

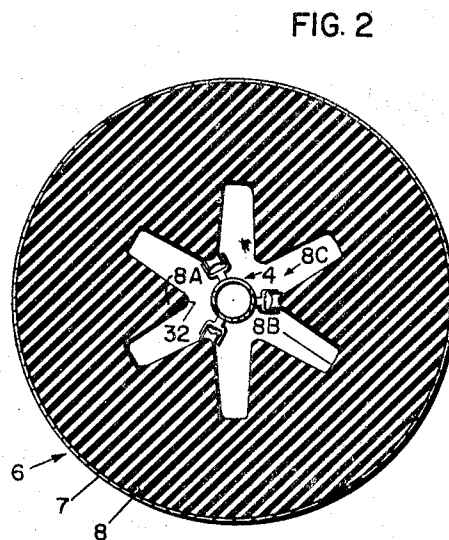
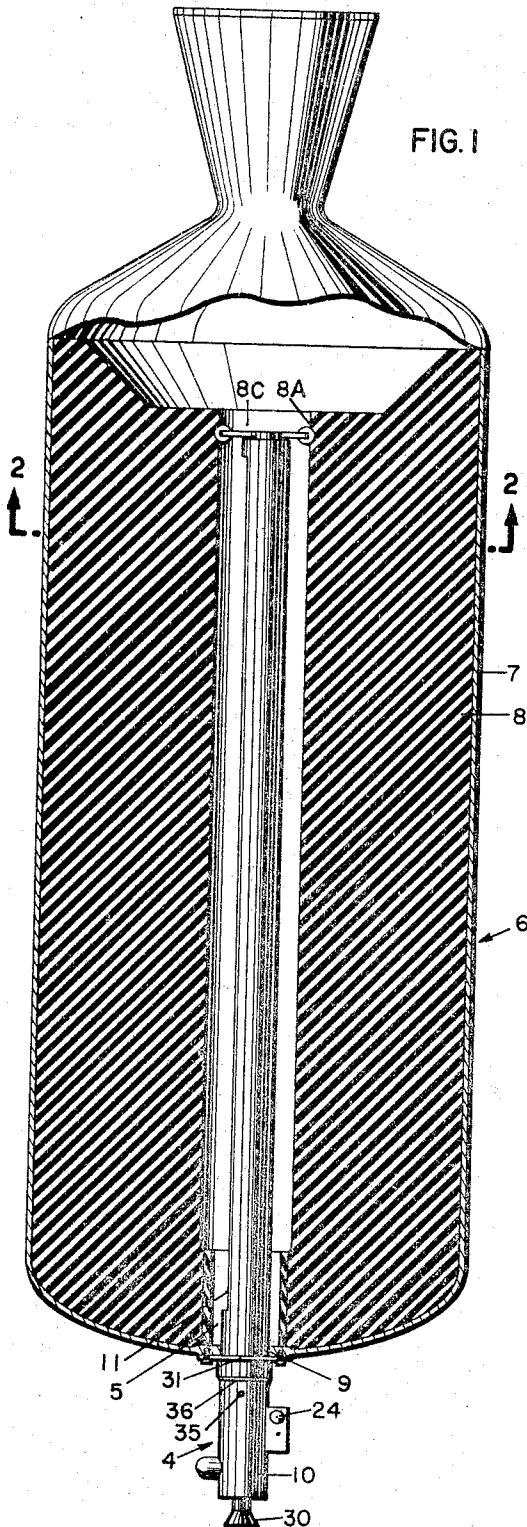
July 4, 1967

J. McCORMAC
BORE INSPECTING DEVICE

3,329,059

Filed Feb. 7, 1962

5 Sheets-Sheet 1



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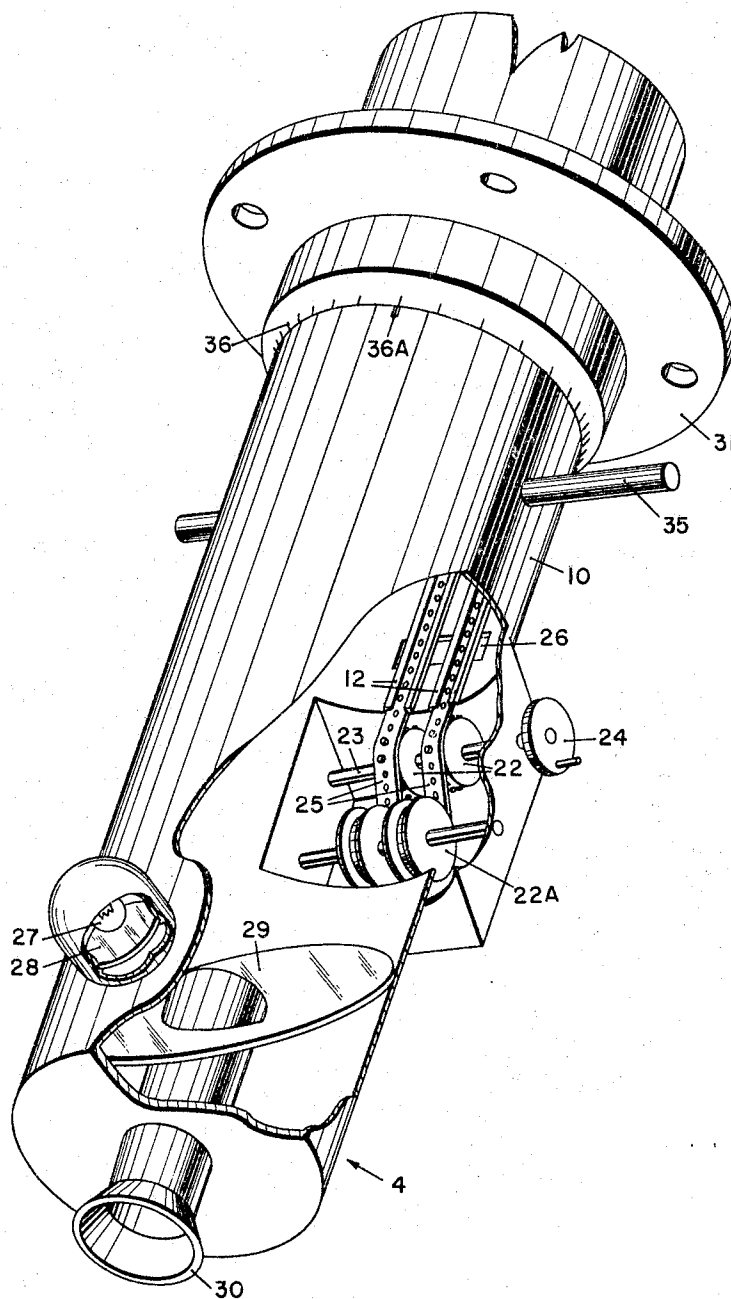
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FIG. 3a



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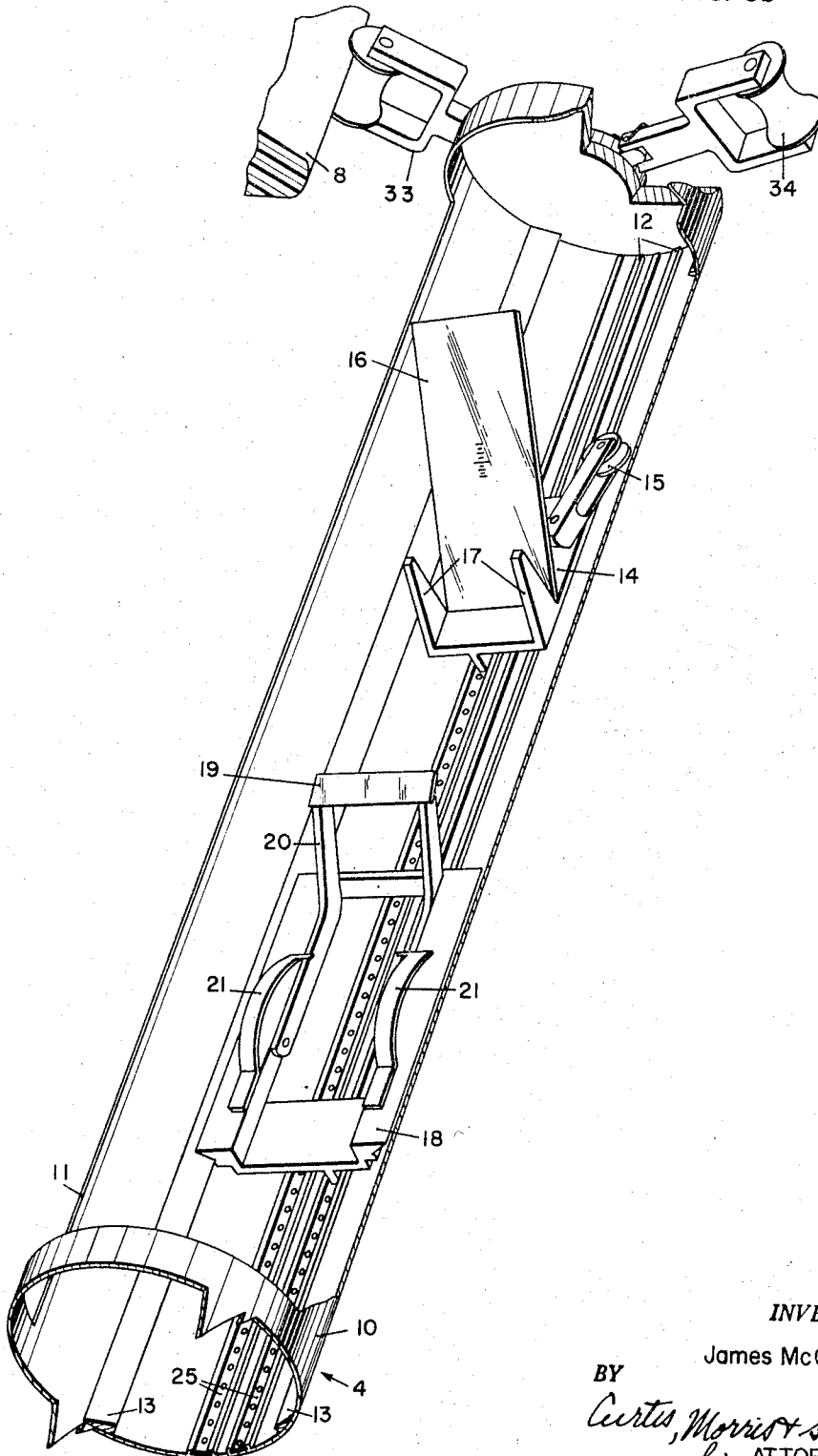
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FIG. 3b



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FIG. 4

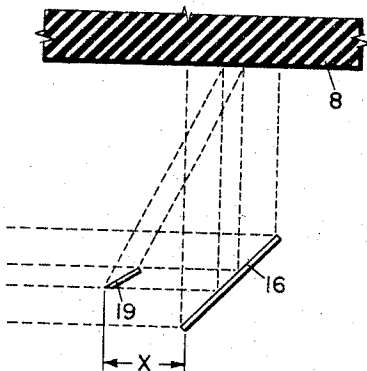


FIG. 5

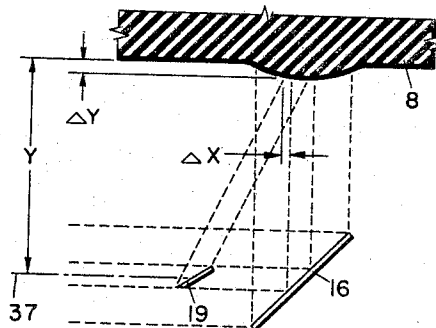


FIG. 6

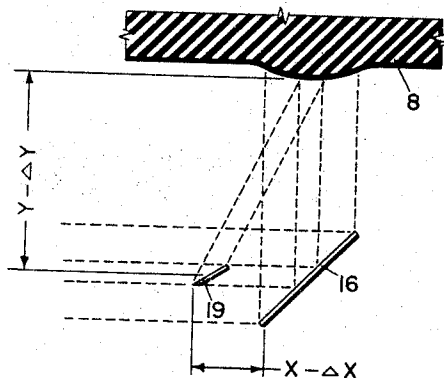


FIG. 7

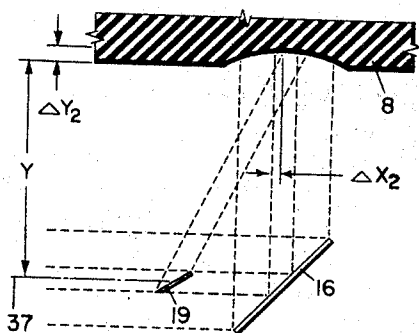
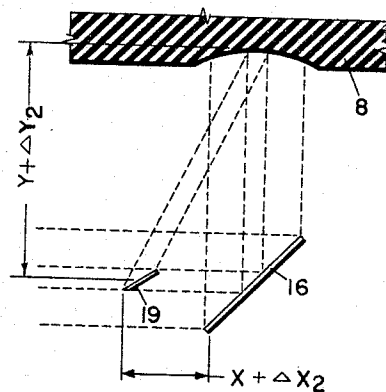


FIG. 8



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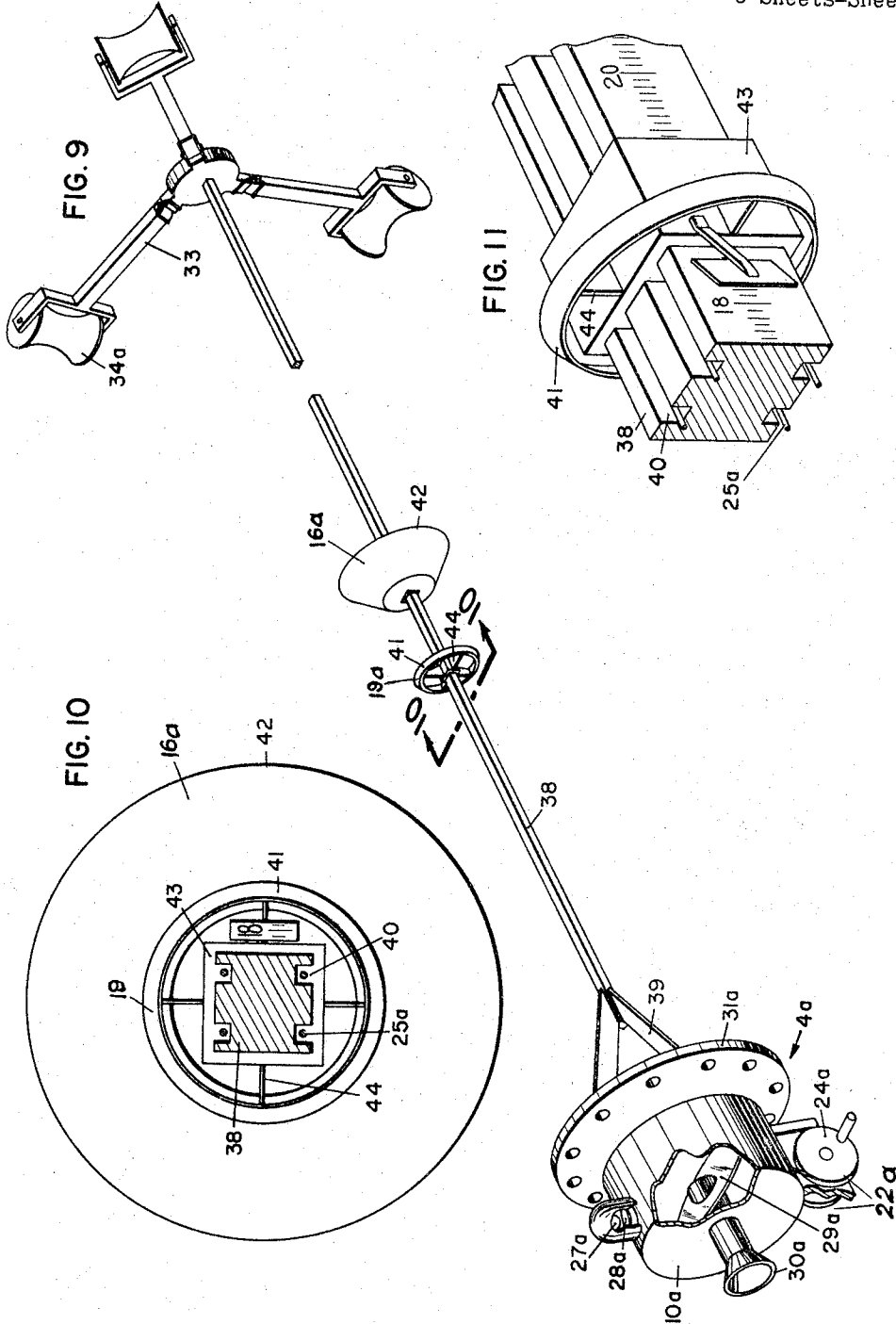
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5 Sheets-Sheet 5



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3,329,059

BORE INSPECTING DEVICE

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8 Claims. (Cl. 88—14)

The present invention relates to inspecting devices and more particularly to devices for inspecting the bore of hollow articles.

Heretofore, there has been a need for a bore inspecting device which is both accurate and adaptable for rugged use. Also, it is desirable to have a bore inspecting device which is adjustable externally of the bore for all variable factors.

With the advent of the space age, it is particularly important to have a device to inspect the bores of solid propellant rocket motors, for if the propellant develops cracks in its surface, or if the propellant breaks away from the casing, the burning area may be increased so that the motor becomes a potential bomb.

It is, therefore, an object of the invention to provide a device for easily and quickly inspecting the bore of a hollow object from outside of the object.

Another object of the invention is to provide a bore inspecting device which may be adjusted and operated by remote control.

Another object of the invention is to provide a device by which cracks and the condition of the surface of the bore may be visually observed.

Another object of the invention is to provide a device for inspecting the bore of a solid propellant rocket engine which is so accurate that a failure of the bond between the propellant and casing may be detected.

Another object of the invention is to provide a bore inspecting device adaptable to be inserted into the igniter hole of a solid propellant rocket engine.

Another object of the invention is to provide a device which can be used to inspect the entire surface of a bore.

Another object of the invention is to provide a device for optically measuring the distance from the centerline of a bore to the surface of a bore without contact with the point being measured.

Another object is to provide a device which may readily distinguish a protrusion from a declivity in the surface of a bore.

A still further object of the invention is to provide an inspecting device of the type indicated which is of a relatively simple, compact and rugged construction, economical to manufacture, non-hazardous to use and reliable in operation.

Other objects and a fuller understanding of the invention may be had by referring to the following description and claims, taken in conjunction with the accompanying drawings.

In the drawings:

FIGURE 1 is a sectional view of a solid propellant rocket engine in side elevation to show a bore inspecting device embodying the invention mounted therein;

FIGURE 2 is a transverse sectional view taken on line 2—2 of FIGURE 1 to show the surface of the propellant to be inspected and the manner of mounting the inspecting device;

FIGURES 3a and 3b are part sectional perspective views of the inspecting device and showing its construction to observe the surface of the propellant visually;

FIGURE 4 is a detail schematic view in side elevation of the two reflectors of the inspecting device properly adjusted so that the two separate beams of light will produce a uniform, composite pattern without overlap on the

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propellant surface within the bore of a solid propellant rocket engine;

FIGURE 5 is a view similar to FIGURE 4 and shown trained upon a bulge in the solid propellant with the distance between reflectors unchanged from that of FIGURE 4;

FIGURE 6 is a view similar to FIGURE 5 with the reflectors readjusted to cause the projected beams to produce a uniform, composite pattern without overlap on the propellant surface;

FIGURE 7 is a detail schematic view similar to FIGURE 4, but trained upon a depression in the solid propellant with the distance between reflectors unchanged from that of FIGURE 4;

FIGURE 8 is a view similar to FIGURE 7, readjusted to cause the projected beams to produce a uniform, composite pattern without overlap on the propellant surface;

FIGURE 9 illustrates an alternate embodiment of the invention in a perspective view;

FIGURE 10 is an enlarged sectional view taken on line 10—10 of FIGURE 9; and

FIGURE 11 is an enlarged perspective view of a portion of FIGURE 9.

With reference to the drawings, a bore inspecting device 4 incorporating the present invention is shown mounted in the axial bore 5 of a rocket engine 6, as shown in FIGURES 1 and 2. The engine 6 comprises a casing 7 having a propellant 8 bonded to the casing and fluted to form alternate lands 8a and grooves 8b and a hollow bore 8c at its axis. Bore inspecting device 4 is inserted through an opening 9 in the casing 7 and propellant 8 at one end of the engine. Opening 9 also is used to mount an ignition device when the rocket engine 6 is prepared for operation. The central axis of device 4 is arranged to coincide with the axis of the rocket engine being inspected.

The inspecting device 4 is illustrated in FIGURES 3a and 3b as comprising a tubular housing 10 having a longitudinal aperture 11, or slot, extending along its side. The housing 10 is a long, thin walled cylinder which may extend the length of the propellant body 8 as illustrated in FIGURE 1.

Returning to FIGURES 3a and 3b, the wall of tubular housing 10 contains along its inner surface two juxtaposed tracks 12 and, angularly displaced therefrom in symmetry, two rails 13 essentially V-shaped in cross-section. Tracks 12 and rails 13 extend throughout the length of housing 10. A movable carriage 14 is arranged so that it can be moved longitudinally along housing 10 and the carriage has a plurality of sheaves 15 which engage and are adapted to roll along rails 13. The carriage 14 has a fixed reflector 16 mounted thereon and extending at an acute angle to the axis of the device 4, preferably at an angle of 45° therewith. The fixed reflector 16 is oriented to reflect light through slot 11 in the housing. As used herein, the word "reflector" will mean any surface capable of reflecting sharp images, such as a mirror or side of a reflecting prism. In the illustrated embodiment, the reflector 16 is a first-surface mirror, the face of which contains an etched, graduated scale. Also mounted on carriage 14 toward the observer and at the sides of reflector 16 are two upright columns 17 which are vertical in front elevation and slightly inclined from the vertical toward reflector 16 in side elevation.

A second movable carriage 18 is located toward the observer relative to carriage 14 within housing 10 and arranged so that it can be moved longitudinally along rails 13. A reflector 19, narrow and rectangular in shape, is mounted on a U-shaped frame 20, the arms of which are pivotally attached to the frame of carriage 18. Flat springs 21, attached to carriage 18 and bearing against the arms of U-frame 20, maintain the frame in a flat

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position against carriage 18 and thus maintain the reflector 19 at an angle relative to the axis of the device 4. This angle is known and must be such that light proceeding along the axis of the device 4 may produce a continuous, composite pattern on the surface of the bore, as reflected thereupon by reflectors 19 and 16. Reflector 19 is oriented to reflect light through slot 11 in housing 10. Either reflector 16 or 19 can be adjustable relative to the other along the axis so that the light patterns reflected from both against a surface may be superimposed thereon.

Either carriage 14 or 18 may be moved back and forth along the rails 13 by separate remote control means which are identical. Each remote control means comprises a toothed sprocket 22 mounted on a shaft 23, one end of which projects through the wall of housing 10 and terminates in a handwheel 24. The teeth of each sprocket 22 engage a series of perforations in a flat metal tape 25 which slides in one of the tracks 12. The exposed end of tape 25 is attached to a projection on the underside of carriage 14 or 18. The other end of tape 25 is wound on a spool (not shown) contained within housing 10. The inwardly projecting lips of track 12 prevent tape 25 from buckling and ensure positive straight line motion of tape 25 as sprocket 22 is rotated. Shafts 23 are mounted on a common axis and are joined within housing 10 by a clutch arrangement (not shown) such that rotation of the handwheel 24 for carriage 14 will move both carriage 14 and carriage 18 in unison, but with handwheel 24 for carriage 14 restricted from rotation, handwheel 24 for carriage 18 can be rotated independently, thus adjusting the relative positions of reflectors 19 and 16.

The undersides of tapes 25 are graduated in inches and fractions thereof and the underside of housing 10 contains a window 26 for external observation of the scale readings relative to an index mark (not shown) and to each other at window 26. Mirrors or prisms may be attached to the window 26 for convenience of the operator in reading the scales.

Referring to FIGURE 3a, a light projecting and a viewing means are illustrated. The light projecting means comprises a housed light source 27, cooled by means, not shown, a focusing lens 28, and a reflector 29 which is, in the illustrated embodiment, a mirror centrally perforated and inclined at such an angle and so shaped as to cooperate with the focusing lens and produce a beam of light from source 27 that will be projected along the axis of the device and parallel thereto. The viewing means comprises a telescope 30 extending through the end of housing 10 and through the perforation of reflector 29.

An adapter 31 is provided near the observation end of the housing 10 for mounting and securing the inspection device 4 to the rocket engine casing 7 around the opening for the igniter as seen in FIGURE 1. FIGURE 2 shows the other end of the housing mounted upon three star points 32 of lands 8a of the solid propellant 8. The housing 10 is supported from the star points 32 by spring-loaded, pivotable arms 33, the extremity of each of which contains a roller 34, shaped to conform to the contour of the star point. Housing 10 is rotatable relative to arms 33 by means of a bearing mounting, not shown. The number of support arms 33 can be varied according to the number of star points 32 of the propellant design.

Rotation is accomplished by means of handles 35 attached to the exterior wall of housing 10 at the observation end of the device. Housing 10 is arranged to rotate within adapter 31. The angular displacement of housing 10 can be measured by the position of an index mark 36A on housing 10 relative to a dial 36, which is calibrated through 360° and mounted on adapter 31.

In operation, the device is inserted into the rocket engine 6 through the hole 9 for the igniter. At the time of insertion, arms 33 are pivoted so that they lie parallel to the central axis of the device. Upon insertion into the main hollow bore 8c of the rocket engine, arms 33 pivot

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by spring action to radial position to contact rollers 34 with star points 8a, thus aligning the device with the central axis of rocket engine 6. The device is secured to casing 7 by adapter 31, as shown in FIGURE 1.

The operator may inspect the interior of the bore of engine 6 through the telescope 30. Light from light source 27 is reflected along the axis of the device 4 and rocket engine 6 by reflector 29. The light beam incident upon reflectors 19 and 16 is reflected through slot 11 in housing 10 onto the surface of the bore, producing light patterns thereon which are visible to the observer. When the reflectors 16 and 19 are not adjusted to produce a continuous, composite pattern of light on the bore surface, the shadow cast upon reflector 16 by reflector 19 creates a shadow or dark area in the pattern produced on the surface of the bore by reflector 16. When properly adjusted the rectangle of light projected to the bore surface by reflector 19 is superimposed upon the dark rectangle produced by its shadow in the light pattern projected thereon by reflector 16. Since this rectangle of light is exactly equal in area to that of the shadow of reflector 19, a continuous, composite pattern of light is produced on the bore surface by light from the two reflectors. The position of reflector 19 relative to reflector 16 along the axis of device 4 is adjusted by rotation of handwheel 24 for carriage 18 while handwheel 24 for carriage 14 is restricted from rotation. Adjustment is made so that the light reflected by reflector 19 is exactly superimposed upon the observed dark area in the pattern produced on the surface of the bore by reflector 16. Thus, a standard distance X between reflectors is established as illustrated in FIGURE 4. The distance X between reflectors 16 and 19, as measured by the differential of the readings of tapes 25 through window 26, has a known relationship to the distance Y between the axis of the device 4 and the surface of the bore, since the angles of inclination of reflectors 19 and 16 are known. Tape 25 can be calibrated to provide direct reading of Y values for any deviation ΔX of distance X from its standard value.

After adjusting the reflectors, carriages 14 and 18 can be moved in unison along rails 13 by turning handwheels 24 for the carriages. In this manner, the surface of the bore can be visually observed for cracks or irregularities. If a protrusion is encountered, as illustrated in FIGURE 5, a dark area appears in the portion of the light pattern on the bore surface which lies away from the observer. Adjustment of reflector 19 is then made as illustrated in FIGURE 6 until the area under observation is again illuminated completely. The distance ΔX along the axis, through which reflector 19 is moved relative to reflector 16 to effect this adjustment, indicates the extent of deviation Δy from the standard distance Y between axis 37 and the bore surface.

If an indentation is encountered as illustrated in FIGURE 7, a dark area appears in the portion of the light pattern which lies toward the observer. Adjustment is made to eliminate the dark area and, as illustrated in FIGURE 8, new values, Y_{x_2} and Δy_2 are obtained.

If it is desired merely to inspect the bore visually, carriage 18 is moved toward carriage 14 such that U-frame 20 bears upon the inclined faces of upright columns 17. Continued movement of carriage 18 causes U-frame 20 to pivot upwardly, thus removing reflector 19 from the observer's field of vision and permitting unobstructed observation of the surface of the bore. Carriages 14 and 18 can be moved in unison while in this position.

After observing one longitudinal section of the bore the inspecting device can be rotated so that another longitudinal area may be inspected. It is, of course, within the spirit and scope of the invention to have either reflector movable with respect to the other or to have both reflectors movable.

With the present device, values of Δy as small as .020" may be detected. If the propellant has broken away from the casing, creating a dangerous increase in burning area,

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a .020" protrusion or more will occur. With reference to measurement, a permanent record of inspection and measurement can be made using photographic equipment or photo cells and recording equipment. Thus, the invention provides an accurate and sensitive means to detect phenomena which has heretofore been very difficult to detect.

FIGURE 9 illustrates a modified construction which is somewhat simplified over that described above. In this embodiment, the housing is greatly reduced in size, the necessity of rotating the instrument is eliminated, and the angles of the mirrors are not adjustable relative to the axis of the inspecting device. As shown, a long frame 38 is centered on the central axis of the rocket-engine cavity in a manner similar to that described above. At one end portion, frame 38 supports the following elements which may have the same form and function or may be identical to those in the first described embodiment of the invention: an adapter 31a and a short housing 10a projecting outwardly therefrom, a source of light 27a, focusing lens 28a, a light-projecting reflector 29a, telescope 30a, pulleys 22a for continuous cables 25a, handwheels 24a for operating the pulleys 22a, and mirrors 19a and 16a on each reflector 41 and 42 for reading the calibrations on frame 38.

Frame 38 is permanently fixed to the adapter 31a by a plurality of thin brackets 39 radially disposed relative to axis; one end portion of frame 38 being fixed by said brackets at a distance from telescope 30a so that frame 38 will not significantly obscure the view through the telescope 30a of the reflectors 16a and 19a, which are yet to be described in detail.

As shown in FIGURE 10, the frame 38 is substantially rectangular in cross-section and is equipped with grooves 40, analogous to the previously described tracks 12. Also, in the present embodiment, the perforated, calibrated metal tapes 25 are replaced by two continuous cables 25a which ride in grooves 40 and serve to adjust the distance between the reflectors 41 and 42 and relative to the observer and to each other. The reflectors 41 and 42 are first-surface conical mirrors on surfaces of truncated cones, the surface of reflector 42 being inclined at an angle to axis of the device 4a so that light from the source 27a may be reflected to the surface of the rocket engine cavity substantially perpendicularly to the axis, and the surface of reflector 41 being inclined at an angle which will permit the light incident thereon to be reflected upon the surface of the bore to form a continuous, composite pattern of light with that reflected thereon by reflector 42. The reflectors 41 and 42 are adapted for sliding movement relative to each other and to the observer upon frame 38 by sleeves 43, each of which is attached to one of the continuous cables 25a.

The end portion of frame 38 which is opposite that which is fixed to adapter 31a is equipped with spring-loaded arms 33a and rollers 34a, similar to those previously described, for support thereof relative to the surface of the rocket-engine cavity.

As seen through the telescope 30a, the reflector 41 is a thin annulus which obscures a very small portion of the inner-edge area of the much-thicker annulus presented by reflector 42; reflector 41 being spaced from its bushing 43 by thin brackets 44 so that the inner edge of reflector 42 may be visible to the observer. When the reflectors 41 and 42 are in proper adjustment relative to one another, the light reflected upon the bore surface by reflector 41 will exactly coincide with the dark, annular pattern otherwise produced by its shadow upon reflector 42. Protrusions or declivities in the surface of the bore may be recognized by the appearance of this shadow in the illuminated pattern thereon in much the same manner as described in the previous embodiment of the invention, and the deviation Δy in the distance Y between the bore surface and the axis 37 may be indicated by the amount of adjustment ΔX of one reflector-

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relative to the other which is necessary to produce a continuous, composite pattern of light on the bore surface.

Hence, in this embodiment of the invention, the observer can simultaneously inspect a 360° annular portion of a bore surface for cracks and imperfections, recognize the nature of surface irregularities, and measure the extent of such irregularities. Since the frame 38 is calibrated and these calibrations are made visible to the observer by a small mirror 26a attached to each reflector 41 and 42, the distance of each reflector from the observer is immediately known, and the distance between reflectors 41 and 42 can be readily deduced.

Although the invention has been described in its preferred and alternate forms with a certain degree of particularity, it is understood that the present disclosure of these forms has been made only by way of example and that numerous changes in the details of construction and the combination and arrangement of parts may be resorted to without departing from the spirit or scope of the invention.

I claim:

1. A device for inspecting the central cavity of hollow articles having regular surfaces concentric to an axis comprising,
 - (a) a source of light, means arranged to project light from said source in a beam along the central axis of said cavity from one end thereof,
 - (b) a first reflector extending across said axis at an acute angle to the central axis of said cavity to intercept a portion of said light and reflect it to the surface of said article surrounding said cavity,
 - (c) a second reflector extending across said axis between said source of light and said first reflector and arranged at an acute angle to the central axis of said cavity in a plane normal to said reflectors, said acute angle of said second reflector being different from and less than the acute angle of said first reflector to said axis and said second reflector being of such a size and shape as to extend radially from said axis in said plane to a lesser degree than said first reflector to intercept a portion of the light that would otherwise fall upon said first reflector and reflect it to the surface of said cavity,
 - (d) means for mounting each of said reflectors for movement along said axis, means for relatively moving the reflectors along the central axis of said cavity to produce a continuous, composite pattern of light reflected from said first and second reflectors on the surface of said article surrounding said cavity, and
 - (e) means at one end of said cavity in the hollow article for observing the image of the illuminated portion of said cavity.
2. A bore inspecting device adapted to be bodily inserted into the bore of an object to be inspected comprising,
 - (a) a track,
 - (b) a source of light, means to project light from said source in a beam along said track and parallel thereto,
 - (c) a first reflector mounted on said track and positioned at an acute angle to said track to reflect light from said source to the surface of said object around said bore,
 - (d) a second, smaller reflector mounted on said track between said light-projecting means and said first reflector and arranged at an acute angle to the axis of said bore in a plane normal to said reflectors, said acute angle of said second reflector being different from and less than the acute angle of said first reflector and being so positioned relative to said first reflector as to extend radially from said axis in said plane to a lesser degree than said first reflector to intercept a portion of the light that would

otherwise fall upon said first reflector and reflect it to the surface of said cavity,

- (e) the means for mounting at least one of said reflectors being adjustable to move said one reflector relative to the other along said track to produce a continuous, composite pattern of light reflected by said first and second reflectors onto the surface of said object surrounding said bore, and

- (f) means at one end of the bore inspecting device for observing the illuminated portion of said bore in said reflectors.

3. A bore inspecting device in accordance with claim 2 in which means are provided for measuring the distance between reflectors.

4. A bore inspecting device in accordance with claim 2 in which the track is mounted for rotation bodily to turn the reflectors to any desired radial angle across the projected rays of light parallel to the track to inspect all surfaces of the bore.

5. A bore inspecting device in accordance with claim 2 in which the reflectors are mounted on separate carriages slidable on said track for movement longitudinally of the track, and the carriage for one of said reflectors being mounted for longitudinal adjustment with respect to the other carriage.

6. A bore inspecting device in accordance with claim 5 in which a remote control means is provided for moving one of said carriages relative to said other carriage while simultaneously observing the reflected light pattern on said bore.

7. A detachable bore inspecting device for solid propellant rocket engines having a casing with an igniter hole, said device being bodily inserted through said hole into a bore to be inspected in said rocket engine and comprising, a tubular housing having an aperture in its side, an adapter at one end of said housing for mounting it in said igniter hole, an adjustable support at the other end of said housing adapted to rest on the wall of said solid propellant surrounding said bore, a light source at one end of said housing, a track extending lengthwise within said housing, a movable carriage mounted on said track, a first remote control means for moving said carriage on said track, a reflector mounted on said carriage to reflect light from said light source through the aperture in said housing onto the surface surrounding said bore, a second carriage mounted on said tracks, a smaller fixed reflector mounted on said second carriage between said light source and said movable reflector, said first and second reflectors being positioned at an acute angle to the axis of the bore in a plane normal to said reflectors, and the acute angle of said second re-

flector being different from and less than the acute angle of said first reflector to said axis and said second reflector being of a shape to extend radially from said axis in said plane to a lesser degree than said first reflector, means for observing the illuminated portion of surface surrounding said bore, a second remote control means for moving said second movable carriage relative to said first carriage while simultaneously observing the reflected light from said movable reflector, and means at the exterior of the bore for measuring the distance between the reflectors.

8. A bore inspecting device adapted to be bodily inserted into a bore to be inspected comprising,

- (a) a longitudinally extending frame,
- (b) means at one end thereof for supporting said frame relative to the surface of the bore,
- (c) means at the opposite end thereof to maintain said frame at the axis of the bore,
- (d) a source of light adjacent one end of the frame and means to project the light from said source along said frame and parallel thereto,
- (e) a first frusto-conical reflector mounted to slide along said frame and intercepting light from said source and reflecting it onto the surface surrounding said bore,
- (f) a second, smaller frusto-conical reflector positioned between said source of light and said first reflector and having a slope different from the slope of the first reflector to intercept a portion of the light and reflect it to the surface of said bore, said first and second frusto-conical reflectors having a common axis and the slope of the second reflector relative to said common axis being different from and less than the slope of the first reflector and of a shape to extend radially from said axis in said plane to a lesser degree than said first reflector,
- (g) means for relatively moving said reflectors along said frame to produce a continuous, composite pattern of light thereon from light reflected by the first and second reflectors, and
- (h) means for observing the illuminated portion of said bore.

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