N70-36808

Dec. 8, 1964 R. STEINBERG ET AL 3,160,567

SOLID STATE POWER MAPPING INSTRUMENT

Filed Aug. 28, 1961 5 Sheets-Sheet 1

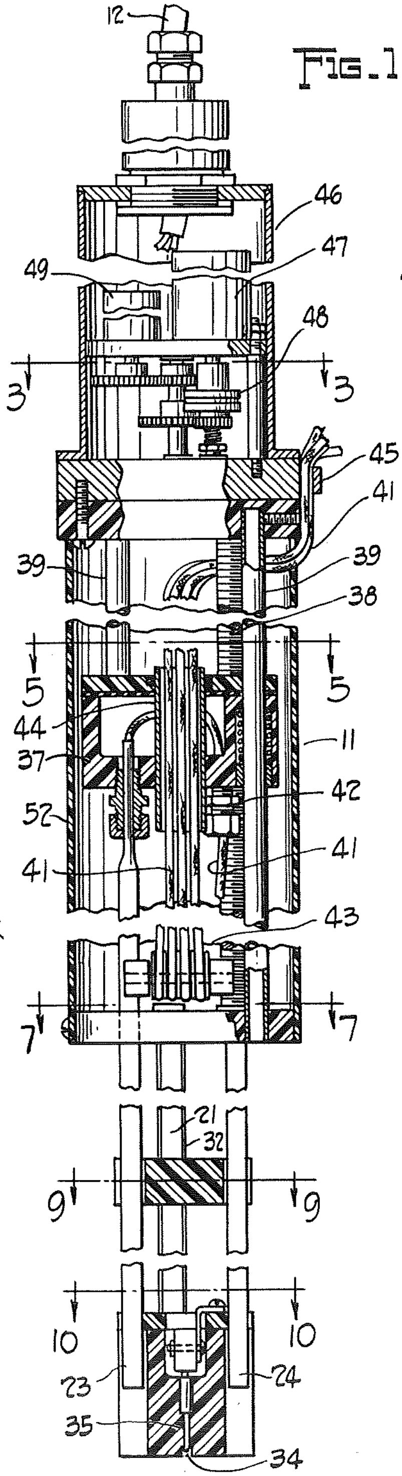

FIG. 1

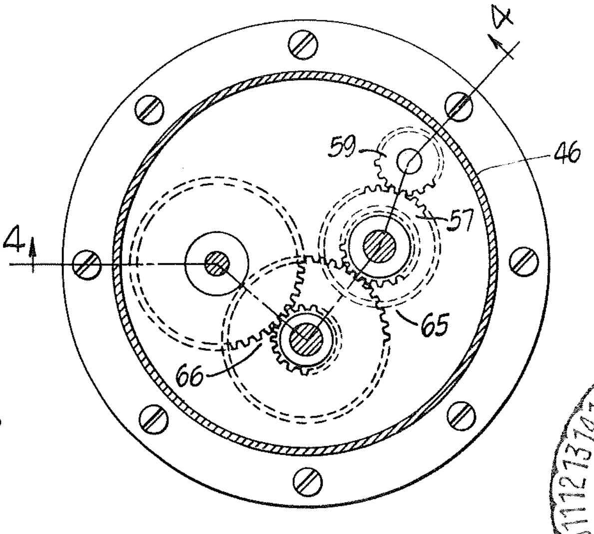

FIG. 3

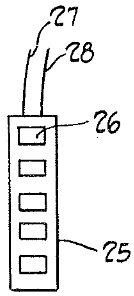

FIG. 16

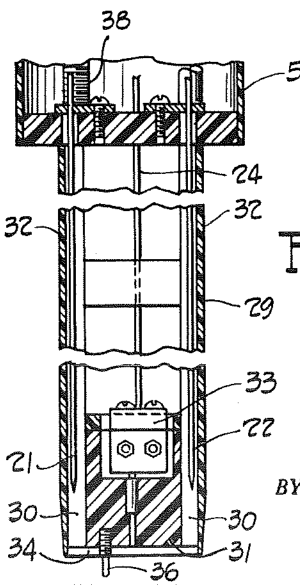

FIG. 2

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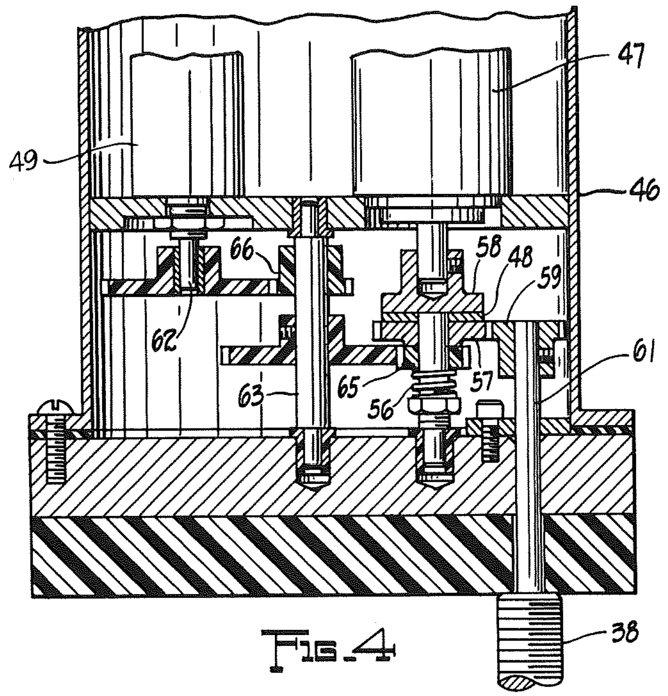

FIG. 4

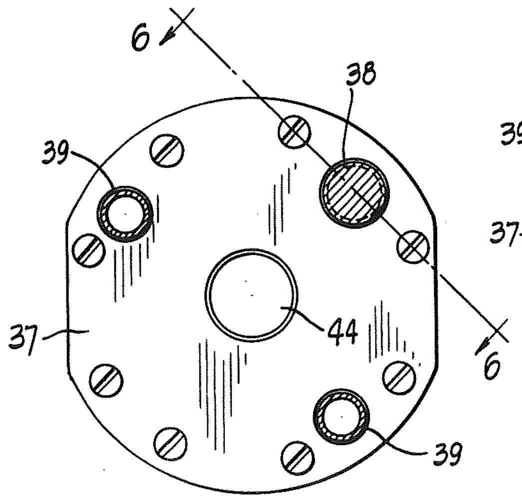

FIG. 5

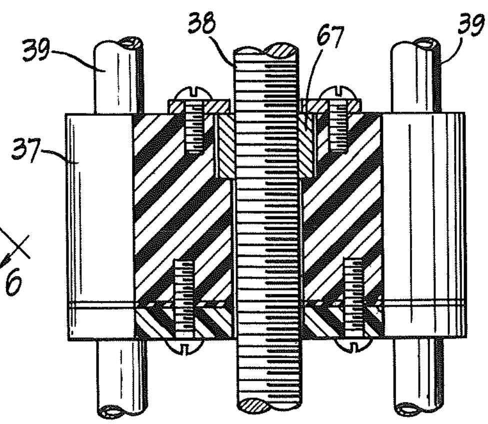

FIG. 6

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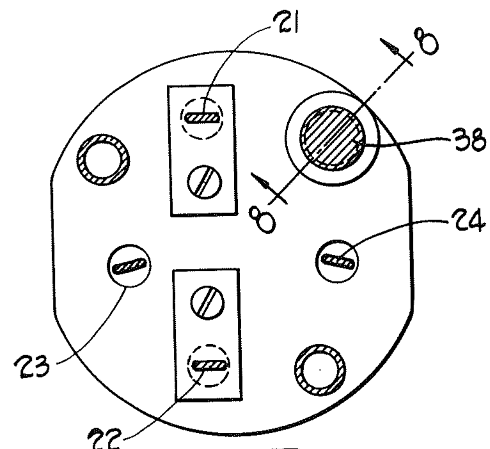

FIG. 7

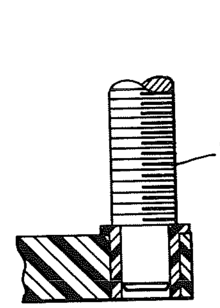

FIG. 8

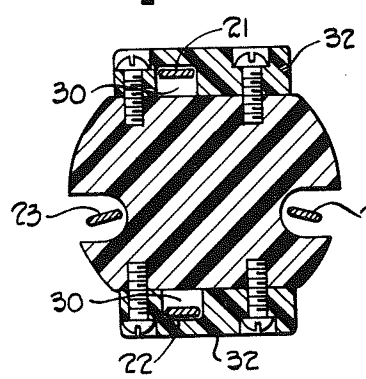

FIG. 9

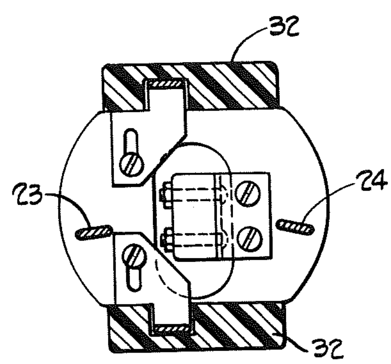

FIG. 10

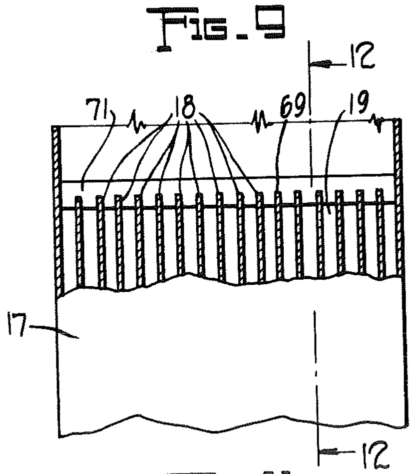

FIG. 11

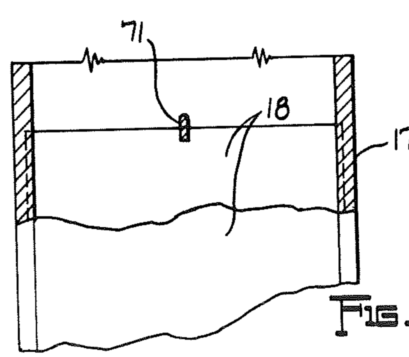

FIG. 12

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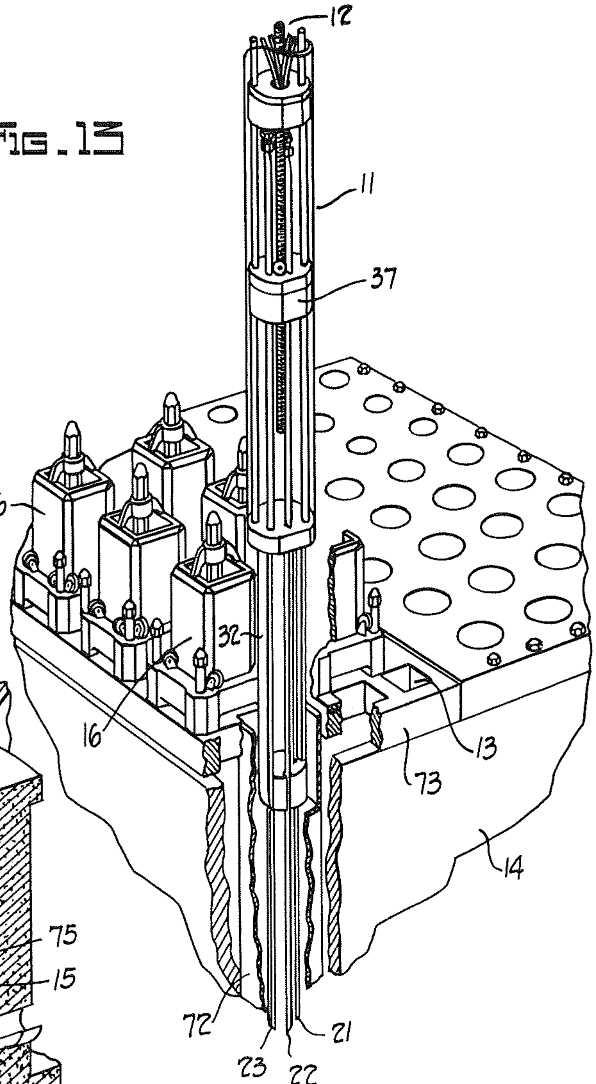
FIG. 13



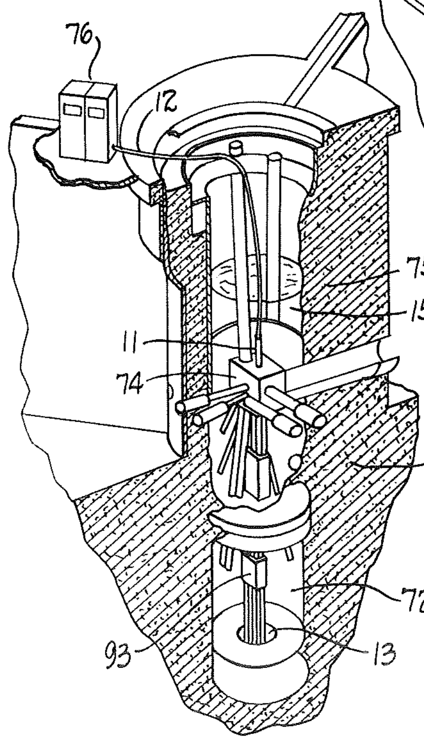


FIG. 14

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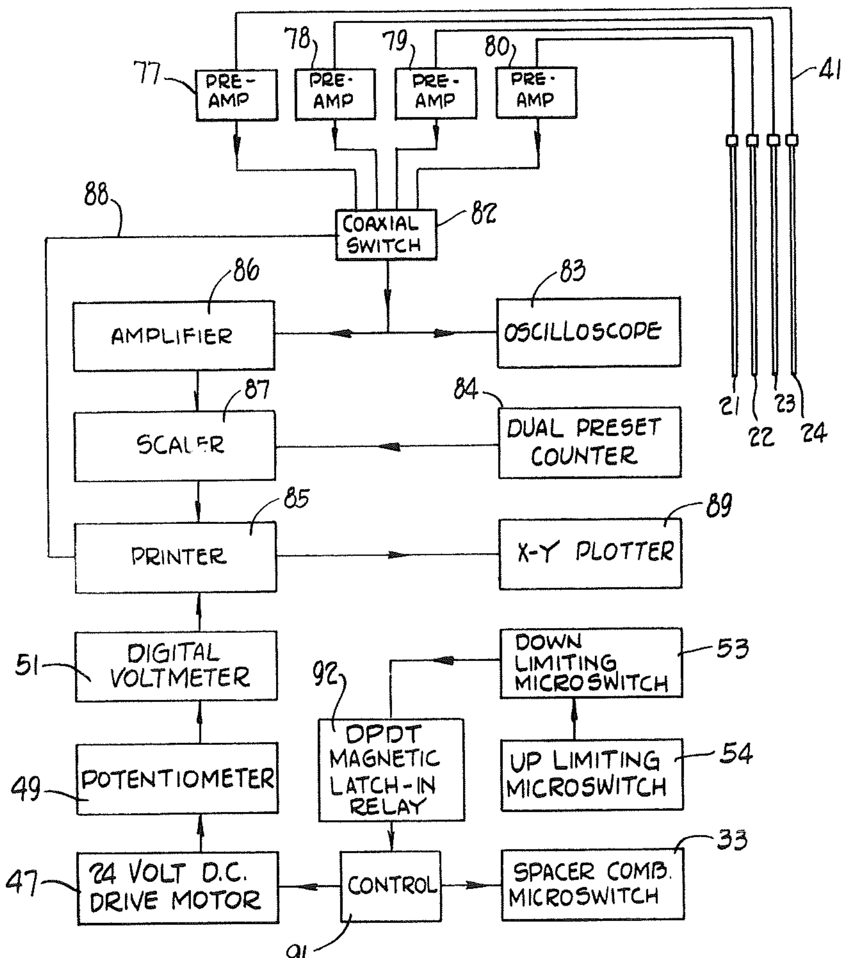

FIG. 15

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United States Patent Office

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3,160,567

SOLID STATE POWER MAPPING INSTRUMENT

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Filed Aug. 28, 1961, Ser. No. 138,540
7 Claims. (Cl. 176—19)
(Granted under Title 35, U.S. Code (1952), sec. 266)

The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

This invention relates to detecting, recording and mapping apparatus, and has for its principal object the provision of improved arrangements for mapping flux and power in nuclear reactors.

An object of the invention is to provide safe, reliable, rugged, sturdy, easily positioned, fast acting means for mapping flux and power in a reactor having closely spaced fuel plates.

A further object of the invention is to enable mapping to be accomplished rapidly under water.

Still another object is to provide a small and compact detector probe which passes readily between fuel plates.

A further object is to minimize effect on the flux in a reactor during mapping thereof and to minimize possibility of marking fuel plates.

Still another object of the invention is to record exactly where a measurement is made.

Still another object of the invention is to enable detector probes to be positioned readily through shielding water and in the vicinity of control rod guide bearing supports which partly obscure fuel elements.

Still another object of the invention is to accomplish fine spatial resolution in the measurement. An additional object is to record measurements instantaneously as they are made without need for subsequent analysis of detecting elements.

Other and further objects, features and advantages of the invention will become apparent as the description proceeds.

In carrying out the invention in accordance with a preferred form thereof, detecting elements are employed comprising silicon pn junction wafers connected in series, each coated with enriched uranium-235. The detecting elements are mounted in fission probes and preferably a plurality of fission probes are employed with means for driving them automatically into space between fuel element plates. Each probe is enclosed in a probe housing, preferably composed of aluminum with signal leads and detecting element potted in paraffin within the housing. A probe guide is provided composed of a suitable material visible under water such as red polymethyl methacrylate and the guide is provided with a head containing a micro-switch and a groove with a micro-switch actuator extended into the groove so that the switch is actuated when the instrument is lowered through shielding water into the tank of a nuclear reactor and the micro-switch actuator engages the spacer comb of a fuel element. Preferably the probe guide head is provided with locating pins which prevent the micro-switch actuator from being engaged unless the guide pins rest between adjacent plates of the fuel element, in which position the probe housings are so located as to travel in spaces between plates when driven downward. For driving the probes downward, a motor is employed with limit switches for automatically reversing the direction of the motor and retracting the probes after a survey has been completed in a given portion of the reactor. A

potentiometer is provided which is coupled to the drive motor and is provided with a digital voltmeter connected to the potentiometer for recording position of the detecting element.

A better understanding of the invention will be afforded by the following detailed description considered in conjunction with the accompanying drawing in which:

FIG. 1 is a view in section with portions broken away of an embodiment of the invention represented as cut by a vertical plane;

FIG. 2 is a fragmentary view of the apparatus of FIG. 1 represented as cut by a vertical plane transverse to the section plane of FIG. 1;

FIG. 3 is a cross-sectional view of the apparatus of FIG. 1 represented as cut by a plane **3—3** indicated in FIG. 1;

FIG. 4 is a fragmentary view of a portion of the apparatus of FIG. 1 represented as cut by a broken vertical plane **4—4** indicated in FIG. 3;

FIG. 5 is a cross-sectional view of the apparatus of FIG. 1 represented as cut by a plane **5—5** indicated in FIG. 1;

FIG. 6 is a fragmentary view of a portion of the apparatus of FIG. 1 represented as cut by a vertical plane **6—6** indicated in FIG. 5 and illustrating the arrangement of the drive screw, guide rods and probe carriage;

FIG. 7 is a view of a cross-section of the apparatus of FIG. 1 represented as cut by a plane **7—7** indicated in FIG. 1;

FIG. 8 is a fragmentary view in longitudinal, vertical section of the apparatus of FIG. 1 illustrating the drive-screw footing and illustrating the portion of the apparatus cut by the plane **8—8** indicated in FIG. 7;

FIGS. 9 and 10 are views of cross-sections of the apparatus of FIG. 1 cut by the planes **9—9** and **10—10**, respectively, indicated in FIG. 1, FIGS. 3 to 10, inclusive, being drawn at double the scale of FIGS. 1 and 2;

FIG. 11 is a view of an 18-plate fuel element and spacer comb partially in section with the upper end box removed;

FIG. 12 is an end view of the comb and plate assembly of FIG. 11, partially in section and with some of the plates broken away at their upper ends;

FIG. 13 is a perspective view of the rapid survey power mapping instrument of FIG. 1 in operating position in the fuel element with fission probes partially extended and the corner of the tank partially broken away;

FIG. 14 is a perspective view of the instrument of FIG. 1 in operating position in a concrete encased reactor tank, together with an instrument panel therefor;

FIG. 15 is a block diagram representing the electrical connections of the instrument panel and the detector probes; and

FIG. 16 is an elevation of a detector unit.

Like reference characters are utilized throughout the drawings to designate like parts.

The start up of any new reactor facility involves a multitude of post-neutron tests that must be carried out before the reactor can be utilized for research or power production. An important post-neutron test that has heretofore been one of the most time consuming concerns the magnitude of the spatial variation of the flux within a core. Many of the computations of reactor behavior and experimental irradiations involve the flux. It is, therefore, important that the flux distribution should be known throughout the core in the greatest possible detail. Although instruments constructed in accordance with the invention are adaptable to most solid-fuel cores, the form of instrument illustrated and described is particularly useful in pool or tank reactors that employ aluminum-clad plate-type fuel elements.

disk **57** also carries gear teeth meshing with a gear **59** secured to an extension **61** of the drive screw **38**.

The motor **47** is also arranged to drive the actuating shaft **62** of the potentiometer **49** through a jack shaft **63** and gearing **65** and **66**. Driving connection between the drive screw **38** and the carriage **37** is made through a threaded block or nut **67** secured in the carriage **37** as shown in FIG. 6.

In order to use the instrument **11**, it is lowered through the water **15** on its own supporting power cable **12**. The plastic probe guide **31** is allowed to pass into the fuel element end box coming to rest atop the fuel plates **18**. Because of the close fit between the probe guide and the fuel element and box, only one of three possible alternatives can occur.

(1) The guide pins **36** more to rest on the leading edge **69** of a fuel plate **18**, in which case the spacer comb **71** could not possibly enter the groove **34** in the probe guide head **31** to actuate the micro-switch circuit by engaging the micro-switch actuator rod **35**.

(2) The guide pins **36** have passed between two fuel plates **18** but the spacer comb **71** has not quite entered the groove **34** in the guide head **31**, in which case the micro-switch circuit cannot be actuated.

(3) The guide pins **36** have passed between two of the fuel plates **18** and the fuel element spacer comb **71** has entered the groove **34**, engaging the micro-switch actuator **35**.

Should the instrument **11** not be positioned correctly on the first attempt, all that is required is to raise the instrument about two centimeters and then lower it again. Experience has shown that it takes no longer than 60 seconds to have the instrument seated correctly on the fuel element. A spacer comb actuated signal light (not shown) may be provided to indicate when the instrument **11** is in the correct operating position and the probes **21**, **22**, **23** and **24** are ready to be driven into the fuel element.

In FIG. 13, as shown, the instrument **11** is fully inserted, between control rods **93**, in one of 22 fuel elements **72**. The probe guide **29** passes between control rod guide bearings **16** through the top grid plate **73** and fuel element end box **74** (a total of 30.5 cm. in the specific apparatus illustrated) before the probe guide head **31** comes into contact with the top of the fuel plates **18**. This may be accomplished although the control rod guide bearing supports **16** actually overhang the entrance to the fuel element and thus limit access to the plates **18**. Where the bearing supports are not symmetrical and as a result the openings to the elements between control rods do not have the same dimensions as that of the remaining fuel elements an interchangable probe guide may be provided for the instrument **11**. One such probe guide is provided for the four fuel elements between control rods and another for the remaining eighteen elements.

In the specific apparatus described, the detector **25** has a thermal neutron sensitivity of approximately 1×10^{-3} counts per neutron per square centimeter. The useful detector lifetime is over 1×10^{13} nvt.

The time involved in making a single traverse will be determined by the available power level, the desired accuracy in counting and the spatial resolution. An insertion rate of 15.2 cm. per minute at a power level of one watt has been chosen to obtain a minimum of 10,000 counts per second and a spatial resolution of 2.54 cm. Thus each of the four probes **21**, **22**, **23** and **24** will supply about 30 measurements, and the complete traverse will take approximately ten minutes (entry and withdrawal). If a higher resolution is desired, a smaller detector may be employed.

A cut away view of the assembly of the reactor tank **75** with the instrument **11** in operating position is shown in FIG. 14. An associated instrument control and readout panel **76** is shown just outside the reactor tank. Since the reactor will be operating at low power during a power mapping survey, only about 3 meters of shielding water **15** are shown above the fuel element core **72**. A temporary platform (not shown) may be constructed inside the tank from which to lower the instrument **11** into position.

FIG. 15 is a block diagram of the control instrument and readout equipment **76** for the power survey instrument **11**, as well as the circuitry contained within the device itself. Individual preamplifiers **77**, **78**, **79** and **80** are provided for the fission probes **21**, **22**, **23** and **24**, respectively, in order to prevent loss of signal in the switching circuit and associated coaxial cable. A single counting channel is utilized with a solenoid-actuated coaxial switch **82** and cycles between probes **21** to **24**. An oscilloscope **83** is provided for monitoring fission pulses, and a dual preset counter **84** is provided for controlling the counting channel. A paper tape printer **85** is provided for printing the data immediately, recording the probe number, position in the fuel element and the count rate. An amplifier **86** and a scaler **87** are interposed between the coaxial switch **82** and the printer **85**, and there is an electrical connection **88** between the coaxial switch **82** and the printer **85** for synchronizing the print out for each probe with the probe connection.

There is a single $x-y$ point plotter **89** in conjunction with the printer **85** in order to afford a visual account of the power variation within the fuel element and to make the data instantly available for analysis upon completion of the traverse.

A motor speed control **91** is interposed between the spacer comb micro-switch **33** and the drive motor **47**, and a double-pole, double-throw magnetic latch-in relay **92** is interposed between the limit switches **53** and **54** and the motor control contactor assembly **91** for reversing the connections and direction of rotation of the drive motor **47** when the down-limiting micro-switch **53** has been actuated, and opening the motor circuit upon the return travel when the up-limiting micro-switch **54** has been actuated.

While the invention has been described as embodied in concrete form and as operating in a specific manner in accordance with the provisions of the patent statutes, it will be understood that the invention is not limited thereto, since various modifications will suggest themselves to those skilled in the art without departing from the spirit of the invention.

What is claimed is:

1. A power survey instrument comprising in combination, a mounting tube, a plurality of fission probes, each of said probes including a detecting element comprising a plurality of silicon pn junction wafers connected in series, each of said wafers being coated with enriched uranium-235, a probe housing composed of aluminum enclosing each probe, signal leads therein and paraffin potting the leads and detector in each housing, a probe guide composed of red polymethyl methacrylate visible under water having a head containing a micro-switch, a supporting cable for the instrument, the probe guide head having a leading surface with a narrow groove therein running its length and a micro-switch actuator extending into the groove, a pair of aluminum guide pins located on a line perpendicular to the direction of said groove, within said mounting tube a water tight carriage composed of polymethyl methacrylate upon which the probes are mounted, an aluminum drive screw and a pair of stainless-steel guide rods carrying said carriage, coaxial signal cables for each probe, pulley mechanism for taking up slack in the signal cables as the probes are driven downward, a drive motor secured to the upper part of the instrument tube, a clutch interconnecting the motor with the drive screw, a potentiometer coupled to the drive screw, a digital voltmeter connected to the potentiometer for recording position of the fission-probe detecting elements, the motor having a water tight housing, the instrument-mounting tube being open to admission of water when the instrument is lowered into water shielding a nuclear reactor, limit switches at each end of travel of the carriage, and motor reversing switches responsive to the limit switches.

2. A power survey instrument for a water moderated

reactor having fuel elements in the form of plates, said instrument comprising in combination a plurality of fission probes, each containing uranium-coated, solid-state detection means, a probe housing enclosing each probe, a probe guide composed of material visible under water having a head containing a micro-switch, a supporting cable for the instrument, the probe guide head having a leading surface with a groove therein and a micro-switch actuator extended into the groove, guide pins located on a line perpendicular to said groove, a water tight carriage upon which the probes are mounted, a drive screw and guide means carrying said carriage, coaxial signal cables for each probe, pulley mechanism for taking up slack in the signal cables as the probes are driven downward, a potentiometer coupled to the drive screw, voltage responsive means connected to the potentiometer for recording position of the detecting element, a motor having a water tight housing, limit switches at each end of travel of the carriage, and motor reversing switches responsive to the limit switches.

3. In a reactor having fuel elements in the form of spaced plates, a power survey instrument comprising a probe guide head having a leading surface with a groove therein, guide pins located on a line perpendicular to said groove for locating the guide head with respect to space between a pair of fuel element plates, a micro-switch carried by said head, a micro-switch actuator extending into said groove and located with respect to the guide pins for engaging a portion of the fuel element when the guide pins are located in a space between the plates, a fission detector, and a moveable probe carrying said fission detector.

4. Apparatus as in claim 3 including a potentiometer coupled to the probe drive means and voltage responsive means electrically connected to the potentiometer for recording the position of the fission detector.

5. A power survey instrument for a reactor with spaced fuel plates separated by an outwardly extending spacer member, said instrument comprising a probe guide head having a leading surface with a groove therein for locating the guide head with respect to space between fuel plates by mating with said spacer member, a fission detector, and means for driving the detector downward from said guide head when said groove is mated with said spacer member.

6. A power survey instrument comprising in combination, a mounting tube, a plurality of fission-probes, a probe housing enclosing each probe, signal leads in each

housing, a probe guide having a head containing a micro-switch, a supporting cable for the instrument, the probe guide head having a leading surface with a narrow groove therein running its length and a micro-switch actuator extended into the groove, a pair of guide pins located on the line perpendicular to the direction of said groove, a water tight carriage within said mounting tube upon which said probes are mounted, a drive screw carrying said carriage, signal cables for each probe, means for taking up the slack in the signal cables as the probes are driven downward, a drive motor secured to the upper part of said tube, a clutch interconnecting the motor with the drive screw, a potentiometer coupled to the drive screw, a digital voltmeter connected to the potentiometer for recording position of the fission-probe detecting elements, said mounting tube being open to the admission of water when the instrument is lowered into water shielding a nuclear reactor, limit switches at each end of travel of said carriage, and motor reversing switches responsive to said limit switches.

7. A power survey instrument comprising in combination, a plurality of fission-probes, a probe housing enclosing each probe, a probe guide having a head containing a micro-switch, the probe guide head having a leading surface with a narrow groove therein and a micro-switch actuator extended into the groove, a pair of guide pins located on a line perpendicular to the direction of said groove, a water tight carriage upon which said probes are mounted, a drive screw carrying said carriage, signal cables for each probe, a drive motor, a clutch interconnecting the motor with said drive screw, a potentiometer coupled to the drive screw, and a digital voltmeter connected to the potentiometer for recording position of the fission-probe detecting element.

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