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ABSTRACT

ON SITE PWR FUEL INSPECTION MEASUREMENTS

FOR OPERATIONAL AND DESIGN VERIFICATION

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PURPOSE OF MEASUREMENTS

The on – site inspection of irradiated Pressurized Water Reactor (PWR) fuel and Non – Fuel Bearing Components (NFBC) is typically limited to visual inspections during refuelings using underwater TV cameras and is intended primarily to confirm whether the components will continue in operation. These inspections do not normally provide data for design verification nor information to benefit future fuel designs.

Japanese PWR utilities and Nuclear Fuel Industries, Ltd. designed, built, and performed demonstration tests of on – site inspection equipment that confirms operational readiness of PWR fuel and NFBC and also gathers data for design verification of these components.

DESCRIPTION OF MEASUREMENTS

On – site fuel inspection system consists of equipment for 13 different measurements that provide useful feedbackdata for design verification, 9 measurements for fuel and 4 for NFBC:

1. Measurements for fuel:
   a. Fuel rod's oxidized film thickness
   b. Fuel rod's profile (diameter)
   c. Fuel rod's bow
   d. Gap between fuel rod's
   e. Grid's spring constant
   f. Visual appearance of interior rods by fiberoptics
   g. Leaf spring force
   h. Thimble tube inside profile (inner diameter)
   i. Fuel pellet positions by γ – ray scanning
2. Measurements of NFBC
   a. Rod's profile and integrity using eddy current encircling coil
   b. Hold down spring force
   c. Visual appearance of inside of hub using fiberoptics
   d. Visual appearance of interior rods using fiberoptics

RESULTS

On – site fuel inspection system was designed and manufactured. Off – site tests were performed using a fuel assembly mockup to verify measurement accuracy and data gathering capability.

On – site tests were performed at one operating plant for about one month. Measurement accuracy, durability, and ease of decontamination of the system were verified to be in accordance with initial design goals.

ON SITE PWR FUEL INSPECTION MEASUREMENT FOR OPERATIONAL AND DESIGN VERIFICATION

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1.Purpose

At periodic inspection of a PWR fuel and NFBC (Non Fuel Bearing Component) only simple appearance check with underwater TV camera has been conducted from the viewpoint of reloading to the core, but detailed information to be reflected to design has not been obtained. A hot laboratory inspection can give detailed information but has some weak points due to restriction based on transporation and reprocessing, delay of feedback of this result as well as limited number of inspeciton items.

To promote research and development of the modified fuel and NFBC durable for future various operating conditions, further detailed information on the fuel and the NFBC is required than those in the past.

For these situations, a proven test was performed for an on－site inspection equipment having similar performance to the hot laboratory to develop practical equipment.

Outline of the equipment and test results are described as follows.

2.Outline of Equipment (see figure 1)

The on－site inspection equipment was designed and manufactured considering measuring accuracy, remote handling performance and integrity of the fuel after measurement.

The on－site inspection system consists of a total of thirteen types of measuring devices that can reflect to the design of the fuel and NFBC Nine units of them were supplied for the fuel and the other four units for NFBC.

For the fuel, the following items can be measured.

* Oxide thickness by an eddy current probe
* Rod outer diameter by a probe type profilometer.
* Rod's bow by a roller type probe
* Rod gap by a probe containing strain gauge
* Spring constant of a support grid by a difference transformer and a load cell
* Direct observation of inside apperance of the fuel by an fiber optics
* Leaf spering force by a difference transformer and a load cell
* Internal inspection of the guide thimble of the control rod measured by an eddy current probe
* Gamma scanning for measurement of position of the pellet in the rod and relative burn up rate on axial direction of four corner rods by Ge detectors

For the NFBC, the following items can be measured.

* Rod outer diameter and rod integrity by a profilometer and a ECT
* Hold down spring force by a load cell and differential transformer
* Direct observation of internal appearance of the hab by a fiber optics
* Direct observation of external appearance by a fibe optics

3.Design and Manufacturing

Design was done considering the following items

* Measuring accuracy
* Remote handling and operability
* Anti – radiation property
* Integrity of the fuel after measurment
* Durability
* Compact and light design
* Easiness of decontamination
* Alignment to handling tools at site

Based on these design criteria, almost of all parts were made of stainless steel and an inspection stand was provided commonly used for fuel measuring on a light design basis. In addition, the surface was buffed for better decontamination.

A computer was used for driving control and measurement of the equipment, and data are stored on a floppy disc as well as output to a printer or a plotter.

Furthermore, VCR and an illumination controller required for image processing were also provided.

4.Off site Test

At open air condition and test pool for development in the Nuclear Fuel Industry Co. Ltd., the performance test on a dummy fuel assembly and a dummy NFBC was conducted.

The test items are as follows

* Smooth operation of the driving mechanism
* Remote handling and operability
* Maintainability
* Integrity of data collection function

Some equipment was modified to improve their performance for better usefull data. This brings clear perspective to establish practical equipment.

5.On site Test

A demonstration test was conducted for the equipment loaded into one operating plant. It took about one month in smooth operation.

6.Test Results and Evaluation

6.1 Thickness of oxide film (see figure 2)

– A target of measuring accuracy of ±5 μm from the off – site test was satisfied.

– The maximum measured data was 28 μm. This was reasonable comparing analytical data of maximum thickness of about 35 μm at 30,000MWd/t burn up.

6.2 Outer diameter of the fuel rod (see figure 3)

- A target of measuring accuracy of ±5 μm was satisfied.

- It is known that a middle section of the fuel rod becomes narrower due to large creep down through progress of burn up. Test result proved this trend is reasonable.

- The maximum ridge height was 15 μm. This was reasonable comparing analytical value from an open code of FEMAXI-III of about 20m μ.

6.3 Fuel rod's bow (see figure 4)

- Measured accuracy was ±0.2mm. This was acceptable.

6.4 Fuel rod gap

- Measured accuracy was ±0.05mm. This was acceptable.

- Rod with a gap less than 1 mm was rejected to insert by a gap sensor because this deviated the measuring region of this equipment with 1.0 to 4.5mm.

6.5 Spring constant of supporting grid

- Measurement was done for two fuel assemblies, average data were 16.3 kg/mm and 16.0 kg/mm. These data were considerably agreed with design value were judged reasonable.

6.6 Appearance inspection of inside the fuel rod

- Resolution was slightly inferior to the off-site test but was available for flaw and dent inspection sufficiently without any practical problem. In addition, no scar and other defect were found to prove integrity of the rod and the grid.

6.7 Leaf spring force

- Measured accuracy was ±0.5% as a reasonable value.

- Measured data lowered design permanent strain curve to show integrity of the leaf spring.

6.8 Inspection of inside of the control rod guide thimble

- Averagve inner diameter was 12.820mm. This shows that after irradiation did not change inner diameter from original shop data of 12.811 to 12.853mm.

An eddy current examination was also done to prove its integrity without thinned section by 20% and more.

6.9 Gamma scanning

- Identified nuclides

(Fuel region) : Kr-106, Cs-134, Cs-137, Zr-95, Nb-95

(Plenum region) : Co-60, Kr-85

- Counting error was about 3% for eight minute measurement.

- The speed of the hoist used for lifting the fuel assembly was large, 35mm/sec, so that pellet inside the rod and distance between pellets could not be measured.

6.10 Outer diameter of NFBC rod

- Outer diameter of the neutron source rod was measured. Its accuracy was ±3 μm acceptable.

6.11 Integrity inspection of NFBC rod

— An eddy current examination was done for BPA rod. No defect with thinned section by 20% or more was found to be acceptable.

6.12 Hold down spring force

— Measured accuracy satisfied data from the off-site test of ± 10%.

6.13 Inspection of inside the hub and rod appearance

— Resolution was rather poor comparing the off-site test, but it was acceptable for practical work. No defect was found inside the hub and rod showing their integrity.

7. Results (see table 1~3)

As a result of the in-site demonstration test, the following data were obtained.

The on-site inspection system was proved to have expected performance concerning measuring accuracy, durability and decontamination. These data also show that the fuel rod has sufficient property after irradiation as expected in design process.

We hope that this equipment will be applied in the fuel development in the future.

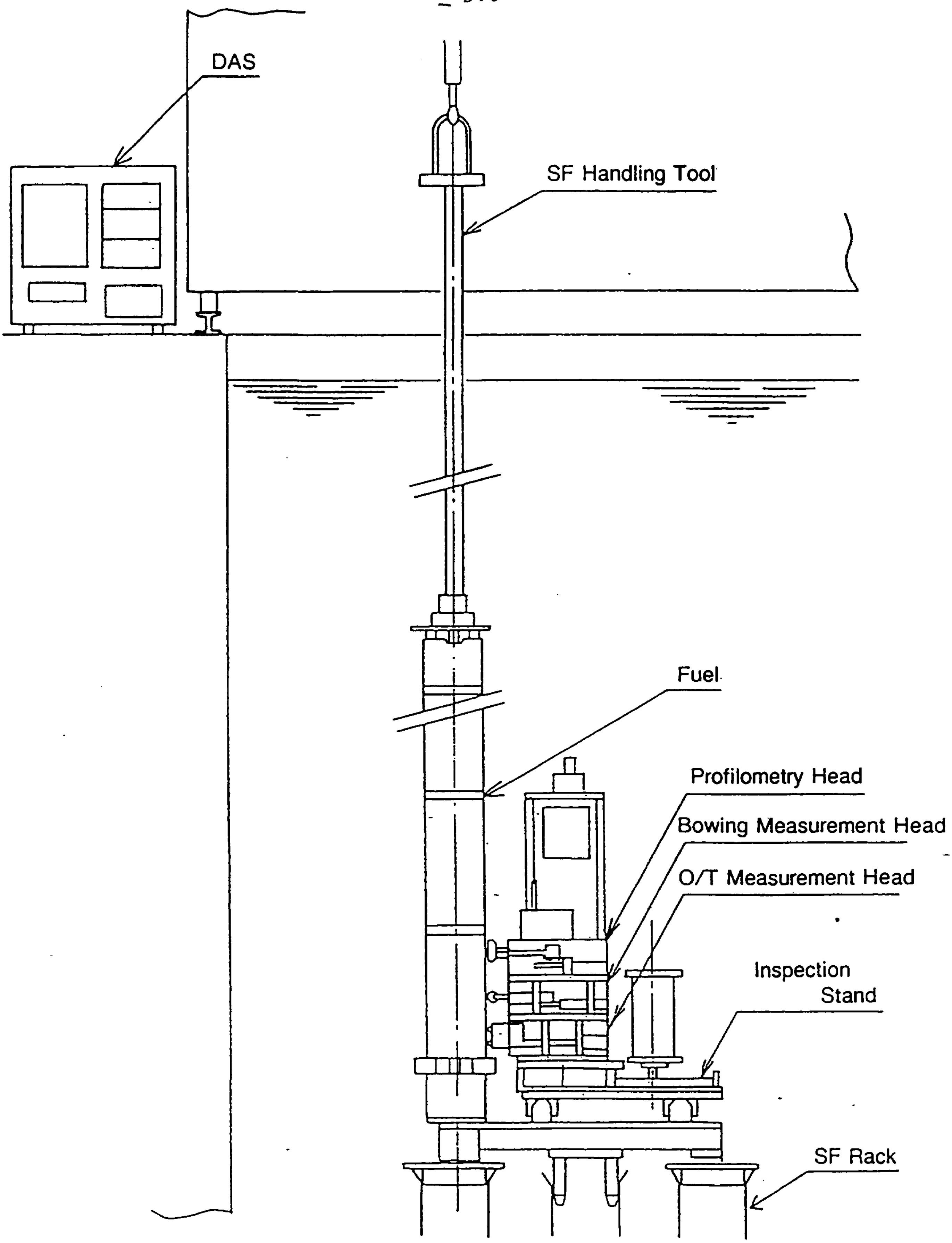

Figure 1 On - Site Fuel Inspection System Test Way

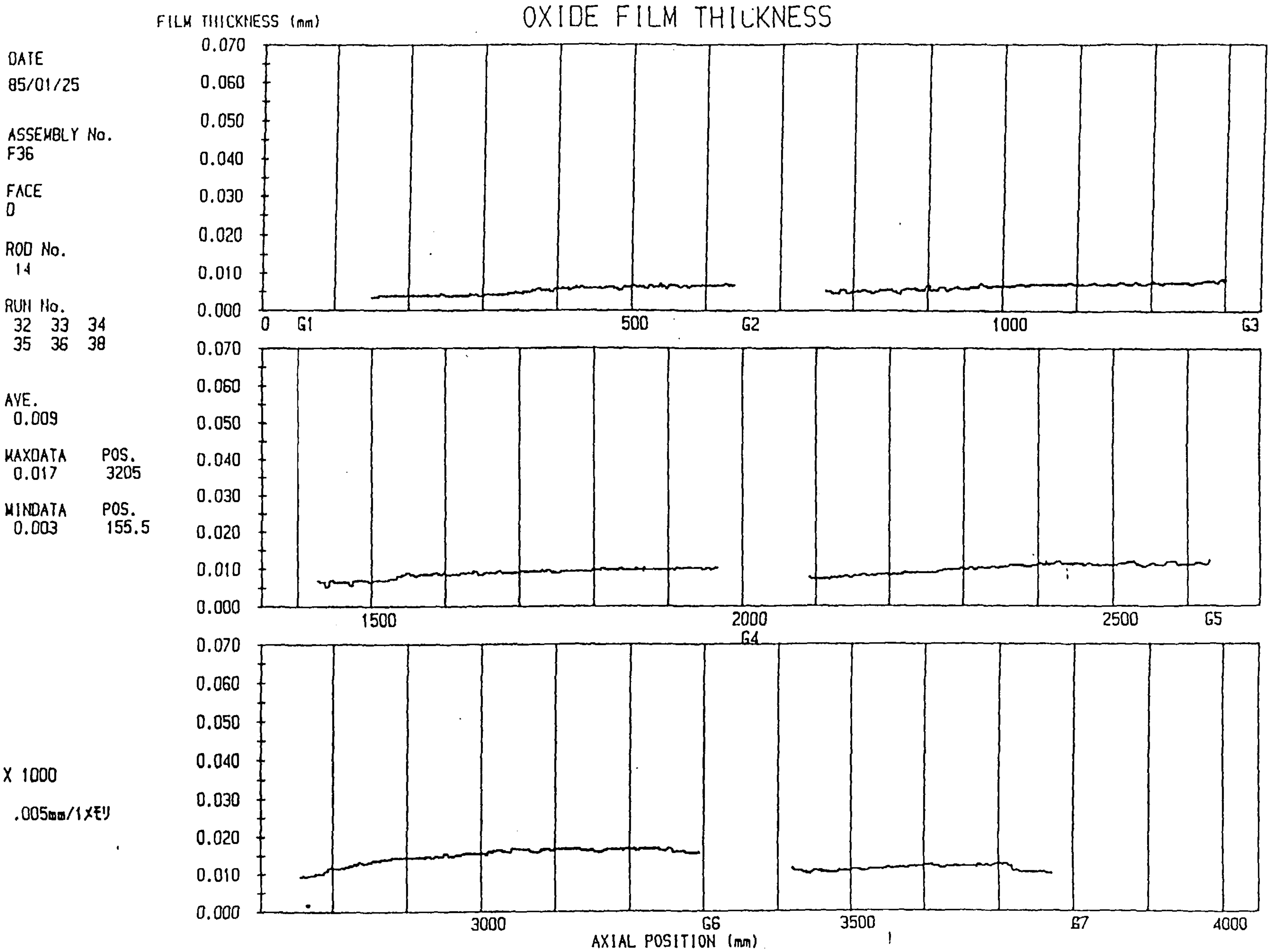

Figure 2 SAMPLE OUTPUT OF OXIDE FILM THICKNESS

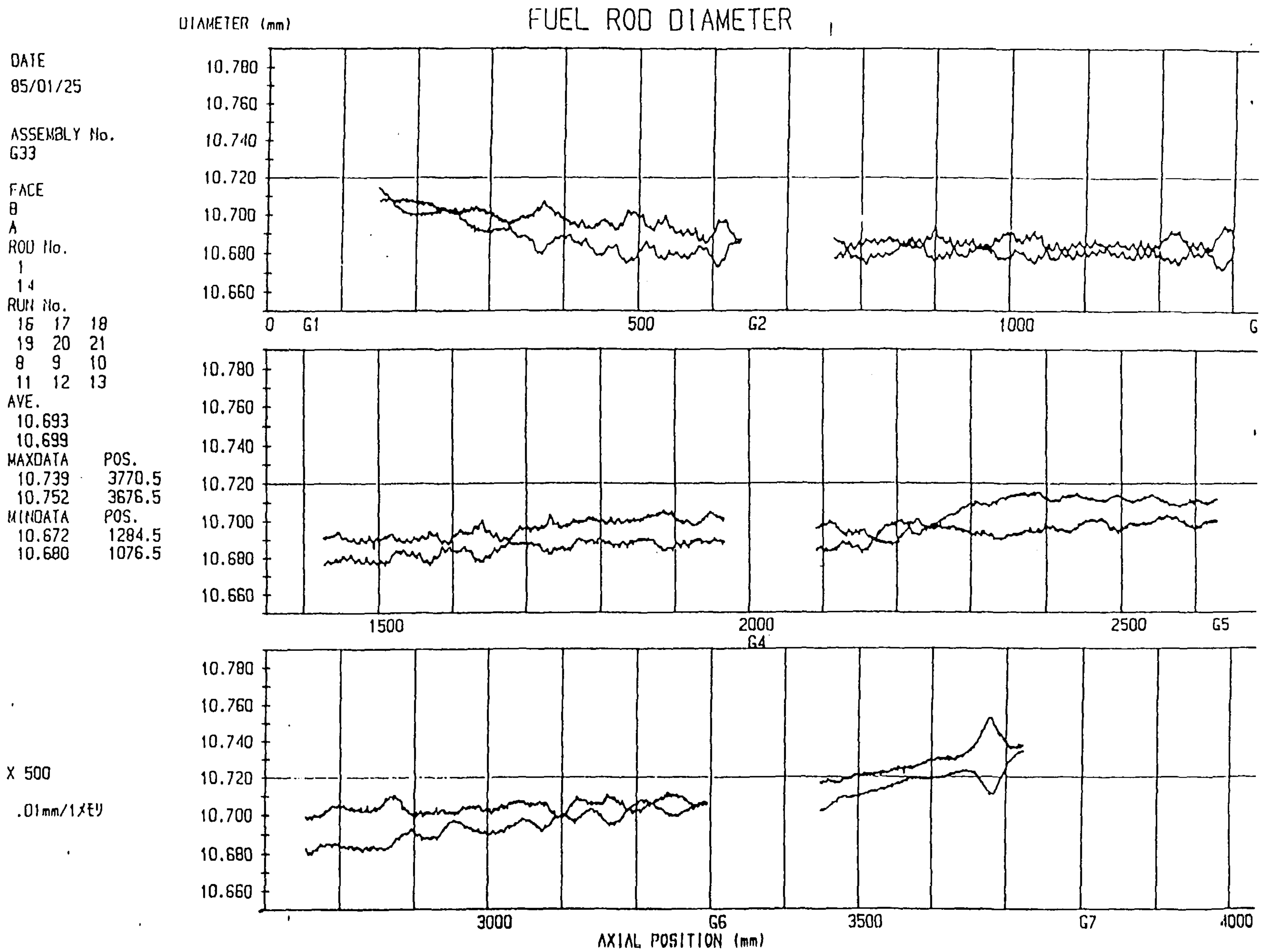

Figure 3 SAMPLE OUTPUT OF FUEL ROD DIAMETER

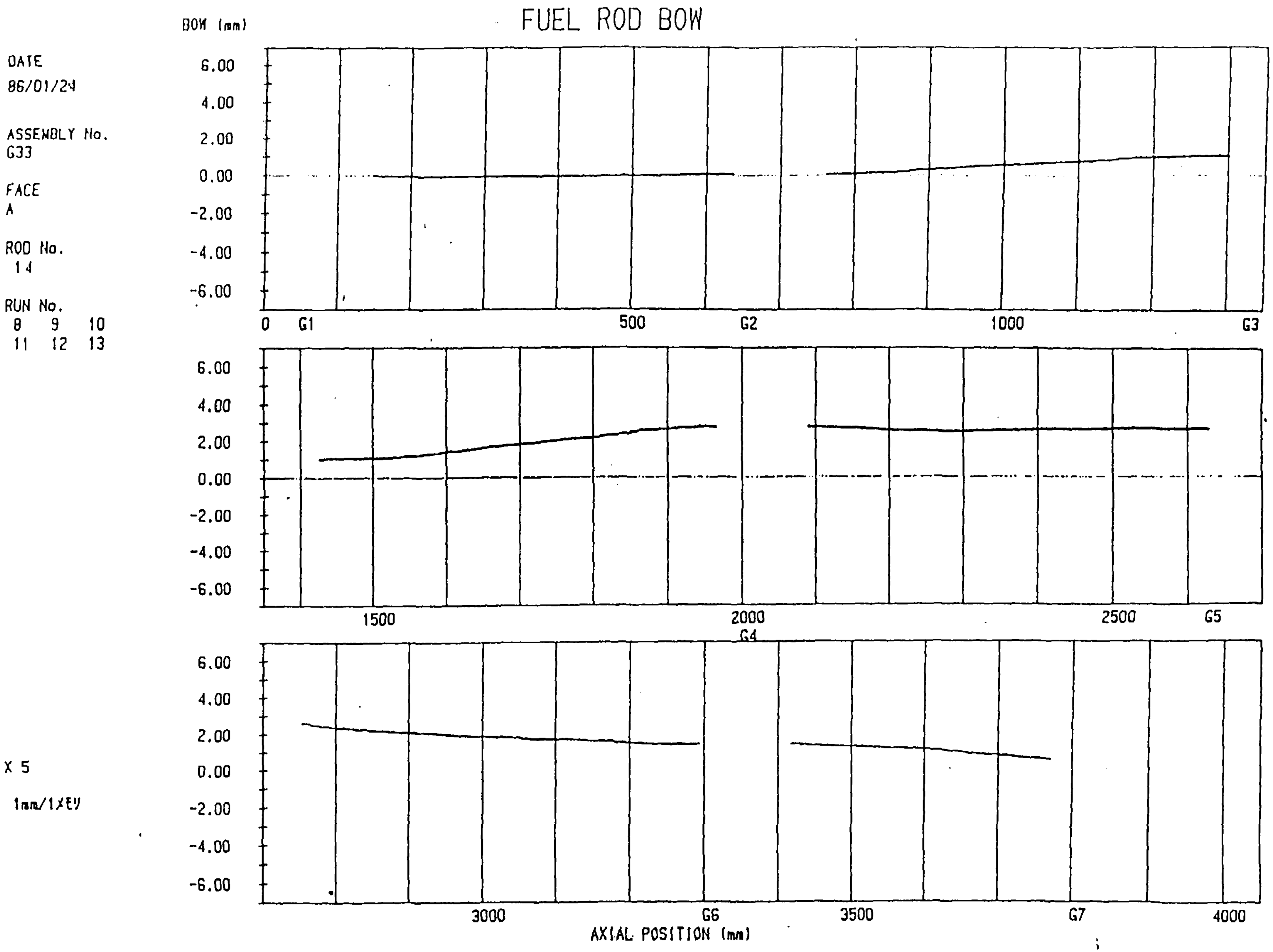

Figure 4 SAMPLE OUTPUT OF FUEL ROD BOW

Table 1 ON-SITE PWR FUEL INSPECTION SYSTEM FOR FUEL (1/2)

No	Item	Method Outline	Information	Accuracy
1.	Oxide Thickness Measurement System	• ECT • contact probe	• Axial Distribution of Oxide Thickness	±3 μm
2.	Rod Profilometry Measurement System	• LVDT • contact needls	• Profilometry (Swelling,Ridging)	±5 μm
3.	Rod Bow Measurement System	• LVDT • contact Roller	• Rod Bow	±0.2mm
4.	Rod Gap Gauge	• Strain Gauge • insert Gap Gauge	• Rod Gap	±0.05mm
5.	Grid Spring Force Measurement System	• Load Cell, LVDT • retract Grid with Fingers	• Spring Constant (Load vs Deflection)	±15 %

Table 2 ON-SITE PWR FUEL INSPECTION SYSTEM FOR FUEL (2/2)

No	Item	Method Outline	Information	Accuracy
6.	Fuel Inside View System	• Fiber Optics • insert Fibers	• Visual Information of Inside Rod	———
7.	Leaf Spring Measurement System	• Load Cell,LVDT • press Leaf Spring	• Spring Constant • Spring Height	±5 %
8.	Guide Thimble Tube Inspection System	• Straingage,ECT • insert probe into Tube	• Inner Tube plofilometry • Fault Detection	±0.03mm
9.	Gamma Scanning System	• Ge Detector • use shielding container	• Axial pellet Location • Corner Rod Burn UP	Counting Error ±3 %

Table 3 ON - SITE PWR FUEL INSPECTION SYSTEM FOR NFBC

No	Item	Method Outline	Information	Accuracy
1.	Rod Profilometry Measurement System	• LVDT • contact Finger	• Profilometry	± 3 μ m
2.	Rod ECT System	• ECT • Encircling Coil	• Fault Detection	———
3.	Holddown Spring Force Measurement System	• Load Cell,LVDT	• Spring Constant • Spring Height	± 10 %
4.	Inside of hub View System	• Fiber Optics • insert Fibers	• Visual Information of Inside hub	———

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