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Test Design, Precharacterization, and Fuel Assembly Fabrication for Instrumented Fuel Assemblies IFA-431 AND IFA-432

November 1977

Prepared for the
Fuel Behavior Research Branch
Division of Reactor Safety Research
U.S. Nuclear Regulatory Commission

Pacific Northwest Laboratory
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TEST DESIGN, PRECHARACTERIZATION, AND FUEL ASSEMBLY FABRICATION FOR INSTRUMENTED FUEL ASSEMBLIES IFA-431 AND IFA-432

C. R. Hann, Project Manager

J. L. Bates	P. E. Hart
D. W. Brite	R. K. Marshall
J. L. Daniel	G. B. Mellinger
N. C. Davis	R. E. Williford

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Pacific Northwest Laboratory
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SUMMARY

This report is a resource document for future analytical and experimental work conducted for the Experimental Verification of Steady State Fuel Codes program as well as other reactor safety research and related industry safety programs. The test rationale, design, fabrication, and pre-irradiation characterization data are included in extensive detail to ensure that all pertinent information on the fuel assemblies will be available for future mathematical modeling and data reduction. The information is necessary to quantify the uncertainty in thermal stored energy and thus reduce restrictions on commercial power plant operation.

Subsequent topical reports describing the irradiation and data analysis will be issued by Pacific Northwest Laboratory (PNL). The topics to be addressed by these reports include the following:

- experimental data
- error and uncertainty analysis of the experimental data
- post irradiation examination
- data analysis of the many separate effects addressed by these experiments
- improved mathematical models developed from the data and analysis

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1.0. INTRODUCTION

The thermal stored energy in a fuel rod is the driving function for the severest postulated nuclear energy-related accident, the loss-of-coolant-accident (LOCA). Because of this, the final acceptance criteria for emergency core cooling systems requires calculation of the stored energy and gap conductance of a fuel rod, both for normal operation and for the duration of the LOCA. Although these calculations are used in the regulation of commercial nuclear power plants, uncertainties in them have caused temporary derating of many power plants and delays in the startup of additional plants. Many of these uncertainties can be attributed to the lack of well-characterized data for fuel irradiated throughout the normal operating power range of commercial nuclear power plants.

Due to this lack of well-characterized data, some computer-coded mathematical models that have been developed to simulate fuel rod behavior over a wide range of postulated conditions are inadequate. These factors together contribute substantially to the stored energy uncertainty. Specifically, the effects of fuel densification and fission gas on the fuel-cladding gap conductance are difficult to quantify, primarily because the applicable data are extremely sparse. As a result, although the total conductance of the fuel rod must be considered in stored energy calculations, the largest uncertainties in those calculations are associated with changes in the gap conditions and their concomitant effects on the gap conductance.

To focus on these uncertainties, two instrumented fuel assemblies have been designed and are being irradiated in the Halden Boiling Water Reactor (HBWR). The fuel assemblies have been designated : IFA-431 - this assembly has a design power of 330 W/cm (10 kW/ft)[a] with a goal burnup of 4000 MWd/MTM; IFA-432 - this assembly has a design power of 490 W/cm (15 kW/ft) and a goal burnup of 20,000 MWd/MTM. General operating parameters for HBWR are given in Table 1-1.

(a) The first time a measurement is given in this document it will be in metric units and followed by the standard equivalent in parentheses. Thereafter, it will be written only in metric.

TABLE 1-1. HBWR Operating Data at 12 MW

Coolant Pressure	3.45 MPa (500 psi)
Heavy Water Saturation Temperature	240°C (464°F)
Plenum Inlet Temperature	237°C (459°F)
Thermal Neutron Flux	$\sim 3 \times 10^{13}$ n/cm^2-sec
Fast Neutron Flux (>1 MeV)	5×10^{11} n/cm^2-sec
Average Fuel Power Density	14.8 W/g

These instrumented fuel assemblies will provide well-characterized experimental data under conditions that realistically simulate light water reactor (LWR) operations. The data will be used to verify United States Nuclear Regulatory Commission (NRC) fuel codes; and it will provide benchmark data for commercial fuel licensing codes submitted by nuclear fuel vendors.

This report is intended to serve the needs of future data analysis and fuel modeling. The organization is therefore based upon a chronological sequence of events describing the design and fabrication of the fuel assemblies as follows:

Section 2.0, Test Rationale - justifies the tests based upon the understanding of fuel safety problems as of July 1974.

Section 3.0, Fuel Rod Design - describes the six rods in each assembly.

Section 4.0, Fuel Assembly Design - describes the assembly hardware.

Section 5.0, Pretest Predictions - provides computer code predictions made with the GAPCON-THERMAL-2 and FRAP-S codes before the assemblies were built and charged.

Section 6.0, Fuel Pellet Fabrication - details the fabrication process for the selected fuel types.

Section 7.0, Fuel Pellet Pre-irradiation Characterization - provides data of most importance to future data analysis and fuel rod modeling.

Section 8.0, Fuel Rod And Assembly Fabrication - describes the final assembly stages conducted by the Halden project staff.

Appendices, The analytical results, fabrication details, precharacterization data, and certifications which support establishment of the initial conditions are given in the appendices to ensure availability of all information on the test assemblies.

2.0 TEST RATIONALE

It is common practice in attempting to simulate the conditions in a nuclear fuel rod, to group a series of mathematical models (based on first principles and/or empirical correlations) into a computer code. It is this code that is used to predict the response of the fuel rod to a wide range of conditions postulated during an evaluation of reactor fuel safety. The results of such codes must be applied with caution, though, for if the code is based on first principles, some limited extrapolations may be made; but if the code is based upon empirical correlations, it should only be used for interpolation. In either case though, well-characterized data is needed in order to test code predictions and quantify the uncertainties in the predictions.

To evaluate applicants' fuel licensing codes, the NRC Division of Technical Review maintains several computer codes, among which are the GAPCON-THERMAL[1,2] and FRAP-S[3] series for stored energy calculations. During the initial development of GAPCON-THERMAL, an extensive amount of data was reviewed in order to select that which was appropriate in either assisting in model development or aiding in verifying the code. As a result of this review, deficiencies were found in the data base for several areas of fuel performance. Several items are of particular concern:

- Fuel rod temperature data, used for calculating stored energy, consisted largely of estimates inferred from microstructural changes such as melt radii or grain growth radii. This process of temperature determination is subject to substantial uncertainties.
- There was no data available to describe the effects of densification upon fuel temperatures.
- Well-characterized data was sparse for fuel life-times of greater than a few days. Thus, very little data existed which described the effects of burnup upon fuel performances.

Therefore, in July 1974 the decision was made to develop a test program that would provide well-characterized data for the dual purposes of model development and code verification. The goal of the current program is to provide the desired information using two instrumented fuel assemblies of six fuel rods each. Specific design considerations are discussed in the following sections.

FUEL ROD THERMAL DESIGN PARAMETERS

Rod 1: Contemporary Rod

A major objective of the program is to provide internal cross-correlation of the data and a means of extrapolating these tests to U.S. commercial nuclear fuel with as many tie points as possible. Accordingly, rod 1 was selected as the standard rod. Its specifications are 95% theoretical density (TD) stable fuel, a 0.0229 cm (0.009 in.) initial diametral gap, helium fill gas, and Boiling Water Reactor -6 (BWR) dimensions. As the BWR pellets are larger, they tend to reduce perturbations induced by thermocouples and minimize the difficulty of extrapolating the data from the Halden tests to commercial plants. Since atypical cladding dimensions are difficult to obtain from commercial sources, cladding procurement problems were minimized by using these typical size pellets. The 95% TD fuel density was selected to

- assure a densification-resistant fuel,
- provide a density typical of 1974 vintage fuel designs, and
- provide a tie point to previous thermal conductivity measurements on unirradiated fuel.

Rod 2: Instantaneous Fuel Densification

The major impact of fuel densification[4] has been the assumption that the fuel undergoes isotropic shrinkage directly proportional to the difference between the fabricated and terminal densities. For example, a 93.5% TD BWR fuel pellet, 1.24 cm (0.488 in.) diameter, would be expected to shrink 0.0124 cm (0.00488 in.) if the NRC criteria of 96.5% TD terminal density were applied. Most BWR fuel rods of this pellet size may be expected to contain an initial diametral gap of 0.0279 - 0.0305 cm (0.011 - 0.012 in.).

Consequently, the shrinkage induced by densification would create a diametral gap of 0.0381 - 0.0432 cm (0.015 - 0.017 in.). When considering tolerances i.e. 0.0038 cm (0.0015 in.) , even larger initial gaps could be expected. Prior to the availability of data from the Edison Electrical Institute/ Electric Power Research Institute (EEI/EPRI) densification program,[5,6] the Halden program,[7] and individual fuel vendor programs, instantaneous densification was assumed.[4] That is, a 0.0406 cm gap (for the example above) was assumed to exist as soon as the plant reached full power.

Accordingly, rod 2 was designed with a 0.0381 cm (0.015 in.) diametral gap to simulate instantaneous densification. The 0.0381 cm gap in the BWR-6 geometry (1.0909 cm cladding inner diameter) yields a gap-to-diameter (G/D) ratio of 3.6% which approximates the G/D ratios typically postulated for densified fuel in either the older BWR or pressurized water reactor (PWR) fuel designs.

Rod 3: Internal Reference

Rod 3 was designed primarily for an independent check of rod powers. It also provides an upper bound for gap conductance and can be used to simulate high burnup rods where the initial gap has been closed by various fuel relocation mechanisms. This rod contains 95% TD stable fuel with an initial diametral gap of 0.0051 cm for IFA-431 and 0.0076 cm for IFA-432 (0.002 and 0.003 respectively). These gaps were chosen to provide good fuel cladding contact at power and yet minimize the potential for cladding failure that might be induced by mechanical interaction. The small gap should be closed at power, thus producing high gap conductances, minimizing the temperature drop across the fuel-cladding interface, and providing a good check of the effective in-reactor thermal conductivity of the fuel. Since thermocouples will indicate the fuel centerline temperatures and cladding temperatures may be calculated, it will be possible to check the rod powers in the assembly. The technique that will be used is based on the conductivity integral.[8]

Rod 4: Effects of Xenon Fill Gas

Experimental irradiations have indicated that the apparent gap conductance in either Xe-or Xe-Kr filled rods is better than the values calculated by accepted analytical codes. Those experimental irradiations may be summarized as follows:

- Cohen et. al[9,10] reported no apparent effect of the gas atmosphere within the rods. Rods having diametral gaps of approximately 0.0076 cm showed no apparent difference between He and He-25% Kr mixtures.
- Horn[11] indicated mixtures of He-38% Xe and He-60% Xe resulted in approximately the same gap conductance as 100% He. Horn's tests were conducted at high heat ratings with initial diametral gaps of approximately 0.0152 cm.
- Lawrence et. al[12] reported that a He-41% Xe mixture had no apparent effect (relative to 100% He) on the experimentally determined gap conductance. These tests consisted of irradiating UO_2-25 wt% PuO_2 rods that had initial diametral gaps of approximately 0.0279 cm to powers of 790 W/cm (24 kW/ft).

To aid in understanding the reported anomalous thermal behavior of Xe-filled rods, rod 4 contains 95% TD stable fuel, a 0.0229 cm diametral gap, and 100% Xe fill gas.

Rod 5: Verification of Fuel Density Stability

New fuel designs under consideration for commercial reactors will use low-density, stable fuel. Results of recent experimental work[5,13] provide the technology required to fabricate low-density (e.g. 92% TD) fuel with the various degrees of stability or resistance to irradiation-induced densification that are required for these new commercial reactor designs. Rod 5 contains 92% TD stable fuel with an initial gap of 0.0229 cm, and should provide one means of verifying recent fuel fabrication technology with regards to the effects of fuel structures on irradiation temperatures. This rod will also be cross-correlated with rod 6.

Rod 6: Densification Kinetics

Rod 6 contains 92% TD unstable fuel and a 0.0229 cm diametral gap. Earlier studies[5,13] have indicated that fuel with a similar structure underwent significant densification during irradiation. Thus, densification models were developed to simulate time-dependent densification using kinetic information obtained from Halden,[7] terminal densities derived from the EEI/EPRI studies,[6] and resintering tests conducted at PNL (Section 7.4). Data from rod 6 will be used to verify NRC densification models[14,15] and to provide a check of applicant-supplied models. Although appropriate data is not currently available, dimensional changes in the unstable fuel and the concomitant effects on the gap conductance are probably not as large as those calculated using 1974-vintage licensing criteria. Further, relocation mechanisms, such as cracking and unrestrained swelling, may mitigate some densification.

ASSEMBLY POWERS AND BURNUPS

The assembly heat ratings were selected to bracket the peak rod powers for the newer generation plants. These plants have incorporated smaller diameter rods and lower rod heat ratings by using larger rod arrays. For example, BWR assembly designs have gone from 7 x 7 to 8 x 8, 9 x 9, and 11 x 11 rod arrays while PWR assemblies have been modified to increase the 14 x 14 rod array to 15 x 15, 16 x 16, or 17 x 17 arrays. The design power of 330 W/cm (10 kW/ft) for IFA-431 and 490 W/cm (15 kW/ft) for IFA-432 will be representative of commercial fuel rods.

Design assembly burnup for IFA-431 is set at 4000 MWd/MTM to ensure complete fuel densification, minimize fuel volume changes induced by fission product swelling, and retain the option of post-irradiation examination (PIE) that confirms gap closure data obtained from previous low burnup rods. IFA-432 has a design burnup of 20,000 MWd/MTM to obtain information on extended burnup effects. So that a direct comparison may be made between IFA-431 and IFA-432, rods 2, 3, and 4 of IFA-432 are removable (and can be replaced with new rods). If this option is exercised, it will occur at approximately 4000 MWd/MTM.

FUEL RELOCATION

The stored thermal energy in a fuel rod depends primarily on the rod power, the fuel thermal conductivity, and the conductance across the fuel-cladding gap. Although the gap conductance is dependent on many interrelated variables,[16,21] the basic components are the effective gap size and the gas thermal conductivity. In other words, if the heat flux is known, gap conductance can be calculated by defining the effective gap width and the conductivity of the gas in the gap. Unfortunately, these two variables are interdependent and difficult to quantify. For example, the large gaps (∿0.038 diametral) postulated for densified fuel produce higher calculated fuel temperatures than gaps of size 0.023 cm diametral, and enhance the release fractions of fission gas. When additional fission gases, with their low thermal conductivities, are released, the gap conductance is degraded. This degradation, in turn, further raises the fuel temperatures. This calculative process then proceeds until an equilibrium temperature is reached (based on the power history of the rod). Concurrently, the gap dimensions are constantly changing due to the contribution of fuel and cladding thermal expansion, cladding creepdown, and fuel relocation. Fuel relocation includes contributions from fuel densification, fuel cracking, crack healing, fission product swelling (restrained and unrestrained), and pellet column eccentricity.

The BOL fuel relocation effects have the largest impact on the thermal stored energy. The effects of densification are postulated to be largely mitigated by BOL gap closure induced by fuel cracking and crack healing combined with unrestrained swelling.[1] The calculated effects of fuel relocation almost completely overwhelm second and third-order parameters such as fuel or cladding surface roughness.

Although the cracking behavior of oxide fuel has been studied in both laboratory and in-reactor tests, the mechanisms are poorly understood. In addition, there exists very little well-characterized data tying fuel relocation directly to fuel temperatures. Reliable prediction of the amount of fuel relocation (a function of heat rating, gap size, burnup, and fuel temperature) will heavily impact the quantifying uncertainties involved in the calculation of gap conductance, and thus stored energy. The data will also be applicable to understanding later-in-life pellet-cladding mechanical interaction (PCMI).

The effects of changes in gap size will be inferred from the readings obtained from the two fuel centerline thermocouples and cladding elongation sensor contained in each rod. If the fuel relocation mechanisms are rapid, the degradation induced by fission gas in the gap should be minimized (at least in IFA-431, 330 W/cm peak power) and the rod temperatures should initially decrease to an equilibrium temperature. Degradation of the initial fill gas thermal conductivity caused by release of adsorbed gases may, however, mask the effects of gap closure at some heat ratings early in life. Confirmation of gap closure is expected to be obtained by detecting the onset of PCMI through the use of the cladding elongation sensors, and possibly, by destructive PIE of selected fuel pin cross sections. However, the elongation sensors will not pinpoint the point of interaction and pellet chips trapped in the gap could bias the results.

Most of the evidence available when these tests were designed suggested that no measurable cladding strain would occur when the fuel was initially relocated, unless the gap was extremely small. That is, little cladding strain is expected at low burnups provided the rod powers remain relatively constant and the gap is sufficiently large to accomodate differential thermal expansion. However, rapid changes in power after the fuel has contacted the cladding should produce cladding strain. The postulation of little cladding strain is based on a number of PIE cladding measurements on various fuel types where the gap was entirely closed by fuel relocation. Since rods 1 (0.0229 cm gap), 2(0.0381 cm gap), and 3 (0.0051 cm gap for IFA-431 and 0.0076 cm gap for IFA-432) will span the range of gap sizes in commercial plants, they should provide the data necessary to develop an improved gap closure model.

The effects of variations in gap geometry have been briefly investigated. As an example, one study was an analytical investigation of fuel pellet eccentricity.[22] The results suggest that fuel eccentricity could significantly lower the fuel centerline temperature. Thus, the fuel column of rod 4 is designed to aid evaluation of the relative effects of eccentricity. To accomplish this, the upper fuel region has been mechanically constrained (within tolerance limits) to a concentric orientation, and the lower fuel region constrained to a fully eccentric orientation.

Because the gap size as well as the gas composition within the gap will vary with time, the data from rod 4 will be particularly valuable in evaluation of the gap closure. This is because Xenon has such a low thermal conductivity that the release of fission gases should have little effect on the gas thermal conductivity. Therefore, any changes in the fuel temperatures of rod 4 should be a direct consequence of changes in the gap size.

FUEL ROD GAS PRESSURES

Pressure transducers are installed in rods 1, 5, and 6 to help evaluate various NRC fission gas release models,[23,24] helium solubility or entrapment, and to check the algorithms used to calculate internal rod pressure. Since the gap dimensions and gas compositions are critical in any gap conductance model, and are interdependent, the various parameters must be separated. (For example, changes in fuel temperature are induced by changes in both dimension and gas composition.) These pressure transducers will also check the capability of various codes to calculate initial rod pressures. These calculations depend on correct summation of internal void volumes, the temperature associated with the void volumes, and the moles of gas within the pin. Data from the initial startup will be the best checkpoint for rod pressure calculations because neither the moles of gas or the void volumes will have undergone substantial changes. Plenum, gap, internal fuel void volume temperatures, and differential thermal expansion will have the largest effect.

Helium entrapment within the fuel is postulated to occur within a few weeks after startup. The amount of entrapment could be a critical parameter for several design or safety situations. For example, PWR rods are now typically prepressurized to preclude cladding collapse and to offset PCMI effects. If sufficient He is trapped in the fuel, the actual operating pressure will be lower than that designed. If a significant amount of helium becomes entrapped in BWR or nonpressurized PWR fuel, the gap conductance could be severely degraded if low conductance, indigenous gases are released to the gap volume.

An important objective of these tests is to verify fission gas release models and to improve the fission gas release data base. Release of Xe and Kr to the gap causes rapid degradation of the gap conductance and consequently raises the stored energy in the fuel rods. Thus, significant inaccuracy of the gas release models will severely distort the thermal calculations. Most fission gas release models are based on a release fraction rather than a release rate. These tests should provide data for development of empirical release rate equations and, subsequently, more mechanistic models.

Besides providing fission gas release data, the pressure transducers may provide a means of following changes in void volumes that are induced by densification. Rod 1, with its 95% TD stable fuel, will provide a reference for rods 5 and 6. Thus, comparison of rod 1 with rod 5 (92% TD stable fuel) will allow correct compensation for stable low density fuel while comparison of rod 5 with rod 6 (92% TD unstable fuel) will allow inference of void volume changes that may be caused by densification.

CROSS-CORRELATION EFFORTS

These tests were designed to ensure that the data could be cross-correlated, provide as many independent checks of data validity as possible, ensure against instrument failure, ensure at least internal consistency on a relative basis, and provide some tie points to commercial plant designs as well as other fuel research programs. One of the basic premises for the test design was to provide a systematic approach that would allow adequate interpolation and extrapolation with computer codes. The first step in this approach was the decision to design IFA-431 and IFA-432 as identical assemblies. The use of identical designs enhances the ability to interpolate over a range of power and also replicates initial conditions. For example, it will be possible to duplicate the data from the first power ramps of IFA-431 with the first ramps of IFA-432. Also, the use of identical assemblies reduces the uncertainties associated with assembly and rod power distributions.

The power profile in HBWR (see Section 5.0) was also considered during the design of the tests. It was decided the top of the rods would be placed at the peak of the axial neutron flux profile, which forces the bottom of the rods to operate at 70-80% of the peak rod power. To take advantage of this power distribution, thermocouples are placed in the top and bottom of each rod. Although no previous tests had been run in HBWR with thermocouples penetrating both endcaps, Halden staff members were able to develop a workable design. This placement of thermocouples in both ends provides an opportunity to check the ability of various codes to interpolate over a short power range within the same rod. If a code cannot adequately perform these calculations, the temperature distribution calculations over a four-meter (13-ft) fuel length are also suspect. Two thermocouples per rod will allow modelers to interpolate between approximately 230 W/cm and 490 W/cm (with internal check points at approximately 330 and 400 W/cm) while single thermocouples would have provided data only at 330 and 490 W/cm. As a result of reactor cycling, data will be obtained over the range of 0-525 W/cm which should span most of the anticipated normal operating powers in commercial plants.

In addition to the selection of assembly powers, additional tie points with commercial plants and other fuel research programs included selecting the BWR-6 fuel geometry and procuring commercial quality tubing. Some of the cladding obtained for this program was shipped to Aerojet Nuclear Company (now EG&G Idaho, Inc.) for use in their Halden tests. Both programs also used the same starting fuel powder for fuel fabrication, which was obtained from the Power Burst Facility (PBF). The length of the rods in both IFA-431 and IFA-432 was designed to be compatible with PBF test trains, as well-characterized irradiated fuel is needed for a number of tests in the PBF program. Some of the fuel structures produced during fuel fabrication were similar to those investigated in the EEI/EPRI UO_2 fuel densification study and will therefore provide a tie point to a much larger structural characterization program.

To assure the best possible thermal data, it is extremely important to correctly assess rod powers and the power distribution within the rods. To do this, seven neutron sensors are placed in each assembly. One sensor is located in the center of the assembly, three are located in the plane containing the upper thermocouples, and three are located in the plane containing the lower thermocouples. This arrangement allows the determination of neutron flux profiles in the assemblies in both the axial and radial directions. In addition, rod 3 (0.0051 - 0.0076 cm diametral gap) is included as an internal power standard. The small gap in rod 3 will be closed at power and thus the temperature gradient across the gap will be minimized. Since the coolant temperature and fuel centerline temperatures will be known, it will be possible to obtain an independent check of rod power at both the top and bottom planes in the assembly. It will also be possible to compare rod powers and fuel temperatures in both assemblies to assure consistent data.

Fuel and Cladding Pre-irradiation Characterization

Physical properties and geometric data for fuel and cladding must for fuel and cladding be extensively precharacterized to improve power calibration and thermal distribution calculations.

Establishing the initial dimensions and void volumes within the pins is also essential for assessment of all thermal calculations. Consequently, the lengths and diameters were measured for each fuel pellet, as well as the cladding for each rod. Each pellet was then identified with a unique number for the purpose of tracing pellet types and position, within the rods. This information will enable determination of the axial distribution of gap volume and the plenum volume. Pellet and cladding roundness profiles were also obtained to illustrate the departure from the ideal co-axial cylinders which are used in most computer code models.

Geometric densities were determined for all pellets, and immersion densities for a significant fraction of the pellets. A correlation was developed relating immersion density to geometric density. This density data will be used in two ways: correcting rod power discrepancies caused by differences in mass distribution, and verifying NRC resintering models used to characterize fuel's propensity to density. Section 7.0 discusses resintering tests conducted on each fuel type.

Thermal diffusivity measurements were taken for each fuel type to a temperature of 1600°C. The thermal conductivity of the fuel as a function of temperature was then determined from information obtained on the diffusivity, heat capacity, and density.[25] Use of this thermal conductivity data, rather than the Lyons[26] conductivity equation as used in the pretest predictions, is expected to improve the post-test analysis. In addition, the thermal diffusivity data will reduce the uncertainty associated with calculating gap conductances from the experimental data.

The EEI/EPRI UO_2 densification program[6] demonstrated the importance of pore-size distribution measurements in characterizing the stability of various fuel types. During this test program an objective is to assure that 95% TD-S[a] fuel types will indeed be stable, while also expecting that the 92% TD-U fuel will undergo large amounts of in-reactor densification. Both fuel densities and pore-size distribution can be measured during PIE, should it prove necessary to verify the relative stability of the fuel types. Archive pellets from each fuel type are being retained to provide a means of reducing variances associated with potential differences in examination techniques used in the pre-and post-test measurements.

Dynamic Temperature Measurements

During the test program planning, PNL requested a series of controlled power cycles for each assembly. As a result, there will be three cycles in each series consisting of a 66 W/cm (2.0 kW/ft) linear drop in power over a 60-second time interval. These tests will yield transient gap conductance data for comparison with pseudo steady-state measurements. Data from the transients should provide a cross-check on the steady-state data and a data base for developing and verifying portions of the transient gap conductance models needed to satisfy the Final Acceptance Criteria for the emergency core cooling system (ECCS).

Summary of Cross-Correlation Design Aspects

Table 2.1 illustrates the amount of cross-correlation that will be possible. In addition to the rod-to-rod comparisons, top-to-bottom comparisons can be made in each rod and separate effects as a function of burnup and power can also be evaluated. Also, design considerations will make possible comparison of these tests to other test programs and commercial operation.

(a) 95% TD-S: The S indicates stable fuel type; U refers to unstable fuel.

TABLE 2-1. Cross-Correlation Matrix

Rod Number	Gap Size	Fuel Relocation	Fuel Eccentricity	Fuel Stability	Gas Composition	Fuel Density	Rod Power	Rod Pressure	Dynamic Temperature
1(9-He-95-5)[a]	X	X			X	X		X	X
2(15-He-95-5)[b][c]	X	X							X
3(2-He-95-5)[b][c]	X	X					X		X
4(9-Xe-95-5)[b]		X	X		X				X
5(9-He-92-5)		X		X		X		X	X
6(9-He-92-u)		X		X				X	X
7(15-He-95-5)									
8(9-He-95-5)									
9(7-He-95-5)									

(a) Example 1(9-He-95-S): 1 identifies the rod, 9 is the nominal diametral gap in mils, He is the fill gas, 95 is the fuel percent theoretical density, and S indicates stable (s) or unstable (u) fuel.
(b) IFA-432 rods which may possibly be removed at 4000 MWd/MTM and be replaced by rods 7, 8, or 9.
(c) Rod 3 of IFA-432 is fabricated with a 0.0076 cm diametral gap.

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3.0 FUEL ROD DESIGN

The BWR-6 fuel rod geometry was selected for relevance to contemporary LWR's. BWR-6 pellets are also larger than PWR pellets, which therefore tends to reduce perturbations caused by instrumentation.

Fuel and Cladding

Each fuel rod used in these tests nominally contains 45 fuel pellets, 1.27 cm (0.5 in.) long, for an active cold fuel length of 57.15 cm. All pellets have flat ends, were enriched to 10 wt% ^{235}U, and were fabricated by compacting and sintering UO_2 powder to the required density (see Section 6.0 for further description). Dysprosium oxide pellets are located at each end of the pellet column to smooth out the flux profile, and a helical spring, located in the plenum, maintains a compact fuel stack. The cladding for all rods is annealed, seamless Zircaloy-2, with an outside diameter of 1.2789 cm (0.5035 in.) and an inside diameter of 1.0909 cm (0.4295 in.). The cladding for both assemblies was purchased by PNL from Sandvik Special Metals Corporation in Kennewick, Washington in accordance with ASTM-B353-71(1) and supplementary PNL specifications (see Appendix A for quality certifications and supplementary specifications).

Fuel Density

A reference fuel density of 95% TD was selected to assure a densification-resistant fuel and to provide a density typical of current fuel designs. Since new designs being considered for commercial reactor fuels will use stable, low density fuel, fuel pellets of 92% TD with stable and unstable structures are included in these tests. The stable fuel will be compared directly with the unstable fuel to obtain information on the effect of densification.

Geometry

Initial cold, diametral fuel-cladding gap sizes of 0.0051, 0.0076, 0.0178, 0.0229, and 0.0381 cm (one fuel size per rod) were selected for these tests. A He-filled rod with an initial diametral gap of 0.0229 cm (rod 1) was the selected test standard. The rods with 0.0381 cm gaps (rod 2) will provide an upper limit for the postulated effects of densification, and will simulate instantaneous densification. Although they are poorly understood, gap closure mechanisms are expected to quickly reduce the gap. Conservatism is thus expected to be reduced in the future for this, one of the most adverse cases used in licensing. The small-gap rods, 0.0051 and 0.0076 cm (rod 3), are designed to produce fuel-cladding contact at power, which will ensure a high gap conductance relative to the other rods. This provides an internal standard to which data from the non-zero hot gap rods can be normalized.

Fill Gas

Five of the six rods in each assembly are backfilled with He at atmospheric pressure. Because of fission gas release, these rods will experience gas thermal conductivity degradation during irradiation. To eliminate the variables of changing gas composition and thermal conductivity, rod 4 was backfilled with Xe at atmospheric pressure. As Xe has the lowest gas thermal conductivity, contamination with fission gases should not affect the thermal conductivity. Therefore, the gas thermal conductivity for rod 4 should remain constant with irradiation. Rod 4 is considered a lower bound to gas thermal conductivity while the He-filled rods at BOL may be considered upper bounds.

Uniqueness of Rod 4

Rod 4 of each assembly has two design features which are not incorporated into any other rod in the test series. First, it is backfilled with Xe gas. Second, through the use of oversized fuel pellets and molybdenum rods, an upper region of the fuel column is concentrically constrained while a lower region of the fuel column is eccentrically constrained (Figure 3-1). These design features allow, first of all, a comparison to other experimental irradiations[2-4] which have indicated that the apparent gap conductance in Xe and Xe-Kr-filled rods is better than that calculated by accepted analytical methods. Second, comparison of the relative gap conductance between the eccentric and concentric portions of the rod may confirm analytical data suggesting that gap eccentricity may enhance heat transfer. The use of Xe fill gas will aid in this analysis by providing a constant gas thermal conductivity throughout the irradiation. Thus, changes in gap size will be the primary determinant of changes in gap conductances.

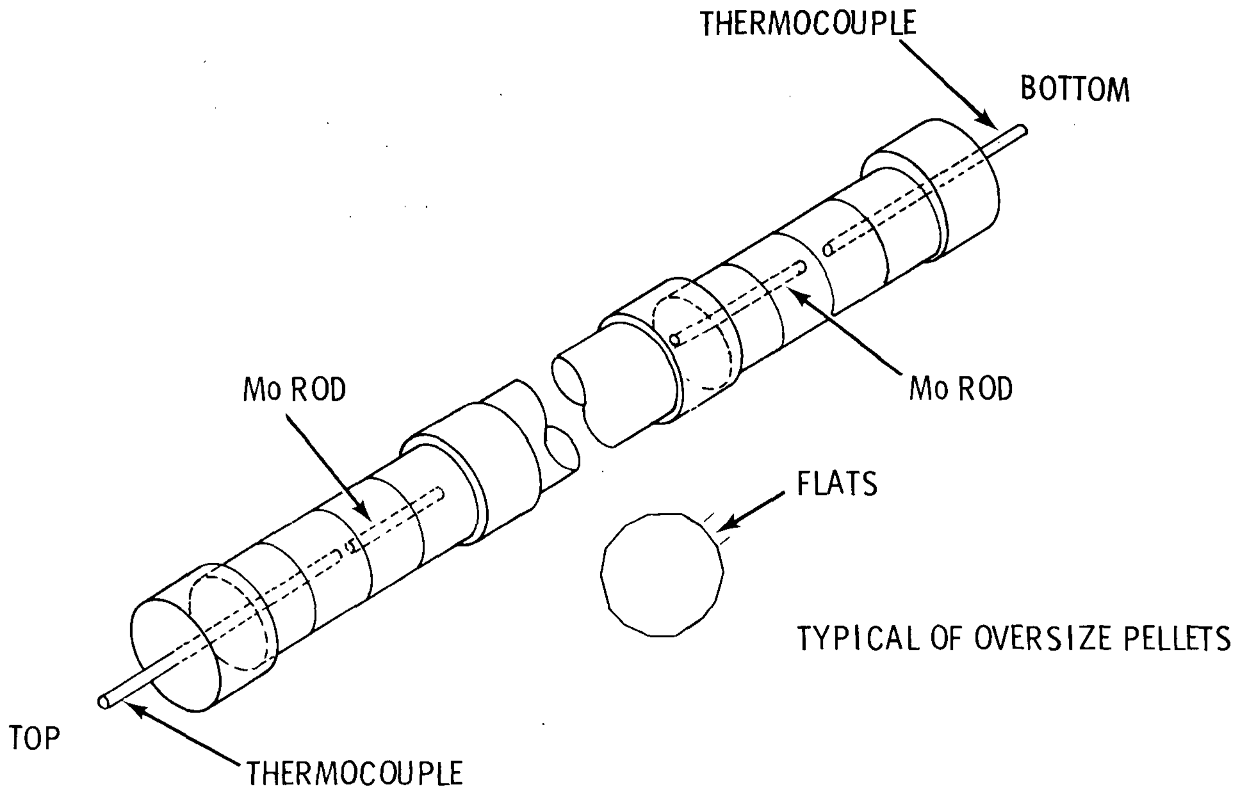

FIGURE 3-1. Stack Arrangement for Rod 4 with Xenon Fill Gas (1 atm)

Instrumentation

Because of the heavy influence of gas mixing and resulting conductivity changes, there is uncertainty as to the accuracy of coupling axial nodes of 4-meter long commercial rods. Therefore, each fuel rod in this test is instrumented with two temperature sensors that are located upon the fuel centerline. One sensor penetrates the fuel stack from the top; the second from the bottom. As a result of this arrangement, the fuel centerline temperature is measured at two axial positions. This data may be used for two different checks: temperatures at two axial nodes provide a check on global models of the fuel rod, and a comparison is provided between the low-power position of a high-power rod (IFA-432) and the high-power position in a low-power rod (IFA-431). All of the temperature sensors are thermocouples, except for one ultrasonic thermometer which is located in the upper region of rod 2, IFA-432.

Additional rod instrumentation consists of cladding elongation sensors for all rods to detect the time and extent of pellet-cladding interaction. Rods 1, 5, and 6 are equipped with pressure transducers to monitor internal fuel rod pressure.

Table 3-1 lists the design parameters and instrumentation for IFA-431 and IFA-432. Figure 3-2 shows details for each fuel rod type.

TABLE 3-1. Design Parameters and Instrumentation for IFA-431 and IFA-432

IFA-431 Peak Power - 10 kW/ft (328 W/cm)

Rod No.	Diameter Pellet in.	Diameter Pellet mm	Cold Diametral Gap[a] in.	Cold Diametral Gap[a] mm	Fill Gas	Fuel Density % TD	Fuel Type[b]	Burnup MWd/MTM	Instrumentation Temperature Upper	Instrumentation Temperature Lower	Pressure	Cladding Length
1	0.4205	10.681	0.009	0.229	He	95	Stable	4,000	TC[c]	TC	PT[d]	ES[e]
2	0.4145	10.528	0.015	0.381	He	95	Stable	4,000	TC	TC	--	ES
3	0.4275	10.858	0.002	0.051	He	95	Stable	4,000	TC	TC	--	ES
4	0.4205	10.681	0.009	0.229	Xe	95	Stable	4,000	TC	TC	--	ES
5	0.4205	10.681	0.009	0.229	He	92	Stable	4,000	TC	TC	PT	ES
6	0.4205	10.681	0.009	0.229	He	92	Unstable	4,000	TC	TC	PT	ES

IFA-432 Peak Power - 15 kW/ft (492 W/cm)

Rod No.	Diameter Pellet in.	Diameter Pellet mm	Cold Diametral Gap[a] in.	Cold Diametral Gap[a] mm	Fill Gas	Fuel Density % TD	Fuel Type[b]	Burnup MWd/MTM	Instrumentation Temperature Upper	Instrumentation Temperature Lower	Pressure	Cladding Length
1	0.4205	10.681	0.009	0.229	He	95	Stable	20,000	TC	TC	PT	ES
2	0.4145	10.528	0.015	0.381	He	95	Stable	4,000[f]	UT[g]	TC	--	ES
3	0.4265	10.833	0.003	0.076	He	95	Stable	4,000[f]	TC	TC	--	ES
4	0.4205	10.681	0.009	0.229	Xe	95	Stable	4,000[f]	TC	TC	--	ES
5	0.4205	10.681	0.009	0.229	He	92	Stable	20,000	TC	TC	PT	ES
6	0.4205	10.681	0.009	0.229	He	92	Unstable	20,000	TC	TC	PT	ES
7	0.4145	10.528	0.015	0.381	He	95	Stable	16,000	--	--	--	--
8	0.4205	10.681	0.009	0.229	He	95	Stable	16,000	--	--	--	--
9	0.4225	10.732	0.007	0.179	He	95	Stable	16,000	--	--	--	--

(a) Cladding for all rods has an OD of 0.5035 in. (12.789 mm) and an ID of 0.4295 in. (10.909 mm). Diametral gap is cladding ID minus pellet diameter.
(b) With respect to in-reactor densification.
(c) TC = Thermocouple
(d) PT = Pressure Transducer
(e) ES = Elongation Sensor
(f) Removable rods replaced by Rods 7, 8, and 9.
(g) UT = Ultrasonic Thermometer

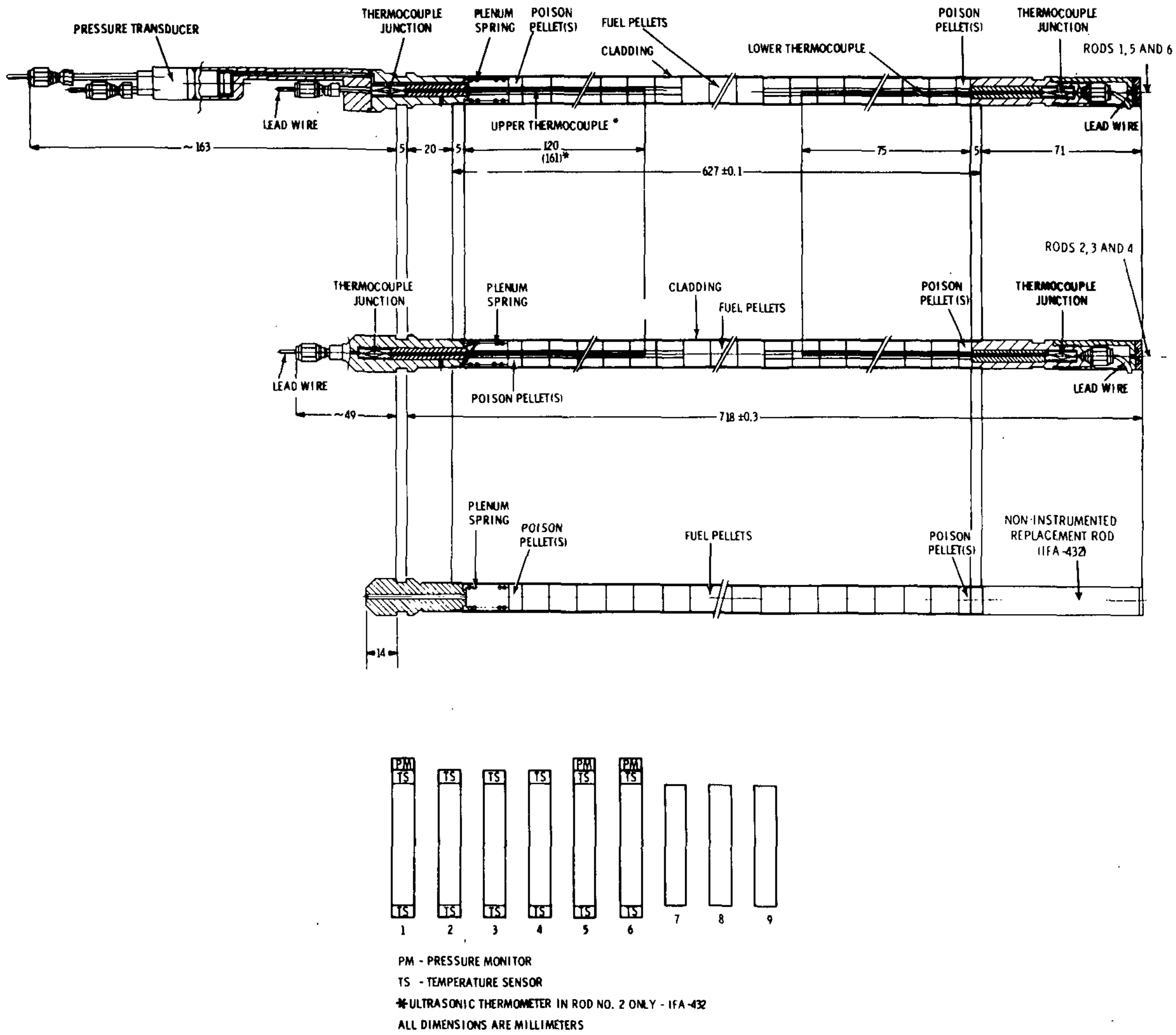

FIGURE 3-2. Schematic Arrangement of Fuel Rods for IFA-431 and IFA-432 (Dimensions are in mm)

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4.0 FUEL ASSEMBLY DESIGN

Each fuel assembly contains six instrumented fuel rods equally spaced around a central cable tube. The two assembly designs are identical except for an ultrasonic thermometer in the upper end of IFA-432, rod 2. The two assemblies are to be irradiated separately and in different reactor channels; IFA-431 in channel 6-14 and IFA-432 in channel 3-8 (see Figure 4-1).

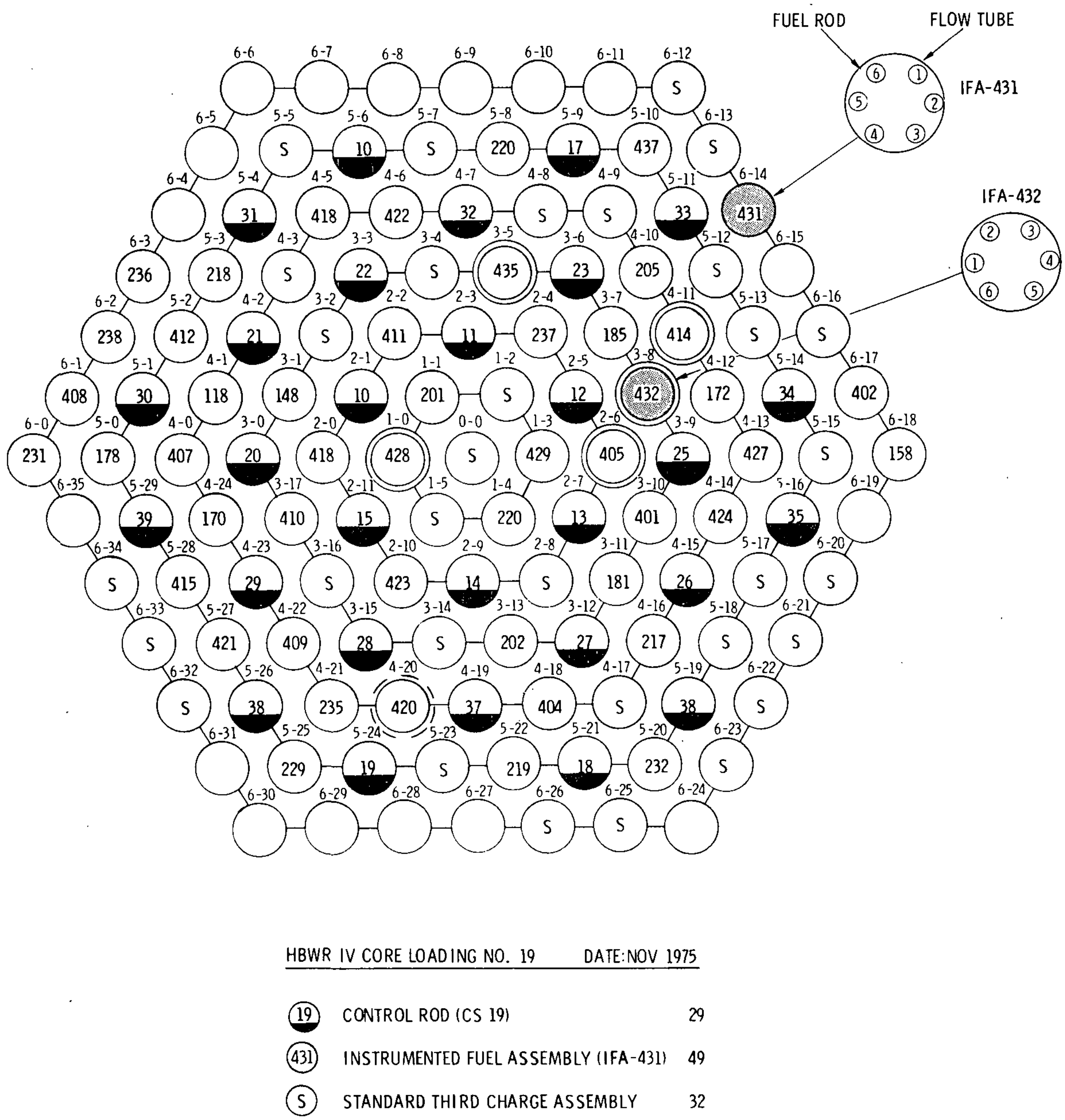

FIGURE 4-1. Core Positions of IFA-431 and IFA-432

Fuel rod parameters to be measured during reactor operation include central fuel temperatures (at two axial locations for all rods), cladding elongation for all rods, and internal rod pressure for rods 1, 5, and 6. The arrangement of IFA-431 in the flow channel is shown in Figure 4.2.

The following fuel assembly parameters will be measured during irradiation:

- fuel channel flow rate (during calibration) - Turbine velocity meters are used to measure the flow rate at the inlet and outlet of the fuel channel.
- coolant temperature rise in the channel - Chromel/alumel thermocouples with insulated junctions are located at the inlet and outlet of the flow channel.

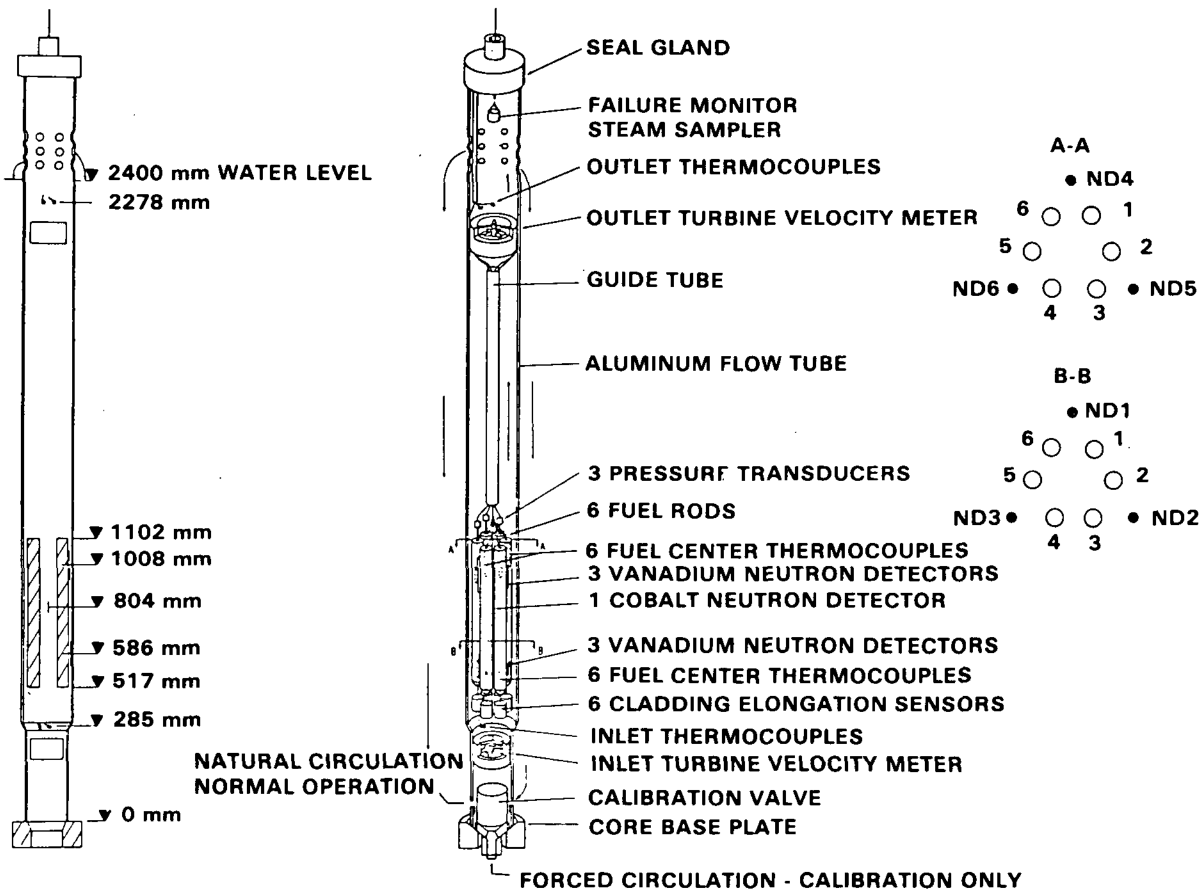

FIGURE 4.2. Schematic of Instrumented Fuel Assembly - IFA-431

- neutron flux - Self-powered beta neutron detectors are used for axial and radial neutron flux measurements. Each fuel assembly has six vanadium detectors (used for steady state measurements) and one cobalt detector (used for transient measurements). The vanadium detectors are equally spaced with three each on two planes. Because each vanadium detector measures the flux over approximately 10 cm, the axial centers of the detectors, for each plane, are located at the axial position of the tips of the thermocouples (see Figure 4.2). The cobalt detector is located in the assembly's middle region.
- fuel rod integrity - Integrity is monitored by analyzing fission product activity in steam samples taken from the flow channel.

Figure 4.3 shows the arrangement of the temperature sensor, neutron detectors, and fuel, relative to the reference axial thermal neutron flux profile.

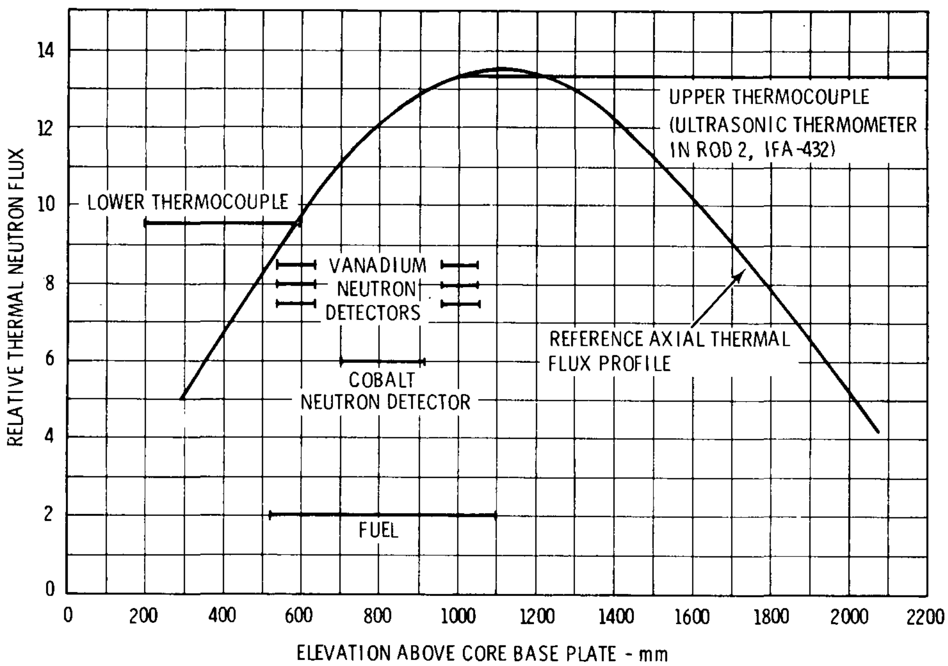

FIGURE 4.3. Arrangement of Temperature Sensors, Neutron Detectors, and Fuel Relative to Reference Axial Thermal Flux Profile, IFA-431 and 432

5.0 PRETEST PREDICTIONS

Pretest predictions for both IFA-431 and IFA-432 were made with the GAPCON-THERMAL-2[1] (9-1-1974 version) and FRAP-S[2] (MOD001-EXPR004-MATPRO MOD003) codes; the input used for these simulations is summarized in Appendix B. The major difference in input for each code was the lack within FRAP-S of 1) a xenon fill gas option, and 2) a fuel densification model. Post-test predictions using actual conditions are planned once the data have been processed.

The predictions for a contemporary rod (rod 1: 95% TD-S fuel, 0.0229 cm diametral gap) from each assembly are presented in Figures 5-1 and 5-2.

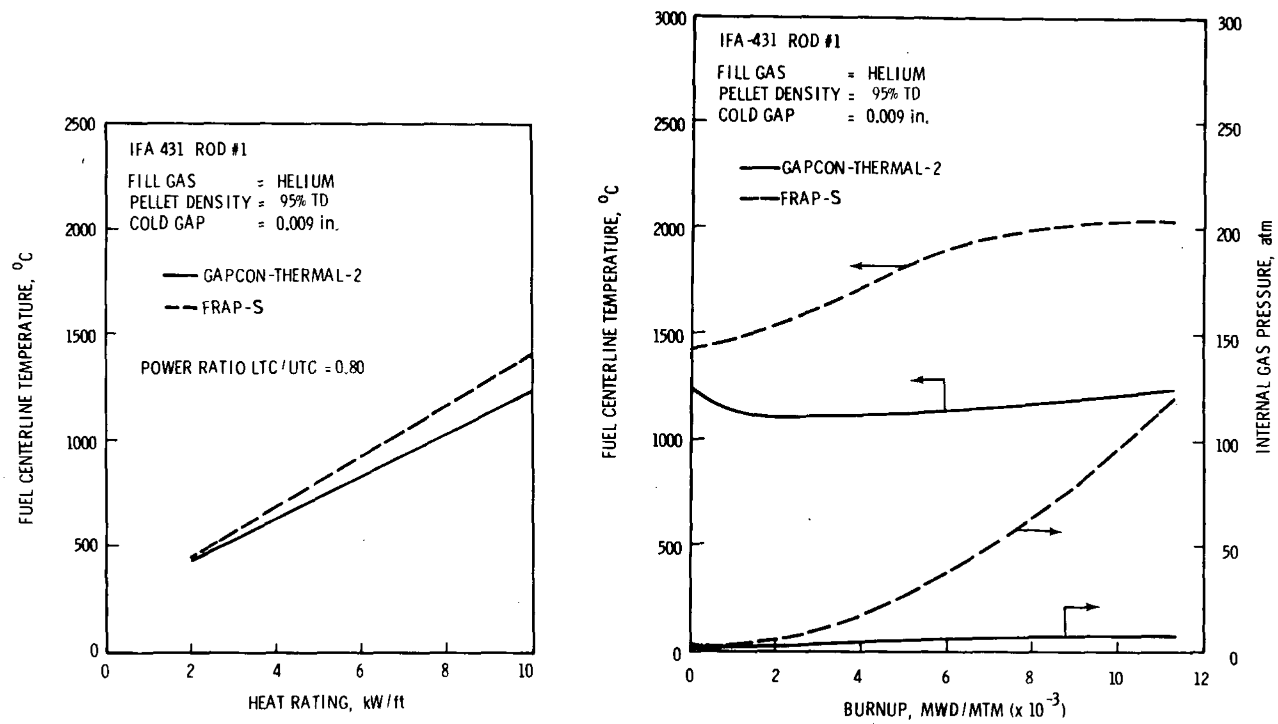

FIGURE 5-1. Predictions for IFA-431, Rod 1 (100% He, 95% TD-S UO_2 0.0229 cm cold gap)

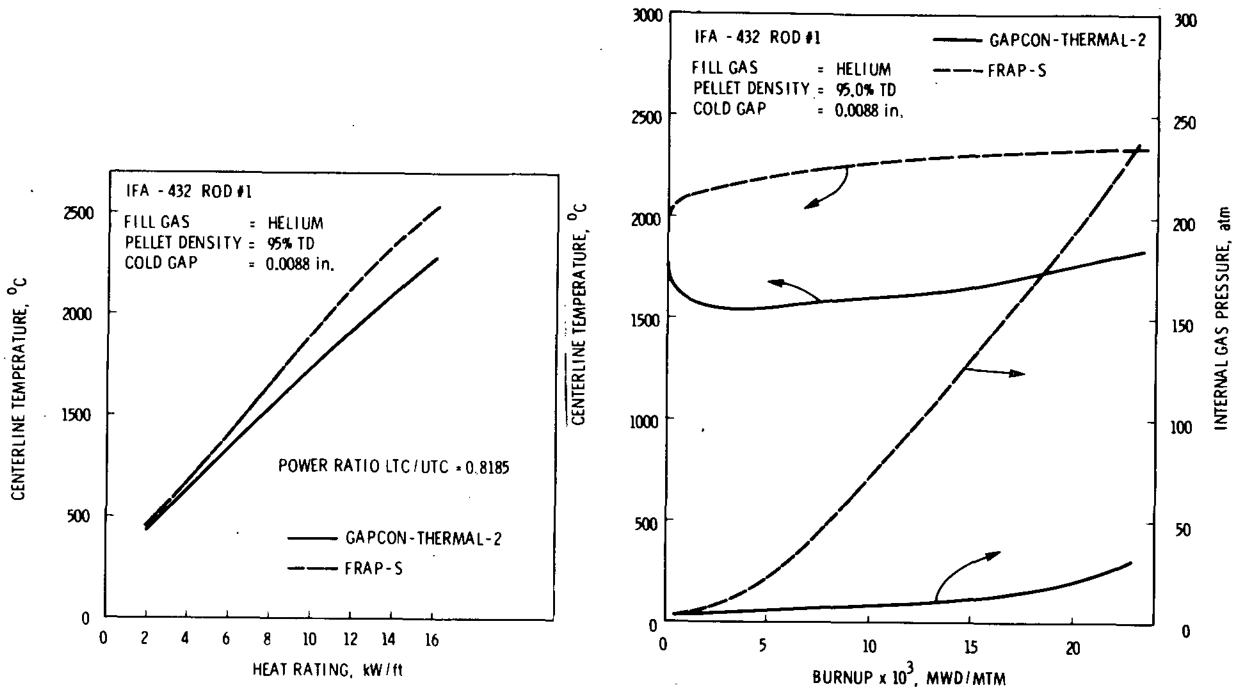

FIGURE 5-2. Predictions for IFA-432, Rod 1 (100% He, 95% TD-S, UO_2 0.0229 cm cold gap)

Similar results for the remaining rods may be found in Appendix B. Tables 5-1 and 5-2 summarize two basic predictions for all six rods in each assembly. As can be seen from these tables, FRAP-S generally predicts higher centerline temperatures and gas pressures, with the exception of rod 6 which contains unstable fuel that is prone to densification. However, comparisons between the two codes for rods 4 and 6 are invalid because the compared version of FRAP-S lacked fuel densification and Xe fill gas options.

TABLE 5-1. A Comparison of GAPCON-THERMAL-2 and FRAP-S Pretest Predictions for IFA-431

Rod Number	Peak Temperature Difference, °C[a]	Peak Pressure Difference, atm[a]
1	+ 810	+113
2	+1120	+175
3	+ 130	- 4
4	+ 570[b]	+112[b]
5	+ 760	+105
6	- 510[c]	+ 33[c]

TABLE 5-2. A Comparison of GAPCON-THERMAL-2 and FRAP-S Pretest Predictions for IFA-432

Rod Number	Peak Temperature Difference, °C[a]	Peak Pressure Difference, atm[a]
1	+700	+210
2	+800	+130
3	+200	+ 40
4	+700[b]	+120[b]
5	+700	+165
6	-400[c]	Very similar[c]

[a] (FRAP-S) - (GAPCON-THERMAL-2).
[b] FRAP-S did not contain a xenon option, argon was used as a fill gas.
[c] Difference due to no densification model in FRAP-S.

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2. J.A. Dearien, G.A. Berna, M.P. Bohn, D.R. Coleman, P.E. MacDonald, J.M. Broughton, "FRAP-S, A Computer Code for the Steady-Stable Analysis of Oxide Fuel Rods." In: FRAP-S Analytical Models and Input Manual, INEL Report I-309. 13.1, January, 1975.

6.0 FUEL PELLET FABRICATION

Fuel pellets for the test assemblies were fabricated from 10% enriched UO_2 powder. This powder was prepared from 18% enriched UO_2 supplied by Aerojet Nuclear Company and depleted UO_2 obtained at Hanford from Atlantic Richfield (ARHCO).

The starting materials in the fabrication process were dissolved, solution-blended, and converted to UO_2 powder. Conversion was by precipitation of ammonium diuranate followed by hydrogen reduction, using technology developed for preparation of fuel for the PBF programs. Figure 6-1 summarizes this fabrication process. Figure 6-2 details the powder quality assurance program.

The pellet fabrication requirements for each rod type are listed in Table 6-1. These requirements were considered in process development tests to determine the final process parameters. Figure 6-3 shows the in-process pellet quality controls and the final inspection requirements. Appendix C contains the process parameters, green pellet data, and summaries of the final inspection process.

Upon completion of fabrication, the pellets were subjected to the following inspections:

Diameter: Measurements to the nearest 0.0001 in. were made on all pellets at three positions; near each end and at the center. All pellets met the specified tolerance of $\pm$ 0.0005 in.

Length: All pellets were measured for length at two locations.

Weight: All pellets were weighed to the nearest 0.001 g.

Density: Geometric density for all pellets was determined from the measured weight and average length and diameter for each pellet. A selected number of the pellets underwent a liquid immersion technique to determine their density. Water was the suspension medium used in this evaluation. Densities based on geometric measurements are expected to be lower than immersion densities, due to the effects of surface roughness and slight chips.

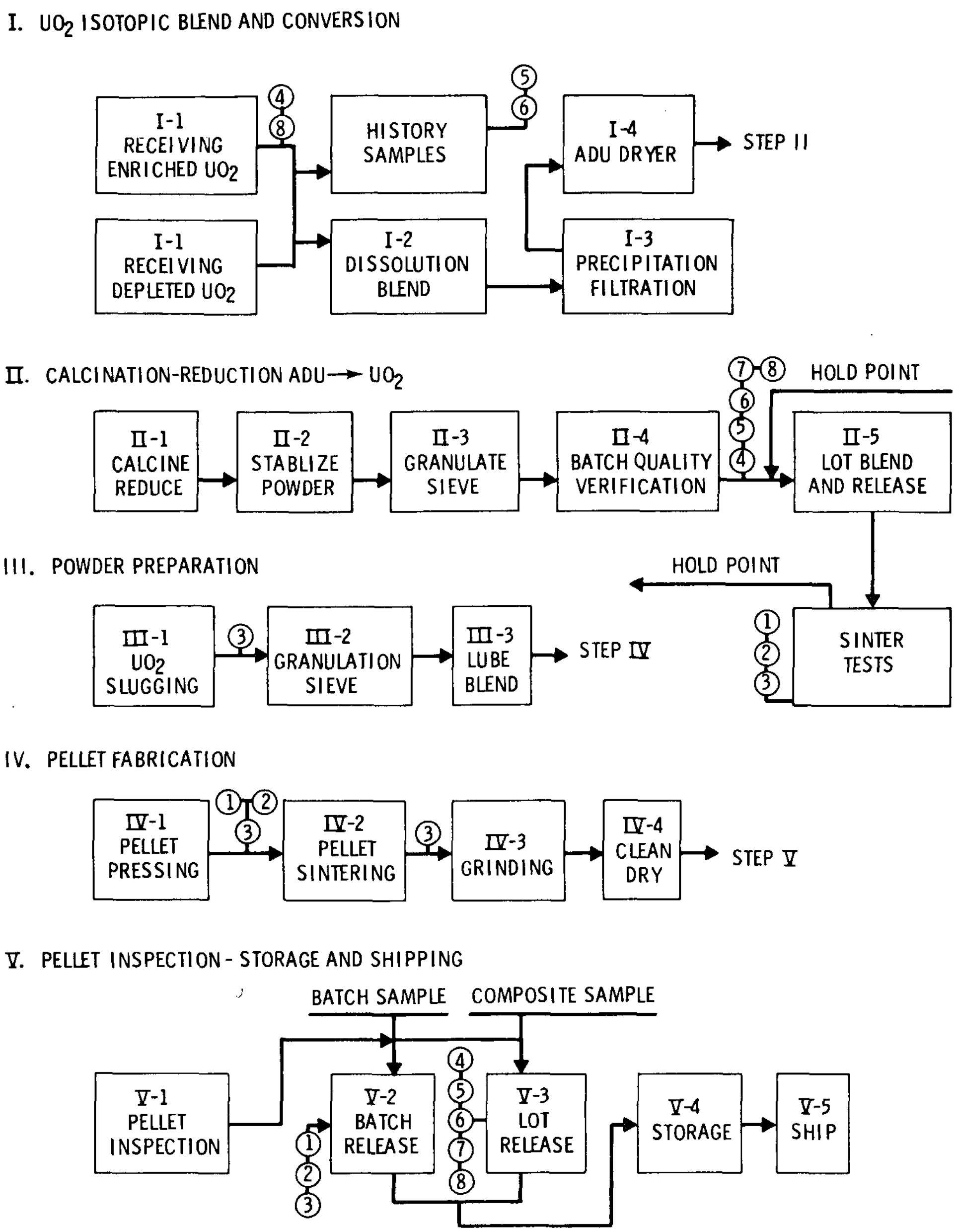


FIGURE 6-1. Pellet Fabrication Process Flow Chart

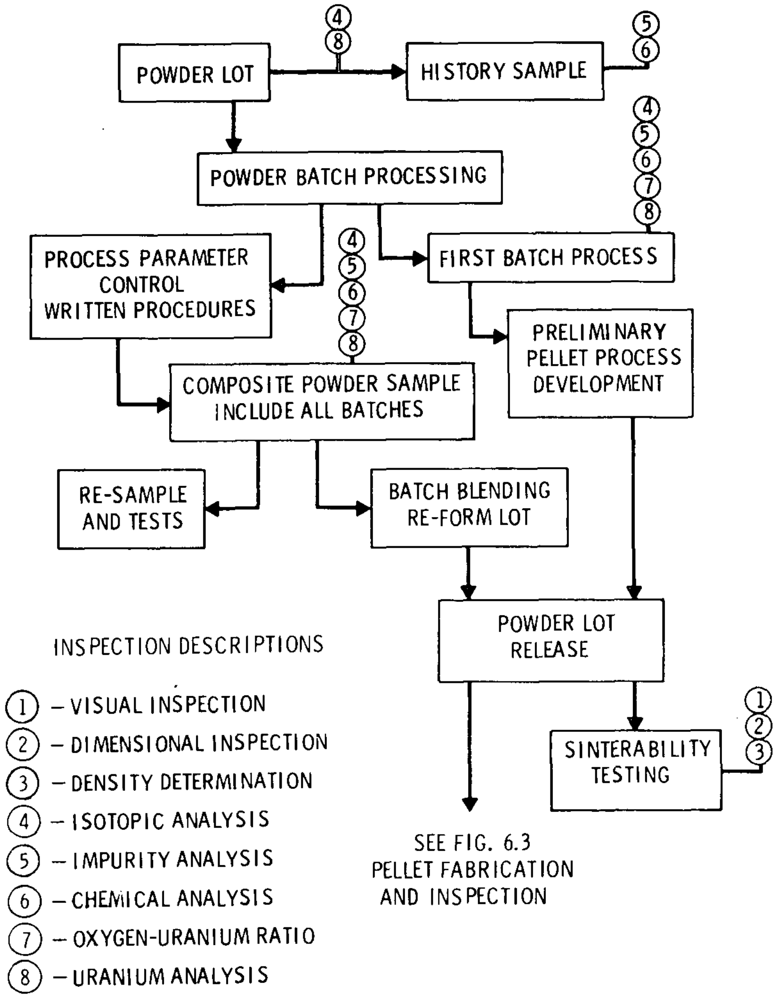


FIGURE 6-2. Powder Quality Assurance Flow Chart

TABLE 6-1. Pellet Requirements According to Rod Number and Assembly Number

Assembly No.	Rod No.	Density %	Fuel Type	Pellet Dia. in.	Fuel Rod Solid	Fuel Rod Drilled	Fuel Rod Total	Archive Solid	Archive Drilled	Archive Total	Overage Solid	Overage Drilled	Overage Total	Grand Total Solid	Grand Total Drilled	Grand Total Total
1	1	95	stable	0.4205	33	12	45	3	2	5	3	2	5	39	16	55
	2	95	stable	0.4145	33	12	45	3	2	5	3	2	5	39	16	55
	3	95	stable	0.4275	33	12	45	3	2	5	3	2	5	39	16	55
	4	95	stable	0.4205 / 0.4275	27 / 0	14(a) / 4(b)	45	3	3(c) / 1(b)	5	3	3(c) / 1(b)	5	33	20 / 6	59
	5	92	stable	0.4205	33	12	45	7	3	10(d)	3	2	5	43	17	60
	6	92	unstable	0.4205	33	12	45	7	3	10(d)	3	2	5	43	17	60
2	1 & 8	95	stable	0.4205	78	12	90	8	2	10	8	2	10	94	16	110
	2 & 7	95	stable	0.4145	78	12	90	8	2	10	8	2	10	94	16	110
	3	95	stable	0.4265	33	12	45	3	2	5	3	2	5	39	16	55
	4	95	stable	0.4205 / 0.4265	27 / 0	14(a) / 4(b)	45	3	3(c) / 1(b)	5	3	3(c) / 1(b)	5	33	20 / 6	59
	9	95	stable	0.4225	45	0	45	5	0	5	5	0	5	55	0	55
	5	92	stable	0.4205	33	12	45	—	—	—	3	2	5	36	14	50
	6	92	unstable	0.4205	33	12	45	—	—	—	3	2	5	36	14	50

(a) Hole diameter in 8 pellets = 0.063"; four drilled on center, 4 drilled 0.005" off center.
(b) Hole diameter = 0.063"; three drilled on center, three drilled 0.005" off center.
(c) Hole diameter in 2 pellets = 0.063" on center and one 0.005" off center. Hole in third pellet = 0.067-0.071".
(d) Includes archive pellets for Assembly 2.

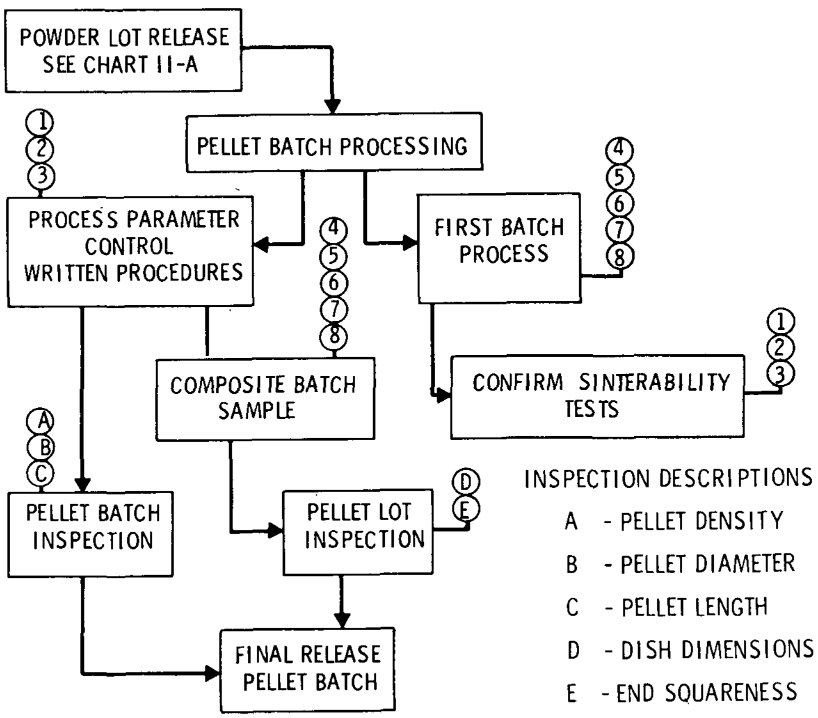


FIGURE 6-3. Pellet Quality Assurance Flow Chart

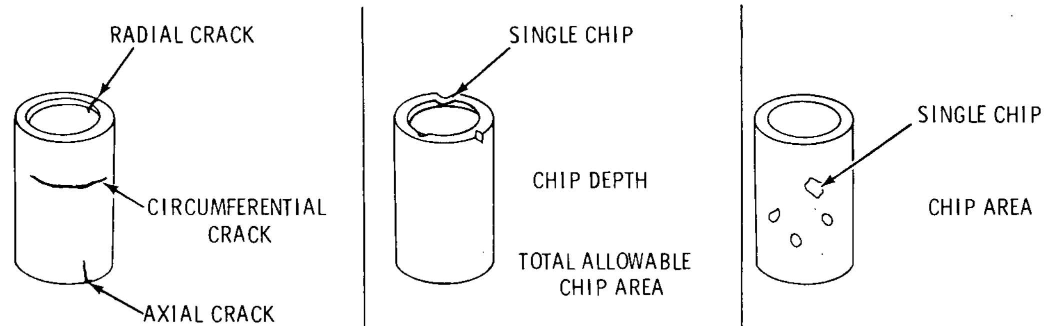
Pellet Defects and Cleanliness: All pellets were inspected for chips and cracks. The PNL visual standard for UO_2 fuel pellets (shown in Figure 6-4) was used as an inspection aid. The pellets were cleaned in an ultrasonic alcohol bath and dried in a forced air oven at approximately 100°C.

Chemical Purity: Appendix C contains a summary of the chemical analysis for both the composite pellet lots and the individual pellet batches.

Microstructure: Microstructures of representative pellets of each fuel type (95% TD-S, 92% TD-S, 92% TD-U) were examined. Discussion of observed structures, and microphotographs will be found in Section 7.0.

The pellets were specially packaged and handled during shipment. They were first placed in a flexible plastic sleeve and separated from one another by staples to prevent chipping. Then, they were placed in secondary containers (metal cans that contained a dessicant (Drierite) to prevent moisture pickup). These cans were then sealed with plastic tape and shipped in DOT-approved fissile material containers.

CRACKS | END CHIPS | CIRCUMFERENTIAL CHIPS



CRACKS

SURFACE CRACKS SHALL NOT EXCEED THE FOLLOWING LIMITS

1. END RADIAL CRACKS $\geq$ 25% OF DIAMETER
2. CIRCUMERENTIAL CRACKS 180^0
3. AXIAL CRACKS SHALL NOT EXCEED 25% OF PELLET LENGTH
4. MICRO CRACKING IS ACCEPTABLE

END CHIPS

END CHIPS SHALL NOT EXCEED THE FOLLOWING LIMITS (SAME LIMITS ON NON-DISHED PELLETS)

1. SINGLE CHIP $\leq$ 10% OF LAND AREA
2. TOTAL CHIPING $\leq$ 25% OF LAND AREA
3. CHIP DEPTH SHALL NOT EXCEED 0.020"

CIRCUMFERENTIAL CHIPS

CIRCUMFERENTIAL CHIPS SHALL NOT EXCEED THE FOLLOWING LIMITS

1. SINGLE CHIPS SHALL NOT EXCEED 3% OF SURFACE AREA
2. TOTAL SURFACE OF CHIPS SHALL NOT EXCEED 10% OF SURFACE AREA
3. DEPTH 0.020"

INSPECTION SHALL REJECT ANY "BORDER-LINE" QUESTIONABLE PELLET

FIGURE 6-4. PNL Visual Standards for UO_2 Fuel Pellets

7.0 FUEL PELLET PREIRRADIATION CHARACTERIZATION

Fuel pellet precharacterization included the following:

- analytical measurements (to determine if the physical characteristics and impurity content of the pellets met PNL specifications)
- density measurements,
- microstructural analysis,
- resintering characteristics,
- thermal diffusivity/conductivity measurements,
- surface characteristics of pellets and cladding.

ANALYTICAL MEASUREMENTS

The fuel pellets were analyzed for weight percent uranium, ratio of oxygen to uranium, isotopic composition, off-gas and ppm carbon, as well as nitrogen, flourine, chlorine, water, and trace impurities. Appendix D contains the results of the analysis, as well as a summary of the analytical techniques (Table D.1). Table C.10, Appendix C lists the specification limits.

The only impurity found to exceed the specifications was the carbon content for the 92% TD-S (fabricated with pore formers) sample pellets. Though the carbon content is controlled because carbon tends to reduce the stability of UO_2 in hot water,[1] carbon contents of up to 350 ppm were found in these samples. However, because the tests will be operated in the failure mode, the high carbon content is not expected to adversely affect them.

DENSITY MEASUREMENTS

As indicated in Section 6, fuel pellet densities were determined through both geometric and liquid immersion techniques.

Geometric Density Measurements

Pellet densities were based on specified measurements: diameters - to within ± 0.0001 in. at three locations on each pellet, lengths - to within ± 0.0001 in. at two locations - weights to within ± 0.0001 g. Because of surface roughness and chips on the pellet edges which result in higher apparent volumes, densities based on geometric measurements were expected to be less than the true bulk values. Measurements were made for all pellets; Appendix E lists dimension and weight measurements and calculated densities for each individual pellet. Figures 7-1 - 7-5 give frequency distributions of the density calculations.

Liquid Immersion Density Measurements

The saturation liquid immersion technique was used to determine the bulk density of a selected number of pellets. Water was used as the suspension medium in this evaluation. Single measurements were made on approximately one-third of the 95% TD-S and all of the 92% TD-S pellets. All 92% TD-U pellets were measured twice. Archive pellets have been retained in case additional measurements are needed.

This immersion technique is a modification of that described in ASTM

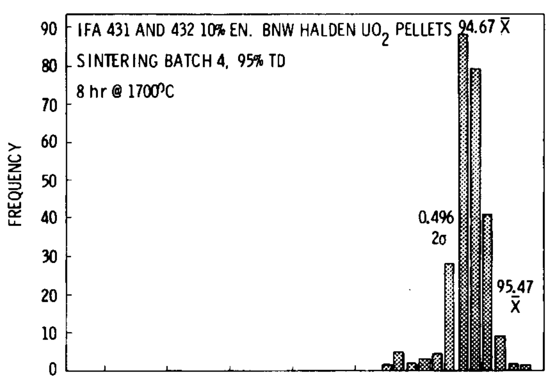


FIGURE 7-1. Density Measurements, Sintering Batch 4, 95% TD Stable Fuel

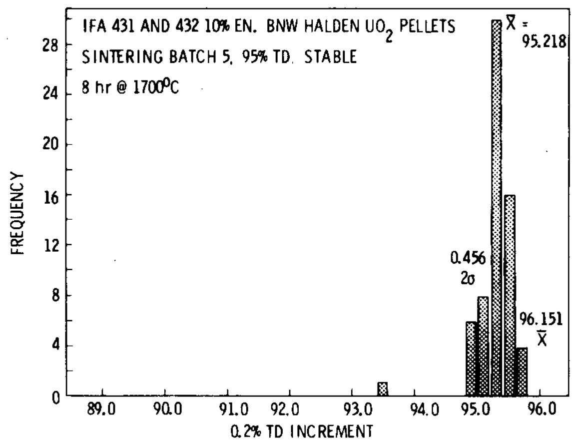


FIGURE 7-2. Density Measurements, Sintering Batch 5, 95% TD Stable Fuel

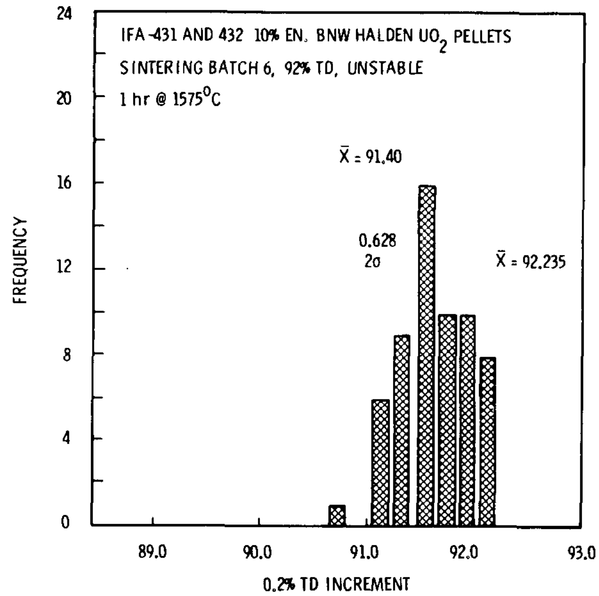


FIGURE 7-3. Density Measurements, Sintering Batch 6, 92% TD Unstable Fuel

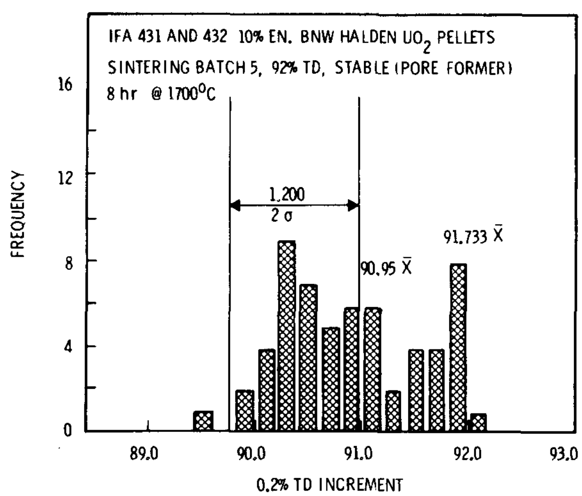


FIGURE 7-4. Density Measurements Sintering Batch 5, 92% TD Stable Fuel

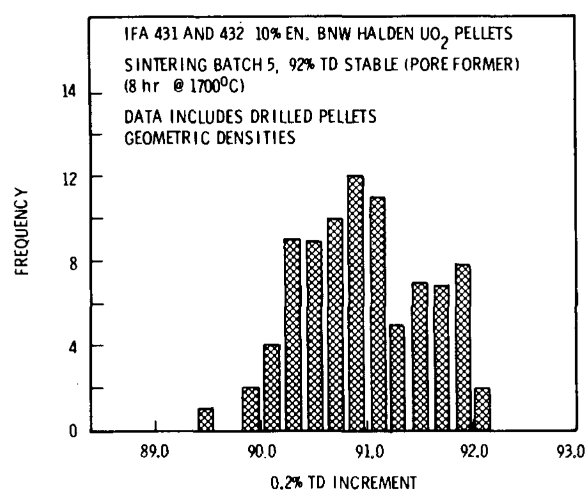


FIGURE 7-5. Density Measurements Sintering Batch 5, 92% TD Stable Fuel

Standard C-373-72.[2] For this technique, three pellet weights are required to determine the pellet density:

- the dry weight,
- the weight of the saturated pellet in air,
- the weight of the saturated pellet, suspended in water

The following equation is then used to calculate the immersion densities.

$$\rho = \frac{W_1}{(W_2-W_3)/\rho_\ell}$$

where

ρ = pellet density, g/cm^3

W_1 = dry weight, g

W_2 = saturated weight, g

W_3 = suspended weight of saturated pellet, g

ρ_ℓ = liquid density, g/cm^3

Appendix E contains the measurements and corresponding results.

Density Correlations

The following correlations were developed to relate the immersion densities to the geometric densities.

- Solid Pellets

  Immersion density = 1.017 x geometric density - 0.1367 % TD $\pm$ 0.25

  Total number of pellets = 245

  Bias: 0.75% TD at 95% TD

  0.71% TD at 92% TD

- Cored Pellets

  Immersion Density = 1.040 x geometric density - 0.2931 %TD $\pm$ 0.33

  Total number of pellets = 91

  Bias: 0.98% TD at 95% TD

  0.86% TD at 92% TD

MICROSTRUCTURE CHARACTERIZATION STUDIES

Results of recent irradiation studies[3-5] indicate that fuel pellet stability toward densification can be correlated with the microstructural characteristics of the fuel. It has been demonstrated in fuel types which have a combination of small pore sizes, a large amount of porosity in pores of less than 1 μm diameter, small grain sizes, and low densities, that the fuels densify during irradiation. The volume fraction of porosity contained in pores of less than 1 μm diameter pores plays a major role in irradiation-induced densification because it has been observed that, during the process, the volume fraction of porosity in this size range decreases.

The present study included a detailed pre-irradiation microstructural characterization of the three fuel types. This was performed for two reasons: so that observed densification behavior could be related with the initial pellet microstructures, and to serve as a basis for evaluating microstructural changes induced by irradiation. It has been demonstrated that the techniques used in this evaluation are amenable to the subsequent study of irradiated fuels.[3-5]

Quantitative descriptions of the pore size distributions, the pore volume distribution, and grain size were developed for each of the fuel types, as described in the following sections.

Experimental Procedures

The quantitative microstructural characterization procedure comprised five separate, but related, tasks:

- selection of specimens
- specimen preparation
- perform microscopy
- take quantitative measurements
- perform computation

Selection of Specimens

Specimens for microstructural evaluation were selected on the basis of their bulk density. This was done to ensure their representativeness of the pellets to be irradiated and resintered. It was concluded that the number of pellet cross sections and individual sites examined were sufficient to adequately assess microstructural homogeneity, including the radial distribution of porosity for each pellet type.

The precision of this examination technique depends on the microstructural homogeneity within the pellets and the number of pores in any single specimen. Previous studies of this type[(3-5)] have shown that these quantitative microscopy procedures have a computational uncertainty of approximately $\pm$ 6% for pore volume fraction determinations and about $\pm$ 11% for pore size/number determinations (based on 16 observation sites).

Specimen Preparation

Grain size and pore distributions were evaluated on polished surfaces of pellet cross sections in this study rather than on fracture surfaces because the former was judged to yield more accurate results. As shown in Figure 7-6, 16 sites were examined on one pellet of each fuel type. These sites were located on transverse mid-plane and longitudinal sections of the pellets. The pellet surfaces were polished in a series of steps, ultimately utilizing a Syntron vibratory polisher with 0.3 μm AlO_2 polishing agent contained in a 2% chromic acid bath.

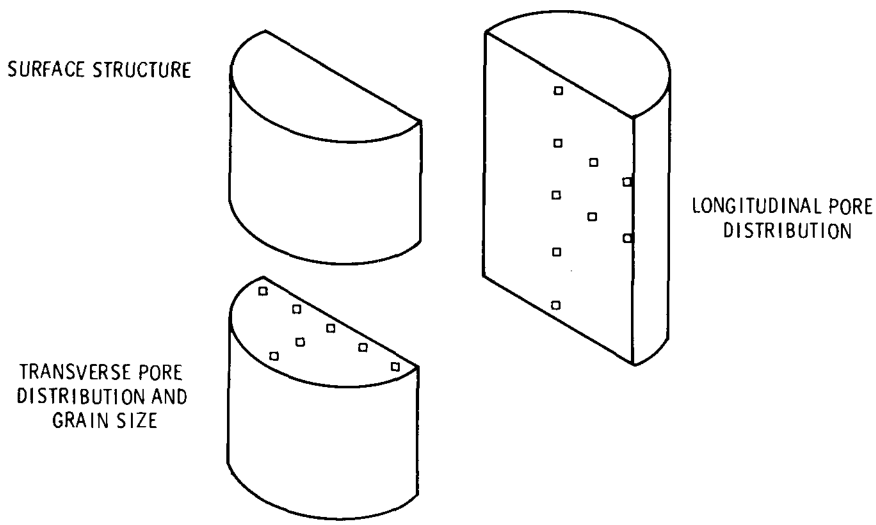


FIGURE 7-6. Pellet Sectioning and Sites Examined for Microstructure Studies

The as-polished surfaces were used for optical examination of pore sizes down to 2 μm. Examination of pores smaller than 2 μm was performed by scanning electron microscopy (SEM) and required the removal of surface smearing and polishing agents entrapped in pores. Chemical etchants that are normally used for surface cleaning markedly change the pore size and shape. But brief vacuum cathodic etching in a controlled manner is highly effective in cleaning the smallest pores of debris without changing pore shape or size.[(2-5)] For grain-size measurements, a chemical etch (H_2O_2 - H_2SO_4) was applied to the transverse section in a separate preparation step.

Microscopy

Covering the entire size range of pores present in the fuel types studied required both light microscopy and electron microscopy. A Zeiss "Ultraphot" light microscope was used to prepare micrographs at 9, 31, and 125-1000X magnification, covering the entire pore and grain-size range above a diameter of 2 μm.

The higher magnification required for observation and measurement of smaller pores was achieved with a JSM-U3 scanning electron microscope. Mapping was conducted at each optical microscopy step to assure that identical areas were examined by both optical microscopy and SEM. The composite mosaic strips at 31X magnification permitted visual correlation of light and electron microscopy at each site. The lowest magnification used for the micrographs, approximately 300X, was chosen to provide an overlapping observation range with the micrographs obtained by light microscopy. Additional higher magnifications to 15,000X were selected to record the smallest pores observable on the pellet surface.

At least one micrograph of each magnification was taken at each of the designated sites; two or three micrographs were taken at the highest SEM magnification to improve the observation statistics. The resulting set of micrographs, ranging in magnification from about 31X to approximately 15,000X, covered the entire pore population in sizes ranging from 0.05 μm to more than 300 μm in diameter. In addition, the roughness of exterior pellet surfaces was examined by SEM at magnifications of 50-1000X.

The electron and optical microscopes were calibrated using several magnification standards, the basic one a certified accuracy calibration grid supplied for the optical microscope by the manufacturer. Cross checks were made between the optical and electron microscope over their common working range of approximately 100-1000X and several additional calibration specimens were used for the higher magnification range in the scanning electron microscopes. The instruments were adjusted to allow direct reading of the correct magnification on the optical microscope, while a calibration curve was prepared for the electron microscope to relate nomimal (meter) magnification values to the true value.

Pore Measurement and Counting

The primary purpose of the quantitative microscopy was to produce an accurate and representative assessment of the pore-size distribution for each fuel type. Measurement and counting of the pores was a critical step in this process that required high accuracy with reasonable speed. A Quantinet 720 (a commercially available quantitative image analyzer that was controlled by a Hewlett-Packard 9830 programmable calculator) was used to analyze prepared prints of the micrographs. The standards used were reference micrographs measured independently with a Zeiss Particle Size Analyzer.

Presently, there are no available mathematical models or computational methods which quantitatively evaluate nonspherical pore structure. Therefore, the size of irregularly shaped pores was calculated the same as spherical pores of equal cross sectional area. In the case of severely elongated porosity, the pores were treated as a chain of interconnected smaller pores. These inter-connected pores were "separated" at each constriction within the long pore and the resulting individual measurements were used as reasonable estimates of the overall volume of the elongated pore. Based on previous studies,[3-5] total pore volumes calculated from pore counts generally agree with those based on density measurements to within 1-3% TD.

Computation of Pore and Grain Characteristics

The pore count and measurement data yielded information describing planes through the pellet on which pores have been randomly sectioned. The mathematical and statistical methodology for converting the two-dimensional data to three-dimensional results had been developed previously.[6,7] These mathematical methods were incorporated into a computer program called LINEST-II which is an extensive updating of the earlier LINEST program.[8] One LINEST-II feature that is particularly useful in this work is the ability to directly interpolate data and then tabulate information of particular interest.

The LINEST-II computer printout includes: a tabulation of the input pore counting and measurement data; a data summation for each magnification; a tabulation of calculated relationships between pore size, density, and volume (each with a 1σ standard deviation calculated for each size range); a summary of calculated and interpolated values for selected pore sizes or volume fractions, and a graphic display of histograms representing the tabulated data. Separate information was obtained, for all combined data as well as for the transversely and longitudinally sectioned pellets, by applying computations to various combinations of the input data. The computations were also applied to obtain information for the radial positions at the periphery, mid-radius, and centerline locations of transverse sections.

Pellet grain sizes were evaluated using the linear intercept method[9] on micrographs taken at peripheral, mid-radius, and centerline positions on the etched transverse sections of one pellet for each fuel type; 100-200 intercepts were counted at each site. Grain size was calculated for each section using:[9]

$$\text{Grain size} = 1.57 \times (\text{average intercept length})$$

The uncertainty for reported grain sizes depends on the measured grain size and number of intercepts counted. An uncertainty of $\pm$ 2 μm is assigned to reported grain sizes of less than 10 μm in diameter; an uncertainty of $\pm$ 5 μm is assigned to reported grain sizes of greater than 20 μm diameter.

Results and Discussion

Discussion of the microstructural characteristics of the three fuel types will be concerned with topics of surface structure, porosity characteristics, and grain size.

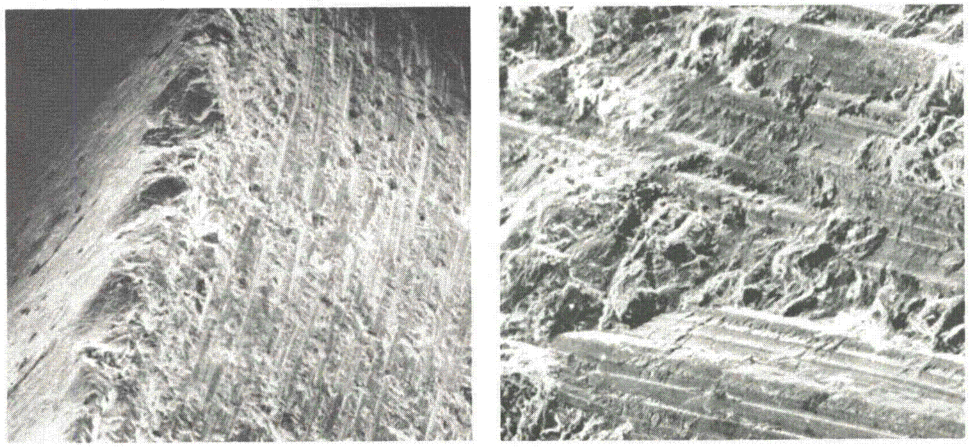
Pellet Surface Structure Characteristics

The exterior surface of one surface-ground pellet of each of the three fuel types was examined by SEM (Figure 7-7). As expected, the surface of all three fuel types was rough and showed the circumferential structures and tearing typical of machined dies and surface-ground pellets. Pellet edges were in reasonably good condition with evidence of only minimal chipping in each case. Due to the surface roughness, pellet-to-cladding contacts will be limited to point rather than line contact.

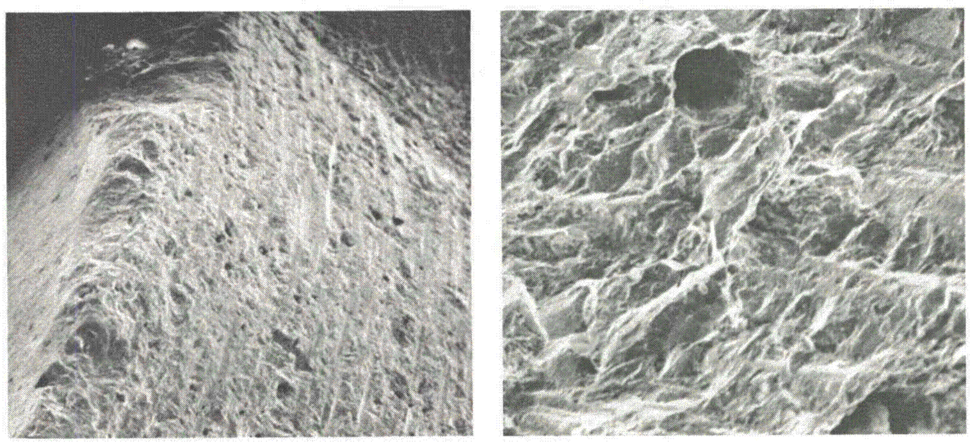
Porosity Characteristics

Two sections of one pellet of each fuel type were examined in detail for porosity characteristics and size distribution (Figures 7-8 - 7-13). Based on previous work, no appreciable pellet-to-pellet variations in pore characteristics within a single fuel type were anticipated.

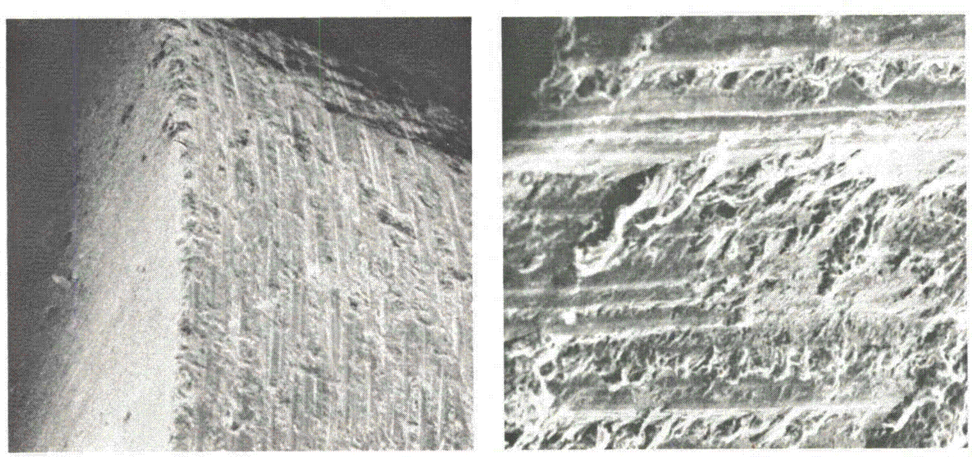
Each fuel type contains unique porosity characteristics. Figures 7-14-7-17 and Tables 7-1 - 7-4 show that the pore volumes calculated from measurements of all pores agree with the bulk density measurements to within 0.2-2.3 volume percent. In a general comparison of the three fuel types (Figure 7-14 and Table 7-1), the 92% TD unstable fuel contained the largest volume of pores having diameters smaller than 1 μm, the 92% TD stable contained the largest volume of pores greater than 10 μm, and the 95% TD stable fuel contained the largest volume of pores between 1 and 10 μm. However, pore populations (number of pores in each size range) do not follow the same relationships, as shown in Figure 7-15 and Table 7-1, because of size/volume distributions within the relatively broad size ranges. Study of the porosity characteristics as a function of radial position in the polished sections (see Figures 7-16 - 7-17 and Tables 7-1 - 7-4) shows that the pore distribution of the 92% TD unstable fuel is the most uniform of the three fuel types. The peripheral region of the 92% TD stable fuel contains less porosity than the mid-radius and central positions; this is particularly noticeable in the volume of sub-micron porosity. In contrast, the other two fuel types showed lowest porosity at mid-radius positions and highest porosity in the central locations.



92% TD Unstable Fuel Pellet

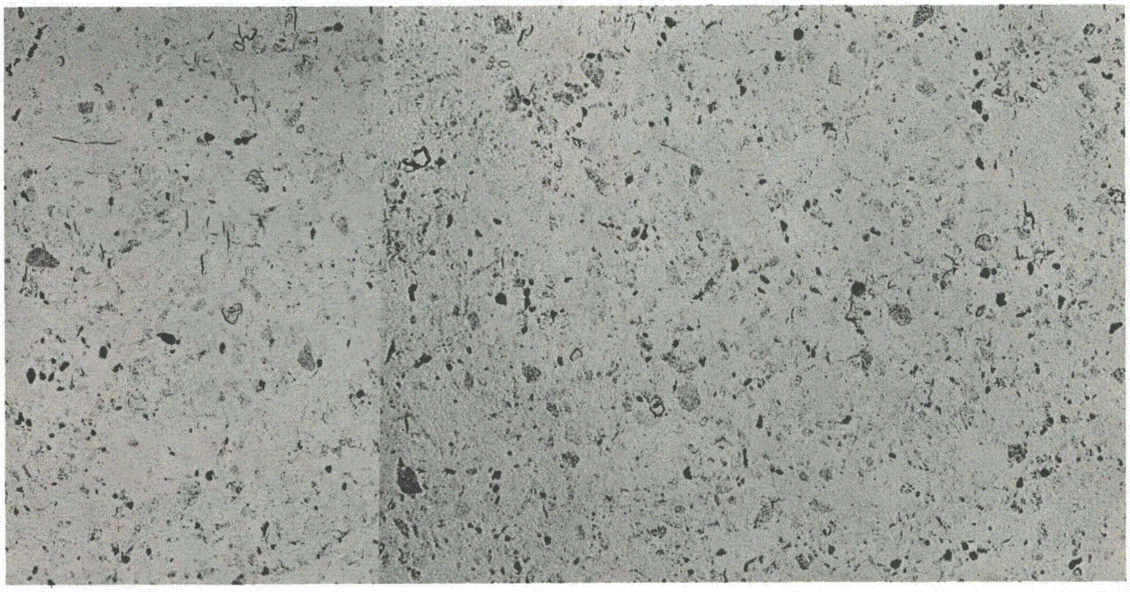


92% TD Stable Fuel Pellet



50X 95% TD Stable Fuel Pellet 500X

FIGURE 7.7. As-sintered and Ground Exterior Surface Structure of the Three UO_2 Fuel Types



Typical Area of Longitudinal Cross Section (30X)

Complete Longitudinal Cross Section near Pellet Axis (8X)

Half of Tranverse Section near Pellet Center (8X)

FIGURE 7.8. Coarse Porosity Characteristics of Fuel Type 92% Unstable Fuel

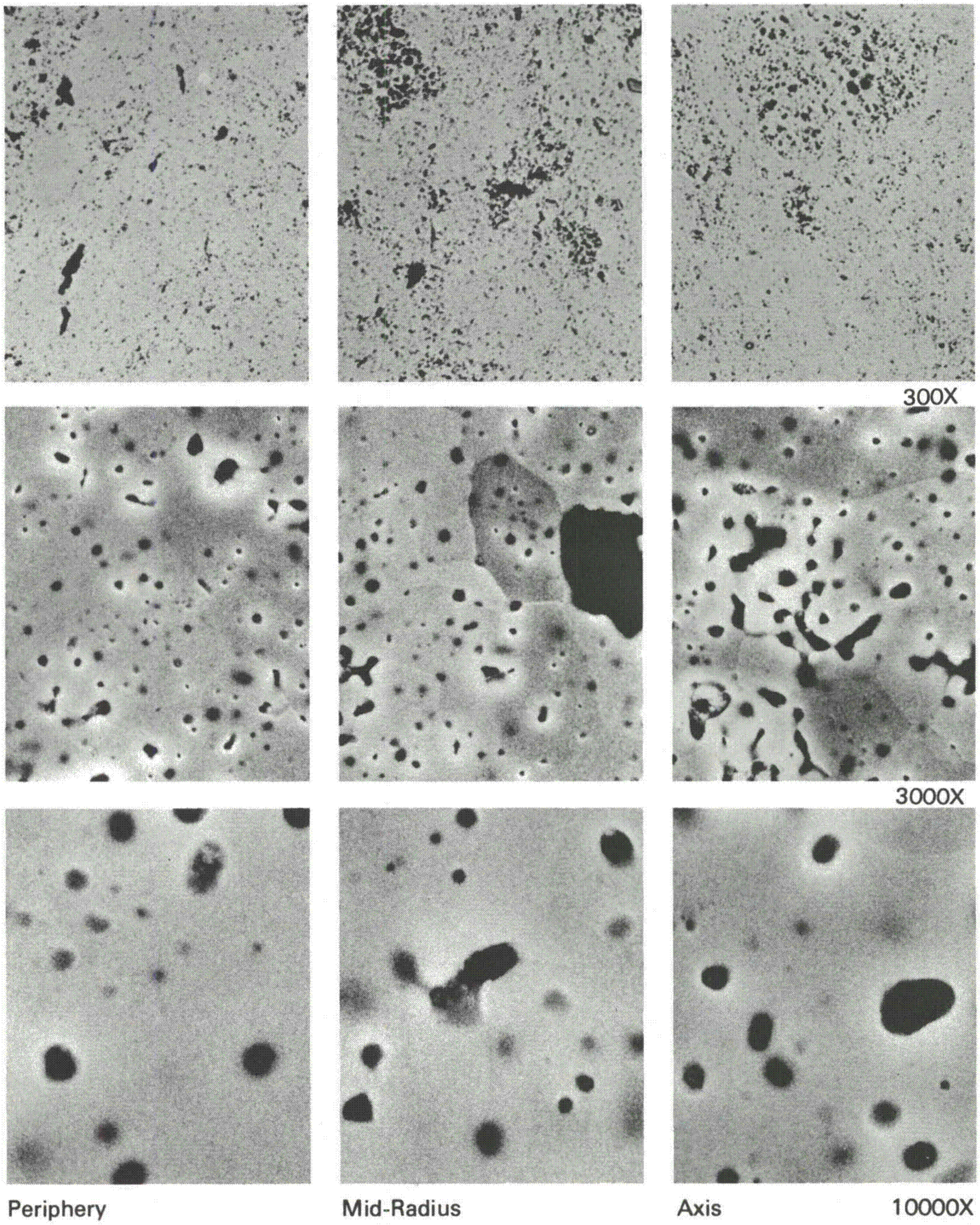
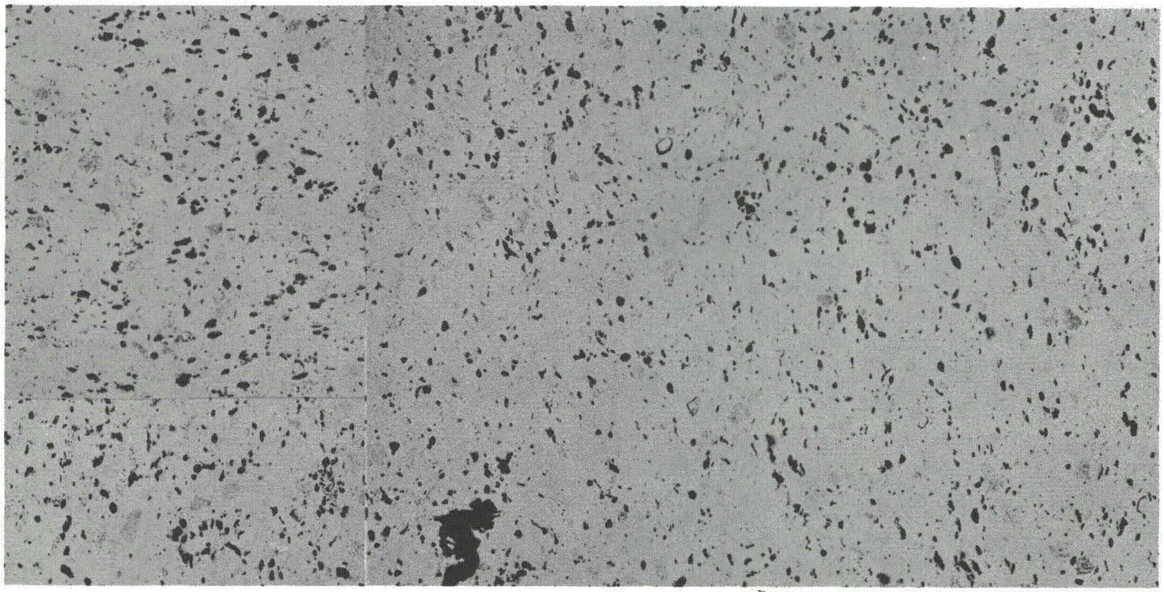
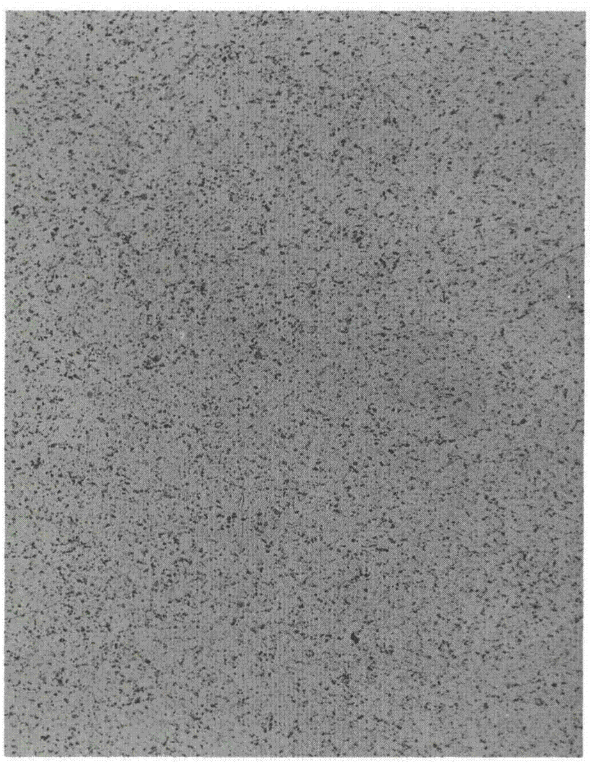


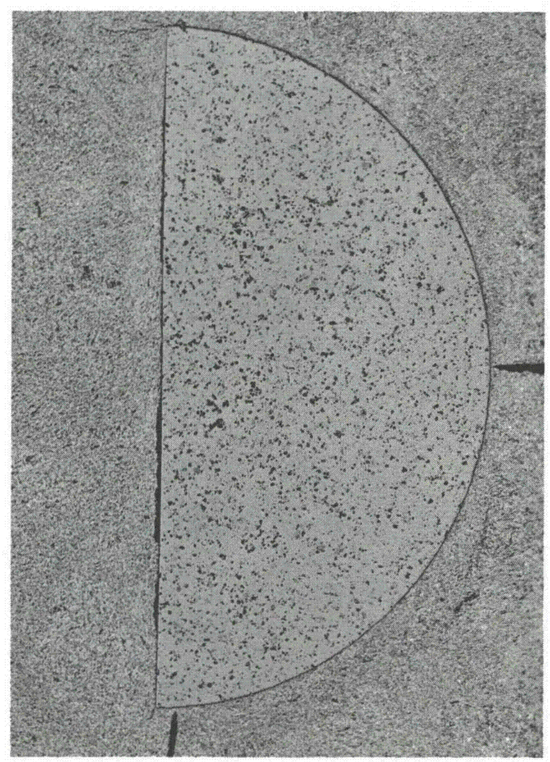
FIGURE 7.9. Typical Fine Porosity Characteristics of 92% Unstable Fuel at Radial Positions (Magnification for Entire Row)



Typical Area of Longitudinal Cross Section (30X)



Complete Longitudinal Cross Section near Pellet Axis (8X)



Half of Tranverse Section near Pellet Center (8X)

FIGURE 7.10. Coarse Porosity Characteristics of 92% Stable Type Fuel (light micrographs)

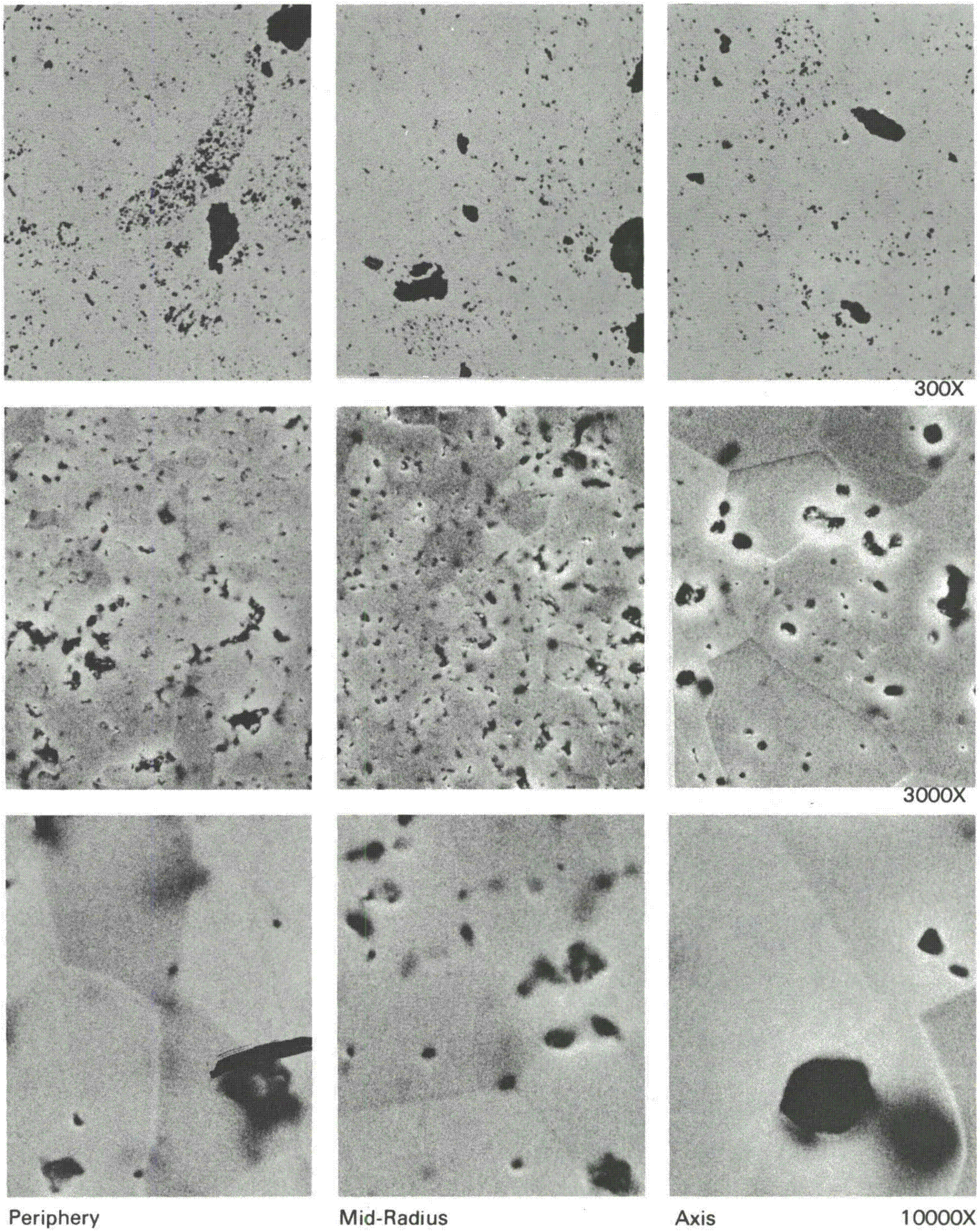
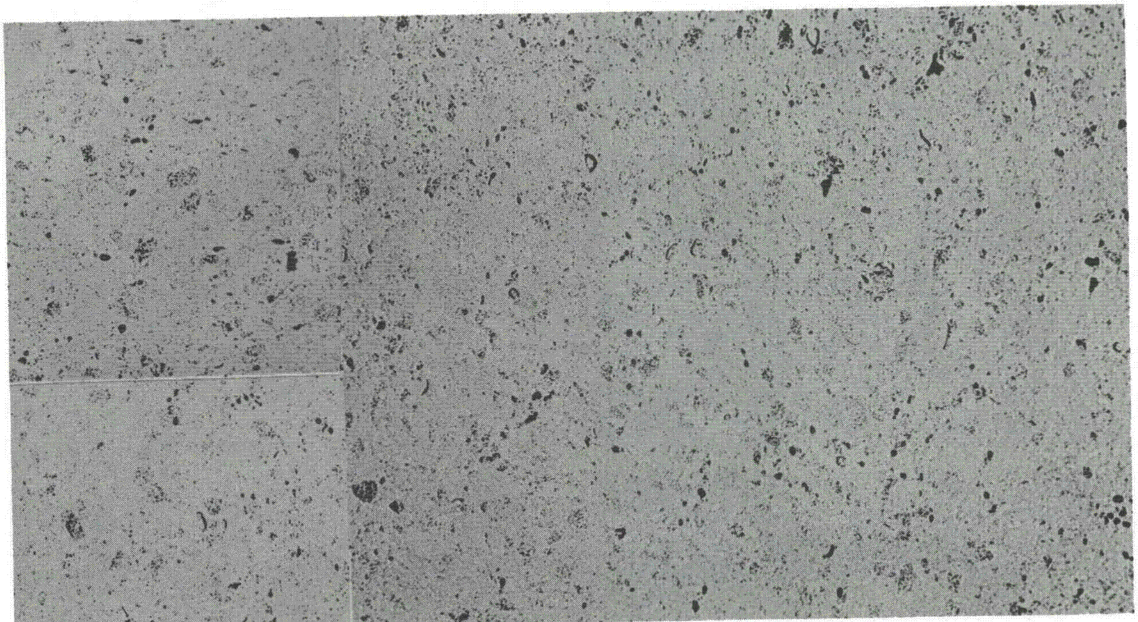
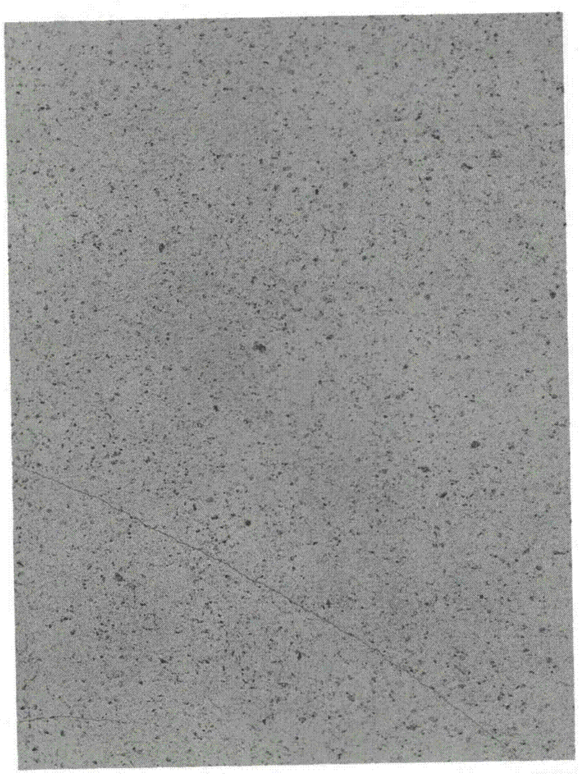


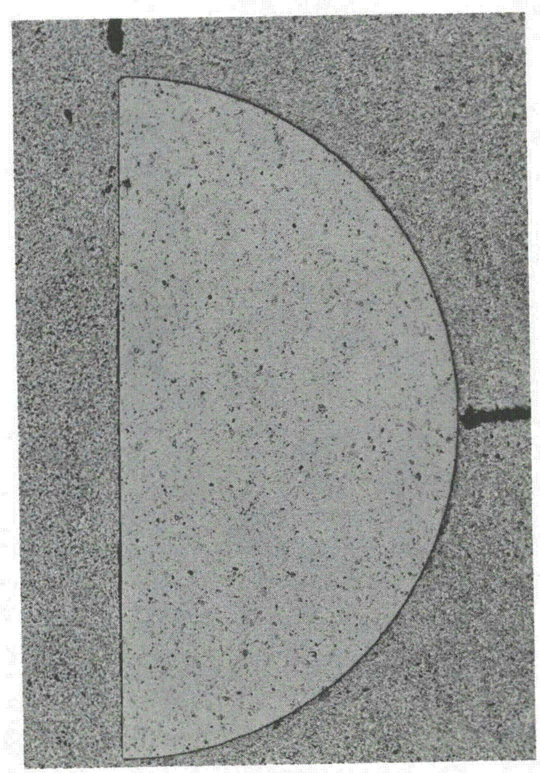
FIGURE 7.11. Typical Fine Porosity Characteristics of 92% Stable Type Fuel at Radial Positions (Magnification for Entire Row)



Typical Area of Longitudinal Cross Section (30X)



Complete Longitudinal Cross Section near Pellet Axis (8X)



Half of Tranverse Section near Pellet Center (8X)

FIGURE 7.12. Coarse Porosity Characteristics of 95% Stable Type Fuel

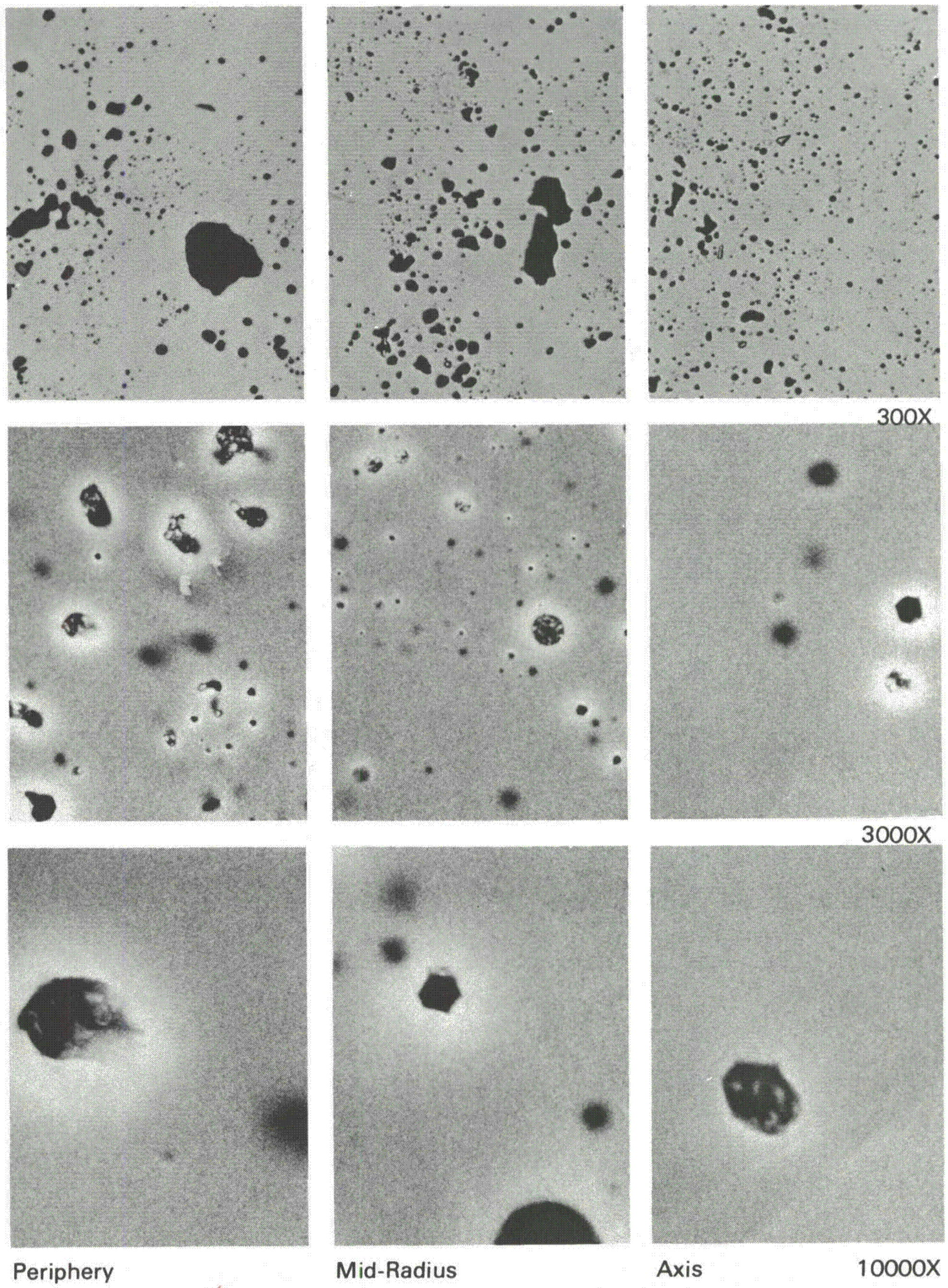


FIGURE 7.13. Typical Fine Porosity Characteristics of 95% Stable Type Fuel at Radial Positions (Magnification for Entire Row)

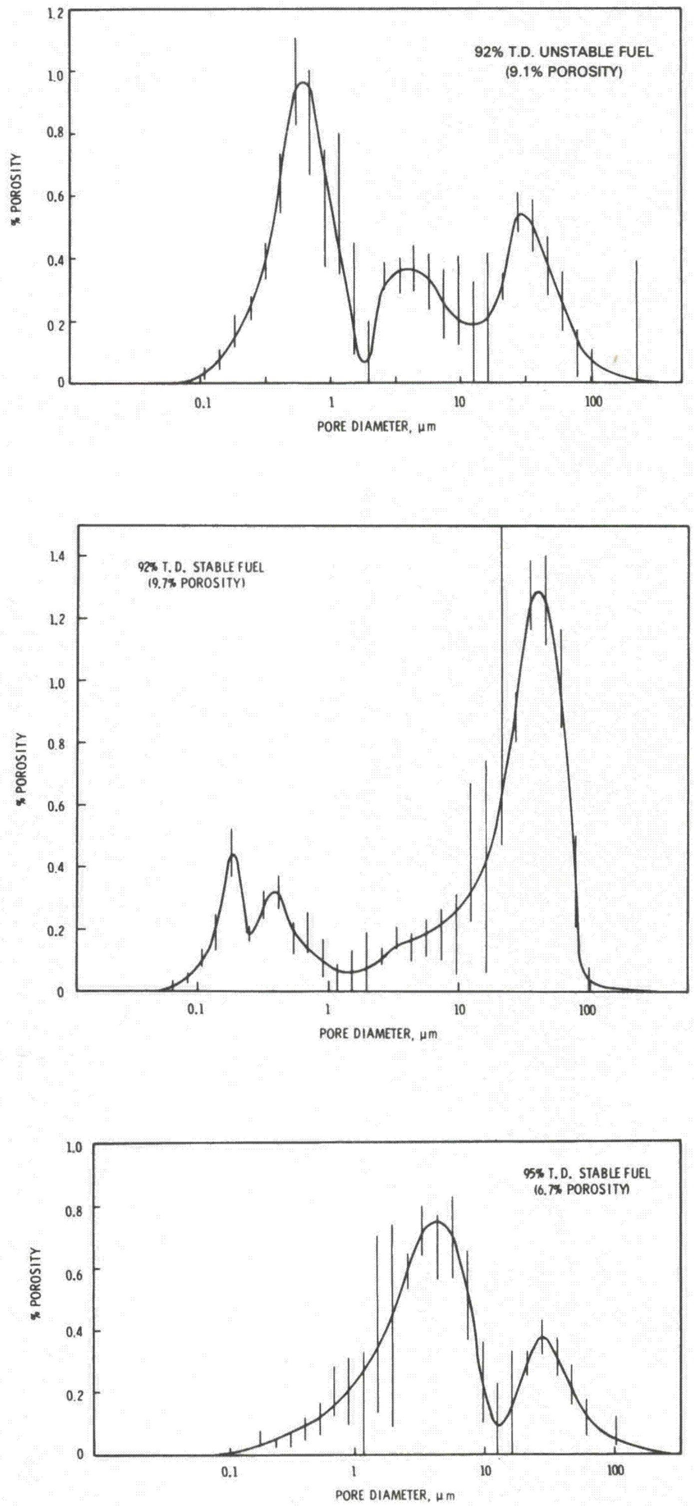


FIGURE 7-14. Pore Size and Volume Distribution in the UO_2 Fuel Pellets (smoothed histograms; vertical lines show 2 confidence limits at mid-point of each size range)

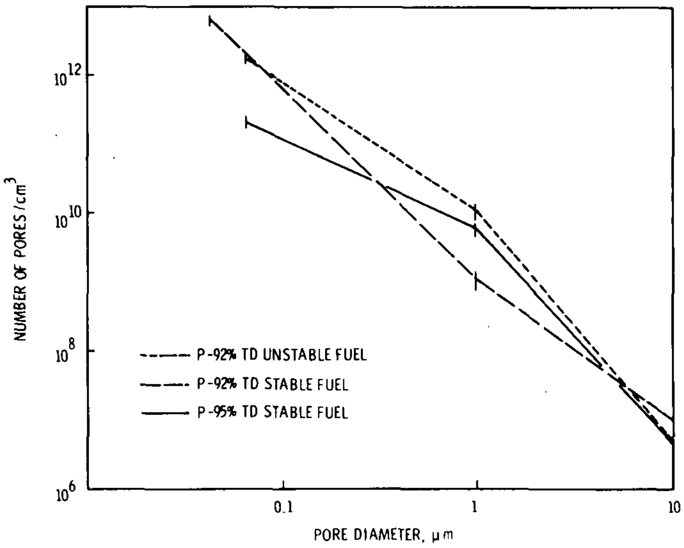


FIGURE 7-15. Cumulative Pore Population of UO_2 Fuel Pellets (number of pores larger than diameters shown)

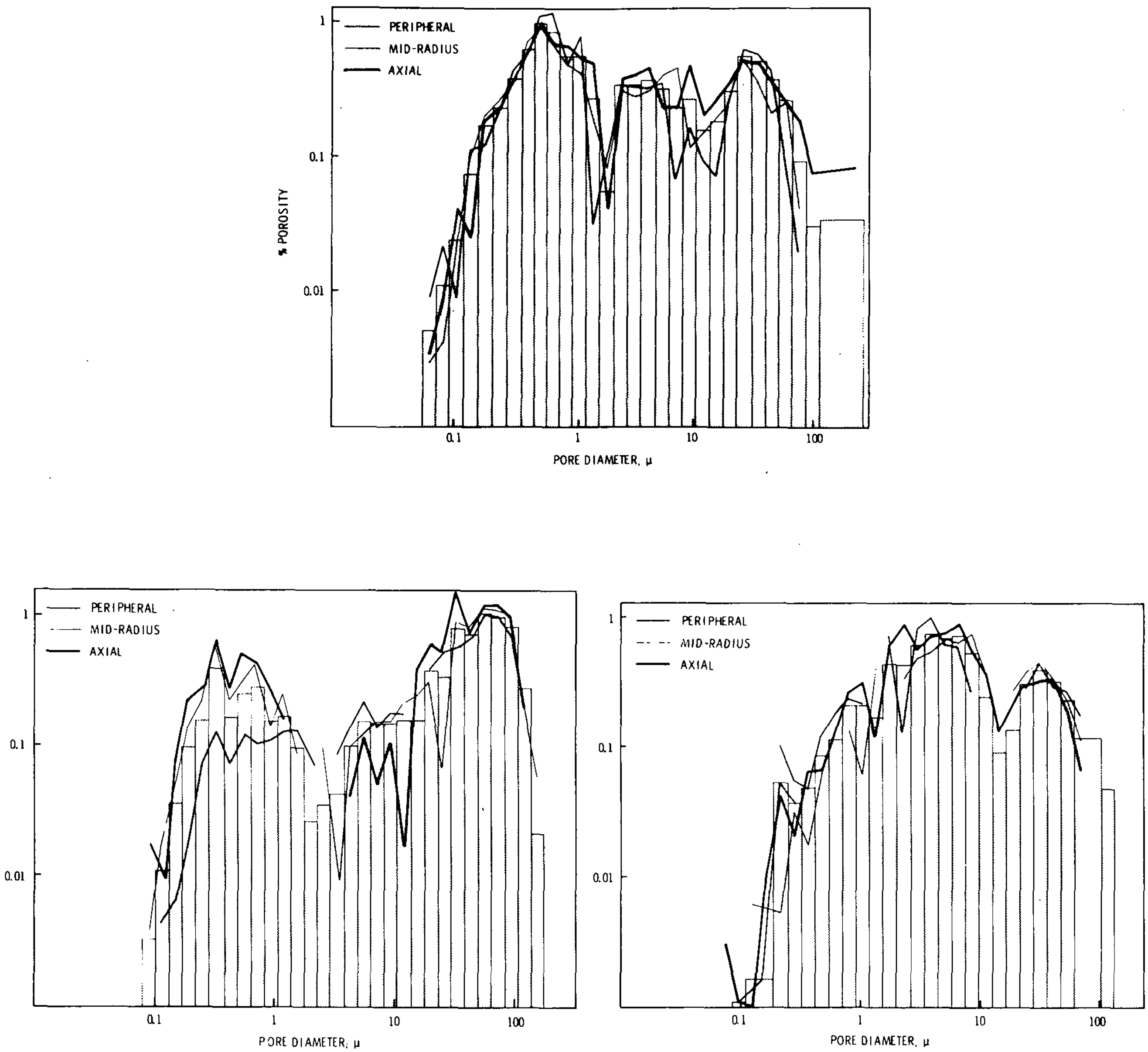


FIGURE 7-16. Radial Distribution of Pore Volume (semi-smoothed histograms; segments of curves join mid-points of the respective size ranges; background histogram shows overage values)

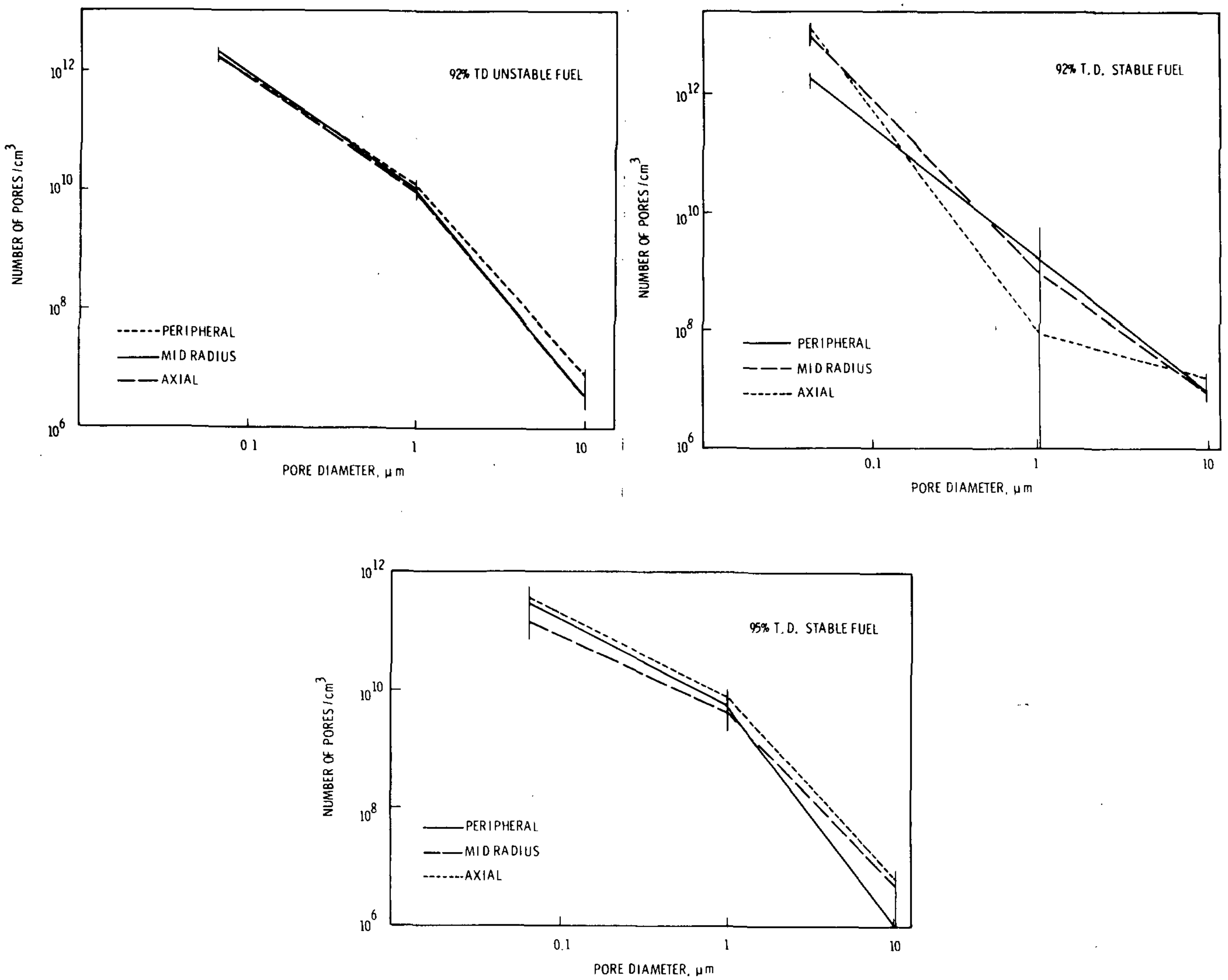


FIGURE 7-17. Radial Distribution of Pore Population (cumulative number of pores larger than diameters shown)

TABLE 7-1 Summary of Calculated Pore Distributions from all Data (16 sites) for each Halden Fuel Type

Specimen (Fuel Type)	92% TD Unstable	92% TD Stable	95% TD Stable
Porosity Volume, %			
by Density Measurement	8.7	8.4	4.4
by Pore Measurement	9.1	9.7	6.7
Pores >1 μm	5.6	7.7	6.1
Pores >10 μm	2.7	6.7	1.8
Pores <1 μm	3.5	2.0	0.6
Pore Diameter, μm			
Median, all	1.8	21	5.1
Median, <1 μm	0.6	0.3	0.6
Median, >1 μm	8.5	36	5.1
Median, <10 μm	32	36	32
Maximum	220	89	100
Pore Population, no./cm^3			
All Pores	1.9×10^{12}	7.0×10^{12}	2.4×10^{11}
Pores >1 μm	1.2×10^{10}	1.2×10^{9}	6.3×10^{9}
Pores >10 μm	5.6×10^{6}	1.1×10^{7}	4.5×10^{6}

TABLE 7-2 Pore Distributions in 92% TD Unstable Fuel Type

Radial Location	Peripheral	Mid-Radius	Axial
Porosity Volume, %			
All Pores	9.0	8.3	9.8
Pores >1 μm	5.0	4.9	6.4
Pores >10 μm	2.5	2.1	3.2
Pores <1 μm	4.0	3.4	3.4
Pore Diameter, μm			
Median, all	1.4	1.4	3.0
Median <1 μm	0.6	0.6	0.6
Median >1 μm	8.5	8.5	11
Median >10 μm	41	32	32
Pore Population, no./cm^3			
All Pores >0.865 μm	2.3×10^{12}	1.8×10^{12}	1.7×10^{12}
Pores >1 μm	1.2×10^{10}	9.7×10^{9}	1.4×10^{10}
Pores >10 μm	3.7×10^{6}	3.7×10^{6}	8.7×10^{6}

TABLE 7-3. Pore Distribution in 92% TD Stable Fuel Type

Radial Location	Peripheral	Mid-Radius	Axial
% Porosity Volume			
All Pores	8.4	10.2	11.9
Pores >1 μm	7.5	7.5	8.8
Pores >10 μm	6.3	6.4	8.2
Pores <1 μm	0.9	2.7	3.1
Pore Diameter, μm			
Median, All	28	21	21
Median <1 μm	0.4	0.3	0.3
Median >1 μm	28	36	28
Median >1 μm	36	36	36
Pore Population, no./cm^3			
All pores >0.04 μm	2.0×10^{12}	1.0×10^{13}	1.4×10^{13}
Pores >1 μm	1.8×10^{9}	9.9×10^{8}	9.5×10^{7}
Pores >10 μm	9.7×10^{6}	9.1×10^{6}	1.7×10^{7}

TABLE 7-4. Pore Distribution in 95% TD Stable Fuel Type

Radial Location	Peripheral	Mid-Radius	Axial
% Porosity Volume			
All Pores	6.5	5.8	7.7
Pores >1 μm	5.7	5.6	7.0
Pores >10 μm	1.6	1.9	1.8
Pores <1 μm	0.8	0.2	0.7
Pore Diameter, μm			
Median, all	3.9	6.6	5.1
Median <1 μm	0.6	0.8	0.8
Median >1 μm	5.1	6.6	5.1
Median >10 μm	41	32	24
Pore Population, no./cm^3			
All Pores >0.065 μm	3.0×10^{11}	1.4×10^{11}	3.8×10^{11}
Pores >1 μm	5.8×10^{9}	4.5×10^{9}	8.3×10^{9}
Pores >10 μm	1.1×10^{6}	5.2×10^{6}	6.8×10^{6}

Specific characteristics of each fuel type are as follows:

92% TD Unstable Fuel

The median pore diameter of this fuel type is 18 μm. The maximum pore size observed was 220 μm. The radial distribution of porosity is nearly uniform across the sections examined as shown in Figures 7-16 and 7-17.

Pores that are smaller than 1 μm in diameter comprise approximately 40% of the total pore volume of this fuel type (3.5 vol% porosity). The unstable behavior displayed by this fuel during resintering tests (observed densification of 2 to 4% TD) is attributed to this volume of sub-micron porosity. The peak in the pore distribution between 10 and 100 μm (Figure 7-14) is attributed to the addition of 0.2 wt% Sterotex during pellet fabrication. Previous studies[3] indicate these larger pores exercise a stabilizing influence on densification, and thus limit the densification achievable during resintering.

92% TD Stable Fuel

The median pore diameter of the 92% TD-S fuel is 21 μm. The maximum pore size observed was 89 μm, which is appreciably less than the 200 μm pores in the 92% TD-U fuel.

Of the total pore volume in this fuel, approximately two-thirds (6.7 vol% porosity) is attributable to pores of diameter greater than 10 m. This distribution results from the use of 1.2 wt% pore former during fabrication. Since sub-micron pores account for 2.0 vol% porosity, this results in a high volume ratio of large-to-small diameter pores and a stable condition. This stability was confirmed by the small densification obtained in resintering tests of this fuel type.

Figures 7-16 and 7-17 show that the radial pore distribution in this fuel type was considerably less uniform than in the 92% TD-U fuel. The most notable feature is a small volume of sub-micron pores around the periphery, which is responsible for the lower total pore volume at the pellet periphery. Also noted was a volume and population decrease in pores of approximately 1 μm in diameter located in the pellet central region.

95% TD Stable Fuel

The medium pore diameter for this fuel type is 5.1 μm, the volume of sub-micron pores is less than 10% of the total pore volume, and the maximum pore diameter observed was 100 μm. The additional small volume of pores which are larger than 10 μm (Figure 7-14) is similar to that occurring in the 92% TD-U fuel and is attributed to the use of 0.2 wt% Sterotex in pellet fabrication. The near absence of sub-micron pores and the relatively low total pore volume suggests a stable fuel. The nearly zero densification observed during resintering tests confirmed this.

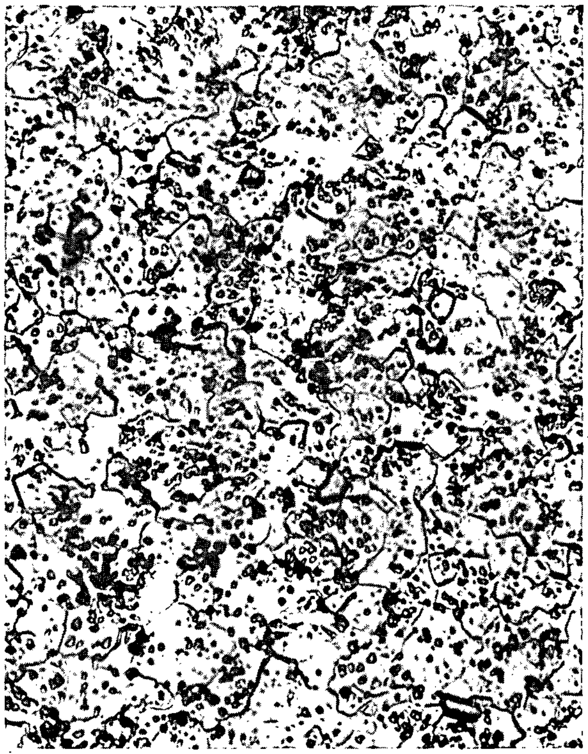
The radial distribution of pores shows no strong trend, although the pore volumes are appreciably scattered (Figures 7-16 and 7-17). The center line pososity is higher than in other regions of the pellet in all pore size ranges. In general, this fuel type displays a uniform, but coarsely distributed, porosity pattern.

Grain Size Characteristics

As-Fabricated Pellets

All three as-fabricated fuel types exhibited radial gradients in grain sizes. The 92% TD-U as-fabricated fuel seen in Figure 7-18 is characterized by a grain size that varies from 2 μm at the pellet periphery to 7 μm at the pellet axis. Randomly distributed localized areas of approximately 60 μm in diameter are scattered throughout the pellet and are characterized by greatly reduced grain size and pore size. These low density regions are believed to be incompletely sintered powder granules formed prior to pellet pressing, during the preslugging and granulation step.

The microstructure of the 92% TD-S fuel shows two different patterns. The grain size of most of the pellets decreases gradually from the pellet surface to the center; this type of microstructure is shown in Figure 7-19a. In one of the four examined 92% TD-S fuel pellets, the grain diameter in the central portion is about 50-60 um and gradually reduces to approximately 10-20 μm near the edge (upper left in Figure 7-19b). One of the pellets was not examined for pore size distribution but the pore size in its central portion is expected to be different than that in the central region of the

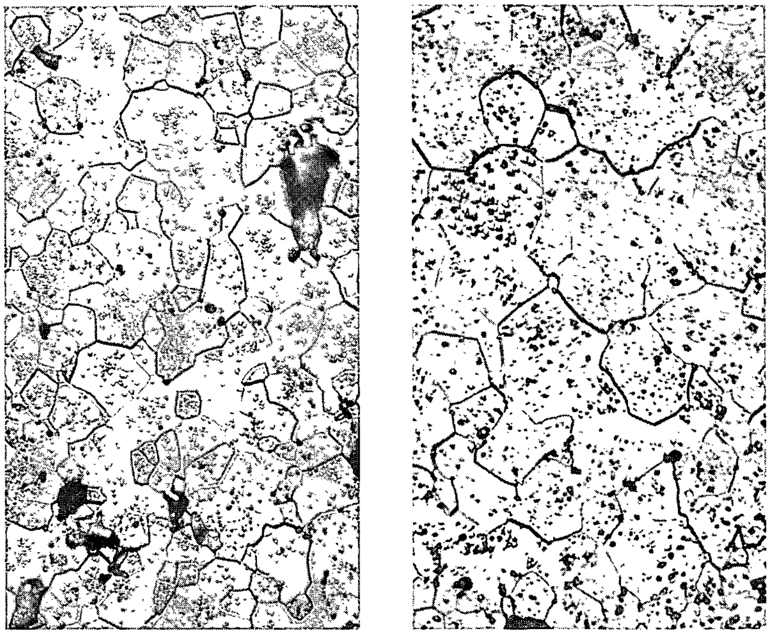


Periphery 1000X

FIGURE 7.18. Microstructure of As-sintered 92% TD Unstable Pellet. Transverse section.

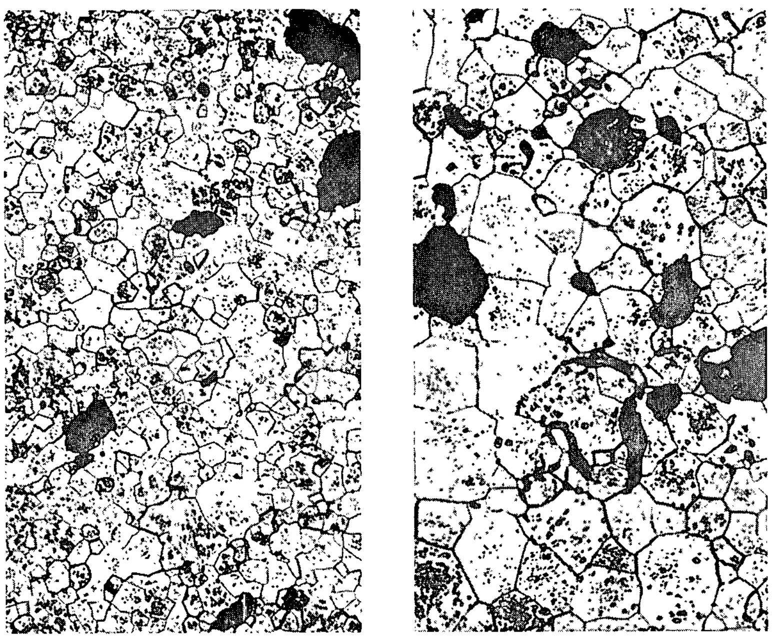
Mid-Radius 1000X

Axis 1000X



Peripheral 500X Mid-Radius 1000X

a. Pellet exhibiting coarse grain size at pellet periphery. Transverse section.



Peripheral 250X Axis 250X

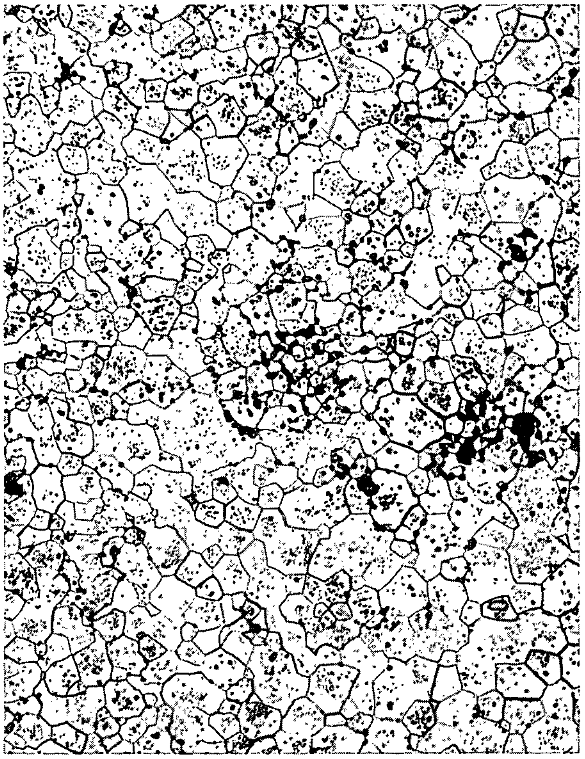
b. Pellet exhibiting coarse grain size at pellet center.

FIGURE 7.19. Microstructures of As-sintered 92% TD Stable Pellets

other three pellets. These observations indicate that significant variations in grain and pore size occur from pellet to pellet in this fuel type. Due to these variations, comparisons between the pre- and post-irradiation grain and pore sizes must be made with care.

The 95% TD-S fuel pellets show a gradation in grain size from 22 μm near the edge to approximately 70 μm at the center (see Figure 7-20). The smaller grains near the edge are in a band approximately 1000 μm wide that extends over the entire pellet surface. A plate-like pattern appears within the large grains in the pellet core, apparently oriented only along crystal planes; initial suggestions were that they might be U_4O_9. However, the 95% TD stable fuel is stoichiometric (O/U ratio = 2.000) and U_4O_9 is probably not present. It was finally concluded through X-ray orientation studies that the plates were not U_4O_9; the plates occur on the (100) planes while U_4O_9 grows on the (111) planes in UO_2.[10,11] The observed plates were also found to be similar in size, appearance, and distribution within the pellets to those described in Chalder's uranium dioxide studies.[12] By using electron microscopy, Chalder showed that the plates had no finite width, and concluded that the plates were "faults" in the UO_2 crystal structure rather than a second phase. That conclusion has also been made here.

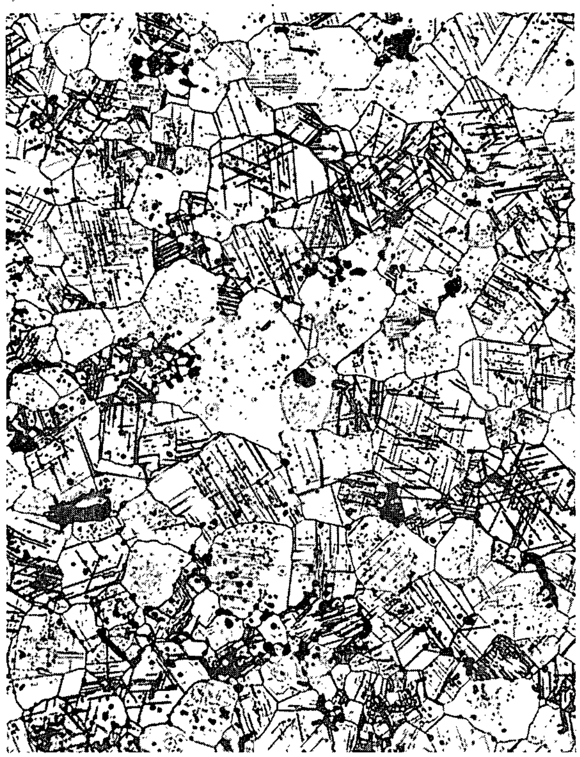
The cause of radial and pellet-to-pellet variation in UO_2 grain and pore size observed in some of the UO_2 pellets is not fully understood. However, this effect is believed to be related to variations in oxygen activity levels within pellets during the initial stages of sintering. It is well known that diffusion-controlled processes, such as sintering, are highly sensitive to oxygen activity. Consequently, if oxygen activity gradients existed during sintering, radial variations in grain size and density could develop within the pellets. If an oxygen gradient existed within the sintering furnace, variations in microstructure could occur from pellet to pellet. Subsequent sintering studies have used UO_2 powders prepared by the same process as that used for this work. In these studies, radial grain size variations and the plate structure observed in the 95% TD-S fuel were completely eliminated by bubbling the hydrogen gas used as a sintering atmosphere through water before it enters the sintering furnace.



Periphery 250X

FIGURE 7.20. Microstructure of As-sintered 95% TD Stable Pellet. Transverse section.

Mid-Radius 125X



Axis 125X

Resintered Pellets

The grain size of all fuel types was found to increase during resintering. As shown in Table 7-5, the amount of increase varied with the test condition, fuel type, and site location. However, as the influence of pellet-to-pellet variations in initial grain size on grain growth has not been assessed, apparent changes in grain size during the tests must be considered to be qualitative.

TABLE 7-5. Grain size of As-Sintered Pellets and Pellets Following 1600 and 1700°C/24 hr Resintering Tests

		As-Fabricated		After 1600°C/ 24 hr Test		After 1700°C/ 24 hr Test	
Type	Position	Section	Grain Size, μm	Section	Grain Size, μm	Section	Grain Size, μm
92% TD Unstable	Peripheral	Trans.	2	Trans.	13	Trans.	26
	Midradius	Trans.	9	Trans.	20	Trans.	37
	Axial	Trans.	7	Trans.	15	Trans.	53
92% TD Stable	Peripheral	Trans.	18	Trans.	17	Trans.	30
	Midradius		(a)	Trans.	20	Trans.	14
	Axial		(a)	Trans.	15	Trans.	15
	Peripheral	Long	14				
	Midradius		11				
	Axial		(a)				
95% TD Stable	Peripheral	Trans.	22	Trans.	34	Trans.	25
	Midradius		69	Trans.	73	Trans.	88
	Axial		70	Trans.	88	Trans.	78
	Peripheral	Long	22				
	Midradius		77				
	Axial		75				

(a) Grain boundaries not well defined; grain size estimated to be about 5 μm.
Long. = Longitudinal; Trans. = Transverse

The grain size of the 92% TD-U pellets increased by a factor of approximately 10 in the peripheral position, and a factor of 7 in the central position during the 1700°C, 24-hr test (see Figure 7-21). The central-to-peripheral variation in grain size decreased from a factor of about three to about two during the tests. Figure 7-22 illustrates the microstructure after the 1600°C, 24-hr resintering test.

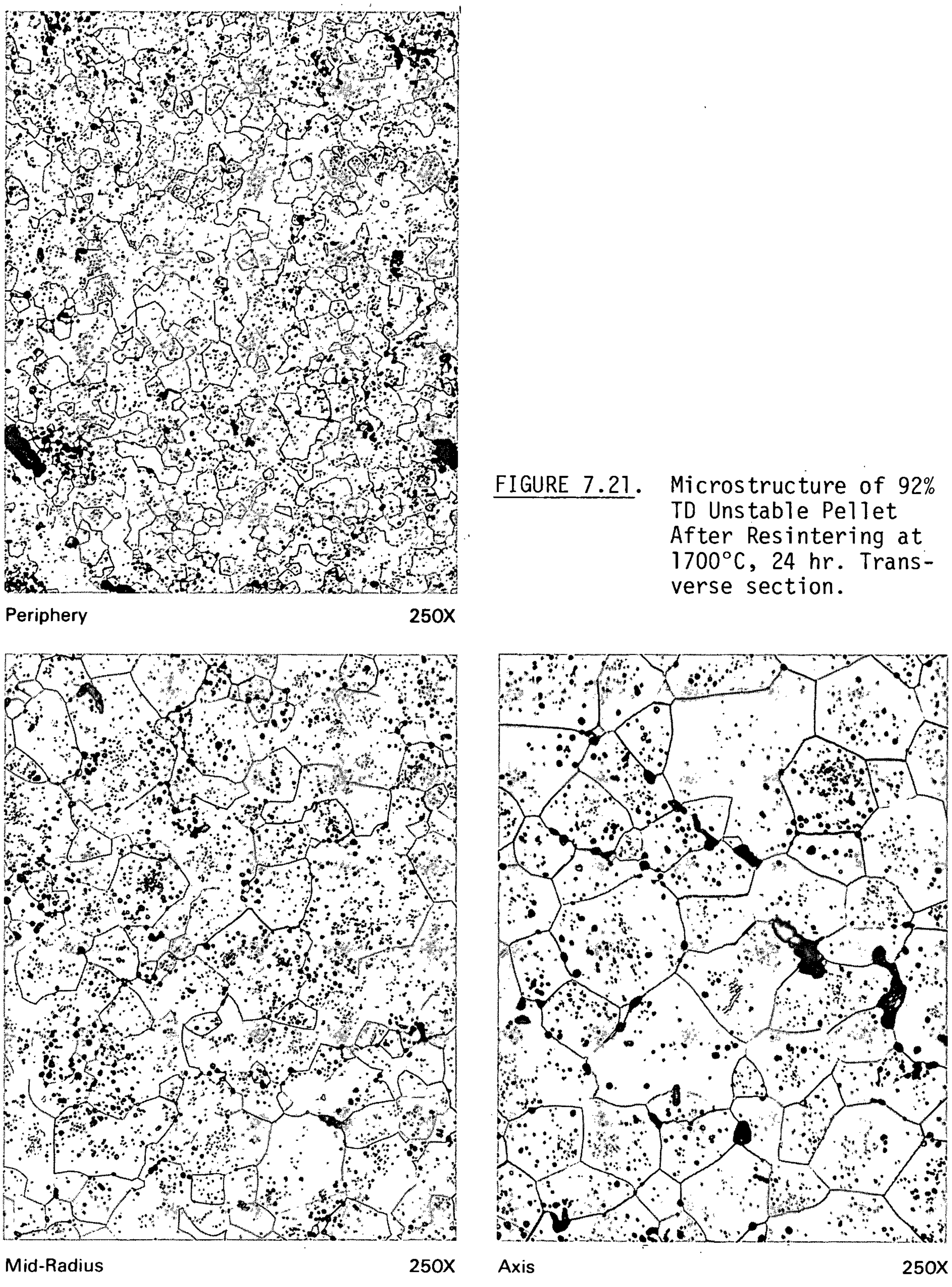
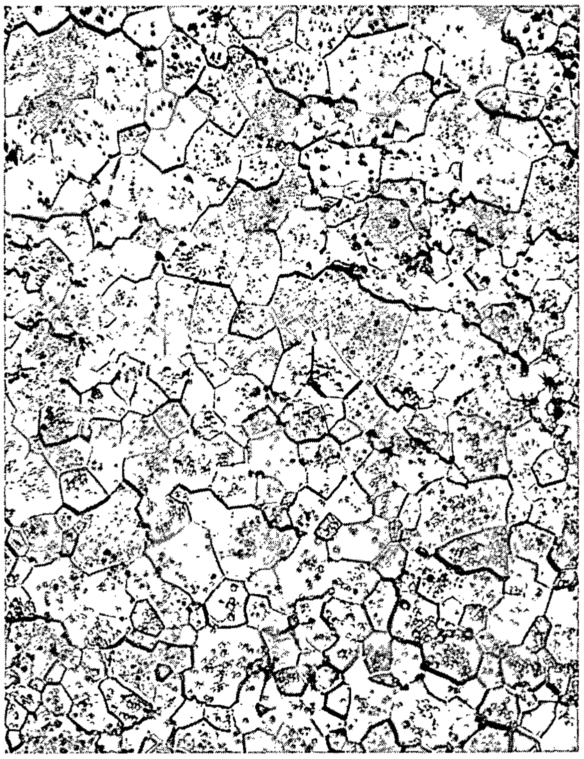
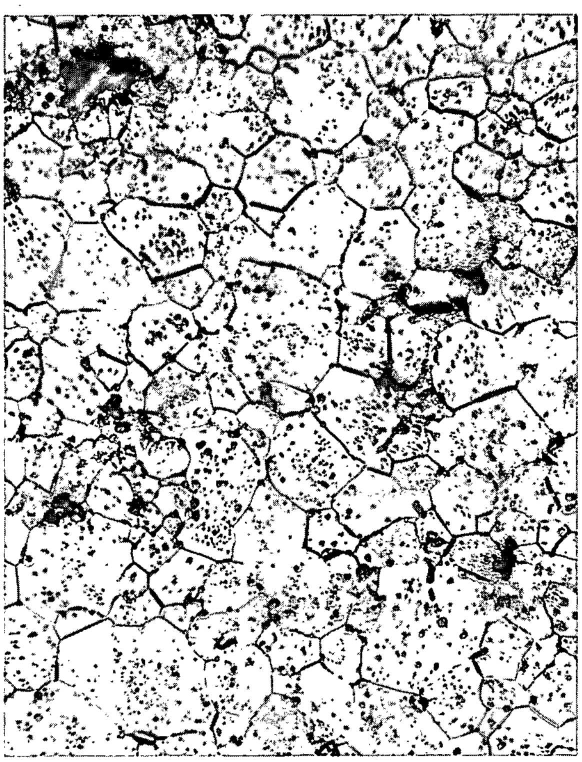


FIGURE 7.21. Microstructure of 92% TD Unstable Pellet After Resintering at 1700°C, 24 hr. Transverse section.

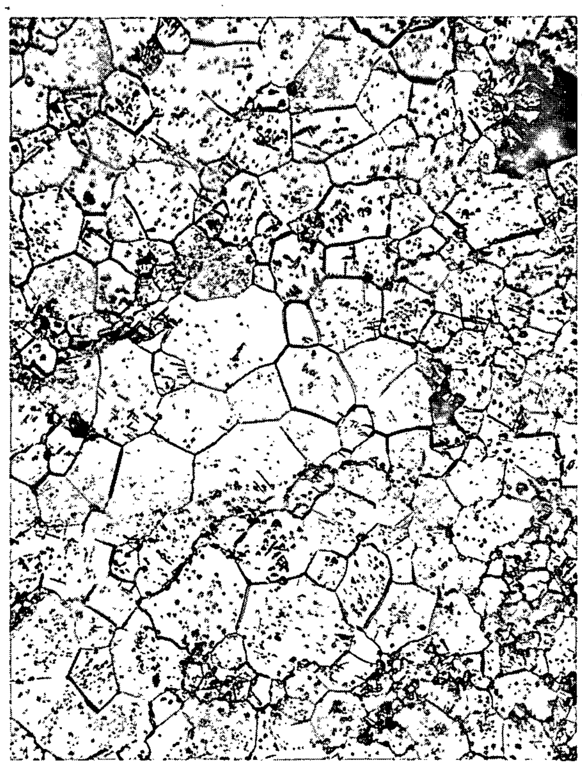


Periphery 500X

FIGURE 7.22. Microstructure of 92% TD Unstable Pellet After Resintering at 1600°C, 24 hr. Transverse section.



Mid-Radius 500X



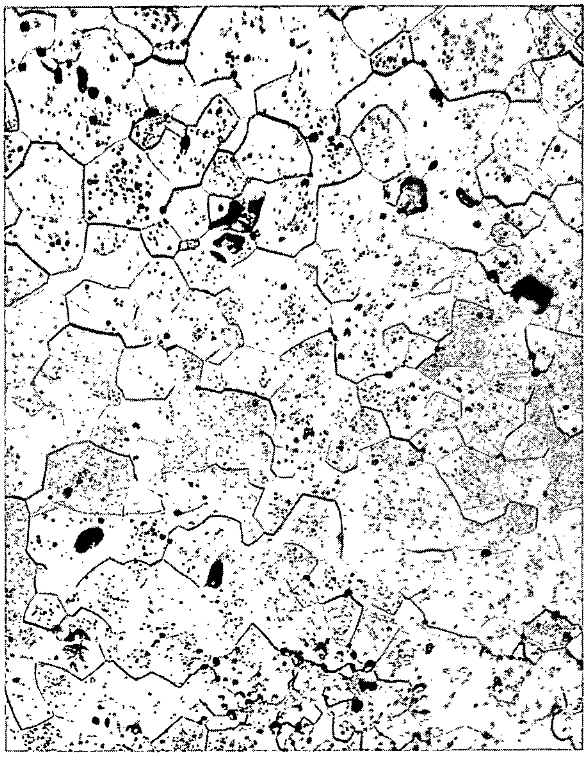
Axis 500X

Due to apparent scatter in the data, it is difficult to assess the amount of grain growth in the 92% TD-S pellets. For example, during the 1600°C, 24-hr test (Figure 7-23) the mid-radius grain size increased from approximately 5 to 20 μm, while during the 1600 C test (Figure 7-24), grain size increased to 14 μm In contrast, the grain size at the peripheral position did not increase during the 1600°C test, but doubled during the 1700°C test. The observed variation in the 92% TD-S fuel behavior during the resintering test may have been caused by the pellet to pellet variation in pore and grain size. However, regardless of such variation in microstructure, the 92% TD S fuel displayed relatively stable density during the resintering rests, due to the numerous large pores created by the addition of 1.2 wt% Sterotex during pellet fabrication.

The grain size of the 95% TD-S fuel, which had the largest grain size of the three fuel types, exhibited increases of 10 to 50%. The increase was dependant upon site location and test conditions. Based on a comparison of Figures 7-20 (as-fabricated), 7-25 (resintered at 1600°C for 24 hours), and 7-26 (resintered at 1700°C for 24 hours), the number of platelets in the 95% TD stable fuel appears to have decreased in concentration during resintering. However, since the pellet to pellet variation of the platelets has not been determined, this observation is qualitative.

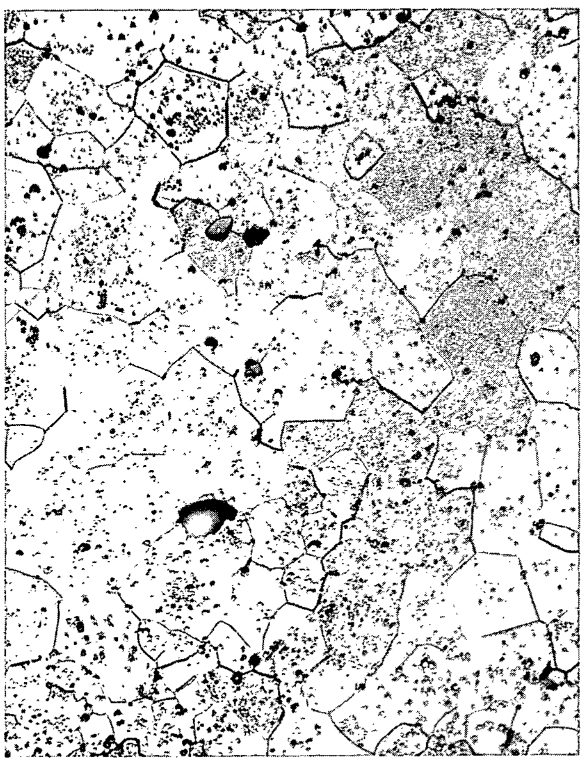
Relationship of Microstructure to Pellet Stability Toward Densification

In the EEI/EPRI Fuel Densification Program,[3] pellet grain size and pore sizes could be characterized by a unique number. Also, changes in pellet density during both the irradiaton test and thermal tests could be correlated with grain size, pore size, and pore volume distributions. In the present program it is not practical to assign a unique value to grain size because of radial gradients in grain size. However, even though radial gradients occur, the micrographs clearly show that the stable 92% and 95% TD fuel types have larger grains, have larger median diameter pore size and contain a smaller amount of porosity in less than 1 m diameter-pores than the 92% TD unstable fuel type. Similar characteristics were observed for stable and unstable UO_2 fuel types in the EEI/EPRI program.[3] Grain-size and pore-size distributions have not been independent variables in any of the reported cases.

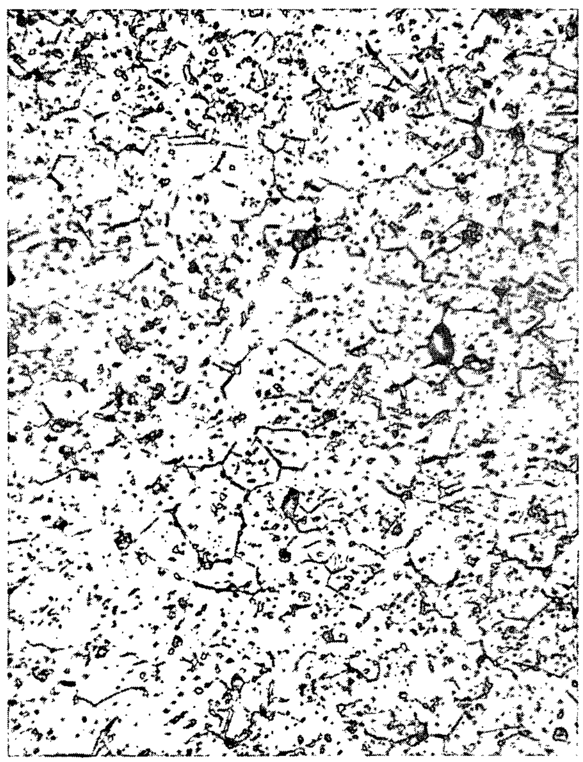


Periphery 500X

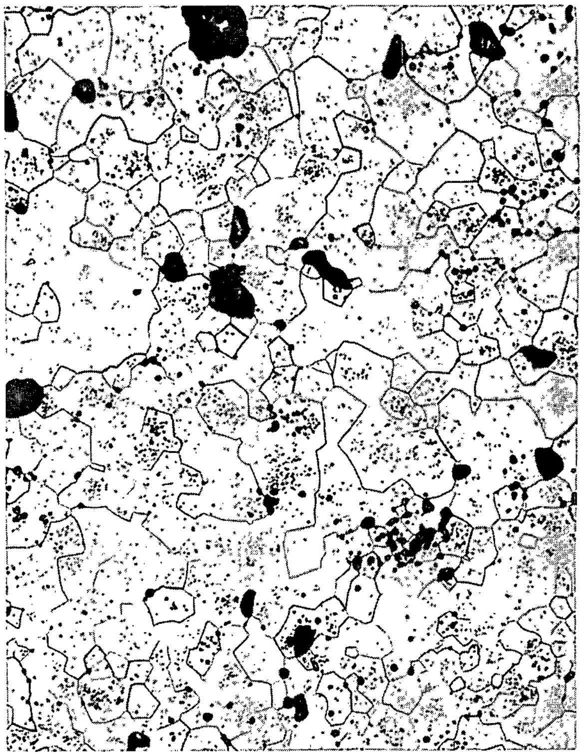
FIGURE 7.23. Microstructure of 92% TD Stable Pellet After Resintering at 1600°C, 24 hr. Transverse section.



Mid-Radius 500X

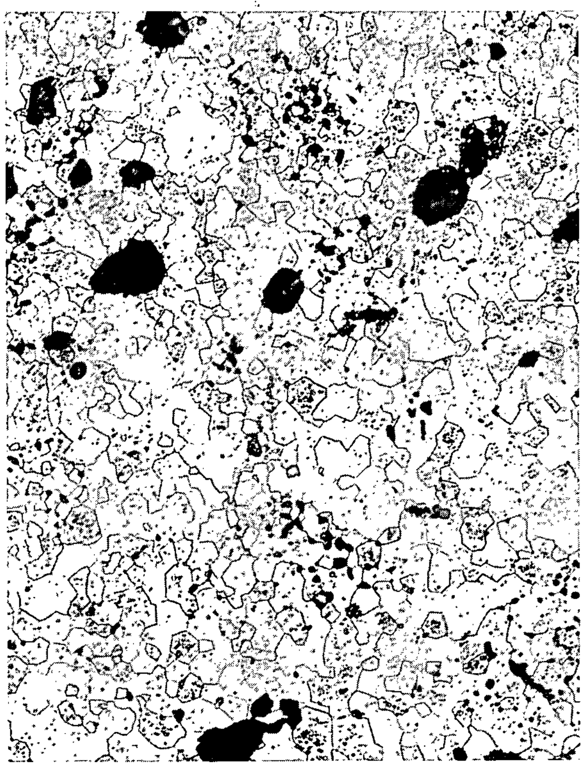


Axis 1000X

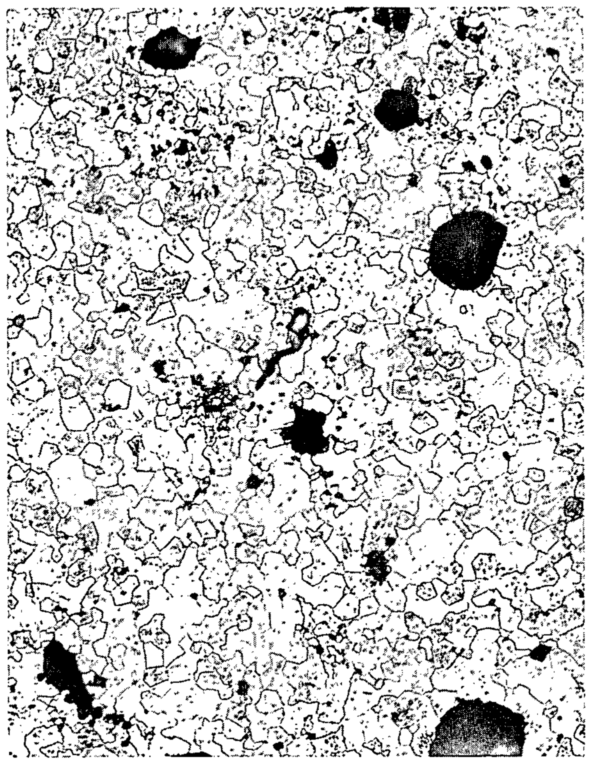


Periphery 250X

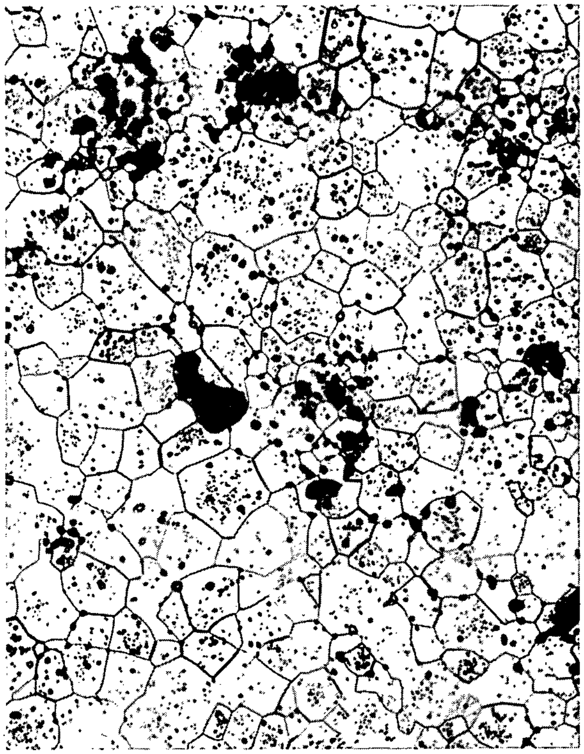
FIGURE 7.24. Microstructure of 92% TD Stable Pellet After Resintering at 1700°C, 24 hr. Transverse section.



Mid-Radius 250X

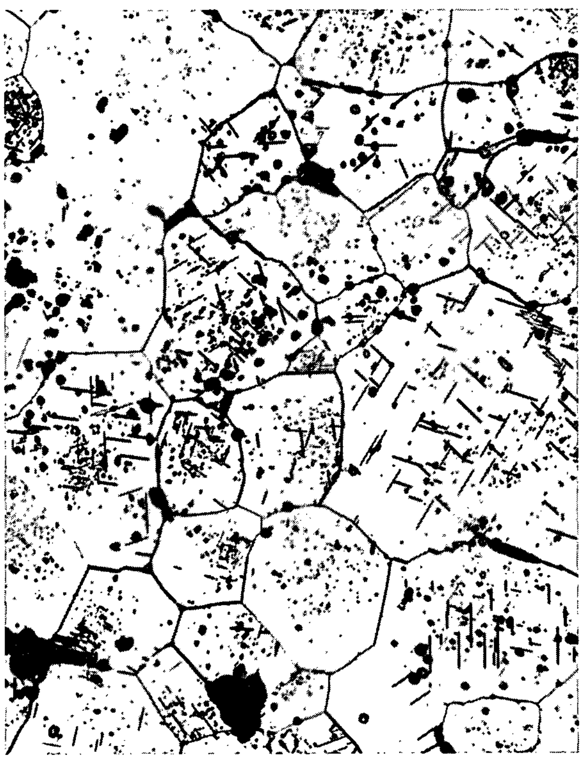


Axis 250X



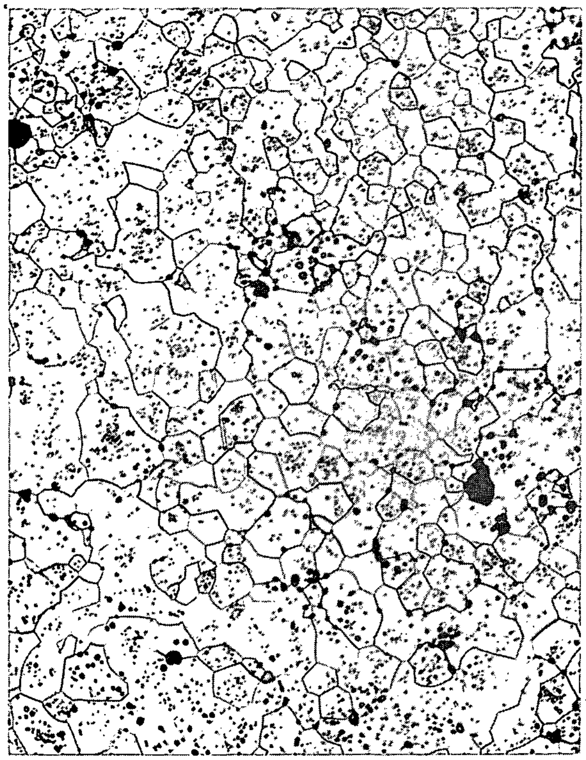
Periphery 250X

FIGURE 7.25. Microstructure of 95% TD Stable Pellet After Resintering at 1600°C, 24 hr. Transverse section.



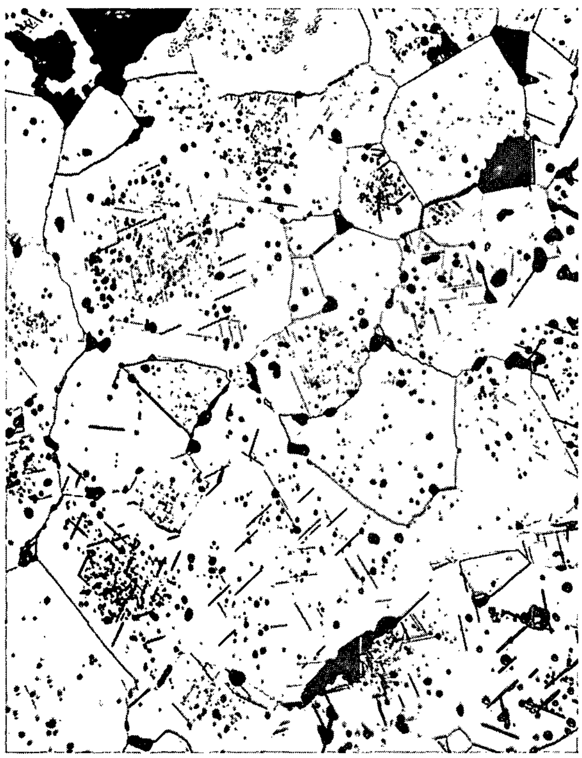
Mid-Radius 250X

Axis 125X

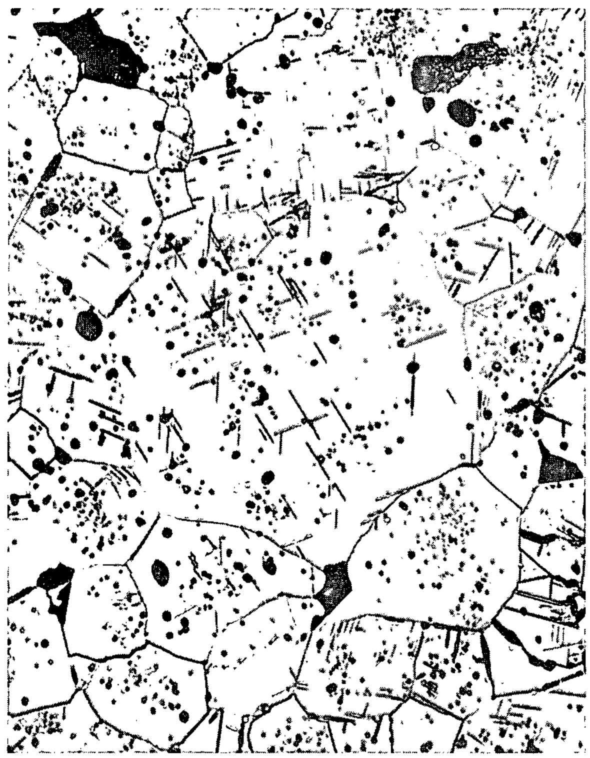


Periphery 250X

FIGURE 7.26. Microstructure of 95% TD Stable Pellet After Resintering at 1700°C, 24 hr. Transverse section.



Mid-Radius 250X



Axis 250X

Therefore, the effect of grain size and pore size distributions on densification cannot be assessed independently.

The use of 1.2 wt% Sterotex in the 92% TD-S fuel has a stabilizing influence on the densification behavior of that fuel type. The peak in the pore distribution curve between 10 and 100 μm for all fuel types is attributed to the use of Sterotex. The relative area in that size range under the curves for both the 92% TD-U and 95% TD-S fuel types (Figure 7-14), in which 0.2 wt% Sterotex was used, is much less than for the 92% TD-S fuel where 1.2 wt% Sterotex was used for intentional formation of large pores. This is desireble for the 92% TD-S fuel because it has been observed that pores in the 10-100 μm size range are stable toward densification during thermal and irradiation tests. These pores act as sinks for vacancies originating at smaller pores, and thereby inhibit densification.

RESINTERING CHARACTERISTICS

Results of the EEI/EPRI Fuel Densification Program(3) and Halden Reactor studies(13) indicate that density changes during thermal resintering studies can be correlated with densification occurring during irradiation (to burnups of approximately 4000 MWd/MTM). Based on these results, it appears that resintering tests are useful for predicting whether specific fuel types will be stable toward densification caused by irradiation.

For the present program, resintering tests performed on the three fuel types may aid in two objectives: further confirmaton of correlations between irradiation induced densification and thermally-induced densification, and evaluation of grain size changes which occur during resintering. The results of the densification and grain size study may be used for both input into the irradiation-induced densification model derived by Marlowe(14) and to serve as a supplemental means for assessing fuel operation temperatures during irradiation. Marlowe has proposed that under both thermal and irradiation test conditions, density changes should be equivalent when the products of the diffusion coefficient and time are equal. In order to evaluate this model, thermal test conditions were selected to meet the required diffusion coefficient/time product equivalency.

Test Rationale

Resintering tests were conducted under five test conditions at 1600 and 1700°C. The 1700°C, 24 hr test condition was selected since it was in compliance with the proposed NRC guideline for predicting maximum irradiation density changes based on resintering test results.[15] The 1600°C, 24 hr condition was selected as a less severe test condition. The 1700°C, 48 hr test consisted of selected 1700°C, 24 hr pellets which were resintered for an additional 24 hr to determine whether the 1700°C, 24 hr test, resulted in stable densities. Based on the proposed diffusion coefficient/time equivalency model of Marlowe, density changes which occur during the 1700°C, 7.8-hr test should be equivalent to those of the 1600°C, 24-hr test. Pellets were heated at the 1700°C, 4 hr condition in order to gain a more complete definition of densification kinetics at 1700°C.

Experimental Procedure

Resintering tests on pellets randomly selected from the production lots were performed in a refractory metal, cold wall furnace in an Ar-8% H_2 atmosphere flowing at 56.6 ℓ/hr (2 ft^3/hr). Cooling and heating rates of 300°C/hr were used. Temperature during the resintering tests was monitored using an optical pyrometer which had been calibrated against a W-5% Re/W-26%Re thermocouple located in the test zone of the furnace. Water immersion and geometric densities were determined prior to and following each of the resintering tests. Grain sizes were determined on polished and etched transverse cross sections of selected pellets using the linear intercept method.[9] Grain size measurements were made at three locations on each of the cross sections, i.e., at pellet center, mid-radius, and pellet edge.

Results and Discussion

Density changes based on water immersion densities and pellet geometrics are reported in Appendix F. For the calculation of density changes based on pellet diameter and length, pellet shrinkage was assumed to be isotropic. Due to irregularities in pellet dimensions and surface roughness, density changes based on water immersion densities are considered to be more accurate than those based on pellet dimensions. They are the densities which will be discussed in this report.

Figure 7-27 shows density changes plotted as a function of pellet initial density for all resintering test conditions. As was found in the EEI/EPRI Fuel Densification Program(3), initial pellet densities of unstable fuel types affect the amount of densification which occurs during the tests. For the 92% TD-U fuel, the amount of densification which occurred varied inversely with the initial density.

For the 92% TD-S fuel, pellets with initial densities of less than 92% TD exhibited small negative density changes, while those with densities greater than 92% TD exhibited little, if any positive density change. While the exact mechanism of the negative density change is unknown, similar results were observed in stable pore-formed fuels in the EEI/EPRI study. For the 95% TD-S fuel, variation in initial density had no effect on the resintering behavior.

The amount of densification which occurred in the 92% TD-U fuel increased in proportion to test temperature and time at test temperature. Based on

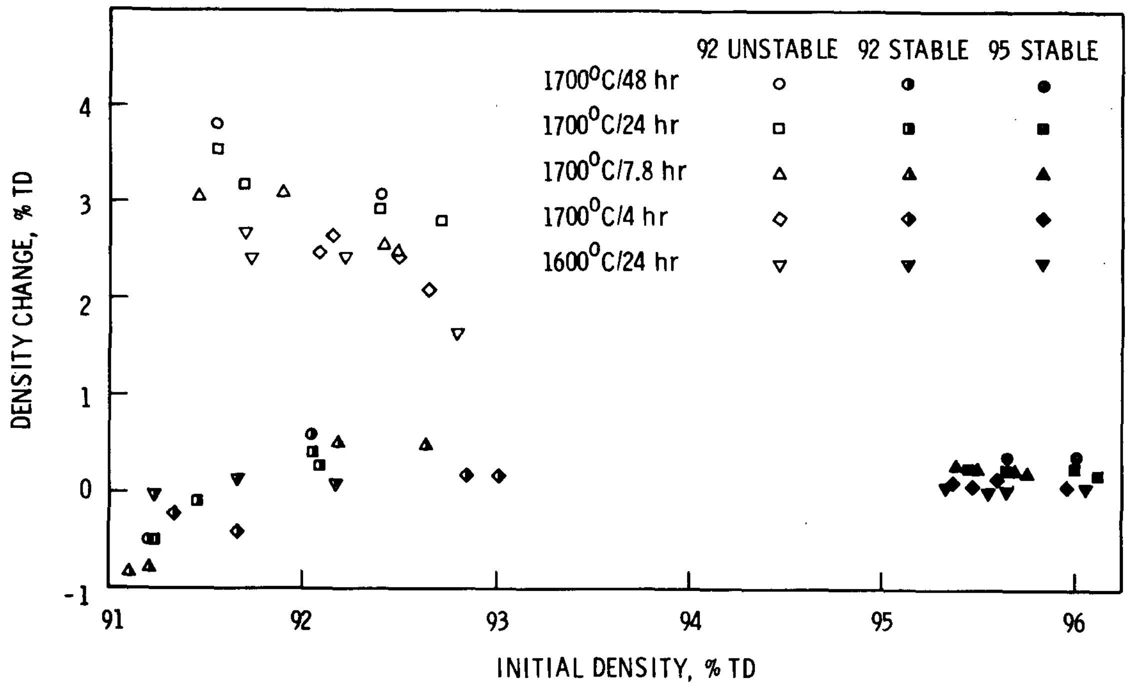


FIGURE 7-27. Influence of Pellet Density on Density Change During Resintering at 1600 and 1700°C

simple sintering kinetic arguments, such behavior was anticipated. For the other fuel types, the effect of test conditions on pellet behavior was less pronounced.

The 92% TD-U fuel pellets were initially sintered at 1575°C. The resultant microstructure had the finest pore and grain size of the three fuel types, (see Tables 7-1 and 7-5). The instability of this fuel type is the result of loss of fine porosity by vacancy diffusion during the tests. The stability of both the 92% TD-S and 95% TD-S fuels is attributed to a large number of pores bigger than 1 μm. The large pores in the 92% TD-S fuel type resulted from the use of 1.2 wt% Sterotex as a pore former. The finer pore sizes of the 95% TD-S fuel were removed during the initial sintering process at 1700°C. The remaining pores (greater than 1 μm) in this structure contribute to the fuel's stability. The larger grain size of this fuel type also enhanced stability.

Based on Marlowe's diffusion coefficient/time equivalency model, where density changes are predicted to be equivalent when diffusion/time products are equal, the 1700°C, 7.8-hr test would be expected to yield density changes comparable to those of the 1600°C, 24-hr test[a] (Table 7-6 contains a summary of these test results). Density changes in the 92% TD-U pellets during the 1700°C, 7.8-hr test appear to be larger than those occurring during the 1600°C, 24-hr test. Where positive density changes occur in the 92% TD-S and 95% TD-S fuels, those which occurred during the 1700°C test appear larger than those which occurred during the 1600°C test. If an uncertainty of 0.3% TD is assigned to the reported density changes,[3] there appear to be no significant differences between the changes which occurred during the two tests. Therefore, these results are not in conflict with Marlowe's diffusion coefficient/time equivalency.

Marlowe,[14] Stehle and Assmann,[16] and Hastings and MacEwen[17] have derived models to describe irradiation-induced densification in fuels.

(a) Calculated times are based on the diffusion coefficient, $D = 2.32 \times 10^{-5} e^{-82000/RT}$ cm^2/sec, used by Marlow[14] for similar calculations.

TABLE 7-6. Results of 1600°C, 24-hr and 1700°C, 7.8 hr Resintering Tests

Type	1600°C/24 Hour Initial Density, % TD	1600°C/24 Hour Density Change, % TD	1700°C/7.8 Hour Initial Density, % TD	1700°C/7.8 Hour Density Change, % TD
92 Unstable	91.68	2.91	91.42	3.29
	91.71	2.64	91.89	3.34
	92.21	2.61	92.42	2.79
	92.79	1.96	92.50	2.69
92 Stable	91.24	-0.03	91.11	-0.93
	91.54	0.13	91.22	-0.88
	91.83	0.20	92.18	0.55
	92.09	0.08	92.63	0.55
95 Stable	95.34	0.06	95.38	0.27
	95.54	0.01	95.49	0.27
	95.65	0.03	95.68	0.24
	96.05	0.05	95.75	0.19

In his derivation, Marlowe assumed that by substituting the irradiation-enhanced diffusion coefficients for the thermally-activated diffusion coefficients, irradiation-induced densification could be described by the final stage sintering model that Coble[18] had derived. Grain growth was assumed to follow Equation 1a during both irradiation and thermal resintering tests.

$$G^3 = G_o^3 + At \qquad (1a)$$

$$G^3 = At \text{ for } G \gg G_o \qquad (1b)$$

where: G = grain size as a function of time, t

G_o = initial grain size m cm

A = a diffusion coefficient dependent constant

Based on these assumptions, Marlowe derived the following equation to describe irradiation-induced densification.

$$\left(\frac{\partial \rho}{\partial t}\right)_{\text{densification}} = \frac{MD^\circ_{irr}\,\mathring{F}}{G_\circ^3 + AD^\circ_{irr}\mathring{F}t} \qquad (2a)$$

where ρ = pellet density, % TD

$\mathring{F}$ = fission rate, fission/cm^3-sec

t = irradiation time, sec

$G_\circ$ = initial grain size, cm

D°_{irr} = 1.27×10^{-29} cm^3/fission

A = structural constant defined by $G^3 = G^3 + ADt'$

t' = thermal test time, sec

G = grain size as a function of time during thermal tests, cm

D = thermally activated diffusion coefficient, cm^2/sec

M = constant defined by $\Delta\rho = \frac{M}{A} \ln\left(1 + \frac{ADt'}{G_\circ 3}\right)$ (2b)

$\Delta\rho$ = change in density during thermal tests, % TD

Equation 2 was then combined with Equation 3 which describes irradiation-induced swelling to yield Equation 4 which describes pellet behavior during irradiation.

$$\left(\frac{\partial \rho}{\partial t}\right)_{\text{swelling}} = -\rho S\mathring{F} \qquad (3)$$

$$\rho = \rho_\circ \exp(-S\mathring{F}t) + \frac{M}{A} \exp\left[-S\left(\frac{G_\circ^3}{AD^\circ_{irr}} + \mathring{F}t\right)\right] \ln\left(1 + \frac{AD^\circ_{irr}\,\mathring{F}t}{G_\circ^{\,3}}\right) \qquad (4)$$

where: $\rho_\circ$ = pellet initial density, % TD

S = fractional volumetric fuel swelling rate, assumed to equal 0.5 vol% per 10^{20} fissions[14]

To predict irradiation-induced densification behavior with Equation 4, the constants A and M must be evaluated based on the resintering test results. However, as described, grain sizes were found to vary by more than a factor of two across the radius of the pellets. Therefore, it is difficult to define a unique value for the constant A for these fuel types. In addition, this data cannot be used readily to verify the grain growth behavior (Equation 1a) assumed by Marlowe in the derivation of Equation 4.

In the derivation of his final stage sintering model, Coble[18] assumed that Equation 1b describes grain growth. The resultant equation predicts that during final stage sintering, thermally-induced density changes are proportional to ln(t). As Figure 7-28 shows, observed density changes for 92% TD-U pellets are approximately proportional to ln(t). Variations from a strict ln(t) relationship may be due to differences in pellet initial densities and sintering which occurred during heating to the isothermal test conditions. However, verification of the assumed grain growth behavior cannot be made with current data.

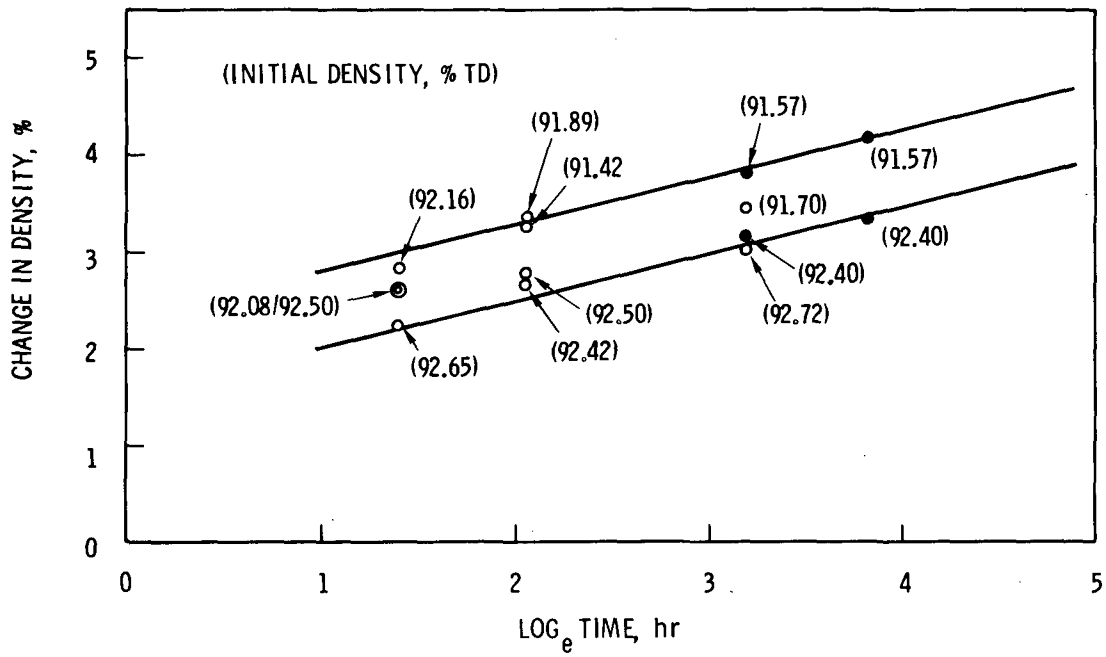


FIGURE 7-28. Change in Unstable 92% TD Pellet Densities at 1700°C as a Function of Log$_e$ Time

As Marlowe discussed, and the EEI/EPRI study indicated, Equation 4 does not predict the observed fission rate and/or temperature dependence of pellet densification at fixed burnup. Despite this deficiency, Marlowe's approach can be used with fair success to predict the irradiation-induced densification the latter study observed in unstable fuel types irradiated at high fission rates. Since the results of the present program cannot define unique values of the empirical constants A and M, Marlowe's model cannot directly be used to predict irradiation-induced densification for the three fuel types studied. However, a modified approach, which does not require an evaluation of initial grain size and grain growth behavior, can be used to predict irradiation-induced densification based on resintering test results.

First, assume that thermally-induced density changes can be represented by:

$$\Delta\rho_{thermal} = B \ln(1 + CDt) \tag{5}$$

where B and C are empirical constants which can be evaluated based on the results of two resintering tests. To produce Equation 5, B replaces the ratio M in Equation 2b while C replaces the ratio $\frac{A}{G_o^3}$. In Equation 4, the same substitution can be made for $\frac{A}{G_o^3}$ and $\frac{M}{A}$ resulting in:

$$\rho = \rho_o \exp(-S\mathring{F}t) + B \exp\left[-S \frac{1}{C\mathring{D}_{irr}} + \mathring{F}t)\right] \ln(1 + C\mathring{D}_{irr}\mathring{F}t) \tag{6}$$

Figure 7-29 shows the results of using Equation 6 to predict irradiation-induced densification for the three fuel types evaluated in the present study. For these calculations, the constants B and C were evaluated using 1600°C, 24-hr/48-hr test data. Since two pellets of each fuel type were subjected to the combined 1700°C, 24-hr/48-hr tests, two sets of B and C values were calculated for each fuel type. For the 92% TD-U fuel, density changes up to 2.9% TD were predicted using this approach, with density changes remaining positive for burnups up to 17,000 MWd/MTM. For the two stable fuels, it is predicted that densities will decrease with increasing burnup.

The models derived by Stehle and Assman[16] and Hastings and MacEwen[17] require quantitative pore size distributions of the fuel types as model input.

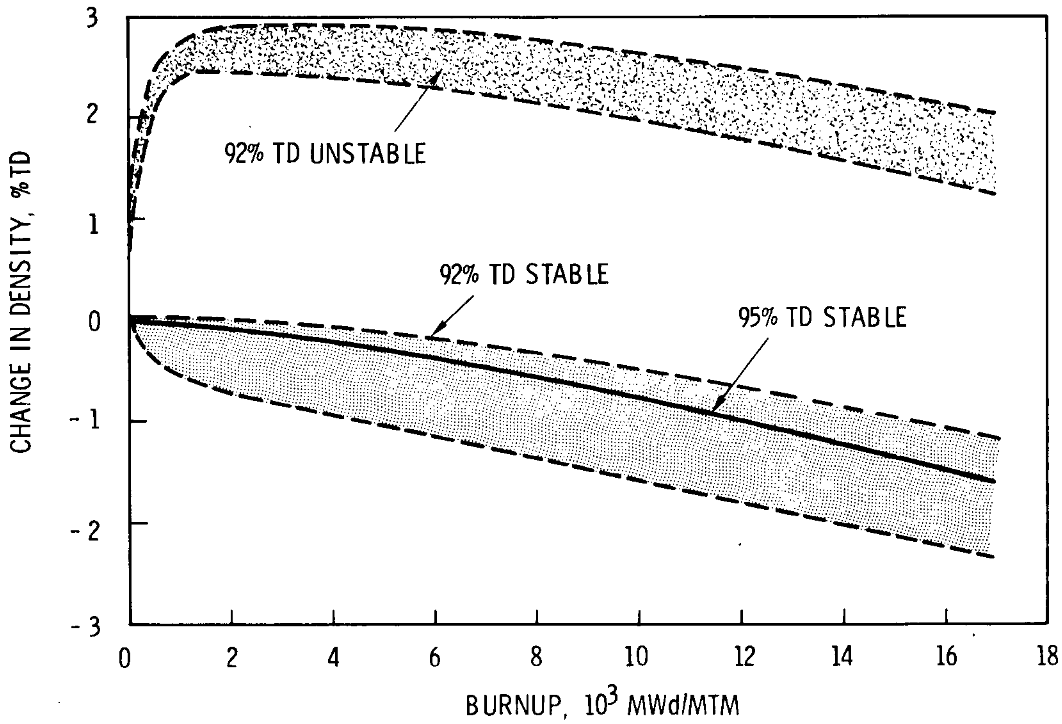


FIGURE 7-29. Predicted Fuel Behavior Using Marlowe's Model

Since this data is presently not available, these models cannot be used to predict irraditaion behavior.

In the NRC densification regulations,(15) irradiation-induced densification is related empirically to thermal resintering test results by the following expressions:

For $\Delta\rho_{thermal} < 4\%$ TD at 1700°C, 24 hr:

$$\Delta\rho_{irr} = 0 \qquad 0 \le BU < 20 \text{ MWd/MTM}$$

$$\Delta\rho_{irr} = m \log(BU) + b \qquad 20 \le BU < 2000 \text{ MWd/MTM} \qquad (7)$$

$$\Delta\rho_{irr} = \Delta\rho_{thermal} \qquad BU \ge 2000 \text{ MWd/MTM}$$

For $\Delta\rho_{thermal} \le 0$:

$$\Delta\rho_{irr} = 0$$

Data from the 1700°C, 24-hr resintering test were used to calculate anticipated pellet densification behavior during irradiation; Figure 7-30 gives plotted results of these calculations. They include maximum and minimum

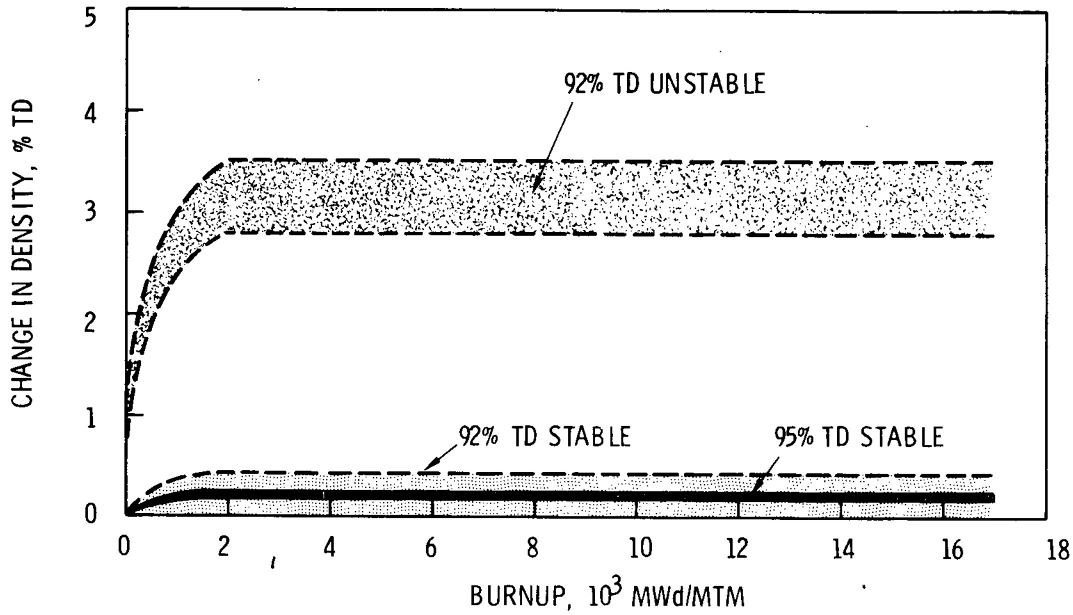


FIGURE 7-30. Fuel Behavior Predicted Using Proposed NRC Resintering Guide

positive thermal density changes and do not consider fission product swelling. As prescribed by the model, maximum irradiation-induced density changes are achieved at a burnup of 2000 MWd/MTM.

Conclusions

During resintering tests, the three fuel types examined in this program exhibited a range of stabilities. The density changes varied with initial pellet density, resintering temperature, and time at temperature. The amount of densification that occurred in the 92% TD-U fuel increased with decreasing pellet density. Lower density pellets of 92% TD-S fuel exhibited negative density changes while the higher density pellets in the series exhibited positive density changes. The 95% TD-S fuel exhibited no significant density changes.

Based on the model proposed by Marlowe(14) and the NRC guideline,(15) it is expected that the 92% TD-U fuel will exhibit irradiation-induced density changes as large as 3% TD. Marlowe's model predicts the stable 92 and 95% TD fuels will exhibit density decreases during irradiation; the NRC guideline (which does not consider the effect of fission product swelling on fuel behavior) predicts increases of up to 0.4% TD.

THERMAL DIFFUSIVITY AND THERMAL CONDUCTIVITY

The purpose of this study was twofold:

- to determine the thermal diffusivity and thermal conductivity of the three fuel types
- to evaluate the effect of heat treatment on diffusivity and conductivity.

The thermal diffusivity of the fuel types was determined using a laser-pulse technique from 100-1600°C; the thermal conductivity was calculated from the measured thermal density, measured density, and known heat capacity.

Experimental Procedures

The technique and apparatus utilized in the present study were used previously to measure the thermal conductivity of "round robin" UO_2 at temperatures up to 2500°C. This method, which has been reported in detail[19], consists of heating one surface of a thin sample disc with a short heat pulse from a 3-7 Joule laser beam that has a pulse width of 1.06 m/sec. The heat pulse passes through the sample, and the temperature transient on the back surface of the sample is measured and recorded. The thermal diffusivity is then determined from the shape of the temperature-versus-time curve.

The temperature transients for this study were optically measured using a liquid nitrogen cooled, indium antimonide, infrared detector. The signal from this detector was displayed on an oscilloscope and recorded on film. Although corrections were made for heat losses, pulse time corrections were not required.

The specimens were held in an Al_2O_3 holder and heated in a tungsten resistance furnace with a dry argon atmosphere at a positive pressure of 2-3 psi. Temperatures were measured using a W-5% Re/W-26% Re thermocouple which had been calibrated to 1650°C against a Pt/Pt-10%Rh thermocouple set in the sample position. The platinum thermocouple had previously been calibrated against a reference platinum thermocouple. The estimated accuracy of the temperature measurement was ± 3°C.

The thermal diffusivity apparatus was calibrated using ARMCO iron[20] and Pyroceram.[a] The iron and Pyroceram thermal diffusivity results agree with the reported values (within experimental error). The data are precise to ± 3% and the accuracy of the measurements was calculated to within ± 5%.

The furnace temperature was raised in increments of 5-10 C/min below 800°C and 20-25 C/min above 800°C. Thermal diffusivity measurements were then made after the temperature was stabilized. Each sample was initially heated to 1300-1400°C and measurements taken at approximate intervals of 100°C. On cooling, measurements were taken at 200-250°C intervals. Subsequently, each sample was heated to 1600-1650°C and held at this temperature for 4-5 1/2 hr. Then, measurements were made to compare the thermal diffusivity before and after heat treatment. The sample was then cooled to room temperature and again heated to 1530-1650°C with measurements being made at 200-300°C intervals.

These samples (UO_2 discs of 1.04 cm in diameter and 0.08-0.09 cm thick) were cut from the center of selected fuel pellets. The densities of the whole pellets had been measured by the water immersion technique, prior to sectioning. In addition, the densities of some discs were determined by geometric and water immersions before and after thermal diffusivity measurements.

Calculation of Thermal Diffusivity and Conductivity

The thermal diffusivity, α(cm^2/sec), was calculated from the relationship

$$\alpha = \frac{t_c \ d^2}{t_{1/2}}$$

where $t_{1/2}$ is the time for the back surface of the sample to reach 1/2 the maximum temperature, t_c is a heat loss correction which is determined from the shape of the time-temperature curve, and d is the sample thickness.

(a) Pyroceram sample and thermal diffusivity data were obtained from the National Bureau of Standards.

The sample thickness was corrected for sample thermal expansion using the expression

$$d = d_o\ (1 + \Delta L/L_o)$$

where $\Delta L/L_o$ is the fractional thermal expansion at temperature T, and d_o is the sample thickness at room temperature. The assumed temperature dependent expression for $\Delta L/L_o$[19] was

$$\Delta L/L_o = -2.0701 \times 10^{-4} + 8.4051 \times 10^{-6}\ T$$

$$+1.6502 \times 10^{-9} T^2 + 2.6128 \times 10^{13} T^3$$

where T is in °C. This expression is valid for a temperature range of 16-2500°C.

The thermal conductivity, (W/cm °C), was calculated for each thermal diffusivity data point from the relationship

$$\lambda = 4.186\ \alpha C_p \rho$$

where C_p(cal/g-C) is the heat capacity and ρ(g/cm^3) is the sample density. The polynomial expression assumed for C_p[19] was

$$C_p = 5.4662 \times 10^{-2} + 9.2506 \times 10^{-5} T - 1.9890 \times 10^{-7} T^2$$

$$+ 2.5575 \times 10^{-10} T^3 - 1.8582 \times 10^{-13}\ T^4 + 6.9070 \times 10^{-17} T^5$$

$$- 9.7477 \times 10^{-21}\ T^6$$

where T is in °C. This relationship is valid for the temperature range 27-2527°C. A density correlation was calculated from the expression:

$$\rho = \frac{\rho_o}{(1 + \Delta L/L_o)^3}$$

where ρ_o is the density at room temperature and $\Delta L/L_o$ is calculated as above.

For those samples whose density and thickness changed after heat treatment, the thermal diffusivity and conductivity were calculated using the d_o and ρ_o values present after heat treatment.

Results and Discussion

The thermal conductivity results, expressed as thermal resistivity ($1/\lambda$), are shown in Figures 7-31-7-33. For these figures, the temperature dependence of the thermal resistivity is expressed as first-and second-order equations calculated from least-squares fits. The density and dimensional measurements, as well as the related heat treatments, are summarized in Table 7-7. Figure 7-34 includes a summary of the second-order thermal conductivity-versus-temperature equations for all three fuel types. These equations may be compared with those for UO_2 thermal conductivity reported by Godfrey et al.[21] and Lyons'[22,23]. Appendix G contains the tabulated data for measured thermal diffusivity, calculated thermal conductivities and thermal resistivity of all fuel types.

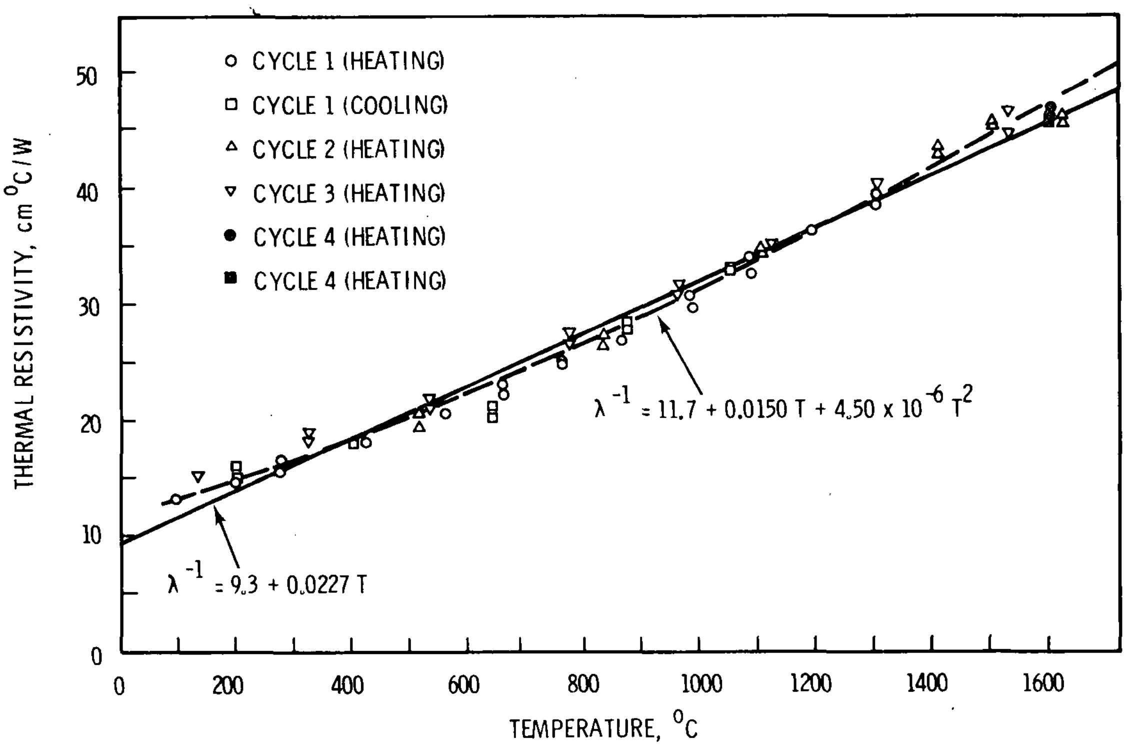


FIGURE 7-31. Thermal Resistivity of 95% TD Stable Fuel Before and After Heat Treatment Near 1600°C (all temperature in°C)

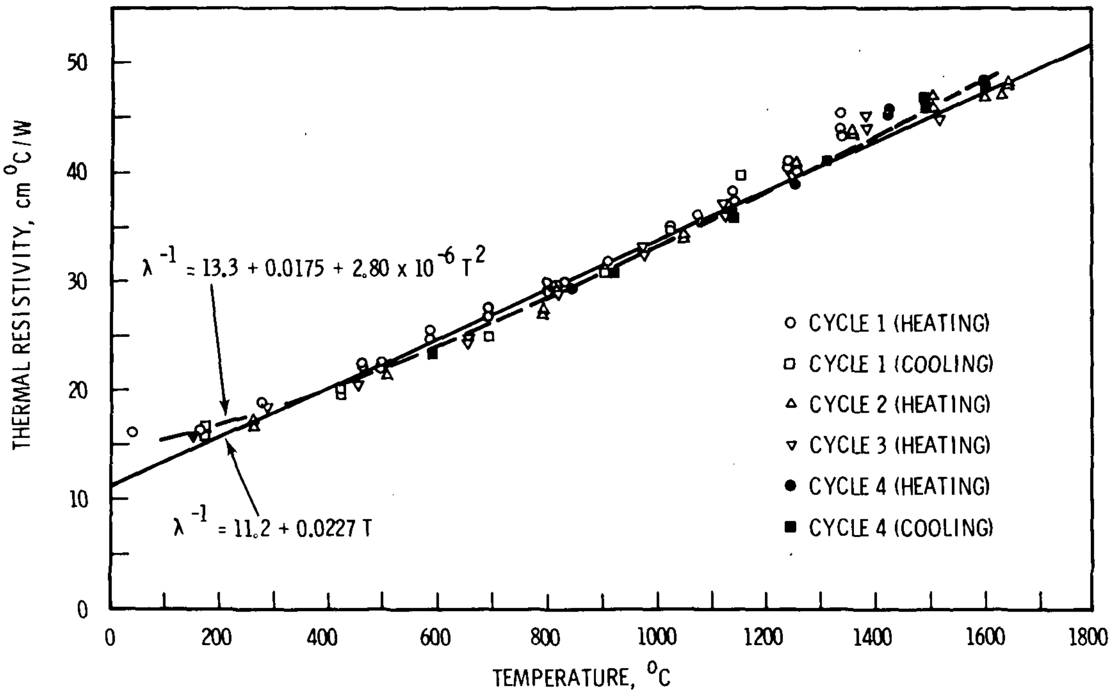


FIGURE 7-32. Thermal Resistivity of 92% TD Unstable Halden UO_2 Before and After Heat Treatment Near 1600°C (all temperatures in °C)

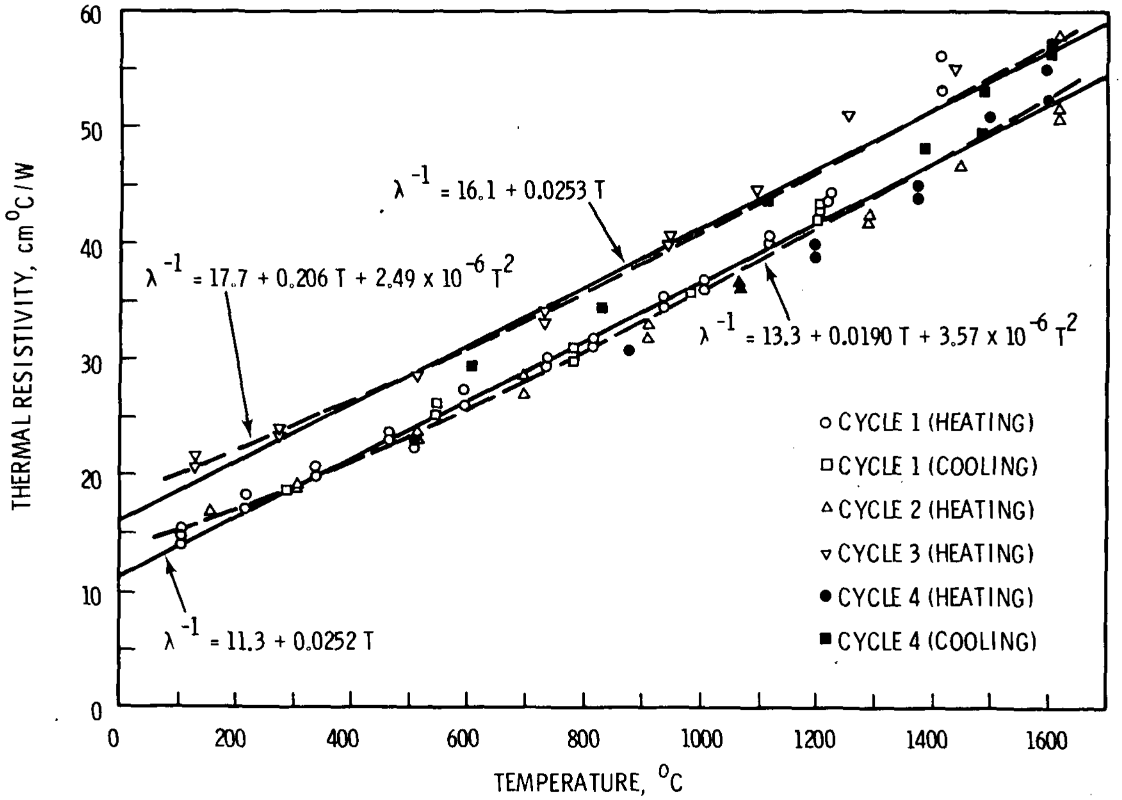


FIGURE 7-33. Thermal Resistivity of 92% TD Stable Halden UO_2 Before and After Heat Treatment Near 1600°C (all temperatures in °C)

The thermal conductivity of the 95% TD-S (Figure 7-31) was unchanged after heating to 1305°C (Cycle 1), 1628°C (Cycle 2), or 1533°C (Cycle 3). Similarly, when a second sample was heated to 1605°C for 4.5 hr (Cycle 4), the thermal conductivity did not change. No changes in the sample thickness could be measured after the run, but there were measured increases of 0.4 and 1.2% in the sample densities after treatment near 1600°C (Table 7-7). The 1.2% increase in density after 4.5 hr at 1605°C is not consistent with density changes during resintering determined in another part of this program. When the measurement is accurate to within ± 3%, the calculated thermal conductivities are insensitive to density changes of 1%.

The thermal conductivity of the 92% TD-U fuel (Figure 7-32) also exhibited no significant change after heating for 5 hr to 1336°C (Cycle 1) or above

TABLE 7-7. Summary of Thermal Temperature and Resulting Changes in Thickness, Resistivity, and Density

Fuel Type: Disc No.	Fuel Type: Cycle No.	Test Conditions: Temperature, °C	Test Conditions: Hold Time, hr	Change in Thickness, %	Change in Resistivity, %	Change in Density, %	Initial Density, % TD
95% TD Stable							
1	1	100-1305	None	-	None		95.6[d]
1	1	1305-203					
1	2	516-1628	4.5	-	None	+0.4	95.6[d]
1	3	134-1533					
2	4	455-1605	4.5	0.0%	None	+1.2	94.6[e]
2	4	1605-1428					
92% TD Unstable							
1	1	40-1336	None	-	None	-	92.2[d]
1	1	1336-175					
1	2	262-1641	4	-	None	-1.6	92.2[d]
1	3	156-1602					
2	4	499-1599[c]	5	-0.6%	None	+0.7	91.7[e]
2	4	1600-591					
92% TD Stable							
1	1	105-1415	None	-	None	-	92.2[d]
1	1	1415-288					
2	2	152-1616	5.5	+3.2%	-40%	-4.7	91.6[d]
2	3	131-1606					
3	4	501-1606[a,b]	4.5	+2.8%	-30%	-2.4	90.7[e]
3	4	1604-604					

a. Extensive microcracking, grain boundary separation, and pore migration.
b. Sample bowed and was fragile.
c. No change in microstructure.
d. Whole pellet density, Δ density based on whole pellet initial density and on disc density after the diffusivity run.
e. Disc specimen on which diffusivity was run.

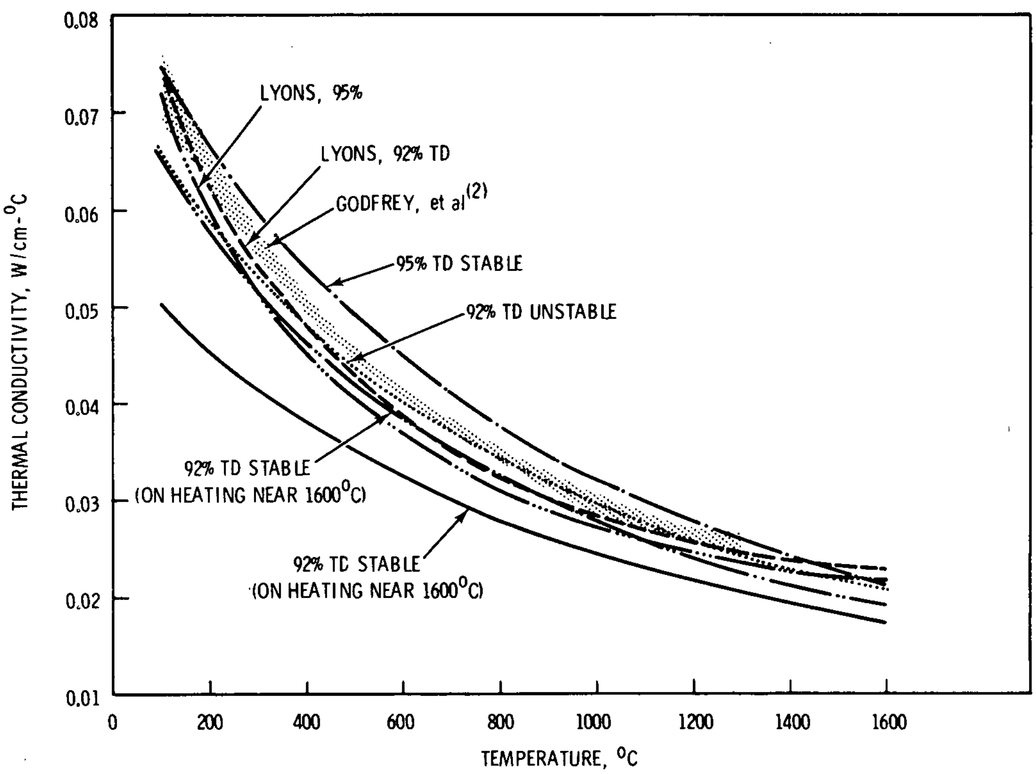


FIGURE 7 34. Thermal Conductivity of Halden UO_2 Type Fuels from Second Order Fit of Data and Comparable Thermal Conductivity for Godfrey et al[19] and Lyons[22,23]

1600°C (Cycles 2, 3, and 4). Also, no significant change in sample thickness was measured. One 92% TD-U disc which was heated to 1641°C for 4 hr (Cycle 2) decreased 1.6% in density while another disc was heated to 1660°C for 5 hr and increased 0.7% in density. Qualitatively, the microstructure of the 92% TD-U fuel appeared unchanged after the heat treatment at 1600°C.

The behavior of the 92% TD-S fuel was substantially different from that of the 92% TD-U and 95% TD-S fuel types. The thermal conductivity did not change after heating to 1415°C. However, two disks heated to higher temperatures did show changes in thermal conductivity as shown in Figures 7-33 and 7-34. The first disc was heated at 1606°C for 4 1/2 hr and exhibited a 30% decrease in thermal conductivity, 2.8% increase in thickness, and a 2.4% decrease in density. The second disc was held at 1616°C for 5 1/2 hr and exhibited a 40% decrease in thermal conductivity, a 3.2% increase in thickness, and a 4.7%

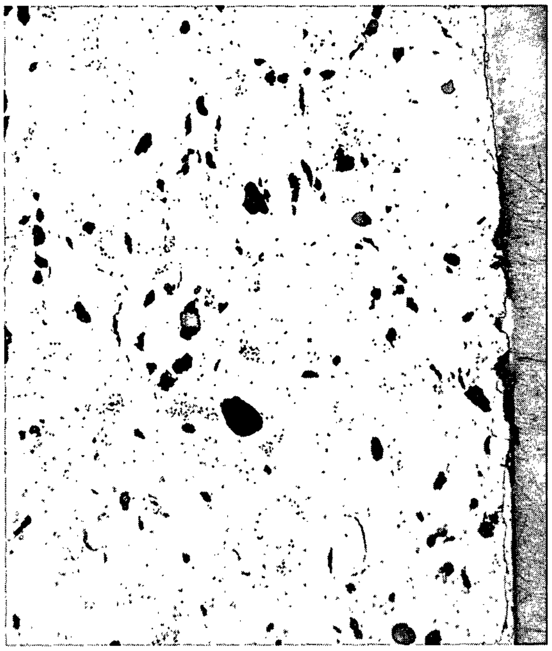
decrease in density. In addition, this disc warped during the run and showed an increase in fragility.

The decreases in thermal conductivity of the 92% TD-S fuel are attributed to significant changes in the microstructure which occurred during heating for 4-5 hr above 1600°C. The 92% TD-S fuel experienced extensive grain boundary separation and/or pore migration (Figures 7-35 and 7-36) which was most pronounced near the periphery of the disc. The microstructure of an adjoining nonheat-treated disc showed a significant microstructural variation from the axial to the peripheral location. Similar microstructural variations were also observed for the whole pellet, which was examined in the microstructural characterization portion of this report. Microstructural examination also indicated that the center of the disc expanded substantially more than the outer edge.

When the whole 92% TD-S fuel pellets were resintered in their entirety at 1600°C, the observed density and dimensional changes did not exceed 1%. Apparently, the higher density region near the exterior surface of the pellet kept the whole pellet from swelling and fracturing during the 1600°C resintering test. However, the disc that was cut from the center of the pellet was not restrained and thus was free to swell and fracture. The cause of this swelling in the discs is not known.

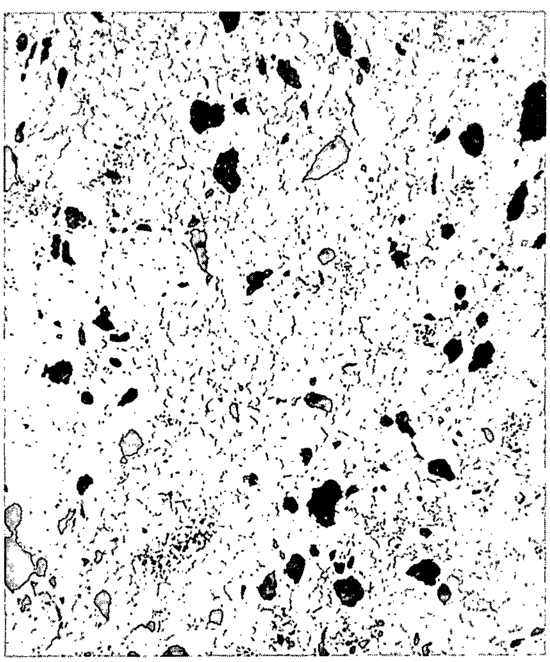
Results of the 1600°C, 24-hr resintering tests can be used to predict the size of the density changes expected to occur during the diffusivity runs for each fuel type:

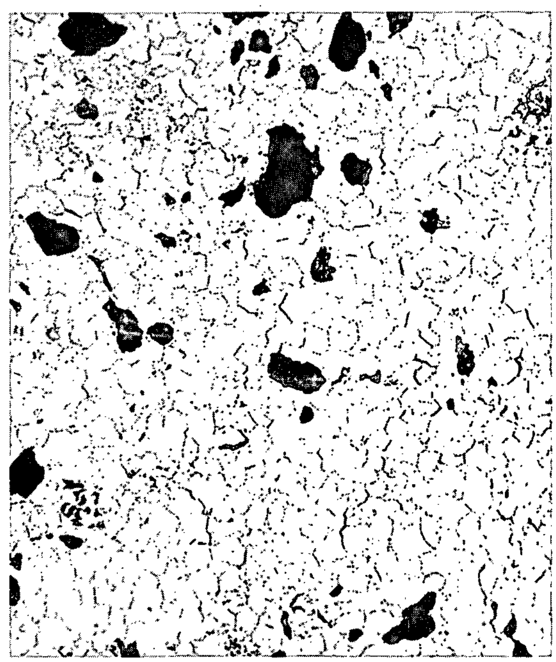
- Based on resintering results, no density change was expected for the 95% TD-S fuel type during the diffusivity measurements. However, a density change of +1.2% was measured on one disc.
- By assuming that the change in density of the 92% TD-U fuel at 1600°C follows a ln time-dependency, and by extrapolation of the data to 4 hr, a change in density of 1-2% during the diffusivity measurements at 1600°C is predicted. However, a change of only +0.7% was measured on a disc.
- For the 92% TD-S fuel, a density change of less than +1% would be anticipated during the 4-5 hr hold at 1600°C. However, density decreases of -4.7 and -2.4% were measured following the diffusivity runs.



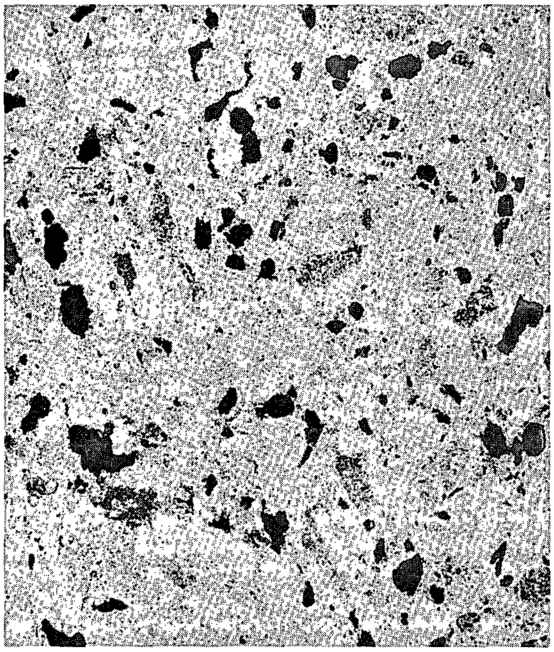
As Fabricated 100X

FIGURE 7.35. Microstructure of 92% TD Stable UO_2 Disc, Transverse Section, Peripheral Position, Before and After 1605°C Hold for 4.5 Hours



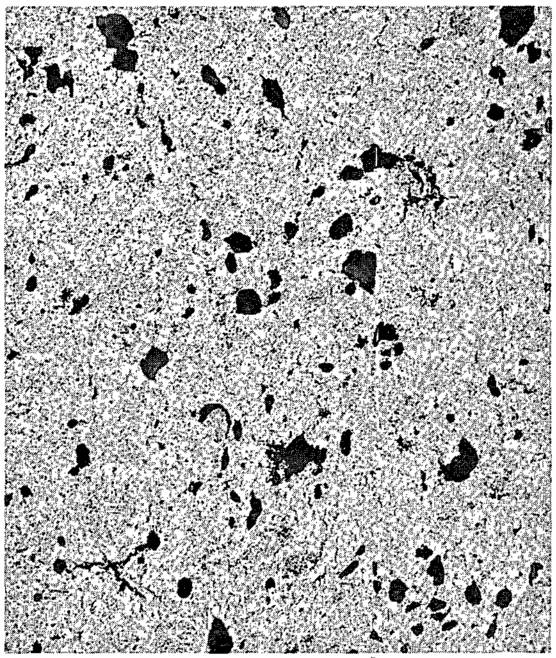


100X After 1605°C Hold 200X



As Fabricated 100X

FIGURE 7.36. Microstructure of 92% TD Stable UO_2, Transverse Section, Axial Position, Before and After 1605°C Hold for 4.5 Hours



100X After 1605°C Hold 200X

Although as yet undetermined, it is believed that a large uncertainty, perhaps $\pm$ 0.5 - 1.0% TD, is associated with the density changes reported for the small fuel discs used in the diffusivity measurements. This uncertainty is due to the high surface-to-volume ratio and low mass of the discs. Therefore, reported density changes of up to 1% TD for the discs are within limits of error for the measurement. The reduction in disc density of 92% TD-S fuel is considered real and is supported by the measured increase in disc thickness and microstructural examination.

As mentioned, microstructural change of the 92% TD stable disc is the cause of the decrease in thermal conductivity for this fuel type. This conclusion is supported by a qualitative evaluation of the parameters derived from the linear relationship of thermal resistivity versus temperature, λ^{-1}= A+BT. The constants A and B have a qualitative meaning relating to lattice conduction in solids. Lattice conduction is defined as the transfer of thermal energy from one vibrating atom to another. In UO_2, the atoms have a defined spatial distribution, and heat transfer can be considered to be an elastic displacement wave moving through the lattice. Any change in the periodicity of these atoms, will cause these elastic waves or photons to scatter, resulting in a decrease of thermal conductivity. Such effects may be caused by inpurities, nonstoichiometry, structural defects (i.e., vacancies, dislocations), and macroscopic changes (such as cracks, pores, and grain boundaries).

The constant A is influenced primarily by the presence of athermal, extrinsic effects, such as impurities, pores, cracks, dislocations (if athermal), and grain boundaries. Constant B is an intrinsic term relating directly to the temperature coefficient of the lattice structure (e.g., lattice parameter, crystallographic structure, phases, or stoichiometry). Thus for UO_2, large changes or differences in A would be expected if the intrinsic nature of the fuel did not change but cracking or porosity occurred.

All data were fitted to this linear equation, including the 92% TD-S fuel before and after the decrease in thermal conductivity. The values for A and B vary depending upon the temperature range since, in general, the λ^{-1}-versus-T curve is slightly "S" shaped; λ^{-1} increases as temperatures increase. This curvature is most pronounced for the 95% TD-S fuel.

Fitting all the data over the entire temperature range, the B values for 92% TD-S and 95% TD-S agree with values for 95% TD UO_2 measured by Godfrey[21] (B = 0.0223 cm/W). However, the B values for the 92% TD-S fuel are significantly different from those of the other two fuel types. This suggests some possible basic differences in the UO_2 lattice structure for the 92% TD-S fuel. The A values for the 92% TD-U and the 92% TD-S fuels before annealing were approximately the same (A = 11.2 - 11.3 cm-°C/W) which is nearly the same as that for Godfrey (A = 11.1 cm-°C/W).

The most significant change for the 92% TD-S fuel after heat treatment above 1600 C is the increase in A (11.3 to 16.3 cm-°C/W); B remained essentially unchanged (0.0252 to 0.0253 cm/W). These results support the conclusion that the decrease in thermal conductivity during heat treatment near 1600 C results from a microstructural change due to increased porosity and/or microcracking, and with little change in the UO_2 lattice structure.

However, the decreased density of the 92% TD-S fuel cannot be used to account solely for the large decrease in thermal conductivity. Even the density correction methods, which predict the largest changes in conductivity, cannot account for the 30-40% decrease in thermal conductivity. Thus, it appears that, although the increase in porosity may contribute to the decrease in thermal conductivity, the major cause for the increase in A is the formation of microcracks with interfaces that act as barriers to heat transport.

Although the first-order equation is convenient for understanding the changes in heat conduction, a better fit of the data can be obtained using a second-order equation:

$$\lambda^{-1} = C + DT + ET^2$$

where C, D, and E are constants. The data for all the samples is summarized in Table 7-7 and Figure 7-34, and compared with that reported by Godfrey[21] and Lyons.[22,23] The thermal conductivity of the 95% TD-S fuel is higher than that of the reference UO_2; the 92% TD-U fuel thermal conductivity is lower at lower temperatures but agrees with that of the reference at higher temperatures. Before and after heat treatments the 92% TD-S fuel is substantially lower than the reference data at all temperatures. Because of the difference in fabrication techniques and resultant microstructures for the three fuel types, it is not surprising that the thermal conductivity valves are different for each fuel type and vary from other reported thermal conductivity data.

Conclusions

The thermal diffusivity was measured from approximate room temperature to near 1600°C; the thermal conductivity for the three fuel types was calculated from this data. The effect of heat treatment near 1600°C in argon on thermal conductivity was measured. The 95% TD-S and 92% TD-U fuel types were unchanged by the heat treatment. The 92% TD-S fuel was not changed after heating to 1415°C, but the thermal conductivity decreased 30-40% after 4-5 hr above 1600°C. This decrease in thermal conductivity is attributed to microstructural change as evidenced by a 2.8-3.2% increase in sample thickness and a 2.4-4.7% decrease in density.

Microstructural, density, and dimensional changes in the 92% TD-S discs appear related to the removal of restraints that are present in the whole pellets. In the whole pellets, the higher density exterior surface of the pellet restrained expansion and fracture. However, when the discs were cut, the restraint was removed. Therefore, it is probable that the properties of the unbroken pellet may be more closely related to the thermal conductivity of the first cycle to 1616°C, prior to the temperature hold. Whether or not similar microstructures develop during irradiation will dictate whether pellet thermal conductivities follow that of the discs measured prior to or following the 1600°C heat treatment.

The thermal conductivity from 20-1600°C for each of the three fuel types is best represented by the following equations:

95% TD Stable Fuel

$$\lambda^{-1} = 11.7 + 1.50 \times 10^{-2} T + 4.50 \times 10^{-6} T^2, \text{ cm-°C/W}$$

92% TD Unstable Fuel

$$\lambda^{-1} = 13.3 + 1.75 \times 10^{-2}T - 2.80 \times 10^{-6}T^2, \text{ cm-°C/W}$$

92% TD Stable Fuel

$$\lambda^{-1} = 13.3 + 1.90 \times 10^{-2}T + 3.57 \times 10^{-6}T^2, \text{ cm-°C/W}$$

PELLET AND CLADDING SURFACE ROUGHNESS AND ROUNDNESS

Surface roughness and roundness measurements were made on three fuel pellets and six samples of cladding. Measurements were made on the cylindrical surface of the pellets and the inside surface of the cladding, and were taken both axially and circumferentially.

The roundness measurements were made on a Moore #3 measuring machine and the surface measurements on a Talysurf #4 machine. The latter is a tracer-type instrument that uses a stylus tracer (tip radius of 2.5 μm) and electrical amplification. The roundness measurements are accurate to at least 0.13 μm the surface roughness to at least 0.025 μm.

The deviation from true roundness at any cross section is defined as the width of the annular area within which the measured profile is confined. This varied from 6.4-14.0 μm for the fuel pellets, and from 5.1-10.2 μm for the cladding. Figures 7-37 and 7-38 show the results for the pellets and cladding respectively. The details are provided in Appendix H.

The surface roughness measurements are characterized by the arithmetic average; a value which the Talysurf machine calculates automatically. The arithmetic average deviation from the center line is

$$\Upsilon = \frac{1.0}{d} \int_{X=0}^{X=d} |y| \, dx$$

where: Υ = arithmetic average deviation from center line
y = ordinate of the curve of the profile
d = length over which the average is taken

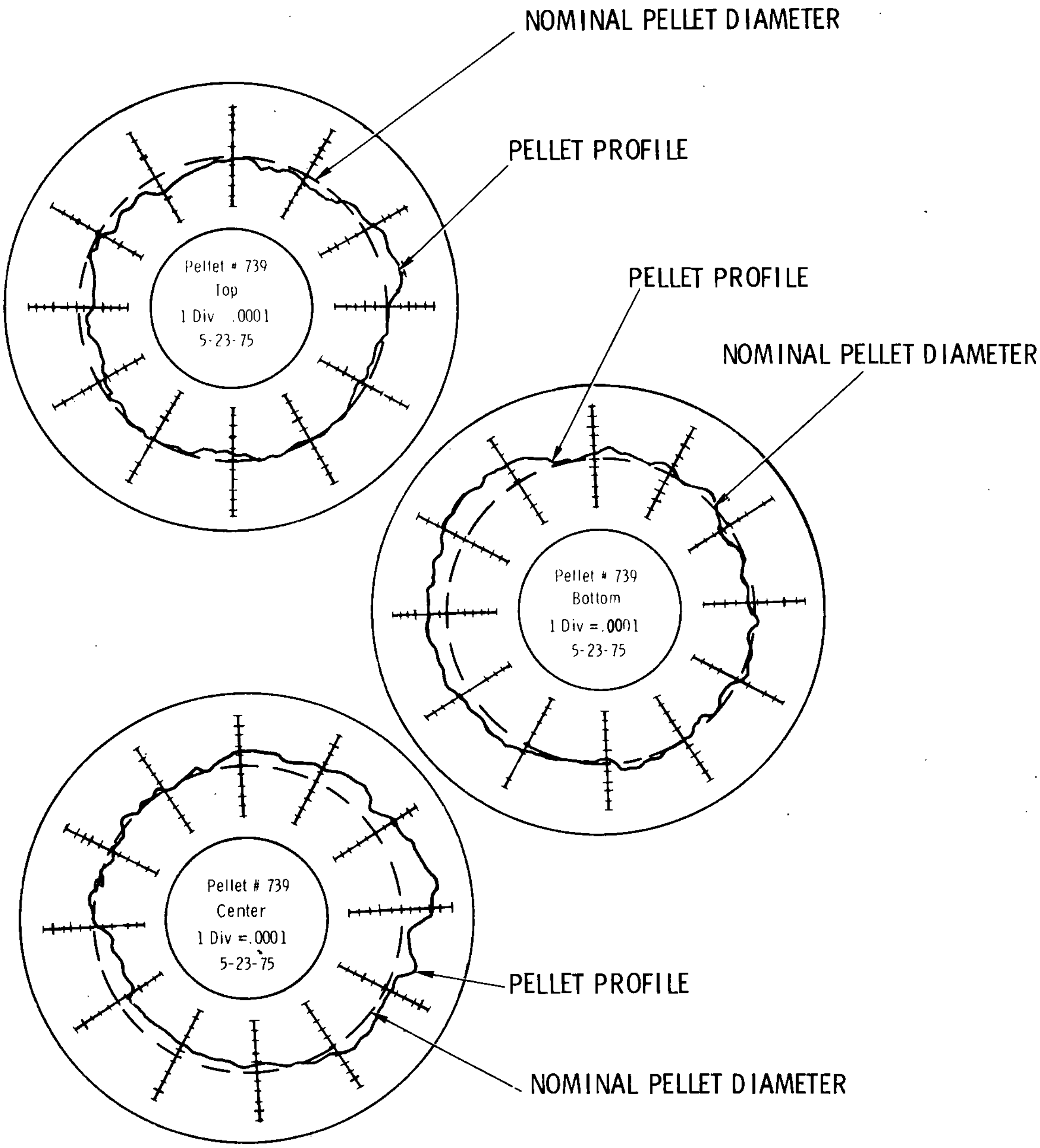


FIGURE 7-37. Fuel Pellet Roundness at Three Locations. Pellet 739. Each Division = 0.0001 in. (2.54 μm)

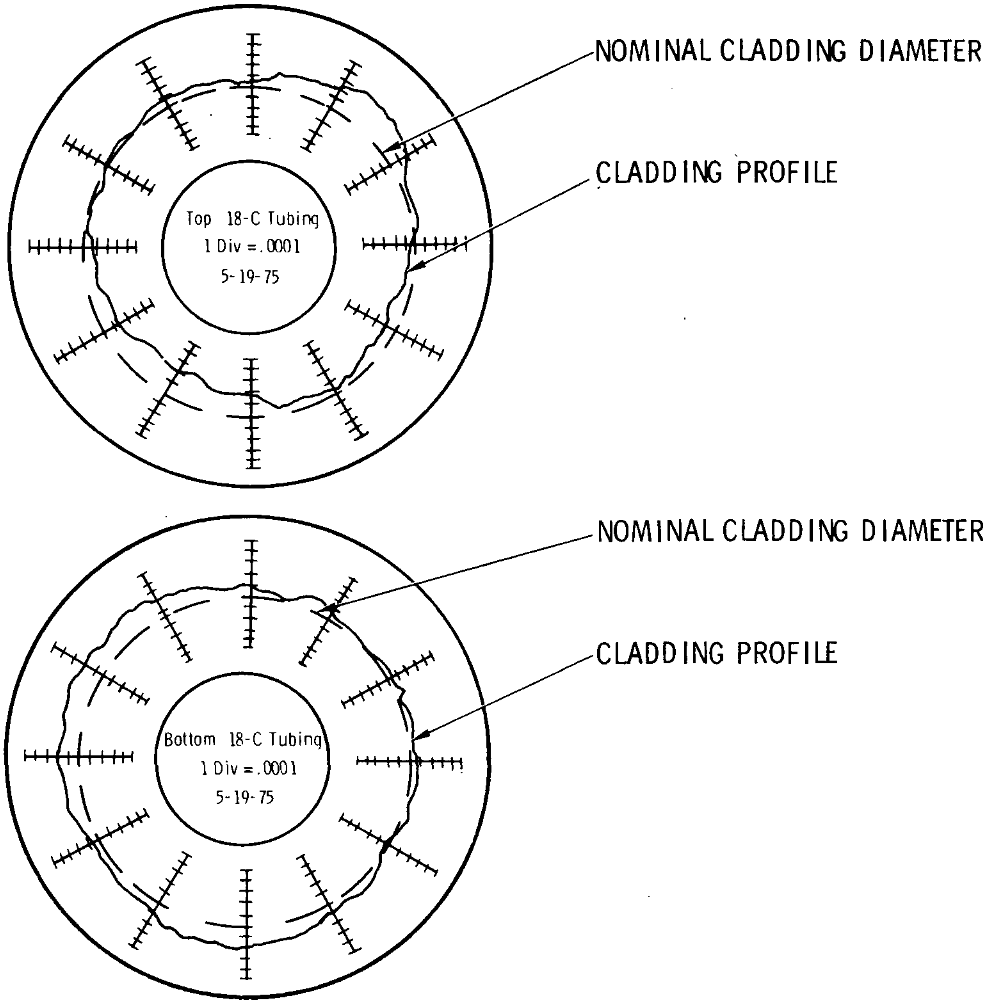
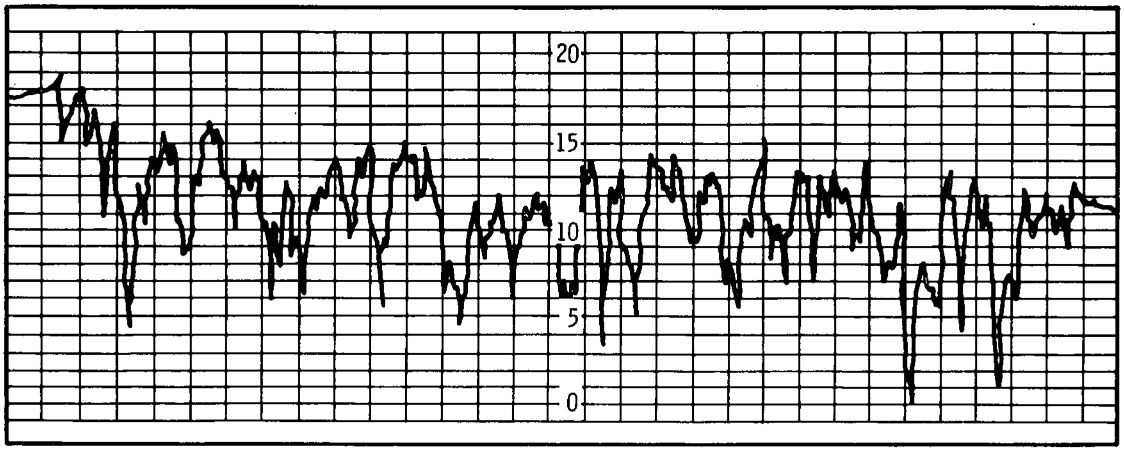


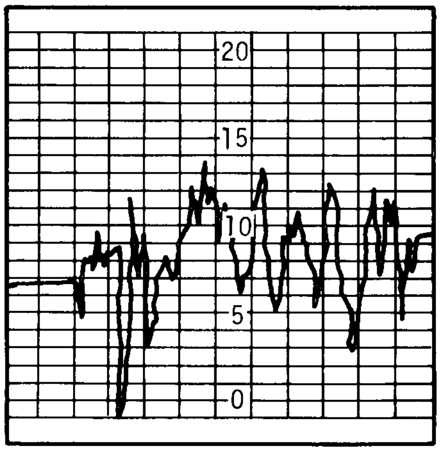
FIGURE 7-38. Cladding Roundness at Two Locations. Sample 18-C. Each Division = 0.0001 in. (2.54 μm)

Arithmetic average values for the fuel pellets ranged from 1.8 - 2.5 μm and those for the cladding ranged from 0.4 - 0.7 μm. Figures 7-39 and 7-40 show typical traces for the pellets and cladding; respectively, Table 7-8 summarizes the measurements.

The root mean square average for surface roughness is also commonly used. Roughness measuring instruments, calibrated for root mean square average, will read approximately 11% higher on a given surface than those calibrated for arithmetic average.

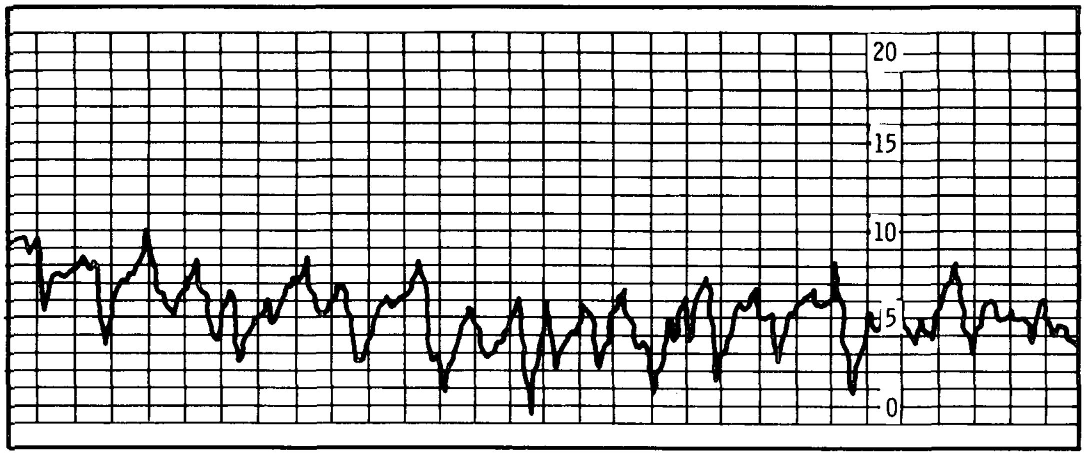


AXIAL

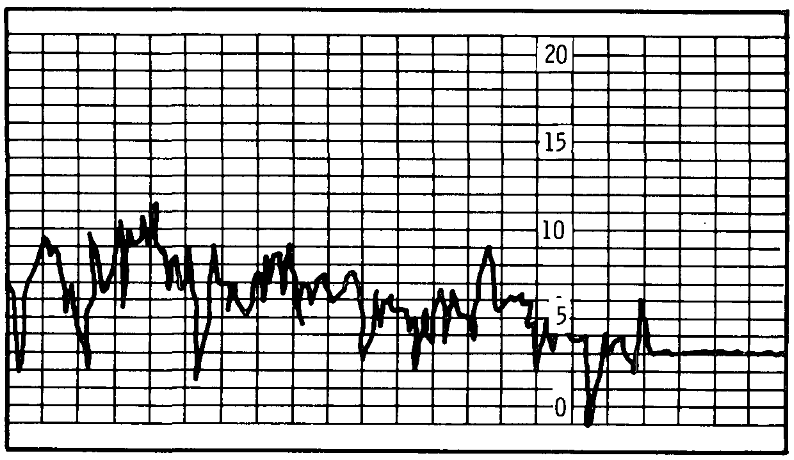


CIRCUMFERENTIAL

FIGURE-7-39. Axial and Circumferential Fuel Pellet Surface Roundness - Pellet 739. Each minor division = 50 μ in. (1.27 μm)



AXIAL



CIRCUMFERENTIAL

FIGURE 7-40. Axial and Circumferential Cladding Surface Roundness - Sample 18. Each minor division = 20 μ in. (0.51 μm)

TABLE 7-8. Summary of Pellet and Cladding Surface Roughness and Roundness Results

	Roundness Deviation		Surface Roughness - Arithmetic Average			
			Axial		Circumferential	
	μm	μin.	μm	μin.	μm	μin.
Pellet	6.4-14.0	250-550	2.0-2.8	80-110	1.8-2.6	71-104
Cladding	5.1-10.2	200-400	0.4-0.7	14-29	0.4-0.6	16-24

REFERENCES

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21. M.F. Lyons, et al., UO_2 Pellet Thermal Conductivity From Irradiation with Central Melting, GEAP-4624, 1964.

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8.0 FUEL ROD AND ASSEMBLY FABRICATION

The fabrication and assembly of IFA-431 and IFA-432 was a PNL and Halden joint project. Sections 6.0 and 7.0 describe fuel pellet fabrication and precharacterization; the responsibility of PNL. Following that work, PNL arranged the pellets in their stacking order and shipped them to Halden. Instrumentation was obtained from two sources: the Idaho National Engineering Laboratory (INEL) supplied thermocouples and Halden supplied all remaining instrumentation. Fuel assembly and inspection of the fuel rods and test assemblies was performed at Halden by Halden personnel.

PELLET STACKING AND SHIPPING

Prior to shipping, PNL arranged the fuel pellets in the desired stacking order (as detailed in Appendix I) for loading into the fuel rods by placing the ordered pellets in polyethylene tubing. To prevent contact and wearing of the pellets during shipping, the tubing was stapled between individual pellets. The fuels were then separated into two shipments, IFA-431 and IFA-432, and sent in DOT-6L containers to Norway via Air West and SAS airlines.

FUEL ROD PRE-IRRIADIATION MEASUREMENTS

Upon completion of assembly at Halden, the fuel rods were subjected to pre-irradiation dimensional characterization at the Kjeller Hot Laboratory: this characterization consisted of length, diameter, and profile measurements. The fuel rods were engraved for identification with their rod number on the lower end plug.

Measurements were made with a vertical profilometer bench; the fuel rods were inserted with their lower ends down. Dimensional measurements were then taken at two angles: 0° and 90°. Zero-degree orientation was specified with an orientation mark on the fuel rod facing the transducer that was making the measurements. Ninety-degree orientation was obtained by rotating the fuel rod 90° clockwise. Appendix J contains the resulting measurements.

INSTRUMENTATION

The following instrumentation was used to acquire the experimental data for the two fuel assemblies:

- fuel centerline thermocouples
- pressure transducers
- elongation detectors
- self-powered neutron detectors

The instrumentation for IFA-431 and IFA-432 is the same except for rod 2, IFA-432; it is equipped with an ultrasonic thermometer at the upper end instead of a thermocouple.

Thermocouples

The thermocouples were fabricated and calibrated by INEL. The thermocouples in both assemblies have grounded junctions with 0.1575 cm outer diameter W/22% Rh sheaths and W 5% Re/W 26% Re seven-stranded thermocouple wires. The thermocouples in IFA-431 have BeO insulators; those in IFA-432 ThO_2 for protection against higher temperatures.

Ultrasonic Thermometer

The ultrasonic thermometer, also fabricated by INEL, has a W/2% ThO_2 sensor and transmission line. The sensors are 8.13 cm long and 0.076 cm in diameter; the transmission line is 11.68 cm long and 0.038 cm in diameter.

Pressure Transducers

The pressure transducers, which measure the internal gas pressure of the fuel rods, are mounted on top of the rods and consist of a thin platinum membrane barrier which separates the gasses in the fuel rod from an external helium source with controlled pressure. The pressure balance across the membrane is indicated by an electric contact resting against the membrane. The fuel rod pressure is taken manually.

Elongation Detectors

The elongation detectors are of the Linear Variable Differential Transformer (LVDT)-type. The LVDT is an electromechanical transducer that produces an electrical output proportional to the displacement of a separate moveable core. In its simplest form, three coils are equally spaced on a cylindrical coil form; a rod-shaped magnetic core is positioned axially inside the coil assembly and provides a path for the magnetic flux linking the coils. Axial movement of the core produces a voltage output which varies linearly with changes in core position. As applied at Halden, the fuel rods are fixed at the upper end and are allowed to elongate in the downward direction. Therefore, the LVDT's are positioned below the lower end of the fuel rods with the LVDT's cores spring loaded and contacting the ends of each fuel rod. Axial elongation of a fuel rod causes the core to move which produces a change in the output voltage of the transducer.

Self-Powered Neutron Detectors

Each assembly is equipped with seven self-powered beta current neutron detectors: six of the detectors use vanadium as an absorber material and one uses cobalt. The vanadium detectors are used to determine the assembly power while the cobalt detector is used for transient experiments because of its rapid response.

DATA ACQUISITION

The outputs from the in-reactor instruments, except the pressure transducers, are connected to a process computer which will scan and log all instrument signals at 15-min intervals. The recorded data will be stored on discs for 24 hr and then transferred to magnetic tape for permanent storage, together with all the information necessary for interpretation of the recorded data.

The pressure transducer is scheduled to be taken manually six times during startup and shutdown, and five times during each 24-hr steady state period.

CLADDING CERTIFICATION

PNL supplemental cladding specifications agreed to by manufacturer.

1. Alloy Composition

   The chemical composition and impurity limits for grade RA-1 (Zry-2) shall conform to Table I of ASTM B353-71 with the maximum oxygen content not to exceed 0.14% by weight.

2. Mechanical Properties

   A) Tubes shall be supplied in the cold and stress relieved condition with the following tensile properties

Test Temperature	0.2% Offset Yield	Ultimate	Elongation in
Room Temperature	60 ksi (minimum)	70 ksi (minimum)	16%
720°F	32 ksi (minimum)	48 ksi (minimum)	16%

   B) Minimum burst pressure tests performed using the open end method. The circumferential elongation measured in the region of failure shall be at least 16%.

3. Dimensions

Inside Diameter	0.4295 ± 0.0005 in.
Outside Diameter	0.5035 ± 0.0010 in.
Wall Thickness, minimum	0.034 in.

   The ID, OD, and wall thickness shall be measured on a 100% basis on each tube and a measurement accuracy of 0.002 in.

4. Surface Finish

   The tubes are to be finished by an acid etch on the ID surface and belt polished on the OD surface to 45 in. or better.

5. Hydride Orientation Ratio

   The hydride orientation ratio shall not exceed 0.30.

During the construction of the fuel rods, Halden used the supplied Zry-2 tubing for specific fuel rods as listed below.

Fuel Rod	Tubing Identification IFA-431	IFA-432
1	8A	9C
2	4B	5C
3	6C	12B
4	12A	25A
5	27A	10C
6	7C	20B
7	-	7A
8	-	20A
9	-	23C

Sandvik Special Metals Corporation

P.O. BOX 6027 KENNEWICK, WASHINGTON 99336 PHONE (509) 586-4131

Invoice No. 4304

Invoice Date December 17, 1974

Your Order No. B5Y777-23524

Vendor Code No. L340

PLEASE REMIT TO:

XXX Sandvik Special Metals Corporation
P.O. Box 6027, Kennewick, Wa. 99336

☐ Sandvik Special Metals Corporation
P.O. Box 360524 M, Pittsburgh, Pa. 15230

Routing CONSOLIDATED FREIGHTWAYS

Shipped Via Truck

Terms Net 30 days

Service charge of 1% per month after_____days from date of invoice

SOLD TO

BATTELLE PACIFIC NORTHWEST LABORATORIES
P.O. Box 999
Richland, WA 99352

ATTN: Accounts Payable

Shipped To

BATTELLE
c/o ARCHO
1116 Building
Richland, WA 99352

Date Shipped December 17, 1974

Freight XXX Collect ☐ Prepaid

Item	Quantity		Unit Price	Amount U.S. Funds
1	1 lot	SANDVIK Zircaoly-2 Seamless Tubes OD 5035" x ID 4295" x Min. Wall 0.034" (tolerances best effort only). Spec. ASTM B353-71 & Supp. Battelle Spec.		

SHIPMENT NO. 1 & FINAL

Box No.	Lot No.	No. Pcs.	Length
473-001	9AF36	7	162" each
	9AF36	59	50" each

PACKING LIST & CERTIFICATION OF QUALITY INSIDE BOX

Gross: 101 lbs.
Tare: 48 lbs.
Net: 53 lbs.

xc: JE Rasberry/Battelle

 SSM-473

SANDVIK SPECIAL METALS CORP. CERTIFICATION OF QUALITY

P. O. BOX 6027 KENNEWICK, WASHINGTON 99336 PHONE (509) 586-4131

TO:	Battelle Pacific Northwest Laboratories	CERT NO:	74460
P. O. NO:	B5Y-777-23524	LOT NO:	9AF36
SPEC. NO:	ASTM B353-71 with exceptions	SSM NO:	473
DWG. NO:		INGOT NO:	393566Q
TYPE:	Sandvik Zircaloy-2 Tubes	Annealed:	918°F, 4 Hrs.
		SHIPMENT DATE:	12/17/74
		QUANTITY:	66

DIMENSIONS: ID: 0.4295" ± 0.0005"
OD: 0.5035" ± 0.0010"
Length: 59 pcs @ 50" ± 1/4"
7 pcs @ 162" ± 1/4"

TENSILE PROPERTIES			
Room	UTS, psi:	105,300	104,200
	0.2% YS, psi:	80,700	80,200
	Elong. 2 in., %:	22	23
720°F	UTS, psi:	64,100	62,600
	0.2% YS, psi:	46,500	46,000
	Elong. 2 in., %:	26.0	28.0
BURST TEST	With Mandrel	Open End	
	Circ. Elong., %:	17,300	17,400
	Circ. Elong. %:	50.0	48.0
HYDRIDE ORIENTATION			
F_n:	OD:	.06	.10
	Mid:	.04	.11
	ID:	.01	.09
CORROSION TEST	3 days	Etched	
Sample	Wt/dm^2:	17	15
	Color:	Lustrous Black	
Std.	Wt/dm^2:		
	Std. No:		
Post-Gaging Inner Surface Sample			
	Color:	Lustrous Black ID	
CHEMICAL ANALYSIS			
	Hydrogen:	17	
	Nitrogen:	21	
	Oxygen:	1200	
	Carbon:		
GRAIN SIZE			
	Long., ASTM:	11.0	11.0
	Trans., ASTM:	11.0	10.5
	Recrystallization Data:	1250°F, 45 minutes	

SURFACE ROUGHNESS

OD, RMS, microinch:	20	20
ID, RMS, microinch:	18	18

DIMENSIONS, STRAIGHTNESS, U/T FLAW & FREE PATH TEST:

We, SANDVIK SPECIAL METALS CORPORATION, certify that all tubes delivered in this lot conform to the requirements of your Purchase Order No. B5Y-777-23524

Manager, Quality Assurance — David R. McLemore, Quality Control Representative

STATE OF WASHINGTON } ss
COUNTY OF BENTON

Subscribed and sworn to before me this ________ day of ________

Notary Public in and for the State of Washington — Residing at

WAK-9

TELEDYNE WAH CHANG ALBANY

P. O. BOX 460
ALBANY, OREGON 97321
(503) 926-4211 TWX (510) 595-0973

TO ADDRESS: Sandvik Special Metals Corporation
P. O. Box 6027
Kennewick, WA 99336

ATTENTION OF: Don Darsow

IN REGARD TO YOUR PURCHASE ORDER NO	7238	DATE	July 1, 1974
ITEM NO	1B	DATE SHIPPED	Ref. P.L.# 3
* DESCRIPTION	Zircaloy- 2 Trex	QUANTITY SHIPPED	136 pcs. 6332.0 lbs.
DIMENSIONS	1.750" O.D.x.300" wall x 12'nom.L	PRODUCTION ORDER NO	B 3203
SPECIFICATIONS	SSM 1021-1 (dtd. 5/4/72) & P. O.	HEAT NO	393566Q Zr-2

THE TEST REPORT FOLLOWS:

*Rotary Forged, Extruded & Rocked - Unannealed

INGOT ANALYSIS

COMPOSITION IN PERCENT

	Spec.	Top	Middle	Bottom
Sn	1.20-1.70	1.56	1.58	1.44
Fe	0.07-0.20	0.15	0.16	0.13
Cr	0.05-0.15	0.10	0.12	0.10
Ni	0.03-0.08	0.06	0.06	0.05
Fe+Cr+Ni	0.18-0.38	0.31	0.34	0.28
Zr	B A L A N C E			

IMPURITIES IN PPM

	Spec.	Top	Middle	Bottom
Al	75	40	43	41
B	0.5	0.2	0.2	0.2
Cd	0.5	<0.2	<0.2	<0.2
Ca	30	<10	<10	<10
C	270	120	130	230
[illegible]	20	<5	<5	<5
Co	20	<10	<10	<10
Cu	50	12	13	12
Hf	100	65	66	69
H	25	<5	<5	8
[illegible]	130	<50	<50	<50
Mg	20	<10	<10	<10
Mn	50	<25	<25	<25
N	80	29	28	34
[illegible]	200	<50	<50	<50
[illegible]	[illegible]0	<25	<25	<25
[illegible]	100	<25	<25	<25
[illegible]	3.[illegible]	1.6	1.1	0.8
[illegible]	[illegible] 140	1190	1130	1350
[illegible]	120	<50	<50	<50
[illegible]	50	<25	<25	<25
[illegible]	200	<100	<100	<100
[illegible]	50	<25	<25	<25
[illegible]	20	<10	<10	<10

INGOT HARDNESS, BHN

[illegible]	(200 max)	163 - 172
Average	(187 max)	168

Ingot contains 77.7 % Sponge.
Spec. min: 40%

TUBE SHELL ANNEAL

Intermediate vacuum anneal
2 hrs @ 1200 °F.

PRODUCT CHEMISTRY, PPM

Element	Spec. max:	1	2
N	80	29	19
H	25	10	16

MICRO NO. 00-574

ASTM GRAIN SIZE AVERAGE

Spec. max: 6

Sample	Results
Long. #1	11.5
Long. #2	11.5

TUBE SHELL ULTRASONIC TEST RESULTS

PS-U10-Rev. 1 (0.012" defect level)
Results - Acceptable

TREX IDENTITY

Per attached layout sheet

rlb

ANALYSIS CERTIFIED BY: Harold G. Cheel

J. R. Sutherlin
Quality Assurance Mgr.

TO ADDRESS
Sandvik Special Metals Corporation
P. O. Box 6027
Kennewick, WA 99336

TELEDYNE WAH CHANG ALBANY

WAK-9

P. O. BOX 460
ALBANY, OREGON 97321
(503) 926-4211 TWX (510) 595-0973

ATTENTION OF: Don Darsow

IN REGARD TO YOUR PURCHASE ORDER NO	7238	DATE	July 1, 1974
ITEM NO	1B	DATE SHIPPED	Ref. P.L.# 3
* DESCRIPTION	Zircaloy- 2 Trex	QUANTITY SHIPPED	136 pcs. 6332.0 lbs.
DIMENSIONS	1.750" O.D.x.300" wall x 12'nom.L	PRODUCTION ORDER NO	B 3203
SPECIFICATIONS	SSM 1021-1 (dtd. 5/4/72) & P. O.	HEAT NO	393566Q Zr-2

THE TEST REPORT FOLLOWS:

*Rotary Forged, Extruded & Rocked - Unannealed

INGOT ANALYSIS

COMPOSITION IN PERCENT

	Spec.	Top	Middle	Bottom
Sn	1.20-1.70	1.56	1.58	1.44
Fe	0.07-0.20	0.15	0.16	0.13
Cr	0.05-0.15	0.10	0.12	0.10
Ni	0.03-0.08	0.06	0.06	0.05
Fe+Cr+Ni	0.18-0.38	0.31	0.34	0.28
Zr	B A L A N C E			

IMPURITIES IN PPM

	Spec.	Top	Middle	Bottom
Al	75	40	43	41
B	0.5	0.2	0.2	0.2
Cd	0.5	<0.2	<0.2	<0.2
Ca	30	<10	<10	<10
C	270	120	130	230
Cl	20	<5	<5	<5
Co	20	<10	<10	<10
Cu	50	12	13	12
Hf	100	65	66	69
H	25	<5	<5	8
Pb	130	<50	<50	<50
Mg	20	<10	<10	<10
Mn	50	<25	<25	<25
N	80	29	28	34
Si	200	<50	<50	<50
Ti	50	<25	<25	<25
W	100	<25	<25	<25
U	3.5	1.6	1.1	0.8
O	900-1400	1190	1130	1350
Cb	120	<50	<50	<50
Mo	50	<25	<25	<25
Ta	200	<100	<100	<100
V	50	<25	<25	<25
Na	20	<10	<10	<10

INGOT HARDNESS, BHN

Range	(200 max)	163 - 172
Average	(187 max)	168

Ingot contains 77.7 % Sponge.
Spec. min: 40%

TUBE SHELL ANNEAL

Intermediate vacuum anneal
2 hrs @ 1200 °F.

PRODUCT CHEMISTRY, PPM

Element	Spec. max:	1	2
N	80	29	19
H	25	10	16

MICRO NO. 00-574

ASTM GRAIN SIZE AVERAGE

Spec. max: 6

Sample	Results
Long. #1	11.5
Long. #2	11.5

TUBE SHELL ULTRASONIC TEST RESULTS

PS-U10-Rev. 1 (0.012" defect level)
Results - Acceptable

TREX IDENTITY

Per attached layout sheet

rlb
ANALYSIS CERTIFIED BY Howard Gilbert
for J. R. Sutherlin
Quality Assurance Mgr.

WAK-9

GENERAL ELECTRIC

NUCLEAR ENERGY DIVISION

GENERAL ELECTRIC COMPANY . . . . . . VALLECITOS NUCLEAR CENTER
VALLECITOS ROAD, PLEASANTON, CALIFORNIA 94566, Phone (415) 862-2211

IRRADIATION PROCESSING OPERATION

REACTIVITY TEST CERTIFICATION

Page 1 of 1

Customer Name Sandvik Special Metals Corp. Service Order# MC 5419
Customer P.O.# 0009 Date September 4, 1974
G.E. Requisition# 254-F3825

1.0 Certification Record
This is to certify that the listed samples were Reactivity Tested at the General Electric Nuclear Test Reactor per specification None.
No determination was made for acceptability or rejectability of the samples.

2.0

	Sample Identification	Test Values	Error Limits
2.1	3566-A1 & 2	37.652 PPM BEQ	None
2.2	3133-B1-6	36.334 PPM BEQ	None
2.3	3129-C1-6	37.885 PPM BEQ	None
2.4			
2.5			
2.6			
2.7			
2.8			
2.9			
2.10			
2.11			
2.12			
2.13			
2.14			
2.15			

RECEIVED
SEP 9 1974
Sandvik Special Metals Corp.

3.0 Date of Test 9/3/74

4.0 Reactor Run No. 6194

5.0 Standards Used for Test: See Below [] N/A [x]

5.1 ____ 5.5 ____ 5.9 ____
5.2 ____ 5.6 ____ 5.10 ____
5.3 ____ 5.7 ____ 5.11 ____
5.4 ____ 5.8 ____ 5.12 ____

General Electric Nuclear Test Reactor

IRRADIATION SERVICES AND RADIOISOTOPES FOR RESEARCH AND INDUSTRY

TO ADDRESS Sandvik Special Metals Corporation
P. O. Box 6027
Kennewick, WA 99336

TELEDYNE WAH CHANG ALBANY WAK-9

P. O. BOX 460
ALBANY, OREGON 97321
(503) 926-4211 TWX (510) 595-0973

ATTENTION OF: D. W. Darsow

IN REGARD TO YOUR PURCHASE ORDER NO	0042	DATE	September 20, 1974
ITEM NO	1	DATE SHIPPED	---
DESCRIPTION	Chemical analysis of Grad RA-1 Zr2	QUANTITY SHIPPED	---
DIMENSIONS	samples per ASTM B353-71	PRODUCTION ORDER NO	C 8955
SPECIFICATIONS	---	HEAT NO	---

THE TEST REPORT FOLLOWS:

ANALYSIS IN PPM

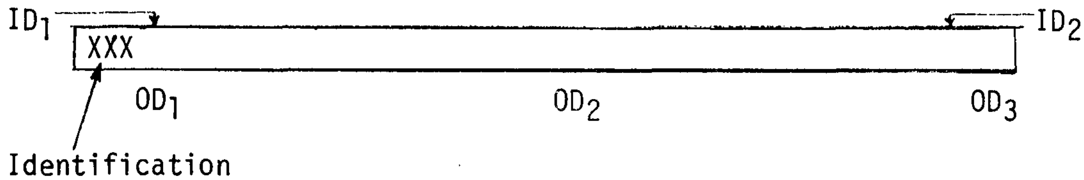
	AB-30	AC-30	AF
C	120	130	100
O	1220	1220	1150
N	26	32	22
H	8	9	12
Hf	50	48	60
Cb	<50	<50	<50
Ta	<100	<100	<100
Sn	1.46%	1.52%	1.49%
Fe	1240	1330	1390
Cr	970	1050	1090
Ni	510	510	560
Cu	12	12	12
Al	35	38	42
B	0.2	0.2	0.2
Cd	<0.2	<0.2	<0.2
Co	<10	<10	<10
Mg	<10	<10	<10
Mn	<25	<25	<25
Mo	<25	<25	<25
Pb	<50	<50	<50
Si	<50	<50	<50
Ti	<25	<25	<25
U	1.0	1.1	1.4
V	<25	<25	<25
W	<25	<25	<25
Cl	<5	<5	<5

RECEIVED
SEP 24 1974
Sandvik Special Metals Corp.

ANALYSIS CERTIFIED BY H. J. Reed
kb
Acting Quality Assurance Manager

Zircaloy-2 Tubing Measurements

Zircaloy-2 tubing measurements on the 16 tubes furnished by BNW for IFA-431 and 432 were made by BNW on December 13, 1974. Outside diameter measurements were made at three locations, near each end and the center. Inside diameter measurements were made at each end of the tube. All measurements are in millimeters.



Tube Ident.	OD_1	OD_2	OD_3	ID_1	ID_2	Length
7A	12.779	12.781	12.779	10.899	10.904	1269.5
8A	12,779	12,779	12.779	10.902	10.904	1269.5
12A	12,779	12,781	12,779	10.899	10.902	1269.7
20A	12,776	12,781	12.781	10.902	10.894	1269.7
25A	12.784	12.779	12.781	10.902	10.902	1269.5
27A	12.781	12.781	12.779	10.904	10.904	1269.5
4B	12.779	12.781	12.779	10.902	10.902	1269.7
12B	12.771	12.779	12.779	10.894	10.904	1269.5
20B	12.779	12.779	12.776	10.902	10.897	1269.7
5C	12.784	12.781	12.784	10.894	10.907	1269.5
6C	12.781	12.784	12.779	10.907	10.904	1269.5
7C	12.776	12.779	12.779	10.902	10.907	1269.7
9C	12.789	12.784	12.784	10.902	10.909	1269.5
10C	12.781	12.781	12.779	10.904	10.904	1269.5
19C	12.779	12.781	12.779	10.899	10.899	1269.7
23C	12.776	12.779	12.779	10.899	10.902	1269.7

PRETEST PREDICTIONS FOR IFA-431 AND IFA-432

Pretest predictions for both fuel assemblies were performed at PNL using the codes GAPCON-THERMAL-2[1] (9/1/1974 version, developed by PNL) and FRAP-S[2] (MOD001-EXPR004-MATPRO-MOD-3, developed by ANC). Input, and results, presented here for each code was based upon planned assembly configuration and materials, and in some cases (e.g. fuel and cladding surface roughness) found later to differ from precharacterization measurements. The input used for these predictions is summarized in Tables B-1 through B-4, and the assumed axial profile is presented in Figure B-1. To simulate burnup effects, three power cycles were assumed with a total burnup of approximately 12,000 MWd/MTM for IFA-431 and approximately 25,000 MWd/MTM for IFA-432. Figures B-2 through B-13 summarize the predictions.

Two major differences were observed between the GAPCON-THERMAL-2 and FRAP-S versions used in these predictions. First, FRAP-S did not have a densification model for analyzing the expected densification of the 92% TD-U fuel in Rod 6. Second, FRAP-S did not have an option for 100% Xe fill gas, thus necessitating the use of Ar for the Rod 4 predictions. For comparison, GAPCON-THERMAL-2 was run with both Xe and Ar fill gas for Rod 4.

(a) Input units and definitions are listed as required for input and defined by manuals.

TABLE B-1. Input for GAPCON-THERMAL-2 Pretest Predictions for IFA-431

Variable	Rod Type 1	2	3	4	5	6
DFS	0.4201	0.4145	0.4275	0.4205	0.4203	0.4204
FRDEN	0.95	0.95	0.95	0.95	0.92	0.92
FRACHE	1.0	1.0	1.0	0.0	1.0	1.0
FRACXE	0.0	0.0	0.0	1.0	0.0	0.0
VPLENZ	0.108	0.118	0.080	0.125	0.109	0.095
LFUEL	22.59	22.63	22.89	23.82	22.84	22.68
LVOIDZ	22.59	22.63	22.89	23.82	22.84	22.68
IDENSF	0	0	0	0	0	1

Common to all rods

ATMOS	1	NCON	0
DCI	0.4293	NFLX	9
DCO	0.5032	NPOW	10
DTEMP	10.0	NPRFIL	1
FR35	0.1	NTIME	15
EXTP	500.0	ROUF	0.3×10^{-4}
IPEAK	0	ROUC	0.12×10^{-4}
IRELOC	1	TINLET	457.0
DVOIDZ	0.0685	ZCLAD	-1
NCLAD	0	IT	0

PROFIL 1.00, 1.07, 1.14, 1.20, 1.25, 1.28, 1.31, 1.34, 1.35, 1.35, 1.34

PSEUDO 2.0, 2.0, 4.0, 6.0, 8.0, 10.0, 10.0, 0.0, 10.0, 0.0, 10.0, 0.0, 10.0, 10.0, 10.0

TIME 0.0, 0.08, 0.2, 0.3, 0.4, 0.5, 2.5, 3.5, 5.5, 6.5, 8.5, 9.5, 70.0, 140.0, 280.0

TABLE B-2. Input for FRAP-S Pretest Predictions for IFA-431

Variable	Rod Type 1	2	3	4	5	6
DP	0.4201	0.4145	0.4275	0.4205	0.4203	0.4204
DEN	95.0	95.0	95.0	95.0	92.0	92.0
IDXGAS	1.0	1.0	1.0	5.0	1.0	1.0

Common to all rods

CPL	0.7460	JDLPR	1.0
DCI	0.4293	JN	11
DCO	0.5032	NT	11
DE	0.0	P2	15 x 1050.0
DSPG	0.350	RDISN	0.0
DSPGW	0.039	ROUGHF	0.3×10^{-4}
ENRCH	10.0	ROUGHC	0.12×10^{-4}
FGPAV	14.7	TOTL	1.8825
GO[(a)]	15 x 0.0	VS	8.0
HDISH	0.0	FA	2.0
HPLT	0.5	ICOR	4.0
ICM	2.0	NOPT	0
IM	15.0	NSP	1
IQ	0.0	PPMN2	0.0
IPLANT	2.0	RC	0.03425

TIME	0.01, 2.4, 4.8, 7.2, 9.6, 12.0, 60.0, 84.0, 132.0, 156.0, 204.0, 228.0, 1680.0, 3360.0, 6720.0
QMPY	1.481, 1.481, 2.963, 4.444, 5.926, 7.407, 7.407, 0.001, 7.407, 0.001, 7.407, 0.001, 7.407, 7.407, 7.407
TW	476.0, 476.0, 479.0, 481.0, 484.0, 487.0, 487.0, 474.0, 486.0, 474.0, 486.0, 474.0, 487.0, 487.0, 487.0
QF	1.00, 1.07, 1.14, 1.20, 1.25, 1.28, 1.31, 1.34, 1.35, 1.35, 1.34
X	0.00, 0.19, 0.38, 0.56, 0.75, 0.94, 1.13, 1.31, 1.51, 1.69, 1.88

(a) 15 x 0.0 is shorthand for 15 values of 0.0.

TABLE B-3. Input for GAPCON-THERMAL-2 Pretest Predictions for IFA-432

Variable	Rod Type 1	2	3	4	5	6
DFS	0.4205	0.4143	0.4264	0.4204	0.4203	0.4203
FRDEN	0.95	0.95	0.95	0.95	0.92	0.92
FRACHE	1.0	1.0	1.0	0.0	1.0	1.0
FRACXE	0.0	0.0	0.0	1.0	0.0	0.0
VPLENZ	0.123	0.139	0.108	0.139	0.120	0.135
LFUEL	23.50	23.24	23.46	23.24	23.53	23.42
LVOIDZ	23.50	23.24	23.46	23.24	23.53	23.42
IDENSF	0	0	0	0	0	1

Common to all rods

ATMOS	1.0	NFLX	9
DCI	0.4293	NPOW	10
DCO	0.5032	NPRFIL	1
DTEMP	10.0	NTIME	15
FR35	0.1	ROUF	0.3×10^{-4}
EXTP	1050.0	ROUC	0.12×10^{-4}
IPEAK	0	SIGHF	2.5×10^{4}
IRELOC	1	TINLET	464
DVOIDZ	0.0685	ZCLAD	-1
NCLAD	0	IT	0
NCON	0		

PROFIL 1.00, 1.07, 1.14, 1.20, 1.25, 1.28, 1.31, 1.34, 1.35, 1.35, 1.34

PSEUDO 2.0, 4.0, 8.0, 12.0, 16.0, 16.0, 0.0, 16.0, 0.0, 16.0, 0.0, 16.0, 16.0, 16.0, 16.0

TIME 0.0, 0.1, 0.2, 0.3, 0.4, 5.0, 6.0, 7.0, 8.0, 9.0, 10.0, 50.0, 150.0, 250.0, 350.0

TABLE B-4. Input for FRAP-S Pretest Predictions for IFA-432

Variable	Rod Type 1	2	3	4	5	6
DP	0.4205	0.4143	0.4264	0.4204	0.4203	0.4203
DEN	95.0	95.0	95.0	95.0	92.0	92.0
IDXGAS	1.0	1.0	1.0	5.0	1.0	1.0
CPL	0.9143	1.0250	0.8106	1.0250	0.8935	0.9972
TOTL	1.958	1.937	1.955	1.937	1.961	1.952
X	0.0	0.0	0.0	0.0	0.0	0.0
	0.1958	0.1937	0.1955	0.1937	0.1961	0.1952
	0.3916	0.3874	0.3910	0.3874	0.3922	0.3904
	0.5874	0.5811	0.5685	0.5811	0.5883	0.5856
	0.7832	0.7748	0.7820	0.7748	0.7844	0.7808
	0.9790	0.9685	0.9775	0.9685	0.9805	0.9760
	1.1748	1.1622	1.1730	1.1622	1.1766	1.1712
	1.3706	1.3559	1.3685	1.3559	1.3727	1.3664
	1.5564	1.5496	1.5640	1.5496	1.5688	1.5616
	1.7622	1.7433	1.7595	1.7433	1.7649	1.7568
	1.9580	1.9370	1.9550	1.9370	1.9610	1.9520

Common to all rods

DCI	0.4293	JDLPR	1.0
DCO	0.5032	JN	11.0
DE	0.0	NT	11.0
DSPG	0.350	P2	15 x 1050.0
DSPGW	0.039	RDISH	0.0
ENRCH	10.0	ROUGHF	0.3×10^{-4}
FGPAV	14.7	ROUGHC	0.12×10^{-4}
GO[(a)]	15 x 0.0	VS	8.0
HDISH	0.0	FA	2.0
HPLT	0.5	ICOR	5.0
ICM	2.0	NOPT	0.0
IM	15.0	NSP	1.0
IQ	0.0	PPMNZ	0.0
IPLANT	2.0	RC	0.03425

QF	0.741, 0.793, 0.844, 0.893, 0.923, 0.950, 0.969, 0.992, 1.000, 1.000, 0.992
QMPY	2.0, 4.0, 8.0, 12.0, 16.0, 16.0, 0.001, 16.0, 0.001, 16.0, 0.001, 16.0, 16.0, 16.0, 16.0
TIME	0.01, 2.4, 4.8, 7.2, 9.6, 120.0, 144.0, 168.0, 192.0, 216.0, 240.0, 1200.0, 3600.0, 6000.0, 8400.0
T	475.0, 477.0, 481.0, 485.0, 490.0, 490.0, 473.0, 490.0, 473.0, 490.0, 473.0, 490.0, 490.0, 490.0, 490.0

(a) 15 x 0.0 is shorthand for 15 values of 0.0.

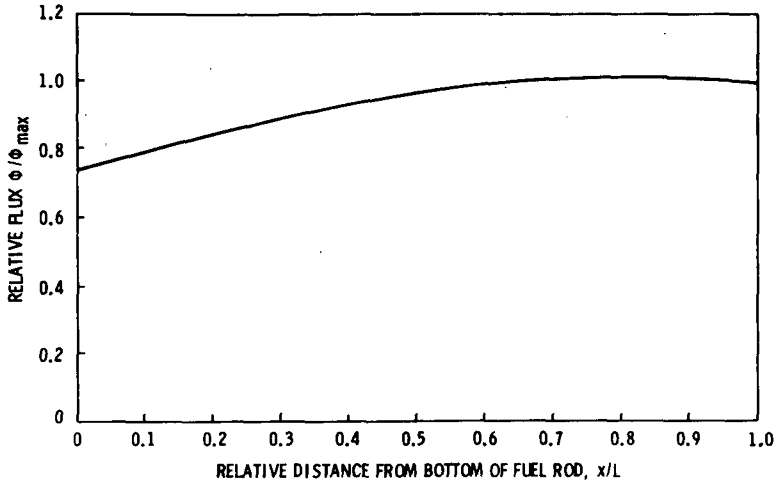


FIGURE B-1. Axial Flux Profile Used on Pretest Predictions for IFA-431 and IFA-432

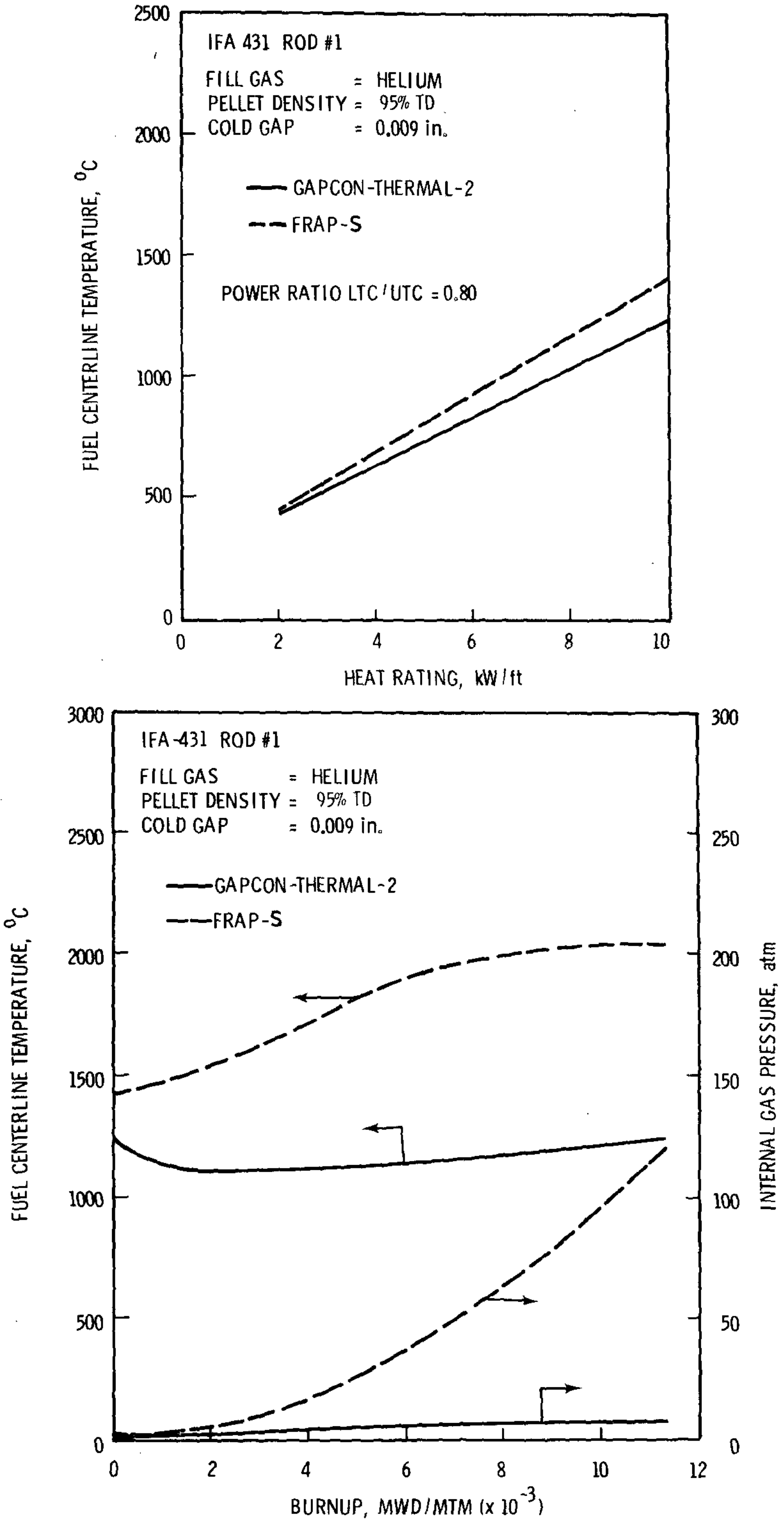


FIGURE B-2. Predictions for IFA-431, Rod 1 (100% He, 95% TD-S UO_2, 0.0229 cm cold gap)

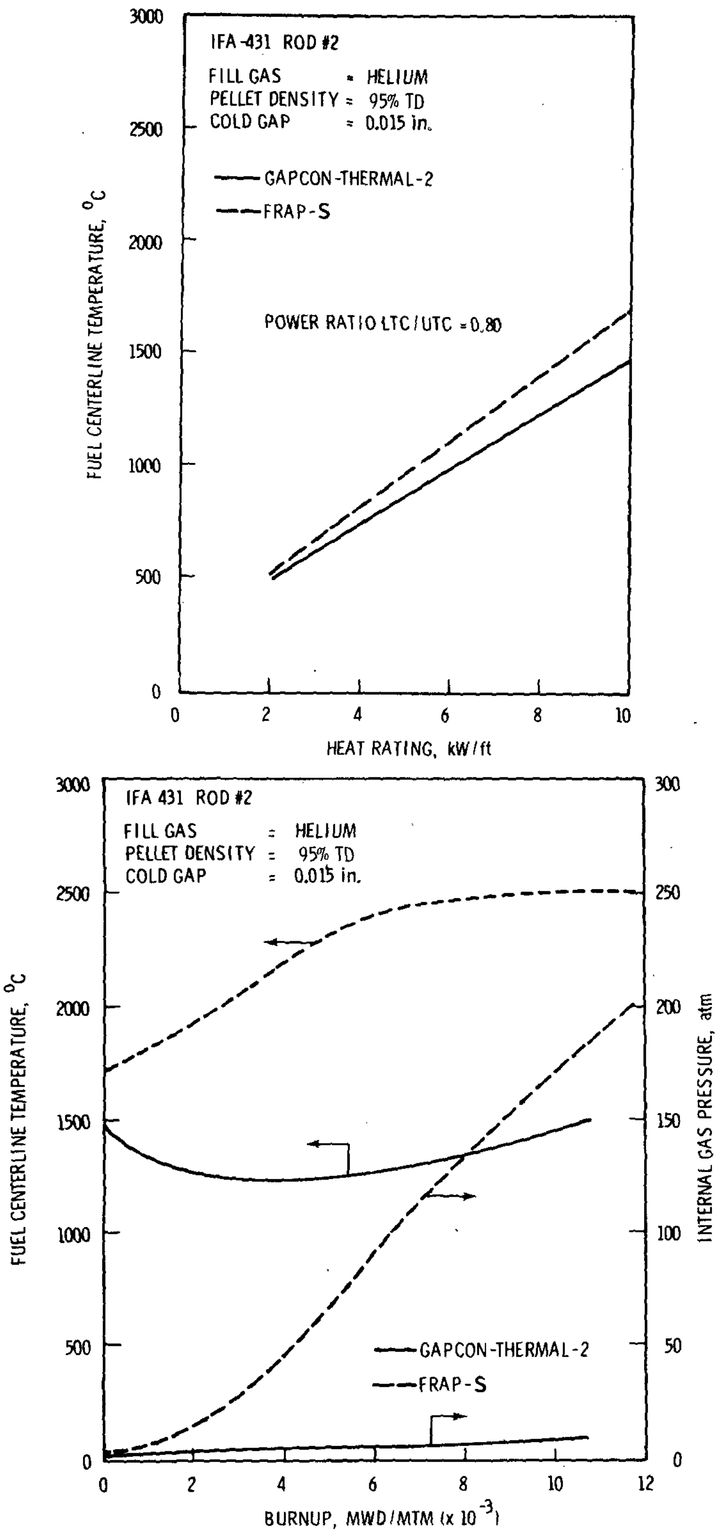


FIGURE B-3. Predictions for IFA-431, Rod 2 (100% He, 95% TD-S UO_2, 0.0381 cm cold gap)

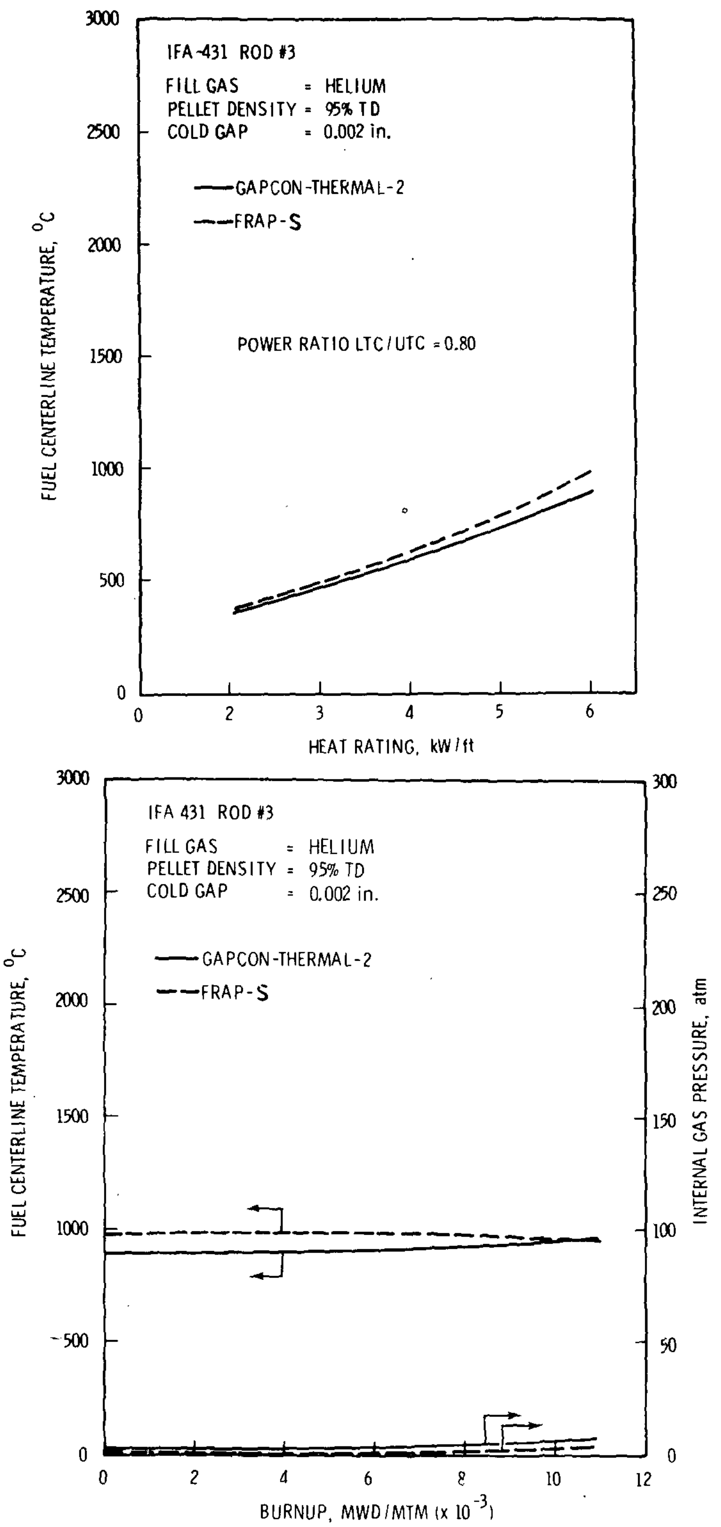


FIGURE B-4. Predictions for IFA-431 Rod, 3 (100% He, 95% TD-S UO_2 0.0051 cm cold gap)

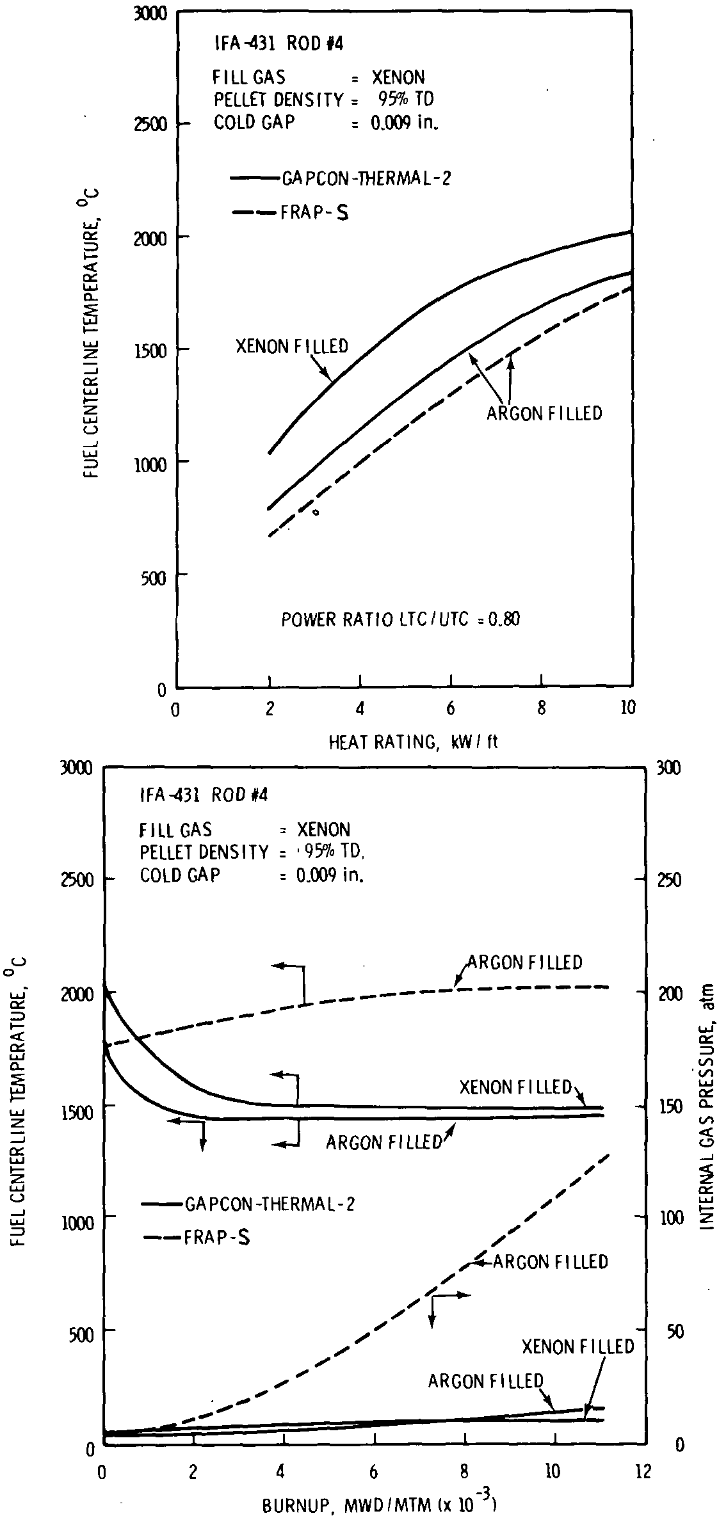


FIGURE B-5. Predictions for IFA-431, Rod 4 (100% Xe, 95% TD-S UO_2, 0.0229 cm cold gap)

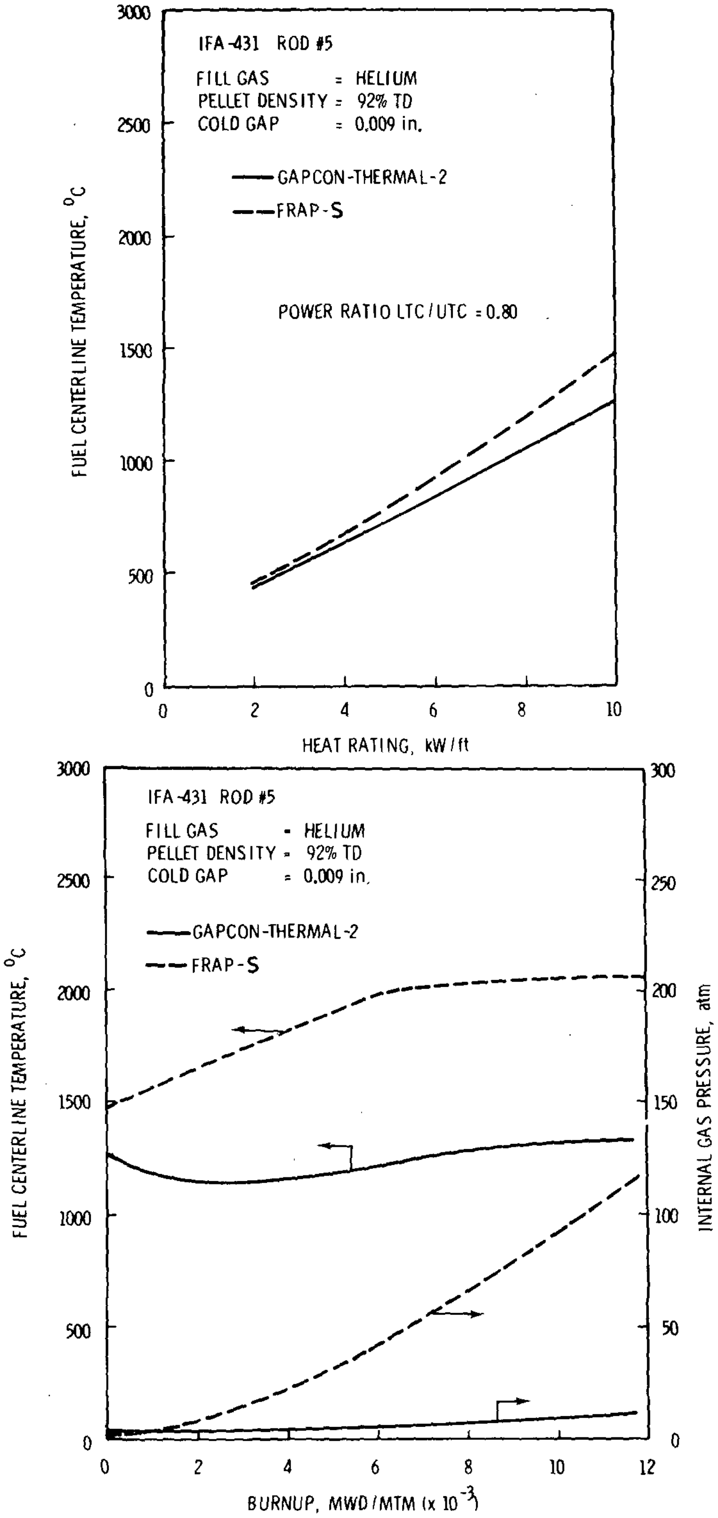


FIGURE B-6. Predictions for IFA-431 Rod 5 (100% He, 92% TD-S UO_2 0.0229 cm cold gap)

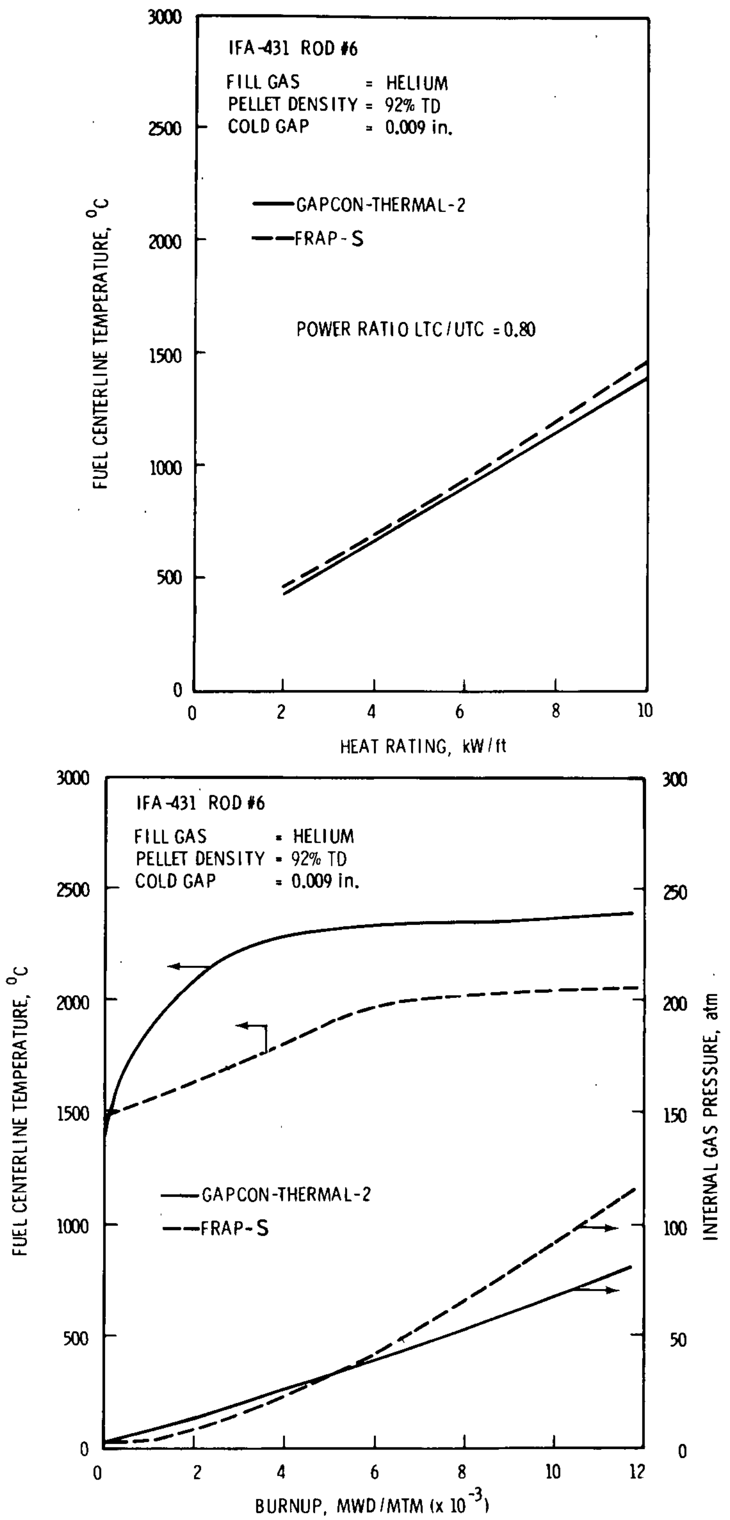
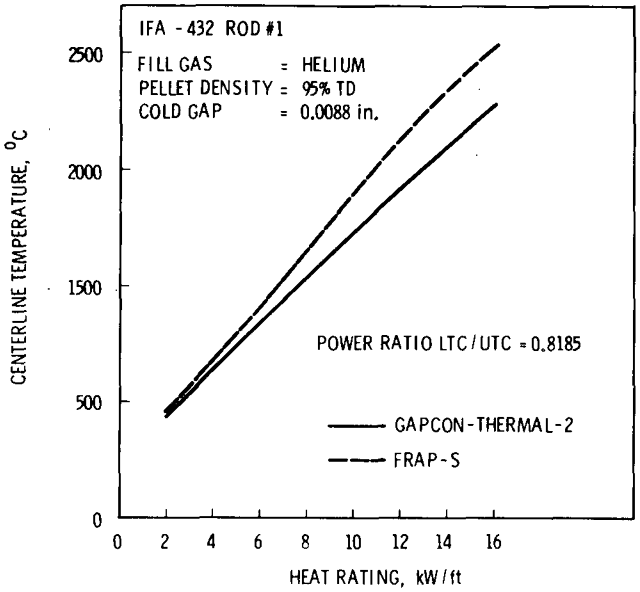


FIGURE B-7. Predictions for IFA-431, Rod 6 (100% He, 92% TD-U UO_2, 0.0229 cm cold gap)



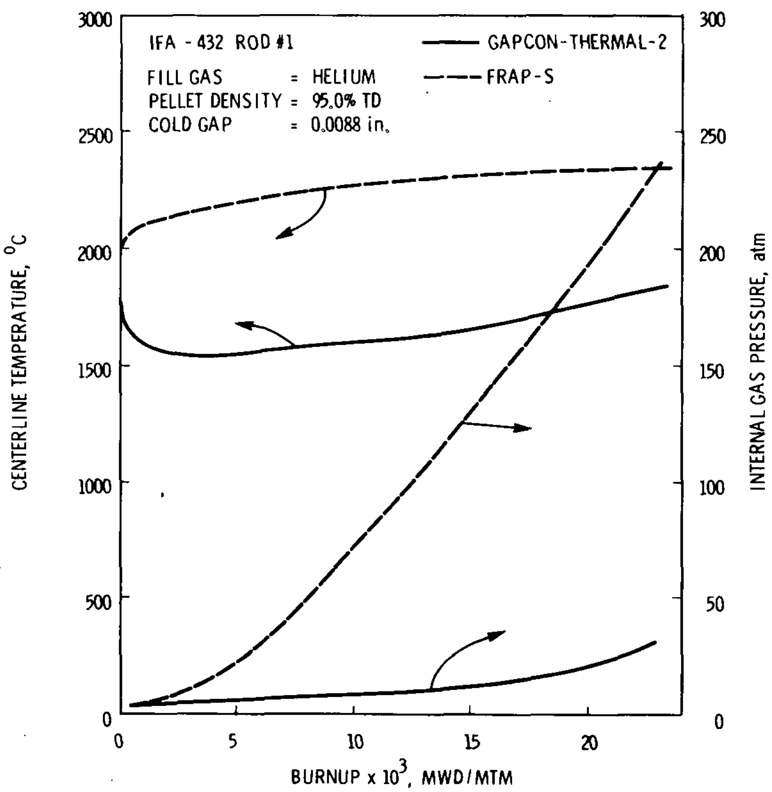
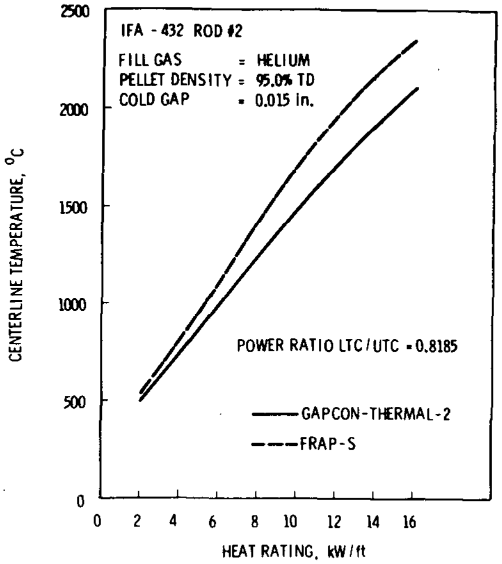


FIGURE B-8. Predictions for IFA-432, Rod 1 (100% He, 95% TD-S UO_2 0.0229 cm cold gap)



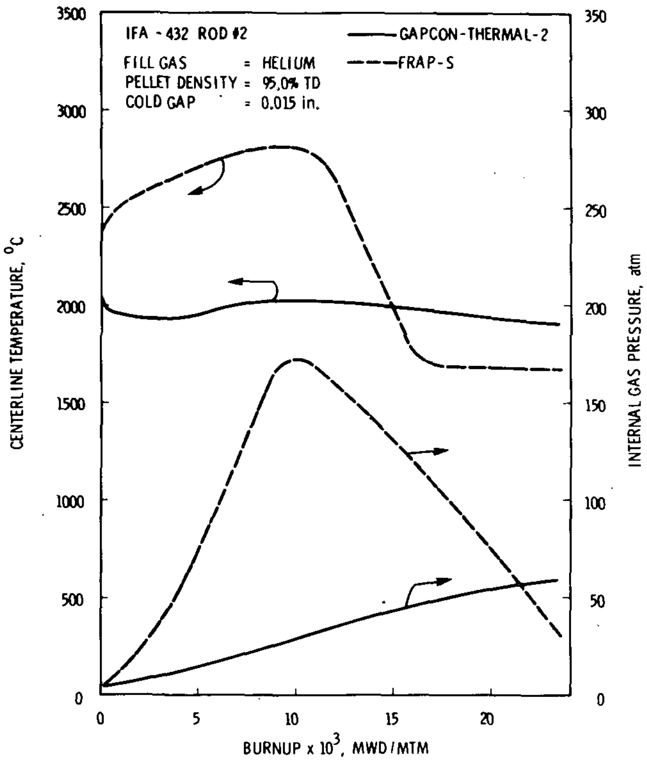
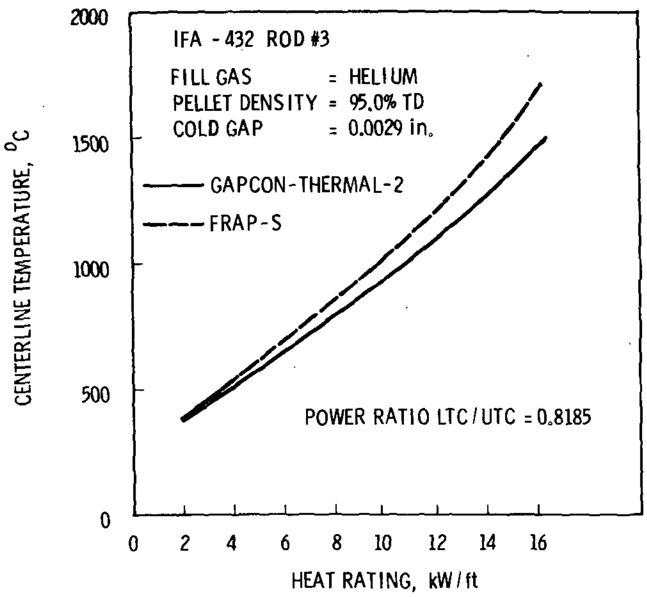


FIGURE B-9. Predictions for IFA-432, Rod 2 (100% He, 95% TD-S UO_2 0.0381 cm cold gap)



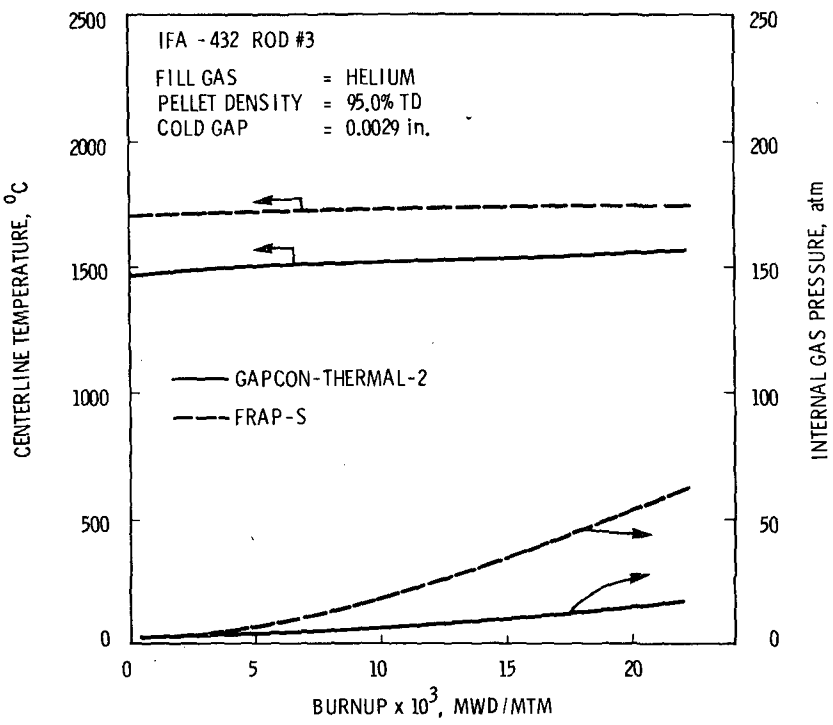


FIGURE B-10. Predictions for IFA-432, Rod 3 (100% He, 95% TD-S UO_2 0.0076 cm cold gap)

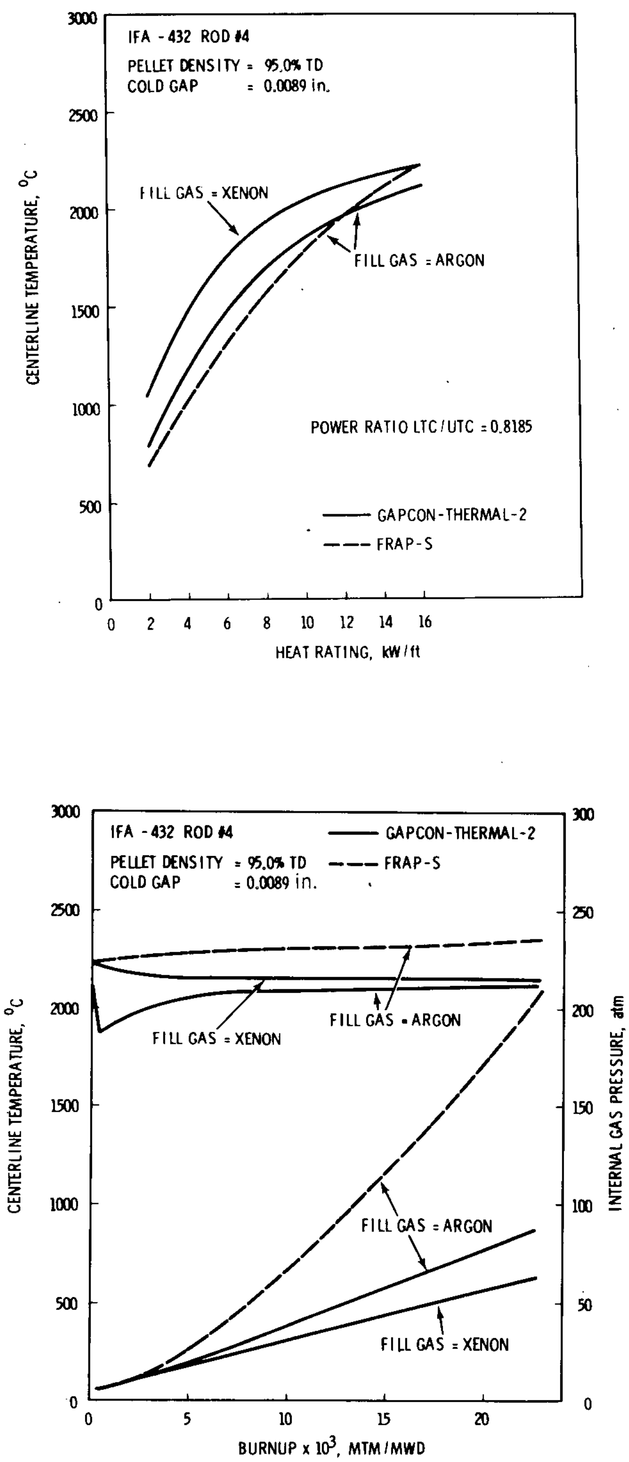
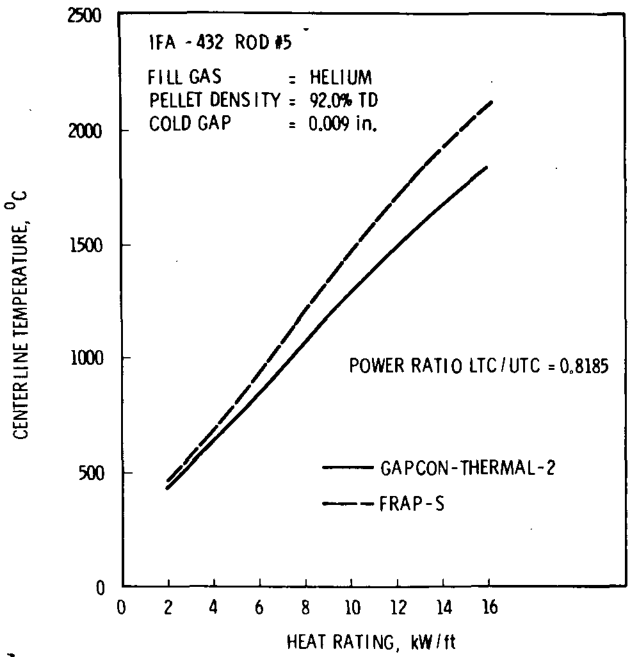


FIGURE B-11. Predictions for IFA-432, Rod 4 (100% Xe, 95% TD-S UO_2 0.0229 cm cold gap)



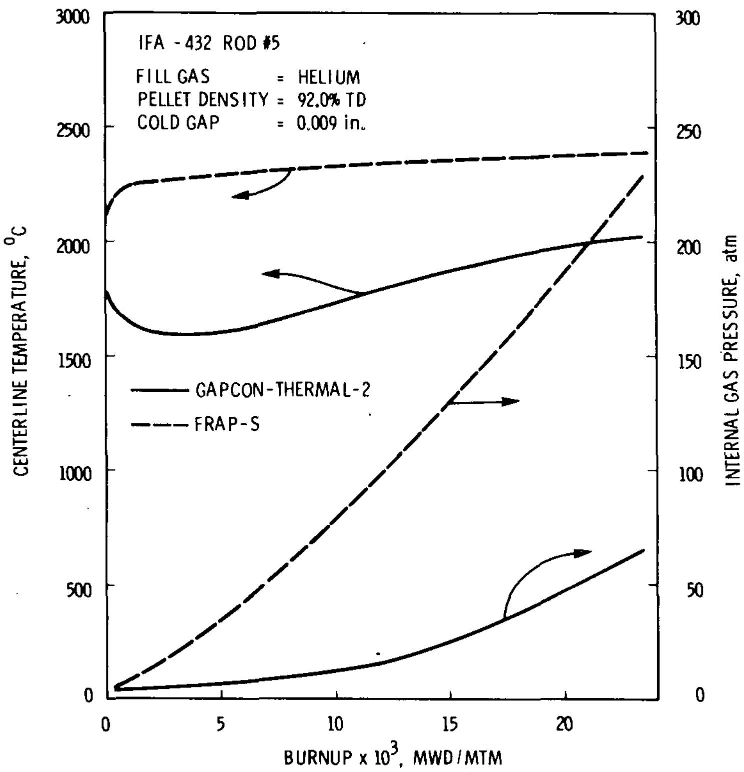
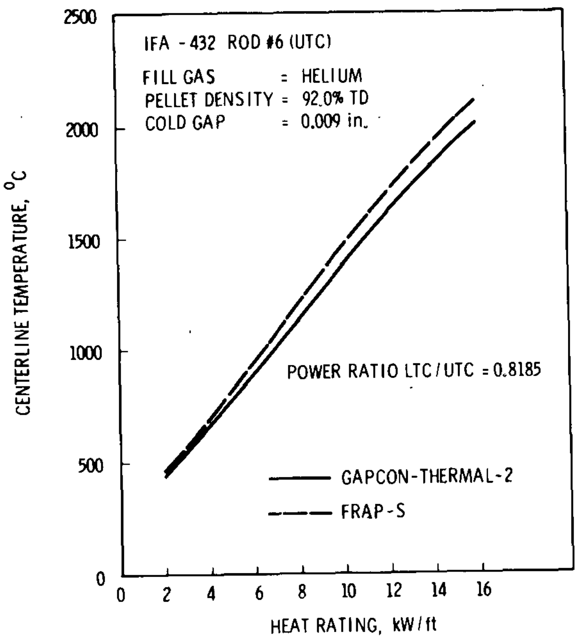


FIGURE B-12. Predictions for IFA-432, Rod 5 (100% He, 92% TD-S UO_2, 0.0229 cm cold gap)



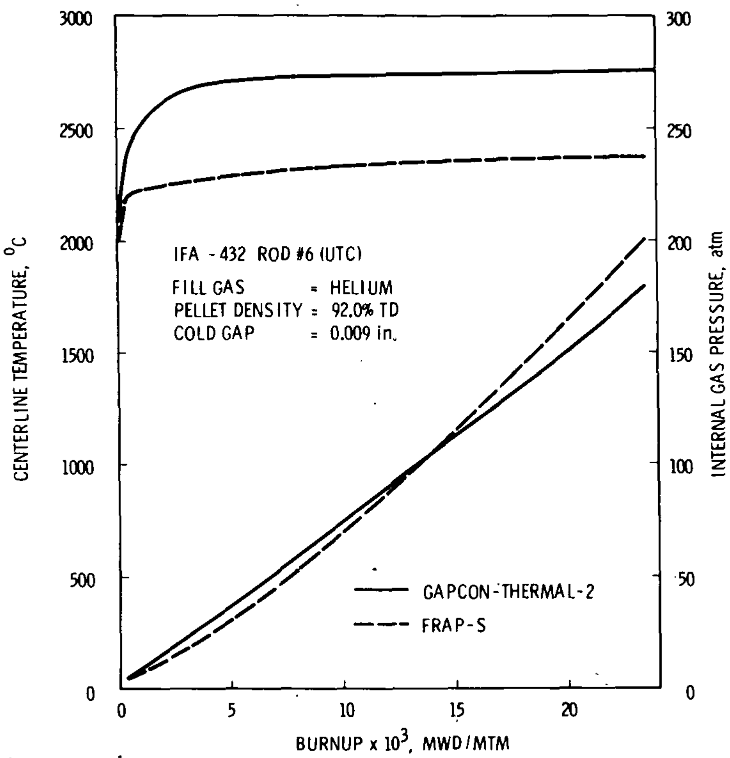


FIGURE B-13. Predictions for IFA-432, Rod 6 (100% He, 92% TD-U UO_2, 0.0229 cm cold gap)

REFERENCES

1. C.E. Beyer, C.R. Hann, D.D. Lanning, F.E. Panisko, and L.J. Parchen, GAPCON-THERMAL-2: A Computer Program for Calculating the Thermal Behavior of an Oxide Fuel Rod, BNWL-1898, Battelle, Pacific Northwest Laboratories, Richland, WA, November 1975.
2. J.A. Dearien, G.A. Berna, M.P. Bohn, D.R. Coleman, P.E. MacDonald, and J.M. Broughton, FRAP-S: A Computer Code for the Steady State Analysis of Oxide Fuel Rods, Volume 1, FRAP-S Analytical Models and Input Manual, INEL Report I-309-1301, January 1975.

UO_2 PELLET FABRICATION PROCESS CONDITIONS AND CERTIFICATION

The procedure followed in the fabrication of fuel pellets for IFA-431 and IFA-432 is outlined in Section 6.0. This appendix provides a record of the original specifications, process parameters, and general summary of the final pellet properties.

The pellets were accumulated at the pellet press into batches, whose identities were maintained throughout sintering, grinding, and inspection. Pellets included in each inspection batch are from a single furnace run. All pellets are from the same starting UO_2 powder lot; lot number 2. For IFA-431 and IFA-432, the 10% enriched, UO_2 pellets were pressed, sintered, and inspected as Pellet Inspection Batches 4, 5, and 6. Following the Powder Certification, Table C.1 summarizes the initial UO_2 powder properties, while Table C.2 identifies each pellet as to power lot number, pellet batch number, and parameter sheet number.

The parameter sheets list the pellet fabrication process parameters that were developed and approved for the fuel pellet fabrication. Following each parameter sheet, the Pellet Fabrication Follower Data Sheet is included. Tables C.3-C.5 list the disposition of each pellet batch. The green pellet properties for each batch are listed in Table C.6 and provide a comparison with the specified properties on the parameter sheets. A final inspection was carried out for each pellet (as discussed in Section 7); Table C.7 summarize those results for each batch. Table C.8 lists the chemical analysis results for each pellet batch.

TABLE C.1. UO_2 Powder Properties, IFA-431 and IFA-432

UO_2 Powder Lot	2
ANC 18% Enriched UO_2 Blend No.	27 (97.7%)
	26 (2.3%)
Weight Percent ^{235}U/Total U	10.06 ± 0.05
Weight Percent U	87.23
Oxygen/Metal Atomic Ratio	2.057
	2.056
Surface Area, M^2/gm	4.1
ppm Cl	10
ppm F	5
ppm C	75
ppm N	10
ppm H_2O @ 400 C	1750
EBC	4.20

TABLE C-2. Pellet Specifications and Identifications

Pellet Specifications Halden - Gapcon Thermal Test Memo, R.K. Marshall to D.W. Brite dated November, 1974	Pellet Identification Parameter Sheet No.	 Powder Lot No.	 Pellet Batch No. Pellet Serial Numbers
Items 1-1, 1-4, 2-1, 2-4	5	2	4 1 - 293 758 - 777
Items 1-1, 2-2	4	2	4 294 - 461
Items 1-3, 2-4, 2-5	6	2	5 462 - 635
Items 1-5, 2-6	7	2	5 778 - 900
Items 1-6, 2-7	8	2	6 636 - 757

UO_2 POWDER CERTIFICATION OF COMPLIANCE

Quality Control Release No. 2

Project: ANC - BNW HALDEN 10% ENRICHED FUEL PELLETS
ANC - P. O. #S-1558

Powder Lot Identification: 2 Lot Size, kg UO_2 21

Sample No. DB-3

Applicable Specifications: P. O. S-1558 and ASTM Standard Specification for Nuclear Grade Sinterable Uranium Dioxide Powder, dated December, 1973.

Review of Analytical Data

The analytical data for the UO_2 powder lot identified above has been reviewed and the reported results comply with the chemical and nuclear requirements of the applicable specifications, with exceptions noted below.* This material is released for sinterability testing.

Signed ______________________

Date ______________________

* Al = 210 ppm, spec = 100 ppm max.
Nitrogen analysis not completed by November 4, 1974. Spec = 200 ppm max.
EBC (excluding N contribution) = 4.18 ppm, spec = 4 ppm max.

Fuels Design and Development Section
Fuels and Materials Department
Battelle - Pacific Northwest Laboratories

UO_2 POWDER CERTIFICATION OF COMPLIANCE

Quality Control Release No. 3

Project: ANC - BNW HALDEN 10% ENRICHED FUEL PELLETS
ANC - P. O. #S-1558

Powder Lot Identification: 2 Lot Size, kg UO_2 21

Sample No. DB-3

Applicable Specifications: P. O. S-1558 and ASTM Standard Specification for Nuclear Grade Sinterable Uranium Dioxide Powder, dated December, 1973.

Review of Analytical Data

The analytical data for the UO_2 powder lot identified above has been reviewed and the reported results comply with the chemical and nuclear requirements of the applicable specifications, with exceptions noted below.* This material is released for pellet fabrication based on oral approval by W. F. Domenico for ANC and C. R. Hann for BNW.

Signed

Date

* Al = 210 ppm - specification = 100 ppm max.
EBC = 4.20 ppm - specification = 4 ppm max.

Fuels Design and Development Section
Fuels and Materials Department
Battelle - Pacific Northwest Laboratories

Parameter Sheet #5, Pellet Batch 4 Date 11-25-74

Project BNW-Hal Lot Number 2 Enrichment 10% Release 2

Pellet Specifications: Table I - For Halden Gapcon-Thermal Irradiations per memo from R. K. Marshall to D. W. Brite. Date 11-20-74 (See comments below)

(Revised 11-25-74)

PELLET FABRICATION PROCESS PARAMETERS

A. Powder Preparation:

Maximum Batch Size: 6.2 Kg Blending Time 20 min (Twinshell)

Slug Density $4.3 \pm .1$ gm/cm^3 Slug Size ∿ 100 grams Control Chart Req'd

Granulation: -20 + 100 mesh with ∿ -100 mesh fines

Lubricant 0.2 wt% Sterotex (computed and weighed to 0.001 gram)

B. Pellet Pressing:

Green Density $5.1 \pm .05$ Green Length $645 \pm .015$ Control Chart Req'd

Press Tooling: 540 punch and die w/ flat ends

Bubble Test Req'd

C. Pellet Sintering: (Pellet Batch No. 4)

Heat Rate 200 Maximum Temperature 1700°C Time 8 hours

Cooling Rate Furnace H_2 Flow 10CFH Purge Argon

Comments:	Dia.	TD	Quantity Drilled	Not Drilled	Total	Extras
Item 1-1	4205	95.0 stable	16	39	55	3
Item 2-1	4205	95.0 stable	16	94	110	5
Item 1-4	4205 / 4275	95.0 stable	16* / 6*	35	57	3
Item 2-4	4205 / 4265	Ditto Item 1-4			57	3

Prepared by N. C. Davis Date 11-25-74

Approved by D. W. Brite Date 11-25-74

* .063 Hole 3 each .005 off center + 3 on center total 6
.063 Hole in 4 of the 16 total - 2 off enter 2 or center
balance of holes to be .067 - .071 dia.

.081" dia. hole green to give .063" sintered
.089" dia. green to give .069" dia. sintered

Pellet Fabrication Follower Data Sheet

Items 1 - 1, 2 - 1, 1 - 4, 2 -4

Date 11-18-74

Project BNW-Hal Lot Number 2 Enrichment 10% Release 2

Powder Preparation: Powder Batch No. 1

Slug Density 4.3 g/cm 3 ± .1 Slug Size ∿ 100 grams

Granulate 2582 -20 + 100 mesh 650 NA -100 mesh Re-slug

Lubricant 0.2 w/o sterotex 7.524 grams 3762* grams UO_2

Blend 20 Min. Operator Lee Sims

Comments * 3762 incl. 100 g for - sinter test 3 - mixed sterotex with twinshell 15 min and roll 5 min or ball mill. 252 grams additional prepared on 12-2-74 to provide 20 extra pellets

Pellet Pressing: Batch No. 4- Identification Pellet No. - 293

Green Density 5.1 ± .05- Green Length 645 ± .015 Quantity 3655 plus 243 plus 758-777

(See control chart attached)

Pellet Sintering: Furnace Run No. 1383 (pellets 1-293) 1385 (pellets 758-777) (Less Sterotex) Date 11-25-74

Time 8 hours Temperature 700°C Pyrometer 1715 N.C. Davis

Average Pellet Diameter ∿ .430 Batch Weight 3627 plus

Operator N.C. Davis

Pellet Grinding: Specified Diameter (See batch 4 pellet disposition sheet)

Batch Weight

Operator

Pellet Cleaning & Drying: Cleaned in alcohol, ultrasonic cleaner and dried ∿ 1 hour at 100°C Operator N. C. Davis

Batch Inspection: 100% Diameter 100% Length NA Dish 100% Density

100% Visual 100% Chips & Cracks

Analytical: X Composite X Isotopic X Chemical

X Oxygen/Uranium X Uranium

Comments Inspection data compiled on compiled on computer sheets

Parameter Sheet #4, Pellet Batch 4 Date 11-25-74

Project BNW-Hal Lot Number 2 Enrichment 10% Release 2

Pellet Specifications: Table I for Halden Gapcon-Thermal Irradiation per memo from R. K. Marshall - D. W. Brite dated 11-20-74. (See comments below) (Revised 11-25-74)

PELLET FABRICATION PROCESS PARAMETERS Total U 2166

A. Powder Preparation:

Maximum Batch Size: 6.2 Kg Blending Time 20 min (twinshell)

Slug Density $4.3 \pm .1$ gm/cm^3 Slug Size ~100 grams Control Chart Req'd

Granulation: -20 + 100 mesh with ~ 20% -100 mesh fines

Lubricant 0.2 wt% Sterotex (computed and weighed to 0.001 gram)

B. Pellet Pressing:

Green Density $5.1 \pm .05$ Green Length $645 \pm .015$ Control Chart Req'd

Press Tooling: 540 Tooling w/ flat punches

Bubble Test Req'd

C. Pellet Sintering: (Pellet Batch No. 4)

Heat Rate 200 per hour Maximum Temperature 1700°C Time 8 hours

Cooling Rate R H_2 Flow 10CFH Purge Argon

Comments:	DIA.	TD	Drilled	Not Drilled	Total	Extras
Item 1-2	0.4145	95% stable	16	39	55	3
Item 2-2	0.4145	95% stable	16	94	110	5

(Green pellets drilled .089 diameter)

Prepared by N. C. Davis Date 11-25-74

Approved by D. W. Brite Date 11-25-74

Pellet Fabrication Follower Data Sheet

Items 1 - 2 and 2 - 2

Date 11-18-74

Project BNW-Hal Lot Number 2 Enrichment 10% Release 2

Powder Preparation:

Slug Density 4.3 ± .1 gm/cm^3 Slug Size ∿ 100 grams

(Control chart attached)

Granulate 1594 -20 + 100 mesh 572 grams -100 mesh NA Re-slug

Lubricant 0.2 w/o sterotex 4.352 grams 2166 grams UO_2

Blend 20 Min. Operator Lee Sims

Comments Add 0.2 w/o sterotex -200 + 325 mesh to the granulated material and blend 20 min: (twinshell)

Pellet Pressing: Batch No. 4 Identification ~~Pellet~~ Pellet No. 294-461

Green Density 5.10 ± .05 Green Length .645 Quantity 2088 gm

(See control chart attached) (Less sterotex)

Pellet Sintering: Furnace Run No. 1383 Date 11-25-74

Time 8 hours Temperature 1700°C Pyrometer 1715 N.C. Davis

Average Pellet Diameter ∿ .430 Batch Weight 2058

Operator N. C. Davis

Pellet Grinding: Specified Diameter (see attached batch 4 pellet disposition sheet)

Batch Weight

Operator

Pellet Cleaning & Drying: Cleaned in alcohol with ultrasonic cleaner and dried 100°C ∿ 1 hour

Operator N. C. Davis

Batch Inspection: 100% Diameter 100% Length NA Dish 100% Density

100% Visual 100% Chips & Cracks

Analytical: X Composite X Isotopic X Chemical

X Oxygen/Uranium X Uranium

Comments * Inspection data by pellet No. provided on computer lists

Parameter Sheet #6, Pellet Batch 5 Date 11-25-74

Project BNW-Hal Lot Number 2 Enrichment 10.0% Release 2

Pellet Specifications: Table I for Halden Gapcon-Thermal Irradiation per memo from R.K. Marshall to D. W. Brite dated 11-20-74 (See comments below) (Revised 11-25-74)

PELLET FABRICATION PROCESS PARAMETERS (Batch 3 Total 2166)

A. Powder Preparation:

Maximum Batch Size: 6.2 Blending Time 20 min (twinshell)

Slug Density $4.3 \pm .1$ gm/cm^3 Slug Size ∿ 100 grams Control Chart Req'd

Granulation: -20 + 100 mesh with ∿ 20% -100 fines

Lubricant 12 wt% Sterotex (computed and weighed to 0.001 gram)

B. Pellet Pressing:

Green Density $5.15 \pm .05$ gm/cm^3 Green Length 645 ± 0.015 Control Chart Req'd

Press Tooling: 540 Tooling w/ flat punches

Bubble Test Req'd

C. Pellet Sintering: (Pellet Batch No. 5)

Heat Rate 200 Maximum Temperature 1700°C Time 8 hours

Cooling Rate R H_2 Flow 10CFH Purge Argon

Comments:

	Dia.	TD	Drilled (.089" dia.)	Not Drilled	Total	Extras
Items 1-3	.4275	95% stable	16	39	55	3
Items 2-4	.4265	95% stable	16	39	55	3
Items 2-5	.4225	95% stable		55	55	3

Prepared by N. C. Davis Date 11-25-74

Approved by D. W. Brite Date 11-25-74

Pellet Fabrication Follower Data Sheet

Items 1 - 3, 2 - 4, 2 - 5

Date 11-22-74

Project BNW-Hal Lot Number 2 Enrichment 10% Release 2

Powder Preparation: Powder Batch No. 3

Slug Density 4.3 $\pm$ .1 gm/cm^3 Slug Size ∿ 100 gram in 2" dia.

Granulate 1731 -20 + 100 mesh 435 -100 mesh NA Re-slug

Lubricant 0.2 w/o sterotex 4.332 grams 2166 grams UO_2

Blend 15 Min. Operator Lee Sims

Comments Blend sterotex 15 min in twinshell and 5 min in Ball Mill

Pellet Pressing: Batch No. 5* Identification 462-635

Green Density 5.15 $\pm$ .05 gm/cm^3 Green Length 645 $\pm$ .015 Quantity 2229

(See control chart attached) (Less sterotex)

Pellet Sintering: Furnace Run No. 1385 Date 12-2-74

Time 8 hours Temperature 1700 $\pm$ 20°C Pyrometer 1715

Average Pellet Diameter 434-428 Batch Weight 2207

Operator N. C. Davis

Pellet Grinding: Specified Diameter (See pellet Batch 5 pellet disposition sheet)

Batch Weight

Operator

Pellet Cleaning & Drying: Cleaned in alcohol in ultrasonic cleaner and dried 100°C ∿ 1 hour. Operator N. C. Davis

Batch Inspection: 100% Diameter 100% Length NA Dish 100% Density

100% Visual 100% Chips & Cracks

Analytical: X Composite X Isotopic X Chemical

C Oxygen/Uranium Uranium

Comments * Batch 5 also incl. powder Batch 4 & 243 gram off center holes for Batch 1

Inspection data compiled on computer lists.

Parameter Sheet #7, Pellet Batch 5 Date 11-15-74

Project BNW-Hal Lot Number 2 Enrichment 10% Release 2

Pellet Specifications: Table I for Halden Gapcon-Thermal Irradiation per memo from R. K. Marshall to D. W. Brite dated 11-20-74 (See comments below) (Revised 11-25-74)

PELLET FABRICATION PROCESS PARAMETERS UO_2 1513

A. Powder Preparation:

Maximum Batch Size: 6.2 Kg Blending Time 20 min (twinshell)

Slug Density 4.2 ± .1 gm/cm^3 Slug Size ~ 100 gram Control Chart Req'd

Granulation: -20 + 100 mesh w/ ~ 20% -100 fines

Lubricant 1.2 wt% Sterotex (computed and weighed to 0.001 gram)

B. Pellet Pressing:

Green Density 5.0 ± .05 g/cm^3 Green Length .640 ± .015 Control Chart Req'd

Press Tooling: 540 Tooling w/ Flat Face Punch

Bubble Test Req'd

C. Pellet Sintering:

Heat Rate 200 Max Maximum Temperature 1700 ± 25°C Time 8

Cooling Rate Furnace H_2 Flow 10CFH Purge Argon

Comments: * Prior to slugging blend 1.0 s/o sterotex to -100 mesh UO_2

	Dia.	TD	Drilled	Not Drilled	Total	Extras
Items 1-5	0.4205	92% stable	17	43	60	6
2-6	0.4205	92% stable	14	36	50	5

* After granulation add - .2

Prepared by N. C. Davis Date 11-20-74

Approved by D. W. Brite Date 11-20-74

Pellet Fabrication Follower Data Sheet

Items 1 - 5 and 2 - 6

Date 11-27-74

Project BNW-Hal Lot Number 2 Enrichment 10% Release 2

Powder Preparation: (Powder Batch 4)

Slug Density $4.3 \pm .1$ gm/cm^3 Slug Size ∿100 grams

Granulate 1112 -20 + 100 mesh 400 -100 mesh NA Re-slug

Lubricant 1.2* w/o sterotex 15.0 3.014 18.014* grams 1512 grams UO_2

Blend 20 min Min. Operator Lee Sims

Comments * 1% sterotex w/ -100 mesh uO_2 + 0.2 w/o after granulation blend 100 gram increments in shaker combine and screen -70 mesh Blend 15 min twinshell - Slug and roll 5 mins on Ball Mill

Pellet Pressing: Batch No. 5-* Pellets No. Identification 778-900

Green Density $5.0 \pm .05$ gm/cm^3 Green Length $.640 \pm .015$ Quantity 1501

(See control chart attached) (Less sterotex)

Pellet Sintering: Furnace Run No. 1385 Date 12-2-74

Time 8 hours Temperature $1700 \pm 25°C$ Pyrometer 1715

Average Pellet Diameter 431-428 Batch Weight 1470

Operator N. C. Davis

Pellet Grinding: Specified Diameter (See attached Pellet Batch 5-pellet disposition)

Batch Weight

Operator

Pellet Cleaning & Drying: alcohol-ultrasonic cleaner and dry 100°C ∿ 1 hour

Operator N. C. Davis

Batch Inspection: 100% Diameter 100% Length NA Dish 100% Density

100% Visual 100% Chips & Cracks

Analytical: X Composite X Isotopic X Chemical

X Oxygen/Uranium X Uranium

Comments * Batch 5 also includes powder batch 3 + .063 dia. off center hole pellet for batch 1 Inspection data on computer lists.

Parameter Sheet #8, Pellet Batch 6 Date 11-25-74

Project BNW-Hal Lot Number 2 Enrichment 10% Release 2

Pellet Specifications: Table I for Halden-Gapcon-Thermal Irradiation per memo.
R. K. Marshall to D. W. Brite dated 11-20-74 (See comments below)

(Revised 11-25-74)

PELLET FABRICATION PROCESS PARAMETERS 1513 grams

A. Powder Preparation:

Maximum Batch Size: 62 Kg Blending Time 20 min (Twinshell)

Slug Density 4.3 ± .1 gm/cm^3 Slug Size ∿ 100 grams Control Chart Req'd

Granulation: -20 + 100 mesh with ∿ 20% -100 fines

Lubricant .2 wt% Sterotex (computed and weighed to 0.001 gram)

B. Pellet Pressing:

Green Density 5.0 ± .05 gm/cm^3 Green Length 635 ± .015 Control Chart Req'd

Press Tooling: 540 tools w/ flat punches

Bubble Test Req'd

C. Pellet Sintering:

Heat Rate 200 Maximum Temperature 1575°C Time 1 hour

Cooling Rate R H_2 Flow 10CFH Purge Argon

Comments:

	Dia.	TD	Quantities Drilled (.086" dia.)	Not Drilled	Total	Extra
Item 1-6	.4205	92% unstable	17	43	60	6
Item 2-7	.4205	92% unstable	14	36	50	5

Drill 37 w/ .086 hole

Prepared by N. C. Davis Date 11-25-74

Approved by D. W. Brite Date 11-25-74

Pellet Fabrication Follower Data Sheet

Item 1 - 6 and 2 - 7

Date 11-26-74

Project BNW-Hal Lot Number 2 Enrichment 10% Release 2

Powder Preparation: Powder Batch No. 5

Slug Density 4.3 g/ ± .1 Slug Size ∿ 100 grams
(Control chart attached)

Granulate 1150 -20 + 100 mesh 363 -100 mesh NA Re-slug

Lubricant 0.2 w/o sterotex 3.026 grams 1513 grams UO_2

Blend 15 Min. Operator Lee Sims

Comments Blend sterotex 15 min in twinshell and 5 min in Ball Jar.

Pellet Pressing: Batch No. 6 Identification 636 thru 757

Green Density 5.0 ± .05 gm/cm^3 Green Length 635 ± .015 Quantity 1489
(See control chart attached) (Less sterotex)

Pellet Sintering: Furnace Run No. 1384 Date 12-2-74

Time 1 hour Temperature 1575°C Pyrometer 1580°C N. C. Davis

Average Pellet Diameter 430-433 Batch Weight 1471

Operator N. C. Davis

Pellet Grinding: Specified Diameter See attached pellet Batch 6 disposition sheet

Batch Weight

Operator

Pellet Cleaning & Drying: Cleaned in alcohol in ultrasonic cleaner, dried 100°C ∿ 1 hour.

Operator

Batch Inspection: 100% Diameter 100% Length NA Dish 100% Density

100% Visual 100% Chips & Cracks

Analytical: X Composite X Isotopic X Chemical

X Oxygen/Uranium X Uranium

Comments Pellet Inspections data compiled on computer list

TABLE C-3. Pellet Batch Disposition

Batch Number 4 Lot Number 2 Release 2

Sintering Run 1383 Time 8 hours Temperature 1700°C

Quantity Green 5743 Sintered 5685

Identification Powder Batch Number 1 Pellets Number 1-293

Powder Batch Number 2 Pellets Number 294-461

Item	Density %TD	Ground Diameter	Cleaned	Quantity Req'd	Quantity Fab.	Weight Grams
1-1	95.0 S	0.4205	✓	39	40	475
1-1 D	95.0 S	0.4205	✓	16	16	187
2-1	95.0 S	0.4205	✓	94	95	1138
2-1 D	95.0 S	0.4205	✓	16	16	186
1-4	95.0 S	0.4205	✓	35	33	395
1-4 A D	95.0 S	0.4205	✓	8	8	93
1-4 B D	95.0 S	0.4205	✓	12	12	140
1-4 C D	95.0 S	04275	✓	6	6	72*
2-4	95.0 S	04205	✓	33	33	395
2-4 A D	95.0 S	04205	✓	8	8	94
2-4 B D	95.0 S	04205	✓	12	12	139
2-4 C D	95.0 S	04265	✓	6	6	72*
1-2	95.0 S	0.4145	✓	39	40	464
1-2 D	95.0 S	0.4145	✓	16	17	189
2-2	95.0 S	0.4145	✓	94	95	1101
2-2 D	95.0 S	0.4145	✓	16	20	223

S = Stable
D - Drilled
* est. wt. Pellet Sides Ground

TABLE C-4. Pellet Batch Disposition

Batch Number 5 Lot Number 2 Release 2

Sintering Run 1385 Time 8 hours Temperature 1700°C

Quantity Green 3730 Sintered 3677

Identification Powder Batch 3-Pellets 462-635

Powder Batch 4-Pellets 778-900

Item	Density %TD	Ground Diameter	Cleaned	Quantity Req'd	Quantity Fab.	Weight Grams
1-3 D	95.0 S	.4275	X	16	16	195
1-3	95.0 S	.4275	X	39	40	500
2-3 D	95.0 S	.4265	X	16	20	243
2-3	95.0 S	.4265	X	39	41	512
2-5	95.0 S	.4225	X	55	58	710
1-5 D	92.0 S	.4205	X	17	18	202
1-5	92.0 S	.4205	X	43	44	506
2-6 D	92.0 S	.4205	X	14	17	192
2-6	92.0 S	.4205	X	36	43	468

D = Drilled
S = Stable

TABLE C-5. Pellet Batch Disposition

Batch Number 6 Lot Number 2 Release 2

Sintering Run 1384 Time 1 hour Temperature 1575°C

Quantity Green 1489 Sintered 1471

Identification Powder Batch Number 5 - Pellets 636-757

Item	Density % TD	Ground Diameter	Cleaned	Quantity Req'd	Quantity Fab.	Weight Grams
1-6 D	92.0 U	.4205	X	17	18	201
1-6	92.0 U	.4205	X	43	44	509
2-7 D	92.0 U	.4205	X	14	19	201
2-7	92.0 U	.4205	X	36	39	440

D = Drilled
U = Unstable

TABLE C-6. Green Pellet Data for Powder Lot No. 2, IFA-431 and IFA-432

	Pellet Batch No. 4		Pellet Batch No. 5		Pellet Batch No. 6
	No. 1 - 293 and 758 - 777	294 - 461	462 - 635	778 - 900	636 - 757
Parameter Sheet No.	5	4	6	7	8
Density (gm/cm^3)	5.1 ± 0.05	5.1 ± 0.05	5.15 ± 0.05	5.0 ± 0.05	5.0 ± 0.05
Length (inches)	0.645 ± 0.015	0.645 ± 0.015	0.645 ± 0.015	0.640 ± 0.015	0.635 ± 0.015
$\overline{X}$ Density	5.09	5.10	5.15	5.00	5.00
Density Range					
High	5.15	5.15	5.21	5.08	5.06
Low	5.03	5.03	5.07	4.96	4.93
$\overline{X}$ Length	0.647	0.639	0.650	0.646	0.640
Length Range					
High	0.659	0.653	0.660	0.659	0.659
Low	0.630	0.630	0.638	0.635	0.628

TABLE C-7. Final Pellet Inspection Summary

Diameter, 100% ± 0.0005
Length, 0.500 ± 0.015 in.
Density, Batch No. 4 - 95% TD
No. 5 - 1-3, 95% TD
1-5, 92% TD
No. 6 - 92% TD

S = Solid
D = Drilled 0.069 ± 0.022 in.
$\bar{X}$ = Mean
σ = Standard deviation

Item No.	Quantity	Diameter 100% ± 0.0005	$\bar{X}$ Length	% TD Geometric Density $\bar{X}$	% TD Geometric Density σ	Immersion Density Quantity	Immersion Density $\bar{X}$	Immersion Density σ	
Pellet Batch No. 4									
IFA-431									
1-1S	33	0.4205	0.5004	94.560	0.332	11	95.266	0.335	
1-1D	12	0.4205	0.5082	94.672	0.197	4	95.327	0.066	
1-2S	33	0.4145	0.5040	94.906	0.139	11	95.555	0.092	
1-2D	12	0.4145	0.5016	94.320	0.125	4	95.073	0.097	
1-4S	27	0.4205	0.5074	94.859	0.166	9	95.578	0.220	
1-4D	6	0.4205	0.5083	94.522	0.107	6	95.472	0.140	
1-4D[a]	8	0.4205	0.5071	94.743	0.232				
IFA-432									
Rod 1	46	0.4205	0.5061	94.809	0.274				
Rod 2	46	0.4145	0.5000	94.509	0.292				
Rod 4	43	0.4205	0.5063	94.868	0.244				
Rod 7	46	0.4145	0.5013	94.618	0.331				
Rod 8	46	0.4205	0.5060	94.917	0.242				
Rod 1	46	-	0.5065	94.849	0.257				
Rod 2	46	-	0.5004	94.515	0.322				
Rod 4	43	-	0.5063	94.868	0.244	Remeasured			
Rod 7	46	-	0.5013	94.618	0.331				
Rod 8	46	-	0.5060	94.917	0.242				
Pellet Batch No. 5									
IFA-431									
1-3S	33	0.4275	0.5096	95.258	0.185	11	96.151	0.140	
1-3D	12	0.4275	0.5090	94.912	0.171	4	95.750	0.133	
1-5S	33	0.4205	0.5070	91.053	0.674	17	91.792	0.547	
1-5D	12	0.4205	0.5095	91.158	0.501	6	92.145	0.391	
IFA-432									
Rod 3	45	0.4265	0.5110	95.244	0.370				
Rod 5	46	0.4205	0.5068	90.892	0.497				
Rod 9	45	0.4225	0.5108	95.274	0.184				
Rod 3	45	-	0.5110	95.244	0.370				
Rod 5	46	-	0.5066	90.886	0.534	Remeasured			
Rod 9	45	-	0.5108	95.270	0.187				
Pellet Batch No. 6									
IFA-431									
1-6S	33	0.4205	0.5051	91.441	0.306	33	92.042	0.295	
1-6D	12	0.4205	0.5006	91.614	0.209	12	92.012	0.144	
1-6S	-	-	-	-	-	33	92.030	0.283	Duplicates
1-6D	-	-	-	-	-	12	92.026	0.133	Duplicates
IFA-432									
2-6S						41	91.708	0.510	
2-6D						17	92.198	0.291	
2-7S						26	92.414	0.212	
2-7S						26	92.378	0.258	Duplicates
2-7S						12	92.379	0.255	
2-7S						12	92.406	0.241	Duplicates
2-7D						18	92.094	0.155	
2-7D						18	92.097	0.153	Duplicates
Rod 6	46	0.4205	0.5048	91.618	0.479				
Rod 6	46		0.5060	91.668	0.486				Duplicates

(a) Special 0.063 ± 0.002 in.

TABLE C.8. Analysis Results for IFA-431 and IFA-432 Pellet Batches 4, 5 and 6

Analysis	Specification Limits	Batch 4	Batch 5	Batch 6	Lot 2 Composite
% ^{235}U	10.0 ± 0.5				9.95
% U	87.6 min	88.04	88.07	88.01	88.23
O/U	1.990 - 2.020	2.000	1.997	2.000	2.000
C, ppm	100	15	240[(a)]	16	
Cl, ppm	25	<10	<10	<10	
F, ppm	5	<5	<5	<5	
N, ppm	75	<10	91	<10	
Gas release					
cc/g @ 1600°C	0.050	0.007	0.003	0.015	
H_2O, ppm @ 400°C		<5	<5	<5	
EBC, ppm[(b)]	7				4.117

(a) 92% TD Pellets, using sterotex pore former, sintered 8 hr, 1700°C using 200°C/hr heating rate.

(b) Equivalent Boron Content

TABLE D-1. Description of Analytical Techniques

Analysis	Technique	Reported Accuracy
% Uranium in UO_2	Controlled potential coulometry; U is converted to U(VI) and selectively reduced to U(IV) at an electrode held at the proper potential.	1σ = 0.2% rel.
O/U Atomic Ratio	Thermogravimetry: Sample is assumed to be stoichiometric after heating to constant weight at 800°C in H_2-Ar atmosphere saturated with H_2O at 0°C. The O/U is calculated from the weight difference before and after heating.	1σ = 0.002 in O/U
Isotopic Composition	Thermal Ionization Mass Spectrometry: Thermally ionized metal atoms are electrically accelerated through a magnetic field and collected at a cathode. Isotopic ratios are proportional to the ratios of the ion currents at specific voltages.	1σ = 0.25% Rel. of ^{235}U content
ppm F, Cl	Pyrohydrolysis: Sample is heated to 1000°C and exposed to water vapor which hydrolyses the F and Cl. Fluorine is measured in the cold trap solution by ion selective electrode measurement and chlorine by precipitation with Ag generated by constant current coulometry.	F <5; Cl <10 Can be stated with 95% Confidence
ppm N	Kjeldahl - Spectrophotometric Method: Sample is dissolved in acid, made strongly basic, and steam distilled. Ammonia evolved is collected in weak acid and measured spectrophotometrically using Nessler reagent.	1σ = 3% rel.
ppm C	Combustion and gas chromatography: Pulverized sample is heated to ~1000°C in a stream of oxygen to remove C as CO_2 which is collected and measured with a gas chromatograph.	1σ = 10% rel.
Trace Impurities 24 elements	Emission spectroscopy: Metallic impurities in the sample emit energy in the form of light when excited in an electric arc. The light is dispersed in a spectrograph, recorded on photographic film and concentrations of impurities are determined from measured intensities of the light emission lines corresponding to specific elements.	±2X
Rare Earths and selected impurities	Spark Source Mass Spectrography: A high voltage RF spark is used to ionize all the elements present in the sample. Ions are electromagnetically separated into beams according to their mass-to-charge ratios, and their concentrations are estimated from the measured densities of the lines formed when the ion beams strike photographic plates.	±3X
ppm H_2O	Constant Voltage Coulometry: Water vaporized into a stream of inert gas from a heated sample is continuously absorbed and simultaneously electrolyzed on a phosphorus pentoxide coated electrode. The total integrated electrolysis current is proportional to the water content of the sample.	1σ = 20% rel.
Sorbed gas release	Vacuum Outgassing: Temperature and pressure of gas evolved at 1600°C are measured once it has been collected in a known volume	1σ = 15% rel.

SAMPLE IDENTIFICATION	Hanford Engineering Development Laboratory	LAB. SERIAL NO. P-6956
Batch #6 BNW Halden Pellet DB-1T	FUELS AND CONTROL SAMPLE ANALYSIS	DATE REC. 12-6-74

SAMPLE SUBMITTER	ADDRESS	PHONE	WORK ORDER NO.
Lester	308 E. TRL	3184	C-56575

TYPE OF MATERIAL:	SPECIAL INSTRUCTIONS	
☐ PuO_2 ☒ UO_2 ☐ MIXED OXIDE:______% PuO_2 ☐ B_4C ☐ OTHERS______		Pu ISOTOPIC:______% 240 U ISOTOPIC: ☐ NORMAL ☒ 10 % ENRICHED B ISOTOPIC: ☐ NATURAL ☐ ____% ENRICHED

NO. OF ANALYSIS		RESULTS
☐	Pu WT. %	
1	U WT. %	88.01
☐	^{241}Am ppm	
1	O/M	2.000
1	C ppm	16
☐	S ppm	
1	OFF-GAS cc/g @ STP	.015
1	Cl ppm	<10
1	F ppm	<5
1	H_2O ppm @400°C	<5
1	N ppm	<10
☐	O ppm	
☐	SOLUBLE C WT %	
☐	SOLUBLE B WT % ☐ HNO_3 ☐ HCl	
☐	TOTAL C WT %	
☐	TOTAL B WT %	

NO. OF ANALYSIS		RESULTS
☐	LOSS ON IGNITION WT %	
☐	DENSITY g/cc	
☐	POROSITY	SEE SPECIAL REPORT
☐	SURFACE AREA M^2/g	
☐	PARTICLE SIZE-MSA (PuO_2 ONLY)	SEE SPECIAL REPORT
☐	PARTICLE SIZE, FISHER SUBSIEVE	
☐	OTHERS	
☐	OTHERS	
	SPECTROCHEMICAL ANALYSES	
☐	SPARK SOURCE GENERAL	SEE SPECIAL REPORT
☐	SPARK SOURCE R.E. + Ta + W	SEE SPECIAL REPORT
☐	EMISSION SPEC. GENERAL	SEE SPECIAL REPORT
	ISOTOPIC ANALYSES	
☐	Pu ISOTOPIC	SEE SPECIAL REPORT
☐	U ISOTOPIC	SEE SPECIAL REPORT
☐	B ISOTOPIC	SEE SPECIAL REPORT

SPECIAL OBSERVATIONS – REMARKS

REPORT APPROVED BY	DATE COMPLETED
M.L.	1-8-75

BD-7340 022 (8 74)

DISTRIBUTION: WHITE Sample Submitter; YELLOW Laboratory Record; PINK Fuels QA; GOLDENROD Originator

SAMPLE IDENTIFICATION	Hanford Engineering Development Laboratory	LAB. SERIAL NO. P-6985
Batch #5 BNW HALDEN Pellet PB-17	FUELS AND CONTROL SAMPLE ANALYSIS	DATE REC. 12-6-74

SAMPLE SUBMITTER	ADDRESS	PHONE	WORK ORDER NO.
LESTER	308 E. TRI.	3184	C-56575

TYPE OF MATERIAL:	SPECIAL INSTRUCTIONS	
☐ PuO_2 ☒ UO_2		Pu ISOTOPIC:________% 240
☐ MIXED OXIDE:________% PuO_2		U ISOTOPIC: ☐ NORMAL ☒ 10 % ENRICHED
☐ B_4C		B ISOTOPIC: ☐ NATURAL
☐ OTHERS____________		☐ _____% ENRICHED

NO. OF ANALYSIS		RESULTS
☐	Pu WT. %	
1	U WT. %	88.07
☐	^{241}Am ppm	
1	O/M	1.997
1	C ppm	229 { RERUN 268
☐	S ppm	
1	OFF-GAS c c/g @ STP	.003
1	Cl ppm	< 10
1	F ppm	< 5
1	@400°C H_2O ppm	< 5
1	N ppm	91 { RERUN [illegible]
☐	O ppm	
☐	SOLUBLE C WT %	
☐	SOLUBLE B WT % ☐ HNO_3 ☐ HCl	
☐	TOTAL C WT %	
☐	TOTAL B WT %	

NO. OF ANALYSIS		RESULTS
☐	LOSS ON IGNITION WT %	
☐	DENSITY g/cc	
☐	POROSITY	SEE SPECIAL REPORT
☐	SURFACE AREA M^2 / g	
☐	PARTICLE SIZE-MSA (PuO_2 ONLY)	SEE SPECIAL REPORT
☐	PARTICLE SIZE, FISHER SUBSIEVE	
☐	OTHERS	
☐	OTHERS	
	SPECTROCHEMICAL ANALYSES	
☐	SPARK SOURCE GENERAL	SEE SPECIAL REPORT
☐	SPARK SOURCE R.E. + Ta + W	SEE SPECIAL REPORT
☐	EMISSION SPEC. GENERAL	SEE SPECIAL REPORT
	ISOTOPIC ANALYSES	
☐	Pu ISOTOPIC	SEE SPECIAL REPORT
1	U ISOTOPIC	SEE SPECIAL REPORT
☐	B ISOTOPIC	SEE SPECIAL REPORT

SPECIAL OBSERVATIONS – REMARKS

REPORT APPROVED BY	DATE COMPLETED
[illegible signature]	[illegible]

BD-7340 022 (8-74)

DISTRIBUTION: WHITE Sample Submitter; YELLOW Laboratory Record; PINK Fuels QA; GOLDENROD Originator

SAMPLE IDENTIFICATION	Hanford Engineering Development Laboratory	LAB. SERIAL NO. P-6984
BATCH #4 BNW HALDEN PELLET DB-16	FUELS AND CONTROL SAMPLE ANALYSIS	DATE REC. 12-6-74

SAMPLE SUBMITTER	ADDRESS	PHONE	WORK ORDER NO.
LESTER	308 E. TRL	3184	C-56575

TYPE OF MATERIAL:

- [ ] PuO_2
- [x] UO_2
- [ ] MIXED OXIDE:________% PuO_2
- [ ] B_4C
- [ ] OTHERS__________

SPECIAL INSTRUCTIONS

Pu ISOTOPIC:__________% 240

U ISOTOPIC:
- [ ] NORMAL
- [x] 10 % ENRICHED

B ISOTOPIC:
- [ ] NATURAL
- [ ] _____% ENRICHED

NO. OF ANALYSIS		RESULTS
	Pu WT. %	
1	U WT. %	88.04
	^{241}Am ppm	
1	O/M	2.000
1	C ppm	15
	S ppm	
1	OFF-GAS c c/g @ STP	.007
1	Cl ppm	<10
1	F ppm	<5
1	@ 400°C H_2O ppm	<5
1	N ppm	<10
	O ppm	
	SOLUBLE C WT %	
	SOLUBLE B WT % [ ] HNO_3 [ ] HCl	
	TOTAL C WT %	
	TOTAL B WT %	

NO. OF ANALYSIS		RESULTS
	LOSS ON IGNITION WT %	
	DENSITY g/cc	
	POROSITY	SEE SPECIAL REPORT
	SURFACE AREA M^2 / g	
	PARTICLE SIZE-MSA (PuO_2 ONLY)	SEE SPECIAL REPORT
	PARTICLE SIZE, FISHER SUBSIEVE	
	OTHERS	
	OTHERS	
	SPECTROCHEMICAL ANALYSES	
	SPARK SOURCE GENERAL	SEE SPECIAL REPORT
	SPARK SOURCE R.E. + Ta + W	SEE SPECIAL REPORT
	EMISSION SPEC. GENERAL	SEE SPECIAL REPORT
	ISOTOPIC ANALYSES	
	Pu ISOTOPIC	SEE SPECIAL REPORT
	U ISOTOPIC	SEE SPECIAL REPORT
	B ISOTOPIC	SEE SPECIAL REPORT

SPECIAL OBSERVATIONS – REMARKS

REPORT APPROVED BY	DATE COMPLETED
MLh	1-8-75

BD-7340-022 (8 74)

DISTRIBUTION: WHITE Sample Submitter; YELLOW Laboratory Record; PINK Fuels QA; GOLDENROD Originator

SAMPLE IDENTIFICATION	Hanford Engineering Development Laboratory	LAB. SERIAL NO.
Composite BNW Halden Pellet DB-15	FUELS AND CONTROL SAMPLE ANALYSIS	R-6983
		DATE REC. 12-6-74

SAMPLE SUBMITTER	ADDRESS	PHONE	WORK ORDER NO.
Lester	3CE E. TRL	3184	C-56575

TYPE OF MATERIAL:

- [ ] PuO_2
- [x] UO_2
- [ ] MIXED OXIDE:______% PuO_2
- [ ] B_4C
- [ ] OTHERS______

SPECIAL INSTRUCTIONS

*S.S - Dy, Eu, Gd, Sm < 0.3 PPM

S.S. - Ba, Cs, Co, Hf, Ta, P, V, Li, B < 0.5 PPM

Pu ISOTOPIC:______% 240

U ISOTOPIC: [ ] NORMAL [x] 10 % ENRICHED

B ISOTOPIC: [ ] NATURAL [ ] ____% ENRICHED

NO. OF ANALYSIS		RESULTS
[ ]	Pu WT. %	
[1]	U WT. %	88.23
[ ]	^{241}Am ppm	
[1]	O/M	2.000
[ ]	C ppm	
[ ]	S ppm	
[ ]	OFF-GAS c c/g @ STP	
[ ]	Cl ppm	
[ ]	F ppm	
[ ]	H_2O ppm	
[ ]	N ppm	
[ ]	O ppm	
[ ]	SOLUBLE C WT %	
[ ]	SOLUBLE B WT % [ ] HNO_3 [ ] HCl	
[ ]	TOTAL C WT %	
[ ]	TOTAL B WT %	

NO. OF ANALYSIS		RESULTS
[ ]	LOSS ON IGNITION WT %	
[ ]	DENSITY g/cc	
[ ]	POROSITY	SEE SPECIAL REPORT
[ ]	SURFACE AREA M^2 / g	
[ ]	PARTICLE SIZE-MSA (PuO_2 ONLY)	SEE SPECIAL REPORT
[ ]	PARTICLE SIZE, FISHER SUBSIEVE	
[ ]	OTHERS	
[ ]	OTHERS	
	SPECTROCHEMICAL ANALYSES	
*[1]	SPARK SOURCE GENERAL	SEE SPECIAL REPORT
[ ]	SPARK SOURCE R.E. + Ta + W	SEE SPECIAL REPORT
[1]	EMISSION SPEC. GENERAL	SEE SPECIAL REPORT
	ISOTOPIC ANALYSES	
[ ]	Pu ISOTOPIC	SEE SPECIAL REPORT
[1]	U ISOTOPIC	SEE SPECIAL REPORT
[ ]	B ISOTOPIC	SEE SPECIAL REPORT

SPECIAL OBSERVATIONS – REMARKS

Please crush pellets to make composite

REPORT APPROVED BY	DATE COMPLETED
MCB	12/17/74

BD-7340-022 (8-74)

DISTRIBUTION: WHITE Sample Submitter, YELLOW Laboratory Record, PINK Fuels QA, GOLDENROD Originator

SAMPLE IDENTIFICATION	Hanford Engineering Development Laboratory	LAB. SERIAL NO.
BNW - HALDEN Pellets DB-19	FUEL AND CONTROL SAMPLE ANALYSIS	P-4996 DATE RECEIVED 12-11-74

SAMPLE SUBMITTER	ADDRESS	PHONE	CHARGE CODE	SAMPLE DISPOSAL
LESTER	308 E TRL	3184	C-56575	[X] DISCARD [ ] RETURN

KIND OF MATERIAL: [X] UO_2 [ ] MIXED OXIDE: % PuO_2 ______ [ ] PuO_2 [ ] BORON CARBIDE [ ] OTHER ______

U ISOTOPIC: [ ] NORMAL [X] ENRICHED 10 %

Pu ISOTOPIC: % 240 ______

B ISOTOPIC: [ ] NATURAL [ ] ENRICHED ______ %

SPECIAL INSTRUCTIONS:

NO. OF ANALYSIS		RESULT	NO. OF ANALYSIS		RESULT
[ ]	Pu WT. %		[ ]	LOSS ON IGNITION WT. %	
[ ]	U WT. %		[ ]	DENSITY g/cc	
[ ]	O/M		[ ]	POROSITY	SEE SPECIAL REPORT
[ ]	TOTAL B WT. %		[ ]	SURFACE AREA M^2/g	
[ ]	TOTAL C WT. %		[ ]	PARTICLE SIZE, MSA	SEE SPECIAL REPORT
[ ] [ ]	SOLUBLE B WT. % HCl HNO_3		[ ]	PARTICLE SIZE, FISHER SUBSIEVE	
[ ]	SOLUBLE C WT. % (FREE)		[ ]		
~~[X]~~	GAS cc/g @ STP		[ ]		
[ ]	Cl ppm		[ ]	SPARK SOURCE	SEE SPECIAL REPORT
[ ]	F ppm		[ ]	RARE EARTHS	SEE SPECIAL REPORT
2	H_2O ppm @400°C	1 - <5 1H - <5	[ ]	W & Ta EMISSION SPEC.	SEE SPECIAL REPORT
[ ]	C ppm		[ ]	EMISSION SPEC.	SEE SPECIAL REPORT
[ ]	N ppm		[ ]	Pu ISOTOPIC	SEE SPECIAL REPORT
[ ]	S ppm		[ ]	U ISOTOPIC	SEE SPECIAL REPORT
[ ]	W ppm		[ ]	B ISOTOPIC	SEE SPECIAL REPORT

SPECIAL OBSERVATIONS - REMARKS:

REPORT APPROVED [signature] DATE COMPLETED 12-12-74

BD-7340-022 (6-72) DISTRIBUTION: WHITE - SAMPLE SUBMITTER PINK-FUELS QA YELLOW - LABORATORY LOGBOOK GOLDENROD- ORIGINATOR

Hanford Company

From: Applied Chemistry and Analysis
Date: 12-13-74
Subject: ISOTOPIC ANALYSIS OF URANIUM
ANALYZED 12-13-74

Hanford Engineering Development Laboratory

TO: J. Lester

cc: File

M. S. #	Lab #	Customer I. D.	Wt. %
1174231	P-6983	DB-15	238 = 89.84 ± 0.05
			236 = 0.106 ± 0.003
			235 = 10.00 ± 0.05
			234 = 0.050 ± 0.001
1174232	P-6985	DB-17	238 = 89.90 ± 0.05
			236 = 0.104 ± 0.003
			235 = 9.95 ± 0.05
			234 = 0.050 ± 0.001
			238 = ±
			236 = ±
			235 = ±
			234 = ±
			238 = ±
			236 = ±
			235 = ±
			234 = ±

Uncertainties are the 95% Confidence Level. Approved: [signature]

SC 6694	Hanford Engineering Development Laboratory SPECTROCHEMICAL ANALYSIS REPORT	CCI SPEC. LAB.

MATERIAL: UO_2 10% Enriched

SUBMITTED BY	SUBMITTER'S NO.	ANALYZED BY	DATE REPORTED
J. Lester		R M Ogden	12-17-74

ELEMENT		ELEMENT		ELEMENT		ELEMENT	
Ag	<10	Hg		Re		Dy	
Al	340	In		Rh		Er	
As		Ir		Ru		Eu	
Au		K	<20	Sb		Gd	
B	<2	La		Sc		Ho	
Ba		Li	<1	Si	<60	Lu	
Be	<2	Mg	<10	Sn	<10	Nd	
Bi		Mn	<10	Sr		Pr	
Ca	<25	Mo	<10	Ta		Sm	
Cd	<2	Na	<100	Th		Tb	
Ce		Nb		Ti	<20	Tm	
Co	<1	Ni	<50	Tl		Yb	
Cr	<25	Os		U			
Cs		P		V	<50		
Cu	<20	Pb	<10	W			
Fe	130	Pd		Y			
Ga		Pt		Zn	<20		
Ge		Pu		Zr			
Hf		Rb					

TYPE OF ANALYSIS

☐ QUALITATIVE

SYMBOL	MEANING	APP'X. CONC.
SS	MAJOR DETECTABLE CONSTITUENT	
S	STRONG	GREATER THAN 1 %
M	MODERATE	1 % TO 0.01 %
T	TRACE	LESS THAN 0.01 %
—	NOT DETECTED	
*	INTERFERENCE	
?	DETECTION UNCERTAIN. INTERFERENCE	

☒ SEMIQUANTITATIVE

SYMBOL	MEANING
G	CONCENTRATION GREATER THAN
L	DETECTABLE CONCENTRATION LESS THAN
—	NOT DETECTED

NUMERICAL VALUES: ☒ PARTS PER MILLION ☐ PERCENT ☐ ______

APPR'X. PRECISION ± FACTOR 2

☐ QUANTITATIVE

SYMBOL	MEANING
GX (LX)	CONC. GREATER THAN (LESS THAN) CALIBRATED WORKING CURVE

NUMERICAL VALUES: ☐ PARTS PER MILLION ☐ PERCENT ☐ ______

APPR'X. PRECISION ± ______

REMARKS: 6694 DB 15 P-6983

REPORT APPROVED [signature]

LABORATORY INFORMATION

SPECTROGRAPH AND SOURCE	SIZE OF SAMPLE	METHOD OF ANALYSIS	PLATE NO.
Direct Reader	50 mg	U-7 1989	

BD-7340-021 (3-73)

SC 308	WESTINGHOUSE HANFORD COMPANY SPARK SOURCE MASS SPECTROGRAPHIC ANALYSIS REPORT	CC: SPEC. LAB

MATERIAL UO_2 10% ENR

SUBMITTED BY	SUBMITTER'S NO.	ANALYZED BY	DATE REPORTED
J. LESTER	DB-15	JE	12/18/74

ELEMENT		ELEMENT		ELEMENT		ELEMENT	
H		Fe		Sb		Os	
He		Co	0.2	Te		Ir	
Li	0.8	Ni		I		Pt	
Be		Cu		Xe		Au	
B	0.3	Zn		Cs	0.05	Hg	
C		Ga		Ba	0.2	Tl	
N		Ge		La		Pb	
O		As		Ce		Bi	
F		Se		Pr		Po	
Ne		Br		Nd		At	
Na		Kr		Pm		Rn	
Mg		Rb		Sm	0.4	Fr	
Al		Sr		Eu	0.5	Ra	
Si		Y		Gd	<0.5	Ac	
P	0.7	Zr		Tb	"	Th	
S		Nb		Dy	0.5	Pa	
Cl		Mo		Ho		U	
Ar		Tc		Er		Np	
K		Ru		Tm		Pu	
Ca		Rh		Yb		Am	
Sc		Pd		Lu		Cm	
Ti		Ag		Hf	<0.3		
V	1	Cd		Ta	<0.5		
Cr		In		W	3		
Mn		Sn		Re			

TYPE OF ANALYSIS

☐ QUALITATIVE	☒ SEMIQUANTITATIVE	☐ QUANTITATIVE
NUMERICAL VALUES ☐ PARTS PER MILLION ☐ PERCENT ☐ ______	NUMERICAL VALUES ☒ PARTS PER MILLION ☐ PERCENT ☐ ______	NUMERICAL VALUES ☐ PARTS PER MILLION ☐ PERCENT ☐ ______
APPR'X PRECISION ± FACTOR ___	APPR'X PRECISION ± FACTOR 3	APPR'X PRECISION ± ______

REMARKS:

REPORT APPROVED Ray [signature]

BD-7340-021 (1-73)

Hanford Engineering Development Laboratory

FUELS AND CONTROL SAMPLE ANALYSIS

SAMPLE IDENTIFICATION: Batch #5 BNW HALDEN Pellet DB-26

LAB. SERIAL NO. P-7163

DATE REC. 1-22-75

SAMPLE SUBMITTER	ADDRESS	PHONE	WORK ORDER NO.
Lester	308 E, TRL	3184	C-56575

TYPE OF MATERIAL:

- [ ] PuO_2
- [x] UO_2
- [ ] MIXED OXIDE:_______% PuO_2
- [ ] B_4C
- [ ] OTHERS________

SPECIAL INSTRUCTIONS

Pu ISOTOPIC:_______% 240

U ISOTOPIC:
- [ ] NORMAL
- [x] 10 % ENRICHED

B ISOTOPIC:
- [ ] NATURAL
- [ ] ____% ENRICHED

NO. OF ANALYSIS		RESULTS
	Pu WT. %	
	U WT. %	
	^{241}Am ppm	
	O/M	Pellet # 77? 7?? 7??
3	C ppm	17 3?6 3??
	S ppm	
	OFF-GAS cc/g @ STP	
	Cl ppm	
	F ppm	
	H_2O ppm	#77? #79? #7??
3	N ppm	73 116 ?3.
	O ppm	
	SOLUBLE C WT %	
	SOLUBLE B WT % [ ] HNO_3 [ ] HCl	
	TOTAL C WT %	
	TOTAL B WT %	

NO. OF ANALYSIS		RESULTS
	LOSS ON IGNITION WT %	
	DENSITY g/cc	
	POROSITY	SEE SPECIAL REPORT
	SURFACE AREA M^2/g	
	PARTICLE SIZE-MSA (PuO_2 ONLY)	SEE SPECIAL REPORT
	PARTICLE SIZE, FISHER SUBSIEVE	
	OTHERS	
	OTHERS	

SPECTROCHEMICAL ANALYSES

	SPARK SOURCE GENERAL	SEE SPECIAL REPORT
	SPARK SOURCE R.E. + Ta + W	SEE SPECIAL REPORT
	EMISSION SPEC. GENERAL	SEE SPECIAL REPORT

ISOTOPIC ANALYSES

	Pu ISOTOPIC	SEE SPECIAL REPORT
	U ISOTOPIC	SEE SPECIAL REPORT
	B ISOTOPIC	SEE SPECIAL REPORT

SPECIAL OBSERVATIONS – REMARKS

REPORT APPROVED BY [illegible signature]

DATE COMPLETED 1-29-75

BD-7340 022 (8 74)

DISTRIBUTION: WHITE Sample Submitter; YELLOW Laboratory Record; PINK Fuels QA; GOLDENROD Originator

IFA-431, GEOMETRIC DENSITIES

IFA-431, Rod 1, Solid Pellets

LOT NO.	SAMPLE NO.	DIAMETER (INCHES) D-1	D-2	D-3	LENGTH (INCHES) L-1	L-2	WEIGHT (GRAMS)	DIA. CENTER VOID (INCHES)	DENSITY (G/CC)	DENSITY (PERCENT T.D.)
1-1	294	.4204E+00	.4203E+00	.4203E+00	.5030E+00	.5020E+00	.11868E+02	.0	.1039E+02	.9477E+02
1-1	295	.4204E+00	.4204E+00	.4204E+00	.5040E+00	.5030E+00	.11873E+02	.0	.1037E+02	.9459E+02
1-1	300	.4203E+00	.4204E+00	.4204E+00	.4980E+00	.4960E+00	.11711E+02	.0	.1036E+02	.9453E+02
1-1	341	.4204E+00	.4204E+00	.4204E+00	.4960E+00	.4960E+00	.11732E+02	.0	.1040E+02	.9488E+02
1-1	342	.4204E+00	.4204E+00	.4203E+00	.5000E+00	.4990E+00	.11801E+02	.0	.1039E+02	.9478E+02
1-1	343	.4204E+00	.4205E+00	.4204E+00	.4960E+00	.4950E+00	.11682E+02	.0	.1036E+02	.9456E+02
1-1	344	.4204E+00	.4205E+00	.4204E+00	.4930E+00	.4960E+00	.11674E+02	.0	.1038E+02	.9468E+02
1-1	347	.4204E+00	.4204E+00	.4204E+00	.5030E+00	.5020E+00	.11861E+02	.0	.1038E+02	.9468E+02
1-1	350	.4204E+00	.4205E+00	.4204E+00	.5020E+00	.5040E+00	.11890E+02	.0	.1039E+02	.9480E+02
1-1	355	.4203E+00	.4205E+00	.4205E+00	.5000E+00	.5010E+00	.11833E+02	.0	.1039E+02	.9482E+02
1-1	361	.4202E+00	.4204E+00	.4203E+00	.4990E+00	.5000E+00	.11762E+02	.0	.1036E+02	.9450E+02
1-1	362	.4205E+00	.4205E+00	.4205E+00	.4970E+00	.4990E+00	.11739E+02	.0	.1036E+02	.9451E+02
1-1	364	.4203E+00	.4204E+00	.4204E+00	.4990E+00	.4970E+00	.11753E+02	.0	.1038E+02	.9468E+02
1-1	365	.4204E+00	.4204E+00	.4204E+00	.4990E+00	.5010E+00	.11815E+02	.0	.1039E+02	.9479E+02
1-1	366	.4204E+00	.4205E+00	.4204E+00	.4990E+00	.4970E+00	.11735E+02	.0	.1036E+02	.9451E+02
1-1	375	.4204E+00	.4204E+00	.4203E+00	.4980E+00	.4990E+00	.11762E+02	.0	.1037E+02	.9466E+02
1-1	381	.4203E+00	.4204E+00	.4203E+00	.4990E+00	.5000E+00	.11790E+02	.0	.1038E+02	.9471E+02
1-1	392	.4204E+00	.4205E+00	.4205E+00	.5020E+00	.5020E+00	.11841E+02	.0	.1037E+02	.9459E+02
1-1	394	.4204E+00	.4204E+00	.4204E+00	.5000E+00	.4980E+00	.11788E+02	.0	.1039E+02	.9476E+02
1-1	395	.4204E+00	.4203E+00	.4202E+00	.4980E+00	.4980E+00	.11753E+02	.0	.1038E+02	.9471E+02
1-1	397	.4204E+00	.4204E+00	.4204E+00	.5020E+00	.5020E+00	.11841E+02	.0	.1037E+02	.9462E+02
1-1	404	.4203E+00	.4204E+00	.4204E+00	.4980E+00	.4980E+00	.11750E+02	.0	.1037E+02	.9466E+02
1-1	405	.4204E+00	.4205E+00	.4203E+00	.5000E+00	.4990E+00	.11751E+02	.0	.1034E+02	.9437E+02
1-1	410	.4205E+00	.4205E+00	.4204E+00	.5020E+00	.5020E+00	.11845E+02	.0	.1037E+02	.9462E+02
1-1	415	.4205E+00	.4205E+00	.4204E+00	.4970E+00	.4950E+00	.11699E+02	.0	.1037E+02	.9458E+02
1-1	421	.4203E+00	.4204E+00	.4204E+00	.5020E+00	.5020E+00	.11860E+02	.0	.1039E+02	.9478E+02
1-1	423	.4203E+00	.4203E+00	.4202E+00	.5000E+00	.5020E+00	.11833E+02	.0	.1039E+02	.9480E+02
1-1	430	.4204E+00	.4205E+00	.4203E+00	.5040E+00	.5030E+00	.11891E+02	.0	.1038E+02	.9473E+02
1-1	432	.4204E+00	.4204E+00	.4203E+00	.5020E+00	.5030E+00	.11870E+02	.0	.1039E+02	.9477E+02
1-1	445	.4205E+00	.4204E+00	.4203E+00	.5050E+00	.5000E+00	.11785E+02	.0	.1031E+02	.9408E+02
1-1	451	.4203E+00	.4205E+00	.4204E+00	.4880E+00	.4880E+00	.11390E+02	.0	.1026E+02	.9362E+02
1-1	456	.4203E+00	.4203E+00	.4202E+00	.5270E+00	.5280E+00	.12301E+02	.0	.1026E+02	.9360E+02
1-1	457	.4204E+00	.4205E+00	.4203E+00	.5020E+00	.5040E+00	.11750E+02	.0	.1027E+02	.9370E+02

TOTAL WEIGHT OF GROUP = 389.229 GRAMS
AVERAGE WEIGHT OF GROUP = 11.7948 GRAMS
AVERAGE DENSITY OF GROUP = 94.560 PERCENT T.D.
AVERAGE PELLET LENGTH OF GROUP = .5004 INCHES
STANDARD DEVIATION OF PELLET DENSITY = .332

IFA-431, Rod 1, Drilled Pellets

LOT NO.	SAMPLE NO.	DIAMETER (INCHES) D-1	D-2	D-3	LENGTH (INCHES) L-1	L-2	WEIGHT (GRAMS)	DIA. CENTER VOID (INCHES)	DENSITY (G/CC)	DENSITY (PERCENT T.D.)
1-1	2	.4203E+00	.4203E+00	.4202E+00	.5140E+00	.5150E+00	.11820E+02	.6850E-01	.1038E+02	.9473E+02
1-1	10	.4204E+00	.4206E+00	.4204E+00	.5140E+00	.5150E+00	.11858E+02	.6850E-01	.1041E+02	.9494E+02
1-1	79	.4204E+00	.4205E+00	.4205E+00	.5090E+00	.5100E+00	.11698E+02	.6850E-01	.1037E+02	.9458E+02
1-1	82	.4203E+00	.4205E+00	.4204E+00	.4990E+00	.5000E+00	.11455E+02	.6850E-01	.1036E+02	.9450E+02
1-1	84	.4201E+00	.4203E+00	.4202E+00	.5110E+00	.5080E+00	.11662E+02	.6850E-01	.1035E+02	.9441E+02
1-1	88	.4201E+00	.4203E+00	.4203E+00	.5010E+00	.5020E+00	.11492E+02	.6850E-01	.1036E+02	.9450E+02
1-1	152	.4200E+00	.4201E+00	.4201E+00	.5170E+00	.5150E+00	.11831E+02	.6850E-01	.1037E+02	.9463E+02
1-1	153	.4202E+00	.4204E+00	.4204E+00	.5110E+00	.5110E+00	.11708E+02	.6850E-01	.1035E+02	.9444E+02
1-1	158	.4201E+00	.4201E+00	.4200E+00	.5060E+00	.5060E+00	.11646E+02	.6850E-01	.1041E+02	.9500E+02
1-1	163	.4201E+00	.4203E+00	.4202E+00	.5060E+00	.5060E+00	.11613E+02	.6850E-01	.1038E+02	.9467E+02
1-1	167	.4203E+00	.4204E+00	.4203E+00	.5060E+00	.5060E+00	.11632E+02	.6850E-01	.1039E+02	.9476E+02
1-1	171	.4200E+00	.4203E+00	.4203E+00	.5030E+00	.5050E+00	.11596E+02	.6850E-01	.1040E+02	.9490E+02

TOTAL WEIGHT OF GROUP = 140.011 GRAMS
AVERAGE WEIGHT OF GROUP = 11.6676 GRAMS
AVERAGE DENSITY OF GROUP = 94.672 PERCENT T.D.
AVERAGE PELLET LENGTH OF GROUP = .5084 INCHES
STANDARD DEVIATION OF PELLET DENSITY = .197

IFA-431, Rod 2, Solid Pellets

LOT NO.	SAMPLE NO.	DIAMETER (INCHES) D-1	D-2	D-3	LENGTH (INCHES) L-1	L-2	WEIGHT (GRAMS)	DIA. CENTER VOID (INCHES)	DENSITY (G/CC)	DENSITY (PERCENT T.D.)
1-2	23	.4144E+00	.4145E+00	.4145E+00	.5070E+00	.5070E+00	.11639E+02	.0	.1038E+02	.9474E+02
1-2	29	.4144E+00	.4145E+00	.4146E+00	.5030E+00	.5040E+00	.11561E+02	.0	.1038E+02	.9475E+02
1-2	34	.4144E+00	.4144E+00	.4143E+00	.5080E+00	.5080E+00	.11678E+02	.0	.1040E+02	.9492E+02
1-2	43	.4146E+00	.4146E+00	.4145E+00	.4980E+00	.5000E+00	.11480E+02	.0	.1040E+02	.9490E+02
1-2	45	.4144E+00	.4144E+00	.4144E+00	.5040E+00	.5060E+00	.11633E+02	.0	.1042E+02	.9510E+02
1-2	50	.4144E+00	.4145E+00	.4145E+00	.5010E+00	.5030E+00	.11522E+02	.0	.1038E+02	.9472E+02
1-2	56	.4145E+00	.4144E+00	.4144E+00	.5050E+00	.5060E+00	.11613E+02	.0	.1039E+02	.9483E+02
1-2	62	.4144E+00	.4145E+00	.4145E+00	.4980E+00	.5000E+00	.11481E+02	.0	.1041E+02	.9495E+02
1-2	109	.4145E+00	.4146E+00	.4145E+00	.5000E+00	.5020E+00	.11501E+02	.0	.1038E+02	.9471E+02
1-2	121	.4144E+00	.4144E+00	.4143E+00	.4980E+00	.5000E+00	.11470E+02	.0	.1040E+02	.9491E+02
1-2	150	.4145E+00	.4146E+00	.4145E+00	.5070E+00	.5080E+00	.11688E+02	.0	.1041E+02	.9502E+02
1-2	201	.4145E+00	.4144E+00	.4144E+00	.5080E+00	.5080E+00	.11689E+02	.0	.1041E+02	.9498E+02
1-2	202	.4145E+00	.4146E+00	.4146E+00	.5090E+00	.5090E+00	.11700E+02	.0	.1039E+02	.9482E+02
1-2	203	.4143E+00	.4144E+00	.4144E+00	.5040E+00	.5040E+00	.11613E+02	.0	.1043E+02	.9514E+02
1-2	206	.4144E+00	.4145E+00	.4145E+00	.5060E+00	.5070E+00	.11662E+02	.0	.1041E+02	.9502E+02
1-2	214	.4144E+00	.4146E+00	.4146E+00	.5080E+00	.5090E+00	.11693E+02	.0	.1040E+02	.9487E+02
1-2	218	.4144E+00	.4145E+00	.4145E+00	.5080E+00	.5080E+00	.11684E+02	.0	.1040E+02	.9492E+02
1-2	222	.4145E+00	.4145E+00	.4144E+00	.4950E+00	.4950E+00	.11405E+02	.0	.1042E+02	.9509E+02
1-2	223	.4143E+00	.4143E+00	.4143E+00	.4990E+00	.5000E+00	.11504E+02	.0	.1043E+02	.9512E+02
1-2	231	.4144E+00	.4146E+00	.4146E+00	.5100E+00	.5090E+00	.11749E+02	.0	.1043E+02	.9514E+02
1-2	242	.4146E+00	.4146E+00	.4146E+00	.5130E+00	.5120E+00	.11802E+02	.0	.1041E+02	.9498E+02
1-2	255	.4144E+00	.4145E+00	.4145E+00	.5110E+00	.5130E+00	.11778E+02	.0	.1041E+02	.9494E+02
1-2	261	.4145E+00	.4145E+00	.4145E+00	.5080E+00	.5100E+00	.11697E+02	.0	.1039E+02	.9482E+02
1-2	266	.4146E+00	.4147E+00	.4147E+00	.5150E+00	.5140E+00	.11829E+02	.0	.1039E+02	.9479E+02
1-2	269	.4146E+00	.4146E+00	.4144E+00	.4960E+00	.4960E+00	.11404E+02	.0	.1040E+02	.9486E+02
1-2	282	.4145E+00	.4146E+00	.4145E+00	.5020E+00	.5030E+00	.11522E+02	.0	.1037E+02	.9460E+02
1-2	283	.4144E+00	.4145E+00	.4144E+00	.4930E+00	.4940E+00	.11328E+02	.0	.1038E+02	.9475E+02
1-2	285	.4144E+00	.4145E+00	.4144E+00	.4970E+00	.4970E+00	.11401E+02	.0	.1038E+02	.9469E+02
1-2	286	.4145E+00	.4145E+00	.4144E+00	.4970E+00	.4980E+00	.11452E+02	.0	.1041E+02	.9500E+02
1-2	287	.4145E+00	.4145E+00	.4145E+00	.5060E+00	.5070E+00	.11652E+02	.0	.1040E+02	.9493E+02
1-2	288	.4144E+00	.4145E+00	.4146E+00	.5030E+00	.5040E+00	.11591E+02	.0	.1041E+02	.9499E+02
1-2	289	.4144E+00	.4144E+00	.4144E+00	.5020E+00	.5000E+00	.11529E+02	.0	.1041E+02	.9500E+02
1-2	290	.4144E+00	.4146E+00	.4145E+00	.5020E+00	.5030E+00	.11561E+02	.0	.1040E+02	.9493E+02

TOTAL WEIGHT OF GROUP = 382.511 GRAMS
AVERAGE WEIGHT OF GROUP = 11.5912 GRAMS
AVERAGE DENSITY OF GROUP = 94.906 PERCENT T.D.
AVERAGE PELLET LENGTH OF GROUP = .5049 INCHES
STANDARD DEVIATION OF PELLET DENSITY = .139

IFA-431, Rod 2, Drilled Pellets

LOT NO.	SAMPLE NO.	DIAMETER (INCHES) D-1	D-2	D-3	LENGTH (INCHES) L-1	L-2	WEIGHT (GRAMS)	DIA. CENTER VOID (INCHES)	DENSITY (G/CC)	DENSITY (PERCENT T.D.)
1-2	302	.4144E+00	.4145E+00	.4144E+00	.4990E+00	.5010E+00	.11133E+02	.6850E-01	.1036E+02	.9449E+02
1-2	303	.4144E+00	.4145E+00	.4144E+00	.5020E+00	.5000E+00	.11133E+02	.6850E-01	.1034E+02	.9430E+02
1-2	306	.4143E+00	.4145E+00	.4144E+00	.5040E+00	.5020E+00	.11190E+02	.6850E-01	.1035E+02	.9442E+02
1-2	309	.4144E+00	.4144E+00	.4144E+00	.5030E+00	.5030E+00	.11141E+02	.6850E-01	.1030E+02	.9401E+02
1-2	311	.4145E+00	.4146E+00	.4145E+00	.4940E+00	.4960E+00	.11020E+02	.6850E-01	.1035E+02	.9443E+02
1-2	313	.4145E+00	.4146E+00	.4144E+00	.5030E+00	.5040E+00	.11190E+02	.6850E-01	.1033E+02	.9428E+02
1-2	315	.4145E+00	.4146E+00	.4145E+00	.5040E+00	.5030E+00	.11192E+02	.6850E-01	.1033E+02	.9428E+02
1-2	316	.4145E+00	.4145E+00	.4145E+00	.5050E+00	.5050E+00	.11238E+02	.6850E-01	.1035E+02	.9440E+02
1-2	317	.4143E+00	.4145E+00	.4145E+00	.5050E+00	.5030E+00	.11207E+02	.6850E-01	.1034E+02	.9436E+02
1-2	319	.4143E+00	.4145E+00	.4145E+00	.5010E+00	.5010E+00	.11123E+02	.6850E-01	.1033E+02	.9421E+02
1-2	329	.4143E+00	.4145E+00	.4145E+00	.5020E+00	.5020E+00	.11158E+02	.6850E-01	.1034E+02	.9432E+02
1-2	337	.4144E+00	.4145E+00	.4144E+00	.4970E+00	.4990E+00	.11071E+02	.6850E-01	.1034E+02	.9434E+02

TOTAL WEIGHT OF GROUP = 133.796 GRAMS
AVERAGE WEIGHT OF GROUP = 11.1497 GRAMS
AVERAGE DENSITY OF GROUP = 94.320 PERCENT T.D.
AVERAGE PELLET LENGTH OF GROUP = .5016 INCHES
STANDARD DEVIATION OF PELLET DENSITY = .125

IFA-431, Rod 3, Solid Pellets

LOT NO.	SAMPLE NO.	DIAMETER (INCHES) D-1	D-2	D-3	LENGTH (INCHES) L-1	L-2	WEIGHT (GRAMS)	DIA. CENTER VOID (INCHES)	DENSITY (G/CC)	DENSITY (PERCENT T.D.)
1-3	477	.4272E+00	.4274E+00	.4274E+00	.5100E+00	.5100E+00	.12526E+02	.0	.1045E+02	.9535E+02
1-3	482	.4274E+00	.4274E+00	.4273E+00	.5150E+00	.5150E+00	.12641E+02	.0	.1044E+02	.9528E+02
1-3	495	.4275E+00	.4275E+00	.4274E+00	.5020E+00	.5040E+00	.12392E+02	.0	.1048E+02	.9558E+02
1-3	496	.4273E+00	.4275E+00	.4274E+00	.5120E+00	.5100E+00	.12560E+02	.0	.1045E+02	.9539E+02
1-3	499	.4273E+00	.4274E+00	.4274E+00	.5050E+00	.5080E+00	.12462E+02	.0	.1047E+02	.9550E+02
1-3	500	.4273E+00	.4275E+00	.4274E+00	.5080E+00	.5060E+00	.12457E+02	.0	.1045E+02	.9536E+02
1-3	502	.4273E+00	.4274E+00	.4274E+00	.5060E+00	.5070E+00	.12458E+02	.0	.1046E+02	.9547E+02
1-3	503	.4274E+00	.4273E+00	.4274E+00	.5020E+00	.5030E+00	.12333E+02	.0	.1044E+02	.9527E+02
1-3	504	.4272E+00	.4273E+00	.4274E+00	.5090E+00	.5090E+00	.12484E+02	.0	.1044E+02	.9523E+02
1-3	506	.4274E+00	.4275E+00	.4274E+00	.5110E+00	.5130E+00	.12589E+02	.0	.1046E+02	.9541E+02
1-3	507	.4274E+00	.4275E+00	.4273E+00	.5080E+00	.5090E+00	.12443E+02	.0	.1041E+02	.9497E+02
1-3	510	.4273E+00	.4273E+00	.4273E+00	.5030E+00	.5050E+00	.12352E+02	.0	.1043E+02	.9516E+02
1-3	511	.4273E+00	.4275E+00	.4275E+00	.5090E+00	.5100E+00	.12528E+02	.0	.1046E+02	.9541E+02
1-3	512	.4274E+00	.4275E+00	.4275E+00	.5120E+00	.5110E+00	.12580E+02	.0	.1046E+02	.9542E+02
1-3	514	.4275E+00	.4276E+00	.4276E+00	.5150E+00	.5140E+00	.12645E+02	.0	.1045E+02	.9531E+02
1-3	515	.4270E+00	.4273E+00	.4273E+00	.5130E+00	.5120E+00	.12583E+02	.0	.1045E+02	.9538E+02
1-3	516	.4273E+00	.4274E+00	.4273E+00	.5100E+00	.5100E+00	.12512E+02	.0	.1044E+02	.9524E+02
1-3	555	.4274E+00	.4274E+00	.4275E+00	.5130E+00	.5120E+00	.12565E+02	.0	.1043E+02	.9514E+02
1-3	559	.4271E+00	.4275E+00	.4275E+00	.5050E+00	.5060E+00	.12382E+02	.0	.1042E+02	.9508E+02
1-3	568	.4273E+00	.4273E+00	.4272E+00	.5150E+00	.5150E+00	.12613E+02	.0	.1042E+02	.9511E+02
1-3	573	.4273E+00	.4274E+00	.4274E+00	.5120E+00	.5100E+00	.12499E+02	.0	.1041E+02	.9494E+02
1-3	578	.4270E+00	.4275E+00	.4275E+00	.5110E+00	.5120E+00	.12525E+02	.0	.1042E+02	.9506E+02
1-3	580	.4273E+00	.4274E+00	.4274E+00	.5100E+00	.5100E+00	.12548E+02	.0	.1047E+02	.9550E+02
1-3	596	.4271E+00	.4273E+00	.4271E+00	.5100E+00	.5110E+00	.12482E+02	.0	.1041E+02	.9500E+02
1-3	598	.4273E+00	.4273E+00	.4273E+00	.5120E+00	.5130E+00	.12532E+02	.0	.1041E+02	.9494E+02
1-3	603	.4271E+00	.4271E+00	.4271E+00	.5120E+00	.5120E+00	.12578E+02	.0	.1046E+02	.9548E+02
1-3	606	.4274E+00	.4272E+00	.4271E+00	.5110E+00	.5130E+00	.12557E+02	.0	.1044E+02	.9526E+02
1-3	607	.4273E+00	.4273E+00	.4274E+00	.5100E+00	.5100E+00	.12530E+02	.0	.1045E+02	.9538E+02
1-3	609	.4275E+00	.4275E+00	.4275E+00	.5110E+00	.5110E+00	.12570E+02	.0	.1046E+02	.9542E+02
1-3	613	.4274E+00	.4274E+00	.4274E+00	.4860E+00	.4860E+00	.11892E+02	.0	.1041E+02	.9496E+02
1-3	616	.4274E+00	.4274E+00	.4272E+00	.5240E+00	.5250E+00	.12877E+02	.0	.1045E+02	.9531E+02
1-3	617	.4273E+00	.4273E+00	.4272E+00	.5120E+00	.5120E+00	.12532E+02	.0	.1042E+02	.9505E+02
1-3	618	.4275E+00	.4275E+00	.4276E+00	.5090E+00	.5090E+00	.12488E+02	.0	.1043E+02	.9516E+02

TOTAL WEIGHT OF GROUP = 412.715 GRAMS
AVERAGE WEIGHT OF GROUP = 12.5065 GRAMS
AVERAGE DENSITY OF GROUP = 95.258 PERCENT T.D.
AVERAGE PELLET LENGTH OF GROUP = .5096 INCHES
STANDARD DEVIATION OF PELLET DENSITY = .185

IFA-431, Rod 3, Drilled Pellets

LOT NO.	SAMPLE NO.	DIAMETER (INCHES) D-1	D-2	D-3	LENGTH (INCHES) L-1	L-2	WEIGHT (GRAMS)	DIA. CENTER VOID (INCHES)	DENSITY (G/CC)	DENSITY (PERCENT T.D.)
1-3	518	.4274E+00	.4276E+00	.4277E+00	.5060E+00	.5080E+00	.12120E+02	.6850E-01	.1043E+02	.9515E+02
1-3	521	.4276E+00	.4276E+00	.4275E+00	.5090E+00	.5100E+00	.12178E+02	.6850E-01	.1043E+02	.9513E+02
1-3	524	.4275E+00	.4276E+00	.4277E+00	.5010E+00	.5000E+00	.11915E+02	.6850E-01	.1038E+02	.9474E+02
1-3	527	.4275E+00	.4275E+00	.4275E+00	.5070E+00	.5070E+00	.12123E+02	.6850E-01	.1043E+02	.9520E+02
1-3	528	.4276E+00	.4276E+00	.4275E+00	.5080E+00	.5060E+00	.12077E+02	.6850E-01	.1039E+02	.9481E+02
1-3	532	.4275E+00	.4275E+00	.4275E+00	.5100E+00	.5100E+00	.12156E+02	.6850E-01	.1040E+02	.9490E+02
1-3	534	.4275E+00	.4275E+00	.4274E+00	.5090E+00	.5100E+00	.12129E+02	.6850E-01	.1039E+02	.9479E+02
1-3	539	.4275E+00	.4275E+00	.4275E+00	.5170E+00	.5170E+00	.12325E+02	.6850E-01	.1040E+02	.9491E+02
1-3	544	.4275E+00	.4275E+00	.4275E+00	.5150E+00	.5150E+00	.12270E+02	.6850E-01	.1040E+02	.9486E+02
1-3	550	.4273E+00	.4275E+00	.4274E+00	.5130E+00	.5110E+00	.12165E+02	.6850E-01	.1037E+02	.9464E+02
1-3	551	.4275E+00	.4275E+00	.4276E+00	.5080E+00	.5090E+00	.12129E+02	.6850E-01	.1041E+02	.9495E+02
1-3	552	.4275E+00	.4275E+00	.4275E+00	.5040E+00	.5050E+00	.12020E+02	.6850E-01	.1040E+02	.9486E+02

TOTAL WEIGHT OF GROUP = 145.607 GRAMS
AVERAGE WEIGHT OF GROUP = 12.1339 GRAMS
AVERAGE DENSITY OF GROUP = 94.912 PERCENT T.D.
AVERAGE PELLET LENGTH OF GROUP = .5090 INCHES
STANDARD DEVIATION OF PELLET DENSITY = .171

IFA-431, Rod 4, Solid Pellets

LOT NO.	SAMPLE NO.	DIAMETER (INCHES) D-1	D-2	D-3	LENGTH (INCHES) L-1	L-2	WEIGHT (GRAMS)	DIA. CENTER VOID (INCHES)	DENSITY (G/CC)	DENSITY (PERCENT T.D.)
1-4	22	.4202E+00	.4204E+00	.4203E+00	.5090E+00	.5080E+00	.12041E+02	.0	.1042E+02	.9503E+02
1-4	33	.4206E+00	.4206E+00	.4204E+00	.5040E+00	.5030E+00	.11902E+02	.0	.1039E+02	.9476E+02
1-4	60	.4204E+00	.4204E+00	.4204E+00	.5010E+00	.5020E+00	.11892E+02	.0	.1043E+02	.9512E+02
1-4	67	.4203E+00	.4204E+00	.4203E+00	.5000E+00	.5020E+00	.11840E+02	.0	.1039E+02	.9483E+02
1-4	92	.4204E+00	.4206E+00	.4203E+00	.5100E+00	.5100E+00	.12031E+02	.0	.1037E+02	.9461E+02
1-4	96	.4203E+00	.4204E+00	.4203E+00	.5120E+00	.5120E+00	.12080E+02	.0	.1038E+02	.9467E+02
1-4	102	.4202E+00	.4205E+00	.4202E+00	.5140E+00	.5140E+00	.12139E+02	.0	.1039E+02	.9478E+02
1-4	106	.4202E+00	.4202E+00	.4201E+00	.5110E+00	.5110E+00	.12082E+02	.0	.1041E+02	.9495E+02
1-4	108	.4202E+00	.4204E+00	.4202E+00	.5180E+00	.5180E+00	.12241E+02	.0	.1040E+02	.9485E+02
1-4	126	.4201E+00	.4203E+00	.4203E+00	.5080E+00	.5090E+00	.12003E+02	.0	.1039E+02	.9476E+02
1-4	129	.4201E+00	.4203E+00	.4203E+00	.5100E+00	.5110E+00	.12072E+02	.0	.1040E+02	.9493E+02
1-4	130	.4203E+00	.4205E+00	.4203E+00	.5130E+00	.5130E+00	.12103E+02	.0	.1037E+02	.9465E+02
1-4	132	.4202E+00	.4204E+00	.4204E+00	.5090E+00	.5100E+00	.12040E+02	.0	.1039E+02	.9482E+02
1-4	134	.4202E+00	.4204E+00	.4202E+00	.5140E+00	.5160E+00	.12131E+02	.0	.1036E+02	.9455E+02
1-4	141	.4202E+00	.4204E+00	.4202E+00	.5000E+00	.5010E+00	.11829E+02	.0	.1040E+02	.9486E+02
1-4	147	.4204E+00	.4205E+00	.4203E+00	.5020E+00	.5020E+00	.11873E+02	.0	.1040E+02	.9487E+02
1-4	148	.4202E+00	.4204E+00	.4203E+00	.5020E+00	.5020E+00	.11850E+02	.0	.1038E+02	.9473E+02
1-4	149	.4203E+00	.4205E+00	.4204E+00	.5060E+00	.5040E+00	.11950E+02	.0	.1040E+02	.9492E+02
1-4	208	.4201E+00	.4204E+00	.4203E+00	.5020E+00	.5040E+00	.11928E+02	.0	.1043E+02	.9518E+02
1-4	217	.4200E+00	.4201E+00	.4201E+00	.5090E+00	.5080E+00	.11998E+02	.0	.1039E+02	.9480E+02
1-4	225	.4201E+00	.4202E+00	.4202E+00	.4990E+00	.4990E+00	.11830E+02	.0	.1043E+02	.9520E+02
1-4	229	.4201E+00	.4203E+00	.4202E+00	.5050E+00	.5060E+00	.11967E+02	.0	.1042E+02	.9505E+02
1-4	243	.4204E+00	.4207E+00	.4206E+00	.5090E+00	.5090E+00	.12049E+02	.0	.1040E+02	.9488E+02
1-4	244	.4201E+00	.4206E+00	.4204E+00	.5110E+00	.5100E+00	.12092E+02	.0	.1042E+02	.9503E+02
1-4	245	.4202E+00	.4204E+00	.4205E+00	.4980E+00	.4960E+00	.11751E+02	.0	.1040E+02	.9486E+02
1-4	256	.4203E+00	.4205E+00	.4203E+00	.5110E+00	.5110E+00	.12070E+02	.0	.1039E+02	.9476E+02
1-4	259	.4202E+00	.4204E+00	.4203E+00	.5120E+00	.5110E+00	.12073E+02	.0	.1038E+02	.9472E+02

TOTAL WEIGHT OF GROUP = 323.857 GRAMS
AVERAGE WEIGHT OF GROUP = 11.9947 GRAMS
AVERAGE DENSITY OF GROUP = 94.859 PERCENT T.D.
AVERAGE PELLET LENGTH OF GROUP = .5074 INCHES
STANDARD DEVIATION OF PELLET DENSITY = .166

IFA-431, Rod 4, Drilled Pellets

LOT NO.	SAMPLE NO.	DIAMETER (INCHES) D-1	D-2	D-3	LENGTH (INCHES) L-1	L-2	WEIGHT (GRAMS)	DIA. CENTER VOID (INCHES)	DENSITY (G/CC)	DENSITY (PERCENT T.D.)
1-4	1	.4203E+00	.4204E+00	.4204E+00	.5110E+00	.5130E+00	.11758E+02	.6850E-01	.1037E+02	.9465E+02
1-4	11	.4205E+00	.4205E+00	.4204E+00	.5130E+00	.5150E+00	.11792E+02	.6850E-01	.1036E+02	.9450E+02
1-4	81	.4204E+00	.4205E+00	.4204E+00	.5060E+00	.5070E+00	.11629E+02	.6850E-01	.1037E+02	.9459E+02
1-4	87	.4202E+00	.4203E+00	.4203E+00	.5050E+00	.5050E+00	.11555E+02	.6850E-01	.1034E+02	.9435E+02
1-4	165	.4203E+00	.4204E+00	.4205E+00	.5050E+00	.5060E+00	.11588E+02	.6850E-01	.1035E+02	.9446E+02
1-4	169	.4204E+00	.4205E+00	.4205E+00	.5060E+00	.5080E+00	.11640E+02	.6850E-01	.1037E+02	.9457E+02

TOTAL WEIGHT OF GROUP = 69.962 GRAMS
AVERAGE WEIGHT OF GROUP = 11.6603 GRAMS
AVERAGE DENSITY OF GROUP = 94.522 PERCENT T.D.
AVERAGE PELLET LENGTH-OF GROUP = .5083 INCHES
STANDARD DEVIATION OF PELLET DENSITY = .107

LOT NO.	SAMPLE NO.	DIAMETER (INCHES) D-1	D-2	D-3	LENGTH (INCHES) L-1	L-2	WEIGHT (GRAMS)	DIA. CENTER VOID (INCHES)	DENSITY (G/CC)	DENSITY (PERCENT T.D.)
1-4	179	.4205E+00	.4204E+00	.4203E+00	.5090E+00	.5080E+00	.11703E+02	.6300E-01	.1035E+02	.9444E+02
1-4	180	.4205E+00	.4205E+00	.4203E+00	.5060E+00	.5080E+00	.11744E+02	.6300E-01	.1042E+02	.9504E+02
1-4	183	.4204E+00	.4205E+00	.4204E+00	.5040E+00	.5050E+00	.11680E+02	.6300E-01	.1041E+02	.9499E+02
1-4	187	.4206E+00	.4206E+00	.4205E+00	.5030E+00	.5020E+00	.11618E+02	.6300E-01	.1039E+02	.9480E+02
1-4	766	.4204E+00	.4205E+00	.4204E+00	.5090E+00	.5090E+00	.11712E+02	.6300E-01	.1035E+02	.9440E+02
1-4	769	.4205E+00	.4205E+00	.4204E+00	.5170E+00	.5160E+00	.11933E+02	.6300E-01	.1039E+02	.9477E+02
1-4	770	.4203E+00	.4204E+00	.4204E+00	.5100E+00	.5120E+00	.11811E+02	.6300E-01	.1040E+02	.9486E+02
1-4	772	.4203E+00	.4203E+00	.4203E+00	.5030E+00	.5020E+00	.11585E+02	.6300E-01	.1037E+02	.9465E+02

TOTAL WEIGHT OF GROUP = 93.786 GRAMS
AVERAGE WEIGHT OF GROUP = 11.7233 GRAMS
AVERAGE DENSITY OF GROUP = 94.743 PERCENT T.D.
AVERAGE PELLET LENGTH OF GROUP = .5077 INCHES
STANDARD DEVIATION OF PELLET DENSITY = .232

IFA-431, Rod 5, Solid Pellets

LOT NO.	SAMPLE NO.	DIAMETER (INCHES) D-1	D-2	D-3	LENGTH (INCHES) L-1	L-2	WEIGHT (GRAMS)	DIA. CENTER VOID (INCHES)	DENSITY (G/CC)	DENSITY (PERCENT T.D.)
1-5	784	.4205E+00	.4205E+00	.4205E+00	.5090E+00	.5090E+00	.11633E+02	.0	.1004E+02	.9163E+02
1-5	786	.4204E+00	.4205E+00	.4204E+00	.4980E+00	.4960E+00	.11378E+02	.0	.1006E+02	.9182E+02
1-5	787	.4203E+00	.4203E+00	.4203E+00	.5110E+00	.5100E+00	.11628E+02	.0	.1002E+02	.9141E+02
1-5	789	.4202E+00	.4204E+00	.4203E+00	.5040E+00	.5040E+00	.11480E+02	.0	.1002E+02	.9141E+02
1-5	790	.4204E+00	.4204E+00	.4204E+00	.4970E+00	.4980E+00	.11391E+02	.0	.1007E+02	.9184E+02
1-5	793	.4206E+00	.4205E+00	.4205E+00	.5120E+00	.5100E+00	.11505E+02	.0	.9892E+01	.9026E+02
1-5	796	.4205E+00	.4205E+00	.4206E+00	.5120E+00	.5120E+00	.11522E+02	.0	.9887E+01	.9021E+02
1-5	797	.4205E+00	.4205E+00	.4205E+00	.5020E+00	.5030E+00	.11330E+02	.0	.9908E+01	.9040E+02
1-5	800	.4204E+00	.4205E+00	.4204E+00	.5070E+00	.5050E+00	.11586E+02	.0	.1006E+02	.9183E+02
1-5	801	.4204E+00	.4206E+00	.4204E+00	.5140E+00	.5150E+00	.11601E+02	.0	.9910E+01	.9042E+02
1-5	802	.4204E+00	.4204E+00	.4204E+00	.5120E+00	.5150E+00	.11581E+02	.0	.9915E+01	.9047E+02
1-5	804	.4204E+00	.4204E+00	.4205E+00	.5050E+00	.5070E+00	.11348E+02	.0	.9858E+01	.8995E+02
1-5	806	.4204E+00	.4205E+00	.4205E+00	.5010E+00	.5020E+00	.11415E+02	.0	.1000E+02	.9128E+02
1-5	807	.4204E+00	.4205E+00	.4205E+00	.5160E+00	.5150E+00	.11808E+02	.0	.1007E+02	.9185E+02
1-5	808	.4204E+00	.4206E+00	.4205E+00	.5100E+00	.5110E+00	.11653E+02	.0	.1003E+02	.9152E+02
1-5	809	.4205E+00	.4205E+00	.4204E+00	.5160E+00	.5170E+00	.11845E+02	.0	.1008E+02	.9196E+02
1-5	810	.4204E+00	.4205E+00	.4204E+00	.5210E+00	.5190E+00	.11908E+02	.0	.1007E+02	.9184E+02
1-5	847	.4203E+00	.4204E+00	.4203E+00	.5050E+00	.5060E+00	.11521E+02	.0	.1002E+02	.9145E+02
1-5	849	.4204E+00	.4205E+00	.4205E+00	.5030E+00	.5030E+00	.11469E+02	.0	.1002E+02	.9143E+02
1-5	852	.4204E+00	.4203E+00	.4204E+00	.5050E+00	.5110E+00	.11506E+02	.0	.9959E+01	.9087E+02
1-5	855	.4204E+00	.4205E+00	.4205E+00	.5060E+00	.5080E+00	.11474E+02	.0	.9946E+01	.9075E+02
1-5	858	.4204E+00	.4204E+00	.4203E+00	.5060E+00	.5060E+00	.11620E+02	.0	.1010E+02	.9213E+02
1-5	861	.4204E+00	.4204E+00	.4203E+00	.5090E+00	.5070E+00	.11448E+02	.0	.9909E+01	.9041E+02
1-5	868	.4205E+00	.4206E+00	.4205E+00	.5020E+00	.5030E+00	.11515E+02	.0	.1007E+02	.9186E+02
1-5	869	.4204E+00	.4205E+00	.4205E+00	.5060E+00	.5050E+00	.11402E+02	.0	.9913E+01	.9045E+02
1-5	870	.4204E+00	.4204E+00	.4203E+00	.5010E+00	.5020E+00	.11393E+02	.0	.9989E+01	.9114E+02
1-5	871	.4203E+00	.4204E+00	.4205E+00	.5030E+00	.5060E+00	.11469E+02	.0	.9994E+01	.9119E+02
1-5	879	.4203E+00	.4204E+00	.4204E+00	.5080E+00	.5080E+00	.11521E+02	.0	.9972E+01	.9099E+02
1-5	886	.4204E+00	.4204E+00	.4203E+00	.4860E+00	.4860E+00	.11019E+02	.0	.9969E+01	.9096E+02
1-5	887	.4206E+00	.4206E+00	.4204E+00	.5050E+00	.5000E+00	.11318E+02	.0	.9896E+01	.9029E+02
1-5	889	.4204E+00	.4205E+00	.4205E+00	.5050E+00	.5070E+00	.11352E+02	.0	.9860E+01	.8996E+02
1-5	890	.4204E+00	.4205E+00	.4205E+00	.5190E+00	.5190E+00	.11649E+02	.0	.9865E+01	.9001E+02
1-5	891	.4204E+00	.4205E+00	.4204E+00	.5100E+00	.5110E+00	.11548E+02	.0	.9943E+01	.9073E+02

TOTAL WEIGHT OF GROUP = 379.836 GRAMS
AVERAGE WEIGHT OF GROUP = 11.5102 GRAMS
AVERAGE DENSITY OF GROUP = 91.053 PERCENT T.D.
AVERAGE PELLET LENGTH OF GROUP = .5070 INCHES
STANDARD DEVIATION OF PELLET DENSITY = .674

IFA-431, Rod 5, Drilled Pellets

LOT NO.	SAMPLE NO.	DIAMETER (INCHES) D-1	D-2	D-3	LENGTH (INCHES) L-1	L-2	WEIGHT (GRAMS)	DIA. CENTER VOID (INCHES)	DENSITY (G/CC)	DENSITY (PERCENT T.D.)
1-5	811	.4202E+00	.4203E+00	.4202E+00	.5030E+00	.5050E+00	.11144E+02	.6850E-01	.9994E+01	.9119E+02
1-5	818	.4202E+00	.4203E+00	.4202E+00	.5020E+00	.5040E+00	.11149E+02	.6850E-01	.1002E+02	.9141E+02
1-5	820	.4204E+00	.4205E+00	.4204E+00	.5040E+00	.5050E+00	.11121E+02	.6850E-01	.9954E+01	.9082E+02
1-5	823	.4202E+00	.4204E+00	.4204E+00	.5060E+00	.5070E+00	.11323E+02	.6850E-01	.1010E+02	.9215E+02
1-5	826	.4202E+00	.4204E+00	.4202E+00	.5110E+00	.5100E+00	.11203E+02	.6850E-01	.9918E+01	.9049E+02
1-5	827	.4203E+00	.4203E+00	.4203E+00	.5130E+00	.5150E+00	.11311E+02	.6850E-01	.9943E+01	.9072E+02
1-5	828	.4202E+00	.4203E+00	.4203E+00	.5130E+00	.5180E+00	.11431E+02	.6850E-01	.1002E+02	.9143E+02
1-5	836	.4203E+00	.4203E+00	.4203E+00	.5220E+00	.5230E+00	.11592E+02	.6850E-01	.1002E+02	.9147E+02
1-5	838	.4204E+00	.4204E+00	.4204E+00	.5110E+00	.5120E+00	.11320E+02	.6850E-01	.9995E+01	.9120E+02
1-5	844	.4203E+00	.4204E+00	.4203E+00	.5070E+00	.5080E+00	.11155E+02	.6850E-01	.9930E+01	.9060E+02
1-5	845	.4203E+00	.4205E+00	.4205E+00	.5070E+00	.5100E+00	.11317E+02	.6850E-01	.1005E+02	.9169E+02
1-5	846	.4202E+00	.4202E+00	.4203E+00	.5070E+00	.5050E+00	.11131E+02	.6850E-01	.9943E+01	.9072E+02

TOTAL WEIGHT OF GROUP = 135.197 GRAMS
AVERAGE WEIGHT OF GROUP = 11.2664 GRAMS
AVERAGE DENSITY OF GROUP = 91.158 PERCENT T.D.
AVERAGE PELLET LENGTH OF GROUP = .5095 INCHES
STANDARD DEVIATION OF PELLET DENSITY = .501

IFA-431, Rod 6, Solid Pellets

LOT NO.	SAMPLE NO.	DIAMETER (INCHES) D-1	D-2	D-3	LENGTH (INCHES) L-1	L-2	WEIGHT (GRAMS)	DIA. CENTER VOID (INCHES)	DENSITY (G/CC)	DENSITY (PERCENT T.D.)
1-6	681	.4205E+00	.4204E+00	.4204E+00	.5080E+00	.5090E+00	.11554E+02	.0	.9988E+01	.9113E+02
1-6	687	.4202E+00	.4204E+00	.4203E+00	.5020E+00	.5020E+00	.11469E+02	.0	.1005E+02	.9169E+02
1-6	688	.4202E+00	.4203E+00	.4204E+00	.5050E+00	.5050E+00	.11560E+02	.0	.1007E+02	.9187E+02
1-6	690	.4204E+00	.4205E+00	.4204E+00	.5000E+00	.5020E+00	.11491E+02	.0	.1008E+02	.9199E+02
1-6	693	.4204E+00	.4204E+00	.4203E+00	.5060E+00	.5060E+00	.11508E+02	.0	.1000E+02	.9124E+02
1-6	699	.4204E+00	.4205E+00	.4204E+00	.5040E+00	.5060E+00	.11556E+02	.0	.1006E+02	.9178E+02
1-6	701	.4203E+00	.4204E+00	.4203E+00	.5140E+00	.5140E+00	.11673E+02	.0	.9987E+01	.9113E+02
1-6	704	.4204E+00	.4204E+00	.4204E+00	.5120E+00	.5130E+00	.11701E+02	.0	.1004E+02	.9158E+02
1-6	706	.4202E+00	.4204E+00	.4203E+00	.5110E+00	.5120E+00	.11701E+02	.0	.1006E+02	.9181E+02
1-6	710	.4204E+00	.4205E+00	.4203E+00	.5100E+00	.5110E+00	.11711E+02	.0	.1009E+02	.9202E+02
1-6	711	.4204E+00	.4205E+00	.4203E+00	.5090E+00	.5100E+00	.11601E+02	.0	.1001E+02	.9133E+02
1-6	712	.4203E+00	.4204E+00	.4203E+00	.5090E+00	.5090E+00	.11589E+02	.0	.1001E+02	.9136E+02
1-6	713	.4204E+00	.4205E+00	.4204E+00	.5100E+00	.5110E+00	.11641E+02	.0	.1002E+02	.9146E+02
1-6	718	.4203E+00	.4205E+00	.4203E+00	.5100E+00	.5100E+00	.11683E+02	.0	.1007E+02	.9190E+02
1-6	719	.4203E+00	.4203E+00	.4202E+00	.5110E+00	.5120E+00	.11691E+02	.0	.1005E+02	.9174E+02
1-6	721	.4203E+00	.4204E+00	.4204E+00	.5120E+00	.5130E+00	.11680E+02	.0	.1002E+02	.9143E+02
1-6	722	.4204E+00	.4204E+00	.4203E+00	.5100E+00	.5090E+00	.11609E+02	.0	.1002E+02	.9141E+02
1-6	727	.4203E+00	.4205E+00	.4204E+00	.5100E+00	.5090E+00	.11629E+02	.0	.1003E+02	.9156E+02
1-6	731	.4203E+00	.4204E+00	.4202E+00	.4950E+00	.4960E+00	.11310E+02	.0	.1004E+02	.9160E+02
1-6	732	.4202E+00	.4203E+00	.4203E+00	.4650E+00	.4650E+00	.10546E+02	.0	.9977E+01	.9103E+02
1-6	733	.4203E+00	.4204E+00	.4203E+00	.4790E+00	.4810E+00	.10912E+02	.0	.9998E+01	.9122E+02
1-6	734	.4203E+00	.4204E+00	.4204E+00	.4990E+00	.4970E+00	.11353E+02	.0	.1002E+02	.9146E+02
1-6	735	.4203E+00	.4204E+00	.4204E+00	.4890E+00	.4910E+00	.11158E+02	.0	.1001E+02	.9136E+02
1-6	740	.4202E+00	.4204E+00	.4202E+00	.5140E+00	.5150E+00	.11741E+02	.0	.1004E+02	.9160E+02
1-6	741	.4203E+00	.4204E+00	.4203E+00	.5220E+00	.5230E+00	.11881E+02	.0	.1000E+02	.9124E+02
1-6	742	.4203E+00	.4204E+00	.4202E+00	.5120E+00	.5120E+00	.11685E+02	.0	.1004E+02	.9159E+02
1-6	743	.4203E+00	.4204E+00	.4204E+00	.5110E+00	.5110E+00	.11592E+02	.0	.9975E+01	.9101E+02
1-6	745	.4203E+00	.4204E+00	.4203E+00	.5150E+00	.5150E+00	.11703E+02	.0	.9994E+01	.9118E+02
1-6	746	.4203E+00	.4203E+00	.4203E+00	.5110E+00	.5100E+00	.11616E+02	.0	.1001E+02	.9132E+02
1-6	747	.4202E+00	.4203E+00	.4202E+00	.5060E+00	.5050E+00	.11491E+02	.0	.1000E+02	.9126E+02
1-6	748	.4202E+00	.4204E+00	.4203E+00	.5050E+00	.5040E+00	.11501E+02	.0	.1003E+02	.9149E+02
1-6	755	.4204E+00	.4205E+00	.4203E+00	.5030E+00	.5020E+00	.11371E+02	.0	.9949E+01	.9077E+02
1-6	756	.4202E+00	.4201E+00	.4201E+00	.5040E+00	.5060E+00	.11443E+02	.0	.9975E+01	.9101E+02

TOTAL WEIGHT OF GROUP = 380.350 GRAMS
AVERAGE WEIGHT OF GROUP = 11.5253 GRAMS
AVERAGE DENSITY OF GROUP = 91.441 PERCENT T.D.
AVERAGE PELLET LENGTH OF GROUP = .5057 INCHES
STANDARD DEVIATION OF PELLET DENSITY = .306

IFA-431, Rod 6 Drilled Pellets

LOT NO.	SAMPLE NO.	DIAMETER (INCHES) D-1	D-2	D-3	LENGTH (INCHES) L-1	L-2	WEIGHT (GRAMS)	DIA. CENTER VOID (INCHES)	DENSITY (G/CC)	DENSITY (PERCENT T.D.)
1-6	640	.4203E+00	.4204E+00	.4204E+00	.4990E+00	.5000E+00	.11130E+02	.6850E-01	.1006E+02	.9183E+02
1-6	641	.4201E+00	.4203E+00	.4203E+00	.5020E+00	.5020E+00	.11121E+02	.6850E-01	.1001E+02	.9136E+02
1-6	642	.4203E+00	.4203E+00	.4203E+00	.5020E+00	.5020E+00	.11176E+02	.6850E-01	.1006E+02	.9178E+02
1-6	645	.4203E+00	.4204E+00	.4203E+00	.5020E+00	.5020E+00	.11183E+02	.6850E-01	.1006E+02	.9183E+02
1-6	646	.4201E+00	.4203E+00	.4203E+00	.4960E+00	.4970E+00	.11039E+02	.6850E-01	.1005E+02	.9169E+02
1-6	647	.4201E+00	.4202E+00	.4202E+00	.5010E+00	.5000E+00	.11118E+02	.6850E-01	.1004E+02	.9164E+02
1-6	649	.4202E+00	.4204E+00	.4203E+00	.4980E+00	.4990E+00	.11092E+02	.6850E-01	.1005E+02	.9173E+02
1-6	652	.4204E+00	.4204E+00	.4205E+00	.5020E+00	.5030E+00	.11158E+02	.6850E-01	.1003E+02	.9149E+02
1-6	653	.4202E+00	.4204E+00	.4203E+00	.4970E+00	.4980E+00	.11033E+02	.6850E-01	.1002E+02	.9143E+02
1-6	654	.4202E+00	.4203E+00	.4204E+00	.4960E+00	.4960E+00	.11039E+02	.6850E-01	.1006E+02	.9176E+02
1-6	661	.4203E+00	.4204E+00	.4204E+00	.5000E+00	.5000E+00	.11120E+02	.6850E-01	.1005E+02	.9166E+02
1-6	669	.4201E+00	.4203E+00	.4203E+00	.5100E+00	.5100E+00	.11274E+02	.6850E-01	.9992E+01	.9117E+02

TOTAL WEIGHT OF GROUP = 133.483 GRAMS
AVERAGE WEIGHT OF GROUP = 11.1236 GRAMS
AVERAGE DENSITY OF GROUP = 91.614 PERCENT T.D.
AVERAGE PELLET LENGTH OF GROUP = .5006 INCHES
STANDARD DEVIATION OF PELLET DENSITY = .209

IFA-431, Extra Pellets

LOT NO.	SAMPLE NO.	DIAMETER (INCHES) D-1	D-2	D-3	LENGTH (INCHES) L-1	L-2	WEIGHT (GRAMS)	DIA. CENTER VOID (INCHES)	DENSITY (G/CC)	DENSITY (PERCENT T.D.)
1-1	13	.4202E+00	.4203E+00	.4203E+00	.5110E+00	.5120E+00	.11711E+02	.6850E-01	.1035E+02	.9441E+02
1-4	78	.4205E+00	.4206E+00	.4205E+00	.5030E+00	.5040E+00	.11548E+02	.6850E-01	.1035E+02	.9445E+02
1-2	336	.4144E+00	.4145E+00	.4144E+00	.5030E+00	.5030E+00	.11178E+02	.6850E-01	.1034E+02	.9430E+02
1-3	549	.4276E+00	.4275E+00	.4275E+00	.5110E+00	.5130E+00	.12218E+02	.6850E-01	.1041E+02	.9499E+02
1-6	656	.4202E+00	.4202E+00	.4202E+00	.4970E+00	.4960E+00	.11060E+02	.6850E-01	.1007E+02	.9188E+02
1-5	833	.4203E+00	.4204E+00	.4202E+00	.5170E+00	.5190E+00	.11399E+02	.6850E-01	.9943E+01	.9072E+02

TOTAL WEIGHT OF GROUP = 69.114 GRAMS
AVERAGE WEIGHT OF GROUP = 11.5190 GRAMS
AVERAGE DENSITY OF GROUP = 93.460 PERCENT T.D.
AVERAGE PELLET LENGTH OF GROUP = .5074 INCHES
STANDARD DEVIATION OF PELLET DENSITY = 1.727

TOTAL WEIGHT OF ALL GROUPS 3189.4540 GRAMS

IFA-431, IMMERSION DENSITIES

IFA-431, Rod 1, Solid Pellets

	SAMPLE NUMBER	PELLET WEIGHT (GRAMS)	WT. OF SATURATED PELLET (GRAMS)	WT OF PELLET SUSPENDED IN WATER (GRAMS)	WT. OF SUSPENSION CAGE (GRAMS)	WATER TEMPEATURE (DEG.C)	WATER DENSITY (GM/CC)	PELLET DENSITY (GM/CC)	PELLET DENSITY (PERCENT T.D.)	SAMPLE NUMBER
1-1	294	.11867E+02	.11868E+02	.11544E+02	.80970E+00	.1940E+02	.9983E+00	.1045E+02	.9538E+02	294
1-1	342	.11802E+02	.11803E+02	.11487E+02	.80990E+00	.1940E+02	.9983E+00	.1046E+02	.9545E+02	342
1-1	350	.11896E+02	.11897E+02	.11571E+02	.80980E+00	.1940E+02	.9983E+00	.1046E+02	.9543E+02	350
1-1	361	.11766E+02	.11767E+02	.11454E+02	.80980E+00	.1940E+02	.9983E+00	.1045E+02	.9538E+02	361
1-1	362	.11747E+02	.11748E+02	.11435E+02	.80960E+00	.1940E+02	.9983E+00	.1045E+02	.9532E+02	362
1-1	364	.11759E+02	.11760E+02	.11447E+02	.80960E+00	.1940E+02	.9983E+00	.1046E+02	.9548E+02	364
1-1	381	.11794E+02	.11795E+02	.11479E+02	.80970E+00	.1940E+02	.9983E+00	.1046E+02	.9541E+02	381
1-1	404	.11756E+02	.11757E+02	.11445E+02	.80960E+00	.1940E+02	.9983E+00	.1046E+02	.9547E+02	404
1-1	405	.11757E+02	.11758E+02	.11445E+02	.80970E+00	.1940E+02	.9983E+00	.1046E+02	.9542E+02	405
1-1	456	.12319E+02	.12320E+02	.11944E+02	.80960E+00	.1940E+02	.9983E+00	.1037E+02	.9463E+02	456
1-1	457	.11757E+02	.11758E+02	.11435E+02	.80960E+00	.1940E+02	.9983E+00	.1036E+02	.9456E+02	457

TOTAL WEIGHT OF GROUP = 130.220 GRAMS
AVERAGE WEIGHT OF GROUP = 11.8382 GRAMS
AVERAGE DENSITY OF GROUP = 95.266 PERCENT T.D.
STANDARD DEVIATION OF PELLET DENSITY = .335

IFA-431, Rod 1, Drilled Pellets

	SAMPLE NUMBER	PELLET WEIGHT (GRAMS)	WT. OF SATURATED PELLET (GRAMS)	WT OF PELLET SUSPENDED IN WATER (GRAMS)	WT. OF SUSPENSION CAGE (GRAMS)	WATER TEMPEATURE (DEG.C)	WATER DENSITY (GM/CC)	PELLET DENSITY (GM/CC)	PELLET DENSITY (PERCENT T.D.)	SAMPLE NUMBER
1-1D	79	.11691E+02	.11694E+02	.11386E+02	.80990E+00	.1760E+02	.9987E+00	.1045E+02	.9532E+02	79
1-1D	88	.11492E+02	.11494E+02	.11206E+02	.80990E+00	.1760E+02	.9987E+00	.1045E+02	.9535E+02	88
1-1D	152	.11834E+02	.11838E+02	.11516E+02	.81000E+00	.1770E+02	.9987E+00	.1044E+02	.9524E+02	152
1-1D	163	.11615E+02	.11618E+02	.11319E+02	.81000E+00	.1770E+02	.9987E+00	.1046E+02	.9539E+02	163

TOTAL WEIGHT OF GROUP = 46.632 GRAMS
AVERAGE WEIGHT OF GROUP = 11.6580 GRAMS
AVERAGE DENSITY OF GROUP = 95.327 PERCENT T.D.
STANDARD DEVIATION OF PELLET DENSITY = .066

IFA-431, Rod 2, Solid Pellets

SAMPLE NUMBER		PELLET WEIGHT (GRAMS)	WT. OF SATURATED PELLET (GRAMS)	WT OF PELLET SUSPENDED IN WATER (GRAMS)	WT. OF SUSPENSION CAGE (GRAMS)	WATER TEMPEATURE (DEG.C)	WATER DENSITY (GM/CC)	PELLET DENSITY (GM/CC)	PELLET DENSITY (PERCENT T.D.)	SAMPLE NUMBER
1-2	29	.11564E+02	.11565E+02	.11272E+02	.80950E+00	.1950E+02	.9983E+00	.1047E+02	.9549E+02	29
1-2	34	.11675E+02	.11675E+02	.11373E+02	.80970E+00	.1950E+02	.9983E+00	.1048E+02	.9563E+02	34
1-2	45	.11634E+02	.11635E+02	.11337E+02	.80980E+00	.1950E+02	.9983E+00	.1048E+02	.9566E+02	45
1-2	62	.11480E+02	.11481E+02	.11197E+02	.81000E+00	.1950E+02	.9983E+00	.1047E+02	.9556E+02	62
1-2	121	.11471E+02	.11472E+02	.11188E+02	.80990E+00	.1940E+02	.9983E+00	.1047E+02	.9549E+02	121
1-2	255	.11776E+02	.11777E+02	.11463E+02	.80960E+00	.1940E+02	.9983E+00	.1046E+02	.9547E+02	255
1-2	269	.11410E+02	.11411E+02	.11134E+02	.80960E+00	.1940E+02	.9983E+00	.1048E+02	.9566E+02	269
1-2	282	.11526E+02	.11527E+02	.11235E+02	.80970E+00	.1940E+02	.9983E+00	.1045E+02	.9537E+02	282
1-2	287	.11653E+02	.11654E+02	.11353E+02	.80970E+00	.1940E+02	.9983E+00	.1048E+02	.9560E+02	287
1-2	288	.11588E+02	.11589E+02	.11295E+02	.80980E+00	.1940E+02	.9983E+00	.1048E+02	.9562E+02	288
1-2	290	.11560E+02	.11560E+02	.11268E+02	.80980E+00	.1940E+02	.9983E+00	.1047E+02	.9556E+02	290

TOTAL WEIGHT OF GROUP = 127.336 GRAMS
AVERAGE WEIGHT OF GROUP = 11.5760 GRAMS
AVERAGE DENSITY OF GROUP = 95.555 PERCENT T.D.
STANDARD DEVIATION OF PELLET DENSITY = .092

IFA-431, Rod 2, Drilled Pellets

SAMPLE NUMBER		PELLET WEIGHT (GRAMS)	WT. OF SATURATED PELLET (GRAMS)	WT OF PELLET SUSPENDED IN WATER (GRAMS)	WT. OF SUSPENSION CAGE (GRAMS)	WATER TEMPEATURE (DEG.C)	WATER DENSITY (GM/CC)	PELLET DENSITY (GM/CC)	PELLET DENSITY (PERCENT T.D.)	SAMPLE NUMBER
1-2D	303	.11140E+02	.11143E+02	.10884E+02	.80990E+00	.1720E+02	.9988E+00	.1041E+02	.9500E+02	303
1-2D	306	.11196E+02	.11198E+02	.10936E+02	.81000E+00	.1720E+02	.9988E+00	.1043E+02	.9518E+02	306
1-2D	309	.11149E+02	.11151E+02	.10893E+02	.80990E+00	.1720E+02	.9988E+00	.1043E+02	.9513E+02	309
1-2D	317	.11216E+02	.11219E+02	.10953E+02	.80990E+00	.1730E+02	.9987E+00	.1041E+02	.9498E+02	317

TOTAL WEIGHT OF GROUP = 44.700 GRAMS
AVERAGE WEIGHT OF GROUP = 11.1750 GRAMS
AVERAGE DENSITY OF GROUP = 95.073 PERCENT T.D.
STANDARD DEVIATION OF PELLET DENSITY = .097

IFA-431, Rod 3, Solid Pellets

	SAMPLE NUMBER	PELLET WEIGHT (GRAMS)	WT. OF SATURATED PELLET (GRAMS)	WT OF PELLET SUSPENDED IN WATER (GRAMS)	WT. OF SUSPENSION CAGE (GRAMS)	WATER TEMPEATURE (DEG.C)	WATER DENSITY (GM/CC)	PELLET DENSITY (GM/CC)	PELLET DENSITY (PERCENT T.D.)	SAMPLE NUMBER
1-3	482	.12645E+02	.12646E+02	.12256E+02	.80970E+00	.1890E+02	.9984E+00	.1053E+02	.9605E+02	482
1-3	499	.12466E+02	.12467E+02	.12097E+02	.81000E+00	.1890E+02	.9984E+00	.1055E+02	.9628E+02	499
1-3	502	.12463E+02	.12464E+02	.12093E+02	.80970E+00	.1890E+02	.9984E+00	.1054E+02	.9615E+02	502
1-3	507	.12444E+02	.12445E+02	.12076E+02	.80990E+00	.1900E+02	.9984E+00	.1053E+02	.9611E+02	507
1-3	514	.12649E+02	.12650E+02	.12261E+02	.80980E+00	.1900E+02	.9984E+00	.1053E+02	.9610E+02	514
1-3	515	.12588E+02	.12588E+02	.12208E+02	.80980E+00	.1900E+02	.9984E+00	.1056E+02	.9632E+02	515
1-3	516	.12518E+02	.12519E+02	.12144E+02	.80970E+00	.1910E+02	.9984E+00	.1055E+02	.9630E+02	516
1-3	573	.12553E+02	.12554E+02	.12172E+02	.80950E+00	.1910E+02	.9984E+00	.1053E+02	.9603E+02	573
1-3	607	.12534E+02	.12535E+02	.12160E+02	.80960E+00	.1910E+02	.9984E+00	.1056E+02	.9634E+02	607
1-3	609	.12572E+02	.12573E+02	.12190E+02	.80970E+00	.1910E+02	.9984E+00	.1053E+02	.9605E+02	609
1-3	617	.12538E+02	.12539E+02	.12158E+02	.80970E+00	.1910E+02	.9984E+00	.1051E+02	.9593E+02	617

TOTAL WEIGHT OF GROUP = 137.970 GRAMS
AVERAGE WEIGHT OF GROUP = 12.5427 GRAMS
AVERAGE DENSITY OF GROUP = 96.151 PERCENT T.D.
STANDARD DEVIATION OF PELLET DENSITY = .140

IFA-431, Rod 3, Drilled Pellets

	SAMPLE NUMBER	PELLET WEIGHT (GRAMS)	WT. OF SATURATED PELLET (GRAMS)	WT OF PELLET SUSPENDED IN WATER (GRAMS)	WT. OF SUSPENSION CAGE (GRAMS)	WATER TEMPEATURE (DEG.C)	WATER DENSITY (GM/CC)	PELLET DENSITY (GM/CC)	PELLET DENSITY (PERCENT T.D.)	SAMPLE NUMBER
1-3D	521	.12178E+02	.12179E+02	.11833E+02	.81000E+00	.1730E+02	.9987E+00	.1052E+02	.9594E+02	521
1-3D	524	.11920E+02	.11922E+02	.11597E+02	.80990E+00	.1740E+02	.9987E+00	.1049E+02	.9574E+02	524
1-3D	550	.12169E+02	.12171E+02	.11822E+02	.81000E+00	.1740E+02	.9987E+00	.1048E+02	.9564E+02	550
1-3D	552	.12022E+02	.12023E+02	.11688E+02	.81000E+00	.1740E+02	.9987E+00	.1049E+02	.9567E+02	552

TOTAL WEIGHT OF GROUP = 48.289 GRAMS
AVERAGE WEIGHT OF GROUP = 12.0721 GRAMS
AVERAGE DENSITY OF GROUP = 95.750 PERCENT T.D.
STANDARD DEVIATION OF PELLET DENSITY = .133

IFA-431, Rod 4, Solid Pellets

SAMPLE NUMBER		PELLET WEIGHT (GRAMS)	WT. OF SATURATED PELLET (GRAMS)	WT OF PELLET SUSPENDED IN WATER (GRAMS)	WT. OF SUSPENSION CAGE (GRAMS)	WATER TEMPEATURE (DEG.C)	WATER DENSITY (GM/CC)	PELLET DENSITY (GM/CC)	PELLET DENSITY (PERCENT T.D.)	SAMPLE NUMBER
1-4	67	.11839E+02	.11841E+02	.11522E+02	.80980E+00	.1770E+02	.9987E+00	.1047E+02	.9555E+02	67
1-4	92	.12032E+02	.12033E+02	.11693E+02	.80960E+00	.1770E+02	.9987E+00	.1045E+02	.9532E+02	92
1-4	106	.12082E+02	.12083E+02	.11740E+02	.80960E+00	.1770E+02	.9987E+00	.1047E+02	.9551E+02	106
1-4	126	.12007E+02	.12010E+02	.11673E+02	.80980E+00	.1770E+02	.9987E+00	.1045E+02	.9537E+02	126
1-4	130	.12101E+02	.12103E+02	.11757E+02	.81000E+00	.1760E+02	.9987E+00	.1046E+02	.9539E+02	130
1-4	132	.12039E+02	.12040E+02	.11702E+02	.81000E+00	.1760E+02	.9987E+00	.1047E+02	.9556E+02	132
1-4	149	.11947E+02	.11948E+02	.11620E+02	.80990E+00	.1760E+02	.9987E+00	.1048E+02	.9565E+02	149
1-4	229	.11969E+02	.11970E+02	.11643E+02	.80990E+00	.1760E+02	.9987E+00	.1051E+02	.9589E+02	229
1-4	245	.11752E+02	.11753E+02	.11447E+02	.81000E+00	.1760E+02	.9987E+00	.1052E+02	.9595E+02	245

TOTAL WEIGHT OF GROUP = 107.769 GRAMS
AVERAGE WEIGHT OF GROUP = 11.9743 GRAMS
AVERAGE DENSITY OF GROUP = 95.578 PERCENT T.D.
STANDARD DEVIATION OF PELLET DENSITY = .220

IFA-431, Rod 4, Drilled Pellets

SAMPLE NUMBER		PELLET WEIGHT (GRAMS)	WT. OF SATURATED PELLET (GRAMS)	WT OF PELLET SUSPENDED IN WATER (GRAMS)	WT. OF SUSPENSION CAGE (GRAMS)	WATER TEMPEATURE (DEG.C)	WATER DENSITY (GM/CC)	PELLET DENSITY (GM/CC)	PELLET DENSITY (PERCENT T.D.)	SAMPLE NUMBER
1-4D	1	.11766E+02	.11769E+02	.11454E+02	.80970E+00	.1710E+02	.9988E+00	.1045E+02	.9537E+02	1
1-4D	74	.11486E+02	.11487E+02	.11200E+02	.80990E+00	.1710E+02	.9988E+00	.1046E+02	.9547E+02	74
1-4D	87	.11563E+02	.11564E+02	.11270E+02	.80990E+00	.1710E+02	.9988E+00	.1046E+02	.9544E+02	87
1-4D	165	.11594E+02	.11596E+02	.11299E+02	.80990E+00	.1720E+02	.9988E+00	.1046E+02	.9545E+02	165
1-4D	169	.11648E+02	.11650E+02	.11348E+02	.81000E+00	.1710E+02	.9988E+00	.1046E+02	.9543E+02	169
1-4D	187	.11616E+02	.11617E+02	.11321E+02	.81000E+00	.1720E+02	.9988E+00	.1049E+02	.9567E+02	187

TOTAL WEIGHT OF GROUP = 69.672 GRAMS
AVERAGE WEIGHT OF GROUP = 11.6120 GRAMS
AVERAGE DENSITY OF GROUP = 95.472 PERCENT T.D.
STANDARD DEVIATION OF PELLET DENSITY = .104

IFA-431, Rod 5, Solid Pellets

	SAMPLE NUMBER	PELLET WEIGHT (GRAMS)	WT. OF SATURATED PELLET (GRAMS)	WT OF PELLET SUSPENDED IN WATER (GRAMS)	WT. OF SUSPENSION CAGE (GRAMS)	WATER TEMPEATURE (DEG.C)	WATER DENSITY (GM/CC)	PELLET DENSITY (GM/CC)	PELLET DENSITY (PERCENT T.D.)	SAMPLE NUMBER
1-5	784	.11634E+02	.11635E+02	.11297E+02	.81000E+00	.1620E+02	.9990E+00	.1012E+02	.9233E+02	784
1-5	786	.11378E+02	.11380E+02	.11067E+02	.81000E+00	.1620E+02	.9990E+00	.1013E+02	.9240E+02	786
1-5	796	.11520E+02	.11522E+02	.11180E+02	.81000E+00	.1620E+02	.9990E+00	.9993E+01	.9118E+02	796
1-5	797	.11328E+02	.11330E+02	.11009E+02	.81000E+00	.1630E+02	.9990E+00	.1001E+02	.9133E+02	797
1-5	800	.11583E+02	.11585E+02	.11254E+02	.81000E+00	.1630E+02	.9990E+00	.1014E+02	.9255E+02	800
1-5	807	.11807E+02	.11809E+02	.11456E+02	.80990E+00	.1630E+02	.9990E+00	.1014E+02	.9250E+02	807
1-5	810	.11908E+02	.11910E+02	.11547E+02	.81000E+00	.1640E+02	.9989E+00	.1014E+02	.9254E+02	810
1-5	847	.11520E+02	.11522E+02	.11192E+02	.80980E+00	.1640E+02	.9989E+00	.1010E+02	.9214E+02	847
1-5	855	.11472E+02	.11475E+02	.11143E+02	.80980E+00	.1640E+02	.9989E+00	.1004E+02	.9161E+02	855
1-5	861	.11447E+02	.11449E+02	.11117E+02	.80990E+00	.1640E+02	.9989E+00	.1002E+02	.9141E+02	861
1-5	870	.11393E+02	.11395E+02	.11075E+02	.81000E+00	.1640E+02	.9989E+00	.1008E+02	.9193E+02	870
1-5	871	.11469E+02	.11471E+02	.11144E+02	.80990E+00	.1650E+02	.9989E+00	.1008E+02	.9197E+02	871
1-5	879	.11520E+02	.11522E+02	.11187E+02	.81000E+00	.1650E+02	.9989E+00	.1005E+02	.9173E+02	879
1-5	886	.11018E+02	.11020E+02	.10732E+02	.80990E+00	.1660E+02	.9989E+00	.1003E+02	.9153E+02	886
1-5	887	.11319E+02	.11320E+02	.11000E+02	.80980E+00	.1660E+02	.9989E+00	.1000E+02	.9127E+02	887
1-5	889	.11350E+02	.11352E+02	.11027E+02	.80980E+00	.1660E+02	.9989E+00	.9985E+01	.9111E+02	889
1-5	890	.11649E+02	.11651E+02	.11293E+02	.80970E+00	.1670E+02	.9989E+00	.9966E+01	.9093E+02	890

TOTAL WEIGHT OF GROUP = 195.312 GRAMS
AVERAGE WEIGHT OF GROUP = 11.4890 GRAMS
AVERAGE DENSITY OF GROUP = 91.792 PERCENT T.D.
STANDARD DEVIATION OF PELLET DENSITY = .547

IFA-431, Rod 5, Drilled Pellets

	SAMPLE NUMBER	PELLET WEIGHT (GRAMS)	WT. OF SATURATED PELLET (GRAMS)	WT OF PELLET SUSPENDED IN WATER (GRAMS)	WT. OF SUSPENSION CAGE (GRAMS)	WATER TEMPEATURE (DEG.C)	WATER DENSITY (GM/CC)	PELLET DENSITY (GM/CC)	PELLET DENSITY (PERCENT T.D.)	SAMPLE NUMBER
1-5D	811	.11137E+02	.11140E+02	.10845E+02	.80970E+00	.1690E+02	.9988E+00	.1007E+02	.9192E+02	811
1-5D	820	.11119E+02	.11122E+02	.10831E+02	.80990E+00	.1690E+02	.9988E+00	.1008E+02	.9201E+02	820
1-5D	823	.11322E+02	.11325E+02	.11023E+02	.80980E+00	.1690E+02	.9988E+00	.1017E+02	.9281E+02	823
1-5D	826	.11201E+02	.11205E+02	.10903E+02	.80970E+00	.1690E+02	.9988E+00	.1006E+02	.9182E+02	826
1-5D	845	.11303E+02	.11306E+02	.11001E+02	.80980E+00	.1690E+02	.9988E+00	.1013E+02	.9243E+02	845
1-5D	846	.11127E+02	.11131E+02	.10837E+02	.80980E+00	.1690E+02	.9988E+00	.1007E+02	.9188E+02	846

TOTAL WEIGHT OF GROUP = 67.208 GRAMS
AVERAGE WEIGHT OF GROUP = 11.2013 GRAMS
AVERAGE DENSITY OF GROUP = 92.145 PERCENT T.D.
STANDARD DEVIATION OF PELLET DENSITY = .391

IFA-431, Rod 6, Solid Pellets

	SAMPLE NUMBER	PELLET WEIGHT (GRAMS)	WT. OF SATURATED PELLET (GRAMS)	WT OF PELLET SUSPENDED IN WATER (GRAMS)	WT. OF SUSPENSION CAGE (GRAMS)	WATER TEMPEATURE (DEG.C)	WATER DENSITY (GM/CC)	PELLET DENSITY (GM/CC)	PELLET DENSITY (PERCENT T.D.)	SAMPLE NUMBER
1-6	681	.11554E+02	.11559E+02	.11220E+02	.81000E+00	.1670E+02	.9989E+00	.1004E+02	.9163E+02	681
1-6	687	.11467E+02	.11469E+02	.11147E+02	.81000E+00	.1670E+02	.9989E+00	.1012E+02	.9235E+02	687
1-6	688	.11563E+02	.11565E+02	.11234E+02	.80990E+00	.1670E+02	.9989E+00	.1012E+02	.9234E+02	688
1-6	690	.11493E+02	.11495E+02	.11171E+02	.80990E+00	.1670E+02	.9989E+00	.1012E+02	.9237E+02	690
1-6	693	.11509E+02	.11513E+02	.11181E+02	.80980E+00	.1660E+02	.9989E+00	.1007E+02	.9189E+02	693
1-6	699	.11560E+02	.11562E+02	.11230E+02	.80970E+00	.1660E+02	.9989E+00	.1012E+02	.9231E+02	699
1-6	701	.11676E+02	.11679E+02	.11331E+02	.81000E+00	.1670E+02	.9989E+00	.1007E+02	.9190E+02	701
1-6	704	.11704E+02	.11705E+02	.11361E+02	.81000E+00	.1680E+02	.9989E+00	.1013E+02	.9243E+02	704
1-6	706	.11698E+02	.11699E+02	.11356E+02	.81000E+00	.1680E+02	.9989E+00	.1013E+02	.9243E+02	706
1-6	710	.11710E+02	.11712E+02	.11369E+02	.80950E+00	.1660E+02	.9989E+00	.1015E+02	.9259E+02	710
1-6	711	.11599E+02	.11603E+02	.11262E+02	.81000E+00	.1680E+02	.9989E+00	.1007E+02	.9186E+02	711
1-6	712	.11590E+02	.11594E+02	.11253E+02	.80960E+00	.1660E+02	.9989E+00	.1007E+02	.9186E+02	712
1-6	713	.11639E+02	.11642E+02	.11298E+02	.81000E+00	.1680E+02	.9989E+00	.1008E+02	.9193E+02	713
1-6	718	.11688E+02	.11690E+02	.11349E+02	.80960E+00	.1650E+02	.9989E+00	.1014E+02	.9255E+02	718
1-6	719	.11688E+02	.11690E+02	.11347E+02	.80960E+00	.1650E+02	.9989E+00	.1013E+02	.9242E+02	719
1-6	721	.11678E+02	.11681E+02	.11333E+02	.80950E+00	.1630E+02	.9990E+00	.1008E+02	.9199E+02	721
1-6	722	.11607E+02	.11610E+02	.11270E+02	.81000E+00	.1690E+02	.9988E+00	.1008E+02	.9200E+02	722
1-6	727	.11627E+02	.11629E+02	.11283E+02	.80940E+00	.1630E+02	.9990E+00	.1005E+02	.9170E+02	727
1-6	731	.11311E+02	.11314E+02	.11002E+02	.80950E+00	.1630E+02	.9990E+00	.1008E+02	.9197E+02	731
1-6	732	.10546E+02	.10549E+02	.10311E+02	.81000E+00	.1690E+02	.9988E+00	.1005E+02	.9169E+02	732
1-6	733	.10910E+02	.10912E+02	.10639E+02	.81010E+00	.1690E+02	.9988E+00	.1006E+02	.9182E+02	733
1-6	734	.11349E+02	.11351E+02	.11039E+02	.81010E+00	.1690E+02	.9988E+00	.1010E+02	.9216E+02	734
1-6	735	.11159E+02	.11161E+02	.10864E+02	.80950E+00	.1640E+02	.9989E+00	.1008E+02	.9194E+02	735
1-6	740	.11744E+02	.11746E+02	.11392E+02	.80950E+00	.1640E+02	.9989E+00	.1009E+02	.9205E+02	740
1-6	741	.11881E+02	.11882E+02	.11516E+02	.81020E+00	.1700E+02	.9988E+00	.1009E+02	.9203E+02	741
1-6	742	.11689E+02	.11691E+02	.11343E+02	.80950E+00	.1640E+02	.9989E+00	.1009E+02	.9206E+02	742
1-6	743	.11592E+02	.11594E+02	.11257E+02	.81020E+00	.1700E+02	.9988E+00	.1009E+02	.9209E+02	743
1-6	745	.11706E+02	.11708E+02	.11357E+02	.80960E+00	.1650E+02	.9989E+00	.1008E+02	.9196E+02	745
1-6	746	.11613E+02	.11615E+02	.11275E+02	.81030E+00	.1700E+02	.9988E+00	.1009E+02	.9203E+02	746
1-6	747	.11490E+02	.11491E+02	.11164E+02	.81020E+00	.1700E+02	.9988E+00	.1008E+02	.9201E+02	747
1-6	748	.11499E+02	.11500E+02	.11173E+02	.80960E+00	.1650E+02	.9989E+00	.1010E+02	.9218E+02	748
1-6	755	.11371E+02	.11379E+02	.11056E+02	.81030E+00	.1700E+02	.9988E+00	.1002E+02	.9143E+02	755
1-6	756	.11441E+02	.11448E+02	.11118E+02	.81030E+00	.1700E+02	.9988E+00	.1002E+02	.9141E+02	756

TOTAL WEIGHT OF GROUP = 380.350 GRAMS
AVERAGE WEIGHT OF GROUP = 11.5258 GRAMS
AVERAGE DENSITY OF GROUP = 92.042 PERCENT T.D.
STANDARD DEVIATION OF PELLET DENSITY = .295

IFA-431, Rod 6, Drilled Pellets

	SAMPLE NUMBER	PELLET WEIGHT (GRAMS)	WT. OF SATURATED PELLET (GRAMS)	WT OF PELLET SUSPENDED IN WATER (GRAMS)	WT. OF SUSPENSION CAGE (GRAMS)	WATER TEMPEATURE (DEG.C)	WATER DENSITY (GM/CC)	PELLET DENSITY (GM/CC)	PELLET DENSITY (PERCENT T.D.)	SAMPLE NUMBER
1-6D	640	.11127E+02	.11130E+02	.10838E+02	.80960E+00	.1670E+02	.9989E+00	.1009E+02	.9202E+02	640
1-6D	641	.11119E+02	.11123E+02	.10831E+02	.80970E+00	.1670E+02	.9989E+00	.1008E+02	.9201E+02	641
1-6D	642	.11172E+02	.11176E+02	.10880E+02	.81000E+00	.1670E+02	.9989E+00	.1009E+02	.9208E+02	642
1-6D	645	.11184E+02	.11187E+02	.10891E+02	.80970E+00	.1670E+02	.9989E+00	.1010E+02	.9213E+02	645
1-6D	646	.11038E+02	.11041E+02	.10757E+02	.80990E+00	.1670E+02	.9989E+00	.1008E+02	.9197E+02	646
1-6D	647	.11115E+02	.11119E+02	.10827E+02	.80970E+00	.1680E+02	.9989E+00	.1008E+02	.9198E+02	647
1-6D	649	.11090E+02	.11094E+02	.10806E+02	.80970E+00	.1680E+02	.9989E+00	.1010E+02	.9212E+02	649
1-6D	652	.11156E+02	.11160E+02	.10864E+02	.80990E+00	.1680E+02	.9989E+00	.1007E+02	.9192E+02	652
1-6D	653	.11027E+02	.11030E+02	.10747E+02	.80970E+00	.1680E+02	.9989E+00	.1008E+02	.9195E+02	653
1-6D	654	.11036E+02	.11039E+02	.10757E+02	.80970E+00	.1680E+02	.9989E+00	.1010E+02	.9212E+02	654
1-6D	661	.11121E+02	.11123E+02	.10834E+02	.80990E+00	.1690E+02	.9988E+00	.1010E+02	.9219E+02	661
1-6D	669	.11271E+02	.11276E+02	.10965E+02	.80980E+00	.1690E+02	.9988E+00	.1004E+02	.9164E+02	669

TOTAL WEIGHT OF GROUP = 133.454 GRAMS
AVERAGE WEIGHT OF GROUP = 11.1212 GRAMS
AVERAGE DENSITY OF GROUP = 92.012 PERCENT T.D.
STANDARD DEVIATION OF PELLET DENSITY = .144

IFA-431, Rod 6, Solid Pellets (Second Measurement)

SAMPLE NUMBER		PELLET WEIGHT (GRAMS)	WT. OF SATURATED PELLET (GRAMS)	WT OF PELLET SUSPENDED IN WATER (GRAMS)	WT. OF SUSPENSION CAGE (GRAMS)	WATER TEMPEATURE (DEG.C)	WATER DENSITY (GM/CC)	PELLET DENSITY (GM/CC)	PELLET DENSITY (PERCENT T.D.)	SAMPLE NUMBER
1-6S	681	.11554E+02	.11561E+02	.11222E+02	.80960E+00	.1720E+02	.9988E+00	.1004E+02	.9165E+02	681
1-6S	687	.11467E+02	.11468E+02	.11147E+02	.80970E+00	.1720E+02	.9988E+00	.1012E+02	.9236E+02	687
1-6S	688	.11563E+02	.11565E+02	.11233E+02	.80970E+00	.1720E+02	.9988E+00	.1011E+02	.9227E+02	688
1-6S	690	.11493E+02	.11495E+02	.11171E+02	.80970E+00	.1720E+02	.9988E+00	.1012E+02	.9236E+02	690
1-6S	693	.11509E+02	.11513E+02	.11191E+02	.80980E+00	.1720E+02	.9988E+00	.1007E+02	.9187E+02	693
1-6S	699	.11560E+02	.11562E+02	.11230E+02	.80970E+00	.1720E+02	.9988E+00	.1011E+02	.9229E+02	699
1-6S	701	.11676E+02	.11679E+02	.11332E+02	.80960E+00	.1720E+02	.9988E+00	.1007E+02	.9192E+02	701
1-6S	704	.11704E+02	.11706E+02	.11361E+02	.80960E+00	.1720E+02	.9988E+00	.1012E+02	.9237E+02	704
1-6S	706	.11698E+02	.11699E+02	.11355E+02	.80960E+00	.1720E+02	.9988E+00	.1012E+02	.9236E+02	706
1-6S	710	.11710E+02	.11712E+02	.11369E+02	.80970E+00	.1720E+02	.9988E+00	.1014E+02	.9256E+02	710
1-6S	711	.11599E+02	.11604E+02	.11262E+02	.80960E+00	.1720E+02	.9988E+00	.1006E+02	.9182E+02	711
1-6S	712	.11590E+02	.11594E+02	.11254E+02	.80980E+00	.1720E+02	.9988E+00	.1007E+02	.9187E+02	712
1-6S	713	.11639E+02	.11642E+02	.11298E+02	.80970E+00	.1730E+02	.9987E+00	.1008E+02	.9194E+02	713
1-6S	718	.11688E+02	.11689E+02	.11349E+02	.80960E+00	.1720E+02	.9988E+00	.1015E+02	.9261E+02	718
1-6S	719	.11688E+02	.11690E+02	.11347E+02	.80980E+00	.1720E+02	.9988E+00	.1013E+02	.9238E+02	719
1-6S	721	.11678E+02	.11681E+02	.11334E+02	.80960E+00	.1720E+02	.9988E+00	.1009E+02	.9202E+02	721
1-6S	722	.11607E+02	.11610E+02	.11270E+02	.80960E+00	.1730E+02	.9987E+00	.1008E+02	.9201E+02	722
1-6S	727	.11627E+02	.11629E+02	.11288E+02	.80980E+00	.1720E+02	.9988E+00	.1009E+02	.9207E+02	727
1-6S	731	.11311E+02	.11314E+02	.11003E+02	.80980E+00	.1720E+02	.9988E+00	.1008E+02	.9196E+02	731
1-6S	732	.10546E+02	.10548E+02	.10310E+02	.80950E+00	.1730E+02	.9987E+00	.1006E+02	.9176E+02	732
1-6S	733	.10910E+02	.10913E+02	.10639E+02	.80940E+00	.1730E+02	.9987E+00	.1006E+02	.9176E+02	733
1-6S	734	.11349E+02	.11352E+02	.11038E+02	.80940E+00	.1730E+02	.9987E+00	.1009E+02	.9205E+02	734
1-6S	735	.11159E+02	.11163E+02	.10865E+02	.80970E+00	.1720E+02	.9988E+00	.1006E+02	.9181E+02	735
1-6S	740	.11744E+02	.11747E+02	.11393E+02	.80970E+00	.1720E+02	.9988E+00	.1008E+02	.9194E+02	740
1-6S	741	.11881E+02	.11883E+02	.11515E+02	.80930E+00	.1730E+02	.9987E+00	.1008E+02	.9198E+02	741
1-6S	742	.11689E+02	.11691E+02	.11343E+02	.80990E+00	.1720E+02	.9988E+00	.1009E+02	.9203E+02	742
1-6S	743	.11592E+02	.11594E+02	.11256E+02	.80950E+00	.1740E+02	.9987E+00	.1009E+02	.9205E+02	743
1-6S	745	.11706E+02	.11708E+02	.11358E+02	.80970E+00	.1720E+02	.9988E+00	.1008E+02	.9193E+02	745
1-6S	746	.11613E+02	.11615E+02	.11274E+02	.80970E+00	.1740E+02	.9987E+00	.1008E+02	.9200E+02	746
1-6S	747	.11490E+02	.11492E+02	.11163E+02	.80940E+00	.1740E+02	.9987E+00	.1008E+02	.9197E+02	747
1-6S	748	.11499E+02	.11501E+02	.11173E+02	.80970E+00	.1720E+02	.9988E+00	.1010E+02	.9215E+02	748
1-6S	755	.11371E+02	.11385E+02	.11061E+02	.80940E+00	.1740E+02	.9987E+00	.1002E+02	.9146E+02	755
1-6S	756	.11441E+02	.11454E+02	.11122E+02	.80970E+00	.1740E+02	.9987E+00	.1002E+02	.9138E+02	756

TOTAL WEIGHT OF GROUP = 380.350 GRAMS
AVERAGE WEIGHT OF GROUP = 11.5258 GRAMS
AVERAGE DENSITY OF GROUP = 92.030 PERCENT T.D.
STANDARD DEVIATION OF PELLET DENSITY = .283

IFA-431, Rod 6, Drilled Pellets (Second Measurement)

SAMPLE NUMBER		PELLET WEIGHT (GRAMS)	WT. OF SATURATED PELLET (GRAMS)	WT OF PELLET SUSPENDED IN WATER (GRAMS)	WT. OF SUSPENSION CAGE (GRAMS)	WATER TEMPEATURE (DEG.C)	WATER DENSITY (GM/CC)	PELLET DENSITY (GM/CC)	PELLET DENSITY (PERCENT T.D.)	SAMPLE NUMBER
1-6D	640	.11127E+02	.11130E+02	.10838E+02	.80970E+00	.1690E+02	.9988E+00	.1009E+02	.9206E+02	640
1-6D	641	.11119E+02	.11123E+02	.10831E+02	.81000E+00	.1690E+02	.9988E+00	.1008E+02	.9194E+02	641
1-6D	642	.11172E+02	.11176E+02	.10880E+02	.80990E+00	.1690E+02	.9988E+00	.1009E+02	.9207E+02	642
1-6D	645	.11184E+02	.11187E+02	.10891E+02	.80970E+00	.1690E+02	.9988E+00	.1010E+02	.9219E+02	645
1-6D	646	.11038E+02	.11041E+02	.10757E+02	.80970E+00	.1690E+02	.9988E+00	.1008E+02	.9200E+02	646
1-6D	647	.11115E+02	.11118E+02	.10827E+02	.80970E+00	.1700E+02	.9988E+00	.1009E+02	.9210E+02	647
1-6D	649	.11090E+02	.11094E+02	.10806E+02	.80970E+00	.1700E+02	.9988E+00	.1010E+02	.9211E+02	649
1-6D	652	.11156E+02	.11160E+02	.10864E+02	.80960E+00	.1700E+02	.9988E+00	.1008E+02	.9196E+02	652
1-6D	653	.11027E+02	.11031E+02	.10747E+02	.80980E+00	.1700E+02	.9988E+00	.1007E+02	.9188E+02	653
1-6D	654	.11036E+02	.11039E+02	.10757E+02	.80980E+00	.1700E+02	.9988E+00	.1009E+02	.9210E+02	654
1-6D	661	.11121E+02	.11124E+02	.10834E+02	.80970E+00	.1700E+02	.9988E+00	.1010E+02	.9218E+02	661
1-6D	669	.11271E+02	.11275E+02	.10965E+02	.80970E+00	.1700E+02	.9988E+00	.1005E+02	.9173E+02	669

TOTAL WEIGHT OF GROUP = 133.454 GRAMS
AVERAGE WEIGHT OF GROUP = 11.1212 GRAMS
AVERAGE DENSITY OF GROUP = 92.026 PERCENT T.D.
STANDARD DEVIATION OF PELLET DENSITY = .133

TOTAL WEIGHT OF ALL GROUPS 2002.7148 GRAMS

IFA-432, GEOMETRIC DENSITIES

IFA-432, Rod 1

	LOT NO.	SAMPLE NO.	DIAMETER (INCHES) D-1	D-2	D-3	LENGTH (INCHES) L-1	L-2	WEIGHT (GRAMS)	DIA. CENTER VOID (INCHES)	DENSITY (G/CC)	DENSITY (PERCENT T.D.)
1	2-1D	4	.4203-00	.4205-00	.4205-00	.4960-00	.4960-00	.11369+02	.6850-01	.1035+02	.9444+02
2	2-1D	5	.4201-00	.4203-00	.4202-00	.5150-00	.5150-00	.11840+02	.6850-01	.1039+02	.9483+02
3	2-1D	6	.4202-00	.4204-00	.4204-00	.5130-00	.5130-00	.11802+02	.6850-01	.1039+02	.9483+02
4	2-1D	7	.4202-00	.4205-00	.4205-00	.4950-00	.4960-00	.11401+02	.6850-01	.1039+02	.9481+02
5	2-1D	12	.4202-00	.4204-00	.4203-00	.5160-00	.5170-00	.11872+02	.6850-01	.1039+02	.9476+02
6	2-9D	18	.4202-00	.4203-00	.4203-00	.5100-00	.5080-00	.11655+02	.6850-01	.1035+02	.9442+02
7	2-1S	25	.4202-00	.4204-00	.4203-00	.5010-00	.5030-00	.11860+02	.0000	.1039+02	.9481+02
8	2-1S	28	.4202-00	.4204-00	.4202-00	.5050-00	.5040-00	.12036+02	.0000	.1050+02	.9576+02
9	2-1S	41	.4203-00	.4204-00	.4204-00	.5030-00	.5030-00	.11902+02	.0000	.1040+02	.9493+02
10	2-1S	66	.4203-00	.4204-00	.4202-00	.5010-00	.5010-00	.11837+02	.0000	.1039+02	.9482+02
11	2-1D	71	.4203-00	.4205-00	.4203-00	.5010-00	.5010-00	.11500+02	.6850-01	.1037+02	.9460+02
12	2-1D	73	.4201-00	.4204-00	.4204-00	.5010-00	.5010-00	.11472+02	.6850-01	.1035+02	.9440+02
13	2-9D	77	.4203-00	.4203-00	.4203-00	.5070-00	.5060-00	.11574+02	.6850-01	.1033+02	.9421+02
14	2-1D	83	.4202-00	.4205-00	.4203-00	.5050-00	.5050-00	.11588+02	.6850-01	.1037+02	.9459+02
15	2-1D	85	.4204-00	.4205-00	.4205-00	.5010-00	.5030-00	.11557+02	.6850-01	.1039+02	.9484+02
16	2-9D	89	.4203-00	.4204-00	.4202-00	.5010-00	.5000-00	.11469+02	.6850-01	.1035+02	.9447+02
17	2-1S	99	.4202-00	.4203-00	.4202-00	.5090-00	.5090-00	.12027+02	.0000	.1040+02	.9486+02
18	2-1S	107	.4204-00	.4205-00	.4203-00	.5010-00	.5010-00	.11838+02	.0000	.1043+02	.9518+02
19	2-1S	112	.4203-00	.4205-00	.4205-00	.5010-00	.4990-00	.11848+02	.0000	.1042+02	.9504+02
20	1-1S	120	.4203-00	.4204-00	.4204-00	.5100-00	.5100-00	.12009+02	.0000	.1035+02	.9447+02
21	2-1S	131	.4204-00	.4204-00	.4202-00	.5110-00	.5110-00	.12062+02	.0000	.1038+02	.9472+02
22	2-1S	140	.4202-00	.4204-00	.4201-00	.5010-00	.5020-00	.11854+02	.0000	.1040+02	.9489+02
23	2-1S	144	.4204-00	.4206-00	.4204-00	.5000-00	.4990-00	.11798+02	.0000	.1038+02	.9472+02
24	2-1D	154	.4204-00	.4207-00	.4206-00	.5140-00	.5130-00	.11761+02	.6850-01	.1034+02	.9430+02
25	2-1D	161	.4203-00	.4203-00	.4203-00	.4970-00	.4980-00	.11422+02	.6850-01	.1037+02	.9465+02
26	2-9D	164	.4204-00	.4205-00	.4204-00	.5020-00	.5030-00	.11549+02	.6850-01	.1038+02	.9469+02
27	2-1D	166	.4205-00	.4206-00	.4205-00	.5070-00	.5070-00	.11650+02	.6850-01	.1037+02	.9463+02
28	2-1D	168	.4202-00	.4205-00	.4204-00	.5040-00	.5060-00	.11611+02	.6850-01	.1039+02	.9476+02
29	2-1D	172	.4202-00	.4204-00	.4203-00	.5090-00	.5100-00	.11719+02	.6850-01	.1039+02	.9483+02
30	2-9D	173	.4204-00	.4205-00	.4204-00	.5070-00	.5070-00	.11670+02	.6850-01	.1039+02	.9483+02
31	2-1D	174	.4204-00	.4206-00	.4205-00	.5060-00	.5090-00	.11685+02	.6850-01	.1039+02	.9483+02
32	2-1S	211	.4203-00	.4205-00	.4202-00	.5080-00	.5050-00	.12016+02	.0000	.1040+02	.9491+02
33	2-1S	219	.4202-00	.4203-00	.4202-00	.5110-00	.5100-00	.12102+02	.0000	.1043+02	.9517+02
34	2-1S	224	.4201-00	.4204-00	.4202-00	.5070-00	.5070-00	.12004+02	.0000	.1042+02	.9505+02
35	2-1S	233	.4202-00	.4203-00	.4202-00	.5120-00	.5120-00	.12108+02	.0000	.1041+02	.9494+02
36	2-1S	234	.4203-00	.4205-00	.4204-00	.5090-00	.5100-00	.12082+02	.0000	.1043+02	.9512+02
37	2-1S	246	.4203-00	.4204-00	.4203-00	.5050-00	.5050-00	.11946+02	.0000	.1040+02	.9492+02
38	2-1S	247	.4202-00	.4204-00	.4204-00	.5060-00	.5070-00	.11998+02	.0000	.1042+02	.9505+02
39	2-1S	257	.4201-00	.4204-00	.4202-00	.5120-00	.5110-00	.12082+02	.0000	.1039+02	.9483+02
40	2-1S	258	.4203-00	.4205-00	.4203-00	.5120-00	.5100-00	.12108+02	.0000	.1042+02	.9506+02
41	2-1S	260	.4202-00	.4205-00	.4204-00	.5150-00	.5150-00	.12180+02	.0000	.1040+02	.9488+02
42	2-1S	267	.4203-00	.4204-00	.4203-00	.5120-00	.5120-00	.12095+02	.0000	.1039+02	.9479+02
43	2-1S	272	.4202-00	.4203-00	.4202-00	.5120-00	.5130-00	.12131+02	.0000	.1041+02	.9502+02
44	2-1S	275	.4203-00	.4204-00	.4201-00	.5060-00	.5070-00	.12020+02	.0000	.1044+02	.9525+02
45	2-1S	277	.4203-00	.4204-00	.4203-00	.4960-00	.4950-00	.11675+02	.0000	.1036+02	.9454+02
46	2-1S	278	.4203-00	.4206-00	.4203-00	.5040-00	.5060-00	.11928+02	.0000	.1038+02	.9475+02

TOTAL WEIGHT OF GROUP = 543.762 GRAMS
AVERAGE WEIGHT OF GROUP = 11.8209 GRAMS
AVERAGE DENSITY OF GROUP = 94.809 PERCENT T.D.
TOTAL LENGTH OF PELLET GROUP= 23.2805INCHES
AVERAGE PELLET LENGTH OF GROUP = .5061 INCHES
STANDARD DEVIATION OF PELLET DENSITY = .274

IFA-432, Rod 2

	LOT NO.	SAMPLE NO.	DIAMETER (INCHES) D-1	D-2	D-3	LENGTH (INCHES) L-1	L-2	WEIGHT (GRAMS)	DIA. CENTER VOID (INCHES)	DENSITY (G/CC)	DENSITY (PERCENT T.D.)
1	2-8D	9	.4144-00	.4145-00	.4144-00	.5170-00	.5160-00	.11473+02	.6850-01	.1033+02	.9426+02
2	2-8D	72	.4145-00	.4145-00	.4144-00	.5030-00	.5030-00	.11171+02	.6850-01	.1033+02	.9423+02
3	2-8D	76	.4144-00	.4144-00	.4145-00	.4940-00	.4940-00	.10988+02	.6850-01	.1035+02	.9439+02
4	2-2S	142	.4143-00	.4144-00	.4144-00	.5000-00	.5000-00	.11471+02	.0000	.1038+02	.9473+02
5	2-8D	160	.4143-00	.4144-00	.4144-00	.5000-00	.4990-00	.11101+02	.6850-01	.1034+02	.9434+02
6	2-8D	162	.4145-00	.4144-00	.4144-00	.5080-00	.5070-00	.11325+02	.6850-01	.1038+02	.9470+02
7	2-2S	210	.4145-00	.4146-00	.4146-00	.5080-00	.5080-00	.11736+02	.0000	.1044+02	.9530+02
8	2-2S	298	.4144-00	.4144-00	.4143-00	.4980-00	.5000-00	.11427+02	.0000	.1036+02	.9455+02
9	2-2D	301	.4143-00	.4143-00	.4143-00	.4980-00	.5000-00	.11072+02	.6850-01	.1033+02	.9422+02
10	2-2D	304	.4142-00	.4142-00	.4142-00	.5050-00	.5050-00	.11208+02	.6850-01	.1033+02	.9429+02
11	2-2D	307	.4142-00	.4143-00	.4142-00	.5010-00	.5010-00	.11115+02	.6850-01	.1033+02	.9424+02
12	2-2D	308	.4143-00	.4144-00	.4144-00	.5010-00	.5010-00	.11119+02	.6850-01	.1033+02	.9421+02
13	2-2D	312	.4142-00	.4143-00	.4143-00	.5020-00	.5030-00	.11164+02	.6850-01	.1034+02	.9436+02
14	2-2D	318	.4142-00	.4143-00	.4142-00	.5030-00	.5030-00	.11178+02	.6850-01	.1035+02	.9440+02
15	2-2D	321	.4144-00	.4145-00	.4144-00	.4990-00	.5010-00	.11121+02	.6850-01	.1034+02	.9439+02
16	2-2D	323	.4143-00	.4144-00	.4143-00	.5010-00	.5010-00	.11131+02	.6850-01	.1034+02	.9433+02
17	2-2D	325	.4143-00	.4144-00	.4143-00	.5010-00	.5020-00	.11122+02	.6850-01	.1032+02	.9416+02
18	2-2D	327	.4142-00	.4143-00	.4142-00	.5040-00	.5050-00	.11172+02	.6850-01	.1031+02	.9407+02
19	2-2D	328	.4143-00	.4144-00	.4144-00	.5000-00	.5000-00	.11108+02	.6850-01	.1034+02	.9431+02
20	2-2D	330	.4142-00	.4143-00	.4142-00	.5000-00	.5010-00	.11093+02	.6850-01	.1032+02	.9415+02
21	2-2D	331	.4143-00	.4143-00	.4142-00	.5030-00	.5040-00	.11167+02	.6850-01	.1032+02	.9419+02
22	2-2D	333	.4143-00	.4143-00	.4143-00	.5010-00	.5020-00	.11140+02	.6850-01	.1034+02	.9433+02
23	2-2D	334	.4143-00	.4143-00	.4142-00	.4950-00	.4970-00	.10991+02	.6850-01	.1031+02	.9411+02
24	2-2S	338	.4143-00	.4144-00	.4143-00	.4970-00	.4960-00	.11421+02	.0000	.1041+02	.9499+02
25	2-2S	345	.4143-00	.4144-00	.4143-00	.4970-00	.4980-00	.11408+02	.0000	.1038+02	.9470+02
26	2-2S	346	.4142-00	.4143-00	.4143-00	.4990-00	.5010-00	.11470+02	.0000	.1039+02	.9476+02
27	2-2S	369	.4143-00	.4143-00	.4143-00	.4930-00	.4900-00	.11235+02	.0000	.1038+02	.9470+02
28	2-2S	380	.4141-00	.4143-00	.4142-00	.5020-00	.5020-00	.11459+02	.0000	.1034+02	.9433+02
29	2-2S	383	.4143-00	.4144-00	.4144-00	.5020-00	.5020-00	.11493+02	.0000	.1036+02	.9453+02
30	2-2S	384	.4142-00	.4143-00	.4142-00	.4960-00	.4950-00	.11370+02	.0000	.1039+02	.9481+02
31	2-2S	385	.4143-00	.4144-00	.4143-00	.4920-00	.4930-00	.11321+02	.0000	.1040+02	.9493+02
32	2-2S	386	.4144-00	.4146-00	.4145-00	.4960-00	.4970-00	.11389+02	.0000	.1037+02	.9465+02
33	2-2S	388	.4144-00	.4143-00	.4143-00	.4980-00	.4980-00	.11410+02	.0000	.1037+02	.9462+02
34	2-2S	389	.4142-00	.4143-00	.4142-00	.4990-00	.4990-00	.11413+02	.0000	.1036+02	.9450+02
35	2-2S	390	.4143-00	.4143-00	.4142-00	.4990-00	.5000-00	.11451+02	.0000	.1038+02	.9470+02
36	2-2S	393	.4143-00	.4144-00	.4143-00	.5010-00	.5010-00	.11482+02	.0000	.1037+02	.9464+02
37	2-2S	398	.4142-00	.4144-00	.4143-00	.4980-00	.5000-00	.11442+02	.0000	.1038+02	.9471+02
38	2-2S	406	.4142-00	.4142-00	.4142-00	.4970-00	.4970-00	.11375+02	.0000	.1037+02	.9458+02
39	2-2S	407	.4144-00	.4145-00	.4144-00	.5000-00	.5000-00	.11490+02	.0000	.1040+02	.9485+02
40	2-2S	414	.4143-00	.4144-00	.4143-00	.4970-00	.4980-00	.11420+02	.0000	.1039+02	.9479+02
41	2-2S	420	.4143-00	.4146-00	.4144-00	.4910-00	.4910-00	.11270+02	.0000	.1038+02	.9474+02
42	2-2S	431	.4144-00	.4145-00	.4145-00	.5010-00	.5030-00	.11513+02	.0000	.1037+02	.9465+02
43	2-2S	437	.4143-00	.4144-00	.4144-00	.4980-00	.5000-00	.11456+02	.0000	.1039+02	.9479+02
44	2-2S	441	.4142-00	.4143-00	.4142-00	.4920-00	.4930-00	.11295+02	.0000	.1039+02	.9475+02
45	2-2S	443	.4143-00	.4144-00	.4144-00	.4980-00	.4990-00	.11430+02	.0000	.1038+02	.9467+02
46	2-2S	459	.4141-00	.4143-00	.4143-00	.5070-00	.5080-00	.11518+02	.0000	.1028+02	.9377+02

TOTAL WEIGHT OF GROUP = 520.124 GRAMS
AVERAGE WEIGHT OF GROUP = 11.3070 GRAMS
AVERAGE DENSITY OF GROUP = 94.559 PERCENT T.D.
TOTAL LENGTH OF PELLET GROUP= 23.0015INCHES
AVERAGE PELLET LENGTH OF GROUP = .5000 INCHES
STANDARD DEVIATION OF PELLET DENSITY = .292

IFA-432, Rod 3

	LOT NO.	SAMPLE NO.	DIAMETER (INCHES) D-1	DIAMETER (INCHES) D-2	DIAMETER (INCHES) D-3	LENGTH (INCHES) L-1	LENGTH (INCHES) L-2	WEIGHT (GRAMS)	DIA. CENTER VOID (INCHES)	DENSITY (G/CC)	DENSITY (PERCENT T.D.)
1	2-3S	476	.4264-00	.4266-00	.4265-00	.5060-00	.5060-00	.12373+02	.0000	.1044+02	.9530+02
2	2-3S	478	.4263-00	.4265-00	.4265-00	.5140-00	.5150-00	.12568+02	.0000	.1044+02	.9523+02
3	2-3S	479	.4262-00	.4263-00	.4262-00	.5130-00	.5140-00	.12499+02	.0000	.1041+02	.9498+02
4	2-3S	498	.4261-00	.4262-00	.4261-00	.5060-00	.5080-00	.12423+02	.0000	.1048+02	.9566+02
5	2-3S	501	.4260-00	.4262-00	.4261-00	.5060-00	.5080-00	.12385+02	.0000	.1045+02	.9538+02
6	2-3S	509	.4262-00	.4263-00	.4262-00	.5150-00	.5160-00	.12343+02	.0000	.1024+02	.9343+02
7	2-3D	519	.4264-00	.4265-00	.4264-00	.5080-00	.5080-00	.12075+02	.6850-01	.1043+02	.9512+02
8	2-3D	520	.4266-00	.4265-00	.4264-00	.5100-00	.5100-00	.12111+02	.6850-01	.1041+02	.9500+02
9	2-3D	523	.4264-00	.4264-00	.4263-00	.5100-00	.5110-00	.12131+02	.6850-01	.1043+02	.9513+02
10	2-3D	530	.4263-00	.4263-00	.4262-00	.5070-00	.5090-00	.12016+02	.6850-01	.1038+02	.9473+02
11	2-3D	531	.4261-00	.4262-00	.4262-00	.5090-00	.5100-00	.12118+02	.6850-01	.1045+02	.9530+02
12	2-3D	533	.4263-00	.4263-00	.4263-00	.5070-00	.5080-00	.12057+02	.6850-01	.1043+02	.9514+02
13	2-3D	535	.4262-00	.4264-00	.4264-00	.5080-00	.5100-00	.12076+02	.6850-01	.1041+02	.9499+02
14	2-3D	537	.4265-00	.4265-00	.4264-00	.5110-00	.5120-00	.12251+02	.6850-01	.1050+02	.9583+02
15	2-3D	540	.4265-00	.4265-00	.4264-00	.5150-00	.5150-00	.12211+02	.6850-01	.1040+02	.9487+02
16	2-3D	545	.4263-00	.4264-00	.4264-00	.5120-00	.5140-00	.12185+02	.6850-01	.1042+02	.9508+02
17	2-3D	546	.4262-00	.4263-00	.4263-00	.5100-00	.5120-00	.12110+02	.6850-01	.1040+02	.9491+02
18	2-3D	547	.4263-00	.4264-00	.4264-00	.5130-00	.5160-00	.12210+02	.6850-01	.1041+02	.9500+02
19	2-3D	549	.4262-00	.4263-00	.4262-00	.5090-00	.5100-00	.12068+02	.6850-01	.1040+02	.9488+02
20	2-3S	562	.4261-00	.4262-00	.4262-00	.5100-00	.5110-00	.12498+02	.0000	.1047+02	.9556+02
21	2-3S	569	.4261-00	.4262-00	.4262-00	.5110-00	.5150-00	.12582+02	.0000	.1049+02	.9574+02
22	2-3S	570	.4262-00	.4262-00	.4261-00	.5150-00	.5150-00	.12569+02	.0000	.1044+02	.9527+02
23	2-3S	572	.4262-00	.4263-00	.4262-00	.5110-00	.5120-00	.12491+02	.0000	.1044+02	.9529+02
24	2-3S	574	.4261-00	.4261-00	.4262-00	.5140-00	.5150-00	.12561+02	.0000	.1045+02	.9531+02
25	2-3S	575	.4263-00	.4264-00	.4261-00	.5180-00	.5180-00	.12646+02	.0000	.1044+02	.9525+02
26	2-3S	577	.4264-00	.4265-00	.4264-00	.5140-00	.5170-00	.12590+02	.0000	.1044+02	.9522+02
27	2-3S	583	.4262-00	.4263-00	.4261-00	.5110-00	.5130-00	.12516+02	.0000	.1046+02	.9541+02
28	2-3S	584	.4263-00	.4264-00	.4264-00	.5150-00	.5150-00	.12596+02	.0000	.1045+02	.9538+02
29	2-3S	587	.4263-00	.4265-00	.4264-00	.5100-00	.5100-00	.12505+02	.0000	.1048+02	.9561+02
30	2-3S	588	.4261-00	.4263-00	.4265-00	.5150-00	.5150-00	.12593+02	.0000	.1045+02	.9539+02
31	2-3S	589	.4259-00	.4262-00	.4261-00	.5160-00	.5170-00	.12612+02	.0000	.1045+02	.9536+02
32	2-3S	590	.4261-00	.4264-00	.4263-00	.5140-00	.5140-00	.12588+02	.0000	.1047+02	.9555+02
33	2-3S	591	.4260-00	.4261-00	.4261-00	.5140-00	.5150-00	.12551+02	.0000	.1044+02	.9527+02
34	2-3S	594	.4263-00	.4264-00	.4262-00	.5140-00	.5140-00	.12557+02	.0000	.1045+02	.9530+02
35	2-3S	597	.4263-00	.4263-00	.4264-00	.5080-00	.5100-00	.12463+02	.0000	.1047+02	.9550+02
36	2-3S	599	.4262-00	.4262-00	.4262-00	.5160-00	.5140-00	.12569+02	.0000	.1044+02	.9525+02
37	2-3S	602	.4262-00	.4263-00	.4263-00	.5080-00	.5090-00	.12422+02	.0000	.1045+02	.9531+02
38	2-3S	605	.4262-00	.4263-00	.4263-00	.5070-00	.5080-00	.12411+02	.0000	.1046+02	.9542+02
39	2-3S	608	.4264-00	.4265-00	.4264-00	.5060-00	.5070-00	.12439+02	.0000	.1049+02	.9574+02
40	2-3S	610	.4261-00	.4261-00	.4261-00	.5000-00	.5030-00	.12268+02	.0000	.1047+02	.9552+02
41	2-3S	611	.4260-00	.4261-00	.4260-00	.4960-00	.4980-00	.12089+02	.0000	.1041+02	.9501+02
42	2-3S	612	.4264-00	.4263-00	.4263-00	.5070-00	.5080-00	.12398+02	.0000	.1044+02	.9529+02
43	2-3S	615	.4261-00	.4262-00	.4262-00	.5210-00	.5220-00	.12722+02	.0000	.1044+02	.9523+02
44	2-3S	619	.4264-00	.4265-00	.4263-00	.5120-00	.5120-00	.12512+02	.0000	.1044+02	.9529+02
45	2-3S	620	.4260-00	.4261-00	.4261-00	.5010-00	.5010-00	.12255+02	.0000	.1047+02	.9553+02

TOTAL WEIGHT OF GROUP = 557.213 GRAMS
AVERAGE WEIGHT OF GROUP = 12.3825 GRAMS
AVERAGE DENSITY OF GROUP = 95.244 PERCENT T.D.
TOTAL LENGTH OF PELLET GROUP= 22.9965INCHES
AVERAGE PELLET LENGTH OF GROUP = .5110 INCHES
STANDARD DEVIATION OF PELLET DENSITY = .370

IFA-432, Rod 4

	LOT NO.	SAMPLE NO.	DIAMETER (INCHES) D-1	D-2	D-3	LENGTH (INCHES) -1	L-2	WEIGHT (GRAMS)	DIA. CENTER VOID (INCHES)	DENSITY (G/CC)	DENSITY (PERCENT T.D.)
1	2-4D	3	.4204-00	.4204-00	.4204-00	.5140-00	.5160-00	.11846+02	.6850-01	.1039+02	.9478+02
2	2-4S	30	.4202-00	.4204-00	.4204-00	.5100-00	.5100-00	.12058+02	.0000	.1040+02	.9487+02
3	2-4S	40	.4202-00	.4202-00	.4202-00	.5060-00	.5050-00	.11954+02	.0000	.1041+02	.9495+02
4	2-4S	44	.4200-00	.4203-00	.4201-00	.5040-00	.5060-00	.11961+02	.0000	.1043+02	.9513+02
5	2-4S	49	.4200-00	.4202-00	.4202-00	.5030-00	.5040-00	.11887+02	.0000	.1039+02	.9482+02
6	2-4S	51	.4201-00	.4202-00	.4201-00	.5030-00	.5030-00	.11878+02	.0000	.1039+02	.9484+02
7	2-4S	57	.4203-00	.4204-00	.4202-00	.5050-00	.5050-00	.11958+02	.0000	.1042+02	.9503+02
8	2-4D	75	.4205-00	.4205-00	.4205-00	.5050-00	.5050-00	.11601+02	.6850-01	.1037+02	.9462+02
9	2-4D	80	.4205-00	.4204-00	.4204-00	.5050-00	.5070-00	.11652+02	.6850-01	.1040+02	.9487+02
10	2-4D	86	.4204-00	.4204-00	.4203-00	.5100-00	.5090-00	.11690+02	.6850-01	.1036+02	.9456+02
11	2-4S	94	.4203-00	.4204-00	.4204-00	.5050-00	.5060-00	.11939+02	.0000	.1039+02	.9475+02
12	2-4S	95	.4203-00	.4202-00	.4202-00	.5110-00	.5120-00	.12099+02	.0000	.1041+02	.9496+02
13	2-4S	104	.4201-00	.4203-00	.4202-00	.5050-00	.5060-00	.11922+02	.0000	.1038+02	.9469+02
14	2-4S	111	.4204-00	.4204-00	.4203-00	.5060-00	.5060-00	.11962+02	.0000	.1039+02	.9484+02
15	2-4S	113	.4202-00	.4204-00	.4203-00	.5010-00	.5020-00	.11911+02	.0000	.1045+02	.9532+02
16	2-4S	115	.4200-00	.4203-00	.4202-00	.5020-00	.5010-00	.11885+02	.0000	.1043+02	.9517+02
17	2-4S	118	.4202-00	.4203-00	.4202-00	.5030-00	.5030-00	.11870+02	.0000	.1038+02	.9474+02
18	2-4S	124	.4202-00	.4203-00	.4203-00	.5090-00	.5080-00	.12003+02	.0000	.1038+02	.9475+02
19	2-4S	133	.4202-00	.4203-00	.4202-00	.5150-00	.5130-00	.12138+02	.0000	.1039+02	.9480+02
20	2-4S	137	.4204-00	.4204-00	.4202-00	.5070-00	.5060-00	.11980+02	.0000	.1040+02	.9491+02
21	2-4S	139	.4201-00	.4203-00	.4202-00	.5040-00	.5050-00	.11913+02	.0000	.1039+02	.9481+02
22	2-4D	157	.4207-00	.4207-00	.4206-00	.5110-00	.5090-00	.11717+02	.6850-01	.1036+02	.9455+02
23	2-4D	170	.4204-00	.4204-00	.4203-00	.5040-00	.5050-00	.11612+02	.6300-01	.1035+02	.9446+02
24	2-4D	175	.4204-00	.4204-00	.4204-00	.5060-00	.5070-00	.11672+02	.6300-01	.1036+02	.9456+02
25	2-4D	176	.4204-00	.4204-00	.4204-00	.5070-00	.5050-00	.11670+02	.6850-01	.1042+02	.9504+02
26	2-4D	181	.4204-00	.4205-00	.4204-00	.5060-00	.5080-00	.11765+02	.6300-01	.1043+02	.9521+02
27	2-4D	182	.4205-00	.4205-00	.4205-00	.5040-00	.5050-00	.11602+02	.6300-01	.1041+02	.9497+02
28	2-4D	186	.4206-00	.4205-00	.4205-00	.5050-00	.5060-00	.11718+02	.6300-01	.1042+02	.9506+02
29	2-4S	209	.4201-00	.4204-00	.4203-00	.5040-00	.5050-00	.11922+02	.0000	.1040+02	.9485+02
30	2-4S	215	.4201-00	.4202-00	.4202-00	.5070-00	.5070-00	.12000+02	.0000	.1042+02	.9505+02
31	2-4S	226	.4202-00	.4201-00	.4201-00	.4970-00	.4990-00	.11829+02	.0000	.1046+02	.9540+02
32	2-4S	236	.4204-00	.4202-00	.4202-00	.5120-00	.5130-00	.12139+02	.0000	.1042+02	.9507+02
33	2-4S	239	.4204-00	.4204-00	.4202-00	.5090-00	.5070-00	.12013+02	.0000	.1040+02	.9489+02
34	2-4S	240	.4201-00	.4203-00	.4202-00	.5080-00	.5100-00	.12058+02	.0000	.1042+02	.9512+02
35	2-4S	251	.4202-00	.4203-00	.4201-00	.5100-00	.5100-00	.12051+02	.0000	.1040+02	.9487+02
36	2-4S	252	.4200-00	.4202-00	.4202-00	.5200-00	.5180-00	.12253+02	.0000	.1039+02	.9482+02
37	2-4S	263	.4202-00	.4203-00	.4203-00	.5100-00	.5130-00	.12110+02	.0000	.1042+02	.9503+02
38	2-4S	264	.4200-00	.4203-00	.4202-00	.5050-00	.5060-00	.11969+02	.0000	.1042+02	.9508+02
39	2-4S	274	.4203-00	.4204-00	.4204-00	.5110-00	.5100-00	.12084+02	.0000	.1041+02	.9497+02
40	2-4D	763	.4204-00	.4204-00	.4205-00	.5050-00	.5050-00	.11658+02	.6300-01	.1038+02	.9471+02
41	2-4D	764	.4204-00	.4204-00	.4204-00	.5020-00	.5010-00	.11597+02	.6300-01	.1040+02	.9489+02
42	2-4D	774	.4205-00	.4205-00	.4204-00	.4980-00	.4990-00	.11462+02	.6300-01	.1034+02	.9432+02
43	2-4D	775	.4205-00	.4205-00	.4205-00	.4910-00	.4900-00	.11264+02	.6300-01	.1032+02	.9419+02

TOTAL WEIGHT OF GROUP = 510.352 GRAMS
AVERAGE WEIGHT OF GROUP = 11.8686 GRAMS
AVERAGE DENSITY OF GROUP = 94.868 PERCENT T.D.
TOTAL LENGTH OF PELLET GROUP= 21.7705INCHES
AVERAGE PELLET LENGTH OF GROUP = .5063 INCHES
STANDARD DEVIATION OF PELLET DENSITY = .244

IFA-432, Rod 5

	LOT NO.	SAMPLE NO.	DIAMETER (INCHES) D-1	D-2	D-3	LENGTH (INCHES) L-1	L-2	WEIGHT (GRAMS)	DIA. CENTER VOID (INCHES)	DENSITY (G/CC)	DENSITY (PERCENT T.D.)
1	2-6S	779	.4203-00	.4204-00	.4204-00	.5090-00	.5090-00	.11631+02	.0000	.1005+02	.9168+02
2	2-6S	780	.4202-00	.4203-00	.4202-00	.5070-00	.5070-00	.11535+02	.0000	.1001+02	.9134+02
3	2-6S	791	.4202-00	.4204-00	.4203-00	.5130-00	.5100-00	.11573+02	.0000	.9952+01	.9080+02
4	2-6S	792	.4203-00	.4203-00	.4203-00	.5080-00	.5050-00	.11421+02	.0000	.9918+01	.9049+02
5	2-6S	794	.4201-00	.4204-00	.4202-00	.4990-00	.5000-00	.11305+02	.0000	.9958+01	.9086+02
6	2-6S	799	.4203-00	.4203-00	.4204-00	.5070-00	.5090-00	.11598+02	.0000	.1004+02	.9161+02
7	1-5	812	.4202-00	.4203-00	.4202-00	.5060-00	.5080-00	.11200+02	.6850-01	.9985+01	.9110+02
8	2-6D	815	.4202-00	.4202-00	.4202-00	.5010-00	.5030-00	.11107+02	.6850-01	.1000+02	.9126+02
9	2-6D	816	.4201-00	.4203-00	.4203-00	.5060-00	.5060-00	.11166+02	.6850-01	.9974+01	.9101+02
10	2-6D	817	.4203-00	.4203-00	.4203-00	.4970-00	.4980-00	.11025+02	.6650-01	.1001+02	.9136+02
11	2-6D	819	.4203-00	.4204-00	.4204-00	.4970-00	.4980-00	.11101+02	.6850-01	.1008+02	.9196+02
12	2-6D	822	.4203-00	.4204-00	.4203-00	.5050-00	.5070-00	.11252+02	.6850-01	.1005+02	.9166+02
13	2-6D	824	.4203-00	.4204-00	.4203-00	.5150-00	.5180-00	.11372+02	.6850-01	.9947+01	.9076+02
14	2-6D	825	.4203-00	.4203-00	.4201-00	.5090-00	.5120-00	.11231+02	.6850-01	.9944+01	.9073+02
15	2-6D	829	.4203-00	.4202-00	.4202-00	.5200-00	.5220-00	.11480+02	.6850-01	.9960+01	.9087+02
16	2-6D	830	.4202-00	.4203-00	.4201-00	.5220-00	.5200-00	.11453+02	.6650-01	.9938+01	.9067+02
17	1-5	831	.4203-00	.4203-00	.4204-00	.5050-00	.5060-00	.11152+02	.6850-01	.9967+01	.9094+02
18	2-6D	832	.4203-00	.4204-00	.4203-00	.5110-00	.5130-00	.11306+02	.6850-01	.9976+01	.9102+02
19	2-6D	834	.4201-00	.4203-00	.4202-00	.5150-00	.5170-00	.11383+02	.6850-01	.9973+01	.9099+02
20	2-6D	835	.4203-00	.4205-00	.4204-00	.5050-00	.5090-00	.11202+02	.6850-01	.9979+01	.9105+02
21	1-5	837	.4202-00	.4203-00	.4203-00	.5070-00	.5090-00	.11208+02	.6850-01	.9971+01	.9097+02
22	2-6D	839	.4202-00	.4203-00	.4202-00	.5100-00	.5120-00	.11364+02	.6850-01	.1005+02	.9171+02
23	2-6D	840	.4203-00	.4204-00	.4203-00	.5170-00	.5170-00	.11391+02	.6850-01	.9954+01	.9082+02
24	2-6D	841	.4203-00	.4204-00	.4203-00	.5130-00	.5140-00	.11328+02	.6850-01	.9966+01	.9093+02
25	2-6D	842	.4201-00	.4202-00	.4202-00	.5100-00	.5110-00	.11260+02	.6850-01	.9973+01	.9099+02
26	2-6D	843	.4201-00	.4202-00	.4202-00	.5070-00	.5090-00	.11237+02	.6850-01	.1000+02	.9125+02
27	2-6S	851	.4204-00	.4204-00	.4204-00	.5000-00	.5020-00	.11362+02	.0000	.9970+01	.9097+02
28	2-6S	859	.4202-00	.4203-00	.4202-00	.4950-00	.4950-00	.11321+02	.0000	.1006+02	.9181+02
29	2-6S	864	.4202-00	.4203-00	.4202-00	.5040-00	.5050-00	.11369+02	.0000	.9915+01	.9047+02
30	2-6S	865	.4204-00	.4204-00	.4203-00	.5000-00	.5000-00	.11273+02	.0000	.9914+01	.9045+02
31	2-6S	867	.4205-00	.4205-00	.4203-00	.5010-00	.5040-00	.11421+02	.0000	.9991+01	.9116+02
32	2-6S	873	.4202-00	.4202-00	.4201-00	.4980-00	.4980-00	.11268+02	.0000	.9959+01	.9086+02
33	2-6S	875	.4203-00	.4203-00	.4202-00	.5070-00	.5060-00	.11426+02	.0000	.9904+01	.9037+02
34	2-6S	876	.4202-00	.4203-00	.4202-00	.5000-00	.5030-00	.11370+02	.0000	.9975+01	.9102+02
35	2-6S	878	.4202-00	.4202-00	.4202-00	.5060-00	.5070-00	.11418+02	.0000	.9920+01	.9051+02
36	2-6S	881	.4202-00	.4204-00	.4202-00	.5140-00	.5150-00	.11688+02	.0000	.9994+01	.9118+02
37	2-6S	882	.4204-00	.4204-00	.4204-00	.5050-00	.5070-00	.11485+02	.0000	.9979+01	.9105+02
38	2-6S	883	.4203-00	.4205-00	.4204-00	.4950-00	.4970-00	.11225+02	.0000	.9949+01	.9078+02
39	2-6S	885	.4202-00	.4205-00	.4203-00	.4950-00	.4950-00	.11169+02	.0000	.9923+01	.9054+02
40	2-6S	888	.4202-00	.4202-00	.4201-00	.4980-00	.4960-00	.11170+02	.0000	.9892+01	.9025+02
41	2-6S	892	.4203-00	.4204-00	.4203-00	.5110-00	.5110-00	.11477+02	.0000	.9877+01	.9012+02
42	2-6S	893	.4205-00	.4204-00	.4203-00	.5100-00	.5100-00	.11378+02	.0000	.9808+01	.8949+02
43	2-6S	894	.4204-00	.4205-00	.4204-00	.5070-00	.5050-00	11363+02	.0000	.9871+01	.9007+02
44	2-6S	895	.4203-00	.4202-00	.4203-00	.5110-00	.5130-00	.11541+02	.0000	.9916+01	.9048+02
45	2-6S	896	.4203-00	.4204-00	.4205-00	.5140-00	.5160-00	.11592+02	.0000	.9896+01	.9029+02
46	2-6S	900	.4202-00	.4204-00	.4203-00	.4980-00	.5020-00	.11254+02	.0000	.9900+01	.9033+02

TOTAL WEIGHT OF GROUP = 521.851 GRAMS
AVERAGE WEIGHT OF GROUP = 11.3446 GRAMS
AVERAGE DENSITY OF GROUP = 90.892 PERCENT T.D.
TOTAL LENGTH OF PELLET GROUP= 23.3140INCHES
AVERAGE PELLET LENGTH OF GROUP = .5068 INCHES
STANDARD DEVIATION OF PELLET DENSITY = .497

IFA-432, Rod 6

	LOT NO.	SAMPLE NO.	DIAMETER (INCHES) D-1	D-2	D-3	LENGTH (INCHES) L-1	L-2	WEIGHT (GRAMS)	DIA. CENTER VOID (INCHES)	DENSITY (G/CC)	DENSITY (PERCENT T.D.)
1	2-7D	637	.4205-00	.4204-00	.4203-00	.5190-00	.5210-00	.11564+02	.6850-01	.1004+02	.9164+02
2	2-7D	638	.4204-00	.4204-00	.4204-00	.4970-00	.5000-00	.11022+02	.6850-01	.9986+01	.9111+02
3	2-7D	643	.4202-00	.4202-00	.4203-00	.4990-00	.5010-00	.11119+02	.6850-01	.1005+02	.9171+02
4	2-7D	644	.4202-00	.4204-00	.4204-00	.4990-00	.5000-00	.11116+02	.6850-01	.1006+02	.9175+02
5	2-7D	648	.4203-00	.4205-00	.4205-00	.4950-00	.4960-00	.11032+02	.6850-01	.1005+02	.9173+02
6	2-7D	650	.4204-00	.4204-00	.4203-00	.4980-00	.5000-00	.11100+02	.6850-01	.1005+02	.9168+02
7	2-7D	651	.4202-00	.4203-00	.4203-00	.5020-00	.5040-00	.11188+02	.6850-01	.1005+02	.9171+02
8	2-7D	657	.4201-00	.4203-00	.4204-00	.4980-00	.5000-00	.11101+02	.6850-01	.1005+02	.9173+02
9	2-7D	659	.4203-00	.4204-00	.4203-00	.4950-00	.4970-00	.11033+02	.6850-01	.1005+02	.9169+02
10	2-7D	662	.4205-00	.4205-00	.4205-00	.4970-00	.4980-00	.11019+02	.6850-01	.9998+01	.9122+02
11	2-7D	663	.4203-00	.4204-00	.4203-00	.4960-00	.4970-00	.10969+02	.6850-01	.9981+01	.9107+02
12	2-7D	664	.4204-00	.4204-00	.4203-00	.4980-00	.4990-00	.11038+02	.6850-01	.1000+02	.9126+02
13	2-7D	665	.4204-00	.4205-00	.4204-00	.4930-00	.4930-00	.10963+02	.6850-01	.1004+02	.9162+02
14	2-7D	666	.4203-00	.4204-00	.4203-00	.5160-00	.5160-00	.11138+02	.6850-01	.9752+01	.8898+02
15	2-7D	667	.4204-00	.4203-00	.4202-00	.4870-00	.4880-00	.10813+02	.6850-01	.1002+02	.9144+02
16	2-7D	668	.4203-00	.4203-00	.4203-00	.5050-00	.5070-00	.11220+02	.6850-01	.1002+02	.9142+02
17	1-6	670	.4202-00	.4203-00	.4203-00	.5100-00	.5110-00	.11322+02	.6850-01	.1002+02	.9145+02
18	2-7D	671	.4206-00	.4205-00	.4204-00	.5110-00	.5120-00	.11349+02	.6850-01	.1002+02	.9138+02
19	2-7D	672	.4203-00	.4203-00	.4202-00	.5090-00	.5100-00	.11282+02	.6850-01	.1001+02	.9131+02
20	2-7S	673	.4203-00	.4205-00	.4203-00	.5060-00	.5070-00	.11587+02	.0000	.1006+02	.9178+02
21	2-7S	674	.4204-00	.4204-00	.4203-00	.5080-00	.5100-00	.11589+02	.0000	.1001+02	.9134+02
22	2-7S	676	.4201-00	.4203-00	.4202-00	.5050-00	.5060-00	.11520+02	.0000	.1003+02	.9150+02
23	2-7S	677	.4202-00	.4203-00	.4203-00	.5040-00	.5050-00	.11508+02	.0000	.1003+02	.9156+02
24	2-7S	678	.4206-00	.4205-00	.4204-00	.5070-00	.5090-00	.11618+02	.0000	.1005+02	.9170+02
25	2-7S	679	.4203-00	.4204-00	.4203-00	.5110-00	.5110-00	.11663+02	.0000	.1004+02	.9158+02
26	2-7S	680	.4203-00	.4203-00	.4203-00	.5030-00	.5040-00	.11501+02	.0000	.1005+02	.9167+02
27	2-7S	682	.4204-00	.4204-00	.4203-00	.5120-00	.5120-00	.11692+02	.0000	.1004+02	.9162+02
28	2-7S	683	.4204-00	.4205-00	.4204-00	.5060-00	.5070-00	.11580+02	.0000	.1005+02	.9170+02
29	2-7S	685	.4202-00	.4204-00	.4204-00	.5050-00	.5060-00	.11584+02	.0000	.1008+02	.9195+02
30	2-7S	686	.4203-00	.4202-00	.4202-00	.5020-00	.5040-00	.11529+02	.0000	.1008+02	.9201+02
31	2-7S	692	.4203-00	.4204-00	.4203-00	.5020-00	.5040-00	.11490+02	.0000	.1005+02	.9166+02
32	2-7S	695	.4205-00	.4203-00	.4202-00	.4990-00	.5010-00	.11445+02	.0000	.1007+02	.9185+02
33	2-7S	696	.4203-00	.4205-00	.4205-00	.4960-00	.4960-00	.11362+02	.0000	.1007+02	.9187+02
34	2-7S	698	.4204-00	.4205-00	.4203-00	.5090-00	.5100-00	.11633+02	.0000	.1004+02	.9159+02
35	2-7S	700	.4204-00	.4204-00	.4202-00	.5100-00	.5100-00	.11680+02	.0000	.1007+02	.9190+02
36	2-7S	702	.4202-00	.4204-00	.4204-00	.5090-00	.5100-00	.11692+02	.0000	.1009+02	.9208+02
37	2-7S	703	.4204-00	.4204-00	.4203-00	.5080-00	.5090-00	.11678+02	.0000	.1010+02	.9214+02
38	2-7S	705	.4203-00	.4204-00	.4203-00	.5100-00	.5100-00	.11680+02	.0000	.1007+02	.9190+02
39	2-7S	707	.4205-00	.4205-00	.4204-00	.5110-00	.5100-00	.11704+02	.0000	.1008+02	.9194+02
40	2-7S	708	.4205-00	.4205-00	.4205-00	.5100-00	.5090-00	.11660+02	.0000	.1006+02	.9176+02
41	2-7S	714	.4203-00	.4204-00	.4204-00	.5040-00	.5020-00	.11541+02	.0000	.1009+02	.9205+02
42	2-7S	726	.4203-00	.4203-00	.4202-00	.5040-00	.5060-00	.11579+02	.0000	.1009+02	.9203+02
43	2-7S	728	.4201-00	.4203-00	.4202-00	.5040-00	.5050-00	.11579+02	.0000	.1010+02	.9215+02
44	2-7S	736	.4204-00	.4205-00	.4204-00	.5130-00	.5130-00	.11710+02	.0000	.1003+02	.9155+02
45	2-7S	738	.4202-00	.4205-00	.4204-00	.5110-00	.5120-00	.11741+02	.0000	.1009+02	.9209+02
46	1-5	814	.4202-00	.4203-00	.4202-00	.5070-00	.5070-00	.11258+02	.6850-01	.1004+02	.9158+02

TOTAL WEIGHT OF GROUP = 524.193 GRAMS
AVERAGE WEIGHT OF GROUP = 11.3955 GRAMS
AVERAGE DENSITY OF GROUP = 91.618 PERCENT T.D.
TOTAL LENGTH OF PELLET GROUP= 23.2225INCHES
AVERAGE PELLET LENGTH OF GROUP = .5048 INCHES
STANDARD DEVIATION OF PELLET DENSITY = .479

IFA-432, Rod 7

	LOT NO.	SAMPLE NO.	DIAMETER (INCHES) D-1	D-2	D-3	LENGTH (INCHES) L-1	L-2	WEIGHT (GRAMS)	DIA. CENTER VOID (INCHES)	DENSITY (G/CC)	DENSITY (PERCENT T.D.)
1	2-2S	90	.4143-00	.4144-00	.4143-00	.5040-00	.5040-00	.11533+02	.0000	.1036+02	.9450+02
2	2-2S	138	.4140-00	.4142-00	.4140-00	.5120-00	.5140-00	.11735+02	.0000	.1037+02	.9459+02
3	2-2S	299	.4144-00	.4146-00	.4145-00	.4990-00	.4990-00	.11461+02	.0000	.1039+02	.9477+02
4	2-2S	339	.4143-00	.4144-00	.4143-00	.4960-00	.4970-00	.11380+02	.0000	.1037+02	.9465+02
5	2-2S	348	.4144-00	.4143-00	.4143-00	.4950-00	.4960-00	.11403+02	.0000	.1042+02	.9504+02
6	2-2S	351	.4144-00	.4145-00	.4144-00	.4990-00	.5000-00	.11462+02	.0000	.1038+02	.9472+02
7	2-2S	352	.4145-00	.4145-00	.4144-00	.4990-00	.4990-00	.11442+02	.0000	.1037+02	.9463+02
8	2-2S	353	.4143-00	.4144-00	.4143-00	.5000-00	.5000-00	.11454+02	.0000	.1037+02	.9460+02
9	2-2S	356	.4143-00	.4144-00	.4144-00	.5030-00	.5030-00	.11551+02	.0000	.1039+02	.9482+02
10	2-2S	357	.4143-00	.4143-00	.4143-00	.5030-00	.5030-00	.11473+02	.0000	.1033+02	.9421+02
11	2-2S	358	.4143-00	.4144-00	.4143-00	.4920-00	.4940-00	.11322+02	.0000	.1039+02	.9484+02
12	2-2S	359	.4143-00	.4144-00	.4143-00	.5010-00	.5010-00	.11461+02	.0000	.1035+02	.9447+02
13	2-2S	360	.4143-00	.4144-00	.4143-00	.5000-00	.5030-00	.11512+02	.0000	.1039+02	.9480+02
14	2-2S	363	.4143-00	.4143-00	.4143-00	.5000-00	.5000-00	.11476+02	.0000	.1039+02	.9480+02
15	2-2S	367	.4143-00	.4144-00	.4144-00	.5000-00	.5000-00	.11457+02	.0000	.1037+02	.9461+02
16	2-2S	368	.4143-00	.4143-00	.4143-00	.4990-00	.5010-00	.11472+02	.0000	.1039+02	.9477+02
17	2-2S	371	.4141-00	.4142-00	.4142-00	.5000-00	.5010-00	.11441+02	.0000	.1035+02	.9448+02
18	2-2S	372	.4145-00	.4146-00	.4144-00	.5000-00	.4990-00	.11473+02	.0000	.1039+02	.9478+02
19	2-2S	373	.4143-00	.4143-00	.4143-00	.4980-00	.5000-00	.11431+02	.0000	.1037+02	.9462+02
20	2-2S	376	.4143-00	.4144-00	.4143-00	.5030-00	.5020-00	.11512+02	.0000	.1037+02	.9461+02
21	2-2S	379	.4142-00	.4143-00	.4143-00	.4990-00	.5000-00	.11455+02	.0000	.1038+02	.9474+02
22	2-2S	382	.4143-00	.4143-00	.4142-00	.5010-00	.5020-00	.11500+02	.0000	.1038+02	.9473+02
23	2-2S	391	.4140-00	.4142-00	.4143-00	.4960-00	.4980-00	.11401+02	.0000	.1039+02	.9481+02
24	2-2S	401	.4145-00	.4146-00	.4145-00	.4940-00	.4940-00	.11329+02	.0000	.1037+02	.9461+02
25	2-2S	412	.4144-00	.4145-00	.4144-00	.4960-00	.4960-00	.11437+02	.0000	.1039+02	.9479+02
26	2-2S	413	.4144-00	.4144-00	.4143-00	.4960-00	.4970-00	.11381+02	.0000	.1037+02	.9465+02
27	2-2S	416	.4145-00	.4146-00	.4145-00	.4990-00	.4990-00	.11451+02	.0000	.1038+02	.9467+02
28	2-2S	417	.4143-00	.4144-00	.4143-00	.4940-00	.4950-00	.11351+02	.0000	.1039+02	.9479+02
29	2-2S	422	.4144-00	.4145-00	.4145-00	.5000-00	.5010-00	.11512+02	.0000	.1040+02	.9492+02
30	2-2S	424	.4142-00	.4143-00	.4144-00	.5020-00	.5030-00	.11546+02	.0000	.1040+02	.9492+02
31	2-2S	425	.4144-00	.4144-00	.4144-00	.5020-00	.5020-00	.11580+02	.0000	.1044+02	.9523+02
32	2-2S	427	.4143-00	.4145-00	.4145-00	.4990-00	.4990-00	.11461+02	.0000	.1039+02	.9480+02
33	2-2S	428	.4144-00	.4145-00	.4145-00	.4980-00	.5000-00	.11482+02	.0000	.1041+02	.9496+02
34	2-2S	429	.4143-00	.4143-00	.4143-00	.5040-00	.5050-00	.11589+02	.0000	.1040+02	.9488+02
35	2-2S	434	.4143-00	.4143-00	.4143-00	.5000-00	.5030-00	.11502+02	.0000	.1038+02	.9473+02
36	2-2S	435	.4145-00	.4146-00	.4146-00	.5030-00	.5030-00	.11570+02	.0000	.1040+02	.9488+02
37	2-2S	436	.4144-00	.4144-00	.4144-00	.5000-00	.5020-00	.11462+02	.0000	.1035+02	.9445+02
38	2-2S	439	.4144-00	.4143-00	.4143-00	.5000-00	.5000-00	.11445+02	.0000	.1036+02	.9453+02
39	2-2S	440	.4144-00	.4144-00	.4144-00	.5030-00	.5040-00	.11564+02	.0000	.1039+02	.9482+02
40	2-2S	444	.4142-00	.4143-00	.4143-00	.4980-00	.4990-00	.11441+02	.0000	.1039+02	.9481+02
41	2-2S	447	.4144-00	.4145-00	.4146-00	.5280-00	.5310-00	.12071+02	.0000	.1031+02	.9407+02
42	2-2S	449	.4143-00	.4143-00	.4143-00	.5000-00	.5000-00	.11350+02	.0000	.1028+02	.9376+02
43	2-2S	452	.4145-00	.4145-00	.4143-00	.5200-00	.5210-00	.11860+02	.0000	.1031+02	.9405+02
44	2-2S	453	.4144-00	.4145-00	.4144-00	.5040-00	.5040-00	.11478+02	.0000	.1030+02	.9400+02
45	2-2S	455	.4144-00	.4144-00	.4144-00	.4930-00	.4950-00	.11233+02	.0000	.1029+02	.9387+02
46	2-2S	458	.4142-00	.4143-00	.4142-00	.5060-00	.5060-00	.11473+02	.0000	.1027+02	.9368+02

TOTAL WEIGHT OF GROUP = 528.377 GRAMS
AVERAGE WEIGHT OF GROUP = 11.4865 GRAMS
AVERAGE DENSITY OF GROUP = 94.618 PERCENT T.D.
TOTAL LENGTH OF PELLET GROUP= 23.0585INCHES
AVERAGE PELLET LENGTH OF GROUP = .5013 INCHES
STANDARD DEVIATION OF PELLET DENSITY = .331

IFA-432, Rod 8

	LOT NO.	SAMPLE NO.	DIAMETER (INCHES) D-1	DIAMETER (INCHES) D-2	DIAMETER (INCHES) D-3	LENGTH (INCHES) L-1	LENGTH (INCHES) L-2	WEIGHT (GRAMS)	DIA. CENTER VOID (INCHES)	DENSITY (G/CC)	DENSITY (PERCENT T.D.)
1	2-1S	24	.4201-00	.4203-00	.4202-00	.5090-00	.5090-00	.11988+02	.0000	.1036+02	.9456+02
2	2-1S	27	.4203-00	.4205-00	.4205-00	.5090-00	.5090-00	.12030+02	.0000	.1039+02	.9479+02
3	2-1S	33	.4203-00	.4205-00	.4203-00	.5060-00	.5040-00	.11955+02	.0000	.1041+02	.9498+02
4	1-1S	35	.4203-00	.4205-00	.4204-00	.5080-00	.5060-00	.12041+02	.0000	.1042+02	.9508+02
5	2-1S	36	.4201-00	.4203-00	.4201-00	.5030-00	.5040-00	.11948+02	.0000	.1044+02	.9529+02
6	1-1S	37	.4202-00	.4203-00	.4203-00	.5060-00	.5050-00	.11971+02	.0000	.1042+02	.9505+02
7	2-1S	38	.4202-00	.4204-00	.4202-00	.5050-00	.5050-00	.11937+02	.0000	.1040+02	.9488+02
8	1-1S	46	.4201-00	.4203-00	.4202-00	.5020-00	.5010-00	.11889+02	.0000	.1043+02	.9519+02
9	2-1S	48	.4203-00	.4204-00	.4204-00	.5030-00	.5050-00	.11941+02	.0000	.1042+02	.9505+02
10	2-1S	53	.4202-00	.4204-00	.4203-00	.4990-00	.5000-00	.11813+02	.0000	.1040+02	.9491+02
11	2-1S	54	.4201-00	.4203-00	.4201-00	.5060-00	.5060-00	.11915+02	.0000	.1036+02	.9456+02
12	2-1S	55	.4203-00	.4204-00	.4203-00	.4980-00	.4980-00	.11817+02	.0000	.1044+02	.9521+02
13	2-1S	58	.4202-00	.4204-00	.4202-00	.5040-00	.5040-00	.11953+02	.0000	.1043+02	.9519+02
14	2-1S	59	.4204-00	.4205-00	.4203-00	.5070-00	.5060-00	.11963+02	.0000	.1038+02	.9474+02
15	2-1S	63	.4202-00	.4205-00	.4204-00	.5050-00	.5070-00	.11973+02	.0000	.1040+02	.9493+02
16	2-1S	64	.4203-00	.4205-00	.4203-00	.5010-00	.5010-00	.11856+02	.0000	.1041+02	.9494+02
17	2-1S	69	.4202-00	.4203-00	.4202-00	.5030-00	.5030-00	.11860+02	.0000	.1037+02	.9466+02
18	2-1S	97	.4202-00	.4203-00	.4202-00	.5100-00	.5100-00	.12020+02	.0000	.1037+02	.9462+02
19	2-1S	100	.4201-00	.4204-00	.4204-00	.5100-00	.5110-00	.12058+02	.0000	.1039+02	.9479+02
20	2-1S	103	.4203-00	.4203-00	.4202-00	.5120-00	.5140-00	.12175+02	.0000	.1044+02	.9526+02
21	2-1S	105	.4204-00	.4205-00	.4204-00	.5030-00	.5040-00	.11911+02	.0000	.1040+02	.9488+02
22	2-1S	117	.4201-00	.4203-00	.4202-00	.5070-00	.5050-00	.11986+02	.0000	.1042+02	.9511+02
23	2-1S	123	.4203-00	.4203-00	.4202-00	.5040-00	.5050-00	.11905+02	.0000	.1038+02	.9472+02
24	2-1S	127	.4201-00	.4204-00	.4202-00	.5040-00	.5050-00	.11911+02	.0000	.1039+02	.9478+02
25	2-1S	128	.4201-00	.4203-00	.4203-00	.5080-00	.5060-00	.11961+02	.0000	.1036+02	.9452+02
26	2-1S	143	.4201-00	.4204-00	.4202-00	.4970-00	.4970-00	.11683+02	.0000	.1034+02	.9437+02
27	1-1S	213	.4202-00	.4203-00	.4202-00	.5100-00	.5070-00	.12055+02	.0000	.1043+02	.9517+02
28	2-1S	216	.4204-00	.4206-00	.4204-00	.5030-00	.5010-00	.11860+02	.0000	.1038+02	.9474+02
29	2-1S	220	.4203-00	.4204-00	.4203-00	.5090-00	.5080-00	.12031+02	.0000	.1041+02	.9494+02
30	2-1S	221	.4202-00	.4205-00	.4202-00	.5020-00	.5020-00	.11880+02	.0000	.1041+02	.9497+02
31	2-1S	227	.4202-00	.4204-00	.4202-00	.4960-00	.4980-00	.11814+02	.0000	.1046+02	.9541+02
32	2-1S	230	.4201-00	.4204-00	.4202-00	.5130-00	.5120-00	.12130+02	.0000	.1041+02	.9502+02
33	1-1S	232	.4202-00	.4202-00	.4202-00	.5060-00	.5070-00	.11998+02	.0000	.1042+02	.9511+02
34	2-1S	235	.4204-00	.4204-00	.4203-00	.5110-00	.5120-00	.12107+02	.0000	.1041+02	.9496+02
35	2-1S	237	.4203-00	.4205-00	.4203-00	.5150-00	.5150-00	.12181+02	.0000	.1040+02	.9489+02
36	2-1S	249	.4203-00	.4204-00	.4202-00	.5110-00	.5100-00	.12060+02	.0000	.1039+02	.9481+02
37	2-1S	253	.4203-00	.4204-00	.4203-00	.5150-00	.5140-00	.12162+02	.0000	.1040+02	.9485+02
38	2-1S	254	.4203-00	.4204-00	.4201-00	.5160-00	.5160-00	.12178+02	.0000	.1038+02	.9473+02
39	2-1S	262	.4202-00	.4205-00	.4203-00	.5120-00	.5120-00	.12098+02	.0000	.1039+02	.9481+02
40	2-1S	265	.4202-00	.4205-00	.4202-00	.5240-00	.5230-00	.12317+02	.0000	.1035+02	.9442+02
41	2-1S	268	.4203-00	.4205-00	.4203-00	.5080-00	.5070-00	.12040+02	.0000	.1043+02	.9518+02
42	2-1S	270	.4203-00	.4203-00	.4203-00	.5140-00	.5120-00	.12152+02	.0000	.1042+02	.9507+02
43	2-1S	276	.4203-00	.4204-00	.4202-00	.5050-00	.5050-00	.11929+02	.0000	.1039+02	.9480+02
44	1-1S	281	.4201-00	.4203-00	.4202-00	.4950-00	.4950-00	.11693+02	.0000	.1040+02	.9485+02
45	1-1S	291	.4204-00	.4204-00	.4203-00	.4920-00	.4920-00	.11698+02	.0000	.1045+02	.9539+02
46	1-1S	292	.4203-00	.4203-00	.4202-00	.4930-00	.4930-00	.11666+02	.0000	.1041+02	.9498+02

TOTAL WEIGHT OF GROUP = 550.509 GRAMS
AVERAGE WEIGHT OF GROUP = 11.9676 GRAMS
AVERAGE DENSITY OF GROUP = 94.917 PERCENT T.D.
TOTAL LENGTH OF PELLET GROUP= 23.2770INCHES
AVERAGE PELLET LENGTH OF GROUP = .5060 INCHES
STANDARD DEVIATION OF PELLET DENSITY = .242

	LOT NO.	SAMPLE NO.	DIAMETER (INCHES) D-1	D-2	D-3	LENGTH (INCHES) L-1	L-2	WEIGHT (GRAMS)	DIA. CENTER VOID (INCHES)	DENSITY (G/CC)	DENSITY (PERCENT T.D.)
1	2-5S	462	.4223-00	.4224-00	.4223-00	.5080-00	.5100-00	.12191+02	.0000	.1043+02	.9520+02
2	2-5S	463	.4222-00	.4223-00	.4223-00	.5100-00	.5110-00	.12243+02	.0000	.1045+02	.9535+02
3	2-5S	465	.4223-00	.4223-00	.4222-00	.5100-00	.5110-00	.12229+02	.0000	.1044+02	.9524+02
4	2-5S	466	.4223-00	.4223-00	.4222-00	.5110-00	.5110-00	.12241+02	.0000	.1044+02	.9524+02
5	2-5S	468	.4223-00	.4223-00	.4223-00	.5080-00	.5080-00	.12141+02	.0000	.1041+02	.9501+02
6	2-5S	469	.4223-00	.4224-00	.4224-00	.5080-00	.5090-00	.12171+02	.0000	.1043+02	.9512+02
7	2-5S	470	.4223-00	.4224-00	.4223-00	.5110-00	.5120-00	.12270+02	.0000	.1045+02	.9535+02
8	2-5S	471	.4224-00	.4223-00	.4223-00	.5070-00	.5060-00	.12161+02	.0000	.1046+02	.9543+02
9	2-5S	472	.4221-00	.4222-00	.4222-00	.5090-00	.5080-00	.12190+02	.0000	.1045+02	.9536+02
10	2-5S	473	.4223-00	.4223-00	.4223-00	.5170-00	.5180-00	.12407+02	.0000	.1045+02	.9531+02
11	2-5S	474	.4223-00	.4223-00	.4223-00	.5180-00	.5190-00	.12424+02	.0000	.1044+02	.9525+02
12	2-5S	475	.4223-00	.4223-00	.4221-00	.5160-00	.5170-00	.12318+02	.0000	.1039+02	.9484+02
13	2-5S	481	.4222-00	.4224-00	.4224-00	.5180-00	.5190-00	.12419+02	.0000	.1043+02	.9520+02
14	2-5S	483	.4222-00	.4223-00	.4223-00	.5170-00	.5170-00	.12381+02	.0000	.1044+02	.9521+02
15	2-5S	484	.4223-00	.4223-00	.4222-00	.5160-00	.5170-00	.12390+02	.0000	.1045+02	.9538+02
16	2-5S	486	.4222-00	.4223-00	.4222-00	.5160-00	.5170-00	.12375+02	.0000	.1044+02	.9528+02
17	2-5S	88	.4223-00	.4223-00	.4223-00	.5160-00	.5160-00	.12361+02	.0000	.1044+02	.9523+02
18	2-5S	90	.4222-00	.4223-00	.4223-00	.5150-00	.5160-00	.12338+02	.0000	.1043+02	.9516+02
19	2-5S	491	.4225-00	.4224-00	.4223-00	.5130-00	.5140-00	.12286+02	.0000	.1042+02	.9507+02
20	2-5S	492	.4223-00	.4223-00	.4223-00	.5150-00	.5160-00	.12337+02	.0000	.1043+02	.9514+02
21	2-5S	494	.4223-00	.4223-00	.4222-00	.5200-00	.5210-00	.12451+02	.0000	.1042+02	.9511+02
22	2-5S	555	.4222-00	.4223-00	.4222-00	.5110-00	.5130-00	.12260+02	.0000	.1044+02	.9522+02
23	2-5S	556	.4222-00	.4222-00	.4223-00	.5160-00	.5160-00	.12383+02	.0000	.1046+02	.9543+02
24	2-5S	558	.4222-00	.4222-00	.4223-00	.5110-00	.5110-00	.12268+02	.0000	.1046+02	.9547+02
25	2-5S	560	.4223-00	.4224-00	.4223-00	.5150-00	.5130-00	.12329+02	.0000	.1045+02	.9534+02
26	2-5S	561	.4223-00	.4223-00	.4222-00	.5130-00	.5140-00	.12311+02	.0000	.1045+02	.9532+02
27	2-5S	564	.4223-00	.4222-00	.4222-00	.5100-00	.5120-00	.12277+02	.0000	.1047+02	.9554+02
28	2-5S	565	.4223-00	.4224-00	.4224-00	.5130-00	.5140-00	.12311+02	.0000	.1044+02	.9528+02
29	2-5S	566	.4222-00	.4223-00	.4223-00	.5150-00	.5150-00	.12321+02	.0000	.1043+02	.9512+02
30	2-5S	571	.4223-00	.4224-00	.4223-00	.5140-00	.5170-00	.12383+02	.0000	.1046+02	.9548+02
31	2-5S	576	.4221-00	.4224-00	.4223-00	.5140-00	.5160-00	.12350+02	.0000	.1045+02	.9534+02
32	2-5S	585	.4224-00	.4224-00	.4223-00	.5160-00	.5170-00	.12391+02	.0000	.1045+02	.9534+02
33	2-5S	600	.4222-00	.4223-00	.4222-00	.5120-00	.5120-00	.12283+02	.0000	.1046+02	.9540+02
34	2-5S	621	.4223-00	.4224-00	.4223-00	.5070-00	.5090-00	.12130+02	.0000	.1040+02	.9491+02
35	2-5S	624	.4222-00	.4223-00	.4223-00	.5000-00	.5010-00	.12013+02	.0000	.1046+02	.9543+02
36	2-5S	625	.4221-00	.4223-00	.4222-00	.5000-00	.5010-00	.12050+02	.0000	.1049+02	.9575+02
37	2-5S	627	.4223-00	.4223-00	.4222-00	.5050-00	.5070-00	.12149+02	.0000	.1046+02	.9546+02
38	2-5S	628	.4223-00	.4223-00	.4223-00	.5020-00	.4990-00	.11982+02	.0000	.1043+02	.9517+02
39	2-5S	629	.4223-00	.4223-00	.4223-00	.5040-00	.5050-00	.12081+02	.0000	.1043+02	.9519+02
40	2-5S	630	.4220-00	.4223-00	.4223-00	.5020-00	.5020-00	.12022+02	.0000	.1044+02	.9525+02
41	2-5S	631	.4223-00	.4222-00	.4223-00	.5010-00	.5020-00	.12039+02	.0000	.1046+02	.9545+02
42	2-5S	632	.4222-00	.4223-00	.4223-00	.5010-00	.5020-00	.11953+02	.0000	.1039+02	.9476+02
43	2-5S	633	.4222-00	.4222-00	.4223-00	.4940-00	.4940-00	.11853+02	.0000	.1046+02	.9541+02
44	2-5S	634	.4223-00	.4224-00	.4224-00	.5070-00	.5070-00	.12183+02	.0000	.1047+02	.9549+02
45	2-5S	635	.4222-00	.4223-00	.4223-00	.5090-00	.5100-00	.12217+02	.0000	.1045+02	.9534+02

TOTAL WEIGHT OF GROUP = 550.863 GRAMS
AVERAGE WEIGHT OF GROUP = 12.2414 GRAMS
AVERAGE DENSITY OF GROUP = 95.274 PERCENT T.D.
TOTAL LENGTH OF PELLET GROUP= 22.9865INCHES
AVERAGE PELLET LENGTH OF GROUP = .5108 INCHES
STANDARD DEVIATION OF PELLET DENSITY = .184

TOTAL WEIGHT OF ALL GROUPS 4807.2433 GRAMS

IFA-432, IMMERSION DENSITIES

IFA-432, Rod 1, Solid Pellets

SAMPLE NUMBER		PELLET WEIGHT (GRAMS)	WT. OF SATURATED PELLET (GRAMS)	WT OF PELLET SUSPENDED IN WATER (GRAMS)	WT. OF SUSPENSION CAGE (GRAMS)	WATER TEMPERATURE (DEG.C)	WATER DENSITY (GM/CC)	PELLET DENSITY (GM/CC)	PELLET DENSITY (PERCENT T.D.)	SAMPLE NUMBER
2-1	41	.1190E+02	.1190E+02	.1157E+02	.8094E+00	.1770E+02	.9987E+00	.1050E+02	.9576E+02	41
2-1	66	.1183E+02	.1183E+02	.1151E+02	.8094E+00	.1770E+02	.9987E+00	.1048E+02	.9558E+02	66
2-1	107	.1188E+02	.1188E+02	.1156E+02	.8096E+00	.1770E+02	.9987E+00	.1047E+02	.9554E+02	107
2-1	112	.1185E+02	.1185E+02	.1154E+02	.8095E+00	.1770E+02	.9987E+00	.1051E+02	.9586E+02	112
2-1	120	.1201E+02	.1201E+02	.1167E+02	.8097E+00	.1770E+02	.9987E+00	.1044E+02	.9528E+02	120
2-1	144	.1179E+02	.1179E+02	.1148E+02	.8096E+00	.1770E+02	.9987E+00	.1048E+02	.9559E+02	144
2-1	224	.1200E+02	.1200E+02	.1167E+02	.8098E+00	.1770E+02	.9987E+00	.1050E+02	.9582E+02	224
2-1	234	.1208E+02	.1208E+02	.1174E+02	.8098E+00	.1770E+02	.9987E+00	.1048E+02	.9561E+02	234
2-1	260	.1217E+02	.1217E+02	.1182E+02	.8094E+00	.1770E+02	.9987E+00	.1048E+02	.9561E+02	260
2-1	272	.1213E+02	.1213E+02	.1178E+02	.8096E+00	.1770E+02	.9987E+00	.1048E+02	.9561E+02	272
2-1	277	.1168E+02	.1168E+02	.1138E+02	.8098E+00	.1770E+02	.9987E+00	.1044E+02	.9524E+02	277

TOTAL WEIGHT OF GROUP = 131.314 GRAMS
AVERAGE WEIGHT OF GROUP = 11.9377 GRAMS
AVERAGE DENSITY OF GROUP = 95.595 PERCENT T.D.
STANDARD DEVIATION OF PELLET DENSITY = .198

IFA-432, Rod 1, Drilled Pellets

SAMPLE NUMBER		PELLET WEIGHT (GRAMS)	WT. OF SATURATED PELLET (GRAMS)	WT OF PELLET SUSPENDED IN WATER (GRAMS)	WT. OF SUSPENSION CAGE (GRAMS)	WATER TEMPERATURE (DEG.C)	WATER DENSITY (GM/CC)	PELLET DENSITY (GM/CC)	PELLET DENSITY (PERCENT T.D.)	SAMPLE NUMBER
2-1D	4	.1137E+02	.1137E+02	.1109E+02	.8097E+00	.1760E+02	.9987E+00	.1046E+02	.9540E+02	4
111	6	.1180E+02	.1180E+02	.1149E+02	.8083E+00	.1740E+02	.9987E+00	.1048E+02	.9563E+02	6
111	18	.1165E+02	.1165E+02	.1135E+02	.8083E+00	.1740E+02	.9987E+00	.1045E+02	.9536E+02	18
2-1D	71	.1150E+02	.1150E+02	.1121E+02	.8098E+00	.1760E+02	.9987E+00	.1046E+02	.9545E+02	71
2-1D	73	.1147E+02	.1147E+02	.1119E+02	.8098E+00	.1760E+02	.9987E+00	.1046E+02	.9547E+02	73
2-1D	85	.1156E+02	.1156E+02	.1127E+02	.8096E+00	.1760E+02	.9987E+00	.1049E+02	.9568E+02	85
111	89	.1147E+02	.1147E+02	.1118E+02	.8084E+00	.1740E+02	.9987E+00	.1044E+02	.9526E+02	89
111	164	.1155E+02	.1155E+02	.1126E+02	.8082E+00	.1740E+02	.9987E+00	.1046E+02	.9544E+02	164
2-1D	166	.1165E+02	.1165E+02	.1135E+02	.8099E+00	.1760E+02	.9987E+00	.1046E+02	.9548E+02	166
2-1D	172	.1172E+02	.1172E+02	.1142E+02	.8097E+00	.1760E+02	.9987E+00	.1048E+02	.9560E+02	172
111	173	.1167E+02	.1167E+02	.1137E+02	.8090E+00	.1750E+02	.9987E+00	.1047E+02	.9554E+02	173

TOTAL WEIGHT OF GROUP = 127.403 GRAMS
AVERAGE WEIGHT OF GROUP = 11.5821 GRAMS
AVERAGE DENSITY OF GROUP = 95.484 PERCENT T.D.
STANDARD DEVIATION OF PELLET DENSITY = .125

IFA-432, Rod 2, Solid Pellets

	SAMPLE NUMBER	PELLET WEIGHT (GRAMS)	WT. OF SATURATED PELLET (GRAMS)	WT OF PELLET SUSPENDED IN WATER (GRAMS)	WT. OF SUSPENSION CAGE (GRAMS)	WATER TEMPEATURE (DEG.C)	WATER DENSITY (GM/CC)	PELLET DENSITY (GM/CC)	PELLET DENSITY (PERCENT T.D.)	SAMPLE NUMBER
2-2	142	.1147E+02	.1147E+02	.1119E+02	.8096E+00	.1870E+02	.9984E+00	.1049E+02	.9570E+02	142
2-2	338	.1142E+02	.1142E+02	.1115E+02	.8100E+00	.1860E+02	.9985E+00	.1048E+02	.9565E+02	338
2-2	369	.1123E+02	.1123E+02	.1097E+02	.8099E+00	.1850E+02	.9985E+00	.1044E+02	.9528E+02	369
2-2	385	.1132E+02	.1132E+02	.1105E+02	.8100E+00	.1840E+02	.9985E+00	.1046E+02	.9543E+02	385
2-2	386	.1139E+02	.1139E+02	.1111E+02	.8100E+00	.1840E+02	.9985E+00	.1047E+02	.9553E+02	386
2-2	388	.1141E+02	.1141E+02	.1113E+02	.8100E+00	.1840E+02	.9985E+00	.1046E+02	.9541E+02	388
2-2	389	.1142E+02	.1142E+02	.1114E+02	.8100E+00	.1830E+02	.9985E+00	.1046E+02	.9541E+02	389
2-2	390	.1145E+02	.1145E+02	.1117E+02	.8100E+00	.1830E+02	.9985E+00	.1046E+02	.9547E+02	390
2-2	407	.1149E+02	.1149E+02	.1120E+02	.8100E+00	.1830E+02	.9985E+00	.1046E+02	.9547E+02	407
2-2	441	.1130E+02	.1130E+02	.1103E+02	.8099E+00	.1820E+02	.9985E+00	.1044E+02	.9529E+02	441
2-2	459	.1152E+02	.1152E+02	.1122E+02	.8100E+00	.1820E+02	.9985E+00	.1036E+02	.9454E+02	459

TOTAL WEIGHT OF GROUP = 125.425 GRAMS
AVERAGE WEIGHT OF GROUP = 11.4021 GRAMS
AVERAGE DENSITY OF GROUP = 95.380 PERCENT T.D.
STANDARD DEVIATION OF PELLET DENSITY = .306

IFA-432, Rod 2, Drilled Pellets

	SAMPLE NUMBER	PELLET WEIGHT (GRAMS)	WT. OF SATURATED PELLET (GRAMS)	WT OF PELLET SUSPENDED IN WATER (GRAMS)	WT. OF SUSPENSION CAGE (GRAMS)	WATER TEMPEATURE (DEG.C)	WATER DENSITY (GM/CC)	PELLET DENSITY (GM/CC)	PELLET DENSITY (PERCENT T.D.)	SAMPLE NUMBER
222	9	.1147E+02	.1147E+02	.1119E+02	.8090E+00	.1750E+02	.9987E+00	.1045E+02	.9537E+02	9
222	76	.1099E+02	.1099E+02	.1075E+02	.8087E+00	.1750E+02	.9987E+00	.1045E+02	.9538E+02	76
222	160	.1110E+02	.1110E+02	.1085E+02	.8087E+00	.1750E+02	.9987E+00	.1043E+02	.9519E+02	160
222	162	.1132E+02	.1132E+02	.1105E+02	.8087E+00	.1750E+02	.9987E+00	.1046E+02	.9546E+02	162
2-20	301	.1107E+02	.1107E+02	.1082E+02	.8102E+00	.1750E+02	.9987E+00	.1043E+02	.9521E+02	301
2-20	304	.1121E+02	.1121E+02	.1094E+02	.8103E+00	.1750E+02	.9987E+00	.1043E+02	.9516E+02	304
2-20	307	.1111E+02	.1111E+02	.1086E+02	.8103E+00	.1750E+02	.9987E+00	.1044E+02	.9522E+02	307
2-20	318	.1118E+02	.1118E+02	.1092E+02	.8102E+00	.1750E+02	.9987E+00	.1044E+02	.9521E+02	318
2-20	327	.1117E+02	.1117E+02	.1091E+02	.8102E+00	.1750E+02	.9987E+00	.1044E+02	.9529E+02	327
2-20	333	.1114E+02	.1114E+02	.1089E+02	.8102E+00	.1750E+02	.9987E+00	.1042E+02	.9511E+02	333
2-20	334	.1099E+02	.1099E+02	.1075E+02	.8103E+00	.1750E+02	.9987E+00	.1043E+02	.9516E+02	334

TOTAL WEIGHT OF GROUP = 122.748 GRAMS
AVERAGE WEIGHT OF GROUP = 11.1589 GRAMS
AVERAGE DENSITY OF GROUP = 95.251 PERCENT T.D.
STANDARD DEVIATION OF PELLET DENSITY = .110

IFA-432, Rod 3, Solid Pellets

	SAMPLE NUMBER	PELLET WEIGHT (GRAMS)	WT. OF SATURATED PELLET (GRAMS)	WT OF PELLET SUSPENDED IN WATER (GRAMS)	WT. OF SUSPENSION CAGE (GRAMS)	WATER TEMPERATURE (DEG.C)	WATER DENSITY (GM/CC)	PELLET DENSITY (GM/CC)	PELLET DENSITY (PERCENT T.D.)	SAMPLE NUMBER
2-3	498	.1242E+02	.1242E+02	.1206E+02	.8098E+00	.1880E+02	.9984E+00	.1056E+02	.9633E+02	498
2-3	562	.1249E+02	.1249E+02	.1212E+02	.8099E+00	.1880E+02	.9984E+00	.1054E+02	.9614E+02	562
2-3	574	.1256E+02	.1256E+02	.1218E+02	.8100E+00	.1880E+02	.9984E+00	.1053E+02	.9604E+02	574
2-3	577	.1258E+02	.1258E+02	.1220E+02	.8098E+00	.1880E+02	.9984E+00	.1052E+02	.9601E+02	577
2-3	587	.1250E+02	.1250E+02	.1213E+02	.8098E+00	.1880E+02	.9984E+00	.1055E+02	.9625E+02	587
2-3	588	.1259E+02	.1259E+02	.1221E+02	.8100E+00	.1870E+02	.9984E+00	.1053E+02	.9607E+02	588
2-3	590	.1252E+02	.1252E+02	.1215E+02	.8100E+00	.1870E+02	.9984E+00	.1054E+02	.9615E+02	590
2-3	594	.1255E+02	.1255E+02	.1217E+02	.8099E+00	.1870E+02	.9984E+00	.1053E+02	.9607E+02	594
2-3	605	.1241E+02	.1241E+02	.1204E+02	.8099E+00	.1870E+02	.9984E+00	.1054E+02	.9618E+02	605
2-3	608	.1243E+02	.1243E+02	.1207E+02	.8098E+00	.1860E+02	.9985E+00	.1059E+02	.9658E+02	608
2-3	610	.1226E+02	.1227E+02	.1191E+02	.8098E+00	.1860E+02	.9985E+00	.1055E+02	.9626E+02	610
2-3	611	.1210E+02	.1210E+02	.1176E+02	.8098E+00	.1860E+02	.9985E+00	.1052E+02	.9596E+02	611
2-3	612	.1239E+02	.1239E+02	.1202E+02	.8098E+00	.1850E+02	.9985E+00	.1052E+02	.9601E+02	612
2-3	615	.1272E+02	.1272E+02	.1232E+02	.8099E+00	.1850E+02	.9985E+00	.1050E+02	.9584E+02	615

TOTAL WEIGHT OF GROUP = 174.523 GRAMS
AVERAGE WEIGHT OF GROUP = 12.4659 GRAMS
AVERAGE DENSITY OF GROUP = 96.135 PERCENT T.D.
STANDARD DEVIATION OF PELLET DENSITY = .123

IFA-432, Rod 3, Drilled Pellets

	SAMPLE NUMBER	PELLET WEIGHT (GRAMS)	WT. OF SATURATED PELLET (GRAMS)	WT OF PELLET SUSPENDED IN WATER (GRAMS)	WT. OF SUSPENSION CAGE (GRAMS)	WATER TEMPERATURE (DEG.C)	WATER DENSITY (GM/CC)	PELLET DENSITY (GM/CC)	PELLET DENSITY (PERCENT T.D.)	SAMPLE NUMBER
2-3D	520	.1210E+02	.1210E+02	.1177E+02	.8100E+00	.1750E+02	.9987E+00	.1052E+02	.9595E+02	520
2-3D	523	.1213E+02	.1213E+02	.1179E+02	.8103E+00	.1750E+02	.9987E+00	.1053E+02	.9604E+02	523
2-3D	530	.1201E+02	.1201E+02	.1168E+02	.8102E+00	.1750E+02	.9987E+00	.1051E+02	.9586E+02	530
2-3D	533	.1204E+02	.1204E+02	.1170E+02	.8103E+00	.1750E+02	.9987E+00	.1052E+02	.9599E+02	533
2-3D	535	.1207E+02	.1207E+02	.1173E+02	.8103E+00	.1750E+02	.9987E+00	.1051E+02	.9588E+02	535
2-3D	547	.1220E+02	.1221E+02	.1186E+02	.8103E+00	.1750E+02	.9987E+00	.1051E+02	.9587E+02	547
2-3D	549	.1206E+02	.1206E+02	.1173E+02	.8103E+00	.1750E+02	.9987E+00	.1051E+02	.9593E+02	549

TOTAL WEIGHT OF GROUP = 84.609 GRAMS
AVERAGE WEIGHT OF GROUP = 12.0870 GRAMS
AVERAGE DENSITY OF GROUP = 95.932 PERCENT T.D.
STANDARD DEVIATION OF PELLET DENSITY = .056

IFA-432, Rod 4, Solid Pellets

SAMPLE NUMBER		PELLET WEIGHT (GRAMS)	WT. OF SATURATED PELLET (GRAMS)	WT OF PELLET SUSPENDED IN WATER (GRAMS)	WT. OF SUSPENSION CAGE (GRAMS)	WATER TEMPEATURE (DEG.C)	WATER DENSITY (GM/CC)	PELLET DENSITY (GM/CC)	PELLET DENSITY (PERCENT T.D.)	SAMPLE NUMBER
2-4	44	.1196E+02	.1196E+02	.1163E+02	.8096E+00	.1770E+02	.9987E+00	.1049E+02	.9569E+02	44
2-4	94	.1194E+02	.1194E+02	.1161E+02	.8096E+00	.1770E+02	.9987E+00	.1047E+02	.9553E+02	94
2-4	118	.1187E+02	.1187E+02	.1155E+02	.8095E+00	.1770E+02	.9987E+00	.1046E+02	.9542E+02	118
2-4	133	.1214E+02	.1214E+02	.1179E+02	.8098E+00	.1770E+02	.9987E+00	.1046E+02	.9547E+02	133
2-4	209	.1192E+02	.1192E+02	.1159E+02	.8096E+00	.1770E+02	.9987E+00	.1048E+02	.9559E+02	209
2-4	215	.1200E+02	.1200E+02	.1166E+02	.8099E+00	.1770E+02	.9987E+00	.1049E+02	.9567E+02	215
2-4	236	.1214E+02	.1214E+02	.1180E+02	.8096E+00	.1770E+02	.9987E+00	.1049E+02	.9569E+02	236
2-4	239	.1201E+02	.1201E+02	.1168E+02	.8098E+00	.1760E+02	.9987E+00	.1049E+02	.9571E+02	239
2-4	240	.1206E+02	.1206E+02	.1172E+02	.8097E+00	.1760E+02	.9987E+00	.1049E+02	.9568E+02	240
2-4	263	.1211E+02	.1211E+02	.1176E+02	.8099E+00	.1760E+02	.9987E+00	.1047E+02	.9553E+02	263
2-4	264	.1197E+02	.1197E+02	.1164E+02	.8098E+00	.1760E+02	.9987E+00	.1049E+02	.9568E+02	264

TOTAL WEIGHT OF GROUP = 132.114 GRAMS
AVERAGE WEIGHT OF GROUP = 12.0103 GRAMS
AVERAGE DENSITY OF GROUP = 95.604 PERCENT T.D.
STANDARD DEVIATION OF PELLET DENSITY = .102

IFA-432, Rod 4, Drilled Pellets

SAMPLE NUMBER		PELLET WEIGHT (GRAMS)	WT. OF SATURATED PELLET (GRAMS)	WT OF PELLET SUSPENDED IN WATER (GRAMS)	WT. OF SUSPENSION CAGE (GRAMS)	WATER TEMPEATURE (DEG.C)	WATER DENSITY (GM/CC)	PELLET DENSITY (GM/CC)	PELLET DENSITY (PERCENT T.D.)	SAMPLE NUMBER
2-4D	3	.1184E+02	.1184E+02	.1152E+02	.8100E+00	.1770E+02	.9987E+00	.1048E+02	.9560E+02	3
2-4D	75	.1159E+02	.1159E+02	.1130E+02	.8100E+00	.1770E+02	.9987E+00	.1046E+02	.9546E+02	75
2-4D	80	.1165E+02	.1165E+02	.1135E+02	.8100E+00	.1770E+02	.9987E+00	.1046E+02	.9545E+02	80
2-4D	170	.1161E+02	.1161E+02	.1131E+02	.8100E+00	.1770E+02	.9987E+00	.1047E+02	.9556E+02	170
2-4D	181	.1176E+02	.1176E+02	.1145E+02	.8100E+00	.1760E+02	.9987E+00	.1049E+02	.9571E+02	181
2-4D	182	.1168E+02	.1168E+02	.1138E+02	.8102E+00	.1760E+02	.9987E+00	.1049E+02	.9572E+02	182
2-4D	775	.1126E+02	.1126E+02	.1099E+02	.8101E+00	.1760E+02	.9987E+00	.1045E+02	.9536E+02	775
2-4F	901	.1094E+02	.1094E+02	.1071E+02	.8090E+00	.1770E+02	.9987E+00	.1049E+02	.9570E+02	901
2-4F	901	.1094E+02	.1094E+02	.1071E+02	.8089E+00	.1760E+02	.9987E+00	.1049E+02	.9570E+02	901
2-4F	902	.1120E+02	.1121E+02	.1095E+02	.8094E+00	.1770E+02	.9987E+00	.1046E+02	.9547E+02	902
2-4F	902	.1120E+02	.1121E+02	.1095E+02	.8091E+00	.1760E+02	.9987E+00	.1047E+02	.9549E+02	902
2-4F	906	.1145E+02	.1146E+02	.1117E+02	.8093E+00	.1770E+02	.9987E+00	.1046E+02	.9541E+02	906
2-4F	906	.1145E+02	.1145E+02	.1117E+02	.8090E+00	.1760E+02	.9987E+00	.1047E+02	.9551E+02	906
2-4F	912	.1107E+02	.1107E+02	.1082E+02	.8090E+00	.1770E+02	.9987E+00	.1043E+02	.9518E+02	912
2-4F	912	.1107E+02	.1107E+02	.1082E+02	.8091E+00	.1760E+02	.9987E+00	.1043E+02	.9519E+02	912

TOTAL WEIGHT OF GROUP = 170.722 GRAMS
AVERAGE WEIGHT OF GROUP = 11.3814 GRAMS
AVERAGE DENSITY OF GROUP = 95.500 PERCENT T.D.
STANDARD DEVIATION OF PELLET DENSITY = .172

, Rod 5, Solid Pellets

	SAMPLE NUMBER	PELLET WEIGHT (GRAMS)	WT. OF SATURATED PELLET (GRAMS)	WT OF PELLET SUSPENDED IN WATER (GRAMS)	WT. OF SUSPENSION CAGE (GRAMS)	WATER TEMPEATURE (DEG.C)	WATER DENSITY (GM/CC)	PELLET DENSITY (GM/CC)	PELLET DENSITY (PERCENT T.D.)	SAMPLE NUMBER
2-6	779	.1163E+02	.1163E+02	.1129E+02	.8097E+00	.1970E+02	.9982E+00	.1009E+02	.9207E+02	779
2-6	780	.1153E+02	.1153E+02	.1120E+02	.8096E+00	.1970E+02	.9982E+00	.1009E+02	.9210E+02	780
2-6	791	.1157E+02	.1157E+02	.1123E+02	.8099E+00	.1710E+02	.9988E+00	.1007E+02	.9190E+02	791
2-6	792	.1141E+02	.1141E+02	.1109E+02	.8097E+00	.1970E+02	.9982E+00	.1001E+02	.9129E+02	792
2-6	794	.1130E+02	.1130E+02	.1098E+02	.8099E+00	.1710E+02	.9988E+00	.1001E+02	.9137E+02	794
2-6	799	.1159E+02	.1159E+02	.1126E+02	.8098E+00	.1970E+02	.9982E+00	.1012E+02	.9233E+02	799
2-6	851	.1136E+02	.1136E+02	.1104E+02	.8097E+00	.1970E+02	.9982E+00	.1007E+02	.9184E+02	851
2-6	859	.1132E+02	.1132E+02	.1101E+02	.8097E+00	.1970E+02	.9982E+00	.1016E+02	.9269E+02	859
2-6	864	.1137E+02.	.1137E+02	.1104E+02	.8096E+00	.1970E+02	.9982E+00	.1002E+02	.9144E+02	864
2-6	865	.1127E+02	.1127E+02	.1096E+02	.8097E+00	.1970E+02	.9982E+00	.1002E+02	.9141E+02	865
2-6	867	.1142E+02	.1142E+02	.1110E+02	.8097E+00	.1970E+02	.9982E+00	.1006E+02	.9179E+02	867
2-6	873	.1127E+02	.1127E+02	.1096E+02	.8096E+00	.1970E+02	.9982E+00	.1005E+02	.9165E+02	873
2-6	875	.1142E+02	.1142E+02	.1109E+02	.8100E+00	.1710E+02	.9988E+00	.1002E+02	.9143E+02	875
2-6	876	.1136E+02	.1136E+02	.1104E+02	.8097E+00	.1970E+02	.9982E+00	.1004E+02	.9164E+02	876
2-6	878	.1141E+02	.1141E+02	.1109E+02	.8097E+00	.1970E+02	.9982E+00	.1003E+02	.9147E+02	878
2-6	881	.1168E+02	.1168E+02	.1134E+02	.8096E+00	.1970E+02	.9982E+00	.1010E+02	.9212E+02	881
2-6	882	.1148E+02	.1148E+02	.1115E+02	.8097E+00	.1970E+02	.9982E+00	.1006E+02	.9178E+02	882
2-6	883	.1122E+02	.1122E+02	.1091E+02	.8097E+00	.1970E+02	.9982E+00	.1004E+02	.9158E+02	883
2-6	885	.1116E+02	.1116E+02	.1086E+02	.8100E+00	.1970E+02	.9982E+00	.1004E+02	.9157E+02	885
2-6	888	.1116E+02	.1116E+02	.1086E+02	.8097E+00	.1710E+02	.9988E+00	.9997E+01	.9122E+02	888
2-6	892	.1147E+02	.1147E+02	.1113E+02	.8097E+00	.1980E+02	.9982E+00	.9972E+01	.9099E+02	892
2-6	893	.1137E+02	.1137E+02	.1104E+02	.8098E+00	.1980E+02	.9982E+00	.9974E+01	.9101E+02	893
2-6	894	.1136E+02	.1136E+02	.1103E+02	.8096E+00	.1980E+02	.9982E+00	.9974E+01	.9100E+02	894
2-6	895	.1154E+02	.1154E+02	.1120E+02	.8098E+00	.1710E+02	.9988E+00	.9987E+01	.9112E+02	895
2-6	896	.1159E+02	.1159E+02	.1124E+02	.8099E+00	.1710E+02	.9988E+00	.9975E+01	.9101E+02	896
2-6	900	.1125E+02	.1125E+02	.1093E+02	.8096E+00	.1980E+02	.9982E+00	.9993E+01	.9117E+02	900

TOTAL WEIGHT OF GROUP = 296.486 GRAMS
AVERAGE WEIGHT OF GROUP = 11.4033 GRAMS
AVERAGE DENSITY OF GROUP = 91.576 PERCENT T.D.
STANDARD DEVIATION OF PELLET DENSITY = .443

IFA-432, Rod 5, Drilled Pellets

	SAMPLE NUMBER	PELLET WEIGHT (GRAMS)	WT. OF SATURATED PELLET (GRAMS)	WT OF PELLET SUSPENDED IN WATER (GRAMS)	WT. OF SUSPENSION CAGE (GRAMS)	WATER TEMPEATURE (DEG.C)	WATER DENSITY (GM/CC)	PELLET DENSITY (GM/CC)	PELLET DENSITY (PERCENT T.D.)	SAMPLE NUMBER
555	812	.1109E+02	.1109E+02	.1082E+02	.8099E+00	.1750E+02	.9987E+00	.1019E+02	.9295E+02	812
2-6D	815	.1109E+02	.1110E+02	.1081E+02	.8098E+00	.1710E+02	.9988E+00	.1009E+02	.9207E+02	815
2-6D	816	.1116E+02	.1117E+02	.1087E+02	.8098E+00	.1710E+02	.9988E+00	.1009E+02	.9208E+02	816
2-6D	817	.1102E+02	.1102E+02	.1075E+02	.8099E+00	.1710E+02	.9988E+00	.1013E+02	.9239E+02	817
2-6D	819	.1109E+02	.1110E+02	.1082E+02	.8099E+00	.1710E+02	.9988E+00	.1018E+02	.9293E+02	819
2-6D	822	.1125E+02	.1125E+02	.1096E+02	.8099E+00	.1710E+02	.9988E+00	.1016E+02	.9267E+02	822
2-6D	824	.1137E+02	.1137E+02	.1105E+02	.8098E+00	.1710E+02	.9988E+00	.1008E+02	.9198E+02	824
2-6D	825	.1122E+02	.1123E+02	.1093E+02	.8098E+00	.1700E+02	.9988E+00	.1009E+02	.9204E+02	825
2-6D	829	.1147E+02	.1147E+02	.1115E+02	.8099E+00	.1700E+02	.9988E+00	.1009E+02	.9207E+02	829
2-6D	830	.1145E+02	.1145E+02	.1113E+02	.8098E+00	.1700E+02	.9988E+00	.1007E+02	.9192E+02	830
555	831	.1115E+02	.1115E+02	.1086E+02	.8098E+00	.1750E+02	.9987E+00	.1008E+02	.9199E+02	831
2-6D	832	.1130E+02	.1130E+02	.1099E+02	.8100E+00	.1700E+02	.9988E+00	.1008E+02	.9200E+02	832
2-6D	834	.1138E+02	.1138E+02	.1107E+02	.8100E+00	.1700E+02	.9988E+00	.1010E+02	.9217E+02	834
2-6D	835	.1120E+02	.1120E+02	.1090E+02	.8098E+00	.1710E+02	.9988E+00	.1013E+02	.9239E+02	835
555	837	.1120E+02	.1120E+02	.1090E+02	.8096E+00	.1750E+02	.9987E+00	.1008E+02	.9199E+02	837
2-6D	839	.1136E+02	.1136E+02	.1105E+02	.8098E+00	.1710E+02	.9988E+00	.1014E+02	.9254E+02	839
2-6D	840	.1139E+02	.1139E+02	.1107E+02	.8099E+00	.1710E+02	.9988E+00	.1007E+02	.9187E+02	840
2-6D	841	.1132E+02	.1133E+02	.1101E+02	.8099E+00	.1710E+02	.9988E+00	.1008E+02	.9195E+02	841
2-6D	842	.1125E+02	.1126E+02	.1095E+02	.8099E+00	.1710E+02	.9988E+00	.1010E+02	.9219E+02	842
2-6D	843	.1123E+02	.1123E+02	.1093E+02	.8098E+00	.1710E+02	.9988E+00	.1010E+02	.9213E+02	843

TOTAL WEIGHT OF GROUP = 225.010 GRAMS
AVERAGE WEIGHT OF GROUP = 11.2505 GRAMS
AVERAGE DENSITY OF GROUP = 92.215 PERCENT T.D.
STANDARD DEVIATION OF PELLET DENSITY = .325

IFA-432, Rod 6, Solid Pellets

	SAMPLE NUMBER	PELLET WEIGHT (GRAMS)	WT. OF SATURATED PELLET (GRAMS)	WT OF PELLET SUSPENDED IN WATER (GRAMS)	WT. OF SUSPENSION CAGE (GRAMS)	WATER TEMPEATURE (DEG.C)	WATER DENSITY (GM/CC)	PELLET DENSITY (GM/CC)	PELLET DENSITY (PERCENT T.D.)	SAMPLE NUMBER
2-7	673	.1158E+02	.1159E+02	.1125E+02	.8094E+00	.1770E+02	.9987E+00	.1011E+02	.9223E+02	673
2-7	674	.1159E+02	.1159E+02	.1125E+02	.8098E+00	.1770E+02	.9987E+00	.1010E+02	.9212E+02	674
2-7	676	.1152E+02	.1152E+02	.1119E+02	.8084E+00	.1980E+02	.9982E+00	.1010E+02	.9212E+02	676
2-7	677	.1151E+02	.1151E+02	.1118E+02	.8084E+00	.1980E+02	.9982E+00	.1009E+02	.9206E+02	677
2-7	678	.1162E+02	.1162E+02	.1128E+02	.8099E+00	.1770E+02	.9987E+00	.1010E+02	.9216E+02	678
2-7	679	.1166E+02	.1166E+02	.1132E+02	.8099E+00	.1780E+02	.9986E+00	.1010E+02	.9220E+02	679
2-7	680	.1150E+02	.1150E+02	.1117E+02	.8099E+00	.1780E+02	.9986E+00	.1011E+02	.9220E+02	680
2-7	682	.1169E+02	.1169E+02	.1134E+02	.8082E+00	.1980E+02	.9982E+00	.1010E+02	.9216E+02	682
2-7	683	.1158E+02	.1158E+02	.1124E+02	.8100E+00	.1780E+02	.9986E+00	.1010E+02	.9219E+02	683
2-7	685	.1158E+02	.1158E+02	.1125E+02	.8077E+00	.1980E+02	.9982E+00	.1014E+02	.9253E+02	685
2-7.	686	.1152E+02	.1153E+02	.1120E+02	.8101E+00	.1790E+02	.9986E+00	.1015E+02	.9265E+02	686
2-7	692	.1149E+02	.1149E+02	.1116E+02	.8080E+00	.1980E+02	.9982E+00	.1011E+02	.9227E+02	692
2-7	695	.1144E+02	.1144E+02	.1112E+02	.8099E+00	.1790E+02	.9986E+00	.1014E+02	.9249E+02	695
2-7	696	.1136E+02	.1136E+02	.1105E+02	.8100E+00	.1790E+02	.9986E+00	.1014E+02	.9256E+02	696
2-7	698	.1163E+02	.1163E+02	.1129E+02	.8061E+00	.1980E+02	.9982E+00	.1010E+02	.9213E+02	698
2-7	700	.1168E+02	.1168E+02	.1134E+02	.8092E+00	.1980E+02	.9982E+00	.1015E+02	.9258E+02	700
2-7	702	.1169E+02	.1169E+02	.1135E+02	.8100E+00	.1790E+02	.9986E+00	.1016E+02	.9271E+02	702
2-7	703	.1168E+02	.1168E+02	.1134E+02	.8100E+00	.1800E+02	.9986E+00	.1015E+02	.9260E+02	703
2-7	705	.1168E+02	.1168E+02	.1134E+02	.8100E+00	.1800E+02	.9986E+00	.1013E+02	.9245E+02	705
2-7	707	.1170E+02	.1171E+02	.1136E+02	.8101E+00	.1800E+02	.9986E+00	.1012E+02	.9234E+02	707
2-7	708	.1166E+02	.1166E+02	.1132E+02	.8091E+00	.1990E+02	.9982E+00	.1012E+02	.9237E+02	708
2-7	714	.1154E+02	.1154E+02	.1122E+02	.8099E+00	.1800E+02	.9986E+00	.1016E+02	.9267E+02	714
2-7	726	.1157E+02	.1158E+02	.1125E+02	.8101E+00	.1810E+02	.9986E+00	.1015E+02	.9256E+02	726
2-7	728	.1157E+02	.1157E+02	.1125E+02	.8102E+00	.1810E+02	.9986E+00	.1016E+02	.9271E+02	728
2-7	736	.1170E+02	.1170E+02	.1136E+02	.8100E+00	.1810E+02	.9986E+00	.1009E+02	.9209E+02	736
2-7	738	.1174E+02	.1174E+02	.1140E+02	.8101E+00	.1810E+02	.9986E+00	.1016E+02	.9270E+02	738

TOTAL WEIGHT OF GROUP = 301.452 GRAMS
AVERAGE WEIGHT OF GROUP = 11.5943 GRAMS
AVERAGE DENSITY OF GROUP = 92.380 PERCENT T.D.
STANDARD DEVIATION OF PELLET DENSITY = .227

IFA-432, Rod 6, Drilled Pellets

	SAMPLE NUMBER	PELLET WEIGHT (GRAMS)	WT. OF SATURATED PELLET (GRAMS)	WT OF PELLET SUSPENDED IN WATER (GRAMS)	WT. OF SUSPENSION CAGE (GRAMS)	WATER TEMPEATURE (DEG.C)	WATER DENSITY (GM/CC)	PELLET DENSITY (GM/CC)	PELLET DENSITY (PERCENT T.D.)	SAMPLE NUMBER
2-7D	637	.1156E+02	.1156E+02	.1123E+02	.8098E+00	.1940E+02	.9983E+00	.1008E+02	.9200E+02	637
2-7D	638	.1102E+02	.1102E+02	.1074E+02	.8100E+00	.1850E+02	.9985E+00	.1010E+02	.9212E+02	638
2-7D	643	.1111E+02	.1111E+02	.1083E+02	.8100E+00	.1850E+02	.9985E+00	.1009E+02	.9210E+02	643
2-7D	644	.1111E+02	.1111E+02	.1082E+02	.8101E+00	.1850E+02	.9985E+00	.1011E+02	.9227E+02	644
2-7D	648	.1103E+02	.1103E+02	.1075E+02	.8102E+00	.1840E+02	.9985E+00	.1009E+02	.9203E+02	648
2-7D	650	.1109E+02	.1110E+02	.1081E+02	.8101E+00	.1840E+02	.9985E+00	.1010E+02	.9217E+02	650
2-7D	651	.1118E+02	.1118E+02	.1089E+02	.8102E+00	.1840E+02	.9985E+00	.1008E+02	.9200E+02	651
2-7D	657	.1109E+02	.1110E+02	.1081E+02	.8100E+00	.1840E+02	.9985E+00	.1011E+02	.9227E+02	657
2-7D	659	.1102E+02	.1103E+02	.1075E+02	.8101E+00	.1840E+02	.9985E+00	.1011E+02	.9220E+02	659
2-7D	662	.1101E+02	.1102E+02	.1074E+02	.8101E+00	.1840E+02	.9985E+00	.1010E+02	.9213E+02	662
2-7D	663	.1094E+02	.1095E+02	.1068E+02	.8102E+00	.1840E+02	.9985E+00	.1011E+02	.9224E+02	663
2-7D	664	.1108E+02	.1108E+02	.1080E+02	.8101E+00	.1840E+02	.9985E+00	.1011E+02	.9224E+02	664
2-7D	665	.1096E+02	.1096E+02	.1069E+02	.8100E+00	.1840E+02	.9985E+00	.1012E+02	.9235E+02	665
2-7D	666	.1118E+02	.1118E+02	.1088E+02	.8101E+00	.1840E+02	.9985E+00	.1007E+02	.9189E+02	666
2-7D	667	.1081E+02	.1081E+02	.1055E+02	.8100E+00	.1850E+02	.9985E+00	.1009E+02	.9202E+02	667
2-7D	668	.1121E+02	.1122E+02	.1091E+02	.8100E+00	.1850E+02	.9985E+00	.1007E+02	.9186E+02	668
666	670	.1132E+02	.1132E+02	.1101E+02	.8099E+00	.1750E+02	.9987E+00	.1008E+02	.9196E+02	670
2-7D	671	.1134E+02	.1135E+02	.1103E+02	.8101E+00	.1850E+02	.9985E+00	.1007E+02	.9184E+02	671
2-7D	672	.1128E+02	.1128E+02	.1097E+02	.8100E+00	.1850E+02	.9985E+00	.1007E+02	.9190E+02	672
666	814	.1125E+02	.1125E+02	.1095E+02	.8093E+00	.1750E+02	.9987E+00	.1011E+02	.9228E+02	814

TOTAL WEIGHT OF GROUP = 222.600 GRAMS
AVERAGE WEIGHT OF GROUP = 11.1300 GRAMS
AVERAGE DENSITY OF GROUP = 92.094 PERCENT T.D.
STANDARD DEVIATION OF PELLET DENSITY = .156

IFA-432, Rod 6, Solid Pellets (Second Measurement)

	SAMPLE NUMBER	PELLET WEIGHT (GRAMS)	WT. OF SATURATED PELLET (GRAMS)	WT OF PELLET SUSPENDED IN WATER (GRAMS)	WT. OF SUSPENSION CAGE (GRAMS)	WATER TEMPERATURE (DEG.C)	WATER DENSITY (GM/CC)	PELLET DENSITY (GM/CC)	PELLET DENSITY (PERCENT T.D.)	SAMPLE NUMBER
2-7	673	.1158E+02	.1159E+02	.1125E+02	.8089E+00	.2070E+02	.9980E+00	.1011E+02	.9222E+02	673
2-7	674	.1159E+02	.1159E+02	.1125E+02	.8090E+00	.2070E+02	.9980E+00	.1010E+02	.9213E+02	674
2-7	676	.1152E+02	.1152E+02	.1119E+02	.8100E+00	.2020E+02	.9981E+00	.1010E+02	.9212E+02	676
2-7	677	.1151E+02	.1151E+02	.1118E+02	.8096E+00	.2020E+02	.9981E+00	.1010E+02	.9215E+02	677
2-7	678	.1162E+02	.1162E+02	.1128E+02	.8090E+00	.2070E+02	.9980E+00	.1010E+02	.9217E+02	678
2-7	679	.1166E+02	.1166E+02	.1132E+02	.8094E+00	.2060E+02	.9980E+00	.1010E+02	.9220E+02	679
2-7	680	.1150E+02	.1150E+02	.1117E+02	.8094E+00	.2060E+02	.9980E+00	.1011E+02	.9221E+02	680
2-7	682	.1169E+02	.1169E+02	.1135E+02	.8096E+00	.2020E+02	.9981E+00	.1011E+02	.9221E+02	682
2-7	683	.1158E+02	.1158E+02	.1124E+02	.8094E+00	.2060E+02	.9980E+00	.1010E+02	.9216E+02	683
2-7	685	.1158E+02	.1158E+02	.1125E+02	.8098E+00	.2020E+02	.9981E+00	.1015E+02	.9259E+02	685
2-7	686	.1152E+02	.1153E+02	.1120E+02	.8092E+00	.2060E+02	.9980E+00	.1015E+02	.9264E+02	686
2-7	692	.1149E+02	.1149E+02	.1117E+02	.8097E+00	.2020E+02	.9981E+00	.1012E+02	.9235E+02	692
2-7	695	.1144E+02	.1144E+02	.1112E+02	.8093E+00	.2050E+02	.9981E+00	.1013E+02	.9242E+02	695
2-7	696	.1136E+02	.1136E+02	.1105E+02	.8093E+00	.2050E+02	.9981E+00	.1015E+02	.9257E+02	696
2-7	698	.1163E+02	.1163E+02	.1129E+02	.8097E+00	.2010E+02	.9981E+00	.1010E+02	.9219E+02	698
2-7	700	.1168E+02	.1168E+02	.1134E+02	.8097E+00	.2010E+02	.9981E+00	.1015E+02	.9257E+02	700
2-7	702	.1169E+02	.1169E+02	.1135E+02	.8095E+00	.2050E+02	.9981E+00	.1016E+02	.9270E+02	702
2-7	703	.1168E+02	.1168E+02	.1134E+02	.8096E+00	.2050E+02	.9981E+00	.1015E+02	.9259E+02	703
2-7	705	.1168E+02	.1168E+02	.1134E+02	.8095E+00	.2050E+02	.9981E+00	.1013E+02	.9246E+02	705
2-7	707	.1170E+02	.1170E+02	.1136E+02	.8095E+00	.2050E+02	.9981E+00	.1012E+02	.9237E+02	707
2-7	708	.1166E+02	.1166E+02	.1132E+02	.8098E+00	.2010E+02	.9981E+00	.1013E+02	.9239E+02	708
2-7	714	.1154E+02	.1154E+02	.1122E+02	.8095E+00	.2050E+02	.9981E+00	.1015E+02	.9264E+02	714
2-7	726	.1157E+02	.1158E+02	.1125E+02	.8094E+00	.2050E+02	.9981E+00	.1015E+02	.9258E+02	726
2-7	728	.1157E+02	.1157E+02	.1125E+02	.8095E+00	.2050E+02	.9981E+00	.1016E+02	.9274E+02	728
2-7	736	.1170E+02	.1170E+02	.1136E+02	.8093E+00	.2050E+02	.9981E+00	.1009E+02	.9210E+02	736
2-7	738	.1174E+02	.1174E+02	.1140E+02	.8096E+00	.2050E+02	.9981E+00	.1016E+02	.9268E+02	738

TOTAL WEIGHT OF GROUP = 301.452 GRAMS
AVERAGE WEIGHT OF GROUP = 11.5943 GRAMS
AVERAGE DENSITY OF GROUP = 92.390 PERCENT T.D.
STANDARD DEVIATION OF PELLET DENSITY = .216

IFA-432, Rod 6, Drilled Pellets (Second Measurement)

	SAMPLE NUMBER	PELLET WEIGHT (GRAMS)	WT. OF SATURATED PELLET (GRAMS)	WT OF PELLET SUSPENDED IN WATER (GRAMS)	WT. OF SUSPENSION CAGE (GRAMS)	WATER TEMPEATURE (DEG.C)	WATER DENSITY (GM/CC)	PELLET DENSITY (GM/CC)	PELLET DENSITY (PERCENT T.D.)	SAMPLE NUMBER
2-7D	637	.1156E+02	.1156E+02	.1122E+02	.8099E+00	.1850E+02	.9985E+00	.1009E+02	.9204E+02	637
2-7D	638	.1102E+02	.1102E+02	.1074E+02	.8096E+00	.1940E+02	.9983E+00	.1010E+02	.9215E+02	638
2-7D	643	.1111E+02	.1111E+02	.1083E+02	.8097E+00	.1940E+02	.9983E+00	.1010E+02	.9220E+02	643
2-7D	644	.1111E+02	.1111E+02	.1082E+02	.8097E+00	.1940E+02	.9983E+00	.1010E+02	.9218E+02	644
2-7D	648	.1103E+02	.1103E+02	.1075E+02	.8096E+00	.1940E+02	.9983E+00	.1010E+02	.9216E+02	648
2-7D	650	.1109E+02	.1110E+02	.1081E+02	.8096E+00	.1940E+02	.9983E+00	.1010E+02	.9219E+02	650
2-7D	651	.1118E+02	.1118E+02	.1089E+02	.8097E+00	.1940E+02	.9983E+00	.1009E+02	.9205E+02	651
2-7D	657	.1109E+02	.1110E+02	.1081E+02	.8096E+00	.1940E+02	.9983E+00	.1010E+02	.9219E+02	657
2-7D	659	.1102E+02	.1103E+02	.1075E+02	.8099E+00	.1950E+02	.9983E+00	.1011E+02	.9225E+02	659
2-7D	662	.1101E+02	.1101E+02	.1074E+02	.8097E+00	.1950E+02	.9983E+00	.1010E+02	.9216E+02	662
2-7D	663	.1094E+02	.1095E+02	.1068E+02	.8097E+00	.1950E+02	.9983E+00	.1011E+02	.9227E+02	663
2-7D	664	.1108E+02	.1108E+02	.1080E+02	.8096E+00	.1950E+02	.9983E+00	.1011E+02	.9223E+02	664
2-7D	665	.1096E+02	.1096E+02	.1069E+02	.8098E+00	.1950E+02	.9983E+00	.1011E+02	.9228E+02	665
2-7D	666	.1118E+02	.1118E+02	.1088E+02	.8098E+00	.1950E+02	.9983E+00	.1007E+02	.9184E+02	666
2-7D	667	.1081E+02	.1081E+02	.1055E+02	.8100E+00	.1950E+02	.9983E+00	.1008E+02	.9200E+02	667
2-7D	668	.1121E+02	.1122E+02	.1091E+02	.8100E+00	.1950E+02	.9983E+00	.1007E+02	.9188E+02	668
2-7D	671	.1134E+02	.1135E+02	.1103E+02	.8098E+00	.1950E+02	.9983E+00	.1007E+02	.9185E+02	671
2-7D	672	.1128E+02	.1128E+02	.1097E+02	.8099E+00	.1950E+02	.9983E+00	.1007E+02	.9187E+02	672

TOTAL WEIGHT OF GROUP = 200.028 GRAMS
AVERAGE WEIGHT OF GROUP = 11.1127 GRAMS
AVERAGE DENSITY OF GROUP = 92.099 PERCENT T.D.
STANDARD DEVIATION OF PELLET DENSITY = .152

IFA-432, Rod 7, Solid Pellets

SAMPLE NUMBER		PELLET WEIGHT (GRAMS)	WT. OF SATURATED PELLET (GRAMS)	WT OF PELLET SUSPENDED IN WATER (GRAMS)	WT. OF SUSPENSION CAGE (GRAMS)	WATER TEMPERATURE (DEG.C)	WATER DENSITY (GM/CC)	PELLET DENSITY (GM/CC)	PELLET DENSITY (PERCENT T.D.)	SAMPLE NUMBER
2-2	90	.1154E+02	.1154E+02	.1125E+02	.8097E+00	.1870E+02	.9984E+00	.1046E+02	.9546E+02	90
2-2	299	.1146E+02	.1146E+02	.1118E+02	.8098E+00	.1860E+02	.9985E+00	.1046E+02	.9547E+02	299
2-2	348	.1141E+02	.1141E+02	.1113E+02	.8100E+00	.1860E+02	.9985E+00	.1049E+02	.9568E+02	348
2-2	357	.1147E+02	.1147E+02	.1119E+02	.8100E+00	.1860E+02	.9985E+00	.1046E+02	.9543E+02	357
2-2	358	.1132E+02	.1132E+02	.1105E+02	.8100E+00	.1860E+02	.9985E+00	.1046E+02	.9548E+02	358
2-2	359	.1146E+02	.1146E+02	.1118E+02	.8099E+00	.1850E+02	.9985E+00	.1046E+02	.9547E+02	359
2-2	363	.1147E+02	.1147E+02	.1119E+02	.8099E+00	.1850E+02	.9985E+00	.1047E+02	.9550E+02	363
2-2	371	.1144E+02	.1144E+02	.1116E+02	.8100E+00	.1840E+02	.9985E+00	.1045E+02	.9536E+02	371
2-2	391	.1140E+02	.1140E+02	.1112E+02	.8100E+00	.1830E+02	.9985E+00	.1046E+02	.9541E+02	391
2-2	416	.1145E+02	.1145E+02	.1117E+02	.8100E+00	.1830E+02	.9985E+00	.1046E+02	.9544E+02	416
2-2	417	.1135E+02	.1135E+02	.1108E+02	.8100E+00	.1830E+02	.9985E+00	.1047E+02	.9553E+02	417
2-2	428	.1148E+02	.1148E+02	.1120E+02	.8099E+00	.1820E+02	.9985E+00	.1047E+02	.9556E+02	428
2-2	439	.1145E+02	.1145E+02	.1117E+02	.8100E+00	.1820E+02	.9985E+00	.1048E+02	.9559E+02	439
2-2	449	.1135E+02	.1135E+02	.1107E+02	.8100E+00	.1820E+02	.9985E+00	.1040E+02	.9487E+02	449
2-2	452	.1186E+02	.1187E+02	.1153E+02	.8100E+00	.1820E+02	.9985E+00	.1038E+02	.9466E+02	452
2-2	453	.1148E+02	.1148E+02	.1119E+02	.8100E+00	.1820E+02	.9985E+00	.1037E+02	.9464E+02	453
2-2	458	.1149E+02	.1148E+02	.1118E+02	.8100E+00	.1820E+02	.9985E+00	.1036E+02	.9453E+02	458

TOTAL WEIGHT OF GROUP = 194.881 GRAMS
AVERAGE WEIGHT OF GROUP = 11.4636 GRAMS
AVERAGE DENSITY OF GROUP = 95.299 PERCENT T.D.
STANDARD DEVIATION OF PELLET DENSITY = .369

IFA-432, Rod 8, Solid Pellets

SAMPLE NUMBER		PELLET WEIGHT (GRAMS)	WT. OF SATURATED PELLET (GRAMS)	WT OF PELLET SUSPENDED IN WATER (GRAMS)	WT. OF SUSPENSION CAGE (GRAMS)	WATER TEMPERATURE (DEG.C)	WATER DENSITY (GM/CC)	PELLET DENSITY (GM/CC)	PELLET DENSITY (PERCENT T.D.)	SAMPLE NUMBER
2-	37	.1197E+02	.1197E+02	.1164E+02	.8096E+00	.1770E+02	.9987E+00	.1048E+02	.9563E+02	37
2-1	53	.1182E+02	.1182E+02	.1150E+02	.8096E+00	.1770E+02	.9987E+00	.1048E+02	.9561E+02	53
2-1	54	.1192E+02	.1192E+02	.1160E+02	.8094E+00	.1770E+02	.9987E+00	.1049E+02	.9567E+02	54
2-1	55	.1181E+02	.1181E+02	.1150E+02	.8094E+00	.1770E+02	.9987E+00	.1049E+02	.9573E+02	55
2-1	59	.1196E+02	.1196E+02	.1162E+02	.8095E+00	.1770E+02	.9987E+00	.1045E+02	.9532E+02	59
2-1	64	.1185E+02	.1185E+02	.1153E+02	.8095E+00	.1770E+02	.9987E+00	.1047E+02	.9556E+02	64
2-1	97	.1202E+02	.1202E+02	.1168E+02	.8096E+00	.1770E+02	.9987E+00	.1046E+02	.9541E+02	97
2-1	123	.1190E+02	.1190E+02	.1158E+02	.8096E+00	.1770E+02	.9987E+00	.1048E+02	.9559E+02	123
2-1	143	.1167E+02	.1167E+02	.1137E+02	.8096E+00	.1770E+02	.9987E+00	.1047E+02	.9556E+02	143
2-1	221	.1188E+02	.1189E+02	.1156E+02	.8096E+00	.1770E+02	.9987E+00	.1049E+02	.9573E+02	221
2-1	227	.1181E+02	.1181E+02	.1150E+02	.8097E+00	.1770E+02	.9987E+00	.1051E+02	.9589E+02	227
2-1	237	.1218E+02	.1218E+02	.1183E+02	.8098E+00	.1770E+02	.9987E+00	.1048E+02	.9559E+02	237
2-1	249	.1206E+02	.1206E+02	.1172E+02	.8097E+00	.1770E+02	.9987E+00	.1047E+02	.9557E+02	249
2-1	270	.1215E+02	.1215E+02	.1180E+02	.8096E+00	.1770E+02	.9987E+00	.1048E+02	.9566E+02	270
2-1	276	.1192E+02	.1192E+02	.1159E+02	.8097E+00	.1770E+02	.9987E+00	.1047E+02	.9552E+02	276
2-1	291	.1169E+02	.1170E+02	.1139E+02	.8095E+00	.1770E+02	.9987E+00	.1049E+02	.9572E+02	291
2-1	292	.1167E+02	.1167E+02	.1137E+02	.8097E+00	.1770E+02	.9987E+00	.1049E+02	.9567E+02	292

TOTAL WEIGHT OF GROUP = 202.277 GRAMS
AVERAGE WEIGHT OF GROUP = 11.8986 GRAMS
AVERAGE DENSITY OF GROUP = 95.615 PERCENT T.D.
STANDARD DEVIATION OF PELLET DENSITY = .130

IFA-432, Rod 9, Solid Pellets

SAMPLE NUMBER		PELLET WEIGHT (GRAMS)	WT. OF SATURATED PELLET (GRAMS)	WT OF PELLET SUSPENDED IN WATER (GRAMS)	WT. OF SUSPENSION CAGE (GRAMS)	WATER TEMPERATURE (DEG.C)	WATER DENSITY (GM/CC)	PELLET DENSITY (GM/CC)	PELLET DENSITY (PERCENT T.D.)	SAMPLE NUMBER
2-5	463	.1225E+02	.1225E+02	.1189E+02	.8100E+00	.1850E+02	.9985E+00	.1051E+02	.9592E+02	463
2-5	472	.1220E+02	.1220E+02	.1185E+02	.8100E+00	.1850E+02	.9985E+00	.1054E+02	.9614E+02	472
2-5	474	.1242E+02	.1243E+02	.1206E+02	.8100E+00	.1850E+02	.9985E+00	.1050E+02	.9585E+02	474
2-5	475	.1232E+02	.1232E+02	.1196E+02	.8100E+00	.1850E+02	.9985E+00	.1051E+02	.9585E+02	475
2-5	483	.1239E+02	.1239E+02	.1202E+02	.8100E+00	.1850E+02	.9985E+00	.1052E+02	.9598E+02	483
2-5	484	.1239E+02	.1239E+02	.1203E+02	.8100E+00	.1850E+02	.9985E+00	.1053E+02	.9604E+02	484
2-5	486	.1238E+02	.1238E+02	.1201E+02	.8100E+00	.1850E+02	.9985E+00	.1052E+02	.9599E+02	486
2-5	490	.1234E+02	.1234E+02	.1198E+02	.8100E+00	.1850E+02	.9985E+00	.1053E+02	.9605E+02	490
2-5	492	.1234E+02	.1234E+02	.1198E+02	.8098E+00	.1840E+02	.9985E+00	.1052E+02	.9601E+02	492
2-5	494	.1245E+02	.1245E+02	.1208E+02	.8098E+00	.1840E+02	.9985E+00	.1051E+02	.9591E+02	494
2-5	558	.1227E+02	.1227E+02	.1192E+02	.8099E+00	.1840E+02	.9985E+00	.1053E+02	.9612E+02	558
2-5	561	.1231E+02	.1231E+02	.1195E+02	.8098E+00	.1840E+02	.9985E+00	.1053E+02	.9610E+02	561
2-5	564	.1228E+02	.1228E+02	.1193E+02	.8098E+00	.1840E+02	.9985E+00	.1056E+02	.9633E+02	564
2-5	566	.1232E+02	.1232E+02	.1197E+02	.8100E+00	.1840E+02	.9985E+00	.1054E+02	.9619E+02	566
2-5	621	.1213E+02	.1213E+02	.1179E+02	.8100E+00	.1840E+02	.9985E+00	.1050E+02	.9583E+02	621
2-5	628	.1198E+02	.1198E+02	.1165E+02	.8099E+00	.1830E+02	.9985E+00	.1052E+02	.9598E+02	628
2-5	630	.1203E+02	.1203E+02	.1170E+02	.8100E+00	.1830E+02	.9985E+00	.1054E+02	.9616E+02	630
2-5	631	.1204E+02	.1204E+02	.1171E+02	.8100E+00	.1830E+02	.9985E+00	.1056E+02	.9631E+02	631
2-5	634	.1219E+02	.1219E+02	.1184E+02	.8100E+00	.1830E+02	.9985E+00	.1055E+02	.9621E+02	634
2-5	635	.1222E+02	.1222E+02	.1188E+02	.8100E+00	.1830E+02	.9985E+00	.1057E+02	.9646E+02	635

TOTAL WEIGHT OF GROUP = 245.238 GRAMS
AVERAGE WEIGHT OF GROUP = 12.2619 GRAMS
AVERAGE DENSITY OF GROUP = 96.072 PERCENT T.D.
STANDARD DEVIATION OF PELLET DENSITY = .171

TOTAL WEIGHT OF ALL GROUPS 3258.2795 GRAMS

TABLE F-1. Results of Resintering Tests

1600°C/24 hr Type	Pellet Id.	Length Pre, In.	Length Post, In.	Length $-3\Delta L/L_o$,(a) %	Diameter Pre, In.	Diameter Post, In.	Diameter $-3\Delta D/D_o$,(a) %	Density Pre, %TD	Density Post, %TD	Density $\Delta\rho/\rho_o$, %
92% TD Unstable	1-6-752	0.5058	0.5011	2.79	0.4204	0.4168	2.57	91.71	94.13	2.64
	1-6-750	0.5118	0.5068	2.93	0.4203	0.4166	2.64	91.68	94.35	2.91
	2-7-675	0.5125	0.5077	2.81	0.4205	0.4171	2.43	92.21	94.62	2.61
	2-7-716	0.5104	0.5069	2.06	0.4205	0.4182	1.64	92.79	94.61	1.96
92%TD Stable	1-5-788	0.5129	0.5124	0.29	0.4205	0.4203	0.14	91.24	91.21	-0.03
	1-5-884	0.5059	0.5055	0.24	0.4203	0.4202	0.07	91.54	91.66	0.13
	2-6-857	0.5051	0.5046	0.30	0.4204	0.4201	0.21	91.83	92.01	0.20
	2-6-880	0.5071	0.5066	0.30	0.4202	0.4202	0.00	92.09	92.16	0.08
95% TD Stable	2-2-411	0.4888	0.4885	0.18	0.4144	0.4144	0.00	95.34	95.40	0.06
	2-1-116	0.5071	0.5066	0.30	0.4203	0.4203	0.00	95.54	95.55	0.01
	2-1-207	0.5060	0.5059	0.06	0.4203	0.4202	0.07	95.65	95.68	0.03
	2-5-579	0.5178	0.5174	0.23	0.4225	0.4225	0.00	96.05	96.10	0.05
1700°C/7.8 Hr.										
92% TD Unstable	1-6-754	0.5088	0.5030	3.42	0.4204	0.4160	3.14	91.42	94.43	3.29
	-691	0.5112	0.5054	3.40	0.4204	0.4162	3.00	91.89	94.96	3.34
	2-7-684	0.5043	0.4998	2.68	0.4207	0.4171	2.57	92.50	94.99	2.69
	-694	0.5026	0.4978	2.87	0.4204	0.4168	2.57	92.42	95.00	2.79
92% TD Stable	1-5-803	0.5109	0.5114	-0.29	0.4205	0.4217	-0.86	91.11	90.26	-0.93
	2-6-805	0.5111	0.5131	-1.17	0.4204	0.4209	-0.36	91.22	90.42	-0.88
	1-5-785	0.5127	0.5118	0.53	0.4205	0.4198	0.50	92.18	92.69	0.55
	2-6-854	0.5036	0.5030	0.36	0.4205	0.4196	0.64	92.63	93.14	0.55
95% TD Stable	2-2-400	0.4968	0.4965	0.18	0.4145	0.4143	0.14	95.38	95.64	0.27
	2-2-370	0.5015	0.5010	0.30	0.4144	0.4141	0.22	95.49	95.75	0.27
	2-1-293	0.4947	0.4947	0.00	0.4203	0.4201	0.14	95.68	95.91	0.24
	2-1-205	0.5059	0.5057	0.12	0.4204	0.4202	0.14	95.75	95.93	0.19
1700°C/4 Hr.										
92% TD Unstable	1-6-744	0.5075	0.5030	2.66	0.4204	0.4168	2.57	92.08	94.49	2.62
	1-6-723	0.5083	0.5027	3.31	0.4202	0.4164	2.71	92.16	94.78	2.84
	2-7-720	0.5115	0.5070	2.64	0.4204	0.4171	2.35	92.50	94.93	2.63
	2-7-724	0.5087	0.5044	2.54	0.4204	0.4174	2.35	92.65	94.73	2.25
92% TD Stable	1-5-783	0.5041	0.5042	-0.06	0.4204	0.4202	0.14	91.34	91.13	-0.23
	2-6-863	0.5044	0.5048	-0.24	0.4203	0.4205	-0.14	91.67	91.27	-0.43
	2-6-853	0.5019	0.5013	0.36	0.4203	0.4200	0.21	92.85	93.03	0.19
	2-6-856	0.4967	0.4962	0.30	0.4204	0.4201	0.21	93.01	93.19	0.19
95% TD Stable	2-2-354	0.4989	0.4986	0.18	0.4145	0.4144	0.07	95.37	95.46	0.09
	2-2-402	0.4972	0.4971	0.06	0.4144	0.4143	0.07	95.46	95.53	0.07
	2-1-65	0.5013	0.5010	0.18	0.4205	0.4203	0.14	95.59	95.72	0.14
	2-5-489	0.5139	0.5138	0.06	0.4224	0.4223	0.07	95.97	96.01	0.04

a.)If shrinkage is isotropic, $\frac{-3\Delta L}{L_o} = \frac{-3\Delta D}{D_o} = \frac{\Delta\rho}{\rho_o}$

b.)Laminations observed after resintering

TABLE F-1. (Cont)

1700°C/24 Hr.										
92% TD Unstable	1-6-751	0.5061	0.4996	3.85	0.4204	0.4154	3.57	91.57	95.10	3.85
	-753	0.5009	0.4953	3.35	0.4204	0.4162	3.00	91.70	94.86	3.45
	-749	0.5285	0.5231	3.07	0.4204	0.4164	2.85	92.40	95.32	3.16
	2-7-715	0.5090	0.5038	3.06	0.4206	0.4166	2.85	92.72	95.53	3.03
92% TD Stable	1-5-897	0.5135	0.5142[(b)]	-0.41	0.4204	0.4210	-0.43	91.21	90.70	-0.56
	-872	0.5050	0.5043	0.42	0.4205	0.4208	-0.21	91.46	91.36	-0.11
	2-6-866	0.5032	0.5028	0.24	0.4204	0.4204	0.14	92.04	92.47	0.47
	1-5-898	0.4976	0.4967	0.54	0.4205	0.4202	0.21	92.09	92.36	0.29
95% TD Stable	2-1-250	0.5123	0.5116	0.41	0.4203	0.4199	0.29	95.65	95.90	0.26
	2-2-408	0.4986	0.4978	0.48	0.4145	0.4141	0.29	95.45	95.71	0.27
	2-5-582	0.5145	0.5139	0.35	0.4224	0.4222	0.14	96.01	96.28	0.28
	-604	0.5127	0.5126	0.06	0.4225	0.4223	0.14	96.13	96.29	0.17
1700°C/48 Hr.										
92 %TD Unstable	1-6-751	0.5061	0.4993	4.03	0.4204	0.4151	3.78	91.57	95.38	4.16
	1-6-749	0.5285	0.5230	3.12	0.4204	0.4160	3.14	92.40	95.49	3.34
92% TD Stable	1-5-897	0.5135	0.5139	-0.23	0.4204	0.4212	-0.57	91.21	90.71	-0.55
	2-6-866	0.5032	0.5021	0.66	0.4204	0.4200	0.29	92.04	92.64	0.65
95% TD Stable	2-1-250	0.5123	0.5114	0.53	0.4203	0.4198	0.36	95.65	96.01	0.38
	2-5-582	0.5145	0.5135	0.58	0.4224	0.4220	0.28	96.01	96.40	0.41

TABLE G-1. Thermal Diffusivity, Conductivity, and Resistivity of 95% Stable TD Halden UO_2

Temperature, °C	Thermal Diffusivity cm^2/sec	Thermal Conductivity watt/cm °C	Thermal Resistivity cm °C/watt
Disc #1, Cycle #1			
100	.0282	.0766	13.00
	.0281	.0763	13.11
190	.0234	.0681	14.68
	.0236	.0687	14.55
279	.0199	.0604	16.57
	.0211	.0040	15.63
423	.0174	.0547	18.28
	.0176	.0553	18.07
562	.0151	.0484	20.66
	.0155	.0497	20.13
662	.0139	.0450	22.21
	.0134	.0434	23.04
764	.0123	.0401	24.93
	.0122	.0398	25.14
870	.0113	.0371	26.97
	.0111	.0362	27.63
989	.0102	.0336	29.72
	.00984	.0325	30.81
1090	.00888	.0294	34.01
	.00928	.0307	32.55
1197	.00826	.0274	36.47
	.00826	.0274	36.47
1305	.00758	.0253	39.50
	.00773	.0258	38.73
1052	.00910	.0301	33.24
	.00918	.0303	32.95
879	.0107	.0351	28.48
	.0109	.0358	27.95
642	.0152	.0492	20.34
	.0145	.0469	21.33
403	.0177	.0555	18.03
	.0175	.0548	18.23

Table G-1 (cont'd)

Temperature, °C	Thermal Diffusivity cm^2/sec	Thermal Conductivity watt/cm °C	Thermal Resistivity cm °C/watt
203	.0211	.0619	16.15
	.0223	.0654	15.28
Cycle #2			
516	.0153	.0488	20.49
	.0161	.0514	19.47
838	.0114	.0373	26.78
	.0111	.0364	27.50
1110	.00866	.0287	34.87
	.00873	.0289	34.59
1415	.00682	.0230	43.51
	.00687	.0232	43.19
1510	.00640	.0219	45.70
	.00644	.0220	45.42
1628	.00016	.0216	46.25
	.00616	.0216	46.25
1630	.00621	.0218	45.83
	.00621	.0218	45.83
Cycle #3			
134	.0237	.0665	15.03
	.0233	.0654	15.28
327	.0173	.0533	18.76
	.0179	.0552	18.13
535	.0143	.0458	21.85
	.0147	.0470	21.26
777	.0112	.0366	27.35
	.0115	.0375	26.63
966	.00956	.0315	31.76
	.00974	.0321	31.17
1124	.00859	.0285	35.14
	.00863	.0284	35.18
1310	.00735	.0245	40.73
	.00738	.0246	40.57
1533	.0649	.0223	44.90
	.0623	.0214	46.77

TABLE G-2. Thermal Diffusivity, Conductivity, and Resistivity of 92% TD Unstable Halden UO_2

Temperature, °C	Thermal Diffusivity cm^2/sec	Thermal Conductivity watt/cm °C	Thermal Resistivity cm °C/watt
Disc #1, Cycle #1			
40	.0249	.0611	16.37
	.0245	.0601	16.64
	.0245	.0601	16.64
160	.0221	.0610	16.39
	.0221	.0610	16.39
	.0221	.0610	16.39
279	.0180	.0529	18.90
	.0178	.0521	19.19
	.0181	.0529	18.90
462	.0147	.0449	22.27
	.0145	.0443	22.97
	.0148	.0452	22.12
587	.0129	.0400	25.00
	.0130	.0403	24.81
	.0126	.0391	25.58
691	.0115	.0361	27.70
	.0117	.0367	27.25
	.0116	.0364	27.47
800	.0108	.0341	29.33
	.0105	.0329	30.40
	.0106	.0332	30.12
911	.00997	.0316	31.65
	.00979	.0311	32.15
	.00992	.0315	31.75
1026	.00905	.0288	34.72
	.00893	.0284	35.21
	.00901	.0287	34.84
1140	.00842	.0269	37.17
	.00812	.0260	38.46
	.00835	.0267	37.45
1242	.00776	.0249	40.16
	.00759	.0244	40.98
	.00765	.0246	40.65

TABLE G-2. (cont'd)

Temperature, °C	Thermal Diffusivity cm^2/sec	Thermal Conductivity watt/cm °C	Thermal Resistivity cm °C/watt
1151	.00787	.0252	39.68
	.00787	.0252	39.68
902	.0102	.0323	30.96
	.0102	.0323	30.96
696	.0127	.0398	25.13
	.0127	.0398	25.13
420	.0163	.0494	20.24
	.0166	.0503	19.88
175	.0220	.0613	16.31
	.0212	.0591	16.92
Cycle #2			
262	.0196	.0570	17.54
	.0201	.0584	17.12
508	.0150	.0461	21.69
	.0150	.0461	21.69
796	.0117	.0369	27.10
	.0115	.0363	27.55
1045	.00916	.0292	34.25
	.00908	.0290	34.48
1256	.00771	.0248	40.32
	.00760	.0244	40.98
1360	.00709	.0229	43.67
	.00706	.0228	43.86
1502	.00658	.0217	46.08
	.00645	.0212	47.17
1593	.00635	.0213	46.95
	.00633	.0212	47.17
1641	.00608	.0207	48.31
	.00612	.0208	48.08
1630	.00624	.0212	47.17
	.00624	.0212	47.17

TABLE G-2 (cont'd)

Temperature, °C	Thermal Diffusivity cm^2/sec	Thermal Conductivity watt/cm °C	Thermal Resistivity cm °C/watt
Cycle #3			
156	.0226	.0622	16.08
	.0227	.0625	16.00
	.0225	.0619	16.16
289	.0186	.0546	18.32
	.0186	.0546	18.32
	.0183	.0538	18.59
454	.0149	.0454	22.03
	.0158	.0482	20.75
	.0158	.0482	20.75
655	.0131	.0410	24.39
	.0129	.0403	24.81
	.0128	.0400	25.00
822	.0109	.0344	29.07
	.0106	.0335	29.85
976	.00969	.0308	32.47
	.00939	.0299	33.44
1126	.00862	.0275	36.36
	.00838	.0268	37.31
1243	.00788	.0253	39.53
	.00765	.0246	40.65
1381	.00698	.0226	44.25
	.00686	.0222	45.05
1515	.00678	.0223	44.84
	.00669	.0220	45.45
1602	.00628	.0211	47.39
	.00628	.0211	47.39
Disc #2, Cycle #4			
499	.0143	.0437	22.89
	.0147	.0449	22.27
847	.0108	.0340	29.40
	.0108	.0340	29.40
1075	.00871	.0277	36.15
	.00871	.0277	36.15

TABLE G-2 (cont'd)

Temperature, °C	Thermal Diffusivity cm^2/sec	Thermal Conductivity watt/cm °C	Thermal Resistivity cm °C/watt
1252	.00801	.0256	39.04
	.00797	.0255	39.23
1428	.00688	.0223	44.82
	.00681	.0221	45.28
1599	.00614	.0206	48.66
	.00614	.0200	48.66

TABLE G-3. Thermal Diffusivity, Conductivity, and Resistivity of 92% TD Stable Halden UO_2

Temperature, °C	Thermal Diffusivity cm^2/sec	Thermal Conductivity watt/cm °C	Thermal Resistivity cm °C/watt
Disc #1, Cycle #1			
105	.0256	.0670	14.93
	.0262	.0686	14.58
	.0251	.0657	15.22
215	.0194	.0548	18.25
	.0191	.0540	18.52
	.0205	.0580	17.24
338	.0169	.0500	20.00
	.0167	.0494	20.24
	.0163	.0482	20.75
465	.0139	.0422	23.70
	.0142	.0431	23.20
591	.0124	.0382	26.18
	.0124	.0382	26.18
	.0118	.0364	27.47
732	.0107	.0334	29.94
	.0108	.0337	29.67
	.0108	.0337	29.67
814	.0102	.0320	31.25
	.0102	.0320	31.25
	.0100	.0314	31.85
935	.00915	.0288	34.72
	.00915	.0288	34.72
	.00896	.0283	35.34
1005	.00872	.0276	36.23
	.00858	.0271	36.90
	.00878	.0277	36.10
1116	.00774	.0245	40.82
	.00780	.0247	40.49
	.00765	.0243	41.15
1219	.00711	.0227	44.15
	.00714	.0227	43.96

TABLE G-3 (cont'd)

Temperature, °C	Thermal Diffusivity cm^2/sec	Thermal Conductivity watt/cm °C	Thermal Resistivity cm °C/watt
Cycle #3			
131	.0182	.0462	21.64
	.0190	.0482	20.73
277	.0150	.0412	24.26
	.0152	.0418	23.94
516	.0120	.0347	28.81
	.0121	.0350	28.57
736	.00981	.0290	34.51
	.01011	.0299	33.48
943	.00830	.0248	40.32
	.00818	.0244	40.91
1099	.00742	.0223	44.92
	.00742	.0223	44.92
1254	.00642	.0194	51.52
	.00645	.0915	51.29
1440	.00590	.0181	55.28
	.00590	.0181	55.28
1606	.00552	.0175	57.20
	.00552	.0175	57.20
Disc #3, Cycle #4			
501	.0146	.0433	23.11
	.0148	.0439	22.80
	.0145	.0430	23.27
878	.0104	.0324	30.84
	.0103	.0321	31.14
	.0104	.0324	30.84
1198	.00803	.0262	38.22
	.00814	.0257	38.98
	.00793	.0250	40.01
1374	.00698	.0222	44.98
	.00717	.0228	43.79
1497	.00639	.0207	48.38
	.00639	.0207	48.38

TABLE G-3 (cont'd)

Temperature, °C	Thermal Diffusivity cm^2/sec	Thermal Conductivity watt/cm °C	Thermal Resistivity cm °C/watt
1415	.00583	.0188	53.19
	.00552	.0178	56.18
	.00583	.0188	53.19
1202	.00728	.0232	43.11
	.00739	.0235	42.47
	.00718	.0229	43.71
983	.00886	.0280	35.73
	.00886	.0280	35.73
778	.0107	.0335	29.88
	.0103	.0322	31.04
545	.0124	.0381	26.26
	.0129	.0396	25.24
288	.0184	.0536	18.66
	.0182	.0530	18.86
Disc #2, Cycle #2			
152	.0216	.0589	16.96
	.0216	.0589	16.96
304	.0176	.0516	19.39
	.0178	.0522	19.73
516	.0142	.0434	23.06
	.0143	0.437	22.90
695	.0119	0.370	26.99
	.0114	.0355	28.18
908	.00996	.0316	31.69
	.00969	.0307	32.58
1066	.00866	.0275	36.43
	.00862	.0273	36.60
1287	.00742	.0237	42.16
	.00737	.0236	42.44
1443	.00663	.0215	46.54
	.00658	.0213	46.89
1616	.00576	.0193	51.78
	.00574	.0192	51.96
1614	.00540	.0172	58.31
	.00542	.0172	58.09

TABLE G-3 (cont'd)

Temperature, °C	Thermal Diffusivity cm^2/sec	Thermal Conductivity watt/cm °C	Thermal Resistivity cm °C/watt
1606	.00576	.0191	52.40
	.00555	.0184	54.39
1604	.00557	.0180	55.67
	.00547	.0176	56.69
1483	.00599	.0188	53.13
	.00649	.0204	49.04
1382	.00670	.0208	48.07
	.00670	.0208	48.07
1112	.00751	.0230	43.53
	.00751	.0230	43.53
830	.00957	.0290	34.52
	.00967	.0293	34.16
604	.0114	.0340	29.44
	.0155	.0343	29.18

FUEL PELLET AND CLADDING SURFACE ROUGHNESS AND ROUNDNESS MEASUREMENTS

Three fuel pellets, one from each fuel type, were used for the surface and roundness measurements. Cladding samples were taken from three tubes identified as 10-B, 18-C, and 23-B which were taken from the same lot as the tubing used for the fuel rod cladding. Six half-sections of tubing were used for the surface roughness measurements, and three full sections for the roundness measurements.

Fuel Pellet Measurements

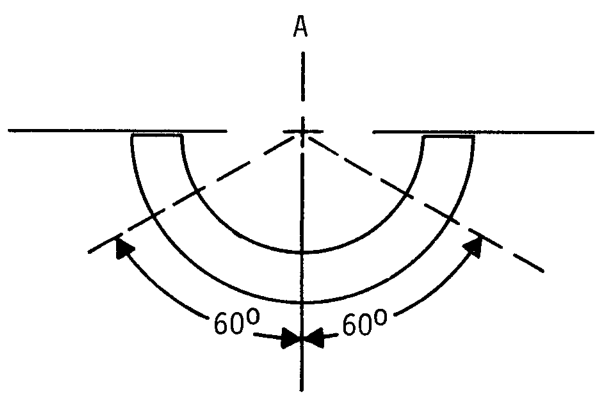
All pellet measurements were made on the cylindrical surface; no measurements were made on the pellet ends. The following measurements were made:

- Axial Surface Roughness - Three measurements spaced approximately 120 apart.
- Circumferential Surface Roughness - One measurement near the center of each pellet and one measurement approximately 0.3 cm from each end of the pellet.

Tubing Surface Roughness Measurements

The six samples of tubing used for the surface roughness measurements were 7.5 cm long half-sections of tubing; the following measurements were made:

- Axial Measurements - One measurement was made at the 0° position and one each approximately 60° from the 0° position on each half-section of tubing as shown below:



- The measurements started approximately 0.3 cm from the end of the tubing section.
- Circumferential Measurements - One measurement was made near the center of each section, and one measurement approximately 1.25 cm from each end of each segment. The measurement extended at least to within 0.15 cm of each edge of the section.

Tubing Roundness Measurements

The three samples of tubing for these measurements were pieces of tubing 15 cm long. The roundness of the inside surface of the tubing was measured at a location approximately 5 cm from each end of the tubing.

Results

The results of the measurements are shown in Tables H-1 and H-2 and in Figures H-1 - H-19.

TABLE H.1. Roundness Measurements for Pellets and Tubing

	Roundness Deviation, In.		
Pellet Type	Top	Center	Bottom
95% TD Stable	0.00030	0.00030	0.00040
92% TD Stable	0.00025	0.00030	0.00030
92% TD Unstable	0.00035	0.00035	0.00030
Tubing No.	Top	Center	Bottom
10-B	0.00025	Not	0.00025
18-B	0.00035	Measured	0.00025
23-B	0.00020		0.00020

TABLE H-2. Surface Roughness Measurements for Pellets and Tubing

Pellet Type	Arithmetic Average - μ in.								
	Axial			Radial					
	1	2	3	Top		Center		Bottom	
				0°	90°	0°	90°	0°	90°
95% TD Stable	80	95	80	83	81	71	114	91	88
92% TD Stable	83	100	110	107	106	91	97	93	94
92% TD Unstable	110	80	95	100	104	86	91	96	96

	Arithmetic Average - μ in.							
	Axial							
	Top			Bottom			Circumferential	
Tubing No.	60°-Left	0°-Center	60°-Right	60°-Left	0°-Center	60°-Right	Top	Bottom
10-B1	14	33	23	16	24	17		19
10-B2	17	26.2	27	18	28	15	22	21
18-C1	22.5	14	22	16	29	18	21	22
18-C2	25	22	24.5	21	23.5	16	22	19
23-B1	24	19	21.5	21	11	18	16	18
23-B2	18	17.5	15	24.5	26	21.5	19	21

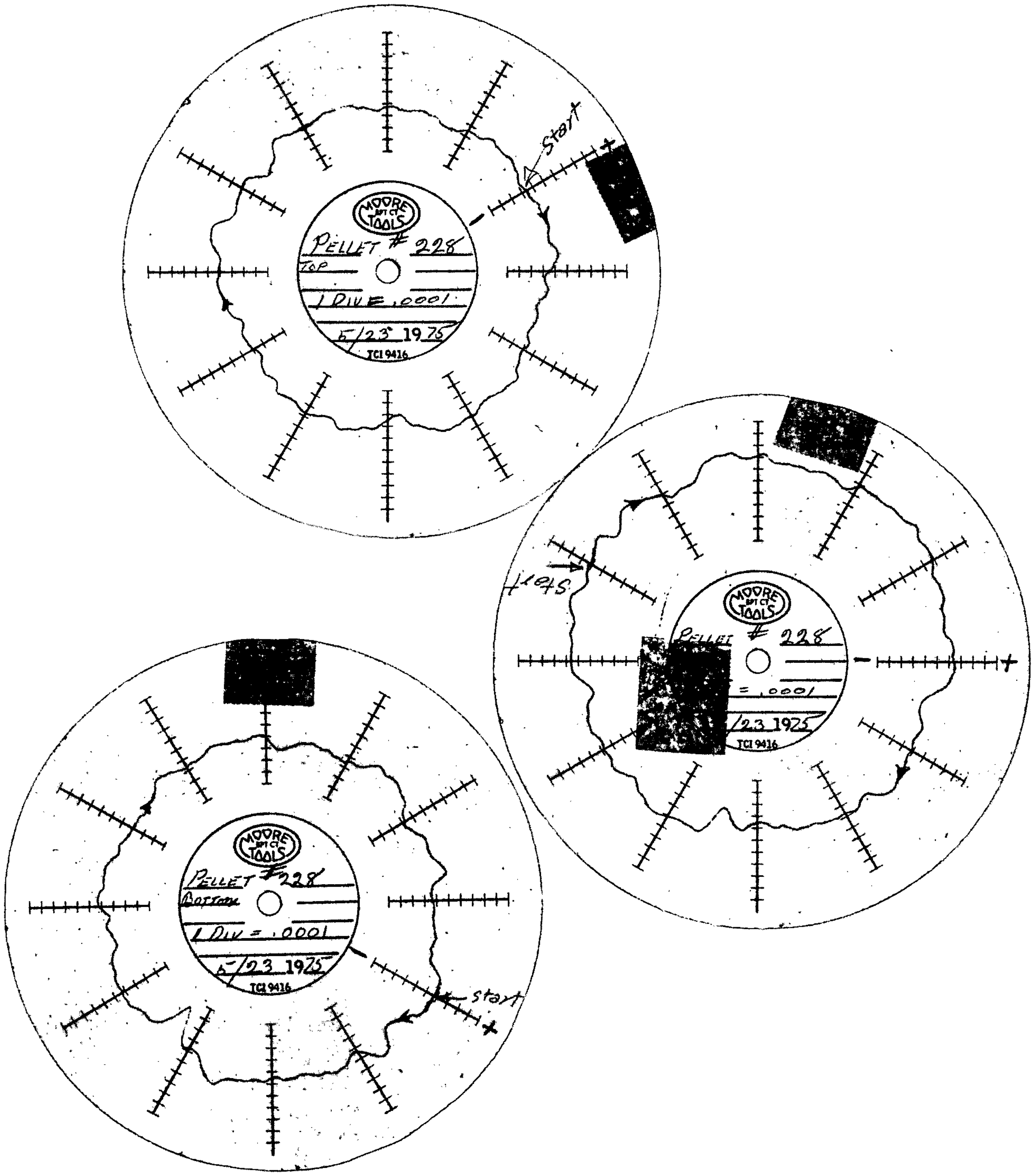


FIGURE H-1. Fuel Pellet Roundness at Three Locations for One 95% TD Stable Fuel Pellet (No. 228). Each Division = 0.0001 in.

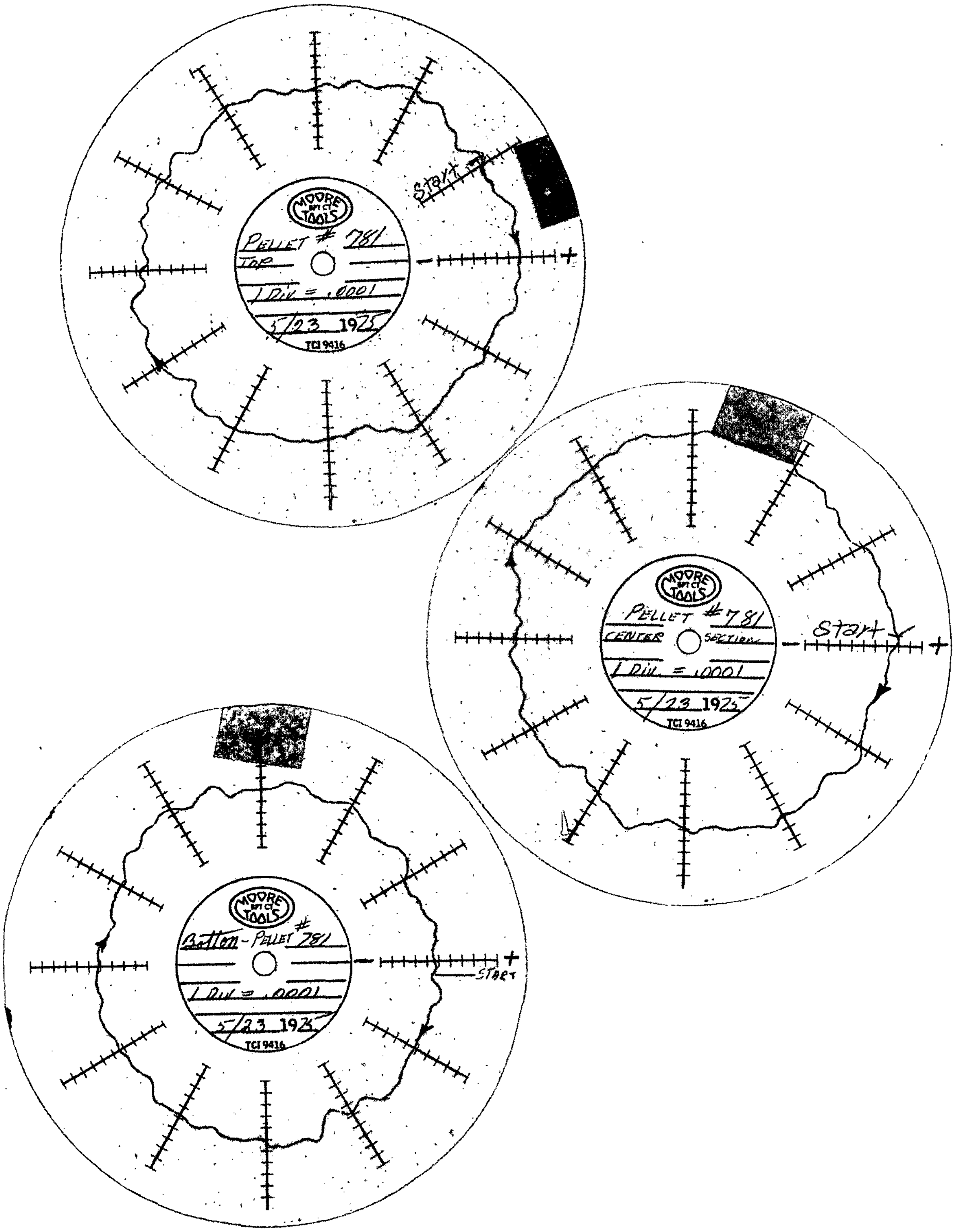


FIGURE H-2. Fuel Pellet Roundness at Three Locations for One 92% TD Stable Fuel Pellet (No. 781). Each Division = 0.0001 in.

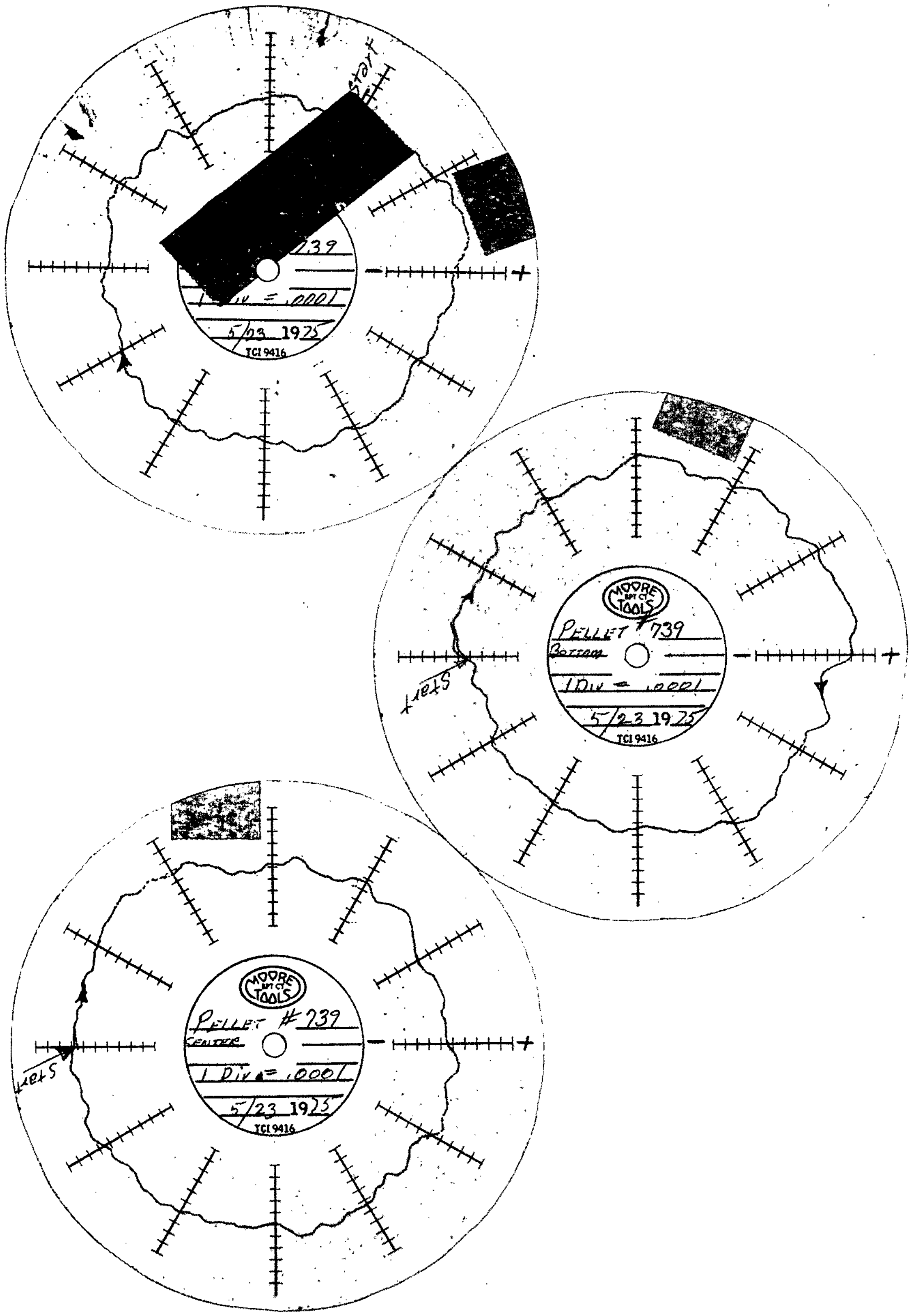


FIGURE H-3. Fuel Pellet Roundness at Three Locations for One 92% TD Unstable Fuel Pellet (No. 739). Each Division = 0.0001 in.

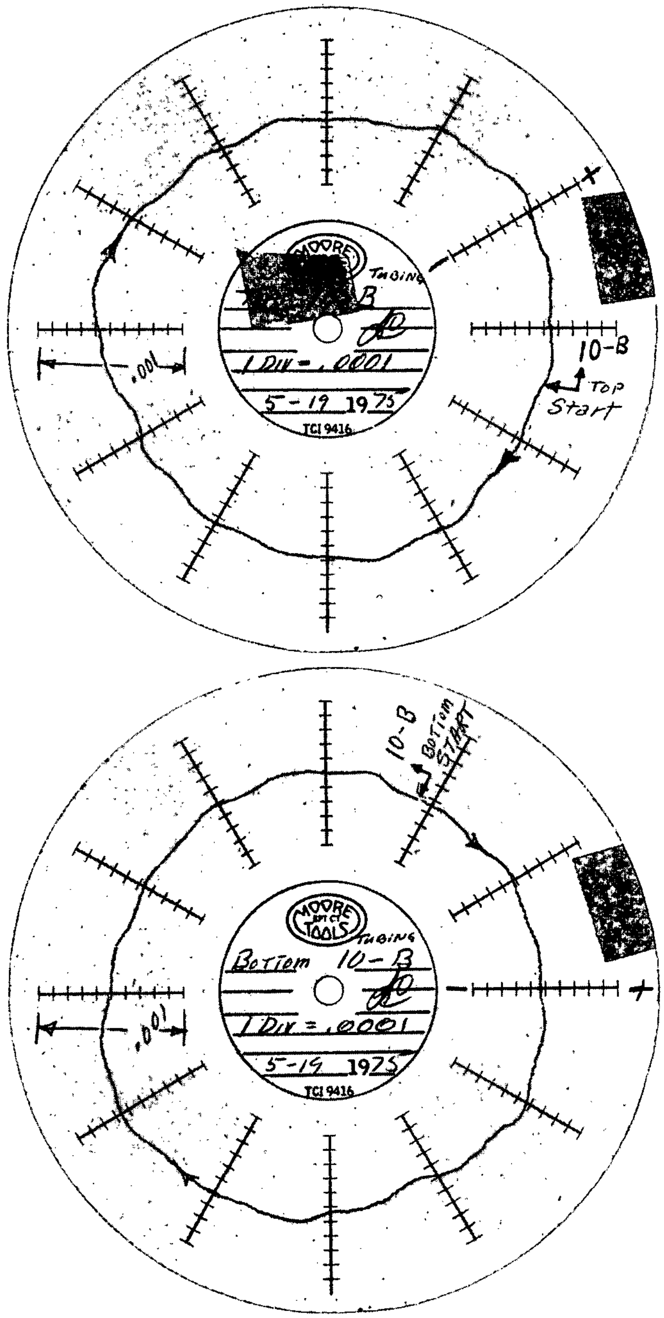


FIGURE H-4. Cladding Inside Surface Roundness at Two Locations
Cladding Number 10B. Each Division = 0.0001 in.

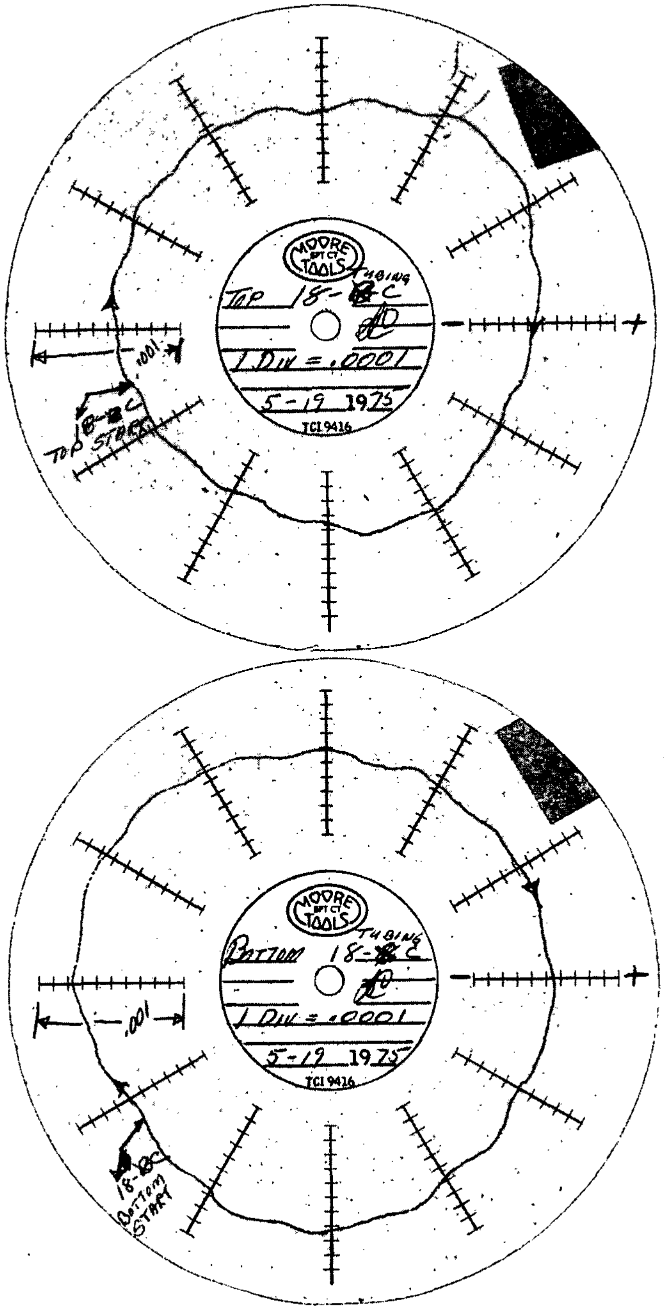


FIGURE H-5. Cladding Inside Surface Roundness at Two Locations Cladding Number 18-C. Each Division = 0.0001 in.

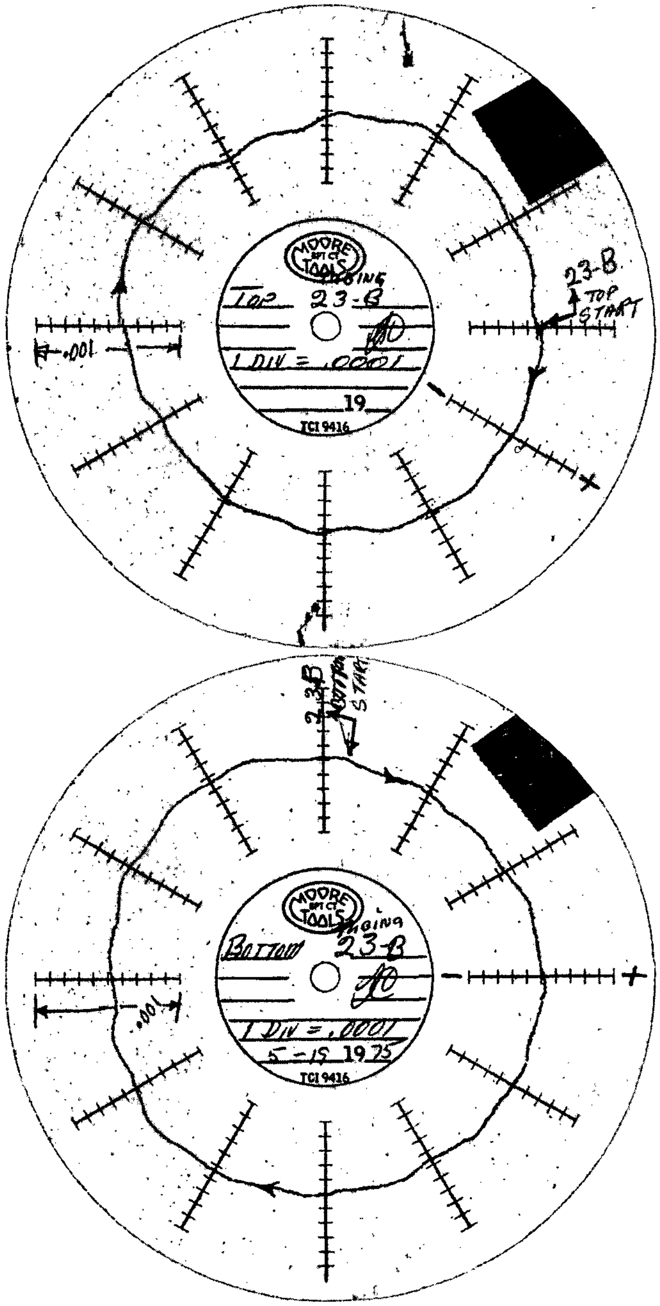


FIGURE H-6. Cladding Inside Surface Roundness at Two Locations Cladding Number 10B. Cladding Number 23-B. Each Division = 0.0001 in.

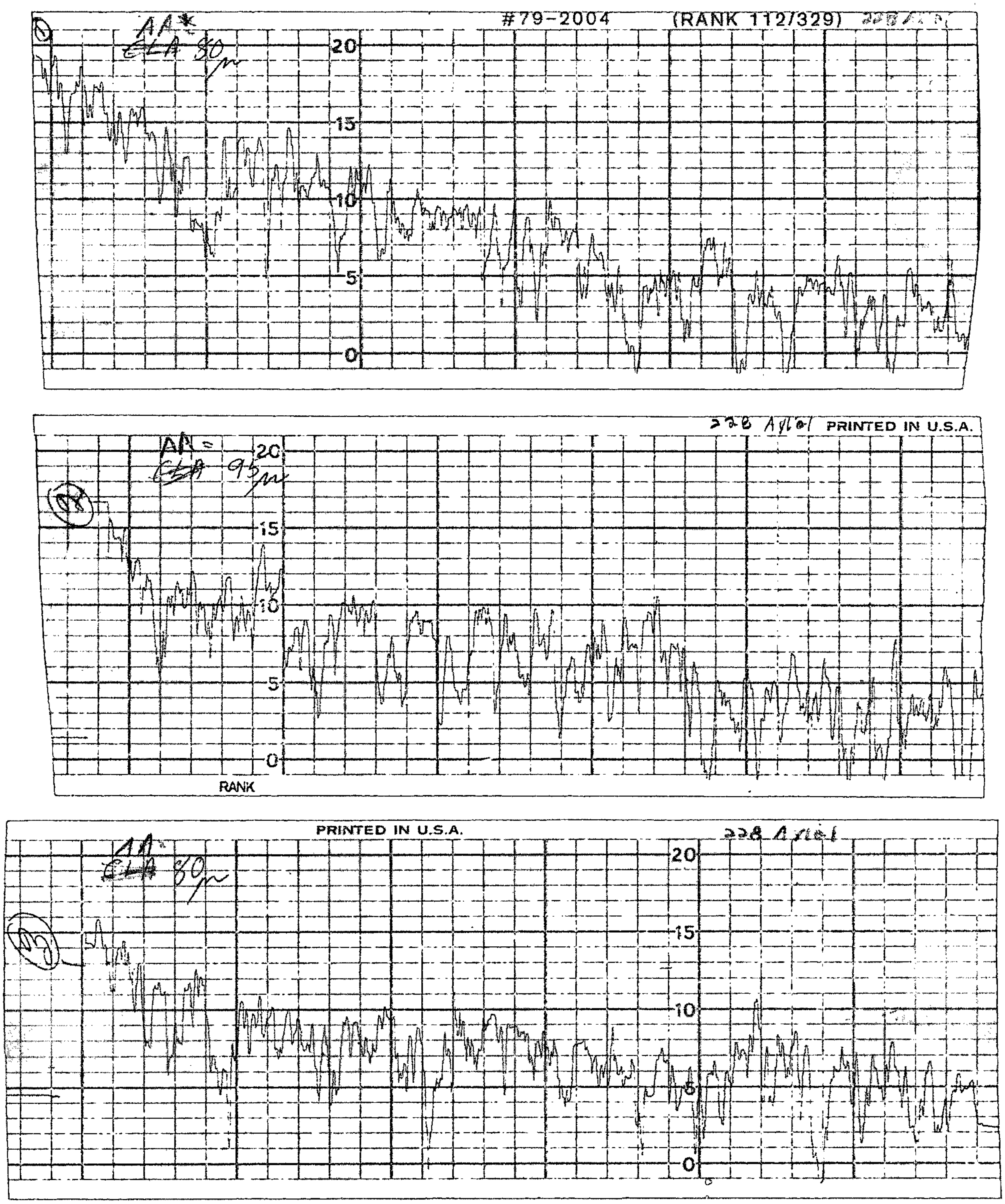


FIGURE H-7. Fuel Pellet Axial Surface Roughness for 95% TD Stable Fuel at Three Locations 120° Apart. Each Minor Division = 50 μ in.

---

*AA = Arithmetic Average

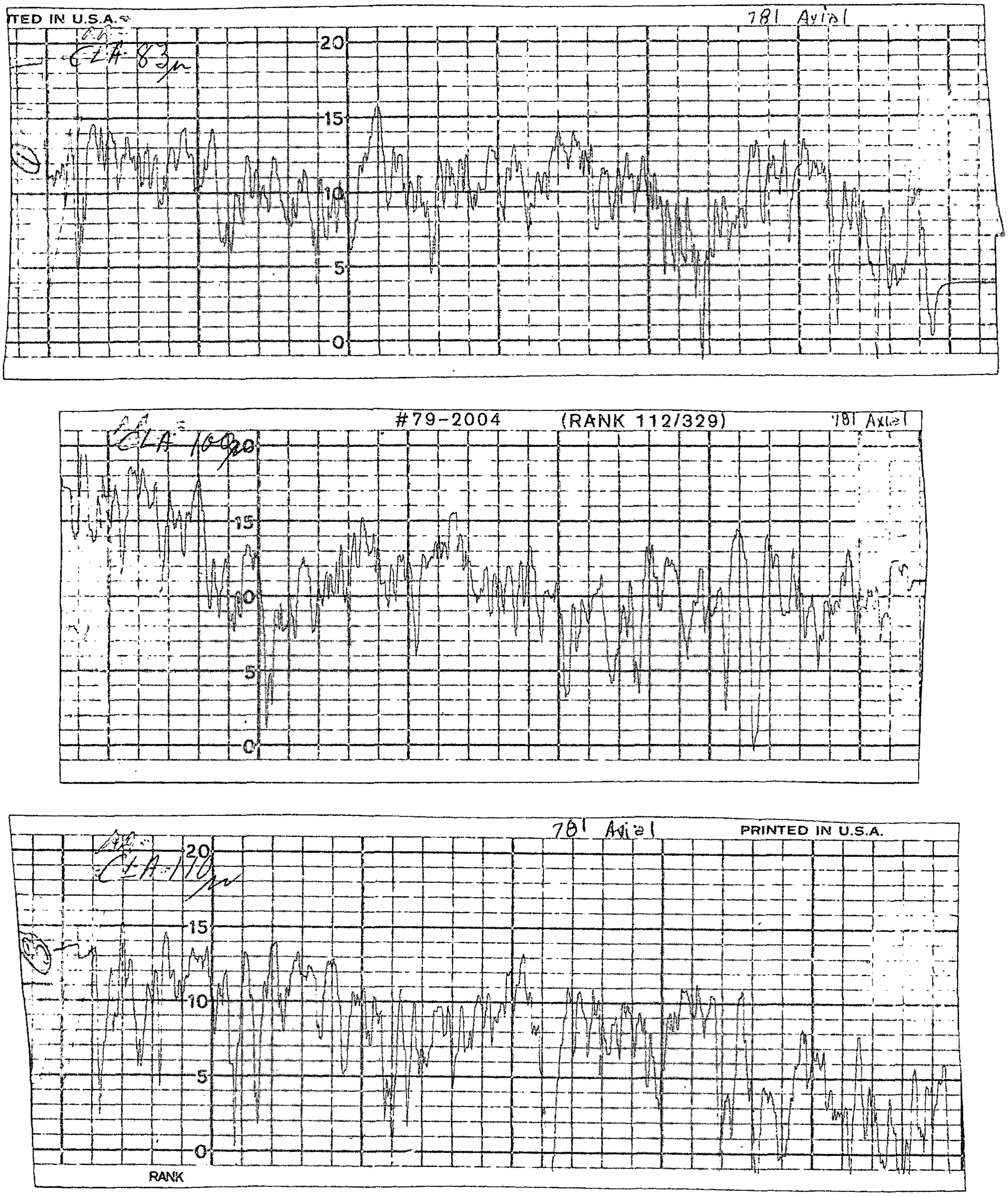


FIGURE H-8. Fuel Pellet Axial Surface Roughness for 92% TD Stable Fuel at Three Locations 120° Apart. Each Minor Division = 50 μ in.

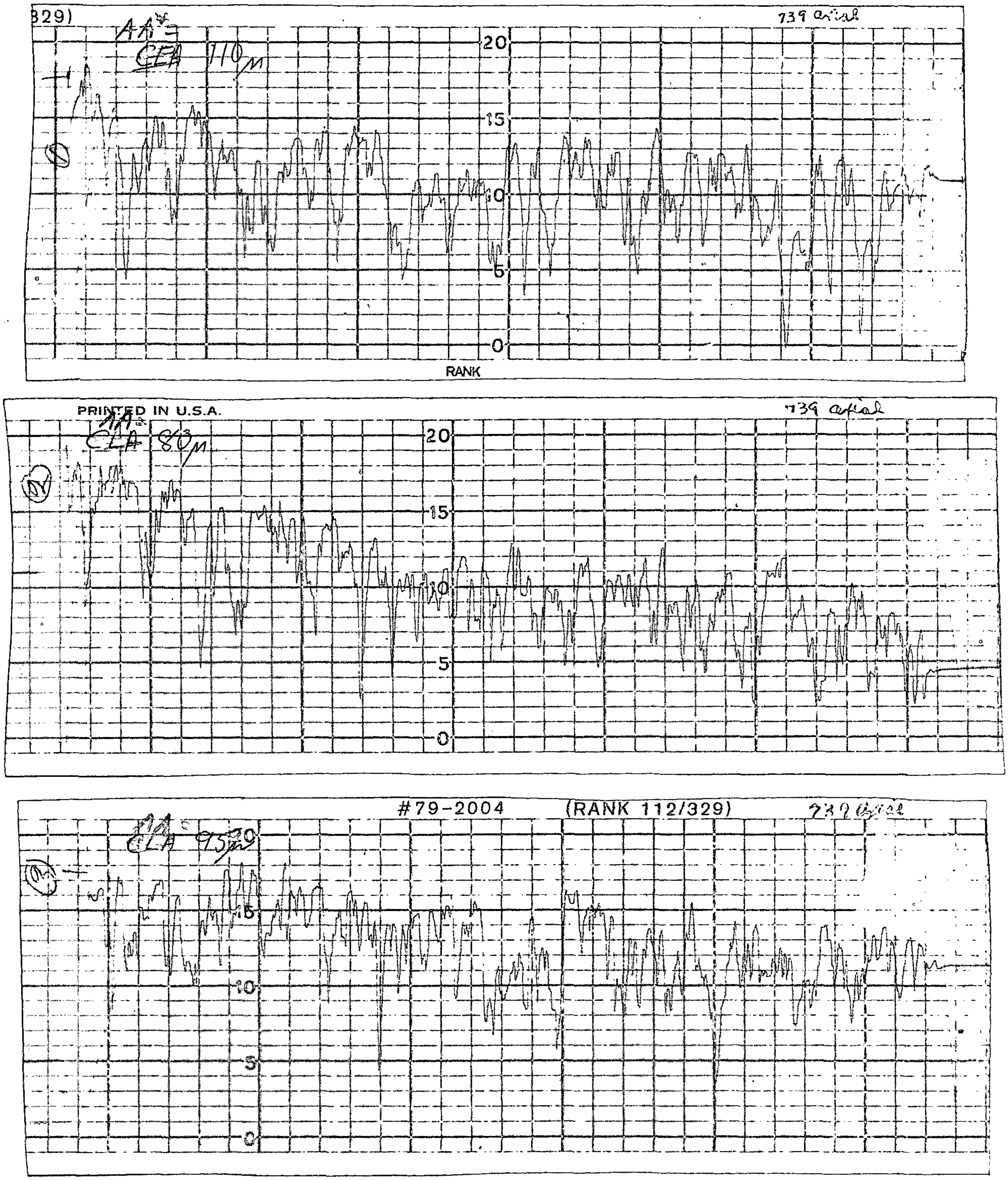


FIGURE H-9. Fuel Pellet Axial Surface Roughness for 92% TD Unstable Fuel at Three Locations 120° Apart. Each Minor Division = 50 μ in.

---

*AA = Arithmetic Average

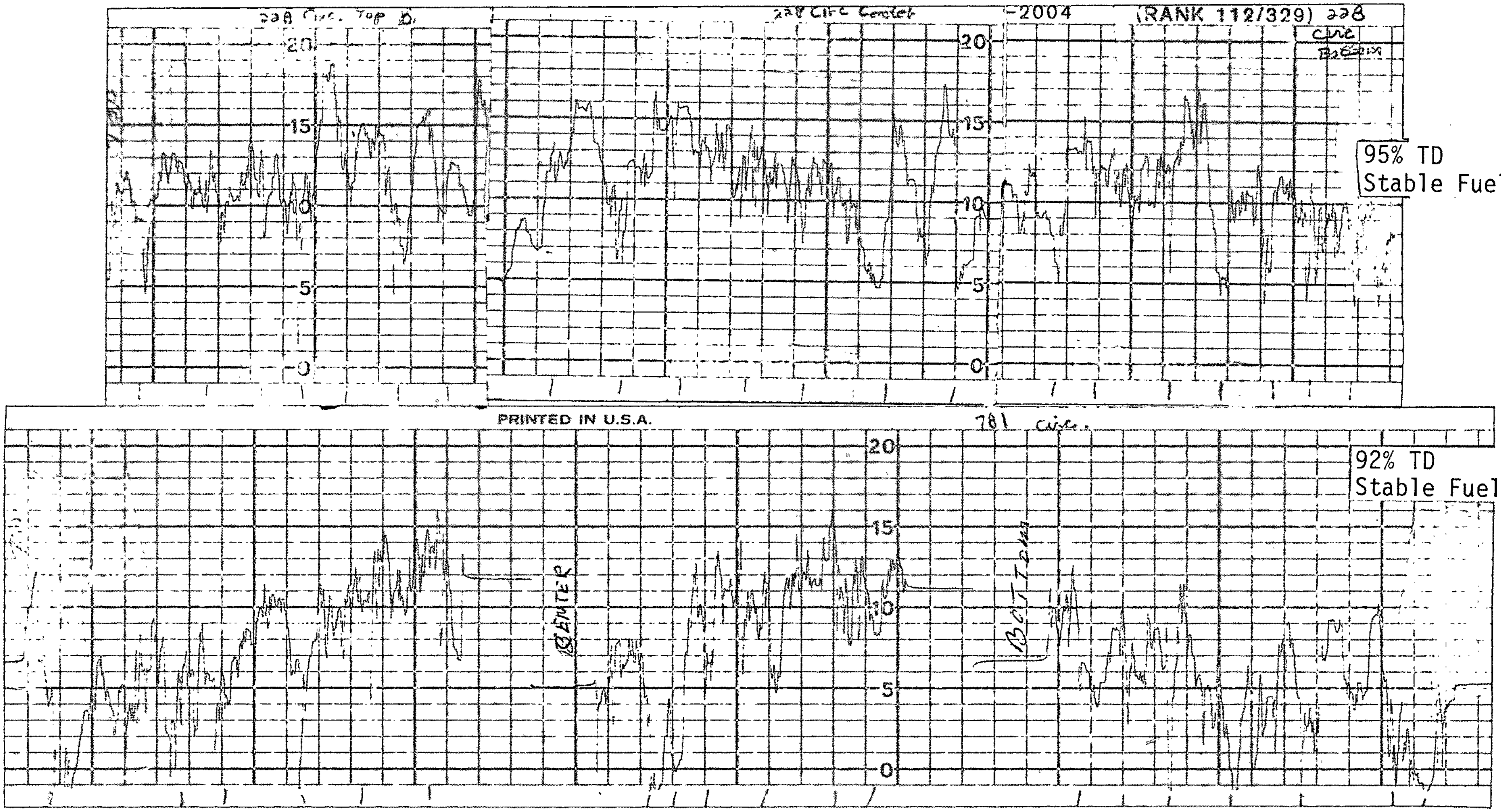


FIGURE H-10. Fuel Pellet Circumferential Surface Roughness for 95% and 92% TD Stable Fuel and for 92% TD Unstable Fuel. Each Minor Division = μ in.

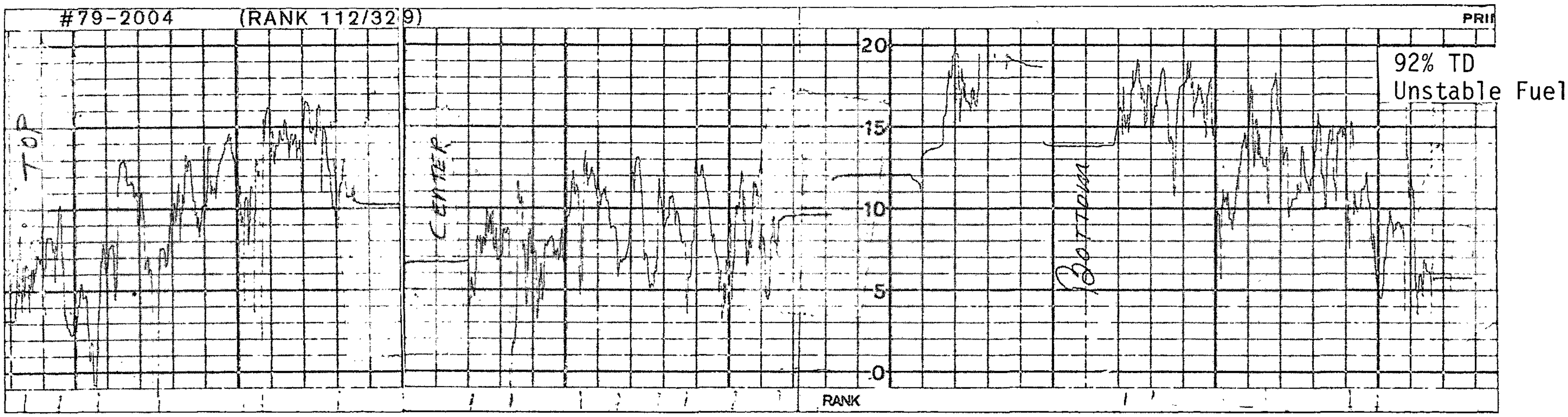


FIGURE H-10. (Contd)

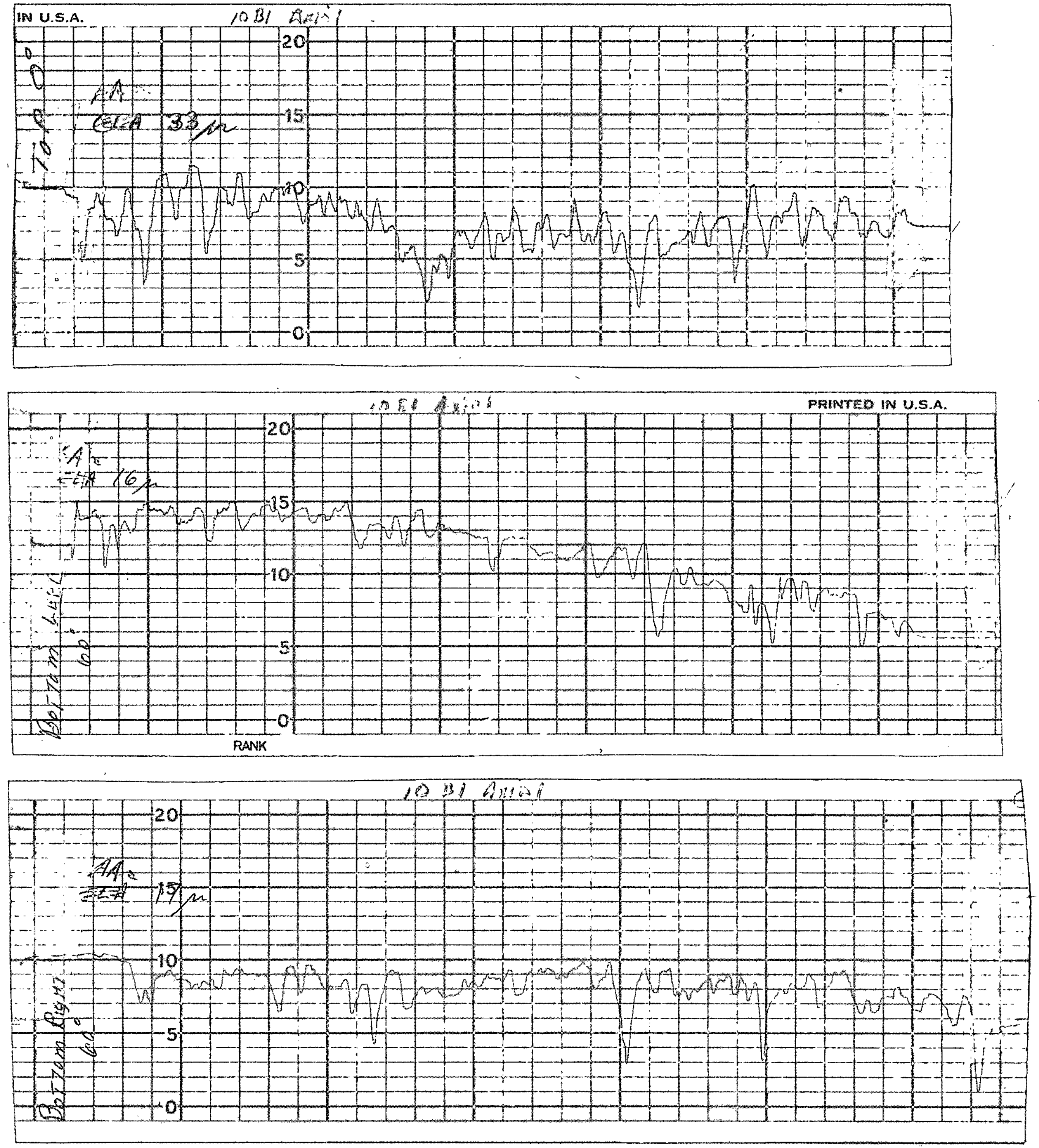
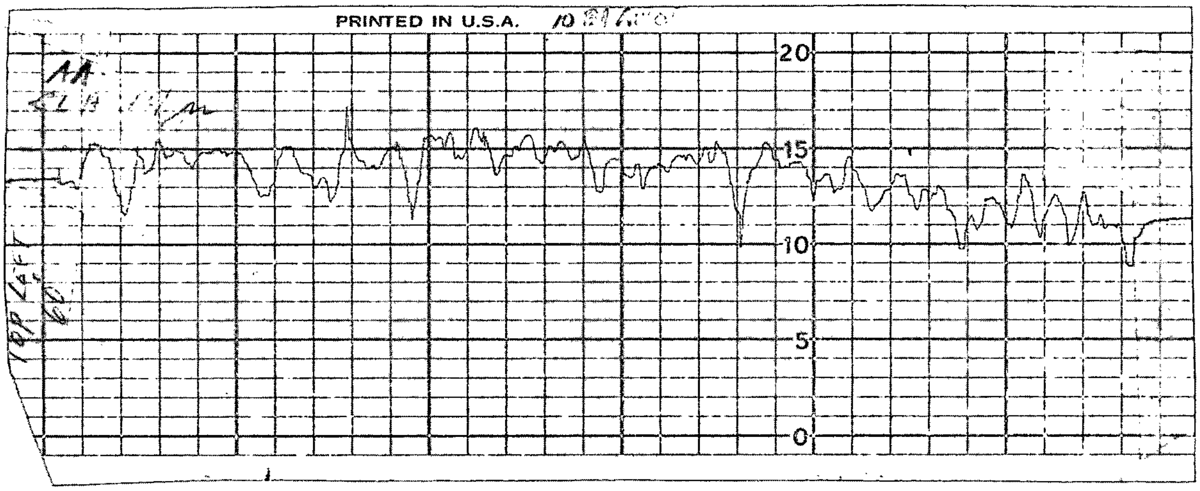
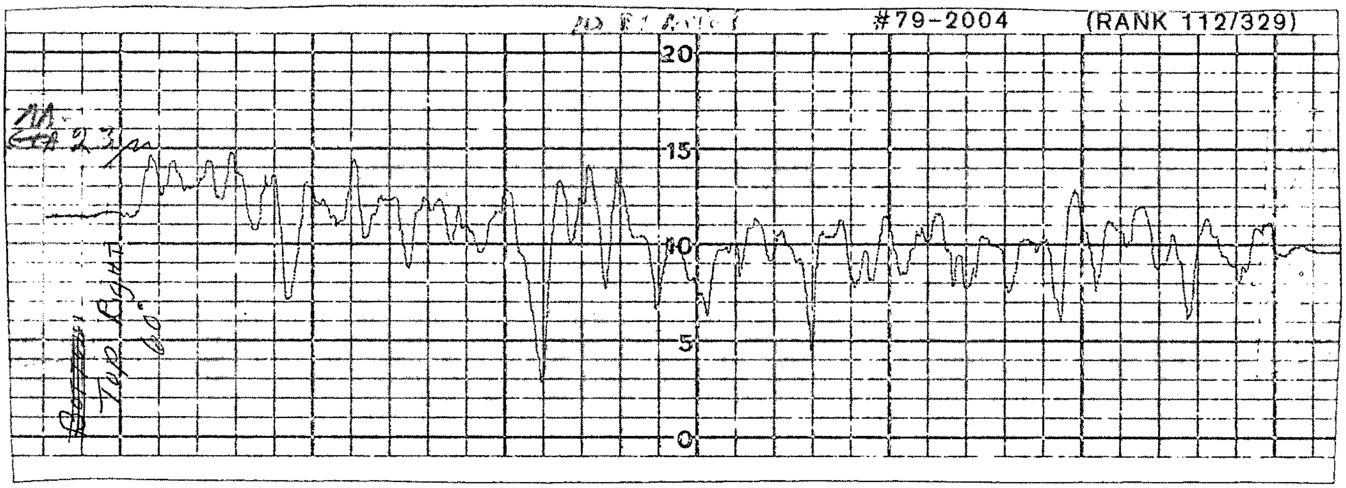


FIGURE H-11. Cladding Axial Surface Roughness at Six Locations. Cladding No. 10B, Half Section 1. Each Minor Division = 20 μ in.

*AA = Arithmetic Average





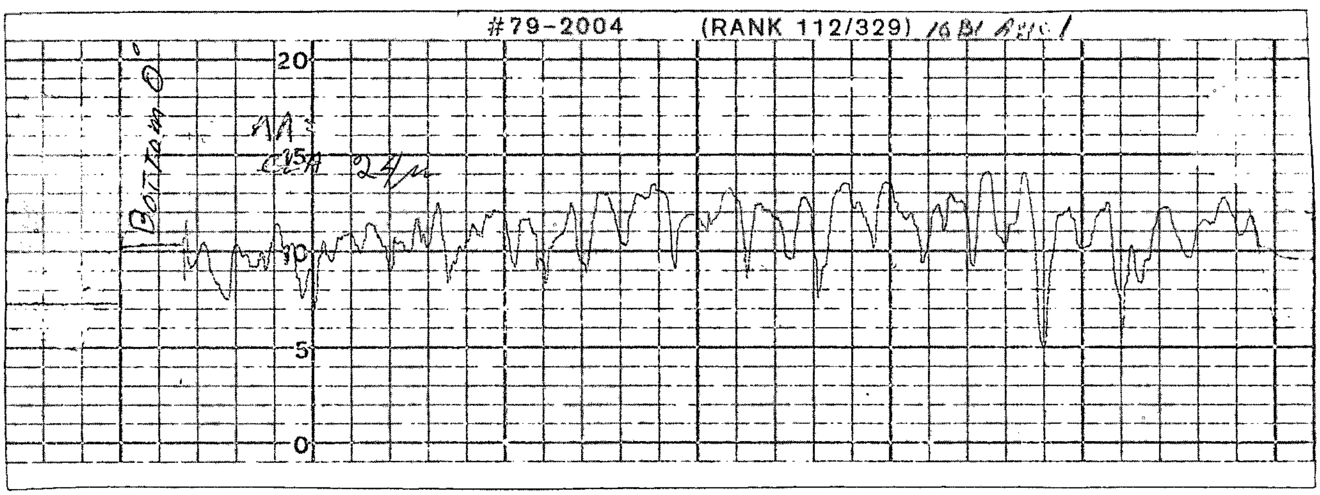


FIGURE H-11. (Contd)

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*AA = Arithmetic Average

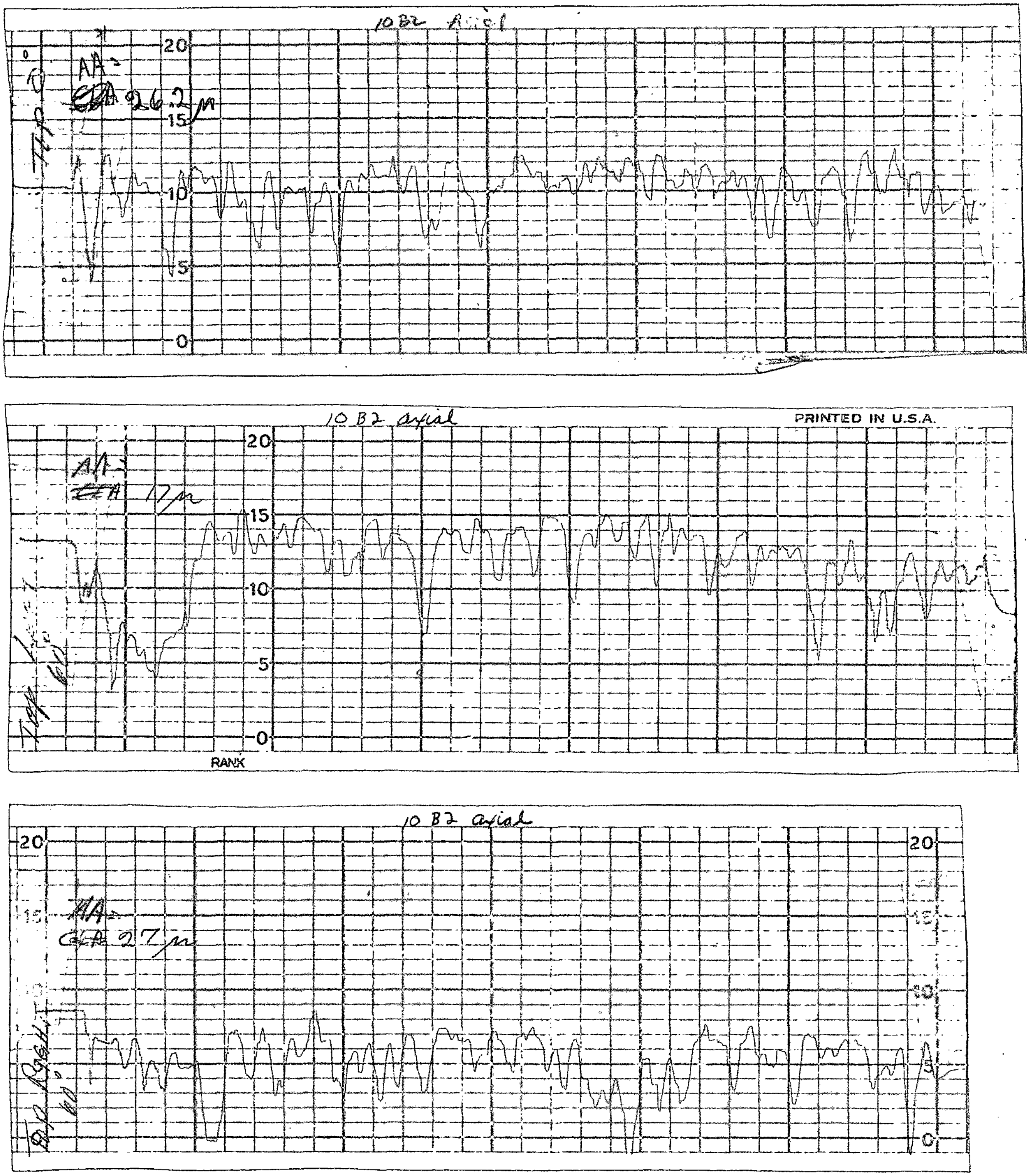

FIGURE H-12. Cladding Axial Surface Roughness at Six Locations. Cladding No. 10B, Half Section 2. Each Minor Division = 20 μ in.

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*AA = Arithmetic Average

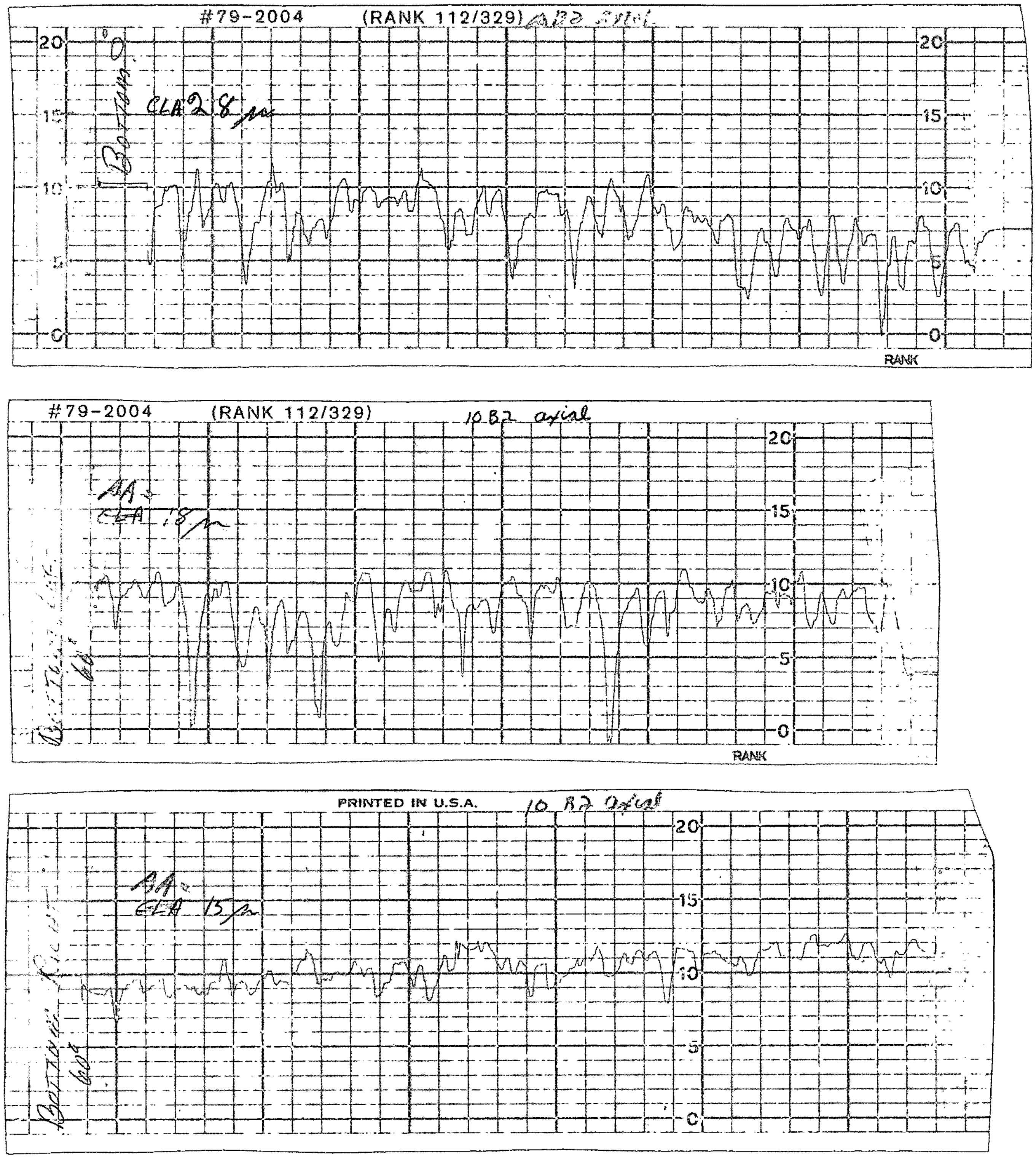

FIGURE H-12. (Contd)

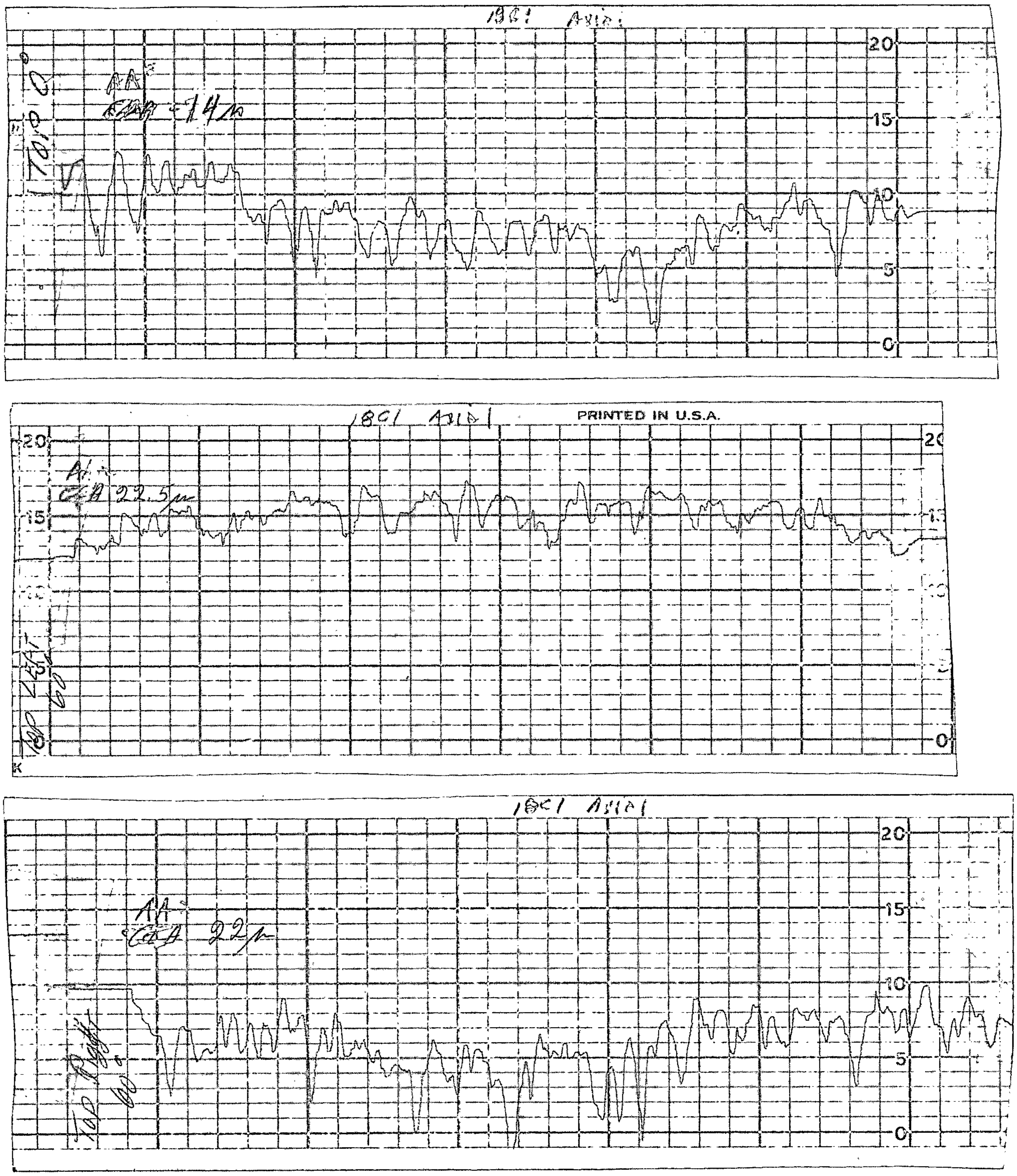

FIGURE H-13. Cladding Axial Surface Roughness at Six Locations. Cladding No. 18C, Half Section 1. Each Minor Division = 20 μ in.

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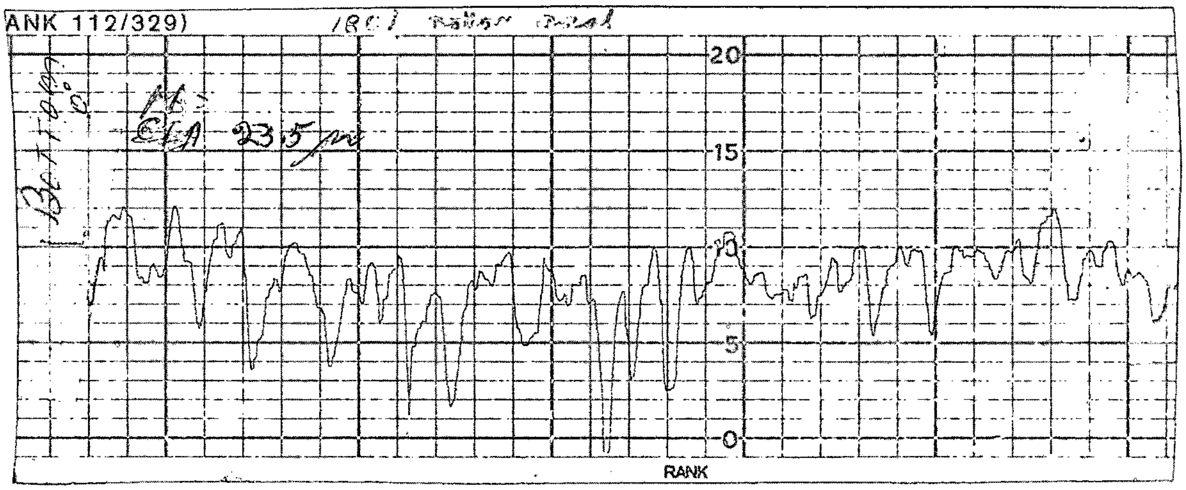
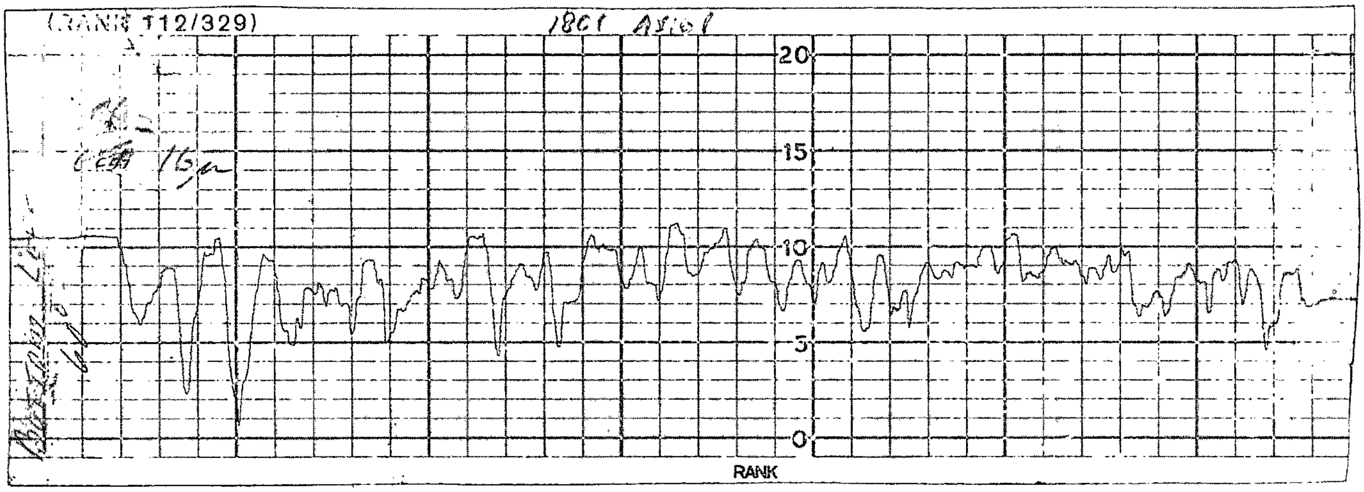
*AA = Arithmetic Average





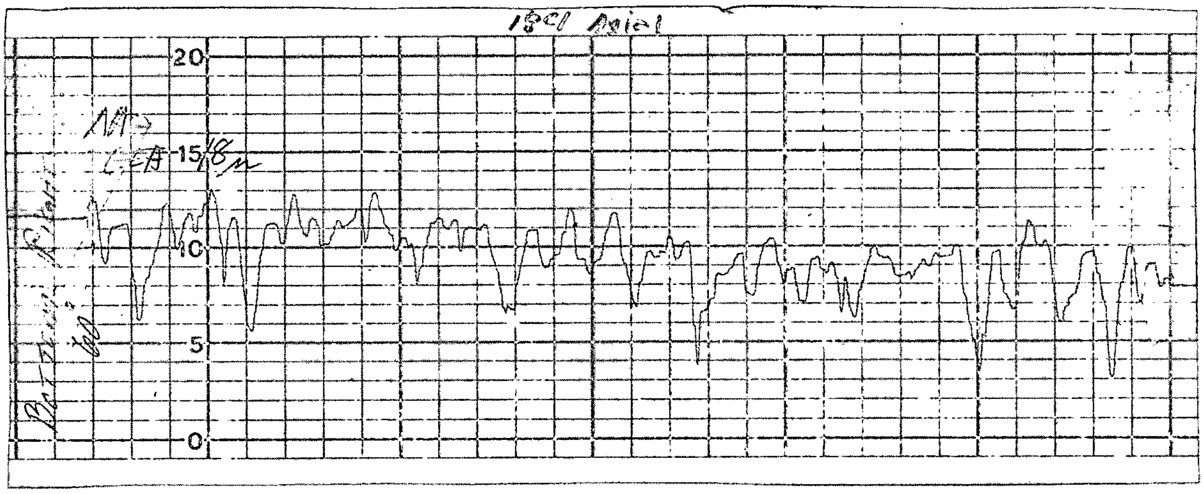


FIGURE H-13. (Contd)

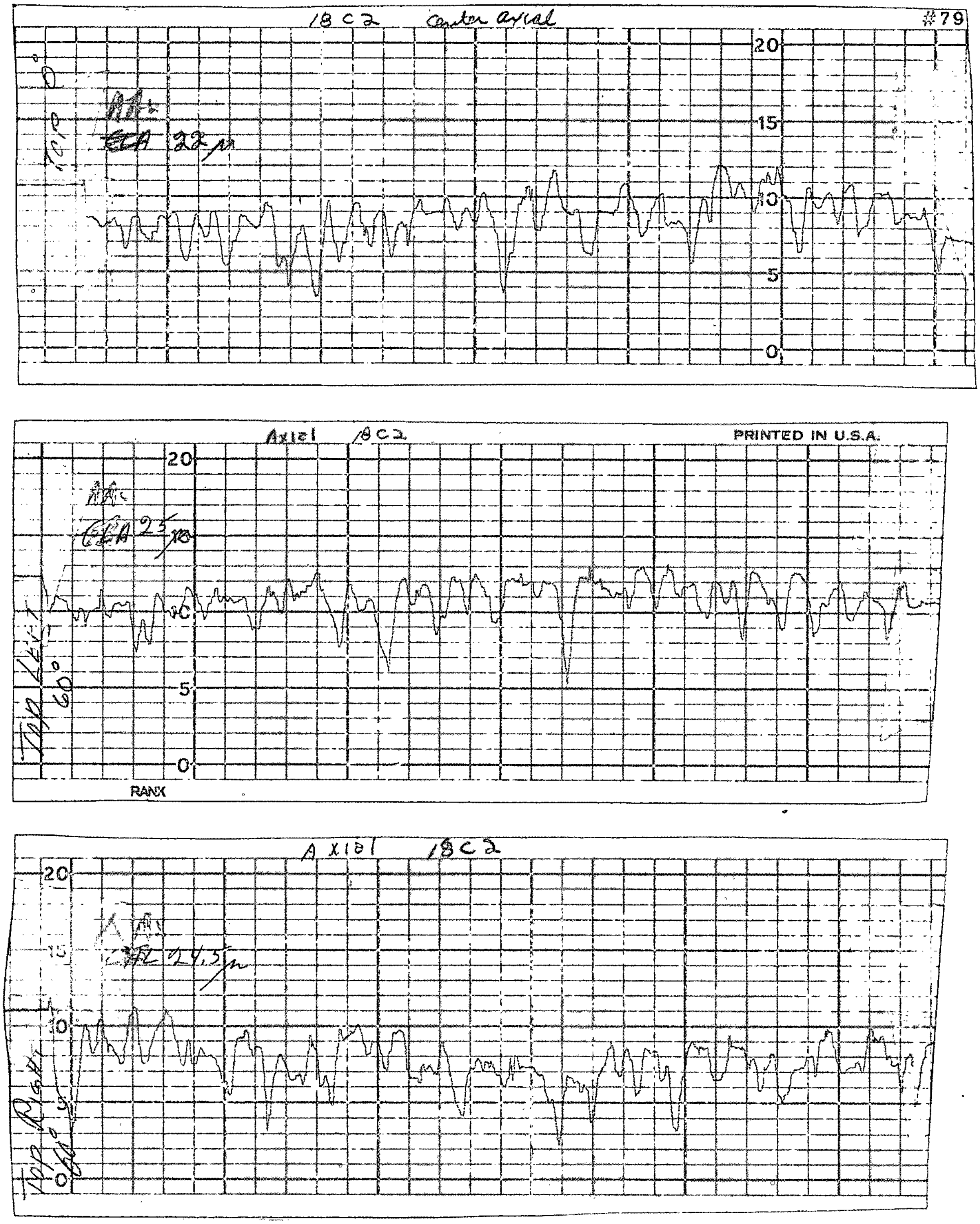


FIGURE H-14. Cladding Axial Surface Roughness at Six Locations. Cladding No. 18C, Half Section 2. Each Minor Division = 20 μ in.

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*AA = Arithmetic Average

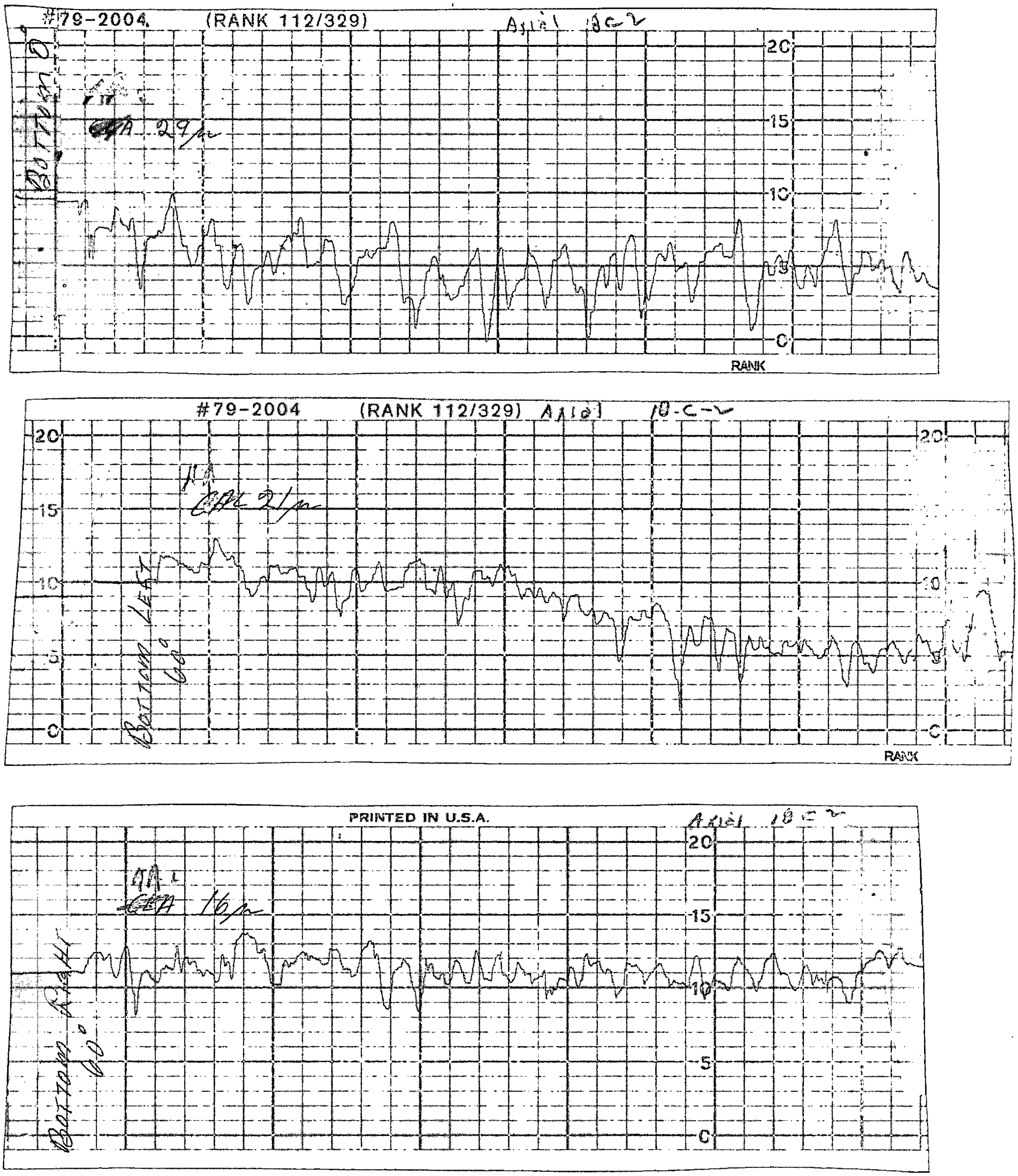

FIGURE H-14. (Contd)

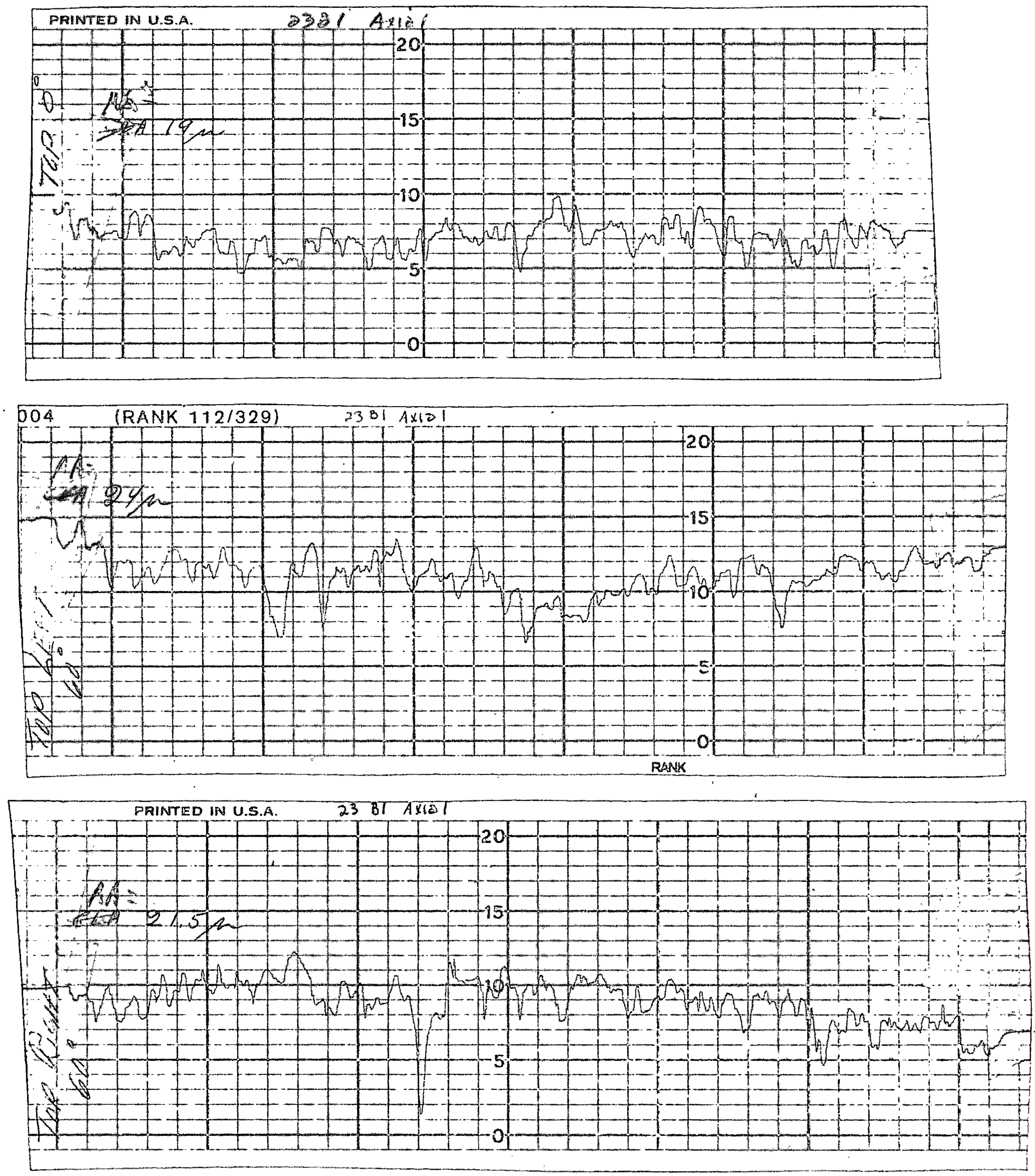

FIGURE H-15. Surface Roughness at Six Locations. Tubing No. 23B, Half Section 1. Each Minor Division = 20 μ in.

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*AA = Arithmetic Average

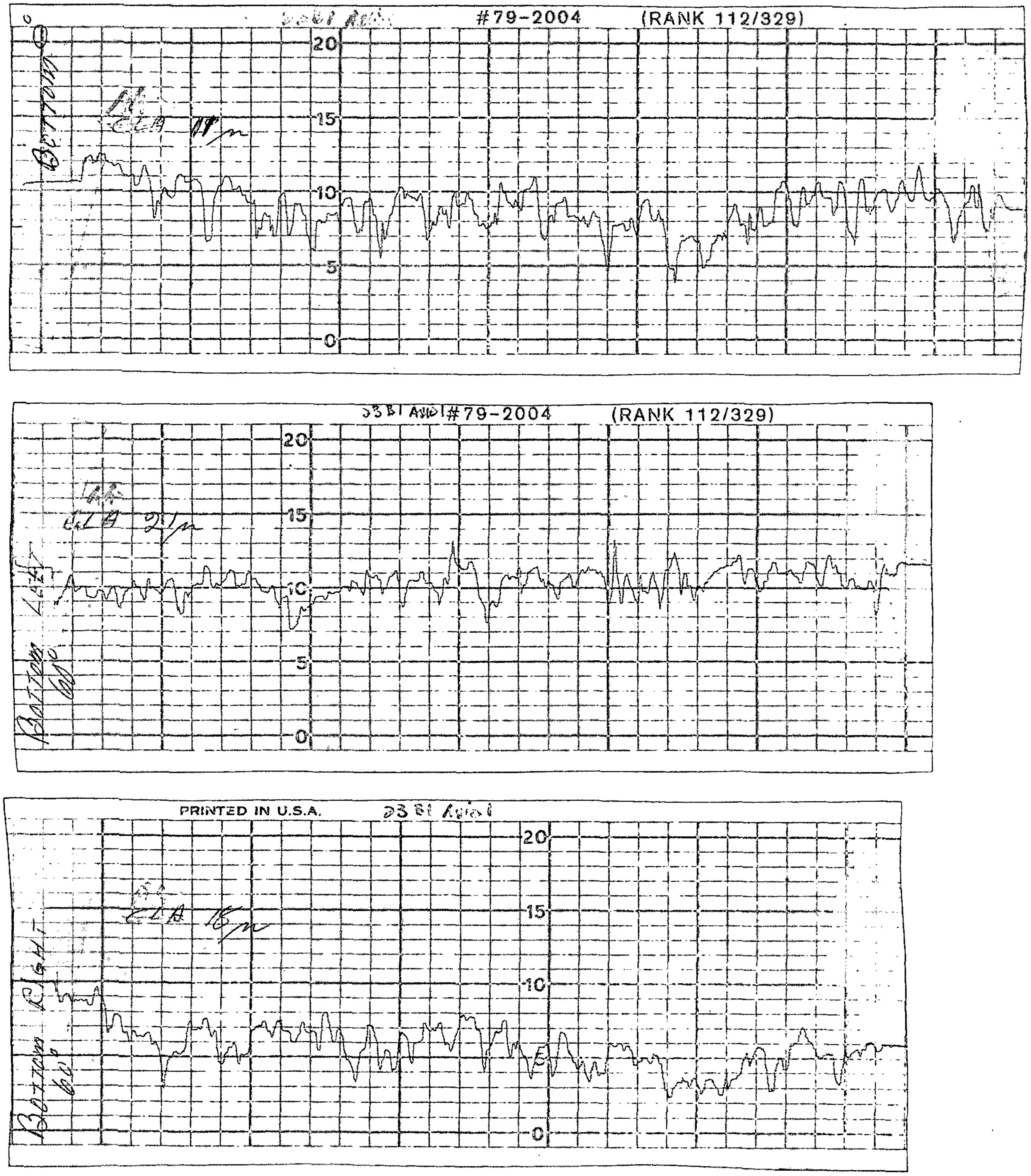


FIGURE H-15. (Contd)

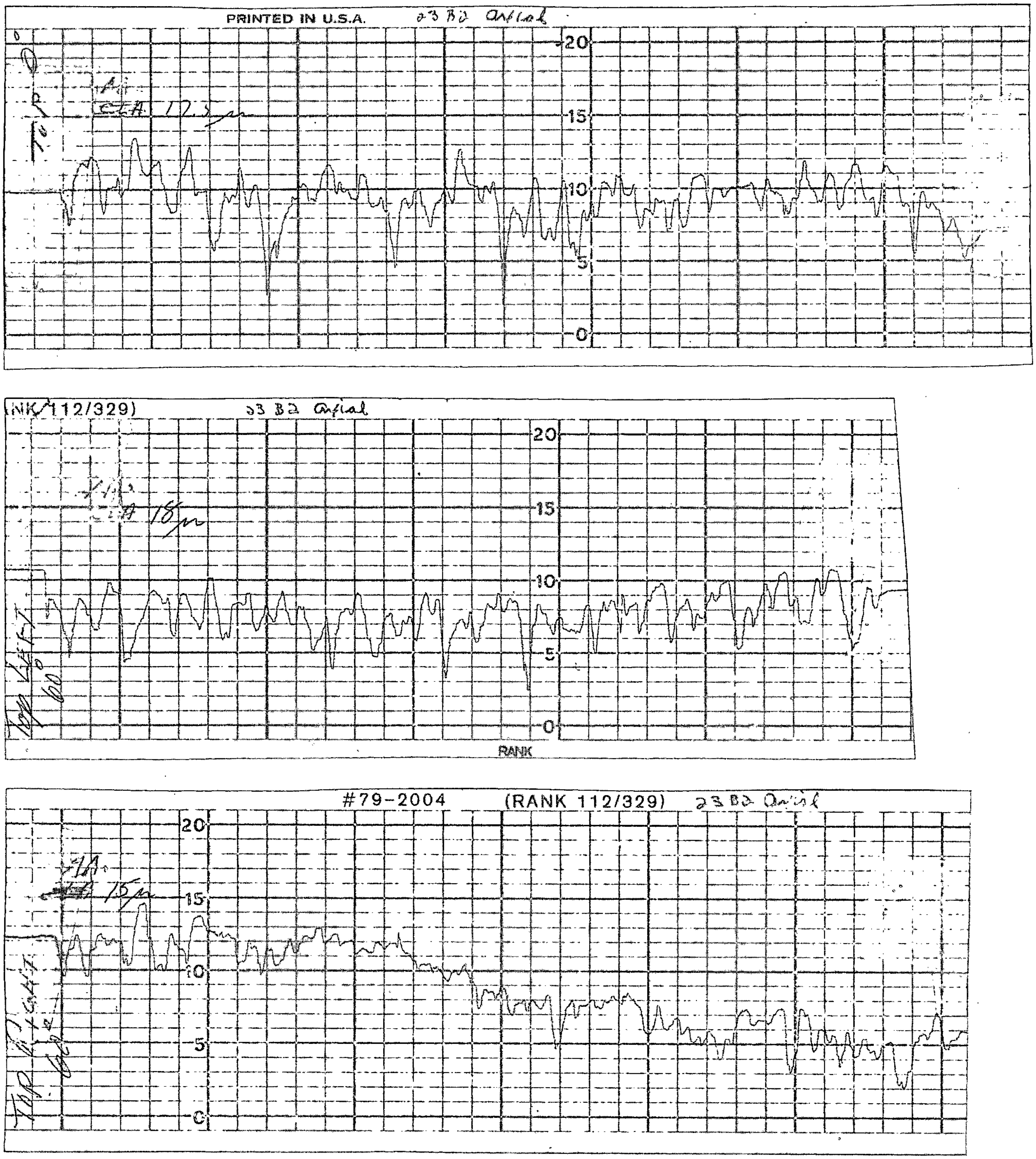


FIGURE H-16. Cladding Axial Surface Roughness at Six Locations. Tubing No. 23B, Half Section 2. Each Minor Division = 20 μ in.

---

*AA = Arithmetic Average

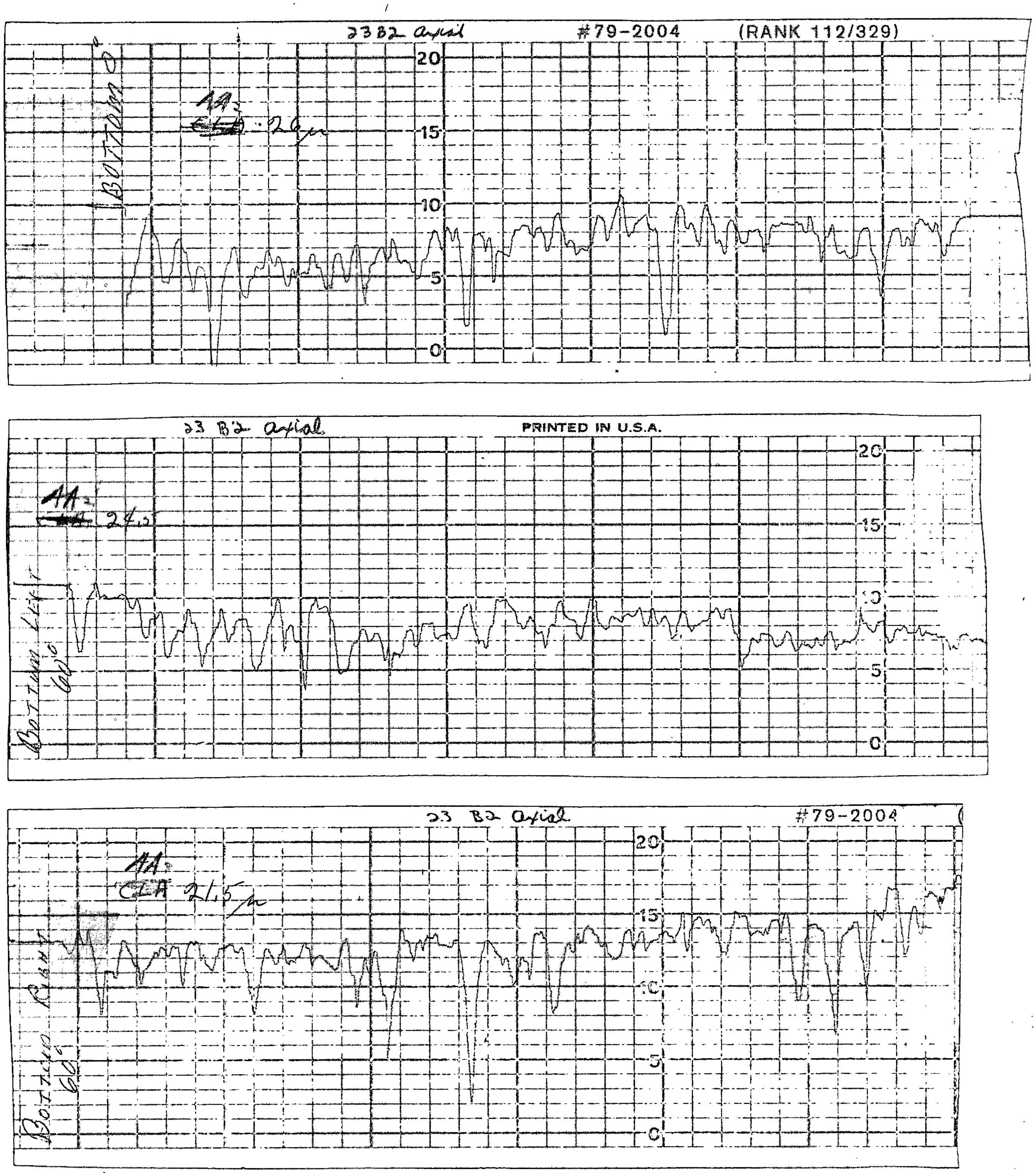


FIGURE H-16. (Contd)

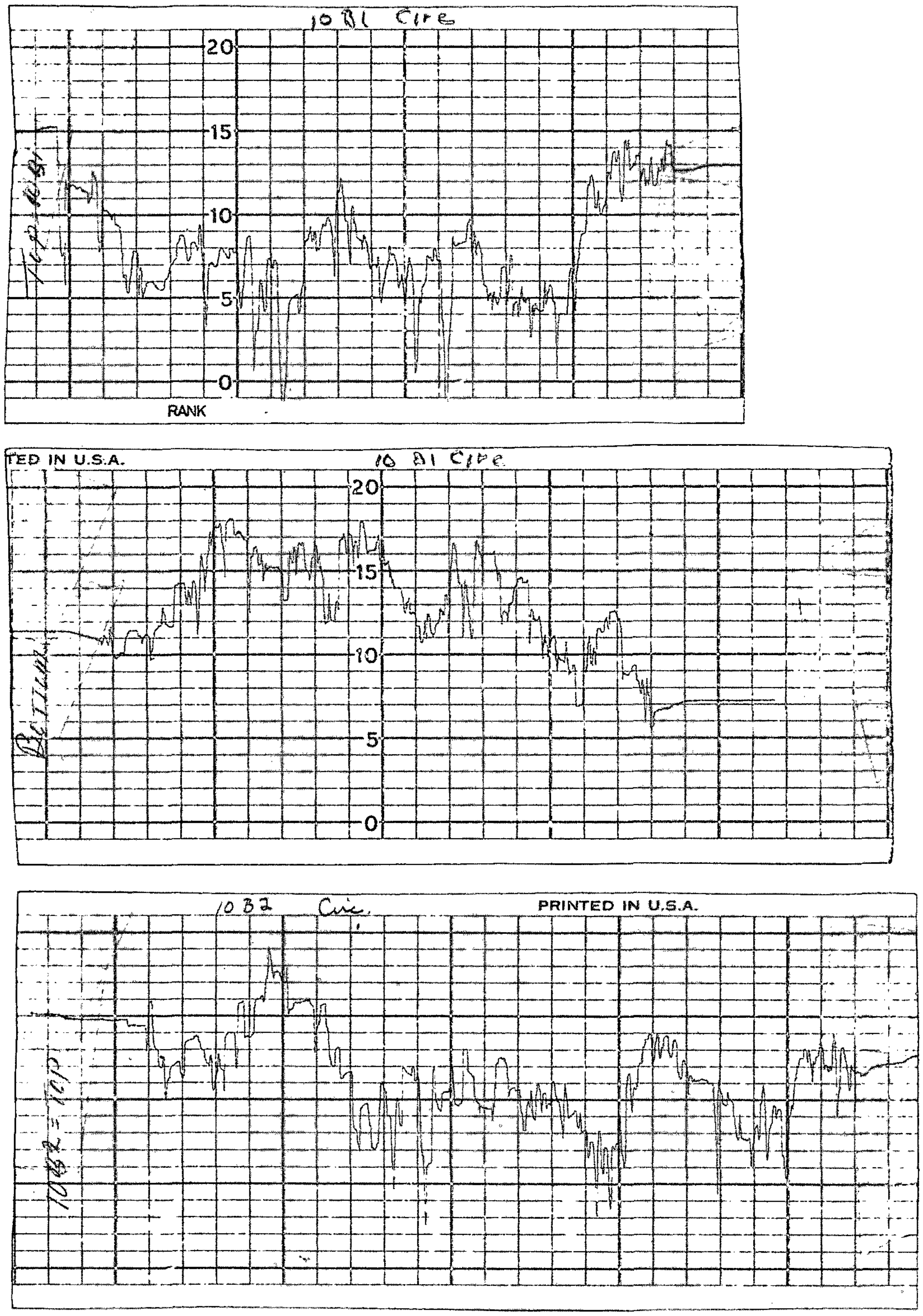


FIGURE H-17. Cladding Circumferential Surface Roughness at Four Locations. Cladding No. 10B. Each Minor Division = 20 μ in.

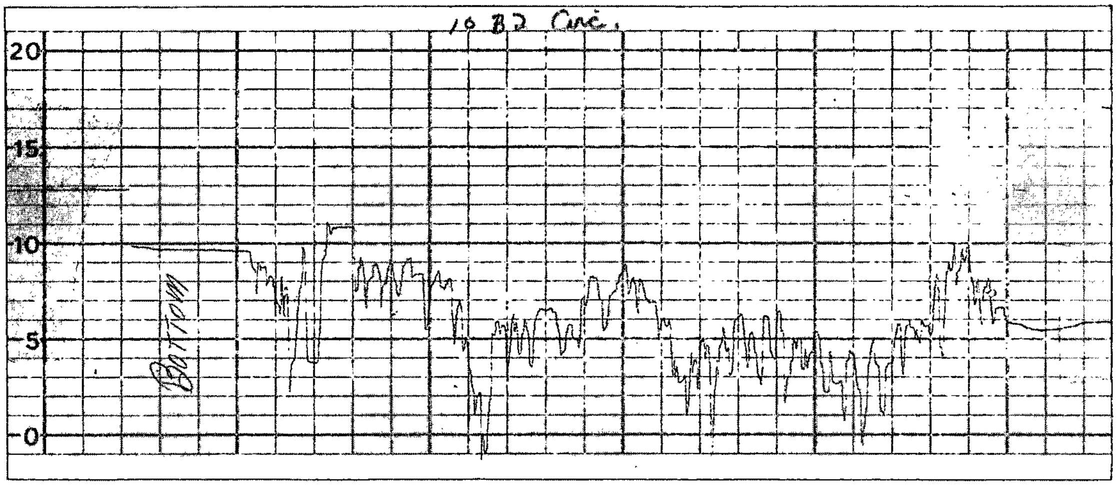


FIGURE H-17. (Contd)

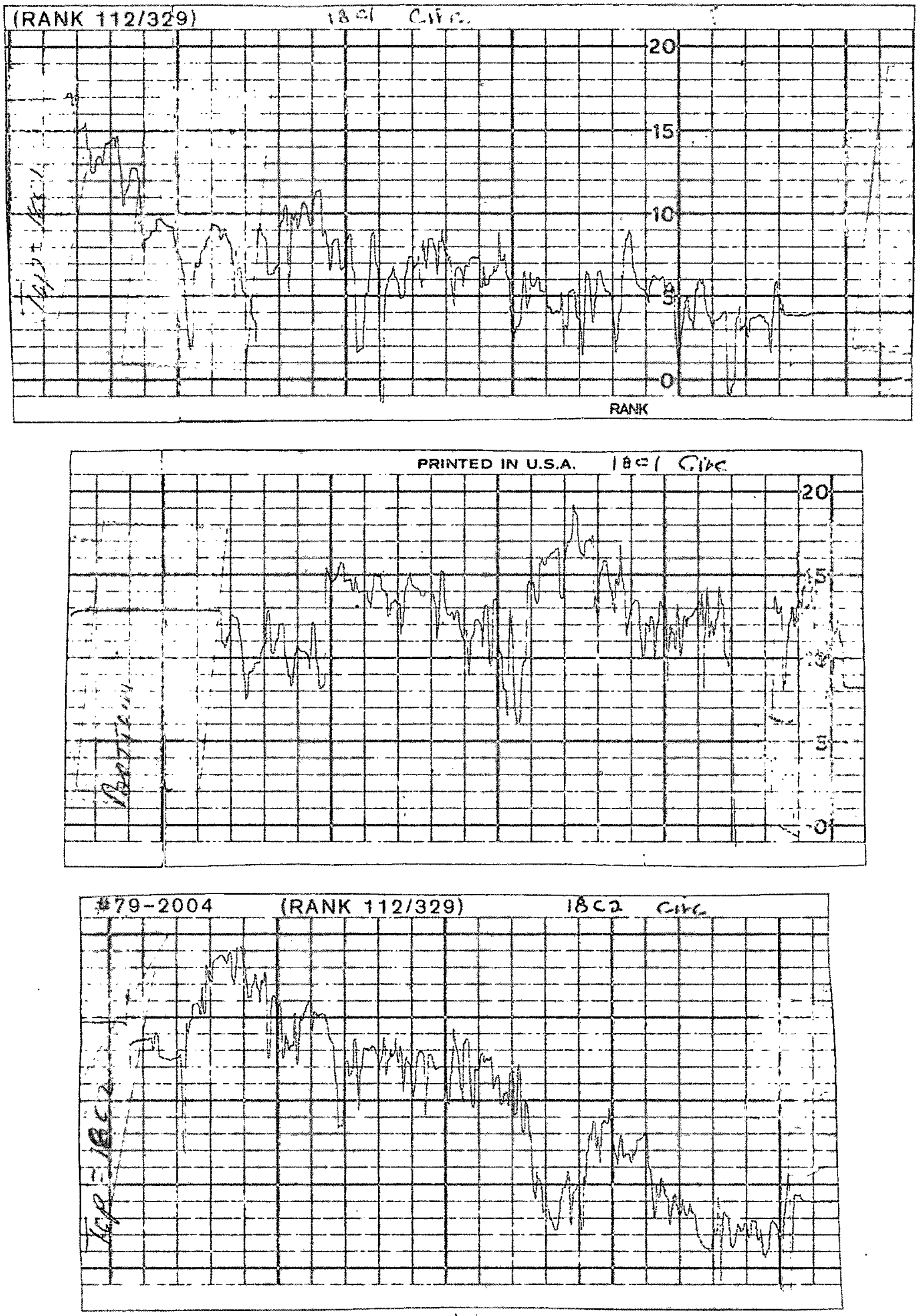


FIGURE H-18. Cladding Circumferential Surface Roughness at Four Locations, Cladding No. 18C. Each Minor Division = 20 μ in.

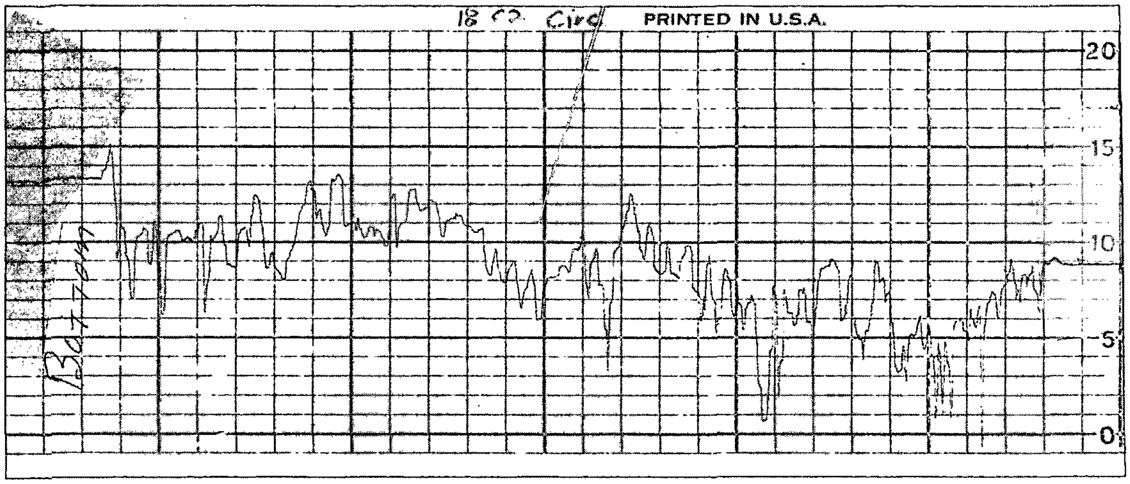


FIGURE H-18. (Contd)

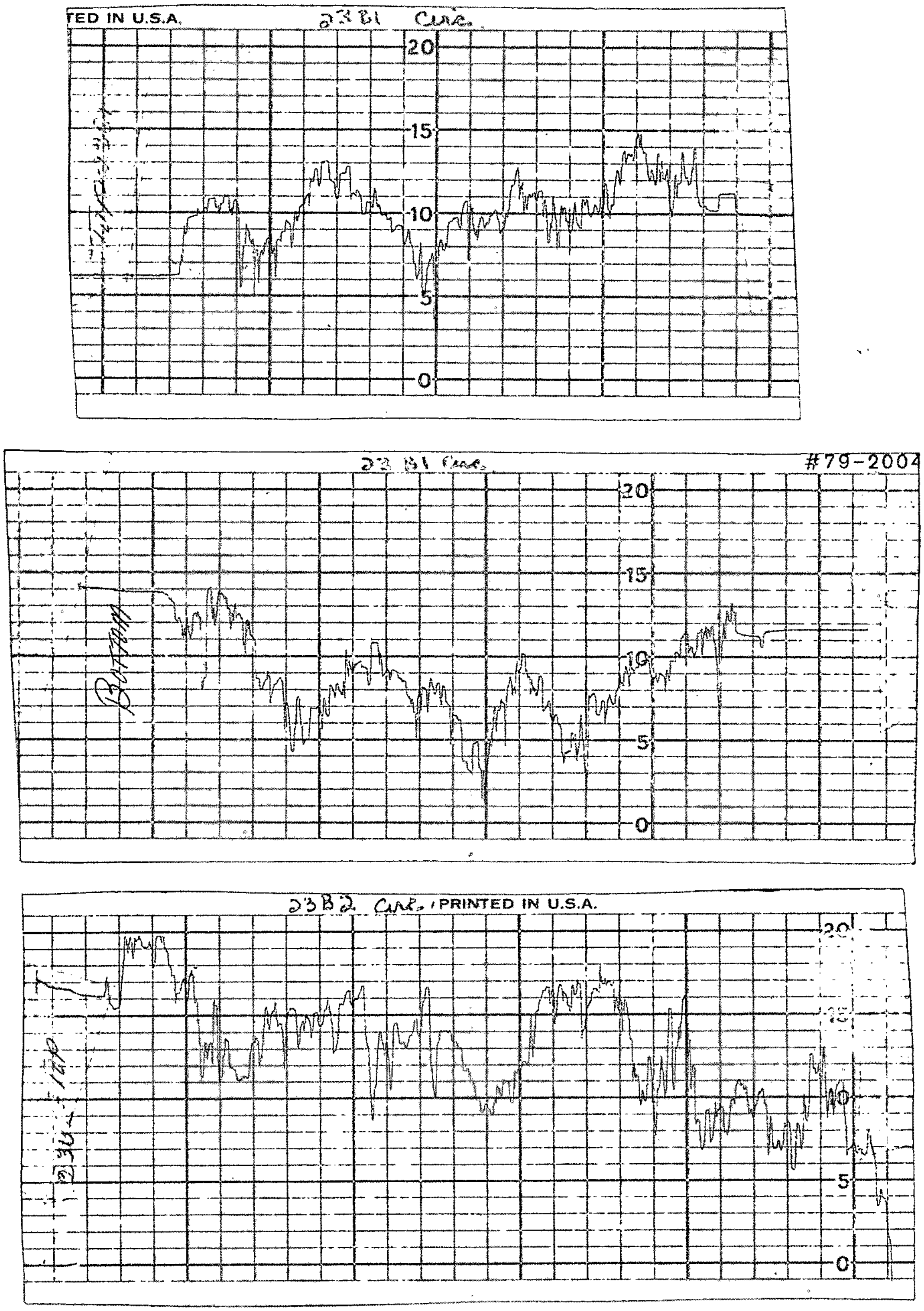


FIGURE H-19. Cladding Circumferential Surface Roughness at Four Locations, Cladding No. 23B. Each Minor Division = 20 μ in.

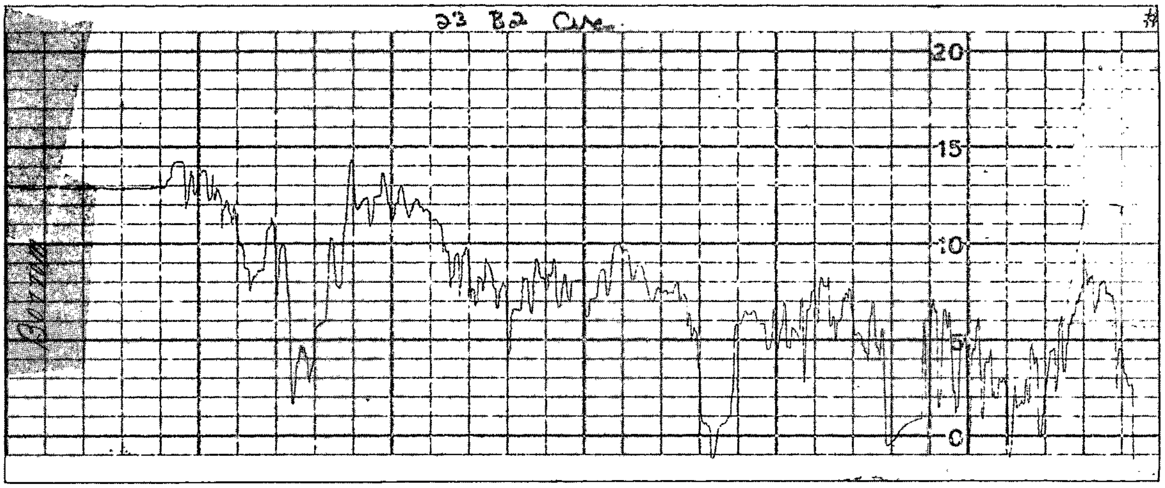
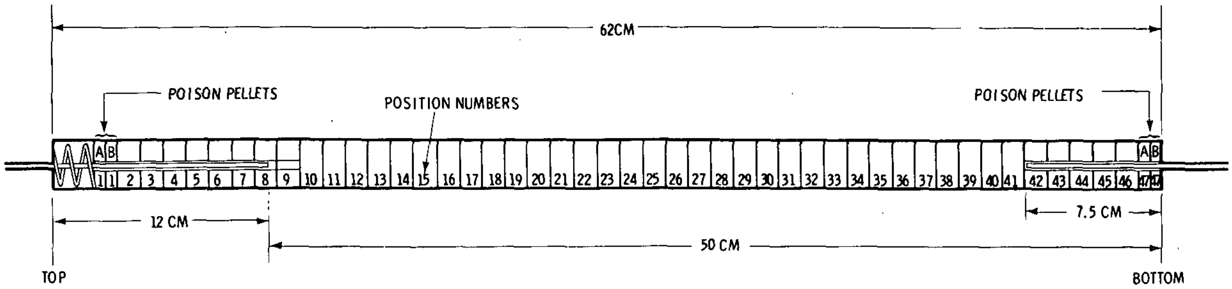


FIGURE H-19. (Contd)



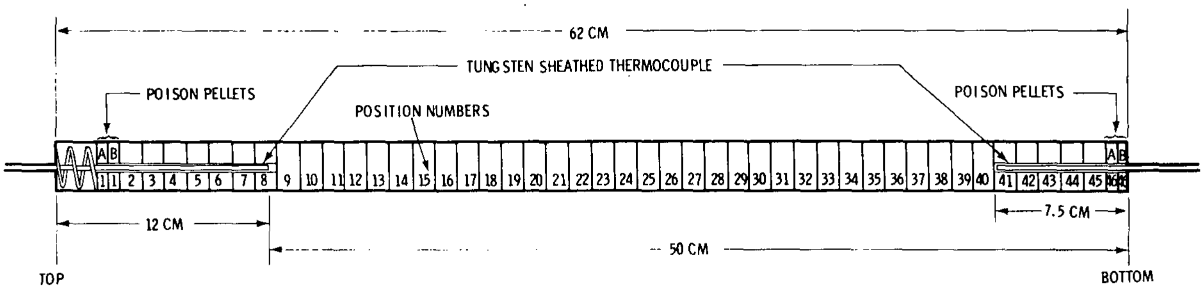
TOTAL NUMBER OF PELLETS IN EACH STACK - 49

NUMBER OF FUEL PELLETS - 45 32 SOLID, 13 DRILLED - 0.175 CM ± 0.005 CM (0.069 ± 0.002 INCH) FURNISHED BY BNW

NUMBER OF POISON PELLETS - 4 DRILLED - 0.175 CM ± 0.005 CM (0.069 ± 0.002 INCH) FURNISHED BY HALDEN

ROD NO.	PELLET DIAMETER IFA-431 CM (inch)	PELLET DIAMETER IFA-432 CM (inch)	FUEL DENSITY % TD	FUEL TYPE	FILL GAS 1 ATM
1	1.0681 (0.4205)	1.0681 (0.4205)	95	STABLE	HELIUM
6	1.0681 (0.4205)	1.0681 (0.4205)	92	UNSTABLE	HELIUM

FIGURE I-1. Stacking Arrangement for Rods 1 and 6



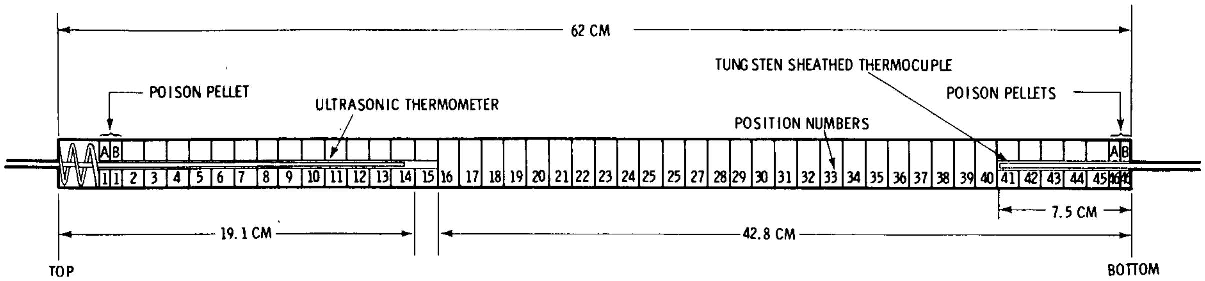
TOTAL NUMBER OF PELLETS IN EACH STACK - 48

NUMBER OF FUEL PELLETS - 44 32 SOLID, 12 DRILLED - 0.175 ± 0.005 CM (0.069 ± 0.002 INCH) FURNISHED BY BNW

NUMBER OF POISON PELLETS - 4 DRILLED - 0.175 ± 0.005 CM (0.069 ± 0.002 INCH) FURNISHED BY HALDEN

ROD NO.	PELLET DIAMETER IFA-431 CM (inch)	PELLET DIAMETER IFA-432 CM (inch)	FUEL DENSITY % TD	FUEL TYPE	FILL GAS 1 ATM
2	1.0528 (0.4145)	--	95	STABLE	HELIUM
3	1.0858 (0.4275)	1.0833 (0.4265)	95	STABLE	HELIUM
5	1.0681 (0.4205)	1.0681 (0.4205)	92	STABLE	HELIUM

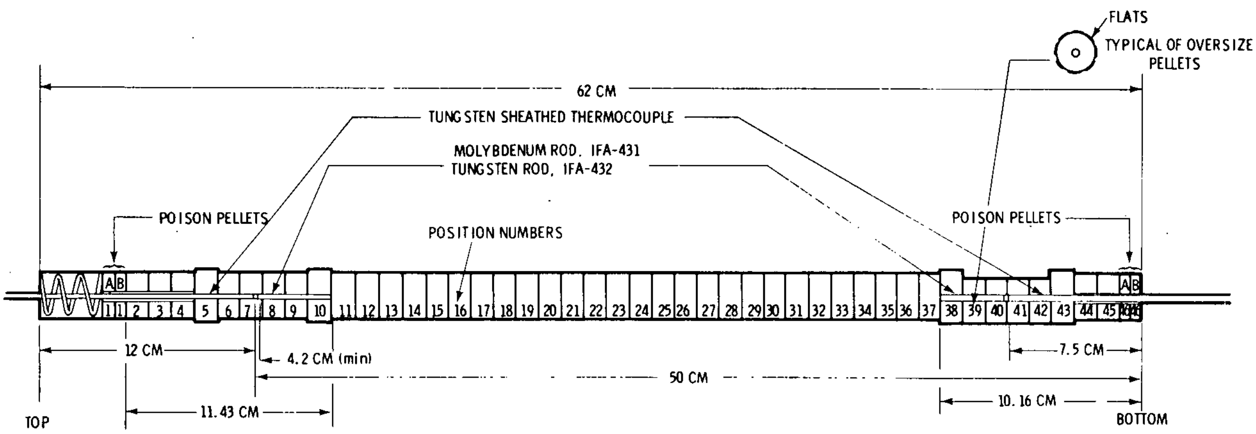
FIGURE I-2. Stacking Arrangement for Rods 2, 3, and 5



TOTAL NUMBER OF PELLETS IN EACH STACK -	48	
NUMBER OF FUEL PELLETS -	44	32 SOLID, 12 DRILLED - 0.175 ± 0.005 CM (0.069 ± 0.002 INCH) FURNISHED BY BNW
NUMBER OF POISON PELLETS -	4	DRILLED - 0.175 ± 0.005 CM (0.069 ± 0.002 INCH) FURNISHED BY HALDEN

ROD NO.	PELLET DIAMETER IFA-432 CM(INCH)	FUEL DENSITY % TD	FUEL TYPE	FILL GAS 1 ATM
2	1.0528 (0.4145)	95	STABLE	HELIUM

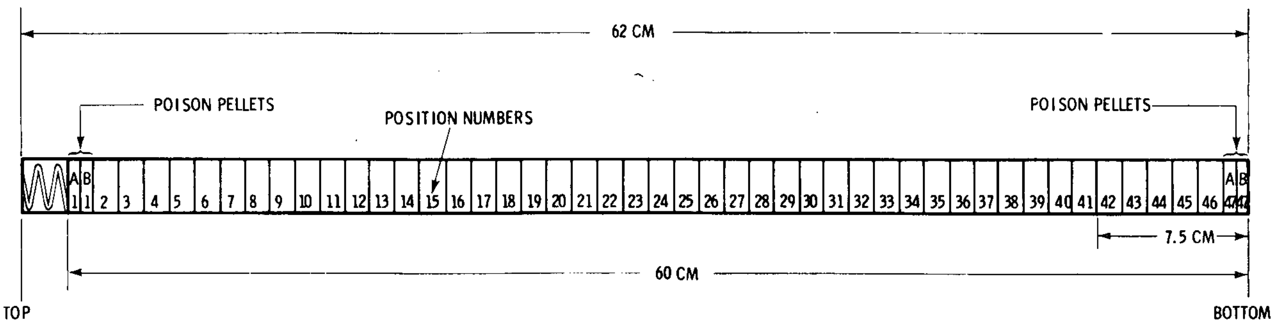
FIGURE I-3. Stacking Arrangement for Rod 2, IFA-432



TOTAL NUMBER OF PELLETS IN STACK -	48	
NUMBER OF FUEL PELLETS -	44	27 SOLID, 17 DRILLED (FURNISHED BY BNW), 95% TD, STABLE
NUMBER OF POISON PELLETS -	4	DRILLED - 0.175 ± 0.005 CM (0.069 ± 0.002 INCH) (FURNISHED BY HALDEN)
FILL GAS -	1	ATM XENON

PELLET POSITION	PELLET DIAMETER IFA-431 CM (inch)	PELLET DIAMETER IFA-432 CM (inch)	HOLE DIAMETER CM (inch)	ON CENTER	0.0127 CM (0.005 INCH) OFF CENTER
12-38	1.0681 (0.4205)	1.0681 (0.4205)	--	--	--
3-5 45-46	1.0681 (0.4205)	1.0681 (0.4205)	0.175 ± 0.005 (0.069 ± 0.002)	YES	--
7-10	1.0681 (0.4205)	1.0687 (0.4205)	0.160 ± 0.005 (0.063 ± 0.002)	YES	--
40-43	1.0681 (0.4205)	1.0681 (0.4205)	0.160 ± 0.005 (0.063 ± 0.002)	--	YES
6, 11, 39, 44	1.0858 (0.4275)	1.0833 (0.4265)	0.160 ± 0.005 (0.063 ± 0.002)	YES	--

FIGURE I-4. Stacking Arrangement for Rod 4



TOTAL NUMBER OF PELLETS IN EACH STACK - 49

NUMBER OF FUEL PELLETS - 45 FURNISHED BY BNW

NUMBER OF POISON PELLETS - 4 FURNISHED BY HALDEN

ROD NO.	PELLET DIAMETER IFA-432 CM (INCH)	FUEL DENSITY % TD	FUEL TYPE	FILL GAS 1 ATM
7	1.0528 (0.4145)	95	STABLE	HELIUM
8	1.0681 (0.4205)	95	STABLE	HELIUM
9	1.0732 (0.4225)	95	STABLE	HELIUM

FIGURE I-5. Stacking Arrangement for IFA-432 Replacement Rods 7, 8, and 9

HALDEN TEST-FUEL COLUMN DATA - IFA-431

Rod No.: 1

Fuel Column Weight: 529.240 grams   Exclusive of poison pellets and replacement pellet

Fuel Column Length: 22.590 in.

Pellet Position	Pellet Ident.	Remarks	Pellet Position	Pellet Ident.	Remarks
1	21/2	poison pellet-top	25	432	
2	167		26	364	I.D
3	10		27	355	
4	158		28	300	
5	171		29	342	I.D
6	84		30	366	
7	163	I.D	31	375	
8	152	I.D	32	457	I.D
9	381	I.D Replaced	33	394	
10	395		34	295	
11	344		35	405	I.D
12	294	I.D	36	445	
13	392		37	347	
14	451		38	350	I.D
15	456		39	397	I.D
16	410		40	365	
17	415		41	361	I.D
18	404	I.D	42	88	I.D
19	343		43	79	I.D
20	430		44	153	
21	341		45	2	
22	362	I.D	46	82	
23	423		47	2x1/2	poison pellet
24	421		Extra	13	used in pos. 9

HALDEN TEST-FUEL COLUMN DATA - IFA-431

Rod No.: 2

Fuel Column Weight: 516.307 grams — Exclusive of poison pellets and replacement pellets

Fuel Column Length: 22.630 in.

Pellet Position	Pellet Ident.	Remarks	Pellet Position	Pellet Ident.	Remarks
1	1x1/2	poison pellet-top	25	50	
2	329		26	288	I.D
3	337		27	218	
4	315		28	206	
5	302		29	287	I.D
6	316		30	23	
7	306	I.D	31	202	
8	317	I.D	32	34	I.D
9	282	I.D Replaced	33	261	
10	203		34	109	
11	222		35	62	I.D
12	255	I.D	36	289	
13	56		37	214	
14	201		38	269	I.D
15	121	I.D	39	242	
16	43		40	223	
17	286		41	45	I.D
18	29	I.D	42	303	I.D
19	231		43	309	I.D
20	150		44	313	
21	266		45	311	
22	290	I.D	46	319	
23	283		47	2x1/2	poison pellet
24	285		Extra	336	Used in pos. 7

HALDEN TEST-FUEL COLUMN DATA - IFA-431

Rod No.: 3

Fuel Column Weight 558.322 grams Exclusive of poison pellets and replacement pellet

Fuel Column Length 22.890 in.

Pellet Position	Pellet Ident.	Remarks	Pellet Position	Pellet Ident.	Remarks
1	1/1/2	poison pellet-top	25	616	
2	528		26	514	I.D
3	551		27	555	
4	539		28	603	
5	534		29	507	I.D
6	544		30	477	
7	521	I.D	31	559	
8	552	I.D	32	617	I.D
9	482	I.D Replaced	33	504	
10	618		34	496	
11	568		35	607	I.D
12	573	I.D	36	503	
13	500		37	512	
14	596		38	515	I.D
15	516	I.D	39	506	
16	576		40	606	
17	613		41	502	
18	609	I.D	42	550	
19	580		43	524	
20	511		44	518	
21	598		45	527	
22	499	I.D	46	532	
23	495		47	2x1/2	poison pellet
24	510		Extra	548	Used in pos. 9

HALDEN TEST-FUEL COLUMN DATA - IFA-431

Rod No.: 4

Fuel Column Weight 533.608 grams Exclusive of poison pellets and replacement pellet

Fuel Column Length 22.82 in.

Pellet Position	Pellet Ident.	Remarks	Pellet Position	Pellet Ident.	Remarks
1	2x1/2	poison pellet-top	25	217	
2	11	removed	26	245	I.D
3	81		27	60	
4	87	I.D	28	225	
5	165	I.D	29	106	I.D
6	178		30	244	
7	183		31	147	
8	180		32	67	I.D
9	179		33	259	
10	187	I.D	34	22	
11	188		35	126	I.D
12	229	I.D	36	141	
13	243		37	148	
14	208		38	132	I.D
15	149	I.D	39	184	
16	134		40	770	
17	129		41	772	
18	92	I.D	42	769	
19	102		43	766	
20	96		44	177	
21	108		45	169	I.D
22	130	I.D	46	1	I.D
23	256		47	2x1/2	poison pellet
24	33		Extra	78	

HALDEN TEST-FUEL COLUMN DATA - IFA-431

Rod No.: 5

Fuel Column Weight: 515.033 grams — Exclusive of poison pellets and replacement pellet

Fuel Column Length: 22.840 in.

Pellet Position	Pellet Ident.	Remarks	Pellet Position	Pellet Ident.	Remarks
1	1x1/2	poison pellet-top	25	889	I.D
2	836		26	804	
3	844		27	886	I.D.
4	827		28	868	
5	828		29	871	I.D
6	811		30	802	
7	846		31	855	I.D
8	820	I.D	32	852	
9	810	Immersion Density replaced	33	887	I.D
10	869		34	809	
11	800	I.D	35	786	I.D
12	787		36	808	
13	797	I.D	37	847	I.D
14	789		38	858	
15	784	I.D	39	796	I.D
16	849		40	801	
17	807	I.D	41	890	I.D
18	806		42	826	I.D
19	870	I.D	43	845	I.D
20	891		44	823	I.D
21	879	I.D	45	818	
22	793		46	838	
23	861	I.D	47	2x1/2	poison pellet
24	790		Extra	833	Used in pos. 9

HALDEN TEST-FUEL COLUMN DATA - IFA-431

Rod No.: 6

Fuel Column Weight: 513.833 grams   Exclusive of poison pellets and replacement pellet

Fuel Column Length: 22.680 in.

Pellet Position	Pellet Ident.	Remarks	Pellet Position	Pellet Ident.	Remarks
1	2x1/2	poison pellet-top	25	722	I.D
2	647	I.D	26	731	
3	646		27	681	
4	652		28	699	
5	653		29	721	
6	661		30	690	
7	641		31	791	
8	649		32	733	
9	710	Replaced	33	741	
10	734		34	735	
11	706		35	742	
12	718		36	687	
13	745		37	713	
14	712		38	746	
15	748		39	704	
16	743		40	740	
17	755		41	688	
18	727		42	640	
19	701		43	645	
20	693		44	669	
21	756		45	642	
22	747		46	654	
23	732		47	2x1/2	poison pellet
24	711		Extra	656	Used in pos. 9

HALDEN TEST-FUEL COLUMN DATA - IFA-432

Rod No.: 1

Fuel Column Weight: 532.151 grams

Fuel Column Length: 22.75 in.

Pellet Position	Pellet Ident.	Remarks	Pellet Position	Pellet Ident.	Remarks
1		poison pellet-top	25	99	I.D.
2	5	I.D.	26	131	I.D.
3	12	I.D.	27	112	I.D.
4	83	I.D.	28	28	I.D.
5	73	I.D.	29	247	I.D.
6	154	I.D.	30	234	I.D.
7	7	I.D.	31	25	I.D.
8	85	I.D.	32	211	I.D.
9	4	I.D.	33	224	I.D.
10	6	I.D.	34	233	I.D.
11	18	I.D.	35	144	I.D.
12	164	I.D.	36	219	I.D.
13	173	I.D.	37	272	I.D.
14	77	I.D.	38	140	I.D.
15	89	I.D.	39	120	I.D.
16	41	I.D.	40	258	I.D.
17	275	I.D.	41	107	I.D.
18	277	I.D.	42	166	I.D.
19	278	I.D.	43	71	I.D.
20	267	I.D.	44	161	I.D.
21	66	I.D.	45	172	I.D.
22	246	I.D.	46	174	I.D.
23	257	I.D.	47		poison pellet
24	260	I.D.			
			Extra	168	

HALDEN TEST-FUEL COLUMN DATA - IFA-432

Rod No.: 2

Fuel Column Weight: 509.021 grams

Fuel Column Length: 22.49 in.

Pellet Position	Pellet Ident.	Remarks	Pellet Position	Pellet Ident.	Remarks
1		poison pellet-top	25	384	I.D.
2	321	I.D.	26	398	I.D.
3	318	I.D.	27	369	I.D.
4	308	I.D.	28	383	I.D.
5	307	I.D.	29	431	I.D.
6	331	I.D.	30	386	I.D.
7	312	I.D.	31	437	I.D.
8	333	I.D.	32	345	I.D.
9	304	I.D.	33	142	I.D.
10	9	I.D.	34	406	I.D.
11	162	I.D.	35	388	I.D.
12	72	I.D.	36	298	I.D.
13	160	I.D.	37	407	I.D.
14	76	I.D.	38	210	I.D.
15	323	I.D.	39	459	I.D.
16	390	I.D.	40	380	I.D.
17	420	I.D.	41	441	I.D.
18	385	I.D.	42	327	I.D.
19	443	I.D.	43	301	I.D.
20	338	I.D.	44	325	I.D.
21	346	I.D.	45	334	I.D.
22	414	I.D.	46	328	I.D.
23	384	I.D.	47		poison pellet
24	393	I.D.			
			Extra	330	

HALDEN TEST-FUEL COLUMN DATA - IFA-432

Rod No.: 3

Fuel Column Weight: 545.103 grams

Fuel Column Length: 22.46 in.

Pellet Position	Pellet Ident.	Remarks	Pellet Position	Pellet Ident.	Remarks
1		poison pellet-top	25	619	
2	545		26	587	I.D.
3	535	I.D.	27	620	
4	540		28	569	
5	530	I.D.	29	605	I.D.
6	519		30	570	
7	523	I.D.	31	509	
8	520	I.D.	32	588	I.D.
9	562	I.D.	33	589	
10	476		34	489	I.D.
11	611	I.D.	35	597	
12	591		36	612	I.D.
13	610	I.D.	37	599	
14	584		38	594	I.D.
15	574	I.D.	39	602	
16	478		40	608	I.D.
17	590	I.D.	41	549	I.D.
18	572		42	547	I.D.
19	583		43	537	
20	615	I.D.	44	533	I.D.
21	501		45	531	
22	479		46		poison pellet
23	577	I.D.			
24	575				
			Extra	546	

HALDEN TEST-FUEL COLUMN DATA - IFA-432

Rod No.: 4

Fuel Column Weight: 519.625 grams

Fuel Column Length: 22.24 in.

Pellet Position	Pellet Ident.	Remarks	Pellet Position	Pellet Ident.	Remarks
1		poison pellet-top	25	251	
2	75	I.D.	26	40	
3	176		27	133	I.D.
4	3	I.D.	28	124	
5	906	I.D.	29	30	
6	181	I.D.	30	264	I.D.
7	175		31	113	
8	170	I.D.	32	274	
9	182	I.D.	33	240	I.D.
10	912	I.D.	34	104	
11	215	I.D.	35	44	I.D.
12	139		36	226	
13	239	I.D.	37	209	I.D.
14	111		38	901	I.D.
15	118	I.D.	39	775	I.D.
16	95		40	764	
17	115		41	763	
18	263	I.D.	42	774	
19	252		43	902	I.D.
20	57		44	80	I.D.
21	236	I.D.	45	157	
22	51		46		poison pellet
23	49		Extra	137	solid
24	94	I.D.	Extra	186	on-center (0.063)
			Extra	86	on-center (0.061)

HALDEN TEST-FUEL COLUMN DATA - IFA-432

Rod No.: 5

Fuel Column Weight: 510.600 grams

Fuel Column Length: 22.78 in.

Pellet Position	Pellet Ident.	Remarks	Pellet Position	Pellet Ident.	Remarks
1		poison pellet-top	25	893	
2	842	I.D.	26	864	
3	834	I.D.	27	881	
4	815	I.D.	28	873	
5	843	I.D.	29	895	
6	830	I.D.	30	896	
7	841	I.D.	31	878	
8	829	I.D.	32	799	
9	816	I.D.	33	882	
10	835	I.D.	34	780	
11	839	I.D.	35	859	
12	819	I.D.	36	885	
13	812	I.D.	37	888	
14	831	I.D.	38	883	
15	837	I.D.	39	876	
16	892	I.D.	40	875	
17	900	I.D.	41	867	
18	865	I.D.	42	840	
19	779	I.D.	43	824	
20	851	I.D.	44	832	
21	791	I.D.	45	817	
22	894	I.D.	46	822	
23	792	I.D.	47		poison pellet
24	794	I.D.			
			Extra	825	

HALDEN TEST-FUEL COLUMN DATA - IFA-432

Rod No.: 6

Fuel Column Weight: 512.629 grams

Fuel Column Length: 22.67 in.

Pellet Position	Pellet Ident.	Remarks	Pellet Position	Pellet Ident.	Remarks
1		poison pellet-top	25	726	
2	671	I.D.	26	686	
3	668	I.D.	27	728	
4	672	I.D.	28	680	
5	663	I.D.	29	703	
6	643	I.D.	30	673	
7	666	I.D.	31	738	
8	657	I.D.	32	676	
9	659	I.D.	33	700	
10	670	I.D.	34	705	
11	814	I.D.	35	674	
12	650	I.D.	36	696	
13	665	I.D.	37	685	
14	638	I.D.	38	708	
15	651	I.D.	39	736	
16	698	I.D.	40	707	
17	679	I.D.	41	714	
18	695	I.D.	42	662	
19	683	I.D.	43	664	
20	692	I.D.	44	667	
21	702	I.D.	45	664	
22	677	I.D.	46	648	
23	682	I.D.	47		poison pellet
24	678	I.D.			
			Extra	637	

HALDEN TEST-FUEL COLUMN DATA - IFA-432

Rod No.: 7

Fuel Column Weight: 516.642 grams

Fuel Column Length: 22.53 in.

Pellet Position	Pellet Ident.	Remarks	Pellet Position	Pellet Ident.	Remarks
1		poison pellet-top	25	449	I.D.
2	435		26	427	
3	339		27	447	
4	424		28	417	I.D.
5	458	I.D.	29	440	
6	376		30	425	
7	363	I.D.	31	357	I.D.
8	434		32	356	
9	358	I.D.	33	444	
10	372		34	439	I.D.
11	452	I.D.	35	367	
12	422		36	413	
13	351		37	299	I.D.
14	90	I.D.	38	352	
15	373		39	391	I.D.
16	353		40	382	
17	416	I.D.	41	348	I.D.
18	429		42	368	
19	360		43	453	I.D.
20	371	I.D.	44	455	I.D.
21	412		45	428	I.D.
22	436		46	401	
23	359	I.D.	47		poison pellet
24	379				
			Extra	138	

HALDEN TEST-FUEL COLUMN DATA - IFA-432

Rod No.: 8

Fuel Column Weight: 538.192 grams

Fuel Column Length: 22.73 in.

Pellet Position	Pellet Ident.	Remarks	Pellet Position	Pellet Ident.	Remarks
1		poison pellet-top	25	37	I.D.
2	46		26	220	
3	59	I.D.	27	103	
4	258		28	276	I.D.
5	54	I.D.	29	268	
6	105		30	36	
7	38		31	221	I.D.
8	64	I.D.	32	262	
9	213		33	58	
10	35		34	53	I.D.
11	143	I.D.	35	24	
12	216		36	48	
13	235		37	55	I.D.
14	291	I.D.	38	117	
15	232		39	292	I.D.
16	33		40	127	
17	227	I.D.	41	270	I.D.
18	100		42	27	
19	230		43	249	I.D.
20	97	I.D.	44	128	
21	69		45	237	I.D.
22	281		46	63	
23	123	I.D.	47		poison pellet
24	254				
			Extra	265	

HALDEN TEST-FUEL COLUMN DATA - IFA-432

Rod No.: 9

Fuel Column Weight: 538.672 grams

Fuel Column Length: 22.45 in.

Pellet Position	Pellet Ident.	Remarks	Pellet Position	Pellet Ident.	Remarks
1		poison pellet-top	25	556	
2	484	I.D.	26	571	
3	585		27	558	I.D.
4	474	I.D.	28	565	
5	555		29	560	
6	631	I.D.	30	472	I.D.
7	491		31	600	
8	630	I.D.	32	486	I.D.
9	469		33	576	
10	635	I.D.	34	490	I.D.
11	632		35	470	
12	494	I.D.	36	475	I.D.
13	633		37	625	
14	564	I.D.	38	628	I.D.
15	627		39	481	
16	561	I.D.	40	492	I.D.
17	624		41	465	
18	634	I.D.	42	621	I.D.
19	468		43	473	
20	629		44	566	I.D.
21	483	I.D.	45	466	
22	488		46		poison pellet
23	471				
24	463	I.D.			
			Extra	462	

PRE-IRRADIATION LENGTH, DIAMETER, AND PROFILE MEASUREMENTS COMPLETED FUEL RODS

The following techniques were used to provide pre-irradiation dimensional measurements of the completed fuel rods for IFA-431 and IFA-432.

Length Measurements

These measurements were made using V-grooves that machined into the fuel rod end plugs for that purpose. The transducer support was brought to the axial position on the lower V-groove which gave the minimum reading on the digital voltmeter (DVM), thus indicating that the 0.2 cm diameter sapphire rod forming the "knife-edge" is centered at the exact axial V-groove position. (In practice this is done by manually stepping the transducer support upwards until, after passing the minimum, the first increase in DVM reading is obtained. One step corresponds to 0.001 cm.) The axial position is then read off a scaler that counts the pulses going to the stepping motor. This procedure is then repeated at the upper V-groove. The difference in the two axial positions is the required distance between the two grooves.

Diameter and Profile Measurements

These measurements were obtained by driving the transducer support upward along the rod at a constant speed (0.2 cm/sec). Two freefloating parallel slides with knife edges are drawn into contact with the rod by connecting springs. A built-in transducer (coil in one slide, core fixed to the other) measures the distance between the knife edges, and thus the rod diameter. Another transducer measures the transverse position of the right-hand slide relative to the bench structures, and thus the rod axial profile. The DC outputs from the two transducer units are fed to a two-channel stripchart recorder and, in parallel, to two DVM's. The paper transport on the stripchart recorder is accomplished by a stepping motor fed by the same oscillator controlling the movement of the transducer support on the profilometer bench. By choosing an appropriate ratio on a frequency divider, the scale on the original recorder chart can be 1:1, 1:2, 1:4, or 1:8. For these measurements a scale of 1:1 was chosen giving 1.0 cm/scale division on the reproductions. The produced plots have the lower end of the rod to the left and the upper end of the rod to the right. Due to the mechanical construction of the two-pen recorder there is an axial displacement of approximately 0.4 scale divisions between the diameter and profile plots.

The sensitivities of the diameter and profile signals were adjusted by using a calibration sleeve (desiginated IFA-411) as the lower support for the rods. This sleeve has two precisely ground regions with accurately measured diameters of 1.2269 and 1.2505 cm. The input sensitivities of the recorder channels were adjusted in such a way that a sensitivity of 10 μm/scale division was obtained for both the diameter and profile curves. The recorder zero of the diameter channel was set to produce the 1.25 cm diameter on the 30 scale division line for IFA-431 and on the 40 scale division line for IFA-432.

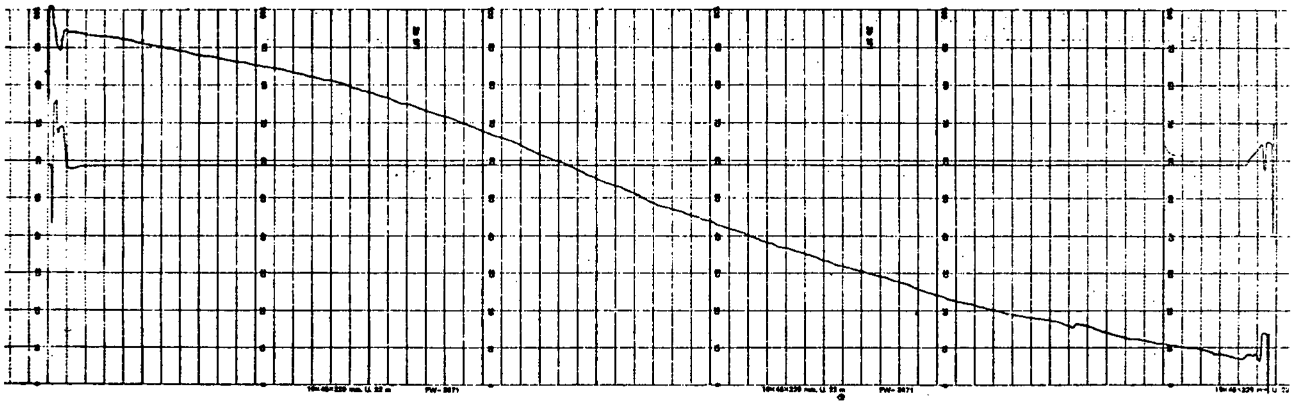
Tables J-1 and J-2 summarize the rod length measurements in both the 0° and 90° orientations for IFA-431 and IFA-432, respectively.

TABLE J-1. Pre-Irradiation Length Measurements for IFA-431

Pin No.	Orientation	Upper (mm)	Lower (mm)	L (mm)
1	0	645.72	.000	645.72
1	90	645.64	.000	645.64
2	0	645.38	.000	645.38
2	90	645.33	.000	645.33
3	0	645.56	.000	645.56
3	90	645.60	.000	645.60
4	0	645.49	.000	645.49
4	90	645.47	.000	645.47
5	0	645.65	.000	645.65
5	90	645.59	.000	645.59
6	0	645.60	.000	645.60
6	90	645.59	.000	645.59

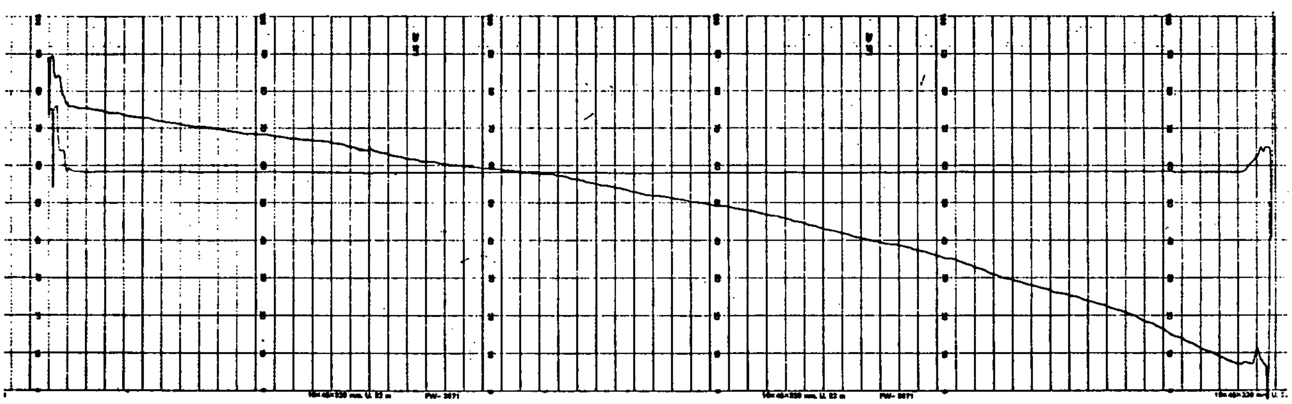
TABLE J-2. Pre-Irradiation Length Measurements for IFA-432

Pin No.	Orientation	Groove Position Upper (mm)	Groove Position Lower (mm)	L (mm)
1	0	645.29	.000	645.29
1	90	645.27	.000	645.27
2	0	645.29	.000	645.29
2	90	645.29	.000	645.29
3	0	645.53	.000	645.53
3	90	645.53	.000	645.53
4	0	645.25	.000	645.25
4	90	645.26	.000	645.26
5	0	645.42	.000	645.42
5	90	645.54	.000	645.54
6	0	645.75	.000	645.75
6	90	645.74	.000	645.74
7	0	645.42	.000	645.42
7	90	645.44	.000	645.44
8	0	645.47	.000	645.47
8	90	645.48	.000	645.48
9	0	645.65	.000	645.65
9	90	645.63	.000	645.63



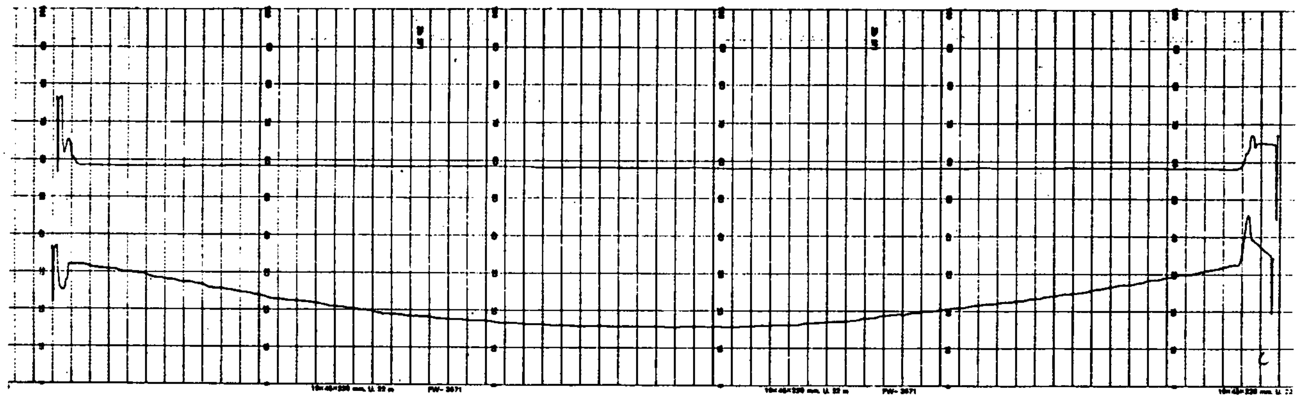
Pre-Irradiation Profile and Diameter
Sensitivity: 10 μ/sc.div.
Axial Scale: 10 mm/sc.div.
Reference Diameter: 12.5 mm on 30 sc.div.

FIGURE J-1. IFA 431, Pin 1, Orientation 0°



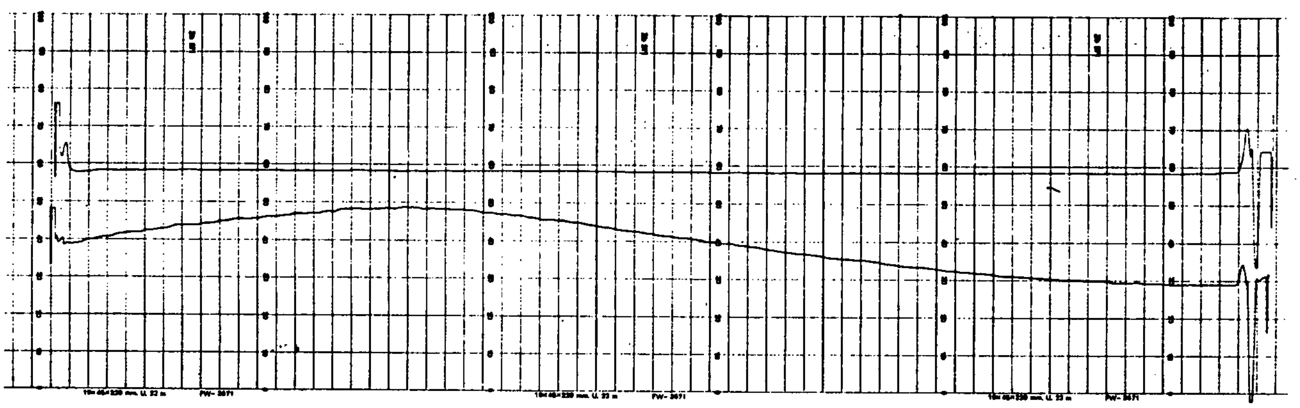
Pre-Irradiation Profile and Diameter
Sensitivity: 10 μ/sc.div.
Axial Scale: 10 mm/sc.div.
Reference Diameter: 12.5 mm on 30 sc.div.

FIGURE J-2. IFA-431, Pin 1, Orientation 90°



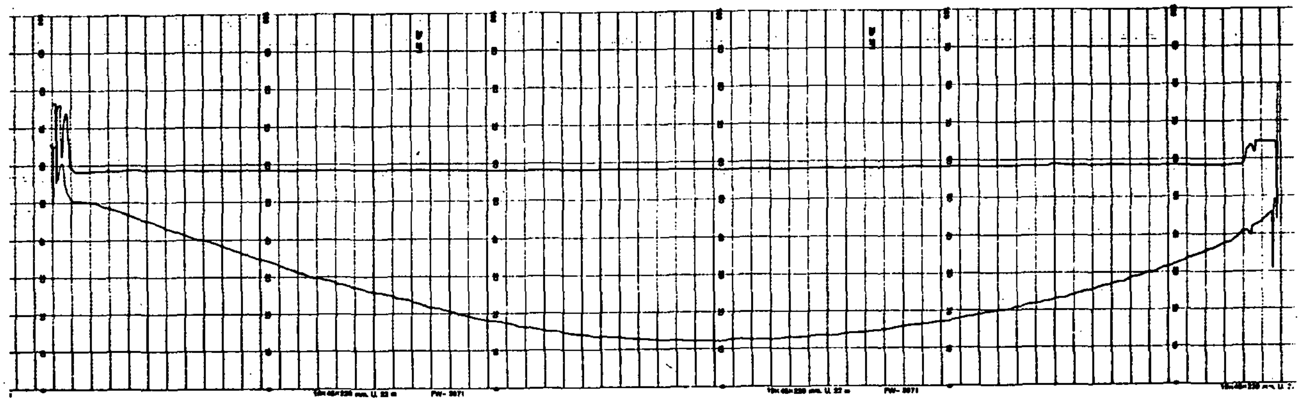
Pre-Irradiation Profile and Diameter
Sensitivity: 10 μ/sc.div.
Axial Scale: 10 mm/sc.div.
Reference Diameter: 12.5 mm on 30 sc.div.

FIGURE J-3. IFA 431, Pin 2, Orientation 0°



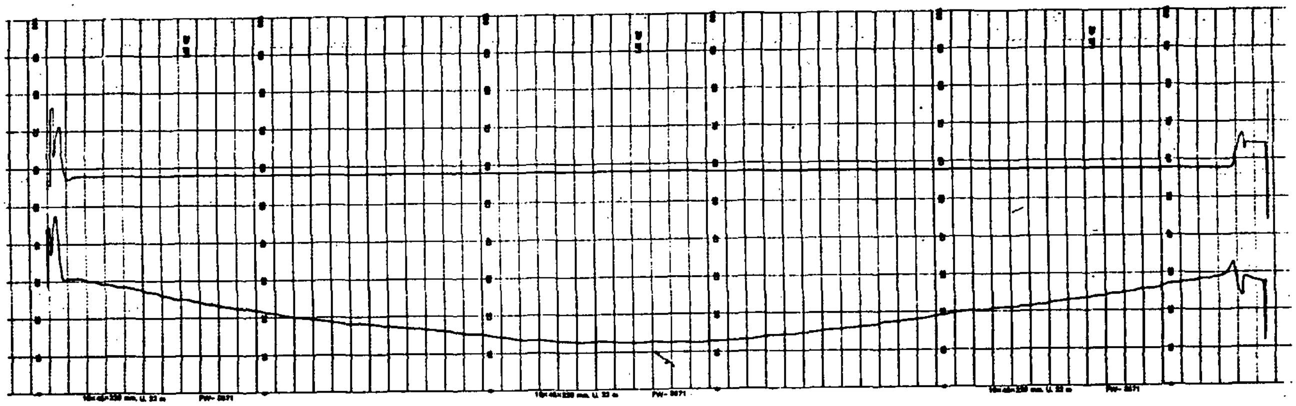
Pre-Irradiation Profile and Diameter
Sensitivity: 10 μ/sc.div.
Axial Scale: 10 mm/sc.div.
Reference Diameter: 12.5 mm on 30 sc.div.

FIGURE J-4. IFA 431, Pin 2, Orientation 90°



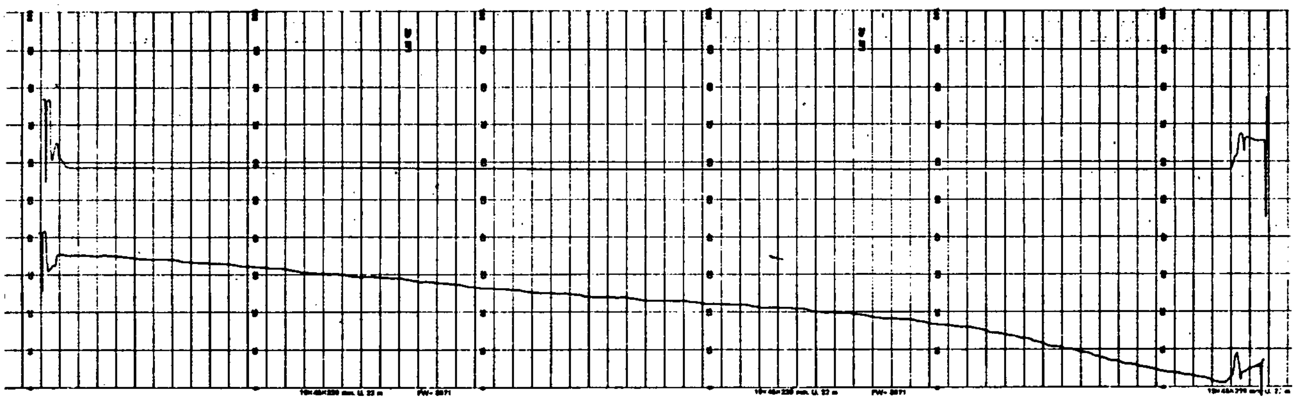
Pre-Irradiation Profile and Diameter
Sensitivity: 10 μ/sc.div.
Axial Scale: 10 mm/sc.div.
Reference Diameter: 12.5 mm on 30 sc.div

FIGURE J-5. IFA 431, Pin 3, Orientation 0°



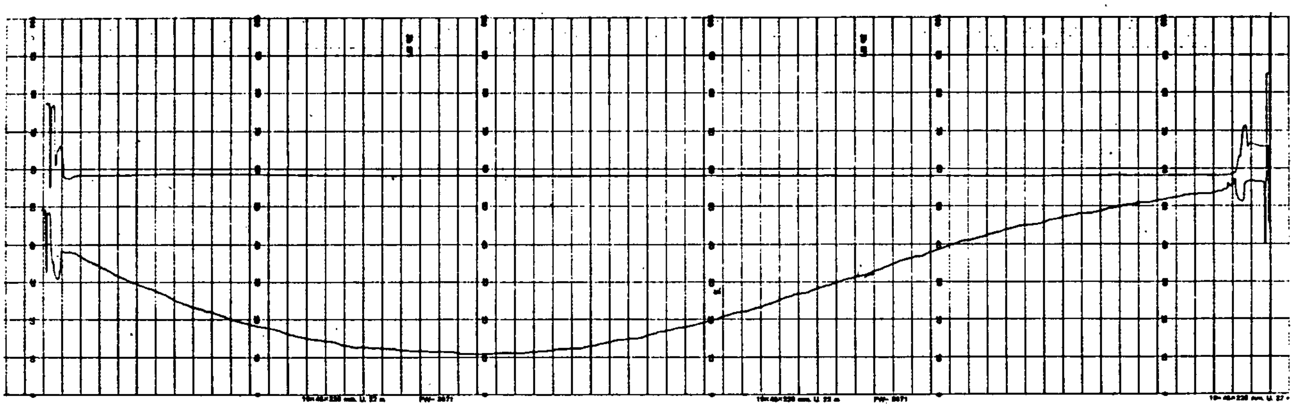
Pre-Irradiation Profile and Diameter
Sensitivity: 10 μ/sc.div.
Axial Scale: 10 mm/sc.div.
Reference Diameter: 12.5 mm on 30 sc.div.

FIGURE J-6. IFA 431, Pin 3, Orientation 90°



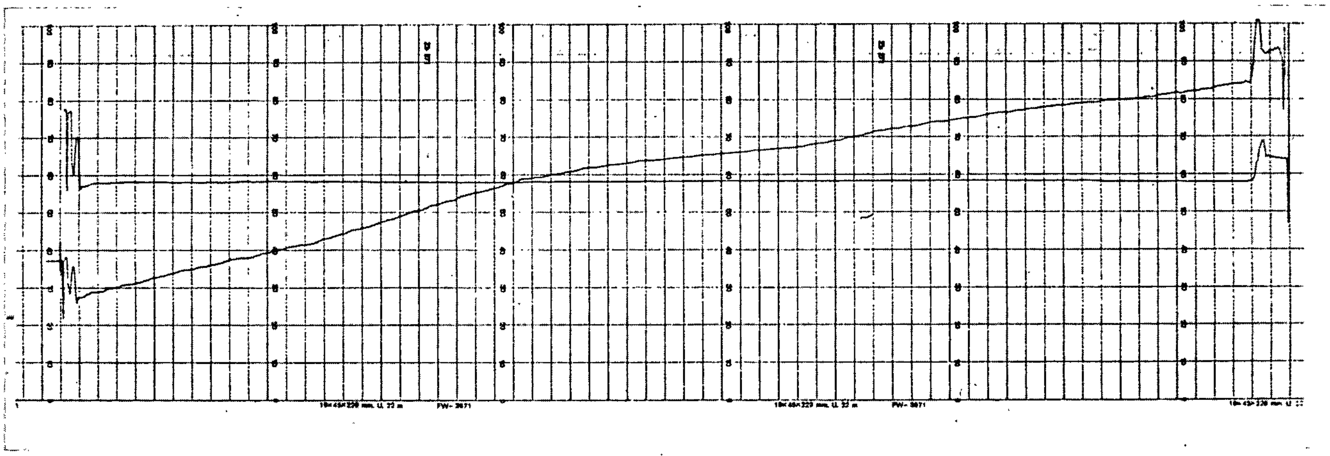
Pre-Irradiation Profile and Diameter
Sensitivity: 10 μ/sc.div.
Axial Scale: 10 mm/sc.div.
Reference Diameter: 12.5 mm on 30 sc.div.

FIGURE J-7. IFA 431, Pin 4, Orientation 0°



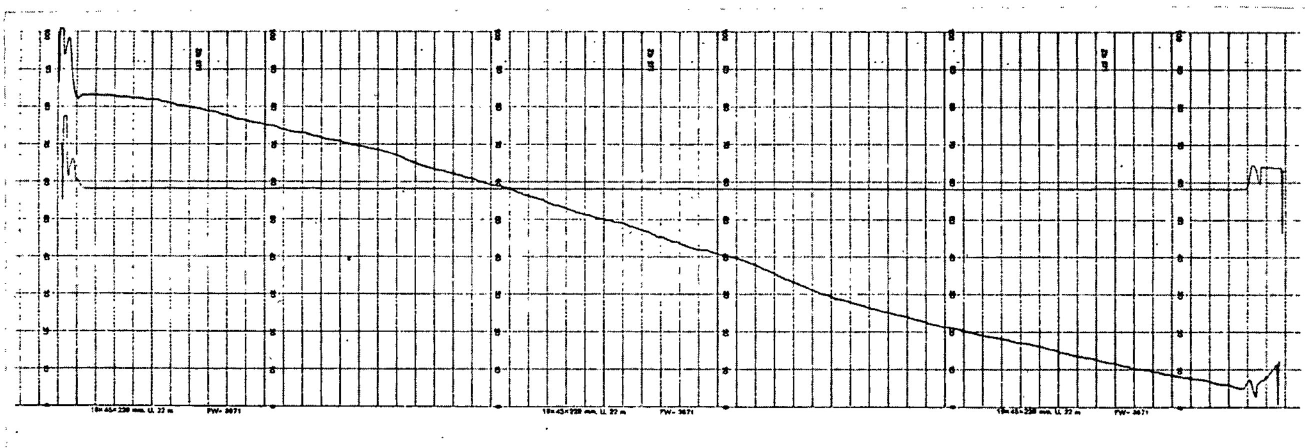
Pre-Irradiation Profile and Diameter
Sensitivity: 10 μ/sc.div.
Axial Scale: 10 mm/sc.div.
Reference Diameter: 12.5 mm on 30 sc.div.

FIGURE J-8. IFA 431, Pin 4, Orientation 90°



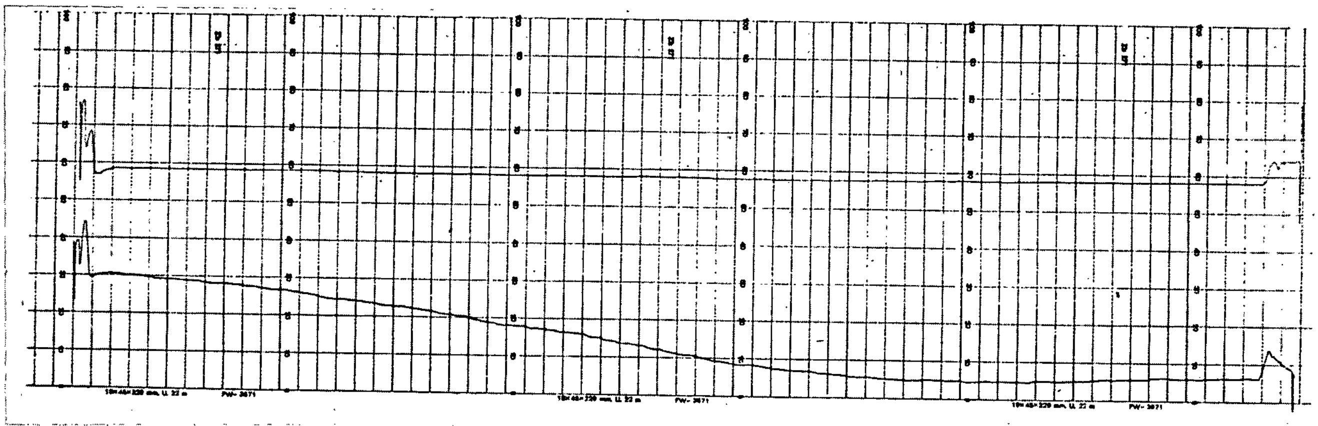
Pre-Irradiation Profile and Diameter
Sensitivity: 10 μ/sc.div.
Axial Scale: 10 mm/sc.div.
Reference Diameter: 12.5 mm on 30 sc.div.

FIGURE J-9. IFA 431, Pin 5, Orientation 0°



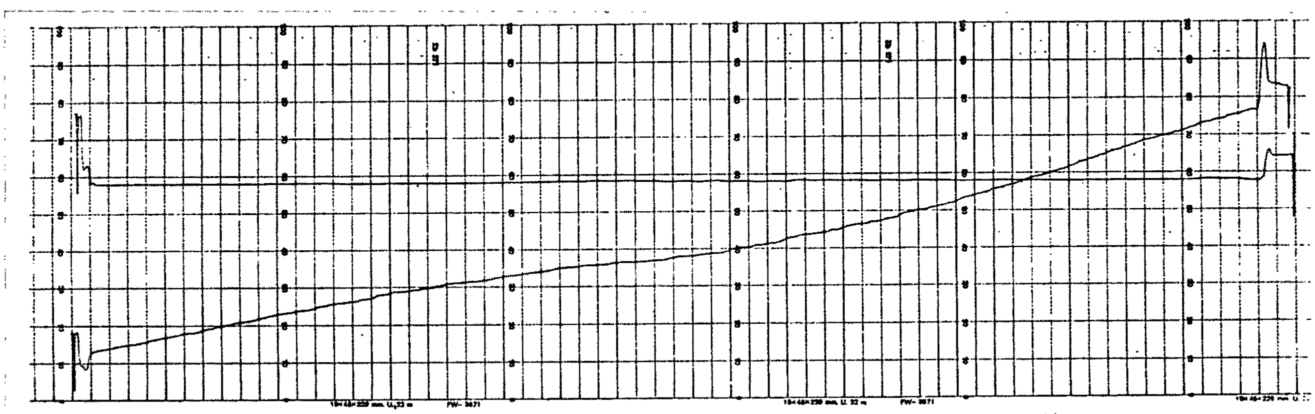
Pre-Irradiation Profile and Diameter
Sensitivity: 10 μ/sc.div.
Axial Scale: 10 mm/sc.div.
Reference Diameter: 12.5 mm on 30 sc.div.

FIGURE J-10. IFA 431, Pin 5, Orientation 90°



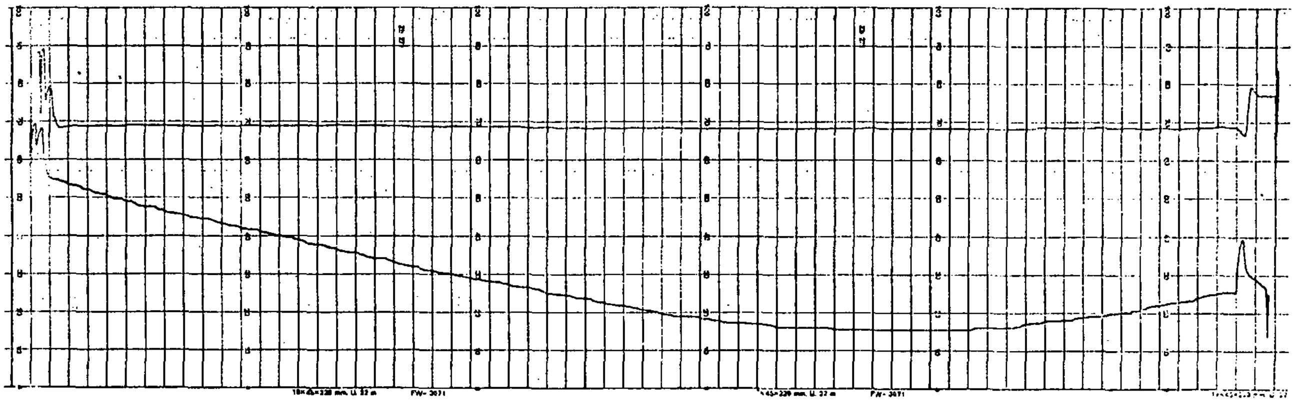
Pre-Irradiation Profile and Diameter
Sensitivity: 10 μ/sc.div.
Axial Scale: 10 mm/sc.div.
Reference Diameter: 12.5 mm on 30 sc.div.

FIGURE J-11. IFA 431, Pin 6, Orientation 0°



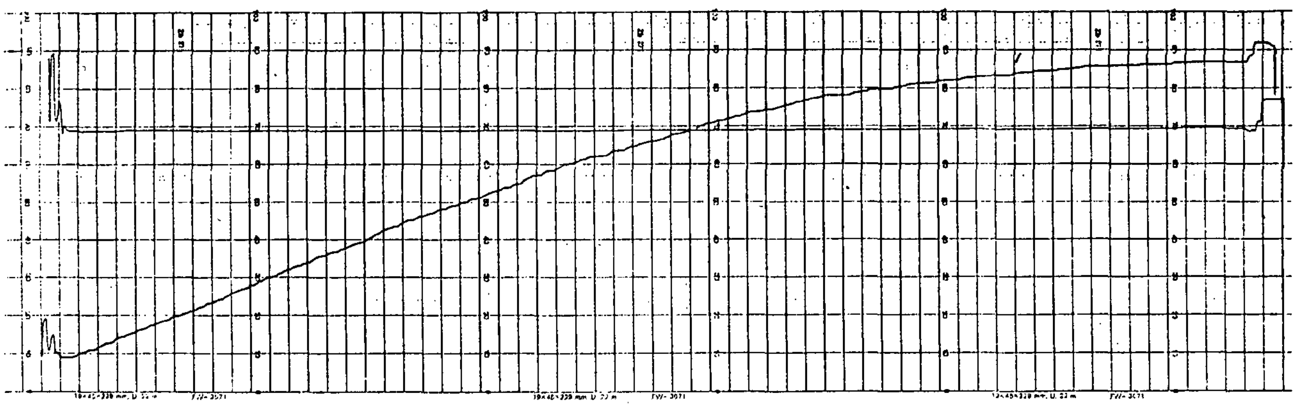
Pre-Irradiation Profile and Diameter
Sensitivity: 10 μ/sc.div.
Axial Scale: 10 mm/sc.div.
Reference Diameter: 12.5 mm on 30 sc.div.

FIGURE J-12. IFA 431, Pin 6, Orientation 90°



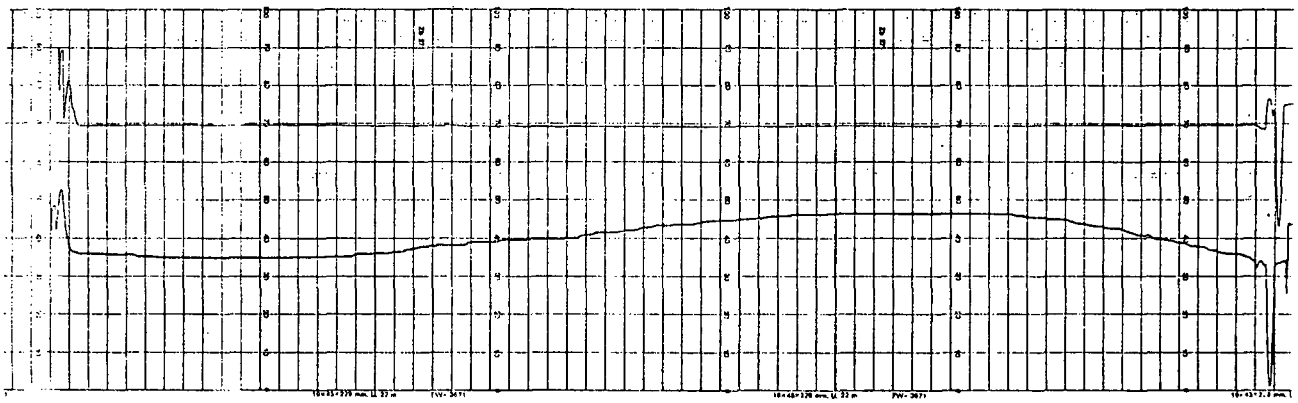
Pre-irradiation Profile and Diameter
Sensitivity: 10 μ/sc.div.
Axial scale: 10 mm/sc.div.
Reference diameter: 12.5 mm on 40 sc.div.

Figure J-13. IFA 432, Pin 1, Orientation 0°



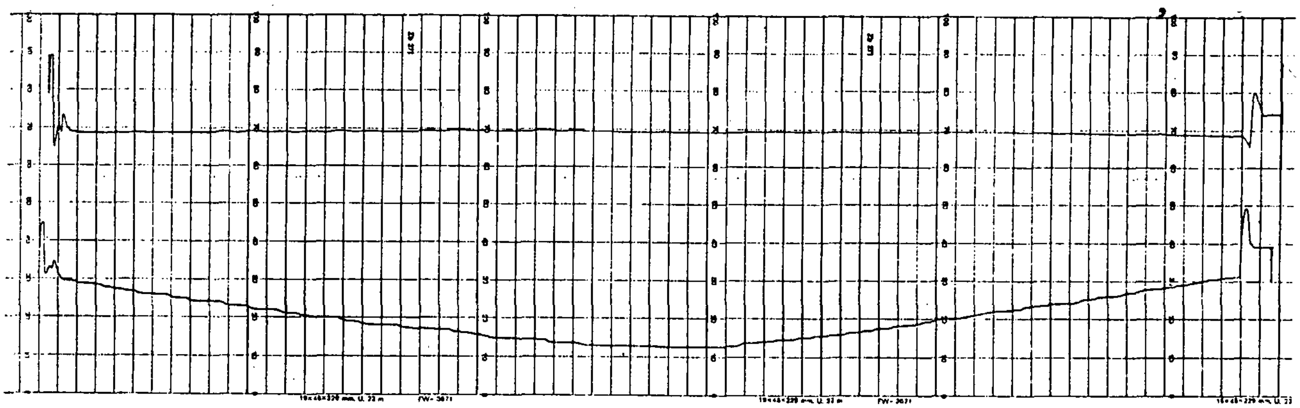
Pre-irradiation Profile and Diameter
Sensitivity: 10 μ/sc.div.
Axial scale: 10 mm/sc.div.
Reference Diameter: 12.5 mm on 40 sc.div.

FIGURE J-14. IFA 432, Pin 1, Orientation 90°



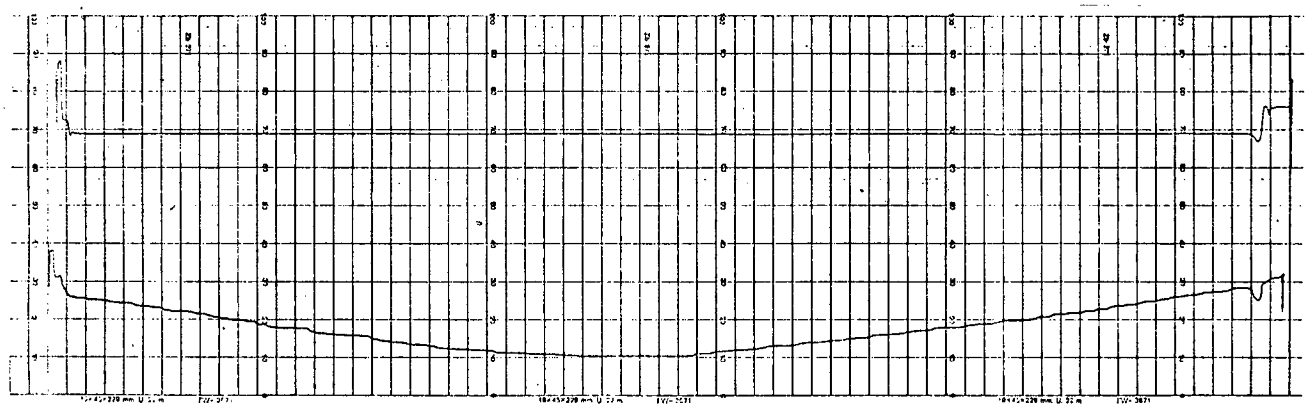
Pre-irradiation Profile and Diameter
Sensitivity: 10 μ/sc.div.
Axial scale: 10 mm/sc.div.
Reference diameter: 12.5 mm on 40 sc.div.

FIGURE J-15. IFA 432, Pin 2, Orientation 0°



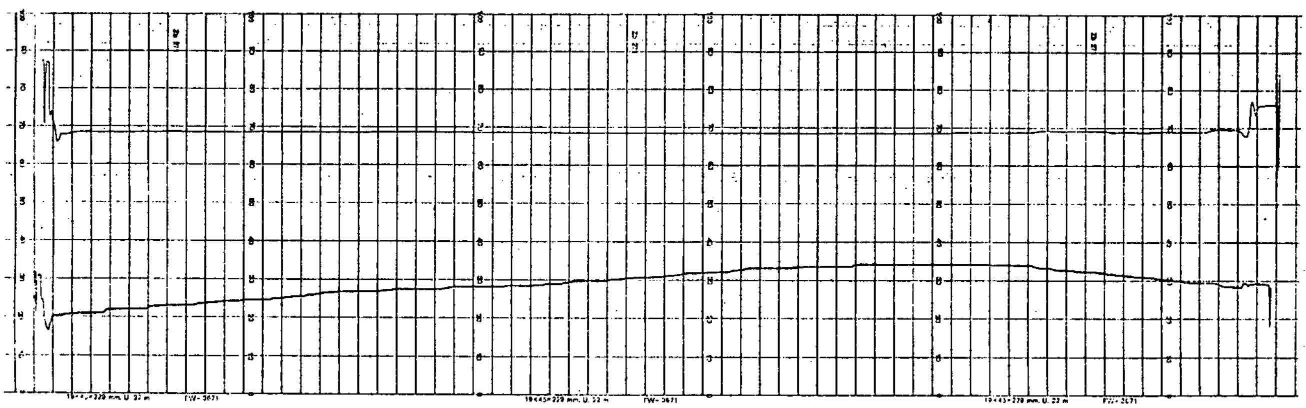
Pre-irradiation Profile and Diameter
Sensitivity: 10 μ/sc.div.
Axial scale: 10 mm/sc.div.
Reference diameter: 12.5 mm on 40 sc.div.

FIGURE J-16. IFA 432, Pin 2, Orientation 90°



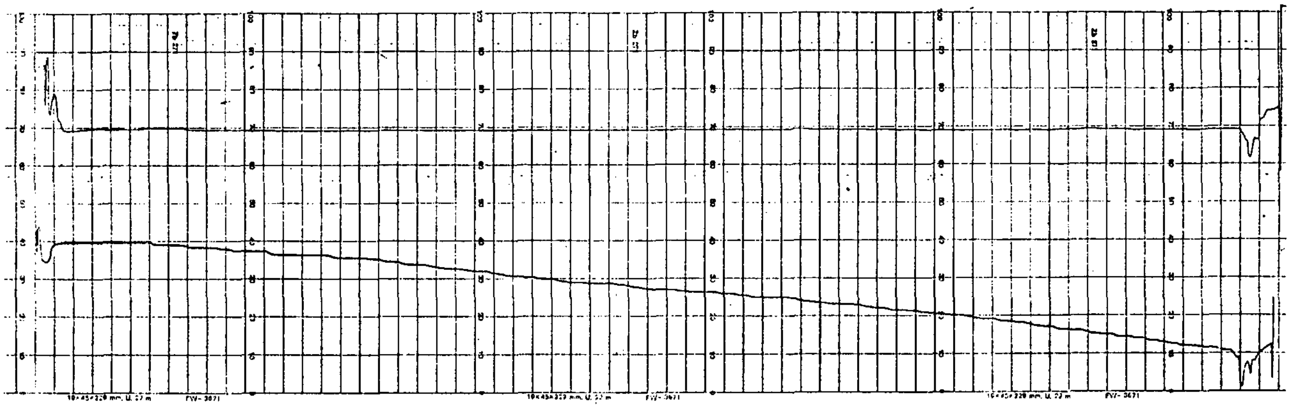
Pre-irradiation Profile and Diameter
Sensitivity: 10 μ/sc.div.
Axial scale: 10 mm/sc.div.
Reference diameter: 12.5 mm on 40 sc.div.

FIGURE J-17. IFA 432, Pin 3, Orientation 0°



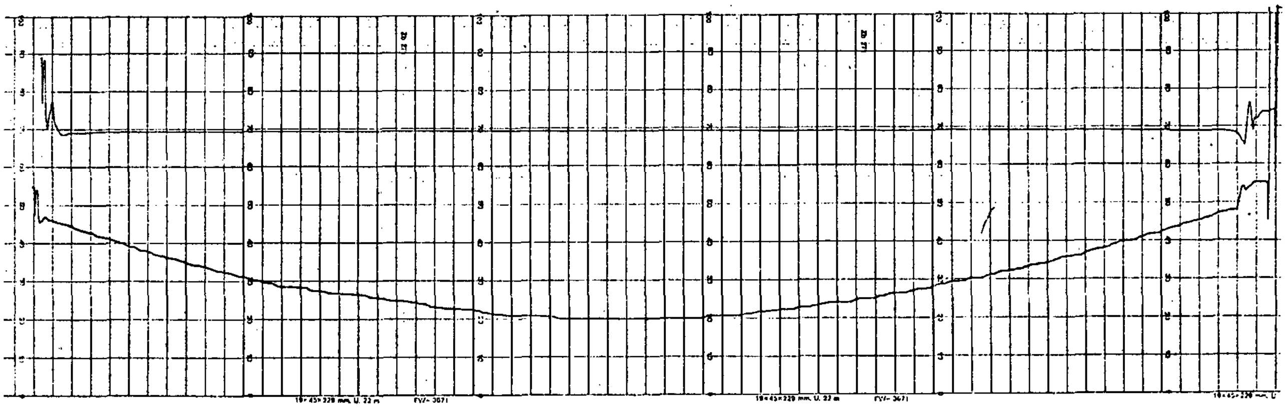
Pre-irradiation Profile and Diameter
Sensitivity: 10 μ/sc.div.
Axial scale: 10 mm/sc.div.
Reference diameter: 12.5 mm on 40 sc.div.

FIGURE J-18. IFA 432, Pin 3, Orientation 90°



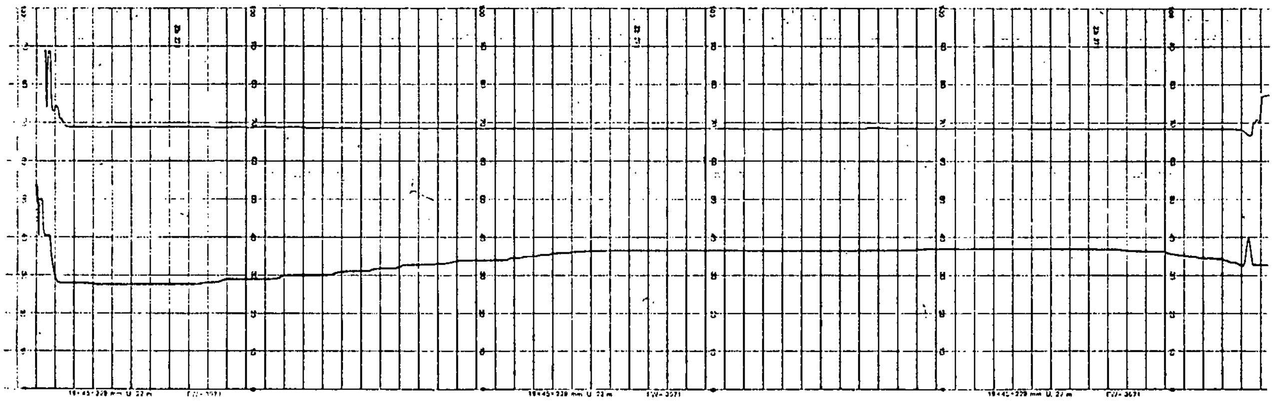
Pre-irradiation Profile and Diameter
Sensitivity: 10 μ/sc.div.
Axial Scale: 10 mm/sc.div.
Reference diameter: 12.5 mm on 40 sc.div.

FIGURE J-19. IFA 432, Pin 4, Orientation 0°



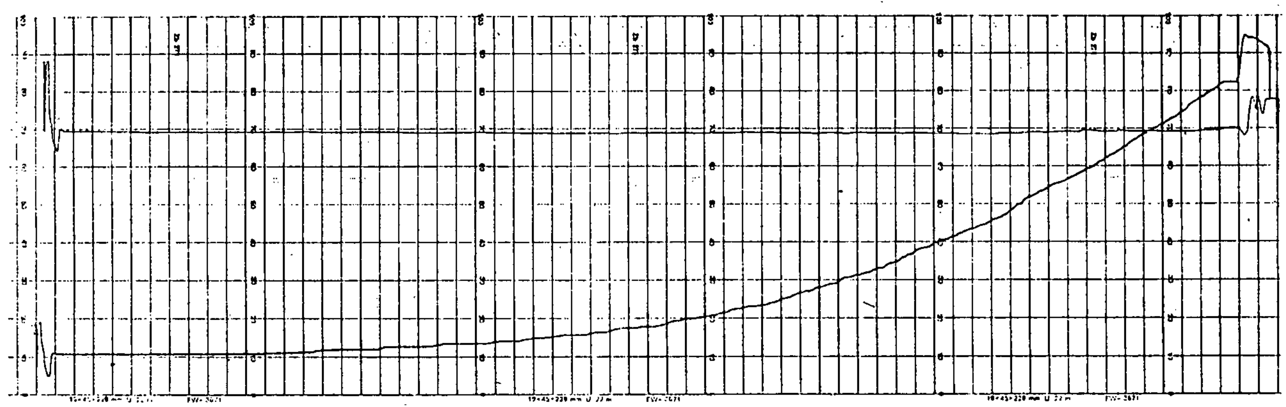
Pre-irradiation Profile and Diameter
Sensitivity: 10 μ/sc.div.
Axial scale: 10 mm/sc.div.
Reference diameter: 12.5 mm on 40 sc.div.

FIGURE J-20. IFA 432, Pin 4, Orientation 90°



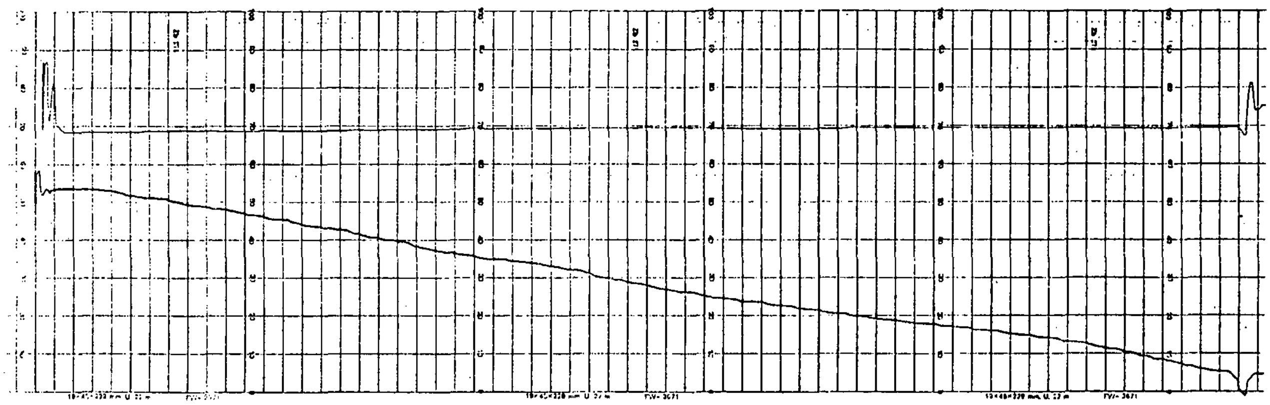
Pre-irradiation Profile and Diameter
Sensitivity: 10 μ/sc.div.
Axial scale: 10 mm/sc.div.
Reference diameter: 12.5 mm on 40 sc.div.

FIGURE J-21. IFA 432, Pin 5, Orientation 0°



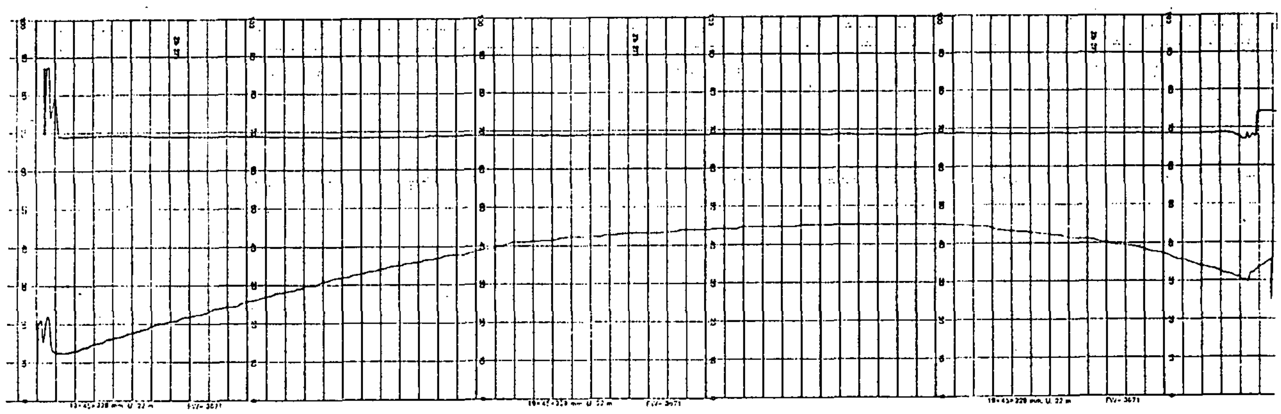
Pre-irradiation Profile and Diameter
Sensitivity: 10 μ/sc.div.
Axial scale: 10 mm/sc.div.
Reference diameter: 12.5 mm on 40 sc.div.

FIGURE J-22. IFA 432, Pin 5, Orientation 90°



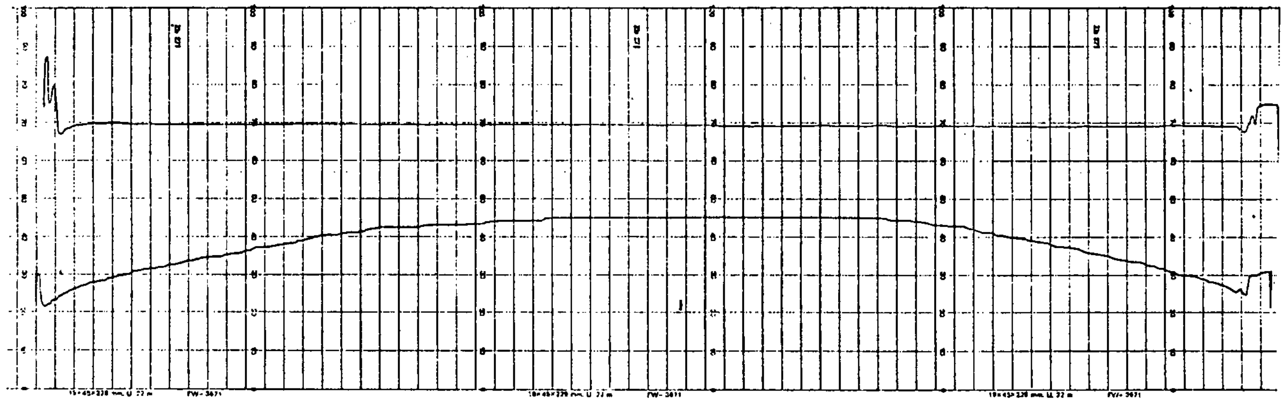
Pre-irradiation Profile and Diameter
Sensitivity: 10 μ/sc.div.
Axial scale: 10 mm/sc.div.
Reference diameter: 12.5 mm on 40 sc.div.

FIGURE J-23. IFA 432, Pin 6, Orientation 0°



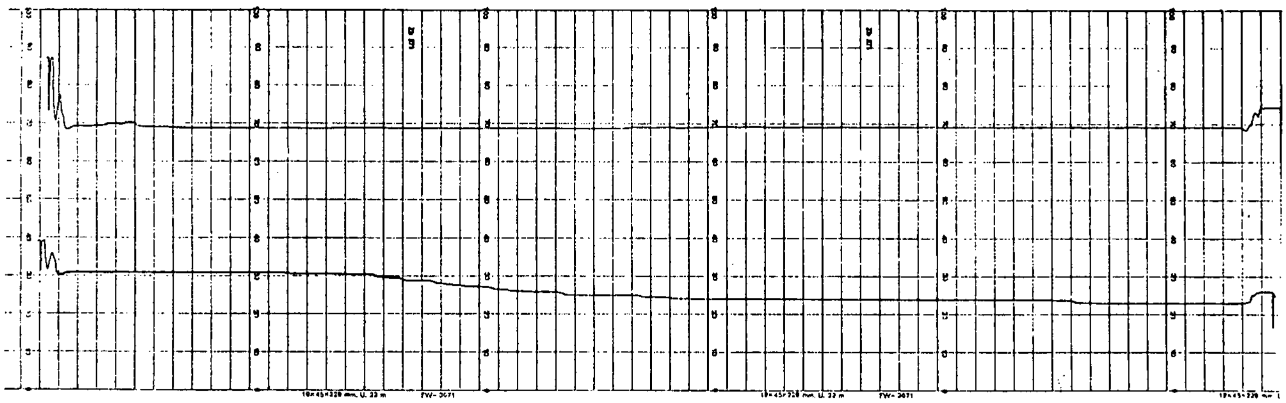
Pre-irradiation Profile and Diameter
Sensitivity: 10 μ/sc.div.
Axial scale: 10 mm/sc.div.
Reference diameter: 12.5 mm on 40 sc.div.

FIGURE J-24. IFA 432, Pin 6, Orientation 90°



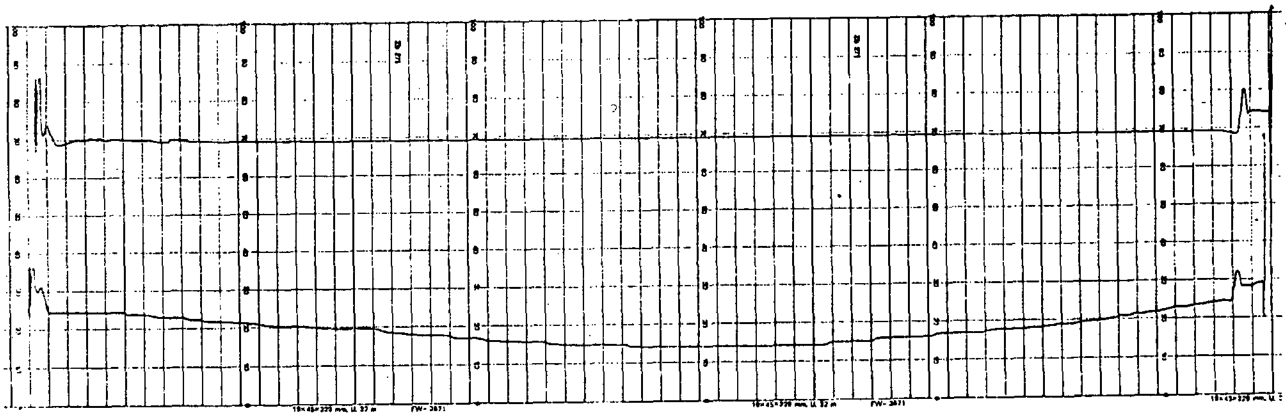
Pre-irradiation Profile and Diameter
Sensitivity: 10 μ/sc.div.
Axial scale: 10 mm/sc.div.
Reference diameter: 12.5 mm on 40 sc.div.

FIGURE J-25. IFA 432, Pin 7, Orientation 0°



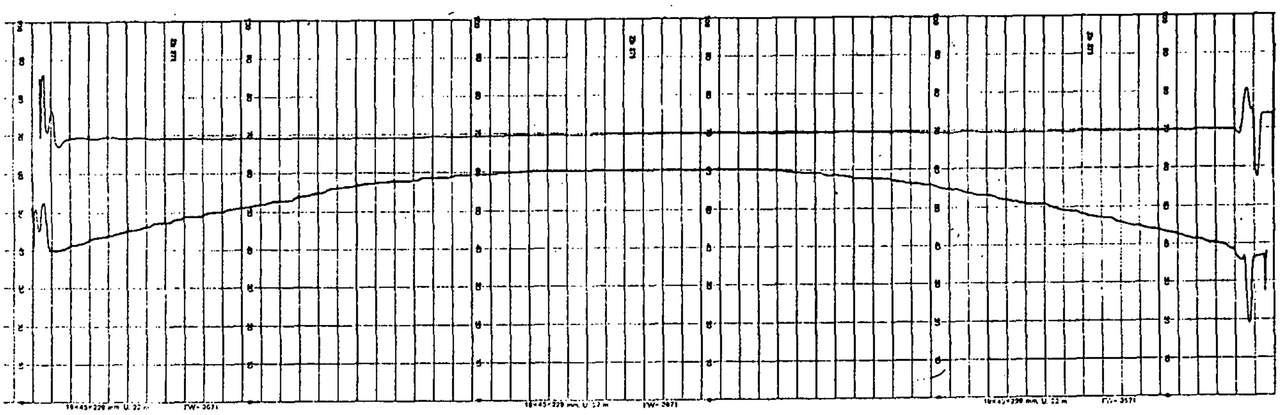
Pre-irradiation Profile and Diameter
Sensitivity: 10 μ/sc.div.
Axial Scale: 10 mm/sc.div.
Reference diameter: 12.5 mm on 40 sc.div.

FIGURE J-26. IFA 432, Pin 7, Orientation 90°



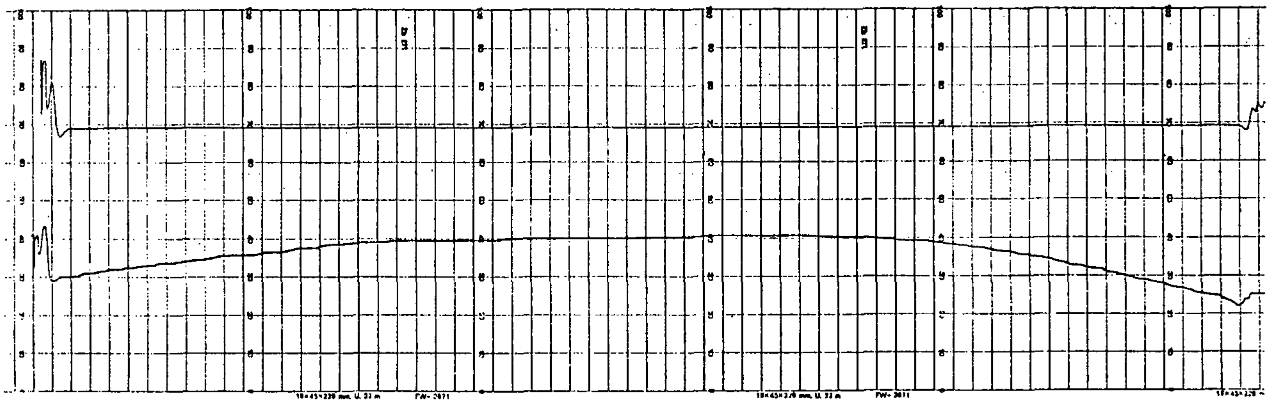
Pre-irradiation Profile and Diameter
Sensitivity: 10 μ/sc.div.
Axial scale: 10 mm/sc.div.
Reference diameter: 12.5 mm on 40 sc.div.

FIGURE J-27. IFA 432, Pin 8, Orientation 0°



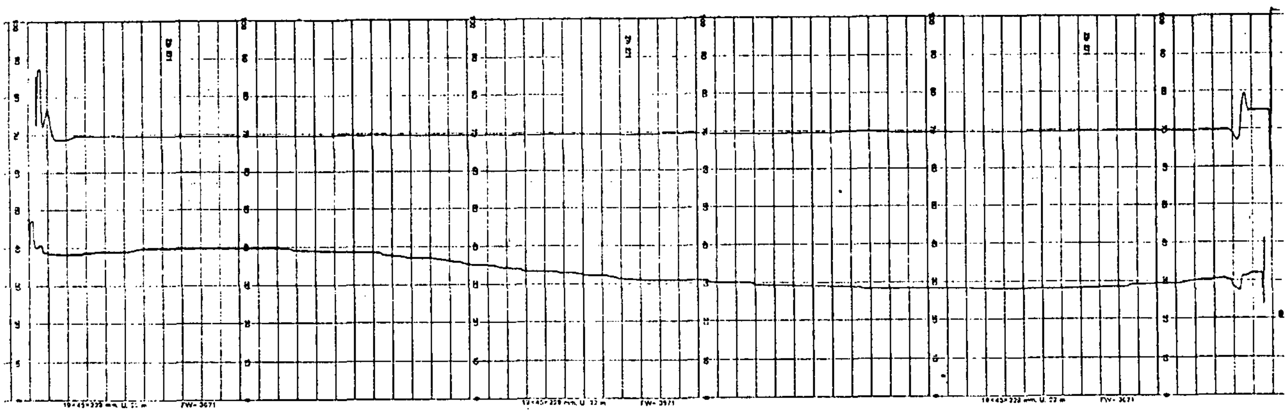
Pre-irradiation Profile and Diameter
Sensitivity: 10 μ/sc.div.
Axial scale: 10 mm/sc.div.
Reference diameter: 12.5 mm on 40 sc.div.

FIGURE J-28. IFA 432, Pin 8, Orientation 90°



Pre-irradiation Profile and Diameter
Sensitivity: 10 μ/sc.div.
Axial scale: 10 mm/sc.div.
Reference diameter: 12.5 mm on 40 sc.div.

FIGURE J-29. IFA 432, Pin 9, Orientation 0°



Pre-irradiation Profile and Diameter
Sensitivity: 10 μ/sc.div.
Axial scale: 10 mm/sc.div.
Reference diameter: 12.5 mm on 40 sc.div.

FIGURE J-30. IFA 432, Pin 9, Orientation 90°

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