Non-Destructive Evaluation (NDE)

Chapter 3

Visual Inspection

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Visual Examination

Visual Examination is a nondestructive examination method used to evaluate an item by observation.

- Used to determine the surface condition of an article, alignment of mating surfaces, compliance with physical requirements (dimensions, settings), etc.
- visual inspection is normally the first step in the examination process employed for locating suspected defects
- Also the oldest and most commonly used NDT method

Why Visual Examination?

- ✓ Does not require special equipment other than good eyesight (optical and mechanical aids optional to improve inspection quality)
- ✓ Low cost
- ✓ can be performed while the machine/system is running, as well as during stoppage

Why Visual Examination?

- ✓ Visual inspection can be immediately applied in a number of areas, such as:
- inspection of cleaning
- checking for corrosion, erosion and deformities
- checking for ruptures, cracks and wear
- monitoring of manometers, pressostats and temperatures
- monitoring of oil level, greasing and greasing apparatus
- monitoring of the operational condition of systems or machines

Physical Principles

The human eye is one of mankind's most fascinating tools. It has greater precision and accuracy than many of the most The human eye is one of mankind's most fascinating tools. It has greater precision and accuracy than many of the most sophisticated cameras. It has unique focusing capabilities and has the ability to work in conjunction with the human brain so that it can be trained to find specific details or characteristics in a part or test piece. It has the ability to differentiate and distinguish between colors and hues as well. The human eye is capable of assessing many visual characteristics and identifying various types of discontinuities. The eye can perform accurate inspections to detect size, shape, color, depth, brightness, contrast, and texture.

Physical Principles

Many inspection factors have been standardized so that categorizing them as major and minor characteristics has become common. Surface finish verification of machined parts has even been developed, and classification can be performed by visual comparison to manufactured finish standards. In the fabrication industry, weld size, contour, length, and inspection for surface discontinuities are routinely specified. Many companies have mandated the need for qualified and certified visual weld inspection. This is the case particularly in the power industry, which requires documentation of training and qualification of the inspector. Forgings and castings are normally inspected for surface indications such as laps, seams, and other various surface conditions.

Advantages of visual inspection

- ✓ It can be a very simple but effective test to perform and often does not need expensive equipment.
- ✓ Experienced operators and advanced equipment make it possible for visual inspection to be very sensitive.
- ✓ It allows discontinuities to be seen and not be just a blip on the screen.
- ✓ Many different surface-breaking discontinuities can be found.
- ✓ Training and experience times can be short.
- ✓ Virtually any component can be examined anywhere on the surface.

Disadvantages of visual inspection

- ✓ Many variables can lead to discontinuities being missed.
- ✓ At its worst, it relies totally on the human factor.
- ✓ Many organizations pay little attention to the proper training of operators.
- ✓ Sub-surface discontinuities will not be seen.

Visual Examination Categories

ASME sectored the visual examination into four categories based on the scope of inspection. The categories are classed as

- VT-1: Exams conducted to detect discontinuities on the surface of components
- VT-2: Exams conducted to detect evidence of leakage from pressure retaining components (tanks, pipes, etc.)
- VT-3: Exams conducted to determine the general mechanical and structural condition of components and their supports
    - Verification of clearances and settings
    - Inspection for loose or missing parts
- VT-4: (which has been eliminated) focused on the conditions relating to the operability of components or devices.

Inspection Requirements

Usually requires a written procedure that outlines the following:

- Type of exam to be performed (VT-1 or VT-3)
- Illumination requirements (ex. 50 foot-candles)
  - 1 foot candle is equal to the amount of light given off by a standard candle at a distance of 1 foot
- Surface preparation requirements
- Acceptance criteria
- Inspection interval (how often inspection must occur)
- Required test documentation

Techniques

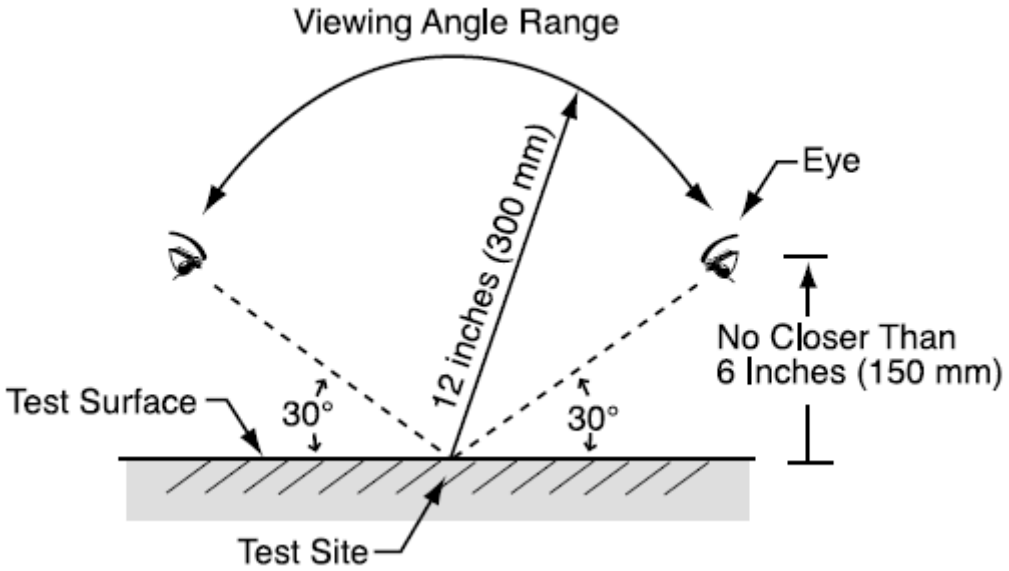
- ***Direct visual exams*** usually occur within 24” of the surface to be examined

  may use mirrors or magnifying lenses

- ***Remote visual exams*** performed in areas that are inaccessible for direct examination (inside of pipes and tanks or in hazardous or radioactive areas)

Techniques

Direct visual testing is defined as using "visual aids such as mirrors, telescopes, cameras, or other suitable instruments."
Direct visual examination is conducted when access allows the eye to be within 25 inches (610 mm) of the surface to be examined, and at an angle not less than 30° to the surface to be examined.



Techniques

Remote visual testing is divided into three categories:

- ✓ borescopes,
- ✓ fiberscopes,
- ✓ and video technology.

These have been developed chronologically.

Equipment

An operator will often be required to locate small discontinuities. This can be very difficult with the naked eye, so optical or/and mechanical aids may be required. Here are some of the most common aids:

Optical Aids

- Microscopes
- Borescopes
- Fiberscopes
- Video Cameras

Mechanical Aids

- Micrometers
- Calipers
- Depth gauges
- Thread pitch gauges
- Feeler gauges
- Weld gauges

Equipment

Lamp

It is obvious that good illumination is required for a successful visual inspection.

A hand held lamp is indispensable. Special lamps such as those fastened to the forehead can be chosen for special jobs. The hand held lamp can be used for revealing faults by shining the light parallel to the surface, whereby irregularities and corroded areas will stand out like a lunar landscape.

Equipment

Mirrors

When inspecting areas not easily accessible a mirror can be of great help.

Depending on the job it can be of any size from the small dentist's mirror which can be stuck into small openings to a much larger mirror which can make the job easier when making external inspection of pipelines placed near the ground or close to a wall.

Equipment

Magnifying glass

A magnifying glass can be used for closer inspection of suspicious-looking areas just as it often will be a natural tool for inspections of precision instruments.

Equipment

Straight steel ruler, square and level

These tools will normally be put to use before the actual measuring takes place.

Sometimes custom-made shapes may have to be constructed in order to perform an inspection.

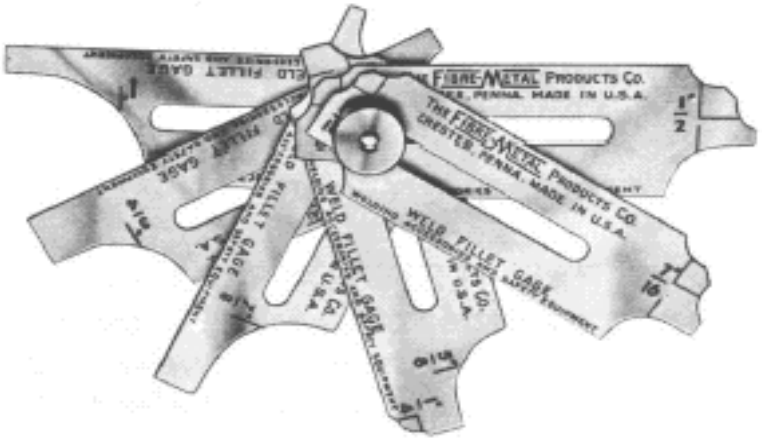
Equipment

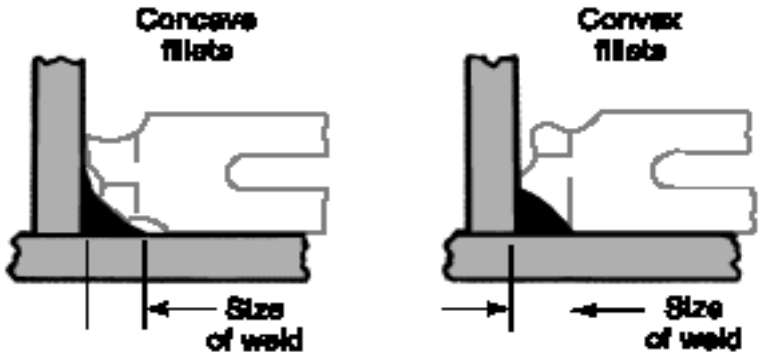
Vernier scale, micrometer, measuring tape, measuring compass and calipers

Depending on the desired accuracy, micrometer, vernier or measuring tape can be used. Indirect measuring by means of measuring compass or calipers may of course also be used, provided one takes into account the risk of errors that may result from indirect measurement. However, new types of compasses have been constructed with built-in measuring dials so that direct measurement can be performed.

Equipment

Welding Gauges





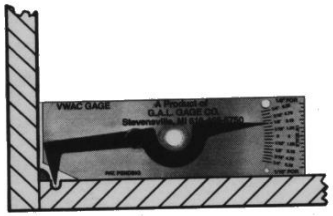
- Fillet gauges measure
  - The “Legs” of the weld
  - Convexity
    - (weld rounded outward)
  - Concavity
    - (weld rounded inward)
  - Flatness

Equipment

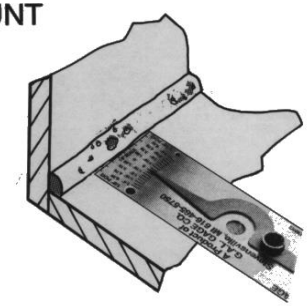
Welding Gauges

Undercut Gauge

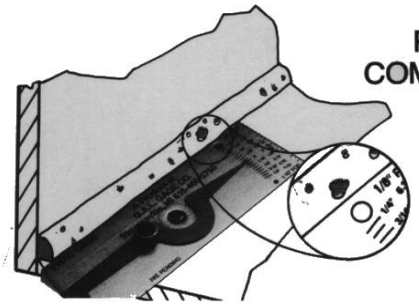
CHECKS UNDERCUT DEPTH



CHECKS AMOUNT OF POROSITY PER LINEAR INCH



CHECKS POROSITY COMPARISON

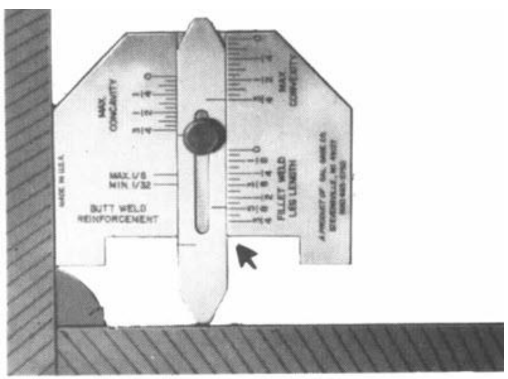


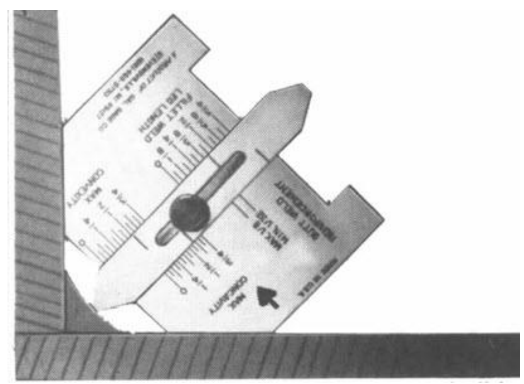
CHECKS CROWN HEIGHT

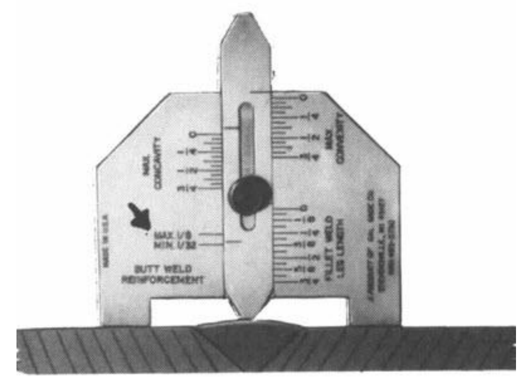
Equipment

Welding Gauges

Palmgrin Gauge



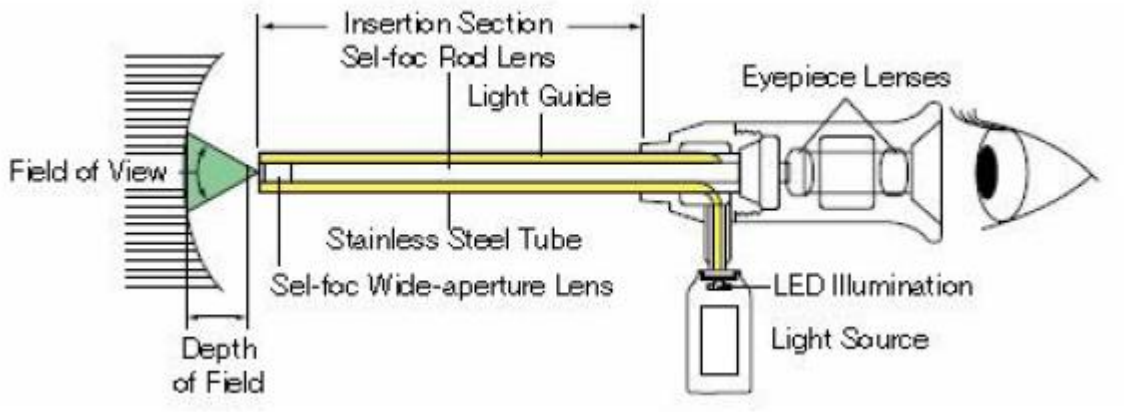




Equipment

Borescopes

"Borescopes," also referred to as "endoscopes," were originally used to inspect the bores of rifles or cannons utilizing a hollow tube and mirror. The second generation of the endoscopes included a relay lens system in a rigid tube. This upgraded the image. Due to its rigid structure, endoscopes are limited to straight-line access.



Equipment

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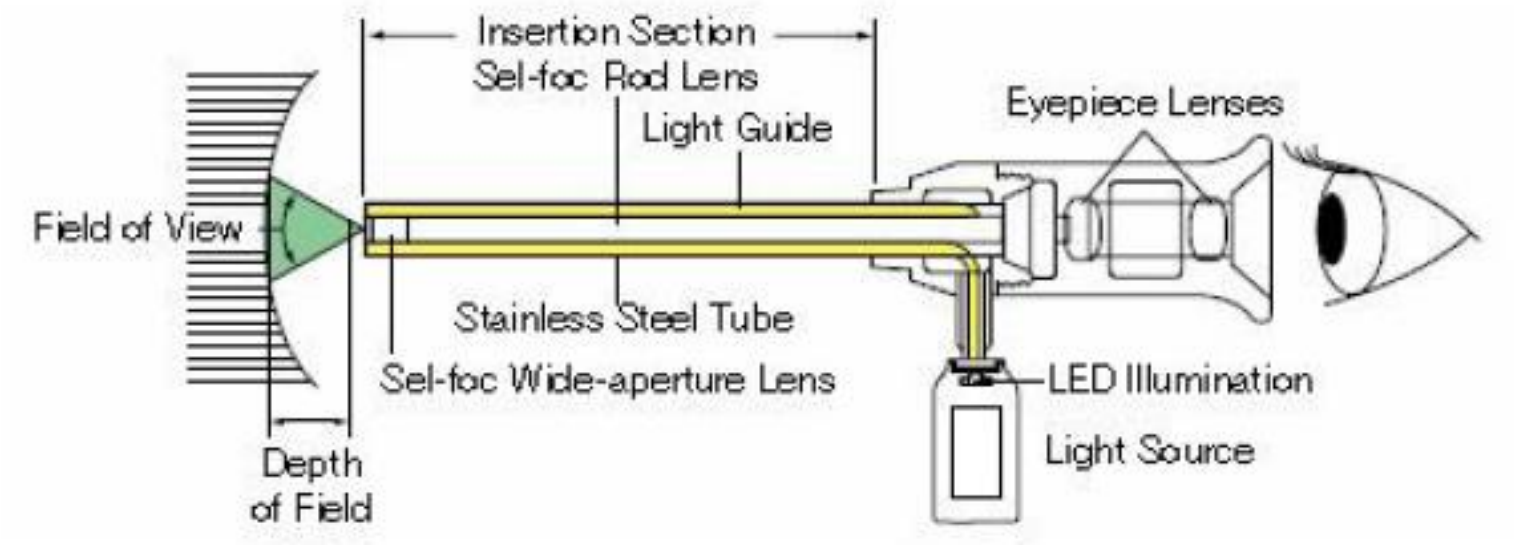
Equipment

Borescopes

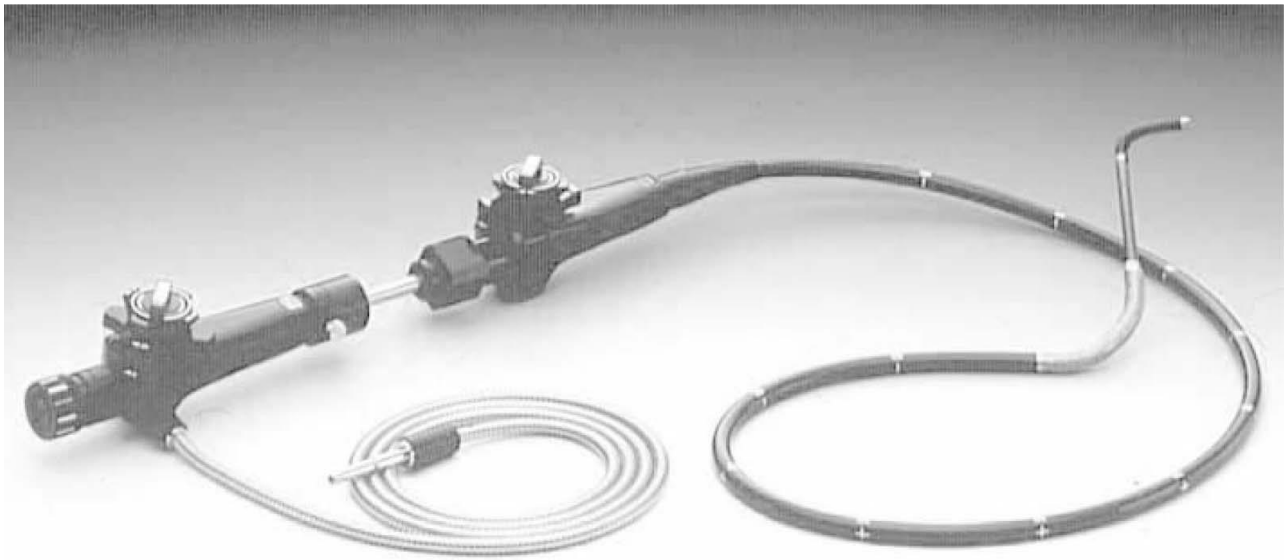
Typical optics at the tip look forward (0°), lateral (45° or 90°), or backwards (110°). This is usually done by a prism (not a mirror). The field of view is dependent on the lens.



Equipment

Fiberscope

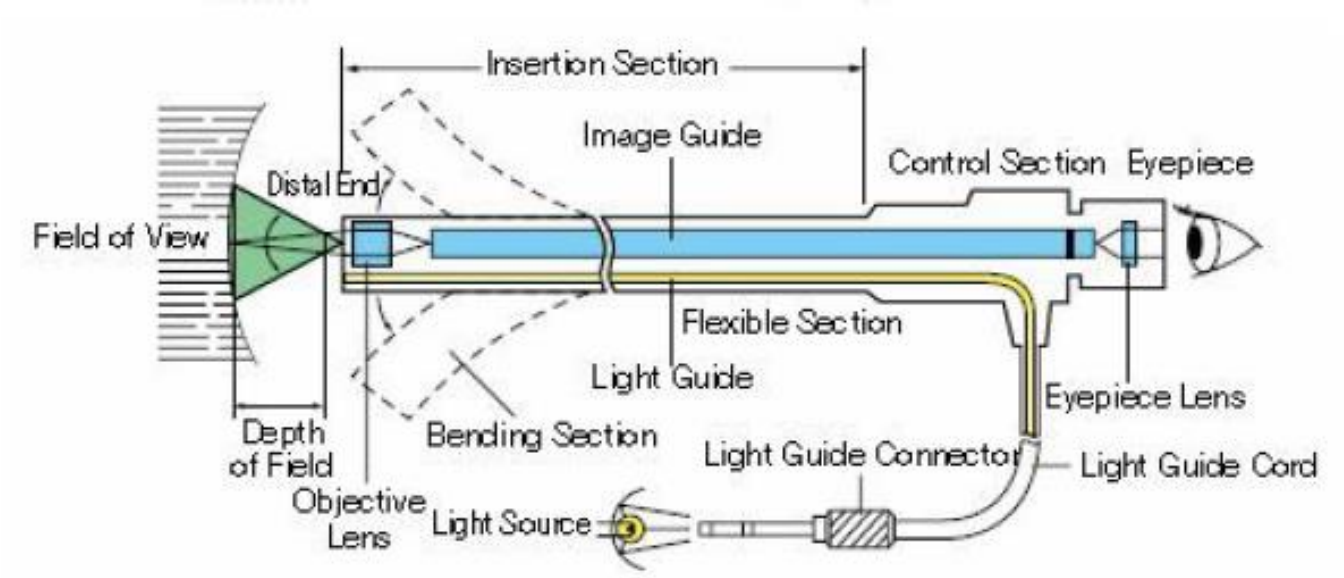
Later innovations corrected the limitation of Borescopes to the straight-line access by providing flexibility to the endoscopes. The introduction of glass fiber bundles and fiber optic image transmission enabled the development of the fiberscope.



Equipment

Fiberscope

Imaging with fiber optic bundles decreased the clarity of the image transmission compared with the rigid lens systems of borescopes; however, this was a small price to pay for the opportunities it presented.



Equipment

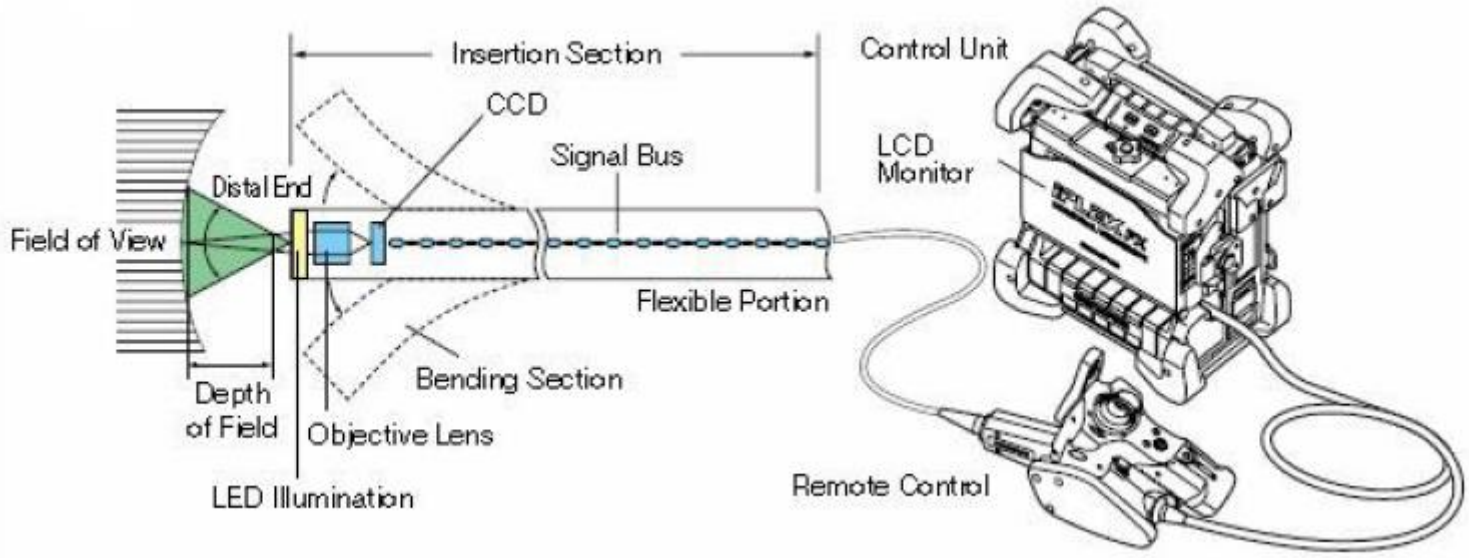
Videoscope

The evolution of the endoscope continued as the problems of eye fatigue associated with the use of endoscopes and fiberscopes prompted the development of various “add-on” cameras or closed circuit TV cameras that allowed for the display of images on a monitor.

Equipment

Videoscope

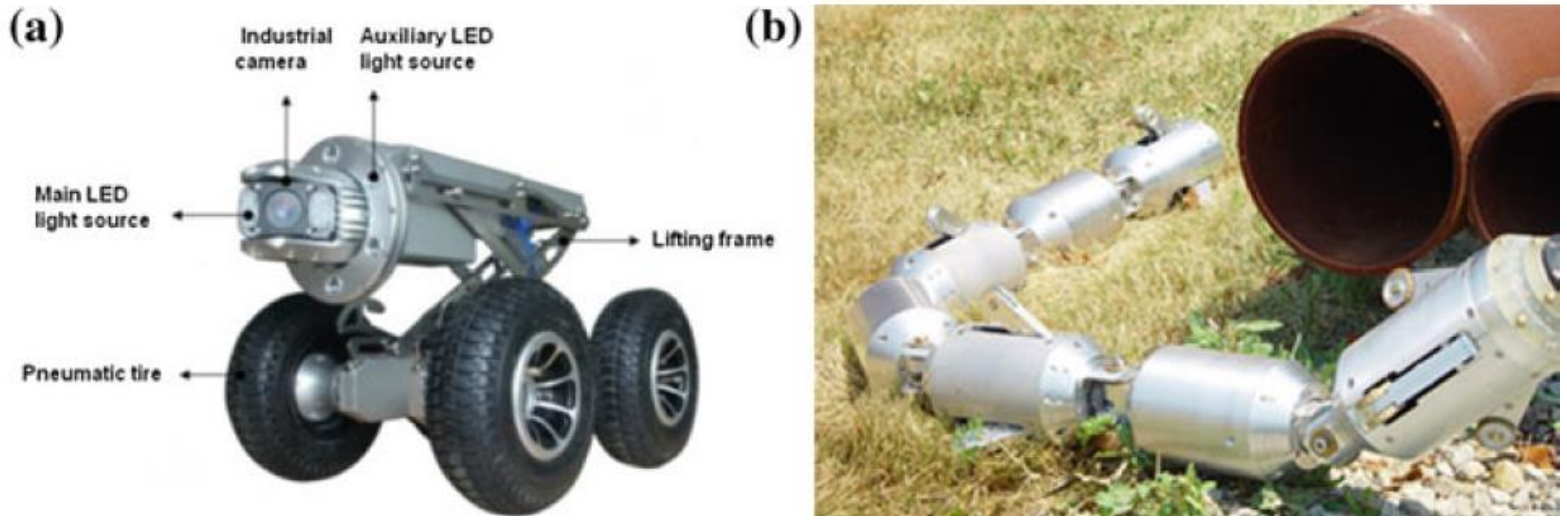
For the acquisition of images all types of cameras can be used, including photo, video or thermal, either directly or with the aid of videoscopes.



Equipment

Pipe-crawlers or robots

Wheel drive locomotion system is one of the most commonly used techniques for driving pipe-crawlers.



a A typical wheel-type pipe inspection robot with an onboard camera system,
b a pressed-fit wheeled robot system

Equipment

Pipe-crawlers or robots

These robots are generally used for large diameter pipes such as drainage pipes. They are also good for variable pipe diameters and high-speed driving. Maximum speed
of such robots is around 163 mm/s . In fact, for medium-sized pipes, the speed is even low about 30–80 mm/s. Of course, for effective SHM, forward speed is not of much concern as higher speed may compromise the accuracy of damage detection. A subgroup of wheeled robots is of the pressed-fit type and is especially suitable for curved pipes and vertical climbing.

Equipment

Pipe-crawlers or robots

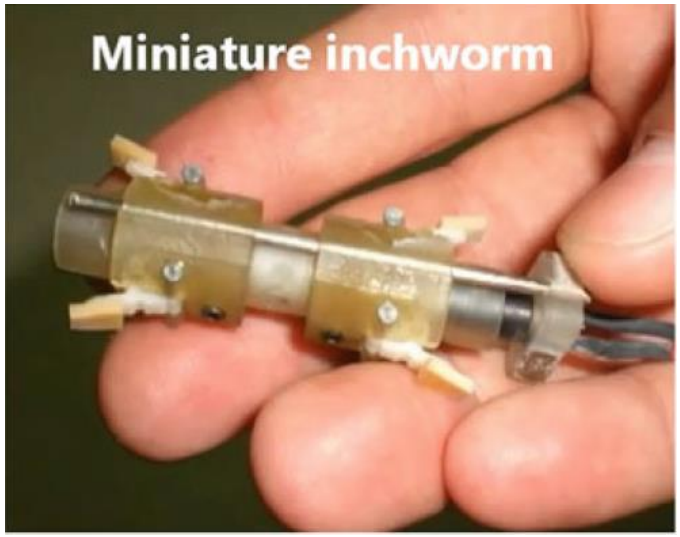
Propulsion-driven systems are generally used in relatively large diameter water and gas pipelines. For such applications, passive robots are developed that can mostly extract the flow energy for locomotion. Pipe Investigation Gauge (PIG). The weight of each module of the robot is limited by the kinetic energy available from the flow.

A propulsion-driven PIG system with magnetic flux sensors

Equipment

Pipe-crawlers or robots

Clamp and pull systems are generally used in smaller pipelines where the space is limited and the flow energy is not sufficient to pull the robot. This system is essentially very similar to the inchworm movement which generates motion by a sequence of rear clamping expanding and front clamping pulling action



A miniature inchworm robot

Practical applications

Hydraulic systems

- *Check these points with the system stopped:*
  - that the oil is clean and clear
  - that the system is clean and dry
- *Check these points with the system in operation:* listen for unusual noises from the motor, pump and piping system, and check:
  - that the oil is clean and clear (must not foam) and that
  - the temperature is correct
  - that the system is intact (no leaks) and that the filter
  - indicators are OK
  - for possible draining of condensation

Practical applications

Belt pulley

- *Check these points with the system stopped:*
    - missing belts and screening
    - belt tracks (belts must not work into the bottom of tracks)
    - that the belts are of equal length (maximum difference
    - equal to half the thickness of the belt)
    - that the belt pulleys are flushed
    - belt tension by pushing the belt downward by hand
    - (downward movement must not exceed 10% of the center
    - distance between the pulleys)
    - the condition of the belts; possible cracks
- *Check these points with the system in operation:*
    - belt noise, missing belts and screening

Practical applications

Electric motor

- *Check these points with the system stopped:*
    - motor mountings
- *Check these points with the system in operation:*
    - listen for unusual noise
    - temperature of bearings
    - working temperature of motor (max. 60 °C)
    - motor for possible vibrations

Practical applications

Gearboxes

Check these points with the system stopped:

- oil level and spilled oil
- gearbox mountings

Check these points with the system in operation: Listen for unusual

- noises from bearings and gear wheel. Check also:
- working temperature of gears (max. 60 °C)
- oil level and spilled oil
- gearbox mountings
- gear vibration

Practical applications

Clutches

Check these points with the system stopped:

- that the clutch plates are secured to the axle
- that the clutch plates are 2-4 mm apart
- that the clutch axles are parallel and precisely aligned
- for warping (e.g. using measuring dial with magnetic
- support) max. 0.1 mm out of true for fast-moving clutch

Check these points with the system in operation:

- listen for abnormal noises from the clutch
- that the mountings are OK

Practical applications

Cooling ventilator

Check these points with the system stopped:

- visual inspection of ventilator blades for wear, cracks and
- possible build-up
- ventilator mounting

Check these points with the system in operation:

- direction of rotation
- for vibrations (may need balancing)
- listen for unusual noises from the ventilator

Practical applications

Compressor

Check these points with the system in operation:

Listen for unusual noises from motor.

Check also the following:

temperature of bearings

- working temperature of motor

motor for possible vibrations

fastening of motor and possible screening

Read manometer for Terminal pressure m a . working pressure: Oil pressure normal: Filter minimum:

Filter max. filter indicator: Water temperature intake normally:

Report any irregularities to the supervisor in charge.

Practical applications

Transportation worm

Check these points with the system stopped:

- fastening of trough
- worm thread (by opening all inspection hatches)

Check these points with the system in operation:

- listen for unusual noise from middle bearings and worm
- threads
- bearing at pulling end for temperature (max. 60 °C)
- gasket housing at pulling end for leakages
- gasket housing and bearing opposite the pulling end

Practical applications

Conveyor belt

Check these points with the system stopped:

- visual inspection of rubber belt for holes and cracks plus scraper for wear
- alignment of the belt on rollers
- state and fastening of all rollers (upper, lower, tightening, driving and turning rollers)
- bearings
- the supports, lubricating pipes and lubricating fittings for build-up of dirt

Practical applications

Chain drive

Check these points with the system stopped:

- for wear of chainwheel teeth
- for wear on roll chain
- tightness of chain by pushing the chain down by hand (downward bending must not exceed 10% of the center distance between the chain wheels)
- that the chain wheels are in alignment and that they are not loose on the axles that screening is all right.

Practical applications

Water pump

Check these points with the system in operation:

- Listen for unusual noises from engine and bearings.
  Check also:
  - temperature of engine (max. 60 °C)
  - gasket housing and pipes for leakages

Practical applications

Welds

Visual inspection of welds is the easiest and also the most important kind of inspection of the state of welded joints.

When performing visual inspection, the first checking should take place without prior cleaning of the weld for rust and dirt because it is often easier to discover any crack formation when the seam has not been cleaned. After this initial inspection a more thorough cleaning of the surface of the weld should be carried out.

During the subsequent visual inspection one should be aware that many irregularities in the weld can look like cracks.

It is recommended that one check the cleaned welds with dye penetrant or even better using the magnet particle method and ultrasonic examination and perhaps even radiography.

Testing Procedures for Visual Testing

The NDT procedure usually has additionally to define the following special technical aspects:

- Special surface preparation;
- Illumination (type, strength, direction);
- Equipment;
- Requested resolution;
- Necessary cleaning and conservation.

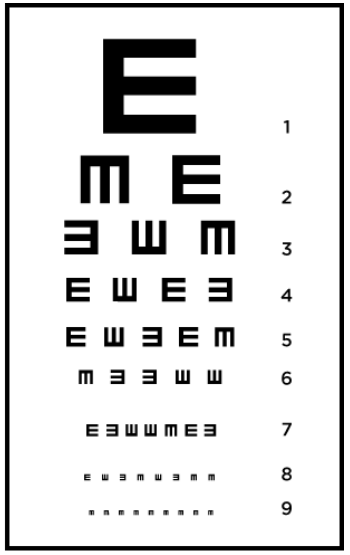
Certification Requirements

Per ASNT Recommended Practice No. SNT-TC-1A, 2011 edition:

Certification Level	Training (hrs)	Minimum Experience in Method (hrs)	Minimum Experience in NDT (hrs)
I	8	70	170
II	16	140	230
Totals:	24	210	400

Certification Requirements

- Must also pass annual eye exams for:
  1) Near vision acuity (sharpness of vision) – Jaeger chart
  2) Far vision acuity – Snellen chart



Certification Requirements

- Must also pass annual eye exams for:
  1) Color vision – Ishihara
     http://colorvisiontesting.com/ishihara.htm