Karpagam Academy of Higher Education

(Deemed to be University)

(Established Under Section 3 of UGC Act 1956)

Pollachi Main Road, Eachanari Post, Coimbatore, Tamil Nadu 641021

FACULTY OF ENGINEERING

Department of Mechanical Engineering

(Aerospace Engineering)

Subject Name : Non-Destructive Testing (NDT)

Subject Code : 15BTARO7E02 (Credits - 3)

Name of the Faculty : R. Suresh Baalaji / AP,

Year/Semester/Section : IV / VII / -

Branch : UG / B. E. / Mechanical Engineering & Automobile Engineering

SYLLABUS

15BTAROE02 NON-DESTRUCTIVE TESTING 3 0 0 3 100

OBJECTIVES:

To provide in-depth knowledge on various techniques of non-destructive testing.

UNIT I: INTRODUCTION

Properties of Materials – Characteristics of Ferrous, Non-ferrous and Alloys. Destructive testing and Non-destructive testing – Classification – Uses and applications. Codes, Standards and Specifications(ASME, ASTM, AWS etc.).

UNIT II PENETRANT TESTING AND MAGNETIC PARTICLE INSPECTION

Introduction to Penetrant Testing – Liquid Penetrants and Dye Penetrants - An Illustration of Penetrant Testing, Advantages of Penetrant Testing, Disadvantages of Penetrant Testing. Introduction to Magnetic Particle Inspection - An Illustration of Magnetic Particle Inspection, Advantages of Magnetic Particle Crack Detection, Disadvantages of Magnetic Particle Crack Detection

UNIT III ULTRASONIC FLAW DETECTION AND RADIOGRAPHY INSPECTION

Introduction to Ultrasonic Flaw Detection ,An Illustration of Ultrasonic Flaw Detection , Advantages of Ultrasonic Flaw Detection, Disadvantages of Ultrasonic Flaw Detection, Principle of Radiography Inspection, Radiation sources, Attenuation in the specimen, Radiographic imaging, Inspection Techniques, Application and limitations, Safety.

UNIT IV EDDY CURRENT AND ELECTRO-MAGNETIC METHODS

Introduction to Eddy Current Testing. An Illustration of Eddy Current Testing Equipment , Advantages of Eddy Current Testing, Disadvantages of Eddy Current Testing

UNIT V NON-DESTRUCTIVE INSPECTION(NDI) AND ITS APPLICATIONS

Inspection of Raw Products, Inspection For In-Service Damage, Power Plant Inspection, Storage Tank Inspection, Aircraft Inspection, Jet Engine Inspection, Pressure Vessel Inspection, Bridge Inspection, Pipeline Inspection.

TEXT BOOKS:

S.NO.	AUTHOR(S)	TITLE OF THE BOOK	PUBLISHER	YEAR OF PUBLICATION
1.	Louis Cartz	Nondestructive Testing	ASM International, Almere, Netherland	1995

2.	Paul E. Mix	Introduction to Nondestructive Testing	John Wiley & Sons,Newyork.	2005

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S.NO.	AUTHOR(S)	TITLE OF THE BOOK	PUBLISHER	YEAR OF PUBLICATION
1.	Baldev Raj, T. Jayakumar, M. Thavasimuthu	Practical Non-destructive Testing	Woodhead Publishing, Cambridge.	2002
2.	J. Blitz, G. Simpson	Ultrasonic Methods of Non-destructive Testing	Springer Science & Business Media	1996

WEB REFERENCES:

https://www.asnt.org/MinorSiteSections/AboutASNT/Intro-to-NDT

https://www.asnt.org/

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www.ndt.net/

www.aindt.com.au/

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Faculty of Engineering

Department of Mechanical Engineering

(*Aerospace Engineering*)

LESSON PLAN

Subject Name/ Code **: Non- Destructive Testing / 15BTAROE02 (Credits - 3)**

Name of the Faculty / Designation **:** R. Suresh Baalaji / Asst. Professor

Branch / Year / Semester / Section **:** UG / B.E./Automobile Engineering **/** IV / VII / -

Sl. No.	No. of Periods	Topics to be Covered	Support Materials
UNIT – I : INTRODUCTION			
1.	1	Properties of Materials	
2.	1	Characteristics of Ferrous Metals	
3.	1	Characteristics of Non-Ferrous Metals	
4.	1	Characteristics of Alloys	Paul E. Mix – Introduction to Non-destructive Testing
5.	1	Characteristics of Destructive Testing	
6.	1	Characteristics of Non-Destructive Testing	
7.	1	Classification, Uses of NDT	
8.	1	Applications of NDT	
9.	1	Codes Standards and Specifications (ASME, ASTM, AWS etc.).	Lecture Notes - KAHE
10.	1	**Tutorial 1:** Summary of Unit I and Part A questions	
Total No. of Hours Planned for Unit - I			**(9L + 1T) 10 Hours**

Sl. No.	No. of Periods	Topics to be Covered	Support Materials
UNIT – II : PENETRANT TESTING AND MAGNETIC PARTICLE INSPECTION			
11.	1	Introduction to Penetrant Testing	
12.	1	Liquid Penetrants and Dye Penetrants	
13.	1	An Illustration of Penetrant Testing	
14.	1	Advantages of Penetrant Testing	
15.	1	Disadvantages of Penetrant Testing	Paul E. Mix – Introduction to Non-destructive Testing
16.	1	Introduction to Magnetic Particle Inspection	
17.	1	An Illustration of Magnetic Particle Inspection	
18.	1	Advantages of Magnetic Particle Crack Detection	
19.	1	Disadvantages of Magnetic Particle Crack Detection	Lecture Notes - KAHE
20.	1	**Tutorial 2:** Summary of Unit II and Part A questions	
Total No. of Hours Planned for Unit - II			**(9L + 1T) 10 Hours**

Sl. No.	No. of Periods	Topics to be Covered	Support Materials
UNIT – III : ULTRASONIC FLAW DETECTION AND RADIOGRAPHY INSPECTION			
21.	1	Introduction to Ultrasonic Flaw Detection	
22.	1	An Illustration of Ultrasonic Flaw Detection	
23.	1	Advantages of Ultrasonic Flaw Detection	
24.	1	Disadvantages of Ultrasonic Flaw Detection	Louis Cartz – Non-destructive Testing
25.	1	Principle of Radiography Inspection	
26.	1	Radiation sources, Attenuation in the specimen	
27.	1	Radiographic imaging	
28.	1	Inspection Techniques	
29.	1	Application and limitations, and Safety	Lecture Notes - KAHE
30.	1	**Tutorial 3:** Summary of Unit III and Part A questions	
Total No. of Hours Planned for Unit - III			**(9L + 1T) 10 Hours**

Sl. No.	No. of Periods	Topics to be Covered	Support Materials
UNIT – IV :			
31.	1	Introduction to Eddy Current Testing	
32.	1	Principle of Eddy Current Testing	
33.	1	Inspect a wide range of different materials and components	
34.	1	Set up and verify equipment settings	
35.	1	Limitations of application of the testing method	Louis Cartz – Non-destructive Testing
36.	1	An Illustration of Eddy Current Testing Equipment	
37.	1	Advantages of Eddy Current Testing	
38.	1	Disadvantages of Eddy Current Testing	
39.	1	Application and limitations, and Safety	Lecture Notes - KAHE
40.	1	**Tutorial 4:** Summary of Unit IV and Part A questions	
Total No. of Hours Planned for Unit - IV			**(9L + 1T) 10 Hours**
Sl. No.	**No. of Periods**	**Topics to be Covered**	**Support Materials**
UNIT – V : NON-DESTRUCTIVE INSPECTION (NDI) AND ITS APPLICATIONS			
41.	1	Inspection of Raw Products	
42.	1	Inspection For In-Service Damage	
43.	1	Power Plant Inspection	
44.	1	Storage Tank Inspection	
45.	1	Aircraft Inspection	Baldev Raj, T. - Practical Non-destructive Testing
46.	1	Jet Engine Inspection	
47.	1	Pressure Vessel Inspection	
48.	1	Bridge Inspection, Pipeline Inspection	
49.	1	Automobile components Inspection	Lecture Notes - KAHE
50.	1	**Tutorial 5:** Summary of Unit V and Part A questions	
Total No. of Hours Planned for Unit - V			**(9L + 1T) 10 Hours**
51.	1	End Semester Possible Questions Discussion	
52.	1	Discussion and Overview of All Five Units	

TEXT BOOKS:

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UNIT	Total No. of Periods Planned	Lecture Periods	Tutorial Periods
I	10	9	1
II	10	9	1
III	10	9	1
IV	10	9	1
V	10	9	1
TOTAL	50	45	05

I. CONTINUOUS INTERNAL ASSESSMENT : 40 Marks
(Internal Assessment Tests: 30, Attendance: 5, Assignment/Seminar: 5)

II. END SEMESTER EXAMINATION : 60 Marks
TOTAL : 100 Marks

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Faculty of Engineering
Department of Mechanical Engineering
(*Aerospace Engineering*)

Subject Name: Non- Destructive Testing **Year / Semester**: IV / VII

Subject Code: 15BTAROE02 **Programme:** UG / B.E. Automobile Engineering

COURSE OBJECTIVE

Ability to demonstrate a systematic understanding of relevant international and national regulations and explain their effects on airport business, planning, design, operations and safety management decisions

To update the students knowledge on various standard and Airside Operation Management systems.

LEARNING OUTCOMES

On successful completion of this course,

1. Analyses the typical operations of airports from a management perspective
2. Identify the economic, political and social role of airports
3. Discuss the benefits and risks of airport privatization
4. Identify and discuss the impact of airport marketing
5. Design and evaluate airport master planning
6. Evaluate airport performance, efficiency, capacity, and delay

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Faculty of Engineering

Department of Mechanical Engineering

NON-DESTRUCTIVE TESTING (NDT)

(Common for Aeronautical, Mechanical, Automobile and Civil Engineering)

Compiled By

Suresh Baalaji.R

Asst. Professor

Department of Mechanical Engineering (Aerospace)

Syllabus

OBJECTIVES:

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Mechanical Properties of Engineering Materials

To finalize the material for an engineering product/application, we should have the knowledge of **Mechanical properties of materials**. The **mechanical properties of a material** are those which effect the mechanical strength and ability of a material to be molded in suitable shape. Some of the typical mechanical properties of a material are listed below-

Strength,	Toughness
Hardness,	Hardenability
Brittleness,	Malleability
Ductility,	Creep and Slip
Resilience,	Fatigue

Strength

It is the **property of a material** which opposes the deformation or breakdown of material in presence of external forces or load. Materials which we finalize for our engineering products, must have suitable mechanical strength to be capable to work under different mechanical forces or loads.

Toughness

It is the ability of a material to absorb the energy and gets plastically deformed without fracturing. Its numerical value is determined by the amount of energy per unit volume. Its unit is Joule/ m^3. Value of toughness of a material can be determined by stress-strain characteristics of a material. For good toughness, materials should have good strength as well as ductility.

For example: brittle materials, having good strength but limited ductility are not tough enough. Conversely, materials having good ductility but low strength are also not tough enough. Therefore, to be tough, a material should be capable to withstand both high stress and strain.

Hardness

It is the ability of a material to resist to permanent shape change due to external stress. There are various measure of hardness – Scratch Hardness, Indentation Hardness and Rebound Hardness.

1. **Scratch Hardness** Scratch Hardness is the ability of materials to the oppose the scratches to outer surface layer due to external force.
2. **Indentation Hardness** It is the ability of materials to oppose the dent due to punch of external hard and sharp objects.
3. **Rebound Hardness** Rebound hardness is also called as dynamic hardness. It is determined by the height of “bounce” of a diamond tipped hammer dropped from a fixed height on the material.

Hardenability

It is the ability of a material to attain the hardness by heat treatment processing. It is determined by the depth up to which the material becomes hard. The SI unit of hardenability is meter (similar to length). Hardenability of material is inversely proportional to the weld-ability of material.

Brittleness

Brittleness of a material indicates that how easily it gets fractured when it is subjected to a force or load. When a brittle material is subjected to a stress it observes very less energy and gets fractures without significant strain. Brittleness is converse to ductility of material. Brittleness of material is temperature dependent. Some metals which are ductile at normal temperature become brittle at low temperature.

Malleability

Malleability is a property of solid materials which indicates that how easily a material gets deformed under compressive stress. Malleability is often categorized by the ability of material to be formed in the form of a thin sheet by hammering or rolling. This mechanical property is an aspect of plasticity of material. Malleability of material is temperature dependent. With rise in temperature, the malleability of material increases.

Ductility

Ductility is a property of a solid material which indicates that how easily a material gets deformed under tensile stress. Ductility is often categorized by the ability of material to get stretched into a wire by pulling or drawing. This mechanical property is also an aspect of plasticity of material and is temperature dependent. With rise in temperature, the ductility of material increases.

Creep and Slip

Creep is the property of a material which indicates the tendency of material to move slowly and deform permanently under the influence of external mechanical stress. It results due to long time exposure to large external mechanical stress with in limit of yielding. Creep is more severe in material that are subjected to heat for long time. Slip in material is a plane with high density of atoms.

Resilience

Resilience is the ability of material to absorb the energy when it is deformed elastically by applying stress and release the energy when stress is removed. Proof resilience is defined as the maximum energy that can be absorbed without permanent deformation. The modulus of resilience is defined as the maximum energy that can be absorbed per unit volume without permanent deformation. It can be determined by integrating the stress-strain cure from zero to elastic limit. Its unit is joule/m^3.

Fatigue

Fatigue is the weakening of material caused by the repeated loading of the material. When a material is subjected to cyclic loading, and loading greater than certain threshold value but much below the strength of material (ultimate tensile strength limit or yield stress limit), microscopic cracks begin to form at grain boundaries and interfaces. Eventually the crack reaches to a critical size. This crack propagates suddenly and the structure gets fractured. The shape of structure affects the fatigue very much. Square holes and sharp corners lead to elevated stresses where the fatigue crack initiates.

Ferrous Materials and Non-Ferrous Metals and Alloys

INTRODUCTION

Ferrous materials/metals may be defined as those metals whose main constituent is iron such as pig iron, wrought iron, cast iron, steel and their alloys. The principal raw materials for ferrous metals is pig iron. Ferrous materials are usually stronger and harder and are used in daily life products. Ferrous material possess a special property that their characteristics can be altered by heat treatment processes or by addition of small quantity of alloying elements. Ferrous metals possess different physical properties according to their carbon content.

IRON AND STEEL

The ferrous metals are iron base metals which include all varieties of iron and steel. Most common engineering materials are ferrous materials which are alloys of iron. Ferrous means iron. Iron is the name given to pure ferrite Fe, as well as to fused mixtures of this ferrite with large amount of carbon (may be 1.8%), these mixtures are known as pig iron and cast iron. Primarily pig iron is produced from the iron ore in the blast furnace from which cast iron, wrought iron and steel can be produced.

CLASSIFICATION OF CARBON STEELS

Plain carbon steel is that steel in which alloying element is carbon. Practically besides iron and carbon four other alloying elements are always present but their content is very small that they do not affect physical properties. These are sulphur, phosphorus, silicon and manganese. Although the effect of sulphur and phosphorus on properties of steel is detrimental, but their percentage is very small. Sulphur exists in steel as iron sulphide which produces red shortness or manganese sulphide which does affect its properties. forging dies. Likewise for production of cold chisels, punches and dies. Springs, broaches and reamers can be produced for steel containing carbon. As the percentage of carbon further increases, it can be used for production of milling cutters, anvils, taps, drills, files, razors, metal cutting tools for lathes, shapers, planner and drawing dies.

WROUGHT IRON

The meaning of “wrought” is that metal which possesses sufficient ductility in order to permit hot and/or cold deformation. Wrought iron is the purest iron with a small amount of slag forged out into fibres. The typical composition indicates 99 per cent of iron and traces of carbon, phosphorus, manganese, silicon, sulphur and slag. During the production process, first all elements in iron (may be C, S, Mn, Si and P) are eliminated leaving almost pure iron molten slag. In order to remove the excess slag, the final mix is then squeezed in a press and reduced to billets by rolling milling. The resulting material would consist of pure iron separated by thin layers of slag material. The slag characteristic of wrought iron is beneficial in blacksmithy/forging operations and provides the material its peculiar fibrous structure. Further, the non-corrosive slag constituent makes wrought iron resistant to progressive corrosion and also helps in reducing effect of fatigue caused by shocks and vibrations.

Wrought iron is tough, malleable and ductile and possesses ultimate tensile strength of 350 N/mm^2. Its melting point is 1530°C. It can neither be hardened nor tempered like steel. The billets of wrought iron can be reheated to form bars, plates, boiler tubing, forgings, crane hook, railway coupling, bolts and nuts, chains, barbed wire, coal handling equipment and cooling towers, etc.

CAST IRON

It is primarily an alloy of iron and carbon. The carbon content in cast iron varies from 1.5 to 4 per cent. Small amounts of silicon, manganese, sulphur and phosphorus are also present in it. Carbon in cast iron is present either in free state like graphite or in combined state as cementite. Cast iron contains so much carbon or its equivalent that it is not malleable. One characteristic (except white cast iron) is that much of carbon content is present in free form as graphite. Largely the properties of cast iron are determined by this fact.

Melting point of cast iron is much lower than that of steel. Most of the castings produced in a cast iron foundry are of grey cast iron. These are cheap and widely used.

The characteristics of cast iron which make it a valuable material for engineering applications are:

Very good casting characteristics.
Low cost
High compressive strength
Good wear resistance
Excellent machinability

The main limitation of this metal is brittleness and low tensile strength and thus cannot be used in those components subjected to shocks.

The varieties of cast iron in common use are:

Grey cast iron
White cast iron
Malleable cast iron
Nodular cast iron
Chilled cast iron
Alloy cast iron

Grey Cast Iron

It is the iron which is most commonly used in foundry work. If this iron is machined or broken, its fractured section shows the greyish colour, hence the name "grey" cast iron. The grey colour is due to the fact that carbon is present in the form of free graphite. A very good characteristic of grey cast iron is that the free graphite in its structure acts as a lubricant. This is suitable for those components/products where sliding action is desired. The other properties are good machinability, high compressive strength, low tensile strength and no ductility.

White Cast Iron

It is so called due to the whitish colour shown by its fracture. White cast iron contains carbon exclusively in the form of iron carbide Fe_3C (cementite). From engineering point of view, white cast iron has limited applications. This is because of poor machinability and possessing, in general, relatively poor mechanical properties. It is used for inferior castings and places where hard coating is required as in outer surface of car wheels. Only crushing rolls are made of white cast iron. But it is used as raw material for production of malleable cast iron.

Malleable Cast Iron

Malleable cast iron is produced from white cast iron. The white cast iron is brittle and hard. It is, therefore, unsuitable for articles which are thin, light and subjected to shock and vibrations or for small castings used in various machine components. The malleable cast iron is produced from white cast iron by suitable heat treatment, i.e., annealing. This process separates the combined carbon of the white cast iron into noddles of free graphite.

Nodular Cast Iron

It is also known as “spheroidal graphite iron” or Ductile iron or High strength “Cast iron”. This nodular cast iron is obtained by adding magnesium to the molten cast iron. The magnesium converts the graphite of cast iron from flake to spheroidal or nodular form. In this manner, the mechanical properties are considerably improved. The strength increases, yield point improves and brittleness is reduced. Such castings can even replace steel components.

Outstanding characteristics of nodular cast iron are high fluidity which allows the castings of intricate shape. This cast iron is widely used in castings where density as well as pressure tightness is a highly desirable quality. The applications include hydraulic cylinders, valves, pipes and pipe fittings, cylinder head for compressors, diesel engines, etc.

Chilled Cast Iron

Quick cooling is generally known as chilling and the iron so produced is “chilled iron”. The outer surface of all castings always gets chilled to a limited depth about (1 to 2 mm) during pouring and solidification of molten metal after coming in contact with cool sand of mould. Sometimes the casting is chilled intentionally and some becomes chilled accidentally to a small depth.

Alloy Cast Iron

Alloying elements are added to cast iron to overcome inherent deficiencies in ordinary cast iron to provide requisite characteristics for special purposes. The alloy cast iron is extremely tough, wear resistant and non-magnetic steel about 12 to 14 per cent manganese should be added.

Nickel: It may be termed as one of the most important alloying elements. It improves tensile strength, ductility, toughness and corrosion resistance.

Chromium: Its addition to steel improves toughness, hardness and corrosion resistance.

Boron: It increases hardenability and is therefore very useful when alloyed with low carbon steels.

Cobalt: It is added to high speed steels to improve hardness, toughness, tensile strength, thermal resistance and magnetic properties. It acts as a grain purifier.

Tungsten: Tungsten improves hardness, toughness, wear resistance, shock resistance, magnetic reluctance and ability to retain hardness at elevated temperatures. It provides hardness and abrasion resistance properties to steel.

Molybdenum: It improves wear resistance, hardness, thermal resistance, ability to retain mechanical properties at elevated temperatures and helps to inhibit temper brittleness.

Vanadium: It increases tensile strength, elastic limit, ductility, shock resistance and also acts as a degaser when added to molten steel. It provides improvement to hardenability of steel.

It is a very good deoxidizer and promotes grain growth. It is the strongest carbide former. Titanium is used to fix carbon in stainless steel and thus prevents the precipitation of chromium-carbide.

Niobium: It improves ductility, decreases hardenability and substantially improves the impact strength. It also promotes fine grain growth.

STAINLESS STEELS

The only material known to engineers which possesses a combination of various properties such as: wide range of strength and hardness, high ductility and formability, high corrosion resistance, good creep resistance, good thermal conductivity, good machinability, high hot & cold workability and excellent surface finish is stainless steel. Alloy steels have been developed for a specific purpose. We shall study them as follows:
They are known as stainless since they do not corrode or rust easily in most of environment and media. Stainless steels can be further divided into the following three categories:

1. Ferritic stainless steel
2. Martensitic stainless steel
3. Austentic stainless steels

TOOL STEELS

High Speed Steel (H.S.S)
Molybdenum High Speed Steel

The various types of annealing process are described below:

Annealing:

Full annealing Partial annealing Isothermal Annealing

Normalizing

Quenching

Tempering

Low Temperature Tempering Medium Temperature Tempering

High temperature tempering

Cyaniding
Nitriding

Carbonitriding Flame Hardening Induction hardening

NON-FERROUS METALS AND ALLOYS

Non-ferrous metals are those which do not contain significant quantity of iron or iron as base metal. These metals possess low strength at high temperatures, generally suffer from hot shortness and have more shrinkage than ferrous metals. They are utilized in industry due to following advantages:

1. High corrosion resistance
2. Easy to fabricate, i.e., machining, casting, welding, forging and rolling
3. Possess very good thermal and electrical conductivity
4. Attractive colour and low density

The various non-metals used in industry are: copper, aluminium, tin, lead, zinc, and nickel, etc., and their alloys.

Copper

The crude form of copper extracted from its ores through series of processes contains 68% purity known as Blister copper. By electrolytic refining process, highly pure (99.9%) copper which is remelted and casted into suitable shapes. Copper is a corrosion resistant metal of an attractive reddish brown colour.

Properties and Uses

High Thermal Conductivity: Used in heat exchangers, heating vessels and appliances, etc.

High Electrical Conductivity: Used as electrical conductor in various shapes and forms for various applications.

Good Corrosion Resistance: Used for providing coating on steel prior to nickel and chromium plating

High Ductility: Can be easily cold worked, folded and spun. Requires annealing after cold working as it loses its ductility.

Aluminium

Aluminium is white metal which is produced by electrical processes from clayey mineral known as bauxite. However, this aluminium ore bauxite is available in India in plenty and we have a thriving aluminium industry.

Properties and Uses

7. Like copper it is also corrosion resistant.
8. It is very good conductor of heat and electricity although not as good as copper.
9. Possesses high ductility and light weight so widely utilized in aircraft industry.
10. Needs frequent annealing if cold worked since it becomes hard after cold working.

11. In view of its ductility and malleability it has replaced copper in electrical transmission and appliances to some extent.

12. It is used in manufacturing of household utensils including pressure cookers.

Lead

Lead is the heaviest of the common metal. Lead is extracted from its ore known as **galena**. It is bluish grey in colour and dull lusture which goes very dull on exposure to air.

Properties and Uses

Its specific gravity is 7.1 and melting point is 360°C.
It is resistant to corrosion and many chemicals do not react with it (even acids).
It is soft, heavy and malleable, can be easily worked and shaped.
Lead is utilized as alloying element in producing solders and plumber's solders.
It is alloyed with brass as well as steel to improve their machinability.
It is utilized in manufacturing of water pipes, coating for electrical cables, acid tanks and roof covering etc.

Tin

It is a brilliant white metal with yellowish tinge. Melting point of tin is 240°C

Properties and Uses

Tin is malleable and ductile, it can be rolled into very thin sheets.
It is used for tinning of copper and brass utensils and copper wire before its conversion into cables.
It is useful as a protective coating for iron and steel since it does corrode in dry or wet atmosphere.
It is utilized for making important alloys such as fine solder and moisture proof packing with thin tin sheets.

Zinc

The chief ores of zinc are **blende** (ZnS) and **calamine** ($ZnCO_3$). Zinc is a fairly heavy, bluish-white metal principally utilized in view of its low cost, corrosion resistance and alloying characteristics. Melting point of zinc is 420°C and it boils at 940°C.

Properties and Uses

High corrosion resistance: Widely used as protective coating on iron and steel. Coating may be provided by dip galvanizing or electroplating.
High fluidity and low melting point: Most suitable metal for pressure die casting generally in the form of alloy.
When rolled into sheets, zinc is utilized for roof covering and for providing a damp proof non-corrosive lining to containers.
The galvanized wires, nails, etc. are produced by galvanizing technique and zinc is also used in manufacture of brasses.

Nickel

About at least 85% of all nickel production is obtained from sulphide ores.

Properties and Uses

1 Pure nickel is tough, silver coloured metal, harder than copper having some but less ductility but of about same strength.
2 It is plated on steel to provide a corrosion resistance surface or layer.
3 Widely used as an alloying element with steel. Higher proportions are advantageously added in the production of steel such as monel or in conel.
4 It possesses good resistance to both acids and alkalis regarding corrosion so widely utilized in food processing equipment.

Magnesium

Principal ores of magnesium are **magnesite**, **carnallite** and **dolomite**. Magnesium is extracted by electrolytic process.

Properties and Uses:

It is the lightest of all metals weighing around two-thirds of aluminium.
The tensile strength of cast metal is the same as that of ordinary cast aluminium, i.e., 90 MPa.
The tensile strength of rolled annealed magnesium is same as that of good quality cast iron.
Magnesium can be easily formed, drawn forged and machined with high accuracy.
In powdered form it is likely to burn, in that situation adequate fire protection measures should be strictly observed.
Its castings are pressure tight and achieve good surface finish. Magnesium castings include motor car gearbox, differential housing and portable tools.

Vanadium

It occurs in conjunction with iron pyrite, free sulphur and carbonaceous matter.

Properties and Uses:

It is silvery white in colour. Its specific gravity is 5.67. Its melting point is 1710°C.
When heated to a suitable temperature it can be hammered into any shape or drawn into wires.
It is used in manufacture of alloy steels.
Vanadium forms non-ferrous alloys of copper and aluminium from which excellent castings can be produced.

Antimony

Chief ore of antimony is **stibnite**. To a small extent, antimony is obtained as a by-product in refining of other metals such as lead, copper silver and zinc.

Properties and Uses

It is silvery white, hard, highly crystalline and so brittle that it may be readily powdered.

Its specific gravity is 6.63 and melting point is 630°C.
It is generally used as an alloying element with most of heavy metals.
Lead, tin and copper are the metals which are most commonly alloyed with antimony.

Cadmium

It is obtained commercially as a by-product in the metallurgy of zinc and to some extent of lead.

Properties and Uses

White metal with bluish tinge, capable of taking a high polish.
Its specific gravity is 8.67 and melts at 321°C.
It is slightly harder than tin but softer than zinc.
It is malleable and ductile and can be readily rolled and drawn into wires.

It is chiefly utilized in antifriction alloys for bearings. It is also used as rust proof coating for iron and steel. Components of automobiles and refrigerator such as nuts, bolts and trimmings, locks and wire products are plated with it.

ALLOYS OF COPPER

Copper alloys are among the best conductors of heat and electricity and they have good corrosion resistance. The common types of copper alloys are brasses and bronzes. The various alloys of copper are discussed as follows:

Brass

All brasses are basically alloys of copper and zinc. Commercially there are two main varieties of brasses:

Alfa brass: Contains upto 36% Zn and rest copper for cold working.

Alfa-Betabrass: Contains 36 to 45% Zn and remainder is copper for hot working.

Bronze

The generally used bronzes are as follows:

Phosphor bronze Gun metal Silicon bronze Bell metal

Manganese Bronze Muntz Metal

Alloys of Aluminium

Aluminium may be alloyed with one or more alloying elements such as copper, manganese, magnesium, silicon and nickel. The addition of small quantities of alloying elements converts the soft and weak aluminium into hard and strong metal, while it retains its light weight.
The main alloys of aluminium are:

Duralumin Y-Alloy Magnalium Hindalium

Alloys of Nickel

German silver Monel metal Nichrome Inconel & incolony

CODES & STANDARD

CODES

Codes are generally the top-tier documents, providing a set of rules that specify the minimum acceptable level of safety for manufactured, fabricated or constructed objects. These may incorporate regulatory requirements and will often refer out to standards or specifications for specific details on additional requirements not specified in the Code itself.

Examples of some commonly used Codes are the ASME Boiler and Pressure Vessel Code (B&PVC) and the AWS D1.1 Structural Welding Code – Steel. The B&PVC covers pressure-related equipment from refineries and unfired pressure vessels to nuclear power generation, and the AWS D1.1 Code covers welded structures of all types.

STANDARDS

Standards are documents that establish engineering or technical requirements for products, practices, methods or operations. Of particular interest to NDT personnel are those standards that provide personnel certification requirements and those that provide requirements for performing NDT tasks.

Examples of certification standards are the ANSI/ASNT CP-189, ASNT Standard for Qualification and Certification of Nondestructive Testing Personnel and the ANSI/ASNT CP-105, ASNT Standard Topical Outlines for Qualification of Nondestructive Testing Personnel.

Examples of NDT performance standards are the ASTM Standard E 709, Standard Guide for Magnetic Particle Testing, and ASTM E 1444, Standard Practice for Magnetic Particle Testing.

GENERAL

ASME	American Society for Mechanical Engineers
ASNT	American Society for Non Destructive Testing
ASTM	American Society for Testing & Materials
AGS	American Gas Society
ANSI	American National Standards Institute
API	American Petroleum Institute
AWS	American Welding Society
AISI	American Iron & Steel Institute
IS	Indian Standards
BS	British Standards
JIS	Japanese Standards
DIN	German Standards
GOST	Russian Standards
ISO	International Organization for Standardization
NBS	National Bureau of Standards
SAE	Society of Automotive Engineers
SIS	Swedish Standards Institute
MIL STD	Military Standard
AMS	Aerospace Materials Specifications

Introduction to Nondestructive Testing

Definition of Non Destructive Testing:

NDT stands for non-destructive testing. In other words it is a way of testing without destroying. This means that the component- the casting, weld or forging, can continue to be used and that the non destructive testing method has done no harm. In today's world where new materials are being developed, older materials and bonding methods are being subjected to higher pressures and loads, NDT ensures that materials can continue to operate to their highest capacity with the assurance that they will not fail within predetermined time limits.

NDT can be used to ensure the quality right from raw material stage through fabrication and processing to pre-service and in-service inspection. Apart from ensuring the structural integrity, quality and reliability of components and plants, today

NDT finds extensive applications for condition monitoring, residual life assessment, energy audit, etc.

Introduction to Nondestructive Testing

For visitors who are not already familiar with NDT, the general information below is intended to provide a basic description of NDT and the most common test methods and techniques used when performing NDT. As such it is not highly detailed or all encompassing, and for more comprehensive information readers should refer to ASNT publications such as the ASNT NDT Handbooks or the ASNT Personnel Training Publications (PTP) Classroom Training Series, all of which are available from ASNT's bookstore. Also, standards covering these test methods are listed on the "Codes and Standards Bodies" page under the NDT Resources Center tab. To maintain consistency, the techniques described for each test method are those listed in the 2011 edition of ASNT's Recommended Practice No. SNT-TC-1A.

What Is Nondestructive Testing?

Nondestructive testing (NDT) is the process of inspecting, testing, or evaluating materials, components or assemblies for discontinuities, or differences in characteristics without destroying the serviceability of the part or system. In other words, when the inspection or test is completed the part can still be used.

In contrast to NDT, other tests are destructive in nature and are therefore done on a limited number of samples ("lot sampling"), rather than on the materials, components or assemblies actually being put into service.

These destructive tests are often used to determine the physical properties of materials such as impact resistance, ductility, yield and ultimate tensile strength, fracture toughness and fatigue strength, but discontinuities and differences in material characteristics are more effectively found by NDT.

Today modern nondestructive tests are used in manufacturing, fabrication and in-service inspections to ensure product integrity and reliability, to control manufacturing processes, lower production costs and to maintain a uniform quality level. During construction, NDT is used to ensure the quality of materials and joining processes during the fabrication and erection phases, and in-service NDT inspections are used to ensure that the products in use continue to have the integrity necessary to ensure their usefulness and the safety of the public.

It should be noted that while the medical field uses many of the same processes, the term "nondestructive testing" is generally not used to describe medical applications.

NDT Test Methods

Test method names often refer to the type of penetrating medium or the equipment used to perform that test. Current NDT methods are: Acoustic Emission Testing (AE), Electromagnetic Testing (ET), Guided Wave Testing (GW), Ground Penetrating Radar (GPR), Laser Testing Methods (LM), Leak Testing (LT), Magnetic Flux Leakage (MFL), Microwave Testing, Liquid Penetrant Testing (PT), Magnetic Particle Testing (MT), Neutron Radiographic Testing (NR), Radiographic Testing (RT), Thermal/Infrared Testing (IR), Ultrasonic Testing (UT), Vibration Analysis (VA) and Visual Testing (VT).

The six most frequently used test methods are MT, PT, RT, UT, ET and VT. Each of these test methods will be described here, followed by the other, less often used test methods.

Magnetic Particle Testing (MT)

Liquid Penetrant Testing (PT)

Radiographic Testing (RT)

Ultrasonic Testing (UT)

Electromagnetic Testing (ET)

Visual Testing (VT)

Acoustic Emission Testing (AE)

Guided Wave Testing (GW)

Laser Testing Methods (LM)

Leak Testing (LT)

Magnetic Flux Leakage (MFL)

Neutron Radiographic Testing (NR)

Thermal/Infrared Testing (IR)

Vibration Analysis (VA)

There are many NDT techniques/methods used, depending on four main criteria:

Material Type

Defect Type

Defect Size

Defect Location

Methods of NDT

1. Penetrant Testing
2. Magnetic Particle Testing
3. Ultrasonic Testing
   i) Ultrasonic Digital Thickness Measurement
   ii) Ultrasonic Straight Beam (A-Scan) Measurement
4. Radiography Testing
   i) Radiographic Film Interpretation – Non Radiographer
   ii) Radiographic Film Interpretation – Radiographer
   iii) Digital Radioscopy
5. Acoustic Emission Testing
6. Electromagnetic Testing
   i) Alternating Current Field Measurement
   ii) Eddy Current Testing
   iii) Flux Leakage Testing
   iv)Remote Field Testing
7. Leak Testing
   i) Bubble Test
   ii) Absolute Pressure Leak Test
   iii) Halogen Diode Leak Test
   iv)Mass Spectrometer Test
8. Neutron Radiography Testing
9. Thermal/Infrared Testing
10. Vibration Analysis
11. Visual Testing

Uses of NDT Methods

- Flaw Detection and Evaluation
- Leak Detection
- Location Determination
- Dimensional Measurements
- Structure and Microstructure Characterization
- Material Sorting and Chemical Composition Determination

Common Application of NDT

1. Inspection of Raw

Products

Forgings

Castings

Extrusions

2. Inspection Following Secondary

Processing Machining

Welding

Grinding

Heat

treating

Plating

3. In-Services Damage Inspection

Cracking
Corrosion
Erosion/Wear
Heat Damage

Sectors

1. Foundry Unit,
2. Forging Unit
3. Pipeline
4. Automotive part Manufacturer
5. Fabricators
6. Steel Producer
7. Thermal Power Plant
8. Nuclear Power Plant
9. Hydro Power Plant
10. Oil Refinery
11. Petro Chemical Unit
12. Chemical Plant
13. Fertilizer Plant
14. Cement Manufacturer
15. Railways
16. Infrastructure & Construction
17. Port, Mechanical, Instrumentation, Commissioning, Aerospace, Wind Power
18. Onshore Offshore Oil & Gas Plant,
19. General Industrial Companies

PENETRANT TESTING (PT)

1. Introduction

PT can apply to detect surface discontinuities which are open to surface and also not extremely rough or porous. This method applied to Metals, Glass, Ceramic, Rubber, and Plastic.PT can detect only surface discontinuities i.e. Cracks, Porosity, Laps, and Pin holes in weld.

2. Procedure

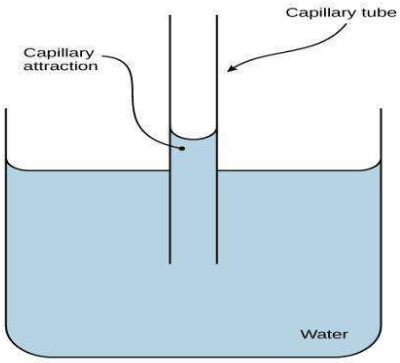
ASME Sec V Article 6

3. Standards

ASME Sec V Article 24 - SE165

4. Principle

Capillary action



5. Types of action

After applying the Penetrant, it will enter into the opening or discontinuity of the job. This is called as capillary action. The developer is having the blotting effect. So it brings out the Penetrant from the discontinuities. It is called as Blotting effect.

6. PT Equipments

1. PENETRANT (Green, Red, Pink)
2. DEVELOPER (White)
3. PENETRANT REMOVER / CLEANER (Colour less)
4. LINT FREE CLOTH
5. LUX METER.
6. UV METER

7. PT methods

1. Visible method

Visible method contains a red dye that provides high contrast against the white developer BG.

2. Fluorescent method contains a fluorescent dye. That fluoresces when exposed to UV (black light) radiation.

8. PT Process

1. Surface Preparation / Pre Cleaning
2. Application of Penetrant
3. Dwell time
4. Remove of Excess Penetrant
5. Application of the developer
6. Developing Time
7. Inspection
8. Post cleaning

9. Advantages

1. Even small fatigue discontinuities on the surface not usually detected by other NDE method can be detected by PT.
2. Parts with complex geometric are routinely inspected.
3. Any non-porous material can be tested.
4. Large areas and large volumes of parts/materials can be inspected rapidly and at low cost.

10. Disadvantages

1. Only surface discontinuities can be finding through this method.
2. Temperature should be maintained at 5˚ to 52 ˚C on the test job.
3. PT can't be conducted for porous material.
   (E.g. Grade 14 cast iron)

Liquid Penetrant Testing (PT)

The basic principle of liquid penetrant testing is that when a very low viscosity (highly fluid) liquid (the penetrant) is applied to the surface of a part, it will penetrate into fissures and voids open to the surface. Once the excess penetrant is removed, the penetrant trapped in those voids will flow back out, creating an indication. Penetrant testing can be performed on magnetic and non-magnetic materials, but does not work well on porous materials. Penetrants may be "visible", meaning they can be seen in ambient light, or fluorescent, requiring the use of a "black" light. The visible dye penetrant process is shown in Figure 7.

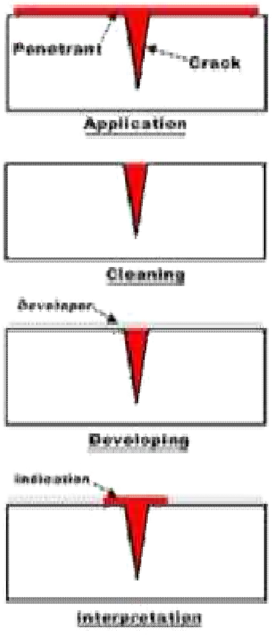


Figure 7

When performing a PT inspection, it is imperative that the surface being tested is clean and free of any foreign materials or liquids that might block the penetrant from entering voids or fissures open to the surface of the part. After applying the penetrant, it is permitted to sit on the surface for a specified period of time (the "penetrant dwell time"), then the part is carefully cleaned to remove excess penetrant from the surface. When removing the penetrant, the operator must be careful not to remove any penetrant that has flowed into voids. A light coating of developer is then be applied to the surface and given time ("developer dwell time") to allow the penetrant from any voids or fissures to seep up into the developer, creating a visible indication. Following the prescribed developer dwell time, the part is inspected visually, with the aid of a black light for fluorescent penetrants. Most developers are fine-grained, white talcum-like powders that provide a color contrast to the penetrant being used.

PT Techniques

Solvent Removable

Solvent Removable penetrants are those penetrants that require a solvent other than water to remove the excess penetrant. These penetrants are usually visible in nature, commonly dyed a bright red color that will contrast well against a white developer. The penetrant is usually sprayed or brushed onto the part, then after the penetrant dwell time has expired, the part is cleaned with a cloth dampened with penetrant cleaner after which the developer is applied. Following the developer dwell time the part is examined to detect any penetrant bleed-out showing through the developer.

Water-washable

Water-washable penetrants have an emulsifier included in the penetrant that allows the penetrant to be removed using a water spray. They are most often applied by dipping the part in a penetrant tank, but the penetrant may be applied to large parts by spraying or brushing. Once the part is fully covered with penetrant, the part is placed on a drain board for the penetrant dwell time, then taken to a rinse station where it is washed with a course water spray to remove the excess penetrant. Once the excess penetrant has been removed, the part may be placed in a warm air dryer or in front of a gentle fan until the water has been removed. The part can then be placed in a dry developer tank and coated with developer, or allowed to sit for the remaining dwell time then inspected.

Post-emulsifiable

Post-emulsifiable penetrants are penetrants that do not have an emulsifier included in its chemical make-up like water-washable penetrants. Post-emulsifiable penetrants are applied in a similar manner, but prior to the water-washing step, emulsifier is applied to the surface for a prescribed period of time (emulsifier dwell) to remove the excess penetrant. When the emulsifier dwell time has elapsed, the part is subjected to the same water wash and developing process used for water-washable penetrants. Emulsifiers can be lipophilic (oil-based) or hydrophilic (water-based).

Introduction to Dye Penetrant Testing

This method is frequently used for the detection of surface breaking flaws in non-ferromagnetic materials.

The subject to be examined is first of all chemically cleaned, usually by vapour phase, to remove all traces of foreign material, grease, dirt, etc. from the surface generally, and also from within the cracks.

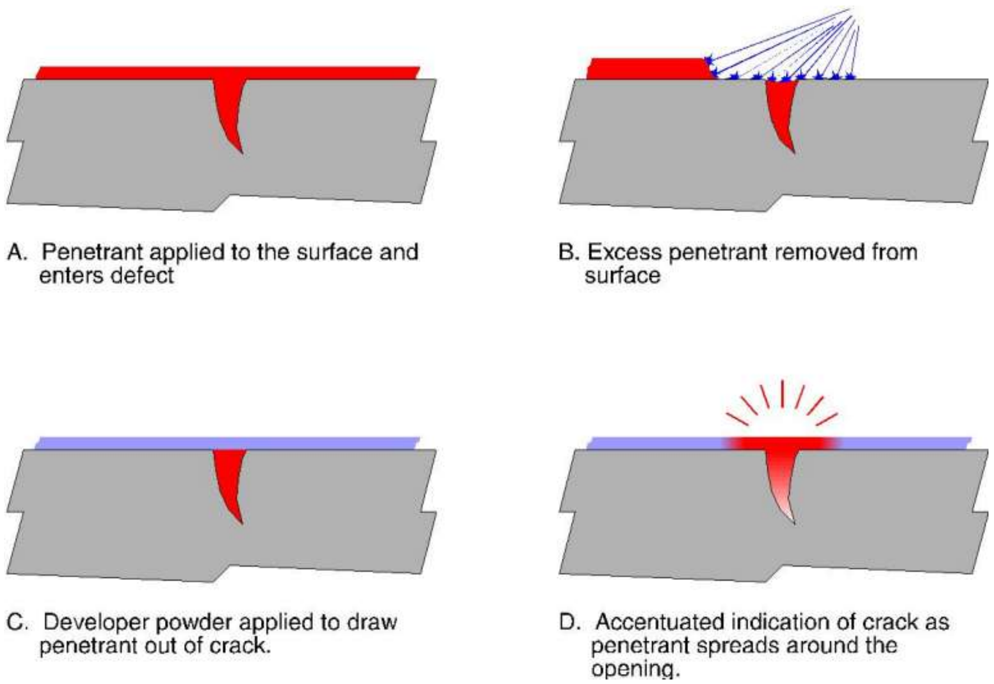
Next the penetrant (which is a very fine thin oil usually dyed bright red or ultra-violet fluorescent) is applied and allowed to remain in contact with the surface for approximately fifteen minutes. Capillary action draws the penetrant into the crack during this period.

The surplus penetrant on the surface is then removed completely and thin coating of powdered chalk is applied.

After a further period (development time) the chalk draws the dye out of the crack, rather like blotting paper, to form a visual, magnified in width, indication in good contrast to the background.

The process is purely a mechanical/chemical one and the various substances used may be applied in a large variety of ways, from aerosol spray cans at the most simple end to dipping in large tanks on an automatic basis at the other end. The latter system requires sophisticated tanks, spraying and drying equipment but the principle remains the same.

An Illustration of Dye Penetrant Testing



Advantages of Dye Penetrant Testing

- Simplicity of operation.
- Best method for surface breaking cracks in non-ferrous metals.
- Suitable for automatic testing, with reservation concerning viewing. (See automatic defect recognition in Magnetic Particle Inspection)
- Quantative.

Disadvantages of Dye Penetrant Testing

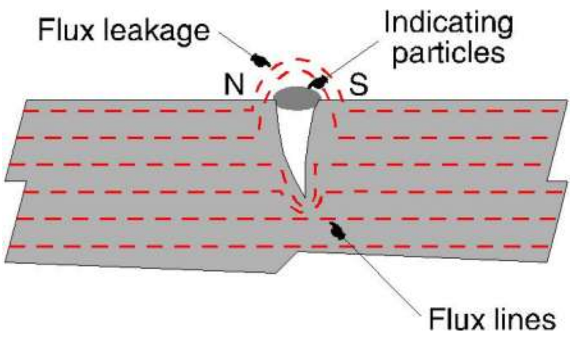
- Restricted to surface breaking defects only.
- Decreased sensitivity.
- Uses a considerable amount of consumables.

Magnetic Particle Testing

Introduction to Magnetic Particle Inspection

This method is suitable for the detection of surface and near surface discontinuities in magnetic material, mainly ferritic steel and iron.

An Illustration of the Principle of Magnetic Particle Inspection



The principle is to generate magnetic flux in the article to be examined, with the flux lines running along the surface at right angles to the suspected defect. Where the flux lines approach a discontinuity they will stray out in to the air at the mouth of the crack. The crack edge becomes magnetic attractive poles North and South. These have the power to attract finely divided particles of magnetic material such as iron fillings. Usually these particles are of an oxide of iron in the size range 20 to 30 microns, and are suspended in a liquid which provides mobility for the particles on the surface of the test piece, assisting their migration to the crack edges. However, in some instances they can be applied in a dry powder form.

The particles can be red or black oxide, or they can be coated with a substance, which fluoresces brilliantly under ultra-violet illumination (black light). The object is to present as great a contrast as possible between the crack indication and the material background.

The technique not only detects those defects which are not normally visible to the unaided eye, but also renders easily visible those defects which would otherwise require close scrutiny of the surface.

There are many methods of generating magnetic flux in the test piece, the most simple one being the application of a permanent magnet to the surface, but this method cannot be controlled accurately because of indifferent surface contact and deterioration in magnetic strength.

Modern equipments generate the magnetic field electrically either directly or indirectly.

In the direct method a high amperage current is passed through the subject and magnetic flux is generated at right angles to the current flow. Therefore the current flow should be in the same line as the suspected defect.

If it is not possible to carry out this method because of the orientation of the defect, then the indirect method must be used. This can be one of two forms:

1. Passing a high current through a coil that encircles the subject.

2. Making the test piece form part of a yoke, which is wound with a current carrying coil. The effect is to pass magnetic flux along the part to reveal transverse and circumferential defects.

If a bar with a length much greater than its diameter is considered, then longitudinal defects would be detected by current flow and transverse and circumferential defects by the indirect method of an encircling coil or magnetic flux flow.

Subjects in which cracks radiating from a hole are suspected can be tested by means of the threading bar technique, whereby a current carrying conductor is passed through the hole and the field induced is cut by any defects. Detection of longitudinal defects in hollow shafts is a typical application of the threader bar technique.

The electricity used to generate the magnetic flux in any of these methods can be alternating current, half wave rectified direct current or full wave rectified direct current. A.C. generated magnetic flux, because of the skin effect, preferentially follows the contours of the surface and does not penetrate deeply into the material. H.W.D.C. penetrates more deeply but is inclined not to follow sharp changes in section. H.W.D.C. is useful for the detection of slightly subsurface defects. The pulsing effect of A.C. and H.W.D.C. gives additional mobility to the indicating particles. D.C. penetrates even more deeply but does not have this facility. Furthermore, demagnetising of the material after D.C. magnetising is far more difficult than after A.C. magnetising.

Normally, to ensure that a test piece has no cracks, it is necessary to magnetise it in at least two directions and after each magnetising - and ink application - visually examine the piece for crack indications.

Since this double process, which would include adjustment of the magnetising equipment controls in between each magnetising takes time it is obviously advantageous to have the facility to reduce the time required. The recent development of the Swinging Field method of multi-directional magnetising will indicate all defects, regardless of their orientation on the surface, with one magnetising shot and therefore requires only one inspection. (Please refer to our paper entitled Faster Magnetic Crack Detection using the Multi-directional Swinging Field Method).

Basically magnetic crack detection equipment takes two forms. Firstly, for test pieces which are part of a large structure, or pipes, heavy castings, etc. which cannot be moved easily, the equipment takes the form of just a power pack to generate a high current. This current is applied to the subject either by contact prods on flexible cables or by an encircling coil of cable. These power packs can have variable amperages up to a maximum of 2000 Amps for portable units, and up to 10,000 Amps for mobile equipments. Both A.C. and H.W.D.C. magnetising current is available. The indicating material is applied by means of a spray and generally the surplus runs to waste.

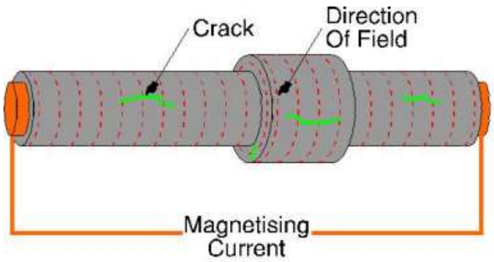
For factory applications on smaller more manageable test pieces the bench type of equipment, as represented by our EUROMAG range, is normally preferred. This consists of a power pack similar to those described above, an indicating ink system which recirculates the fluid, and facilities to grip the work piece and apply the current flow or magnetic flux flow in a more methodical, controlled manner. The work pieces are brought to the equipment and can be individually tested. Subjects up to approximately 100" long can be accommodated is such equipments and can be loaded by crane if necessary. This type of universal equipment is ideally suited to either investigative work or routine quality control testing.

These bench type equipments often incorporate a canopy to prevent direct light falling on the subject so that ultra-violet fluorescent material can be used to the best effect. The indicating particles may be suspended in very thin oil (kerosene) or water. In some circumstances the indicating medium can be applied dry.

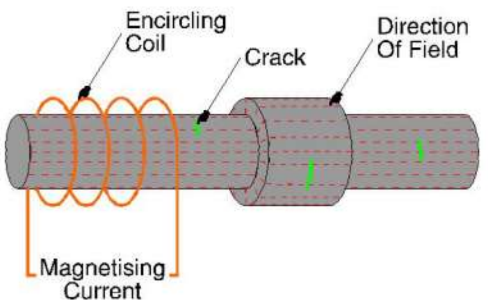
These equipments are suited to production work and in certain circumstances can be automated to the extent of loading, magnetising, inking and unloading. The work pieces still have to be viewed by eye for defect indications.

Specialised equipments are also frequently manufactured to test a particular size and type of test piece.

1 An Illustration of Magnetic Particle Inspection



Schematic arrangement for detecting longitudinal defects using current flow through the subject. The source of the current can be a portable / mobile power pack or, in the case of a bench unit, from the built-in power pack.



Schematic arrangement of an encircling coil for the detection of circumferential and transverse defects. The coil may be cable wrapped round loosely or wound on a former, as in a bench unit.

Advantages of Magnetic Particle Crack Detection

- Simplicity of operation and application.
- Quantitative.
- Can be automated, apart from viewing. (Though modern developments in automatic defect recognition can be used in parts of simple geometry e.g. billets and bars. In this case a special camera captures the defect indication image and processes it for further display and action)

Disadvantages of Magnetic Particle Crack Detection

- Restricted to ferromagnetic materials.
- Restricted to surface or near surface flaws.
- Not fail safe in that lack of indication could mean no defects or process not carried out properly.

MPT is a Non Destructive Testing (NDT) process for detecting surface and subsurface discontinuities in ferroelectric materials such as iron, nickel, cobalt, and some of their alloys.

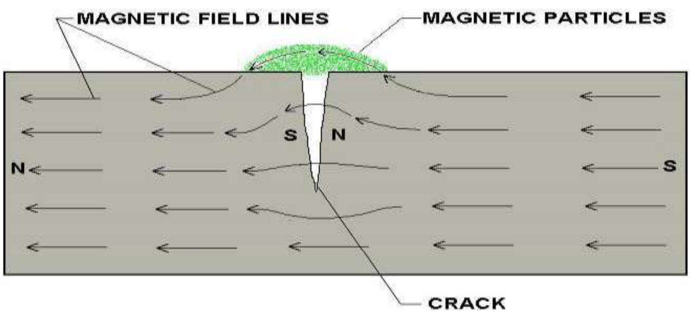
* Surface & Sub Surface discontinuities can be find through
this MPI AC current = Only Surface
DC current = Up to 6mm from the surface

2. Procedure - ASME Sec V Article 7

3. Standards - ASME Sec V Article 25 – SE- 709

4. Basic Principle:

Magnetic Flux Leakage



5. Magnetism Properties :

Generally a magnet is having two poles namely North Pole and South Pole.

If a magnet is broken into number of pieces, Each piece forms as a an individual magnet (North pole & South Pole). In a magnet opposite poles will attract and the same poles will repel.

The strength of the magnetic field is very high in the end poles of the magnet.Inside the magnet, flux lines will travel from South Pole to North Pole and the outside of the magnet lines will travel from North Pole to South Pole. The group of particle motion in a magnet is called as domains. In a material the domains are situated in its own direction.

6. <u>Types of Magnetic Materials:</u> (According to the Magnetism)

1. Diamagnetic Materials (-ve Susceptibility -Ability of material to be Magnetized)
   This type of materials would have negative magnetism/ Susceptibility, So MPI can not be conducted on this materials. <u>Examples:</u> Gold, Copper, Aluminum

2. Paramagnetic Materials (Small Positive Susceptibility)
   These materials would have small positive magnetism/ Susceptibility, MPT can't be conducted on this materials also. <u>Examples:</u> Magnesium, lithium, Molybdenum.

3. Ferromagnetic Materials (Positive Susceptibility)
   Ferro magnetic materials would have positive magnetism/ Susceptibility; MPI can be conduct on this type of materials. <u>Examples:</u> Iron, Cobalt, Nickel and Iron based materials.

13. <u>Properties of Ferromagnetic Materials:</u>

1. Permeability - It is an energy which magnetic flux is established. Carbon content is low.
2. Reluctance - It is nothing but the opp of the permeability. (Resistance of Magnetism)
3. Residual Magnetism - Amount of magnetism retained in the job after magnetization.
4. Retentivity - The ability of material to retain residual magnetism
5. Cohesive Force/De Magnetization - The process of removing residual magnetism.

<u>8.Types of medium / Method</u>

1. Dry method - The source should be in dry type. Iron powder is a sample for dry method.
2. Wet method. The medium should be mixed with either with kerosene or with water. This type of medium is called as wet medium.

9. <u>Temperature Limit:</u>

1. Wet method can be done up to 53°C Temperature jobs.
2. Dry method can be done up to 315°C Temperature jobs.

10. Basic Procedure

Basic steps involved:

1. Component pre-cleaning
2. Introduction of magnetic field
3. Application of magnetic media
4. Interpretation of magnetic particle indications
5. De Magnetization

11. Advantages of Magnetic Particle Inspection:

- Can detect both surface and near sub-surface defects.
- Can inspect parts with irregular shapes easily.
- Fast method of inspection and indications are visible directly on the specimen surface.
- Considered low cost compared to many other NDT methods.
- Is a very portable inspection method especially when used with battery powered equipment.

12. Limitations of Magnetic Particle Inspection

- Cannot inspect non-ferrous materials such as aluminum, magnesium or most stainless steels.
- Inspection of large parts may require use of equipment with special power requirements.
- Some parts may require removal of coating or plating to achieve desired inspection sensitivity.
- Limited subsurface discontinuity detection capabilities. Maximum depth sensitivity is approximately 6mm (under ideal conditions).
- Post cleaning, and post demagnetization is often necessary.
- Alignment between magnetic flux and defect is important.

MT Techniques

Yokes

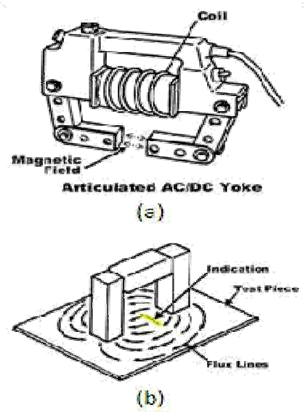


Figure 2

Most field inspections are performed using a Yoke, as shown at the right. As shown in Figure 2(a), an electric coil is wrapped around a central core, and when the current is applied, a magnetic field is generated that extends from the core down through the articulated legs into the part. This is known as longitudinal magnetization because the magnetic flux lines run from one leg to the other.

When the legs are placed on a ferromagnetic part and the yoke is energized, a magnetic field is introduced into the part as shown in (b). Because the flux lines do run from one leg to the other, discontinuities oriented perpendicular to a line drawn between the legs can be found. To ensure no indications are missed, the yoke is used once in the position shown then used again with the yoke turned 90^o so no indications are missed. Because all of the electric current is contained in the yoke and only the magnetic field penetrates the part, this type of application is known as *indirect* induction.

Prods

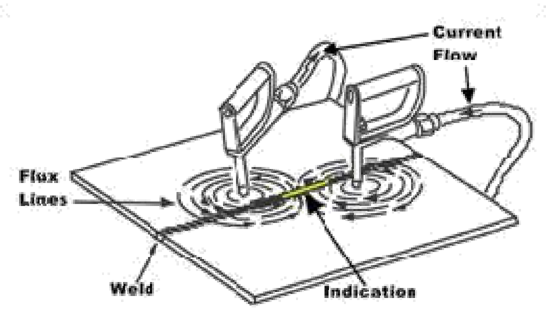


Figure 3

Prod units use *direct* induction, where the current runs through the part and a circular magnetic field is generated around the legs as shown in Figure 3. Because the magnetic field between the prods is travelling perpendicular to a line drawn between the prods, indications oriented parallel to a line drawn between the prods can be found. As with the yoke, two inspections are done, the second with the prods oriented 90^{o} to the first application.

Coils

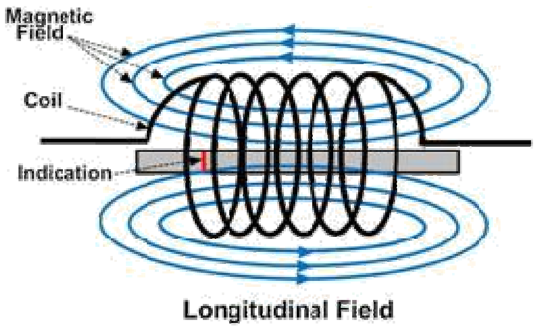


Figure 4

Electric coils are used to generate a longitudinal magnetic field. When energized, the current creates a magnetic field around the wires making up the coil so that the resulting flux lines are oriented through the coil as shown at the right. Because of the longitudinal field, indications in parts placed in a coil are oriented transverse to the longitudinal field.

Heads

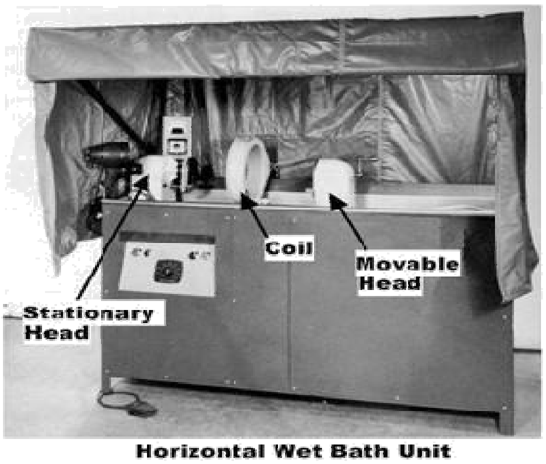
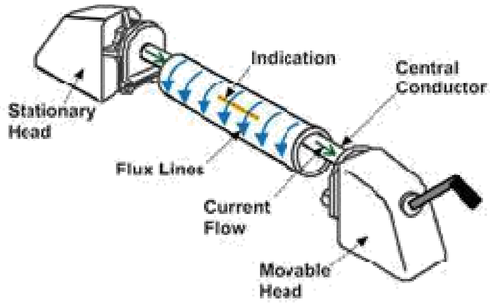


Figure 5

Most horizontal wet bath machines ("bench units") have both a coil and a set of heads through which electric current can be passed, generating a magnetic field. Most use fluorescent magnetic particles in a liquid solution, hence the name "wet bath." A typical bench unit is shown at the right. When testing a part between the heads, the part is placed between the heads, the moveable head is moved up so that the part being tested is held tightly between the heads, the part is wetted down with the bath solution containing the magnetic particles and the current is applied while the particle are flowing over the part. Since the current flow is from head to head and the magnetic field is oriented 90^o to the current, indications oriented parallel to a line between the heads will be visible. This type of inspection is commonly called a "head shot."

Central Conductor



Central Conductor

Figure 6

When testing hollow parts such as pipes, tubes and fittings, a conductive circular bar can be placed between the heads with the part suspended on the bar (the "central conductor") as shown in Figure 6. The part is then wetted down with the bath solution and the current is applied, travelling through the central conductor rather than through the part. The ID and OD of the part can then be inspected. As with a head shot, the magnetic field is perpendicular to the current flow, wrapping around the test piece, so indications running axially down the length of the part can be found using this technique.

ULTRASONIC TESTING

Introduction to Ultrasonic Flaw Detection

This technique is used for the detection of internal and surface (particularly distant surface) defects in sound conducting materials.

The principle is in some respects similar to echo sounding. A short pulse of ultrasound is generated by means of an electric charge applied to a piezo electric crystal, which vibrates for a very short period at a frequency related to the thickness of the crystal. In flaw detection this frequency is usually in the range of one million to six million times per second (1 MHz to 6 MHz). Vibrations or sound waves at this frequency have the ability to travel a considerable distance in homogeneous elastic material, such as many metals with little attenuation. The velocity at which these waves propagate is related to the Young's Modulus for the material and is characteristic of that material. For example the velocity in steel is 5900 metres per second, and in water 1400 metres per second.

Ultrasonic energy is considerably attenuated in air, and a beam propagated through a solid will, on reaching an interface (e.g. a defect, or intended hole, or the backwall) between that material and air reflect a considerable amount of energy in the direction equal to the angle of incidence.

For contact testing the oscillating crystal is incorporated in a hand held probe, which is applied to the surface of the material to be tested. To facilitate the transfer of energy across the small air gap between the crystal and the test piece, a layer of liquid (referred to as 'couplant'), usually oil, water or grease, is applied to the surface.

As mentioned previously, the crystal does not oscillate continuously but in short pulses, between each of which it is quiescent. Piezo electric materials not only convert electrical pulses to mechanical oscillations, but will also transduce mechanical oscillations into electrical pulses; thus we have not only a generator of sound waves but also a detector of returned pulses. The crystal is in a state to detect returned pulses when it is quiescent. The pulse takes a finite time to travel through the material to the interface and to be reflected back to the probe.

The standard method of presenting information in ultrasonic testing is by means of a cathode ray tube, in which horizontal movement of the spot from left to right represents time elapsed. The principle is not greatly different in digitised instruments that have a LCD flat screen. The rate at which the spot moves is such that it gives the appearance of a horizontal line on the screen. The system is synchronised electronically so that at the instant the probe receives its electrical pulse the spot begins to traverse the screen. An upward deflection (peak) of the line on the left hand side of the screen is an indication of this occurrence. This peak is usually termed the initial pulse.

Whilst the base line is perfectly level the crystal is quiescent. Any peaks to the right of the initial pulse indicate that the crystal has received an incoming pulse reflected from one or more interfaces in the material. Since the spot moves at a very even speed across the tube face, and the pulse of ultrasonic waves moves at a very even velocity through the material, it is possible to calibrate the horizontal line on the screen in terms of absolute measurement. The use of a calibration block, which produces a reflection from the back wall a known distance away from the crystal together with variable controls on the flaw detector, allows the screen to be calibrated in units of distance, and therefore determination of origins of returned pulses obtained from a test piece.

It is therefore possible not only to discover a defect between the surface and the back wall, but also to measure its distance below the surface. It is important that the equipment is properly calibrated and, since it is in itself not able to discriminate between intended boundaries of the object under test and unintended discontinuities, the operator must be able to identify the origin of each peak. Further as the pulses form a beam it is also possible to determine the plan position of a flaw.

The height of the peak (echo) is roughly proportional to the area of the reflector, though there is on all instruments a control, which can reduce or increase the size of an indication - variable sensitivity in fact. Not only is part of the beam reflected at a material/air interface but also at any junction where there is a velocity change, for example steel/slag interface in a weld.

Probing all faces of a test piece not only discovers the three-dimensional defect and measures its depth, but can also determine its size. Two-dimensional (planar) defects can also be found but, unlike radiography, it is best that the incident beam impinges on the defect as near to right angles to the plane as possible. To achieve this some probes introduce the beam at an angle to the surface. In this manner longitudinal defects in tubes (inner or outer surface) are detected.

Interpretation of the indications on the screen requires a certain amount of skill, particularly when testing with hand held probes. The technique is, however, admirably suited to automatic testing of regular shapes by means of a monitor - an electronic device that fits into the main equipment to provide an electrical signal when an echo occurs in a particular position on the trace. The trigger level of this signal is variable and it can be made to operate a variety of mechanical gates and flaw warnings. Furthermore, improvements in computer technology allow test data and results to be displayed and out-putted in a wide variety of formats.

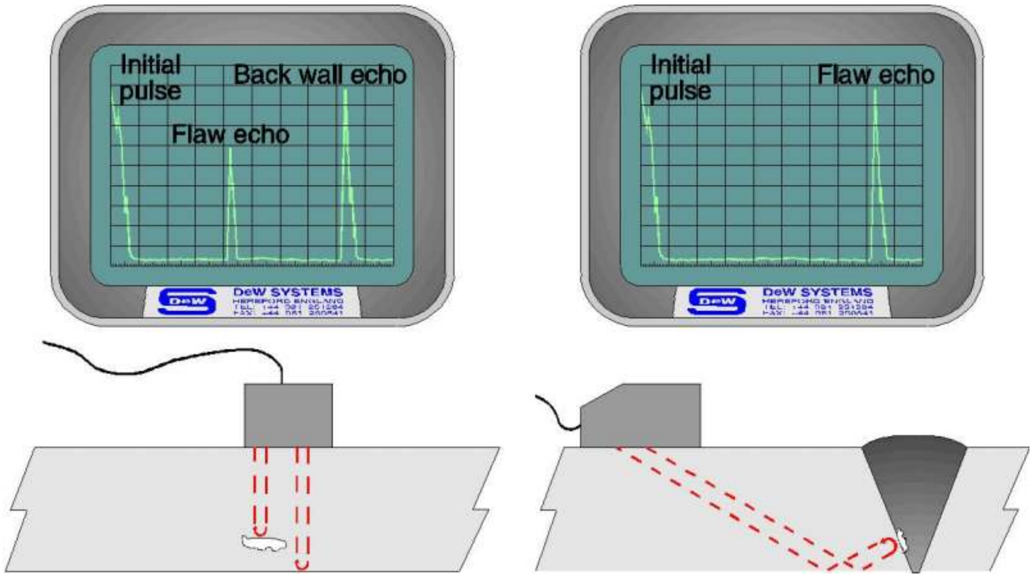
Modern ultrasonic flaw detectors are fully solid state and can be battery powered, and are robustly built to withstand site conditions.

Since the velocity of sound in any material is characteristic of that material, it follows that some materials can be identified by the determination of the velocity. This can be applied, for example in S.G. cast irons to determine the percentage of graphite nodularity.
This process can also be automated and is now in use in many foundries. Typical equipment is the Qualiron.

When the velocity is constant, as it is in a wide range of steels, the time taken for the pulse to travel through the material is proportional to its thickness. Therefore, with a properly calibrated instrument, it is possible to measure thickness from one side with an accuracy in thousandths of an inch. This technique is now in very common use.

A development of the standard flaw detector is the digital wall thickness gauge. This operates on similar principles but gives an indication, in LED or LCD numerics, of thickness in absolute terms of millimetres. These equipments are easy to use but require prudence in their application.

An Illustration of Ultrasonic Flaw Detection



Schematic diagram of ultrasonic detection of slag in steel section using a normal probe.

Schematic diagram of the use of an angle probe to detect defects not directly under the probe. Such as in weld inspection.

Advantages of Ultrasonic Flaw Detection

- Thickness and lengths up to 30 ft can be tested.
- Position, size and type of defect can be determined.
- Instant test results.
- Portable. Extremely sensitive if required.
- Capable of being fully automated.
- Access to only one side necessary.
- No consumables.

Disadvantages of Ultrasonic Flaw Detection

- No permanent record available unless one of the more sophisticated test results and data collection systems is used.
- The operator can decide whether the test piece is defective or not whilst the test is in progress.
- Indications require interpretation (except for digital wall thickness gauges).
- Considerable degree of skill necessary to obtain the fullest information from the test.
- Very thin sections can prove difficult.

- The sound range above 20 KHZ (or) 20,000HZ is called as an ULTRASONIC SOUND (or) ULTRASOUND.

Sound Classification:

Subsonic < 16HZ

Sonic - 16HZ – 20KHZ

Ultrasonic > 20,000 HZ

- The sound energy is introduced & propagates through the materials in the form of waves.
- Whenever the sound waves meet another interface of different acoustic impedance part of energy will be reflected back.
- The same occurs when it meets cracks, lamination or any other discontinuities.
- Sound generated above 20,000 HZ is called Ultrasound.
- The reflected wave signal is transformed into electrical signal by the transducer & is displayed on a screen.

2. Procedure:

ASME Sec V Article: 4 (Weld) &

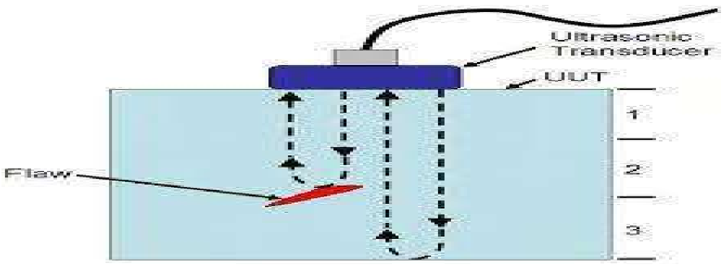
Article: 5 (Raw Materials).

3. Principle:

Acoustic Impedance mismatch
↓ ↓
Sound Resistance of material.

4. Generation of ultrasonic sound energy:

Sound is created when something vibrates.



5. Ultrasonic Transducers:

It converts Electrical Energy into ultrasonic energy by utilizing a phenomenon known as the PIEZOELECTRIC EFFECT.

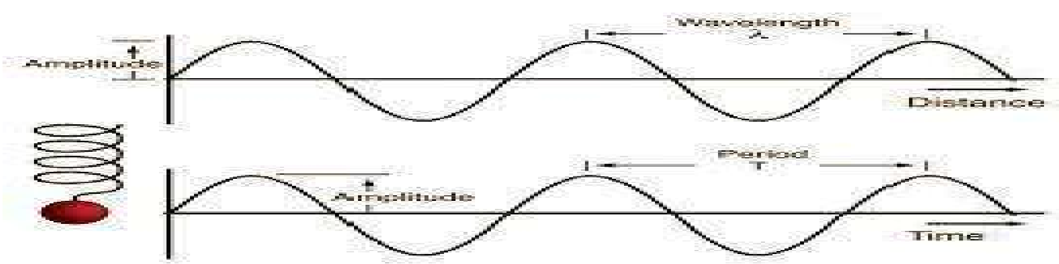
6. Crystal Material:

1. Quartz or Silicon oxide (SiO3)
2. Lithium sulphate (LiSo4)
3. Lead Zirconate (Pb Zr O3)
4. Lead Zirconate Titanate (Pb Z1 O3 T1 O3)
5. Barium Titanate (Ba Ti O3)

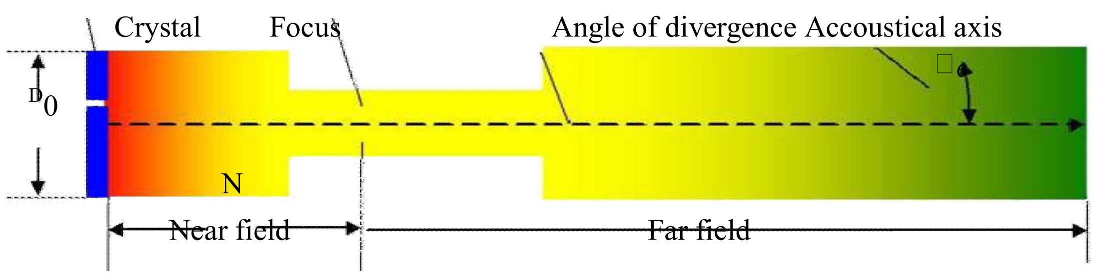
7. Cable:

1) Lemo cable.
2) BNC.

8. Fundamentals of Wave:



9. Propagation of Sound:



Dead Zone:

Seen on the CRT as an extension of the initial pulse the DZ is the ringing time of the crystal & it is minimized by the damping medium behind the crystal.

Near Zone:

In this region, the sound intensity is variable owing to wave interference; therefore flaws lying in this zone may appear smaller or larger than their actual size.

$$\boxed{N=D^2/4\lambda}$$

D- Diameter of crystal

λ – Wavelength of sound

Far Zone:

Beyond the near zone the far zone exists, in this region the beam divergence occurs, resulting in delay in the sound intensity as the distance from the crystal increased.

10. Modes of Propagation /Types of Waves:

1. Longitudinal or Compression waves.
2. Shear or Transverse.
3. Surface or Raleigh waves.
4. Plate or Lamb.

11. Types of Probes:

a. Normal probe.
b. T/R Probe.
c. Angle Probe.

12. Factors Affecting the Propagation of Ultrasound: General :

Dependent on the density & Elastic properties of that materials & types of waves transmitted

Factors:

- Test materials grain size.
- Attenuation
- Acoustic impedance of the test material

13. Total Attenuation Loss:

Attenuation is defined as the loss in intensity of the ultrasonic beam.

2 main causes for attenuation are,

Scattering & Absorption.

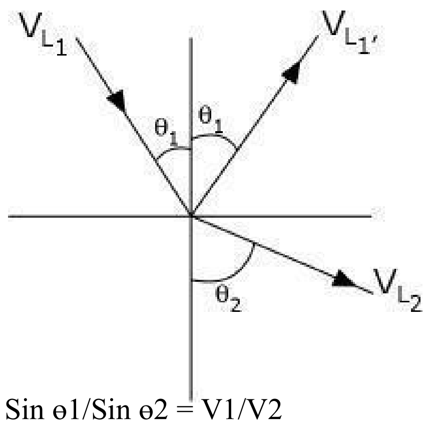
14. Acoustic Impedance:

Z is the resistance of a material to passage of ultra sound.

e- Density / v-Velocity.

Z= e*v

15. Snell's Law:



Sin ɵ1/Sin ɵ2 = V1/V2

ɵ1 – Angle of incident.

ɵ2 – Angle of refraction.

V1 – Angle of incident.

V2 – Angle of refraction.

16. Decibel: (DB)

DB is a logarithmic base unit to compare sound intensities.

DB = 20 log 11 H1/H2.

$\boxed{\text{H1 = 100\%}}$

17. Couplant:

Exclude any air that may be present b/w probe & test surface.

E.g.: water, oil, grease, polycell & glycerin.

Air – High acoustic impedance.

19. Types of Testing:

1. Pulse echo technique.
2. Through transmission technique.
3. Reasonance technique.

20. Ultrasonic Flow Detectors:

UT equipment basically comprises of

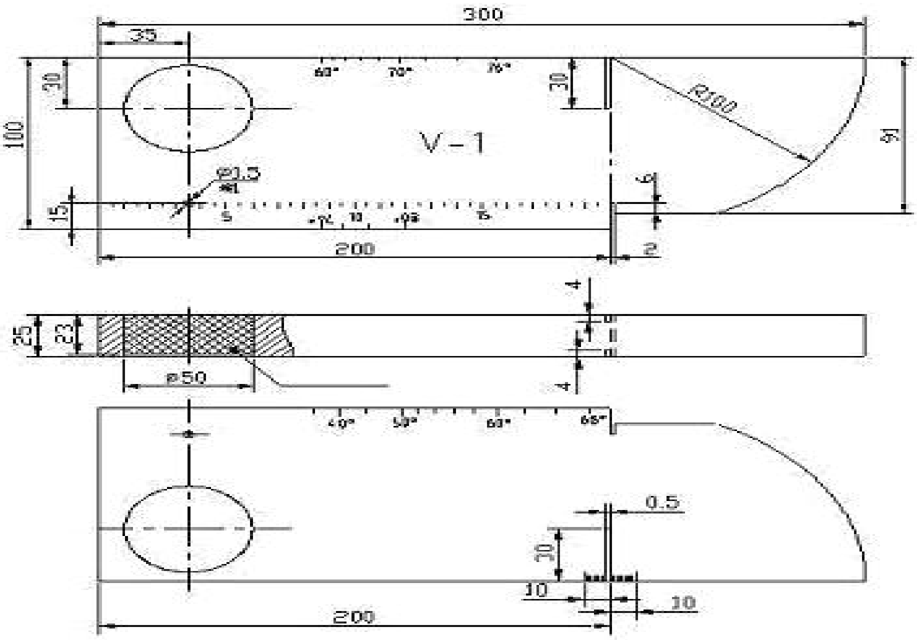
- (ULTRA SOUND) Pulse generator.
- Receiver & its amplification.
- Display system.

21. Calibration Block

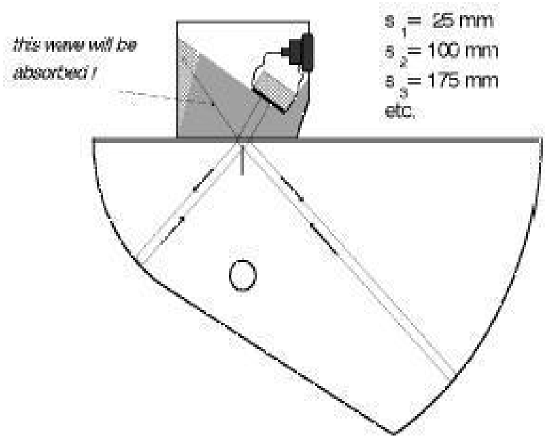
1. V1 Block (or) I.I.W V1 Block.
2. V2 Block (or) I.I.W V2 Block.

1. V1 Blocks or IIW (V1)

IIW – INTERNATIONAL INSTITUTE OF WELDING



2. V2 Blocks or IIW (V2)



22. Reference Test Block

1. DAC Block.
2. Flat Bottom Block.

23. UT Formulas

1. Probe selection:

ɵ = 90(degree) - T (Thickness of job)

Generally:

1. 5-25mm = 70 degree
2. 25-50mm = 60 degree
3. Above 50mm = 45degree

2. Beam path (W):

W or B.P = T/Cosɵ

3. Skip distance:

S.D = T * Tan ɵ (or) S.D = B.P * Sin ɵ

25. Advantages:

1. Portable – Inexpensive.
2. Immediate result.
3. Wide range of material thickness can be inspected.

26. Disadvantages:

1. High degree of skill required.
2. Materials are rough, irregular in shape are difficult to inspect.
3. Surface must be accessible to transmit ultra sound.
4. Linear defect – undetected.
5. Calibration needed.

Ultrasonic Testing (UT)

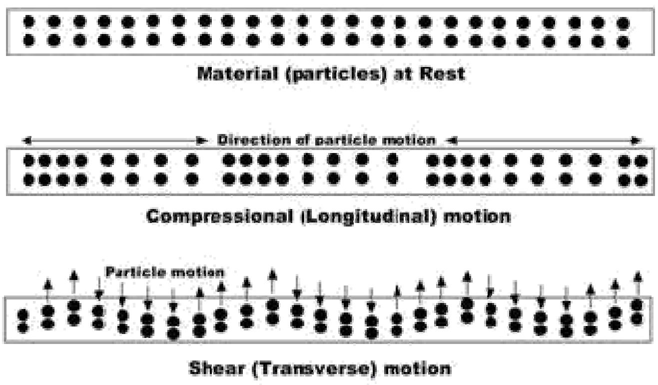


Figure 10

Ultrasonic testing uses the same principle as is used in naval SONAR and fish finders. Ultra-high frequency sound is introduced into the part being inspected and if the sound hits a material with different acoustic impedance (density and acoustic velocity), some of the sound will reflect back to the sending unit and can be presented on a visual display. By knowing the speed of the sound through the part (the acoustic velocity) and the time required for the sound to return to the sending unit, the distance to the reflector (the indication with the different acoustic impedance) can be determined. The most common sound frequencies used in UT are between 1.0 and 10.0 MHz, which are too high to be heard and do not travel through air. The lower frequencies have greater penetrating power but less sensitivity (the ability to "see" small indications), while the higher frequencies don't penetrate as deeply but can detect smaller indications.

The two most commonly used types of sound waves used in industrial inspections are the compression (longitudinal) wave and the shear (transverse) wave, as shown in Figure 10. Compression waves cause the atoms in a part to vibrate back and forth parallel to the sound direction and shear waves cause the atoms to vibrate perpendicularly (from side to side) to the direction of the sound. Shear waves travel at approximately half the speed of longitudinal waves.

Sound is introduced into the part using an ultrasonic transducer ("probe") that converts electrical impulses from the UT machine into sound waves, then converts returning sound back into electric impulses that can be displayed as a visual representation on a digital or LCD screen (on older machines, a CRT screen). If the machine is properly calibrated, the operator can determine the distance from the transducer to the reflector, and in many cases, an experienced operator can determine the type of discontinuity (like slag, porosity or cracks in a weld) that caused the reflector. Because ultrasound will not travel through air (the atoms in air molecules are too far apart to transmit ultrasound), a liquid or gel called "couplant" is used between the face of the transducer and the surface of the part to allow the sound to be transmitted into the part.

UT Techniques

Straight Beam

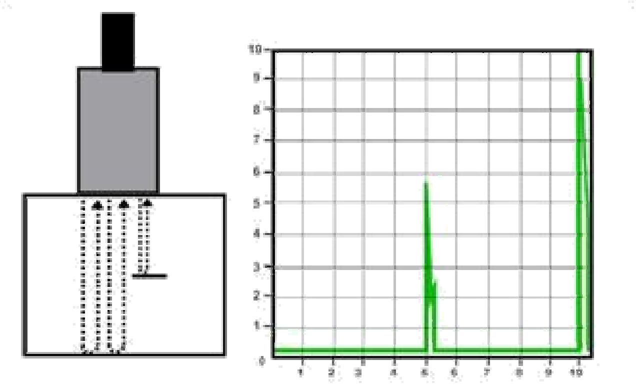
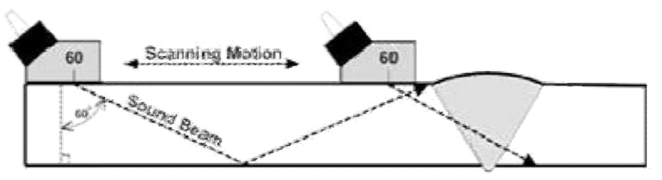


Figure 11

Straight beam inspection uses longitudinal waves to interrogate the test piece as shown at the right. If the sound hits an internal reflector, the sound from that reflector will reflect to the transducer faster than the sound coming back from the back-wall of the part due to the shorter distance from the transducer. This results in a screen display like that shown at the right in Figure 11. Digital thickness testers use the same process, but the output is shown as a digital numeric readout rather than a screen presentation.

Angle Beam



Angle Beam Testing

Figure 12

Angle beam inspection uses the same type of transducer but it is mounted on an angled wedge (also called a "probe") that is designed to transmit the sound beam into the part at a known angle. The most commonly used inspection angles are 45°, 60° and 70°, with the angle being calculated up from a line drawn through the thickness of the part (not the part surface). A 60° probe is shown in Figure 12. If the frequency and wedge angle is not specified by the governing code or specification, it is up to the operator to select a combination that will adequately inspect the part being tested.

In angle beam inspections, the transducer and wedge combination (also referred to as a "probe") is moved back and forth towards the weld so that the sound beam passes through the full volume of the weld. As with straight beam inspections, reflectors aligned more or less perpendicular to the sound beam will send sound back to the transducer and are displayed on the screen.

Immersion Testing

Immersion Testing is a technique where the part is immersed in a tank of water with the water being used as the coupling medium to allow the sound beam to travel between the transducer and the part. The UT machine is mounted on a movable platform (a "bridge") on the side of the tank so it can travel down the length of the tank. The transducer is swivel-mounted on at the bottom of a waterproof tube that can be raised, lowered and moved across the tank. The bridge and tube movement permits the transducer to be moved on the X-, Y- and Z-axes. All directions of travel are gear driven so the transducer can be moved in accurate increments in all directions, and the swivel allows the transducer to be oriented so the sound beam enters the part at the required angle. Round test parts are often mounted on powered rollers so that the part can be rotated as the transducer travels down its length, allowing the full circumference to be tested. Multiple transducers can be used at the same time so that multiple scans can be performed.

Through Transmission

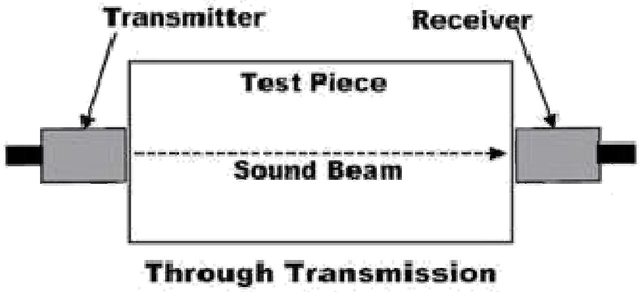


Figure 13

Through transmission inspections are performed using two transducers, one on each side of the part as shown in Figure 13. The transmitting transducer sends sound through the part and the receiving transducer receives the sound. Reflectors in the part will cause a reduction in the amount of sound reaching the receiver so that the screen presentation will show a signal with lower amplitude (screen height).

Phased Array

Phased array inspections are done using a probe with multiple elements that can be individually activated. By varying the time when each element is activated, the resulting sound beam can be "steered", and the resulting data can be combined to form a visual image representing a slice through the part being inspected.

Time of Flight Diffraction

Time of Flight Diffraction (TOFD) uses two transducers located on opposite sides of a weld with the transducers set at a specified distance from each other. One transducer transmits sound waves and the other transducer acting as a receiver. Unlike other angle beam inspections, the transducers are not manipulated back and forth towards the weld, but travel along the length of the weld with the transducers remaining at the same distance from the weld. Two sound waves are generated, one travelling along the part surface between the transducers, and the other travelling down through the weld at an angle then back up to the receiver. When a crack is encountered, some of the sound is diffracted from the tips of the crack, generating a low strength sound wave that can be picked up by the receiving unit. By amplifying and running these signals through a computer, defect size and location can be determined with much greater accuracy than by conventional UT methods.

RADIOGRAPHY TESTING

Introduction to Radiography

This technique is suitable for the detection of internal defects in ferrous and non-ferrous metals and other materials.

X-rays, generated electrically, and Gamma rays emitted from radio-active isotopes, are penetrating radiation which is differentially absorbed by the material through which it passes; the greater the thickness, the greater the absorbtion. Furthermore, the denser the material the greater the absorbtion.

X and Gamma rays also have the property, like light, of partially converting silver halide crystals in a photographic film to metallic silver, in proportion to the intensity of the radiation reaching the film, and therefore forming a latent image. This can be developed and fixed in a similar way to normal photographic film.

Material with internal voids is tested by placing the subject between the source of radiation and the film. The voids show as darkened areas, where more radiation has reached the film, on a clear background. The principles are the same for both X and Gamma radiography.

In X-radiography the penetrating power is determined by the number of volts applied to the X-Ray tube - in steel approximately 1000 volts per inch thickness is necessary. In Gamma radiography the isotope governs the penetrating power and is unalterable in each isotope. Thus Iridium 192 is used for $^1/_2$" to 1" steel and Caesium 134 is used for $^3/_4$" to $2^1/_2$" steel.

In X-radiography the intensity, and therefore the exposure time, is governed by the amperage of the cathode in the tube. Exposure time is usually expressed in terms of milliampere minutes. With Gamma rays the intensity of the radiation is set at the time of supply of the isotope. The intensity of radiation from isotopes is measured in Becquerel’s and reduces over a period of time. The time taken to decay to half the amount of curies is the half life and is characteristic of each isotope. For example, the half life of Iridium 192 is 74 days, and Caesium 134 is 2.1 years. The exposure factor is a product of the number of curies and time, usually expressed in curie hours. The time of exposure must be increased as the isotope decays - when the exposure period becomes uneconomical the isotope must be renewed.

As the isotope is continuously emitting radiation it must be housed in a container of deleted uranium or similar dense shielding material, whilst not exposed to protect the environment and personnel.

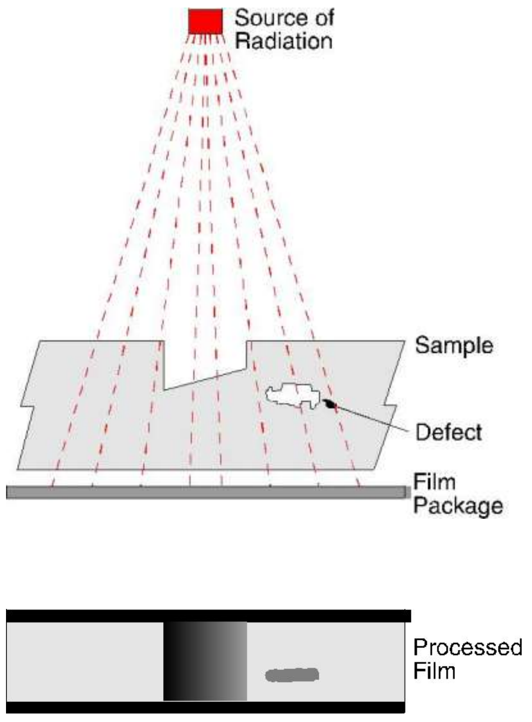
To produce an X or Gamma radiograph, the film package (comprising film and intensifying screens - the latter being required to reduce the exposure time - enclosed in a light tight cassette) is placed close to the surface of the subject.

The source of radiation is positioned on the other side of the subject some distance away, so that the radiation passes through the subject and on to the film. After the exposure period the film is removed, processed, dried, and then viewed by transmitted light on a special viewer.

Various radiographic and photographic accessories are necessary, including such items as radiation monitors, film markers, image quality indicators, darkroom equipment, etc. Where the last is concerned there are many degrees of sophistication, including fully automatic processing units. These accessories are the same for both X and Gamma radiography systems.

Also required are such consumable items as radiographic film and processing chemicals.

2.2 An illustration of Radiography



Schematic illustration of a typical exposure arrangement for radiography. The source of radiation can be either an X-ray tube or a radioactive isotope.

The resultant radiograph shows the subject as seen from the source.

Recent developments in radiography permit ‘real time’ diagnosis. Such techniques as computerised tomography yield much important information, though these methods maybe suitable for only investigative purposes and not generally employed in production quality control.

Advantages of Radiography

- Information is presented pictorially.
- A permanent record is provided which may be viewed at a time and place distant from the test.
- Useful for thin sections.
- Sensitivity declared on each film.
- Suitable for any material.

Disadvantages of Radiography

- Generally an inability to cope with thick sections.
- Possible health hazard.
- Need to direct the beam accurately for two-dimensional defects.
- Film processing and viewing facilities are necessary, as is an exposure compound.
- Not suitable for automation, unless the system incorporates fluoroscopy with an image intensifier or other electronic aids
- Not suitable for surface defects.
- No indication of depth of a defect below the surface

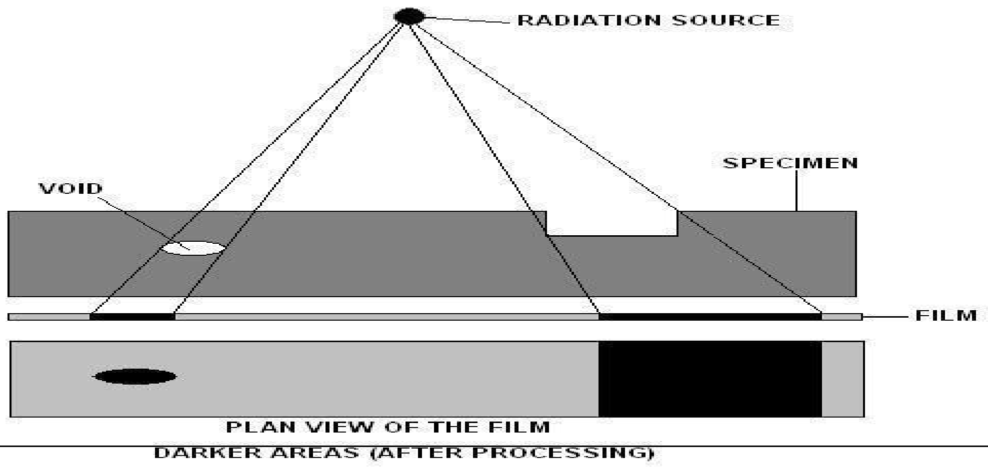
RT is based on exposure of the components to short wave length

electromagnetic radiation in the form of x-rays or gamma rays from the

suitable source.

The amount of radiation absorbed by a particular part is a function of its thickness & density.

This radiation variation can be detected with the aid of photographic films.



- False interpretation of film will affect productivity.
- Only certified personnel can able to interpret the result.

2. Procedure:

ASME SEC: V Article: 2 /Article: 22

3. Principle:

Penetration & Differential Absorption.

4. Properties of Electromagnetic Radiation:

1. Reflection, refraction & diffraction.
2. Penetration
3. Absorption
4. Ionizing ability

5. Types of RT:

1. X-RAY
2. Gamma-RAY

6. Types of Isotopes:

1. Natural Isotopes:

   Uranium, Thorium, Radium.

2. Artificial Isotopes:

   Iridium, Cobalt, Cesium.

7. Disintegration Law:

The unstable atom in the radio active nuclei emits alpha particle, beta & gamma rays to become a stable nucleus. This process is called disintegration law.

8. Half Life Period: It is the time taken for half of the existing unstable nucleus to become stable size & shape of isotopes.

CURIE:

The disintegration per second.

1 curie = $3.7*10^{10}$

9. Gamma Radiography:

1. Gamma rays are produced by a radio isotope.
2. A radio isotope has unstable nuclei that do not leave enough binding energy to hold the nucleus together.
3. The spontaneous break down of an atomic nucleus resulting in the release of energy & matter is known as radioactive decay.

10. Source:

Source	Half life period	Thickness of job to be Radiographed
Iridium(Ir 192)	74.6 days	Upto 75mm
Cobalt(co 60)	5.3 years	25 to 225mm
Cesium (ce 137)	22 years	40 to 100mm

11. Steps before RT:

1. Request.

1. Barricade Rope
2. Survey Meter
3. Dosi Meter
4. Film Badge
5. Penetrometer
6. Selection of film
7. Lead number box
8. Selection of source.

12. RT Techniques: (methods)

1. SWSI – Single wall single image.
2. DWSI – Double wall single image.
3. DWDI – Double wall double image.

14. Radiation Doses andS Effects :

1. 0-5 RAD Safe.
2. 10-50 Slight chances for cancer & decreases in blood cell.
3. 50-100 This dose will increases the chances for getting cancer.
4. 100-300 Nausea, vomiting, & long period cancer.

5. 300-500 Loss of hair, severe medical attention should be given for survival, death will occur in absence of medical attention.

6. 500-1200 Death within few days.

7. > 10000 Death within few hours.

15. Advantages:

1. Can be used to inspect virtually all materials.

2. Detects surface and subsurface defects.

3. Ability to inspect complex shapes and multi-layered structures without disassembly.

4. Minimum part preparation is required.

5. Permanent test record is obtained.

16. Disadvantages:

1. Extensive operator training and skill required.

2. Access to both sides of the structure is usually required.

3. Field inspection of thick section can be time consuming.

4. Relatively expensive equipment investment is required.

5. Possible radiation hazard for personnel.

6. Depth of discontinuity is not indicated.

Radiographic Testing (RT)

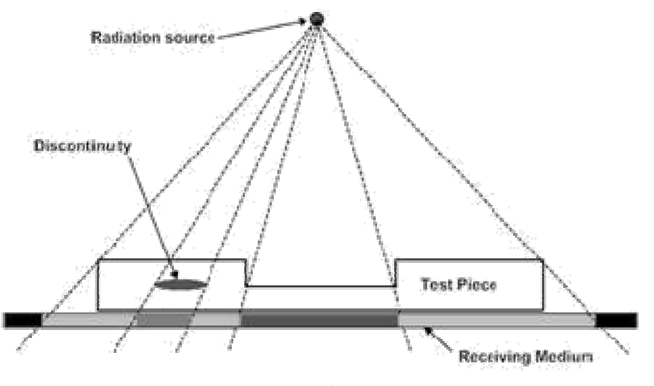


Figure 8

Industrial radiography involves exposing a test object to penetrating radiation so that the radiation passes through the object being inspected and a recording medium placed against the opposite side of that object. For thinner or less dense materials such as aluminum, electrically generated x-radiation (X-rays) are commonly used, and for thicker or denser materials, gamma radiation is generally used.

Gamma radiation is given off by decaying radioactive materials, with the two most commonly used sources of gamma radiation being Iridium-192 (Ir-192) and Cobalt-60 (Co-60). IR-192 is generally used for steel up to 2-1/2 - 3 inches, depending on the Curie strength of the source, and Co-60 is usually used for thicker materials due to its greater penetrating ability.

The recording media can be industrial x-ray film or one of several types of digital radiation detectors. With both, the radiation passing through the test object exposes the media, causing an end effect of having darker areas where more radiation has passed through the part and lighter areas where less radiation has penetrated. If there is a void or defect in the part, more radiation passes through, causing a darker image on the film or detector, as shown in Figure 8.

RT Techniques

Film Radiography

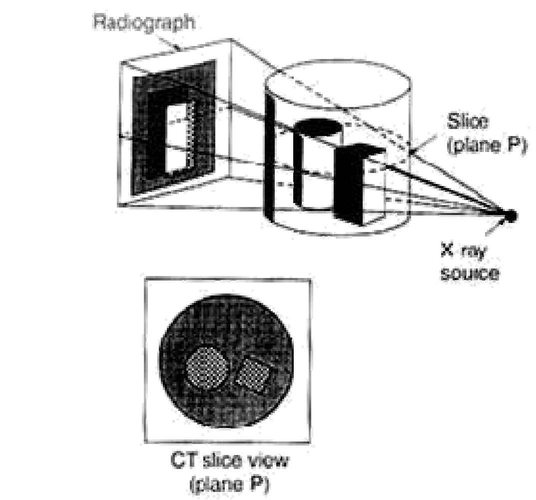
Film radiography uses a film made up of a thin transparent plastic coated with a fine layer of silver bromide on one or both sides of the plastic. When exposed to radiation these crystals undergo a reaction that allows them, when developed, to convert to black metallic silver. That silver is then "fixed" to the plastic during the developing process, and when dried, becomes a finished radiographic film.

To be a usable film, the area of interest (weld area, etc.) on the film must be within a certain density (darkness) range and must show enough contrast and sensitivity so that discontinuities of interest can be seen. These items are a function of the strength of the radiation, the distance of the source from the film and the thickness of the part being inspected. If any of these parameters are not met, another exposure ("shot") must be made for that area of the part.

Computed Radiography

Computed radiography (CR) is a transitional technology between film and direct digital radiography. This technique uses a reusable, flexible, photo-stimulated phosphor (PSP) plate which is loaded into a cassette and is exposed in a manner similar to traditional film radiography. The cassette is then placed in a laser reader where it is scanned and translated into a digital image, which take from one to five minutes. The image can then be uploaded to a computer or other electronic media for interpretation and storage.

Computed Tomography



CT image vs. a radiographic image
Figure 9

Computed tomography (CT) uses a computer to reconstruct an image of a cross sectional plane of an object as opposed to a conventional radiograph, as shown in Figure 9. The CT image is developed from multiple views taken at different viewing angles that are reconstructed using a computer. With traditional radiography, the position of internal discontinuities cannot be accurately determined without making exposures from several angles to locate the item by triangulation. With computed tomography, the computer triangulates using every point in the plane as viewed from many different directions.

Digital Radiography

Digital radiography (DR) digitizes the radiation that passes through an object directly into an image that can be displayed on a computer monitor. The three principle technologies used in direct digital imaging are amorphous silicon, charge coupled devices (CCDs), and complementary metal oxide semiconductors (CMOSs). These images are available for viewing and analysis in seconds compared to the time needed to scan in computed radiography images. The increased processing speed is a result of the unique construction of the pixels; an arrangement that also allows a superior resolution than is found in computed radiography and most film applications.

VISUAL TESTING

1. Introduction

Visual testing requires adequate illumination on the test surface and proper eye-sight of the tester. The most effective visual testing requires training.

Visual testing can be classified as direct visual testing, remote visual testing and translucent visual testing. Often the equipment needed is simple.

A portable light, a mirror, a 2X or 4X hand lens, illuminated magnifier with magnification 5X or 10X. For internal inspection, light lens systems such as bore scopes allow remote surfaces to be examined.

More sophisticated devices using fiber optics, it permits the introduction of the device into very small access holes and channels. Most of these systems provide for the attachment of a camera to permit permanent recording.

2. Procedure

ASME Sec - V, Article 9 /

Acceptance Criteria: Sec. VIII Division 1 (Welds)

3. Application

(a) Checking the surface condition of the component.

(b) Checking the alignment of mating surfaces.

(c) Checking the shape of the component.

(d) Checking the evidence of leaking.

(e) Checking for internal side defects.

4. Physical Requirements

Personnel shall have an annual vision test to assure natural or corrected near distance acuity such that they are capable of reading standard J-1 letters on standard Jaeger test type charts for near vision. Equivalent near vision tests are acceptable.

5. Equipment Used In Visual Inspection

5.1 Equipment used for visual examination shall include

a) Measuring instruments and gauges

b) Templates for measuring Edge preparation and fillet welds

c) Spirit levels

d) Hand magnifying glass (magnification usually 2–3X).

e) Illuminated magnifier (magnification 5–10X)

f) Bore scope or intrascope with built-in illumination (magnification 2–3X).

g) Mirrors, Shims

5.2 Wherever required, calibrated instruments shall be used for examination

6. Types of Technique / Examination

1. Direct Visual Examination

Direct visual examination may usually be made when access is sufficient to place the eye within 24 in. (600 mm) of the surface to be examined and at an angle not less than 30 deg to the surface to be examined. The minimum light intensity is 1000 lux (100 footcandles).

2. Remote Visual Examination

Remote visual examination may have to be substituted for Direct visual examination. Remote visual examination may use Visual aids such as mirrors, telescopes, fiber optics, cameras, or other suitable instruments.

3. Translucent Visual Examination

Translucent visual examination is a supplement of direct visual examination. The method of Translucent visual examination uses the aid of artificial lighting. which can contained in an illuminator that produces directional lighting.

7. Surface Condition

Surface prepared by gas cutting or arc cutting for welding shall be uniform and smooth and shall be free of all loose scale and slag accumulations.

The surface to be welded shall be clean and free of scale, rust, oil, grease, slag, detrimental oxides and other deleterious foreign materials.

The surface of the fillet weld shall merge smoothly with the surfaces joined.

8. Method of Examination

1. The material specification and dimensions shall be verified based on applicable drawing.
2. Edge preparation and weld fit up shall be verified with respect to the applicable drawing & WPS.
3. Fit up alignment shall be verified using steel rules and spirit level.
4. Groove angle and root gap shall be verified using templates.
5. Employment of qualified welder and usage of correct welding consumables shall be verified with 'List of Qualified Welders' and WPS.
6. Weld surface(s) shall be verified for the finish and cleanliness.
7. Fillet welds shall be verified using fillet gauges.
8. Cleanliness of Inside bore shall be inspected using hand lamp or Torch light.

9. Acceptance Standard of Butt Welds

1 Cracks, Pin holes and lack of fusion are not acceptable

2 Alignment tolerance shall not exceed the value given in Table-I. Below.

Section Thickness (mm)	Joint Categories	
	A	B, C and D
Upto 13.0, inc	1/4 t	1/4 t
Over 13.0 to 19.0, incl.	3.2mm	1/4 t
Over 19.0 to 38.0, incl	3.2mm	4.8mm
Over 38.0 to 51.0,incl.	3.2mm	1/8 t
Over 51.0	Lesser of 1/16 or 10 mm	Lesser of 1/8 t or 19mm

't' is the nominal thickness of the thinner section at the joint

3 The reduction in thickness shall not exceed 0.8 mm or 10% of the nominal thickness of the adjoining surface, whichever is less.

4 The Thickness of the weld reinforcement on each face shall not exceed the value given in Table II

10. Acceptance Standard for Fillet Welds

1 Fillet welds shall meet the requirements of applicable drawing.

2 The reduction of the thickness of the base metal due to the welding process at the edges of the fillet weld shall be as per CI. 7.3 and 7.4.

11. Inspection Evaluation

All examinations shall be evaluated in terms of the acceptance standards of the referencing Code Section.

12. Inspection Documentation

(a) The date of the examination

(b) Identification of the part or component examined.

(c) Standards / Acceptance criteria used

(d) Technique used.

(e) Equipments used.

(f) Results of the examination

13. Advantage of Visual Testing

(a) Testing is simple

(b) Testing speed is high

(c) Cost is low

(d) Less training

(e) On-line testing possibility

(f) Permanent record available

14. Limitation for Visual Testing

(a) Can detect only surface defects

(b) Difficulty in sizing depth of defects

Visual Testing (VT)

Visual testing is the most commonly used test method in industry. Because most test methods require that the operator look at the surface of the part being inspected, visual inspection is inherent in most of the other test methods. As the name implies, VT involves the visual observation of the surface of a test object to evaluate the presence of surface discontinuities. VT inspections may be by Direct Viewing, using line-of sight vision, or may be enhanced with the use of optical instruments such as magnifying glasses, mirrors, boroscopes, charge-coupled devices (CCDs) and computer-assisted viewing systems (Remote Viewing). Corrosion, misalignment of parts, physical damage and cracks are just some of the discontinuities that may be detected by visual examinations.

Acoustic Emission Testing (AE)

Acoustic Emission Testing is performed by applying a localized external force such as an abrupt mechanical load or rapid temperature or pressure change to the part being tested. The resulting stress waves in turn generate short-lived, high frequency elastic waves in the form of small material displacements, or plastic deformation, on the part surface that are detected by sensors that have been attached to the part surface. When multiple sensors are used, the resulting data can be evaluated to locate discontinuities in the part.

Guided Wave Testing (GW)

Guided wave testing on piping uses controlled excitation of one or more ultrasonic waveforms that travel along the length of the pipe, reflecting from changes in the pipe stiffness or cross sectional area. A transducer ring or exciter coil assembly is used to introduce the guided wave into the pipe and each transducer/exciter . The control and analysis software can be installed on a laptop computer to drive the transducer ring/exciter and to analyze the results. The transducer ring/exciter setup is designed specifically for the diameter of the pipe being tested, and the system has the advantage of being able to inspect the pipe wall volume over long distances without having to remove coatings or insulation. Guided wave testing can locate both ID and OD discontinuities but cannot differentiate between them.

Laser Testing Methods (LM)

Laser Testing includes three techniques, Holography, Shearography and Profilometry. As the method name implies, all three techniques user lasers to perform the inspections.

LM Techniques

Holographic Testing

Holographic Testing uses a laser to detect changes to the surface of a part as it deforms under induced stress which can be applied as mechanical stress, heat, pressure, or vibrational energy. The laser beam scans across the surface of the part and reflects back to sensors that record the differences in the surface created by that stress. The resulting image will be a topographical map-like presentation that can reveal surface deformations in the order of 0.05 to 0.005 microns without damage to the part. By comparing the test results with an undamaged reference sample, holographic testing can be used to locate and evaluate cracks, delaminations, disbonds, voids and residual stresses.

Laser Profilometry

Laser Profilometry uses a high-speed rotating laser light source, miniature optics and a computer with high-speed digital signal processing software. The ID surface of a tube is scanned in two dimensions and the reflected light is passed through a lens that focuses that light onto a photo-detector, generating a signal that is proportional to the spot's position in its image plane. As the distance from the laser to the ID surface changes, the position of the focal spot on the photo-detector changes due to parallax, generating a high resolution three-dimensional image of the part surface that represents the surface topography of the part. This technique can be used to detect corrosion, pitting, erosion and cracks in pipes and tubes.

Laser Shearography

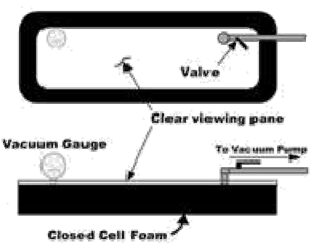
Laser Shearography applies laser light to the surface of the part being tested with the part at rest (non-stressed) and the resulting image is picked up by a charge-coupled device (CCD) and stored on a computer. The surface is then stressed and a new image is generated, recorded and stored. The computer then superimposes the two patterns and if defects such as voids or disbonds are present, the defect can be revealed by the patterns developed. Discontinuities as small as a few micrometers in size can be detected in this manner.

Leak Testing (LT)

Leak Testing, as the name implies, is used to detect through leaks using one of the four major LT techniques: Bubble, Pressure Change, Halogen Diode and Mass Spectrometer Testing. These techniques are described below.

LT Techniques

Bubble Leak Testing



Basic Vacuum Box

Figure 15

Bubble Leak Testing, as the name implies, relies on the visual detection of a gas (usually air) leaking from a pressurized system. Small parts can be pressurized and immersed in a tank of liquid and larger vessels can be pressurized and inspected by spraying a soap solution that creates fine bubbles to the area being tested. For flat surfaces, the soap solution can be applied to the surface and a vacuum box (Figure 15) can be used to create a negative pressure from the inspection side. If there are through leaks, bubbles will form, showing the location of the leak.

Pressure Change Testing

Pressure Change Testing can be performed on closed systems only. Detection of a leak is done by either pressurizing the system or pulling a vacuum then monitoring the pressure. Loss of pressure or vacuum over a set period of time indicates that there is a leak in the system. Changes in temperature within the system can cause changes in pressure, so readings may have to be adjusted accordingly.

Halogen Diode Testing

Halogen Diode Testing is done by pressurizing a system with a mixture of air and a halogen-based tracer gas. After a set period of time, a halogen diode detection unit, or "sniffer", is used to locate leaks.

Mass Spectrometer Testing

Mass Spectrometer Testing can be done by pressurizing the test part with helium or a helium/air mixture within a test chamber then surveying the surfaces using a sniffer, which sends an air sample back to the spectrometer. Another technique creates a vacuum within the test chamber so that the gas within the pressurized system is drawn into the chamber through any leaks. The mass spectrometer is then used to sample the vacuum chamber and any helium present will be ionized, making very small amounts of helium readily detectable.

Magnetic Flux Leakage (MFL)

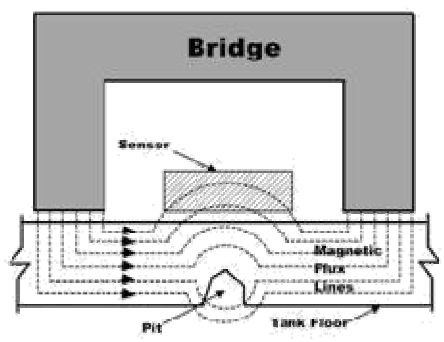


Figure 16

Magnetic Flux Leakage detects anomalies in normal flux patterns created by discontinuities in ferrous material saturated by a magnetic field. This technique can be used for piping and tubing inspection, tank floor inspection and other applications. In tubular applications, the inspection head contain is made up of drive and sensor coils and a position transducer that are connected by cable back to the power source and signal processing computer. This head is placed around the pipe or tube to be inspected and the drive coil is energized, creating a magnetic field in the part. As the head travels along the length of the part, variations in the wall thickness due to corrosion, erosion, pitting etc., will cause a change in the magnetic flux density can be picked up by the sensor and sent back to the computer. The location of this signal is sent by the position transducer so that the area detected can be marked for further evaluation. This technique can be done without removing the insulation, resulting in a fast, economic way to inspect long runs of pipe or tubing.

Tank floor inspection applies the same principle, but uses a series of magnetic field generators ("bridges") and sensors (as shown in Figure 16) located side by side across the front of a vacuum sweeper-like machine. The bridges generate a magnetic field that saturates the tank floor, and any reduction in thickness or loss of material due to pitting or corrosion will cause the field to "leak" upwards out of the floor material where it can be picked up by the sensors. On very basic machines, each sensor will be connected to an audio and/or visual display that lets the operator know there is an indication; more advanced machines can have both visual displays and recording capability so that the results can be stored, analyzed and compared to earlier results to monitor discontinuity growth.

Neutron Radiographic Testing (NR)

Neutron radiography uses an intense beam of low energy neutrons as a penetrating medium rather than the gamma- or x-radiation used in conventional radiography. Generated by linear accelerators, betatrons and other sources, neutrons penetrate most metallic materials, rendering them transparent, but are attenuated by most organic materials (including water, due to its high hydrogen content) which allows those materials to be seen within the component being inspected. When used with conventional radiography, both the structural and internal components of a test piece can be viewed.

Thermal/Infrared Testing (IR)

Thermal/Infrared Testing, or infrared thermography, is used to measure or map surface temperatures based on the infrared radiation given off by an object as heat flows through, to or from that object. The majority of infrared radiation is longer in wavelength than visible light but can be detected using thermal imaging devices, commonly called "infrared cameras." For accurate IR testing, the part(s) being investigated should be in direct line of sight with the camera, i.e., should not be done with panel covers closed as the covers will diffuse the heat and can result in false readings. Used properly, thermal imaging can be used to detect corrosion damage, delaminations, disbonds, voids, inclusions as well as many other detrimental conditions.

Vibration Analysis (VA)

Vibration analysis refers to the process of monitoring the vibration signatures specific to a piece of rotating machinery and analyzing that information to determine the condition of that equipment. Three types of sensors are commonly used: displacement sensors, velocity sensors and accelerometers.

Displacement sensors uses eddy current to detect vertical and/or horizontal motion (depending on whether one or two sensors are used) and are well suited to detect shaft motion and changes in clearance tolerances.

Basic velocity sensors use a spring-mounted magnet that moves through a coil of wire, with the outer case of the sensor attached to the part being inspected. The coil of wire moves through the magnetic field, generating an electrical signal that is sent back to a receiver and recorded for analysis. Newer model vibration sensors use time-of-flight technology and improved analysis software. Velocity sensors are commonly used in handheld sensors.

Basic accelerometers use a piezoelectric crystal (that converts sound waves to electrical impulses and back) attached to a mass that vibrates due to the motion of the part to which the sensor casing is attached. As the mass and crystal vibrate, a low voltage current is generated which is passed through a pre-amplifier and sent to the recording device. Accelerometers are very effective for detecting the high frequencies created by high speed turbine blades, gears and ball and roller bearings that travel at much greater speeds than the shafts to which they are attached.

Electromagnetic Testing (ET)

Electromagnetic testing is a general test category that includes Eddy Current testing, Alternating Current Field Measurement (ACFM) and Remote Field testing. While magnetic particle testing is also an electromagnetic test, due to its widespread use it is considered a stand-alone test method rather as than an electromagnetic testing technique. All of these techniques use the induction of an electric current or magnetic field into a conductive part, then the resulting effects are recorded and evaluated.

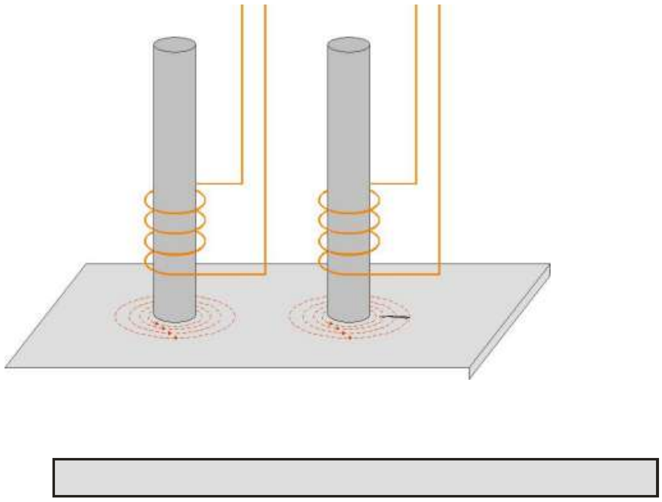
ET Techniques

Introduction to Eddy Current Testing

The main applications of the eddy current technique are for the detection of surface or subsurface flaws, conductivity measurement and coating thickness measurement. The technique is sensitive to the material conductivity, permeability and dimensions of a product.

Eddy currents can be produced in any electrically conducting material that is subjected to an alternating magnetic field (typically 10Hz to 10MHz). The alternating magnetic field is normally generated by passing an alternating current through a coil. The coil can have many shapes and can between 10 and 500 turns of wire.

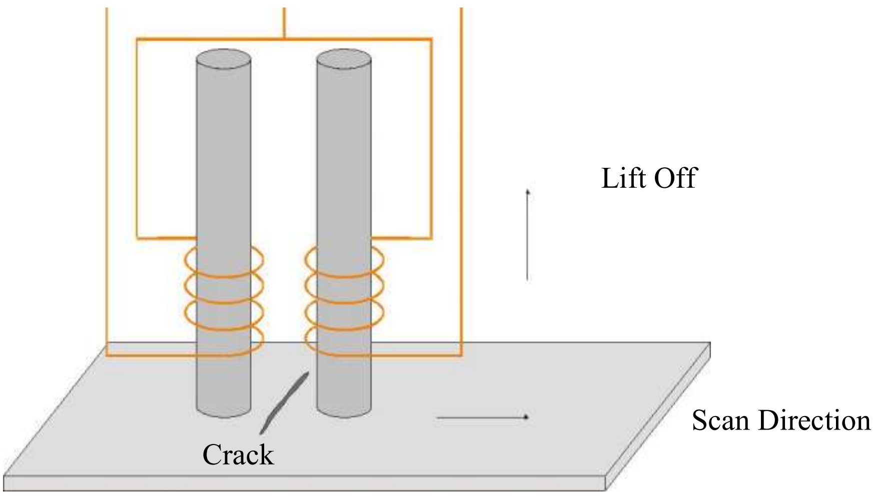
The magnitude of the eddy currents generated in the product is dependent on conductivity, permeability and the set up geometry. Any change in the material or geometry can be detected by the excitation coil as a change in the coil impedance. The most simple coil comprises a ferrite rod with several turns of wire wound at one end and which is positioned close to the surface of the product to be tested. When a crack, for example, occurs in the product surface the eddy currents must travel farther around the crack and this is detected by the impedance change. See Fig.1.



A	- No Crack - Circular pattern	**B**	- Surface Crack - Distorted Circle - Currents go round and under the crack (Increased Impedance)

Figure 1 - Coil with single winding

Coils can also be used in pairs, generally called a driven pair, and this arrangement can be used with the coils connected differentially. In this way 'lift off' (distance of the probe from the surface) signals can be enhanced. See Fig.2.



- Coils windings are in a bridge

- Scan accross the crack so that each winding sees the crack in turn
- Lift off signals which occur simultaneously and are cancelled out

Figure 2 - Coil with two windings, known as a driver pair or differential probe

Coils can also be used in a transformer type configuration where one coil winding is a primary and one (or two) coil windings are used for the secondaries. See Fig.3.

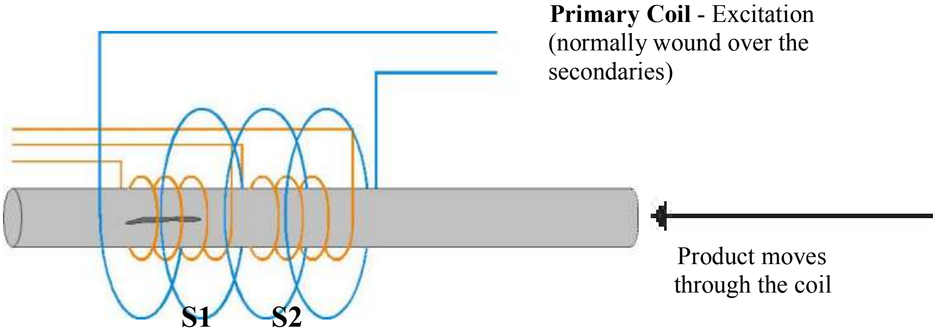


Figure 3 - Transformer type coil with 3 windings

The detected eddy current signals contain amplitude and phase information and which can be displayed on CRT type displays – non digital displays. Signals can be displayed as the actual, i.e. absolute signal, or with appropriate electronics, only a signal change is displayed. The best results are obtained where only one product parameter is changes, e.g. the presence of a crack.

In practice changes in eddy current signals are caused by differences in composition, hardness, texture, shape, conductivity, permeability and geometry. In some cases the effects of the crack can be hidden by changes in other parameters and unnecessary rejection can occur. However, the coils can be selected for configuration, size and test frequency in order to enhance detection of cracks, conductivity, metal loss etc. as required.

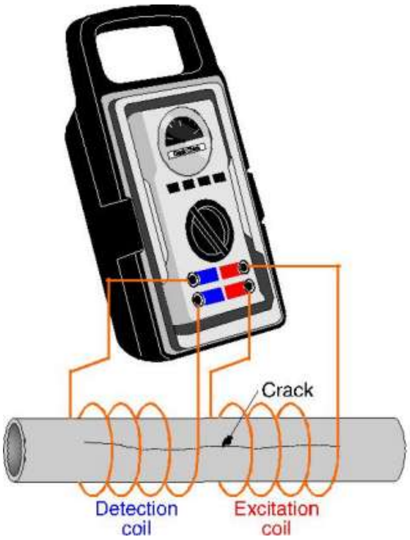
The depth to which the eddy currents penetrate a material can be changed by adjusting the test frequency – the higher the frequency, the lower the penetration; however, the lower the frequency, the lower sensitivity to small defects. Larger coils are less sensitive to surface roughness and vice versa. The latest electronic units are able to operate a wide range of coil configurations in absolute or differential modes and at a wide range of frequencies.

For surface testing for cracks in single or complex shaped components, coils with a single ferrite cored winding are normally used. The probe is placed on the component and 'balanced' by use of the electronic unit controls. As the probe is scanned across the surface of the component the cracks can be detected. See Fig.1 Where surfaces are to be scanned automatically the single coil windings are suitable only if the lift off distance is accurately maintained. Generally differential coil configurations are used with higher speed scanning systems where lift off effects, vibration effects, etc. can be cancelled out to an acceptable extent. See Fig.2. Tubes, bar and wire can be inspected using an encircling coil and these usually have a coil configuration with one primary and two secondaries connected differentially. See Fig.3.

Most eddy current electronics have a phase display and this gives an operator the ability to identify defect conditions. In many cases signals from cracks, lift off and other parameters can be clearly identified. Units are also available which can inspect a product simultaneously at two or more different test frequencies. These units allow specific unwanted effects to be electronically cancelled in order to give improved defect detection.

The eddy current test is purely electrical. The coil units do not need to contact the product surface and thus the technique can be easily automated. Most automated systems are for components of simple geometry where mechanical handling is simplified.

An Illustration of Eddy Current Testing Equipment



Schematic illustration of eddy current testing of drawn tube for longitudinal defects.

Advantages of Eddy Current Testing

- Suitable for the determination of a wide range of conditions of conducting material, such as defect detection, composition, hardness, conductivity, permeability etc. in a wide variety of engineering metals.
- Information can be provided in simple terms: often go/no go. Phase display electronic units can be used to obtain much greater product information.
- Extremely compact and portable units are available.
- No consumables (except probes – which can sometimes be repaired).
- Flexibility in selection of probes and test frequencies to suit different applications.
- Suitable for total automation.

Disadvantages of Eddy Current Testing

- The wide range of parameters which affect the eddy current responses means that the signal from a desired material characteristic, e.g. a crack, can be masked by an unwanted parameter, e.g. hardness change. Careful selection of probe and electronics will be needed in some applications.
- Generally tests restricted to surface breaking conditions and slightly sub-surface flaws.

Eddy Current Testing

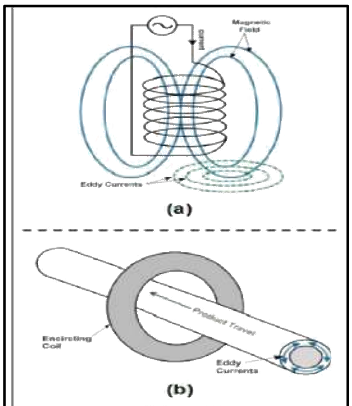


Figure 14

Eddy Current Testing uses the fact that when a an alternating current coil induces an electromagnetic field into a conductive test piece, a small current is created around the magnetic flux field, much like a magnetic field is generated around an electric current. The flow pattern of this secondary current, called an "eddy" current, will be affected when it encounters a discontinuity in the test piece, and the change in the eddy current density can be detected and used to characterize the discontinuity causing that change. A simplified schematic of eddy currents generated by an alternating current coil ("probe") is shown in Figure 14-a. By varying the type of coil, this test method can be applied to flat surfaces or tubular products. This technique works best on smooth surfaces and has limited penetration, usually less than ¼".

Encircling coils (Figure 14-b) are used to test tubular and bar-shaped products. The tube or bar can be fed through the coil at a relatively high speed, allowing the full cross-section of the test object to be interrogated. However, due to the direction of the flux lines, circumferentially oriented discontinuities may not be detected with this application.

Alternating Current Field Measurement

Alternating Current Field Measurement (ACFM) uses a specialized probe that introduces an alternating current into the surface of the test piece, creating a magnetic field. In parts with no discontinuities this field will be uniform, but if there is a discontinuity open to the surface, the magnetic field will flow around and under the discontinuity, causing a disruption of the field that can be detected by sensors within the probe. The resulting feedback can then be fed to software that can determine the length and depth of the discontinuity. ACFM provides better results on rough surfaces than Eddy Current and can be used through many surface coatings.

Remote Field Testing

Remote Field Testing (RFT) is most commonly used to inspect ferromagnetic tubing due to the presence of a strong skin effect found in such tubes. Compared to standard eddy current techniques, remote field testing provides better results throughout the thickness of the tube, having approximately equal sensitivity at both the ID and OD surfaces of the tube. For non-ferromagnetic tubes, eddy current tends to provide more sensitivity.

Non-Destructive Testing Methods & Applications

				Flaw Type			
Material	**Surface Cracks & Flaws**	**Sub-Surface Cracks & Flaws**	**Internal Flaws & Discontinuities**	**Lack of Bond or Lack of Fusion**	**Non-Metallic Inclusions - Slag, Porosity**	**Material Quality**	**Laminations, Thickness Measurement**
Ferrous Forgings & Stampings	M.T.	M.T. U.T.	R.T. U.T.		R.T. U.T.		U.T.
Ferrous Raw Materials & Rolled Products	M.T.	M.T. U.T.	U.T.		M.T. U.T.		U.T.
Ferrous Tube & Pipe	M.T. E.T.	M.T. U.T.	U.T.	U.T.	M.T. U.T.		U.T.
Ferrous Welds	M.T. U.T.	U.T.	R.T. U.T.	R.T. U.T.	R.T. U.T.		U.T.
Steel Castings	M.T.	M.T. U.T.	R.T. U.T.		R.T. U.T.		U.T.
Iron Castings	M.T.	U.T. E.T.	U.T.		R.T. U.T.	U.T.	U.T.
Non-Ferrous Components & Materials	P.T. E.T.		R.T. U.T.	U.T.	P.T. U.T.		U.T.

Ferrous Components Finished	**M.T.**	**U.T.** **E.T.**	**R.T.** **U.T.**	**U.T.**	**M.T.** **U.T.**		**U.T.**
Non-Ferrous Components Finished	**P.T.** **E.T.**	**U.T.** **E.T.**	**R.T.** **U.T.**		**U.T.** **E.T.**		**U.T.**
Aircraft Ferrous Components	**R.T.** **M.T.** **E.T.**	**M.T.** **U.T.**	**R.T.** **U.T.**	**U.T.**	**M.T.** **U.T.**		**U.T.**
Aircraft Non-Ferrous Components	**R.T.** **P.T.** **E.T.**	**R.T.** **U.T.**	**R.T.** **U.T.**	**U.T.**	**P.T.** **U.T.**		**U.T.**

R.T. - X or Gamma Radiography M.T. - Magnetic Particle Inspection

P.T. - Dye Penetrant **U.T.** - Ultrasonic

E.T. - Eddy Current

Aerospace Industry	Testing components including aero-engine, Landing gear and air frame parts during production
Aircraft Overhaul	Testing components during overhaul including aero-engine and landing gear components
Automotive Industry	Testing Brakes-Steering and engine safety critical components for flaws introduced during manufacture. Iron castings – material quality. Testing of diesel engine pistons up to marine engine size.
Petrochemical & Gas Industries	Pipe-Line and tank internal corrosion measurement from outside. Weld testing on new work. Automotive LPG tank testing
Railway Industry	Testing locomotive and rolling stock axles for fatigue cracks. Testing rail for heat induced cracking. Diesel locomotive engines and structures.
Mining Industry	Testing of pit head equipment and underground transport safety critical components.
Agricultural Engineering	Testing of all fabricated, forged and cast components in agricultural equipment including those in tractor engines.
Power Generation	Boiler and pressure vessel testing for weld and plate defects both during manufacturing and in subsequent service. Boiler pipe work thickness measurement and turbine alternator component testing.
Iron Foundry	Testing ductile iron castings for metal strength on 100% quality control basis.
Shipbuilding Industry	Structural and welding testing. Hull and bulkhead thickness measurement. Engine components testing.
Steel Industry	Testing of rolled and re-rolled products including billets, plate sheet and structural sections.
Pipe & Tube Manufacturing Industry	Raw plate and strip testing. Automatic ERW tube testing. Oil line pipe spiral weld testing.

1 LIQUID PENETRANT TESTING (PT)

1. Liquid penetrant testing is based on the principle of:

    (a) sound waves

    (b) Magnetic domains

    (c) X rays

    (d) <u>Capillary action</u>

2. A penetrant that is self-emulsifying is called:

    (a) Solvent removable

    (b) <u>Water washable</u>

    (c) Post-emulsified

    (d) Dual sensitivity method

3. A penetrant process which employs an emulsifier as a separate step in the penetrant removal process is called:

    (a) Solvent removable

    (b) Water washable

    (c) <u>Post-emulsified</u>

    (d) Dual sensitivity method

4. A penetrant process in which excess penetrant is removed with an organic solvent is called:

    (e) <u>Solvent removable</u>

    (f) Water washable

    (g) Post-emulsified

(h) Dual method

5. Which of the following discontinuity types could typically be found with a liquid penetrant test?

    (i) Internal slag in a weld

    (j) Internal slag in a casting

    (k) Sensitization in austenitic stainless steel

    (l) <u>Fatigue cracks</u>

6. Which of the following pre-cleaning processes is not recommended?

    (a) Detergent cleaning

    (b) Vapour degreasing

    (c) <u>Shot blasting</u>

    (d) Ultrasonic cleaning

7. A wire brush should be used for pre-cleaning:

    (e) When grease and oil must be removed

    (f) Only as a last resort

    (g) <u>When rust is to be removed</u>

    (h) When grinding burrs must be removed

8. Which of the following penetrants contains an emulsifying agent?

   (a) Solvent removable

   (b) <u>Water washable</u>

   (c) Post emulsifiable

   (d) Fluorescent

9. What is the function of an emulsifier?

   (a) To remove the excess penetrant

   (b) To develop indications with a post emulsifiable penetrant system

   (c) To assist penetration with a post emulsifiable penetrant system

   (d) <u>To make a post emulsifiable penetrant water washable</u>

10. What is the preferred method of removing paint prior to performing a penetrant testing?

   (a) Sand blast

   (b) <u>Chemical removers</u>

   (c) Power wire brush

   (d) Shot blast

11. Acceptable methods of penetrant application are:

   (e) Spraying

   (f) Dipping

(g) Brushing

(h) <u>All of the above</u>

12. The time period during which penetrant remains on the surface of the test piece is called:

(a) <u>Dwell time</u>

(b) Soaking time

(c) Fixing time

(d) Development time

13. A developer aids penetrant bleed out because of:

(e) Adequate removal of the excess penetrant

(f) Providing a contrasting background for visible dye indications

(g) <u>Capillary action</u>

(h) Proper emulsifier action

14. Typical ranges of emulsifier dwell times are:

(a) 5 to 10 minutes

(b) 30 seconds to 1 minute

(c) <u>1 to 3 minutes</u>

(d) 5 to 10 minutes

15. The colour of fluorescent penetrant under the presence of a UV light is:

(e) <u>Yellow-green</u>

(f) Red

(g) Blue

(h) Green

16. When performing a fluorescent penetrant examination, excess penetrant is normally removed:

(a) By a hydrophilic scrubber

(b) <u>Under UV light</u>

(c) By solvent spray

(d) By vapour degreasing

17. During a visible, solvent removable penetrant test, complete penetrant removal is indicated by:

(e) Absence of red indications on the test piece surface

(f) Clean rinse water

(g) Completion of the rinse cycle

(h) <u>Absence of red dye on the cleaning towels</u>

18. Which of the following is a function of a developer

(a) Providing a contrasting background for visible dye indications

(b) Making the penetrant water washable

(c) Penetrating into discontinuities open to the surface

(d) Dissolve organic soils on the test piece surface

19. Which of the following developers is applied before the drying operation?

(e) Dry

(f) Non-aqueous wet

(g) Water based wet

(h) None of the above

20. The most sensitive type of developer for the detection of fine discontinuities is:

(i) Water soluble

(j) Non-aqueous wet

(k) Dry

(l) Water suspendable

21. What is a disadvantage of using the fluorescent penetrant process?

(a) Lower visibility of indications

(b) Must be performed in a darkened area with aid of a UV lamp

(c) Easily washed with water

(d) High visibility of indications

22. Which of the following developers is applied by brush, spraying or dipping?

(a) Non-aqueous wet

(b) <u>Water based wet</u>

(c) Dry

(d) Dual sensitivity

23. The causes of non relevant indications are:

(a) Insufficient removal of excess surface penetrant

(b) Penetrant on operators hands

(c) <u>Threads, keyways, splines, sharp corners, press fits, blind holes, rough surfaces</u>

(d) Contaminated work surfaces

24. Which of the following metals must be tested with low halogen sulphur free penetrant materials:

(e) Copper, silver, gold

(f) Nickel based alloys, certain stainless steel materials

(g) Steel, iron, aluminium

(h) <u>Plastic, wood, paper</u>

25. Penetrant testing is limited by its inability to test which of the following materials:

(a) Aluminium

(b) Ceramics

(c) Porous materials

(d) <u>Moulded rubber</u>

26. The typical temperature ranges for conducting a liquid penetrant test is:

(e) 60 to 100ºC

(f) <u>10 to 60ºF</u>

(g) 16 to 52ºC

(h) 10 to 20ºK

27. Surface breaking porosity will show what type of relevant indications when a welded aluminium plate is tested with the liquid penetrant method:

(i) Linear indications

(j) <u>Square indications</u>

(k) Triangular indications

(l) Rounded indications

28. Cracks, lack of penetration, lack of fusion which are surface breaking on a welded aluminium plate which has been liquid penetrant tested will show as:

(a) Linear indications

(b) Rounded indications

(c) <u>Square indications</u>

(d) Triangular indications

29. The principle on which liquid penetrant testing is based on is:

(a) Capillary action of the penetrant

(b) Capillary action of cleaner/solvent

(c) Capillary action of developer

(d) None of the listed is correct

30. Penetrants may be applied to the surface of part by :

(a) Spraying

(b) Dipping

(c) Pouring

(d) All of the above methods are acceptable

31. Liquid penetrants can be classified into the types of dyes they contain:

(a) Visible/colour contrast

(b) Fluorescent

(c) Dual sensitivity

(d) All of the listed is correct

32. The advantages of using a visible solvent removable penetrant versus a post emulsified fluorescent penetrant is:

(e) No UV light is needed

(f) The technique is well suitable for site tests or spot checks

(g) No water or emulsifiers are needed

(h) <u>No extra equipment is needed</u>

(i) All of the advantages listed above are correct

33. Which of the following discontinuities would you not expect to find in a casting?

(a) Shrinkage cracks

(b) Incomplete penetration

(c) <u>Cold shuts</u>

(d) Porosity

34. The act of determining the cause of an indication is called

(e) <u>Interpretation</u>

(f) Inspection

(g) Evaluation

(h) Determination

35. The act of determining the effect of a discontinuity of the usefulness of a part is called:

(i) Interpretation

(j) Inspection

(k) <u>Evaluation</u>

(l) Determination

36. When viewed under black light, developer appears:

(a) Yellow-green

(b) <u>Blue-black</u>

(c) White

(d) Pinkish white

37. Which of the following is an advantage of a dry developer?

(a) Ease of handling

(b) Non-corrosive

(c) No hazardous vapours

(d) <u>All of the above</u>

38. Which of the following developers would you expect to be the least sensitive?

(a) Water suspendable wet (immersion)

<u>(b) Water suspendable wet (spray)</u>

(c) Water soluble (spray)

(d) Water soluble (immersion)

39. Which of the following developers would you expect to be the most sensitive?

(a) Water suspendable wet (immersion)

(b) Water suspendable wet (spray)

(c) Water soluble (spray)

<u>(d) Water soluble (immersion)</u>

40. Dual purpose penetrants are viewed under what type of light?

(a) White light

(b) Black light

<u>(c) Both a and b</u>

(d) None of the above

4 ULTRASONIC TESTING (UT)

1. The divergence of an ultrasonic beam is dependent on:

(a) Transducer wavelength and diameter

(b) Test specimen density

(c) The sound wave's angle of incidence

(d) The degree of damping of the ultrasonic transducer

2. When a longitudinal wave is incident upon an inclined interface between zero degrees and the first critical angle:

(a) The sound beam is totally reflected

(b) Only shear waves are produced in the second material

(c) Shear waves and longitudinal waves are produced in the second material

(d) Only longitudinal waves are produced in the second material

3. The piezoelectric material in a search unit which vibrates to produce ultrasonic waves is called:

(a) A backing material

(b) A lucite wedge

(c) A transducer element or crystal

(d) A couplant

4. When a longitudinal wave is incident upon an inclined interface and is refracted at ninety degrees, the angle of the incident longitudinal wave is called:

(a) The Snell constant

(b) The Snell angle

(c) The mode conversion constant

(d) The first critical angle

5. When a longitudinal wave sound beam passes through an acoustic interface at some angle other than zero degrees:

(a) Surface waves are generated

(b) Plate waves are generated

(c) Reflection, refraction and mode conversion will occur

(d) The first critical angle is reached

6. Which of the following can be a source of spurious ultrasonic signals?

(a) Surface roughness of the test piece

(b) Mode conversion within the test piece

(c) Shape or contour of the test piece

(d) All of the above

7. A noisy base line, or hash may result in:

(a) Laminations in the test piece

(b) Discontinuities at an angle to the test piece surface

(c) Large grain size

(d) Fatigue cracks

8. Sound waves which travel on the surface of a solid in a manner similar to waves on a water surface are called:

(a) Rayleigh waves

(b) Shear waves

(c) Primary waves

(d) Compression waves

9. Lamb waves are formed in a part which has:

(a) A thickness greater that about ten wavelengths

(b) A thickness approximately equal to the wavelength

(c) Low acoustic impedance compared to the transducer crystal material

(d) A thickness of about four wavelengths

10. Which type(s) of sound wave modes will propagate through liquids?

(a) Longitudinal

(b) Shear

(c) Surface

(d) All of the above

11. When the motion of the particles of a medium is transverse to the direction of propagation, the wave being transmitted is called a:

(a) Longitudinal wave

(b) Shear wave

(c) Surface wave

(d) Lamb wave

12. Which of the following test frequencies would generally provide the best penetration in a 12 inch thick specimen of coarse-grained steel?

(a) 1.0 MHz

(b) 2.25 MHz

(c) 5.0 MHz

(d) 10 MHz

13. An oscilloscope display in which the screen base line is adjusted to represent the one way distance in a test piece is called a:

(a) A scan display

(b) B scan display

(c) C scan display

(d) D scan display

14. A common use of ultrasonic testing is:

(a) Cleaning

(b) Detecting of sub-surface indications

(c) Determination of the test piece ductility

(d) Communications

15. Sound waves of a frequency beyond the hearing range of the human ear are referred to as ultrasonic waves or vibrations, and the term embraces all vibrational waves of frequency greater than approximately:

(a) 20 kHz

(b) 2 MHz

(c) 2 kHz

(d) 200 kHz

16. Y cut crystals produce:

(a) Longitudinal waves

(b) Shear waves

(c) Lamb waves

(d) Surface waves

17. The cable that connects the ultrasonic instrument to the search unit is specially designed so that one conductor is centred inside another. The technical name for such a cable is:

(a) BX cable

(b) Conduit

(c) Coaxial cable

(d) Ultrasonic conductor cable grade 20

18. As ultrasonic frequency increases:

(a) Wavelength increases

(b) Wavelength decreases

(c) Sound velocity increases

(d) Sound velocity decreases

19. In an A scan presentation, the amplitude of vertical indications on the screen represents the:

(a) Amount of ultrasonic sound energy returning to the search unit

(b) Distance travelled by the search unit

(c) Thickness of material being tested

(d) Elapsed time since the ultrasonic pulse was generated

20. Which of the following circuits converts electrical energy to ultrasonic energy?

(a) The pulse generator

(b) The transducer

(c) The transformer

(d) The power supply

21. An instrument display in which the horizontal base line represents elapsed time and the vertical deflection represents signal amplitudes is called:

(a) A scan

(b) B scan

(c) C scan

(d) A time line display

22. Which of the following circuits provides short duration, high energy pulses which are used to excite the transducer?

(a) The pulse generator

(b) The amplifier

(c) The transducer

(d) The clock

23. A cross section view of a test piece is produced by which of the following?

(a) A scan

(b) B scan

(c) C scan

(d) A time line display

24. Echo amplitude losses may be caused by:

(a) Entry surface roughness

(b) Coarse grain size

(c) Discontinuity orientation

(d) All of the above

25. Which of the following circuits provide current to operate the ultrasonic instrument?

(a) The pulse generator

(b) The amplifier

(c) The power supply

(d) The sweep generator

26. Which type(s) of sound wave modes will propagate through solids?

(a) Longitudinal

(b) Shear

(c) Surface

(d) All of the above

27. The longitudinal wave incident angle at which the refracted shear wave angle equals ninety degrees is called:

(a) The Snell angle

(b) The Snell constant

(c) The first critical angle

(d) The second critical angle

28. The amount of beam divergence from a crystal is primarily dependent on the:

(a) Type of test

(b) Tightness of crystal backing in the search unit

(c) Frequency and crystal size

(d) Pulse length

29. X cut crystals produce:

(a) Longitudinal waves

(b) Shear waves

(c) Lamb waves

(d) Surface waves

30. All other factors being equal, which of the following modes of vibration has the greatest velocity?

(a) Shear wave

(b) Transverse wave

(c) Surface wave

(d) Longitudinal wave

31. In immersion testing, the position of the search unit is often varied to transmit sound into the test part at various angles to the front surface. Such a procedure is referred to as:

(a) Angulation

(b) Dispersion

(c) Reflection testing

(d) Refraction

32. The velocity of surface waves is approximately _______________ the velocity of shear waves in the same material.

(a) Two times

(b) Four times

(c) One half

(d) Nine-tenths

33. An ultrasonic instrument control which allows moving an A scan display to the left or right without changing the distance between any echoes displayed is called:

(a) The sweep length or range control

(b) The damping control

(c) The sweep delay

(d) The pulse length control

34. A 25 MHz search unit would most likely be used during:

(a) Straight beam contact testing

(b) Immersion testing

(c) Angle beam contact testing

(d) Surface wave contact testing

35. A technique in which two transducers are used, one on each side of the test piece, is called:

(a) Angle beam testing

(b) Modified immersion testing

(c) Through transmission testing

(d) Twinning

36. Sound beam intensity is irregular in the area called:

(a) The near field

(b) The far field

(c) The beam spread

(d) The delay line

37. A more highly damped transducer crystal results in:

(a) Better resolution

(b) Better sensitivity

(c) Lower sensitivity

(d) Poorer resolution

38. The process of comparing an instrument or device with a standard is called:

(a) Angulation

(b) Calibration

(c) Attenuation

(d) Correlation

55. Typical ultrasonic testing frequencies are:

(a) 50 kHz to 1 MHz

(b) 200 kHz to 25 MHz

(c) 10 MHz to 100 MHz

(d) 1 MHz to 5 MHz

56. ‘25 million cycles per second’ can also be stated as:

(a) 25 kHz

(b) 2500 kHz

(c) 25 MHz

(d) 25 Hz

MAGNETIC PARTICLE TESTING

1. A magnetic particle testing is most likely to find subsurface discontinuities in:

(a) Soft steels with high permeability

(b) Soft steels with low permeability

(c) Hardened steels with low permeability

(d) Hardened steels with high permeability

2. The most effective NDT method for locating surface cracks in ferromagnetic materials is:

(a) Ultrasonic testing

(b) Radiographic testing

(c) Magnetic particle testing

(d) Liquid penetrant testing

3. A discontinuity which is produced during solidification of the molten metal is called:

(a) Inherent

(b) Processing

(c) Service

(d) None of the above

4. Pipe would be classified as what type of discontinuity?

(a) Inherent

(b) Processing

(c) Service

(d) None of the above

5. A seam would be classified as what type of discontinuity?

(a) Inherent

(b) Processing

(c) Service

(d) None of the above

6. A lamination in steel plate would be classified as what type of discontinuity?

(a) Inherent

(b) Processing

(c) Service

(d) None of the above

7. Cracks which are caused by alternating stresses above a critical level are called:

(a) Stress corrosion cracks

(b) Cycling cracks

(c) Critical cracks

(d) Fatigue cracks

8. Cracks which are caused by a combination of tensile stress and corrosion are called:

(a) Stress corrosion cracks

(b) Cycling cracks

(c) Critical cracks

(d) Fatigue cracks

9. Which of the following are ferromagnetic materials?

(a) Aluminium, iron, copper

(b) Iron, copper, nickel

(c) Copper, aluminium, silver

(d) Iron, cobalt, nickel

10. The reverse magnetising force necessary to remove a residual magnetic field from a test piece after it has been magnetically saturated is called:

(a) Hysteresis

(b) Coercive force

(c) Demagnetising flux

(d) Reverse saturation

11. Magnetic lines of force enter and leave a magnet at:

(a) Saturation

(b) L/D ratios of greater than 4 to 1

(c) Flux concentration points

(d) Poles

12. The ease with which a magnetic field can be established in a test piece is called:

(a) Reluctance

(b) Retentivity

(c) Permeability

(d) Electromagnetism

13. Opposition to establishment of a magnetic field is called:

(a) Reluctance

(b) Retentivity

(c) Permeability

(d) Electromagnetism

14. The ability of a material to remain magnetic after the magnetising force is removed is called:

(a) Reluctance

(b) Retentivity

(c) Permeability

(d) Electromagnetism

15. A magnetic field which is contained completely within the test piece is called a:

(a) Confined field

(b) Longitudinal field

(c) Circular field

(d) Saturated field

16. Which of the following produces a circular field?

(a) Coil

(b) Head shot

(c) Yoke

(d) All of the above

17. A technique used to find transverse discontinuities at the ends of longitudinally magnetised bars by the use of transient currents is called:

(a) A coil technique

(b) A fast break technique

(c) A yoke technique

(d) A head shot

18. A leakage field is strongest when a discontinuity interrupts the magnetic flux lines at an angle of:

(a) Zero degrees

(b) 45 degrees

(c) 90 degrees

(d) 180 degrees

19. The best method of inducing a circular field in a tube is by a:

(a) Central conductor

(b) Head shot

(c) Coil

(d) Prod technique

20. The most common source of DC current for magnetic particle testing is:

(a) Motor generators

(b) Rectified AC

(c) Storage batteries

(d) None of the above

21. Fields generated in ferromagnetic material with AC current are useful for locating:

(a) All discontinuities

(b) Surface cracks

(c) Subsurface discontinuities

(d) Internal porosity

22. A common rule of thumb to use for current required in circular magnetisation:

(a) 1000 amps/25mm of diameter

(b) 1000 ampere turns/25mm of diameter

(c) 1000 amps/25mm of prod spacing

(d) None of the above

23. The formula, NI = 45000/(L/D), is used to calculate the proper magnetising current for:

(a) Prod magnetization

(b) A head shot

(c) A central conductor

(d) Coil magnetization

24. For direct contact magnetising methods, the magnetic field is oriented in what direction relative to the current direction?

(a) Parallel

(b) At 45 degrees

(c) At 90 degrees

(d) At 180 degrees

25. For direct contact magnetising methods, current should be flowing in what direction relative to expected discontinuities?

(a) Parallel

(b) At 45 degrees

(c) At 90 degrees

(d) At 180 degrees

26. The magnetic field outside a conductor decreases:

(a) Exponentially

(b) In a linear manner

(c) Inversely with distance

(d) Inversely with the square of distance

27. Which of the following describes the shape of particles used for dry magnetic particle testing?

(a) Spherical

(b) Angular

(c) Elongated

(d) Mixture of elongated and globular

28. Which of the following *particles* would be most sensitive?

(a) Wet

(b) Dry

(c) Depends on the test piece permeability

(d) None of the above

30. Which of the following colours is readily available for magnetic particle test powder?

(a) Red

(b) Gray

(c) Black

(d) All of the above

31. A magnetic particle testing technique in which the test piece is magnetised and magnetic particles applied after the magnetising force has been removed is called the:

(a) Magnetic method

(b) Continuous method

(c) Residual method

(d) Discontinuous method

32. Which of the following characteristics would be most important in a test piece which is to be tested using the residual method?

(a) High rententivity

(b) High permeability

(c) Low reluctance

(d) Low permeability

33. The wet method is superior to dry particles for detecting:

(a) Subsurface discontinuities

(b) Fine surface cracks

(c) Open surface cracks

(d) None of the above

34. The residual method is applicable to:

(a) Surface discontinuities only

(b) Subsurface discontinuities only

(c) Either surface or subsurface discontinuities

(d) All but tight surface cracks

35. A disadvantage of fluorescent magnetic particles is:

(a) Darkened area and black light are required

(b) Abnormally high sensitivity

(c) Only dry particles are available

(d) Only wet concentrate is available

36. A common physiological effect of black light inspection on the inspector is:

(a) Burned retinas of the eyes

(b) Rejected cornea syndrome

(c) Eye fatigue

(d) Retarded iris control

37. A common physiological effect of black light inspection on the inspector is:

(a) Burned retinas of the eyes

(b) Rejected cornea syndrome

(c) Eyeball fluorescence

(d) Retarded iris control

38. Most fluorescent dyes used for magnetic particle testing fluoresce what colour?

(a) Blue green

(b) Yellow green

(c) Blue black

(d) Red orange

39. The best available source of black light for inspection is:

(a) The mercury vapour lamp

(b) The fluorescent tube

(c) The incandescent bulb

(d) Sunlight

40. Which of the following would be likely to cause variations in the output of an inspection black light?

(a) Voltage fluctuations

(b) Aged bulb

(c) Dirty filter

(d) All of the above

RADIOGRAPHIC TESTING (RT)

1. Which of the following types of intensifying screens are not used in industrial radiography?

(a) Lead

(b) Fluorescent

(c) Silver halide

(d) All of the above

2. Betatrons are used to produce X rays in what range?

(a) Several MeV

(b) 50-500 keV

(c) 500-1000 keV

(d) 0-50 keV

3. Which of the following is an isotope not artificially produced for industrial use:

(a) Ir-192

(b) Ra-226

(c) Co-60

(d) All of the above

4. One half value layer of lead for Iridium-192 is approximately:

(a) 12 mm

(b) 4 mm

(c) 2 mm

(d) 25 mm

5. One half value layer of lead for Cobalt-60 is approximately:

(a) 12 mm

(b) 6 mm

(c) 2 mm

(d) 25 mm

6. The film processing step in which the undeveloped silver bromide is removed from the film emulsion is called:

(a) Development

(b) Stop bath

(c) Fixing

(d) Rinsing

7. A radiation producing device which emits radiation of one or a few discreet wavelengths is:

(a) An X ray machine

(b) A linear accelerator

(c) A gamma ray source

(d) A betatron

8. The intensifying action of lead screens is caused by:

(a) Secondary X ray emission

(b) Secondary gamma ray emissions

(c) Fluorescence of lead screens

(d) Electron emission

9. Most of the energy applied to an X ray tube is converted into:

(a) X rays

(b) Light

(c) Heat

(d) Ultraviolet radiation

10. Radiography of tubular sections using a double wall, double viewing technique is mainly applicable to sections:

(a) Over 38 mm in diameter

(b) 88 mm in diameter or less

(c) 125 mm in diameter and less

(d) Under 25 mm in diameter

11. Which of the following is the most common method of packaging film?

(a) Individual sheets for use in cassettes

(b) Rolls

(c) Pre-packaged ('day-pack')

(d) All of the above

12. Which of the following types of radiation is particulate?

(a) X

(b) Gamma

(c) Alpha

(d) None of the above

13. A detrimental effect of fluorescent screens might be:

(a) High definition

(b) Screen mottle

(c) Non-linear attenuation

(d) Displaced core effect

14. The penetrating power of an X ray machine is indicated by:

(a) Milliamperage

(b) Tube voltage

(c) Filament current

(d) Anode current

15. Thicker materials would normally be inspected using:

(a) Lower kV X rays

(b) Higher mA X rays

(c) Higher kV X rays

(d) Lower mA X rays

16. Another name for a penetrameter is:

(a) Radiographic shim

(b) Image quality indicator

(c) Density standard

(d) Acceptance standard

17. The silver nitrate spot test can be used to:

(a) Check the film for film quality

(b) Check for under developed films

(c) Check for film artifacts

(d) All the above answers are correct

18. The difference in densities seen on a radiograph due to section changes in an item is:

(a) Film contrast

(b) Radiographic contrast

(c) Subject contrast

(d) Radiographic sensitivity

19. Which type of film would exhibit the coarsest grain?

(a) Slow

(b) Medium

(c) Fast

(d) No difference in the grain sizes

20. A straight, dark line in the centre of the film of a weld cap would probably be:

(a) Porosity

(b) Undercut

(c) Tungsten inclusions

(d) A linear crack

21. Which one of the following steps is necessary to dissolve the undarkened silver salt crystals in the film emulsion:

(a) Developing

(b) Fixing

(c) Washing

(d) None of the above

22. Approximately what energy X ray machine would be required to have penetrating

power equivalent to a Cobalt-60 source:

(a) 600 keV

(b) 1.2 MeV

(c) 2 MeV

(d) None of the above

23. The normal range of steel that is radiographed using Ir-192 is:

(a) 5 mm–20 mm

(b) 25 mm – 75 mm

(c) 0.5 mm – 5 mm

(d) 75 mm – 150 mm

24. The focal spot size of an X ray machine must be known in order to determine:

(a) The geometric unsharpness

(b) Kilovoltage peak output

(c) Required mA setting

(d) Exposure time

25. What is the minimum age in years at which a person may perform radiography :

(a) 15

(b) 18

(c) 21

(d) 30

26. A densitometer is an instrument that measures:

(a) Radiographic contrast

(b) Radiographic sensitivity

(c) Radiographic density

(d) Radiographic resolution

27. A dark, irregular indication which is located adjacent to the toe of the weld would probably be:

(a) Undercut

(b) Incomplete penetration

(c) Porosity

(d) Tungsten inclusions

28. A term which refers to the smallest detail visible in a radiograph is called:

(a) Radiographic sensitivity

(b) Radiographic contrast

(c) Subject contrast

(d) Film contrast

29. Which type of gamma ray source would be used to radiograph a weld in 150 mm thick steel plate?

(a) Ir-192

(b) Co-60

(c) Tm-170

(d) Cs-137

30. The radiation quality of a gamma ray source is determined by:

(a) The size of the source

(b) The type of isotope to be used

(c) Can be varied by the operator

(d) Ci strength of the source

31. Generally, X ray output is changed by changing the:

(a) Atomic number of the anode

(b) Tube current of the unit

(c) Supply voltage to the unit

(d) Atomic weight of the cathode

32. For a particular isotope, gamma radiation intensity is determined by:

(a) Type isotope used

(b) Energy level of gamma rays in source

(c) Source strength in curies

(d) None of the above

33. A term used to describe the range of radiation intensities falling on the film during exposure is:

(a) Film contrast

(b) Radiographic contrast

(c) Subject contrast

(d) Radiographic sensitivity

34. An expression which is used to describe the slope of a film characteristic curve is:

(a) Film latitude

(b) Film contrast

(c) Film sensitivity

(d) Film gradient

35. Which of the following factors affect film graininess?

(a) Wavelengths of radiation

(b) Film processing conditions

(c) Film speed

(d) All of the above

36. The amount of radioactivity which corresponds to 3.7 × 1010 disintegrations per second is called:

(a) 0.01 gray (1 rad)

(b) 1 Farad

(c) 37 GBq (1 curie)

(d) 10 mSv (1 roentgen)

37. Which of the following actions is performed by lead screens?

(a) Absorbs a portion of the primary radiation beam

(b) Preferentially absorbs soft X rays

(c) Emits electrons under gamma and X ray fields

(d) All of the above

38. The total radiation dose received equals:

(a) The radiation intensity

(b) The source size in curies

(c) Radiation intensity times time of exposure

(d) Radiation intensity divided by the square of the distance from the source

39. Which of the following is the most common type of X ray tube?

(a) Bipolar

(b) Unipolar

(c) Long anode

(d) None of the above

40. A reaction which occurs when a radiation beam of 15 MeV is partially absorbed by a test piece would probably be:

(a) The Compton effect

(b) The photoelectric effect

(c) Pair production

(d) Any of the above