PART 3
BORESCOPES

Fiber Optic Borescopes

The industrial fiber optic borescope is a flexible, layered sheath protecting two fiber optic bundles, each comprising thousands of glass fibers. One bundle serves as the image guide and the other bundle helps illuminate the test object.

Light travels only in straight lines but optical glass fibers bend light by internal reflection and so can carry light around corners (see Fig. 13). Such fibers are 9 to 30 μm (0.4 to 1.2 mil) in diameter or roughly one-tenth the thickness of a human hair.

A single fiber transmits very little light, but thousands of fibers may be bundled for transmission of light and images. To prevent the light from diffusing, each fiber consists of a central core of high quality optical glass coated with a thin layer of another glass with a different refractive index (Fig. 14). This cladding acts as a mirror—all light entering the end of the fiber is reflected internally as it travels (Fig. 13) and cannot escape by passing through the sides to an adjacent fiber in the bundle.

Although the light is effectively trapped within each fiber, not all of it emerges from the opposite end. Some of the light is absorbed by the fiber itself and the amount of absorption depends on the length of the fiber and its optical quality. For example, plastic fiber can transmit light and is less expensive to produce than optical glass but plastic is less efficient in its transmission and unsuitable for use in fiber optic borescopes.

Fiber Image Guides

The fiber bundle used as an image guide (see Fig. 15) carries the image formed by the objective lens at the distal end or tip of the borescope back to the eyepiece. The image guide must be a coherent bundle: the individual fibers must be precisely aligned so that they are in identical relative positions at their terminations.

Image guide fibers range from 9 to 17 μm (0.35 to 0.67 mil) in diameter. Their size is one of the factors affecting resolution, although the preciseness of alignment is far more important.

FIGURE 13. Internal reflection of light in an optic fiber can be used to move the light path in a curve

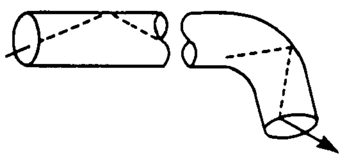

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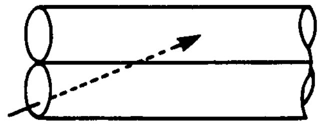
FIGURE 14. Light paths in fiber bundles: (a) uncoated fibers allow light to travel laterally through the bundle and (b) coated fibers restrict the light's path to its original fiber

(a)



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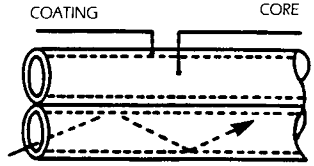

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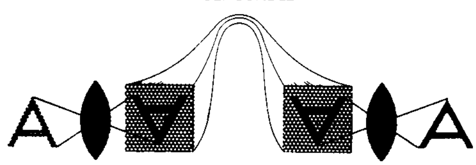
FIGURE 15. Optical fiber bundle used as an image guide



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Note that a real image is formed on both highly polished faces of the image guide. Therefore, to focus a fiber optic borescope for different distances, the objective lens at the tip must be moved in or out, usually by remote control at the eyepiece section. A separate diopter adjustment at the eyepiece is necessary to compensate for differences in eyesight.

Fiber Light Guides

Another fiber bundle carries light from the an external high intensity source to illuminate the test object. This is called the *light guide bundle* and is noncoherent (see Fig. 16). These fibers are about 30 μm (1.2 mil) in diameter and the size of the bundle is determined by the diameter of the scope.

Fiber optic borescopes usually have a controllable bending section near the tip so that the inspector can direct the borescope during testing and can scan an area inside the test object. Fiber optic borescopes are made in a variety of diameters, some as small as 3.7 mm (0.15 in.), in lengths up to 10 m (30 ft), and with a choice of viewing directions at the tip.

Rigid Borescopes

The rigid borescope (see Fig. 17) was invented to inspect the bore of rifles and cannons. It was a thin telescope with a small lamp at the top for illumination. Most rigid borescopes now use a fiber optic light guide system as an illumination source.

The image is brought to the eyepiece by an optical train consisting of an objective lens, sometimes a prism, relay lenses and an eyepiece lens. The image is not a real image but an aerial image: it is formed in the air between the lenses. This means that it is possible to both provide diopter correction for the observer and to control the objective focus with a single adjustment to the focusing ring at the eyepiece.

FIGURE 16. Diagram of a typical fiber optic borescope

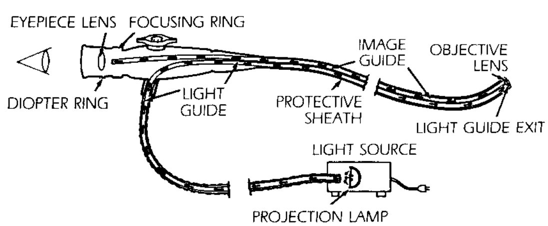

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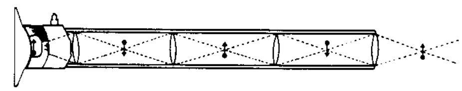
FIGURE 17. Typical lens system in a rigid borescope



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Focusing a Rigid Borescope

The focus control in a rigid borescope greatly expands the depth of field over nonfocusing or fixed focus designs. At the same time, focusing can help compensate for the wide variations in eyesight among inspectors.

Figures 18 and 19 emphasize the importance of focus adjustment for expanding the depth of field. Figure 18 was taken at a variety of distances with fixed focus. Figure 19 was

FIGURE 18. Borescope images for a variety of distances with fixed focus (see Fig. 19): (a) at 75 mm (3 in.), (b) at 200 mm (8 in.) and (c) at 300 mm (12 in.)

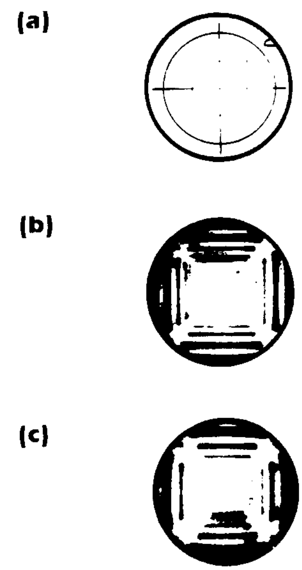

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FIGURE 19. Borescope images with variable focus (see Fig. 18): (a) 75 mm (3 in.), (b) 200 mm (8 in.) and (c) 300 mm (12 in.)

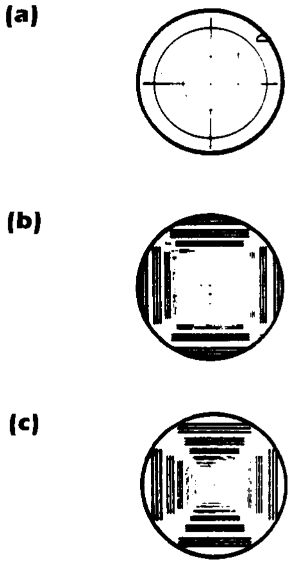

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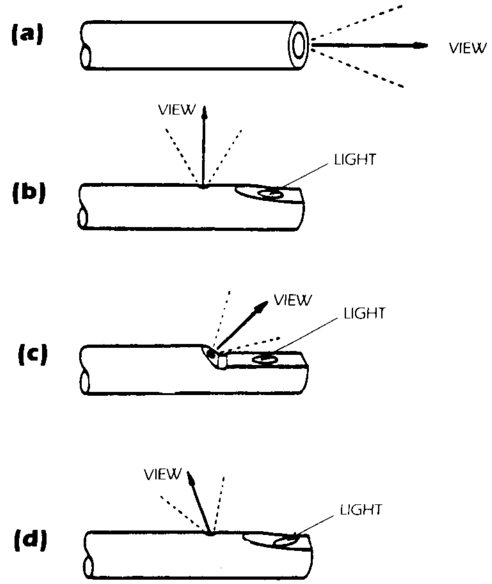
FIGURE 20. Borescope direction of view: (a) direct, (b) side, (c) forward oblique and (d) retrospective



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taken at the same distances as in Fig. 18 but with a variable focus, producing much sharper images.

Need for Specifications

Because rigid borescopes lack flexibility and the ability to scan areas, specifications regarding length, direction of view and field of view become more critical for achieving a valid visual test. For example, the direction of view should always be specified in degrees rather than in letters or words such as *north, up, forward,* or *left.* Tolerances should also be specified.

Some manufacturers consider the eyepiece to be zero degrees and therefore a direct view rigid borescope (Fig. 20a) is 180 degrees. Other manufacturers start with the borescope tip as zero degrees and then count back toward the eyepiece, making a direct-view 0 degrees.

Setup of a Rigid Borescope

To find the direction and field of view during visual testing with a rigid borescope, place a protractor scale on a board or worktable. Position the borescope carefully so it is parallel to the zero line, with the lens directly over the center mark on the protractor. Remember that the optical center of a borescope is usually 25 to 50 mm (1 to 2 in.) behind the lens window.

By sighting through the borescope, stick pins into the board at the edge of the protractor to mark the center and both the left and right edges of the view field. This simple procedure gives both the direction of view and the field of view (see Figs. 21 and 22).

Miniborescope

One variation of the rigid borescope is called the *miniborescope* (see Fig. 23). In this design, the relay lens train is replaced with a single, solid fiber. The fiber diffuses ions in a parabola from the center to the periphery of the housing, giving a graded index of refraction. Light passes through the fiber and at specific intervals an image is formed.

The solid fiber is about 1 mm (0.4 in.) in diameter, making it possible to produce high quality and thin rigid borescopes from 1.7 to 2.7 mm (0.07 to 0.11 in.) in diameter. The lens aperture is so small that the lens has an infinite depth of field (like a pinhole camera) and no focusing mechanism is needed.

FIGURE 21. Field of view for a rigid borescope

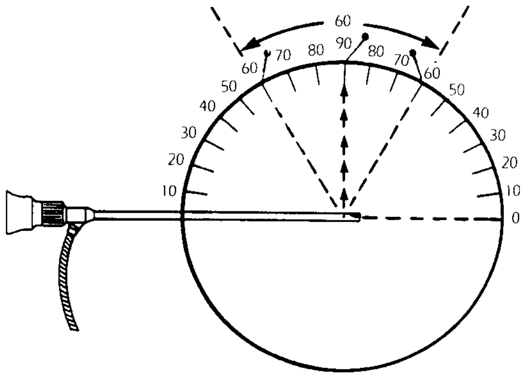

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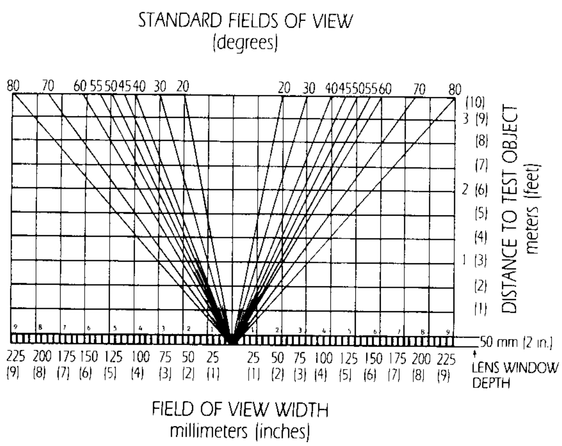
FIGURE 22. Field of view width for varying distances



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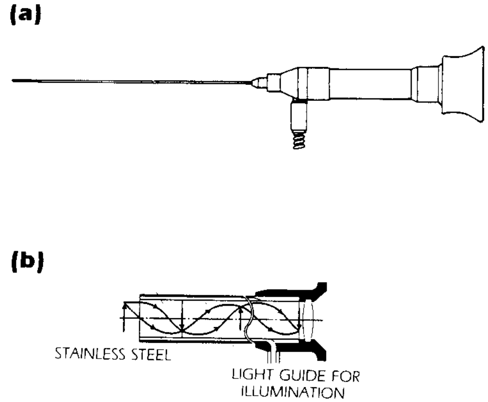
Accessories

Many accessories are available for rigid borescopes. Instant cameras, 35 mm cameras, and video cameras can be added to provide a permanent record of a visual test. Closed circuit television displays, with or without video tape, are common as well. Also available are attachments at the eyepiece permitting dual viewing or right angle viewing for increased accessibility.

FIGURE 23. Miniborescope wide angle lens: (a) general shape and (b) lens detail



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Special Purpose Borescopes

Angulated borescopes are available with forward oblique, right angle or retrospective visual systems. These instruments usually consist of an objective section with provision for attaching an eyepiece at right angles to the objective section's axis. This permits inspection of shoulders or recesses in areas not accessible with standard borescopes.

Calibrated borescopes are designed to meet specific test requirements. The external tubes of these instruments can be calibrated to indicate the depth of insertion during a test. Borescopes with calibrated reticles are used to determine angles or sizes of objects in the field when held at a predetermined working distance.

Panoramic borescopes are built with special optical systems to permit rapid panoramic scanning of internal cylindrical surfaces of tubes or pipes.

Wide field borescopes have rotating objective prisms to provide fields of view up to 120 degrees. One application of wide field borescopes is the observation of models in wind tunnels under difficult operating conditions.

Ultraviolet borescopes are used during fluorescent magnetic particle and fluorescent penetrant tests. These borescopes are equipped with ultraviolet lamps, filters and special transformers to provide the necessary wavelengths.

Waterproof and *vaporproof borescopes* are used for internal tests of liquid, gas or vapor environments. They are completely sealed and impervious to water or other types of liquid.

Water cooled or *gas cooled borescopes* are used for tests of furnace cavities, jet engine test cells and for other high temperature applications.

Typical Industrial Borescope Applications

Aviation Industry

The use of borescopes for tests of airplane engines and other components without disassembly has resulted in substantial savings in costs and time. A borescope of 11 mm (0.44 in.) diameter by 380 mm (15 in.) working length can be used by maintenance and service departments for visual testing of engines through spark plug openings, without dismantling the engines. An excellent view of the cylinder wall, piston head, valves and valve seats is possible and several hundred hours of labor are saved for each engine test. Spare engines in storage can also be inspected for corrosion of cylinder wall surfaces.

Aircraft propeller blades are visually tested during manufacture. The entire welded seam of a blade can be inspected internally for cracks and other discontinuities. Propeller hubs, reverse pitch gearing mechanisms, hydraulic cylinders, landing gear mechanisms and electrical components also can be inspected with borescopes. Aircraft wing spars and struts are inspected for evidence of fatigue cracks and rivets and wing sections cam be tested visually for corrosion. Borescopes used for tests of internal wing tank surfaces and wing corrugations subject to corrosion have saved airlines large sums of money by reducing the time aircraft are out of service.

Automotive Industry

Borescopes are widely used in the manufacturing and maintenance divisions of the automotive industry. Engine cylinders can be examined through spark plug holes without removing the cylinder head. The cylinder wall, valves and piston head can be visually tested for excess wear, carbon deposits and surface discontinuities. Crankcases and crankshafts are examined through wall plug openings without removing the crankcase. Transmissions and differentials are similarly inspected.

Borescopes are also useful for locating discontinuities such as cracks or blowholes in castings and forgings. Machined components such as cross bored holes can be examined for internal discontinuities. Borescopes are used to inspect cylinders for internal surface finish after honing. Tapped holes, shoulders or recesses also can be observed. Inaccessible areas of hydraulic systems, small pumps, motors and mechanical or electrical assemblies can be visually tested without dismantling the engine.

Machine Shops

Borescopes find applications in production machine shops, tool and die departments and in ferrous, nonferrous and alloy foundries. In production machine operations, borescopes of various sizes and angles of view are used to examine internal holes, cross bored holes, threads, internal surface finishes and various inaccessible areas encountered in machine and mechanical assembly operations. Specific examples are visual tests of machine gun barrels, rifle bores, cannon bores, machine equipment and hydraulic cylinders.

In tool and die shops, borescopes are used to examine internal finishes, threads, shoulders, recesses, dies, jigs, fixtures, fittings and the internal mating of mechanical parts. In foundries, borescopes are widely used for internal inspections to locate discontinuities, cracks, porosity and blowholes. Borescopes are also used for tests of many types of defense materials, including the internal surface finish of rocket heads, rocket head seats and guided missile components.

Power Plants

In steam power plants, borescopes are used for visual tests of boiler tubes for pitting, corrosion, scaling or other discontinuities. Borescopes used for this type of work are usually made in 2 or 3 m (6 or 9 ft) sections. Each section is designed so that it can be attached to the preceding section, providing an instrument of any required length.

Other borescopes are used to examine turbine blades, generators, motors, pumps, condensers, control panels and other electrical or mechanical components without dismantling. In nuclear plants, borescopes offer the advantage that the inspector can be in a low radiation field while the distal, or sensor, end is in a high radiation field.

Chemical Industry

Visual tests of high pressure distillation units are used to determine the internal condition of tubes or headers. Evaporation tubes, fractionation units, reaction chambers, cylinders, retorts, furnaces, combustion chambers, heat exchangers, pressure vessels and many other types of chemical process equipment are inspected with borescopes or extension borescopes

Tank cars are inspected for internal rust, corrosion and the condition of outlet valves. Cylinders and drums can be examined for internal conditions such as corrosion, rust or other discontinuities.

TABLE 3. Comparison of vision types and angles of obliquity

Type of Vision	Angle of Obliquity (degrees)	Angular Field (degrees)
Direct	0	45
Forward oblique	25	50
Forward vision	45	45
Right angle	90	50
Retrospective	135	45
Circumferential	0	45
	90	15

Petroleum Industry

Borescopes are used for visual tests of high pressure catalytic cracking units, distillation equipment, fractionation units, hydrogenation equipment, pressure vessels, retorts, pumps and similar process equipment. Use of the borescope in the examination of such structures is doubly significant. Not only does it allow the examination of inaccessible areas without the lost time and expense incurred in dismantling, it avoids breakdown and the ensuing costly repair.

Borescope Optical Systems

Borescopes are precise optical devices containing a complex system of prisms, achromatic lenses and plain lenses that pass light to the observer with high efficiency. An integral light source is usually located at the objective end of the borescope to provide illumination for the test object.

Angles of Vision

To meet a wide range of visual testing applications, borescopes are available in various diameters and working lengths to provide various angles of vision for special requirements. The most common types of vision are: (1) right angle, (2) forward oblique, (3) direct and (4) retrospective (see Fig. 20).

These types of vision are characterized by different angles of obliquity for the central ray of the visual field, with respect to the forward direction of the borescope axis (see Table 3).

General Characteristics

Desirable properties of borescopic systems are large field of vision, no image distortion, accurate transmission of color values and adequate illumination.

The brightest images are obtained with borescopes of large diameter and short length. As the length of the borescope is increased, the image becomes less brilliant because of light losses from additional lenses required to transmit the image. To minimize such losses, lenses are typically coated with antireflecting layers to provide maximum light transmission.

Optical Components

The optical system of a borescope consists of an objective, a middle lens system, correcting prisms and an ocular section (see Fig. 24). The objective is an arrangement of prisms and lenses mounted closely together. Its design determines the angle of vision, the field of view and the amount of light gathered by the system.

The middle lenses conserve the light entering the system and conduct it through the borescope tube to the eye with a minimum loss in transmission. Design of the middle lenses has an important effect on the character of the image. For this reason, the middle lenses are achromatic, each lens being composed of two elements with specific curvatures and indexes of refraction. This design preserves sharpness of the image and true color values.

Depending on the length of the borescope, the image may need reversal or inversion or both, at the ocular. This is accomplished by a correcting prism within the ocular for borescopes of small diameter and by erecting lenses for larger designs.

Depth of Focus, Field of View and Magnification

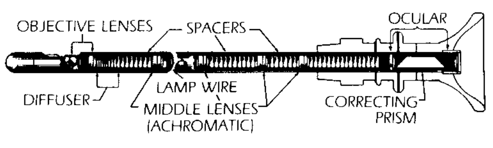
The depth of focus for a borescopic system is inversely related to the numerical aperture N.

$$N = n \sin a \qquad \text{(Eq. 1)}$$

Where:

n = the refractive index of the object space; and
a = the angle subtended by the half diameter of the entrance pupil of the optical system.

FIGURE 24. Sectional view of a typical borescope, showing relationship of parts in its optical system



The entrance pupil is that image of any of the lens apertures, imaged in the object space, which subtends the smallest angle at the object plane. Because the numerical aperture of borescope systems is usually very small compared with that of a microscope, the corresponding depth of focus is exceedingly large. This permits the use of fixed focus eyepieces in many small and moderately sized instruments.

Field of view, on the other hand, is relatively large, generally on the order of 50 degrees of angular field. This corresponds to a visual working field of about 25 mm (1 in.) diameter at 25 mm (1 in.) from the objective lens. At different working distances, the diameter of the field of view varies almost directly with the working distance (see Fig. 22).

Magnification of a borescope's optical system is given by the relation:

$$M = m_1 \times m_2 \times m_3 \qquad \text{(Eq. 2)}$$

where m_1, m_2 and m_3 are the magnifications of the objective, middle lenses and ocular. The total magnification of borescopes varies with diameter and length but generally ranges from about 2× to 8× in use. Note that the linear magnification of a given borescope changes with working distance and is about inversely proportional to the object distance. A borescope with 2× magnification at 25 mm (1 in.) working distance therefore will magnify 4× at 13 mm (0.5 in.) distance.

FIGURE 25. Components of typical borescope system (case not shown)

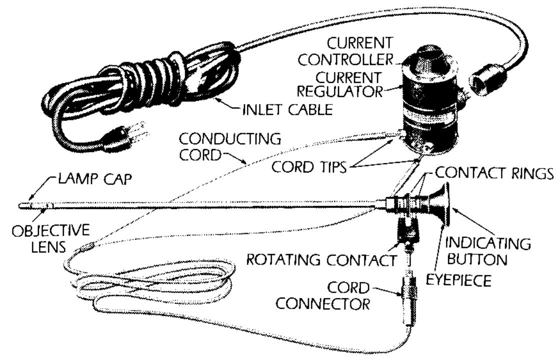
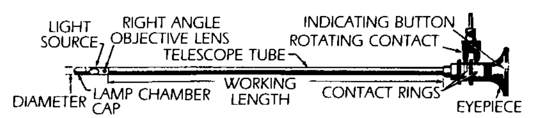


FIGURE 26. A typical right angle borescope



Borescope Construction

A borescopic system usually consists of one or more borescopes having integral or attached illumination, additional sections or extensions, a battery handle, battery box or transformer power supply and extra lamps, all designed to fit in a portable case (see Fig. 25). The parts of a fixed length borescope for right angle vision are shown in Fig. 26. Also shown is a lamp at the objective end of the device. In this configuration, insulated wires are located between the inner and outer tubes of the borescope and serve as electrical connections between the lamp and the contacts at the ocular end. A contact ring permits rotation of the borescope through 360 degrees for scanning the object space without entangling the electrical cord. In other models, a fixed contact post is provided for attachment to a battery or a transformer, or the illumination is provided by fiber optic light guides (see Fig. 16).

Borescopes with diameters under 37 mm (1.5 in.) are usually made in sections, with focusing eyepieces, interchangeable objectives and high power integral lamps. This kind of borescope typically consists of an eyepiece or ocular section, a 1 or 2 m (3 or 6 ft) objective section, with 1, 2 or 3 m (3, 6 or 9 ft) extension sections. The extensions are threaded for fitting and ring contacts are incorporated in the junctions for electrical connections. Special optics can be added to increase magnification when the object is viewed at a distance.

Eyepiece extensions at right angles to the axis of the borescope can be supplied, with provision to rotate the borescope with respect to the eyepiece extension, for scanning the object field.

Right Angle Borescopes

The right angle borescope is usually furnished with the light source positioned ahead of the objective lens (see Fig. 26). The optical system provides vision at right angles to the axis of the borescope and covers a working field of about 25 mm (1 in.) diameter at 25 mm (1 in.) from the objective lens.

Applications of the right angle borescope are widespread. The instrument permits testing of inaccessible corners and internal surfaces. It is available in a wide range of lengths, in large diameters or for insertion into apertures as small as 2.3 mm (0.09 in.). It is the ideal instrument for visual tests of rifle and pistol barrels, walls of cylindrical or recessed holes and similar components.

Another application of the right angle borescope is inspection of the internal entrance of cross holes, where it may be critical to detect and remove burrs and similar irregularities that interfere with correct service. Drilled oil leads in castings can be visually inspected, immediately following the drilling operation, for blowholes or other discontinuities that cause rejection of the component. Right angle borescopes can be equipped with fixtures to provide fast routine tests of parts in production. The device's portability allows occasional tests to be made at any point in a machining cycle

Forward Oblique Borescopes

The forward oblique system is a design that permits the mounting of a light source at the end of the borescope yet also allows forward and oblique vision extending to an angle of about 55 degrees from the axis of the borescope.

A unique feature of this optical system is that, by rotating the borescope, the working area of the visual field is greatly enlarged.

Retrospective Borescope

The retrospective borescope has an integral light source mounted slightly to the rear of the objective lens. For a bore with an internal shoulder whose surfaces must be accurately tooled, the retrospective borescope provides a unique method of accurate visual inspection.

Direct Vision Borescope

The direct vision instrument provides a view directly forward with a typical visual area of about 19 mm (0.75 in.) at 25 mm (1 in.) distance from the objective lens. The light carrier is removable so that the two parts can be passed successively through a small opening.

Sectioned Borescopes

Borescopes under 38 mm (1.5 in.) diameter are often made in pieces, with the objective section 1 or 2 m (3 or 6 ft) in length. The additional sections are 1, 2 or 3 m (3, 6 or 9 ft) long with threaded connections. These sections may be added to form borescopes with lengths up to 15 m (45 ft) for diameters under 37 mm (1.5 in.).

Tables 4 through 7 list the diameters and working lengths of typical borescopes. For special applications, custom made sizes and designs are available.

TABLE 4. Specifications of right angle borescopes

Borescope Diameter millimeters (inches)	Typical Working Length Ranges millimeters (inches)	Lamp Voltage
1.75 (0.07)	38 to 100 (1.5 to 4)	1.5
2.25 (0.09)	50 to 313 (2 to 12.5)	1.5
2.75 (0.11)	113 to 300 (4.5 to 12)	2.5
3.5 (0.14)	100 to 750 (4 to 30)	2.5
4 (0.16)	150 to 750 (6 to 30)	2.5
4.65 (0.186)	88 to 700 (3.5 to 28)	2.5
5.25 (0.21)	188 to 450 (7.5 to 18)	2.5
5.8 (0.232)	225 to 1,500 (9 to 60)	2.5
6.5 (0.26)	450 to 1,550 (8 to 62)	2.5
6.5 (0.26)	200 to 375 (8 to 15)	6.0
6.9 (0.276)	75 to 1,550 (3 to 62)	2.5
6.9 (0.276)	250 to 400 (10 to 16)	6.0
9.75 (0.39)	138 to 1,175 (5.5 to 47)	4.5
9.75 (0.39)	1,500 to 4,500 (60 to 180)	4.5
9.75 (0.39)	500 to 750 (20 to 30)	12.0
10.9 (0.436)	200 to 300 (8 to 12)	4.5
10.9 (0.436)	375 (15)	12.0
12.25 (0.49)	625 (25)	4.5

Special Purpose Borescopes

Borescopes can be built to meet many special visual testing requirements. The factors affecting the need for custom designs include: (1) the length and position of test area, (2) its distance from the entry port, (3) the diameter and location of the entry port and (4) inspector distance from the entry port.

Environmental conditions such as temperature, pressure, water immersion, chemical vapors or ionizing radiation are important design factors. The range of special applications is partly illustrated by the examples given below.

Miniature Borescopes

Miniature borescopes are made in diameters as small as 1.75 mm (0.07 in.), including the light source. They are useful because they can go into small holes. Inspection of microwave guide tubing is a typical application.

Periscopes

A large periscopic instrument with a right angle eyepiece and a scanning prism at the objective end is shown in Fig. 27. This instrument is 125 mm (5 in.) in diameter and 9 m (27 ft) long. It is sectioned and provides for visual or photographic study of models in wind tunnels. A field of view 70 degrees in azimuth by 115 degrees in elevation is covered by this design.

The cave borescope is a multiangulated, periscopic instrument used for remote observation of otherwise inaccessible areas.

Indexing Borescope

Butt welds in pipes or tubing 200 mm (8 in.) in diameter or larger can be visually tested with a special 90 degree indexing borescope. The instrument is inserted in extended form through a small hole drilled next to the weld seam and is then indexed to the 90 degree position by rotation of a knob at the eyepiece.

TABLE 5. Specifications of section borescopes with working lengths of 1, 2 and 3 m (3, 6 and 9 ft) and extension sections of 1, 2 and 3 m (3, 6 and 9 ft)

Borescope Diameter millimeters (inches)	Maximum Length meters (feet)	Maximum Lamp Voltage	Type of Vision
13 (0.5)	10 (30)	24	Right angle, forward oblique or flexible right angle
19 (0.75)	12 (36)	24	Right angle, direct vision, forward oblique or circumferential
25 (1)	13 (39)	24	Right angle, direct vision or forward oblique
34 (1.375)	15 (45)	48	Right angle, direct vision or retrospective

The objective head is then centered within the tube for viewing the weld. A second knob at the eyepiece rotates the objective head through 360 degrees for scanning the weld seam. Another application of this instrument is for inspecting the inside surface of cathode ray tubes.

Panoramic Borescopes

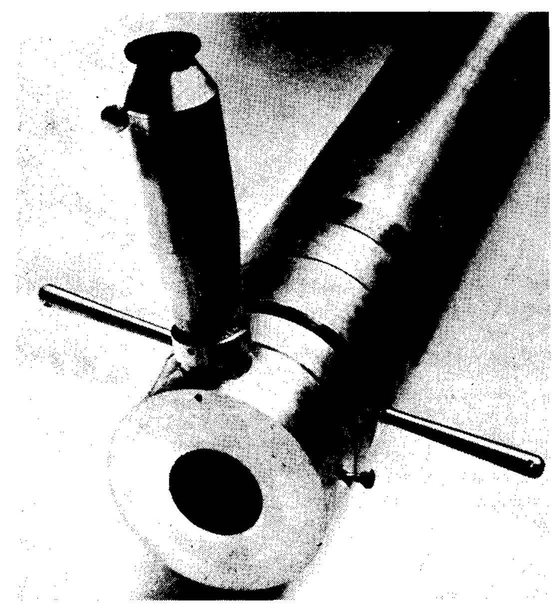
The panoramic borescope has a scanning mirror mounted in front of the objective lens system. Rotation of the mirror is accomplished by means of an adjusting knob at the ocular end of the instrument. This permits scanning in one plane to cover the ranges of forward oblique, right angle and retrospective vision (see Fig. 28).

Another form of panoramic borescope permits rapid scanning of the internal cylindrical surfaces of tubes or pipes. This instrument has a unique objective system that simultaneously covers a cylindrical strip 30 degrees wide around the entire 360 degrees with respect to the axis of the borescope. The diameter of this instrument is 25 mm (1 in.) and the working length is 1 m (3 ft) or larger.

TABLE 6. Specifications of forward oblique borescopes

Borescope Diameter millimeters (inches)	Working Lengths millimeters (inches)	Lamp Voltage
2.25 (0.09)	50 (2)	1.5
2.75 (0.11)	138 to 600 (5.5 to 24)	2.0
3.5 (0.14)	113 to 550 (4.5 to 22)	2.5
4 (0.16)	250 (10)	2.5
4.65 (0.186)	88 to 750 (3.5 to 30)	2.5
5.25 (0.21)	178, 432 (7, 17)	2.5
5.8 (0.232)	275 to 300 (11, 12)	2.5
6.5 (0.26)	150 to 1,500 (6 to 60)	2.5
9.75 (0.39)	900, 1,800 (36, 72)	3.0
10.9 (0.436)	250, 375 (10, 15)	12.0

FIGURE 27. Eyepiece end of large wind tunnel periscope



Reading Borescopes

Low power reading borescopes are used in plant or laboratory setups for viewing the scales of instruments such as cathetometers at moderately remote locations. The magnification is about 3× at 1 m (3 ft) distance.

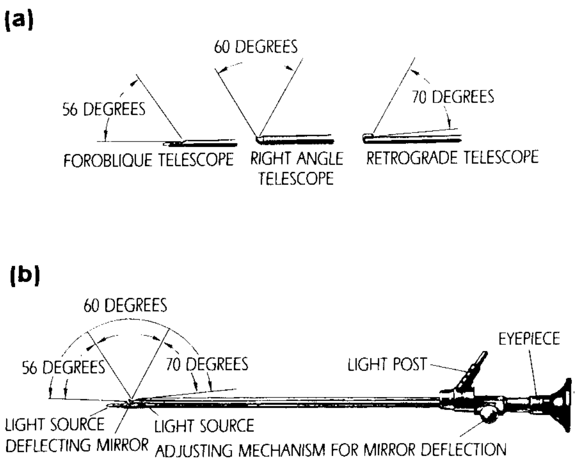
TABLE 7. Specifications of borescopes with separate light carriers

	Diameters millimeters (inches)				
Type	Combined	Light Carriers	Borescope	Working Lengths millimeters (inches)	Voltage
1	3.5 (0.17)	2 (0.08)	2.25 (0.09)	119 (4.75)	2.0
1	4.7 (0.186)			88 (3.5)	2.5
1	6.4 (0.255)	*	*	119, 188 (4.75, 7.5)	2.5
1	9.75 (0.39)	5.3 (0.212)	4.7 (0.186)	188 to 1,250 (7.5 to 50)	2.5
1	11 (0.436)	3, 4 (12, 16)	2.5		
1	13 (0.5)			131 (5.25)	2.5
2	3.5 (0.17)	2 (0.08)	2.25 (0.09)	119 (4.75)	2.0
2	9.75 (0.39)	5.3 (0.212)	4.7 (0.186)	188 to 600 (7.5 to 24)	2.5
3	4.9 (0.195)	1.90 (0.075)	2.9 (0.117)	113 (4.5)	2.0
					2.5
3	6 (0.24)			206 (8.25)	
3	7.2 (0.286)	2.8 (0.113)	4 (0.16)	213 (8.5)	2.5
3	9.75 (0.39)	5.3 (0.212)	4.7 (0.186)	188, 600 (7.5, 24)	2.5
4	6 (0.24)	*	*	188, 463 (7.5 to 18.5)	2.5
4	7.3 (0.29)	*	*	207, 219 (8.25, 8.75)	2.5
4	9.3 (0.371)			250 (10)	2.5
5	6 (0.24)			375, 900 (15, 36)	12.0
5	9.5 (0.38)			207 (8.25)	2.5
5	9.75 (0.39)	5.3 (0.21)	(0.186)	188 (7.5)	2.5

* PERMANENTLY MOUNTED

LEGEND
1. RIGHT ANGLE
2. FORWARD OBLIQUE
3. DIRECT
4. RETROSPECTIVE
5. FORWARD

FIGURE 28. Panoramic borescope: (a) comparative ranges of vision and (b) panoramic system components



Photographic Adaptations

Many borescopes also include the ability to record with still photography, motion picture or video tape. For example, still pictures on 35 mm film can be taken with a borescope fitted with an adapter designed for the purpose. A telescopic system with a movable prism built into the adapter operates on the reflex principle, permitting observation of the visual field of the borescope up to the instant of photographic exposure. High intensity light sources incorporated into the borescope provide illumination for 16 mm circular pictures on 35 mm film. Motion pictures are possible with a fiber optic light source or a rod illuminator that eliminates electrical connections and the heat of a lamp from the objective end of the borescope. This is especially valuable where explosive vapors are present.

Photography of the interiors of large power plant furnaces during operation has been done since the 1940s using a unit power periscope and camera.[1] The periscope extends through the furnace wall and relays the optical image to the camera. A water cooled jacket protects the optical system and the camera from the furnace's high temperatures. With this equipment, still and motion picture studies have been made of the movement of the fuel bed and the action of the powdered fuel burner in furnaces operating at full load.