Dec. 16, 1958 W. E. KELLER ET AL 2,864,280

DEVICE FOR INSPECTING THE STRAIGHTNESS OF BORES

Filed April 4, 1956 5 Sheets-Sheet 1

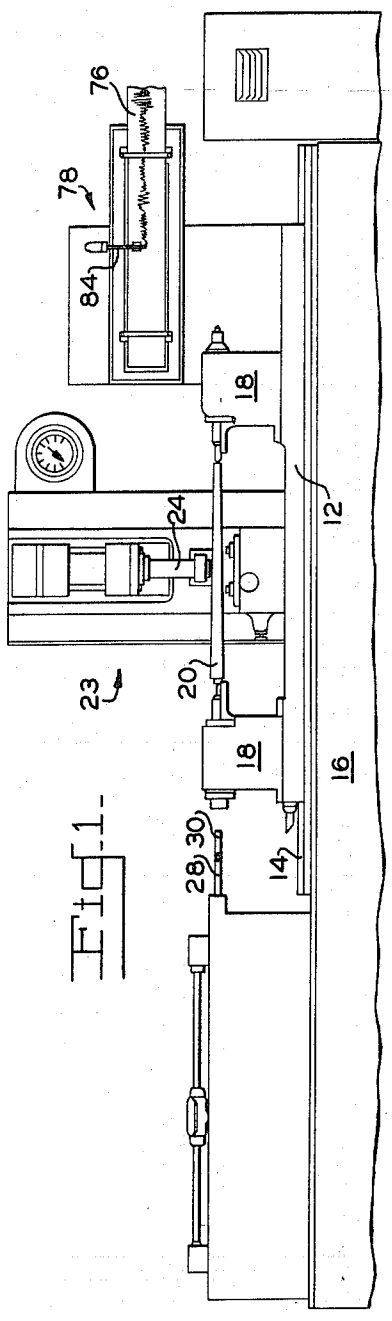


Fig. 1.

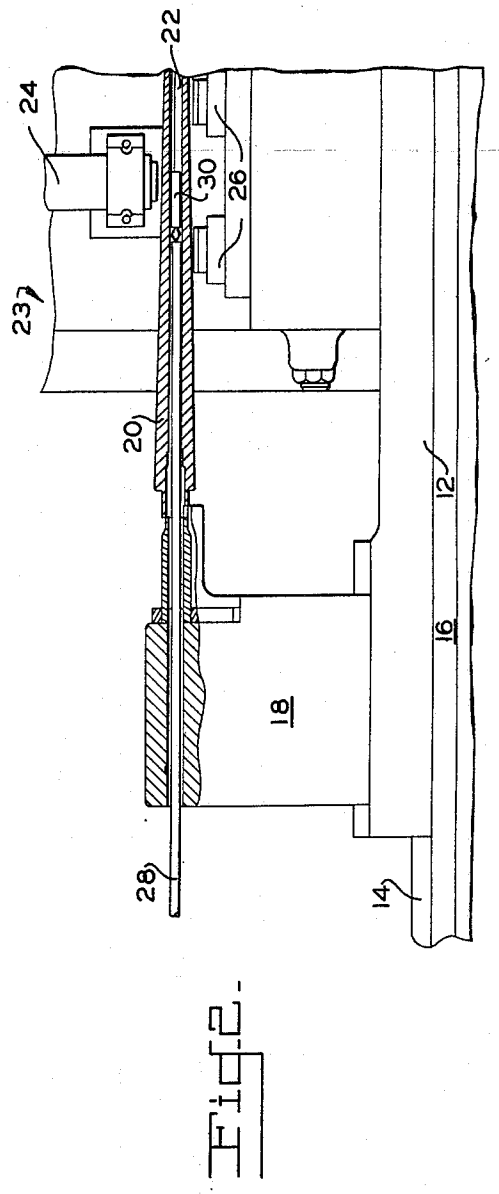


Fig. 2.

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DEVICE FOR INSPECTING THE STRAIGHTNESS OF BORES

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Fig. 3.

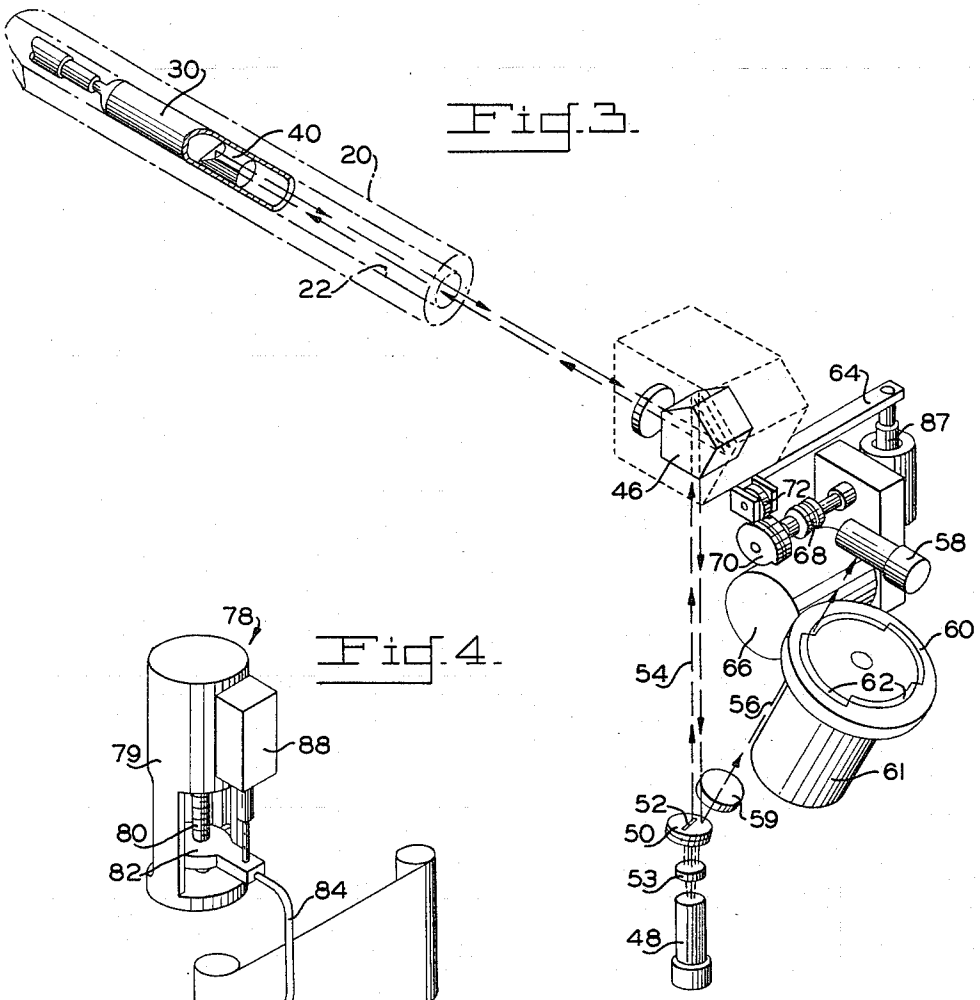


Fig. 4.

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DEVICE FOR INSPECTING THE STRAIGHTNESS OF BORES

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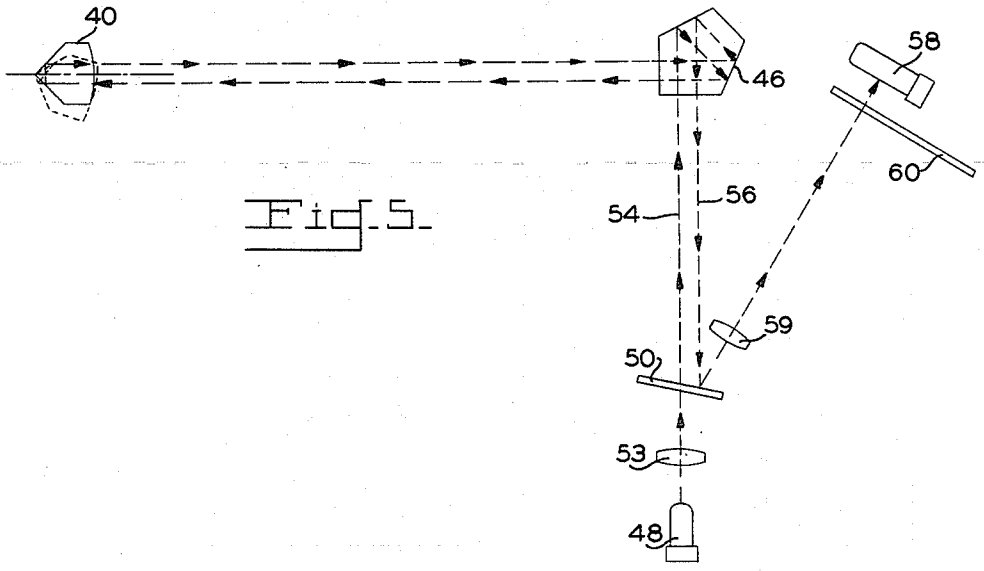


Fig. 5.

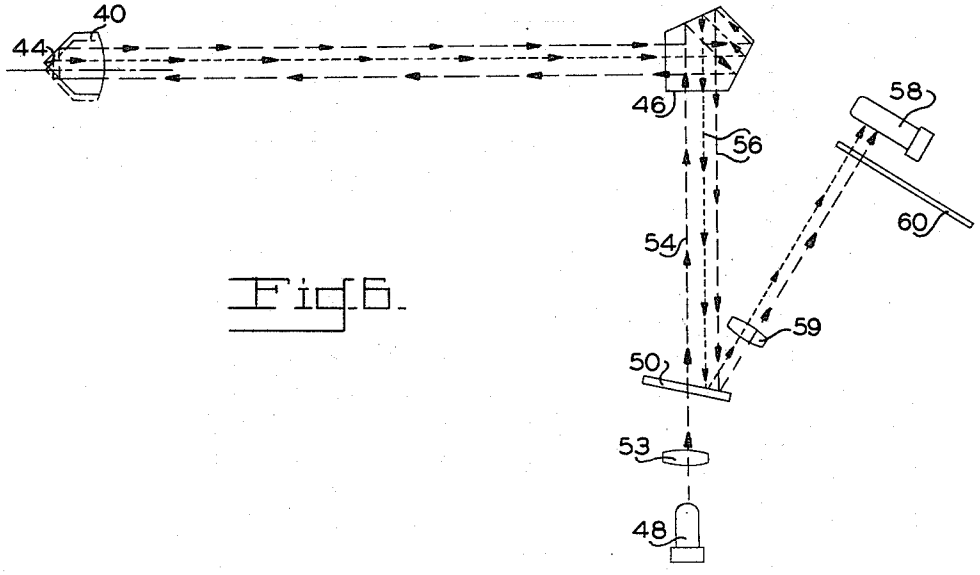


Fig. 6.

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DEVICE FOR INSPECTING THE STRAIGHTNESS OF BORES

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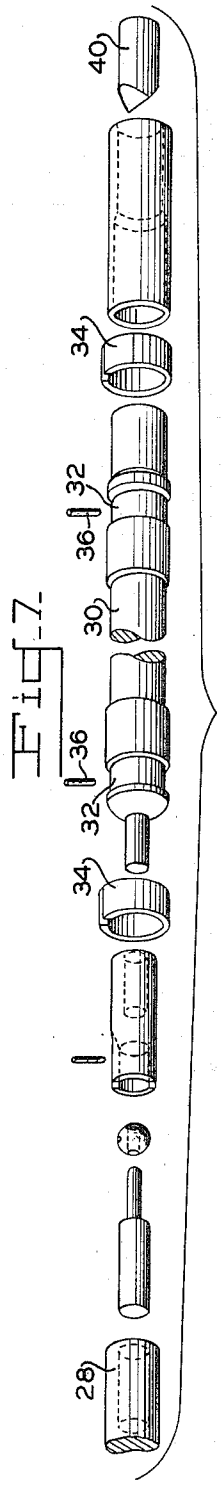


Fig. 7.

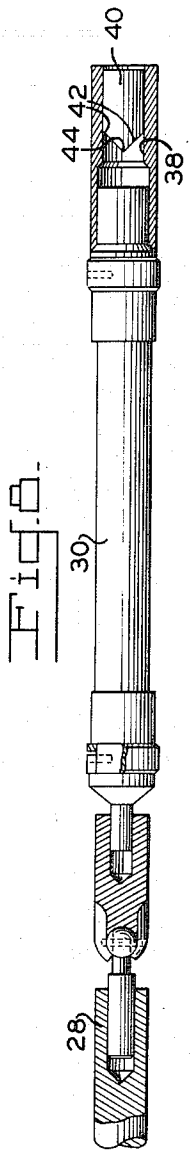


Fig. 8.

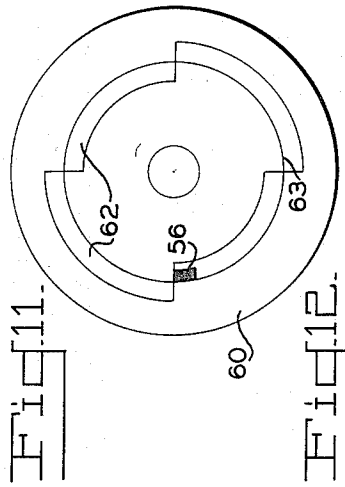


Fig. 11.

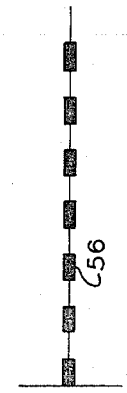


Fig. 12.

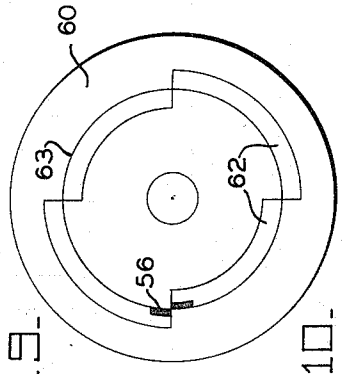


Fig. 9.

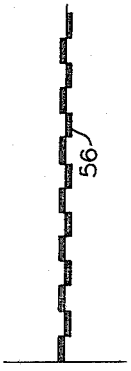


Fig. 10.

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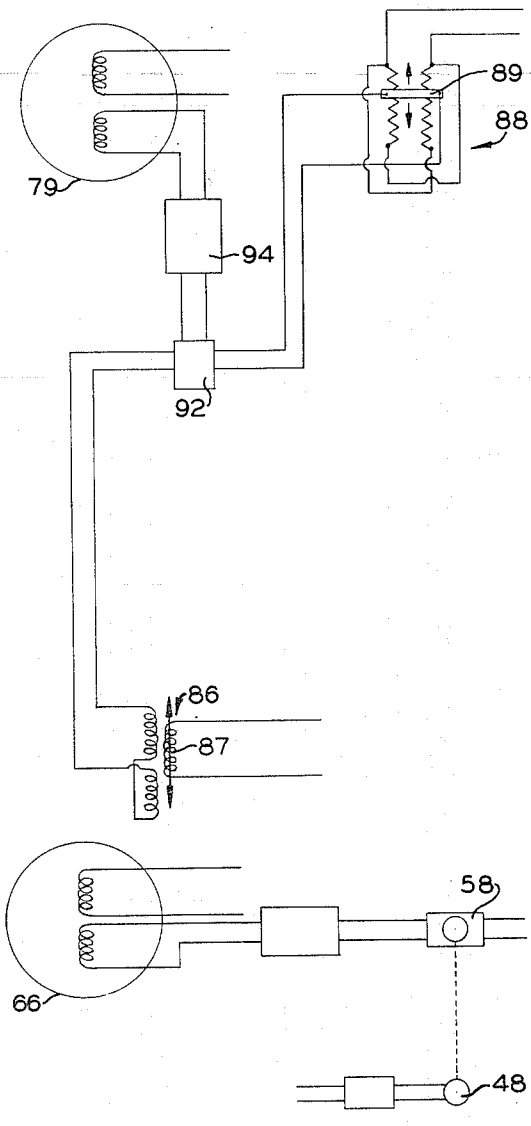
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DEVICE FOR INSPECTING THE STRAIGHTNESS OF BORES

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Fig. 13.



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2,864,280

Patented Dec. 16, 1958

2,864,280

DEVICE FOR INSPECTING THE STRAIGHTNESS OF BORES

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Application April 4, 1956, Serial No. 576,224

4 Claims. (Cl. 88—14)

This invention relates to means for checking the straightness of bores and pertains more particularly to a device which checks, measures and records the longitudinal contours of the bore of a firearm barrel and which may be used in direct conjunction with a barrel straightening machine.

Various means have been devised for checking and measuring the straightness of gun barrels. One commonly used in the production lines of barrel manufacturers is referred to as "line straightening." In this method, a straight reference line is reflected along the longitudinal surface of the bore. If the bore is not straight, the image of the line will be wavy. Through experience an operator can approximate by the amount and position of waviness where and how much to straighten the barrel. This method obviously requires considerable experience on the part of the operator and the results are only qualitative as the amount of bend in the barrel is not measurable hereby and only through long experience can the position of the bend be located.

Another method commonly used in production lines utilizes a straight rod of fixed length and diameter which is passed through the bore of the barrel. If the rod passes through the barrel without binding, the barrel is considered to be straight. If the rod binds, the barrel is considered to be bent. The tolerances of the bend are set by fixing the diameter and length of the rod. This method however is not satisfactory as the rod may be bent in handling and, therefore, give erroneous results. The force exerted on the rod in passing it through the barrel may also affect the result as a large enough force will cause the rod to bend inside the barrel bore and assume bore shape. It is also obvious that any burr or roughness in the bore surface would give a faulty indication.

Another method, used to a considerable extent by German ordnance manufacturers, utilizes the measurement of relative bore slope for determining the deviation of a barrel bore from axial alignment. By this method a plug provided with a surface mirror on the front end is inserted into the bore of the barrel and the barrel then drawn over it. An autocollimator projects a cross onto the mirror surface of the plug and is reflected therefrom onto a screen. As the barrel is drawn over the plug, the plug assumes a position in the bore in accordance with the slope of the section of the barrel in which the plug lies. The light beam consequently is reflected onto the screen at an angle which depends upon the slope of the barrel section. The slopes of the bore is determined mathematically by the position of the reflected cross relative to a fixed, predetermined reference on the screen, taking into consideration the degree of magnification, or by calibrated divisions on the screen.

In this method however the result gives only an indication of the angle of slope of the bend and does not directly measure the deviation which is greatest at the apex of the bend where the slope is 0.

It is an object of this invention to provide a device which measures directly the deviation of a bend in the bore of a barrel and which may be used in direct conjunction with a bore straightening machine.

It is another object of this invention to provide a device which checks deviations in a barrel bore by optical means and which measures and graphically records the deviations by electrical means.

It is still another object of this invention to provide optical means which indicates any radial deviations of a bore from axial alignment and is unresponsive to longitudinal slope in the bore alone.

It is a further object of this invention to provide a device for measuring deviation of a barrel bore from axial alignment at the operating center of a barrel straightening machine.

The specific nature of the invention as well as other objects and advantages thereof will clearly appear from a description of a preferred embodiment as shown in the accompanying drawings in which:

Fig. 1 is a side view showing the bore checking device of this invention mounted to a bore straightening machine;

Fig. 2 is an enlarged partially cross-sectioned side view showing the rod and prism plug in position within the bore of the barrel;

Fig. 3 is a schematic view of the optical system of the device;

Fig. 4 is an enlarged perspective view of the recording portion of the device;

Fig. 5 is a schematic view of the optical system showing how angular displacement of the prism, without vertical displacement of the apex, does not affect the path of the reflected beam;

Fig. 6 is a view similar to Fig. 5 but showing how the path of the reflected beam is affected by vertical displacement of the prism apex;

Fig. 7 is an enlarged, exploded view of the rod and plug assembly;

Fig. 8 is an enlarged partially cross-sectioned view of the rod and plug assembly;

Fig. 9 is an enlarged end view of the beam splitting disc showing the reflected beam centered with the transparencies;

Fig. 10 is a schematic view showing the continuous passage of light through the transparencies of the beam splitting disc when the reflected ray is centered with the transparencies;

Fig. 11 is similar to Fig. 9 but showing the reflected beam away from the center of the transparencies;

Fig. 12 is similar to Fig. 10 but showing the interrupted passage of the reflected beam through one pair of the transparencies in the beam splitting disc when the reflected beam is off center; and

Fig. 13 is a schematic view of the electrical system of the device.

Shown in the figures is a bore straightening machine comprised of a carriage **12** which is movable along longitudinal ways **14** on a base **16**. Carriage **12** is provided with a pair of spaced hollow centers **18** arranged to support a barrel **20** therebetween and permit axial access to bore **22** of such barrel from either end thereof.

Mounted to base **16** is a hydraulic press **23** having a ram **24** which is movable downwardly against barrel **20** when mounted between centers **18**. Projecting upwardly from base **16** so that barrel **20** will pass thereover in close relationship during movement of carriage **12** is a pair of anvils **26** which are spaced equidistantly on each side of ram **24**. Whereby, operation of press **23** moves ram **24** against barrel **20** between anvils **26** to bend the barrel at such section.

Mounted to base **16** so as to be movable as by hydraulic means into one end of bore **22** is a rod **28** which is

secured against rotation. A cylindrical plug **30** is joined to the end of rod **28** which is insertable into bore **22** by a hinged connection which permits vertical displacement of such plug from a predetermined reference position by any vertical deviation in bore **22**. Provided adjacent the ends of plug **30** are annular rectangular grooves **32** in each of which there is received a compressible split ring **34**. Rings **34** are secured to the plug by pins **36** and thereby maintain plug **30** in resilient contact with the surface of bore **22** during passage therethrough to transfer to such plug any vertical angularity present in the bore.

Extending axially into plug **30** from the free end thereof is a well **38** in which there is securely mounted as by wax means a prism **40**. Prism **40** is of roof type and is provided at the inner end with a pair of plane reflecting surfaces **42** which are disposed at right angles to each other and meet to form an apex **44**. Prism **40** is mounted in plug **30** so that apex **44** is disposed transversely of the vertical plane of the bore straightening machine. By surfaces **42** being disposed at 90° to each other a beam of light projected along bore **22** and against one of the surfaces is reflected to the opposite one thereof and returned from such opposite surface along the bore parallel with the incident beam and spaced vertically therefrom according to the position, relative to apex **44**, at which the incident beam is intercepted by such surfaces.

Provided adjacent the end of barrel **20**, opposite that in which rod **28** is inserted, is a pentaprism **46**, which is mounted as hereinafter described in line with the axis of bore **22**, and a light source **48**. Source **48** provides a light which is constant and without ripple and is disposed with pentaprism **46** in a plane which is right angular to the axis of bore **22**. The faces of pentaprism **46** are arranged, as best noted in Fig. 3, so that rays from light source **48** are reflected therefrom along bore **22** to prism **40**. Located between light source **48** and pentaprism **46** is a condenser lens **53** and a glass metal-backed mirror **50** having a rectangular reticle **52** formed by the removal of a section of the metallic backing. As best shown in Fig. 3, reticle **52** passes a rectangular beam of light, noted at **54**, from light source **48** to pentaprism **46** after the rays are straightened out by condenser lens **53**. Beam **54** is reflected from prism **40**, as a reflected beam **56**, to pentaprism **46** and therefrom to mirror **50**. As reflected beam **56** is parallelly spaced, as hereinbefore noted, from incident beam **54**, such reflected beam is intercepted by the reflecting portion of mirror **50** away from reticle **52**. Mirror **50** is tilted so that such reflected beam is reflected therefrom to a photomultiplier tube **58**.

Disposed between mirror **50** and photomultiplier tube **58** is a projection lens **59** which enlarges the image of reticle **52** and consequently any deflection of such image, and projects it onto a beam splitting disc **60** which is rotated by a synchronous electric motor **61** at a constant 1800 R. P. M. Disc **60** is encircled by four quarterly segmental transparencies **62** which are, as best shown by Figs. 9 and 11, concentric with the axis of the disc and are alternately disposed on opposite sides of a reference line **63**. The ends of the inner and outer transparencies **62** are radially aligned and reference line **63**, which is coincident with the inner walls of the outer transparencies and the outer walls of the inner transparencies, is arranged to bisect reflected beam **56** when coincident with a predetermined reference path. Thus, when reflected beam **56** is coincident with the reference path, a portion of reflected beam **56** is passed by the transparencies **62** on both sides of reference line **63** and so photomultiplier tube **58** receives a steady light signal as is shown by Figs. 9 and 10. However, when reflected beam **56** moves away from the reference path, reflected beam **56**, as best shown by Figs. 11 and 12, is passed by only one pair of the transparencies **62**, which may be on one side or the other of reference line **63** depending upon which way the reflected beam has moved. Therefore, as beam splitting disc **60** is revolving at 1800 R. P. M., photomultiplier tube **58** receives a 60-cycle signal which converts the direct current supplied thereto to a 60-cycle alternating current having a phase which is determined by which pair of the transparencies **62** provides the signal.

Pentaprism **46** is mounted on a frame **64** which is adapted for slidable movement along the vertical plane of the bore straightening machine. Movement of pentaprism **46** is provided by a phase-sensitive electric motor **66** which is connected by a gear train **68** to a rotary cam **70** which cooperates with a roller **72** on frame **64** for raising and lowering such pentaprism. Current for motor **66** is provided by the amplified alternating current supplied from photomultiplier tube **58** when the light signal is interrupted and the direction of such motor is controlled by the frequency phase of such alternating current. Therefore, upward and downward movements of pentaprism **46** are determined by the phase signal of beam splitting disc **60** as resulting from the position of reflected beam **56** relative to the reference path

A chart **76**, as of paper material, is mountable to carriage **12** so as to advance simultaneously with barrel **20** and a recording device **78** is mounted to base **16** so as to inscribe a line on such chart, as hereinafter described, while being moved by such carriage. Recording device **78** includes a servo, electrically-operated motor **79** and a threaded shaft **80** which is disposed parallel with chart **76** and is rotatable by such motor. Threadably mounted on shaft **80** in a nonrotating traveler **82** from which there extends a stylus **84** arranged to inscribe a line on the face of chart **76** when moved with barrel **20**.

The position of stylus **84** on the face of chart **76** is governed by the raising and lowering of traveler **82** by the reversible rotation of motor **79**. Direction and amount of rotation of motor **79** is determined by the movement of pentaprism **46** through a conventional variable differential transformer **86** having a movable armature coil **87**, which is responsive to movement of such pentaprism, and a linear variable differential potentiometer **88** having a movable contact **89**, which is responsive to movement of traveler **82**. When pentaprism **46** is moved the change in the voltage signal induced in the stationary windings of transformer **86** is directly proportional to movement of coil **87**. The signal is amplified by a conventional amplifier system **94** and used to drive motor **79**. A matching network **92** is provided for combining the signal from transformer **86** with that provided by potentiometer **88** so that the signal from such transformer is canceled when the required travel of stylus **84** has been reached.

Whereby, vertical movement of apex **44**, during travel of plug **30** through bore **22** while barrel **20** is traversed by carriage **12**, is translated by optical and photoelectric means to pentaprism **46** and movement of such pentaprism is magnified and communicated to stylus **84**. Consequently, the relative position of stylus **84** indicates any deviations of bore **22** from the theoretical axis thereof directly under ram **24**.

To facilitate straightening any deviation noted in barrel **20**, there is provided a suitable limiting switch (not shown) which is connected to press **23** for adjustably limiting movement of ram **24**. Whereby, the operator by checking the reading on chart **76** under stylus **84**, which is the record of the deviation directly below ram **24**, may adjust the limiting switch to the recorded deviation and operation of the press will cause ram **24** to deflect barrel **20** the desired amount.

It is to be noted that by the device of this invention measurements are taken of the vertical displacements of apex **44** from a predetermined path, which is the theoretical axis of bore **22**. Any change in angularity of the center line of plug **30** will not affect the path of deflected beam **56**, as best shown in Fig. 5, provided apex **44** is

not deflected vertically. Thus, the measurements recorded on chart 76 are those of the actual vertical displacement in bore 22 and not of the relative slope as produced by prior devices. Further, by apex 44 being positioned directly under ram 24 there is provided ready information for straightening barrel 20 and the barrel need not be repositioned for straightening.

From the foregoing it is clearly apparent that there is herein provided a novel means of checking and measuring radial deviations along the longitudinal contours of a bore which adds considerably to the art.

Although a particular embodiment of the invention has been described in detail herein, it is evident that many variations may be devised within the spirit and scope thereof and the following claims are intended to include such variations.

We claim:

1. A device for checking the straightness of the bore of a tube including a light source, a pentaprism mounted for movement radial of the axis of the bore, a mirror disposed between said light source and said pentaprism, a reticle engraved in said mirror for passing a beam of light from said light source to said pentaprism for reflection therefrom along the bore, a roof prism having an apex and being movable along the bore according to the longitudinal contour thereof for returning said beam of light in a reflected beam to said pentaprism for reflection therefrom to said mirror with said reflected beam being parallel with said beam of light and variably spaced therefrom according to the radial relationship of said apex to the axis of the bore, electrical means responsive to movement of said reflected beam after being reflected from said mirror for moving said pentaprism to maintain said reflected beam along a predetermined path during movement of said roof prism in the bore, and means for recording the movement of said pentaprism.

2. A device for checking the straightness of the bore of a tube including a light source, a pentaprism mounted for movement in the vertical plane of the device and in alignment with the axis of the bore, motor means operable by a phase alternatable electric current for moving said pentaprism in opposite directions, a mirror disposed between said light source and said pentaprism, a reticle engraved in said mirror for passing a beam of light from said light source to said pentaprism for reflection therefrom along the bore, a roof prism having an apex and being movable along the bore according to the longitudinal contour thereof for returning said beam of light in a reflected beam to said pentaprism for reflection therefrom to said mirror parallel with said beam of light and variably spaced therefrom according to the radial relationship of said apex to the axis of the bore, means responsive to the position of the image of said reticle for alternating the phase of the electric current to said motor means for moving said pentaprism to maintain said reflected beam along a predetermined path during movement of said roof prism in the bore, and means for recording movement of said pentaprism.

3. A device for checking the straightness of the bore of a tube including a light source, a pentaprism mounted for movement in the vertical plane of the device adjacent one end of the bore, motor means operable by a phase alternatable electric current for moving said pentaprism in opposite directions, a mirror disposed between said light source and said pentaprism, a reticle engraved in said mirror for passing a beam of light from said light source to said pentaprism for reflection therefrom at 90° along the bore, a roof prism having an apex and being movable along the bore according to the longitudinal contour thereof for returning said beam of light in a reflected beam to said pentaprism for reflection therefrom to said mirror parallel with said beam of light and variably spaced therefrom according to the radial relationship of said apex to the axis of the bore, photoelectric means controlling the current to said motor means, a rotary beam splitting disc disposed in the path of said reflected beam between said mirror and said photoelectric means, staggered equally-spaced transparencies in said disc for controlling passage of said reflected beam to said photoelectric means and giving signals for zero electric current to said motor means when said reflected beam is coincident with a predetermined path and for a current of selected phase to said motor means for moving said pentaprism to return said reflected beam to said predetermined path when said reflected beam moves away therefrom through a deviation in the bore, and a stylus electrically responsive to movement of said pentaprism.

4. For a tube straightening machine having a carriage for traversing a tube under a press having a ram actuatable against the tube, a device for checking the straightness of the bore of the tube while being traversed under the ram including a light source, a pentaprism mounted for movement in the vertical plane of the device adjacent one end of the bore, motor means responsive to changes in the phase of a phase alternatable electric current for moving said pentaprism in opposite directions, a mirror disposed between said light source and said pentaprism, a reticle engraved in said mirror for passing a beam of light from said light source to said pentaprism for reflection therefrom along the bore, a roof prism having an apex and being movable along the bore according to the longitudinal contour thereof for returning said beam of light in a reflected beam to said pentaprism for reflection therefrom to said mirror parallel with said beam of light and variably spaced therefrom along said vertical plane according to the radial relationship of said apex to the axis of the bore, photoelectric means controlling the electric current to said motor means, a rotary beam splitting disc disposed in the path of said reflected beam between said mirror and said photoelectric means, staggered equally-spaced transparencies in said disc for controlling passage of said reflected beam to said photoelectric means to give a signal thereto for a zero electric current to said motor means when said reflected beam is coincident with a predetermined path and a current of selected phase to said motor means for returning said reflected beam to said predetermined path when said reflected beam moves away therefrom, linkage means for flexibly holding said prism with said apex centered under the ram while the tube is transversed thereunder by the carriage, a chart movable with the carriage, and stylus means electrically responsive to movement of said pentaprism for recording on said chart any deviation in the bore along the vertical plane.

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