www.tcreng.com

Technical Training Courses

Metallurgy, Corrosion, Failure Investigation, RBI, Damage Mechanisms, Fitness-For-Service and NDT Training classes in India

2010

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1. Executive Summary

TCR Engineering is a leading provider of technical courses targeted towards plant inspection, maintenance and operations personnel in India in the areas of Metallurgy, Corrosion Studies including sour gas corrosion detection, Remaining Life and Failure Investigation. TCR Engineering also offers a results-oriented and focused curriculum for training on Non Destructive Testing (NDT) in a number of subjects.

The training curriculum from TCR Engineering is formalized to provide custom training programs, best practices and leading knowledge in material testing. The training facility is equipped with latest technologies. You will find an opportunity to improve the skills of your metallurgist, engineers and technicians.

TCR Engineering has formed a partnership with PP SIMTECH Solutions Ltd (UK), acclaimed specialists in providing asset integrity managing technology services and related training globally. Due to this alliance, we are providing jointly with PP SIMTECH, training courses in application of the three core technological areas in modern asset integrity management, i.e. Risk Based Inspection, Damage Mechanisms and Fitness-for-Service.

TCR Engineering's trainers have several years of experience in the technical training industry. The training style is highly effective, and our trainers are all professionals in the technical education field, most with years of experience both in the classroom and with applied technology skills. TCR Engineering's classrooms and training facilities are second to none.

At TCR Engineering, we believe in a "coaching" approach to training. An effort is made to try to ensure that the students spend most of their time in class actively learning with exercises and lab work. Our ASNT Level II certification is based on ASNT standard SNT-TC-1A as well as the newly released CP-189 standard.

TCR Engineering understands the changing and dynamic nature of this industry. A dedicated Curriculum Developer researches and qualifies new courseware for purchase, licensing, or develops/ partners with a vendor for courseware ensuring that our courseware standards and materials stay current.

Unlike other training schools, TCR Engineering adopts and promotes the train-the-trainer approach. Should you like the trainer to stay and interact with your team post-training phase, we can assist in the same. TCR Engineering can also custom tailor a class to suit your company´s unique requirement. To conduct these courses we require minimum 4 students and can accommodate a max of 10 students per class.

The technical training fees include theoretical training, practical, and examination. The classes are run on dedicated equipment with trainers that have over 10 years of teaching experience. Unlike other classes, our curriculum is closely aligned with industry requirements and has close parallels to the working style of active projects that are run at large companies.

All courses are designed to impart practical knowledge that can be applied immediately to the outside world. These will provide engineers and technicians with the capability to improve their testing techniques, learn how to perform advanced tests, and help assure how to meet standards. From novice to an expert, courses are designed to learn more in the field of material sciences. Courses can be personalized based on the needs of our clients. TCR has the capability to conduct a course for 20 candidates at the same time.

Candidates will receive training from experienced metallurgists, engineers and laboratory technicians. Our instructors have a minimum of 15+ years of experience in the industry. Each NDT trainer is ASNT Level III certified. TCR trainers have field experience in the areas of Aerospace, Defense, Automotive, Chemical Processing, Defense, Nuclear Power, Scrap and Capital Goods manufacturing.

TCR Engineering runs the technical courses from its training centre in Mumbai, India, in addition to providing on-site training where required.

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2. Technical Training Courses Offered by TCR Engineering

The courses offered by TCR Engineering include:

Metallurgy
Mechanical Metallurgy Laboratory – Level I
Mechanical Metallurgy Laboratory – Level II
Microstructure Characterization
Metallurgy for Plant Executives and NDT Inspectors
Metallurgy for Non Metallurgists

Corrosion Studies
Sour Gas Corrosion Testing – Level I
Sour Gas Corrosion Testing – Level II

Asset Integrity Managing Technologies
Living With Defects - Fitness for Service (FFS) Assessment
Arm Yourself With Damage Mechanisms (DMs) Knowledge
Requirements for Implementing Risk Based Inspection (RBI) Best Practice

Failure and Root Cause Analysis : Guide and Techniques

Non Destructive Testing
Introduction to NDT for Plant Executives
Ultrasonic Testing – Level I
Ultrasonic Testing – Level II
Magnetic Particle Testing – Level I and II
Dye Penetrant Testing – Level I and II
Eddy Current Testing – Level I
Eddy Current Testing – Level II
Radiography Testing – Level II
Visual Testing – Level II
Thermography – Level I

Welding Courses
Gas Tungsten Arc Welding for Qualified Welder (TIG, 6G)
Shield Metal Arc Welding (SMAW) for Qualified Welder

All courses, unless specified in advanced with the client will be conducted at TCR Engineering's training room at its office in Mumbai located at:

TCR Engineering Services Pvt. Ltd. (India)
Attn: Training
Plot No. EL–182, MIDC–TTC, Electronic Zone,
Behind NELCO, Mhape, Navi Mumbai, Maharashtra,
INDIA – 400 710
Tel: +91-(22)-67380900 - 999
Tel: +91-(22)-27612324, 27631508, 27610921-22-23,
Fax: +91-(22)-27612044

Dates for scheduling of each class will be announced when a minimum of at least 6 students sign up for a given batch.

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3. Metallurgy

The multi-disciplinary certified and experienced personnel team of professionals at TCR Engineering includes: metallurgical, mechanical, electrical, and chemical engineers; materials scientists; chemists; physicists; NDT inspectors and computer scientists who have the qualifications, the education and the experience to meet rigorous standards in the testing field, whether serving the Private and Public Sector, Government or the Military.

A. Mechanical Metallurgy Laboratory – Level I

This course covers the following topics:

Part I Mechanical fundamentals
- Introduction to mechanical metallurgy
- Stress and strain relationships of elastic behavior
- Elements of the theory of elasticity

Part II Metallurgical fundamentals
- Plastic deformation of single crystals
- Dislocation theory
- Strengthening mechanisms
- Fracture

Upon completing this course the students will have a good understanding on the subject area including:

- Interaction of stress and strain on materials in elastic and plastic manners will be understood.
- Deformation behavior of metals due to dislocation interaction as well as strengthening mechanisms of metals will be addressed.
- Different methods of mechanical testing will be highlighted along with the interpretation of sensible information from the obtained data such that mechanical assessments are appropriately selected for the required applications.
- Metallurgical aspects which affect mechanical properties of materials will be discussed.
- Finally cause of material failure will be possible solutions will be discussed.

The duration of this course is 3 days and it is conducted by a Senior Metallurgist. Students will be given a course completion certificate at the end of this course.

B. Mechanical Metallurgy Laboratory – Level II

This course covers the following topics:

Part III Applications to materials testing
- Tensile test
- Hardness test
- Bend test
- Engineering Measurements
- Brittle fracture and impact testing
- Fatigue of materials
- Creep and stress rupture

This course aims to provide practical skills on mechanical testing of metals including hardness, tensile, torsion, creep, impact, bending and fatigue testing. Students are required to extract and interpret sensible information from mechanical test data as well as to give explanation on relationships between metallurgy of the metals and their mechanical properties.

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Upon completing this course the students will have a good understanding on the subject area including:

- Students will understand the principles and the use of engineering measurements by employing different measuring tools and methods in order to suit the desired applications.
- To understand the meaning of the measured values in engineering applications.
- Students will understand the principles of hardness testing, i.e., Rockwell, Brinell and Vickers hardness tests.
- Students are able to explain variations in hardness properties of selected materials such as aluminium, steel, brass and welded metals and can explain factors that might affects their hardness properties.
- Students can select appropriate macro-micro hardness testing techniques for suitable materials-property analysis.
- Students are able to analyze the obtained hardness values in relevant to the nature of each material to be measured and use this information as a tool for selecting suitable materials for engineering applications.
- Students will understand the principle of a uniaxial tensile testing and gain their practices on operating the tensile testing machine to achieve the required tensile properties.
- Students are able to explain load-extension and stress-strain relationships and represent them in graphical forms.
- To evaluate the values of ultimate tensile strength, yield strength, % elongation, fracture strain and Young's Modulus of the selected metals when subjected to uniaxial tensile loading.
- Students can explain deformation and fracture characteristics of different materials such as aluminium, steels or brass when subjected to uniaxial tensile loading.
- Students are required to study the principle of impact testing using metals which are susceptible to brittle fracture such as mild steels.
- Types of fracture in metals are investigated using the fracture energy absorption criterion.
- Students can explain the meaning and use of Ductile-to-Brittle-Transition-Temperature Curve (DBTT) and explain the relationship between the absorbed energy of the specimen and its fracture surfaces. Identify the transition temperature of the tested materials.
- Students are capable of interpreting the obtained experimental data for the selection of engineering materials.
- Students will study the principles of bend testing, practice their testing skills and interpreting the experimental results of the provided materials when failed under three-point bending.
- Investigate responses of metals when subjected to bending
- Determine parameters such as bend strength, yield strength in bending and elastic modulus.
- Students can interpret the obtained test data and select appropriate engineering materials for their intended uses in order to prevent creep failures.

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- Students will understand the principles of torsion testing, practice their testing skills and interpreting the experimental results of the provided materials when failed under torsion.

- To determine the maximum shearing stress, shear stress at proportional limit, shear modulus or modulus of rigidity and relationships between torque and degree of rotation of the tested materials.

- Students are able to differentiate the ability of materials such as cast iron and brass to withstand torque prior to torsion failure. Analysis and interpretation of the test parameters obtained should be carried out in relation to the failure nature of each material.

- Students are capable of selecting materials for engineering applications associated with torsion.

- Students will study the principal of creep testing and practice the testing procedure.

- Students should be able to explain the causes of creep in metals, creep deformation and be able to indicate factors influencing creep behavior in metals.

- Students can analyze the obtained creep data and use it for the selection of appropriate engineering materials to prevent creep failures.

The duration of this course is 10 days and it is conducted by a Senior Metallurgist. Students will be given a course completion certificate at the end of this course.

C. Microstructure Characterization Training

Good understanding of microstructures is the hallmark of any metallurgist. Students taking this course from TCR Engineering will get hands on experience in working with microscopes; replica's as well as we performing analysis on TCR's uniquely designed MiC 3.0 software.

Students will be able to get a basic understanding of Macro and Micro examination including Weld Examination, Case Depth and Decarburization Measurement. Micro Hardness Testing and Coating/Plating evaluation.

The students will be able to:

- Determine the micro structural degradation due to creep
- Calculate the graphitization
- Evaluate the depth or width of decarburization
- Determine the phase/volume percentage
- Calculate grain growth
- Inclusion Rating Determination
- Particle Size Measurement
- Volume Percentage Calculation
- Particle Count Measurement
- Porosity Evaluation
- Coating Thickness Measurement

The duration of this course is for 5 days and it is conducted by a Senior Metallurgist. Students will be given a course completion certificate at the end of this course.

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D. Metallurgy for Plant Executives and NDT Inspectors

This dynamic three-day course for non metallurgists, including designers, engineers, technicians, sales engineers and purchasers, is designed to give your company a strong competitive edge in today's rapidly changing marketplace.

The course focus is on translating complex principles and procedures into easy to understand terms that will enable participants to gain a valuable working understanding of the fundamental principles of metallurgy as well as the basic structure, properties, heat treatment and processing of metals and alloys.

Metallurgy pervades the full gamut of engineering product design and processes. It is the basis from which optimum properties for a given design are determined. Product life and maintenance are key issues in all manufacturing product design using metals. Component properties must be adequate to ensure the desired product life in complex environments involving wear, corrosion, and elevated temperatures. Metallurgy is thus a vital basis of every major engineering field, and it contributes to virtually all engineering applications where a metallic component or system experiences use.

Practical training with significant benefits.
This interactive, highly practical course will be of significant benefit to anyone who needs a working understanding of metals and their applications, those with no previous training in metallurgy, technical, laboratory, and sales personnel, engineers from other disciplines, management and administrative staff, and non-technical support staff. Participants will gain a technical familiarization with ferrous and non-ferrous metals and their processing and optimization to meet specific product needs.

Emphasis will be given to the foundational concepts of metallic structures and phases and the latest developments in material processing, in combination with an overview of metallurgy, which will provide a solid foundation and understanding of the significance and impact of metallurgy in product design, whether you:

- Are seeking ways to cut costs, improve performance and increase profitability.
- Have employees who want to learn more about complementary or competitive technologies.
- Have employees who want to update present knowledge of metals, processing, and optimization.
- Have employees who are just starting out in the field and need a basic knowledge of metallurgy.

Participants will join in discussions guided by course instructors, who will encourage questions, comments, and participation at all times. There will also be opportunities to exchange ideas with the instructors and other participants during breaks, lunch, and after class adjourns. With this interactive format and the dynamic instructors, participants will find this intensive course to be extremely beneficial, as well as motivating and thoroughly enjoyable.

Key Course Topics.
The ways in which metal alloys are structured, how the structure affects their performance, how mechanical properties of metals are measured, and what influences these properties; what steels and cast irons are and what processing and chemical parameters influence their performance; what aluminum alloy metallurgy is and what influences their mechanical properties; how the environment affects the performance and durability of metals – and much more, as shown in the Course Highlights listed below.

Introduction: Why Metallurgy?

Metal Basics: Characteristics of metals, atomic arrangements and bonding, crystal structures, grains and precipitates, strengthening mechanisms, deformation, and phase diagrams.

Real Engineering Materials: Basic processing and properties, Fe-C diagram, metals and materials types.

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Shape Forming: Melt/cast, cold/warm work, forge, draw, extrude, powder metallurgy shaping.

Heat Treatment: Processes, properties/microstructure effects, steels, cast irons, super alloys, and non-ferrous including Al and Ti alloys.

Mechanical Properties: Hardness, stress-strain, fatigue, toughness, creep, property envelopes.

Joining: Welding, brazing, soldering, cladding.

Emerging Materials/Processes: Composites, nano materials, grain boundary engineering.

Failure Analysis: Wear and corrosion mechanisms: Hardness, stress-strain, fatigue, toughness, creep, property envelopes.

Surface Engineering: Failure mechanism solutions, coatings and diffusion based treatments.

Summary: Course summary and group discussion.

The duration of this course is for 3 days and it is conducted by a Senior Metallurgist. Students will be given a course completion certificate at the end of this course.

E. Metallurgy for Non-Metallurgists

This course will cover the following topics:

1. Introduction to Metals: - Scope and Applications, Important metals used.
2. Structure of Metals: - Crystal structure, thermal curve for solidification , simple binary diagrams, allotropic modifications of iron, iron carbon diagram, Various phases of iron, corresponding microstructures.
3. Steels: - Effect of alloying elements on the properties of iron, major types of steels, Stainless steels.
4. Heat Treatment of Metals: - TTT and CCT diagrams, Hardenability, different heat treatments for steel, procedures, equipments, quechants, Introduction to case and surface hardening.
5. Non-Ferrous Metals: - industrial applications, major groups, heat treating procedures.
6. Casting Methods and Cast Irons: - Sand casting, die casting, centrifugal casting, investment casting, processing of castings.
7. Types of cast irons, microsturctural features and salient charactertics.
8. Metal Forming: - Cold and Hot working, Forging, rolling, extrusion and swaging at high temperature. Cold rolling, wire drawing, cutting piercing etc.
9. Joining: - Basic of welding, sources of energy, methods of shielding, types of welding methods, SMAW, GTAW, GMAW , SAW. Methods of cutting.
10. Performance during Service: - Failure of metals during service, Failure modes, Failure due to Fatigue, Wear and high temp, Definition of corrosion, different types, methods of prevention.
11. Mechanical Testing & NDT: - Description of testing methods, NDT methods.

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Detailed Three day program will be as follows:

DAY-1

9.00 to 9.15	Welcome and Introduction
9.15 to 10.45	Role of metallurgy in Plant components
10.45 to 12.15	Basics of metallurgy, for ferrous and non ferrous alloys
12.15 to 13.30	Lunch Break
13.30 to 15.00	Basics of heat treatment keeping in view of plant components
15.00 to 15.15	Tea Break
15.15 to 16.45	Damage mechanisms- Fatigue, Creep and Corrosion in plant components
16.45 to 17.45	Applications of first hand metallurgical fundamentals in practical consideration

DAY-2

9.00 to 12.00	Advanced Materials for plant technology and their consideration.
13.00 to 13.45	Lunch Break
13.45 to 14.45	Balading system and turbine blade failures
14.45 to 15.00	Tea Break
15.00 to 16.00	Inspections and Testing Part:
16.00 to 17.00	Corrosion fundamentals for plants

DAY-3

9.00 to 11.00	Remaining life assessment – of plant components
11.00 to13.00	Weld failure and it's prevention.
13.00 to 13.45	Lunch Break
13.45 to 14.45	Plant components and their quality assurance
14.45 to 15.00	Tea Break
15.00 to 16.00	How to go for indigenization of imported components – to increase self reliance
16.00 to 17.00	Discussion and distributions of certificates

The duration of this course is for 3 days and it is conducted by a Senior Metallurgist. Students will be given a course completion certificate at the end of this course.

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4. Corrosion Studies

A. Sour Gas Corrosion Testing – Level I

Corrosion of metals has imposed a serious threat on industry, the society and the nation in terms of both money and manpower. General statistics reveals that overall cost due to corrosion of metals amounts to at least 2-4% of GNP. This loss not only included the cost of replacement of metals, but also the damage to products by contamination, shut down of production, loss of efficiency and in psychological factors associated with failure or explosion of equipments. This loss can be reduced effectively to the tune of 20-25% by the application of appropriate and upgraded knowledge of corrosion and corrosion control science. Present course is an attempt in this direction which includes the basics and applied aspects of diffraction forms of corrosion and introduces to the recent developments in corrosion science and engineering with special emphasis on sour gas corrosion.

Module 1: Basics of Sour Gas Corrosion
HIC
SSC

Module 2: Review of Standards
Understanding of NACE TM0284 - resistance of pipeline and pressure vessel plate steels to Hydrogen Inducted Cracking caused by hydrogen absorption from aqueous sulfide corrosion.

Understanding of NACE TM 0177, EFC 16 and 17 - Sulfide stress corrosion cracking (SSCC) test occurs when a susceptible material is exposed to a corrosive environment containing water and H_2S at a critical level of applied or residual tensile stress.

Module 3: Sample Preparation

Module 4: Review Sample under Microscope

Module 5: Hardness Testing
Selection of type of harness based on type of steel grade and geometry of specimen.
Operation of hardness testing Machines.
Calibration of hardness machine .
Selection of indenter.
Standard practice of harness testing as per ASTM E384, E10 , E92 and E18 .
Calculation of hardness number .
Conversion of one hardness to other type of hardness as per ASTM E140.

Module 6: Grain Size Analysis:
Selection of sample for grain size analysis.
Micro constituent of steel.
Standard practice of grain size analysis as per ASTM E112, E930, E1382.
Parameter setting for optical microscope for grain size analysis
Evaluation of Grain size

Module 7: Determination of Inclusion Rating:
Basic Knowledge of different type of non metallic inclusions in steel
Selection of sample for inclusion rating
Physical appearance of inclusions in cast steel/iron
Physical appearance of inclusion rolled product.
Standard practice for inclusion rating as per ASTM E45 and ASTM E1245 specification
Calibration of optical microscope
Parameter setting for optical microscope for inclusion analysis
Evaluation of inclusion content in steel.

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The duration of this course is for 5 days and it is conducted by a Senior Metallurgist. Students will be given a course completion certificate at the end of this course.

B. Sour Gas Corrosion Testing – Level II

The topics covered in this course include:

Module 1: Hydrogen Induce Cracking (HIC) and Sulfide Stress Corrosion Cracking (SSCC) - 4 point bend Test
Measuring dimension of samples and calculating required test solution volume.
Cleaning and test for degreasing as per ASTM F21. Calculation of deflection based on applied load which depends on steel grade.
Entering required data for the test.
N2 purging and H2S gas bubbling for HIC and SSCC (4 point bend test) .
Idiomatic titration of test solution.
Monitoring and inspection of test.
Neutralization of test solution before deposing to waste tank.
Record of chemical consumption and waste solution.
Evaluate test result .

Module 2: Sulfide Stress corrosion cracking (SSCC) test, Uni-axial Constant Tensile Load
Calculate applied load based on the steel grade.
Loading and un loading of test specimen into the testing machine .
Familiarization with gas management.
Selection of required parameters to enter the test mask.
Evaluation of results.

Module 3: Ultrasonic Crack Detector
Setting ultrasonic crack detector's parameters for Ist and 2nd operational level .
Select appropriate speed and resolution to get correct value.
Calibration of machine .
Select proper analysis line for calculating HIC parameters .
Print and save the raw data of scanned samples.

The duration of this course is for 5 days and it is conducted by a Senior Metallurgist. Students will be given a course completion certificate at the end of this course.

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5. Asset Integrity Managing Technologies

TCR Engineering has formed an alliance with PP SIMTECH Solutions Ltd (UK), an acclaimed specialist in providing asset integrity managing technology services and related training globally. Via our alliance we are jointly offering training courses in the application of the three core technological areas in modern asset integrity management of plants operated by oil & gas exploration; oil refining and gas processing; petrochemical, chemical and fertilizer manufacturing; power generation and sea water desalination industries :-

A. Requirements for Implementing Risk Based Inspection (RBI) Best Practice

B. Arm yourself with Damage Mechanisms (DMs) Knowledge

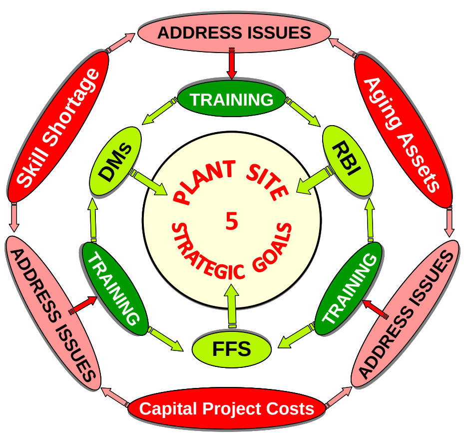
C. Living with Defects – Fitness-For-Service (FFS) Assessment

Meeting Industry Critical Needs

A structured approach to effective, economic, safe and reliable management of static equipment asset integrity involves the application of Risk Based Inspection (**RBI**) technology and Fitness-For-Service (**FFS**) assessment techniques based on active and potential Damage Mechanisms (**DMs**) and their root causes. These **three core subject areas** are closely interlinked and complement each other in demonstrating equipment integrity.

For example, for many deteriorating or aging plant items the RBI process is supported by FFS assessments to derive the optimum remaining life and inspection intervals based on acceptable level of risk and consequences of failure. A comprehensive knowledge of DMs and their root causes in static equipment deterioration and the knowledge of DMs driven plant operating limits and other risk mitigation measures are central to correct application of RBI and FFS.

Only this integrated application knowledge of RBI, FFS and DMs combined with a holistic approach will provide a 'Defence in Depth' approach to asset integrity management at <u>optimum</u> costs, throughout a plant's life cycle. Importantly, it guarantees delivery of the FIVE strategic goals aimed for by plant sites.



These training courses proactively address the main issues in order to support the plant sites. The diagram highlights the current issues faced by industry and the way in which effective training in the 3 critical subject areas successfully fills the knowledge & skills gap and helps plant sites achieve their strategic goals.

Strategic Goals aimed for by Plant Sites:

1. *Desired operational reliability between TAs*
2. *Desired optimum plant run-length time between TAs*
3. *Maximum cost effective life out of aging equipment*
4. *Optimum inspection interval for each item*
5. *Optimum spend on CapEx; Optimum spend on RevEx*

Who Should Attend?

It is imperative that a thorough understanding and application knowledge of RBI, FFS and DMs is essential for practicing professional engineers who are involved in any of the following areas of work:-

- ➲ Equipment Inspection
- ➲ Metallurgy & Corrosion
- ➲ Plant Operations
- ➲ Process Design
- ➲ Equipment Design
- ➲ Root Cause Analysis
- ➲ Process Chemistry
- ➲ RBI
- ➲ FFS

Why? These engineers are charged with the responsibility to collectively manage asset integrity at optimum costs and underpin delivery of plant site strategic goals, from design stage to decommissioning.

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Training Concept and Focus

These training courses are carefully designed to match the foregoing needs. The training ***Course Outline*** in each subject area includes the necessary theoretical knowledge plus all important practical aspects which must be considered when applying these integrated technologies, to ensure success in all situations.

Benefit to the Participant

Through this responsible ethos, those attending will attain the self assurance needed to correctly apply these technologies, have confidence in the end outcome and will be able to confidently substantiate the resulting perceived benefits.

Our Difference

TCR Engineering -PP SIMTECH training experts have many decades of hands-on experience in the development and successful and effective application of these asset integrity managing integrated technologies. Through our alliance we take great pride in effective transfer of this integrated knowledge and technical "know how" to those attending these courses.

These specialised training courses are developed and presented by these experts - engineers who are involved in and have been at the forefront of the development of best practices in RBI technology and successfully implementing it at various plant sites globally for more than 14 years. Furthermore, they have been involved in the development of British Standard codes BS PD 6493 & BS 7910 for Fitness-For-Service (FFS) assessment for more than 20 years. In 2002, they championed the development of Damage Mechanisms (DMs) susceptibility assessment models for nearly 70 DMs for effective application of RBI. Several plant sites are now using this guidance; by all engineers as a reference document in their working disciplines, plus it is used by site teams when conducting studies such as HAZOP and Root Cause analysis.

An added value of these courses is that the acquired integrated knowledge promotes and embraces a "working together" culture at plant sites, which in turn has a positive influence on the achievement of the 5 strategic goals.

A. Requirements for Implementing Risk Based Inspection (RBI) Best Practice

Only the implementation of best practices in RBI brings immense benefits to plant sites. However, it is emphasized that there are no short cuts to this process. For example, compromising the quality of the RBI team study by not providing sufficient study time in order to reduce project timescales or project costs will have a detrimental effect on the confidence that can be placed on the RBI study output. As such the claimed outcomes of improvements in plant reliability, safety and financial benefits are questionable and so is the management decision to buy into this output and implement it in the hope that they are going to achieve the claimed benefits.

Benefits to those attending:

This coaching imparts a valuable knowledge of what constitutes a reliable RBI technology and best practice for successful implementation. These skills are crucial for effective management of static equipment asset integrity. Engineers attending will achieve the following which supports the 5 strategic goals aimed for by plant sites.

1. Acquire the knowledge and skills which are required to become:-
   - A competent RBI study facilitator after participation in RBI team studies
   - A competent RBI study team member representing his/her respective skill discipline

They will be able to:-

2. Define:
   - Plant site strategic goals driven by effective asset integrity management
   - The reasons for and benefits of implementing RBI
   - The link between RBI objectives, RBI study output, resulting RBI benefits and the 5 strategic goals

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- The role of each engineering discipline; the required interaction; sharing of information with other core engineering disciplines involved in RBI implementation
- Mandatory management obligations, support and commitments when implementing RBI
- The scope of RBI study data requirements for each equipment item or piping corrosion loop, e.g. process fluid streams data (including when and where to take fluid stream samples for chemical analysis), inspection history, known DMs and rates, operating history/changes
- DMs which apply to static equipment assets; common damage causing chemicals; their effects
- The RBI study process and the output requirements
- The RBI process involved in the re-assessment of inspection intervals based on feedback from remaining life/FFS calculations
- The process involved for subsequent updates of the initial RBI study and its output, following inspections or operational changes

3. Recommend:

- Suitable risk mitigation measures when necessary for an item (e.g. material upgrade, design and/or operational change, inhibitors, protective coatings, remaining life/FFS calculations)
- A process to 'de-bottleneck' inspections of items which restrict achievement of desired plant run-length time between TAs as well as provide guide to optimise plant run-length time between TAs based on inspections de-bottlenecking outcome & decisions

4. Champion the delivery of an RBI implementation project successfully through understanding of the complete logistics and aspects involved, such as :-

- Senior management support requirements
- Site strategic goals, RBI objectives, deliverables & KPIs
- Selecting the most reliable RBI technology/service provider based on RBI best practices
- Selecting a supporting software where data, RBI technology/study process and team decisions are transparent and auditable with the facility for future updates of the RBI study and output
- Defining comprehensiveness of the team study and study output
- Selecting the RBI team members, defining expertise and role
- Devising RBI team study time/project period based on availability of team members from site
- Implementation of the RBI study output
- Converting RBI output into benefits as defined in plant site RBI objectives/site strategic goals
- Managing future updating of the initial RBI study and output
- Implementing RBI driven plant site procedural changes; Managing KPIs

Additionally and specific to each engineering discipline:-

5. Inspection Engineers attending will be able to:-

- Prepare detailed RBI inspection plans for each item and each piping corrosion loop
- Optimise inspection intervals, with due consideration given to achieving site strategic goals.
- Decide if inspection type is intrusive or non intrusive & whether it can be done online or offline
- Assign speculative inspections & inspection sampling as appropriate
- Define anticipated repairs for next TA

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6. Operation Engineers, Process Engineers and Process Chemists attending will be able to:-
    - Gain knowledge of the impact of day-to-day operational changes or planned revamps on equipment integrity
    - Implement RBI defined operating limits and control mechanisms including the necessary changes to their operating procedures and site practices

7. Maintenance Engineers attending will be able to:-
    - Implement the RBI defined maintenance activities and control mechanisms, including the necessary changes to their procedures and site practices

8. Design Engineers involved in capital projects or existing plant revamps attending will be able to:-
    - Improve their equipment design ability by considering the effects of common damage causing chemicals and process conditions which initiate DMs together with DMs risks and consequences of failure in relation to the equipment material, design features and construction issues.

9. Metallurgists and Corrosion Engineers attending will be able to:-
    - Better define and manage DMs related tasks based on the overall knowledge they gained in RBI technology process and the role of engineers from other technical disciplines at plant site

10. FFS Assessment Engineers attending will be able to:-
    - Improve their assessment skills by considering in their assessment the effects of common damage causing chemicals; process conditions and operational aspects which initiate or propagate DMs; the DMs risks and consequences of failure in relation to the equipment

11. All engineers listed above will gain a clear knowledge of the following which promotes the “working together” culture which in turn has a positive influence on the plant site 5 strategic goals:-
    - the specific responsibilities defined above for each discipline within the RBI process and how these responsibilities interact with their own area of work
    - each others role in his/her area of work

The course duration is 5 days. Engineers will be given a course completion certificate at the end of this course.

Course Outline

1. Why RBI and Requirements for Effective Implementation

- RBI vs. Traditional Inspection Practice
- Plant site RBI objectives
- Plant site Management commitment & support
- Appointing Single Point Accountability (SPA) at site & SPA role
- Championing effective delivery of the RBI project – *what’s involved?*

2. Delivery of perceived benefits from Implementing RBI?

- RBI Output and how this is related to the Objectives & end benefits
- Confidence in implementing the RBI output to achieve the benefits
- Setting up & Measuring Key Performance Indicators (KPI)

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3. **RBI Methodologies –** *What's available?*

- API 580/581 and UK HSE (Health & Safety Executive) Guidance
- PP SIMTECH methodology incorporating leading edge of RBI Best-Practice
- Selecting the right RBI technology and the Service Provider

4. **RBI Study Data & Practical Requirements**

- Understanding of common damage causing chemicals, applied loads and external environment
- Knowledge of damage mechanisms which apply to static equipment assets
- Dealing with connected piping between items – *defining Piping Corrosion Loops (PCLs)*
- RBI Study Data scope for each PCL and each Item (vessels, storage tanks, etc)
- Addressing uncertain data issues (e.g. assign stream locations for chemical analysis)
- Defining HSE & Business Consequence of Failure based on Failure Modes
- RBI study 'Ground Rules'

5. **Key aspects of RBI Team Study requirements & process**

- Team members, Expertise and Role
- Treating each Item & each PCL in RBI study
- Identifying applicable Damage Mechanisms (DMs) for each Item
- Identifying applicable Damage Mechanisms (DMs) for each PCL
- Assessing Failure Modes, Consequence & Probability of failure applicable to each of the identified DMs
- Evaluating Risk Profile of identified DMs for each item & each PCL, plus overall risk profile of each Item & each PCL
- RBI Team Study Output tasks for **each Item & each PCL**
  - → Optimising inspection interval / Optimising Inspection plan reliably
    - Assigning Intermediate Inspection & Major Inspection OR Major Inspection only
    - Assigning Inspection type (Intrusive vs. Non-Intrusive; Online or Offline)
    - Assigning Inspection method and inspection locations; consideration of NDT effectiveness & capability
    - Assigning 'Speculative Inspections' and 'Inspection Sampling' as appropriate
  - → Guide to 'de-bottleneck' inspections of items which restrict achievement of desired Plant run-length time between TAs
  - → Optimising Plant run-length time between TAs based on inspections de-bottlenecking outcome & decisions
  - → Defining RBI based integrity driven Operating Limits and Maintenance Activities
  - → Defining other risk mitigation measures; other actions, e.g. remaining life / fitness-for-service (FFS) calculations

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→ Feedback of results of remaining life / fitness-for-service (FFS) calculations into DMs risk assessment to improve inspection intervals and inspection scope

→ Defining anticipated significant repairs at next TA (help plan ahead to mitigate over-run of planned TA time)

6. RBI Software Minimum Requirements

- Understanding the RBI process, implementation of the RBI team study and study output, subsequent management of the RBI cycle from 'design to decommissioning' of a plant
- Understanding the software needs to **support** these from 'design stage to decommissioning'
- The role of PP SIMTECH rbiAsyst™ (RBI Assurance System) software and how it supports the complete best practice of the RBI implementation process and the subsequent RBI cycle

7. Implementing RBI Study Output & Deliverables at a plant site – *what's involved?*

- Conversion of RBI study output to the 5 strategic goals aimed for by plant sites via the RBI implementation project objectives
- Aspects on site procedural changes related to Inspection, Operation, Process, Corrosion Management & Maintenance Departments
- Responsibilities of Inspection, Operation, Process, Corrosion & Maintenance Departments.

8. Sustaining RBI process successfully at a plant site – *what's involved?*

- Updating initial RBI study and output – *when and why?*
- Inspection reporting the RBI way
- Managing Inspection plans (intervals & inspection requirements),
- Managing RBI defined Operating Limits
- Managing RBI defined Maintenance Activities

9. Engineers Learning Tasks –

- RBI team study of a typical equipment item
- RBI team study of a piping corrosion loop

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B. Arm yourself with Damage Mechanisms Knowledge

A structured approach to economic, safe and reliable management of static equipment assets involves 2 critical technologies – Risk Based Inspection (RBI) and Fitness-For-Service (FFS). They are closely linked and complement each other in demonstrating integrity of an item throughout its lifetime at optimum costs.

The knowledge of Damage Mechanisms (DMs) and their root causes in static equipment deterioration is central to this process. Only this information can support the reliable application of these technologies, so that it gives the required confidence in assessment results. The importance of all engineers involved in inspection, integrity, plant operations, process design & equipment design having a thorough understanding of these DMs is therefore crucial as each of these disciplines have an important role to play in effective management of asset integrity via RBI and FFS technologies.

Benefits to those attending:

This coaching imparts a comprehensive knowledge of nearly 70 Damage Mechanisms (including those listed in API 571) relating to plants operating in oil & gas exploration; oil refining and gas processing; petrochemical, chemical and fertilizer manufacturing; power generation and sea water desalination industries.

Engineers attending this course will acquire the following required knowledge which supports the 5 strategic goals aimed for by plant sites via the application of RBI and FFS technologies.

Engineers attending this course will :-

1. Better manage equipment integrity through learning:-
    - The key conditions which initiate damage
    - key factors which influence damage (↓detrimental factors versus ↑beneficial factors)
    - Where DMs may be found & areas for inspection (general location and specific location)
    - The important role DMs play in deriving RBI based equipment inspection intervals and inspection methods
    - The important role DMs play in conducting FFS assessments and the resulting decisions

2. Be able to:-
    - Confidently help support the identification of applicable active and potential DMs which apply to an equipment item, interconnected piping, storage tanks or pipelines during RBI team studies or when involved in FFS assessments
    - Recommend mitigation methods related to materials, design, process and operating envelope, which are used to eliminate or minimise damage
    - Recommend matching inspection methods and/or monitoring, for example types of NDT; physical and operational monitoring

3. Additionally:-
    - Plant Operations engineers, process engineers and process chemists will gain knowledge of common damage causing chemicals and their effects on equipment integrity and the impact of day-to-day operational changes or planned revamps on equipment integrity
    - Plant Mechanical and Maintenance engineers will learn the reasons for and the way in which to prioritise DMs related equipment maintenance activities and as a result will be able to optimise maintenance costs whilst managing their workload more efficiently

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- Design engineers involved in capital projects or existing plant revamps will learn about common damage causing chemicals and process conditions which initiate damage mechanisms, whilst at the same time learn about material aspects, design features and construction heat treatments which reduce susceptibility of equipment deterioration, thus improving their equipment design ability in enhancing plant operational reliability within desired plant run-length times between TAs
- FFS Assessment engineers will improve their assessment skills by considering in their assessment the effects of common damage causing chemicals; process conditions and operational aspects which initiate or propagate DMs and the interaction DMs which may have an influence on the FFS assessment

The course duration is 5 days. Engineers will be given a course completion certificate at the end of this course.

Course Outline:

1. Aspects related to Material Damage Mechanisms (DMs) – *an Overview*

- Common materials used in process equipment construction (C/Steel to Zirconium)
- Basic metallurgy of materials, effects of welding and heat treatment
- Equipment construction issues
- Effect of hydraulic test (new and in-service)
- Damage mechanism Failure Mode and its influence on Consequences of failure
- DMs importance in Risk Based Inspection (RBI) technology and its implementation
- DMs importance in Remaining Life calculations and Fitness-For-Service (FFS) assessments

2. Common damage causing chemicals & process conditions – *an Overview*

- Organic acids, salts, aldehydes and other organic compounds
- Inorganic acids, salts, alkalis and other inorganic compounds
- Other specific chemicals (e.g. H_2, H_2S, CO, CO_2, NH_3, Amines, Halides, etc)
- Cooling water aspects
- Temperature, pressure, two phase flow, flow rates & velocity, deposits
- Free water or moisture in some chemicals
- Fluctuating or cyclic loads (e.g. pressure, thermal, vibration)
- Externally damaging environment & related maintenance activities
- Effect of process revamp / operational changes & Management of Change

3. Nearly 70 Damage Mechanisms (DMs) are covered under Thinning types, Cracking types (surface & embedded) and Material Property damage types (surface and through thickness); for each DM, following are considered:

- DM description and common susceptible materials
- Key conditions which initiate damage
- Characteristics
- DM type – time dependent, time independent

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- Damage rate assessment considerations and techniques
- Damage susceptibility assessment considerations and techniques
- Initial construction integrity –relevance
- Key Factors that influence damage (↑ beneficial factors)
- Key Factors that influence damage (↓ detrimental factors)
- Special factors leading to increased sensitivity to the mechanism
- Where Found (general and specific locations)
- Areas for inspection – equipment based, Corrosion Loop based
- Areas for inspection – speculative inspection and inspection sampling
- Inspection Methods to match the DMs (types of NDT; effectiveness & capability)
- Monitoring (physical & operational monitoring)
- Mitigation (related to material, design, process, operating envelope, maintenance)
- Other preventative measures

4. Mandatory Aspects to consider for reliable identification of applicable DMs for the following equipment types:

- Vessels all types (e.g. reactors, crackers, converters, strippers, absorbers, drums, spheres, columns, reboilers, condensers, other heat exchangers, fired heaters, reformers, etc)
- Interconnected Piping between vessels ; All types of Storage Tanks
- Boiler Units (furnace tubes & headers, de-aerators, steam drum, downcomers, superheater tubes & headers, attemporators, economisers, feed water and steam piping, flue gas duct and chimney, etc)
- Desalination plant equipment items and piping
- Fluid Transporting Pipelines (outside plant battery fence)
- Industry Process Units covering Gas processing, Oil refining, Petrochemicals producing, Fertiliser manufacturing, Power Generation and Sea Water Desalination – General DMs considerations

5. Engineers Learning Tasks – identification of DMs via team based exercises; covering following equipment types:

- Vessel item – in new projects and operating facility
- Piping Corrosion Loop – in new projects and operating facility
- Storage Tank – in new projects and operating facility

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C. 'Living with Defects' - Fitness-For-Service (FFS) Assessment

When plant items are replaced or when repairs are carried out simply because of non-compliance with the original design code or the corrosion allowance has been used up, the cost implication to companies are enormous. The application of proven FFS technology is changing the way in which such decisions are made to optimize spend, whilst ensuring safety and reliability of the affected equipment.

Benefits to those attending:

This coaching imparts constructive knowledge of why, when and how to apply FFS assessment methodologies to a variety of equipment integrity related problems encountered in the oil and gas exploration; oil refining and gas processing; petrochemical, chemical and fertilizer manufacturing; power generation and sea water desalination industries.

The resulting skills are crucial for effective management of static equipment asset integrity via RBI and to get the best out of the RBI process.

Engineers attending this course will acquire the following required knowledge which supports the 5 strategic goals aimed for by plant sites.

Engineers attending this course will be able to:-

1. Gain a thorough understanding of the various types of equipment integrity and inspection interval affecting problems faced in industry due to material damage, equipment design code non-compliance, construction defects or operational aspects

2. Acquire a valuable appreciation of when to apply FFS technology to address these issues

3. Formulate the scope of root cause investigations which may be needed for an FFS assessment

4. Choose the appropriate FFS assessment method or combination of methods to solve a given problem

5. Acquire the essential knowledge needed to carry out and/or project manage an effective FFS assessment

6. Understand the results of the assessments to help make informed decisions, for example:
    - To 'run item as is' and at 'what optimum inspection interval'
    - To 'monitor defect' and at 'what optimum monitoring frequency'
    - To 'repair or replace' item and 'latest date it should be carried out'
    - To 'revise operating conditions' to match condition of item
    - To 'modify design' and/or 'upgrade material'

      or
    - A combination of any / all of the above

7. Learn:-
    - The importance of DMs knowledge for competently carrying out an FFS assessment
    - The important role FFS assessments and resulting decisions play in effective implementation of RBI and to get the best benefit out of RBI implementation

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The course duration is 5 days. Engineers will be given a course completion certificate at the end of this course.

Course Outline:

1. Basics of Fitness-For-Service (FFS) assessment – *an overview*

- Equipment design philosophy
- Design codes principles (ASME, API, British Standard BS 5500)
- Issues related to design code compliance for equipment in service
- What is FFS assessment and why this technology is used
- FFS assessment principles and codes such as API 579, BS 7910
- Scope of FFS application (equipment types)
- Design codes vs. FFS assessment codes
- FFS acceptance criteria – based on code
- FFS acceptance criteria – based on risk & consequences of failure *(PP SIMTECH technology)*
- FFS assessment benefits
- Importance of FFS assessment results in effective implementation of RBI
- Importance of applicable DMs knowledge in FFS assessments

2. FFS assessment considerations and assessment logic under following situations

- Presence of a flaw by thinning mechanism
- Presence of a flaw by cracking mechanism
- Material properties change and/or metallurgical damage
- Concerns on thinning beyond corrosion allowance
- Concerns on construction aspects not satisfying code requirements
- Concerns on not meeting current design standards or best practices
- Concerns on current operating conditions or fault scenarios
- Changes in operating conditions which are more onerous than current
- Operation under high temperature creep environment
- Operation under mechanical or thermal fatigue environment

3. FFS assessment scope and techniques for various types of damage and operating conditions

- Brittle Fracture and permissible low temperature and pressure conditions
- General Metal Loss and remaining life
- Localised Metal Loss and remaining life
- Pitting Corrosion and remaining life
- Fatigue Damage and remaining life under cyclic load service
- Creep Damage and remaining life under high temperature service

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- Crack-Like Flaws and remaining life
- Shell out-of-roundness, weld Misalignment, peaking at weld seams
- Stress Corrosion Cracking
- Hydrogen Blisters, HIC and SOHIC
- Laminations
- Dents/Gouges and remaining life
- Fire Damage and remaining life

4. FFS assessments aspects to consider under the following criteria

- Understanding the problem and defining what is required from the FFS assessment
- Plant operational issues covering normal operation, fault scenarios, start-up and shutdown conditions, which need to be considered to define scope of FFS assessment
- Active/Potential damage mechanisms and the scope of root cause investigations
- Choosing the appropriate FFS method(s); Defining expertise & data requirements
- Gathering data, Completing the assessment, Analysing results, Feeding to RBI study
- Making informed decisions and delivering solutions
- Documentation and Report contents

5. Engineers Learning Tasks – FFS assessments via team based exercises; covering a number of damage types and equipment items

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6. Failure and Root Cause Analysis: Guide and Techniques

A GUIDE TO INVESTIGATING MATERIAL AND COMPONENT FAILURE

The training module aims to integrate mechanical design, manufacturing processes, mechanical behaviour and microstructural analysis. In the interactive and modular course, the participants learn to determine the root causes of metallurgical failures. The participants are explained how to perform nondestructive, mechanical, metallurgical, and chemical tests by both portable and laboratory metallographic techniques. Optical and scanning electron micrographs and fractographs will be studied. The multi disciplinary nature of failure analysis benefits participants by integrating many subjects and requiring the use of modern equipments.

This training program provides an extensive analysis into the different types of material and component failures observed in industrial enterprises. Take this opportunity to also discuss solutions to manufacturing problems and get advice from the workshop leaders and your peers towards selecting the appropriate materials to improve overall product quality, reduce costs, and enhance customer satisfaction. You will also have time to discuss welding problems and hear solutions to improve the weld process.

In this workshop, you will address and resolve:

- Typical root cause metallurgical failure mechanisms
- Boiler, heat exchanger and pressure vessel failure
- Pipeline failure
- Lifting equipment and fastener failures
- Gear, shaft and weld failure analysis
- Root cause analysis through metallurgical approach
- Analysis procedure
- Preventing reoccurrence of the failure by in-situ metallography approach

By attending this training program, you will benefit by:

- Developing in-house solutions to your manufacturing problems
- Improving overall product quality through appropriate materials selection
- Quickly recognizing the different types of failure for particular units

The duration of this course is for 1 day and it is conducted by failure analysis experts from TCR Engineering. Students will be given a course completion certificate at the end of this course.

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7. Non Destructive Testing

A. Introduction to NDT for Plant Executives

This course introduces all NDT Methods. The course is designed for individuals who want to have basic knowledge about NDT. The course will include Demonstrations.

Topics covered in this course will include:

Material Processes 2 hours
Defects in Castings, forgings, drawing, machining

Visual Testing 6 hours
Welding processes
Weld defects, weld inspections
Visual inspection tools

Liquid Penetrant Testing 4 hours

Magnetic Particle Testing 4 hours

Ultrasonic Testing 8 hours
Thickness measurements
Crack detection

Radiography Testing 8 hours
Inspection process and interpretation

Eddy Current Testing 6 hours
Surface inspection
Tubing inspection

Personnel Certification 2 hours
SNT-TC-1A
CP-189

The duration of this course is for 5 days and it is conducted by NDT experts from TCR Engineering. Students will be given a course completion certificate at the end of this course.

B. Ultrasonic Testing – Level I

This course introduces the basic principles of ultrasonics and prepares the candidate for Thickness Measurement and other 0-degree inspections. (See Level II Course Outline for Angle Beam Testing)

This course prepares a candidate to

- Perform Specific Calibrations
- Specific NDT
- Specific Evaluations for Accept or Reject Determinations according to written Instructions
- Record Results

TRAINING

Training Material is presented in Module that are followed by Quizzes

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CERTIFICATION MODULE

Personnel Certification: ASNT SNT-TC-1A. Candidates must score a minimum of 70 % in each test and a minimum of 80% average for all the three tests.

MODULE 1: MANUFACTURING DISCONTINUITIES

- Types of Discontinuities: – Inherent, Processing and Service
- Casting Discontinuities: - Hot Tear, Cold Shut, Porosity, Shrinkage
- Primary Processing Discontinuities including discontinuities in Rolling, Forging, Drawing, Extruding
- Secondary Processing Discontinuities including discontinuities in Grinding, Heat Treating, Machining, Welding, Plating
- Service Discontinuities:- Erosion, Wear, Fatigue, Corrosion, Creep, Hydrogen Attack

MODULE 2: WAVE MODES
- Time Period and Frequency
- Wavelength
- Wave Modes including Longitudinal, Shear, Surface and Lamb Waves
- Velocity of Waves
- Calculation of Velocity
- Factors Affecting Velocity - Temperature, Stress
- Laboratory Measurement of Velocity

MODULE 3: ACOUSTIC IMPEDANCE
- Acoustic Impedance
- Calculation of Acoustic Impedance
- Reflection and Transmission Coefficients
- Transmission through a layer

MODULE 4: REFRACTION AND REFLECTION (Covered in Level I and II training)
- Reflection and Refraction
- Snell's Law
- Mode Conversion
- First and Second Critical Angle
- Creeping Waves
- Problems on Mode Conversion

MODULE 5: PIEZOELECTRIC TRANSDUCER
- Wave Interference: Constructive and Destructive
- Sound Field
- Near Field
- Far Field
- Beam Spread
- Problems on Near Field and Beam Spread
- Laboratory measurement of Beam Spread
- Principles of Piezoelectricity
- Curie Temperature
- Transducer damping
- Bandwidth
- Type of Transducers
- Contact and Immersion Transducers
- Dual Element, Delay Line, Angle Beam Transducer
- Couplant

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MODULE 6: PULSER RECEIVER
- Ultrasonic Instrumentation - Analog
- Ultrasonic Instrumentation - Digital
- Time Base
- Pulse Repetition Rate
- Types of Ultrasonic Display – A, B and C Scan
- Gates
- Calibration of Ultrasonic Equipment - Time and Amplitude Linearity (Level II)

MODULE 7: ATTENUATION
- Sound Attenuation
- Causes for Attenuation
- Attenuation Measurement
- Calculation of Amplification
- Laboratory - Measurement of Attenuation

MODULE 8: THICKNESS MEASUREMENT
- Test Modes
- Thickness Measurement
- Thickness Measurement Frequency
- Screen Calibration
- Problems
- Laboratory - Thickness measurement, Corrosion Mapping

MODULE 9: IMMERSION TESTING
- Advantages and Limitations of Immersion Testing
- Technique
- Minimum Water Path calculation
- Types of Immersion Testing Transducers
- Bubbler/Squirter Technique
- Wheel Type Transducer

MODULE 10: FLAW DETECTION - 0 DEGREE
- Lamination, Corrosion Mapping, Base Metal defects, Bolts
- Laboratory scanning on lamination and forged sample as per SA-578 and SA-388

PRACTICALS
- Velocity measurement
- Thickness Measurement
- Thickness Scanning
- Plates
- Tubes
- Corroded samples
- Bolt Inspection
- Laminated Plates

EXAMINATIONS
General
Specific and Practical

The duration of this course is for 5 days and it is conducted by NDT experts from TCR Engineering. Students will be given an ASNT Level I certificate at the end of this course.

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C. Ultrasonic Testing – Level II

Prerequisite for this Class is Level I Ultrasonics

SCOPE

This course introduces the basic principles of ultrasonics and prepares the candidate for Angle Beam Inspections.

This course prepares a candidate to
- Perform Specific Calibrations
- Specific NDT
- Interpretation of Codes
- Evaluations for Accept or Reject Determinations according to written Instructions
- Record Results

TRAINING
Training Material is presented in Module that are followed by Quizzes

CERTIFICATION MODULE (Covered in Level I Training)

MODULE 1: MANUFACTURING DISCONTINUITIES (Covered in Level I Training)

MODULE 2: WAVE MODES (Covered in Level I Training)

MODULE 3: ACOUSTIC IMPEDANCE (Covered in Level I Training)

MODULE 4: REFRACTION AND REFLECTION (Covered in Level I and II)
- Reflection and Refraction
- Snell's Law
- Mode Conversion
- First and Second Critical Angle
- Creeping Waves
- Problems on Mode Conversion

MODULE 5: PIEZOELECTRIC TRANSDUCER (Covered in Level I Training)

MODULE 6: PULSER RECEIVER
- Calibration of Ultrasonic Equipment - Time and Amplitude Linearity
- All other Topics Covered in Level I Training

MODULE 7: ATTENUATION (Covered in Level I Training)

MODULE 8: THICKNESS MEASUREMENT (Covered in Level I Training)

MODULE 9: IMMERSION TESTING (Covered in Level I Training)

MODULE 10: FLAW DETECTION - 0 DEGREE (Covered in Level I Training)

MODULE 11: CALIBRATION BLOCKS
- IIW Block Type I
- IIW Block Type II
- Miniature Angle Beam / Rompass Block
- DSC Block
- AWS Resolution Block
- Step Wedge
- Area- Amplitude Block
- Distance- Amplitude Block

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MODULE 12: ANGLE BEAM INSPECTION
- Selection of Screen Range
- Measurement of Beam Exit Point
- Measurement of Actual Refracted Angle
- Calibration using IIW, Rompass and DSC Block
- Sensitivity and Resolution
- Reference Amplitude
- Distance Amplitude Correction Curve
- Distance Gain Size
- Discontinuity Length Sizing using 6 dB and 20 dB drop method
- Discontinuity Evaluation
- Angle Selection
- Surface Distance, Skip Distance, Depth, Full V Path
- Plotting of Discontinuities like Crack, Lack of Fusion, Lack of Penetration, Slag, Porosity in welds
- Worksheet: Plotting of discontinuities for butt welds

MODULE 13: WRITING AN ULTRASONIC PROCEDURE
- ASME Section V
- Essential Variables
- Non Essential Variables

MODULE 14: CODES AND STANDARDS
- ASME Section V, Article 4, 2004 Edition
- ASME Section VIII

Additional Codes Standards as per student's requirements (please discuss this at the time of registration)

INTRODUCTION TO ADVANCED TECHNIQUES
Time of Flight Diffraction
Phased Arrays

PRACTICALS
Shear Wave Testing on API Pipe Samples with Weld defects – ID Cracks, OD Cracks, Slag, Porosity, Lack of Fusion, and Lack of Penetration

EXAMINATIONS
General
Specific
Practical
Candidates must score a minimum of 70 % in each test and a minimum of 80% average for all the three tests.

The duration of this course is for 5 days and it is conducted by NDT experts from TCR Engineering. Students will be given an ASNT Level II certificate at the end of this course.

D. Magnetic Particle Testing – Level I and Level II

SCOPE
This course covers the principles of Magnetic Particle Testing and prepares a candidate to
- Setup and calibrate equipment
- Interpret and Evaluate Results with respect to Applicable Codes, Standards and Specifications
- Familiar with the scope and limitations of the Methods
- Write test reports.

TRAINING
Training Material is presented in Module that are followed by Quizzes

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GENERAL TRAINING
Personnel Certification: ASNT SNT-TC-1A

MODULE 1: MANUFACTURING DISCONTINUITIES
- Types of Discontinuities: Inherent, Processing and Service
- Casting Discontinuities: Hot Tear, Cold Shut, Porosity, Shrinkage
- Primary Processing Discontinuities including discontinuities in Rolling, Forging, Drawing, Extruding
- Secondary Processing Discontinuities including discontinuities in Grinding, Heat Treating, Machining, Welding, Plating
- Service Discontinuities: Erosion, Wear, Fatigue, Corrosion, Creep, Hydrogen Attack

MODULE 2: THEORY OF MAGNETISM
- Magnetic field, Lines of force, Flux density
- Definitions of Permeability, Reluctance, Retentivity, Residual Magnetism and Coercive Force
- Diamagnetic, Paramagnetic and Ferromagnetic materials
- Leakage flux
- Fleming's Right Hand and Left Hand Rule
- Types of Magnetic Fields: Circular, Longitudinal, Vector
- Hysteresis Curve

MODULE 3: METHODS OF MAGNETIZATION
- Magnetization By Means of Electric Current
- Types of current AC, HWDC
- Circular field: Head Shot (Direct Contact), Prods and Central Conductor Techniques, Offset Central Conductor
- Advantages and disadvantages of circular field
- Longitudinal field: Coils and Yoke
- Advantages and disadvantages of Longitudinal Field
- AC and DC Field Distribution in a Magnetic and a Nonmagnetic Conductor
- Demagnetization

MODULE 4: EQUIPMENT
- Equipment consideration
- Wet Horizontal, Mobile and Portable Equipments
- Fluorescent testing, Black Light
- Accessories

MODLULE 5: MEDIUMS AND THEIR PREPARATION
- Dry and Wet method
- Particles: Dry and Wet
- Properties of particles
- Visibility of particles
- Methods of Application
- Contamination of Magnetic Particles
- Settling Test Procedure
- Concentration for Wet suspensions as per ASME Sec V Article 7
- Bath Maintenance

MODLULE 6: APPLICATIONS
- Residual and Continuous Method
- Magnetic Particle Inspection of Solid Cylindrical Parts, Gears, Multiple diameter Articles, Discs, Hollow Cylindrical Articles
- Selection of proper method of magnetization
- Verification of magnetic fields
- Checking the adequacy of field using the Pie gauge, shims
- Magnetic Rubber Inspection

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MODULE 7: TYPES OF INDICATIONS
- Interpretation including Relevant, False, Non-relevant indications

MODULE 8: Codes and Standards (SPECIFIC TRAINING)
- MT Inspection Procedures

Codes
- ASME Section V Article 7 2004
- ASME Section VIII (Accept/Reject Criteria)
- ASME B 31.1 – Power Piping
- ASME B 31.3 – Petrochemical Piping

Standards
- ASTM E-709
- ASTM E-1444

Other codes and standards can be discussed if prearranged with the instructor at the time of registration

PRACTICAL TRAINING
- MT Yoke: Dry Visible, Wet Visible, Wet Fluorescent
- Central Conductor
- Coil Shot - Longitudinal
- Ketos (Betz) Ring – Depth of penetration
- Training on Weld defect samples

EXAMINATIONS
- General
- Specific
- Practical

Candidates must score a minimum of 70 % in each individual test and a minimum average of 80% in all three tests.

The duration of this course is for 3 days and it is conducted by NDT experts from TCR Engineering. Students will be given an ASNT Level II certificate at the end of this course.

E. Liquid/Dye Penetrant Testing – Level I and Level II

SCOPE
This course covers the principles of Liquid Penetrant Testing and prepares a candidate to
- Setup and calibrate equipment
- Interpret and Evaluate Results with respect to Applicable Codes, Standards and Specifications
- Familiar with the scope and limitations of the Methods
- Write test reports.

TRAINING
Training Material is presented in Module that are followed by Quizzes

GENERAL TRAINING
Personnel Certification: ASNT SNT-TC-1A

MODULE 1: MANUFACTURING DISCONTINUITIES
- Types of Discontinuities: Inherent, Processing and Service
- Casting Discontinuities: Hot Tear, Cold Shut, Porosity, Shrinkage
- Primary Processing Discontinuities including discontinuities in Rolling, Forging, Drawing, Extruding

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• Secondary Processing Discontinuities including discontinuities in Grinding, Heat Treating, Machining, Welding, Plating
• Service Discontinuities:- Erosion, Wear, Fatigue, Corrosion, Creep, Hydrogen Attack

MODULE 2: PRINCIPLES
• Purpose of Liquid Penetrant Testing
• Physical Principles
• Wetting Characteristics and Contact Angle
• Wetting Ability
• Force of Cohesion and Surface Tension
• Capillary Action
• Viscosity
• Application of Penetrant: Dwell Time
• Reversed Capillary Action
• Visibility of Indication
• Categories of Test Processes
• Types of Dye: Type I and Type II
• Methods of Removal of excess Penetrant including Water Washable, Emulsifiers and Solvent Removable
• Sensitivity Levels – ½, 1, 2, 3, 4
• Selection of Process
• Limitations of Penetrant Testing

MODULE 3: BASIC STEPS
This module covers the basic steps involved in the following processes
• Method A – Water Washable
• Method B – Lipophilic Emulsifier
• Method C – Solvent Removable
• Method D – Hydrophilic Emulsifier

MODULE 4: PRE AND POST CLEANING
• Choice of Cleaning Method
• Different Cleaning Methods including Detergent, Solvent, Alkaline, Steam, Ultrasonic cleaning, Vapor Degreasing

MODULE 5: APPLICATION OF PENETRANTS AND DEVELOPERS
• Different ways of applying penetrants
• Standard Temperature Limits
• Dwell time
• Drying
• Drying Parameters
• Drying Time Limits
• Application of Developers
• Types of Developers
• Developing Time
• Fluorescent Inspection
• Black Light, Black Light Warm Up Time,
• Visual Adaptation
• Post Cleaning

MODULE 6: INTERPRETATION
• Interpretation of Test Results
• Flow Chart for Interpretation
• Types of Indications like True, False, Relevant and Non Relevant indications
• Categories of Indications: - Rounded and Linear
• Evaluation of Indications
• ASTM E-433 Reference Photographs of Indications types

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MODULE 7: CODES & STANDARDS (SPECIFIC TRAINING)
Codes
• ASME Section V, Article 6
• ASME Section VIII, Appendix 8 (Accept/Reject Criteria)

Standards
• ASTM E-165
• ASTM E –1417
• Other codes and standards can be discussed at the request of the students. Please make such requests at time of registration

PRACTICAL TRAINING

Visible
• Solvent Removable

Fluorescent
• Water Washable
• Solvent Removable
• Emulsifier both Hydrophilic and Lipophilic

Tests on Weld samples

EXAMINATIONS
• General
• Specific
• Practical Tests
Candidates must score a minimum of 70 % in each test and a minimum of 80% average for all the three tests.

The duration of this course is for 3 days and it is conducted by NDT experts from TCR Engineering. Students will be given an ASNT Level II certificate at the end of this course.

F. Visual Testing – Level II

SCOPE
This in-depth course prepares a candidate to conduct Visual Examinations.

This course prepares a candidate to
• Setup and calibrate equipment
• Interpret and Evaluate Results with respect to Applicable Codes, Standards and Specifications
• Familiar with the scope and limitations of the Methods and ability to write test reports

GENERAL TRAINING

1. Introduction:-
• Definition of visual testing.
• History of visual testing applications.
• Overview of visual testing applications.

2. Definitions :-

• Standard terms and their meanings in the employer's industry.

3. Fundamentals:-

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- Vision
- Lighting
- Materials attributes
- Environmental factors
- Visual perception
- Direct and indirect methods

4. Equipments (as applicable)
- Mirrors
- Magnifier
- Borescopes
- Fiberscopes
- Closed-circuit television
- Light sources and special lighting
- Gages, templates, scales, micrometers, calipers, special tools, etc.
- Automated System
- Computer-enhanced systems

5. Manufacturing Processes
- Inherent and Processing Discontinuities
- Casting and its defects
- Forging, rolling, drawing and defects
- Surface Texture

6. In-Service Defects
- Fatigue
- Corrosion
- Wear

7. Welding
- Expectations of a weld
- Welding terms
- Welding processes: SMAW, GTAW, GMAW, & FCAW
- Welding codes: ASME, AWS, API and NBIC
- Welding filler materials (F and A numbers)
- Base materials (P numbers)
- Weld nomenclature (parts of a weld)
- Welding joints
- Welding symbols
- Welding defects: Their causes, detection, repairs, and prevention
- Inspection acceptance criteria: ASME and AWS
- What is the purpose of a visual welding inspector ?
- Weld inspection tools: Fillet welds gage, high-low gage, stud weld test gage, etc.
- Heat treatments
- Pumps and Valves
- Bolting

8. Employer-Defined Application

(Includes a description of inherent, processing and service discontinuities)
- Materials-based materials
- Metallic materials, including welds.
- Organic-based materials
- Other materials (employer-defined)

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9. Visual Testing to specific procedures

- Selection of parameters
  1) Inspection objectives
  2) Inspection checkpoints
  3) Sampling plans
  4) Inspection patterns
  5) Documented procedures
     - Test standards/calibrations
     - Classification of indications per acceptance criteria
     - Reports and documentation.

10. Vision

- The eye
- Vision Limitations
- Disorders
- Employer's vision examination methods

11. Lighting

- Fundamentals of light
- Lighting measurements
- Recommended lighting levels
- Lighting techniques for inspection

12. Materials Attributes

- Cleanliness
- Color
- Condition
- Shape
- Size
- Temperature
- Texture
- Type

13. Environmental and Physiological Factors :-

- Atmosphere
- Cleanliness
- Comfort
- Distance
- Elevation
- Fatigue
- Health
- Humidity
- Mental attitude
- Position
- Safety
- Temperature

14. Visual Perception

- What your eyes see
- What your mind sees
- What others perceive
- What the designer, engineer, etc. wants you to see

15. Equipments

- Automated systems
- Borescopes

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- Close-circuit television
- Computer based systems
- Fiberscopes
- Gages, micrometers, calipers, templates, scales, etc.
- Imaging systems
- Light sources and special lighting.
- Magnifiers
- Mirrors
- Special optical systems
- Standard lighting

16. Employee-Defined Application
- Mineral-based material
- Metallic materials(including welds)
- Organic-based materials
- Other materials and products(employer defined)

17. Acceptance/Rejection Criteria
- Subjective basis (qualitative)
- Objective basis (quantitative)
- Evaluation of results per acceptance criteria.

18. Recording and Reports
- Subjective methods
- Objective methods
- Recording methods

SPECIFIC TRAINING
Visual Inspection Codes
- AWS D1.1 (steel), D1.2 (Aluminum)
- ASME Section I, V, VIII, 31.1, 31.3

PRACTICAL TRAINING
Evaluate defects in Weld Samples

EXAMINATIONS
- General
- Specific
- Practical

Candidates must score a minimum of 70 % in each test and a minimum of 80% average for all the three tests.

The duration of this course is for 3 days and it is conducted by NDT experts from TCR Engineering. Students will be given an ASNT Level II certificate at the end of this course.

G. Radiography Testing – Level II

COURSE OUTLINE

1. Review of Basic Radiographic Principles
- Interaction of radiation with matter.
- Math review
- Exposure calculations
- Geometric exposure principles
- Radiographic-image quality parameters

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2. Darkroom Facilities, Techniques, and processing

- Facilities and equipments
  1) Automatic film processor vs manual processing
  2) Safe lights
  3) Viewer lights
  4) Loading lights
  5) Miscellaneous equipments

- Film loading
  1) General rule for handling unprocessed film.
  2) Types of film packaging
  3) Cassette-loading techniques for sheet and roll

- Protection of radiographic film in storage.

- Processing of film – manual
  1) Developer and replenishment
  2) Stop Bath
  3) Fixer and replenishment
  4) Washing
  5) Prevention of water spots
  6) Drying

- Automatic film processing

- Film filing and storage
  1) Retentio0n-life measurements
  2) Long term storage
  3) Filing and separation techniques

- Unsatisfactory Radiographs :-causes and cures
  1) High film density
  2) Insufficient film density
  3) High contrast
  4) Low contrast
  5) Poor identification
  6) Fog
  7) Light leaks
  8) Artifacts

- Film density
  1) Step-wedge comparison film
  2) Densitometers

3. Indications, discontinuities, and defects

- Indications
- Discontinuities
  1) Inherent
  2) Processing
  3) Service
- Defects

4. Manufacturing Processes and Associated Discontinuities

- Casting processes and associated discontinuities
  1) Ingots, blooms, and billets
  2) Sand casting

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3) Centrifugal casting
4) Investment casting

- Wrought processes and associated discontinuities
  1) Forgings
  2) Rolled products
  3) Extruded products

- Welding processes and associated discontinuities
  1) Submerge arc welding (SAW)
  2) Shielded metal arc welding (SMAW)
  3) Gas metal arc welding (GMAW)
  4) Flux corded arc welding(FCAW)
  5) Gas tungsten arc welding(GTAW)
  6) Resistance welding
  7) Special welding processes-electron beam, electro slag, electro gas, etc.

5. Radiological safety principles Review

- Controlling personal exposure
- Time, distance, shielding concepts
- ALARA (as low as reasonably achievable) concepts
- Radiation-detection equipments.
- Exposure device operating characteristics

6. Radiographic Viewing

- Film illuminator requirements
- Background Lighting
- Multiple-Composite viewing
- Penetrameter placement
- Film identification
- Location markers
- Film density measurements
- Film artifacts

7. Application Techniques

- Multiple film techniques
  1) Thickness-variation parameters
  2) Film speed
  3) Film latitude
- Enlargement and projection
- Geometrical relationships
  1) Geometrical unsharpness
  2) Penetrameter sensitivity
  3) Source -to -film distance
  4) Focal-spot size
- Triangular methods for discontinuity location
- Localized magnification
- Film handling techniques

8. Evaluation of castings

- Casting-methods review
- Casting discontinuities
- Origin and typical orientation of discontinuities
- Radiographic appearance
- Welding codes/standards- applicable acceptance criteria
- Reference radiographs or pictograms

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9. Evaluation of weldments
- Welding-method review
- Welding discontinuities
- Origin and typical orientation of discontinuities
- Radiographic appearance
- Welding codes/standards-applicable acceptance criteria
- Reference radiographs or pictograms

10. Standards, codes and Procedures for Radiography
- ASTM E94/E142
- Acceptable radiographic techniques and setups
- Applicable employer procedures
- Procedure for radiograph parameter verification
- Radiographic reports.

The duration of this course is for 5 days and it is conducted by NDT experts from TCR Engineering. Students will be given an ASNT Level II certificate at the end of this course.

H. Eddy Current Testing – Level I

SCOPE

This course prepares a candidate to Perform Surface Eddy Current Inspection and
- Perform Specific Calibrations
- Specific NDT
- Specific Evaluations for Accept or Reject Determinations according to written Instructions
- Record Results

TRAINING

GENERAL TRAINING

Electrical Parameters
- Resistance
- Inductance
- Impedance

Electromagnetism
- Faraday's Law
- Lenz's Law

Eddy Current Theory
- Generation of Eddy Currents
- Impedance changes by Eddy Currents
- Effect of change of impedance on instrumentation

Impedance Curves
- Conductivity Curve
- Lift Off Curve
- Permeability

Types of Eddy Current Sensing Elements
- Probes
    - Absolute
    - Differential
- Lift-off
- Theory of operation

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Materials
- Inspection of Non-Ferromagnetic Materials
- Inspection of Ferromagnetic Materials

Special Probes
- Lift Off Insensitive
- Fastener Probes- Ring Probe

Calibration Standards
- Conductivity Standards
- EDM notch Surface Standards

Applications
- Surface Inspection
- Inspection of Airframes
- Airframe Fastener Inspection
- Turbine Blade Inspection
- Inspection of Petrochemical Piping
- Surface Weld Inspection

SPECIFIC TRAINING
Surface ECT Procedure
ASME Section V

PRACTICAL TRAINING
Setting up the Instrument
Selection of Frequency
Calibrations
Test on Various Samples
Prepare test Report

EXAMINATIONS
- General
- Specific
- Practical Tests

Candidates must score a minimum of 70% in each test and a minimum of 80% average for all the three tests.

The duration of this course is for 5 days and it is conducted by NDT experts from TCR Engineering. Students will be given an ASNT Level I certificate at the end of this course.

I. Eddy Current Testing – Level II

SCOPE
This course covers ECT probes, ECT Instrumentation and prepares an inspector to perform Tubing Inspections

This course prepares a candidate to
- Setup and calibrate equipment
- Interpret and Evaluate Results with respect to Applicable Codes, Standards and Specifications
- Familiar with the scope and limitations of the Methods
- Write test reports

TRAINING
GENERAL TRAINING

Electromagnetic Theory

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- Eddy Current Theory
- Types of Eddy Current sensing probes

Factors that affect Coil Impedance
- Test part
- Conductivity
- Permeability
- Thickness

Test system
- Frequency
- Coupling
- Field strength
- Test coil and shape

Probes Design
- Surface Inspection Probes
- Tube Inspection Probes

Non Ferromagnetic Tubing Inspection- Conventional ECT
- ASME Calibration Standard
- Bobbin Probe
- Differential and Absolute Inspection
- Selection of Probe Size
- Selection of ECT frequency
- Depth Curves
- Sizing if defects

Ferromagnetic Tubing Inspection- Remote Field ECT
- RFECT Theory
- Probes
- Selection of Probe Size
- Selection of Probe Frequency
- Impedance Plane Analysis

ECT Instruments
- Minimum requirements for Surface Inspection
- Portable Instrumentation
- Minimum requirements for Tubing Inspection
- Computer Controlled Instrumentation
- Sampling Rate and Pull Speed

SPECIFIC TRAINING

Codes and Standards
- ASME Section V
- ASTM Standards

PRACTICAL TRAINING

Setting up the Instrument
Selection of Frequencies for Tube Inspection
Selection of Probe Size
Calibrations
Depth Curve
Data Acquisition
Test on Various Samples
Prepare test Report

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EXAMINATIONS
• General
• Specific
• Practical Tests
Candidates must score a minimum of 70% in each test and a minimum of 80% average for all the three tests.

The duration of this course is for 5 days and it is conducted by NDT experts from TCR Engineering. Students will be given an ASNT Level II certificate at the end of this course.

J. Thermography – Level I

The Level I Infrared Thermography Training Course, taught by internationally known Level III in Thermography is geared to the new infrared camera user and focuses on its use for a variety of condition monitoring/predictive maintenance applications.

- Introduction to thermal imaging and measurement systems for predictive maintenance applications.

- Collect quality data, accurate temperature readings, and account for measurement effects such as distance and emissivity using infrared cameras.

- Interpret thermograms and make informed decisions using heat transfer concepts to analyze thermal images, and see the latest in infrared inspection report generation and database software.

- Avoid costly mistakes - learn to distinguish between hot spots and reflections, direct vs. indirect readings and qualitative vs. quantitative thermography.

- Field applications that simulate real-world infrared applications.

- Successful Level I Thermography Training course completion provides Level I Thermographer Certification. TCR's Level I Infrared Course meets all Level I ASNT-SNT-TC-1A recommendations for thermal/infrared testing, as established by the American Society for Non-Destructive Testing (ASNT).

Recommended Training for Level I Thermal/Infrared Testing: Basic Thermal/Infrared Physics Course

1.0 The nature of heat-what is it and how is it measured/expressed?
1.1 Instrumentation
1.2 Scales and conversions

2.0 Temperature –what is it and how is it measured/expressed?
2.1 Instrumentation
2.2 Scales and conversions

3.0 Heat Transfer Modes Familiarization
3.1 Heat conduction fundamentals
3.1.1 Fourier’s law of heat conduction (concept)
3.1.2 Conductivity/resistance basis
3.2 Heat convection fundamentals
3.2.1 Newton’s law of cooling (concept)
3.2.2 Film coefficient/film resistance basics
3.3 Heat radiation fundamentals
3.3.1 Stefan-Boltzmann law (concept)
3.3.2 Emissivity/obsorptivity/reflectivity/transmissivity basis (Kirchhoff’s ;aw)

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4.0 Radiosity Concepts Familiarization
4.1 Reflectivity
4.2 Transmissivity
4.3 Absorptivity
4.4 Emissivity
4.5 Infrared radiometry and imaging
4.6 Spatial resolution concepts
4.6.1 Field of view (FOV)
4.6.2 Instantaneous field of view (IFOV) – ref. ASTM E-1149
4.6.3 Spatial resolution for temperature measurement – the Split Resonance Function (SRF)
4.6.4 Measurement Instantaneous Field of View (MIFOV)
4.7 Error potential in radiant measurements (an overview)

Basic Thermal/Infrared Operating Course

1.0 Introduction
1.1 Thermography defined
1.2 How infrared imagers work
1.3 Differences among imagers and alternative equipment
1.4 Operation of infrared thermal imager
1.4.1 Selecting the best perceptive
1.4.2 Image area and lens selection for required details
1.4.3 Optimizing the image
1.4.4 Basic temperature measurement
1.4.5 Basic emissivity measurement
1.5 Operation of support equipment for infrared surveys

2.0 Checking Equipment Calibration with Blackbody References

3.0 Infrared Image and Documentation Quality
3.1 Elements of a good infrared image
3.1.1 Clarity (focus)
3.1.2 Dynamic range of the image
3.1.3 Recognizing and dealing with reflections
3.1.4 Recognizing and dealing with spurious convection
3.2 Recording
3.2.1 Video tape
3.2.2 Photographic images
3.2.3 Video photo cameras
3.2.4 Digital recording
3.2.5 Videoprinters

4.0 Support Data Collection
4.1 Environmental data
4.2 Emissivity
4.2.1 Measurement
4.2.2 Estimation
4.2.3 Surface modification
4.3 Surface reference temperature
4.4 Identification and other

Basic Thermal/Infrared Applications Course

1.0 Detecting Thermal Anomalies Resulting from Differences in Thermal Resistance (Quasi-steady-state Heat Flow)
1.1 Large surface-to-ambient temperature difference

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1.2 Small surface-to-ambient temperature difference

2.0 Detecting Thermal/Anomalies Resulting from Differences in Thermal Capacitance, Using System of Environmental Heat Cycles

3.0 Detecting Thermal Anomalies Resulting from Differences in Physical State

4.0 Detecting Thermal Anomalies Resulting from Fluid Flow Problems

5.0 Detecting Thermal Anomalies Resulting from Friction

6.0 Detecting Thermal Anomalies Resulting from Nonhomogeneous Exothermic or Endothermic Conditions

7.0 Field Quantification of Point Temperatures
7.1 Simple techniques for emissivity
7.2 Typical (high emissivity) applications
7.3 Special problem of low emissivity applications

The duration of this course is for 5 days and it is conducted by NDT experts from TCR Engineering. Students will be given an ASNT Level I certificate at the end of this course.

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8. Welding Courses

A. Gas Tungsten Arc Welding for Qualified Welder (TIG, 6G)

The GTAW course will include;

- GTAW process operation and safety
- Auxilliary equipment and systems
- Filler materials
- Weld joints and weld types
- Manual welding techniques
- Welding procedures for manual welding steel and steel alloys
- Welding procedures for manual welding pipe
- Checking your welds
- Quality control inspection
- Weld repair
- Qualification and certification

B. Shield Metal Arc Welding (SMAW) for Qualified Welder

The SMAW course will include:

- SMAW process operation and safety
- Auxilliary equipment and systems
- Electrode materials
- Weld joints and weld types
- Manual welding techniques
- Welding procedure for manual welding steel and steel alloys
- Welding procedure for manual welding pipe
- Checking your welds
- Quality control inspection
- Weld repair
- Qualification and certification

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9. Excellent Training Resources

We are dedicated to the belief that people are our most important asset. Whatever the nature of the challenge, whether meeting the quality assurance needs of corporations or the simplest NDT education on hand, it is our passionate, committed and empowered people who ultimately make the difference. Trust is at the core of all ethical business dealings. Trust that others will do as they say and trust that we will live up to our commitments.

One key to building trust is being transparent in the way we communicate with others, and by providing timely and accurate information. TCR's diverse and experienced professionals and educators work together toward a common goal of excellence in every aspect of the business.

A. V.K. Bafna, Director, TCR Engineering

Mr. V.K. Bafna is the Founder and Managing Director of TCR Engineering Services, Mumbai, India, a partner at TCR Advanced Engineering Services in Baroda, India and a JV partner of TCR Kuwait, TCR Engineering and TCR Malaysia.

Mr. Bafna started TCR Engineering Services in 1973 and successfully led the company with outstanding year after year financial results. A visionary with sound material sciences experience, strong business acumen and relentless sincerity, he is the father of this organization and the key management executive to mould and mature the organization. With clear sense of purpose and urgency, realizing the need of the industry TCR became India's reliable and leading ISO 17025 accredited materials testing & contract research firm.

Through hard work, dedication, integrity and love for his field, Mr. Bafna gained 35 years of practical experience in the areas of corrosion detection, chemical analysis, mechanical testing, failure analysis and materials characterization. He has introduced innovative methods for Corrosion Studies, Non Destructive Testing and is a pioneer in showcasing the advantages of XRF-based positive material identification to the industry.

With strong domestic and international management experience driving market share, revenue, profit growth coupled with specialized material sciences knowledge, Mr. Bafna´s leadership has resulted in exceptional annual growth rates. Under his direction, TCR continues to build a seasoned management team and organically expand across multiple geographies, verticals, and practice lines. TCR today has two test laboratories in Mumbai - India, a state-of-the-art laboratory in Baroda – India, labs in Middle Easat in Kuwait and Saudi Engineering and Sales/Representative Offices in Maryland, USA and Malaysia. His superior strategic aptitude has widened the horizons of TCR to include RoHS, RBI, Inspection Services, Material Sciences Training Institute and Resource Outsourcing.

Building a customer base of Fortune 1000 companies with trusted leadership and advice, Mr. Bafna has developed and defined a new approach to the material testing, research and inspection services delivery model that increases the speed and efficiency while maintaining the high quality standards of the laboratory.

Mr. Bafna, is a gold medalist from the University of Indore and has two masters degrees to his credit. He has done Master of Engineering from the University of Toronto, Canada and Master of Industrial Management from the Clarkson College of Technology, Potsdam, New York.

V.K. Bafna is a member of various professional organizations such as American Society for Testing and Materials, Institute of Standard Engineers, ASM International, NACE, Non Destructive Testing Society of India, and Indian Institute of Metals. He is an ex-committee member of ASM India chapter.

Mr. Bafna's vast expertise in the field of laboratory testing has brought numerous laurels to TCR notable amongst them is an award of appreciation from the Indian Space Research Organization (ISRO) for the company's contribution to the Project ASLV. He has conducted workshop on "Value Driven Maintenance and Reliability for Process Industries" at International Quality and Productivity Center (IQPC) at Abu Dhabi, UAE in Sept. 2006 as

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well as conducted a seminar on "World Class Laboratory Management" at the Asia-Pac Conference, Mumbai, India in June 2006.

B. Paresh Haribhakti, Director & Chief Failure Analyst, TCR Engineering

Mr. Paresh Haribhakti is the Managing Director of TCR Advanced Engineering Services in Baroda, India (a TCR Engineering Services partner company).

With more than 250 failure investigation cases of power plants, fertilizers, chemicals and petrochemicals industries, Mr. Haribhakti has intensive work experience to his credentials. He has solved materials engineering problems and performed failure analysis on components from petrochemical plants, oil and gas transmission pipelines, offshore structures, ships, pharmaceutical plants, food processing equipment, gas turbine engine components, and weldments.

Mr. Haribhakti investigates the available physical evidence, and performs the necessary tests to develop the most probable accident scenario. He simplifies complex engineering theory into easy to understand and useable concepts. He uses simple analogies, every day examples, and laymen terms to explain data and findings so clients, corporate executives, government officials, or attorneys may easily understand engineering concepts.

Mr. Haribhakti has specific experience in welding, heat treating and materials technology for oil & gas drilling and production applications, including production tubing, casing and downhole motor failures. Recently, Mr. Haribhakti was lead member of the Failure Investigation team consulting to Asia's largest refinery, RIL-Jamnagar, India for damage assessment work during a fire incident in their VGO-HT2 Plant. He has provided damage assessment of Hydrocracker reactors at Baiji refinery Iraq and also helped a customer procure second hand equipment from Taiwan by a Health assessment approach.

He is skilled in the use and application of scanning electron microscopy (SEM) in support of failure analysis and fracture identification. Mr. Haribhakti also undertakes Optical metallography and interpretation of microstructures, Remaining Life Assessment, provides Heat treatment solutions and studies the degradation of microstructure under high temperature high pressure conditions. He has done extensive research in study of hydrogen embrittlement of steels and stainless steels.

Research oriented creativeness of Mr. Haribhakti spearheaded the development of a powerful image analysis software for Metallurgical use - the Microstructure Characterizer Software (MiC). He has also developed a well respected chemical composition mapping method for identification of dilution in weld zone. He performs color metallography to increase the capabilities of interpretation of microstructure. He has also developed custom electrolytic polishing for carbon and alloy steel material.

Mr. Haribhakti is a Founder member of Metallography Society of India. He is an active member of the Institute of Engineers, Institute of Foundry Man, Indian Institute of Metals and Indian Institute of Welding. Mr. Haribhakti is a B.E. (Metallurgy) and M.E. (Materials Technology) from M.S. University, Vadodara.

C. Mr. Ron Selva, Engineering Director, PP SIMTECH – a TCR Engineering partner company

Mr. Ron Selva has over 35 years of experience in design, construction, Damage Mechanisms inspection and integrity management of static equipment items of a plant. His credentials include:

Mr. Selva is the Engineering Director of PP SIMTECH Solutions Ltd, a TCR Engineering partner company, based in the UK and a founder member of the company in 1997. The company specializes in providing asset integrity managing technology services globally.

Under Mr. Selva's leadership PP SIMTECH is renowned for the development of a robust and innovative RBI technology process during the late nineties. This technology process is considered as "unparalleled in its application", in articles published by companies such as British Petroleum and GPIC (Bahrain), compared to any other RBI methods available in the market. This best practice technology process is also supported by a fully transparent and auditable rbiAsyst™ software system, which was jointly developed with British Petroleum in

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2001 and is fully owned by PP SIMTECH. In recent years, he has successfully developed a robust and practical methodology for linking Fitness-For-Service (FFS) assessment results into the RBI assessment process.

He has over 14 years experience in RBI implementation and facilitating RBI team studies, covering a variety of plants in oil, gas, petrochemical, fertilizer manufacturing & sea water desalination industries.

Mr. Selva has over 35 years of industry recognised experience in design, construction, Damage Mechanisms inspection, and risk based integrity management of static equipment items of a plant.

During the 1980's, he was responsible for the development of an innovative FFS assessment methodology and safety case arguments using fracture mechanics technology, which was used in the evaluation and verification of the long term integrity of nuclear reactor pressure vessels and other critical equipments in the primary pressure circuit. The safety case based on this principle was successfully presented to the UK Nuclear Installation Inspectorate and the Nuclear Safety Advisory Committee to the UK Parliament. Due to its success, the application of this methodology and the logic was later extended to cover other critical and high consequence equipment items in the refining, petrochemical and fertilizer industry. These procedures have been later incorporated into the UK and European Standards and Guidance related to Fitness-For-Service (FFS) and inspection interval assessments of equipment containing thinning damage or crack-like defects.

Mr. Selva successfully developed methods and carried out several high profile FFS and inspection assessments to resolve complex problems widespread across the industry relating to a variety of critical equipment items experiencing different types of damage. For example, NH3 storage tanks affected by SCC; large storage spheres in refineries affected by H2 damage; superheater headers subjected to creep/fatigue damage and reheat cracking; pressure swing absorbers affected by fatigue cracking; deaerators and industrial boilers subjected to corrosion fatigue; heavy wall reactors made of Hastelloy material affected by Inter Granular Corrosion and SCC.

In 2002, along with a team of senior metallurgists from PP SIMTECH and two multi-national refining and petrochemical client companies, he championed the development of susceptibility assessment models for nearly 70 Damage Mechanisms relating to oil & gas, petrochemical, fertilizer, power generation and sea water desalination industries for effective use in RBI implementation team studies and FFS assessments.

Mr. Selva is an active member of several British Standards Institute (BSI) Technical Committees responsible for the development of codes and standards: Since 1989 – involved in the development of FFS assessment codes PD 6493 and BS 7910, many of these procedures are now included in the FFS guidance API 579; from 1991 – involved in the development of the Pressure Vessel Design and Construction code BS 5500; since 1999 – involved in the development of the High Temperature Creep Assessment guidance. Additionally, he is credited for his substantial contribution to the development of the European Guidelines for NH3 storage tanks inspection intervals assessment, using RBI and FFS technologies.

He has several years experience of delivering training in static equipment Design, FFS, RBI and DMs to inspection & design engineers and RBI study team members from various engineering disciplines.

Due to global recognition of his knowledge in asset integrity managing technologies, Mr. Selva has presented several papers on RBI Best Practice and Fitness-For-Service by invitation from high profile clients and organisers of various technical conferences worldwide.

D. Mr. T. Dalton, Principal Metallurgist, PP SIMTECH (UK) – a TCR Engineering partner company

Mr Dalton has nearly 30 years experience covering Failure investigations and Damage Mechanisms (DMs) assessment of all types of static and rotating equipment items in both new and aging plants.

Such work has been related to mechanical, thinning, metallurgical and cracking damage encountered on a wide range of equipment items of plants with diverse operating conditions involving many types of process chemicals and materials of construction. The equipment materials involved include carbon and low alloy steels, stainless steels, nickel alloys, copper alloys, aluminium alloys and other more exotic materials such as titanium and zirconium.

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He has expert knowledge of all types of DMs applicable to equipment items of plants operating in the oil, gas, petrochemical, chemical, fertilizer manufacturing and power generating industries.

He is conversant with ASME, API and BS codes relevant to design, construction, welding and inspection.

Mr. Dalton has acted as an expert witness for failure analysis and root cause investigations.

He has presented papers in subject areas such as DMs and root cause analysis at international conferences and has several years of experience in delivering training of Inspection Engineers in welding technology, material damage and failure mechanisms as well as training of RBI study team members represented by various engineering disciplines.

Mr Dalton has been active in RBI for several years – as an RBI Specialist Engineer for the facilitation of RBI team studies or as an RBI study team member for the provision of specialist expertise as a Metallurgist / Corrosion Engineer in the identification of active and potential DMs including provision of proactive support to the RBI team in the assessment of associated DMs risks and RBI inspection intervals including RBI operating limits.

Having an extensive materials technology and root cause failure analysis background and working in a multi-discipline team environment over several years with RBI Engineers, plant Inspection Engineers, plant Operations Engineers, plant Process Engineers & Chemists, Design Engineers & NDT Specialists, has enhanced his overall knowledge and understanding of change effects on plant operational and maintenance activities and their influence on various DMs & their damage rates and equipment inspection intervals, as well as the required interaction between these disciplines.

E. Dr. G. E. Prasad

Retd. Head Materials Characterization Section BARC, Ex Hon. Secretary of Indian Nuclear Society

Dr. G.E. Prasad is a well known personality in the field of Metallurgical Investigations and Failure Analysis. He has been associated with Dept. of Atomic Energy till he retired in 2001. Dr. Prasad has also represented India in a 3 member team who was involved in Kanishka (Air India Jet) blast case. He has numerous investigations of failure in Heavy Water Project, DAE and governmental institutions around the country. Dr. Prasad has been a General Secretary of such renowned societies as Indian Institute of Metals (Mumbai Chapter), Material Research Society (Mumbai Branch) and Indian Nuclear Society (Mumbai). He is the ex. honorary secretary of the Indian Nuclear Society.

F. Mr. C.V. Srinivasan

UNDP Corrosion Specialist

Mr. Srinivasan is the Technical Director, Nishi Engineers Pvt Ltd Chennai with over 42 years of professional experience. He has published 38 papers on Corrosion, Metallurgy, Welding, N.D.T in various International and National Conferences on Corrosion, metallurgy, Welding, Non-Destructive Testing, Vibration + Journals from 1965 onwards including UNDP conferences. His expertise includes conducting Third Party & Statutory Inspection / Certification of LPG/Butane/Pentane / Ammonia/ VCM/ Chlorine / Nitrogen/ Oxygen Static Storage Vessels (Bullets / Spheres), Petroleum / Methanol/ Diesel/ HSD/ LSD/ Kerosene etc Storage vessels, Used Pressure Vessels / Used Lifting Machines / Lifting Tools, Cranes, Hoists etc.

He is an expert in conducting Risk Analysis and Safety Audit for Chemical, Fertilizer, Petro-chemical, Refinery, Steel Industries and also provides consultancy in Corrosion, Metallurgical Studies (including Failure Analysis) for Plant equipment / piping etc failures. He assists in guiding on Non-Destructive Inspection, In-situ Metallography of special equipment / piping during project stage or after some years usage as well as providing Vibration Engineering Consultancy for high speed turbo-compressor rotating machinery / high speed pumps, blowers, fans etc on a need basis.

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G. Dr. Rajendra Kumar

Advisory Board Member at TCR

Dr. Rajendra Kumar is a renowned metallurgist of our country. He is a doctorate from world famous University of Sheffield, UK. Dr. Rajendra Kumar was the Director of National Metallurgical Laboratory, Jamshedpur and a former Director of Regional Research Laboratory, Bhopal.

Dr. Rajendra Kumar has more than 150 publications in national and international journals of repute. He has been a committee member of IBR for failure investigation. He has written three books on metallurgy.

H. Dr. P. B. Joshi

Advisory Board Member at TCR

Dr. P B Joshi is a professor in Department of Metallurgical and Materials Engineering, Faculty of Technology and Engineering, Maharaja Sayajirao University, Vadodara.

He is a Ph. D. in Material Engineering. Dr Joshi is having more than 25 years of teaching experience in the field of metallurgy. He has more than 50 research publications in International journals & National journals, and authored a book titled “Materials for Electrical and Electronic Contacts”.

I. Mr. Jagdish Baad

Advisory Board Member at TCR

Mr. Jagdish Baad is Bachelor of Technology in Metallurgical Engineering with First Class honors from IIT, Mumbai. He is having experience of 25 years in forge shop, steel, cast iron, S.G. Iron and Non¬ferrous foundries. He has worked reached to Sr. Management position starting from the Engineer level. He has handled Turn key projects related to Foundry Mechanization, Quality Assurance and Product management of critical castings for turbine, material handling and wear resistance applications. Some of them are first of its kind.

For last 12 years Mr. Baad has been consulting on TQM¬Product Management of Castings & Forgings and metallurgical related turnkey projects. Well versed in kaizen, Edward Debono /Osborn techniques in creativity management. Energy audits related to metallurgical processes.

He is Life member of various institutions such as Institute of Indian Foundrymen , Indian Institute of Metals ,Indian Society of Non¬destructive Testing, Indian Institute of Welding Metallography Society of India, Alumni Association of IIT Mumbai.

J. Mr. K. Ravindran

NDT Level III

Mr. Ravindran has the unique distinction of holding the ASNT NDT Level III certification in 11 subjects including RT, UT , MT , PT, VT, ET, LT, IR ,AE, VR and NR. He also carried the AWS CWI certifications. He has an overall experience of 25 years in inspection field of castings, forgings, pressure vessels (Designing, fabrication inspection) and pipe lines inspection. He is familiar in Destructive and Nondestructive inspection technique, as applicable to Welds, castings, forgings etc as well as inspection of raw materials with relevant specifications. He is thoroughly familiar with all the relevant applicable Codes and Standards for Nondestructive Testing and well versed in the documentation procedures. He is a post Graduate in physics, Post Graduate Diploma in Radiation Protection by Bombay University BARC (INDIA). He has over ten years experience in conducting training courses and classes all most in all methods of NDT, welding technology and casting and foundry technology.

K. S. S. Shanbhag, Chief Metallurgist

Mr. Shanbhag is a chief Metallurgist with over 26 years of experience. He serves as a technical expert on the most complex metallurgical testing projects.

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Mr. Shanbhag is "Hands-on" in the laboratory and performs material testing, analysis and results interpretation of numerous samples analyzed through the laboratory including mechanical, chemical, metallography and corrosion. He is part of the investigative team that performs failure and root cause analysis of failed components.

He performs and assists in routine metallurgy, including micro preparation, etching, phase counting, grain size measurement, micro structural assessment etc. He administers the mechanical test laboratory when team members are conducting tests such as Tensile, Charpy Impact, Sour Gas corrosion testing including HIC and SSCC, and Microstructure Analysis.

He interfaces with the machining department to ensure that samples are prepared as per the ASTM, NACE, BS, IS or client-specified standards. Mr. Shanbhag reviews, recommends and implements new and enhanced testing equipment or protocols. He has the unique ability to research and analyze information of considerable difficulty and draw valid conclusions. He has a strong understanding of QA principals (NABL and ISO/IEC 17025) and good inter-personal skill.

Mr. Shanbhag is skilled in mentoring, supervising, evaluating, training and motivating employees. He provides guidance and counsel to fellow team members and is capable of cross-training department personnel to perform job functions in various testing areas.

Interface with customers and vendors in technical issues related to materials and special processes. Assist the customer relations team and help resolve issues in a timely and effective manner. Contributes to the improvement of metallurgical testing department by advising on new test equipments and latest innovative procedures.

Mr. Shanbhag has a Bachelor of Engineering in Metallurgy.

L. Surendra Singh, Mechanical Laboratory Dept. Head

Mr. Singh has strong material testing laboratory experience. He is familiar with the metallurgy of carbon, alloy and stainless steels, superalloys, and with ASTM, ASME, API, IS and NACE material standards and specifications, and with both destructive and nondestructive test methodology. He has strong experience in evaluating properties of materials, materials characterization and behavior, materials specifications, mechanical testing, corrosion detection, machining of materials, and laboratory design and operation.

Mr. Singh has coordinated, planned and overseen internal test programs, and is accomplished as a customer liaison, program manager. He keeps himself abreast of all innovations in the sour gas corrosion field by reading scientific journals, industry specifications and participating in technical discussions. He also has extensive knowledge in physical and chemical testing, corrosion, failure analysis, materials selection, welding qualification and Metallography.

He leads a team that is adept at performing various corrosion including inter-granular corrosion attack, weight loss corrosion, pitting corrosion, Sour gas corrosion tests such as sulfide stress cracking (SSCC), salt spray, stress corrosion cracking, and hydrogen-induced cracking (HIC) for oil and gas, power, construction, shipping, petrochemical and process industries.

Mr. Singh has extensive knowledge of failure investigations on metallic components related to chemical/refinery plants and to general engineering. Experience ranges from cast iron, engineering steels, aluminum, copper alloys, stainless steels, and nickel base alloys to titanium. This includes all aspects of metallurgical investigations of offshore, marine, refinery and automotive components such as; turbine blades, compressors, gearboxes, motors, pumps, rotors, shafts, valves, pipe work, fasteners, boilers, pressure vessels, plain bearings, rolling bearings, gears, pistons, spark plugs, crankshafts, camshafts, engine valves and associated valve components.

Mr. Singh is well experienced in the Microstructure Characterizer Software, which has been developed internally at TCR, for grain size measurement, volume fraction, nodularity assessment, case depth measurement. Mr. Kapse has deep rooted understanding in metallurgy including micro preparation, etching techniques, phase counting, and microstructure assessment etc.

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Mr. Singh completed Masters in Technology in Corrosion Science and Engineering at IIT Mumbai and B.E in Chemical Engineering from National Institute of Technology, Surathkal Karnataka. Mr. Singh has extensive knowledge in aqueous corrosion, high temperature corrosion, cathodic protection, fracture and failure analysis, physical and mechanical metallurgy, welding science and protective coating.

Mr. Singh has performed various experiments using slow strain rate test, constant load test, electrochemical potentiostat and polarization test, stress corrosion cracking, hydrogen induced cracking, salt spray test and oxalic acid etch test. His M. Tech thesis entitled "Stress Corrosion Cracking in Commercial Grade Martensitic Stainless Steel" was supervised by Prof. V.S. Raja of IIT Mumbai.

Mr. Singh has specific experience in application of XRD, E-DAX, SEM, Optical Metallography and Electro-Chemical Potentiostat and polarization technique.

Mr. Singh is an active member in professional organization of Society of Surface and Protective Coating (SSPC) India Chapter.

M. Jaidev Patel, ASNT Level III, NDT Expert

Mr. Patel has 15 years of experience in QA /QC inspection in oil and Gas industry, Petrochemical and refineries and is qualified as a ASNT LEVEL III UT, MT. He is experienced in pressure vessel fabrication (static equipment) inspection and Third Party Inspection of materials like plates, pipes, forgings, casting at a vendor's location. He also has hands on experience in NDT (UT, MT, PT) and Radiographic Film interpretation and Destructive testing of various materials.

N. Gopul Patel, General Manager Scientific Research

Mr. Patel is a post graduate from Sardar Patel University. He has an extensive knowledge of vacuum Technology and has worked as Scientific officer at Department of Science and technology sponsored Research centre. He has hands on experience of operation and calibration of various sophisticated analytical instruments such as Transmission Electron Microscope, Scanning Electron Microscope with EDS, X Ray Diffraction, ICP OES, spectrometers, Thermal Analyzers such as DSC, TGA. He has experience of various advanced methods of material characterization and have worked extensively in the field of microscopy. He has been trained for Operation of Electron microscope at PHILLIPS, The Netherlands.

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