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PIPING INSPECTION  
INSTRUMENT CARRIAGE

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## PIPING INSPECTION INSTRUMENT CARRIAGE

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## BACKGROUND OF THE INVENTION

## 1. Field of the Invention:

The present invention relates to apparatus for inspecting piping. More particularly, the present invention relates to an instrument carriage for use with a pipe crawler to inspect the structural integrity of the interior surface of piping. The United States Government has rights in this invention pursuant to Contract No. DE-AC09-89SR18035 between the U.S. Department of Energy and Westinghouse Savannah River Company.

## 15 2. Discussion of Background:

Numerous instrumentation exists for verifying the integrity of piping, including devices for examining their interior and exterior surfaces. Quite often, a scanning device such as an ultrasonic scanner can be used to inspect the exterior surface of piping that is readily 20 accessible.

For piping that is not readily accessible, such as buried piping or piping carrying radioactive or other hazardous materials, devices that inspect the piping's interior surface are often the only means for verifying the integrity of the piping. Some inspection means are self-25 propelled pipe crawlers having the desired instrumentation mounted thereon. For example, see the pipe crawling devices described by

Metal et al in US patent 4,856,337, Cowell in US patent 3,926,040 and Weber et al in US patent 4,460,920.

Other inspection devices consist of carriages transported through the piping by pipe crawlers or other means. A suitable pipe 5 crawler for the present invention and other instrument carriages is described in commonly-assigned US patent 5,121,694, whose disclosure is incorporated herein by reference. Also, see commonly-assigned US patent 5,018,451 for a description of another pipe crawler that could be used to move a pipe inspection carriage.

10 Inspection carriages are well known in the art. Some carriages carry a plurality of inspection equipment, such as ultrasonic probes, eddy current sensors, cameras and the like, but often have limited mobility within the piping once transported therein. Still other carriages carry only selected instruments but offer greater degrees of 15 movement for using the transported equipment.

For example, Nottingham et al, in US patent 4,864,862, disclose an ultrasonic inspection system featuring a carriage with two radial support assemblies that can move separately to tilt transducers mounted on the carriage.

20 In US patent 5,189,915, Reinhart et al disclose an ultrasonic inspection method and apparatus having a carriage that includes a plurality of search units mounted on a housing located between two centering donuts. Each donut contains three dowels spaced 120° apart, for centering the device within the pipe interior. The carriage is also 25 capable of supplying couplant.

Gunkel, in US patent 3,766,775, discloses a transducer assembly that is rotated within the interior of piping. The device is mounted on

a rotatable shaft, and the transducer mechanism is stabilized within the pipe by a portable stand. A motor extending from the portable stand controls the movement of the transducer assembly.

Despite the number of carriages that exist, it is desirable to have  
5 an instrument-carrying carriage for ultrasonic inspection of piping interior that has greater axial range, yet is still dimensioned to negotiate piping bends.

#### SUMMARY OF THE INVENTION

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The present invention solves the problems associated with the range of axial movement of the inspection instrumentation not addressed by the prior art. According to its major aspects and broadly stated, the present invention is a carriage for pipe inspection  
15 equipment. In particular, it is an instrument carriage for use with a pipe crawler or other locomotion means for performing internal inspections of piping surfaces. The carriage has a front leg assembly, a rear leg assembly and a central support therebetween for mounting an instrument arm having inspection instrumentation. The instrument  
20 arm has means mounted distally for axially aligning a pair of inspection instruments and means for extending the inspection instruments radially outward to position the inspection instruments on the piping interior. Also, the carriage has means for rotating the central support and the front leg assembly with respect to the rear leg  
25 assembly so that the inspection instruments azimuthally scan the piping interior. The instrument carriage allows performance of all piping

inspection operations with a minimum of moving parts, thus decreasing the likelihood of performance failure.

A major feature of the present invention is the use of the Y-arm for axial movement of the inspection instruments. The Y-arm is 5 mounted preferably at the distal end of the instrumentation arm, thus axial movement is performed at a location radially displaced from, rather than closer to, the body of the carriage. The advantage of this feature is that the axial movement range of the inspection instruments is increased and more than one inspection instrument can be mounted 10 to the Y-arm for inspection. As a result, much more area can be scanned and much more inspection data can be generated with a minimum of instrument movement once the instrument carriage is positioned.

Another feature of the present invention is the hollow central 15 tube. Besides connecting and maintaining the spacing between the front and rear leg assemblies, the central tube is hollow and dimensioned to house and protect all cabling and wiring necessary for the operation of the instrument carriage and all instruments mounted thereon. This feature significantly reduces the amount of exposed 20 wiring that can snag or restrict movement of the instrument carriage during operation.

Still another feature is the rotation motor and gear assembly. The rotation motor, which is mounted on the rear leg assembly, and the gear assembly, which is rotatably connected to the rear leg 25 assembly, allow the inspection instruments to be moved azimuthally along the piping interior by rotating the central tube and front leg assembly with respect to the rear leg assembly, thereby simplifying the

instrumentation motion necessary for inspection. Also, the rotation of the central tube and front leg assembly minimizes the irregular twisting and displacement of the cabling and wiring housed in the central tube and throughout the carriage.

5 Another feature of the present invention is the linear actuator. The linear actuator is an air-powered assembly that functions to extend the Y-arm and inspection instruments radially outward until the inspection instruments are operably positioned on the interior surface of the piping. This feature contributes to the overall simplification of  
10 movement of the inspection instruments during operation, thereby requiring fewer parts and allowing greater freedom of movement and inspection range for the carriage.

Other features and advantages of the present invention will be apparent to those skilled in the art from a careful reading of the  
15 Detailed Description of a Preferred Embodiment presented below and accompanied by the drawings.

#### BRIEF DESCRIPTION OF THE DRAWINGS

20 In the drawings,

Fig. 1 is a perspective view of an instrument carriage according to a preferred embodiment of the present invention;

Fig. 2 is a detailed view of a first side of the instrument carriage of Fig. 1;

25 Fig. 3 is a detailed view of a second side of the instrument carriage of Fig. 1; and

Fig. 4 is a detailed view of the second side of the instrument carriage showing movement of the extending and axial movement means.

## 5 DETAILED DESCRIPTION OF A PREFERRED EMBODIMENT

In the following description similar components are referred to by the same reference numeral in order to simplify the understanding of the sequential aspect of the drawings.

10 Referring to Figs. 1-3, the instrument carriage 20 in its preferred embodiment is a front leg assembly 22, a rear leg assembly 24, a central tube 26 for rigidly maintaining the spacing between front leg assembly 22 and rear leg assembly 24, and an instrumentation arm (shown generally as 28) for carrying a plurality of inspection 15 instruments 30 used in inspecting the interior surface of piping or other structures.

Rear leg assembly 24 has a hollow, flexible coupling 32 for connecting instrument carriage 20 to a pipe crawler (not shown). A standard connection arrangement, such as a flange 34 with a plurality 20 of screws 36 (see Fig. 1), is used to fixably mount instrument carriage 20 to the pipe crawler.

The pipe crawler used with instrument carriage 20 can be any type of locomotion means capable of pulling or preferably pushing instrument carriage 20 through piping having a diameter between 25 approximately 12 inches and 16 inches. A suitable pipe crawler for use with instrument carriage 20 is the kind taught in commonly-

assigned US patent 5,121,694, whose disclosure is incorporated herein by reference.

Front leg assembly 22 is a front plate 42, preferably made of aluminum or similar material, having a plurality of radially extendible leg cylinders 44 mounted thereon and spaced equally apart. Similarly, rear leg assembly 24 is a rear plate 46, preferably made of aluminum or similar material, having a plurality of radially extendible leg cylinders 44 mounted thereon and equidistant from one another. The distal end of each leg cylinder has a foot 48, preferably with a ball 10 caster 49, for engaging the interior surface of the pipe being inspected when the leg cylinder is extended radially.

In addition to leg cylinders 44, rear leg assembly 24 has a bearing housing 52 for rotatably connecting central tube 26 to rear leg assembly 24 so that rear leg assembly 24 and central tube 26 are 15 axially aligned with bearing housing 52.

Central tube 26 is preferably a hollow, slender, symmetric housing made of aluminum or similar material. Central tube 26 has a front flange 54 and a rear flange 56 (shown best in Figs. 2-3), both of which are permanently attached to central tube 26. Front flange 54 is 20 used for fixably attaching central tube 26 to front leg assembly 22 using conventional mounting means such as screws and the like.

Attached to central tube 26 is instrumentation arm 28, which preferably comprises a mounting block 62 having a linear actuator 64, an axial movement arm 66, an instrument support 68 and a motor 72 25 or other means for moving instrument support 68 along axial movement arm 66.

Mounting block 62 is fixably attached to one side of central tube 26 using any suitable connecting means, such as a plurality of screws or the like. The top of mounting block 62 has a mounting plate (not shown) that is pushed upwards by linear actuator 64, which is

5 preferably an air-powered ram/cylinder combination (as shown in Fig. 4). A pair of actuator stops 74 move with linear actuator 64 to prevent linear actuator 64 from overextending the mounting plate. Because of the mounting location and orientation of mounting block 62, the upward movement of the mounting plate moves

10 instrumentation arm 28 radially outward from central tube 26.

Motor 72 has a housing fixably mounted to the mounting plate by conventional means, such as a plurality of screws or the like. Axial movement arm 66 is mounted to one side of motor 72 so that axial movement arm 66 is oriented as shown in Figs. 1-3, that is parallel to

15 central tube 26. Motor 72 is oriented within its housing so that a rotating arm 82 (shown in Fig. 3) extends through axial movement arm 66 at one end thereof and has a drive sprocket 84 fixably attached thereto.

Axial movement arm 66 can be any suitable arm that supports

20 inspection instrumentation and provides axial movement thereof, but is preferably the Y-arm from a P-Scan AWS-6 scanner, which is manufactured by P-Scan and is part of their external pipe inspection kit. Also, motor 72 is preferably the motor as part of the P-Scan external pipe inspection kit, but with a modified housing.

25 Compared to previous pipe crawler instrumentation carriages, the Y-arm from a P-Scan AWS-6 scanner is configured for using multiple probes and is very compact for the amount of linear or axial

travel it provides. Also, the Y-arm, as is, is suitable for keeping a proper orientation of the probes with the interior surface of a pipe wall with sufficient compliance. Moreover, the Y-arm can supply couplant directly to the probes.

5       Drive sprocket 84 is used in operable connection with an endless belt 86 and a driven sprocket 88 to slide instrument support 68 axially along axial movement arm 66 (as shown in Fig. 4). Preferably, axial movement arm is approximately 11" long, thus, taking into consideration the size of instrument support 68, inspection instruments  
10 30 are afforded axial movement of approximately 8" in this configuration.

Instrument support 68 is dimensioned to mount at least one and preferably two inspection instruments 30 such as ultrasonic probes, eddy current probes and the like. Inspection instruments 30 are  
15 commercially available and spring mounted on clamps 92 using a plurality of linkages 94, or alternatively, coiled springs (not shown). In the preferred embodiment, linkages 94 that offer a vertical "play" of approximately 2" are used. Using clamps 92, inspection instruments 30 are connected to instrument support 68.

20       Preferably, inspection instruments 30 are a pair of ultrasonic probes, which are used to determine the distance to a wave-reflecting internal crack or other flaw in the interior of piping. In use, the ultrasonic probes direct ultrasonic signals into the interior surface of piping of other structures using the signal generator portion of the  
25 probes. Flaws in the piping represent acoustic discontinuities that reflect back a portion of the signal energy to the signal receiver

portion of the probes. For convenience, some ultrasonic probes are equipped to function as both signal generator and receiver.

In the present invention, when the ultrasonic probes are used as inspection instruments 30, each probe preferably functions as both the 5 signal generator and receiver. Thus, preferably, the first probe is oriented on instrument support 68 to produce 45° shear waves to look for and measure intergranular stress corrosion cracking (SCC) and the second probe is oriented on instrument support 68 to produce 90° "straight-through" waves for measuring wall thickness of the piping 10 being inspected. Both measurements are needed in the normal inspection process.

Alternatively, eddy current probes can be used as inspection instruments 30. Eddy current probes test magnetic properties and look for a change in those properties present due to welding or other 15 instigators.

Rear flange 56 of central tube 26 is fixably attached to a rotating means having a flanged portion 96 and a nosepiece 96 that inserts into and rotates within bearing housing 52. Preferably, a large annular rotation gear 102 is coupled between the rotating means and 20 rear leg assembly 24 so that when rear flange 56 of central tube 26 is fixably attached to flanged portion 96, rotation gear 102 rotates both central tube 26 and front leg assembly 22 with respect to rear leg assembly 24.

Rotation gear 102 is driven by use of a rotation motor 104 25 fixably mounted on rear leg assembly 24. Rotation motor 104 has a rotation pinion 106 mounted on a sprocket 108 that passes through an aperture (not shown) formed in rear leg assembly 24. Rotation motor

104 can be any commercially available motor having the requisite specifications for proper operation of rotation gear 102.

In order to rotate central tube 26 with respect to rear leg assembly 24, rotation motor 104 is operated to rotate sprocket 108, 5 which rotates rotation pinion 106, in the desired direction. Rotation pinion 106 has a plurality of teeth that mesh with a corresponding plurality of teeth along the peripheral edge of annular rotation gear 102 so that annular rotation gear 102 rotates when rotation pinion 106 is rotated.

10 Annular rotation gear 102 has a raised head (not shown) mounted thereon that aligns with a mechanical stop 112 (see Fig. 2) mounted on rear leg assembly 24. Mechanical stop 112 is positioned on rear leg assembly 24 so that it comes into contact with the raised head once annular rotation gear 102 has been rotated just beyond 360° 15 (approximately 365°).

Preferably, rotation motor 104 comes equipped with a built-in encoder 114 or similar means for tracking precisely the rate of incremental rotation and the rate at which rotation motor 104 rotates annular rotation gear 102, and consequently central tube 26 and front 20 leg assembly 22. Such rotational monitoring is important and necessary in processing inspection data. Also, industry standards for scanning surfaces such as piping interiors must be adhered to and require a certain degree of accuracy with respect to rotational monitoring.

25 Central tube 26 is preferably dimensioned to house and allow passage of all wiring and tubing of instrumentation carriage 20. Thus, central tube 26 effectively eliminates almost all exposed cabling that

could otherwise snag within the piping or restrict movement as central tube 26 rotates. Preferably, wiring enters instrument carriage 20 from the pipe crawler through coupling 32 and passes through the center of bearing housing 52 and rear leg assembly 24 to central tube

5 26. Also, a plurality of ports 116 are formed in central tube 26 so that the wiring can access appropriate equipment at appropriate places along central tube 26.

Preferably, carriage 20 has a plurality of cameras (not shown) mounted thereto to provide aid in positioning carriage 20 in the 10 desired location within the piping. Cameras can be mounted on front leg assembly 22, rear leg assembly 24, and central tube 26. Also, cameras are mounted on central tube 26 midway between front and rear leg assemblies 22, 24 for viewing various portions of the piping region to be inspected.

15 Instrument carriage 20 is controlled through an umbilical cable running from the rear of instrument carriage 20 back through the pipe crawler and the interior of the piping to a control cabinet. The umbilical cable routes control signals for air valves, air for leg cylinders 44, data signals from inspection instruments 30, and 20 electrical power for motor operation. Alternatively, the valve for supplying air to leg cylinders 44 can be conveniently located on the pipe crawler or back at the controls.

In use, instrument carriage 20 is used with a pipe crawler for 25 inspecting the interior surface of piping having a diameter approximately 12 inches to approximately 16 inches. Initially, all leg cylinders 44 are retracted and rear leg assembly 24 connects instrument carriage 20 to the front of the pipe crawler via flexible

coupling 32 and all necessary wiring is run from the pipe crawler to instrument carriage 20 for proper operation.

Once entering the piping, instrument carriage 20 is preferably pushed through the piping interior to the desired position using

- 5 locomotion provided by the pipe crawler and the viewing assistance of the mounted cameras. Ball casters 49 provide instrument carriage 20 with the directional smoothness to roll axially down the piping interior. Flexible coupling 32 allows the pipe crawler and carriage 20 combination to negotiate elbows in the piping. Preferably, instrument
- 10 carriage 20 is eventually positioned so that an area to be inspected is approximately midway between front and rear leg assemblies 22, 24.

Once in the desired position within the piping, leg cylinders 44 are radially extended until casters 49 engage the interior surface of the piping so that instrument carriage 20 remains centered in the piping.

- 15 Then, linear actuator 64 radially extends instrumentation arm 28 until inspection instruments 30 are operably positioned along the interior surface of the piping. Instrument support 68 can be slid axially in either direction, in the manner discussed above, to position the inspection instruments 30 preferably on either side of the weld being
- 20 inspected. When inspecting welds, the desired inspection region is preferably within 3" on either side of the weld, which is the most crucial area to be scanned for defects. Since inspection instruments 30 are preferably clamped on instrument support 68, the distance between inspection instruments 30 can be increased or decreased as necessary
- 25 depending on the type of feature being inspected.

Next, using rotation motor 104 as discussed above, central tube 26 and front leg assembly 22 are rotated incrementally so that

inspection instruments 30 travel azimuthally along the interior of the piping. Once again, ball casters 49 provide instrument carriage 20 with the directional smoothness to roll azimuthally. During this movement, the pipe crawler preferably has a firm grip within the 5 interior of the piping, thus allowing such rotation to occur without difficulty. In the present invention, the preferred use of two inspection instruments 30 eliminates the need for a single inspection instrument being rotated at each inspection site. That is, previous 10 single probe carriages moved the inspection probe in a systematic square wave path along weld.

Once inspection instruments 30 have scanned the entire circumference of the piping interior, that is, central tube 26 has rotated just over 360° (approximately 365°), the head mounted on rear plate 46 will hit stop 112, and operational controls will reverse the 15 direction of rotation to "unwind" central tube 26 and inspection instruments 30 to their original azimuthal position. Then, linear actuator 64 will retract inspection instruments 30 and carriage 20 will be repositioned axially along the piping interior for the next scan.

It will be apparent to those skilled in the art that many changes 20 and substitutions can be made to the preferred embodiment herein described without departing from the spirit and scope of the present invention as defined by the appended claims.

## ABSTRACT OF THE DISCLOSURE

A pipe inspection instrument carriage for use with a pipe crawler or other locomotion means for performing internal 5 inspections of piping surfaces. The carriage has a front leg assembly, a rear leg assembly and a central support connecting the two assemblies and for mounting an instrument arm having inspection instruments. The instrument arm has means mounted distally thereon for axially aligning the inspection instrumentation and means for 10 extending the inspection instruments radially outward to operably position the inspection instruments on the piping interior. Also, the carriage has means for rotating the central support and the front leg assembly with respect to the rear leg assembly so that the inspection instruments azimuthally scan the piping interior. The instrument 15 carriage allows performance of all piping inspection operations with a minimum of moving parts, thus decreasing the likelihood of performance failure.

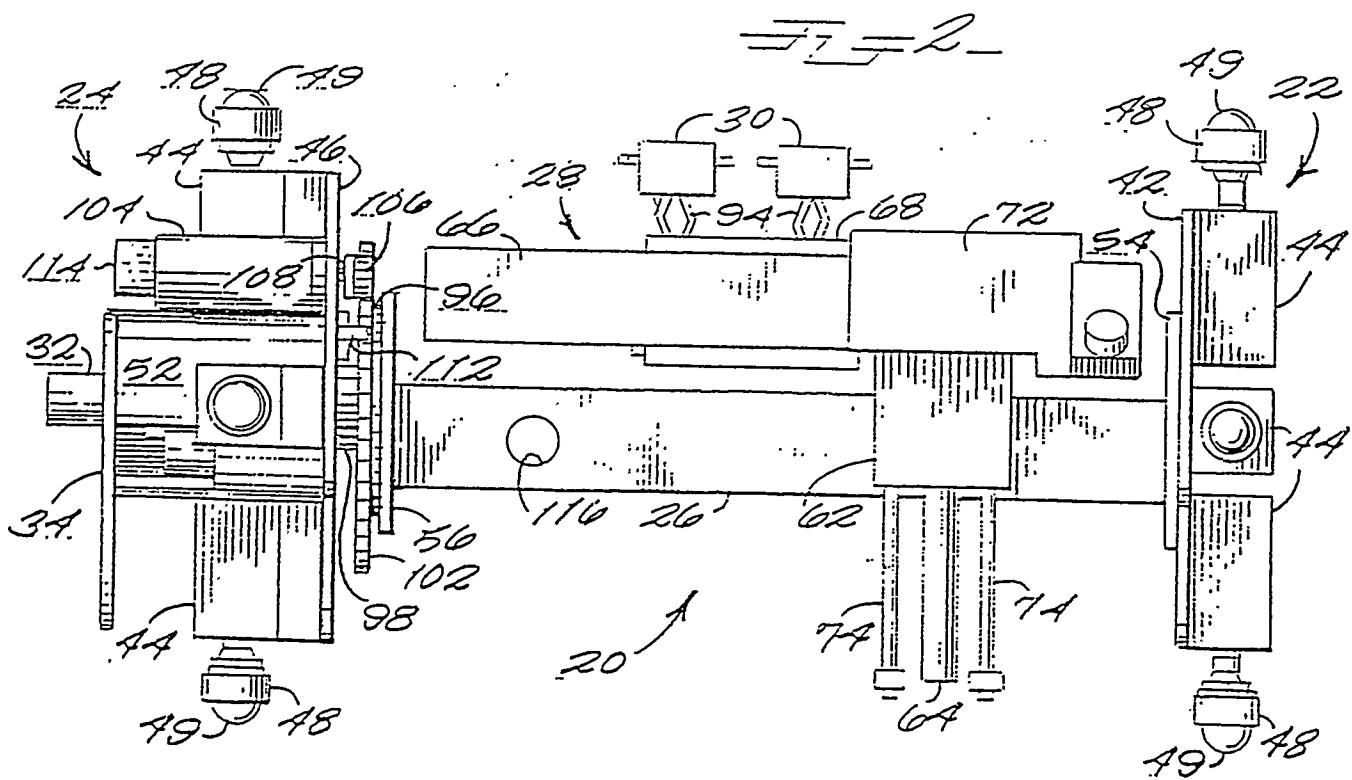
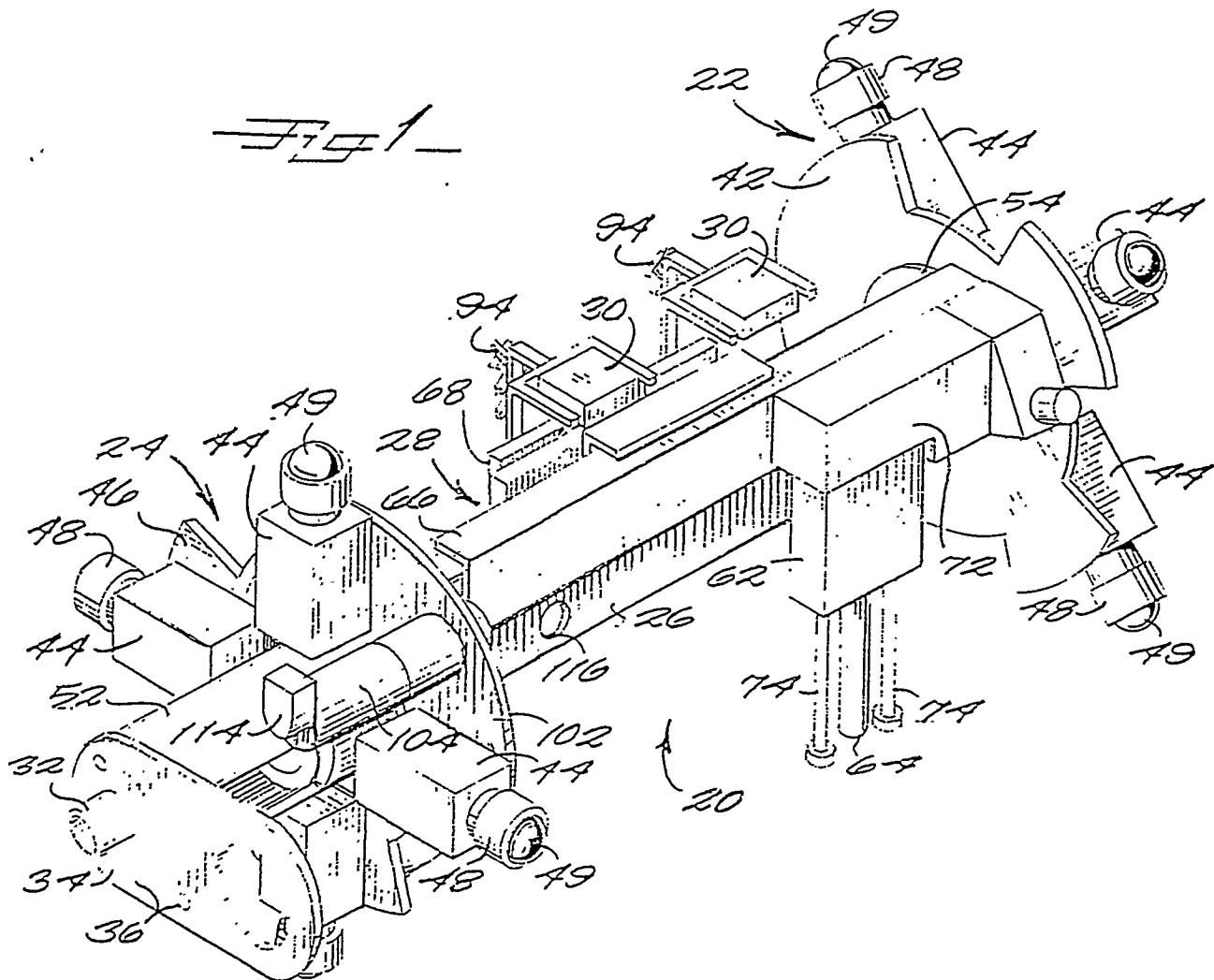


FIG 3

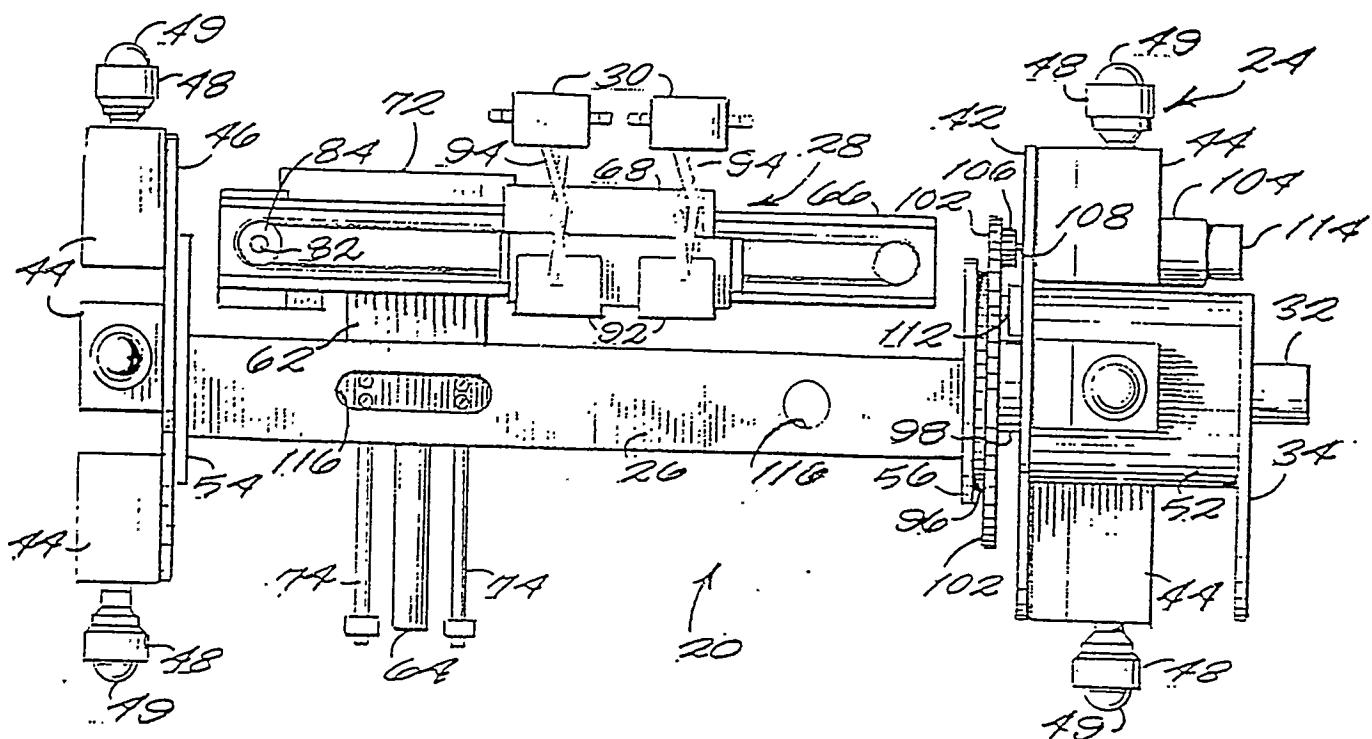


FIG 4

