CONF-791103--53

GA-A15496

DEVELOPMENT OF A SURVEILLANCE ROBOT FOR DIMENSIONAL AND VISUAL INSPECTION OF FUEL AND REFLECTOR ELEMENTS FROM THE FORT ST. VRAIN HTGR

by

C. F. WALLROTH, N. I. MARSH, C. M. MILLER,
J. J. SAURWEIN, and T. L. SMITH

MASTER

DATA PUBLISHED: NOVEMBER 1979

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

GENERAL ATOMIC COMPANY

GA-A15496

DISCLAIMER

This book was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DEVELOPMENT OF A SURVEILLANCE ROBOT FOR DIMENSIONAL AND VISUAL INSPECTION OF FUEL AND REFLECTOR ELEMENTS FROM THE FORT ST. VRAIN HTGR

by

C. F. WALLROTH, N. I. MARSH, C. M. MILLER,
J. J. SAURWEIN, and T. L. SMITH

This is a preprint of a paper to be presented at the ANS/AIF Winter Meeting, 27th Conference on Remote Systems Technology, November 11-16, 1979, San Francisco, California, and to be published in the Proceedings.

Work supported in part by
Department of Energy
Contract DE-AT03-76ET35300

GENERAL ATOMIC PROJECTS 6400 AND 4041
DATE PUBLISHED: NOVEMBER 1979

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

GENERAL ATOMIC COMPANY

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

ABSTRACT

A robotic device has been developed for dimensional and visual inspection of irradiated HTGR core components. The robot consists of a rotary table and a two-finger probe, driven by stepping motors, and four remotely controlled television cameras. Automated operation is accomplished via minicomputer control. A total of 51 irradiated fuel and reflector elements were inspected at a fraction of the time and cost required for conventional methods.

1. INTRODUCTION

A robotic device has been developed by General Atomic Company (GA) for dimensional and visual inspection of irradiated fuel and reflector elements of the Fort St. Vrain High-Temperature Gas-Cooled Reactor (HTGR) near Denver, Colorado. The system comprises an automatic dimensional data on-line facility and is designed to inspect complete core regions at a fraction of the time and cost required for conventional remote inspection methods. The operation is done at the reactor site within the Hot Service Facility by interfacing with the fuel handling machine. The data obtained from these inspections monitor the performance of graphite blocks in the core and are used for verification of HTGR design methods.

2. DESCRIPTION OF METROLOGY ROBOT

The metrology robot (Fig. 1) consists of a rotary table, which positions a hexagonal core component in a vertical configuration, and a two-finger replaceable probe (Fig. 2) with the capability to move in an x, y, and z Cartesian coordinate system. The drive systems are powered by four programmable stepping motors whose travel can be preselected by numbered thumb-wheel controls. Each full step of the motors allows 0.025-mm (0.001-in.) movement in the x and y directions, 0.032-mm (0.00125-in.) movement in the z direction, and 0.03° of rotation. The stepping motors are coupled with free-wheeling d.c. motors which serve as auxiliary drive systems. The motor drives are modularized for quick replacement and maintenance. The coordinates of the probe are predetermined by three drives including rotation, with the fourth system driving the probe into the test object. The probe contains a displacement system to allow activation of two redundant microswitch systems, one of which has overload shutoff capability.

The coordinates of the probe table are determined by a magnetic encoder system (Sony Magnescales) and a resistivity measurement system of rotary potentiometers as a redundant backup system. The displacement of the probe itself has two Cartesian measurement systems, i.e., linear potentiometers and linear variable differential transformers (LVDTs). The position of the rotary table is measured by a resolver system, with a dual rotary potentiometer system as redundant readout.

Data are recorded by a microprocessor controlled data logger (Accurex Autodata 9) with paper printout and magnetic tape deck. For automated operation and on-line evaluation, an LSI 11 minicomputer system (Nuclear Data ND6620) is used, with the data logger recording system as a backup. The control and data acquisition units are shown in Fig. 3.

The robot is instrumented with ten resistivity thermometers (RTDs) for temperature monitoring and compensation. System heatup occurs from decay heat of the irradiated fuel elements and the heat generated by the lighting required for visual inspections. Radiation- and temperature-resistant components are used as much as practicable.

System contamination during data acquisition and gross gamma activities are measured by a miniature Geiger-Muller tube and CaTe crystal. Motor function and maintenance operations can be surveyed via an intercom system. Three remotely controlled black and white television camera systems for performing visual inspections are mounted on the robot. A color camera system located some distance from the robot is also used for performing visual inspections.

Operation of the metrology robot is in a fully automated closed-loop mode. This includes computer verification of proper movement and corrective actions without any, or only minimum, operator interface; intrinsic search routines are available to account for irradiation-induced shrinkage and bow of the graphitic core components. Comparison of redundant measurement devices, as well as on-line data reduction, is done by the computer.

This allows the system to automatically overcome potential malfunctions, such as motor stalling or missing an intended hole or surface. System redundancy is used to maximize data output and minimize downtime.

3. DESCRIPTION OF METROLOGICAL AND VISUAL INSPECTIONS

A metrological inspection consists of two calibration and five test modules:

Calibration Module I	On the calibration cube for probe deflection.
Calibration Module II	On the rotary table for table orientation.
Test Module I	Inspection of six vertical block surfaces at up to 11 axial locations with 5 measurements.
Test Module II	Chord measurements at the top of the element only to determine the distance across the flats (radial strain).
Test Module III	Inspection of axial length at the top surface of the block in 54 locations to determine bulk length change (axial strain) and radial bow distribution.
Test Module IV	Measurement of the distance between and diameter of ≤40 coolant holes at the top surface.
Test Module V	Determination of the proportional changes in axial length from four fiducial holes drilled into each of the six corners of special surveillance and test elements.

The time required for a metrological inspection of a full-size fuel element depends on the thoroughness of the inspection. The full-length inspection of a surveillance element includes 604 measurements on the block and requires approximately 4-1/2 h. The abbreviated inspection generally employed for nonsurveillance elements includes 370 measurements and requires approximately 3 h.

Visual inspections, which are performed concurrently with the metrological inspections, are done with four remotely controlled television camera systems and recorded on video tape in black and white or in color. All six sides and the top and bottom surfaces of the block are inspected. All surfaces of the block are also photographed as part of the visual inspection.

4. ROBOT DEVELOPMENT AND PERFORMANCE

Conceptual development of the metrology robot began in 1974 and detailed design was initiated in 1975. By the end of 1976 the basic unit was constructed, which was a manually operated metrology device for analog data acquisition. Since then the system has undergone major design changes for redundancy, digital data acquisition, on-line data reduction, operation at elevated temperatures up to 300°C at the fuel element surface, and fully automated operation via minicomputer controlled stepping motor drives and microprocessor-based data logging. Programmable manual operation of the redesigned system was achieved in June 1978, and fully automated operation in the open-loop mode was accomplished in December 1978. Fully automated closed-loop operation was achieved in May 1979.

During a 26-day test period in June 1979, 53 complete fuel element inspections were performed in the laboratory on a dummy fuel element at room and elevated temperatures. In the subsequent surveillance inspection at the Fort St. Vrain reactor site during July 1979, 51 surveillance fuel and reflector elements from core segment 1 were inspected. The robot and its control and peripheral hardware performed extremely well over the 27 days of nearly continuous operation. Robot availability was 100% for the task. The total time that irradiated elements were on the robot was 325 h. Robot components received doses up to 3×10^6 rad and experienced temperatures close to 60°C without any observable detrimental effects.

The visual examination found all 51 elements in good condition, and very valuable and accurate graphite strain data were obtained. Repeated measurements made during each inspection on a precisely machined calibration cube mounted on the turntable platform of the robot indicated a worst case accuracy of ±0.2 mm and an average accuracy of ±0.05 mm.

The robot was sent back to GA in San Diego, where it was successfully decontaminated and placed into the laboratory for "hands-on" post-operation testing and integration with a second robotic system for gamma spectroscopic core surveillance.

5. ACKNOWLEDGEMENT

The authors wish to thank all who helped them develop and operate the robot.

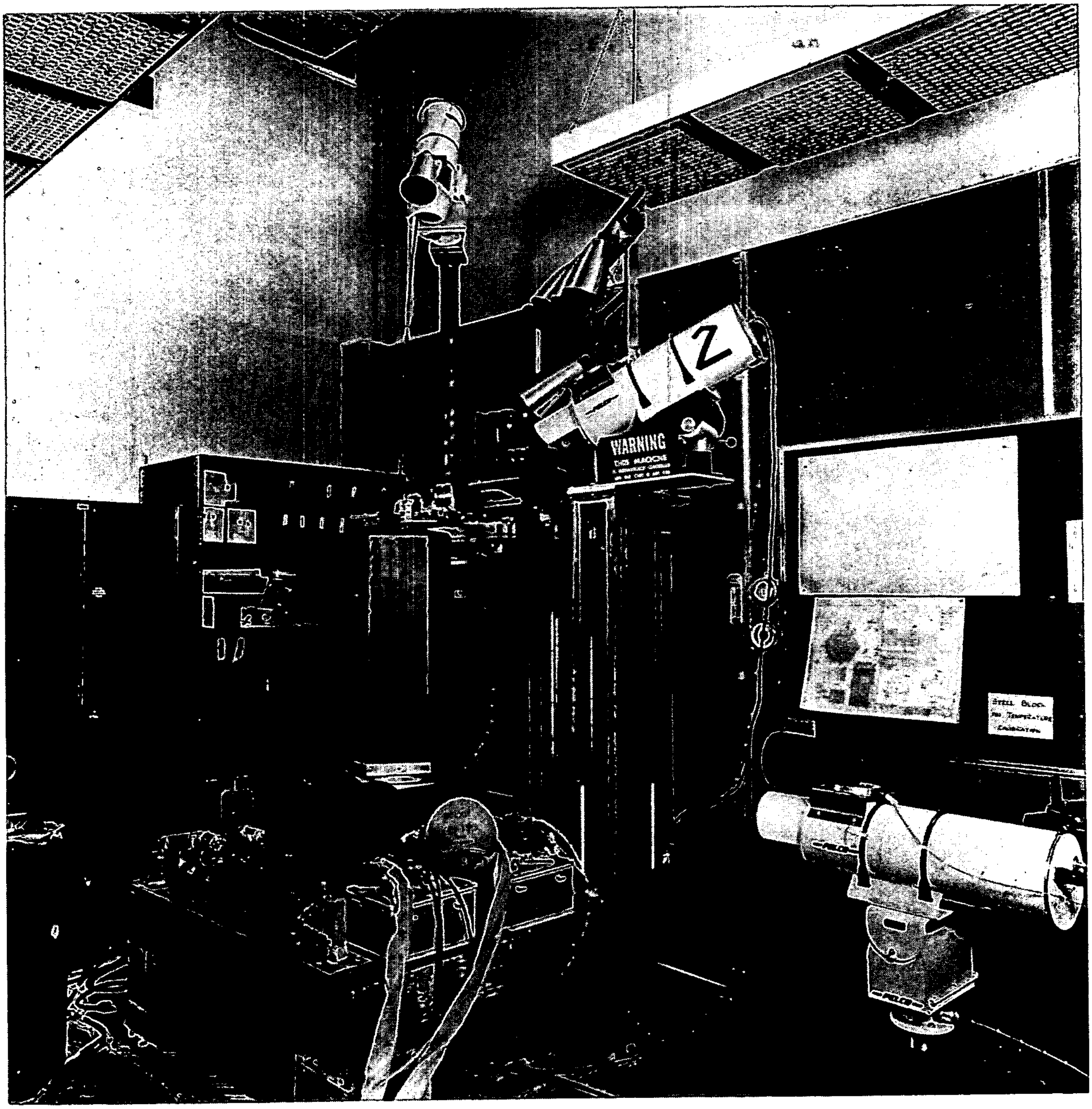

Fig. 1. Metrology robot, June 1979

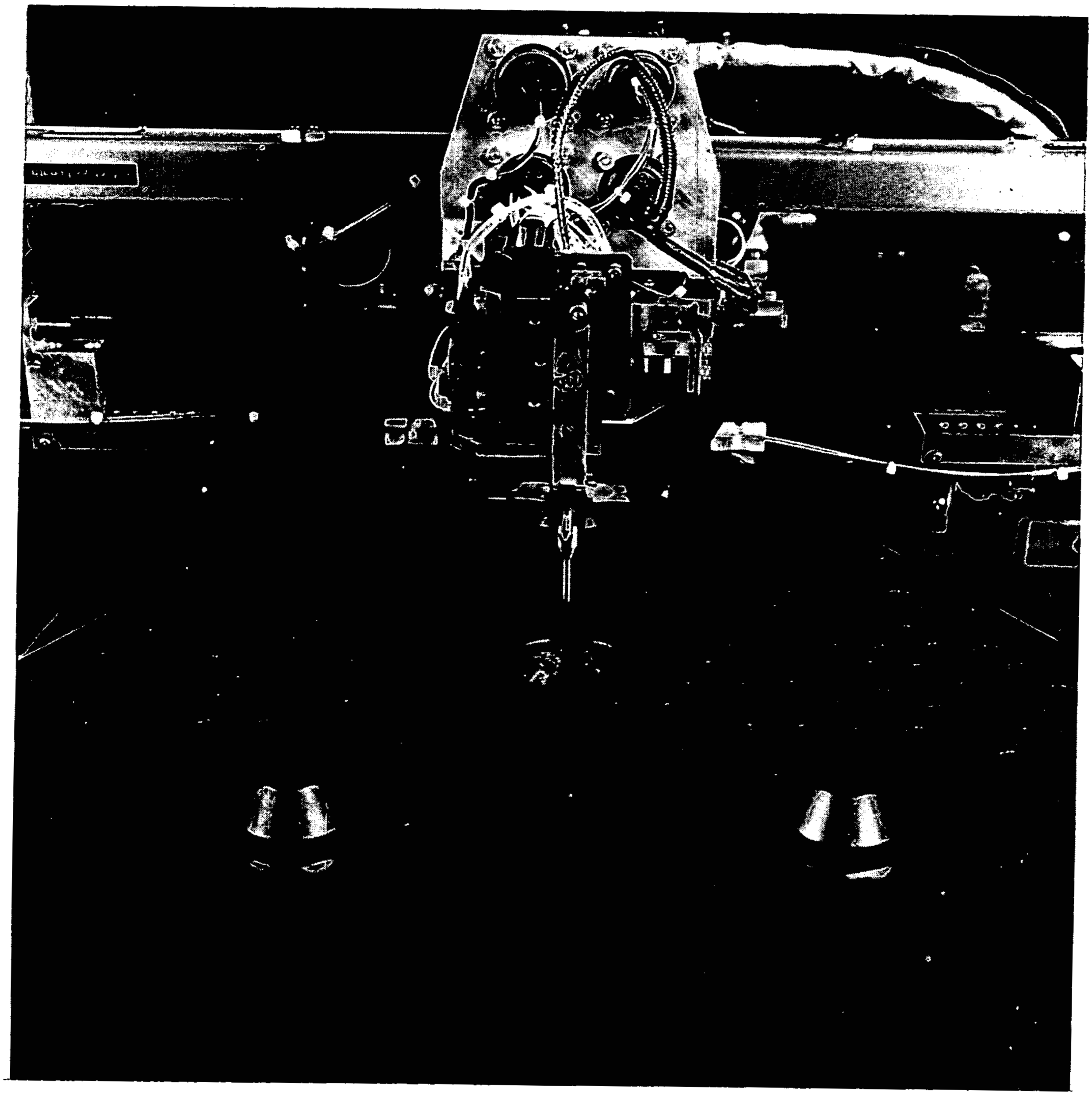

Fig. 2. Metrology robot probe performing coolant hole measurement

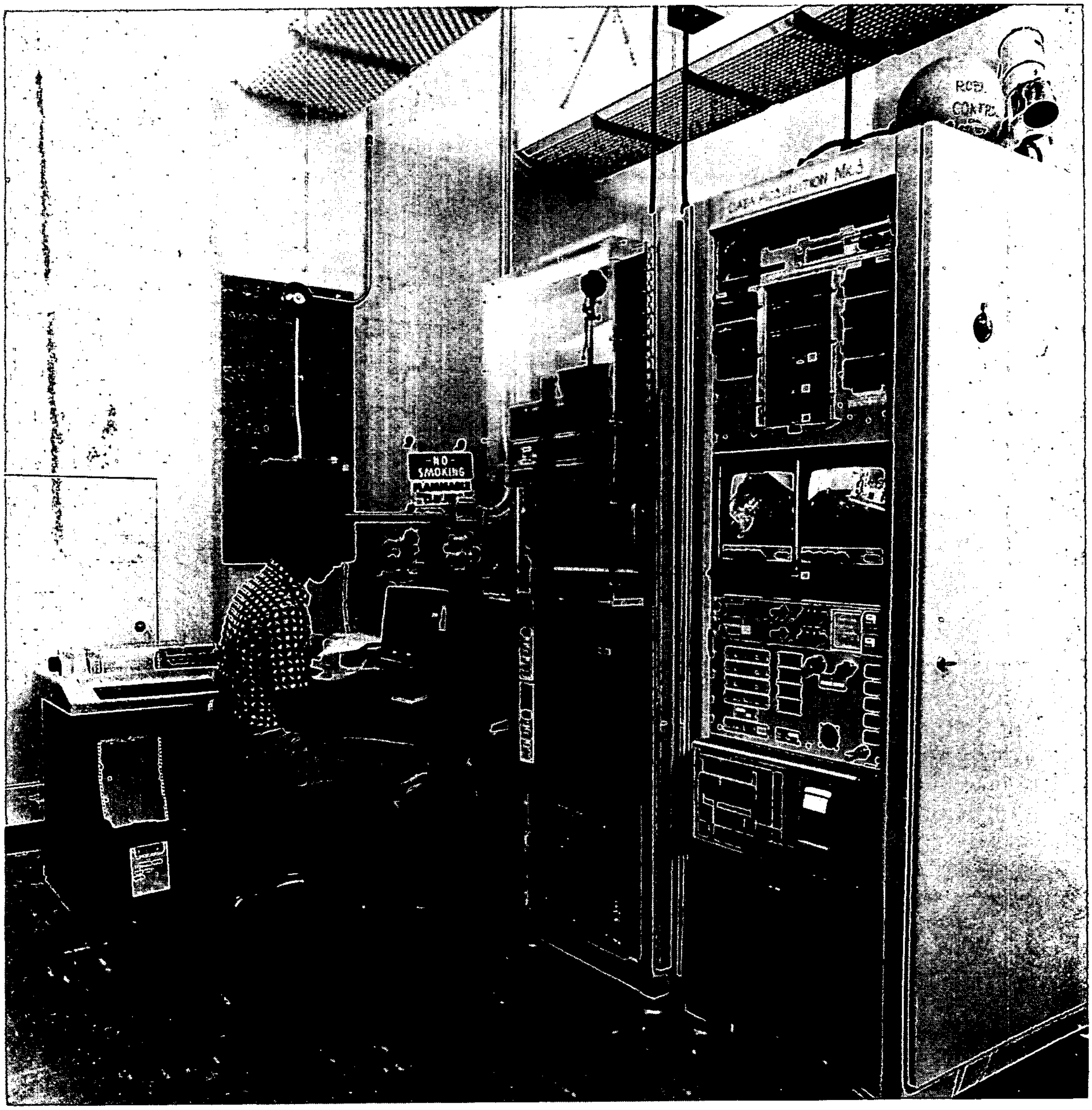

Fig. 3. Metrology robot data acquisition and control system