

[54] **DEVICE FOR GUIDING SENSOR
MOVEMENT WITHIN A TUBE**

[75] Inventor: **Thomas E. Cowell**, Woodland Hills,
Calif.

[73] Assignee: **Rockwell International Corporation**,
El Segundo, Calif.

[22] Filed: **Sept. 4, 1973**

[21] Appl. No.: **394,428**

[52] **U.S. Cl.**..... **73/67.8 S**

[51] **Int. Cl.**..... **G01n 29/04**

[58] **Field of Search**..... **73/67.8 S, 67.5 R, 67.8 R,
73/67.9**

[56] **References Cited**

UNITED STATES PATENTS

3,091,959 6/1963 Hanstock et al..... 73/67.8 S
3,111,027 11/1963 Moffatt et al..... 73/67.8 S

FOREIGN PATENTS OR APPLICATIONS

1,600,873 9/1970 France..... 73/67.8 S

Primary Examiner—James J. Gill

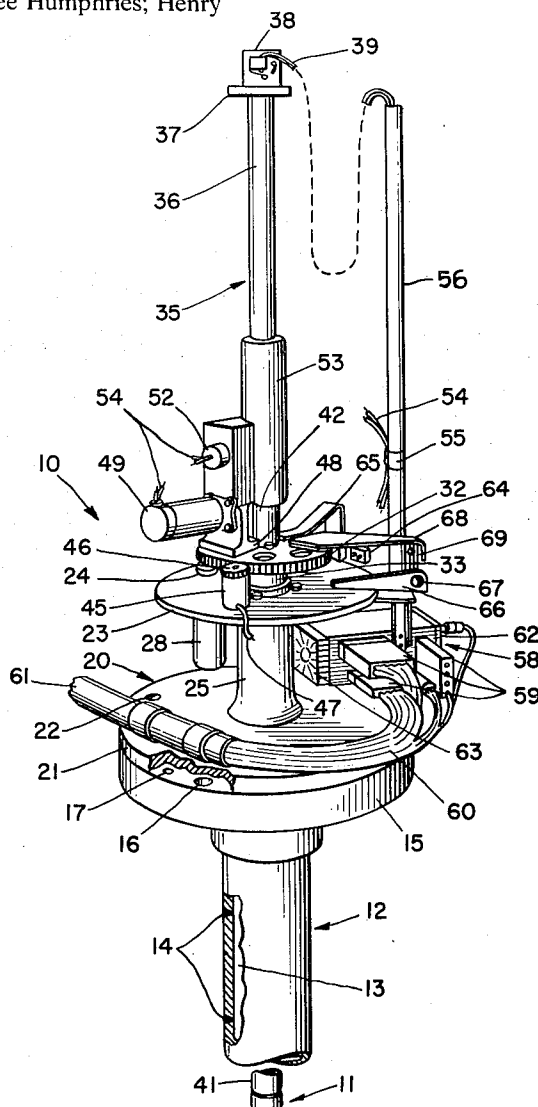
Attorney, Agent, or Firm—L. Lee Humphries; Henry
Kolin; Clark E. DeLarvin

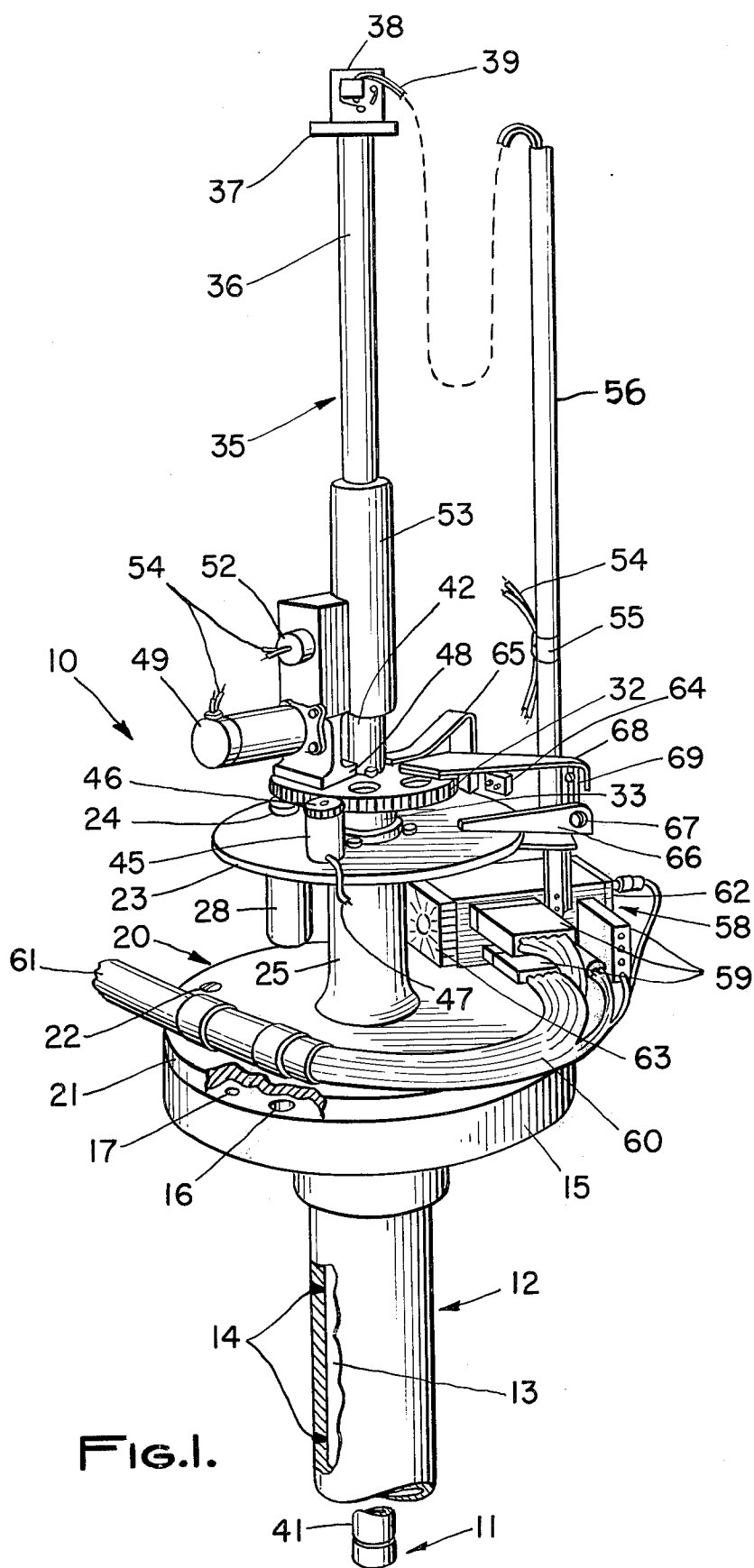
[57]

ABSTRACT

A drive assembly is clamped upon an end of a tube whose interior is to be generally traversed in controlled increments of movement by a working head secured to an elongated carrier pipe. One side of the carrier pipe is formed with a longitudinally extending drive slot, and a different side of the carrier pipe is formed with a gear rack. Dual motors of the drive assembly may be operated to precisely position the working head within the tube. One motor for controlling rotational movement of the carrier pipe is coupled to a drive gear mounting a drive element projecting into the drive slot. The other motor for controlling axial movement of the carrier pipe has a pinion gear arranged in meshing engagement with the gear rack. The working head may be a sensor such as an ultrasonic transducer for inspecting interior walls of the tube for flaws. An actuator linked to a remote control unit functions to cause the dual motors to operate separately or simultaneously to reposition the carrier pipe and allow the sensor to scan and detect conditions of the tubular interior walls.

18 Claims, 3 Drawing Figures





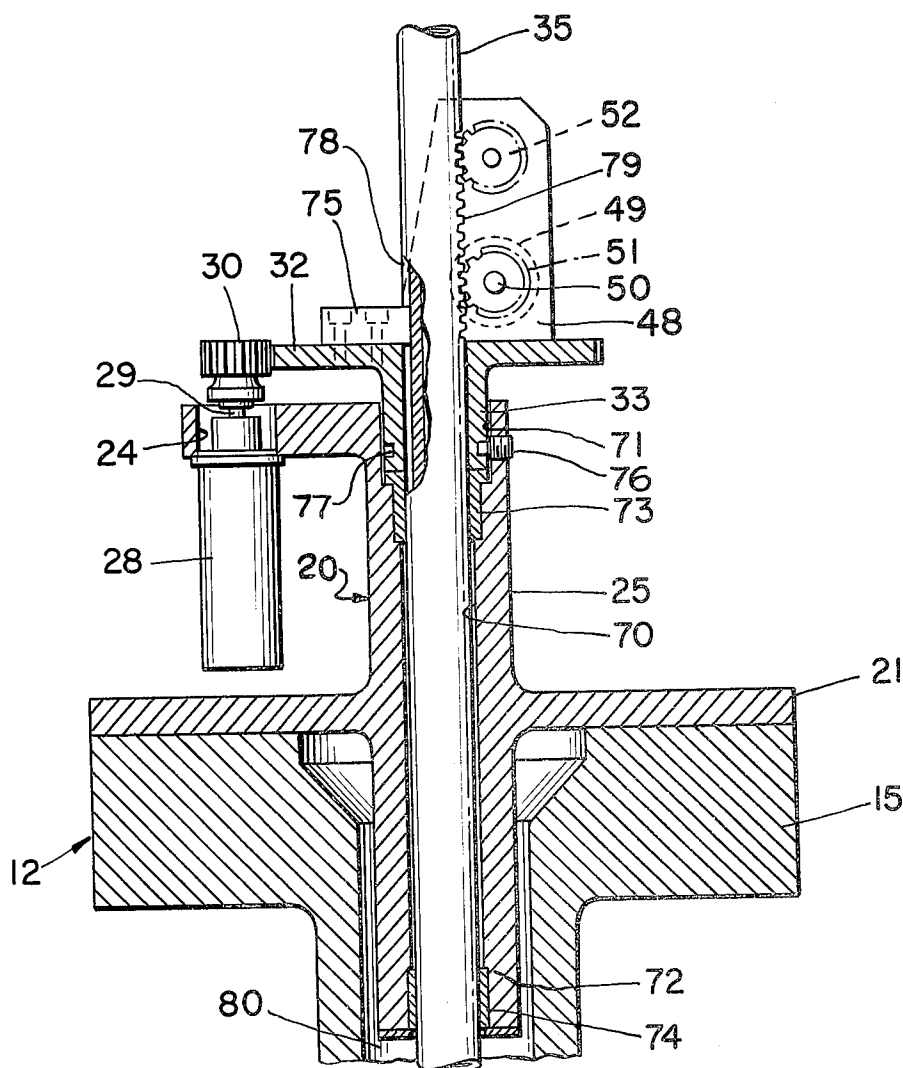


FIG. 2.

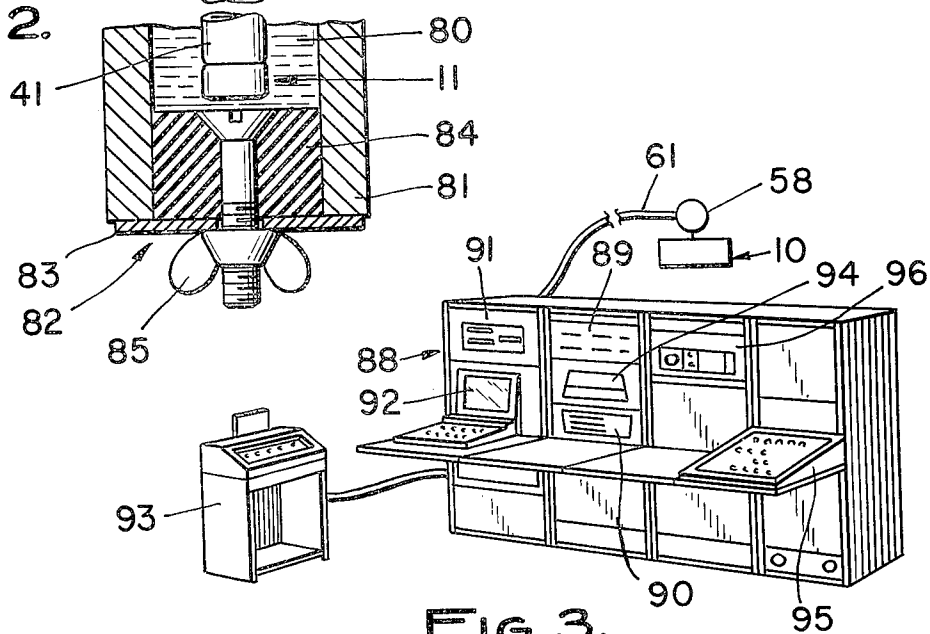


FIG. 3.

DEVICE FOR GUIDING SENSOR MOVEMENT WITHIN A TUBE

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention generally relates to control mechanisms for positioning objects within a confined space and more specifically relates to precisely repositioning a sensor within a tube such as a nuclear reactor vessel component in order to accomplish nondestructive testing, such as inspection of the tubular interior wall for flaws.

2. Description of the Prior Art

Difficulties have been encountered in the use of conventional mechanisms for inspecting interior tubular walls to detect possible surface and volume flaws. The control mechanisms for guiding mechanical movement and positioning of the sensor are relatively cumbersome and time consuming to operate, inaccurate in attempting to position the sensor, and generally produce unreliable or spurious data.

The present device is of particular interest and utility in providing for remote automatic inspection, particularly in both longitudinal and azimuthal directions, of the interior surfaces and walls of tubes utilized in control rod housings of nuclear reactor vessels and in steam generator piping.

SUMMARY OF THE INVENTION

In its broader aspects, this invention relates to a positional control mechanism which may be used in various environments for essentially guiding mechanical movement within a tube, particularly in axial and annular directions.

A mounting base defining a central guideway is structured for removable placement on one end of a tube whose interior walls are to be inspected or worked upon, for example. A drive gear is rotatably coupled to the mounting base and includes a drive element. An elongated carrier pipe extends through the drive gear and mounting base central guideway and is formed along one longitudinally extending portion with a drive slot and along a different longitudinally extending portion with a gear rack. A working head is secured to the carrier pipe.

A first motor is connected to the mounting base and operatively coupled with the drive gear to cause rotation by the carrier pipe. A second motor is connected to the drive gear and operatively coupled to the gear rack to selectively cause axial movement of the carrier pipe. Actuator means is provided to operate the first motor and second motor to thereby cause movement of the carrier pipe and repositioning of the working head within the tube.

The mounting base may more specifically include a cover plate structured to fit over one end of the tube and a pedestal spaced from the cover plate and arranged to mount the first motor and generally hold the first motor between the cover plate and itself. A sleeve of the mounting base which defines the central passage-way extends between the cover plate and pedestal. The sleeve is formed with an insert portion at one end for projecting into the tube and is formed at its other end with a socketed cavity for accommodating and seating the drive gear.

Both the first motor and second motor are reversible electric motors with their power take-off shafts carrying pinion gears.

In a particular embodiment of this invention the working head is a sensor constructed to inspect the interior wall conditions of the tube. The sensor may, for example, be an ultra-sonic transducer and the tube may be a control rod mechanism housing fixed in place within a nuclear reactor.

The actuator means may be linked to or incorporated as part of a remote control unit equipped to transmit command signals to the first and second motors in accordance with a predetermined program in order to periodically reposition the sensor within the tube. The remote control unit may embody an analog-to-digital converter coupled to receive analog signals from the sensor in order to convert the analog signals to digital signals. Encoder means is provided for sensing the rotational and axial movements of the carrier pipe and transmitting this data in the form of electrical signals to the remote control unit for evaluation and storage.

BRIEF DESCRIPTION OF THE DRAWINGS

The benefits and unique aspects of this invention will be fully understood when the following detailed description is studied in conjunction with the drawings in which:

FIG. 1 is a perspective, partially fragmentary view showing a control device for guiding sensor movement within a tube as constructed in accordance with this invention;

FIG. 2 is a side elevational, sectional and partially fragmentary view illustrating certain details of the embodiment of this invention as shown in FIG. 1; and,

FIG. 3 is a partially schematic view of the drive assembly and actuator components of this invention and a partially perspective view of a remote control unit which may be used to activate and monitor certain actions of other components.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to the drawings and primarily to FIG. 1, the comprehensive positional control mechanism of this invention includes a drive assembly 10 for precisely guiding the mechanical movement of a working head 11 situated within a vessel or tube 12.

The working head 11 is any type of electromechanical or mechanical device for performing work or coacting with other objects and materials to accomplish work. The working head 11 may, for example, be a sensor in the form of a transducer for detecting flaws and irregularities on the interior wall of the tube 12. For purposes of illustration, this invention shall be described by considering the working head 11 to be an ultra-sonic transducer for detecting imperfections or flaws in weld joints 14 or other interior wall volumes of the tube 12 or its surface 13.

The tube 12 may represent a control rod housing or vessel situated in place within a nuclear reactor, under which conditions the sensor may subject the tubular interior walls to non-destructive testing in the form of scanning and detection.

The tube 12 is shown with a pair of axially spaced annular weld joints 14 and a radially extending flange 15. A plurality of circumferentially spaced mounting holes 16 are formed in flange 15 along with one or more indexing or locating notches 17.

Drive assembly 10 incorporates a mounting base 20 which has a table or cover plate 21 removably secured to the tube flange 15 by way of circumferentially spaced bolts 22. Mounting base 20 has a pedestal 23 formed with a circular mounting space 24. Linking cover plate 21 and pedestal 23 as an integral or rigid unit is a sleeve 25 which defines a central guideway coaxially aligned with the longitudinal axis of tube 12.

Installed within mounting space 24, as best shown in FIG. 2, is a reversible electrical motor 28 whose power take-off shaft 29 carries a pinion gear 30. The axis of shaft 29 is parallel with but offset from the axis of sleeve 25.

The teeth of pinion gear 30 are interengaged with the teeth of a drive gear 32 shown as a spur gear which has a depending hub 33 inserted and journaled within sleeve 25 so that motor 28 can be selectively operated to rotate spur gear 32 relatively to stationary mounting base 20.

An elongated carrier pipe 35 of circular cross section extends through and is coaxially aligned with spur gear 32 and sleeve 25. An outer or exposed portion 36 of carrier pipe 35 mounts a cap 37 which carries an electrical limit switch package 38. Electrical wires 39 connected to bracket 38 supply electrical energy and signals to the working head or ultra-sonic transducer 11 and carry feedback data in the form of analog signals from the transducer 11. Pipe 35 may be a slotted rod.

A lower portion 41 of the carrier pipe 35 is shown attached to the transducer 11 and an intermediate part 42 is shown adjacent spur gear 32.

A data encoder 45 is secured to pedestal 23 and has a gear 46 interengaged with spur gear 32 so that all rotational movement may be detected and transmitted in the form of signals through wire 47 to a remote control unit.

Fixed to the upper face of spur gear 32 is a bracket 48 which mounts another reversible electrical motor 49 whose power take-off shaft 50, as best shown in FIG. 2, carries a pinion gear 51. Motor 49 operates to cause axial movement of the carrier pipe 35 as an associated encoder 52 detects any lengthwise displacement and transmits such data to a remote control unit.

Fixed to an upper portion of bracket 48 is an annular shield 53, which totally surrounds and encloses the carrier pipe 35 and serves as a guard to prevent electrical wires 54 extending to motor 28 and encoder 52 from becoming tangled or caught on some nearby component. Electrical wires 54 are secured at another point along their length by a brace 55 to a hollow column 56 that guides and orients the bundle of electrical wires 39 leading to the electrical limit switch package 38.

The first motor 28 which may be operated to rotate carrier pipe 35 and the second motor 49 that may be operated to cause axial or lengthwise movement by the carrier pipe 35, are activated and generally controlled by an actuator means 58. The actuator means 58 in turn is, preferably and for purposes of illustration, operated by electrical command signals initiated at a remote control unit as shall be subsequently described. The actuator means 58 incorporates a plurality of electrical modular units 59 which are coupled to individual bundles of wires associated with a cable 60 housed within a cable conduit 61. A housing 62 associated with the actuator means 58 packages a number of components including a cooling unit 63.

Mounted on the pedestal 23 of mounting base 20 is a limit switch 64 positioned within the circular path of

movement of a striking plate 65 fixed to the upper face of spur gear 32. The coaction between limit switch 64 and striking plate 65 serves to specifically control the arcuate movement of spur gear 32 and carrier pipe 35 to guarantee one complete revolution. The motor 28 following a dwell period, for example, may be selectively activated to impart reverse or counter motion and thereby revolve the carrier pipe 35 in the opposite direction.

A mechanical stop 66 formed with an aperture 67 is also secured to the pedestal 23. A plate 68 fixed to spur gear 32 projects radially outwardly and mounts a swinging link 69 set to register with aperture 67. Mechanical stop 66 and plate 68 serve as a safety factor to restrict movement of carrier pipe 35 to a point just beyond one revolution in the event that the limit switch 64 experiences malfunctioning.

Referring now primarily to FIG. 2, the sleeve 25 of mounting base 20 defines a central guideway 70 of circular cross-section which accommodates movement by the carrier pipe 35. The outer or exposed end of sleeve 25 is formed with a socketed cavity 71 and the bottom part of sleeve 25 defines an insert portion 72 which fits within tube 12 to an extent limited by contact between tube flange 15 and the mounting base cover plate 21. A pair of annular bushings 73 and 74 are fixed within sleeve 25 at axially spaced locations to accommodate movement of carrier pipe 35. A set screw 76 projects into an annular groove 77 to engage spur gear 32 and thereby restrict its longitudinal movement.

The upper face of spur gear 32 mounts a drive element 75 in the form of a key which projects radially inwardly into a drive slot or key way 78 formed along a longitudinally extending portion of the carrier pipe 35. Drive slot 78 is parallel to the longitudinal axis of carrier pipe 35 and extends substantially from end-to-end along carrier pipe 35. Drive slot 78 is sized to receive the radially inwardly projecting tip of drive element 75 so that motion of motor 28 may be transmitted to cause rotational movement of carrier pipe 35.

On a diametrically opposed or at least different longitudinally extending portion of carrier pipe 35, a recessed gear rack 79 is formed. The teeth of gear rack 79 are arranged in constant meshing engagement with the teeth of pinion gear 51 fixed to motor 49. The movement of motor 49 is transmitted through pinion gear 51 to the gear rack 79 to shift carrier pipe 35 axially in either selected direction.

The ultra-sonic transducer within or constituted by working head 11 is immersed in a suitable liquid 80 confined in a space between tube 12 and mounting base 20. To assist in creating and maintaining a leak-proof liquid coupling, the base 81 of tube 12 carries a plug 82 which has a closure 83 and a rubber mass 84. A tightening element 85 extending through rubber mass 84 may be selectively used to squeeze the rubber mass 84 and generally compress the plug 82 in place.

Referring now primarily to FIG. 3, the actuator means 58 associated with drive assembly 10 is operatively coupled through cable conduit 61 to a suitable remotely located control unit 88. The details of remote control unit 88 are disclosed in copending U.S. Pat. application Ser. No. 248,466 filed Apr. 28, 1972 (now U.S. Pat. No. 3,857,052) for an "Inspection and Analysis System," which application is assigned to the assignee of this invention.

Control unit 88 includes an analog-to-digital converter 89, a computer 90, a memory unit 91, a visual

display unit 92, a teletype 93, a "hard copy" device 94, a manual control panel 95 and an inspection unit 96. These components of control unit 88 serve to collectively control the operation and exact positioning of transducer 11, visually display various information such as the analog signals detected by the transducer and generally monitor all activities. The inspection unit 96 may, for example, be a Model 725 Immerscope manufactured by Tektran Corporation. Other suitable inspection units are also commercially available, for example, a Reflectoscope Model No. UM771 inspection unit manufactured by Sperry Division of Automation Industries.

The computer 90 of remote control unit 88 in accordance with a program, sends command signals through the actuator means 58 to the motors 28 and 49 which in turn are activated to cause sensor 11 to sequentially scan and inspect predetermined volume segments of the tube inside wall. Analog signals detected by the sensor 11 are transmitted to the inspection unit 96 and thereafter are sent to the analog-to-digital converter 89, for conversion to digital signals and/or "hard" copy three-dimensional prints.

Computer 90 may be programmed to send signals commanding the motors 28 and 49 to operate independently or concurrently in accordance with the predetermined program selected to force sensor 11 to precisely and comprehensively scan the tube interior surface 13 and walls for volume flaws.

For purposes of illustration, this invention has generally been described in connection with the environment of inspecting welding imperfections or other flaws present within interior walls of nuclear reactor control rod housings. The positional control mechanism is also capable of operating in a broad variety of other non-destructive testing situations, such as in the inspection of internal welds, associated with instrumentation nozzles and checking the inner walls of steam generator pipes.

The working head could under other circumstances be appropriately modified for use in television monitoring, painting, polishing, photography, sandblasting, welding, etc.

OPERATION

Keeping the above construction in mind, it can be understood how disadvantages of conventional positional control mechanisms are overcome of substantially eliminated by this invention.

The positional control mechanism of this invention can be particularly used for in-service inspection of control rod vessels or housings installed within nuclear reactors, as well as for pre-service inspection.

The particular operation of the motors 28 and 49 depends upon the sequence and direction of command signals from the actuator means 58. The actuator means 58 may be constructed to generate and transmit signals itself or to transmit or relay signals received from the remote control unit 88.

In the described embodiment of this invention, the command signals are initiated by the remote control unit 88 in accordance with a particular predetermined program. The command signals first cause the reversible electric motor 28 to orbit intermittently through 360° forcing the sensor 11 to move stepwise while scanning annular segments of the tube interior wall. Motor 28 is thereafter returned by counter-rotation to its initial position. The command signals thereafter cause

the other reversible electric motor 49 to move a predetermined increment, forcing the carrier pipe 35 and sensor 11 to shift axially to the next adjacent position. The motor 28 is again caused to force the sensor to scan this next annular segment of the tubular interior wall.

These dual movements imparted alternately by the motors 28 and 49 continue through their cycles until the tubular interior wall has been fully scanned and inspected.

Throughout its operation, the sensor 11 detects data with respect to volume elements and sends this data back to the analog-to-digital converter 89 for conversion to digital signals. This data may be interpreted to indicate the presence of flaws in weld joints, such as slag inclusions or irregular voids may be detected.

From the foregoing it will be evident that the present invention has provided a positional control mechanism in which all of the various advantages are fully realized. While the principle, preferred construction, and mode of operation have been described in connection with a particular embodiment for purposes of illustration, it should be understood that the invention may be practiced in other forms within the scope of the claims.

I claim:

1. A positional control mechanism for guiding mechanical movement within a tube, comprising:

- a. a mounting base defining a central guideway and structured for removable placement on an end of a tube;
- b. a drive gear having an opening therethrough in alignment with the central guideway and a drive element extending into the opening, the drive gear being rotatably coupled to the mounting base;
- c. an elongated carrier pipe extending through the opening in the drive gear and mounting base central guideway and formed along one longitudinally extending portion with a drive slot for receiving the drive element and along a different longitudinally extending portion with a recessed gear rack;
- d. a working head carried by the carrier pipe;
- e. a first motor (28) connected to the mounting base and operatively coupled with the drive gear to cause rotation of the carrier pipe;
- f. a second motor (49) mounted on the drive gear and operatively coupled with the gear rack to selectively cause axial movement of the carrier pipe;
- g. actuator means for operating the first motor and second motor to cause movement of the carrier pipe and repositioning of the working head within the tube; and,
- h. bearing means located in the mounting base central guideway for receiving the carrier pipe in sliding, rotatable engagement.

2. The structure according to claim 1 wherein the mounting base includes:

- a cover plate structured to fit over one end of the tube,
- a pedestal spaced from the cover plate and arranged to mount the first motor and generally hold the first motor between the cover plate and itself, and
- the bearing means comprise two annular bushings (73 and 74) fixed within the central guideway in axially spaced locations.

3. The structure according to claim 2 wherein the mounting base includes:

- a sleeve which defines the central passageway and extends between the cover plate and pedestal, the

- sleeve being formed with an insert portion at one end for projection into the tube and a socketed cavity at the other end for seating the drive gear.
4. The structure according to claim 1 wherein: the first motor is a reversible electric motor with a power take-off shaft mounting a first pinion gear, and,
- the drive gear is a spur gear drivingly interengaged with the first pinion gear.
5. The structure according to claim 4 wherein: the drive element is a radially inwardly extending key, and,
- the drive slot is a key way that slidably receives the key and extends along the major portion of the length of the carrier pipe.
6. The structure according to claim 1 wherein: the second motor is a reversible electrical motor with a power take-off shaft mounting a second pinion gear drivingly interengaged with the gear rack.
7. The structure according to claim 1 wherein: the first motor is a first reversible electrical motor with a power take-off shaft mounting a first pinion gear,
- the drive gear is a spur gear drivingly interengaged with the first pinion gear,
- the drive element is a radially inwardly extending key,
- the drive slot is a key way that slidably receives the key and extends along the major portion of the length of the carrier pipe, and,
- the second motor is a second reversible electric motor with a power take-off shaft mounting a second pinion gear drivingly interengaged with the gear rack.
8. The structure according to claim 1 wherein: the working head is a sensor constructed to inspect the interior wall conditions of the tube.
9. The structure according to claim 8 including: a remote control unit equipped with means to transmit command signals through the actuator means to the first and second motors in accordance with a pre-determined program in order to periodically reposition the sensor.
10. The structure according to claim 9 wherein the remote control unit includes: an analog-to-digital converter connected to receive analog signals from the sensor and serving to convert the analog signals to digital signals.
11. The structure according to claim 10 wherein: the sensor is an ultra-sonic transducer.
12. A positional control mechanism for guiding mechanical movement within a tube for inspection of the interior wall volume of said tube comprising:
- a mounting base removably placed on an end of the tube, the mounting base having a sleeve that defines a central guideway;
 - a spur gear having an opening therethrough in alignment with the central guideway and a drive element in the form of a key extending into the

- opening, the spur gear being rotatably coupled to the mounting base;
- an elongated carrier pipe coaxially aligned with and extending through the opening in the spur gear and mounting base sleeve and inserted in the tube, the carrier pipe being formed along one longitudinally extending portion with a drive slot in the form of a key way for receiving the drive element and along a different longitudinally extending portion with a recessed gear rack;
 - a sensor carried by the carrier pipe;
 - a first motor (28) connected to the mounting base and operatively coupled with the spur gear to cause rotation of the carrier pipe;
 - a second motor (49) mounted on the spur gear and operatively coupled with the gear rack to selectively cause axial movement of the carrier pipe; and,
 - actuator means for operating the first motor and the second motor to reposition the sensor within the tube and allow the sensor to scan the interior wall conditions of the tube.
13. The structure according to claim 12 wherein: the first motor is a reversible electric motor with a power take-off shaft mounting a first pinion gear interengaged with the spur gear, and,
- the second motor is a reversible electric motor with a power take-off shaft mounting a second pinion gear interengaged with the gear rack.
14. The structure according to claim 13 including: stop means including a limit switch for controlling rotation of the carrier pipe to guarantee 360°.
15. The structure according to claim 12 including: a remote control unit equipped with means to transmit command signals through the actuator means to the first and second motors in accordance with a predetermined program in order to periodically reposition the sensor.
16. The structure according to claim 15 including: encoder means for sensing rotational and axial movement of the carrier pipe and transmitting electrical signals to the remote control unit for evaluation, and,
- an analog-to-digital converter connected to receive analog signals from the sensor and serving to convert the analog signals to digital signals.
17. The structure according to claim 12 wherein: the sensor is an ultra-sonic transducer,
- the tube and mounting base are coupled in a fluid-tight relationship,
- a space formed between the tube and carrier pipe is filled with liquid immersing the transducer, and,
- a plug is removably inserted within the opposite end of the tube.
18. The structure according to claim 17 wherein: the tube is a control rod mechanism housing fixed in place within a nuclear reactor.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE
CERTIFICATE OF CORRECTION

PATENT NO. : 3,926,040

DATED : December 16, 1975

INVENTOR(S) : Thomas E. Cowell

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 3, line 18, "relatively" should read --relative--;
line 40, "40" should read --49--.

Column 5, line 48, "of" should read --or--.

Column 6, line 36, "mouting" should read --mounting--.

Column 7, lines 17 and 21, "electrical" should read
--electric-- (both occurrences).

Signed and Sealed this

Nineteenth Day of October 1976

[SEAL]

Attest:

RUTH C. MASON
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents and Trademarks