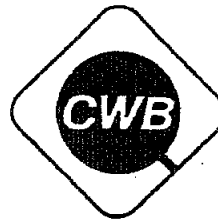


Basic Inspection Technology

PART OF THE CWB CERTIFICATE PROGRAMS



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BASIC INSPECTION TECHNOLOGY

LESSON OBJECTIVES

This module gives an introduction to the technology of inspection of welded fabrication and the following areas are covered.

- Functions and qualifications of an inspector.
- Inspection procedures and reports.
- Visual Inspection.
- Radiography.
- Ultrasonics.
- Magnetic particle inspection.
- Dye penetrant inspection.
- Acoustic Emission.

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INSPECTION

Inspection of assemblies fabricated by manual arc welding involves a great many factors which cannot be covered in any code or specification. These factors include not only the fundamental principles of the actual operation of welding and a knowledge of common weld faults, but also related subjects associated with the process, such as basic properties of welds and parent metal, testing methods and interpretation of drawings and specifications.

An inspector acts as a responsible representative of an organization which may be either the manufacturer, the purchaser, or some outside agency. His decisions are governed by some form of written lists of requirements which others have drawn up, but which he must be able to interpret both as to limitations and intent.

Because of the variety of welded structures requiring inspection, no one class of inspector is expected to be proficient in all types of inspection. A shop inspector employed by a fabricator makes routine checks of materials, dimensions, workmanship, finish and other details to ensure that design requirements are met. Such inspection is as much a part of production as the necessary welding and machine operations.

Independent inspections are on a basis different from that of routine shop inspection. An inspector cannot possibly check all details of each part of the product. Any such checks must be limited to spot checks or random samples, unless the inspector has reason to believe that code or specification requirements are not being met.

In any case, the inspector should enter a shop with two main thoughts in mind, namely, to obtain a good job properly fabricated to the applicable code or specification, and to expedite the completion and delivery as much as possible. A capable inspector has the advantage of knowing what should be furnished and just what his employer wants, whereas the fabricator is often handicapped by not being fully informed and familiar with the product.

Qualification of a Welding Inspector

An inspector should have excellent eyesight and his physical strength and agility should be sufficient to permit efficient work. He should be familiar with codes, particularly with the one which governs the work he is inspecting, and should have good judgement in their interpretation and application.

He should have had actual experience in the inspection of welding, and it is always advantageous for him to have had personal experience in welding in at least the shielded metal arc (manual) processes. He should be competent to determine, by observing the actual welding operation, whether an operator is securing proper fusion and penetration. *He should know what constitutes a good weld, what conditions are likely to create defects, and how to detect any defects that may occur.*

He should be conversant with filler metal specifications covering stick and continuous electrodes, and know the limitations of various grades. He should be familiar with various non-destructive tests for welding and be able to interpret and evaluate accurately the results of such tests.

His temperament should be such that he can co-operate with the manufacturer and preserve friendly relations between the fabricator and purchaser, but still obtain the required results. He must at all times be honest in his work and dealings with the manufacturer.

He should be familiar with reading drawings and should thoroughly understand welding symbols. He should also be able to write complete, concise and clear reports.

Functional Requirements and Duties of a Welding Inspector

The duties of a welding inspector will, for most types of structures, follow the general sequence of fabrication and will relate to those details pertaining directly to the welding operations (routine checks of materials, dimensions, workmanship etc.). Some of these duties are outlined as follows:-

- Interpretation of drawings and specifications.
- Verification of procedures, and operator qualification.
- Checking applications of approved welding procedures and repair work.
- Selection of production test samples, and the interpretation and evaluation of test results.
- Preparation of records and reports.

The inspector may be called on to interpret that portion of the drawing and specifications concerned with the welding operations, and it is his duty to study those documents in advance in order to display confidence in the execution of his responsibilities. This confidence will reduce or eliminate hesitancy in decisions he may be called on to make, and will serve to assist in the scheduled completion of the work.

Situations may arise where deviations from drawings and detailed specifications are necessary during fabrication of any structure. Where such deviations are warranted, the inspector may be called on to obtain official approval for such changes from the agency responsible for the design and specification.

Where a formal system of processing deviations exists, the inspector may be required to assist the reviewing group which processes the deviation report to its final completion.

Verification of Procedure and Operator Qualification

One of the requirements of codes and specifications pertaining to welding is that which stipulates that the fabricator details the welding procedure he intends to use. The reasons for this requirement, and the importance of adhering to such procedures, are complex. It is sufficient to state here that the requirements have a legal basis, and that aside from these procedures, they are absolutely necessary to control the welding operations and the quality of the structure.

Prior to welding being carried out on a contract, it is the duty of the inspector to verify that welding procedures have been established and approved. Approvals may be either internal to the organization doing the fabrication, or external (client, jurisdiction etc.), or both.

He must ensure that any changes made in the welding procedure do not exceed the limits prescribed, such as changes in essential variables, and that if they do that, the procedure specifications

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are changed accordingly. He must then further ascertain whether requalification of the procedure is required; if it is required, he must see that this is done before proceeding with fabrication.

Codes and specifications pertaining to weldments usually require that welding operators be qualified in accordance with prescribed procedures. It is the inspector's duty to see that each welding operator working on a contract has been properly qualified, and that they carry out work only within the limits of their qualifications.

Checking Application of Approved Welding Procedures and Repair Work

The passing of a qualification test does not ensure proper application of the qualified welding procedure. Therefore, adequate inspection is necessary to determine that the qualified procedure is being properly and competently applied. Practices among different shops will vary, but in all cases the final result should be the same. The inspector, therefore, will encounter various welding practices, but must never attempt to convert one shop's methods to those of another simply because he may be more familiar with one than the other.

It is essential that the inspector be fair and endeavour to exercise sound judgement when applying visual or other inspection procedures, and when assessing the acceptability of the welding. It is his responsibility to see that weldments requiring repair are correctly and properly marked to indicate the location and nature of repair required, and also to judge the acceptability of the repaired welds.

Selection of Production Test Samples, and Interpretation and Evaluation of Test Results

In some types of welding fabrication, inspection of the finished product may be performed on samples selected by the inspector from the production line. Sometimes the selection of such samples is left to the judgement and discretion of the inspector instead of being definitely described by the specification or code.

In such cases the number of samples selected should not be excessive but should be sufficient to determine that the required standards are being met in production. Various tests or treatments may be prescribed for these samples, such as radiography, hydrostatic tests, stress relieving, etc. It is the inspector's duty to see that these tests are properly carried out.

When the various tests have been performed in accordance with the requirements, the inspector must evaluate the results and decide whether they meet the specified requirements. If they do not meet the acceptance standards in every detail, he must make a thorough study of the results and requirements before an acceptance or rejection is made.

Preparation of Records and Reports

Any work performed to a specification or code which requires tests will also require detailed records. However, whether records are required or not, the inspector should keep adequate notes of his inspection work.

It is also his duty to check the records and ensure that they are complete, accurate, in accordance with requirements and available as and when required. The reports and records should be written in a clear and concise form in order that Management and other departments, or whoever else may be

concerned, will have no difficulty in interpreting their meaning. It is also necessary that the inspector himself will be able to understand his own reports when they are the only records available several months later.

The organization of inspection activities, to include the inspection of *all* characteristics which would include the functional requirements of the welding inspector, are discussed under *Visual Welding Inspection*.

VISUAL WELDING INSPECTION

Visual welding inspection is of great importance because it constitutes the principal basis of acceptance for many types of weldments.

It is one of the most extensively used methods of inspection because it is easy to apply, is fast, is relatively inexpensive and, provided the inspection report format is properly organized, gives very important information with regard to the welding operator, the weld, and the general conformity of the weldment to specification requirements.

Welding inspection should begin prior to the actual fabrication operations. The inspector should examine the drawings, specifications, welding procedures and consumables, condition of the welding equipment, and weld operator qualifications. He should also ensure that the parent metal to be joined conforms to the specification requirements, and that it is free from such defects as laminations, laps, seams, scale or other harmful surface conditions.

When the components are assembled for welding, the inspector should note incorrect root openings, improper edge preparation and alignment, and other features of joint preparation that may affect the quality of the welded joint. The inspector should check the details of the work while welding is in progress and these details may include maintaining pre-heat conditions, welding speed and deposition rate, welding current, etc. In short, the inspector must ensure that the weld operator is working in accordance with an approved welding procedure.

Inspection after welding and heat treatment (where required) completes the inspection cycle. At this time the inspector checks the finished weldment for weld width, bead or weave appearance surface defects such as crater cracks, porosity, longitudinal and transverse cracks, non-fusion problems and undercut. Reinforcements should be also checked to ensure adherence to specification requirements. Dimensional checks of the welded component should be carried out at this stage to make sure that the welding process has not distorted the finished assembly beyond drawing tolerances.

As is the case with all other inspection and testing activities, welding inspection should form a part of the planned operations which are set in place to produce a completed fabrication. With the foregoing in mind, it is logical to organize the inspection portions of the fabrication sequence into rational procedures or checklists which will serve not only to standardize inspections but which will also provide a format for the documentation of inspection activities. The following examples will illustrate the foregoing points.

Assume that a pressure vessel is being fabricated and that the first operations consist of preparing, rolling and welding a plate to form a part of the vessel shell. A probable checklist for the inspector would be:-

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INSPECTION ACTIVITY	ACCEPTABLE	NOT ACCEPTABLE
1) Check that plate material conforms with that which is specified on the drawing. 2) Inspect joint preparations to ensure that they conform with drawing requirements. 3) Inspect joint preparations to ensure that they are free from laminations, cracks and other discontinuities which would cause welding problems. 4) After rolling, check the cylinder for dimensional accuracy. 5) Check the weld joint fit-up for gap and misalignment (hi - lo). 6) Sign-off acceptance of assembly for welding operations to continue. Before welding is initiated, the inspector should check the following: a) The welding operator is qualified. b) The operator is cognisant of the approved procedure to which he will weld. c) The supply of consumables is in accordance with those stipulated in the procedure.		
	 Inspector's Signature	

Methods of Testing

The methods commonly used in testing and inspecting welds for the defects previously listed are of two types:— *non-destructive*, and *destructive*. The terms in themselves are descriptive and it is obvious that non-destructive testing would include visual, radiographic, ultrasonic, etc. The term *destructive* might be interpreted erroneously as destructive of the whole weld fabrication by means of an overload test. This, however, is not so, and the word is commonly used to mean some form of mechanical test applied to a typical sample of a weld, or to a section cut from a weld. Such tests are described in Module 12. In the category of non-destructive tests are proof tests which are usually associated with some form of visual inspection for certain types of containers and structures.

Radiography

Radiography is the most commonly used non-destructive method for the detection of sub-surface volumetric discontinuities in welds.

The radiographic method can be applied to most welded joints but is largely confined to butt and corner joints.

As with all testing methods, radiography has certain limitations and it is incumbent upon the welding inspector to have some knowledge of both the methods of radiography used in the inspection of welds: X-Radiography and Gamma-Radiography. Both X-Rays and Gamma rays have extremely short wave lengths and it is this characteristic which enables them to penetrate objects opaque to ordinary light. The two types of radiation can affect sensitized photographic film.

X-Rays are generated in an X-Ray tube by propelling (at high speeds) a stream of electrons against a target constructed of materials with high atomic numbers and high melting point such as tungsten. The electron stream interacts with the atomic structure of the target material, temporarily dislodging electrons. Energy is generated from this dislodgement action, 99% of which is heat and 1% X-Rays. The heat is dissipated by the copper anode and cooling media in the tube housing, and the X-Rays are projected (in a cone from the target material) against the weld undergoing test. See Fig. 1.

The density of the electron stream is controlled by the current (M/A) input, and the wave length (and therefore the penetrating ability of the X-Rays) is controlled by the high voltage input (KV) across the tube.

The system as can be seen from the foregoing is electrical and no ionizing radiation is generated or retained in the system when it is switched off. In addition, the wave length, and therefore the penetrating power, is adjustable.

The equipment is cumbersome and even the units designed for portability are relatively heavy and awkward to manoeuvre. Fig. 2 shows the control box and X-Ray unit positioned to radiograph a weld.

Gamma Rays, as used in radiography, emanate from a radioisotope.

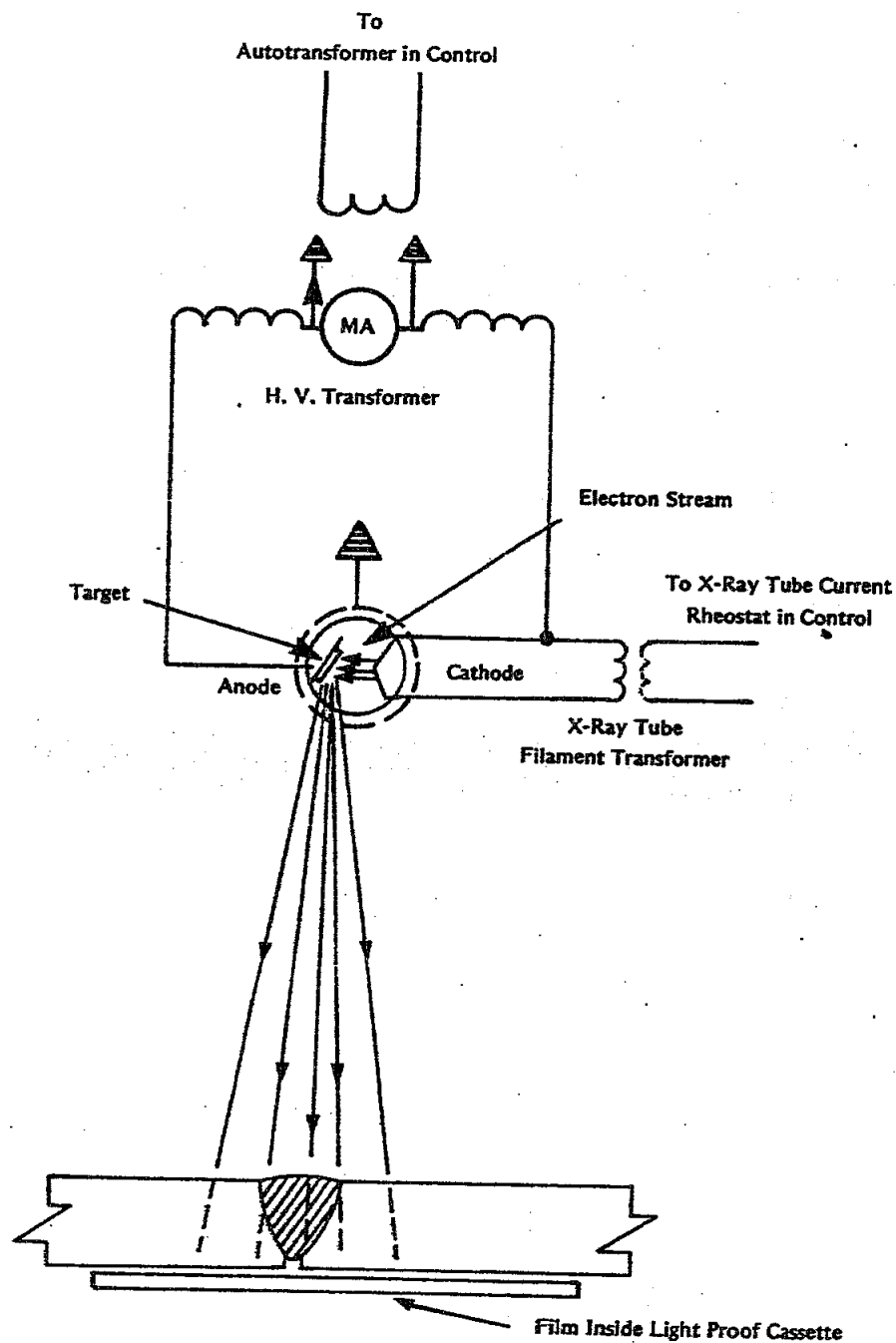
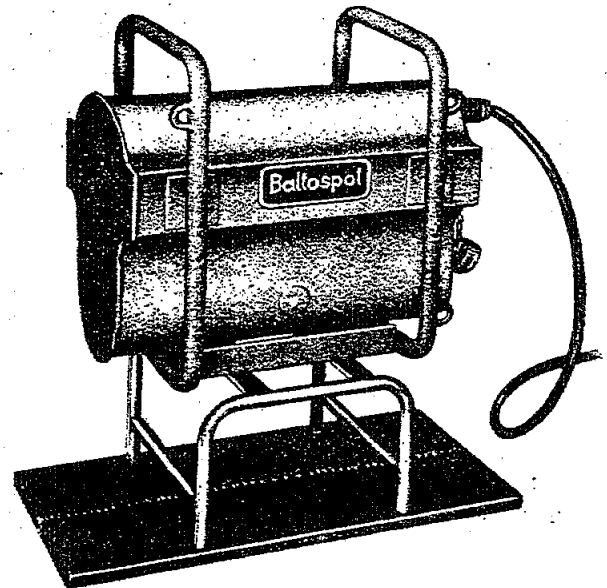


Fig. 1 — Basic Circuit of Self Rectified X-Ray Apparatus



Control Box



X-Ray Unit Positioned to Radiograph a Weld

Fig. 2

Small amounts of materials, such as Cobalt 59 or Iridium 191, are placed in a nuclear reactor and subjected to neutron bombardment. During this time the atomic structure of the Co 59 or Ir 191 captures a neutron. The material is then called Cobalt 60 or Iridium 192 and is in an unstable condition.

In the natural order of things the structure constantly strives to return to a stable condition and in so doing releases energy in the form of Gamma Rays.

The wave lengths of the gamma rays are fixed by the type of isotope (Co 60 or Ir 192) which emits them. Co 60 has wave lengths which are much shorter than Ir 192 and therefore have more penetrating ability.

The sources of radiation are constantly emitting ionizing radiation and cannot be shut off. The sources, therefore are shielded in a protective casing manufactured from extremely dense material such as lead or tungsten. The material absorbs the radiation and protects the operator from exposure (See Fig. 3).

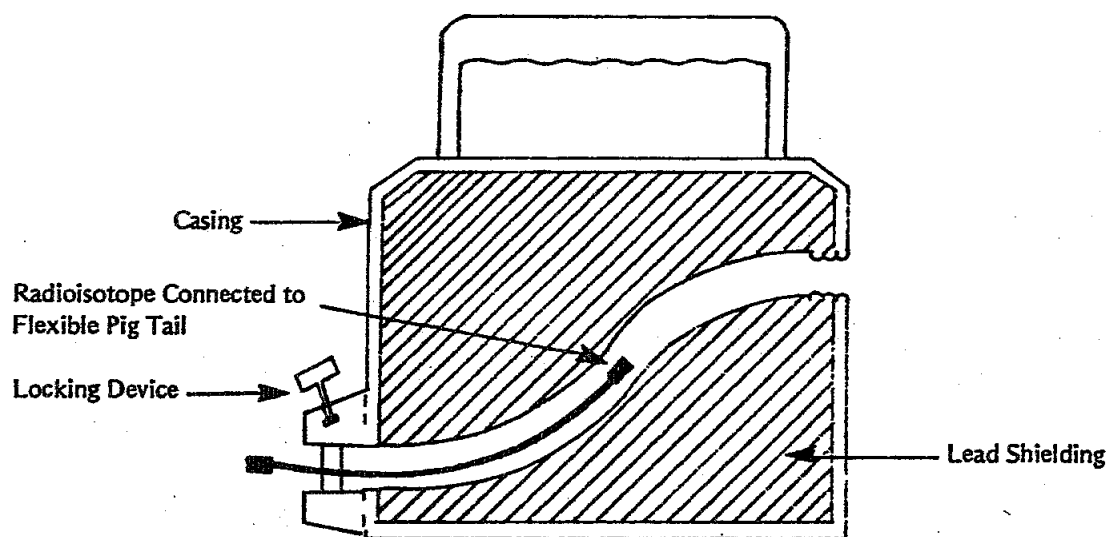


Fig. 3 – Cutaway View of a Typical Isotope Camera

When the source is to be used, it is remotely handled and projected to a position from which the radiation passes through the weld and onto a film, as shown in Fig. 4.

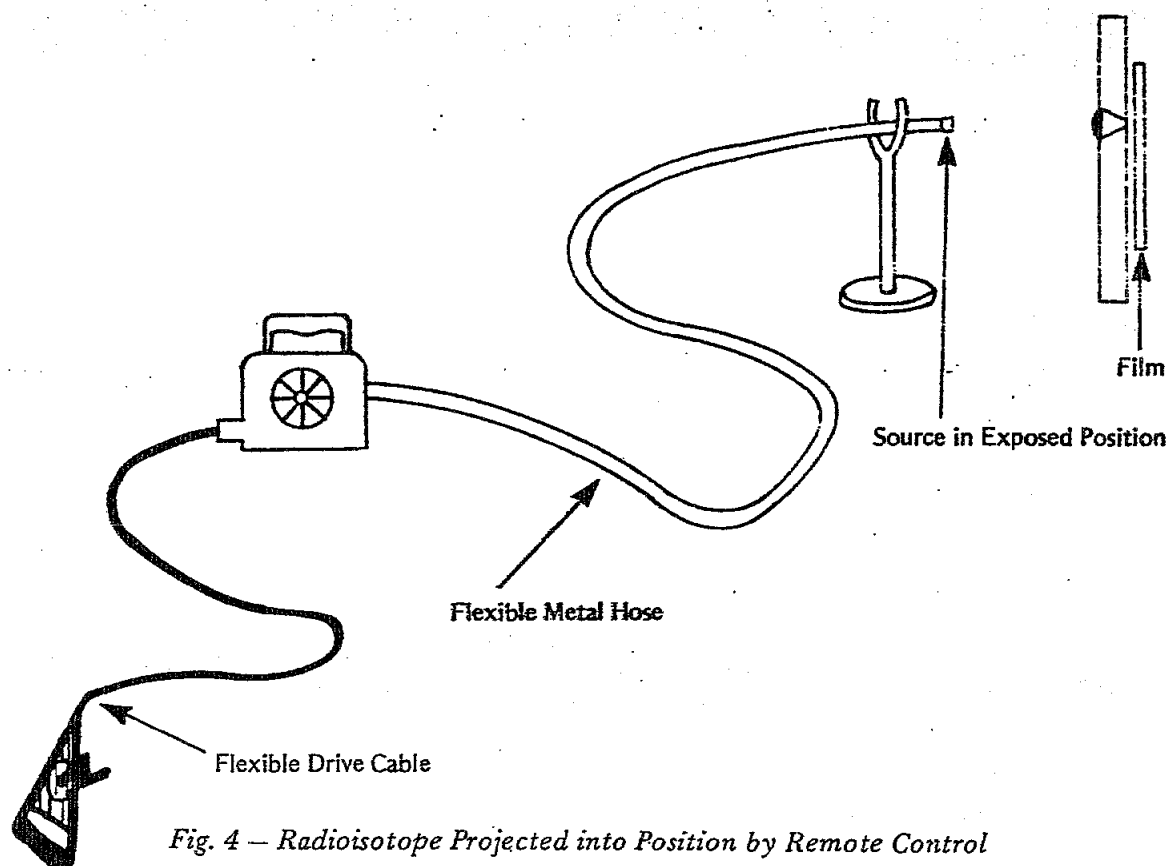
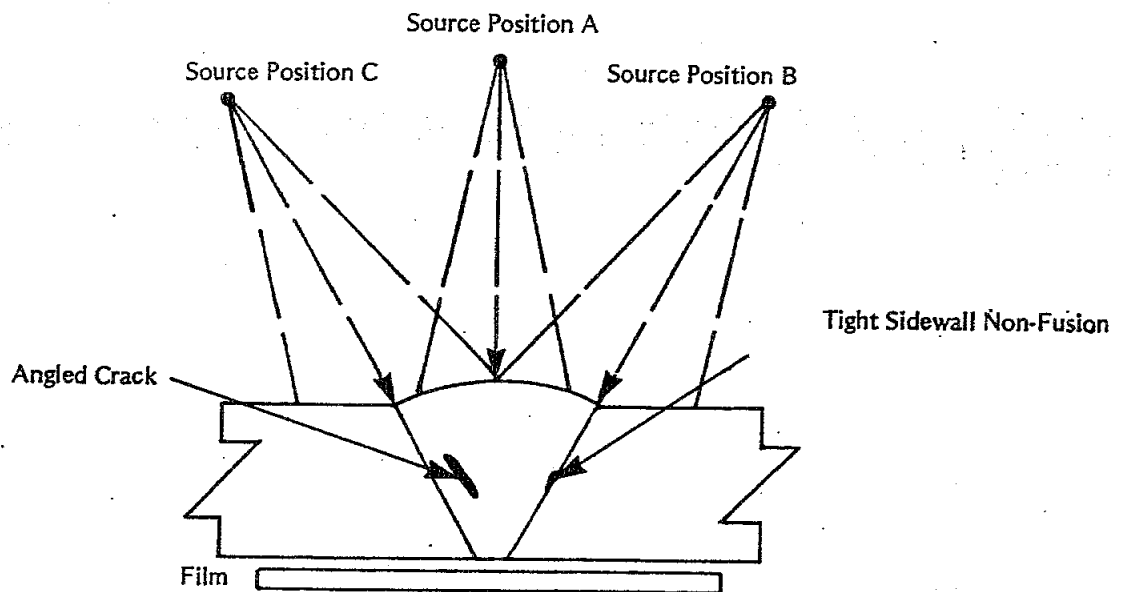


Fig. 4 – Radioisotope Projected into Position by Remote Control

As X or Gamma radiation is directed at the weld a certain amount will be absorbed by the structure of the metal and the remainder will pass through, onto a film which is placed into position. The amount of radiation absorption depends upon the material type and thickness; each material (steel, aluminum, copper, etc.) having a different coefficient of absorption.

When a weld has internal discontinuities such as slag or gas holes, more radiation will reach the film under these areas than in an adjacent area which has no discontinuities and is therefore absorbing more radiation. In this manner differential amounts of radiation reach the film and react on the sensitized emulsion in varying degrees. These differences in radiation absorption through a defective weld appear on the developed film as shadows and are interpreted by the shape and density as to what they represent. (Slag, porosity, gas holes, etc.)

When a defect in a weld does not constitute a relatively substantial difference in the total cross section of the weld, the difference of radiation absorption will be less and therefore the image on the film will not be pronounced. With certain defects such as tight cracks, cold lap, lack of side wall fusion etc., there is a strong likelihood that no discernable image will appear on the film. Where the beam of radiation is not directed into the plane of defect, Fig. 5, the defect can be completely missed.



- Source Position A — No Shadows on Film
- Source Position B — Shadow of Sidewall - Non-Fusion on Film
- Source Position C — Shadow of Angled Crack on Film

Fig. 5

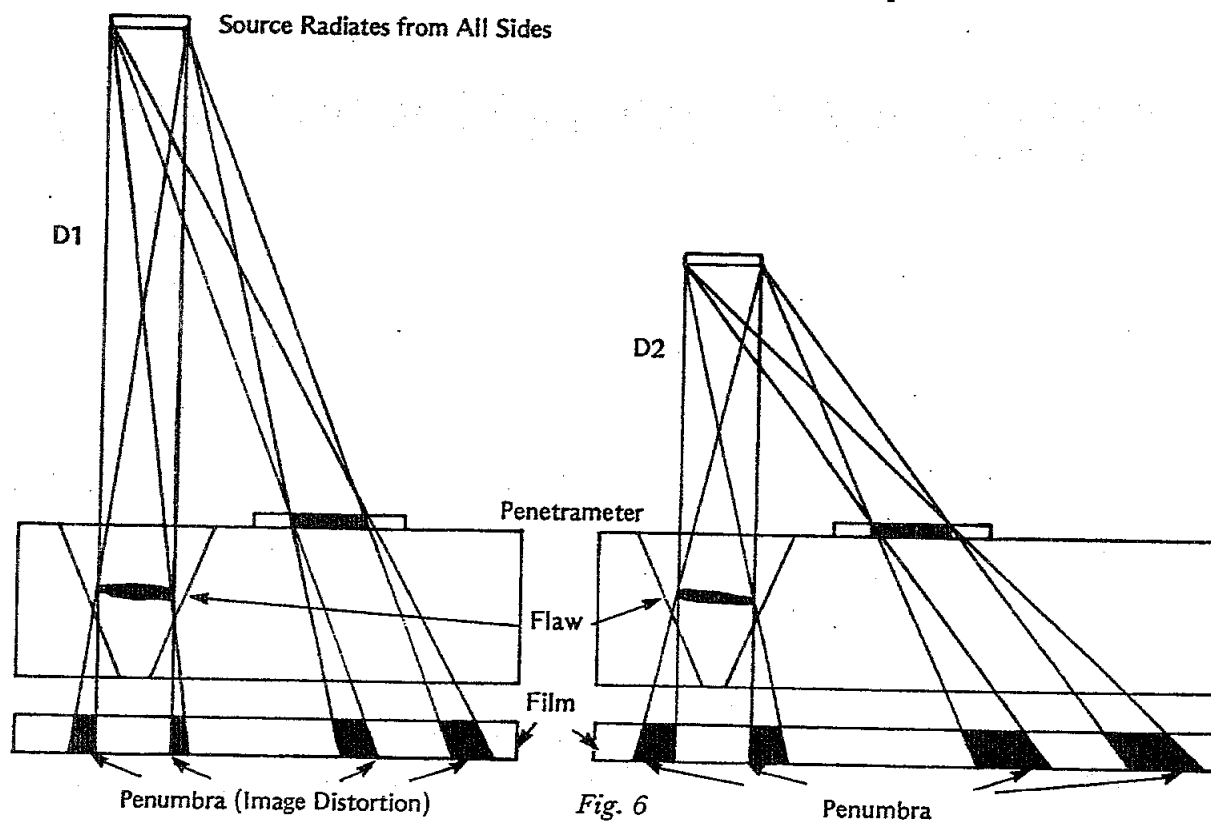
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In general, radiographs made with X-Rays are superior to those made with Gamma Rays mainly due to the fact that, with the X-Ray equipment, wave lengths can be adjusted. In steel up to 2", this fact is demonstrated by superior radiographic sensitivity and clarity of the defect image. Above 2", the wavelengths necessary to penetrate the steel are of the same order of magnitude to those of gamma radiation so that radiographic sensitivity is reduced somewhat.

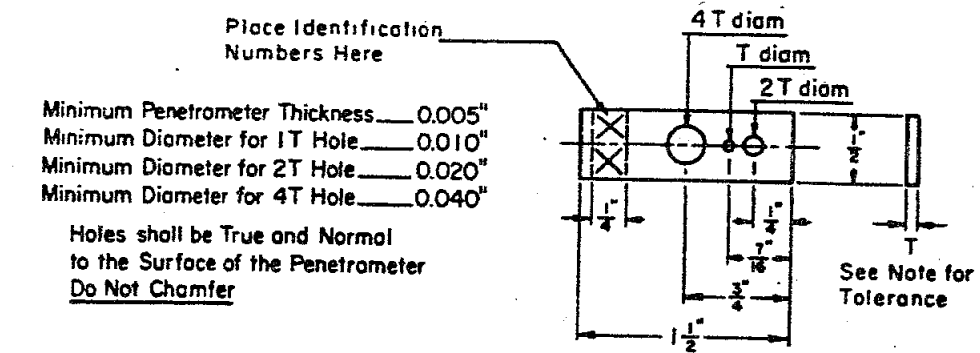
Construction codes such as ASME Boiler & Pressure Vessel Code, Section VIII, CSA Standard W59 & AWS D1.1, etc., dictate that the way in which a radiograph is produced (procedure) will meet specific requirements. One of these requirements which is important to a welding inspector is the use of a device known as a *penetrameter*. The penetrameter, also known as the *image quality indicator* (IQI), Figs. 6 and 7 (b), is placed on the parent material adjacent to the area of the weld which is to be radiographed *on the side of the material which is closest to the source of radiation*. Figs. 7 (a) and (b) indicate the size and placement of ASME B & PV Code penetrameters. Fig. 8 indicates the placement of CSA W59 penetrameters.

The penetrameter has holes, and sometimes slots of specific dimensions machined into it. The sizes of the holes are relative to the thickness of the device. In general, the construction codes will dictate that a penetrameter thickness shall be 2% of the thickness of the material which is to be radiographed.

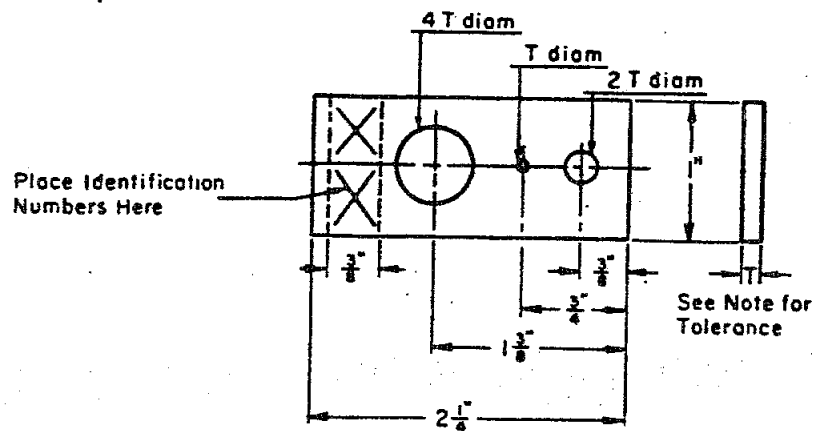
Although some schools of thought equate the size of the smallest defect discernable in the weld with the smallest hole discernable in the penetrameter, this is open to serious dispute. The penetrameter, is therefore used to assess the quality of the *radiographic technique*.



Reduction of Source to Film Distance (D) adds to the image distortion. Penetrameters serve to preclude this possibility because the image must be clear enough to enable the interpreter to see the outline and the qualifying holes.



Design for penetrometer thickness from 0.005 in. and including 0.050 in.
 From 0.005 in. through 0.012 in. see Table 1.
 From 0.012 in. through 0.020 in. Made in 0.0025-in. increments.
 From 0.020 in. through 0.050 in. Made in 0.005-in. increments.
 Penetrometer thicknesses between the increments indicated are permitted, provided they do not exceed the maximum thickness required.



Design for penetrometer thickness from 0.060 in. to 0.160 in. incl.
 Made in 0.010-in. increments.

Fig. 7 (a)

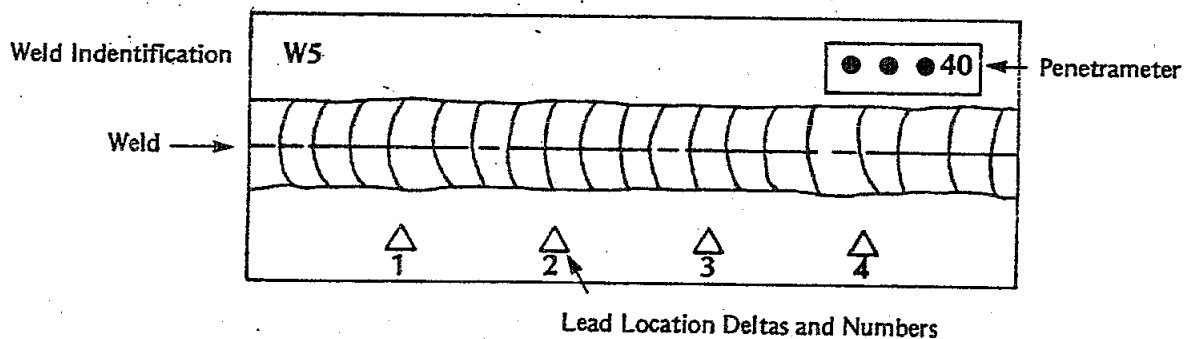


Fig. 7 (b)

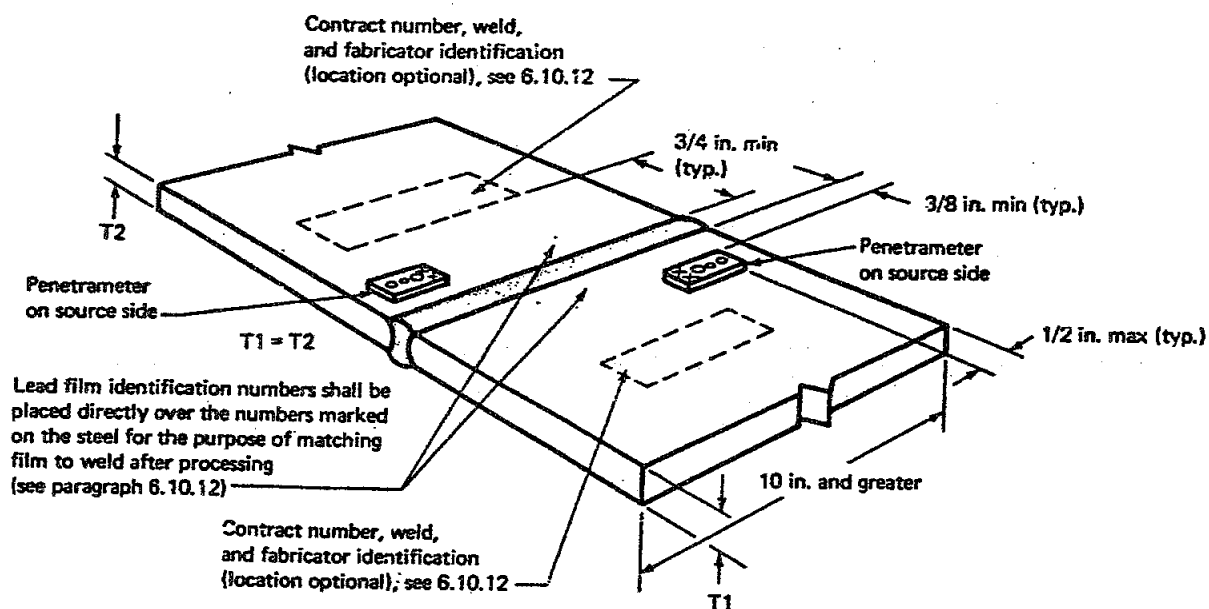


Fig. 8 (a) – Radiograph Identification and Penetrometer Location on Approximately Equal Thickness Joints

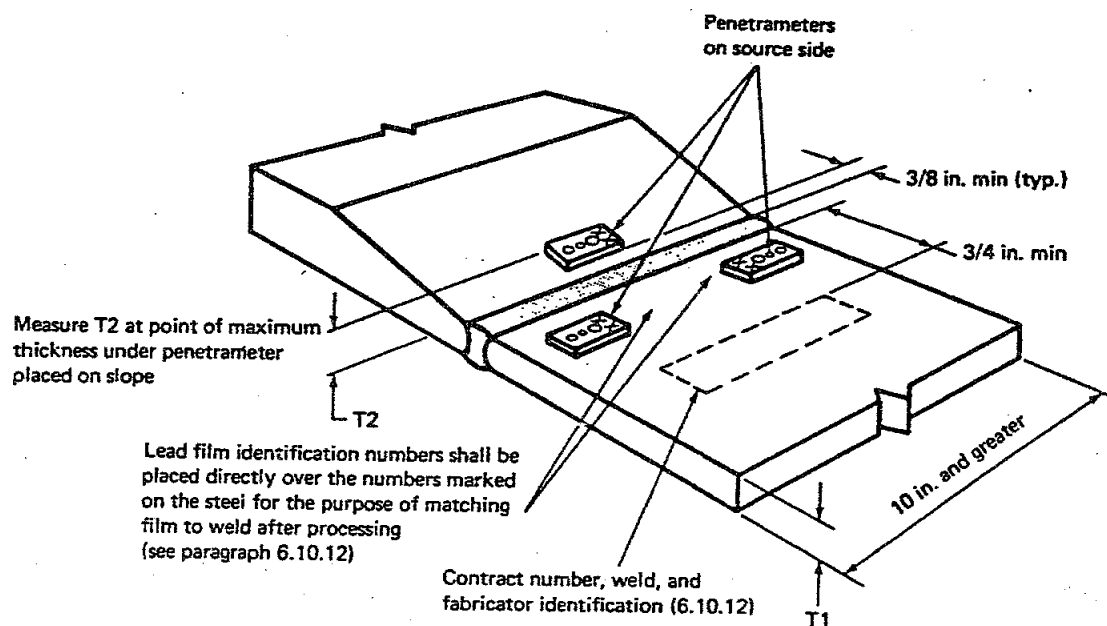


Fig. 8 (b) – Radiograph Identification and Penetrometer Location on Transition Joints

According to the ASME Boiler and Pressure Vessel Codes, at least one penetrameter shall be used for each exposure, to be placed at one end of the exposed length, parallel and adjacent to the weld seam. Where the source is placed to radiograph a circumferential seam with one 360° exposure, three penetrameters located at 120° intervals shall be used.

The thickness of the penetrameter shall not be more than 2% of the thickness of the plate. In each penetrameter there shall be three holes of diameter equal to one, two and four times the penetrameter thickness; but in no case less than .010". Tables in the codes indicate which of the holes must appear as images on the radiographs. Each penetrameter has numbers affixed to it which identify the material and minimum thickness of the plate. Figs. 6, 7 (a) and 7 (b) illustrate the ASME Code penetrameter and placement.

In other codes and standards, penetrameter size and hole dimensions may be different, as in CSA Standard W59.

Standards of acceptability, for welds subject to radiographic examination, have been set up by various code committees and are detailed in codes and standards such as ASME Sections I, III and VIII, API 650, CSA Standard W59. ANSI B31.1 etc.

Some fabrication shops use radiography as a quality control tool even when the welding is not required to be radiographed. In this event, acceptance standards are set in an arbitrary manner by company management.

When the radiographic report specifies that defect indications are unacceptable the defective area of the weld is removed and the cavity re-welded. The repair is then radiographed in accordance with the original procedure.

Radiography is the most successful and reliable method for non-destructive testing of welds. There are limitations to the test method, some of which have been pointed out. Where the limits of the method have been defined, it is probable that an alternative test, such as ultrasonics, will serve to complement radiography.

Extreme caution must be used when operating both X-Ray and Gamma Ray equipment. The radiation is ionizing and dangerous to health. All radiation areas must be quarantined and posted.

X-Ray Fluoroscopy

This system is used to good advantage in production line system such as automatic long seam welding of pipe in a piping mill.

Fluoroscopy utilizes an X-Ray tube and a screen which fluoresces when radiation strikes its surface. The geometric arrangement of the X-Ray source, object under test, and imaging screen is the same as that used in normal radiography.

The system is not as sensitive as the X-Ray film technique because sharp image definition is somewhat more reduced due to the nature of the fluorescent material, limited brightness and the large grain size of fluoroscopic screens.

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Direct viewing of a fluoroscopic screen can subject the observer to relatively high body doses of radiation. In order to preclude this undesirable physical hazard, closed circuit television systems can be applied to industrial fluoroscopy. Remote viewing is therefore possible.

The speed of scanning a weld using conventional fluoroscopic examination has been estimated to be about 1.4 inches per second for accurate inspection. The smallest resolvable defect for a specific system is in the order of 0.012".

The main advantages of a fluoroscopic system are:-

- a) Instant test results (no delay due to film processing)
- b) Film costs are eliminated

Disadvantages include:-

- a) Reduced image definition
- b) Lack of permanent test records

Ultrasonic Testing

For many years railroad wheels and similar items were subjected to hammer tests. The pitch of the sound emanating from the wheel indicated to the inspector whether the wheel was flawed or not. The sound waves emitted during these tests were of frequencies up to 20 KHz, (20,000 cycles per second) that is, they were audible to the human ear.

One of the modern methods of testing welds is called *ultrasonic testing*. This method utilizes sound frequencies between 20 KHz to approximately 10. Mhz (10,000,000 cycles per second).

Ultrasonic sound waves are generated by applying electric pulses to piezoelectric crystals such as quartz or barium titanate. These crystals vibrate, and electrical energy is transferred into mechanical energy. In effect, when the crystal is placed on a material (i.e. steel) *the pulses turn the crystal into a hammer*.

The two main ultrasonic beam modes used in weld testing are *longitudinal* and *shear*. Longitudinal waves are propagated as pressure waves, that is, the particles of the material under test oscillate in the direction travelled by the ultrasonic waves as shown in Fig. 9.

As can be seen in Fig. 10 when shear waves are propagated, the particle motion is transverse to the wave direction.

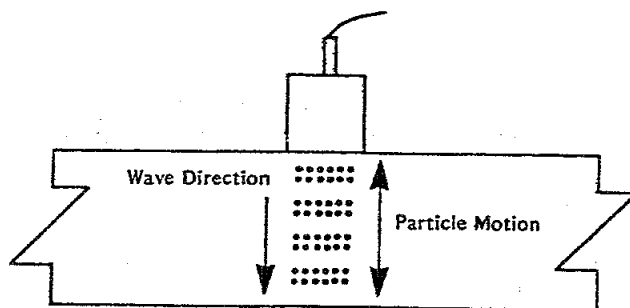


Fig. 9 — Longitudinal Wave Propagation

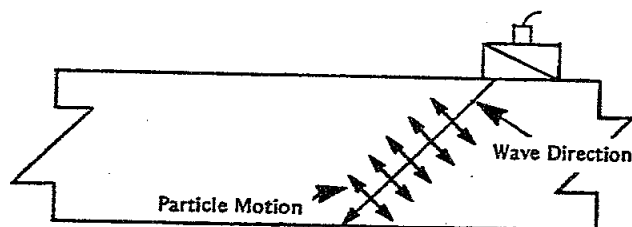


Fig. 10 — Shear Wave Propagation

The mechanical energy is transmitted through the particles of the material undergoing test. The velocity at which the ultrasonic beam moves through material is constant for that specific material and for the wave mode. (Longitudinal Wave or Shear Wave). For example, in carbon steel a longitudinal wave beam moves at a velocity of .585 centimeters per micro second and a shear wave beam at a velocity of .323 centimeters per micro second.

When a change occurs in the material (such as a void caused by a defect), the velocity of the beam changes and what is known as *acoustic mismatch* occurs. When this happens, part of the sound beam is reflected back to the crystal, transformed back into electrical energy and projected on to an oscilloscope.

Any flaw in the material will cause acoustic mismatch and reflect the ultrasonic beam. The complete cycle of this action is shown in Fig. 11.

This phenomena of reflection due to acoustic mismatch is the basis of all ultrasonic testing.

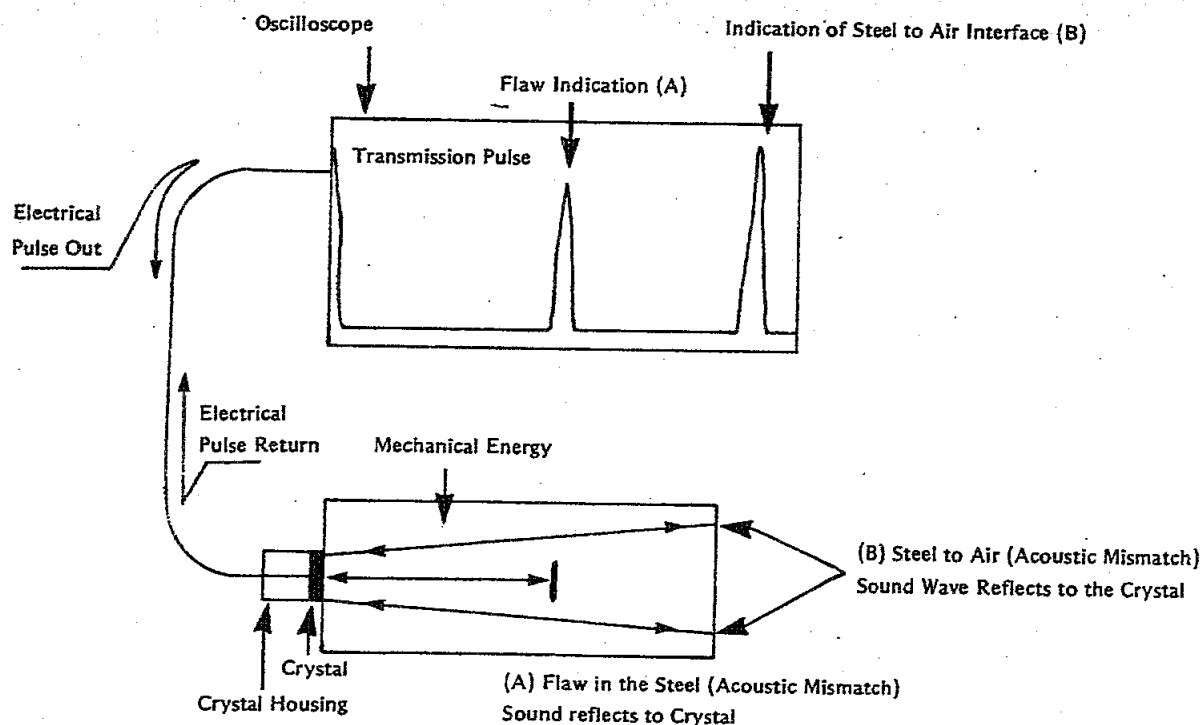


Fig. 11

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Weld testing using ultrasonics requires very precise procedures both for calibrating the test equipment and locating and evaluating discontinuities. As indicated previously, both longitudinal and shear wave modes can be generated. In weld testing both modes are used. Fig. 12 briefly illustrates the different modes.

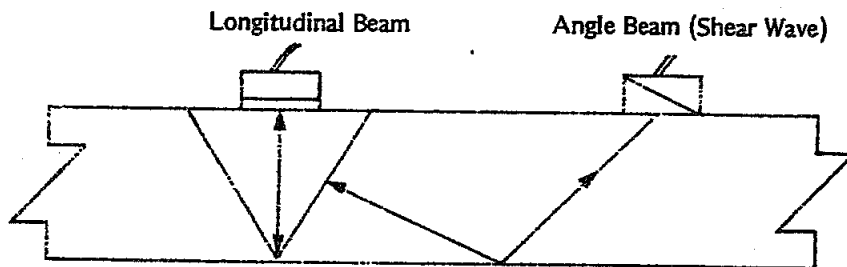


Fig. 12

The ultrasonic test system, as described, can be used for testing welds in almost any thickness except that, under approximately 1/8", interpretation of test results would be so difficult as to render the test impracticable. On thin sections other ultrasonic test methods using resonance are sometimes used.

The system used for weld testing is extremely sensitive, and provided that the wave length is short enough, can detect extremely small defects.

The system will detect all types of defects, but, in order to provide a maximum indication on the oscilloscope, the ultrasonic beam should strike the major face of the defect at 90° . For this reason evaluation of a weld defect is usually done using more than one angle (i.e., 45° and 60°).

Before an ultrasonic operator can start to test a weld he must know certain facts in order to generate the correct technique. The following describes a few examples:-

1. The Welding Method

Reason:

Knowledge of the welding method is important, particularly when the operator is evaluating the type of defect. For example, slag would not normally occur in a weld deposited with the bare wire gas shielded method. Tungsten inclusions would not be found in a weld made with stick electrodes.

2. The Type of Material and Heat Treat Condition

Reason:

He must know the material velocity because it will affect his distance and angle calculations. Heat treatment in some materials affects velocity slightly.

3. The Joint Design

Reason:

He must know the angles of the weld bevel because one of the angle beams he selects must interact as closely as possible with the bevel at 90° in order to detect lack of sidewall fusion. For example, if the weld bevel is 30° one of the probes will be 60° ($60^\circ + 30^\circ = 90^\circ$) and if the bevel is 35° , the probe selection would be 55° (See Fig. 13).

Where the weld joint configuration is such that the ultrasonic beam cannot be manipulated so that it will interact with the bevel, or other areas of interest, at 90° , an alternate method to the single transducer technique may be used (See Figs. 14 and 15). This method is known as the *pitch and catch* technique and, as can be seen from the illustrations, the ultrasonic beam is projected by the transmitting transducer against the reflecting surface, and is reflected by that surface to a receiving transducer.

A backing strip can affect the technique and a difference in the thickness of the plate being joined can affect the technique.

If an ultrasonic test operator does not have detailed knowledge of the test subject, he cannot perform an adequate test.

Most of the ultrasonic test systems used in shop or field conditions do not provide for a permanent record of test results. The interpretation is usually made by the operator. From this it can be seen that he must be reliable and a person of integrity, as well as being highly trained, and that his written reports must be accurate and reliable.

Once a technique has been detailed, the actual test is completed in a relatively short time.

The nature, size and orientation of a specific fault is not easy to plot. This evaluation process requires considerable experience and judgement.

Radiography can be used to complement the ultrasonic tests by first using ultrasonics to rapidly locate the fault, and then radiographing the area to both define the problem and have a permanent record. Conversely ultrasonics complements radiography due to its ability to define tight lack of fusion and cracks much more satisfactorily than radiography. It can also be used to locate the depth of a defect disclosed by radiography. This information is extremely valuable in welds which are accessible from two sides, to determine from which side a repair should be made.

Figs. 13, 14 and 15 illustrate a number of techniques used to detect straight sided defects, both perpendicular, and angled.

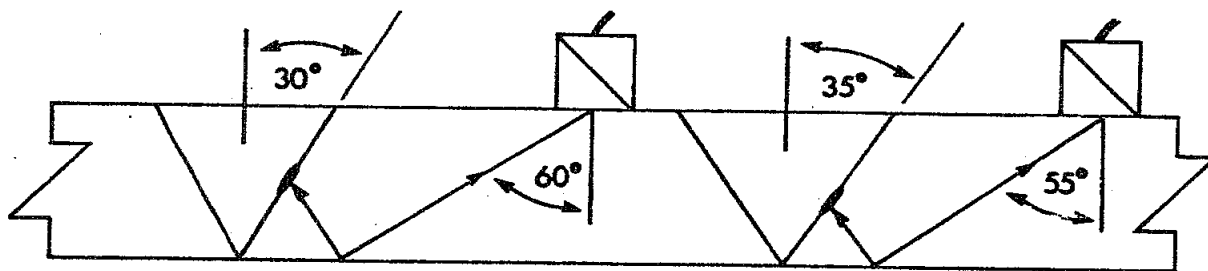


Fig. 13 – Single V Weld
Lack of Side Wall Fusion - Probe Selection Predicated on Bevel Angle

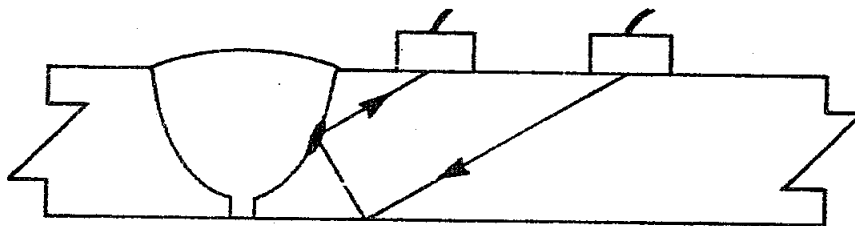


Fig. 14 – Double J Weld
Lack of Side Wall Fusion - Pitch and Catch Method - Weld Preparation Almost Perpendicular

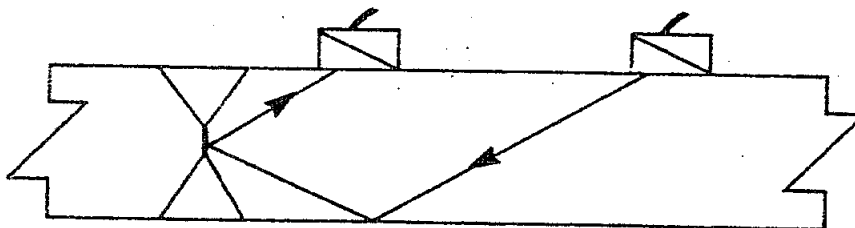


Fig. 15 – Double V Butt Weld
Incomplete Penetration - Pitch and Catch Method - Reflecting Surface Perpendicular

Fig. 16 illustrates an ultrasonic unit with a single probe, and Fig. 17 shows a technique using an angle probe to detect lack of penetration in butt welds welded from one side.

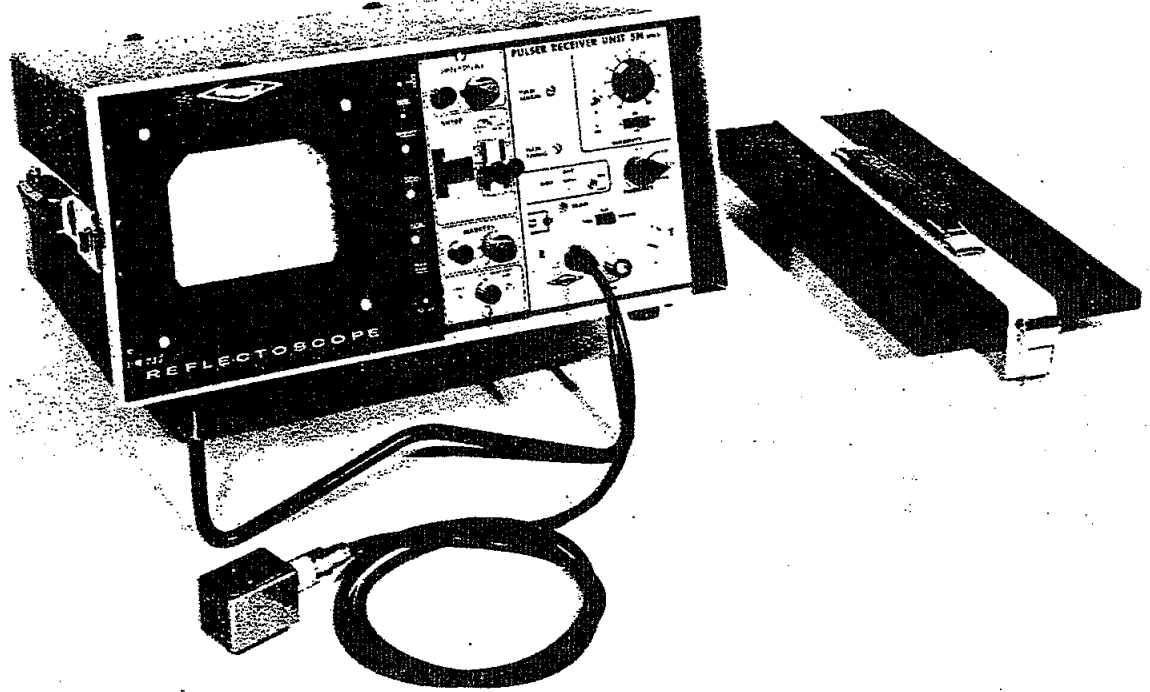


Fig. 16 – Portable Ultrasonic Instrument

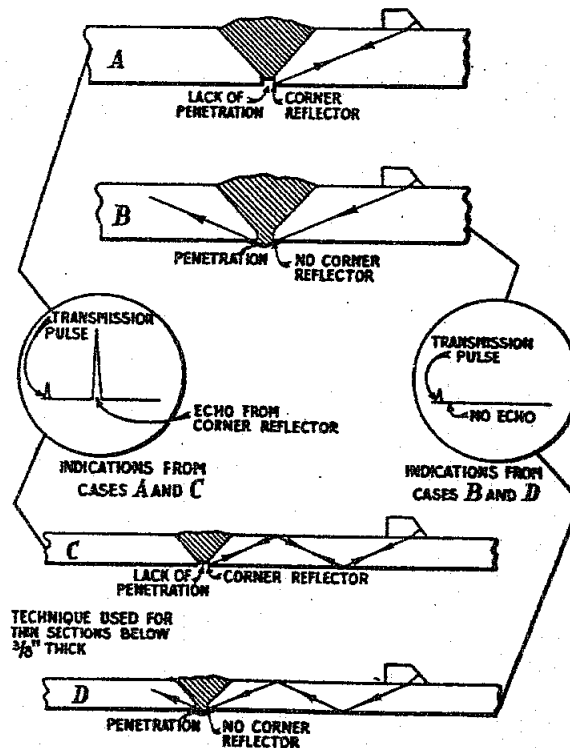


Fig. 17 – Lack of Penetration Indicated by Echo Blip on Ultrasonic Oscilloscope, Schematic Diagram

Basic Inspection Technology

Magnetic Particle Inspection

Another method of testing, *Magnetic Particle Inspection*, utilizes a magnetic field which is induced in steel or other magnetic ferrous alloys.

If this field is interrupted by a discontinuity, such as a crack in the material, the field will become distorted at the point, and a north and south pole will form at each point of material separation (Fig. 18).

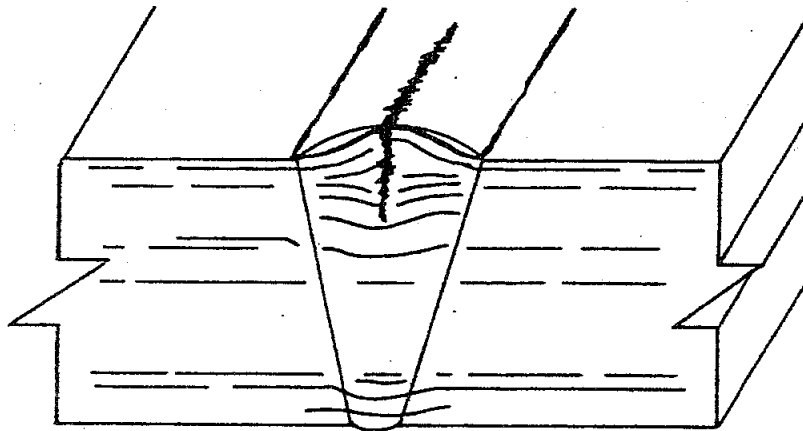


Fig. 18

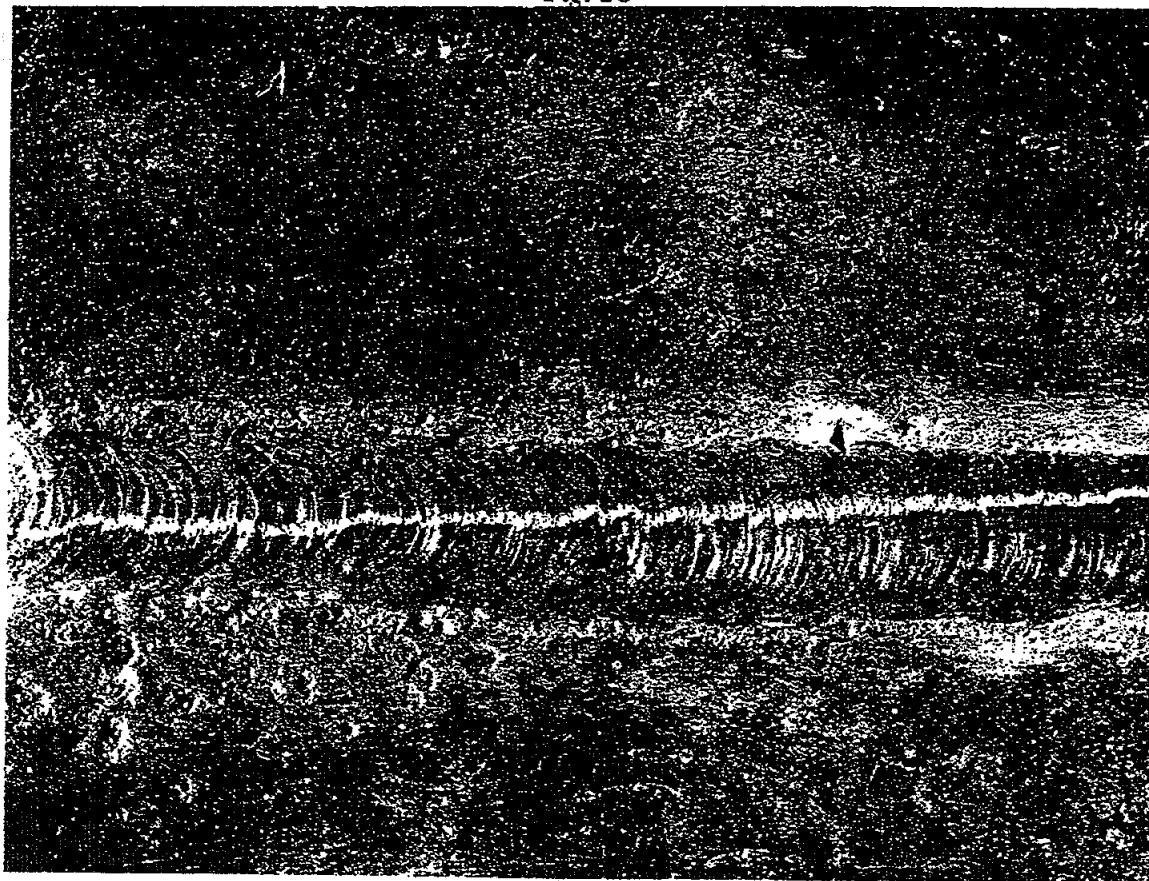


Fig. 19 — Magnetic Lines of Force Follow Path Around Surface Defect; Leakage Field Formed at Surface of Weld Attracts and Holds Magnetic Powder in Sharp, Well-Defined Build-Up

If fine magnetic particles are applied by spraying or dusting onto the test object, the north and south poles of the crack faces will attract the particles, which will form a visible bridge across the gap. See Fig. 19.

The magnetic field can be induced into the part in a number of ways depending upon the form and finish of the part.

The most common way to induce the field in the testing of welds is by the prod method using *direct current or alternating current*.

When direct current is used it is possible to detect surface defects as well as linear defects which are sub-surface and do not break to the surface of the weld.

Alternating current is normally used where defects break the surface of the weld or component under test. The prods are positioned in such a manner that the magnetic field intersects with the defect. For this reason the prods should be placed in two positions in order to detect linear defects parallel to the direction of weld, and linear defects transverse to the direction of weld. See Fig. 20.

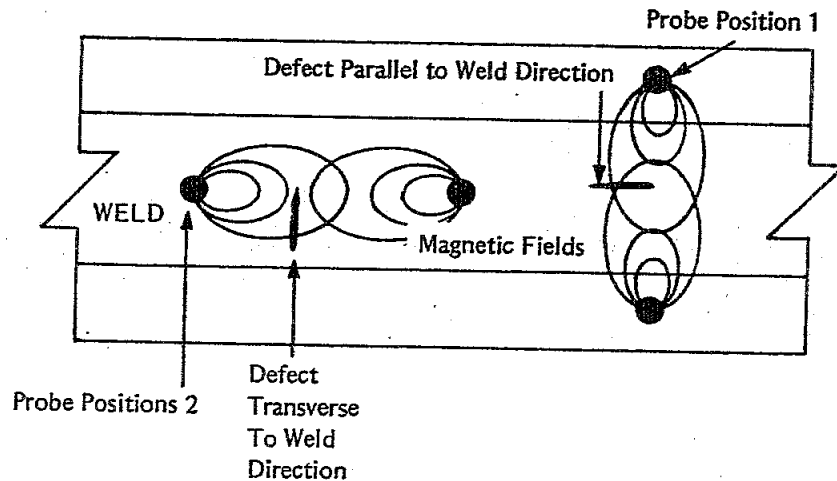


Fig. 20

The surface roughness of the weld will cause some loss of effectiveness and sensitivity, but even in these circumstances it is an excellent tool to disclose major weld defects, which otherwise would have been missed.

The equipment used in magnetic particle testing of welds can be extremely bulky and awkward to handle, or it can be light and portable. The heavy equipment is used to generate high DC current which is used where a sub-surface linear defect must be disclosed.

The lighter equipment, such as *AC Yokes* or *permanent magnets*, is used when defects penetrate to the surface of the weld, but are still too tightly structured to be detected by normal visual inspection. Magnetic particle testing can be used in all positions including overhead, and semi-skilled persons can be used to perform the actual test. However, the test results must be interpreted by a skilled and qualified magnetic particle operator. Fig. 21 illustrates a portable magnetic particle inspection unit.



Fig. 21 – Portable Magnetic Particle Inspection Unit

Because the test is a magnetic method it is not applicable to materials which are non-magnetic, such as aluminum, brass, bronze and austenitic stainless steels.

The magnetic particles used as the detection medium are fine iron powders of various colours (to provide a contrast against a given background).

Another type of detecting media is a solution of iron powder and a suspension medium. The iron particles in this method are coated with a fluorescent material which is most brilliant when viewed under a near ultra-violet light (black light). The fluorescent method is not recommended for use on material in the as-welded condition because random fluorescent materials may be retained in the crevices of the weld bead and this may confuse the inspector.

Liquid Penetrant Inspection

Liquid penetrant inspection is one of the oldest methods of non-destructive testing, and is based on a very simple process. A liquid penetrant is applied to the surface of a weld, and is permitted to dwell on the weld for a specific period of time during which it penetrates into any discontinuities open at the surface. When the dwell time is completed, the excess penetrant that remains on the surface is carefully removed. (If liquids are used to remove excess penetrant material, the operator

must ensure that the surface is dry before the next step in the procedure takes place.) An absorbent light-coloured powder (*developer*) is now applied to the surface. This developer acts like a blotter and draws out the penetrant which has seeped into cavities in the weld surface. As the penetrant is drawn out, it spreads into the thin layer of developer forming visible indications. The indications are actually much wider than the cavities with which they are associated, and there is a direct correlation between the *amount* of 'bleed out' of the penetrant material, and the depth of the cavity.

It is very important to ensure that the weld is free of grease, oil and dirt prior to applying the penetrant materials. It is also important to clean all penetrant materials from the weld and parent metal after the test is completed and the test results noted.

Figs. 22 to 26 illustrate the steps taken in the liquid penetrant testing of welds.

Clean the weld zone surface with a solvent to remove grease, dirt, etc. The penetrant cannot enter the cavity if it is plugged with foreign material.

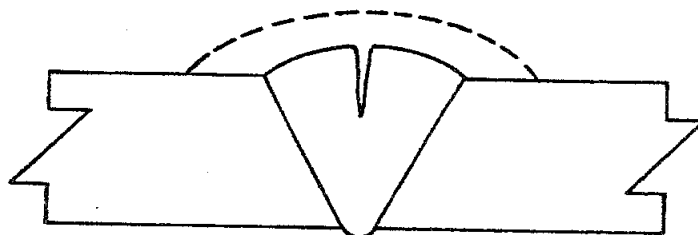


Fig. 22

Apply liquid penetrant to the weld zone and allow to dwell for the recommended period of time. Note that by capillary action the fissure in the weld is filled with penetrant.

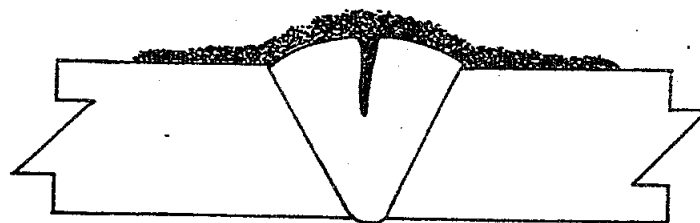


Fig. 23

After the dwell time is complete, remove surface penetrant. A fine water spray (when the penetrant is water soluble) or solvent remover is used for this operation and it must be ensured that the surface is clean and dry.

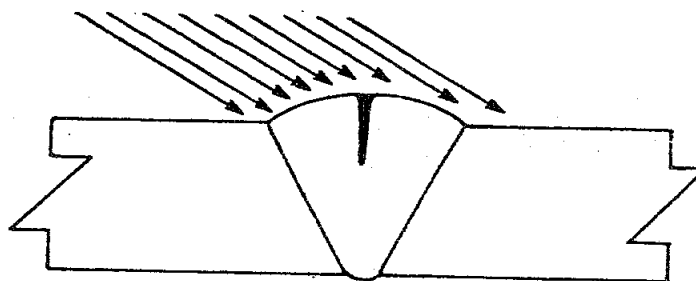


Fig. 24

Basic Inspection Technology

Apply the developing medium and, after a prescribed time, the penetrant is drawn from the cavity to form the visible indication.

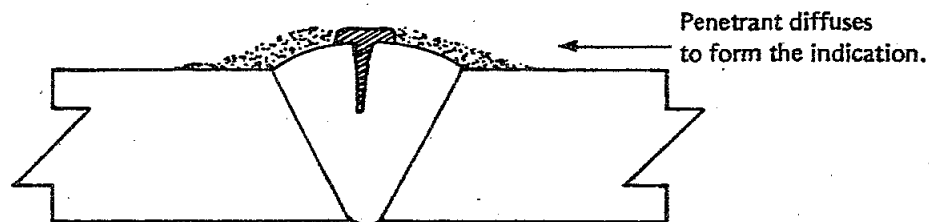


Fig. 25

Clean all traces of penetrant materials from the component using water or solvent depending on the type of penetrant used.

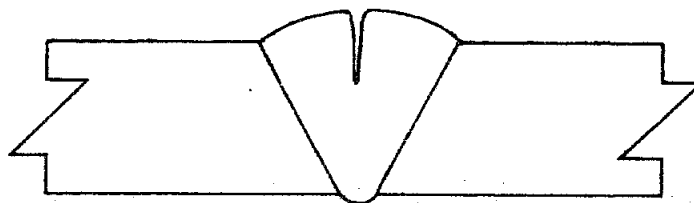


Fig. 26

There are several types of penetrant materials on the market. When choosing the type of penetrant materials, the inspector should be aware that where austenitic stainless steels are being tested, some specifications limit the halogens which can be present in the liquids. It should be remembered that halogens can cause stress corrosion cracking under certain conditions. In the welding and testing of nuclear components, the materials used in penetrant testing must be certified as to halogen content.

The two basic types of penetrant are:

- 1) *Visible Dye*, (that is, the penetrant is coloured to provide a contrast) and the viewing in this method is done under white light.
- 2) *Fluorescent Dyes*, the viewing of which is done under ultra-violet or "black light" (near ultra-violet light).

The penetrant testing methods are reasonably quick to apply and obtain test results but not as fast as magnetic particle testing, and although penetrant testing is done on both austenitic and carbon steels, it is more efficient to use magnetic particle testing on the carbon steels.

When using penetrants on welds which have not been dressed, much care must be taken in cleaning the surplus penetrant out of the ripples, otherwise confusion is the rule when attempting to interpret the test results.

Detection of leaks by fluorescent penetrant through welded joints in tanks and containers is very effective. The operator applies the penetrant on one side of the weld, and after a suitable time the penetrant travels through any leak path and is revealed by scanning the opposite side under black light.

In addition to the normal detection of cracks and leaks, this method is particularly suited to revealing micro cracks in welds, and has also been used in liner tightness tests in the inspection of welds made in attaching corrosion resistant liners to vessel walls, and in the testing of weld overlay.

Acoustic Emission Analysis

Acoustic Emission Analysis utilizes stress waves produced by defects propagating in a material under load. Piezoelectric transducers and preamplifiers are placed in predetermined localities on a structure.

Stress waves are detected by the transducers, amplified and passed through a system of computers and graphic equipment. The data is then analyzed as to location of the site of the stress waves. Cause of the indications is investigated by applying conventional non-destructive tests such as ultrasonics, radiography, etc., at the location from where the signals are emanating.

This system of detecting propagating defects is extremely sophisticated, and is costly to apply. At the present time, it is applied to some heavy walled pressure vessels in the nuclear and petroleum refining industry, but it is not in general use as an inspection tool.

Fig. 27 illustrates some of the instrumentation used in Acoustic Emission Analysis.

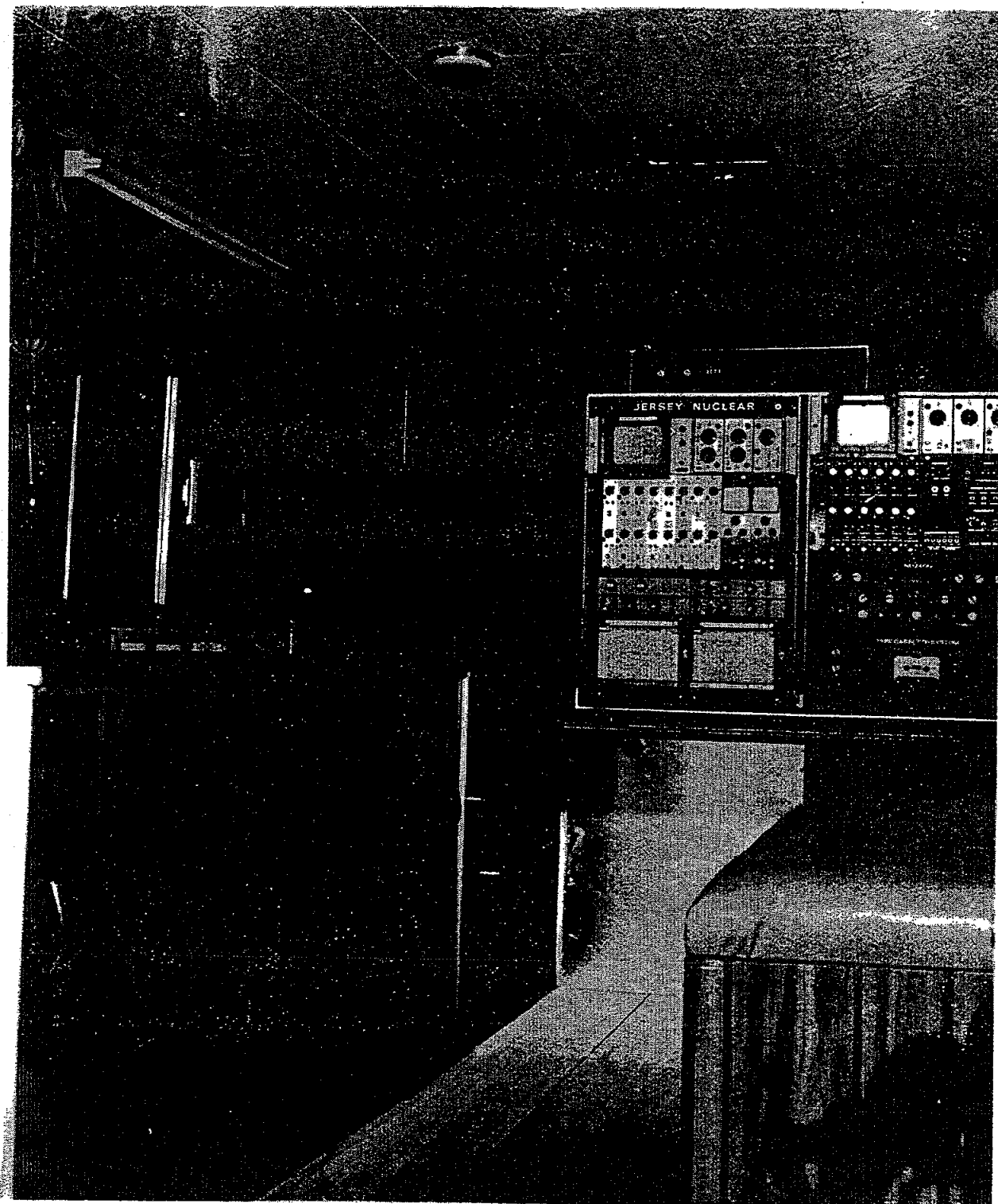
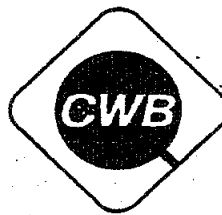


Fig. 27 — Acoustic Emission Analysis Instrumentation Mobile Unit

GUIDES AND EXERCISES

MODULE 11

BASIC INSPECTION TECHNOLOGY



BASIC INSPECTION TECHNOLOGY

MODULE 11

Guides & Exercises

To obtain maximum benefit from this module we suggest that you follow this guide and complete the exercises as indicated. It is important that you work through the text methodically, studying each section thoroughly before moving on. The exercises are designed to give you an indication of whether you have learned the material and can move on or whether you need to go back and study the section again.

Do the exercises honestly. They will not help you unless you take them seriously. If you get a question wrong go back through the text until you understand where you have gone wrong and know the correct answer.

The length of time required to complete the module will vary from student to student. Find your own pace. Do not rush. Remember you are trying to teach yourself something, not win a race.

Some people like to underline sections when they read a text. We suggest that you use caution if you do this. What you think is important first time you read it may be different after reading it three times. We suggest you read a section three times thoroughly before highlighting anything.

The last exercise is designed to give you an indication of whether you are ready to take the WIC closed-book exams. The exercise questions are of a similar standard to the official exams. Do not take the exam until you feel you are ready and you may wish to study several Modules before taking the exams on each. The details of the examination procedures are on a separate sheet.

If you have any difficulties with this Module do not hesitate to ask for help. You may find you learn more by attending some of the seminars and you should also contact your local WIC Chapter to see if they can be of assistance. Remember, if you fail the examination you can always try again later.

Guide 1

Carefully read pages 2 to 5 and answer the following questions:

1. An inspector acts as a responsible representative of an organization, (circle one letter only)
 - a) His decisions are governed by some form of written list of requirements which he has drawn up.
 - b) His decisions are governed by some form of written lists of requirements which others have drawn up.
 - c) His decisions are governed entirely by his own opinions.

2. True or False?

Because of the variety of welded structures requiring inspection, an inspector is required to be proficient in all types of inspection.

3. One of the qualifications of a welding inspector is: (circle one letter only)
 - a) He must possess formal qualifications and certification in various non-destructive tests.
 - b) He should be able to interpret and evaluate accurately the results of various non-destructive tests.
 - c) He must be a certified Engineering Technologist.

4. Where deviations from the drawings are warranted, the inspector (Circle one letter only)
 - a) Authorizes approval of such deviations.
 - b) May be called on to obtain official approval.
 - c) Must reject the work without any further consideration.

5. True or False?

Procedures are not absolutely necessary to control the welding operations and quality of the structure.

6. At what stage should welding inspection begin?

Check your answers for accuracy. If any of your answers are wrong re-study the guide subject matter until you understand it.

MODULE 11

Guide 2

Carefully read pages 7 to 15 and answer the following questions:

1. Radiography is the most commonly used non-destructive method for the detection of in welds. (Circle one letter only)

- a) Underbead non-fusion
- b) Surface discontinuities
- c) Volumetric discontinuities
- d) Crack-like discontinuities

2. During the generation of X-rays electron interaction with the atomic structure of the target material produces energy.

What percentage of this energy is in the form of:

- a) Heat
- b) X-rays

3. True or False?

Gamma radiation emitted by a radioisotope of Co60 has wave lengths which are longer than 1R192.

4. In general, radiographs made with Gamma-rays are to those made with X-rays. (Circle one letter only)

- a) Superior
- b) Equal
- c) Inferior
- d) Superior on steel thicknesses under 1/2"

MODULE 11

Guide 2 continued

5. In general, the construction codes relating to radiography will specify that a penetrameter shall be of the thickness of the material which is to be radiographed. (Circle one letter only)
- a) 5%
 - b) 10%
 - c) 3.5%
 - d) 2.0%
 - e) 6%
6. Standards of acceptance for welds subject to radiographic examination are detailed in various codes and standards. Name three of these codes or standards.
7. Why must extreme caution be used when operating X-ray and Gamma ray equipment?

Check your answers for accuracy. If any of your answers are wrong re-study the guide subject matter until you understand it.

MODULE 11

Guide 3

Carefully read pages 16 to 22 and answer the following questions:

1. Complete the following:

Ultrasonic testing of welds utilizes sound frequencies between and

2. Complete the following:

The two main ultrasonic beam modes used in weld testing are and

3. When a change occurs in the material (such as a void caused by a defect), the velocity of the ultrasonic beam changes and what is known as occurs. (Circle one letter)

- a) Beam profile
- b) Raleigh wave propagation
- c) Acoustic mismatch
- d) Pulse differential

4. Complete the following:

'Ultrasonic' sound waves are generated by applying electric pulses to..... crystals.

5. The velocity of a shear wave in carbon steel is: (circle one letter)

- a) .585 cm Micro Second
- b) .323 cm " "
- c) .486 cm " "
- d) .383 cm " "

MODULE 11

Guide 3 continued

6. In order to provide a maximum indication on the oscilloscope the ultrasonic beam should strike the major face of the defect at an angle of (Circle one letter)
- a) 40°
 - b) 60°
 - c) 90°
 - d) 75°
 - e) 80°
7. What ultrasonic beam angle should be used in order to detect lack of side wall fusion in a single V butt weld in which the bevel of the joint configuration is set at an angle of 30°? (Circle one letter)
- a) 50°
 - b) 45°
 - c) 60°
 - d) 70°
 - e) 35°
8. Complete the sentence:
- When ultrasonic testing a Double V Butt weld to detect incomplete penetration the method used is known as

Check your answers for accuracy. If any of your answers are wrong re-study the guide subject matter until you understand it.

MODULE 11

Guide 4

Carefully read pages 22 to 24 and answer the following questions:

1. True or False?

Magnetic particle inspection utilizes a magnetic field which is induced in non-magnetic materials.

2. When magnetic particle testing welds what is the most common way to induce the magnetic field when using direct or alternating current?

3. What type of current is used when the object of a magnetic particle test is to detect sub-surface defects?

4. True or False?

Magnetic particle testing can be used in all positions, including overhead.

5. Is the fluorescent magnetic particle method recommended for use for testing welds in the as welded condition?

Check your answers for accuracy. If any of your answers are wrong re-study the guide subject matter until you understand it.

MODULE 11

Guide 5

Carefully read pages 24 to 27 and answer the following questions:

1. Why is it necessary to clean the weld zone surface with a solvent to remove grease and dirt?
2. After penetrant is applied and dwell time is complete it is necessary to remove the surface penetrant. What are the two methods of removal listed in the test?
3. Complete the sentence:

Some specifications limit halogen content in penetrant test materials because under certain conditions they can cause in austenitic stainless steels.
4. When using penetrants on welds which have not been dressed, care must be taken in cleaning the surplus penetrant out of the ripples. Why?
5. Complete this sentence:

Acoustic Emission Analysis utilizes produced by defects propagating in a material under load.

Check your answers for accuracy. If any of your answers are wrong re-study the guide subject matter until you understand it.

MODULE 11

ANSWERS

Guide 1

1. (b)
2. False
3. (b)
4. (b)
5. False
6. Welding inspection should begin prior to actual fabrication operations.

Guide 2

1. (c)
2. (a) 99% (b) 1%
3. False
4. (c)
5. (d)
6. ASME Section I, II, and VIII, API 650, CSA Standard W59, ANSI B31.1
7. The radiation is ionizing and dangerous to health.

Guide 3

1. 20 Khz to 10 Mhz
2. Longitudinal and Shear
3. (c)
4. Piezoelectric
5. (b)
6. (c)
7. (c)
8. Pitch and Catch

MODULE 11

ANSWERS continued

Guide 4

1. False
2. Prod Method
3. Direct
4. True
5. No

Guide 5

1. The penetrant cannot enter the cavity if it is plugged with foreign material.
2. Fine water spray or solvent remover.
3. Stress corrosion cracking.
4. There will be confusion when attempting to interpret the test results.
5. Stress waves.

MODULE 11

TEST

This test is designed to determine whether you are ready to attempt the formal examination.

Complete the ANSWER SHEET and compare the results with the TEST KEY. If you have a pass mark less than 70% you are advised to re-study the material.

1. Which of the following might be considered as a destructive test?
 - (a) a macro section cut from a weld
 - (b) ultrasonic
 - (c) acoustic emission
 - (d) radiography
 - (e) visual
2. The two main ultrasonic beam modes are:
 - (a) shear and rotary
 - (b) longitudinal and compression
 - (c) longitudinal and shear
 - (d) compression and raleigh
 - (e) surface and longitudinal
3. Ultrasonic testing involves sound waves having a frequency of:
 - (a) over 20 Mhz
 - (b) over 20 Khz to approximately 10 Mhz
 - (c) up to 20 Khz
 - (d) up to 2000 hz
 - (e) up to 5 Khz
4. When a change occurs in a material (such as slag inclusion) the velocity of the ultrasonic beam changes and what is known as.....occurs.
 - (a) transmission
 - (b) energy transference
 - (c) cross-talk
 - (d) oscilloscope jump
 - (e) acoustic mismatch

MODULE 11

TEST continued

5. What is the welding inspector's responsibility with respect to weldments requiring repairs?
 - (a) to judge the acceptability of the repaired welds
 - (b) to ensure that a proper welding procedure is being followed
 - (c) to ensure that such weldments are correctly marked in order to indicate the location and nature of the repairs
 - (d) to see that these are made by qualified welders
 - (e) all of the above

6. Which type of NDT utilizes stress waves produced by defects propagating in a material under load?
 - (a) ultrasonics
 - (b) acoustic emission
 - (c) magnetic particle
 - (d) radiography
 - (e) dye-penetrant

7. What is the most common way to induce a magnetic field into welds to be tested by the magnetic particle inspection method?
 - (a) with computer reactions
 - (b) it depends on the type of steel being welded
 - (c) using alternating current with HF pulses
 - (d) by direct or alternating current
 - (e) by electronic equipment

8. When using radiography, what type of defect is difficult to detect?
 - (a) tight cracks
 - (b) blowholes
 - (c) tungsten inclusions
 - (d) electrode stubs
 - (e) slag inclusions

Basic Inspection Technology

MODULE 11

TEST continued

9. What is the proper sequence to develop a visible indication of defects when using the liquid penetrant inspection method?
- (a) apply penetrant, clean off weld, allow dwell time, apply developer
 - (b) clean weld zone, apply penetrant, remove penetrant, apply developer
 - (c) clean surface, apply developer, apply penetrant, clean off part
 - (d) clean surface, apply developer, apply penetrant, remove penetrant
 - (e) apply penetrant, leave for full dwell time, clean off penetrant, clean weld zone
10. Magnetic particle inspection will be used when examining:
- (a) bronzes and brasses
 - (b) aluminum
 - (c) austenitic stainless steel
 - (d) mild low alloy steels
 - (e) (a) and (c)

**Canadian Welding Bureau
Answer Sheet - Module 11**

Complete the "Answer Sheet" and compare the results with the "Test Key". If you have a pass mark less than 70%, you are advised to re-study the material.

Please circle only ONE letter corresponding to the answer you think is most correct.

QUESTION	ANSWERS				
1	a	b	c	d	e
2	a	b	c	d	e
3	a	b	c	d	e
4	a	b	c	d	e
5	a	b	c	d	e
6	a	b	c	d	e
7	a	b	c	d	e
8	a	b	c	d	e
9	a	b	c	d	e
10	a	b	c	d	e

The answer key below is provided for your use in the event that you wish to retest yourself.

QUESTION	ANSWERS				
1	a	b	c	d	e
2	a	b	c	d	e
3	a	b	c	d	e
4	a	b	c	d	e
5	a	b	c	d	e
6	a	b	c	d	e
7	a	b	c	d	e
8	a	b	c	d	e
9	a	b	c	d	e
10	a	b	c	d	e

**Canadian Welding Bureau
Test Key - Module 11**

Compare your answer sheet to this key.

QUESTION	ANSWERS				
1	(a)	b	c	d	e
2	a	b	(c)	d	e
3	a	(b)	c	d	e
4	a	b	c	d	(e)
5	a	b	c	d	(e)
6	a	(b)	c	d	e
7	a	b	c	(d)	e
8	(a)	b	c	d	e
9	a	(b)	c	d	e
10	a	b	c	(d)	e