United States Patent [19]

Greenberger

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[54] **HYDRAULIC MILLS**

[75] Inventor: **Joseph Irwin Greenberger,** Pittsburgh, Pa.

[73] Assignee: **Wean United, Inc.,** Pittsburgh, Pa.

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[52] **U.S. Cl.** **72/21,** 72/238

[51] **Int. Cl.** **B21b 37/00**

[58] **Field of Search** .... 72/8, 21, 35, 238, 72/239; 318/660, 657, 608; 91/363 A, 363 R

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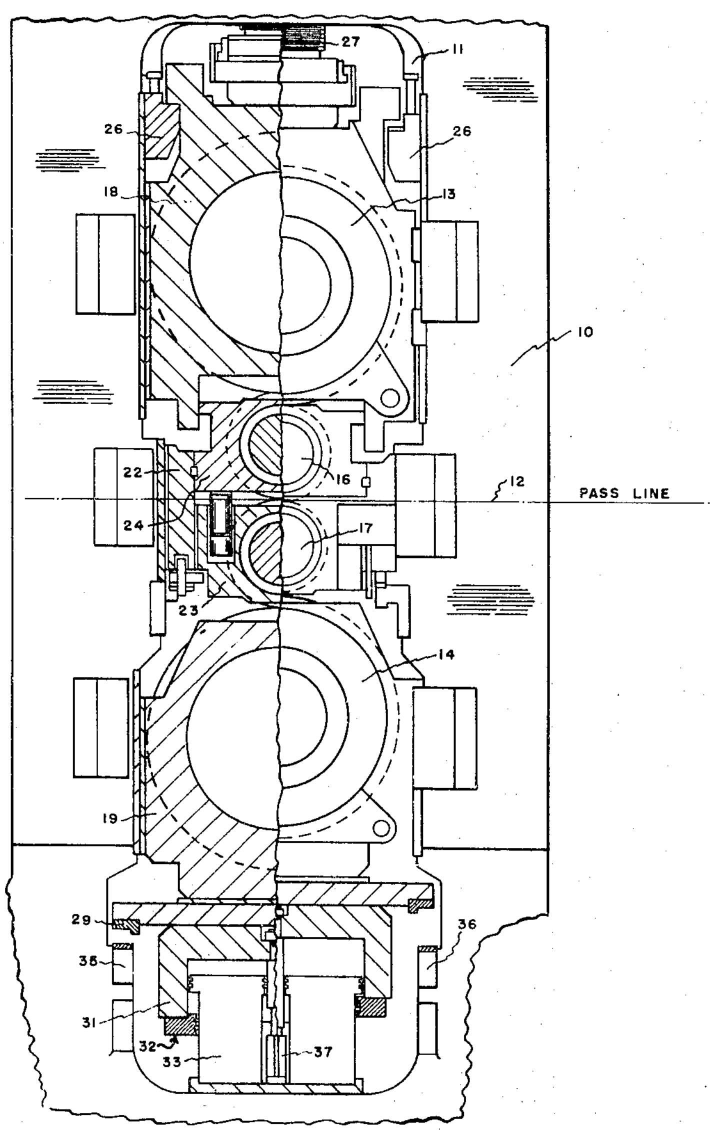
Primary Examiner—Milton S. Mehr
Attorney—Henry C. Westin

[57] **ABSTRACT**

The disclosure of the present invention relates to a rolling mill having hydraulic piston cylinder assemblies for controlling the gap of the work rolls of the mill. Linear INDUCTOSYNS (the term INDUCTOSYN being a registered United States trademark of the INDUCTOSYN CORPORATION) are arranged in openings provided in the pistons of the piston-cylinder assemblies for measuring accurately the relative movement of the pistons and cylinders as a function of changes in the roll gap caused by rolling variations. Because of the inherent capabilities of INDUCTOSYNS, they require no additional adjustment features, even though relatively large adjustments are required to maintain a fixed mill passline.

2 Claims, 5 Drawing Figures



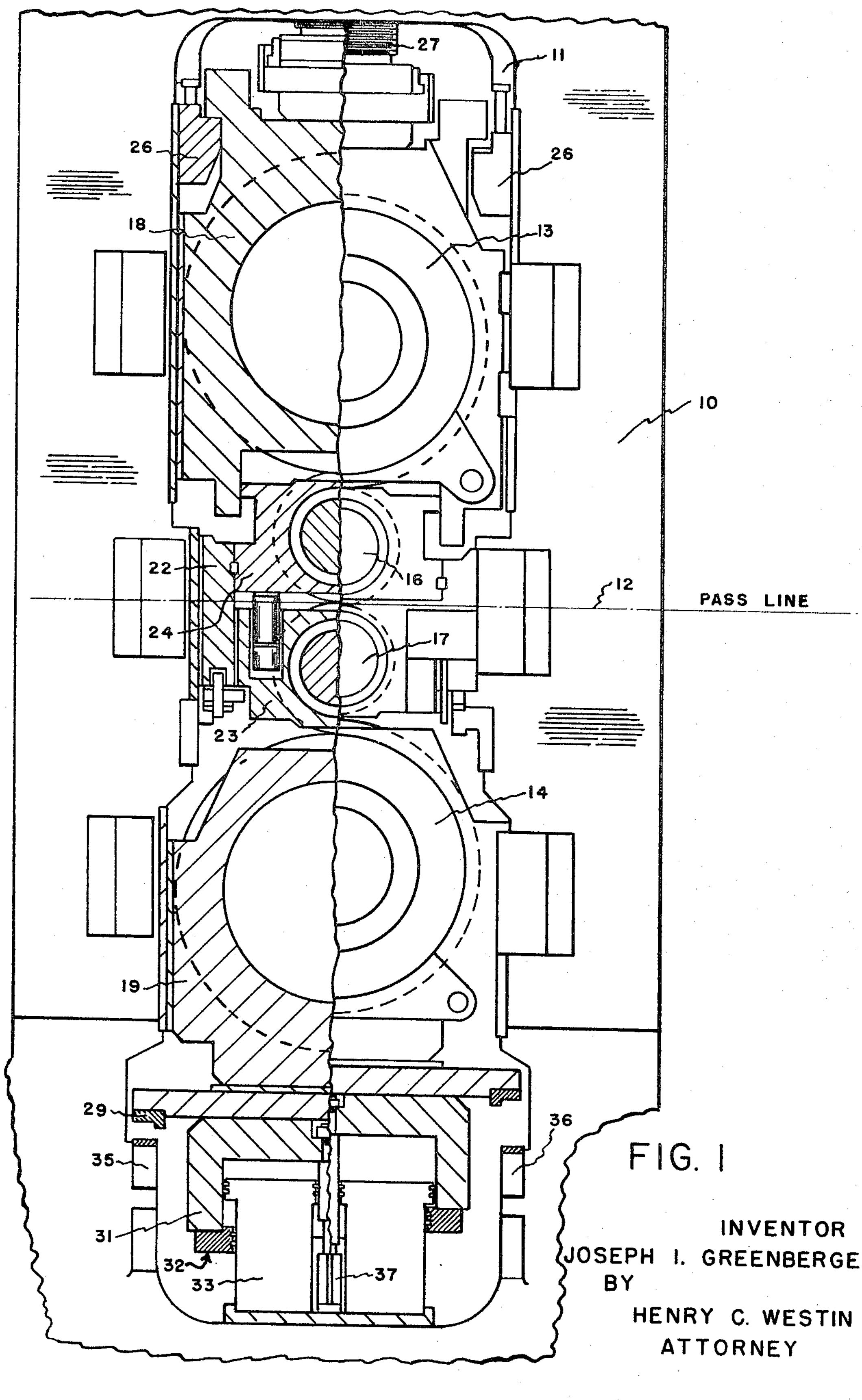


FIG. I

INVENTOR
JOSEPH I. GREENBERGER
BY
HENRY C. WESTIN
ATTORNEY

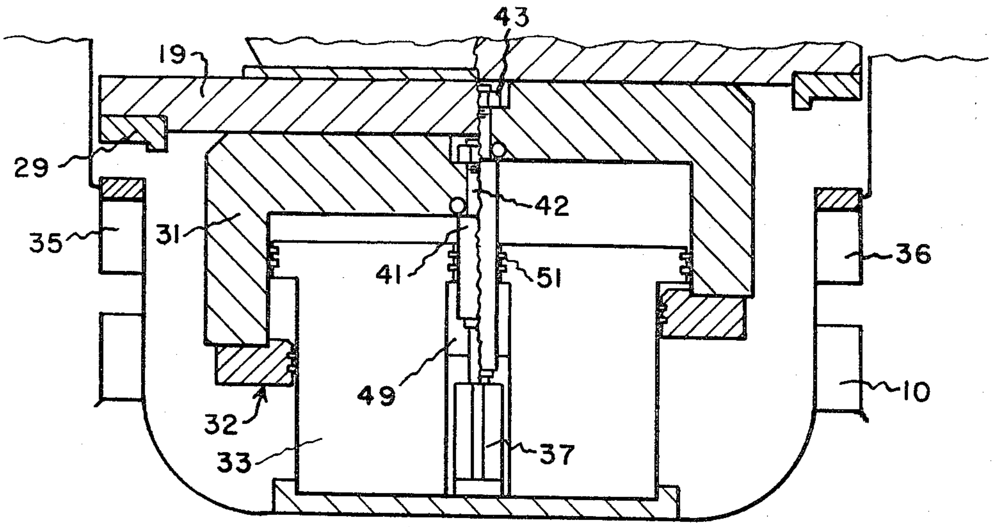


FIG. 2

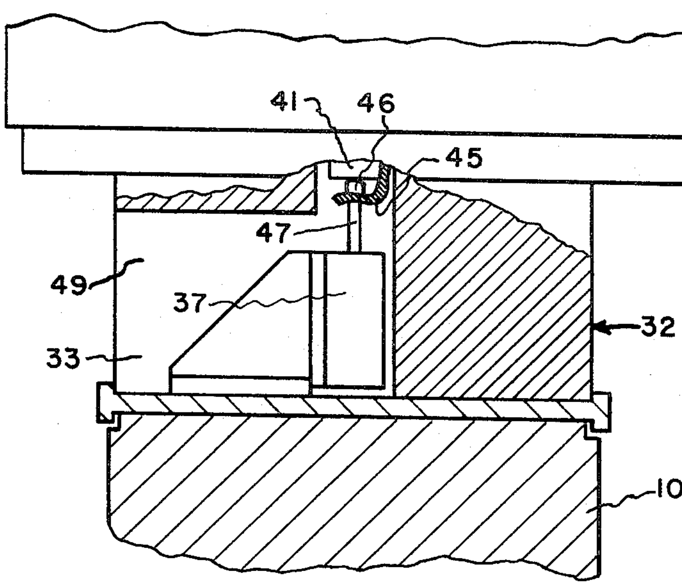


FIG. 3

INVENTOR
JOSEPH I. GREENBERGER
BY
HENRY C. WESTIN
ATTORNEY

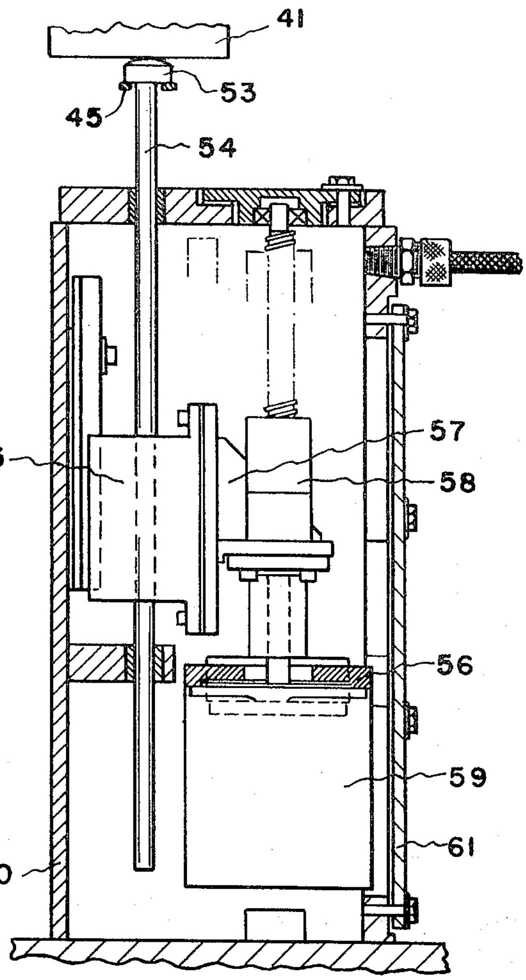


FIG. 4

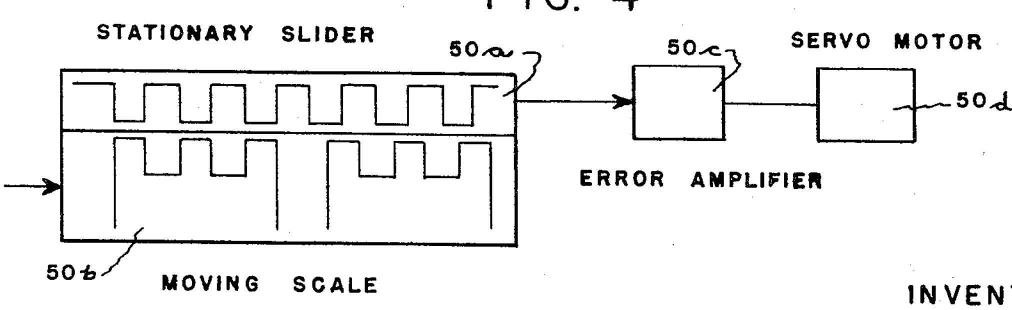


FIG. 5

INVENTOR
JOSEPH I. GREENBERGER
BY
HENRY C. WESTIN
ATTORNEY

HYDRAULIC MILLS

In present day rolling mills of the type employed to roll metal strip, such as, for example, cold rolled annealed carbon steel, there is a great need for improving the accuracy, reliability and performance of present methods and devices employed for measuring changes in roll gap of the rolling mill during the rolling operation. Such mills of the hydraulic type, as well as hydraulic hot strip mills, have used load meter devices or other direct position indicators, both of which have been found to possess a number of serious limitations. For one thing, the accuracy and acceptable range within which they are capable of working are not adequate in many cases. In mills where passline is to be maintained at a fixed elevation, even though rolls of different diameters are to be employed, a separate special adjustment device is required to reposition the load meter device or position transducer to be operative within their narrow working range.

The great majority of such devices and transducers, moreover, have been employed in sets of two for each cylinder assembly in order to eliminate effects of tilting of the cylinder components. Such an arrangement greatly adds to the complexity and expense of the gap control equipment in addition to increasing maintenance problems.

The present invention provides a method and apparatus of controlling the gap of a rolling mill or like apparatus wherein a linear INDUCTOSYN is employed to produce accurately a signal representative of the amount of change in the roll gap. Such a device has an inherent accuracy through a relatively large range of linear motion so that in a mill requiring a fixed passline, no additional means is required to reposition the INDUCTOSYN when different-sized rolls are employed.

It is a further object of the present invention to provide linear INDUCTOSYNS in a mill having a pair of fluid piston-cylinder assemblies for controlling roll gap, wherein a single linear INDUCTOSYN is provided for each piston-cylinder assembly arranged to measure relative movement of the piston and cylinder for each assembly as a function of a change in the roll gap of the mill.

It is a still further object of the present invention to provide in hydraulic rolling mills a linear variable differential transformer (LVDT) position transducer for each hydraulic cylinder in combination with a special electrical motor for repositioning the LVDTs to be in their optimum range of accuracy after the rolls have been reset for passline control.

Another object of the present invention relates to an hydraulic mill wherein an opening is provided in the piston of the piston-cylinder assembly employed for gap control of the mill and into which opening a position transducer is mounted in a manner to be carried by the piston and adapted to measure the displacement of the piston relative to the cylinder as a function of change of roll gap of the mill.

These objects, as well as other novel features and advantages of the present invention, will be better understood when the following description is read along with the accompanying drawings of which:

FIG. 1 is an elevational view, partly in section, of a rolling mill incorporating the features of the present invention in which the left-hand portion indicates the position of the illustrated components of the mill when the mill employs maximum diameter rolls; whereas, the right-hand portion of the drawing illustrates the position of the components when minimum diameter rolls are being employed,

FIG. 2 is an enlarged view of the lower portion of the rolling mill illustrated in FIG. 1,

FIG. 3 is an end view of FIG. 2,

FIG. 4 is a sectional view of a second embodiment of the position transducer illustrated in previous figures, and

FIG. 5 is an electrical diagram of the INDUCTOSYN and associated control elements.

In referring first to FIG. 1, there is illustrated the window of one of two identical housings of a 4-high cold rolling mill for rolling strip material constructed generally in accordance with well-known designs. There is shown one of the upright mill housings **10** having an elongated vertical window **11** through which there are received, with reference to a passline **12**, opposed backup rolls **13** and **14** which support, in the customary manner, smaller diameter work rolls **16** and **17**. The backup rolls are rotatably carried by bearing chock assemblies **18** and **19** which are received in the window **11**. An upper work roll chock **22** is provided with an opening **24** for receiving in a nested relationship a lower work roll chock **23**. In accordance with well-known practice, each backup chock **18** is engaged by a pair of roll balance hanger bars **26** of a balance cylinder assembly, not shown. Each backup chock **18** is also engaged indirectly at its top portion in the customary manner by the mill screw **27**.

At the bottom of the mill the backup chock **19** rests on a horizontal platform that forms part of the backup roll changing sled **29** which, in turn, is supported by the cylinder **31** of a piston-cylinder assembly **32**, the piston thereof being identified as **33**, in which arrangement the cylinder moves relative to the stationary piston **33**. In accordance with general practice, the sled **29** is adapted to rest on a pair of rails **35** and **36** when in its roll changing position. Since FIG. 1 is designed to depict the rolling position of the components, there is clearance between the sled **29** and rails **35** and **36**.

As noted previously, the right-hand side of FIG. 1 illustrates the condition with minimum diameter rolls, whereas the left-hand side illustrates the condition with maximum diameter rolls, which explains the difference in the elevational disposition of the cylinder **31**, with reference to the left and right-hand sides of FIG. 1, with respect to the passline **12**. In other words, when the mill is employing minimum diameter rolls, it is necessary to lift the lower work roll **17** and the lower backup roll **19** so as to place the upper peripheral surface of the work roll tangentially to the passline **12**. As previously noted, it is the requirement that the rolls be so positioned with respect to the passline that led to the discovery of the present invention. In this connection, it will be noted with respect to the piston-cylinder assembly **32** that there is inserted within the piston **33** and connected to the cylinder **31** a position transducer **37** designed to detect changes in the relative positions between the piston **33** and the cylinder **31**. Such changes will represent changes in the gap between the work rolls **16** and **17**, which gap changes will result in error in the gage being rolled and necessitate a correction in the gap in order that constant gage material may be rolled.

As noted previously, the second spaced-apart housing, not shown, will also employ a piston-cylinder assembly similar to the assembly **32** which will have a position transducer similar to the transducer **37.**

FIGS. **2** and **3** represent an enlargement of the piston-cylinder assembly **32** illustrated in FIG. **1,** in which connection it will be noticed that at its upper portion it takes the form of a vertical movable plunger **41** which includes a projecting stem **42** which, through the means of a nut **43,** is secured to the cylinder **31.** Accordingly, in this construction the plunger **41** will move with the cylinder **31.** At the lower end of the plunger **41** there is provided, as best shown in FIG. **3,** a clip **45** which is open radially to receive and fit under a button **46** of a vertical rod **47** that protrudes from the position transducer **37.** The position transducer itself is received in a radial opening **49** which, as shown in FIG. **2,** takes the form of a narrow slot formed in the piston **33** of the cylinder assembly **32.** As shown in FIGS. **2** and **3,** the position transducer **37** rests on the bottom of the piston **33** and is supported by the piston. Unit **37** can be removed quickly from its operative position for maintenance purposes by simply disconnecting the electrical connection and moving the unit towards the left as one views FIG. **3,** during which movement the button **46** will slide out of the clip **45.**

Before leaving FIG. **2** it will be noted that between the plunger **41** and the piston **33** there are provided sealing rings **51** that prevent the fluid from escaping from the piston-cylinder assembly **32.**

It is a particular feature of the present invention to provide an INDUCTOSYN, as the position transducer **37.** As noted before, this term is a registered trademark of Inductosyn Corporation and has been selected for use in the rolling mills in view of its inherent capabilities of measuring very small displacement of elements very accurately over a large linear motion. This allows its utilization, even though adjustment of the lower rolls for passline control may vary up to 5 inches.

FIG. **5** shows diagrammatically the stationary and moving windings **50*a*** and **50*b*,** respectively, of the INDUCTOSYN **37.** A single-phase voltage is applied to the scale **50*b*,** which is the linear equivalent of the rotary INDUCTOSYN rotor, and sine and cosine voltages appear on the two-phase windings of the slider or stator. The receiver slider, not shown, is energized by the transmitter slider **50*a*** and the receiver scale output is the error voltage, which becomes zero when the transmitter and receiver are in alignment. The error signal in the case of passline adjustment and control is produced by a digital summer and for roll gap control by an analog summer, the summers and required amplifier being indicated at **50*c*.** The error signal is fed to a servo-motor **50*d*** that operates the piston-cylinder assembly **32.** Thus, the INDUCTOSYN inherently can accommodate large linear motions for passline adjustments in which the repetitive discrete cycles of the windings on relative movement thereof are digitally summed, and yet can be extremely accurate and sensitive for fine roll gap changes, during which only a fraction of a cycle is measured in an analog manner.

The present invention is not limited to the use of INDUCTOSYNS and, as illustrated in FIG. **4,** other forms of position transducers, such as an LVDT (linear variable differential transformer), can be employed; for example, as manufactured by Schaevitz Engineering of Pennsauken, New Jersey, U. S. A., and described in their Technical Bulletin AA-1*b*, Copyright 1955. However, in view of the fact that such devices do not have the linear motion range within the accuracies required, it is necessary to provide an adjustment device to compensate for a change in rolls in order to maintain the lower work roll **17** on passline **12.** It will be appreciated that the position transducer and associated parts shown in FIG. **4** are meant to be a substitution of the unit **37** illustrated in FIGS. **1, 2** and **3** so that FIG. 4 shows the bottom portion of the plunger **41** engaged by a button **53** which is held against the plunger **41** by the clip **45** associated with the plunger **41.** The button **53** forms the top portion of a rod **54** of a position transducer **55** that takes the form of an LVDT unit. It will be appreciated that the rod **54** moves relative to the LVDT **55** and that such movement is measured by the LVDT as a function of a change in the gap between work rolls **16** and **17.** The unit **55** is connected by a bracket **57** to a precision ball screw unit **58** which, in turn, is connected to an electrical stepping motor **59,** the motor itself being fixed to a shelf **56** of the total enclosure **70.** The stepping motor may take the form of the type manufactured by Superior Electric Company of Bristol, Connecticut, U. S. A., known by their registered trademark as SLO-SYN. In this arrangement the physical linear travel of the position transducer **55** will be related to the maximum adjustment that must be made with reference to the different roll sizes, which adjustment is made through the operation of the stepping motor **59.** Once the passline change has been made and the LVDT is electrically nulled with reference to its midpoint, the stepping motor ceases to function and the short stroke and extremely sensitive and accurate LVDT will then measure gap changes.

It will be appreciated by those skilled in the art that the actual mode of control of the mill with reference to obtaining gap control may vary in accordance with well-known technology. One of the advantages of the two embodiments disclosed is that they lend themselves very well to various forms of mill control. By way of example only, the two arrangements can be employed to measure very accurately the change in the gap between the work rolls **16** and **17** to produce a signal of such change, which signal can be utilized in accordance with the control method set forth in U. S. Pat. No. 3,492,056 which issued on Jan. 20, 1970 to J. W. O'Brien and U. S. Pat. No. 3,496,743 which issued on Feb. 24, 1970 to M. D. Stone.

The two embodiments of the present invention can be employed also to allow the operator of the mill to reposition the roll gap specific amounts with respect to a calibrated zero position. One example of such a mill would be where it is possible and desirable to make a periodic recalibration of the true gap condition with respect to a calibrating rolling pressure.

In accordance with the provisions of the patent statutes, I have explained the principle and operation of my invention and have illustrated and described what I consider to represent the best embodiment thereof.

I claim:

1. In a rolling mill having a pair of rolls that form a roll gap into which a workpiece is fed for rolling,

a fluid piston-cylinder assembly for adjusting one of the rolls relative to the other roll to change said roll gap, said piston -cylinder assembly including a movable member and a stationary member,

an opening formed in an interior portion of said stationary member a linear displacement measuring means arranged in said opening to measure the relative movement between the piston and cylinder of said piston-cylinder assembly said opening having an entrance portion extending perpendicularly both to the direction of movement of said piston- cylinder assembly and to the major axis of said linear displacement measuring means, said entrance portion being of a size to permit easy removal and replacement of said linear displacement measuring means to and from said interior portion without removal of the piston -cylinder assembly from said rolling mill.

2. In a rolling mill according to claim **1** wherein said movable member and said stationary member respectively comprise a cylinder and a piston and wherein said measuring means includes a projecting stem engageable with the cylinder, and

a spring means to engage said stem to retain it in contact with said cylinder.

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