

## Industrial Radiography Testing & Technique (NDT)

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### **Abstract:**

This paper provides the recent advances and researches about non-destructive testing paper covers the review on the capabilities of NDT applications such as Visual Testing (VT), Ultrasonic Testing (UT), Radiographic Testing (RT), Electromagnetic Testing (ET), Acoustic Emission (AE) and Dye Penetrate testing( DPT) with respect to advantages and disadvantages of these methods. Further methods are classified on basis of their intrinsic characteristics and their applications. Mostly, an NDT evaluator uses only one non-destructive test method to perform the evaluation. If the scope of work is straight forward, using a single test method is acceptable. However, there are times when a single test method does not provide enough information about the material integrity And thereby combination of different methods is essential. Non destructive testing is widely applied in power plants, aerospace, nuclear industry, military and defiance, storage tank inspection, pipe and tube inspection and composite defects characterization. This paper mainly focuses on the scope of NDT application for composite materials The use of Industrial Radiography for examining the quality of Weld joints is very popular worldwide. In India, many welding activities like construction and laying the huge pipelines for gas and water transportation and distribution as well construction of storage tanks are performed. The objects are working under high pressure and therefore, it is important to produce the weld beads with high quality. Industrial radiography uses ionizing radiation to view objects in a way that cannot be seen otherwise. The method has grown out of engineering, and is a major element of Non destructive testing (NDT) to inspect materials for hidden flaws. The radiation caused by these facilities is very dangerous however, with the use of new technologies and proper protection, risks of injury and death associated with radiation can be greatly reduced. Radiographic Testing (RT) is widely used in industries, at airport for security checks, medical applications etc. to detect anomalies in materials and human bodies. Radiographic Testing is the common NDT methods used in the construction and fabrication industries for the oil & gas sectors using welding, gas/liquid transmission pipelines, casting foundries, and condition monitoring in existing oil & gas refineries and facilities. This paper will discuss radiographic testing sensitivity using industrial X-ray films mainly on welds and castings. No in-depth discussion in related science and physics, merely the perspective of an industrial radiographer based on his experience.

**Keywords:** IQI, Quantitative, Qualitative, DIN- sensitivity, contrast, definition, geometric un-sharpness RT,UT MT DPT ET, NDT, TAEC,,AE ET SFD LOP ,LOF,UNDER FIL UNDER CUT.

## 1. Introduction:

Radiography is non-destructive testing (NDT) method to find out the internal discontinuities present in a component or assembly. It is based on differential absorption of penetrating radiation by the part being inspected. Nondestructive testing are methods to evaluate material integrity for surface or internal flaws or metallurgical condition without interfering in any way with the destruction of the material or its suitability for service. The basic principle for the detection of anomalies using radiographic testing method is the difference in radiation absorption coefficients properties exhibits by different materials. The images are captured in a recording medium. The recording medium used may be X-ray film, phosphorous imaging plates, diodes etc. Industrial X-ray films are the common recording medium used for these applications.

**RADIOGRAPHIC TESTING SENSITIVITY-** Like all other NDT methods, certain detection sensitivity is required for the technique to ensure detectability of desired anomalies. In industrial radiography, Radiographic Sensitivity is a **QUALITATIVE** term referring to the size of the smallest detail that can be recorded and discernible on the film/radiograph, or to the ease with which the images of small details can be recorded. Image Quality Indicator (IQI) which provides **QUANTITATIVE** measurement is used to determine the adequacy of a radiographic technique, but not intended to determine the smallest flaw that can be detected.

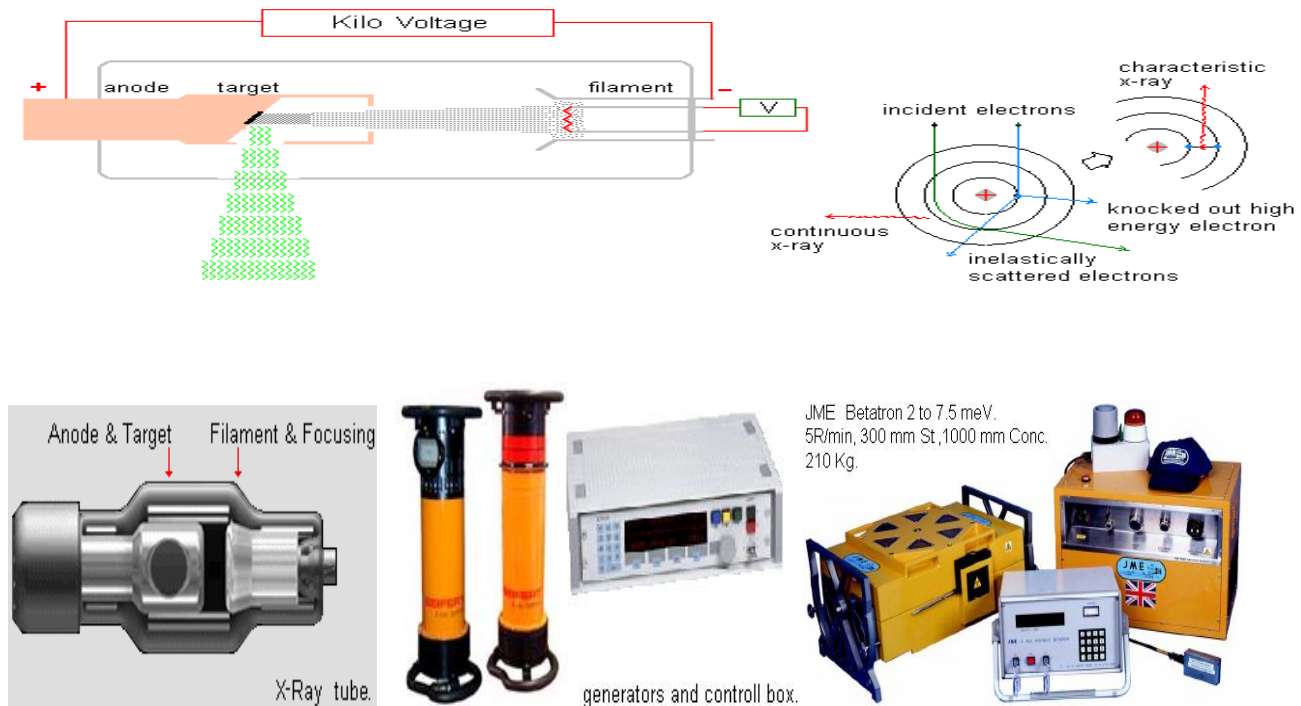
[A] There are varieties of methods to evaluate materials and components as per their state of application. The field of Non-Destructive Evaluation (NDE) or Non-Destructive Testing (NDT) involves the identification and characterization of damages or defect on the surface and interior of materials without cutting apart or otherwise altering the material. In other words, NDT refers to the assessment or evaluation and inspection process of materials or components for characterization or finding defects and flaws in comparison with some standards without altering the original attributes or harming the object being tested. NDT techniques make available or provide a cost effective means of testing of a sample for individual investigation and examination or may be applied on the whole material for checking in a production quality control system.

[B] In many cases, the approach to finding a defect requires more than use of a single NDT test method. It may require a combination of methods and also exploratory, invasive openings. A better understanding of the background, advantages and limitation of each NDT method is essential in ensuring the success of the evaluation. Understanding one NDT method alone may not be enough to ensure the success in solving the problem at hand.

[C] A wide variety of non destructive testing methods plays most important roles in testing of composite materials. The applications of composite NDT may include in many places such as in manufacturing, pipe and tube manufacturing, storage tanks, aerospace, military and defense, nuclear industry, and composite defects characterization. Damage in composite materials can arise during material processing, fabrication of the component or in-service activities among which cracks, porosity and delamination are the most common defects.

[D] Numerous techniques are used in the composite NDT field, including radiographic testing, visual testing (VT) or visual inspection (VI), ultrasonic testing, thermographic testing, infrared thermograph testing, acoustic emission testing (AE), acoustic-ultrasonic, electromagnetic testing, stereography testing, optical testing, liquid penetrate testing and magnetic particle testing. This paper reviews various NDT methods for defect identification and characterization in material and composite and find out most efficient method

Radiation is such a powerful and dangerous divine rays that humans cannot see by themselves, coming in contact with it can cause serious illness or death to a person. Dr. HARDEV



If X-ray is less, then gamma is more, if it is beneficial, then if it is used incorrectly, it is more harmful. DR. HARDEV

“The new evidence of the work done by searching with discretion in any word or field through in depth study and efforts is called Research ” Dr.Hardev IES UNIVERSITY

**2.0 Visual Inspection** > visual inspection is particularly effective for detecting macroscopic flaws, such as poor welds. Many welding defects are macroscopic such as crater cracking, undercutting, slag inclusion, incomplete penetration welds, and the like. Likewise, VI is also suitably used for detecting flaws in composite structures and piping of all types. Bad welds or joints, missing fasteners or components, poor fits, wrong dimensions, improper surface finish, large cracks, cavities, dents, inadequate size, wrong parts, lack of code approval stamps and similar proofs of testing.

**3.0 Radiography Testing** > Radiography technique has a benefit or advantages over some of the other NDT methods in that the radiography provides a permanent reference for the internal soundness of the object that is radiographic. The x-ray emitted from a source has an ability to penetrate metals as a function of the accelerating voltage in the x-ray emitting tube. If any defect or irregularities such as void present in the object are radiography, more x-rays will pass in that area and the film under the part in turn will have more exposure or spot light than in the non-void areas. The sensitivity of x-rays is nominally 2% of the materials thickness. Thus for a piece of steel having a thickness of 25mm, the smallest void that could be detected from this x ray would be 0.5mm in dimension. For this reason, parts are often radiography in different planes. A thin crack does not show up unless the x-rays ran parallel to the plane the crack. We also find out that Gamma radiography is identical or similar to x-ray radiography in function. However this method is less popular because it has a disadvantage of hazards during the handling radioactive materials. This technique is appropriate for the detection of internal flaws or 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 absorption.

**“Testing is a plan which when done repeatedly gives new or old results, we call it testing” Dr.Hardev**

**Image Quality Indicator (IQI)** which provides QUANTITATIVE measurement is used to determine the adequacy of a radiographic technique, but not intended to determine the smallest flaw that can be detected.

DIN WIRE TYPE PENETRA METER		
1ISO 7	6 ISO 10	10ISO16
3.2	1.0	0.40
2.5	0.8	0.32
2.0	0.63	0.24
1.6	0.50	0.20
1.25	0.40	0.16
1.0	0.32	0.13
0.80	0.25	0.10

**DIN-** Deutsche Industries Norm (German Industrial Norm)

62 –Year of invention of pentrameters 1962

**FE-** ferrous Steel / Ferrous Alloys

DIN WIRE TYPE	USED THIKNESS RANGE
1 ISO 7	>50MM
6 ISO 12	>19MM<50MM
10ISO 16	<UP TO 19MM

**“Technique is a simple and clear way to do any work in less time and achieve good skill ”**

**Dr.Hardev**

**“Technology is the process by which humans make problems easy and simple to solve and provide a new direction by using solutions” Dr.Hardev**

**4.0 Dye Penetrate Testing** > This technique is based on the ability of a liquid to be drawn into a "clean" surface breaking flaw by capillary action. Materials that are commonly inspected using DPT or LPI include metals (aluminum, steel, titanium, copper, etc.), glass, many ceramic materials, rubber, plastics. The penetrate which is used in dye penetrate testing may be applied to all non-ferrous materials and ferrous materials; we also known that for ferrous components magnetic-particle inspection is often used instead for its subsurface detection capability. DPT is used to detect defects in casting, forging and welding surface defects such as hairline cracks, surface porosity, leaks in new products, and fatigue cracks on in-service or in operating components. LPI is based upon capillary action, where as low surface tension fluid penetrates into clean and dry surface-breaking discontinuities. Penetrate may be applied to the test component or specimen by dipping, spraying, or brushing. After adequate penetration time has been allowed, the excess penetrate is removed and a developer is applied. The main advantage of using a developer in DPT is that it helps to draw penetrates out of the flaw so that an unseen or invisible indication becomes visible to the inspector. Inspection is performed under ultraviolet or white light, depending on the type of dye used fluorescent or non fluorescent (visible).

**5.0 Ultrasonic Testing** > The ultrasonic technique is used for the detection of internal defects in sound conducting materials. The principle of operation of ultrasonic testing is in some respects similar to echo sounding. A short pulse of ultrasound is generated by means of an electric charge applied to a piezoelectric 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 1 MHz to 6 MHz Vibrations or sound waves at this frequency have the ability to travel a significant distance in homogeneous elastic material, such as many metals with very little attenuation. For example the velocity in steel is 5900 meters per second, and in water 1400 meters per second. Ultrasonic testing employs an extremely diverse set of methods based upon the generation and detection of mechanical vibrations or waves within test objects. Cathode ray tube is the standard method of presenting information in ultrasonic testing, in which horizontal movement of the spot from left to right represents time elapsed. The rate at which the spot moves is such that it gives the appearance of a horizontal line on the screen.

**6.0 Magnetic Particle Inspection**> This method uses magnetic fields and small magnetic particles, such as iron filings to detect flaws in components. The only requirement from an inspect ability standpoint is that the component being in specter must be made of a ferromagnetic material such iron, nickel, cobalt, or some of their alloys, since these materials are materials that can be magnetized to a level that will allow the inspection to be effective. In its simplest application, an electromagnet yoke is placed on the surface of the part to be examined, a kerosene-iron filling

Defects in Composites	
Delimitations	Missing Adhesive
Disbands	Disoriented Fibers/ Ply
Porosity	Wavy Fibers
Contamination	Misallocated Ply/ Details
Improper Cure	Impact Damage
Resin Rich/Poor	Thermal Damage
Damaged Fiber	Thickness Variation
Voids	Dimensional Problem
Cracks	Interface Integrity
LOP ,LOF,UNDER FIL UNDER CUT	Interface Integrity

Combination of the non destructive testing methods and a need for continuous monitoring of the composite material structural condition supports a rapid development and advances in health monitoring applications and eventual prognostics of the structural degradation. These all factors have significant effect on testing of composites through non-destructive methods

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**7.0 S.Gholizadeh [A]** reviewed the non-destructive testing (NDT) methods for the evaluation of composites. Composite tools are mostly used in critical-safety applications in aircraft primary construction. So to know the incipient faults in composite material, the non destructive testing techniques are very much essential. Gholizadeh uses different NDT methods such as visual inspection, ultrasonic technique, Thermograph testing and more to evaluating faults in composite material. The best NDT technique chosen is depending upon the safety of operation and cost incurred during the operation. In addition, non-destructive tests use physical principles to identify and evaluate faults or destructive defects.

**Malcolm K. Lim et al [B]** describes the use of different non destructive techniques. Some time from one NDT method we could not get the required result so that we use the combination of the NDT techniques to get more detail information and result. In this paper two NDT ultrasonic testing and impulse Response method has been used to evaluate the condition of concrete and defect on concrete structure. By using these techniques together we find out more accurate condition of concrete. The Ultrasonic Pulse Velocity method relies on the time of flight of sonic



energy in concrete, to determine the wave propagation velocity. The reduction in velocity is normally an indication that a potential anomaly is present at that test point. On the other hand, IR testing measures the global response of a structure and tends to be influenced by conditions between adjacent test points, and edge or boundary effects.

**YANG Zhan-feng et al [C]** describes the nonlinear ultrasonic testing technique for micro-damage of TATB based Polymer Bonded Explosive (PBX). Ultrasonic non-destructive testing technique is used to evaluate the defects inside explosive parts. For PBX parts examination, the linear wave theory based ultrasonic testing method such as the ultrasonic Pulsed Echo method or transmission method is mainly used. From the research we find out that the materials damage and property degradation are always come with some kind of non-linear mechanical behaviors, result in the non-linear ultrasonic transmission, such as the forming of the high-order harmonic wave. The non-linear ultrasonic techniques used in the research of micro-damage and performance of PBX parts can be meaningful, which will present a new method for the evaluation of the micro-damage and its expansion regularity as well as the reliability of explosives storage. During this examination we found out that the Ultrasonic linear parameters such as gain or velocity were not changed obviously during the whole fatigue cycle loading process. Concluding to this work author suggested that the ultrasonic linear parameters are not sensitive to accumulation and development of micro-damage, unlike ultrasonic nonlinear coefficient, which was very sensitive to that.

**M. Rojek et al [D]** explained the Fatigue and ultrasonic testing of epoxy-glass composites. Epoxy-glass composites are useful and apply more and more frequently as high performance engineering materials. Also they find applications in such demanding and challenging fields as civil engineering, car industry, electronic industry, aerospace technology and many others. During composites development and exploitation many degrading processes take place. Main degrading influences are thermal ageing, radiation and chemical attack, creep and fatigue. It shows the relationship between the degree of strength degradation caused by fatigue and the changes of ultrasonic wave characteristics such as wave velocity and damping coefficient. A good correlation between velocity of ultrasonic wave propagation and the degree of strength degradation of epoxy-glass composites caused by fatigue was found. Ultrasounds can be applied as useful tool to assessment of fatigue degradation of polymer composites. This explains the mechanical properties such as flexural strength and flexural modulus decrease as a result of cyclic loadings. We also find out that the Strong dependence between velocity of ultrasound wave propagation and number of loading cycles. Velocity of sound propagation is decreasing as load increasing

**Dr.HARDEV IES UNIVERSITY** - stated that Non-destructive testing techniques typically use a probing energy form to determine material properties or to indicate the presence of material discontinuities (surface, internal or concealed). It was also found that most of the non destructive testing techniques are primarily being used in many places such as in the aerospace industry, manufacturing industries and have likely to be used for evaluating civil work and infrastructures. From this paper, it is concluded that there is a need of more research work which is carried out so that these techniques are applicable for field use for civil infrastructure. This paper reviews the dissimilar or different works in the area of NDT and trying to find out most recent developments and trends available in industries and other fields in order to minimize damages, minimize the total equipment cost and maximize the safety of equipment, machine, structures and materials There are a number of NDT techniques which might be suitable for thick- walled carbon composite components. From this paper we found that delimitation is the main type of defect that exists within the component which lead to in-homogeneity within the composite component. Examination size longer than 1 mm has to be detected. In Radiography the object is penetrated with short wavelength electromagnetic radiation. The total amount of radiation that passes through the object is captured by a detector. The absorption is a function of density and thickness of the material. Another method called Computed Tomography is used for thick walled carbon fiber component. This scanning technique is used to generate an exact three-dimensional cross sectional image of the entire part. Typical defects that can be detected using this Computed Demography technique are delaminating, undulations, porosities, fiber cracks or impact damages. Thermograph testing makes use of infrared

(IR) imaging to detect defects within the component. Although Computed Tomography equipment is significantly more expensive than Ultrasonic Technique and thermograph equipment, it is a proven or established system with high reliability and a much better traceability

#### 8.0 **INDUSTRIAL RADIOGRAPHY INFORMATION NOTE (Draft) Purpose of this document:**

To provide you, our client, with information you need if you are to ensure that radiography can be conducted on your site with minimum disruption to work;

To ensure that we have the information we need from you to assure you that the work will be conducted efficiently and safely.

The information given here is necessarily very general. It is strongly advised that details of the work are discussed with

us well in advance. It is emphasized that while the radiographer is responsible for the safe use of his equipment, *you have overall responsibility for safety.*

#### 8.1 **What is radiography, and why is safety an issue?**

Radiography involves the use of a beam of radiation to create an image which shows the internal structure of an otherwise opaque object. The radiation can damage living tissue and precautions must be taken to ensure no-one is damaged by the process.

#### 9. **Single Wall Exposure Techniques [ welds ] :**

This is the most used and recommended technique for radiographic recording where two opposite sides of a solid test object are accessible.

#### **10. Exposure preparations :**

**Radiation source / energy :** is selected based on test material absorption, thickness to be examined and type of the film. Optimum contrast with minimum 2% recording sensitivity are the requirements.

**Visual examination :** Visually detected surface imperfections which will produce images on the radiograph shall be rectified before shooting.

**Segment marking :** The weld length is divided into suitable number of segments A –B / 0 –1 etc and marked such that the marks remain on the object till the weld is accepted. Identical segment marking is necessary on the source side and the film side of the object for accurately positioning the film and other accessories around the weld.

**Film Size :** shall be at least 2" more than the length of the segment to be examined. Width shall be sufficient to record the weld, all markers and the complete pentameter outline.

**SFD :** Minimum SFD is to be calculated using the SFD equation. Thumb rule, 10 times the object thickness and 1.1 X length of the film, which is greater. Recommended minimum SFD is 15".

**Location Markers :** shall be placed on the marks near the weld, in sequence 1, 2, 3 / A, B, C etc on the source side of the object, unless a predetermined overlapping length between successive films is used.

**Identification Markers :** as required, shall appear in each film, placed near the weld.

**Pentameter :** 2 % of the thickness being examined. Can also be selected from the table of the applicable specifications / procedures. Weld reinforcement to be included in pentameter selection. Pentameter must be attached to the source side of the object.

**Wire type :** to be fixed near the location marker and across the weld, the thinnest wire in the set towards the location marker.

**Hole type :** to be fixed near the location marker, 3.2 mm away and parallel to the weld, 2T hole towards the location marker.

**Shim :** used to simulate the weld reinforcements, to be placed under the hole type pentameter only, thickness of the shim should be nearly equal to the total weld reinforcement. Shim may be single or staked thin sheets and must be larger than the size of the pentameter.

**Set up :** Location markers are fixed on the source side marks and radiograph identification markers are fixed near the weld using adhesive tapes. The applicable pentameter is fixed on the source side and near a location marker also with tapes. The film is then attached in close contact with the surface, opposite to the source side using magnets or adhesive tapes.

Using a magnetic supporting stand, the exposure point of the source guide tube is secured exactly at the central axis of the segment under examination and at a distance equal to the SFD. The object should be positioned such that the recording plane of the film is perpendicular to the imaging radiation beam. The film is then irradiated through the object for the required exposure time.

**Panoramic exposures :** This is also a single wall technique used for hollow circular components where the inside of the bore is accessible for centering the source point. Circumferential weld joints in pipes and pressure vessels are frequently examined using this technique. The entire joint is recorded in a single exposure. A roll film or a number of films are used with 1" overlap between successive films. Location markers are fixed at regular intervals. Identification markers are fixed as required. Minimum three pentameters must be attached at 120° to each other.

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### ***11 . Radiography in a client's workshop:***

Much of the background for this section comes not from direct experience but from conversations with contract radiographers. The following brief summary is intended only to give a flavor of the issue. It is a frequent requirement for radiography to be performed in a client's workshop. The radiographer's work is often seen to be an imposition. There is little understanding of why the shop must be vacated. It would seem that in extreme cases reactions can include physical violence. However the issue here does not stop at vacating the workshop. Quite a number of contract radiographers have been surprised at the suggestion that they should enquire as to what lies behind the back wall of the workshop. It may be the next door business, or even the crib- room for the client's workshop, the workmen who have just vacated the shop now seated in a row half a meter away from where the source is exposed with only a radiation-transparent block wall for shielding. I have suggested to various radiography contractors that they might prepare an information sheet which could help resolve these issues by encouraging effective communication and assisting their clients to prepare for the work. I am not aware that this has been done, and perhaps there are compelling arguments (legal and political) against the idea, but I have attached a suggested document which may be a useful start. Alertest 660 B. This has a lock that acts on the winding mechanism in such a way that the winding mechanism cannot be removed from the control port unless the pigtail is in the stored position. In the situation we encountered it would have taken significant time to cut through the winder cable sheath in order to recover the radioisotope. We would have had to get additional tools, which would have involved making the



return trip down and back up 120 feet of cat ladder, fully in the radiation beam and with no option to choose a shielded route. But the question is, why is the control port locked at all? There is no reasonable way in which the pigtail can emerge from this end. Locking the winder does not ensure that the delivery tube is in place, and there are tales of radiographers (perhaps exhausted during a 3am shift!) failing to connect the delivery tube before winding out. It would make far more sense to place the lock at the delivery port. If it is interlocked with the delivery tube the source cannot be wound out until everything is connected. Manufacturers: please note!

(It is appreciated that an additional simple mechanism would be required to prevent the pigtail from going forward if the delivery tube is attached before the winding cable, and that this should not prevent it coming back.)

## **12.0 Conclusions:**

Based on the literature survey and review, it is concluded that their various non destructive techniques are available for defect investigation in composite, material, and construction material (concrete). These non-destructive techniques are used in various places such as in aerospace industry, manufacturing industry and civil infrastructures. These techniques have advantages and limitation depending upon their uses and application. We also conclude that from literature survey those composite tools are mostly used in critical-safety applications for example in aircraft primary constructions, the non-destructive testing of composite materials has become more crucial and demanding. The review of researches carried out in recent past show that no single non-destructive test methods provide us sufficient result about defect characterization in composite material because they have their own limitation . So the combination of two or more techniques is used in order to get better result and increase the effectiveness of investigation. The reliability and confidence level of non-destructive test is typically increased by using multiple test methods. For complex part examination ultrasonic technique is widely used. From above research we conclude that further research work is carried out for getting a more promising result in the field of composite material testing. The focus on safety issues in the public eye, the press and legislation is ever increasing, and the potential consequences of even a minor incident involving radiation are rising proportionally. The incidents that have occurred on our site strongly suggest that similar un-reported incidents have occurred elsewhere. Changes in attitude and action are needed. It is not suggested that what has been proposed above is the only possible solution. The essential points are for the management of sites where radiography is performed: To be clear as to where responsibility lies; To ensure those responsible have understood and accepted the responsibility; To ensure those responsible have the resources (including information) needed and are in a position to achieve what is expected. The situation with the gamma camera is, in my view, that the gamma camera lock must be installed on the delivery port instead of the control port.

## **13.0 SUMMARY”**

- 1) Beta radiations can be absorbed completely. But X and gamma radiations cannot be absorbed completely.
- 2) Interactions of X and gamma radiations, in any material, are similar.
- 3) X and gamma radiations undergo three types of interactions in any materials:  
Photoelectric effect, Compton effect and Pair production.
- 4) For energies of interest in industrial radiography, only photoelectric effect and Compton interactions are important.
- 5) PHOTOELECTRIC EFFECT is important at low energies. It decreases as energy of radiation increases. It increases as atomic number of the absorbing material increases.
- 6) COMPTON EFFECT is important at low energies. It decreases with energy. It does not vary with the atomic number of the absorbing material.
- 7) IONIZATION is a process, in which electrons are knocked off (removed) from an atom.
- 8) EXCITATION is a process, in which electrons are raised from an inner orbit to an

outer orbit.

- 9) Alpha, beta and gamma radiations can cause ionization or excitation. Hence, these radiations are called IONIZING RADIATIONS.
- 10) Higher atomic number material, like lead, uranium, absorb X and gamma radiations better than lower atomic number material, like plastic, aluminum
- 11) HALF VALUE THICKNESS (HVT) of any material reduces the radiation intensity at a place of half of the original intensity.
- 12) TENTH VALUE THICKNESS (TVT) of any material reduces the radiation intensity at a place to one tenth of the original intensity.

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