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NUCLEAR FUEL EXAMINATION FACILITY WINFRITH

A COMPUTER CONTROLLED MACHINE FOR THE ASSESSMENT OF SHAPE CHANGES OF IRRADIATED GRAPHITE SLEEVES FROM ADVANCED GAS COOLED REACTOR FUEL ELEMENTS

by

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SUMMARY

Fuel rods in an advanced gas cooled reactor cluster are supported by a grid and two braces located by inner and outer graphite sleeves. The dimensions of these sleeves change during service due to a combination of irradiation creep and radiolytic corrosion in the carbon dioxide coolant.

The machine described will measure the length and diameter of the sleeves from all the CEGB's reactors together with sleeve bow and end face distortion. Measurement is by transducers driven to the required location by stepping motors and the complete measurement sequence is controlled by a programme stored in a PET Commodore computer. The output is collected on a floppy disc system from which it is passed back to the computer for assessment and tabulation before storage on an archive disc in a format suitable for report reproduction.

1 INTRODUCTION

The assessment of dimensional changes in irradiated fuel elements from the Commercial Advanced Gas Cooled Reactors (CAGRs) is an important aspect of the post-irradiation programme. In particular the dimensions of the graphite sleeves, which contain the fuel pins supported by a grid and two braces, change during service due to a combination of irradiation creep and radiolytic corrosion in the carbon dioxide coolant.

This paper describes a purpose-built rig, designed to measure the diameter, length, bow and the end-profile of inner and outer graphite sleeves for all the types of CAGR fuel element, received by the Active Handling Facility at AEE Winfrith. The rig employs a microcomputer to control stepping motor movement, transducer reading and data analysis, also prompting the operator at each stage of the measurement routine. Results are given of the commissioning trials of the rig and the problems associated with operation of a necessarily complex engineering structure are assessed.

2 ENGINEERING ASPECTS

The prime requirement of any equipment to be used in a hot cell environment is one of ease of handling. All operations must have the possibility of being carried out simply and effectively using remote handling equipment; this consideration applies equally to the stages within the measurement routine and to general maintenance of the rig components. Such constraints define fairly closely the design of a complex engineering structure.

2.1 General Construction

The metrology rig (Fig 1) supports the graphite sleeve (Fig 2) undergoing measurement on four accurately aligned rollers; one pair of which can be rotated using a stepping motor. The two transducers used to measure diameter and bowing are supported on the traversing bridge which is driven by another stepping motor through the leadscrew.

End profile units (Fig 3) are located at either end. These provide a housing for the transducers used to assess end profiles and can be set to accommodate two different diameters for both the centre heights required. In this way all types of graphite sleeve from the present generation of CAGRs can be measured. The transducers are rotated using DC servo motors with positional information obtained from a potentiometer located in each motor.

2.2 Conversion for inner sleeve measurement

Since inner sleeves are much shorter than the outer sleeves and have smaller diameters, it is necessary to fit additional rollers to raise the centre height into an equivalent position to that of the outer sleeve in order to measure them. The supplementary rollers fit through cut-outs on the cradle and provide a direct drive from the main support rollers.

A removable plate mounted on the traversing bridge provides a datum for measuring the length of the inner sleeve. By incrementing the stepping motor until the end of the sleeve contacts the right hand end squareness unit (detected by a change in the transducer output) a length can be computated.

An inner sleeve in position and undergoing measurement is shown in Fig 4.

3 CONTROL AND INTERFACING

A Commodore PET microcomputer is used to control the metrology rig and analyse the data which is collected from the transducers. Custom made interfacing (Fig 5b) allows the computer to drive the stepping motors and DC servo motors from the parallel port (the user port) of the computer.

Output from the transducers and the potentiometers is accepted by the processor as a digital signal from a 12-bit analog to digital convertor through the resident serial interface port; this is in fact designed to the IEEE 488 standard. Figure 5a shows the system organisation schematically.

The control program is loaded into the Random Access Memory of the microcomputer from disc at the beginning of each working day. This interactive software defines the order of measurement and provides an updated display of the data as it is collected. At crucial points in the routine prompts are given to the operator and the measurements will only proceed when a correct response is given to the microcomputer via the keyboard.

4 MEASUREMENT ROUTINE

The sequence of operations required to assess the post irradiation dimensions and shapes of the fuel elements is defined by the control program. A simplified flow diagram representing a measurement run for outer graphite sleeves is shown in figure 6.

Once begun, the program sets up working space for variable storage, opens appropriate files and loads the machine code subroutine before moving into the calibration mode. Two independent standards are used to calibrate the transducers for the length and diameter measurements. A simple algorithm produces a linear fit to both sets of calibration data and these equations are used to calculate the various dimensions of the sleeve under test.

During the measurement phase of the operation the microcomputer alternately drives the transducers to the required location and then reads the digitally converted signal produced at each position. These are stored as points in a pre-dimensional array. After each stage in the procedure the operator is asked to decide if valid data has been obtained and if the results appear to be incorrect the measurements are repeated. In this way it is possible to monitor each stage of the operation and decrease the possibility of spurious results.

The final results are then stored in disc files which can be interrogated at a later date when detailed analysis is required for assessment of fuel performance. As a backup facility, a hardcopy printout is also produced; this ensures that the information is available for assessment even if the disc stored data becomes corrupted.

5 RESULTS OF COMMISSIONING TRIALS

A series of measurements to determine the length and diameter of an unirradiated outer sleeve together with its end-squareness have been carried out. The outer sleeve was of the Hinkley design and was machined (Fig 7) to simulate variations in lengh, diameter and end profile. It was not possible to produce a bow in the sleeve by machining.

The results are set out in the table where they are compared with those obtained by standard, high accuracy, measurement techniques. At this stage it seems probable that length and diameter changes will be obtained to an average accuracy of 0.03 mm. The end profile can only be simply determined if the bow is small and in this case a similar accuracy is obtained.

The next stage of commissioning will involve measuring the length and diameter of inner sleeves.

6 DISCUSSION

This rig has the advantage of being able to fully characterise the shape of all the types of graphite sleeves which are in use. Once loaded, the measurement sequence does not require use of manipulators and this considerably eases the problem of in-cave location. In addition the limited operator intervention required is expected to reduce the number of measurement errors.

The disadvantages of the machine are that it is large and complex. The former is not a serious problem given the limited manipulator access needed. It will only be possible to judge the effects of complexity after a prolonged period of in-cave use. This will enable an assessment of how the time needed to repair faults will limit availability.

The out-of-cave commissioning trials indicate that the machine will reduce measurement time whilst giving more information than the existing system. An important part of this saving arises from the improvement in data handling.

Development of this rig represents a further step in the movement towards automation of in-cave measurement. Following the graphite rigs installation, commissioning of a machine for the routine measurement of shape changes in CAGR fuel pins will be completed.

7 ACKNOWLEDGEMENTS

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TABLE: The results of sleeve measurement trials

Dimension	Inspection	Metrology Rig	Difference
Length			
Position 0	1036.76	1036.83±0.0006	+ 0.07
1	1039.00	1039.01±0.0008	+ 0.01
2	1033.72	1033.69±0.0009	- 0.03
3	1039.03	1039.08±0.0009	+ 0.05
4	1039.07	1039.11±0.0013	+ 0.04
5	1034.70	1034.74±0.0018	+ 0.04
6	1039.07	1039.08±0.0006	+ 0.01
Diameter Position			
15 mm from spigot	238.15	238.13±0.0008	- 0.02
A	237.70	237.68±0.0015	- 0.02
B	237.17	237.14±0.0030	- 0.03
C	236.70	236.65±0.0015	- 0.05
mid point	238.13	238.10±0.0038	- 0.03
250 mm from step	238.13	238.09±0.0023	- 0.04
15 mm from step	238.16	238.17±0.0038	- 0.01

Note Measurement positions refer to figure 7.
All dimensions are in millimetres.

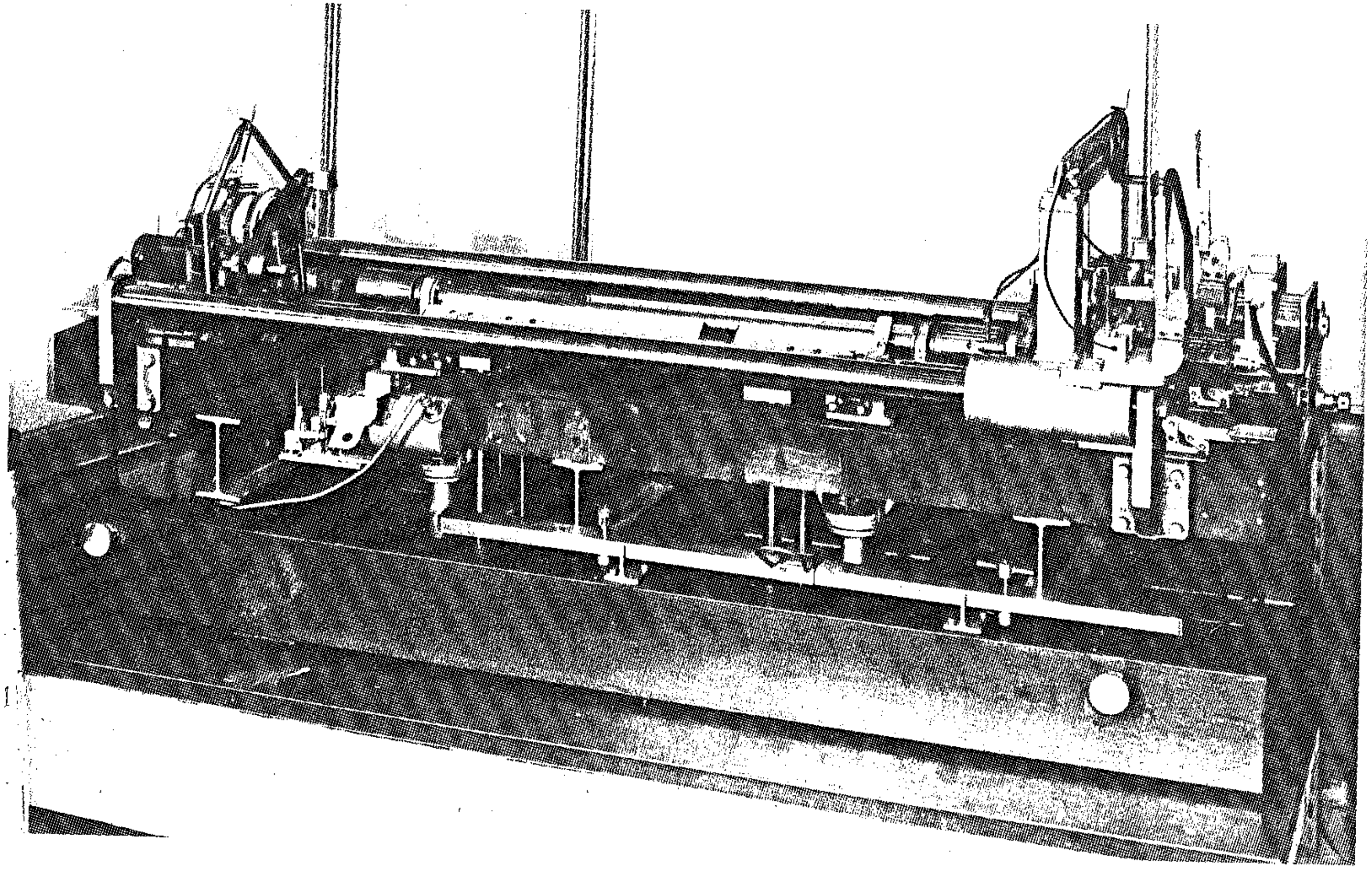

Figure 1 The Graphite Metrology Rig

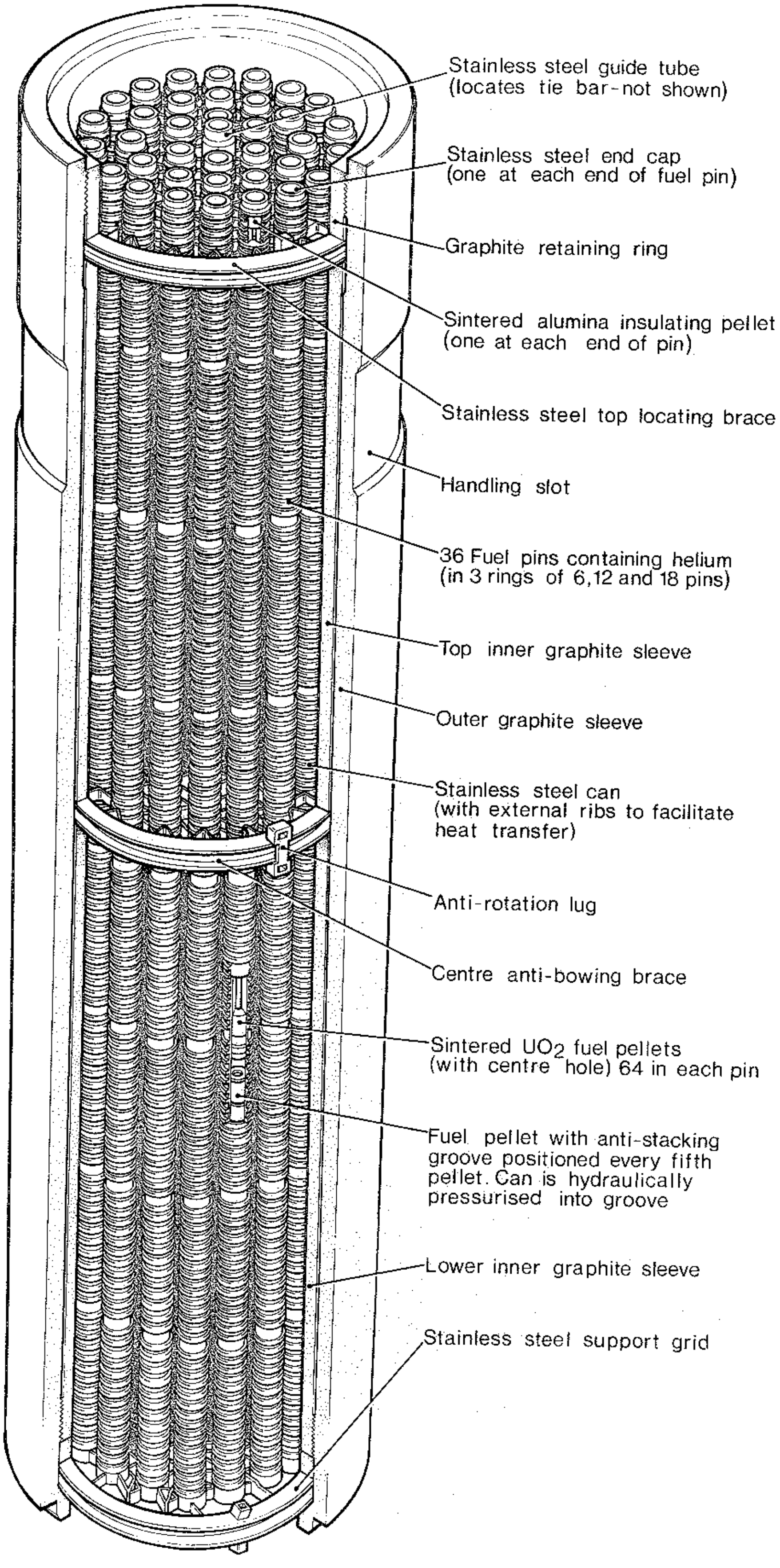

FIG.2. CAGR FUEL ELEMENT

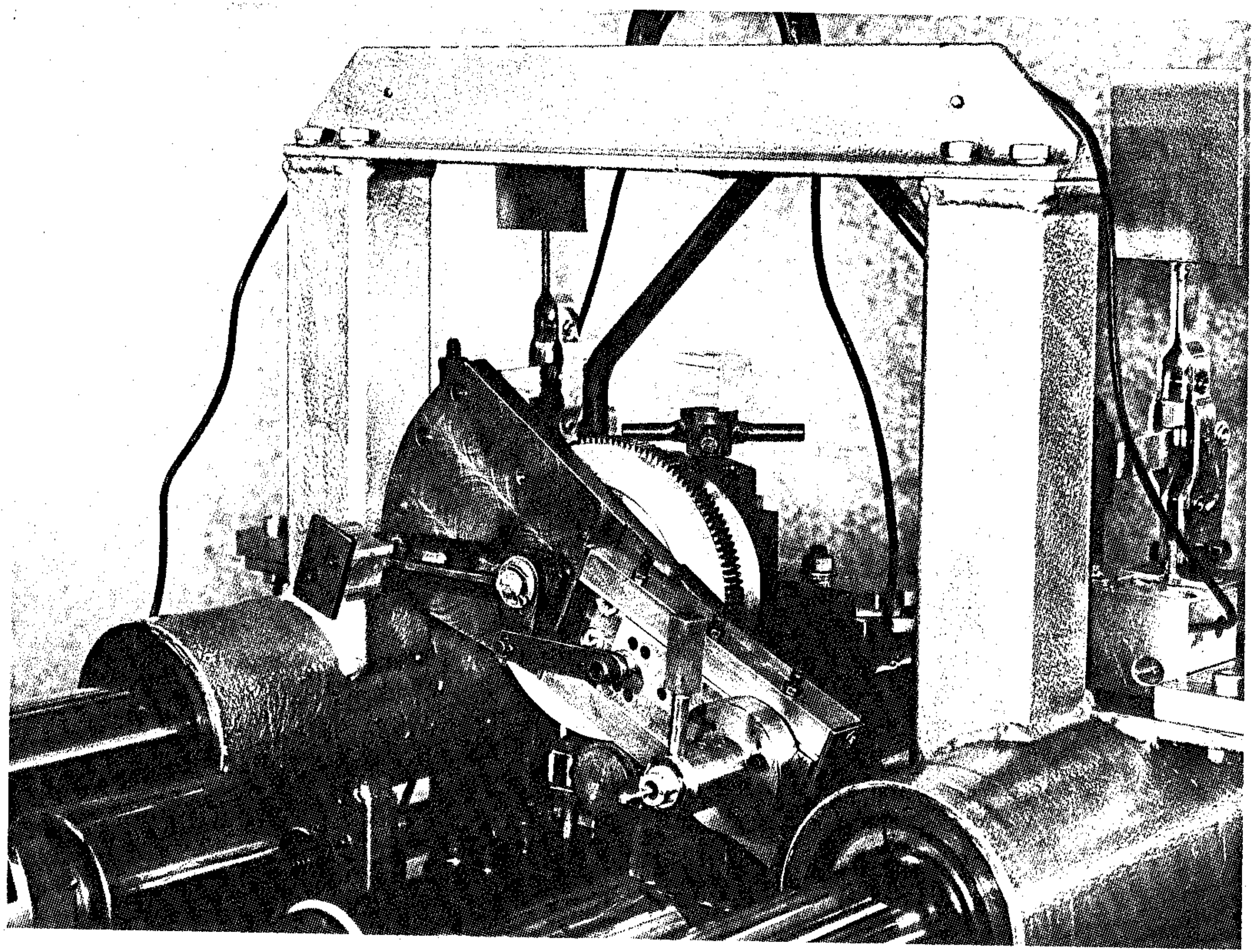

Figure 3 The end profile units showing transducer mountings

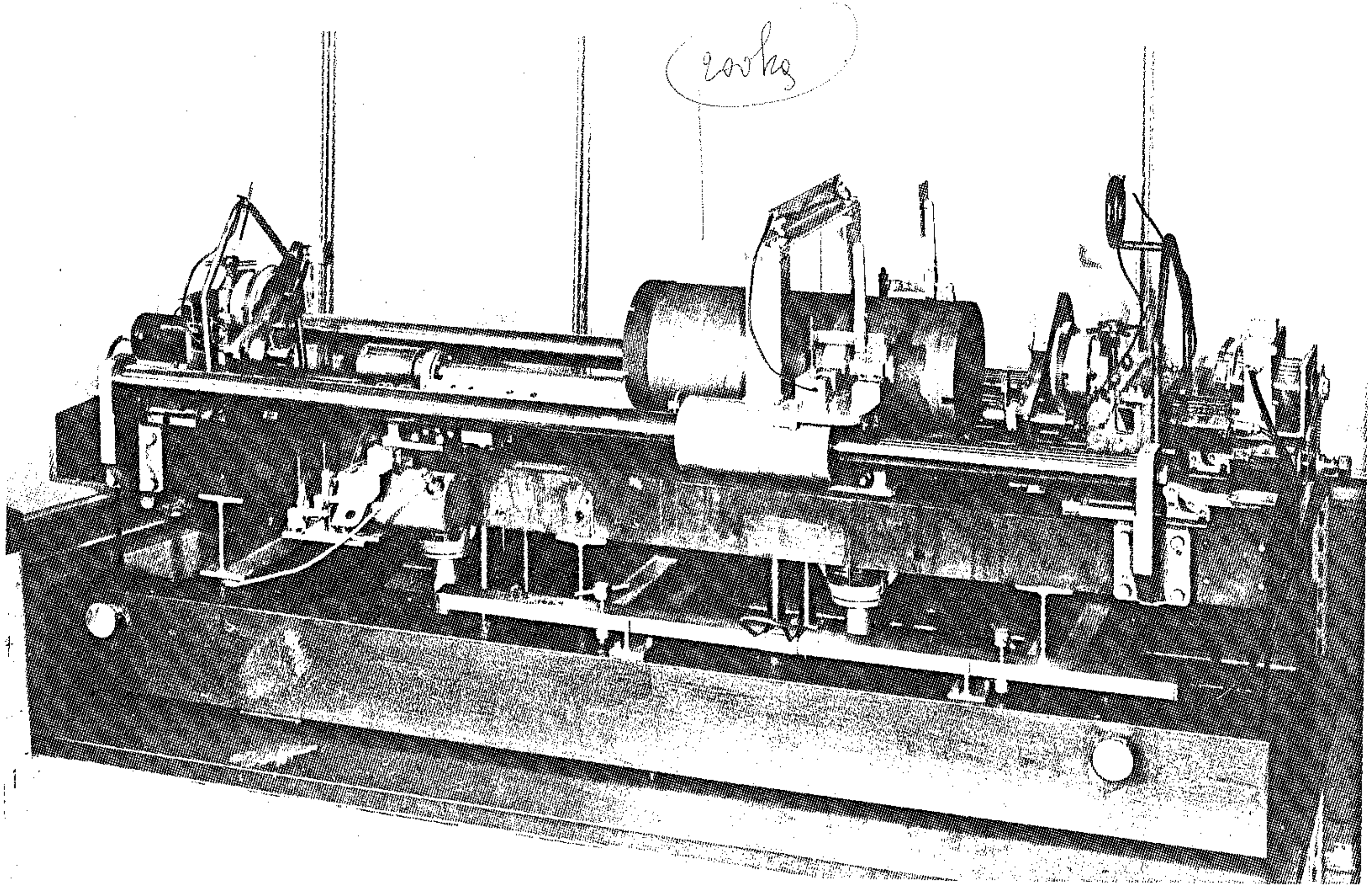

Figure 4 An Inner Sleeve Undergoing Diameter Determination

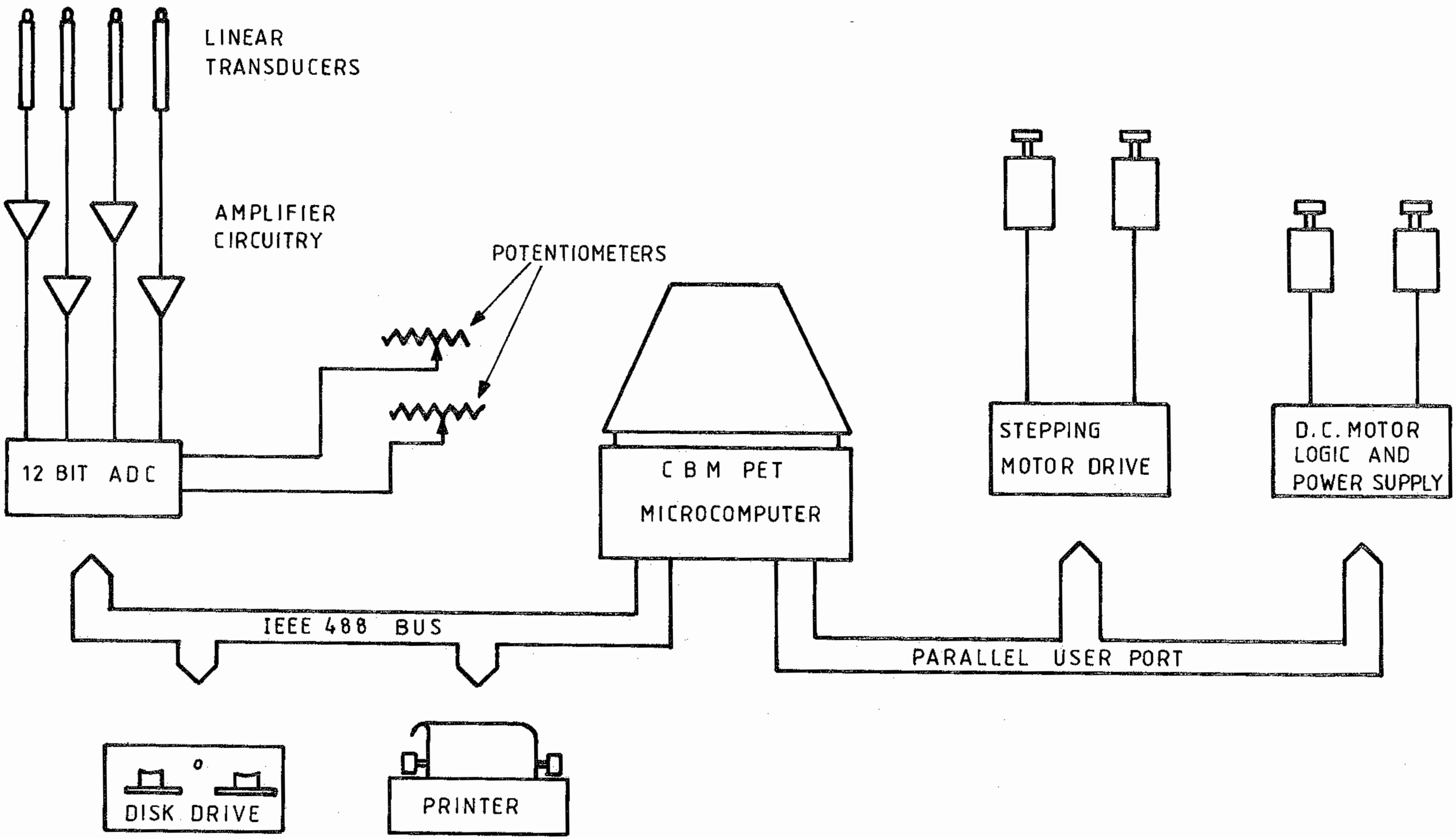

FIG.5a SCHEMATIC LAYOUT OF MICROCOMPUTER, INTERFACING AND ACTIVE COMPONENTS

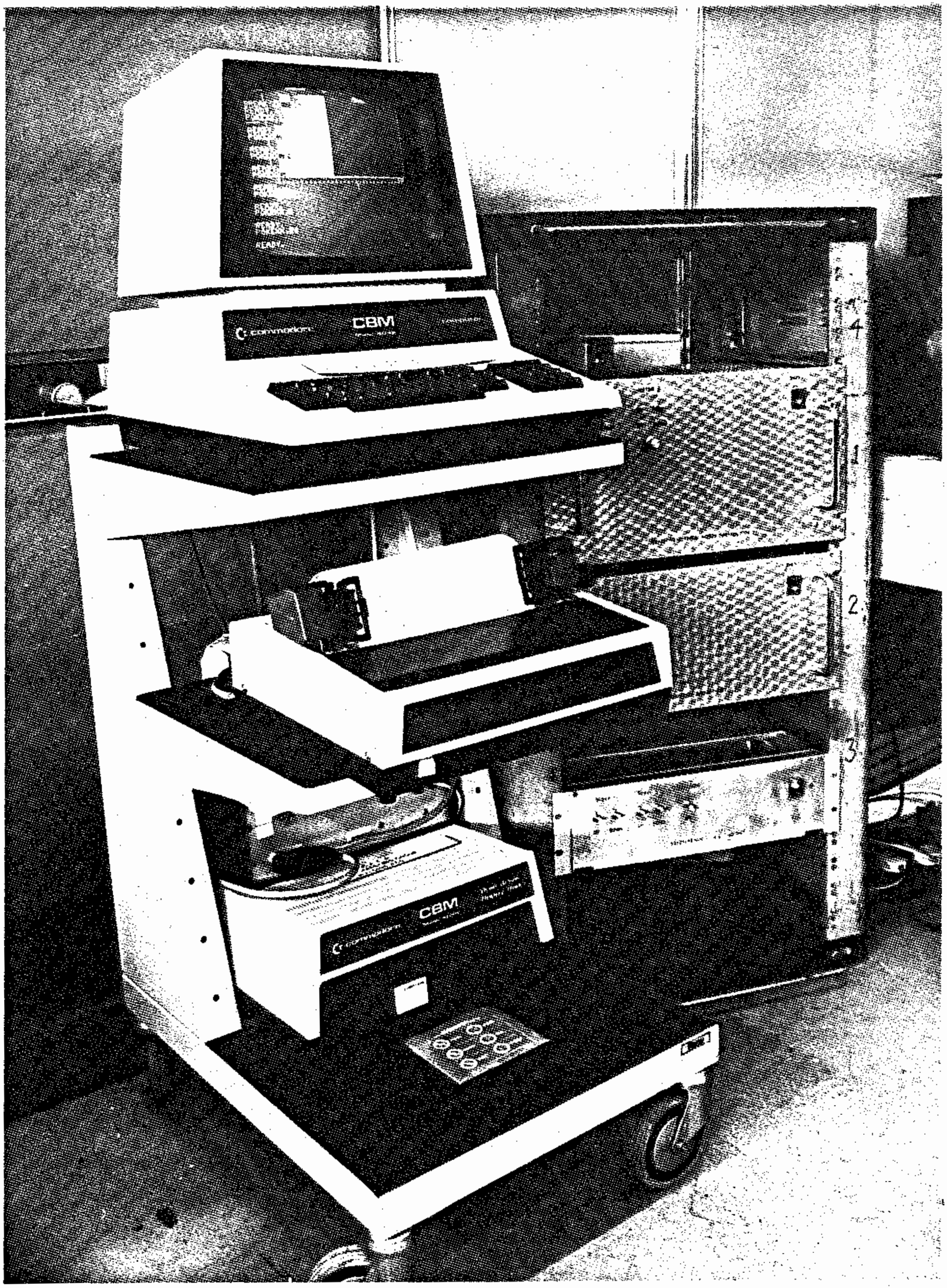

Figure 5b The Microcomputer controller and interface unit

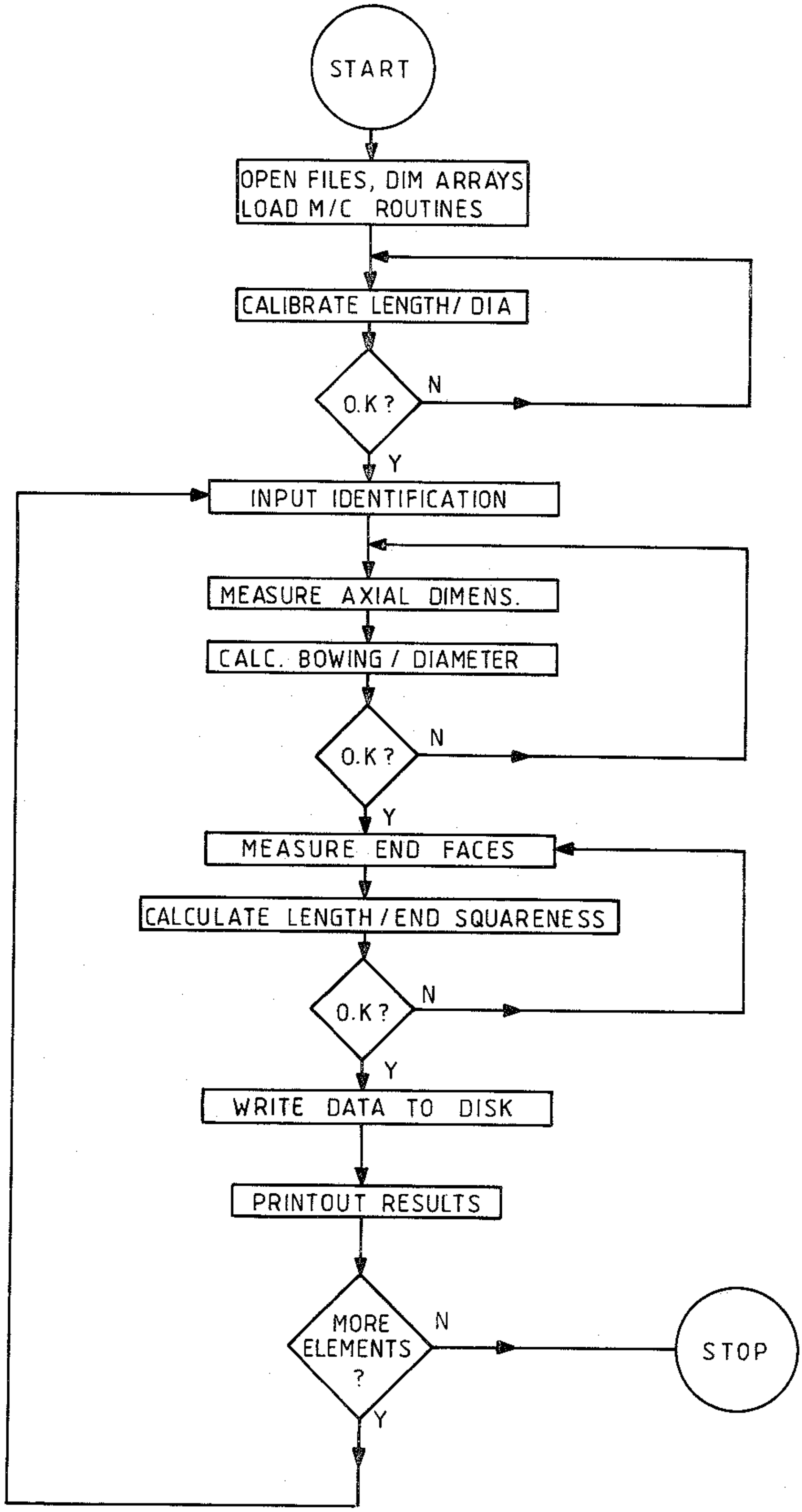

FIG. 6. THE MEASUREMENT ROUTINE FOR OUTER GRAPHITE SLEEVES