.5	0.8	

NA = Not analyzed

APPENDIX F

BARE FRAGMENT WEIGHT GAIN DATA

APPENDIX F

BARE FRAGMENT WEIGHT GAIN DATA

A complete listing of the as-measured Test Series B bare fragment weight gain data is provided in Table F.1. Also included are the percent weight gains for the bare fragment specimens. Specimens from which samples were removed for analytical examination are footnoted; more information on the removed samples may be found in Section 4 and Appendix K. Provided in Figures F.1 through F.12 are plots of weight gain as a function of time for the bare fragment specimens in each oven. Note that data are excluded from these plots for specimens that had sudden unexplained shifts (increases or decreases)^(a) in weight gain; an example is specimen 8B-4 with a drop in weight in Run 6.

Additional points, which should be noted in regards to the data presented in Table F.1, are:

- Net bare fragment specimen weights are listed in Table F.1. Net weight was calculated by subtracting the pre-test weight of the empty weigh boat from the as-measured total weight of the weigh boat and bare fragment specimen. This assumes that there was no change in weight of the weigh boat, which is supported by the measured negligible weight changes for empty weigh boats (see Appendix H). Specimen weight gain was calculated from the net weight values.
- Instances where there was a measured decrease in weight from the previous run are generally assumed to be due to fuel spillage during handling; however, such spillage was not noticed or confirmed. No attempt has been made to correct the data in Table F.1 to account for possible spillage. Analyses in the text have either excluded these samples entirely or have only considered the data prior to an observed weight decrease.
- The run start weight (RSW) and the run end weight (REW) are the net bare fragment specimens' weight at the start and end of a run, respectively.

(a) Sudden shifts, increases or decreases of weight, were postulated to be due to gains or losses of material from the weight boats during handling. However, this was never confirmed. No foreign materials were observed in boats, nor were pieces of spent fuel observed in the bottom of the ovens.

Generally, the RSW is set equal to the REW from the previous run (i.e., the weigh boats were not reweighed at the start of a run). In the instances where fuel fragments were removed, RSW was determined by reweighing the sample after removal of the fragments or powder.

- The initial starting weight (ISW) is the net bare fragment specimen weight prior to oxidation testing. Generally, the ISW remained constant from run to run. However, fragments or powder from selected specimens were occasionally removed for analytical examination at the end of a run after the specimen had been weighed. For these cases, an adjustment to the ISW was made for the following run to obtain the correct weight gain for subsequent runs. The adjusted ISW for a run "i" was calculated as follows:

$$ISW_i = \frac{(RSW_i) / (ISW_{i-1})}{(REW_{i-1})}$$

where ISW is the initial start weight, RSW is the run start weight, REW is the run end weight, and i is the run number. Note: REW_{i-1} minus RSW_i equals the weight of the fuel fragments removed.

TABLE F.1. Test Series B Bare Fragment Weight Gain Data

Oven	Specimen	Run	Elapsed Time, h	Initial Weight, g	Run Start Weight, g	Run End Weight, g	Cumulative Weight Gain, %
1	1B-1	1	2129.3	22.028	22.028	22.232	0.93
1	1B-1	2	2849.3	22.028	22.232	22.319	1.32
1	1B-1	3	5104.6	22.028	22.319	22.694	3.02
1	1B-1	4	7217.0	22.028	22.694	22.810	3.55
1	1B-1	5	11495.8	22.028	22.810	22.917	4.04
1	1B-1	6	14446.7	22.028	22.917	23.105	4.89
1	1B-1	7	21980.1	22.028	23.105	23.246	5.53
1	1B-1	8	35221.4	22.028	23.246	23.530	6.82
1	1B-1	9	38071.2	22.028	23.530	23.638	7.31
1	1B-2	1	2129.3	24.222	24.222	24.296	0.31
1	1B-2	2	2849.3	24.222	24.296	24.367	0.60
1	1B-2	3	5104.6	24.222	24.367	24.492	1.11
1	1B-2	4	7217.0	24.222	24.492	24.529	1.27
1	1B-2	5	11495.8	24.222	24.529	24.585	1.50
1	1B-2	6	14446.7	24.222	24.585	24.625	1.66
1	1B-2	7	21980.1	24.222	24.625	24.934	2.94
1	1B-2	8	35221.4	24.222	24.934	25.248	4.24
1	1B-2	9	38071.2	24.222	25.248	25.325	4.55
1	1B-3	1	2129.3	24.307	24.307	24.381	0.30
1	1B-3	2	2849.3	24.307	24.381	24.377	0.29
1	1B-3	3	5104.6	24.307	24.377	24.488	0.74
1	1B-3	4	7217.0	24.307	24.488	24.519	0.87
1	1B-3	5	11495.8	24.307	24.519	24.571	1.09
1	1B-3	6	14446.7	24.307	24.571	24.601	1.21
1	1B-3	7	21980.1	24.307	24.601	24.817	2.10
1	1B-3	8	35221.4	24.307	24.817	25.117	3.33
1	1B-3	9	38071.2	24.307	25.117	25.191	3.64
1	1B-4	1	2129.3	45.110	45.110	45.170	0.13
1	1B-4	2	2849.3	45.110	45.170	45.210	0.22
1	1B-4	3	5104.6	45.110	45.210	45.456	0.77
1	1B-4	4	7217.0	45.110	45.456	45.506 ^(a)	0.88
1	1B-4	5	11495.8	45.005	45.400	45.470	1.03
1	1B-4	6	14446.7	45.005	45.470	45.600 ^(a)	1.32
1	1B-4	7	21980.1	44.373	44.960	45.250	1.94
1	1B-4	8	35221.4	44.373	45.250	45.600	2.77
1	1B-4	9	38071.2	44.373	45.600	45.730	3.06
1	1B-5	1	2129.3	23.802	23.802	23.838	0.15
1	1B-5	2	2849.3	23.802	23.838	23.858	0.24
1	1B-5	3	5104.6	23.802	23.858	23.922	0.50
1	1B-5	4	7217.0	23.802	23.922	23.938	0.57
1	1B-5	5	11495.8	23.802	23.938	23.969	0.70
1	1B-5	6	14446.7	23.802	23.969	23.392	-1.72
1	1B-5	7	21980.1	23.802	23.392	23.596	-0.87
1	1B-5	8	35221.4	23.802	23.596	23.846	0.18
1	1B-5	9	38071.2	23.802	23.846	23.921	0.50

TABLE F.1. Contd.

<u>Oven</u>	<u>Specimen</u>	<u>Run</u>	<u>Elapsed Time, h</u>	<u>Initial Weight, g</u>	<u>Run Start Weight, g</u>	<u>Run End Weight, g</u>	<u>Cumulative Weight Gain, %</u>
1	1B-6	1	2129.3	7.260	7.260	7.269	0.12
1	1B-6	2	2849.3	7.260	7.269	7.276	0.22
1	1B-6	3	5104.6	7.260	7.276	7.298	0.52
1	1B-6	4	7217.0	7.260	7.298	7.304	0.61
1	1B-6	5	11495.8	7.260	7.304	7.318	0.80
1	1B-6	6	14446.7	7.260	7.318	7.326	0.91
1	1B-6	7	21980.1	7.260	7.326	7.375	1.58
1	1B-6	8	35221.4	7.260	7.375	7.456	2.70
1	1B-6	9	38071.2	7.260	7.456	7.477	2.99
1	1B-7	1	2129.3	23.300	23.300	23.328	0.12
1	1B-7	2	2849.3	23.300	23.328	23.346	0.20
1	1B-7	3	5104.6	23.300	23.346	23.404	0.45
1	1B-7	4	7217.0	23.300	23.404	23.419	0.51
1	1B-7	5	11495.8	23.300	23.419	23.451	0.65
1	1B-7	6	14446.7	23.300	23.451	23.477	0.76
1	1B-7	7	21980.1	23.300	23.477	23.621	1.38
1	1B-7	8	35221.4	23.300	23.621	23.860	2.40
1	1B-7	9	38071.2	23.300	23.860	23.928	2.70
1	1B-8	1	2129.3	24.832	24.832	24.849	0.07
1	1B-8	2	2849.3	24.832	24.849	24.860	0.11
1	1B-8	3	5104.6	24.832	24.860	24.887	0.22
1	1B-8	4	7217.0	24.832	24.887	24.897	0.26
1	1B-8	5	11495.8	24.832	24.897	24.920	0.35
1	1B-8	6	14446.7	24.832	24.920	24.747	-0.34
1	1B-8	7	21980.1	24.832	24.747	24.814	-0.07
1	1B-8	8	35221.4	24.832	24.814	24.950	0.48
1	1B-8	9	38071.2	24.832	24.950	25.003	0.69
1	1B-9	1	2129.3	25.175	25.175	24.214	-3.82
1	1B-9	2	2849.3	25.175	24.214	24.227	-3.77
1	1B-9	3	5104.6	25.175	24.227	24.257	-3.65
1	1B-9	4	7217.0	25.175	24.257	24.270	-3.59
1	1B-9	5	11495.8	25.175	24.270	24.294	-3.50
1	1B-9	6	14446.7	25.175	24.294	24.309	-3.44
1	1B-9	7	21980.1	25.175	24.309	24.433	-2.95
1	1B-9	8	35221.4	25.175	24.433	24.616	-2.22
1	1B-9	9	38071.2	25.175	24.616	24.683	-1.95
1	1B-10	1	2129.3	20.092	20.092	20.107	0.07
1	1B-10	2	2849.3	20.092	20.107	20.118	0.13
1	1B-10	3	5104.6	20.092	20.118	20.144	0.26
1	1B-10	4	7217.0	20.092	20.144	20.155	0.31
1	1B-10	5	11495.8	20.092	20.155	20.177	0.42
1	1B-10	6	14446.7	20.092	20.177	20.191	0.49
1	1B-10	7	21980.1	20.092	20.191	20.299	1.03
1	1B-10	8	35221.4	20.092	20.299	20.453	1.80
1	1B-10	9	38071.2	20.092	20.453	20.512	2.09

TABLE F.1. Contd.

Oven	Specimen	Run	Elapsed Time, h	Initial Weight, g	Run Start Weight, g	Run End Weight, g	Cumulative Weight Gain, %
1	1B-11	1	2129.3	23.690	23.690	23.711	0.09
1	1B-11	2	2849.3	23.690	23.711	23.726	0.15
1	1B-11	3	5104.6	23.690	23.726	23.767	0.33
1	1B-11	4	7217.0	23.690	23.767	23.784	0.40
1	1B-11	5	11495.8	23.690	23.784	23.817	0.54
1	1B-11	6	14446.7	23.690	23.817	23.840	0.63
1	1B-11	7	21980.1	23.690	23.840	24.055	1.54
1	1B-11	8	35221.4	23.690	24.055	24.261	2.41
1	1B-11	9	38071.2	23.690	24.261	24.343	2.76
1	1B-12	1	2129.3	16.156	16.156	16.155	-0.01
1	1B-12	2	2849.3	16.156	16.155	16.160	0.02
1	1B-12	3	5104.6	16.156	16.160	16.160	0.02
1	1B-12	4	7217.0	16.156	16.160	16.161	0.03
1	1B-12	5	11495.8	16.156	16.161	16.169	0.08
1	1B-12	6	14446.7	16.156	16.169	16.169	0.08
1	1B-12	7	21980.1	16.156	16.169	16.173	0.11
1	1B-12	8	35221.4	16.156	16.173	16.174	0.11
1	1B-12	9	38071.2	16.156	16.174	16.176	0.12
2	2B-1	1	1626.2	17.652	17.652	17.820	0.95
2	2B-1	3 ^(b)	4334.4	17.652	17.825	17.974	1.82
2	2B-1	4	6593.9	17.652	17.974	18.105	2.57
2	2B-1	5	8655.4	17.652	18.105	18.129	2.70
2	2B-1	6	14179.9	17.652	18.129	18.115	2.62
2	2B-1	7	21716.2	17.652	18.115	18.275	3.53
2	2B-1	8	33578.0	17.652	18.275	18.618	5.47
2	2B-2	1	1626.2	24.759	24.759	24.803	0.18
2	2B-2	3	4334.4	24.759	24.808	24.856	0.39
2	2B-2	4	6593.9	24.759	24.856	24.920	0.65
2	2B-2	5	8655.4	24.759	24.920	24.938	0.72
2	2B-2	6	14179.9	24.759	24.938	24.971	0.86
2	2B-2	7	21716.2	24.759	24.971	25.046	1.16
2	2B-2	8	33578.0	24.759	25.046	25.328	2.30
2	2B-3	1	1626.2	43.910	43.910	43.950	0.09
2	2B-3	3	4334.4	43.910	43.960	44.040	0.30
2	2B-3	4	6593.9	43.910	44.040	44.150	0.55
2	2B-3	5	8655.4	43.910	44.150	44.210	0.68
2	2B-3	6	14179.9	43.910	44.210	44.220 ^(a)	0.71
2	2B-3	7	21716.2	42.480	42.780	43.160	1.60
2	2B-3	8	33578.0	42.480	43.160	43.560	2.54

TABLE F.1. Contd.

Oven	Specimen	Run	Elapsed Time, h	Initial Weight, g	Run Start Weight, g	Run End Weight, g	Cumulative Weight Gain, %
2	2B-4	1	1626.2	24.988	24.988	25.024	0.14
2	2B-4	3	4334.4	24.988	25.026	25.075	0.35
2	2B-4	4	6593.9	24.988	25.075	25.144	0.62
2	2B-4	5	8655.4	24.988	25.144	25.159	0.68
2	2B-4	6	14179.9	24.988	25.159	25.190	0.81
2	2B-4	7	21716.2	24.988	25.190	25.385	1.59
2	2B-4	8	33578.0	24.988	25.385	25.695	2.83
2	2B-5	1	1626.2	24.553	24.553	24.585	0.13
2	2B-5	3	4334.4	24.553	24.588	24.632	0.32
2	2B-5	4	6593.9	24.553	24.632	24.695	0.58
2	2B-5	5	8655.4	24.553	24.695	24.700	0.60
2	2B-5	6	14179.9	24.553	24.700	24.734	0.74
2	2B-5	7	21716.2	24.553	24.734	24.875	1.31
2	2B-5	8	33578.0	24.553	24.875	25.165	2.49
2	2B-6	1	1626.2	21.216	21.216	21.240	0.11
2	2B-6	3	4334.4	21.216	21.242	21.271	0.26
2	2B-6	4	6593.9	21.216	21.271	21.317	0.48
2	2B-6	5	8655.4	21.216	21.317	21.325	0.51
2	2B-6	6	14179.9	21.216	21.325	21.345	0.61
2	2B-6	7	21716.2	21.216	21.345	21.413	0.93
2	2B-6	8	33578.0	21.216	21.413	21.586	1.74
2	2B-7	1	1626.2	24.947	24.947	24.967	0.08
2	2B-7	3	4334.4	24.947	24.968	24.996	0.20
2	2B-7	4	6593.9	24.947	24.996	25.033	0.34
2	2B-7	5	8655.4	24.947	25.033	25.032	0.34
2	2B-7	6	14179.9	24.947	25.032	25.067	0.48
2	2B-7	7	21716.2	24.947	25.067	25.207	1.04
2	2B-7	8	33578.0	24.947	25.207	25.434	1.95
2	2B-8	1	1626.2	31.621	31.621	31.647	0.08
2	2B-8	3	4334.4	31.621	31.649	31.693	0.23
2	2B-8	4	6593.9	31.621	31.693	31.764	0.45
2	2B-8	5	8655.4	31.621	31.764	31.782	0.51
2	2B-8	6	14179.9	31.621	31.782	31.774	0.48
2	2B-8	7	21716.2	31.621	31.774	31.863	0.77
2	2B-8	8	33578.0	31.621	31.863	32.107	1.54
2	2B-9	1	1626.2	31.590	31.590	31.603	0.04
2	2B-9	3	4334.4	31.590	31.606	31.665	0.24
2	2B-9	4	6593.9	31.590	31.665	31.741	0.48
2	2B-9	5	8655.4	31.590	31.741	31.746	0.49
2	2B-9	6	14179.9	31.590	31.746	31.746 ^(a)	0.49
2	2B-9	7	21716.2	30.985	31.138	31.221	0.76
2	2B-9	8	33578.0	30.985	31.221	31.505	1.68

TABLE F.1. Contd.

Oven	Specimen	Run	Elapsed Time, h	Initial Weight, g	Run Start Weight, g	Run End Weight, g	Cumulative Weight Gain, %
2	2B-10	1	1626.2	26.855	26.855	26.897	0.16
2	2B-10	3	4334.4	26.855	26.899	26.977	0.45
2	2B-10	4	6593.9	26.855	26.977	27.069	0.80
2	2B-10	5	8655.4	26.855	27.069	27.067	0.79
2	2B-10	6	14179.9	26.855	27.067	27.069	0.80
2	2B-10	7	21716.2	26.855	27.069	27.155	1.12
2	2B-10	8	33578.0	26.855	27.155	27.464	2.27
2	2B-11	1	1626.2	24.808	24.808	24.859	0.21
2	2B-11	3	4334.4	24.808	24.861	24.933	0.50
2	2B-11	4	6593.9	24.808	24.933	25.007	0.80
2	2B-11	5	8655.4	24.808	25.007	25.001	0.78
2	2B-11	6	14179.9	24.808	25.001	25.007 ^(a)	0.80
2	2B-11	7	21716.2	24.347	24.542	24.618	1.11
2	2B-11	8	33578.0	24.347	24.618	24.882	2.20
2	2B-12	1	1626.2	16.018	16.018	16.020	0.01
2	2B-12	3	4334.4	16.018	16.021	16.021	0.02
2	2B-12	4	6593.9	16.018	16.021	16.029	0.07
2	2B-12	5	8655.4	16.018	16.029	16.027	0.06
2	2B-12	6	14179.9	16.018	16.027	16.030	0.07
2	2B-12	7	21716.2	16.018	16.030	16.033	0.09
2	2B-12	8	33578.0	16.018	16.033	16.035	0.11
3	3B-1	1	474.2	20.824	20.824	21.154	1.58
3	3B-1	2	1704.0	20.824	21.154	21.391	2.72
3	3B-1	3	3578.8	20.824	21.391	21.529	3.39
3	3B-1	4	4870.7	20.824	21.529	21.584	3.65
3	3B-1	5	6001.8	20.824	21.584	21.592	3.69
3	3B-1	6	8135.4	20.824	21.592	21.644	3.94
3	3B-1	7	12068.2	20.824	21.644	21.682	4.12
3	3B-1	8	18234.9	20.824	21.682	21.723	4.32
3	3B-1	9	29606.2	20.824	21.723	21.763	4.51
3	3B-1	10	36259.6	20.824	21.763	21.808	4.73
3	3B-2	1	474.2	24.797	24.797	24.878	0.33
3	3B-2	2	1704.0	24.797	24.878	25.025	0.92
3	3B-2	3	3578.8	24.797	25.025	25.199	1.62
3	3B-2	4	4870.7	24.797	25.199	25.300	2.03
3	3B-2	5	6001.8	24.797	25.300	25.360	2.27
3	3B-2	6	8135.4	24.797	25.360	25.456	2.66
3	3B-2	7	12068.2	24.797	25.456	25.506	2.86
3	3B-2	8	18234.9	24.797	25.506	25.641	3.40
3	3B-2	9	29606.2	24.797	25.641	25.721	3.73
3	3B-2	10	36259.6	24.797	25.721	25.816	4.11

TABLE F.1. Contd.

Oven	Specimen	Run	Elapsed Time, h	Initial Weight, g	Run Start Weight, g	Run End Weight, g	Cumulative Weight Gain, %
3	3B-3	1	474.2	23.845	23.845	23.901	0.23
3	3B-3	2	1704.0	23.845	23.901	23.997	0.64
3	3B-3	3	3578.8	23.845	23.997	24.111	1.12
3	3B-3	4	4870.7	23.845	24.111	24.177	1.39
3	3B-3	5	6001.8	23.845	24.177	24.217	1.56
3	3B-3	6	8135.4	23.845	24.217	24.303	1.92
3	3B-3	7	12068.2	23.845	24.303	24.378	2.24
3	3B-3	8	18234.9	23.845	24.378	24.567	3.03
3	3B-3	9	29606.2	23.845	24.567	24.722	3.68
3	3B-3	10	36259.6	23.845	24.722	24.860	4.26
3	3B-4	1	474.2	43.990	43.990	44.030	0.09
3	3B-4	2	1704.0	43.990	44.030	44.250	0.59
3	3B-4	3	3578.8	43.990	44.250	44.590	1.36
3	3B-4	4	4870.7	43.990	44.590	44.730	1.68
3	3B-4	5	6001.8	43.990	44.730	44.820	1.89
3	3B-4	6	8135.4	43.990	44.820	44.980	2.25
3	3B-4	7	12068.2	43.990	44.980	45.090	2.50
3	3B-4	8	18234.9	43.990	45.090	45.640	3.75
3	3B-4	9	29606.2	43.990	45.640	46.197	5.02
3	3B-4	10	36259.6	43.990	46.197	46.780	6.34
3	3B-5	1	474.2	24.168	24.168	24.218	0.21
3	3B-5	2	1704.0	24.168	24.218	24.395	0.94
3	3B-5	3	3578.8	24.168	24.395	24.582	1.71
3	3B-5	4	4870.7	24.168	24.582	24.661	2.04
3	3B-5	5	6001.8	24.168	24.661	24.697	2.19
3	3B-5	6	8135.4	24.168	24.697	24.718	2.28
3	3B-5	7	12068.2	24.168	24.718	24.746	2.39
3	3B-5	8	18234.9	24.168	24.746	24.794	2.59
3	3B-5	9	29606.2	24.168	24.794	24.848	2.81
3	3B-5	10	36259.6	24.168	24.848	24.950	3.24
3	3B-6	1	474.2	44.790	44.790	44.820	0.07
3	3B-6	2	1704.0	44.790	44.820	44.960	0.38
3	3B-6	3	3578.8	44.790	44.960	45.180	0.87
3	3B-6	4	4870.7	44.790	45.180	45.270	1.07
3	3B-6	5	6001.8	44.790	45.270	45.330	1.21
3	3B-6	6	8135.4	44.790	45.330	45.440	1.45
3	3B-6	7	12068.2	44.790	45.440	45.540	1.67
3	3B-6	8	18234.9	44.790	45.540	45.810	2.28
3	3B-6	9	29606.2	44.790	45.810	46.235	3.22
3	3B-6	10	36259.6	44.790	46.235	46.650	4.15

TABLE F.1. Contd.

Oven	Specimen	Run	Elapsed Time, h	Initial Weight, g	Run Start Weight, g	Run End Weight, g	Cumulative Weight Gain, %
3	3B-7	1	474.2	45.140	45.140	45.170	0.07
3	3B-7	2	1704.0	45.140	45.170	45.290	0.33
3	3B-7	3	3578.8	45.140	45.290	45.470	0.73
3	3B-7	4	4870.7	45.140	45.470	45.550	0.91
3	3B-7	5	6001.8	45.140	45.550	45.590	1.00
3	3B-7	6	8135.4	45.140	45.590	45.680	1.20
3	3B-7	7	12068.2	45.140	45.680	45.780	1.42
3	3B-7	8	18234.9	45.140	45.780	46.010	1.93
3	3B-7	9	29606.2	45.140	46.010	46.432	2.86
3	3B-7	10	36259.6	45.140	46.432	46.900	3.90
3	3B-8	1	474.2	46.500	46.500	46.530	0.06
3	3B-8	2	1704.0	46.500	46.530	46.700	0.43
3	3B-8	3	3578.8	46.500	46.700	46.970	1.01
3	3B-8	4	4870.7	46.500	46.970	47.070	1.23
3	3B-8	5	6001.8	46.500	47.070	47.130	1.35
3	3B-8	6	8135.4	46.500	47.130	47.250	1.61
3	3B-8	7	12068.2	46.500	47.250	47.380	1.89
3	3B-8	8	18234.9	46.500	47.380	47.950	3.12
3	3B-8	9	29606.2	46.500	47.950	48.627	4.57
3	3B-8	10	36259.6	46.500	48.627	49.170	5.74
3	3B-9	1	474.2	44.350	44.350	43.640	-1.60
3	3B-9	2	1704.0	44.350	43.640	43.770	-1.31
3	3B-9	3	3578.8	44.350	43.770	43.560	-1.78
3	3B-9	4	4870.7	44.350	43.560	43.620	-1.65
3	3B-9	5	6001.8	44.350	43.620	43.650	-1.58
3	3B-9	6	8135.4	44.350	43.650	43.730	-1.40
3	3B-9	7	12068.2	44.350	43.730	43.830	-1.17
3	3B-9	8	18234.9	44.350	43.830	44.100	-0.56
3	3B-9	9	29606.2	44.350	44.100	44.516	0.37
3	3B-9	10	36259.6	44.350	44.516	44.930	1.31
3	3B-10	1	474.2	44.710	44.710	44.730	0.04
3	3B-10	2	1704.0	44.710	44.730	44.840	0.29
3	3B-10	3	3578.8	44.710	44.840	45.020	0.69
3	3B-10	4	4870.7	44.710	45.020	45.070	0.81
3	3B-10	5	6001.8	44.710	45.070	45.100	0.87
3	3B-10	6	8135.4	44.710	45.100	45.170	1.03
3	3B-10	7	12068.2	44.710	45.170	45.280	1.27
3	3B-10	8	18234.9	44.710	45.280	45.650	2.10
3	3B-10	9	29606.2	44.710	45.650	46.157	3.24
3	3B-10	10	36259.6	44.710	46.157	46.550	4.12

TABLE F.1. Contd.

Oven	Specimen	Run	Elapsed Time, h	Initial Weight, g	Run Start Weight, g	Run End Weight, g	Cumulative Weight Gain, %
3	3B-11	1	474.2	43.900	43.900	43.910	0.02
3	3B-11	2	1704.0	43.900	43.910	44.010	0.25
3	3B-11	3	3578.8	43.900	44.010	44.090	0.43
3	3B-11	4	4870.7	43.900	44.090	44.140	0.55
3	3B-11	5	6001.8	43.900	44.140	44.150	0.57
3	3B-11	6	8135.4	43.900	44.150	44.190	0.66
3	3B-11	7	12068.2	43.900	44.190	44.310	0.93
3	3B-11	8	18234.9	43.900	44.310	44.720	1.87
3	3B-11	9	29606.2	43.900	44.720	45.186	2.93
3	3B-11	10	36259.6	43.900	45.186	45.580	3.83
3	3B-12	1	474.2	15.873	15.873	15.898	0.16
3	3B-12	2	1704.0	15.873	15.898	15.908	0.22
3	3B-12	3	3578.8	15.873	15.908	15.907	0.21
3	3B-12	4	4870.7	15.873	15.907	15.925	0.33
3	3B-12	5	6001.8	15.873	15.925	15.926	0.33
3	3B-12	6	8135.4	15.873	15.926	15.938	0.41
3	3B-12	7	12068.2	15.873	15.938	16.003	0.82
3	3B-12	8	18234.9	15.873	16.003	16.231	2.26
3	3B-12	9	29606.2	15.873	16.231	16.248	2.36
3	3B-12	10	36259.6	15.873	16.248	16.480	3.82
4	4B-1	1	283.1	27.861	27.861	28.150	1.04
4	4B-1	2	756.3	27.861	28.150	28.318	1.64
4	4B-1	3	1544.0	27.861	28.318	28.440	2.08
4	4B-1	4	2810.5	27.861	28.440	28.593	2.63
4	4B-1	5	3716.1	27.861	28.593	28.718	3.08
4	4B-1	6	4937.8	27.861	28.718	28.798	3.36
4	4B-1	7	7170.5	27.861	28.798	28.851	3.55
4	4B-1	8	12975.4	27.861	28.851	28.863	3.60
4	4B-1	9	17130.2	27.861	28.863	28.926	3.82
4	4B-1	10	25509.7	27.861	28.926	28.968	3.97
4	4B-1	11	30555.6	27.861	28.968	28.995	4.07
4	4B-1	12	36121.6	27.861	28.995	29.011	4.13
4	4B-2	1	283.1	25.136	25.136	25.253	0.47
4	4B-2	2	756.3	25.136	25.253	25.351	0.86
4	4B-2	3	1544.0	25.136	25.351	25.486	1.39
4	4B-2	4	2810.5	25.136	25.486	25.767	2.51
4	4B-2	5	3716.1	25.136	25.767	25.893	3.01
4	4B-2	6	4937.8	25.136	25.893	25.915	3.10
4	4B-2	7	7170.5	25.136	25.915	25.927	3.15
4	4B-2	8	12975.4	25.136	25.927	25.928	3.15
4	4B-2	9	17130.2	25.136	25.928	25.947	3.23
4	4B-2	10	25509.7	25.136	25.947	25.962	3.29
4	4B-2	11	30555.6	25.136	25.962	25.979	3.35
4	4B-2	12	36121.6	25.136	25.979	25.986	3.38

TABLE F.1. Contd.

Oven	Specimen	Run	Elapsed Time, h	Initial Weight, g	Run Start Weight, g	Run End Weight, g	Cumulative Weight Gain, %
4	4B-3	1	283.1	24.740	24.740	24.840	0.40
4	4B-3	2	756.3	24.740	24.840	24.928	0.76
4	4B-3	3	1544.0	24.740	24.928	25.050	1.25
4	4B-3	4	2810.5	24.740	25.050	25.278	2.17
4	4B-3	5	3716.1	24.740	25.278	25.406	2.69
4	4B-3	6	4937.8	24.740	25.406	25.459	2.91
4	4B-3	7	7170.5	24.740	25.459	25.484	3.01
4	4B-3	8	12975.4	24.740	25.484	25.486	3.02
4	4B-3	9	17130.2	24.740	25.486	25.511	3.12
4	4B-3	10	25509.7	24.740	25.511	25.532	3.20
4	4B-3	11	30555.6	24.740	25.532	25.554	3.29
4	4B-3	12	36121.6	24.740	25.554	25.566	3.34
4	4B-4	1	283.1	44.680	44.680	44.740	0.13
4	4B-4	2	756.3	44.680	44.740	44.850	0.38
4	4B-4	3	1544.0	44.680	44.850	45.050	0.83
4	4B-4	4	2810.5	44.680	45.050	45.510	1.86
4	4B-4	5	3716.1	44.680	45.510	45.810	2.53
4	4B-4	6	4937.8	44.680	45.810	45.930	2.80
4	4B-4	7	7170.5	44.680	45.930	46.030	3.02
4	4B-4	8	12975.4	43.622	44.940	44.950	3.05
4	4B-4	9	17130.2	43.622	44.950	45.170 ^(a)	3.55
4	4B-4	10	25509.7	43.004	44.530	45.030	3.23
4	4B-4	11	30555.6	43.004	45.030	45.220	3.67
4	4B-4	12	36121.6	43.004	45.220	45.420	4.13
4	4B-5	1	283.1	24.621	24.621	24.671	0.20
4	4B-5	2	756.3	24.621	24.671	24.555	-0.27
4	4B-5	3	1544.0	24.621	24.555	24.900	1.13
4	4B-5	4	2810.5	24.621	24.900	25.132	2.08
4	4B-5	5	3716.1	24.621	25.132	25.241	2.52
4	4B-5	6	4937.8	24.621	25.241	25.294	2.73
4	4B-5	7	7170.5	24.621	25.294	25.325	2.86
4	4B-5	8	12975.4	24.621	25.325	25.330	2.88
4	4B-5	9	17130.2	24.621	25.330	25.374	3.06
4	4B-5	10	25509.7	24.621	25.374	25.479	3.48
4	4B-5	11	30555.6	24.621	25.479	25.600	3.98
4	4B-5	12	36121.6	24.621	25.600	25.632	4.11

TABLE F.1. Contd.

Oven	Specimen	Run	Elapsed Time, h	Initial Weight, g	Run Start Weight, g	Run End Weight, g	Cumulative Weight Gain, %
4	4B-6	1	283.1	44.720	44.720	44.750	0.07
4	4B-6	2	756.3	44.720	44.750	44.820	0.22
4	4B-6	3	1544.0	44.720	44.820	44.950	0.51
4	4B-6	4	2810.5	44.720	44.950	45.270	1.23
4	4B-6	5	3716.1	44.720	45.270	45.550	1.86
4	4B-6	6	4937.8	44.720	45.550	45.720	2.24
4	4B-6	7	7170.5	44.720	45.720	45.940	2.73
4	4B-6	8	12975.4	44.720	45.940	45.990	2.84
4	4B-6	9	17130.2	44.720	45.990	46.150	3.20
4	4B-6	10	25509.7	44.720	46.150	46.390	3.73
4	4B-6	11	30555.6	44.720	46.390	46.600	4.20
4	4B-6	12	36121.6	44.720	46.600	46.690	4.41
4	4B-7	1	283.1	44.760	44.760	44.790	0.07
4	4B-7	2	756.3	44.760	44.790	44.860	0.22
4	4B-7	3	1544.0	44.760	44.860	44.980	0.49
4	4B-7	4	2810.5	44.760	44.980	45.240	1.07
4	4B-7	5	3716.1	44.760	45.240	45.470	1.59
4	4B-7	6	4937.8	44.760	45.470	45.640	1.97
4	4B-7	7	7170.5	44.760	45.640	45.880 ^(a)	2.50
4	4B-7	8	12975.4	43.306	44.390	44.480	2.70
4	4B-7	9	17130.2	43.306	44.480	44.700	3.21
4	4B-7	10	25509.7	43.306	44.700	44.950	3.79
4	4B-7	11	30555.6	43.306	44.950	45.130	4.20
4	4B-7	12	36121.6	43.306	45.130	45.210	4.40
4	4B-8	1	283.1	43.810	43.810	43.850	0.09
4	4B-8	2	756.3	43.810	43.850	43.930	0.27
4	4B-8	3	1544.0	43.810	43.930	44.110	0.68
4	4B-8	4	2810.5	43.810	44.110	44.460	1.48
4	4B-8	5	3716.1	43.810	44.460	44.650	1.92
4	4B-8	6	4937.8	43.810	44.650	44.730	2.10
4	4B-8	7	7170.5	43.810	44.730	44.840	2.35
4	4B-8	8	12975.4	43.810	44.840	44.930	2.56
4	4B-8	9	17130.2	43.810	44.930	45.050	2.83
4	4B-8	10	25509.7	43.810	45.050	45.280	3.36
4	4B-8	11	30555.6	43.810	45.280	45.370	3.56
4	4B-8	12	36121.6	43.810	45.370	45.490	3.83

TABLE F.1. Contd.

<u>Oven</u>	<u>Specimen</u>	<u>Run</u>	<u>Elapsed Time, h</u>	<u>Initial Weight, g</u>	<u>Run Start Weight, g</u>	<u>Run End Weight, g</u>	<u>Cumulative Weight Gain, %</u>
4	4B-9	1	283.1	44.400	44.400	44.430	0.07
4	4B-9	2	756.3	44.400	44.430	44.490	0.20
4	4B-9	3	1544.0	44.400	44.490	44.630	0.52
4	4B-9	4	2810.5	44.400	44.630	44.920	1.17
4	4B-9	5	3716.1	44.400	44.920	45.150	1.69
4	4B-9	6	4937.8	44.400	45.150	45.260	1.94
4	4B-9	7	7170.5	44.400	45.260	45.440	2.34
4	4B-9	8	12975.4	44.400	45.440	45.550	2.59
4	4B-9	9	17130.2	44.400	45.550	45.800	3.15
4	4B-9	10	25509.7	44.400	45.800	46.110	3.85
4	4B-9	11	30555.6	44.400	46.110	46.250	4.17
4	4B-9	12	36121.6	44.400	46.250	46.030	3.67
4	4B-10	1	283.1	44.430	44.430	44.460	0.07
4	4B-10	2	756.3	44.430	44.460	44.520	0.20
4	4B-10	3	1544.0	44.430	44.520	44.650	0.50
4	4B-10	4	2810.5	44.430	44.650	44.930	1.13
4	4B-10	5	3716.1	44.430	44.930	45.110	1.53
4	4B-10	6	4937.8	44.430	45.110	45.220	1.78
4	4B-10	7	7170.5	44.430	45.220	45.400	2.18
4	4B-10	8	12975.4	44.430	45.400	45.530	2.48
4	4B-10	9	17130.2	44.430	45.530	45.830	3.15
4	4B-10	10	25509.7	44.430	45.830	46.140	3.85
4	4B-10	11	30555.6	44.430	46.140	46.260	4.12
4	4B-10	12	36121.6	44.430	46.260	46.330	4.28
4	4B-11	1	283.1	48.170	48.170	48.190	0.04
4	4B-11	2	756.3	48.170	48.190	48.250	0.17
4	4B-11	3	1544.0	48.170	48.250	48.380	0.44
4	4B-11	4	2810.5	48.170	48.380	48.680	1.06
4	4B-11	5	3716.1	48.170	48.680	48.830	1.37
4	4B-11	6	4937.8	48.170	48.830	48.910	1.54
4	4B-11	7	7170.5	48.170	48.910	49.030	1.79
4	4B-11	8	12975.4	48.170	49.030	49.220	2.18
4	4B-11	9	17130.2	48.170	49.220	49.470	2.70
4	4B-11	10	25509.7	48.170	49.470	49.890	3.57
4	4B-11	11	30555.6	48.170	49.890	50.020	3.84
4	4B-11	12	36121.6	48.170	50.020	50.100	4.01

TABLE F.1. Contd.

Oven	Specimen	Run	Elapsed Time, h	Initial Weight, g	Run Start Weight, g	Run End Weight, g	Cumulative Weight Gain, %
4	4B-12	1	283.1	15.946	15.946	15.947	0.01
4	4B-12	2	756.3	15.946	15.947	15.956	0.06
4	4B-12	3	1544.0	15.946	15.956	15.981	0.22
4	4B-12	4	2810.5	15.946	15.981	16.125	1.12
4	4B-12	5	3716.1	15.946	16.125	16.179	1.46
4	4B-12	6	4937.8	15.946	16.179	16.275	2.06
4	4B-12	7	7170.5	15.946	16.275	16.388	2.77
4	4B-12	8	12975.4	15.946	16.388	16.507	3.52
4	4B-12	9	17130.2	15.946	16.507	17.012	6.69
4	4B-12	10	25509.7	15.946	17.012	17.023	6.75
4	4B-12	11	30555.6	15.946	17.023	17.039	6.85
4	4B-12	12	36121.6	15.946	17.039	17.180	7.74
5	5B-1	1	330.8	23.337	23.337	23.555	0.93
5	5B-1	2	735.2	23.337	23.555	23.690	1.51
5	5B-1	3	1384.0	23.337	23.690	23.773	1.87
5	5B-1	4	2830.8	23.337	23.773	23.905	2.43
5	5B-1	5	4052.5	23.337	23.905	23.936	2.57
5	5B-1	6	4990.6	23.337	23.936	23.952	2.64
5	5B-1	7	5639.4	23.337	23.952	23.956	2.65
5	5B-1	8	6643.5	23.337	23.956	23.987	2.79
5	5B-1	9	12470.9	23.337	23.987	23.999	2.84
5	5B-1	10	17589.6	23.337	23.999	24.038	3.00
5	5B-1	11	27184.0	23.337	24.038	24.055	3.08
5	5B-1	12	29423.2	23.337	24.055	24.067	3.13
5	5B-1	13	35345.6	23.337	24.067	24.112	3.32
5	5B-2	1	330.8	24.612	24.612	24.714	0.41
5	5B-2	2	735.2	24.612	24.714	24.815	0.82
5	5B-2	3	1384.0	24.612	24.815	24.891	1.13
5	5B-2	4	2830.8	24.612	24.891	25.063	1.83
5	5B-2	5	4052.5	24.612	25.063	25.116	2.05
5	5B-2	6	4990.6	24.612	25.116	25.152	2.19
5	5B-2	7	5639.4	24.612	25.152	25.172	2.28
5	5B-2	8	6643.5	24.612	25.172	25.272	2.68
5	5B-2	9	12470.9	24.612	25.272	25.296	2.78
5	5B-2	10	17589.6	24.612	25.296	25.381	3.12
5	5B-2	11	27184.0	24.612	25.381	25.410	3.24
5	5B-2	12	29423.2	24.612	25.410	25.425	3.30
5	5B-2	13	35345.6	24.612	25.425	25.474	3.50

TABLE F.1. Contd.

Oven	Specimen	Run	Elapsed Time, h	Initial Weight, g	Run Start Weight, g	Run End Weight, g	Cumulative Weight Gain, %
5	5B-3	1	330.8	44.900	44.900	44.940	0.09
5	5B-3	2	735.2	44.900	44.940	45.020	0.27
5	5B-3	3	1384.0	44.900	45.020	45.100	0.45
5	5B-3	4	2830.8	44.900	45.100	45.390	1.09
5	5B-3	5	4052.5	44.900	45.390	45.570	1.49
5	5B-3	6	4990.6	44.900	45.570	45.730	1.85
5	5B-3	7	5639.4	44.900	45.730	45.850	2.12
5	5B-3	8	6643.5	44.900	45.850	46.150	2.78
5	5B-3	9	12470.9	44.900	46.150	46.280	3.07
5	5B-3	10	17589.6	44.900	46.280	46.460	3.47
5	5B-3	11	27184.0	44.900	46.460	46.540	3.65
5	5B-3	12	29423.2	44.900	46.540	46.580	3.74
5	5B-3	13	35345.6	44.900	46.580	46.720	4.05
5	5B-4	1	330.8	45.110	45.110	45.150	0.09
5	5B-4	2	735.2	45.110	45.150	45.210	0.22
5	5B-4	3	1384.0	45.110	45.210	45.290	0.40
5	5B-4	4	2830.8	45.110	45.290	45.560	1.00
5	5B-4	5	4052.5	45.110	45.560	45.690	1.29
5	5B-4	6	4990.6	45.110	45.690	45.820	1.57
5	5B-4	7	5639.4	45.110	45.820	45.910	1.77
5	5B-4	8	6643.5	45.110	45.910	46.150	2.31
5	5B-4	9	12470.9	45.110	46.150	46.340	2.73
5	5B-4	10	17589.6	45.110	46.340	46.580	3.26
5	5B-4	11	27184.0	45.110	46.580	46.720	3.57
5	5B-4	12	29423.2	45.110	46.720	46.770	3.68
5	5B-4	13	35345.6	45.110	46.770	46.980	4.15
5	5B-5	1	330.8	45.660	45.660	45.750	0.20
5	5B-5	2	735.2	45.660	45.750	45.870	0.46
5	5B-5	3	1384.0	45.660	45.870	46.010	0.77
5	5B-5	4	2830.8	45.660	46.010	46.470	1.77
5	5B-5	5	4052.5	45.660	46.470	46.690	2.26
5	5B-5	6	4990.6	45.660	46.690	46.850	2.61
5	5B-5	7	5639.4	45.660	46.850	46.940	2.80
5	5B-5	8	6643.5	45.660	46.940	47.120	3.20
5	5B-5	9	12470.9	45.660	47.120	47.160	3.29
5	5B-5	10	17589.6	45.660	47.160	47.380	3.77
5	5B-5	11	27184.0	45.660	47.380	47.520	4.07
5	5B-5	12	29423.2	45.660	47.520	47.550	4.14
5	5B-5	13	35345.6	45.660	47.550	47.730	4.53

TABLE F.1. Contd.

<u>Oven</u>	<u>Specimen</u>	<u>Run</u>	<u>Elapsed Time, h</u>	<u>Initial Weight, g</u>	<u>Run Start Weight, g</u>	<u>Run End Weight, g</u>	<u>Cumulative Weight Gain, %</u>
5	5B-6	1	330.8	43.790	43.790	43.830	0.09
5	5B-6	2	735.2	43.790	43.830	43.900	0.25
5	5B-6	3	1384.0	43.790	43.900	43.980	0.43
5	5B-6	4	2830.8	43.790	43.980	44.260	1.07
5	5B-6	5	4052.5	43.790	44.260	44.400	1.39
5	5B-6	6	4990.6	43.790	44.400	44.520	1.67
5	5B-6	7	5639.4	43.790	44.520	44.590	1.83
5	5B-6	8	6643.5	43.790	44.590	44.800	2.31
5	5B-6	9	12470.9	43.790	44.800	44.980	2.72
5	5B-6	10	17589.6	43.790	44.980	45.230	3.29
5	5B-6	11	27184.0	43.790	45.230	45.360	3.59
5	5B-6	12	29423.2	43.790	45.360	45.400	3.68
5	5B-6	13	35345.6	43.790	45.400	45.600	4.13
5	5B-7	1	330.8	44.630	44.630	44.660	0.07
5	5B-7	2	735.2	44.630	44.660	44.700	0.16
5	5B-7	3	1384.0	44.630	44.700	44.760	0.29
5	5B-7	4	2830.8	44.630	44.760	45.010	0.85
5	5B-7	5	4052.5	44.630	45.010	45.150	1.17
5	5B-7	6	4990.6	44.630	45.150	45.280	1.46
5	5B-7	7	5639.4	44.630	45.280	45.350	1.61
5	5B-7	8	6643.5	44.630	45.350	45.550	2.06
5	5B-7	9	12470.9	44.630	45.550	45.730	2.46
5	5B-7	10	17589.6	44.630	45.730	46.050	3.18
5	5B-7	11	27184.0	44.630	46.050	46.530	4.26
5	5B-7	12	29423.2	44.630	46.530	46.600	4.41
5	5B-7	13	35345.6	44.630	46.600	47.050	5.42
5	5B-8	1	330.8	36.726	36.726	36.767	0.11
5	5B-8	2	735.2	36.726	36.767	36.838	0.30
5	5B-8	3	1384.0	36.726	36.838	36.929	0.55
5	5B-8	4	2830.8	36.726	36.929	37.252	1.43
5	5B-8	5	4052.5	36.726	37.252	37.428	1.91
5	5B-8	6	4990.6	36.726	37.428	37.525	2.18
5	5B-8	7	5639.4	36.726	37.525	37.559	2.27
5	5B-8	8	6643.5	36.726	37.559	37.669	2.57
5	5B-8	9	12470.9	36.726	37.669	37.747	2.78
5	5B-8	10	17589.6	36.726	37.747	37.919	3.25
5	5B-8	11	27184.0	36.726	37.919	38.100	3.74
5	5B-8	12	29423.2	36.726	38.100	38.116	3.78
5	5B-8	13	35345.6	36.726	38.116	38.310	4.31

TABLE F.1. Contd.

Oven	Specimen	Run	Elapsed Time, h	Initial Weight, g	Run Start Weight, g	Run End Weight, g	Cumulative Weight Gain, %
5	5B-9	1	330.8	36.875	36.875	36.958	0.23
5	5B-9	2	735.2	36.875	36.958	37.077	0.55
5	5B-9	3	1384.0	36.875	37.077	37.213	0.92
5	5B-9	4	2830.8	36.875	37.213	37.673	2.16
5	5B-9	5	4052.5	36.875	37.673	37.930	2.86
5	5B-9	6	4990.6	36.875	37.930	38.040	3.16
5	5B-9	7	5639.4	36.875	38.040	38.084	3.28
5	5B-9	8	6643.5	36.875	38.084	38.157	3.48
5	5B-9	9	12470.9	36.875	38.157	38.200	3.59
5	5B-9	10	17589.6	36.875	38.200	38.311	3.89
5	5B-9	11	27184.0	36.875	38.311	38.380	4.08
5	5B-9	12	29423.2	36.875	38.380	38.420	4.19
5	5B-9	13	35345.6	36.875	38.420	38.550	4.54
5	5B-10	1	330.8	36.461	36.461	36.539	0.21
5	5B-10	2	735.2	36.461	36.539	36.649	0.52
5	5B-10	3	1384.0	36.461	36.649	36.777	0.87
5	5B-10	4	2830.8	36.461	36.777	37.207	2.05
5	5B-10	5	4052.5	36.461	37.207	37.457	2.73
5	5B-10	6	4990.6	36.461	37.457	37.575	3.06
5	5B-10	7	5639.4	36.461	37.575	37.625	3.19
5	5B-10	8	6643.5	36.461	37.625	37.695	3.38
5	5B-10	9	12470.9	36.461	37.695	37.750	3.54
5	5B-10	10	17589.6	36.461	37.750	37.820	3.73
5	5B-10	11	27184.0	36.461	37.820	37.850	3.81
5	5B-10	12	29423.2	36.461	37.850	37.880	3.89
5	5B-10	13	35345.6	36.461	37.880	37.940	4.06
5	5B-11	1	330.8	37.032	37.032	37.140	0.29
5	5B-11	2	735.2	37.032	37.140	37.273	0.65
5	5B-11	3	1384.0	37.032	37.273	37.407	1.01
5	5B-11	4	2830.8	37.032	37.407	37.841	2.18
5	5B-11	5	4052.5	37.032	37.841	38.058	2.77
5	5B-11	6	4990.6	37.032	38.058	38.157	3.04
5	5B-11	7	5639.4	37.032	38.157	38.200	3.15
5	5B-11	8	6643.5	37.032	38.200	38.260	3.32
5	5B-11	9	12470.9	37.032	38.260	38.290	3.40
5	5B-11	10	17589.6	37.032	38.290	38.350	3.56
5	5B-11	11	27184.0	37.032	38.350	38.380	3.64
5	5B-11	12	29423.2	37.032	38.380	38.390	3.67
5	5B-11	13	35345.6	37.032	38.390	38.440	3.80

TABLE F.1. Contd.

<u>Oven</u>	<u>Specimen</u>	<u>Run</u>	<u>Elapsed Time, h</u>	<u>Initial Weight, g</u>	<u>Run Start Weight, g</u>	<u>Run End Weight, g</u>	<u>Cumulative Weight Gain, %</u>
5	5B-12	1	330.8	16.109	16.109	16.118	0.06
5	5B-12	2	735.2	16.109	16.118	16.145	0.22
5	5B-12	3	1384.0	16.109	16.145	16.179	0.43
5	5B-12	4	2830.8	16.109	16.179	16.349	1.49
5	5B-12	5	4052.5	16.109	16.349	16.505	2.46
5	5B-12	6	4990.6	16.109	16.505	16.613	3.13
5	5B-12	7	5639.4	16.109	16.613	16.677	3.53
5	5B-12	8	6643.5	16.109	16.677	16.851	4.61
5	5B-12	9	12470.9	16.109	16.851	17.061	5.91
5	5B-12	10	17589.6	16.109	17.061	18.938	17.56
5	5B-12	11	27184.0	16.109	18.938	18.828	16.88
5	5B-12	12	29423.2	16.109	18.828	18.671	15.90
5	5B-12	13	35345.6	16.109	18.671	19.001	17.95
6	6B-1	1	3191.8	27.446	27.446	27.577	0.48
6	6B-1	2	5347.2	27.446	27.577	27.814	1.34
6	6B-1	3	7467.7	27.446	27.814	27.859	1.50
6	6B-1	4	13177.0	27.446	27.859	27.876	1.57
6	6B-1	5	19916.2	27.446	27.876	28.206	2.77
6	6B-1	6	33375.5	27.446	28.206	28.396	3.46
6	6B-1	7	36730.8	27.446	28.396	28.380	3.40
6	6B-2	1	3191.8	24.905	24.905	24.958	0.21
6	6B-2	2	5347.2	24.905	24.958	25.038	0.53
6	6B-2	3	7467.7	24.905	25.038	25.062	0.63
6	6B-2	4	13177.0	24.905	25.062	25.076	0.69
6	6B-2	5	19916.2	24.905	25.076	25.156	1.01
6	6B-2	6	33375.5	24.905	25.156	25.447	2.18
6	6B-2	7	36730.8	24.905	25.447	25.460	2.23
6	6B-3	1	3191.8	43.830	43.830	43.860	0.07
6	6B-3	2	5347.2	43.830	43.860	43.920	0.21
6	6B-3	3	7467.7	43.830	43.920	43.940	0.25
6	6B-3	4	13177.0	43.830	43.940	43.940	0.25
6	6B-3	5	19916.2	43.830	43.940	44.040	0.48
6	6B-3	6	33375.5	43.830	44.040	44.110	0.64
6	6B-3	7	36730.8	43.830	44.110	44.110	0.64
6	6B-4	1	3191.8	44.610	44.610	44.630	0.04
6	6B-4	2	5347.2	44.610	44.630	44.670	0.13
6	6B-4	3	7467.7	44.610	44.670	44.680	0.16
6	6B-4	4	13177.0	44.610	44.680	44.680	0.16
6	6B-4	5	19916.2	44.610	44.680	44.740	0.29
6	6B-4	6	33375.5	44.610	44.740	44.800	0.43
6	6B-4	7	36730.8	44.610	44.800	44.800	0.43

TABLE F.1. Contd.

<u>Oven</u>	<u>Specimen</u>	<u>Run</u>	<u>Elapsed Time, h</u>	<u>Initial Weight, g</u>	<u>Run Start Weight, g</u>	<u>Run End Weight, g</u>	<u>Cumulative Weight Gain, %</u>
6	6B-5	1	3191.8	46.590	46.590	46.620	0.06
6	6B-5	2	5347.2	46.590	46.620	46.670	0.17
6	6B-5	3	7467.7	46.590	46.670	46.690	0.21
6	6B-5	4	13177.0	46.590	46.690	46.680	0.19
6	6B-5	5	19916.2	46.590	46.680	46.740	0.32
6	6B-5	6	33375.5	46.590	46.740	46.770	0.39
6	6B-5	7	36730.8	46.590	46.770	46.770	0.39
6	6B-6	1	3191.8	45.120	45.120	45.130	0.02
6	6B-6	2	5347.2	45.120	45.130	45.160	0.09
6	6B-6	3	7467.7	45.120	45.160	45.170	0.11
6	6B-6	4	13177.0	45.120	45.170	45.170	0.11
6	6B-6	5	19916.2	45.120	45.170	45.200	0.18
6	6B-6	6	33375.5	45.120	45.200	45.230	0.24
6	6B-6	7	36730.8	45.120	45.230	45.230	0.24
6	6B-7	1	3191.8	44.820	44.820	44.830	0.02
6	6B-7	2	5347.2	44.820	44.830	44.870	0.11
6	6B-7	3	7467.7	44.820	44.870	44.870	0.11
6	6B-7	4	13177.0	44.820	44.870	44.870	0.11
6	6B-7	5	19916.2	44.820	44.870	44.890	0.16
6	6B-7	6	33375.5	44.820	44.890	44.920	0.22
6	6B-7	7	36730.8	44.820	44.920	44.900	0.18
6	6B-8	1	3191.8	33.828	33.828	33.840	0.04
6	6B-8	2	5347.2	33.828	33.840	33.872	0.13
6	6B-8	3	7467.7	33.828	33.872	33.882	0.16
6	6B-8	4	13177.0	33.828	33.882	33.876	0.14
6	6B-8	5	19916.2	33.828	33.876	33.901	0.22
6	6B-8	6	33375.5	33.828	33.901	33.911	0.25
6	6B-8	7	36730.8	33.828	33.911	33.909	0.24
6	6B-9	1	3191.8	30.804	30.804	30.860	0.18
6	6B-9	2	5347.2	30.804	30.860	30.902	0.32
6	6B-9	3	7467.7	30.804	30.902	30.931	0.41
6	6B-9	4	13177.0	30.804	30.931	30.922	0.38
6	6B-9	5	19916.2	30.804	30.922	30.964	0.52
6	6B-9	6	33375.5	30.804	30.964	30.993	0.61
6	6B-9	7	36730.8	30.804	30.993	30.993	0.61
6	6B-10	1	3191.8	26.259	26.259	26.289	0.11
6	6B-10	2	5347.2	26.259	26.289	26.342	0.32
6	6B-10	3	7467.7	26.259	26.342	26.359	0.38
6	6B-10	4	13177.0	26.259	26.359	26.352	0.35
6	6B-10	5	19916.2	26.259	26.352	26.418	0.61
6	6B-10	6	33375.5	26.259	26.418	26.493	0.89
6	6B-10	7	36730.8	26.259	26.493	26.495	0.90

TABLE F.1. Contd.

Oven	Specimen	Run	Elapsed Time, h	Initial Weight, g	Run Start Weight, g	Run End Weight, g	Cumulative Weight Gain, %
6	6B-11	1	3191.8	18.556	18.556	18.510	-0.25
6	6B-11	2	5347.2	18.556	18.510	18.565	0.05
6	6B-11	3	7467.7	18.556	18.565	18.574 ^(a)	0.10
6	6B-11	4	13177.0	18.505	18.523	18.465 ^(a)	-0.22
6	6B-11	5	19916.2	18.272	18.233	18.279	0.04
6	6B-11	6	33375.5	18.272	18.279	18.362	0.49
6	6B-11	7	36730.8	18.272	18.362	18.364	0.50
6	6B-12	1	3191.8	15.603	15.603	15.604	0.01
6	6B-12	2	5347.2	15.603	15.604	15.613	0.06
6	6B-12	3	7467.7	15.603	15.613	15.612	0.06
6	6B-12	4	13177.0	15.603	15.612	15.610	0.04
6	6B-12	5	19916.2	15.603	15.610	15.613	0.06
6	6B-12	6	33375.5	15.603	15.613	15.609	0.04
6	6B-12	7	36730.8	15.603	15.609	15.608	0.03
7	7B-1	1	1594.5	21.734	21.734	21.918	0.85
7	7B-1	2	3387.0	21.734	21.918	22.047	1.44
7	7B-1	3	5686.8	21.734	22.047	22.143	1.88
7	7B-1	4	8038.3	21.734	22.143	22.163	1.97
7	7B-1	5	13888.2	21.734	22.163	22.199	2.14
7	7B-1	6	20436.2	21.734	22.199	22.330	2.74
7	7B-1	7	31356.5	21.734	22.330	22.551	3.76
7	7B-1	8	37002.4	21.734	22.551	22.613	4.04
7	7B-2	1	1594.5	25.292	25.292	25.548	1.01
7	7B-2	2	3387.0	25.292	25.548	25.600	1.22
7	7B-2	3	5686.8	25.292	25.600	25.699	1.61
7	7B-2	4	8038.3	25.292	25.699	25.730	1.73
7	7B-2	5	13888.2	25.292	25.730	25.797	2.00
7	7B-2	6	20436.2	25.292	25.797	25.949	2.60
7	7B-2	7	31356.5	25.292	25.949	26.280	3.91
7	7B-2	8	37002.4	25.292	26.280	26.362	4.23
7	7B-3	1	1594.5	44.960	44.960	45.000	0.09
7	7B-3	2	3387.0	44.960	45.000	45.090	0.29
7	7B-3	3	5686.8	44.960	45.090	45.170	0.47
7	7B-3	4	8038.3	44.960	45.170	45.180	0.49
7	7B-3	5	13888.2	44.960	45.180	45.210	0.56
7	7B-3	6	20436.2	44.960	45.210	45.480	1.16
7	7B-3	7	31356.5	44.960	45.480	45.820	1.91
7	7B-3	8	37002.4	44.960	45.820	45.910	2.11

TABLE F.1. Contd.

Oven	Specimen	Run	Elapsed Time, h	Initial Weight, g	Run Start Weight, g	Run End Weight, g	Cumulative Weight Gain, %
7	7B-4	1	1594.5	24.835	24.835	24.682	-0.62
7	7B-4	2	3387.0	24.835	24.682	24.720	-0.46
7	7B-4	3	5686.8	24.835	24.720	24.783	-0.21
7	7B-4	4	8038.3	24.835	24.783	24.797	-0.15
7	7B-4	5	13888.2	24.835	24.797	24.841	0.02
7	7B-4	6	20436.2	24.835	24.841	24.925	0.36
7	7B-4	7	31356.5	24.835	24.925	25.190	1.43
7	7B-4	8	37002.4	24.835	25.190	25.279	1.79
7	7B-5	1	1594.5	22.984	22.984	22.424	-2.43
7	7B-5	2	3387.0	22.984	22.424	22.466	-2.25
7	7B-5	3	5686.8	22.984	22.466	22.523	-2.01
7	7B-5	4	8038.3	22.984	22.523	22.547	-1.90
7	7B-5	5	13888.2	22.984	22.547	22.603 ^(a)	-1.66
7	7B-5	6	20436.2	22.661	22.285	22.342	-1.41
7	7B-5	7	31356.5	22.661	22.342	22.435	-1.00
7	7B-5	8	37002.4	22.661	22.435	22.484	-0.78
7	7B-6	1	1594.5	25.104	25.104	25.164	0.24
7	7B-6	2	3387.0	25.104	25.164	25.208	0.41
7	7B-6	3	5686.8	25.104	25.208	25.263	0.63
7	7B-6	4	8038.3	25.104	25.263	25.288	0.73
7	7B-6	5	13888.2	25.104	25.288	25.346	0.96
7	7B-6	6	20436.2	25.104	25.346	25.413	1.23
7	7B-6	7	31356.5	25.104	25.413	25.556	1.80
7	7B-6	8	37002.4	25.104	25.556	25.640	2.14
7	7B-7	1	1594.5	24.293	24.293	24.333	0.16
7	7B-7	2	3387.0	24.293	24.333	24.363	0.29
7	7B-7	3	5686.8	24.293	24.363	24.412	0.49
7	7B-7	4	8038.3	24.293	24.412	24.429	0.56
7	7B-7	5	13888.2	24.293	24.429	24.472	0.74
7	7B-7	6	20436.2	24.293	24.472	24.517	0.92
7	7B-7	7	31356.5	24.293	24.517	24.614	1.32
7	7B-7	8	37002.4	24.293	24.614	24.680	1.59
7	7B-8	1	1594.5	25.253	25.253	25.274	0.08
7	7B-8	2	3387.0	25.253	25.274	25.295	0.17
7	7B-8	3	5686.8	25.253	25.295	25.320	0.27
7	7B-8	4	8038.3	25.253	25.320	25.326	0.29
7	7B-8	5	13888.2	25.253	25.326	25.352	0.39
7	7B-8	6	20436.2	25.253	25.352	25.384	0.52
7	7B-8	7	31356.5	25.253	25.384	25.496	0.96
7	7B-8	8	37002.4	25.253	25.496	25.556	1.20

TABLE F.1. Contd.

Oven	Specimen	Run	Elapsed Time, h	Initial Weight, g	Run Start Weight, g	Run End Weight, g	Cumulative Weight Gain, %
7	7B-9	1	1594.5	24.569	24.569	24.617	0.20
7	7B-9	2	3387.0	24.569	24.617	24.658	0.36
7	7B-9	3	5686.8	24.569	24.658	24.701	0.54
7	7B-9	4	8038.3	24.569	24.701	24.722	0.62
7	7B-9	5	13888.2	24.569	24.722	24.782	0.87
7	7B-9	6	20436.2	24.569	24.782	24.841	1.11
7	7B-9	7	31356.5	24.569	24.841	24.928	1.46
7	7B-9	8	37002.4	24.569	24.928	24.980	1.67
7	7B-10	1	1594.5	22.978	22.978	23.031	0.23
7	7B-10	2	3387.0	22.978	23.031	23.086	0.47
7	7B-10	3	5686.8	22.978	23.086	23.128	0.65
7	7B-10	4	8038.3	22.978	23.128	23.149	0.74
7	7B-10	5	13888.2	22.978	23.149	23.216	1.04
7	7B-10	6	20436.2	22.978	23.216	23.308	1.44
7	7B-10	7	31356.5	22.978	23.308	23.438	2.00
7	7B-10	8	37002.4	22.978	23.438	23.513	2.33
7	7B-11	1	1594.5	23.180	23.180	23.226	0.20
7	7B-11	2	3387.0	23.180	23.226	23.285	0.45
7	7B-11	3	5686.8	23.180	23.285	23.319	0.60
7	7B-11	4	8038.3	23.180	23.319	23.339	0.69
7	7B-11	5	13888.2	23.180	23.339	23.414 ^(a)	1.01
7	7B-11	6	20436.2	22.005	22.227	22.345	1.55
7	7B-11	7	31356.5	22.005	22.345	22.494	2.22
7	7B-11	8	37002.4	22.005	22.494	22.583	2.63
7	7B-12	1	1594.5	15.892	15.892	15.890	-0.01
7	7B-12	2	3387.0	15.892	15.890	15.897	0.03
7	7B-12	3	5686.8	15.892	15.897	15.921	0.18
7	7B-12	4	8038.3	15.892	15.921	15.921	0.18
7	7B-12	5	13888.2	15.892	15.921	15.937	0.28
7	7B-12	6	20436.2	15.892	15.937	15.960	0.43
7	7B-12	7	31356.5	15.892	15.960	15.970	0.49
7	7B-12	8	37002.4	15.892	15.970	15.987	0.60
8	8B-1	1	260.4	26.447	26.447	26.673	0.85
8	8B-1	2	638.9	26.447	26.673	26.877	1.63
8	8B-1	3	1360.4	26.447	26.877	26.979	2.01
8	8B-1	4	2347.3	26.447	26.979	27.107	2.50
8	8B-1	5	3517.4	26.447	27.107	27.237	2.99
8	8B-1	6	4523.3	26.447	27.237	27.395	3.58
8	8B-1	7	5487.8	26.447	27.395	27.469	3.86
8	8B-1	8	6495.8	26.447	27.469	27.490	3.94
8	8B-1	9	10018.7	26.447	27.490	27.522	4.06
8	8B-1	10	14033.3	26.447	27.522	27.553	4.18
8	8B-1	11	22607.0	26.447	27.553	27.614	4.41
8	8B-1	12	33169.8	26.447	27.614	27.679	4.66

TABLE F.1. Contd.

<u>Oven</u>	<u>Specimen</u>	<u>Run</u>	<u>Elapsed Time, h</u>	<u>Initial Weight, g</u>	<u>Run Start Weight, g</u>	<u>Run End Weight, g</u>	<u>Cumulative Weight Gain, %</u>
8	8B-2	1	260.4	23.638	23.638	23.750	0.47
8	8B-2	2	638.9	23.638	23.750	23.864	0.96
8	8B-2	3	1360.4	23.638	23.864	23.957	1.35
8	8B-2	4	2347.3	23.638	23.957	24.221	2.47
8	8B-2	5	3517.4	23.638	24.221	24.468	3.51
8	8B-2	6	4523.3	23.638	24.468	24.514	3.71
8	8B-2	7	5487.8	23.638	24.514	24.517	3.72
8	8B-2	8	6495.8	23.638	24.517	24.522	3.74
8	8B-2	9	10018.7	23.638	24.522	24.549	3.85
8	8B-2	10	14033.3	23.638	24.549	24.383	3.15
8	8B-2	11	22607.0	23.638	24.383	24.406	3.25
8	8B-2	12	33169.8	23.638	24.406	24.425	3.33
8	8B-3	1	260.4	40.430	40.430	40.450	0.05
8	8B-3	2	638.9	40.430	40.450	40.570	0.35
8	8B-3	3	1360.4	40.430	40.570	40.710	0.69
8	8B-3	4	2347.3	40.430	40.710	41.160	1.81
8	8B-3	5	3517.4	40.430	41.160	41.590	2.87
8	8B-3	6	4523.3	40.430	41.590	41.800	3.39
8	8B-3	7	5487.8	40.430	41.800	41.910	3.66
8	8B-3	8	6495.8	40.430	41.910	41.950	3.76
8	8B-3	9	10018.7	40.430	41.950	42.010	3.91
8	8B-3	10	14033.3	40.430	42.010	42.070	4.06
8	8B-3	11	22607.0	40.430	42.070	42.180	4.33
8	8B-3	12	33169.8	40.430	42.180	42.490	5.10
8	8B-4	1	260.4	24.359	24.359	24.403	0.18
8	8B-4	2	638.9	24.359	24.403	24.552	0.79
8	8B-4	3	1360.4	24.359	24.552	24.684	1.33
8	8B-4	4	2347.3	24.359	24.684	24.972	2.52
8	8B-4	5	3517.4	24.359	24.972	25.120	3.12
8	8B-4	6	4523.3	24.359	25.120	24.576	0.89
8	8B-4	7	5487.8	24.359	24.576	24.595	0.97
8	8B-4	8	6495.8	24.359	24.595	24.609	1.03
8	8B-4	9	10018.7	24.359	24.609	24.647	1.18
8	8B-4	10	14033.3	24.359	24.647	24.668	1.27
8	8B-4	11	22607.0	24.359	24.668	24.710	1.44
8	8B-4	12	33169.8	24.359	24.710	24.745	1.58

TABLE F.1. Contd.

<u>Oven</u>	<u>Specimen</u>	<u>Run</u>	<u>Elapsed Time, h</u>	<u>Initial Weight, g</u>	<u>Run Start Weight, g</u>	<u>Run End Weight, g</u>	<u>Cumulative Weight Gain, %</u>
8	8B-5	1	260.4	45.300	45.300	45.310	0.02
8	8B-5	2	638.9	45.300	45.310	45.400	0.22
8	8B-5	3	1360.4	45.300	45.400	45.510	0.46
8	8B-5	4	2347.3	45.300	45.510	45.830	1.17
8	8B-5	5	3517.4	45.300	45.830	46.300	2.21
8	8B-5	6	4523.3	45.300	46.300	46.670	3.02
8	8B-5	7	5487.8	45.300	46.670	46.900	3.53
8	8B-5	8	6495.8	45.300	46.900	46.970	3.69
8	8B-5	9	10018.7	45.300	46.970	47.030	3.82
8	8B-5	10	14033.3	45.300	47.030	47.090	3.95
8	8B-5	11	22607.0	45.300	47.090	47.230	4.26
8	8B-5	12	33169.8	45.300	47.230	47.390	4.61
8	8B-6	1	260.4	44.890	44.890	44.900	0.02
8	8B-6	2	638.9	44.890	44.900	44.980	0.20
8	8B-6	3	1360.4	44.890	44.980	45.080	0.42
8	8B-6	4	2347.3	44.890	45.080	45.390	1.11
8	8B-6	5	3517.4	44.890	45.390	45.830	2.09
8	8B-6	6	4523.3	44.890	45.830	46.200	2.92
8	8B-6	7	5487.8	44.890	46.200	46.460	3.50
8	8B-6	8	6495.8	44.890	46.460	46.540	3.68
8	8B-6	9	10018.7	44.890	46.540	46.610	3.83
8	8B-6	10	14033.3	44.890	46.610	46.670	3.97
8	8B-6	11	22607.0	44.890	46.670	46.800	4.25
8	8B-6	12	33169.8	44.890	46.800	46.970	4.63
8	8B-7	1	260.4	45.640	45.640	45.660	0.04
8	8B-7	2	638.9	45.640	45.660	45.760	0.26
8	8B-7	3	1360.4	45.640	45.760	45.890	0.55
8	8B-7	4	2347.3	45.640	45.890	46.350	1.56
8	8B-7	5	3517.4	45.640	46.350	46.750	2.43
8	8B-7	6	4523.3	45.640	46.750	46.990	2.96
8	8B-7	7	5487.8	45.640	46.990	47.180	3.37
8	8B-7	8	6495.8	45.640	47.180	47.260	3.55
8	8B-7	9	10018.7	45.640	47.260	47.330	3.70
8	8B-7	10	14033.3	45.640	47.330	47.400	3.86
8	8B-7	11	22607.0	45.640	47.400	47.530	4.14
8	8B-7	12	33169.8	45.640	47.530	47.800	4.73

TABLE F.1. Contd.

<u>Oven</u>	<u>Specimen</u>	<u>Run</u>	<u>Elapsed Time, h</u>	<u>Initial Weight, g</u>	<u>Run Start Weight, g</u>	<u>Run End Weight, g</u>	<u>Cumulative Weight Gain, %</u>
8	8B-8	1	260.4	44.030	44.030	44.050	0.05
8	8B-8	2	638.9	44.030	44.050	44.130	0.23
8	8B-8	3	1360.4	44.030	44.130	44.260	0.52
8	8B-8	4	2347.3	44.030	44.260	44.680	1.48
8	8B-8	5	3517.4	44.030	44.680	45.070	2.36
8	8B-8	6	4523.3	44.030	45.070	45.300	2.88
8	8B-8	7	5487.8	44.030	45.300	45.510	3.36
8	8B-8	8	6495.8	44.030	45.510	45.590	3.54
8	8B-8	9	10018.7	44.030	45.590	45.660	3.70
8	8B-8	10	14033.3	44.030	45.660	45.720	3.84
8	8B-8	11	22607.0	44.030	45.720	45.850	4.13
8	8B-8	12	33169.8	44.030	45.850	46.110	4.72
8	8B-9	1	260.4	44.480	44.480	44.490	0.02
8	8B-9	2	638.9	44.480	44.490	44.560	0.18
8	8B-9	3	1360.4	44.480	44.560	44.650	0.38
8	8B-9	4	2347.3	44.480	44.650	44.970	1.10
8	8B-9	5	3517.4	44.480	44.970	45.400	2.07
8	8B-9	6	4523.3	44.480	45.400	45.740	2.83
8	8B-9	7	5487.8	44.480	45.740	45.980	3.37
8	8B-9	8	6495.8	44.480	45.980	46.080	3.60
8	8B-9	9	10018.7	44.480	46.080	46.170	3.80
8	8B-9	10	14033.3	44.480	46.170	46.230	3.93
8	8B-9	11	22607.0	44.480	46.230	46.350	4.20
8	8B-9	12	33169.8	44.480	46.350	46.480	4.50
8	8B-10	1	260.4	44.690	44.690	44.700	0.02
8	8B-10	2	638.9	44.690	44.700	44.770	0.18
8	8B-10	3	1360.4	44.690	44.770	44.870	0.40
8	8B-10	4	2347.3	44.690	44.870	45.220	1.19
8	8B-10	5	3517.4	44.690	45.220	45.610	2.06
8	8B-10	6	4523.3	44.690	45.610	45.940	2.80
8	8B-10	7	5487.8	44.690	45.940	46.160	3.29
8	8B-10	8	6495.8	44.690	46.160	46.270	3.54
8	8B-10	9	10018.7	44.690	46.270	46.360	3.74
8	8B-10	10	14033.3	44.690	46.360	46.426	3.88
8	8B-10	11	22607.0	44.690	46.426	46.550	4.16
8	8B-10	12	33169.8	44.690	46.550	46.700	4.50

TABLE F.1. Contd.

Oven	Specimen	Run	Elapsed Time, h	Initial Weight, g	Run Start Weight, g	Run End Weight, g	Cumulative Weight Gain, %
8	8B-11	1	260.4	46.770	46.770	46.790	0.04
8	8B-11	2	638.9	46.770	46.790	46.840	0.15
8	8B-11	3	1360.4	46.770	46.840	46.920	0.32
8	8B-11	4	2347.3	46.770	46.920	47.260	1.05
8	8B-11	5	3517.4	46.770	47.260	47.600	1.77
8	8B-11	6	4523.3	46.770	47.600	47.870	2.35
8	8B-11	7	5487.8	46.770	47.870	48.110	2.87
8	8B-11	8	6495.8	46.770	48.110	48.260	3.19
8	8B-11	9	10018.7	46.770	48.260	48.390	3.46
8	8B-11	10	14033.3	46.770	48.390	48.510	3.72
8	8B-11	11	22607.0	46.770	48.510	48.670	4.06
8	8B-11	12	33169.8	46.770	48.670	48.850	4.45
8	8B-12	1	260.4	16.420	16.420	16.424	0.02
8	8B-12	2	638.9	16.420	16.424	16.429	0.05
8	8B-12	3	1360.4	16.420	16.429	16.440	0.12
8	8B-12	4	2347.3	16.420	16.440	16.489	0.42
8	8B-12	5	3517.4	16.420	16.489	16.608	1.14
8	8B-12	6	4523.3	16.420	16.608	16.739	1.94
8	8B-12	7	5487.8	16.420	16.739	16.874	2.76
8	8B-12	8	6495.8	16.420	16.874	16.991	3.48
8	8B-12	9	10018.7	16.420	16.991	17.262	5.13
8	8B-12	10	14033.3	16.420	17.262	17.809	8.46
8	8B-12	11	22607.0	16.420	17.809	18.595	13.25
8	8B-12	12	33169.8	16.420	18.595	18.827	14.66
9	9B-1	2. ^(c)	347.8	23.995	23.995	24.303	1.28
9	9B-1	3	826.6	23.995	24.303	24.383	1.62
9	9B-1	4	1446.3	23.995	24.383	24.426	1.80
9	9B-1	5	2362.1	23.995	24.426	24.471	1.98
9	9B-1	6	3201.9	23.995	24.471	24.531	2.23
9	9B-1	7	4349.7	23.995	24.531	24.690	2.90
9	9B-1	8	5020.5	23.995	24.690	24.770	3.23
9	9B-1	9	5401.0	23.995	24.770	24.812	3.40
9	9B-1	10	6145.4	23.995	24.812	24.836	3.50
9	9B-1	11	7615.5	23.995	24.836	24.896	3.75
9	9B-1	12	9325.1	23.995	24.896	24.945	3.96
9	9B-1	13	14073.2	23.995	24.945	24.991	4.15
9	9B-1	14	19493.2	23.995	24.991	25.043	4.37
9	9B-1	15	25391.1	23.995	25.043	25.070	4.48
9	9B-1	16	32421.9	23.995	25.070	25.137	4.76

TABLE F.1. Contd.

Oven	Specimen	Run	Elapsed Time, h	Initial Weight, g	Run Start Weight, g	Run End Weight, g	Cumulative Weight Gain, %
9	9B-2	2	347.8	23.988	23.988	24.182	0.81
9	9B-2	3	826.6	23.988	24.182	24.368	1.58
9	9B-2	4	1446.3	23.988	24.368	24.491	2.10
9	9B-2	5	2362.1	23.988	24.491	24.525	2.24
9	9B-2	6	3201.9	23.988	24.525	24.557	2.37
9	9B-2	7	4349.7	23.988	24.557	24.659	2.80
9	9B-2	8	5020.5	23.988	24.659	24.769	3.26
9	9B-2	9	5401.0	23.988	24.769	24.807	3.41
9	9B-2	10	6145.4	23.988	24.807	24.825	3.49
9	9B-2	11	7615.5	23.988	24.825	24.881	3.72
9	9B-2	12	9325.1	23.988	24.881	24.904	3.82
9	9B-2	13	14073.2	23.988	24.904	24.933	3.94
9	9B-2	14	19493.2	23.988	24.933	24.955	4.03
9	9B-2	15	25391.1	23.988	24.955	24.964	4.07
9	9B-2	16	32421.9	23.988	24.964	24.977	4.12
9	9B-3	2	347.8	23.752	23.752	23.962	0.88
9	9B-3	3	826.6	23.752	23.962	24.108	1.50
9	9B-3	4	1446.3	23.752	24.108	24.244	2.07
9	9B-3	5	2362.1	23.752	24.244	24.288	2.26
9	9B-3	6	3201.9	23.752	24.288	24.321	2.40
9	9B-3	7	4349.7	23.752	24.321	24.416	2.80
9	9B-3	8	5020.5	23.752	24.416	24.503	3.16
9	9B-3	9	5401.0	23.752	24.503	24.535	3.30
9	9B-3	10	6145.4	23.752	24.535	24.550	3.36
9	9B-3	11	7615.5	23.752	24.550	24.602	3.58
9	9B-3	12	9325.1	23.752	24.602	24.621	3.66
9	9B-3	13	14073.2	23.752	24.621	24.646	3.76
9	9B-3	14	19493.2	23.752	24.646	24.663	3.84
9	9B-3	15	25391.1	23.752	24.663	24.671	3.87
9	9B-3	16	32421.9	23.752	24.671	24.681	3.91
9	9B-4	2	347.8	23.361	23.361	23.483	0.52
9	9B-4	3	826.6	23.361	23.483	23.616	1.09
9	9B-4	4	1446.3	23.361	23.616	23.817	1.95
9	9B-4	5	2362.1	23.361	23.817	23.916	2.38
9	9B-4	6	3201.9	23.361	23.916	23.987	2.68
9	9B-4	7	4349.7	23.361	23.987	24.168	3.45
9	9B-4	8	5020.5	23.361	24.168	24.251	3.81
9	9B-4	9	5401.0	23.361	24.251	24.273	3.90
9	9B-4	10	6145.4	23.361	24.273	24.285	3.96
9	9B-4	11	7615.5	23.361	24.285	24.325	4.13
9	9B-4	12	9325.1	23.361	24.325	24.336	4.17
9	9B-4	13	14073.2	23.361	24.336	24.358	4.27
9	9B-4	14	19493.2	23.361	24.358	24.375	4.34
9	9B-4	15	25391.1	23.361	24.375	24.385	4.38
9	9B-4	16	32421.9	23.361	24.385	24.396	4.43

TABLE F.1. Contd.

Oven	Specimen	Run	Elapsed Time, h	Initial Weight, g	Run Start Weight, g	Run End Weight, g	Cumulative Weight Gain, %
9	9B-5	2	347.8	44.880	44.880	45.060	0.40
9	9B-5	3	826.6	44.880	45.060	45.180	0.67
9	9B-5	4	1446.3	44.880	45.180	45.530	1.45
9	9B-5	5	2362.1	44.880	45.530	45.990	2.47
9	9B-5	6	3201.9	44.880	45.990	46.300	3.16
9	9B-5	7	4349.7	44.880	46.300	46.540	3.70
9	9B-5	8	5020.5	44.880	46.540	46.590	3.81
9	9B-5	9	5401.0	44.880	46.590	46.640	3.92
9	9B-5	10	6145.4	44.880	46.640	46.670	3.99
9	9B-5	11	7615.5	44.880	46.670	46.750	4.17
9	9B-5	12	9325.1	44.880	46.750	46.860	4.41
9	9B-5	3	14073.2	44.880	46.860	47.010	4.75
9	9B-5	14	19493.2	44.880	47.010	47.190	5.15
9	9B-5	15	25391.1	44.880	47.190	47.360	5.53
9	9B-5	16	32421.9	44.880	47.360	47.820	6.55
9	9B-6	2	347.8	25.110	25.110	25.181	0.28
9	9B-6	3	826.6	25.110	25.181	25.246	0.54
9	9B-6	4	1446.3	25.110	25.246	25.404	1.17
9	9B-6	5	2362.1	25.110	25.404	25.567	1.82
9	9B-6	6	3201.9	25.110	25.567	25.699	2.35
9	9B-6	7	4349.7	25.110	25.699	25.861	2.99
9	9B-6	8	5020.5	25.110	25.861	26.011	3.59
9	9B-6	9	5401.0	25.110	26.011	26.054	3.76
9	9B-6	10	6145.4	25.110	26.054	26.073	3.84
9	9B-6	11	7615.5	25.110	26.073	26.122	4.03
9	9B-6	12	9325.1	25.110	26.122	26.140	4.10
9	9B-6	13	14073.2	25.110	26.140	26.169	4.22
9	9B-6	14	19493.2	25.110	26.169	26.190 ^(a)	4.30
9	9B-6	15	25391.1	23.072	24.064	24.075	4.35
9	9B-6	16	32421.9	23.072	24.075	24.091	4.42
9	9B-7	2	347.8	36.673	36.673	36.798	0.34
9	9B-7	3	826.6	36.673	36.798	36.912	0.65
9	9B-7	4	1446.3	36.673	36.912	37.229	1.52
9	9B-7	5	2362.1	36.673	37.229	37.551	2.39
9	9B-7	6	3201.9	36.673	37.551	37.750	2.94
9	9B-7	7	4349.7	36.673	37.750	37.910	3.37
9	9B-7	8	5020.5	36.673	37.910	37.960	3.51
9	9B-7	9	5401.0	36.673	37.960	37.990	3.59
9	9B-7	10	6145.4	36.673	37.990	38.010	3.65
9	9B-7	11	7615.5	36.673	38.010	38.060	3.78
9	9B-7	12	9325.1	36.673	38.060	38.120	3.95
9	9B-7	13	14073.2	36.673	38.120	38.200	4.16
9	9B-7	14	19493.2	36.673	38.200	38.310	4.46
9	9B-7	15	25391.1	36.673	38.310	38.380	4.65
9	9B-7	16	32421.9	36.673	38.380	38.590	5.23

TABLE F.1. Contd.

Oven	Specimen	Run	Elapsed Time, h	Initial Weight, g	Run Start Weight, g	Run End Weight, g	Cumulative Weight Gain, %
9	9B-8	2	347.8	45.670	45.670	45.830	0.35
9	9B-8	3	826.6	45.670	45.830	45.960	0.63
9	9B-8	4	1446.3	45.670	45.960	46.280	1.34
9	9B-8	5	2362.1	45.670	46.280	46.690	2.23
9	9B-8	6	3201.9	45.670	46.690	46.990	2.89
9	9B-8	7	4349.7	45.670	46.990	47.270	3.50
9	9B-8	8	5020.5	45.670	47.270	47.350	3.68
9	9B-8	9	5401.0	45.670	47.350	47.430	3.85
9	9B-8	10	6145.4	45.670	47.430	47.460	3.92
9	9B-8	11	7615.5	45.670	47.460	47.550	4.12
9	9B-8	12	9325.1	45.670	47.550	47.680	4.40
9	9B-8	13	14073.2	45.670	47.680	47.900	4.88
9	9B-8	14	19493.2	45.670	47.900	48.280	5.71
9	9B-8	15	25391.1	45.670	48.280	48.590	6.39
9	9B-8	16	32421.9	45.670	48.590	49.450	8.28
9	9B-9	2	347.8	46.240	46.240	46.380	0.30
9	9B-9	3	826.6	46.240	46.380	46.480	0.52
9	9B-9	4	1446.3	46.240	46.480	46.800	1.21
9	9B-9	5	2362.1	46.240	46.800	47.190	2.05
9	9B-9	6	3201.9	46.240	47.190	47.540	2.81
9	9B-9	7	4349.7	46.240	47.540	47.870	3.53
9	9B-9	8	5020.5	46.240	47.870	47.960	3.72
9	9B-9	9	5401.0	46.240	47.960	48.010	3.83
9	9B-9	10	6145.4	46.240	48.010	48.040	3.89
9	9B-9	11	7615.5	46.240	48.040	48.130	4.09
9	9B-9	12	9325.1	46.240	48.130	48.230	4.30
9	9B-9	13	14073.2	46.240	48.230	48.390	4.65
9	9B-9	14	19493.2	46.240	48.390	48.560	5.02
9	9B-9	15	25391.1	46.240	48.560	48.700	5.32
9	9B-9	16	32421.9	46.240	48.700	42.260	-8.61
9	9B-10	2	347.8	45.610	45.610	45.730	0.26
9	9B-10	3	826.6	45.610	45.730	45.820	0.46
9	9B-10	4	1446.3	45.610	45.820	46.080	1.03
9	9B-10	5	2362.1	45.610	46.080	46.480	1.91
9	9B-10	6	3201.9	45.610	46.480	46.850	2.72
9	9B-10	7	4349.7	45.610	46.850	47.200	3.49
9	9B-10	8	5020.5	45.610	47.200	47.290	3.68
9	9B-10	9	5401.0	45.610	47.290	47.330	3.77
9	9B-10	10	6145.4	45.610	47.330	47.360	3.84
9	9B-10	11	7615.5	45.610	47.360	47.430	3.99
9	9B-10	12	9325.1	45.610	47.430	47.500	4.14
9	9B-10	13	14073.2	45.610	47.500	47.600	4.36
9	9B-10	14	19493.2	45.610	47.600	47.710 ^(a)	4.60
9	9B-10	15	25391.1	40.381	42.240	42.300	4.75
9	9B-10	16	32421.9	40.381	42.300	49.330	22.16

TABLE F.1. Contd.

Oven	Specimen	Run	Elapsed Time, h	Initial Weight, g	Run Start Weight, g	Run End Weight, g	Cumulative Weight Gain, %
9	9B-11	2	347.8	46.280	46.280	46.390	0.24
9	9B-11	3	826.6	46.280	46.390	46.470	0.41
9	9B-11	4	1446.3	46.280	46.470	46.700	0.91
9	9B-11	5	2362.1	46.280	46.700	47.040	1.64
9	9B-11	6	3201.9	46.280	47.040	47.390	2.40
9	9B-11	7	4349.7	46.280	47.390	47.790	3.26
9	9B-11	8	5020.5	46.280	47.790	47.920	3.54
9	9B-11	9	5401.0	46.280	47.920	47.980	3.67
9	9B-11	10	6145.4	46.280	47.980	48.000	3.72
9	9B-11	11	7615.5	46.280	48.000	48.080	3.89
9	9B-11	12	9325.1	46.280	48.080	48.140	4.02
9	9B-11	13	14073.2	46.280	48.140	48.240	4.24
9	9B-11	14	19493.2	46.280	48.240	48.330	4.43
9	9B-11	15	25391.1	46.280	48.330	48.380	4.54
9	9B-11	16	32421.9	46.280	48.380	48.520	4.84
9	9B-12	2	347.8	15.928	15.928	15.933	0.03
9	9B-12	3	826.6	15.928	15.933	15.974	0.29
9	9B-12	4	1446.3	15.928	15.974	16.084	0.98
9	9B-12	5	2362.1	15.928	16.084	16.266	2.12
9	9B-12	6	3201.9	15.928	16.266	16.577	4.07
9	9B-12	7	4349.7	15.928	16.577	16.847	5.77
9	9B-12	8	5020.5	15.928	16.847	16.990	6.67
9	9B-12	9	5401.0	15.928	16.990	17.010	6.79
9	9B-12	10	6145.4	15.928	17.010	17.025	6.89
9	9B-12	11	7615.5	15.928	17.025	17.147	7.65
9	9B-12	12	9325.1	15.928	17.147	17.328	8.79
9	9B-12	13	14073.2	15.928	17.328	17.804	11.78
9	9B-12	14	19493.2	15.928	17.804	18.132	13.83
9	9B-12	15	25391.1	15.928	18.132	18.157	13.99
9	9B-12	16	32421.9	15.928	18.157	18.225	14.42
10	10B-1	2. ^a	1701.9	26.492	26.492	26.525	0.12
10	10B-1	3	4603.5	26.492	26.525	26.608	0.44
10	10B-1	4	6742.6	26.492	26.608	26.633	0.53
10	10B-1	5	8733.9	26.492	26.633	26.670	0.67
10	10B-1	6	14566.8	26.492	26.670	26.697	0.77
10	10B-1	7	18958.4	26.492	26.697	26.848	1.34
10	10B-1	8	32277.5	26.492	26.848	27.298	3.04
10	10B-1	9	36134.2	26.492	27.298	27.355	3.26

^a Oven 10, Run 1 intentionally shut off to recheck specimen weights. 64.9 hours of exposure added to the Run 2 time.

TABLE F.1. Contd.

Oven	Specimen	Run	Elapsed Time, h	Initial Weight, g	Run Start Weight, g	Run End Weight, g	Cumulative Weight Gain, %
10	10B-2	2	1701.9	22.861	22.861	22.871	0.04
10	10B-2	3	4603.5	22.861	22.871	22.907	0.20
10	10B-2	4	6742.6	22.861	22.907	22.921	0.26
10	10B-2	5	8733.9	22.861	22.921	22.942	0.35
10	10B-2	6	14566.8	22.861	22.942	22.961	0.44
10	10B-2	7	18958.4	22.861	22.961	23.062	0.88
10	10B-2	8	32277.5	22.861	23.062	23.402	2.37
10	10B-2	9	36134.2	22.861	23.402	23.490	2.75
10	10B-3	2	1701.9	23.496	23.496	23.502	0.03
10	10B-3	3	4603.5	23.496	23.502	23.516	0.09
10	10B-3	4	6742.6	23.496	23.516	23.521 ^(a)	0.10
10	10B-3	5	8733.9	23.201	23.226	23.237	0.16
10	10B-3	6	14566.8	23.201	23.237	23.245 ^(a)	0.19
10	10B-3	7	18958.4	23.014	23.058	23.118	0.45
10	10B-3	8	32277.5	23.014	23.118	23.205	0.83
10	10B-3	9	36134.2	23.014	23.205	23.256	1.05
10	10B-4	2	1701.9	44.660	44.660	44.670	0.02
10	10B-4	3	4603.5	44.660	44.670	44.680	0.04
10	10B-4	4	6742.6	44.660	44.680	44.690	0.07
10	10B-4	5	8733.9	44.660	44.690	44.700	0.09
10	10B-4	6	14566.8	44.660	44.700	44.697	0.08
10	10B-4	7	18958.4	44.660	44.697	44.770	0.24
10	10B-4	8	32277.5	44.660	44.770	44.830	0.38
10	10B-4	9	36134.2	44.660	44.830	44.870	0.47
10	10B-5	2	1701.9	36.802	36.802	36.808	0.02
10	10B-5	3	4603.5	36.802	36.808	36.823	0.06
10	10B-5	4	6742.6	36.802	36.823	36.824	0.06
10	10B-5	5	8733.9	36.802	36.824	36.832	0.08
10	10B-5	6	14566.8	36.802	36.832	36.834	0.09
10	10B-5	7	18958.4	36.802	36.834	36.878	0.21
10	10B-5	8	32277.5	36.802	36.878	36.900	0.27
10	10B-5	9	36134.2	36.802	36.900	36.934	0.36
10	10B-6	2	1701.9	46.400	46.400	46.400	0.00
10	10B-6	3	4603.5	46.400	46.400	46.420	0.04
10	10B-6	4	6742.6	46.400	46.420	46.420 ^(a)	0.04
10	10B-6	5	8733.9	45.900	45.920	45.930	0.07
10	10B-6	6	14566.8	45.900	45.930	45.940 ^(a)	0.09
10	10B-6	7	18958.4	44.551	44.590	44.640	0.20
10	10B-6	8	32277.5	44.551	44.640	44.650	0.22
10	10B-6	9	36134.2	44.551	44.650	44.660	0.24

TABLE F.1. Contd.

Oven	Specimen	Run	Elapsed Time, h	Initial Weight, g	Run Start Weight, g	Run End Weight, g	Cumulative Weight Gain, %
10	10B-7	2	1701.9	46.000	46.000	46.010	0.02
10	10B-7	3	4603.5	46.000	46.010	46.010	0.02
10	10B-7	4	6742.6	46.000	46.010	46.010	0.02
10	10B-7	5	8733.9	46.000	46.010	46.020	0.04
10	10B-7	6	14566.8	46.000	46.020	46.020	0.04
10	10B-7	7	18958.4	46.000	46.020	46.060	0.13
10	10B-7	8	32277.5	46.000	46.060	46.050	0.11
10	10B-7	9	36134.2	46.000	46.050	45.960	-0.09
10	10B-8	2	1701.9	46.520	46.520	46.520	0.00
10	10B-8	3	4603.5	46.520	46.520	46.530	0.02
10	10B-8	4	6742.6	46.520	46.530	46.530	0.02
10	10B-8	5	8733.9	46.520	46.530	46.540	0.04
10	10B-8	6	14566.8	46.520	46.540	46.540	0.04
10	10B-8	7	18958.4	46.520	46.540	46.570	0.11
10	10B-8	8	32277.5	46.520	46.570	46.570	0.11
10	10B-8	9	36134.2	46.520	46.570	46.570	0.11
10	10B-9	2	1701.9	43.270	43.270	43.280	0.02
10	10B-9	3	4603.5	43.270	43.280	43.280	0.02
10	10B-9	4	6742.6	43.270	43.280	43.280	0.02
10	10B-9	5	8733.9	43.270	43.280	43.290	0.05
10	10B-9	6	14566.8	43.270	43.290	43.290	0.05
10	10B-9	7	18958.4	43.270	43.290	43.330	0.14
10	10B-9	8	32277.5	43.270	43.330	43.330	0.14
10	10B-9	9	36134.2	43.270	43.330	43.330	0.14
10	10B-10	2	1701.9	45.930	45.930	45.930	0.00
10	10B-10	3	4603.5	45.930	45.930	45.940	0.02
10	10B-10	4	6742.6	45.930	45.940	45.940 ^(a)	0.02
10	10B-10	5	8733.9	45.320	45.330	45.340 ^(a)	0.04
10	10B-10	6	14566.8	45.250	45.270	45.270 ^(a)	0.04
10	10B-10	7	18958.4	44.590	44.610	44.650	0.13
10	10B-10	8	32277.5	44.590	44.650	44.650	0.13
10	10B-10	9	36134.2	44.590	44.650	44.650	0.13
10	10B-11	2	1701.9	45.870	45.870	45.880	0.02
10	10B-11	3	4603.5	45.870	45.880	45.890	0.04
10	10B-11	4	6742.6	45.870	45.890	45.890	0.04
10	10B-11	5	8733.9	45.870	45.890	45.900	0.07
10	10B-11	6	14566.8	45.870	45.900	45.900	0.07
10	10B-11	7	18958.4	45.870	45.900	45.950	0.17
10	10B-11	8	32277.5	45.870	45.950	45.950	0.17
10	10B-11	9	36134.2	45.870	45.950	45.950	0.17

TABLE F.1. Contd.

<u>Oven</u>	<u>Specimen</u>	<u>Run</u>	<u>Elapsed Time, h</u>	<u>Initial Weight, g</u>	<u>Run Start Weight, g</u>	<u>Run End Weight, g</u>	<u>Cumulative Weight Gain, %</u>
10	10B-12	2	1701.9	15.746	15.746	15.746	0.00
10	10B-12	3	4603.5	15.746	15.746	15.747	0.01
10	10B-12	4	6742.6	15.746	15.747	15.746	0.00
10	10B-12	5	8733.9	15.746	15.746	15.750	0.03
10	10B-12	6	14566.8	15.746	15.750	15.750	0.03
10	10B-12	7	18958.4	15.746	15.750	15.754	0.05
10	10B-12	8	32277.5	15.746	15.754	15.753	0.04
10	10B-12	9	36134.2	15.746	15.753	15.749	0.02
11	11B-1	1	491.7	24.332	24.332	24.581	1.02
11	11B-1	2	1491.6	24.332	24.581	24.764	1.78
11	11B-1	3	2771.3	24.332	24.764	24.986	2.69
11	11B-1	4	4158.1	24.332	24.986	25.084	3.09
11	11B-1	5	5545.4	24.332	25.084	25.077	3.06
11	11B-1	6	7633.1	24.332	25.077	25.076	3.06
11	11B-1	7	12821.8	24.332	25.076	25.074	3.05
11	11B-1	8	16685.4	24.332	25.074	25.091	3.12
11	11B-1	9	24918.2	24.332	25.091	25.093	3.13
11	11B-1	10	35338.0	24.332	25.093	25.116	3.22
11	11B-2	1	491.7	23.854	23.854	23.950	0.40
11	11B-2	2	1491.6	23.854	23.950	24.055	0.84
11	11B-2	3	2771.3	23.854	24.055	24.345	2.06
11	11B-2	4	4158.1	23.854	24.345	24.449	2.49
11	11B-2	5	5545.4	23.854	24.449	24.471	2.59
11	11B-2	6	7633.1	23.854	24.471	24.487	2.65
11	11B-2	7	12821.8	23.854	24.487	24.520	2.79
11	11B-2	8	16685.4	23.854	24.520	24.610	3.17
11	11B-2	9	24918.2	23.854	24.610	24.635	3.27
11	11B-2	10	35338.0	23.854	24.635	24.708	3.58
11	11B-3	1	491.7	23.308	23.308	23.384	0.33
11	11B-3	2	1491.6	23.308	23.384	23.477	0.73
11	11B-3	3	2771.3	23.308	23.477	23.697	1.67
11	11B-3	4	4158.1	23.308	23.697	23.807	2.14
11	11B-3	5	5545.4	23.308	23.807	23.839	2.28
11	11B-3	6	7633.1	23.308	23.839	23.862	2.38
11	11B-3	7	12821.8	23.308	23.862	23.907	2.57
11	11B-3	8	16685.4	23.308	23.907	24.007	3.00
11	11B-3	9	24918.2	23.308	24.007	24.036	3.12
11	11B-3	10	35338.0	23.308	24.036	24.108	3.43

TABLE F.1. Contd.

Oven	Specimen	Run	Elapsed Time, h	Initial Weight, g	Run Start Weight, g	Run End Weight, g	Cumulative Weight Gain, %
11	11B-4	1	491.7	22.992	22.992	23.038	0.20
11	11B-4	2	1491.6	22.992	23.038	23.117	0.54
11	11B-4	3	2771.3	22.992	23.117	23.335	1.49
11	11B-4	4	4158.1	22.992	23.335	23.443	1.96
11	11B-4	5	5545.4	22.992	23.443	23.473	2.09
11	11B-4	6	7633.1	22.992	23.473	23.501 ^(a)	2.21
11	11B-4	7	12821.8	22.677	23.179	23.263	2.58
11	11B-4	8	16685.4	22.677	23.263	23.415 ^(a)	3.25
11	11B-4	9	24918.2	22.309	23.035	23.086	3.49
11	11B-4	10	35338.0	22.309	23.086	23.214	4.06
11	11B-5	1	491.7	44.240	44.240	44.270	0.07
11	11B-5	2	1491.6	44.240	44.270	44.360	0.27
11	11B-5	3	2771.3	44.240	44.360	44.600	0.81
11	11B-5	4	4158.1	44.240	44.600	44.660	0.95
11	11B-5	5	5545.4	44.240	44.660	44.730	1.11
11	11B-5	6	7633.1	44.240	44.730	44.800	1.27
11	11B-5	7	12821.8	44.240	44.800	45.000	1.72
11	11B-5	8	16685.4	44.240	45.000	45.140	2.03
11	11B-5	9	24918.2	44.240	45.140	45.240	2.26
11	11B-5	10	35338.0	44.240	45.240	45.360	2.53
11	11B-6	1	491.7	44.560	44.560	44.580	0.04
11	11B-6	2	1491.6	44.560	44.580	44.650	0.20
11	11B-6	3	2771.3	44.560	44.650	44.840	0.63
11	11B-6	4	4158.1	44.560	44.840	44.900	0.76
11	11B-6	5	5545.4	44.560	44.900	44.950	0.88
11	11B-6	6	7633.1	44.560	44.950	45.000	0.99
11	11B-6	7	12821.8	44.560	45.000	45.280	1.62
11	11B-6	8	16685.4	44.560	45.280	45.440	1.97
11	11B-6	9	24918.2	44.560	45.440	45.570	2.27
11	11B-6	10	35338.0	44.560	45.570	45.910	3.03
11	11B-7	1	491.7	35.173	35.173	35.204	0.09
11	11B-7	2	1491.6	35.173	35.204	35.271	0.28
11	11B-7	3	2771.3	35.173	35.271	35.446	0.78
11	11B-7	4	4158.1	35.173	35.446	35.487	0.89
11	11B-7	5	5545.4	35.173	35.487	35.507	0.95
11	11B-7	6	7633.1	35.173	35.507	35.536	1.03
11	11B-7	7	12821.8	35.173	35.536	35.680	1.44
11	11B-7	8	16685.4	35.173	35.680	35.792 ^(a)	1.76
11	11B-7	9	24918.2	34.027	34.626	34.709	2.01
11	11B-7	10	35338.0	34.027	34.709	34.936	2.67

TABLE F.1. Contd.

Oven	Specimen	Run	Elapsed Time, h	Initial Weight, g	Run Start Weight, g	Run End Weight, g	Cumulative Weight Gain, %
11	11B-8	1	491.7	46.150	46.150	46.170	0.04
11	11B-8	2	1491.6	46.150	46.170	46.260	0.24
11	11B-8	3	2771.3	46.150	46.260	46.480	0.72
11	11B-8	4	4158.1	46.150	46.480	46.540	0.85
11	11B-8	5	5545.4	46.150	46.540	46.600	0.98
11	11B-8	6	7633.1	46.150	46.600	46.670	1.13
11	11B-8	7	12821.8	46.150	46.670	46.920	1.67
11	11B-8	8	16685.4	46.150	46.920	47.340 ^(a)	2.58
11	11B-8	9	24918.2	44.181	45.320	45.680	3.39
11	11B-8	10	35338.0	44.181	45.680	46.070	4.28
11	11B-9	1	491.7	44.490	44.490	44.500	0.02
11	11B-9	2	1491.6	44.490	44.500	44.560	0.16
11	11B-9	3	2771.3	44.490	44.560	44.750	0.58
11	11B-9	4	4158.1	44.490	44.750	44.800	0.70
11	11B-9	5	5545.4	44.490	44.800	44.850	0.81
11	11B-9	6	7633.1	44.490	44.850	44.900	0.92
11	11B-9	7	12821.8	44.490	44.900	45.100	1.37
11	11B-9	8	16685.4	44.490	45.100	45.250	1.71
11	11B-9	9	24918.2	44.490	45.250	45.370	1.98
11	11B-9	10	35338.0	44.490	45.370	45.650	2.61
11	11B-10	1	491.7	43.270	43.270	43.280	0.02
11	11B-10	2	1491.6	43.270	43.280	43.340	0.16
11	11B-10	3	2771.3	43.270	43.340	43.510	0.55
11	11B-10	4	4158.1	43.270	43.510	43.560	0.67
11	11B-10	5	5545.4	43.270	43.560	43.600	0.76
11	11B-10	6	7633.1	43.270	43.600	43.640	0.86
11	11B-10	7	12821.8	43.270	43.640	43.810	1.25
11	11B-10	8	16685.4	43.270	43.810	43.970	1.62
11	11B-10	9	24918.2	43.270	43.970	44.120	1.96
11	11B-10	10	35338.0	43.270	44.120	44.340	2.47
11	11B-11	1	491.7	46.160	46.160	46.180	0.04
11	11B-11	2	1491.6	46.160	46.180	46.230	0.15
11	11B-11	3	2771.3	46.160	46.230	46.380	0.48
11	11B-11	4	4158.1	46.160	46.380	46.410	0.54
11	11B-11	5	5545.4	46.160	46.410	46.460	0.65
11	11B-11	6	7633.1	46.160	46.460	46.500	0.74
11	11B-11	7	12821.8	46.160	46.500	46.710	1.19
11	11B-11	8	16685.4	46.160	46.710	47.170 ^(a)	2.19
11	11B-11	9	24918.2	44.594	45.570	45.570	2.19
11	11B-11	10	35338.0	44.594	45.570	45.900	2.93

TABLE F.1. Contd.

Oven	Specimen	Run	Elapsed Time, h	Initial Weight, g	Run Start Weight, g	Run End Weight, g	Cumulative Weight Gain, %
11	11B-12	1	491.7	16.333	16.333	16.334	0.01
11	11B-12	2	1491.6	16.333	16.334	16.340	0.04
11	11B-12	3	2771.3	16.333	16.340	16.345	0.07
11	11B-12	4	4158.1	16.333	16.345	16.358	0.15
11	11B-12	5	5545.4	16.333	16.358	16.371	0.23
11	11B-12	6	7633.1	16.333	16.371	16.376	0.26
11	11B-12	7	12821.8	16.333	16.376	16.441	0.66
11	11B-12	8	16685.4	16.333	16.441	16.872	3.30
11	11B-12	9	24918.2	16.333	16.872	16.873	3.31
11	11B-12	10	35338.0	16.333	16.873	17.241	5.56
12	12B-1	1	61.5	25.681	25.681	26.175	1.92
12	12B-1	2	181.3	25.681	26.175	26.226	2.12
12	12B-1	3	774.8	25.681	26.226	26.255	2.24
12	12B-1	4	1080.2	25.681	26.255	26.316	2.47
12	12B-1	5	1344.3	25.681	26.316	26.337	2.55
12	12B-1	6	1679.4	25.681	26.337	26.395	2.78
12	12B-1	7	2011.9	25.681	26.395	26.469	3.07
12	12B-1	8	2516.7	25.681	26.469	26.612	3.63
12	12B-1	9	3237.9	25.681	26.612	26.842	4.52
12	12B-1	10	3976.7	25.681	26.842	26.930	4.86
12	12B-1	11	4606.9	25.681	26.930	26.965	5.00
12	12B-1	12	5429.7	25.681	26.965	26.997	5.12
12	12B-1	13	9467.0	25.681	26.997	27.124	5.62
12	12B-1	14	13597.2	25.681	27.124	27.216	5.98
12	12B-1	15	14751.3	25.681	27.216	27.229	6.03
12	12B-1	16	16307.7	25.681	27.229	27.245	6.09
12	12B-1	17	18491.4	25.681	27.245	27.264	6.16
12	12B-1	18	20793.1	25.681	27.264	27.310	6.34
12	12B-1	19	23003.0	25.681	27.310	27.342	6.47
12	12B-1	20	24173.9	25.681	27.342	27.370	6.58
12	12B-1	21	29313.2	25.681	27.370	27.377	6.60
12	12B-1	22	31661.3	25.681	27.377	27.404	6.71

TABLE F.1. Contd.

Oven	Specimen	Run	Elapsed Time, h	Initial Weight, g	Run Start Weight, g	Run End Weight, g	Cumulative Weight Gain, %
12	12B-2	1	61.5	23.736	23.736	24.002	1.12
12	12B-2	2	181.3	23.736	24.002	24.156	1.77
12	12B-2	3	774.8	23.736	24.156	24.280	2.29
12	12B-2	4	1080.2	23.736	24.280	24.342	2.55
12	12B-2	5	1344.3	23.736	24.342	24.362	2.64
12	12B-2	6	1679.4	23.736	24.362	24.411	2.84
12	12B-2	7	2011.9	23.736	24.411	24.392	2.76
12	12B-2	8	2516.7	23.736	24.392	24.498	3.21
12	12B-2	9	3237.9	23.736	24.498	24.673	3.95
12	12B-2	10	3976.7	23.736	24.673	24.745	4.25
12	12B-2	11	4606.9	23.736	24.745	24.777	4.39
12	12B-2	12	5429.7	23.736	24.777	24.796	4.47
12	12B-2	13	9467.0	23.736	24.796	24.883	4.83
12	12B-2	14	13597.2	23.736	24.883	24.935	5.05
12	12B-2	15	14751.3	23.736	24.935	24.943	5.09
12	12B-2	16	16307.7	23.736	24.943	24.948	5.11
12	12B-2	17	18491.4	23.736	24.948	24.954	5.13
12	12B-2	18	20793.1	23.736	24.954	24.981	5.25
12	12B-2	19	23003.0	23.736	24.981	24.995	5.30
12	12B-2	20	24173.9	23.736	24.995	25.012	5.38
12	12B-2	21	29313.2	23.736	25.012	25.014	5.38
12	12B-2	22	31661.3	23.736	25.014	25.029	5.45
12	12B-3	1	61.5	24.608	24.608	24.704	0.39
12	12B-3	2	181.3	24.608	24.704	24.784	0.72
12	12B-3	3	774.8	24.608	24.784	25.135	2.14
12	12B-3	4	1080.2	24.608	25.135	25.218	2.48
12	12B-3	5	1344.3	24.608	25.218	25.243	2.58
12	12B-3	6	1679.4	24.608	25.243	25.299	2.81
12	12B-3	7	2011.9	24.608	25.299	25.366	3.08
12	12B-3	8	2516.7	24.608	25.366	25.478	3.54
12	12B-3	9	3237.9	24.608	25.478	25.665	4.30
12	12B-3	10	3976.7	24.608	25.665	25.748	4.63
12	12B-3	11	4606.9	24.608	25.748	25.779 ^(a)	4.76
12	12B-3	12	5429.7	24.243	25.397	25.419	4.85
12	12B-3	13	9467.0	24.243	25.419	25.512	5.23
12	12B-3	14	13597.2	24.243	25.512	25.575	5.49
12	12B-3	15	14751.3	24.243	25.575	25.577	5.50
12	12B-3	16	16307.7	24.243	25.577	25.585	5.54
12	12B-3	17	18491.4	24.243	25.585	25.595	5.58
12	12B-3	18	20793.1	24.243	25.595	25.625	5.70
12	12B-3	19	23003.0	24.243	25.625	25.641	5.77
12	12B-3	20	24173.9	24.243	25.641	25.659	5.84
12	12B-3	21	29313.2	24.243	25.659	25.661	5.85
12	12B-3	22	31661.3	24.243	25.661	25.685	5.95

TABLE F.1. Contd.

Oven	Specimen	Run	Elapsed Time, h	Initial Weight, g	Run Start Weight, g	Run End Weight, g	Cumulative Weight Gain, %
12	12B-4	1	61.5	44.300	44.300	44.410	0.25
12	12B-4	2	181.3	44.300	44.410	44.510	0.47
12	12B-4	3	774.8	44.300	44.510	45.200	2.03
12	12B-4	4	1080.2	44.300	45.200	45.670	3.09
12	12B-4	5	1344.3	44.300	45.670	45.760	3.30
12	12B-4	6	1679.4	44.300	45.760	45.930	3.68
12	12B-4	7	2011.9	44.300	45.930	46.040	3.93
12	12B-4	8	2516.7	44.300	46.040	46.180	4.24
12	12B-4	9	3237.9	44.300	46.180	46.350	4.63
12	12B-4	10	3976.7	44.300	46.350	46.450	4.85
12	12B-4	11	4606.9	44.300	46.450	46.520	5.01
12	12B-4	12	5429.7	44.300	46.520	46.620	5.24
12	12B-4	13	9467.0	44.300	46.620	46.940	5.96
12	12B-4	14	13597.2	44.300	46.940	47.230	6.61
12	12B-4	15	14751.3	44.300	47.230	47.260	6.68
12	12B-4	16	16307.7	44.300	47.260	47.310	6.79
12	12B-4	17	18491.4	44.300	47.310	47.340	6.86
12	12B-4	18	20793.1	44.300	47.340	47.430	7.07
12	12B-4	19	23003.0	44.300	47.430	47.520	7.27
12	12B-4	20	24173.9	44.300	47.520	47.602	7.45
12	12B-4	21	29313.2	44.300	47.602	47.640	7.54
12	12B-4	22	31661.3	44.300	47.640	47.810	7.92
12	12B-5	1	61.5	36.376	36.376	36.431	0.15
12	12B-5	2	181.3	36.376	36.431	36.463	0.24
12	12B-5	3	774.8	36.376	36.463	36.851	1.31
12	12B-5	4	1080.2	36.376	36.851	37.187	2.23
12	12B-5	5	1344.3	36.376	37.187	37.290	2.51
12	12B-5	6	1679.4	36.376	37.290	37.429	2.89
12	12B-5	7	2011.9	36.376	37.429	37.540	3.20
12	12B-5	8	2516.7	36.376	37.540	37.700	3.64
12	12B-5	9	3237.9	36.376	37.700	37.850	4.05
12	12B-5	10	3976.7	36.376	37.850	37.920	4.24
12	12B-5	11	4606.9	36.376	37.920	37.950	4.33
12	12B-5	12	5429.7	36.376	37.950	37.990	4.44
12	12B-5	13	9467.0	36.376	37.990	38.140	4.85
12	12B-5	14	13597.2	36.376	38.140	38.290	5.26
12	12B-5	15	14751.3	36.376	38.290	38.310	5.32
12	12B-5	16	16307.7	36.376	38.310	38.330	5.37
12	12B-5	17	18491.4	36.376	38.330	38.360	5.45
12	12B-5	18	20793.1	36.376	38.360	38.410	5.59
12	12B-5	19	23003.0	36.376	38.410	38.450	5.70
12	12B-5	20	24173.9	36.376	38.450	38.490	5.81
12	12B-5	21	29313.2	36.376	38.490	38.510	5.88
12	12B-5	22	31661.3	36.376	38.510	38.540	5.96

TABLE F.1. Contd.

Oven	Specimen	Run	Elapsed Time, h	Initial Weight, g	Run Start Weight, g	Run End Weight, g	Cumulative Weight Gain, %
12	12B-6	1	61.5	46.690	46.690	46.780	0.19
12	12B-6	2	181.3	46.690	46.780	46.840	0.32
12	12B-6	3	774.8	46.690	46.840	47.410	1.54
12	12B-6	4	1080.2	46.690	47.410	48.060	2.93
12	12B-6	5	1344.3	46.690	48.060	48.200	3.23
12	12B-6	6	1679.4	46.690	48.200	48.400	3.66
12	12B-6	7	2011.9	46.690	48.400	48.550	3.98
12	12B-6	8	2516.7	46.690	48.550	48.720	4.35
12	12B-6	9	3237.9	46.690	48.720	48.920	4.78
12	12B-6	10	3976.7	46.690	48.920	49.080	5.12
12	12B-6	11	4606.9	46.690	49.080	49.170 ^(a)	5.31
12	12B-6	12	5429.7	45.970	48.410	48.490 ^(a)	5.48
12	12B-6	13	9467.0	45.870	48.380	48.770	6.32
12	12B-6	14	13597.2	45.870	48.770	49.140 ^(a)	7.13
12	12B-6	15	14751.3	44.544	47.720	47.750	7.20
12	12B-6	16	16307.7	44.544	47.750	47.820	7.35
12	12B-6	17	18491.4	44.544	47.820	47.840	7.40
12	12B-6	18	20793.1	44.544	47.840	47.900	7.53
12	12B-6	19	23003.0	44.544	47.900	48.080	7.94
12	12B-6	20	24173.9	44.544	48.080	48.130	8.05
12	12B-6	21	29313.2	44.544	48.130	48.140	8.07
12	12B-6	22	31661.3	44.544	48.140	48.320	8.48
12	12B-7	1	61.5	45.880	45.880	45.960	0.17
12	12B-7	2	181.3	45.880	45.960	46.020	0.31
12	12B-7	3	774.8	45.880	46.020	46.640	1.66
12	12B-7	4	1080.2	45.880	46.640	47.220	2.92
12	12B-7	5	1344.3	45.880	47.220	47.330	3.16
12	12B-7	6	1679.4	45.880	47.330	47.500	3.53
12	12B-7	7	2011.9	45.880	47.500	47.610	3.77
12	12B-7	8	2516.7	45.880	47.610	47.770	4.12
12	12B-7	9	3237.9	45.880	47.770	47.940	4.49
12	12B-7	10	3976.7	45.880	47.940	48.060	4.75
12	12B-7	11	4606.9	45.880	48.060	48.170	4.99
12	12B-7	12	5429.7	45.880	48.170	47.220	2.92
12	12B-7	13	9467.0	45.880	47.220	47.650	3.86
12	12B-7	14	13597.2	45.880	47.650	48.040	4.71
12	12B-7	15	14751.3	45.880	48.040	48.080	4.80
12	12B-7	16	16307.7	45.880	48.080	48.160	4.97
12	12B-7	17	18491.4	45.880	48.160	48.200	5.06
12	12B-7	18	20793.1	45.880	48.200	48.270	5.21
12	12B-7	19	23003.0	45.880	48.270	48.480	5.67
12	12B-7	20	24173.9	45.880	48.480	48.440	5.58
12	12B-7	21	29313.2	45.880	48.440	48.510	5.73
12	12B-7	22	31661.3	45.880	48.510	48.710	6.17

TABLE F.1. Contd.

Oven	Specimen	Run	Elapsed Time, h	Initial Weight, g	Run Start Weight, g	Run End Weight, g	Cumulative Weight Gain, %
12	12B-8	1	61.5	45.070	45.070	45.120	0.11
12	12B-8	2	181.3	45.070	45.120	45.150	0.18
12	12B-8	3	774.8	45.070	45.150	45.490	0.93
12	12B-8	4	1080.2	45.070	45.490	46.000	2.06
12	12B-8	5	1344.3	45.070	46.000	46.170	2.44
12	12B-8	6	1679.4	45.070	46.170	46.410	2.97
12	12B-8	7	2011.9	45.070	46.410	46.560	3.31
12	12B-8	8	2516.7	45.070	46.560	46.740	3.71
12	12B-8	9	3237.9	45.070	46.740	46.910	4.08
12	12B-8	10	3976.7	45.070	46.910	46.980	4.24
12	12B-8	11	4606.9	45.070	46.980	47.020	4.33
12	12B-8	12	5429.7	45.070	47.020	47.590	5.59
12	12B-8	13	9467.0	45.070	47.590	47.770	5.99
12	12B-8	14	13597.2	45.070	47.770	47.970	6.43
12	12B-8	15	14751.3	45.070	47.970	47.990	6.48
12	12B-8	16	16307.7	45.070	47.990	48.020	6.55
12	12B-8	17	18491.4	45.070	48.020	48.050	6.61
12	12B-8	18	20793.1	45.070	48.050	48.110	6.75
12	12B-8	19	23003.0	45.070	48.110	48.170	6.88
12	12B-8	20	24173.9	45.070	48.170	48.230	7.01
12	12B-8	21	29313.2	45.070	48.230	48.260	7.08
12	12B-8	22	31661.3	45.070	48.260	48.330	7.23
12	12B-9	1	61.5	46.090	46.090	46.160	0.15
12	12B-9	2	181.3	46.090	46.160	46.210	0.26
12	12B-9	3	774.8	46.090	46.210	46.800	1.54
12	12B-9	4	1080.2	46.090	46.800	47.220	2.45
12	12B-9	5	1344.3	46.090	47.220	47.330	2.69
12	12B-9	6	1679.4	46.090	47.330	47.510	3.08
12	12B-9	7	2011.9	46.090	47.510	47.670	3.43
12	12B-9	8	2516.7	46.090	47.670	47.890	3.91
12	12B-9	9	3237.9	46.090	47.890	48.090	4.34
12	12B-9	10	3976.7	46.090	48.090	45.760	-0.72
12	12B-9	11	4606.9	46.090	45.760	45.800 ^(a)	-0.63
12	12B-9	12	5429.7	44.490	44.210	44.250 ^(a)	-0.54
12	12B-9	13	9467.0	44.430	44.190	44.330	-0.23
12	12B-9	14	13597.2	44.430	44.330	44.430	0.00
12	12B-9	15	14751.3	44.430	44.430	44.440	0.02
12	12B-9	16	16307.7	44.430	44.440	44.460	0.07
12	12B-9	17	18491.4	44.430	44.460	44.480	0.11
12	12B-9	18	20793.1	44.430	44.480	44.520	0.20
12	12B-9	19	23003.0	44.430	44.520	44.550	0.27
12	12B-9	20	24173.9	44.430	44.550	44.590	0.36
12	12B-9	21	29313.2	44.430	44.590	44.610	0.41
12	12B-9	22	31661.3	44.430	44.610	44.640	0.47

TABLE F.1. Contd.

Oven	Specimen	Run	Elapsed Time, h	Initial Weight, g	Run Start Weight, g	Run End Weight, g	Cumulative Weight Gain, %
12	12B-10	1	61.5	17.394	17.394	17.488	0.54
12	12B-10	2	181.3	17.394	17.488	17.538	0.83
12	12B-10	3	774.8	17.394	17.538	17.714	1.84
12	12B-10	4	1080.2	17.394	17.714	17.882	2.81
12	12B-10	5	1344.3	17.394	17.882	17.906	2.94
12	12B-10	6	1679.4	17.394	17.906	17.961	3.26
12	12B-10	7	2011.9	17.394	17.961	18.003	3.50
12	12B-10	8	2516.7	17.394	18.003	18.073	3.90
12	12B-10	9	3237.9	17.394	18.073	18.129	4.23
12	12B-10	10	3976.7	17.394	18.129	18.152	4.36
12	12B-10	11	4606.9	17.394	18.152	18.159 ^(a)	4.40
12	12B-10	12	5429.7	16.987	17.734	17.744	4.46
12	12B-10	13	9467.0	16.987	17.744	17.785	4.70
12	12B-10	14	13597.2	16.987	17.785	17.813	4.86
12	12B-10	15	14751.3	16.987	17.813	17.820	4.90
12	12B-10	16	16307.7	16.987	17.820	17.823	4.92
12	12B-10	17	18491.4	16.987	17.823	17.827	4.95
12	12B-10	18	20793.1	16.987	17.827	17.848	5.07
12	12B-10	19	23003.0	16.987	17.848	17.863	5.16
12	12B-10	20	24173.9	16.987	17.863	17.880	5.26
12	12B-10	21	29313.2	16.987	17.880	17.883	5.27
12	12B-10	22	31661.3	16.987	17.883	17.896	5.35
12	12B-11	1	61.5	15.909	15.909	15.991	0.52
12	12B-11	2	181.3	15.909	15.991	16.030	0.76
12	12B-11	3	774.8	15.909	16.030	16.182	1.72
12	12B-11	4	1080.2	15.909	16.182	16.362	2.85
12	12B-11	5	1344.3	15.909	16.362	16.384	2.99
12	12B-11	6	1679.4	15.909	16.384	16.435	3.31
12	12B-11	7	2011.9	15.909	16.435	16.470	3.53
12	12B-11	8	2516.7	15.909	16.470	16.527	3.88
12	12B-11	9	3237.9	15.909	16.527	16.574	4.18
12	12B-11	10	3976.7	15.909	16.574	16.481	3.60
12	12B-11	11	4606.9	15.909	16.481	16.487	3.63
12	12B-11	12	5429.7	15.909	16.487	16.497	3.70
12	12B-11	13	9467.0	15.909	16.497	16.532	3.92
12	12B-11	14	13597.2	15.909	16.532	16.560	4.09
12	12B-11	15	14751.3	15.909	16.560	16.566	4.13
12	12B-11	16	16307.7	15.909	16.566	16.569	4.15
12	12B-11	17	18491.4	15.909	16.569	16.573	4.17
12	12B-11	18	20793.1	15.909	16.573	16.595	4.31
12	12B-11	19	23003.0	15.909	16.595	16.610	4.41
12	12B-11	20	24173.9	15.909	16.610	16.624	4.49
12	12B-11	21	29313.2	15.909	16.624	16.627	4.51
12	12B-11	22	31661.3	15.909	16.627	16.639	4.59

TABLE F.1. Contd.

Oven	Specimen	Run	Elapsed Time, h	Initial Weight, g	Run Start Weight, g	Run End Weight, g	Cumulative Weight Gain, %
12	12B-12	1	61.5	10.720	10.720	10.728	0.07
12	12B-12	2	181.3	10.720	10.728	10.727	0.07
12	12B-12	3	774.8	10.720	10.727	10.785	0.61
12	12B-12	4	1080.2	10.720	10.785	10.923	1.89
12	12B-12	5	1344.3	10.720	10.923	11.000	2.61
12	12B-12	6	1679.4	10.720	11.000	11.101	3.55
12	12B-12	7	2011.9	10.720	11.101	11.182	4.31
12	12B-12	8	2516.7	10.720	11.182	11.255	4.99
12	12B-12	9	3237.9	10.720	11.255	11.286	5.28
12	12B-12	10	3976.7	10.720	11.286	11.295	5.36
12	12B-12	11	4606.9	10.720	11.295	11.326	5.65
12	12B-12	12	5429.7	10.720	11.326	11.358	5.95
12	12B-12	13	9467.0	10.720	11.358	11.694	9.09
12	12B-12	14	13597.2	10.720	11.694	11.855 ^(a)	10.59
12	12B-12	15	14751.3	9.913	10.963	10.976	10.72
12	12B-12	16	16307.7	9.913	10.976	11.133	12.31
12	12B-12	17	18491.4	9.913	11.133	11.031	11.28
12	12B-12	18	20793.1	9.913	11.031	11.055	11.52
12	12B-12	19	23003.0	9.913	11.055	11.374	14.74
12	12B-12	20	24173.9	9.913	11.374	11.459	15.60
12	12B-12	21	29313.2	9.913	11.459	11.157	12.55
12	12B-12	22	31661.3	9.913	11.157	11.365	14.65

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- (a) A sample was removed from this specimen at the end of this run and after this measurement.
- (b) Oven 2, Run 2, was shut off prematurely after 9 hours of exposure time; the 9 hours were added to the total time for Run 3. Specimens were reweighed prior to the start of Run 2, therefore end-of-Run 1 and beginning-of-Run 2 weights may vary slightly.
- (c) Oven 9, Run 1, was shut off prematurely after 34.3 hours of exposure due to temperature controller problems; the 34.3 hours were added to the total time for Run 2. Specimens were not reweighed prior to the start of Run 2.

FIGURE F.1. Weight Gain for Bare Fragment Specimens in Oven 1 (150°C, 20°C dew point)

FIGURE F.2. Weight Gain for Bare Fragment Specimens in Oven 2 (150°C, 40°C dew point)

FIGURE F.3. Weight Gain for Bare Fragment Specimens in Oven 3 (170°C, 20°C dew point)

FIGURE F.4. Weight Gain for Bare Fragment Specimens in Oven 4 (190°C, 20°C dew point)

F.47

FIGURE F.5. Weight Gain for Bare Fragment Specimens in Oven 5 (190°C, 40°C dew point)

FIGURE F.6. Weight Gain for Bare Fragment Specimens in Oven 6 (135°C, 40°C dew point)

FIGURE F.7. Weight Gain for Bare Fragment Specimens in Oven 7 (150°C, 0°C dew point)

FIGURE F.8. Weight Gain for Bare Fragment Specimens in Oven 8 (190°C, 0°C dew point)

F.51

FIGURE F.9. Weight Gain for Bare Fragment Specimens in Oven 9 (210°C, 20°C dew point)

FIGURE F.10. Weight Gain for Bare Fragment Specimens in Oven 10 (135°C, 0°C dew point)

F.53

FIGURE F.11. Weight Gain for Bare Fragment Specimens in Oven 11 (170°C, 20°C dew point)

FIGURE F.12. Weight Gain for Bare Fragment Specimens in Oven 12 (230°C, 20°C dew point)

APPENDIX G

BARE FRAGMENT POWDER FORMATION TIMES

APPENDIX G

BARE FRAGMENT POWDER FORMATION TIMES

Visual examinations of bare fragment specimens were conducted following each oven run. Observations such as powder formation, color changes, cracking of fragments, etc., were recorded. Provided in Tables G.1 through G.12 are qualitative summaries of powder formation for each specimen, plus other appropriate visual observations. The qualitative summaries of powder formation provided in the tables are defined as follows:

- NP - no powder observed
- T - trace of powder observed (<1% powder)
- N - noticeable powder observed (1-30% powder)
- S - substantial powder observed (30-60% powder)
- E - extreme amount of powder observed (60-100% powder)
- C - complete transformation to powder (100% powder)

TABLE G.1. Estimated Volume Percent Powder Formed on Bare Fragment Specimens in Oven 1
(150°C, 20°C dew point)

Time, h	Run	Volume Percent Powder ^a											
		1B-12 (0.0)	1B-4 (7.7)	1B-11 (11.7)	1B-10 (17.1)	1B-9 (18.5)	1B-8 (23.0)	1B-1 (23.7)	1B-5 (27.2)	1B-6 (28.4)	1B-7 (28.4)	1B-2 (29.5)	1B-3 (29.5)
2129.3	1	b											
2849.3	2												
5104.6	3 ^v	NP	T	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP
7217.0	4	NP	N	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP
11495.8	5	NP ^c	N	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP
14446.7	6	NP	N	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP
21980.1	7 ^d	NP	N	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP
35221.4	8	NP	N	N	N	T	T	NP	T	NP	T	N	N
38071.2	9	NP	N	N	N	T	T	T	T	T	T	N	N

V - Viton™ gaskets introduced beginning with this run.

G.2

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- (a) Numbers in parentheses below specimen IDs are burnups in MWd/kgM.
 (b) No visual examination results for runs 1 and 2 because of hot cell operational difficulties.
 (c) Non-irradiated pellet surfaces rough and pitted; light-colored circular patches.
 (d) Some granulated particles observed without powder formation.

TABLE G.2. Estimated Volume Percent Powder Formed on Bare Fragment Specimens in Oven 2
(150°C, 40°C dew point)

Time, h	Run	Volume Percent Powder ^a											
		2B-12 (0.0)	2B-3 (7.8)	2B-7 (13.4)	2B-8 (14.6)	2B-9 (21.4)	2B-1 (23.7)	2B-6 (24.9)	2B-10 (28.0)	2B-4 (28.4)	2B-5 (28.4)	2B-2 (29.5)	2B-11 (34.4)
1626.2	1	b											
1626.2	2												
4334.5	3	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP
6593.9	4 ^v	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP
8655.4	5 ^c	T	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP
14179.9	6	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP
21716.2	7	NP	N	NP	T	NP	NP	NP	NP	NP	T	NP	NP
33578.0	8 ^d	NP	N	N	N	T	T	N	NP	T	T	T	NP

V - Viton™ gaskets introduced beginning with this run.

G.3

-
- (a) Numbers in parentheses below specimen IDs are burnups in MWd/kgM.
 - (b) No visual examinations for runs 1 and 2 because of hot cell operational difficulties.
 - (c) Some brown-colored patches observed.
 - (d) Some flaking on fragments observed.

TABLE G.3. Estimated Volume Percent Powder Formed on Bare Fragment Specimens in Oven 3
(170°C, 20°C dew point)

Time, h	Run	Volume Percent Powder ^a											
		3B-12 (0.0)	3B-4 (7.9)	3B-11 (8.7)	3B-8 (12.5)	3B-10 (16.0)	3B-9 (19.6)	3B-6 (23.5)	3B-7 (23.5)	3B-1 (23.7)	3B-2 (29.5)	3B-3 (29.5)	3B-5 (34.0)
474.2	1	b											
1704.0	2												
3578.8	3 ^v	N	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP
4870.7	4	N	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP
6001.8	5 ^c	N	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP
8135.4	6	N	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP
12068.2	7 ^d	S	NP	T?	NP	NP	NP	NP	NP	NP	NP	NP	NP
18234.9	8	S	NP	N	NP	NP	NP	NP	NP	NP	NP	NP	NP
29606.2	9	S	NP	N	NP	NP	NP	NP	NP	NP	NP	NP	NP
36259.6	10	S	NP	N	NP	NP	NP	NP	NP	NP	NP	NP	NP

V - Viton™ gaskets introduced beginning with this run.

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- (a) Numbers in parentheses below specimen IDs are burnups in MWd/kgM.
 (b) No visual examinations for runs 1 and 2 because of hot cell operational difficulties.
 (c) Foreign object (manipulator part?) removed from boats 3B-2 and 3B-6.
 (d) Hairline cracks observed in some fragments.

TABLE G.4. Estimated Volume Percent Powder Formed on Bare Fragment Specimens in Oven 4
(190°C, 20°C dew point)

Time, h	Run	Volume Percent Powder ^a											
		4B-12 (0.0)	4B-4 (7.9)	4B-8 (12.5)	4B-11 (17.5)	4B-9 (19.1)	4B-10 (19.6)	4B-6 (23.3)	4B-7 (23.5)	4B-1 (23.7)	4B-2 (29.5)	4B-3 (29.5)	4B-5 (32.4)
283.1	1	b											
756.3	2												
1544.0	3												
2810.5	4 ^v												
3716.1	5	N	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP
4937.8	6	N ^c	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP
7170.5	7	S	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP
12975.4	8 ^d	S	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP
17130.2	9	E	T	T	T	T	T	NP	T	NP	NP	NP	NP
25509.7	10 ^e	E	T	T	T	T	T	NP	T	NP	NP	NP	NP
30555.6	11	E	T	T	T	T	T	T	T	NP	NP	NP	T
36121.6	12	E	T	T	T	T	T	T	T	NP	NP	NP	T

V - Viton™ gaskets introduced beginning with this run.

G.5

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- (a) Numbers in parentheses below specimen IDs are burnups in MWd/kgM.
 (b) No visual examinations for runs 1 through 4 because of hot cell operational difficulties.
 (c) Orange-brown colored patches observed.
 (d) Deep cracks observed in some fragments.
 (e) Fragment cracking observed to have increased.

TABLE G.5. Estimated Volume Percent Powder Formed on Bare Fragment Specimens in Oven 5
(190°C, 40°C dew point)

Time, h	Run	Volume Percent Powder ^a											
		5B-12 (0.0)	5B-7 (10.1)	5B-5 (12.5)	5B-8 (16.0)	5B-6 (18.0)	5B-9 (22.4)	5B-3 (22.6)	5B-4 (23.0)	5B-1 (23.7)	5B-10 (27.5)	5B-2 (29.5)	5B-11 (34.4)
330.8	1	b											
735.2	2												
1384.0	3												
2830.8	4 ^v	E	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP
4052.5	5	E	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP
4990.6	6	E	NP ^c	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP
5639.4	7	E	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP
6643.5	8	E	T	NP	NP	NP	T	NP	NP	NP	NP	NP	NP
12470.9	9	E	T?	NP	NP	NP	T	NP	NP	NP	NP	NP	NP
17589.6	10	C ^d	NP	NP	NP	NP	T	NP	NP	NP	T	NP	NP
27184.0	11 ^e	C	T	NP	NP	NP	T	NP	NP	NP	T	NP	T
29423.2	12	C	N	T	NP	NP	N	NP	T	NP	T	NP	T
35345.6	13	C	N	T	T	T	N	T	T	NP	T	NP	T

G.9 V - Viton™ gaskets introduced beginning with this run.

-
- (a) Numbers in parentheses below specimen IDs are burnups in MWd/kgM.
 (b) No visual examinations for runs 1 through 3 because of hot cell operational difficulties.
 (c) Cracks beginning to breakup fragments.
 (d) Powder observed to adhere to weight boat.
 (e) Deep cracks observed in fragments.

TABLE G.6. Estimated Volume Percent Powder Formed on Bare Fragment Specimens in Oven 6
(135°C, 40°C dew point)

Time, h	Run	Volume Percent Powder ^a											
		6B-12 (0.0)	6B-5 (8.0)	6B-3 (12.2)	6B-8 (15.1)	6B-7 (17.0)	6B-6 (17.2)	6B-4 (18.5)	6B-9 (21.5)	6B-1 (23.7)	6B-10 (28.0)	6B-2 (29.5)	6B-11 (34.4)
3191.8	1	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP
5347.2	2 ^v	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP
7467.7	3 ^b	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP
13177.0	4	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP
19916.2	5 ^c	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP
33379.5	6 ^d	NP	NP	NP	NP	NP	NP	NP	T	NP	NP	NP	NP
36730.8	7	NP	NP	NP	NP	NP	NP	NP	T	NP	NP	NP	NP

V - Viton™ gaskets introduced beginning with this run.

G.7

-
- (a) Numbers in parentheses below specimen IDs are burnups in MWd/kgM.
 - (b) Light-colored patches and dark nodules observed on some fragments.
 - (c) Light (white)-colored nodules observed on some fragments.
 - (d) Cracks observed in some fragments.

TABLE G.7. Estimated Volume Percent Powder Formed on Bare Fragment Specimens in Oven 7
(150°C, 0°C dew point)

Time, h	Run	Volume Percent Powder ^a											
		7B-12 (0.0)	7B-3 (7.6)	7B-11 (9.9)	7B-10 (15.3)	7B-9 (19.6)	7B-8 (20.8)	7B-1 (23.7)	7B-7 (26.3)	7B-4 (26.4)	7B-5 (28.4)	7B-6 (28.4)	7B-2 (29.5)
1594.5	1	b											
3387.0	2	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP
5686.8	3 ^v	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP
8038.3	4 ^c	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP
13888.2	5 ^d	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP
20436.2	6 ^e	N	T	NP	NP	NP	NP	T	NP	NP	NP	NP	NP
31356.5	7 ^f	N	N	T	T	NP	NP	T	NP	T	NP	NP	T
37002.4	8 ^g	N	N	T	T	T	T	T	T	T	NP	NP	T

V - Viton™ gaskets introduced beginning with this run.

G.8

-
- (a) Numbers in parentheses below specimen IDs are burnups in MWd/kgM.
 - (b) No visual examinations for run 1 because of hot cell operational difficulties.
 - (c) Many fragments light gray instead of dark; some light-colored patches observed.
 - (d) Fragment surfaces appearing "dull" instead of shiny; some weigh boat oxidation/corrosion.
 - (e) Cracking of fragments observed.
 - (f) Some orange-colored spots observed.
 - (g) Some fragments with a blueish color observed.

TABLE G.8. Estimated Volume Percent Powder Formed on Bare Fragment Specimens in Oven 8 (190°C, 0°C dew point)

		Volume Percent Powder ^a											
Time, h	Run	8B-12 (0.0)	8B-3 (7.9)	8B-7 (12.5)	8B-8 (12.5)	8B-11 (16.8)	8B-10 (18.7)	8B-9 (19.8)	8B-6 (23.5)	8B-5 (23.7)	8B-1 (23.7)	8B-2 (29.5)	8B-4 (33.5)
260.4	1	b											
638.9	2												
1360.4	3												
2347.3	4 ^v												
3517.4	5	E	NP	NP	NP	T	T	NP	NP	NP	NP	NP	NP
4523.3	6	E	NP	NP	NP	T	T	NP	NP	NP	NP	NP	NP
5487.8	7	E	NP	NP	NP	T	T	NP	NP	NP	NP	NP	NP
6495.8	8	E	NP	NP	NP	T	T	NP	NP	NP	NP	NP	NP
10018.7	9 ^c	C	NP	NP	NP	T	T	NP	T	T	NP	NP	T
14033.3	10	C	NP	NP	NP	T	T	T	N	N	NP	NP	N
22607.0	11	C	NP	NP	NP	T	T	T	N	N	NP	NP	N
33169.8	12	C	NP	NP	NP	N	T	T	N	N	NP	NP	N

V - Viton™ gaskets introduced beginning with this run.

G.9

- (a) Numbers in parentheses below specimen IDs are burnups in MWd/kgM.
 (b) No visual examinations for runs 1 through 4 because of hot cell operational difficulties.
 (c) Deep cracks in fragments observed.

TABLE G.9. Estimated Volume Percent Powder Formed on Bare Fragment Specimens in Oven 9
(210°C, 20°C dew point)

Time, h	Run	Volume Percent Powder ^a											
		9B-12 (0.0)	9B-8 (7.7)	9B-5 (12.5)	9B-9 (17.2)	9B-1 (23.7)	9B-11 (23.7)	9B-10 (23.8)	9B-6 (24.4)	9B-4 (27.6)	9B-2 (29.5)	9B-3 (29.5)	9B-7 (32.6)
347.8	1	b											
826.6	2												
1446.3	3 ^v												
2362.1	4												
2362.1	5	E	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP
3201.9	6	E	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP
4349.7	7	E	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP
5020.5	8 ^c	E	NP	NP	T	NP	NP	NP	NP	NP	NP	NP	NP
5401.0	9 ^d	E	NP	NP	T	NP	NP	T	NP	NP	NP	NP	T
6145.4	10	C	T	NP	T	NP	NP	T	NP	NP	NP	NP	T
7615.5	11	E	T	NP	N	NP	T	T	NP	NP	NP	NP	T
9325.1	12	E	T	NP	N	NP	N	N	NP	NP	NP	NP	N
14073.2	13	E	T	NP	N	T	N	N	NP	NP	NP	NP	N
19493.2	14 ^e	E	T	NP	N	NP	N	N	NP	NP	NP	NP	N
25391.1	15	E	T	T	N	T	N	N ^f	T	T	T	NP	N
32421.9	16	E	T	T	N	T	N	N	T	T	T	NP	N

V - Viton™ gaskets introduced beginning with this run.

-
- (a) Numbers in parentheses below specimen IDs are burnups in MWd/kgM.
 (b) No visual examinations for runs 1 through 4 because of hot cell operational difficulties.
 (c) Many fragments observed to have cracks.
 (d) Rust-colored patches observed on some fragments.
 (e) Fragments observed to begin having "dull" appearance.
 (f) Orange-colored spots observed on fragments.

TABLE G.10. Estimated Volume Percent Powder Formed on Bare Fragment Specimens in Oven 10
(135°C, 0°C dew point)

Time, h	Run	Volume Percent Powder ^a											
		10B-12 (0.0)	10B-6 (7.9)	10B-4 (12.5)	10B-7 (16.7)	10B-8 (17.0)	10B-9 (17.2)	10B-1 (23.7)	10B-10 (24.2)	10B-11 (24.2)	10B-3 (27.6)	10B-2 (29.5)	10B-5 (34.1)
1701.9	1	b											
4603.5	2												
4603.5	3 ^v	NP	NP ^c	NP	NP	NP	NP	NP	NP	T	NP	NP	NP
6742.6	4	NP	NP	NP	NP	NP	NP	NP	T	T	NP	NP	NP
8733.9	5	NP	NP	NP	NP	NP	NP	NP	T	T	NP	NP	NP
14566.8	6	NP	NP	NP	NP	NP	NP	NP	N	N ^d	NP	NP	NP
18958.4	7	NP	NP	NP	NP	NP	NP	NP	N	N ^d	NP	NP	NP
32277.4	8	NP	NP	NP	NP	NP	NP	NP	N	N	NP	NP	NP
36134.2	9	NP	NP	NP	NP	NP	NP	NP	N	N	NP	NP	NP

V - Viton™ gaskets introduced beginning with this run.

G.11

-
- (a) Numbers in parentheses below specimen IDs are burnups in MWd/kgM.
 (b) No visual examinations for runs 1 and 2 because of hot cell operational difficulties.
 (c) Brown hue observed on faces of some fragments.
 (d) Different estimate due to different observers.

TABLE G.11. Estimated Volume Percent Powder Formed on Bare Fragment Specimens in Oven 11
(170°C, 20°C dew point)

Time, h	Run	Volume Percent Powder ^a											
		11B-12 (0.0)	11B-8 (8.0)	11B-5 (12.0)	11B-9 (17.2)	11B-10 (17.2)	11B-6 (19.4)	11B-1 (23.7)	11B-11 (24.2)	11B-4 (27.6)	11B-2 (29.5)	11B-3 (29.5)	11B-7 (33.7)
491.7	1	b											
1491.6	2												
2771.3	3 ^v												
4158.1	4	T	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP
5545.4	5 ^c	T	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP
7633.1	6	N	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP
12821.8	7	N	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP
16685.4	8 ^d	S	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP
24918.2	9	E	N	NP	T	T	NP	NP	T	NP	NP	NP	NP
35338.0	10	E	N	NP	N	T	NP	NP	T	NP	NP	NP	NP

V - Viton™ gaskets introduced beginning with this run.

-
- (a) Numbers in parentheses below specimen IDs are burnups in MWd/kgM.
 (b) No visual examinations for runs 1 through 3 because of hot cell operational difficulties.
 (c) Brown-colored patches observed on some specimens.
 (d) Cracks observed in fragments; fragments developing "dull" appearance.

TABLE G.12. Estimated Volume Percent Powder Formed on Bare Fragment Specimens in Oven 12
(230°C, 20°C dew point)

Time, h	Run	Volume Percent Powder ^a											
		12B-12 (0.0)	12B-6 (8.0)	12B-7 (8.0)	12B-4 (12.0)	12B-8 (17.2)	12B-5 (17.7)	12B-1 (23.7)	12B-9 (24.2)	12B-3 (26.8)	12B-2 (29.5)	12B-11 (33.9)	12B-10 (34.4)
61.5	1	^b											
181.3	2												
774.8	3												
1080.2	4 ^v												
1344.3	5												
1679.4	6	E	N	N	N	NP	NP	NP	NP	NP	NP	NP	NP
2011.9	7	E	N	N	N	NP	NP	NP	NP	NP	NP	NP	NP
2516.7	8	C	N	N	N	T	NP	NP	NP	NP	NP	NP	NP
3237.9	9	C	N	N	N	T	NP	NP	NP	NP	NP	NP	NP
3976.7	10 ^c	C	N	N	N	T	NP	NP	NP	NP	NP	NP	NP
4606.9	11 ^d	C	N	N	N	N	NP	NP	T	NP	NP	T	T
5429.7	12 ^e	C	S	N	N	N	T	T	N	NP	T	T	T
9467.0	13	C	S	N	N	N	NP	NP	N	NP	NP	T	T
13597.2	14	C	S	N	S	N	NP	N	N	NP	T	T	N
14751.3	15	C	S	N	S	N	T	N	N	T	T	T	N
16307.7	16	C	S	N	S	N	T	N	N	T	T	T	N
18491.4	17	C ^f	S	S	S	N	T	N	N	T	T	T	N
20793.1	18 ^g												
23003.0	19	C	S	S	S	N	N	N	N	T	T	T	N
24173.9	20	C	S	S	S	N	N	N	N	^h	NP	^h	N
29313.2	21 ⁱ	C	S	S	S	N	N	N	N	T	T	T	N
31661.3	22	C	S	S	S	N	N	N	N	T	T	T	N

V - Viton™ gaskets introduced beginning with this run.

- (a) Numbers in parentheses below specimen IDs are burnups in MWd/kgM.
 (b) No visual examinations for runs 1 through 5 because of hot cell operational difficulties.
 (c) Orange and brown-colored patches observed on fragments.
 (d) Multiple cracks observed in fragments; fragments are friable.
 (e) Brown-colored patches appear to be on original pellet surfaces.
 (f) Clumps of powder are bright orange in color.
 (g) No visual examination.
 (h) No comment on powder; differences in estimates due to different observers.
 (i) Some fragments apparently falling apart at crack sites.

APPENDIX H

EMPTY WEIGH BOAT OXIDATION DATA

APPENDIX H

EMPTY WEIGH BOAT OXIDATION DATA

An empty weigh boat was added to each test oven to determine if oxidation of the boats contributed to the cumulative weight gain measured for the spent fuel bare fragments. The weigh boats were weighed during interim examinations, as were the bare fragment and rod segment specimens; the empty weigh boat data is listed in Table H.1. All weigh boats were placed at the front of the bottom shelf. The weigh boats were constructed of aluminum with approximate dimensions of 5.1x5.1x3.8 cm (2x2x1.5 inches).

As is evident from the data listed in Table H.1, there was essentially no weight gain for the weight boats and, therefore, it may be concluded that there was no oxidation of the aluminum. Because all the empty weigh boats were added to the ovens after the switch from silicone to Viton™ oven gaskets, it may also be concluded that fluorine in the oven atmospheres did not affect the weigh boats. Therefore, it may be concluded that measured weight gains for the spent fuel bare fragments were due only to changes in the spent fuel and not to changes in the weigh boats.

TABLE H.1. Empty Weigh Boat Oxidation Data

Oven 1 (135°C, 0°C dew point)

<u>Run</u>	<u>Cumulative Time, hr</u>	<u>Measured Weight, g</u>	<u>Cumulative Weight Gain, %</u>
start	0.0	22.426	--
4	2112.4	22.426	0.000
5	6391.2	22.428	+0.009
6	9342.1	22.428	+0.009
7	16875.5	22.429	+0.013
8	30116.8	22.427	+0.004
9	32966.6	22.426	0.000

Oven 2 (150°C, 40°C dew point)

<u>Run</u>	<u>Cumulative Time, hr</u>	<u>Measured Weight, g</u>	<u>Cumulative Weight Gain, %</u>
start	0.0	22.451	--
4	2259.5	22.451	0.000
5	4321.0	22.447	-0.018
6	9845.5	22.449	-0.009
7	17381.9	22.450	-0.004
8	29243.7	22.460	+0.040

Oven 3 (170°C, 20°C dew point)

<u>Run</u>	<u>Cumulative Time, hr</u>	<u>Measured Weight, g</u>	<u>Cumulative Weight Gain, %</u>
start	0.0	22.579	--
4	1291.9	22.579	0.000
5	2423.0	22.578	-0.004
6	4556.6	22.579	0.000
7	8489.4	22.582	+0.013
8	14656.2	22.584	+0.022
9	26027.5	22.583	+0.018
10	32680.9	22.581	+0.009

TABLE H.1. Continued

Oven 4 (190°C, 20°C dew point)

<u>Run</u>	<u>Cumulative Time, hr</u>	<u>Measured Weight, g</u>	<u>Cumulative Weight Gain, %</u>
start	0.0	22.586	--
5	905.8	22.588	+0.009
6	2127.5	22.588	+0.009
7	4360.2	22.586	0.000
8	10165.1	22.588	+0.009
9	14319.9	22.590	+0.018
10	22699.4	22.588	+0.009
11	27745.3	22.590	+0.018
12	33311.3	22.587	+0.004

Oven 5 (190°C, 40°C dew point)

<u>Run</u>	<u>Cumulative Time, hr</u>	<u>Measured Weight, g</u>	<u>Cumulative Weight Gain, %</u>
start	0.0	22.548	--
5	1221.7	22.548	0.000
6	2159.8	22.550	+0.009
7	2808.6	22.547	-0.004
8	3812.7	22.549	+0.004
9	9640.1	22.548	0.000
10	14758.9	22.551	+0.013
11	24353.3	22.548	0.000
12	26592.5	22.550	+0.009
13	32514.9	22.547	-0.004

Oven 6 (135°C, 40°C dew point)

<u>Run</u>	<u>Cumulative Time, hr</u>	<u>Measured Weight, g</u>	<u>Cumulative Weight Gain, %</u>
start	0.0	22.412	--
2	2155.4	22.412	0.000
3	4275.9	22.411	-0.004
4	9985.2	22.411	-0.004
5	16724.4	22.412	0.000
6	30183.7	22.409	-0.013
7	33539.0	22.409	-0.013

TABLE H.1. Continued

Oven 7 (150°C, 0°C dew point)

<u>Run</u>	<u>Cumulative Time, hr</u>	<u>Measured Weight, g</u>	<u>Cumulative Weight Gain, %</u>
start	0.0	22.571	--
3	2299.8	22.571	0.000
4	4651.3	22.570	-0.004
5	10500.7	22.571	0.000
6	17048.7	22.573	+0.009
7	27969.0	22.572	+0.004
8	33614.9	22.568	-0.013

Oven 8 (190°C, 0°C dew point)

<u>Run</u>	<u>Cumulative Time, hr</u>	<u>Measured Weight, g</u>	<u>Cumulative Weight Gain, %</u>
start	0.0	22.744	--
6	1005.9	22.743	-0.004
7	1970.4	22.741	-0.013
8	2978.4	22.742	-0.009
9	6501.3	22.742	-0.009
10	10515.9	22.747	+0.013
11	19089.6	22.745	+0.004
12	29652.4	22.744	0.000

Oven 9 (210°C, 20°C dew point)

<u>Run</u>	<u>Cumulative Time, hr</u>	<u>Measured Weight, g</u>	<u>Cumulative Weight Gain, %</u>
start	0.0	22.563	--
7	1147.8	22.564	+0.004
8	1818.6	22.562	-0.004
9	2199.1	22.562	-0.004
10	2943.5	22.563	0.000
11	4413.6	22.566	+0.013
12	6123.2	22.563	0.000
13	10871.3	22.570	+0.031
14	16291.3	22.566	+0.013
15	22189.2	22.568	+0.022
16	29220.0	22.568	+0.022

TABLE H.1. Continued

Oven 10 (135°C, 0°C dew point)

<u>Run</u>	<u>Cumulative Time, hr</u>	<u>Measured Weight, g</u>	<u>Cumulative Weight Gain, %</u>
start	0.0	22.423	--
4	2139.1	22.422	-0.004
5	4130.4	22.427	+0.018
6	9963.2	22.426	+0.013
7	14354.8	22.428	+0.022
8	27673.9	22.426	+0.013
9	31530.6	22.424	+0.004

Oven 11 (170°C, 20°C dew point)

<u>Run</u>	<u>Cumulative Time, hr</u>	<u>Measured Weight, g</u>	<u>Cumulative Weight Gain, %</u>
start	0.0	22.714	--
5	1386.7	22.714	0.000
6	3474.4	22.712	-0.009
7	8663.1	22.713	-0.004
8	12526.7	22.718	+0.018
9	20759.5	22.714	0.000
10	31179.3	22.711	-0.013

Oven 12 (230°C, 20°C dew point)

<u>Run</u>	<u>Cumulative Time, hr</u>	<u>Measured Weight, g</u>	<u>Cumulative Weight Gain, %</u>
start	0.0	22.484	--
9	721.2	22.484	0.000
10	1460.0	22.484	0.000
11	2090.7	22.483	-0.004
12	2913.5	22.482	-0.009
13	6950.8	22.484	0.000
14	11081.0	22.488	+0.018
15	12235.1	22.489	+0.022
16	13791.4	22.489	+0.022
17	15975.1	22.487	+0.013
18	18276.8	22.489	+0.022
19	20486.7	22.489	+0.022
20	21657.6	22.491	+0.031
21	26796.9	22.491	+0.031
22	29145.0	22.490	+0.027

APPENDIX I

ROD SEGMENT WEIGHT GAIN DATA

APPENDIX I

ROD SEGMENT WEIGHT GAIN DATA

Provided in Table I.1 is a complete listing of the weight gain data collected for the rod segments; this includes measured pretest and end-of-run rod segment weights, and calculated segment-average weight gains; segment-average weight gains were determined by attributing all weight gain to the UO_2 . The runs for which rod segments were observed to have split are indicated, and other observations are noted.

As noted in Sections 2 and 3, the rod segments were visually examined at the conclusion of each oven run; in most cases a photographic record was also made. Provided in Table I.2 is a summary of the rod segment visual examinations; only observations such as cladding splitting or significant changes in the visual appearance are provided in the table.

TABLE I.1. Rod Segment Weight Gain Data - Test Series B

Rod ID	Temp. °C	Oven	Fuel Type	Burnup, MWd/kgM	Pretest Rod Wt., g	Pretest UO ₂ Wt., g	Run #	Total Time, h	End-of-Run Rod Wt., g	End-of-Run UO ₂ Wt., g	Segment-Average Wt. Gain	
											g	wt%
6B-c1	135	6	HBR	*	151.16	88.16	5	6739.2	151.26	88.26	0.10	0.11
							6	20198.5	151.44	88.44	0.28	0.32
							7	23553.8	151.48	88.48	0.32	0.36
7B-c2	150	7	PB	29.5	146.80	79.34	6	6548.0	147.13	79.67	0.33	0.42
							7	17468.3	147.44	79.98	0.67	0.84
							8	23114.2	147.72	80.26	0.92	1.16(a)
4B-c6	150	1	QC	12.0	260.51	144.79	6	2950.9	260.60	144.88	0.09	0.06
							7	10484.3	260.80	145.08	0.29	0.20
							8	23725.6	261.03	145.31	0.52	0.36
7B-c3	150	1	HBR	*	145.45	82.93	9	26575.4	261.08	145.36	0.57	0.39
							6	2950.9	145.51	82.99	0.06	0.07
							7	10484.3	145.71	83.19	0.26	0.31
2B-c1	150	2	PB	29.5	144.34	76.88	8	23725.6	146.19	83.67	0.74	0.89
							9	26575.4	146.28	83.73	0.83	1.00
							7	7536.4	144.66	77.20	0.32	0.42
2B-c2	150	2	HBR	*	149.14	86.14	8	19398.2	144.94	77.48	0.60	0.78
							7	7536.4	149.34	86.34	0.20	0.23
							8	19398.2	149.58	86.58	0.44	0.51
3B-c2	170	3	HBR	*	148.20	80.74	8	6166.8	148.65	81.19	0.45	0.56
							9	17538.1	149.67	82.21	1.47	1.82
							10	24191.5	149.96	82.50	1.76	2.18
3B-c3	170	3	HBR	*	150.36	82.90	8	6166.8	150.78	83.32	0.42	0.51
							9	17538.1	151.91	84.45	1.55	1.87
							10	24191.5	152.22	84.74	1.86	2.24(a)
9B-c4	170	3	QC	14.8	199.82	90.66	8	6166.8	200.11	90.95	0.29	0.32
							9	17538.1	200.38	91.22	0.56	0.62
							10	24191.5	200.56	91.40	0.74	0.82
8B-c2	170	11	QC	22.0	264.76	149.04	9	8232.8	265.93	150.21	1.17	0.79
							10	18652.6	266.63	150.90	1.87	1.25
							9	8232.8	234.86	125.70	0.33	0.26
9B-c3	170	11	QC	7.7	234.53	125.37	10	18652.6	235.88	126.72	1.35	1.08
							9	8232.8	143.51	76.05	0.93	1.24
							10	18652.6	144.03	76.57	1.45	1.93
10B-c1	170	11	PB	29.5	142.58	75.12	9	8232.8	214.83	124.57	0.85	0.69
							10	18652.6	216.14	125.88	2.16	1.75
							9	8232.8	220.71	111.55	0.23	0.21
10B-c4	170	11	M	30.9	213.98	123.72	10	18652.6	221.60	112.44	1.12	1.01
							9	8232.8	226.79	117.63	0.45	0.38
							10	18652.6	227.28	118.12	0.94	0.80
11B-c1	170	11	QC	7.7	220.48	111.32	11	8573.7	233.24	124.08	0.59	0.48
							12	19136.5	235.16	126.00	2.51	2.03
							11	8573.7	211.58	121.32	0.27	0.22
11B-c4	170	11	QC	16.2	226.34	117.18	12	19136.5	213.55	123.29	2.24	1.85
							10	8379.5	131.62	64.16	0.94	1.49
							11	13425.4	132.14	64.68	1.46	2.31
1B-c3	190	8	QC	7.7	232.65	123.49	12	18997.2	132.64	65.18	1.96	3.10(a)
							10	8379.5	236.09	123.65	0.72	0.59
							11	13425.4	236.74	124.30	1.37	1.11
8B-c1	190	8	PB	29.5	143.00	75.54	12	18997.2	237.85	125.41	2.48	2.02
							10	8379.5	209.13	118.87	0.71	0.60
							11	13425.4	210.51	120.25	2.09	1.77
8B-c5	190	8	HBR	*	144.97	81.97	12	18997.2	211.97	121.71	3.55	3.00
							11	8573.7	145.66	82.66	0.69	0.84
							12	19136.5	145.79	82.79	0.82	1.00
9B-c1	190	8	M	33.5	211.31	121.05	11	8573.7	211.58	121.32	0.27	0.22
							12	19136.5	213.55	123.29	2.24	1.85
							10	8379.5	131.62	64.16	0.94	1.49
4B-c2	190	4	PB	29.5	130.68	63.22	11	13425.4	132.14	64.68	1.46	2.31
							12	18997.2	132.64	65.18	1.96	3.10(a)
							10	8379.5	236.09	123.65	0.72	0.59
4B-c3	190	4	QC	7.3	235.37	122.93	11	13425.4	236.74	124.30	1.37	1.11
							12	18997.2	237.85	125.41	2.48	2.02
							10	8379.5	209.13	118.87	0.71	0.60
4B-c4	190	4	M	31.3	208.42	118.16	11	13425.4	210.51	120.25	2.09	1.77
							12	18997.2	211.97	121.71	3.55	3.00
							11	8573.7	147.33	79.87	1.46	1.86
1B-c2	190	5	PB	29.5	145.87	78.41	12	11833.6	147.54	80.08	1.67	2.13
							13	17756.7	147.86	80.40	1.99	2.54(a)
							11	9594.4	147.33	79.87	1.46	1.86

Rod ID	Temp. °C	Oven	Fuel Type	Burnup, MWd/kgM	Pretest Rod Wt., g	Pretest UO ₂ Wt., g	Run #	Total Time, h	End-of-Run Rod Wt., g	End-of-Run UO ₂ Wt., g	Segment-Average Wt. Gain	
											g	wt%
3B-c1	190	5	QC	7.7	223.53	114.37	11	9594.4	224.72	115.56	1.19	1.04
							12	11833.6	225.15	115.99	1.62	1.42
							13	17756.7	225.86	116.70	2.33	2.04
4B-c7	190	5	M	31.5	199.86	113.85	11	9594.4	200.88	114.87	1.02	0.90
							12	11833.6	201.33	115.32	1.47	1.29
							13	17756.7	202.53	116.51	2.66	2.34
5B-c1	190	5	HBR	*	140.52	79.12	11	9594.4	141.54	80.14	1.02	1.29
							12	11833.6	141.89	80.49	1.37	1.73
							13	17756.7	142.35	80.95	1.83	2.31
9B-c2	190	5	M	33.7	204.76	118.75	11	9594.4	206.32	120.31	1.56	1.31
							12	11833.6	206.68	120.67	1.92	1.62
							13	17756.7	207.58	121.57	2.82	2.37(a)
8B-c4	210	9	QC	13.0	217.28	101.56	12	1709.6	218.08	102.36	0.80	0.79
							13	6457.7	219.56	103.84	2.28	2.24
							14	11877.7	219.80	104.08	2.52	2.48
							15	17775.6	220.73	105.01	3.35	3.40(c)
9B-c5	210	9	HBR	*	128.29	65.29	12	1709.6	129.71	66.71	1.42	2.17
							13	6457.7	130.31	67.31	2.02	3.09(b)
10B-c2	230	12	QC	7.0	236.69	127.53	15	1154.1	238.01	128.85	1.32	1.04
							16	2710.4	239.10	129.94	2.41	1.89
10B-c3	230	12	QC	23.4	261.63	145.91	17	4894.1	240.08	130.92	3.39	2.66(d)
							15	1154.1	263.82	148.10	2.19	1.50
							16	2710.4	264.99	149.27	3.36	2.30
							17	4894.1	265.31	149.59	3.68	2.52
11B-c2	230	12	QC	23.0	259.89	144.17	18	7195.8	265.79	150.07	4.16	2.85(b)
							15	1154.1	260.42	144.70	0.53	0.37
							16	2710.4	261.56	145.84	1.67	1.16
							17	4894.1	263.02	147.30	3.13	2.17
							18	7195.8	263.40	147.68	3.51	2.43
							19	9405.7	263.72	148.00	3.83	2.68
							20	10576.6	263.85	148.13	3.96	2.75
							21	15715.9	264.55	148.83	4.66	3.23
11B-c3	230	12	M	33.3	212.82	122.56	22	18064.0	265.30	149.62	5.45	3.78(a)
							15	1154.1	213.34	123.08	0.52	0.42
							16	2710.4	214.01	123.75	1.19	0.97
							17	4894.1	214.77	124.51	1.95	1.59
							18	7195.8	215.70	125.44	2.88	2.35
							19	9405.7	216.53	126.27	3.71	3.03(d)

* Burnup has not been determined at this time. (HBR G9C)

- (a) Split rod segment observed at conclusion of final run.
- (b) Split rod segment observed. Rod segment permanently removed from oven.
- (c) Rod segment removed from oven after 3.4% weight gain and samples taken for analytical examinations. Island spots of thicker oxide were evident on the surface. The notched end cap was heavily oxidized.
- (d) This rod segment split and a small amount of fuel was lost prior to weighing, thus the weight gain is a minimum. Rod segment removed from the testing matrix.

Fuels: PB = Point Beach
HBR = H. B. Robinson
QC = Quad Cities
M = Monticello

TABLE I.2. Summary of Rod Segment Visual Examinations

<u>Oven</u>	<u>Rod</u>	<u>Run</u>	<u>Time, hr</u>	<u>Comment</u>
6 (135°C, 40°C dew point)				
	6B-c1	5	6739.2	darkening of endcaps
	HBR	6	20198.5	darkening of endcaps from run 5
		7	23553.8	apparent darkening of endcaps; little change in appearance of main Zircaloy cladding or cleaned zones at rod segment ends from run 6
7 (150°C, 0°C dew point)				
	7B-c2	6	6548.0	darkening of endcaps; light interaction on cleaned zones at rod segment ends
	PB	7	17468.3	corrosion of main Zircaloy cladding
		8	23114.2	split, straight, about 2½ to 3 cm each side of defect; rough texture to endcaps
1 (150°C, 20°C dew point)				
	4B-c6	6	2950.9	no photo
	QC	7	10484.3	darkening of endcaps
		8	23725.6	darkening of endcaps from run 7
		9	26575.4	little apparent change from run 8
	7B-c3	6	2950.9	no photo
	HBR	7	10484.3	slight darkening of endcaps
		8	23725.6	darkening of end caps from run 7
		9	26575.4	further darkening of end caps; little change from run 8 in cleaned zone of cladding at ends of segment
2 (150°C, 40°C dew point)				
	2B-c1	7	7536.4	slight darkening of endcaps
	PB	8	19398.2	darkening of end caps from run 7
	2B-c2	7	7536.4	little change from pretest
	HBR	8	19398.2	darkening of end caps from run 7
3 (170°C, 20°C dew point)				
	3B-c2	8	6166.8	little change from pretest
	HBR	9	17538.1	little change from run 8
		10	24191.5	some darkening of end caps from run 9
	3B-c3	8	6166.8	little change from pretest
	HBR	9	17538.1	little change from run 8
		10	24191.5	split, straight, 1.5 to 2.5 cm to each side of defect; slight darkening of endcaps from run 9
	9B-c4	8	6166.8	little change from pretest
	QC	9	17538.1	little change from run 8
		10	24191.5	little change in appearance from run 9

TABLE I.2. Continued

<u>Oven</u>	<u>Rod</u>	<u>Run</u>	<u>Time, hr</u>	<u>Comment</u>
11 (170°C, 20°C dew point)				
	8B-c2	9	8232.8	little change from pretest
	QC	10	18652.6	some interaction on end caps and cleaned zones at rod segment ends; slight darkening of main Zircaloy cladding
	9B-c3	9	8232.8	little change from pretest
	QC	10	18652.6	some interaction on end caps and cleaned zones at rod segment ends; little change to main Zircaloy cladding
	10B-c1	9	8232.8	little change from pretest
	PB	10	18652.6	some interaction on end caps and cleaned zones at rod segment ends; little change to main Zircaloy cladding
	10B-c4	9	8232.8	little change from pretest
	M	10	18652.6	some interaction on end caps and cleaned zones at rod segment ends; slight change to main Zircaloy cladding
	11B-c1	9	8232.8	little change from pretest
	QC	10	18652.6	some interaction on end caps and cleaned zones at rod segment ends; little change to main Zircaloy cladding
	11B-c4	9	8232.8	little change from pretest
	QC	10	18652.6	some interaction on end caps and cleaned zones at rod segment ends; little change to main Zircaloy cladding
8 (190°C, 0°C dew point)				
	1B-c3	11	8573.7	darkening of endcaps
	QC	12	19136.5	rough texture to endcaps; main Zircaloy cladding retains bright appearance
	8B-c1	11	8573.7	split, mostly straight, full-length into heat affected zones of cladding
	PB			
	8B-c5	11	8573.7	light interaction on endcaps
	HBR	12	19136.5	darkened endcaps; some darkening of cleaned zones at rod segment ends
	9B-c1	11	8573.7	darkening of endcaps
	M	12	19136.5	cleaned zone at rod segment ends shows corroded appearance

TABLE I.2. Continued

Oven	Rod	Run	Time, hr	Comment
4 (190°C, 20°C dew point)				
	4B-c2	10	8379.5	darkening of endcaps
	PB	11	13425.4	further darkening of endcaps; cleaned zones at rod segment ends showing darkening
		12	18997.2	split, straight, greater than 2 cm to each side of defect; rod segment end with notched endcap shows greatest impact - endcap corroded with rough texture
	4B-c3	10	8379.5	darkening of endcaps and cleaned zones at rod segment ends
	QC	11	13425.4	growth of "nodules" on cladding surface
		12	18997.2	endcaps have rough texture; further growth of nodules while underlying Zircaloy still has bright appearance
	4B-c4	10	8379.5	darkening of endcaps and cleaned zones at rod segment ends; developing "layer" over main portion of Zircaloy cladding
	M	11	13425.4	"layer" appears deeper; further darkening of endcaps and cleaned zones
		12	18997.2	further depth to "layer", increasing light color; rough texture to endcaps and cleaned zones
5 (190°C, 40°C dew point)				
	1B-c2	11	9594.4	darkening of endcaps
	PB	12	11833.6	further darkening of endcaps
		13	17756.7	split, straight, about 1/2 cm to each side, very tight, hard to see; no significant change to main Zircaloy cladding
	3B-c1	11	9594.4	darkening of endcaps and cleaned zones of rod ends
	QC	12	11833.6	further darkening of endcaps
		13	17756.7	nodules on main Zircaloy cladding surface better defined than pretest; main cladding surface retains shiny appearance
	4B-c7	11	9594.4	darkening of endcaps
	M	12	11833.6	corrosion in cleaned zone of rod segment ends; nodules on main Zircaloy cladding becoming more apparent
		13	17756.7	rough appearance to endcaps; light gray and rough appearance to main cladding

TABLE I.2. Continued

<u>Oven</u>	<u>Rod</u>	<u>Run</u>	<u>Time, hr</u>	<u>Comment</u>
5	5B-c1 HBR	11	9594.4	darkening of endcaps
		12	11833.6	little change from run 11
		13	17756.7	white product around lip of defect; not much change to main portion of Zircaloy cladding - some increase in definition of a few nodules
	9B-c2 M	11	9594.4	darkening of endcaps; cleaned zones at rod segment ends show rough appearance
		12	11833.6	whitish appearance around defect; enhancement of nodules
		13	17756.7	split, straight, about 1/2 cm to each side of defect, very tight crack; heavy corrosion in cleaned zones at rod segment ends
9 (210°C, 20°C dew point)				
8B-c4 QC	12	1709.6	no photo	
	13	6457.7	slight change from run 12	
	14	11877.7	interaction on notched endcap	
	15	17775.6	removed prior to split; heavy corrosion on notched endcap; some enhancement of nodules on cladding	
9B-c5 HBR	12	1709.6	no photo	
	13	6457.7	split, straight, full length into heat-affected zone of cladding; some corrosion of cleaned zone at rod segment ends	
12 (230°C, 20°C dew point)				
10B-c2 QC	15	1154.1	little change from pretest	
	16	2710.4	little change from run 15	
	17	4894.1	split, full length, spiraling, one end cap essentially loose; slight corrosion on loose endcap	
10B-c3 QC	15	1154.1	little change from pretest	
	16	2710.4	one endcap showing gray corrosion product	
	17	4894.1	both endcaps showing gray corrosion product	
	18	7195.8	split, straight, about 2 cm to each side of defect; both endcaps showing heavy corrosion product; little change to main Zircaloy cladding	

TABLE I.2. Continued

<u>Oven</u>	<u>Rod</u>	<u>Run</u>	<u>Time, hr</u>	<u>Comment</u>
12	11B-c2 QC	15	1154.1	little change from pretest
		16	2710.4	
		17	4894.1	
		18	7195.8	one endcap showing darkening, the other endcap showing gray corrosion product
		19	9405.7	both endcaps showing gray corrosion product, some difference between ends
		20	10576.6	endcaps showing gray corrosion
		21	15715.9	
		22	18064.0	split, slight spiral, full length; endcaps heavily corroded; well-defined nodules on main Zircaloy cladding
	11B-c3 M	15	1154.1	little change from pretest
		16	2710.4	slight endcap corrosion
		17	4894.1	one endcap showing darkening, the other endcap showing gray corrosion product
		18	7195.8	both endcaps showing gray corrosion product, one more heavily than the other
		19	9405.7	split, straight, almost full length; both endcaps heavily corroded; some increased oxidation of nodules

APPENDIX J

ROD SEGMENT CLADDING PROFILOMETRY DATA

APPENDIX J

ROD SEGMENT CLADDING PROFILOMETRY DATA

The cladding diameter of the rod segment specimens was measured before the tests and at the end of each run in an attempt to detect dimensional changes that might be related to oxidation-induced swelling of the irradiated UO_2 . These measurements were initially performed using a remotely operable, in-cell laser micrometer system. However, the laser system failed because of radiation damage to the optics and the cladding diameter measurements for the remainder of the testing were performed using a manual dial caliper.

A description of the laser system and its operation is provided in Thornhill, Campbell, and Thornhill (1988). Two profilometry scan sets of the rod segments were typically made. The first scan set consisted of full segment length scans. These scans were done with a 1.3 cm (0.5 in.) spacing--"rough scan"--and performed with the rod segment rotated at 10° intervals from 10° to 180° . The second scan set was done over an approximately 7.6 cm (3 in.) long region centered at the artificial defect site. These scans were done with a 0.03 cm (0.02 in.) spacing--"fine scan"--and with the rod segment rotated at 10° intervals from 10° to 180° . The angle orientation was relative to the notch machined into one endcap of each rod segment.

In addition to the laser micrometer scans, and solely after the laser system failed, a manual caliper was used to measure cladding diameter at five locations along each rod. The five locations are indicated in Figure J.1, along with the two orientations along which diameters were measured. Each diameter was measured three times to provide an average value. Provided in Table J.1 are the caliper measurements of rod segment diameters; also provided is information as to what laser micrometer scans were completed.

The manual caliper cladding profilometry data were evaluated to determine end-of-test hoop strain at the rod segment defect sites; the derived hoop strain values are provided in Table J.2. Because significant shifts in measured diameters were recorded for some segments from examination to examination (for example, 2B-c1 from pretest to Run 7 to Run 8), possibly due

to different personnel making the measurements, changes in strain were evaluated by normalizing the diameter measurements for each run to the position 1 measurement for that run; strains reported in Table J.2 are based on these normalized diameters. Although some rod segments had apparent end-of-test strains by this method, it was seen that such apparent strains were due to diameter differences along the rod segment that existed at the beginning of the test; for example, segment 7B-c3. Strains reported in Table J.2 may be reasonably ascribed to the oxidation process. In general, non-split rod segments displayed no strain at the defect site. The segments that split displayed strain only after the run in which they split; most measured hoop strains were less than 2%.

Rod segments 8B-c4 and 9B-c5 were the only segments for which laser profilometry data are available for three consecutive examinations (pretest plus two oven runs). Laser profilometry data for 8B-c4 are presented in Figures J.2 and J.3 for the 0° (180°) and 90° orientations respectively. As is evidenced by the data in the figures, this segment displayed no change in diameter through its first two oven runs (Runs 12 and 13). Laser profilometry data for 9B-c5 are presented in Figures J.4 and J.5 for the 0° (180°) and 90° orientations respectively. As is evidenced by the data in these figures, this segment displayed no change in diameter after its first oven run (Run 12), but then displayed a large increase after Run 13 during which the rod segment split. Stress relaxation of the cladding after splitting contributed to the measured increase in diameter.

REFERENCE

Thornhill, C. K., T. K. Campbell, and R. E. Thornhill. 1988. Storage of LWR Spent Fuel in Air. Volume 1 - Design and Operation of a Fuel Oxidation Test Facility. PNL-6640, Vol. 1, Pacific Northwest Laboratory, Richland, Washington.

TABLE J.1. Rod Segment Profilometry, Vernier Caliper

Rod Segment	Run #	Segment Wt, g	Comp ^b	Angle	Rod Diameters, in. ^a				
					Pos.1	Pos.2	Pos.3	Pos.4	Pos.5 ^c
Oven 1									
4B-c6	pretest	260.51	no	0	laser profilometry				
				90					
	6	260.60	no	0	0.565	0.564	0.565	0.566	0.569
				90	0.567	0.567	0.566	0.566	0.565
	7	260.80	yes	0	0.565	0.565	0.565	0.564	0.564
				90	0.565	0.566	0.566	0.565	0.566
	8	261.03	yes	0	0.566	0.565	0.566	0.564	0.565
				90	0.565	0.565	0.564	0.566	0.565
	9	261.08	yes	0	0.570	0.571	0.571	0.570	0.570
				90	0.568	0.568	0.567	0.568	0.567
7B-c3	pretest	145.45	no	0	laser profilometry				
				90					
	6	145.51	no	0	0.419	0.420	0.420	0.419	0.420
				90	0.417	0.417	0.419	0.419	0.420
	7	145.71	yes	0	0.416	0.416	0.416	0.418	0.416
				90	0.417	0.417	0.419	0.417	0.418
	8	146.19	yes	0	0.417	0.416	0.416	0.415	0.416
				90	0.416	0.416	0.417	0.418	0.418
	9	146.28	yes	0	0.418	0.419	0.419	0.418	0.418
				90	0.420	0.421	0.422	0.423	0.421
Oven 2									
2B-c1	pretest	144.34	no	0	0.416	0.418	0.417	0.422	0.420
				90	0.413	0.413	0.414	0.413	0.414
	7	144.66	yes	0	0.416	0.414	0.416	0.418	0.417
				90	0.424	0.426	0.424	0.420	0.421
	8	144.94	yes	0	0.411	0.412	0.415	0.416	0.415
				90	0.418	0.420	0.416	0.413	0.413
2B-c2	pretest	149.14	no	0	0.418	0.418	0.417	0.419	0.419
				90	0.419	0.418	0.417	0.418	0.416
	7	149.34	yes	0	0.419	0.418	0.419	0.419	0.419
				90	0.418	0.416	0.418	0.419	0.417
	8	149.58	yes	0	0.416	0.416	0.417	0.416	0.417
				90	0.415	0.416	0.416	0.416	0.415

TABLE J.1. Continued

Rod Segment	Run #	Segment Wt. g	Comp ^b	Angle	Rod Diameters, in. ^a					
					Pos.1	Pos.2	Pos.3	Pos.4	Pos.5 ^c	
Oven 3										
3B-c2	pretest	148.20	no	0	no laser or caliper profilometry					
				90						
	8	148.65	yes	0	0.419	0.419	0.419	0.419	0.417	
				90	0.416	0.415	0.415	0.419	0.420	
	9	149.67	yes	0	0.418	0.418	0.419	0.420	0.417	
				90	0.414	0.414	0.414	0.414	0.416	
3B-c3	10	149.96	yes	0	0.423	0.422	0.423	0.422	0.419	
				90	0.419	0.419	0.418	0.418	0.419	
	pretest	150.36	no	0	no laser or caliper profilometry					
				90						
	8	150.78	yes	0	0.418	0.418	0.418	0.415	0.418	
				90	0.416	0.416	0.417	0.419	0.418	
split	9	151.91	yes	0	0.417	0.416	0.417	0.417	0.418	
				90	0.414	0.416	0.416	0.417	0.415	
	10	152.22	yes	0	0.422	0.420	0.424	0.420	0.422	
				90	0.418	0.420	0.421	0.420	0.419	
	9B-c4	pretest	199.82	no	0	laser profilometry				
				90						
9B-c4	8	200.11	yes	0	0.563	0.565	0.563	0.563	0.562	
				90	0.562	0.564	0.563	0.562	0.563	
	9	200.38	yes	0	0.564	0.563	0.563	0.563	0.563	
				90	0.564	0.564	0.564	0.564	0.564	
	10	200.56	yes	0	0.566	0.567	0.566	0.566	0.565	
				90	0.565	0.566	0.565	0.565	0.565	
Oven 4										
4B-c2	pretest	130.68	no	0	laser profilometry					
				90						
	10	131.62	yes	0	0.415	0.419	0.418	0.417	0.416	
				90	0.421	0.416	0.419	0.421	0.421	
	11	132.14	yes	0	0.413	0.417	0.417	0.414	0.413	
				90	0.419	0.415	0.418	0.420	0.419	
split	12	132.64	yes	0	0.418	0.420	0.426	0.418	0.419	
				90	0.422	0.422	0.426	0.427	0.426	
	4B-c3	pretest	235.37	no	0	laser profilometry				
				90						
	10	236.09	yes	0	0.566	0.567	0.567	0.568	0.567	
				90	0.567	0.568	0.566	0.568	0.566	
4B-c3	11	236.74	yes	0	0.566	0.565	0.565	0.564	0.565	
				90	0.568	0.566	0.566	0.566	0.565	
	12	237.85	yes	0	0.574	0.572	0.575	0.573	0.572	
				90	0.572	0.571	0.570	0.571	0.569	

TABLE J.1. Continued

Rod Segment	Run #	Segment Wt. g	Comp ^b	Angle	Rod Diameters, in. ^a				
					Pos.1	Pos.2	Pos.3	Pos.4	Pos.5 ^c
4B-c4	pretest	208.42	no	0	laser profilometry				
				90					
	10	209.13	yes	0	0.500	0.500	0.500	0.500	0.500
				90	0.500	0.501	0.501	0.500	0.500
	11	210.51	yes	0	0.514	0.513	0.515	0.512	0.512
				90	0.514	0.515	0.513	0.512	0.511
Oven 5 1B-c2	12	211.97	yes	0	0.523	0.524	0.525	0.523	0.523
				90	0.523	0.524	0.522	0.520	0.520
	pretest	145.87	no	0	laser profilometry				
				90					
	11	147.33	yes	0	0.418	0.415	0.415	0.413	0.415
				90	0.417	0.419	0.420	0.421	0.420
split	12	147.54	yes	0	0.418	0.413	0.414	0.411	0.412
				90	0.413	0.416	0.419	0.418	0.416
	13	147.86	yes	0	0.420	0.418	0.419	0.416	0.418
				90	0.415	0.417	0.419	0.419	0.418
	pretest	223.53	no	0	laser profilometry				
				90					
3B-c1	11	224.72	yes	0	0.567	0.567	0.566	0.566	0.569
				90	0.567	0.568	0.568	0.567	0.568
	12	225.15	yes	0	0.567	0.566	0.566	0.566	0.566
				90	0.566	0.566	0.567	0.566	0.566
	13	225.86	yes	0	0.569	0.572	0.571	0.573	0.570
				90	0.566	0.570	0.570	0.567	0.568
4B-c7	pretest	199.86	no	0	laser profilometry				
				90					
	11	200.88	yes	0	0.496	0.493	0.495	0.496	0.494
				90	0.495	0.494	0.495	0.496	0.495
	12	201.33	yes	0	0.500	0.498	0.498	0.498	0.498
				90	0.499	0.497	0.497	0.497	0.496
5B-c1	13	202.53	yes	0	0.503	0.500	0.503	0.503	0.501
				90	0.501	0.497	0.500	0.501	0.499
	pretest	140.52		0	no laser or caliper profilometry				
				90					
	11	141.54	yes	0	0.419	0.418	0.419	0.419	0.418
				90	0.418	0.420	0.418	0.419	0.418
	12	141.89	yes	0	0.416	0.415	0.416	0.418	0.417
				90	0.417	0.416	0.415	0.416	0.416
	13	142.35	yes	0	0.423	0.422	0.422	0.422	0.422
				90	0.423	0.420	0.419	0.420	0.420

TABLE J.1. Continued

Rod Segment	Run #	Segment Wt, g	Comp ^b	Angle	Rod Diameters, in. ^a					
					Pos.1	Pos.2	Pos.3	Pos.4	Pos.5 ^c	
9B-c2	pretest	204.76	no	0	laser profilometry					
				90						
	11	206.32	yes	0	0.497	0.494	0.497	0.494	0.494	
				90	0.494	0.497	0.494	0.497	0.496	
	12	206.68	yes	0	0.498	0.496	0.500	0.497	0.497	
				90	0.496	0.496	0.496	0.496	0.495	
split	13	207.58	yes	0	0.503	0.498	0.507	0.500	0.502	
				90	0.501	0.501	0.500	0.500	0.503	
Oven 6										
6B-c1	pretest	151.16	no	0	0.419	0.420	0.420	0.418	0.416	
				90	0.417	0.418	0.417	0.418	0.419	
	5	151.26	yes	0	0.418	0.418	0.420	0.417	0.416	
				90	0.419	0.418	0.418	0.418	0.419	
	6	151.44	yes	0	0.417	0.417	0.418	0.417	0.416	
				90	0.417	0.417	0.417	0.417	0.418	
	7	151.48	yes	0	0.420	0.422	0.422	0.421	0.420	
				90	0.422	0.420	0.421	0.420	0.421	
Oven 7										
7B-c2 ^d	pretest	146.80	no	0	0.414	0.415	0.418	0.417	0.416	
				90	0.413	0.412	0.410	0.412	0.412	
	6	147.13	yes	0	0.416	0.417	0.419	0.418	0.416	
				90	0.414	0.414	0.412	0.413	0.416	
	7	147.44	yes	0	0.416	0.417	0.417	0.416	0.417	
				90	0.414	0.413	0.413	0.413	0.413	
	split	8	147.72	yes	0	0.415	0.418	0.421	0.418	0.416
				90	0.413	0.415	0.417	0.415	0.413	
Oven 8										
1B-c3	pretest	232.65	no	0	laser profilometry					
				90						
	11	233.24	yes	0	0.563	0.564	0.563	0.563	0.563	
				90	0.563	0.562	0.563	0.563	0.563	
	12	235.16	yes	0	0.564	0.563	0.562	0.563	0.563	
				90	0.563	0.564	0.564	0.564	0.564	
8B-c1										
pretest	143.00	no	0	laser profilometry						
			90							
split	11	145.15	yes	0	0.417	0.424	0.430	0.423	0.423	
				90	0.423	0.426	0.430	0.430	0.420	

TABLE J.1. Continued

Rod Segment	Run #	Segment Wt., g	Comp ^b	Angle	Rod Diameters, in. ^a				
					Pos.1	Pos.2	Pos.3	Pos.4	Pos.5 ^c
8B-c5	pretest	144.97	no	0	laser profilometry				
				90					
	11	145.66	yes	0	0.416	0.416	0.416	0.416	0.415
				90	0.415	0.415	0.415	0.415	0.416
	12	145.79	yes	0	0.416	0.415	0.418	0.418	0.417
				90	0.414	0.413	0.413	0.413	0.413
9B-c1	pretest	211.31	no	0	laser profilometry				
				90					
	11	211.58	yes	0	0.493	0.493	0.492	0.492	0.492
				90	0.492	0.492	0.492	0.492	0.492
	12	213.55	yes	0	0.507	0.506	0.503	0.503	0.498
				90	0.503	0.500	0.505	0.503	0.502
Oven 9									
8B-c4	pretest	217.28	no	0	laser profilometry				
				90					
	12	218.08	no	0	laser profilometry				
				90					
	13	219.56	no	0	laser profilometry				
				90					
	14	219.80	yes	0	0.565	0.564	0.565	0.564	0.565
				90	0.563	0.564	0.565	0.564	0.563
rod pulled	15	220.73	yes	0	0.567	0.567	0.568	0.565	0.565
				90	0.566	0.567	0.567	0.567	0.567
9B-c5	pretest	128.29	no	0	laser profilometry				
				90					
	12	129.71	no	0	laser profilometry				
				90					
split	13	130.31	no	0	laser profilometry				
				90					
Oven 10 - no rod segments									
Oven 11									
8B-c2	pretest	264.76	no	0	laser profilometry				
				90					
	9	265.93	yes	0	0.567	0.568	0.567	0.567	0.567
				90	0.566	0.567	0.566	0.566	0.568
	10	266.63	yes	0	0.565	0.566	0.566	0.565	0.567
				90	0.566	0.565	0.564	0.563	0.565

TABLE J.1. Continued

Rod Segment	Run #	Segment Wt., g	Comp ^b	Angle	Rod Diameters, in. ^a				
					Pos.1	Pos.2	Pos.3	Pos.4	Pos.5 ^c
9B-c3	pretest	234.53	no	0	laser profilometry				
				90					
	9	234.86	yes	0	0.567	0.568	0.570	0.569	0.570
				90	0.568	0.568	0.567	0.568	0.567
	10	235.88	yes	0	0.566	0.567	0.568	0.568	0.566
				90	0.566	0.567	0.568	0.567	0.568
10B-c1	pretest	142.58	no	0	laser profilometry				
				90					
	9	143.51	yes	0	0.420	0.420	0.418	0.417	0.416
				90	0.416	0.418	0.421	0.422	0.422
	10	144.03	yes	0	0.419	0.420	0.418	0.417	0.414
				90	0.415	0.415	0.417	0.418	0.419
10B-c4	pretest	213.98	no	0	laser profilometry				
				90					
	9	214.83	yes	0	0.494	0.494	0.494	0.495	0.494
				90	0.494	0.494	0.495	0.494	0.494
	10	216.14	yes	0	0.500	0.498	0.496	0.495	0.494
				90	0.498	0.496	0.496	0.496	0.497
11B-c1	pretest	220.48	no	0	laser profilometry				
				90					
	9	220.71	yes	0	0.569	0.567	0.567	0.570	0.566
				90	0.567	0.569	0.567	0.567	0.568
	10	221.60	yes	0	0.566	0.566	0.566	0.566	0.566
				90	0.568	0.566	0.566	0.565	0.565
11B-c4	pretest	226.34	no	0	laser profilometry				
				90					
	9	226.79	yes	0	0.563	0.563	0.564	0.564	0.563
				90	0.563	0.563	0.563	0.564	0.563
	10	227.28	yes	0	0.562	0.567	0.567	0.565	0.564
				90	0.563	0.563	0.563	0.565	0.564
Oven 12									
10B-c2 ^e	pretest	236.69	no	0	laser profilometry				
				90					
	15	238.01	yes	0	"fine" laser profilometry only				
				90					
	16	239.10	yes	0	0.566	0.566	0.566	0.567	0.566
				90	0.566	0.567	0.566	0.566	0.566
split	17	240.08	yes	0	not measured due to split				
				90	N/A	0.606	0.597	0.594	0.569

TABLE J.1. Continued

Rod Segment	Run #	Segment Wt. g	Comp ^b	Angle	Rod Diameters, in. ^a				
					Pos.1	Pos.2	Pos.3	Pos.4	Pos.5 ^c
10B-c3 ^f	pretest	261.63	no	0 90	laser profilometry				
	15	263.82	yes	0 90	0.562	0.561	0.562	0.561	0.561
	16	264.99	yes	0 90	0.561	0.562	0.561	0.562	0.561
	17	265.31	yes	0 90	0.559	0.559	0.559	0.560	0.558
split	18	265.79	yes	0 90	0.560	0.560	0.561	0.560	0.561
					0.562	0.563	0.569	0.561	0.562
					0.562	0.563	0.566	0.563	0.563
11B-c2	pretest	259.89	no	0 90	laser profilometry				
	15	260.42	yes	0 90	"fine" laser profilometry only				
	16	261.56	yes	0 90	0.560	0.562	0.561	0.562	0.562
	17	263.02	yes	0 90	0.563	0.562	0.563	0.563	0.563
	18	263.40	yes	0 90	0.559	0.559	0.558	0.559	0.559
	19	263.72	yes	0 90	0.562	0.561	0.561	0.561	0.561
	20	263.85	yes	0 90	0.562	0.562	0.561	0.562	0.562
	21	264.55	yes	0 90	0.563	0.563	0.563	0.563	0.563
split	22	265.30	yes	0 90	0.561	0.562	0.562	0.562	0.562
					0.561	0.561	0.561	0.561	0.560
					0.565	0.568	0.567	0.565	0.566
					0.566	0.568	0.569	0.568	0.569
					0.566	0.563	0.562	0.562	0.561
					0.566	0.563	0.562	0.562	0.562
					0.585	0.574	0.576	0.567	0.566
					0.587	0.583	0.576	0.580	0.575
11B-c3	pretest	212.82	no	0 90	0.495	0.495	0.496	0.495	0.495
	15	213.34	yes	0 90	0.495	0.495	0.495	0.494	0.495
	16	214.01	yes	0 90	0.493	0.493	0.494	0.495	0.493
	17	214.77	yes	0 90	0.494	0.494	0.493	0.493	0.494
	18	215.70	yes	0 90	0.495	0.495	0.497	0.494	0.495
split	19	216.53	yes	0 90	0.496	0.495	0.495	0.494	0.495
					0.491	0.491	0.492	0.491	0.491
					0.493	0.493	0.493	0.493	0.494
					0.494	0.494	0.497	0.496	0.495
					0.496	0.496	0.495	0.496	0.496
					0.496	0.501	0.502	0.501	0.497
					0.497	0.499	0.500	0.497	0.495

TABLE J.1. Continued

Footnotes for Table J.1:

- (a) Average of 3 measurements
- (b) Comp = composite photo taken of rod segment
- (c) 0 degrees: endcap notch flat horizontal
90 degrees: endcap notch flap vertical
Pos.1: 1.5" from defect toward notched end
Pos.2: 0.75" from defect toward notched end
Pos.3: at defect site
Pos.4: 0.75" from defect toward non notched end
Pos.5: 1.5" from defect toward non notched end
- (d) 7B-c2: pretest diameters at 0, 1.0, and 2.0 inches from defect
- (e) 10B-c2: run 17 diameters at 0, 1.0, and 2.0 inches from defect
- (f) 10B-c3: run 18 diameters, additional measurements:
pos/0°/90°: ~1.13 (notched)/0.561/0.564
~1.13 (non-notched)/0.560/0.565

TABLE J.2. End-of-Test Hoop Strain at Rod Segment Defect Sites

<u>Segment</u>	<u>End-of-Test Status</u>	<u>Defect Site Hoop Strain</u>	<u>Comments</u>
Oven 1			
4B-c6	intact	none	
7B-c3	intact	none	beginning of test variation in diameter
Oven 2			
2B-c1	intact	none	beginning of test variation in diameter
2B-c2	intact	none	
Oven 3			
3B-c2	intact	none	
3B-c3	split	1.0% @ 0° 0.7% @ 90°	split 2 cm to each side of defect
9B-c4	intact	none	
Oven 4			
4B-c2	split	1.9% @ 0° 1.0% @ 90°	split 2 cm to each side of defect
4B-c3	intact	none	
4B-c4	intact	0.4% @ 0°? none @ 90°	
Oven 5			
1B-c2	split	0% @ 0° ~1% @ 90°	split 0.5 cm to each side of defect
3B-c1	intact	0.4% @ 0° 0.7% @ 90°	
4B-c7	intact	none	
5B-c1	intact	none	
9B-c2	split	0.8% @ 0° ~0% @ 90°	split 0.5 cm to each side of defect
Oven 6			
6B-c1	intact	none	beginning of test variation in diameter
Oven 7			
7B-c2	split	1.5% @ 0° 1.0% @ 90°	split 3 cm to each side of defect
Oven 8			
1B-c3	intact	none	
8B-c1	split	3.1% @ 0° 1.7% @ 90°	full-length split
8B-c5	intact	none	
9B-c1	intact	none	

TABLE J.2. Continued

<u>Segment</u>	<u>End-of-Test Status</u>	<u>Defect Site Hoop Strain</u>	<u>Comments</u>
Oven 9			
8B-c4	intact	none	
9B-c5	split	LASER	
Oven 11			
8B-c2	intact	none	
9B-c3	intact	none	
10B-c1	intact	none	
10B-c4	intact	none	
11B-c1	intact	none	
11Bc-4	intact	none	
Oven 12			
10B-c2	split	0° not measured 6.55 @ 90°	full-length split
10B-c3	split	1.3% @ 0° 0.7% @ 90°	split 2 cm to each side of defect
11B-c2	split	1.8% @ 0° ~0% @ 90° ^a	full-length split
11B-c3	split	1.2% @ 0° 0.6% @ 90°	

^a 2.1% strain at Pos. 1.

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FIGURE J.1. Schematic Indicating Locations for Manual Cladding Profilometry

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8bc4_1.ppl
8bc4_1.r12
8bc4_1.r13

FIGURE J.2. Laser Micrometer Scans of Rodlet 8B-c4 (0° or 180°)

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8bc4_f.ppl
8bc4_f.r12
8bc4_f.r13**FIGURE J.3.** Laser Micrometer Scans of Rodlet 8B-c4 (90°)

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9bc5_f.ppl
9bc5_f.r12
9bc5_f.r13

FIGURE J.4. Laser Micrometer Scans of Rodlet 9B-c5 (0° or 180°)

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9bc5_f.ppl
9bc5_f.r12
9bc5_f.r13FIGURE J.5. Laser Micrometer Scans of Rodlet 9B-c5 (90°)

APPENDIX K

SUMMARY OF ANALYTICAL EXAMINATIONS PERFORMED THROUGH 1988

APPENDIX K

SUMMARY OF ANALYTICAL EXAMINATIONS PERFORMED THROUGH 1988

Provided in this Appendix are two tables that summarize Test Series B samples examined (Table K.1), and the results of those analyses (Table K.2), that were previously reported by Thomas, et. al. (1989).

Table K.1. Samples of Bare Fragment Specimens that were Examined by Thomas, et. al. (1989).

Sample I.D. No.	Specimen I.D.	Source Reactor (Rod)	Oxidation Temp. °C	Burnup MWd/kgM	Exposure Time, hrs.	Weight Gain, %	TEM	SEM	SAM	XRD
86-37	86-21	Monticello	none	33.3	N/A (0A08-4)	N/A	X	X		
86-25	10B-10	Quad Cities-1	135	24.2	6763 (1C02-4)	0.022	X	X		
86-24	10B-6	Quad Cities-1	135	7.9	6763 (1A01-2)	0.043		X		
87-03 (p)	10B-10	Quad Cities-1	135	24.2	8754 (1C02-4)	0.044		X	X	X
87-169	10B-6	Quad Cities-1	135	7.9	14587 (1A01-2)	0.087		X	X	X
86-26a	6B-11	Monticello	135	34.4	7468 (0A08-4)	0.097	X			
86-32	10B-3	H.B. Robinson	135	27.6	6763 (HBRG9T)	0.102	X			
87-164	6B-11	Monticello	135	34.4	13177 (0A08-4)	0.100	X	X		X
87-166	2B-9	Monticello	150	21.4	14180 (0A03-4)	0.494				X
87-165	2B-3	Quad Cities-1	150	7.8	14180 (1B02-4)	0.71		X	X	
87-163	7B-5	H.B. Robinson	150	28.4	13888 (HBRG9T)	0.80	X	X	X	X
86-38 (p)	1B-4	Quad Cities-1	150	7.7	7344 (1B02-4)	0.88		X	X	X
87-162	7B-11	H.B. Robinson	150	9.9	13888 (HBRG9T)	1.01	X			
87-168	1B-4	Quad Cities-1	150	7.7	14447 (1B02-4)	1.33		X	X	X
87-175	11B-7	Monticello	170	33.7	16685 (5D18-3)	1.76				X

Table K.1. Continued

Sample I.D. No.	Specimen I.D.	Source Reactor (Rod)	Oxidation Temp., °C	Burnup MWd/kgM	Exposure Time, hrs.	Weight Gain, %	TEM	SEM	SAM	XRD
86-33	11B-4	H.B. Robinson	170	27.6	7633 (HBRG9T)	2.21	X	X		X
86-28	4B-7	Quad Cities-1	190	23.5	7171 (1A01-1)	2.50	X	X		X
87-172	11B-8	Quad Cities-1	170	8.0	16685 (1A01-2)	2.58		X		X
86-27a	4B-4	Quad Cities-1	190	7.9	7171 (1B02-4)	3.02	X	X	X	X
87-174	11B-4	H.B. Robinson	170	27.6	16685 (HBRG9T)	3.25		X		
86-30	12B-9	Quad Cities-1	230	24.2	4617 (1C02-4)	>4.34	X			
87-02 (p)	12B-9	Quad Cities-1	230	24.2	5430 (1C02-4)	4.34		X		X
86-34	12B-3	H.B. Robinson	230	26.8	4607 (HBRG9T)	4.76	X			
86-29	12B-6	Quad Cities-1	230	8.0	4607 (1A01-2)	5.31		X	X	X
87-01 (p)	12B-6	Quad Cities-1	230	8.0	5430 (1A01-2)	5.48				X
88-01 (p)	12B-6	Quad Cities-1	230	8.0	13597 (1A01-2)	7.13				X
88-02 (p)	12B-12	Nonirradiated	230	0.0	13597	10.59		X		X

(p): Powder samples. Other samples were obtained from fragments.

ID = Identification number.

Table K.2. Analysis Results for Samples Examined by Thomas, et al (1989).

Sample I.D. No.	Oxidation Temp., °C	Burnup, MWd/kgM	Exposure Time, h	Average O/M	Results
87-163	150	28.4	13888	2.14	XRD: ~70% UO ₂ , 30% U ₄ O ₉ . TEM: Extensive U ₄ O ₉ formation along grain boundaries. Dense UO ₂ /U ₄ O ₉ grains with few microcracks. SEM: Thin oxide scale on intergranular fracture surfaces; tightly bound grains.
86-38 (p)	150	7.7	7217	2.15	XRD: ~50:50 UO ₂ :U ₄ O ₉ ; 15% α-U ₃ O ₇ . SEM: Powder particles are multigrain fragments, coated with thick nodular scale.
87-162	150	9.9	13888	2.17	XRD: ~100% U ₄ O ₉ . TEM: Dense U ₄ O ₉ with few microcracks. Irregular grain boundaries with unidentified fill material.
87-168	150	7.7	14447	2.22	XRD: ~55% UO ₂ , 45% U ₄ O ₉ . SEM: Thick oxide scale on grain boundary surfaces.
87-175	170	33.7	16685	2.30	XRD: ~45% UO ₂ , 55% U ₄ O ₉ .
86-33	170	27.6	7633	2.37	XRD: ~25% UO ₂ , 75% U ₄ O ₉ . TEM: Extensively microcracked U ₄ O ₉ with scattered fine grains of U ₃ O ₈ . Complex diffraction patterns. SEM: Thin smooth scale, tightly bound grains on fracture surfaces.
86-28	190	23.5	7171	2.42	XRD: ~100% U ₄ O ₉ . TEM: Highly altered structure with extensively microcracked U ₄ O ₉ grains; fine-grained phase (U ₃ O ₈) and small bubbles along microcracks. Complex diffraction patterns. SEM: Nodular scale on grain boundary fracture surfaces.
87-172	170	8.0	16685	2.44	XRD: U ₄ O ₉ /U ₃ O ₇ mixture with trace U ₃ O ₈ . SEM: Thin nodular scale and intact grain boundaries on fracture surfaces; thick scale, loose grains near external surface.

Table K.2. Continued

Sample I.D. No.	Oxidation Temp., °C	Burnup, MWd/kgM	Exposure Time, h	Average O/M	Results
87-163	150	28.4	13888	2.14	XRD: ~70% UO ₂ , 30% U ₄ O ₉ . TEM: Extensive U ₄ O ₉ formation along grain boundaries. Dense UO ₂ /U ₄ O ₉ grains with few microcracks. SEM: Thin oxide scale on intergranular fracture surfaces; tightly bound grains.
86-38 (p)	150	7.7	7217	2.15	XRD: ~50:50 UO ₂ :U ₄ O ₉ ; 15% α-U ₃ O ₇ . SEM: Powder particles are multigrain fragments, coated with thick nodular scale.
87-162	150	9.9	13888	2.17	XRD: ~100% U ₄ O ₉ . TEM: Dense U ₄ O ₉ with few microcracks. Irregular grain boundaries with unidentified fill material.
87-168	150	7.7	14447	2.22	XRD: ~55% UO ₂ , 45% U ₄ O ₉ . SEM: Thick oxide scale on grain boundary surfaces.
87-175	170	33.7	16685	2.30	XRD: ~45% UO ₂ , 55% U ₄ O ₉ .
86-33	170	27.6	7633	2.37	XRD: ~25% UO ₂ , 75% U ₄ O ₉ . TEM: Extensively microcracked U ₄ O ₉ with scattered fine grains of U ₃ O ₈ . Complex diffraction patterns. SEM: Thin smooth scale, tightly bound grains on fracture surfaces.
86-28	190	23.5	7171	2.42	XRD: ~100% U ₄ O ₉ . TEM: Highly altered structure with extensively microcracked U ₄ O ₉ grains; fine-grained phase (U ₃ O ₈) and small bubbles along microcracks. Complex diffraction patterns. SEM: Nodular scale on grain boundary fracture surfaces.
87-172	170	8.0	16685	2.44	XRD: U ₄ O ₉ /U ₃ O ₇ mixture with trace U ₃ O ₈ . SEM: Thin nodular scale and intact grain boundaries on fracture surfaces; thick scale, loose grains near external surface.

K.5

Table K.2. Continued

Sample I.D. No.	Oxidation Temp., °C	Burnup, MWd/kgM	Exposure Time, h	Average O/M	Results
86-27a	190	7.9	7171	2.50	XRD: All α - U_3O_7 . No U_3O_8 . TEM: Dense ordered phase in prior UO_2 grains. (May be U_3O_7). Grains are cut by veins containing unidentified fine-grained polycrystalline phase. SEM: Moderately thick nodular scale on intergranular fracture surfaces; Lines on grain surfaces match veins seen by TEM.
87-174	170	27.6	16685	2.55	SEM: Thick oxide scale; some microcracks. XRD: ~100% U_4O_9 .
86-30	230	24.2	4607	>2.73	TEM: Highly altered structure with network of microcracked veins containing fine-grained U_3O_8 . Diffraction indicates phases are mostly fluorite structure type.
87-02(p)	230	24.2	5430	>2.73	XRD: Mostly U_4O_9 plus minor U_3O_8 . Trace dehydrated schoepite ($\text{UO}_3 \cdot \text{H}_2\text{O}$). SEM: Powder particles are clusters of loosely connected grains. Grains show highly altered structure with intersecting veins
86-34	230	26.8	4607	2.80	TEM: Highly altered structure with microcracks and veins filled with fine-grained U_3O_8 . Complex mixture of U_3O_8 and fluorite-type structures.
86-29	230	8.0	4607	2.89	XRD: Mostly U_3O_8 and U_4O_9 with schoepite and dehydrated schoepite. Estimate ~60% U_3O_8 . SEM: Particles consist of loosely bound grain clusters; nodular, textured oxide scale covers each grain.
87-01(p)	230	8.0	5430	2.93	XRD: Mostly U_3O_8 with some U_4O_9 dehydrated schoepite and schoepite. Estimate ~60% U_3O_8 .
88-01(p)	230	8.0	13597	3.20	XRD: U_3O_8 , dehydrated schoepite and schoepite, plus minor U_4O_9 .
88-02(p)	230	0.0	13597	3.78	XRD: Schoepite, unidentified phase (probably a hydrate), U_3O_8 and dehydrated schoepite. No UO_2 -structure phase. SEM: Thick, flowery oxide scale covering each grain; particles consist of loosely bound grain clusters.

(p): Powder samples. Other samples were obtained from fragments.

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