TCR ADVANCED

Optimizing Asset Integrity

Over 2 decades of Excellence

Company Profile | www.tcradvanced.com

Year Established	1999
Services Offered	200+
Total No. of Investigations	6000+
Total No. of Employees	120+
Total Cumulative Industry Expertise	500+

ABOUT TCR ADVANCED

Established in 1999, TCR Advanced Engineering Pvt. Ltd. is a leading service provider for optimizing Asset Integrity. With its extensive experience and applied research in damage mechanisms and metallurgy, TCR Advanced provides solutions to a large number of national & global customers to bring about transformation along with enormous safety and economic benefits.

A service partner company of TCR Engineering Services Pvt. Ltd.

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WHAT WE DO

SERVICES OFFERED BY TCR ADVANCED

TCR Advanced Engineering's ability to provide value to our metal testing customers is based on organizing multiple talents into a focused set of technological capabilities. TCR Advanced provides several testing services, no matter which discipline you choose, one thing is certain, when you send a sample to TCR Advanced, you can have confidence in the results, because you are working with a company that has a reputation for being meticulous.

SPECIALIZED CAPABILITIES

Failure Analysis
Fitness For Service
Remaining Life Assessment
In-Situ Metallography
SEM & EDS
Risk Based Inspection
Technical help on Indigenization
Specialized Metallography
Critical Weld Solutions
Corrosion Testing
Material Testing
Energy Audit
Fire Damage Assessment
Engineering Design Review
Vendor & Material Selection
Training by Evolve

ADVANCED NDT CAPABILITIES

HTHA
TOFD & Phased Array
Videoscopy
Eddy Current Testing
Acoustic Pulse Reflectometry
Acoustic Eye
Automated Reformer Tube
Inspection System (ARTiS)
Helium Leak Testing
Positive Metal Identification (PMI)
Thermography
Heat Exchanger Tube Inspection
Ferrography
Robotic Inspection of Tanks
Heat Treatment Facility

SPECIALIZED CAPABILITIES

I. FAILURE & ROOT CAUSE ANALYSIS

TCR Advanced prides itself for its deep knowledge and has garnered best practices from success stories compiled from over 6000 failure investigation assignments, which include major projects in manufacturing and metallurgical failures on ASME boilers, pressure vessels, gas turbine engine components, oil and gas transmission pipelines, food processing equipment, heat exchangers, medical supplies, refineries, petrochemical plants, aircraft/aerospace, offshore structures, industrial machinery, weldments and ships.

The Failure Analysis Team's strength lies in the evaluation of high temperature and high-pressure failures. The Failure Analysis Team at TCR Advanced Engineering has experience in the materials space, metallurgical, welding, quality assurance, and forensic engineering fields. The analysis is conducted by engineers holding advanced degrees in metallurgy, mechanical, civil, chemical, and electrical engineering.

Procedure to conduct a Failure Analysis

Cause of failure is determined using state-of-the-art analytical and mechanical procedures and often includes simulated service testing. A combination of analysis and physical testing locates problems and provides recommendations for solutions.

The complete evaluation sequence is summarized as under:

- Collection of background data and selection of samples
- Preliminary examination of the failed part
- Complete metallurgical analysis of failed material
- A thorough examination of the failed part including Macroscopic and Microscopic examination and analysis (electron microscopy, if needed)
- If necessary tests may also include Weld Examination, Case Depth, Decarburization Measurement, Coating/ Plating Evaluation, Surface Evaluation and/or Grain Size Determination
- Chemical analysis (bulk, local, surface corrosion products, deposits or coating and microprobe analysis)
- Tests to simulate environmental and physical stress that may have played a role in the failure
- Analysis of fracture mechanics
- Selection and testing of alternative products and/or procedures that will significantly improve performance
- On-site evaluation and consulting services and Formulation of conclusions and writing the report (Including recommendations)

Failure Investigation Report

- Description of the failed component
- Service condition at the time of failure
- Prior service history
- Manufacturing and processing history of component
- Mechanical and metallurgical study of failure
- Metallurgical evaluation of quality
- Summary of failure causing mechanism
- Recommendations for prevention of similar failures

II. FITNESS FOR SERVICE

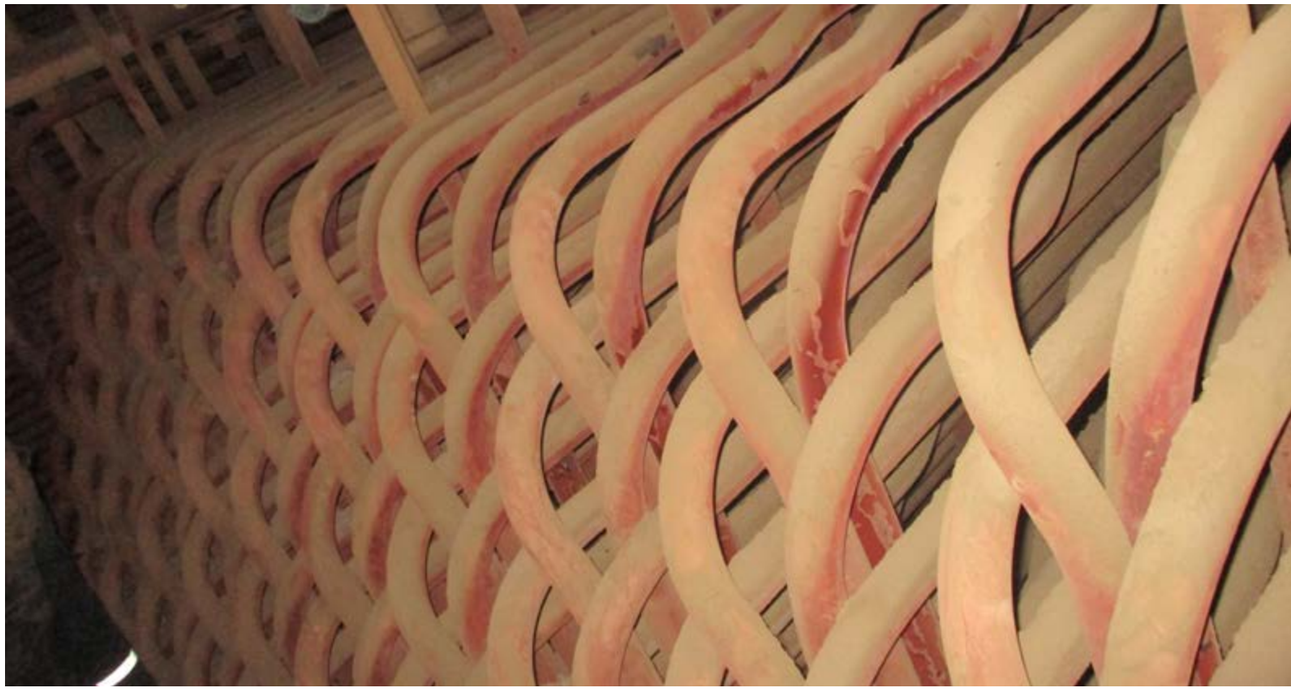
TCR Advanced provides fitness for service assignments in India and abroad for chemical, Petrochemical, Fertilizer, power plants and their components. TCR's FFS methodology is primarily based on API 579, BS 7910 and correlated with engineering calculations, actual characterization/ flaw/degradation, along with fracture mechanical calculations. It is a practical tool that assists the management to select the alternative action of whether to run, repair or replace the equipment. The heuristic aspect of the useful remaining life of the equipment at the time of the inspection is also part of the FFS study.

ASME, API, BS 5500 & other recognized design codes provide rules for design and fabrication of new items of the plant e.g. pressure vessels, piping & storage tanks.

The purpose of FFS assessment is not simply to continue the component in its service beyond its serviceable life but to ensure utilization of full potential concerning present damage assessment. Additionally, the fitness for service assessment of components can help set up proper inspection schedules, modified maintenance procedures and more of online monitoring systems.

III. REMAINING LIFE ASSESSMENT

TCR Advanced undertakes Damage Assessment work for the equipment / components exposed to accidents in the industry. Integrity of Reactor/Pipeline/Heat exchanger etc. can be found out with the help of modern NDT Techniques. If required representative samples are drawn to undertake detailed lab study. The usefulness of equipment is derived based on metallurgical requirements and operational details.



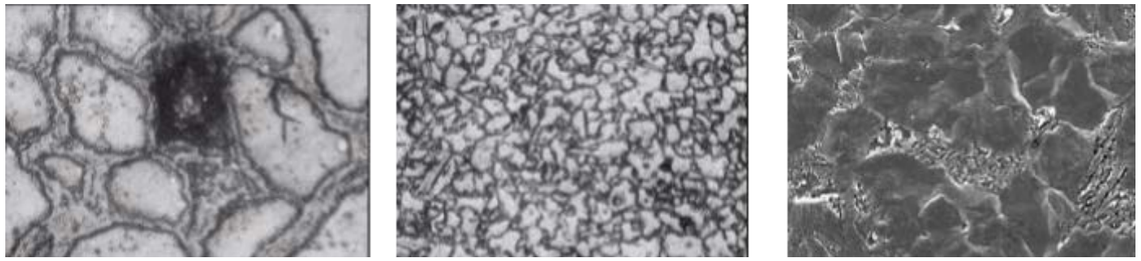
IV. IN-SITU METALLOGRAPHY - EARLY WARNING

Performed as an NDT service, In-Situ Metallography from TCR Advanced determines in-service degradation of critical components of process plants operating under high temperature, high pressure or corrosive atmosphere. TCR's Metallurgists have strong experience in the interpretation of microstructures. More than 10,000 replica microstructure interpretations have been logged and captured to our databases. These databases contain extensive information from various plants that have been captured over the course of us performing this service.

IV. IN-SITU METALLOGRAPHY (CONTD.)

The databases also include rare collections of varying microstructure damage levels for various industries such as power, oil and gas, petrochemical, fertilizers, and other process industries. The In-Situ Metallography team is highly skilled in the art of replica preparation. TCR has custom developed special purpose in-situ polishing devices which assist to enable metallographic polishing in difficult locations and allows the field services team to carry out high-quality replication even on warm components.

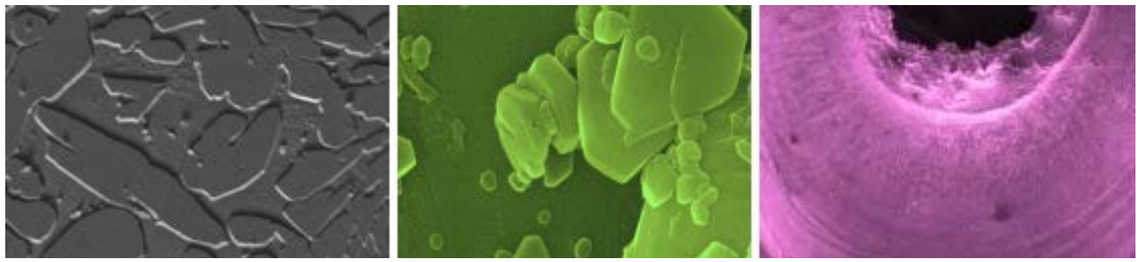
Examples of Replicated structures



V. SCANNING ELECTRON MICROSCOPE & EDS

TCR Advanced has procured state of the art Scanning Electron Microscope (SEM) attached with Energy Dispersive Spectrometer (EDS) system. SEM is a great diagnostic tool for:

- Failure investigation
- Fractography
- Quality control
- Morphology & identification of localized defects
- Identifying corrosion products at microscopic levels
- Identifying Surface coating or plating
- Particle size & shape analysis
- Characterizing creep in microstructure
- Identifying submicron features in microstructure
- Identification of Inclusions in metals.



The large detector area of 20 mm^2 gives better count rate at lower accelerating voltages and lower spot sizes resulting in improved accuracy and quantification of elements which is sometimes is a limitation of the conventional EDS detectors with 10 mm^2 area.

VI. RISK BASED INSPECTION

TCR's RBI team study improves both, the team's efficiency and knowledge sharing at the plant site along with enhancing communication across all departments. Additionally, it captures valuable plant knowledge from senior engineers in the team, encourages the training of junior engineers and augments corporate memory.

The technology is designed to facilitate the successful implementation of RBI technology processes at plant sites across oil and petrochemical industries, chemical, fertilizer and power plants. The technology causes an increase in plant availability, ensures cost saving, minimizes shutdowns, encourages changes in inspection strategies and intervals, and promotes improved safety compliance.

VII. TECHNICAL HELP ON INDIGENIZATION

In order to generate baseline standard for indigenization, multiple metallurgical studies are undertaken to identify status and properties of imported components by different methods including destructive/non-destructive studies. Technical help is provided to decide on the right manufacturing route or process and to develop quality checks on indigenously created components. TCR's proprietary approach seeks structural details from the client across several areas to optimize indigenization support:

Working condition of component | **Type of loading and stresses** | **Design and operation condition** | **Service history of component** | **Life of an important component**

VIII. SPECIALIZED METALLOGRAPHY

Specialized Metallography service especially color metallography, one of the strongest capabilities of TCR owing to its extensive research in this area of work. TCR Advanced has expertise in determining the various phases of the microstructure of material using color etching technique, which is commonly known as 'tint etching'. This etching has been used to color the phases present in many alloys such as cast irons, steels, stainless steels, nickel-base alloys, copper- base alloys, etc. for their phase identification. Color metallography is a useful method for characterizing microstructures of steel with multiple phases.

IX. SOLUTIONS TO CRITICAL WELD PROBLEMS

TCR Advanced has vast expertise of solving critical weld repair solution of the aged plant components. The repair weld solutions can salvage the critical components of process plant and can make huge saving in terms of production loss. The repair weld technology requires in depth understanding of metallurgical degradations vise-versa operating conditions. The off shoot of knowledge bank at TCR Advanced is the successful stories behind more than 6000 failure investigations of the industries. This insight in to the failure mechanisms has strengthen the knowledge of TCR technical team which is directly implemented for repair weld solution.

The engineering consulting team can be approached with detailed history of problem. Our team can reach to your sight within 24 hrs. and start generating information and data on the components to be repaired. For successful repair a mock up test is necessary from the same material preferably for the aged material of similar grade.

X. CORROSION TESTING

Corrosion Studies and Corrosion Testing is undertaken by TCR Advanced as per ASTM, DIN, or as per individual client requirements. TCR Advanced has an in-house team of industry-specific experts to provide corrosion consulting, advisory services on corrosion prevention and corrosion control services including materials selection in a laboratory or on-site inspection.

TCR's staff with specific industry expertise covers a variety of corrosion problems that are encountered in industries such as oil and gas production, oil and gas transmission, energy conversion systems, and nuclear power systems. The objective of the corrosion detection department at TCR is to provide quality service. A wide variety of corrosion related tests is undertaken at TCR Advanced to determine the susceptibility to intergranular corrosion, pitting corrosion, stress corrosion cracking, etc. The range of instruments available to perform these tests is unrivaled in across geographies. TCR can also carry out testing under third party inspection agencies like LRS, TUV, DNV, ABS, BV among other inspection agencies.

XI. MATERIAL TESTING

A. CHEMICAL ANALYSIS

TCR Advanced is providing chemical analysis facilities for accurate characterization and identification of metals & alloys. By wet chemical analysis and by Optical emission spectrophotometer using advanced Spectra lab machine SPECTROMAXx is capable of accurately analyzing the Iron base, copper base, nickel base and aluminum base alloys. It has more than 35 Certified Reference Materials (CRM) which ensures the highest accuracy in test results.

TCR Advanced is equipped with Portable XRF based spectrometer for Positive Material Identification. This is an NDT technique used for analysis of alloy content in the material. It cannot detect the nonmetallic elements; typical PMI results are accurate to ±10%. This is very useful technique in material sorting, scrap identification etc. TCR Advanced also provides services chemical analysis at site by portable SPECTRO through its service partner company. With this equipment one can analyze all elements including Carbon, Sulfur, Phosphorous, Silicon apart from alloy elements. TCR Advanced has added EDS analyzer to the SEM UNIT for identifying the chemical composition of localized area such as plating, coating or localized corrosion defects.

B. MECHANICAL TESTING

TCR Advanced provides a comprehensive range of Mechanical Testing. The Mechanical Testing Facility consists of Universal testing machine, Rockwell hardness tester, Brinell cum Vickers hardness testing machine, Micro Vickers hardness testing machine, Impact testing machine etc. TCR Advanced conducts tensile tests for understanding the strength characteristics of a material and provides precise determination of Proof Stress by the attachment of electronic extensometers. The following tests are also carried out: Welder Qualification test, Welding Procedure qualification tests, Bend Tests, Compression Tests, Flaring and Flattening Tests on Universal testing machine. The mechanical testing personnel of TCR Advanced are well aware of the requirements in various national & International codes of testing such as IS, ASTM, DIN, EN, API, ASME, AWS.

Superior technology, responsive versatility, and quality performance ensures reliable and fast turnaround on all test results. Experienced technicians at TCR Advanced are capable of low stress grinding and machining sub-size specimens to very close tolerances. We have designed several fixtures for tensile testing of end products without machining them to tensile test specimens.

C. METALLURGICAL TESTING

Metallurgists at TCR Advanvced are qualified experts in Metallographic preparation & examination to evaluate the characteristics of metals. We can assess a material's heat treatment condition, microstructure, and forming process. The team undertakes Macro and Micro examination including Weld Examination, Case Depth and Decarburization Measurement. Micro Hardness Testing and Coating/Plating evaluation is also undertaken. The Metallography laboratory has the state-of-the-art Inverted Metallurgical Microscope Olympus GX51 and three other inverted microscopes attached with CCD camera of capturing metal structures on Image processing workstation for Image Analysis. TCR Advanvced has developed Microstructure Characterizer (MiC) software that assists metallurgists for analysis of images to determine depth of decarburization, phase/volume percentage, grain size, inclusion rating, particle size, Nodularity, nodule count, porosity and coating thickness, Austenite spacing.

TCR Advanced has taken a lead in certifying Heat Treatment Quality aspect from microstructure point of view. A conventional acceptance criterion for heat treatment is through hardness testing.

C. METALLURGICAL TESTING (Cont.)

We certify following heat treatments:

Bulk

Normalizing
Homogenization
Solution Annealing
Hardening & Tempering
Precipitation Hardening

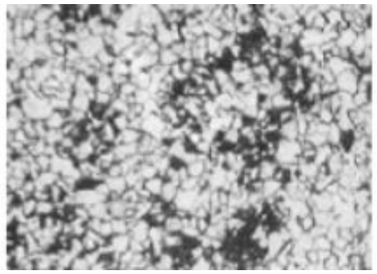
Surface

Nitriding
Carburizing
Carbonitriding
Hard Surfacing
Induction Hardening

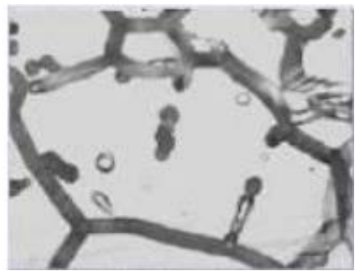
Metal & Alloys

Steel
Cast Iron
Super Alloys
Nickel Alloys
Copper Alloys
Stainless Steel
Aluminum Alloys
Heat Resistant Alloys

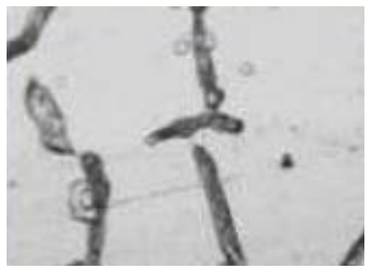
As cast carbon steel



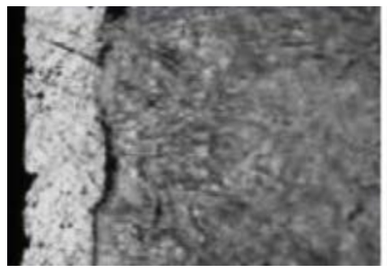
Normalized carbon steel



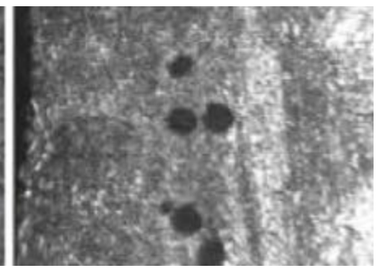
Intergranular carbide precipitation Solution annealing is not satisfactory



Isolated carbide precipitation Solution annealing is not satisfactory



White layer developed during gas nitriding process Undesirable structure



Porosities developed with Sulphur nitriding treatment

XII. ENERGY AUDIT

TCR Advanced conducts an energy audit for inspection, survey, and analysis of energy flow for the purpose of energy conservation in a building, process plant or system. Our team of experts will help you reduce the amount of energy input into the system without negatively affecting the output(s). In commercial and industrial real estate, an energy audit is the first step in identifying opportunities to reduce energy expenditure and carbon footprints.

XIII. FIRE DAMAGE ASSESSMENT

TCR Advanced has expertise in Fire Damage Assessment and Fire Risk Assessment Techniques to ascertain the extent of damage due to fire. The construction material used in petrochemical plants is selected based on extensive research and experience and adheres to specific guidelines to meet international standards, which deal with different manufacturing procedures, chemical composition, and mechanical properties.

XIV. ENGINEERING DESIGN REVIEW

TCR Advanced has an in-house capacity to review engineering design for piping, pressure vessels, heat exchangers and heaters. We provide design and analysis services such as Computer Aided Designing (CAD) Engineering Design, Legacy Data Conversion, Detailing Plant & Process Layout, CAM, Computer Aided Engineering (CAE) including Finite Element Modeling, Structural Analysis and Noise, Vibration, Harshness (NVH) analysis, and Project Management Services

XV. PART 1: VENDOR EVALUATION

Vendor evaluation is a system for recording and ranking the performance of a supplier in terms of a variety of issues, which may include delivery performance and the quality of components. TCR helps in assessing and approving the potential line of suppliers of the company through various quantitative and qualitative evaluation measures. TCR's services include:

- Factory audit
- Process audit for metallurgical components
- Q.C. audit
- Design review

XV. PART 2: MATERIAL SELECTION

Our corrosion and metallurgical experts with the help of design experts can undertake challenges related to material selection for chemical and petrochemical industries especially for:

- Establishing new process applications
- To increase the life of a component
- Changes in Design
- Engineering components

The laboratory is equipped with specific testing machines, advanced metallography and accelerated corrosion testing like electrochemical testing.

XV. PART 3: INSPECTION & QUALITY ASSURANCE

TCR Advanced, through its service partner company's office, provides inspection and quality assurance services to help retailers, trading partners, importers and manufacturers assess product quality and meet the regulatory requirements of their industry vertical. Independent, third-party inspection and quality assurance services results in improved product quality, with a reduction in customer complaints, noncompliance and product recalls. The on-site inspection team covers the all states across India and abroad. The pricing structure for the on-site inspection services is set competitively and is based on man-day charges.

TCR Advanced undertakes total quality improvements for stringent requirements against international specifications.

XVI. TRAINING BY EVOLVE

Evolve by TCR aims to build a technically proficient manpower pool to meet global industry requirements. It offers a vast and comprehensive array of skill-based development programs at its flagship centre in Vadodara. Evolve by TCR conducts short-term courses and provides training and developments solutions to individuals, enterprises, and institutions. Training programs at TCR Evolve are conducted by industry veterans and subject matter experts who employ the latest pedagogy for a seamless learning experience.

ADVANCED NDT CAPABILITIES

At TCR Advanced, a team comprising of qualified and expert metallographers and metallurgists to carry out in situ metallography testing (Replica), also have qualified NDT technicians (ASNT Level-II) performing Ultrasonic Flaw detection, Magnetic Particle and Liquid Dye Penetrant testing, Ultrasonic Thickness Gauging survey, Hardness Testing Storage/Sphere Tank Inspection, Eddy Current testing, Helium Leak detection, Internal Oxide scale thickness measurement for boiler tubes. Field service Metallography and structural inspection are also offered. Our experienced personnel are respected for their integrity and recognized by all the relevant inspection authorities. Our NDT services are routinely performed in the following sectors: petrochemical, automotive, construction, transport, defense and general engineering.

TCR Advanced offers advanced NDT testing facilities such as Eddy Current testing, Internal Oxide scale measurement for Boiler tubes, Helium Leak testing, Thermography, MFL (Magnetic Flux leakage for tank bottom), Hardness testing by UCI (Ultrasonic Contact Impedance) Method using Kraut Kremer Hardness tester.

TCR Advanced is now offering services of new and upcoming heat Exchanger tube inspection technique acoustic Eye based on Acoustic Pulse reflectometry principle. This is an ultrafast flaw detection technique with detection time less than 10 seconds per tube. It can detect blockages apart from pitting or punctures- useful for detecting extent of cleaning, to increase efficiency of heat exchanger.

TCR has IRIS DVR 5 Videoscope and an indigenously developed borescope machine which can be used to carry of visual inspection of closed inaccessible spaces such as tube ID surface, vessels. Our videoscope probe can be inserted up to 10 mm dia holes. In the year 2013 TCR Advanced became the first NABL accredited lab in Gujarat for NDT testing. In the year 2014 TCR added Crack depth Meter, Ferritometer and Surface roughness measurement facilities at lab and site testing

I. HIGH TEMPERATURE INSPECTION

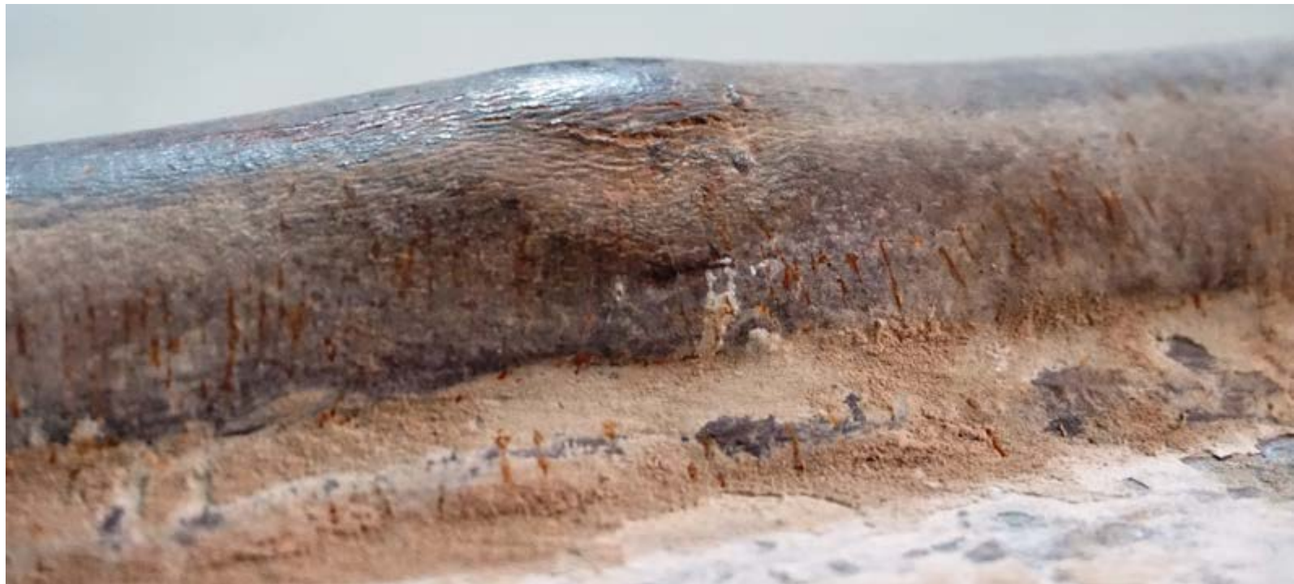
High-temperature hydrogen attack (HTHA) is observed in steel that is exposed to a temperature of 200 °C or more. At such a high temperature, atomic hydrogen diffuses in steel. This hydrogen reacts with carbon present in the steel and forms CH4. The methane that is formed bubbles and forms voids at the grain boundary.

$MC + 4H = M + CH4$

These bubbles exert pressure and also coalesce resulting into fissures. The growth of voids and fissures weakens the metal, leading to a major crack. This reaction decarburizes the steel, produces micro cracks/fissures and lowers toughness of steel but not necessarily cause a loss in thickness.

II. TOFD & PHASED ARRAY

When PAUT and TOFD techniques are judiciously performed together, the quality of testing increases when compared with radiography, i.e. the integrity of weld joints inspected with TOFD or PAUT is higher than those inspected using radiography. At times the combined inspection cost for PAUT + TOFD may seem higher than conventional radiography testing but since these advanced ultrasonic methods do not involve any radiation hazards and other jobs can be carried out in the vicinity of such testing, leading to a direct saving associated beside time saved in production/fabrication. The speeds of PAUT + TOFD inspection in one scan shortens the overall inspection time and eliminates the time-loss associated with RT.



III. VIDEOSCOPY / BOROSCOPY

TCR Advanced Engineering provides videoscopy/ Borescope inspection services. We have a state of the art Iris 5 DVR videoscope which has total probe length of 7.5 mts and 8 mm probe dia, which is suitable for carrying videoscopy in a component with opening as small as 10 mm. The IRIS DVR is equipped with 4 way articulation to give 360 degree field view. It has a high resolution CCD camera for HD Video recording and interchangeable objective lenses for changing the degree of viewing and field of view. The videoscope is useful in many fields such as Aerospace, Wind Turbines, Gas turbines, Oil & Gas Industries, Chemical Industries, Power generation plants, quality control and internal weld inspection.

IV. EDDY CURRENT TESTING

The Eddy current test is not a volumetric technique. This is a surface technique and can readily detect very shallow surface defects (fatigue crack, inter-granular stress corrosion cracks etc.), sub surface defects (inclusions, voids etc.) within a depth of 6 mm. It can also identify pitting, cracking, microbiological induced corrosion damage, support wear, erosion etc. and hence is a widely used tool for in-service inspection of heat exchangers. This Nondestructive testing using a multi frequency Eddy Current system would examine surface and sub-surface areas of materials with suitable electrical conductive and magnetic properties. The instrument used allows Inspection of a large variety of materials and provides documentation of the inspection all in one unit. Our Engineers are well trained in carrying out the test at Site and interpret the results accurately, depicting the actual condition of the tubes based on the test results, particularly very competent in resolving between defects and non-relevant indications. All Eddy current testing jobs were carried out by Level II qualified engineers with a throughput of about 800 tubes per day.

V. ACOUSTIC EYE

Acoustic Eye's breakthrough, non-invasive solution for today's hard-to-inspect tubes up to 4" inner diameter enables ultra-fast, accurate inspection of boilers, Fin Fans and other heat exchangers, regardless of tube shape or material. Featuring patented Acoustic Pulse Reflectometer (APR) technology, Dolphin G3™ is an advanced, yet easy-to-use tool that overcomes the limitations of many conventional inspection techniques. With its simple operation, automated analysis & report generation, there is far less dependency on operator expertise. Providing reliable inspection of even the most challenging tube sizes and configurations, Acoustic Eye increases inspection cycle efficiency, leading to operational cost savings.

VI. AUTOMATED REFORMER TUBE INSPECTION SYSTEM (ARTIS)

ARTiS is abbreviated for Automated Reformer Tube Inspection System. TCR ADVANCED has indigenously developed an automated robotic crawler to aid ultrasonic inspection of reformer tubes. It provides tabular and interactive digital output. The 1st point on every tube is referred at bottom of tube climbing up to the 14 meters height and provides tube data at every 0.1 meter distance. The ARTiS can simultaneously collect the tube data such as ultrasonic dB level of attenuation, diameter of tube and bowing angle at every location. An interactive, graphical user interface is part of digital report along with conventional hardcopy print in tabular format. The major advantages of the ARTiS are as follows.

VII. HELIUM LEAK TESTING

TCR Advanced performs Helium Leak testing in India to detect and locate leaks in
- Pressure increase in a vacuum - reservoir or
- Pressure decrease in pressure – tank

This includes welded, brazed, adhesion-bonded and other assemblies. The requirement of leak testing is quantized by the maximum allowable leak rate.

TCR Advanced Helium Leak Testing instrument has a roughing capacity of 10 m3/h (7 cfm) with usable helium sensitivity in the 10-11 atm.cc/s range. The unit has a dedicated sniffing unit, based on a well-proven leak testing concept, and is also available for outboard leak testing applications. The leak rate value is 1 mbar l/s, if in a vacuum-reservoir with a volume of one litre, the pressure rises in one second about one mbar or in a pressure-reservoir it drops about one mbar in one second.

VIII. POSITIVE METAL IDENTIFICATION

The PMI division at TCR Advanced Engineering has expert engineering and inspection workforce to undertake incoming material inspection and can provide on-site alloy verification for quality control and stock control purposes. TCR can analyze both melt and weld for comprehensive maintenance assessment.

IX. THERMOGRAPHY

It is used to find out temperature anomalies present in the equipment during their operation. This is a non-contact method of testing and viewing is done remotely. Even helicopters can be used for testing large regions. This is a very recent addition of the NDE. Any hot object emits the heat radiation. An Infrared sensor which can pick up such radiation to form the image of the hot body. The hot and cold regions on the surface can be analyzed for the healthy condition of the object. Thermography is useful for applications such as Deposits or blockages in pipe lines carrying hot or cold fluids, Refractory or insulation deterioration in Furnaces, Boilers, heaters, converters etc. Electric sub-stations for control panels, transformers, switch gear etc. for overloading, lose or damaged contacts, Overheated bearings in rotary equipment e.g. Motors, generators, turbines etc.

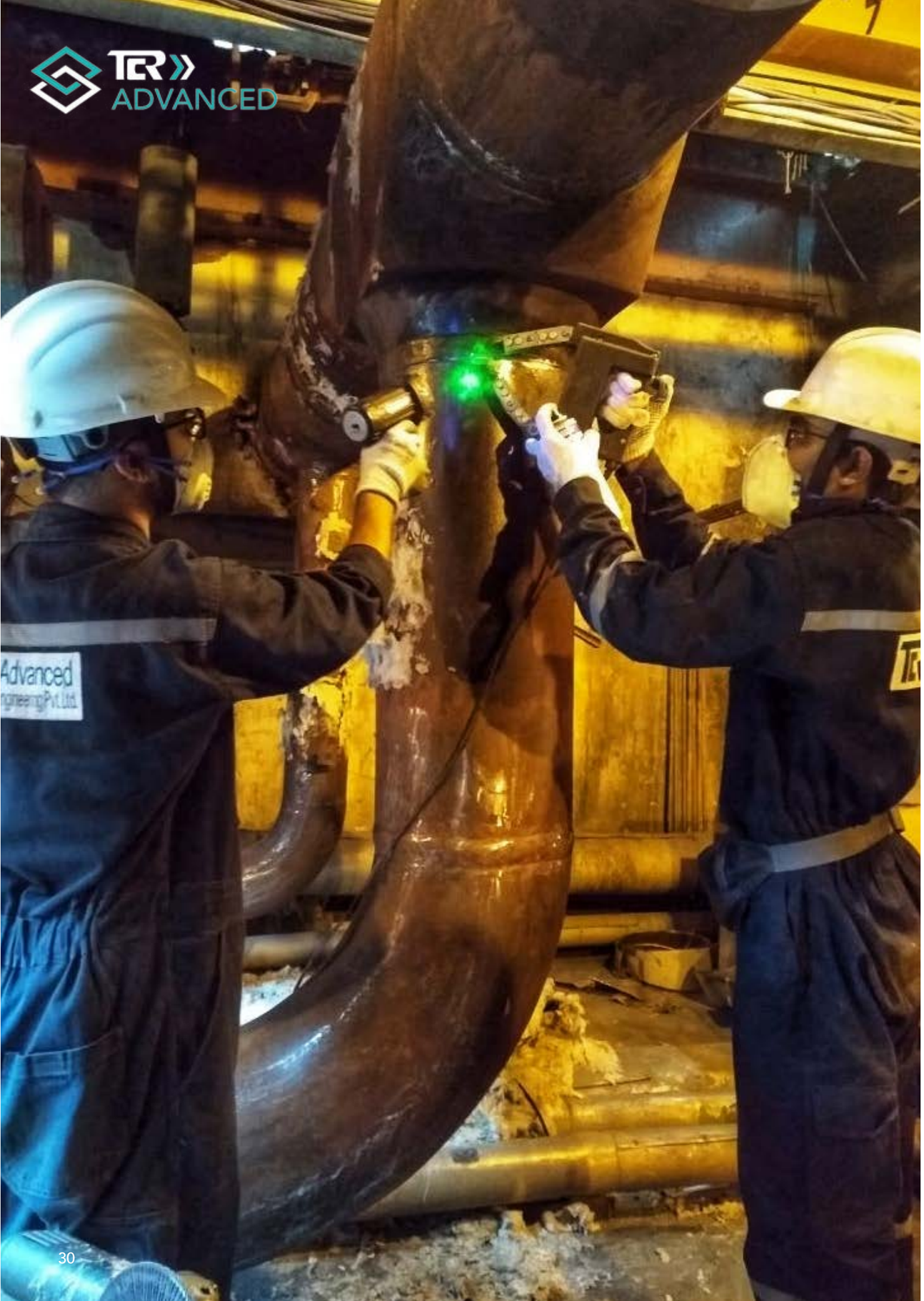
X. HEAT EXCHANGER TUBE INSPECTION

Periodic inspection of heat exchanger tube is inevitable as it affects the heat transfer phenomenon leading to forced shutdowns. Inspection of heat exchanger tubes for internal damage is no longer a lengthier, tiresome, time-consuming and expertise-involving procedure with the advent of advanced NDT methods like ECT, RFET, MFL, APR, IRIS, Leak testing and videoscopy. TCR has expertise in heat exchanger tube inspection using these techniques:

- Eddy current testing
- Acoustic pulse reflectometry
- Videoscopy
- Leak testing

XI. FERROGRAPHY

Ferrography or oil analysis is a series of laboratory tests to determine the condition of used Lubricants in equipment /components, over a period. A trend of wear particle distribution and their Concentration typically presents the condition of the Equipment also it provides opportunity for Maintenance programs from breakdown to be proactive.



XII. ROBOTIC INSPECTION OF TANKS

This technique uses an automatic robotic crawler to enter in to the Tank for collecting data such as thickness, Ultrasonic soundness, visual inspection by video camera while tank is in service. the robotic crawler systematically scans the tank bottom with an array of eight ultrasonic transducers and relays high volume of UT data for analysis. The in tank service follows a digital inspection grid and collects more than 200000 UT scans(based on the average scan pattern in a 100 ft dia. Tank) for computer analysis. The robot pushes sludge aside as it travels, performs cleaning and unnecessary waste disposal in many cases. Some of the salient features of this technique eliminates the high cost of taking down your tanks. The testing can be completed as per API 653 inspection in days instead of weeks or months. Reduce environmental and safety risks without opening the tank or due to manned entry.

XIII. HEAT TREATMENT FACILITY

TCR Advanced offers post weld heat treatment by using electricity as source of heating for stress relieving of weld joints. All TCR's heat treatment services are designed to minimize downtime, improve structural integrity, and enhance effective plant life. Additionally, depending on the mobility of the required equipment many of our heating processes can be applied on-site or at your facility.

TCR has specialized fully automatic programmable equipment capable of controlling Heating rate, Holding time and cooling rate to carry out a wide range of heat treatment processes like post weld heat treatment of PQR test coupons, and various components. TCR is capable of doing Post weld heat treatment of carbon steel piping welds (pipe-work, headers, flange joints, valves and branches) by means of the electrical resistance method, in the form of ceramic heater pads. The Heat treatment equipment is supplied with chart recorder to record up to 8 thermocouples simultaneously for meeting the critical requirement of heat treatment.

ABOUT US

TCR ADVANCED: OPTIMIZING ASSET INTEGRITY

TCR Advanced Engineering was established in 1999 to provide credible solutions that ensured uninterrupted operation of assets, improved productivity and enhanced safety in compliance with all environmental standards. Located in Vadodara, TCR Advanced Engineering is a service partner of TCR Engineering Services, Mumbai.

TCR Advanced aims to be the best at all that they do -- the goal is to make a positive difference, help clients overcome their challenges, and maximize their success. TCR Advanced has successfully conducted over 6000 investigations and has served over 1700 clients nationally and globally. TCR enables companies across the globe to efficiently manage plant operations and optimize asset integrity. TCR continuously provides innovative solutions that help its clients create an advantage from every opportunity.

At the helm of TCR Advanced is Paresh Haribhakti an industry expert and an acclaimed author. He has authored "Failure Investigation of Boiler Tubes: A Comprehensive Approach' which is published by the prestigious ASM International. Paresh's expertise and experience have led TCR Advanced to redefine the failure investigation and asset integrity industry by focussing on client results and not just reports.

VIRENDRA KUMAR BAFNA
Founder & Visionary
TCR Engineering Services Pvt. Ltd.

TCR JOURNEY: BUILDING TRUST SINCE 1973

The mother entity TCR Engineering Services was incorporated in 1973 and has over the years grown to be India's leading material testing and research company. It was the vision of Mr. V. K. Bafna, the founder, a keen metallurgist to provide real, sustainable solutions to companies that would drive progress for them. He infused the principles of precision, transparency and reliability in all actions due to which, TCR today is a trusted service provider for top-notch companies across the globe. A visionary with sound material sciences experience, strong business acumen and relentless sincerity, the TCR Advanced matured under his able guidance.

Since its inception, TCR treated all its clients equally; whether it is Fortune 500 companies or Small-medium businesses, it delivers results with the same speed and efficiency without compromising on quality. TCR recognizes the significance of developing relationships that echo their culture of mutual respect and unwavering ethics. For over five decades, TCR is focused on bringing to life great ideas and business solutions that drive growth for their clients. The company has many 'firsts' to its credit and has become a thought leader in the industry because of its pioneering work. TCR has a growing global presence and is rooted in behaving ethically in all their interactions with their employees, partners and their customers.

TCR ADVANCED

ABOUT US
ADVANTAGE TCR ADVANCED

TCR Advanced is an industry leader and has worked on some very critical problems for organizations all over the world. TCR Advanced has over 500 years of cumulative metallurgical and advisory experience that it has gathered from unique assignments. This knowledge can greatly benefit the industry and enable new and existing professionals to hone their skills. This thought was the reason for launching TCR Evolve, the training arm of TCR Advanced.

TCR believes that true success lies in empowering their clients for growth, where reports are more than just a report-they should deliver actionable insights, foresight to help navigate challenges and provide solutions to maximize performance. TCR strives to ensure that in all its services, responsiveness is fundamental, reliability and transparency are its strengths and repeatability is its reward.

1. **COLLABORATION:** This is the bedrock for TCR's service delivery approach. TCR aligns with clients, fostering engagements into long-term partnerships. No matter what the challenge is, TCR focuses on delivering practical, enduring results to equip their clients for growth.

2. **HIGHLY COMPETENT TEAM:** The quality of people is the cornerstone of TCR's ability to address the needs of its clients. TCR makes tremendous investments in identifying highly talented people, developing their skills and building an environment that encourages their growth. TCR can assemble a team with the most appropriate expertise and experience in the shortest possible time.

3. **DEEP SECTORIAL EXPERTISE:** TCR brings its experience gained over the last 40 years in the field of material testing, inspection and quality assurance with strong commitment and adherence to the ISO 17025 standards. The technical teams are highly experienced having conducted over 1500 failure analysis projects. TCR is on the approved list of SABIC, Tasnee, APPC, Schlumberger and Reliance for Failure Analysis Services. The company has access to Scanning Electron Microscopy with EDAX and Optical Inverted Metallurgical Microscopes.

4. **DIVERSIFIED PROBLEM SOLVING:** TCR helps clients address their business complexities and deliver business value throughout the life cycle of any client initiative. This includes assessment, research, testing services, advisory capabilities, development and solution design, integration, deployment, inspection and support for long-term sustainability.

APPROVALS & ACCREDITATIONS

OUR ACCREDITATION TO GLOBAL QUALITY STANDARDS

National Accreditation Board for Testing and Calibration Laboratories
(A Constituent Board of Quality Council of India)

CERTIFICATE OF ACCREDITATION

TCR ADVANCED ENGINEERING PRIVATE LIMITED

has been assessed and accredited in accordance with the standard

ISO/IEC 17025:2005

'General Requirements for the Competence of Testing & Calibration Laboratories'

for its facilities at

250-252/9, GIDC, Makarpura, Naren Hardware Lane, Vadodara, Gujarat

in the field of

TESTING

Certificate Number TC-6739 (In lieu of T-1330, T-1331 & T-2697)
Issue Date 14/10/2017 Valid Until 13/10/2019

This certificate remains valid for the Scope of Accreditation as specified in the annexure subject to continued satisfactory compliance to the above standard & the relevant requirements of NABL.

(To see the scope of accreditation of this laboratory, you may also visit NABL website www.nabl-india.org)

Signed for and on behalf of NABL

N. Venkateswaran
Program Director

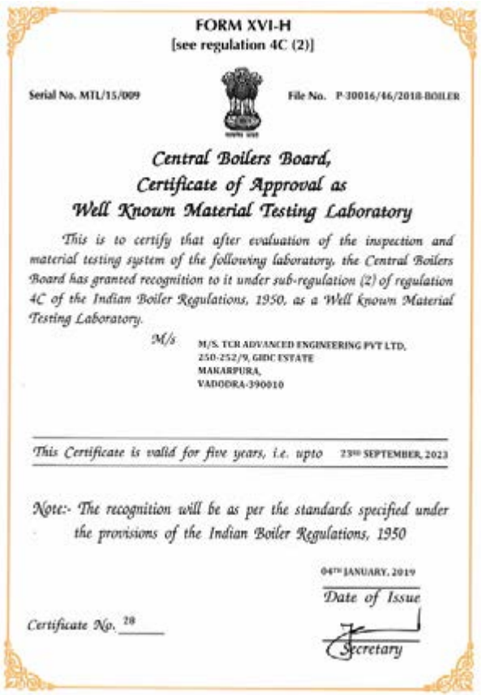
Anil Relia
Chief Executive Officer

NABL Certificates

TCR Advanced Engineering accredited by NABL as per international standard ISO-IEC-17025 in chemical, mechanical, and non-destructive testing disciplines. The NABL certification is issued by the National Accreditation Board for Testing and Calibration Laboratories, Department of Science and Technology, Government of India. NABL provides accreditation to laboratories that perform tests/calibrations in accordance with ISO 17025. ISO/IEC 17025 includes quality system requirements of ISO 9001 and other additional requirements to demonstrate that the said laboratory is technically competent with the ability to produce technically valid data and results.

Central Board for Boiler

In the year 2014, TCR Advanced Engineering received approval of " well known Remnant Life Assessment organization" as well as "well known Material Testing Laboratory" by Central Boilers Board (CBB), Government of India, Ministry of commerce and industries. With this approval, TCR's can carry out life assessment jobs and certify the fitness of boiler components as per Indian Boiler Regulation (IBR).



FORM XVI-H
[see regulation 4C (2)]

Serial No. MTL/15/009 File No. P-30016/46/2018-BOILER

Central Boilers Board,
Certificate of Approval as
Well Known Material Testing Laboratory

This is to certify that after evaluation of the inspection and material testing system of the following laboratory, the Central Boilers Board has granted recognition to it under sub-regulation (2) of regulation 4C of the Indian Boiler Regulations, 1950, as a Well Known Material Testing Laboratory.

M/s M/S. TCR ADVANCED ENGINEERING PVT LTD,
250-252/9, GIDC ESTATE
MAKARPURA,
VADODRA-390010

This Certificate is valid for five years, i.e. upto 23RD SEPTEMBER, 2023

Note:- The recognition will be as per the standards specified under the provisions of the Indian Boiler Regulations, 1950

04TH JANUARY, 2019
Date of Issue

Certificate No. 28

Secretary

FORM XVI-I
[See Regulation 4C (2)]

Serial No. RLAO/15/018 File No. 8(22)/2017-Boilers

Central Boilers Board
Certificate of Approval as
Well Known Remnant Life Assessment Organisation

This is to certify that after evaluation of the inspection and material testing system of the following firm, the Central Boilers Board has granted recognition to it under sub-regulation (2) of regulation 4C of the Indian Boiler Regulations, 1950 as a Well Known Remnant Life Assessment Organisation for carrying out Remnant Life Assessment of boilers operating upto and above 120 Kgs./cm² pressure

M/s TCR Advanced Engineering Pvt. Limited,
250-252/9, GIDC Estate,
Makarpura,
Vadodara-390 010
Gujarat

This Certificate is valid for five years, i.e. upto 24th May, 2022

29th June, 2017
Date of Issue

Certificate No. 088

Secretary

National Accreditation Board for Testing and Calibration Laboratories
(A Constituent Board of Quality Council of India)

SCOPE OF ACCREDITATION

Laboratory: TCR Advanced Engineering Private Limited, 250-252/9, GIDC, Makarpura, Naren Hardware Lane, Vadodara, Gujarat

Accreditation Standard: ISO/IEC 17025: 2005

Certificate Number: TC-6739 (In lieu of T-1330, T-1331 & T-2697) Page 1 of 10

Validity: 14.10.2017 to 13.10.2019 Last Amended on 12.01.2018

Sl.	Product / Material of Test	Specific Test Performed	Test Method Specification against which tests are performed	Range of Testing / Limits of Detection
		CHEMICAL TESTING		
1.	METALS & ALLOYS			
1.	Carbon and low alloy steel	Carbon	ASTM E415-17, IS 8811(1998)	0.005% to 1.10%
		Sulfur		0.003% to 0.35%
		Phosphorous		0.003% to 0.15%
		Manganese		0.15% to 2.00%
		Silicon		0.02% to 2.00%
		Chromium		0.03% to 1.70%
		Nickel		0.005% to 1.70%
		Molybdenum		0.01% to 1.80%
		Copper		0.005% to 0.40%
		Titanium		0.01% to 0.50%
		Tungsten		0.05% to 0.60%
		Nitrogen		0.005% to 0.01%
		Vanadium		0.005% to 0.35%
		Tin		0.005% to 0.10%
		Niobium		0.005% to 0.75%
		Aluminium		0.010% to 1.20%
2.	Stainless steel, Tools steel	Carbon	ASTM E1086-14 IS 9879 (1998)	0.010% to 4.30%
		Sulfur		0.003% to 0.35%
		Phosphorous		0.010% to 0.060%
		Manganese		0.26% to 12.00%
		Silicon		0.10% to 2.00%
		Chromium		0.50% to 26.0%
		Nickel		0.10% to 25.0%
		Molybdenum		0.040% to 9.50%
		Copper		0.030% to 4.0%
		Vanadium		0.03% to 2.50%
		Cobalt		0.010% to 8.50%
		Titanium		0.050% to 1.0%
		Tungsten		0.050% to 18.00%

Vivek Vardhan
Convenor

N. Venkateswaran
Program Director

Recognition by MNC & Inspection Agency

TCR Advanced is one of the select few testing laboratories in India to be on the approved vendor list of various MNC, public and private limited companies including Bharat Heavy Electrical Ltd., Nuclear Power Corporation of India Ltd. (NPCIL), Larsen & Toubro Ltd. (L&T), Engineers India Ltd. (EIL), Toyo Engineering India Ltd., Oil & Natural Gas Commission (ONGC), Bhabha Atomic Research Centre (BARC), Vikram Sarabhai Space Centre (VSSC), Department of Defense, DGS&D, Indian Railways, Mumbai Municipal Corporation, Department of Telecommunications, Electronic Corporation of India Ltd and others.

TCR is also approved by several international third-party inspection agencies including Halliburton, Schlumberger, Wartsila, American Bureau of Shipping (USA), Bureau Veritas (France), Lloyds Register of Shipping (UK), Det-Norske Veritas (Norway), SGS (India) Ltd. Indian Register of Shipping, Mercantile Marine Dept, Bureau of Indian Standards etc.

ABOUT US
OUR MANAGEMENT TEAM

TCR demonstrates a "one team" attitude that is reflected in its leadership in all practices and offices across TCR. TCR's strength lies in its people. They have driven individuals who work in teams with cutting-edge technologies set in an environment of transparency to deliver pragmatic action. The teams constantly re-engineer themselves to be more responsive to customer needs by identifying challenges and facilitating solutions that promote growth and deliver exceptional results for their clients, their communities and their people. Meet our exceptional talents by reading their profiles below:

A LATE SHRI VIRENDRA BAFNA, *Founder and Visionary*

Late Shri. V.K. Bafna was founder of TCR Conglomerate with TCR Engineering Services, Mumbai as its flagship organization. He was visionary with sound material sciences experience, strong business acumen and relentless sincerity, TCR Advanced matured under his able guidance. With clear sense of purpose and urgency, 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 had introduced innovative methods for Corrosion Studies, Non-Destructive Testing and was a pioneer in showcasing the advantages of XRF-based positive material identification to the industry.

Mr. Bafna, was a gold medalist from the University of Indore and had 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. Mr.V.K. Bafna was 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 was 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. TCR group companies progressed and grew under his able guidance.

B PARESH U. HARIBHAKTI, *Chief Failure Analyst and Managing Director*

Committed to driving innovative ideas while implementing pragmatic solutions to transform organizations, Paresh has been the catalyst for TCR Advanced's global reach. An acclaimed author, industry expert, a sought after mentor and coach to young metallurgists, Paresh is widely recognized for his passion and expertise.

Paresh Haribhakti has been at the helm of TCR Advanced Engineering Services(a TCR Engineering Services partner company) since its inception. He is a pioneer in promoting in-situ metallography, has solved more than 5000 industrial problems and is an acclaimed boiler tube failure investigation expert.

Paresh has authored 'Failure Investigation of Boiler Tubes: A Comprehensive Approach' and has the rare distinction of being published by ASM International, USA.

He has been driven to build an organization that is deeply committed to making a real difference by solving complex problems and making meaningful progress. He has worked on many complex metallurgical challenges and Failure Analysis assignments across various industries with one purpose: to deliver measurable results.

Under Paresh's leadership, TCR Advanced has grown in scale and diversity. His business success is driven by ensuring that the client is at the core of everything. Combining deep expertise with a clear understanding of client needs, he consistently attempts to deliver business value to his clients. These underlying tenets drive the overall culture of speed and excellence at TCR advanced.

Paresh has a post-graduate in Materials Technology from M.S. University. He has contributed to a number of leading metallurgical and engineering journals, as well as given presented papers at several conferences across the world. An active leader not only in the business world but in the community as a whole, Paresh's accomplishments are numerous. He is the founder member of Metallography Society of India and is an active member of the Institute of Engineers, Institute of Foundry Man, Indian Institute of Metals and Indian Institute of Welding. Paresh is passionate about knowledge sharing and believes that it promotes active learning. His commitment to training led him to create 'TCR Evolve', a learning academy for aspiring and existing professionals to hone their skills.

C ROHIT BAFNA, *Director Global Sales*

Passionate about building and transforming businesses, driving innovation, coaching and building high-performance teams, Rohit has been the powerful force behind the TCR's global presence. His sound leadership, boundless energy, exemplary foresight, and innate ability to bring out the best in people around him, gives him an exceptional edge over his contemporaries.

He wears several hats with utmost elan and has the unique ability to see the big picture. Under his leadership, brand TCR undertook a transformational digital initiative in the late 1990's on an ambitious scale that was unseen and unheard of in the world of material testing.

From being the pioneer of web presence before the advent of online business to preparing for the future by building an online community on social media, he has done it all with astonishing impact on the ecosystem. A focused strategic intent, paired with a hands-on-approach makes him an exemplary leader.

Several prestigious clients that have trusted TCR to carry out material testing and quality assurance services have been successfully secured by Mr.Rohit including Caterpillar, Aventech, Elliot Company, Komline-Sanderson, Constar, Xalloy, Sys-Concept and the US Army. Mr. Bafna has the cost and technical responsibility for the execution of the specific contract(s), including devising the planning, directing, and coordinating of project activities to ensure that project objective are accomplished within the prescribed time and funding parameters. Where sub-contracts are required, Mr. Bafna manages the development of specifications, statements of work, evaluation criteria, and requests for proposal. Mr. Bafna works with the material testing laboratory and engineering consulting divisions to analyze proposals with respect to cost/risk/quality, lead source selections and negotiation teams and monitors subcontract costs, schedules, and technical performance. He has undergone extensive training on Ultrasonic Testing using Time of Flight Diffraction (TOFD) at Olympus in Quebec, Canada.

Previously, Rohit held senior leadership roles in the areas of International Business Development with Mphasis and Verizon from 1996-2008. Based out of Washington DC, he implemented multiple Techno + Customer-Centric Business solutions for clients including Chase, ABN AMRO, Singapore Airlines, Novartis. He was known for his in-depth understanding of customer pain points and translating that into magical solutions.

D GOPUL PATEL, *General Manager (Technical)*

As a postgraduate from Sardar Patel University, he brings extensive knowledge of Vacuum Technology and has worked as a scientific officer at the Department of science and technology sponsored research center. 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 has worked extensively in the field of microscopy. He has been trained for the operation of the Electron microscope at PHILLIPS, The Netherlands and Pemtron, Korea.

Gopul has also handled India's First Environmental Scanning Electron Microscope with EDAX analyzer for more than five years. He is qualified as NDT level II in M.T., P.T., U.T., and E.T and is responsible for the establishing & implementing management system at TCR Advanced and its functionality. He is actively involved in establishing new testing facilities at the lab as well as on site. Gopul has played an instrumental role in establishing custom designed web-based sample management system for handling sample flow in the laboratory.

E KETAN UPADHYAY, *General Manager (Reliability)*

Ketan brings an experience of 23 years in the field of NDE, Acoustic emission techniques, Vibration measurement, and signature analysis, Failure Investigations, microstructure interpretation, Scanning electron microscopy and digital imaging system. He has worked as a metallurgist at few of India's largest fertilizers and petrochemicals complex, GSFC Ltd.

Having done B.E. (Metallurgy) from M.S. University of Vadodara, he is responsible for fabrication inspection, providing welding procedures for maintenance and relevant heat treatments, troubleshooting against organic and inorganic corrosion and microbial-induced corrosion.

He is a qualified level II for Acoustic Emission testing (IISC Bangalore), Vibration Analyst VT-II (Entec IRD) and Ultrasonic Flaw Detection (EEC Mumbai) techniques. He is actively involved in Plant reliability Engineering and risk-based inspection projects for different components such as heater piping, reactors and static equipment of petrochemical and refinery industries. He is well familiar with API/ASME/ASTM/JIS codes and ASM literature. His association with TCR Advanced Engineering strengthens the Remaining Life Assessment, Failure Investigations, and Advanced Non Destructive Examination projects. He has played an instrumental role in developing an automated reformer tube inspection system (ARTiS) at TCR Advanced.

F KAMLESH RANA, *Senior Manager (Testing)*

Mr. Rana is a having vast experience of fabrication and forging fields. He holds a Diploma in Mechanical engineering and has worked extensively in pipe manufacturing and forging industries. He has more than 20 years of experience. He has headed the quality and assurance department of various forge shops. He is a qualified internal auditor for ISO 9001 and has handled API audits. Mr. Rana is in-charge of chemical and mechanical testing at TCR.

ABOUT US
OUR ADVISORY PANEL OF EXPERTS

TCR has assembled a strong team of external experts who will provide technical leadership to the company. TCR Advanced draws on this experience to provide the best solutions for their clients The highly talented team of experts includes:

1 DR. RAJENDRA KUMAR

Dr. Kumar is a world-renowned metallurgist of our country. He is a doctorate from the 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. He is the recipient of Metallurgist of the Year Award for the year 1966.

2 DR. P. B. JOSHI

Dr. Joshi was a professor in the 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”.

3 DR. K. BABA PAI

Dr. Pai was the former Head of the Department of Metallurgical & Materials Engineering Faculty of Technology & Engineering, M.S. University. He is a Ph.D. from IIT Mumbai. He is having more than 29 years of experience in the Educational field. He began his career as a lecturer in 1989 and became a professor in the Metallurgical and Materials Engineering department. Under his able guidance, more than 4 Students were awarded a PhD. He has more than 90 national and international publications in reputed journals. Dr. Pai is actively involved in providing Testing and industrial consultancy assignments for many industries of Gujarat.

ABOUT US

OUR ADVISORY PANEL OF EXPERTS (CONT.)

4

JAGDISH BAAD

Mr. Baad is Bachelor of Technology in Metallurgical Engineering with First Class honors from IIT, Mumbai. He has working 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 Turnkey projects related to Foundry Mechanization, Quality Assurance and Product management of critical castings for the turbine, material handling and wears resistance applications. Some of them are first of its kind. For the last 12 year, he has been running an independent consultancy, related to TQM-Product Management of Castings & Forgings and metallurgical related turnkey projects. Mr. Baad is well versed in kaizen, Edward Debono /Osborn techniques in creativity management. Energy audits related to metallurgical processes. He is a 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.

5

PRAKASH BHRAMBHATT

Mr. Brahmbhatt is Ex-GM inspection dept. of M/s RIL Erstwhile IPCL. His area of responsibilities during his association with RIL includes inspection & maintenance from health assessment & reliability/integrity angle for LDPE, PPCP, PBR-I, PBR-II, PP-IV, LAB, EG plants. Since last 32 years he is working in the field of fabrication, maintenance welding, inspection, testing, up keeping, metallurgy/material science, corrosion, health assessment, reliability & integrity monitoring of piping &static equipment in the petrochemical process plants. Familiar with all different type API/ASME/ASTM/ASM etc. codes & standards in respect of inspection, NDT, welding & material of construction used in such plants in above areas/fields. He was appointed as a faculty on inspection &testing, metallurgy, welding in process plants in training center of IPCL/RIL-VMD. He was also a competent person for pressure vessel testing for GFA compliance.

6

DR. MUKESH PANDYA

Dr. Pandya is Ex-DGM (Research) from Gujarat State Fertilizer Company (GSFC) Limited, India's premier fertilizer company. He has a Ph.D. in corrosion from Gujarat University. He has more than 25 years of experience in corrosion evaluation, materials selection, failure investigation and online corrosion monitoring in chemical, petrochemical and fertilizer industries. He possesses in-depth knowledge of various forms of corrosion. His is having vast experience

in conducting laboratory and field experiments on corrosion measurements as per national and international standards. He has been a member of National Association of Corrosion Engineers (NACE) the USA, for 8 years. He has provided consultancy services to many industries in India and also successfully carried out international collaborative projects with M/s Avesta, Sweden, M/s Krupp VDM Germany and M/s Cormon UK.

7

HEMANT PRADHAN

Mr. Pradhan is a Mechanical Engineer with over 34 years of experience in design, detail engineering services, projects, inspection, mechanical construction, procurement, estimation, etc. for fertilizer and petrochemical plants and projects. His major experience field of expertise has been designing, detailed engineering, troubleshooting of fertilizer plants like ammonia, urea, DAP, ASP, AS, phosphoric acid, sulphuric acid, etc.; petrochemical plants like Caprolactam, Melamine, Nylon-6, and utility/co-generation/ boiler, water treatment plants. He is also involved in engineering jobs for installing new projects, de-bottlenecking, capacity augmentation, plant modifications, the addition of new sections; troubleshooting; estimation; procurement; inspection; expediting for more than 30 years. He has participated in design conferences at international and national level with process licensors/ detail engineering firms like M/s Enco, Switzerland; M/s INCRO SA, Spain; Tunisian Joint Venture, Tunisia; M/s Schmidt & Clemens, Germany M/s Davy Powergas, M/s Uhde, M/s Linde, at India. He has vast experience in executing troubleshooting jobs in major plant equipment like Primary Reformer, Air Pre-heaters, Waste Heat Boilers, Various Heat Exchangers, Isothermal Shift Reactor, Urea Reactor, High-Pressure Decomposer, high-pressure plunger pumps & their discharge piping, Contact Furnace, Decomposer, Sulphur combustion furnace boiler, etc. Mr. Pradhan has headed various departments like Inspection, Mechanical Construction, Workshop, and Phosphoric Acid and Fiber Unit plants. He also has experience in dealing with statutory authorities and third party inspection agencies.

8

AWDHESH KUMAR SINGH

Mr. Singh is a power sector professional having more than 42 years of professional experience. He holds Bachelor's Degrees in Science & Engineering and Master's Degree in Technology from Indian Institute of Technology, Delhi. He started his professional career in the year 1975 in Steam Turbine Engineering Department of BHEL, Hardwar. Shri AK Singh received his initial training in the area of design of steam turbine blades at Muelheim Works of M/s Kraft Werk Union in West Germany and subsequently in the mid-1990s worked on an R&D project on "Design of Advanced Low-Pressure Steam Turbine Blading" with M/s Siemens in Germany. During his tenure of 22 years with M/s BHEL, he developed many Steam Turbine Flow-Path Designs which have been implemented in many 210 & 250 MW rating machines installed across the country. These machines are more efficient and are having better Heat Rate which had been validated to the

satisfaction of respective customers. In 1996, Shri AK Singh joined the Power Generation Segment of M/s Asea Brown Boveri Ltd. at Vadodara in Senior Management Cadre. He received training at the Mannheim Works of M/s ABB in Germany.

Mr. Singh worked with ABB Power Generation, Vadodara as the Head of Engineering group for large utility steam turbines. He was a member of the Power Segment Technology Team of ABB India. Shri AK Singh represented ABB India as Engineering Manager on global committees formed for developing technical solutions in the area of Retrofit and R&M. He was Manager of Turbine Spare Parts Centre of ABB India. As a strategic Supply Management Initiative, he led a Cross-functional Commodity Team and established the manufacture of Industrial turbine blades at Baroda. From 2000 to 2002, Mr. AK Singh worked as a Professor of Mechanical Engineering with Sardar Patel University and Gujarat University. From 2002 to 2009, Mr. AK Singh worked with Electrical Research & Development Association (ERDA), Vadodara where he rose to become its CEO & Director. During his tenure as Director, ERDA established itself as the premier testing, calibration and research organization of the country. International Business Excellence Award was conferred on Mr. AK Singh by the International Study Circle, New Delhi for the stupendous growth of ERDA. From April 2011 to October 2015, Prof. AK Singh worked as a Senior Faculty with Power Training Institute of M/s L&T Power at the L&T Knowledge City, Vadodara. He provides technology training on Steam Turbines and dwells on the comparative features of steam turbines offered by the OEMs across the globe. From December 2015 to February 2017, Shri AK Singh was associated with M/s L&T-Sargent & Lundy Limited, Vadodara as Principal Consultant for providing consultancy in the domain of Residual Life Assessment, Renovation & Modernization, Condition and Asset Management of Thermal Power Plants. Mr. Awadhesh Kumar Singh is presently associated with M/s TCR Advanced Engineering Pvt. Ltd., Vadodara.

OUR WORK
MARQUEE CLIENTS

TCR Advanced Engineering believes in establishing long-term, strategic relationships with customers as opposed to short-term, opportunity-based engagements. TCR has had the chance to serve over 3500+ customers across multiple industry verticals and has a long-standing track record of delivering quality assurance services to some of the best-known refineries and organizations in the field of oil and gas chemicals, electronics, construction, power generation, automotive, defense, aerospace, mining, pharmaceutical, biotechnology, manufacturing, process industry and all of the major public sector verticals.

CASE STUDY
KEY PROJECTS

A. INLAND ENGAGEMENTS

Metallurgical Damage assessment- Provided consultancy Asia's largest grass root refinery, RIL Jamnagar, India for damage assessment work during a fire incident in VGO-HT2 Plant

TCR Advanced was engaged to assess the metallurgical integrity of different components and equipment including pipelines, flanges, Heat Exchangers, Reactors, etc. to judge the extent of damage by microstructure examination at Reliance Industries Limited Jamnagar at the time of major fire incident of VGO-HT2 plant. Total 1200 microstructures were prepared and evaluated at the site to judge go no go condition of the refinery components. The dedicated team of TCR Advanced has worked round the clock and completed the marathon assignments in the record 15 days time. The metallurgical experts from TCR Advanced had provided the judgments based on our vast experience of evaluation of different Refinery components and failure investigation related expertise.

To derive at critical decisions simulated heat treatments conditions were done in the laboratory to generate the identical microstructural conditions pertaining to weld and other low alloy steel material exposed to an accidental fire. Data on mechanical properties were generated vis-à-vis damaged conditions and risk-based assessments were made to judge the integrity of the different components. The judgments on affected and unaffected structure were made by exercising the knowledge on location selection which is of paramount importance during damage assessments job.

Health assessment of entire Hydrogen plant for Godrej Industries limited Valia, Gujarat

We had a bend failure in our hydrogen line in 2006 and we contacted TCR Advanced Engineering Pvt. Ltd., Vadodara to conduct an in-depth root cause failure analysis. The work carried out by the dedicated team of TCR helped Godrej Industries to take necessary corrective actions for the second-hand plant of "Hydrogen Generation" procured from England. The entire plant was thoroughly assessed by NDT and metallography with Health Assessment approach by TCR. The components included Reformer section, Pigtails, SS pipelines /Carbon steel/Alloy steel pipelines Heat exchangers, etc. TCR's assessment approach is scientific by knowledge of the anticipated degradation mechanism of different components with organized teamwork by trained and qualified manpower.

TCR also provided services on Remaining life Assessment of aged components by destructive analysis and Repair Weld Procedures of aged Incoloy 800H header joints by TCR Advanced.

CASE STUDY
KEY PROJECTS

A. INLAND ENGAGEMENTS (Cont.)

Remaining life assessments of Power and Utility Boilers of Hindustan lever limited

Total 8-Boilers of different capacities were evaluated for their remaining life by detailed metallurgical approach. Based on the operational and design/construction of the boiler their damage mechanisms were anticipated. With NDT, In-situ metallography and chemical analysis of Boiler feed water/scales and corrosion products vis-à-vis metallurgical degradations under microstructure were compared. The safer remaining life was evaluated based on microstructure degradations and thickness measurements criteria's. The recommendations were made to operate these boilers for safe and efficient use. TCR Advanced has very rich data based on different power boilers which are operated from 10Mw to 250 MW capacity. TCR Advanced is also engaged by different RLA agencies to undertake metallography evaluation which is most critical in Life assessments.

Provided repair weld solution on used Incoloy 800H Header of Ammonia Plant of Gujarat State Fertilizers and chemicals limited- India's largest Fertilizers and Petrochemical complex

M/s GSFC, Baroda has Fertilizer & Chemical Plants at Fertilizernagar, Baroda. In April-May 2007, TCR Advanced Engineering P Ltd was apprised about the loss of weldability in the Tee components located between hot & cold headers of Primary Reformer, of Ammonia-IV plant. It was a dire need to formulate the welding procedure to achieve crack-free weld joint, to put back the plant in operations at the earliest. Considering fundamental inferences from microstructure degradations and reviewing of various reports of analysis/ tests and discussions, the most probable reason for the loss of weldability is judged with an objective to provide a solution to improve the weldability and formulated weld procedure. Prima facie, the probable reason for loss of weldability seems to be associated with carbide coarsening & their agglomeration under the microstructure observations. Also, carbide alignment was noticed under the influence of complex stresses of operation. As per the fundamental understating if the carbide precipitations could be re-dissolved in the matrix by sending important alloying elements like Niobium and Chromium back into the solution. An elaborate repair welding procedure is suggested in the report that principally accentuates on carrying out "Solution Annealing Heat Treatment". Finally, the effectiveness of solution annealing heat treatment has to be assessed to propitiate proper procedure for repair welding purely on metallurgical considerations which can only mitigate the grave situation as a result of post-weld cracking that had put the production at grinding halt.

Consultancy to provide weld procedure to meet with stringent quality test requirements of snamprogetti specification for Urea Plant for a fabricator

As a requirement, to be used in a Urea plant the M.S. plate is to be overlaid with stainless steel welding. The base material is SA 516 Gr. 70. The weld over lay is of 6 mm thickness. As per the Snamprogetti specification, the chemical composition on the surface of over lay should be 2 RE69, which is equivalent to 310 MoLN. The essential requirement is that the surface shall be free from deleterious phases like carbides, delta ferrite and sigma phase, whose sensitivity for deterioration in the presence of Urea is extremely high.

Several prototype trials were conducted at GMM Pfaulder Ltd Works. All of them were failing in IGC test as per ASTM 262 Practice 'A'. In view, of the critical nature of the requirement, the matter was referred to TCR Advanced Eng. Pvt Ltd. They suggested different welding procedures having varying parameters. The aim was to achieve faster cooling rates with low heat inputs. IGC and metallography were carried out on all the weld samples. The suitable welding procedure has been recommended that is passing IGC ASTM 262 Practice 'A' and showing freedom to sigma phase precipitation which cleared the most stringent corrosion test requirements.

In addition to this, an evaluation was made to find out the effectiveness of the SR treatment which is done after the first overlay over carbon steel tube sheet. The approach of the micro-hardness profile was adopted. These tests were conducted on a sample having a single layer and the one accepted in the IGC practice A as per ASTM 262.

Crevice Corrosion & Electrochemical Study for ITER- India

As a service partner company of TCR Engineering Services Pvt. Ltd., TCR Advanced have undertaken the electrochemical study of the prestigious work which is useful for materials selection and evaluation for shielding materials of Boronated stainless steels. Electrochemical studies have been performed under the pressurized system and using stainless steel autoclaves and at different temperatures. It provided the comparison with different grades of materials with respect to pitting tendency under the stipulated chemistry. The project is undertaken by the consortium of 8 countries as headquarters at France. TCR got the opportunity to work under the ITER India.

Material selection for Corrosion service at Solvay

M/s Solvay Specialties India Private Limited is manufacturing products such as Veradel and PEEK. There were frequent incidences of finding corrosion of varying degree in reactors & vessels used for the production. This was affecting the Quality of products produced by the plant. In view of the seriousness of the matter, TCR Advanced was approached to carry out laboratory accelerated corrosion tests on different samples at varying conditions. The purpose of the exposure tests was to find out the suitability of SS 304, SS 316L Inconel600, Hastelloy C276, SS 2205, SMO 254 and Al 6XN materials for defined process conditions in welded and as received conditions in the condition of the actual reactor and monitor them regularly by destructive as well as weight loss method.

CASE STUDY
KEY PROJECTS

A. INLAND ENGAGEMENTS (Cont.)

This exercise is done to evaluate the different materials of construction in the actual process environment to decide for suitable material for the given process.

RLA Study at Reliance Patalganga plant

The M/s. Reliance Industries Limited, Patalganga plant was commissioned in the year 1987. It deals with the production of various commodities, including nylon and rayon. Some of the products Manufactured in Patalganga plant are

- Para-Xylene (Px) from raw material, Naphtha
- Purified Terephthalic Acid (PTA) from raw material, Para-Xylene
- Polyester Filament Yarn (PFY) from raw material, PTA & MEG
- Polyester Staple Fibre (PSF) from raw material, PTA & MEG
- Linear Alkyl Benzene (LAB) from raw material, Kerosene - n paraffin

The production of the above needs multiple process handling and importantly heating furnaces. As the plants are aged, it is the need of time to assess various heaters for their safe operating life. The company has decided to carry out Remaining Life Assessment (RLA) of these heaters and to continue them in service. TCR has successfully carried out the RLA of 4 heaters in the plant.

Fitness for service - Isomerization reactor of refinery

An accidental temperature rise of 710 °C had occurred in the isomerization reactor which was designed up to 350 °C temperature. The reactor is the 20-meter height with 3 m diameter used in hydrogen service. A team of experts from TCR decided the approach based on the API 579, ASME FFS-1. All the anticipated damage mechanisms were identified as a vis-à-vis future operational requirement. The plant had limitation not to open the reactor in view of platinum catalyst inside the reactor. The team TCR decided to take this challenge and detailed NDT approach was formulated by in-house NDT experts. The assessment was done with thorough metallurgical inputs as well as simulation study on the reactor material. All mechanical properties were evaluated with degradation in view of temperature exposure. With the application of AUBT and ToFD techniques the reactor was thoroughly investigated. Based on the testing, assessment and FFS calculation the reactor was declared fit for service. The reactor is in use without any problems that have saved huge economic losses to the company.

Fitness for service – VGO reactor and exchanger

HMEL experienced a major fire on VGO reactor and exchanger. The evaluation job of damage assessment was entrusted to TCR Advanced. An immediate mobilization was undertaken by TCR.

A. OVERSEAS ENGAGEMENTS

Damage assessment of hydrocrack reactors of refinery Baiji, Iraq: Total 6 hydro cracker reactors manufactured by Kobe Steel Japan had developed blisters at the SS 347 weld overlay form Inside. The health assessment approach was undertaken with detailed microstructure examinations form OD /ID with different etching technique to find out the extent of degradations in terms of sigma phase and carbide precipitations and other degradation due to prolonged use. The reason for blisters was identified and the inputs were provided to repair welding of the Reactors.

Metallurgical input for a health assessment to procure second-hand equipment from Taiwan for Gujarat Flurochemicals Ltd: The high-grade Inconel 600 Reactor were to be imported from Taiwan by GFL. TCR Advanced was deputed to judge the health of these Reactors and recovery columns by undertaking various NDT Test. The health of this equipment was judged to provide the final decisions on procurements which helped the company to not only get the writhe equipment by finding out the safe useful life.

Remaining life assessment for a package Boiler for Bangladesh Unilever limited: RLA was conducted for package boiler at Unilever Bangladesh limited and certain tubes were asked to replace.

The ball mill assessment at Kuwait Cement company, Kuwait: TCR Advanced was approached for metallurgical assessment of cracks observed on the Ball mill, a piece of very critical equipment, for a cement mill. A detailed report was subjected to the reasons of carking by undertaking the NDT approach of assessments.

Failure investigation of an underground pipeline of NG: After the hydro test, the pipeline was filled with liquid nitrogen by mistake and the entire pipeline was burst open from the underground region. Root cause analysis was done to find out the reason for failure and remedial measures were suggested to find out the health of the entire pipeline.

Shell Gas Terminal, Sri Lanka: Under the accidental attack from the terrorist, an LPG plant was damaged by the splinters and bullets. TCR Advanced had undertaken detailed metallography and WFMPI study on the bullet hit regions and the extent of damage was identified. A highly skilled team from TCR Advanced had visited the site and conducted an onsite evaluation on the LPG bullet. A detailed report was submitted along with observations.

Natore Chemicals, Nigeria: A client from fertilizer industry experienced a cracking problem at the bottom portion of the atmospheric storage tank of anhydrous ammonia. On-site examination along with a sample was brought to the laboratory for root cause failure investigation. The root cause of the problem was identified as corrosion in the bottom part during the idling period of the plant. The entire plant was kept out of service for about 10 years during that time water got accumulated at the bottom and provided the preferential corrosion from the HAZ region which appeared as crack. The client was M/s Proplant USA.

Omaniffco, Oman: TCR Advanced supported the client in solving a problem of repeated leakage in the ammonia discharge line with a pipe material of ASTM A333 Gr. 6 and failed from the weld joint. The pipe sample was received in the laboratory for root cause failure investigation. A detailed metallurgical approach revealed the cause of the problem as vibrational stresses and prevailing corrosive coastal atmosphere.

SWCC, KSA: As backend laboratory, TCR Advanced provides the supports to TCR Arabia by undertaking Boiler RLA and health assessment jobs. Failure investigation and Remaining life assessment jobs are undertaken for power generation Boilers, high temperature, and high-pressure components.

SABIC, KSA: Metallurgical root cause failure investigation are done from TCR Advanced to provide a variety of plants having chemical, petrochemical fertilizers and refinery equipment.

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CASE STUDY
FAILURE INVESTIGATION & ANALYSIS

I. PRIMARY SUPER HEATER R-4 ZONE TUBE OF A 140 MW BOILER

The MOC of the tube is TU 15 CD 205. The service life of the tube is 7 years before failure. The steam temperature & pressure of the tube are and 450°C and 140 kg/cm2 respectively. The tube has OD 63.5mm and ID 5.5mm. Tubes are located horizontally with flue gas passes vertically.

1. Scanning Electron Microscopy (SEM): Upon SEM examination conducted by engineers at TCR, it revealed the presence of inter-granular cracks and the presence of numerous creep cavities at the grain boundary. Presence of micro-cracks is observed more towards the outer surface and nearby crack region. The severity of cracks and cavity reduces when we move away from the main crack.

2. Microstructure Examination: Crack displayed inter-granular nature of propagation with many small parallel cracks adjacent to the main crack is observed. This examination was done at the TCR Engineering laboratory using a Leco Image Analyzer at 300X.

In the present case, the failure of the tube seems to have occurred due to long term overheating, above allowable design temperature, could be due to higher velocity of flue gas at this region or impingement of flue gases on tube surface facing flue gas or improper steam flow.

II. RADIANT COIL OF A CRACKER FURNACE H-130 REFINERY

In a bottom-fired furnace tube failure have experienced service of 14 months against the normal life of 6 to 7 yrs. MOC of the tube is 25 Cr/35 Ni. The average tube metal temperature remains between 1000 to 1100 °C temperatures. As per the manufacturer data, these tubes are designed for 1150°C. The pressure inside the tube is 1 kg/cm2g.

1. Scanning Electron Microscopy (SEM): SEM analysis conducted by a failure investigation team from TCR Engineering revealed a progressive nature of the fracture, especially towards the OD side. However, a majority of the evidence on fracture surface was masked under heavy scaling, which is generally expected under such service.

2. Microstructure Examination: The crack is associated with carburizing more so at the outer surface with decreasing the depth of carburizing toward ID. Another important evidence of crack originating outer diameter and progressing towards ID. This magnification was done at the TCR Engineering laboratory using a Leco Image Analyzer at 300X.

In the present case, the failure of the tube has occurred due to localized overheating, which reduced ductility and failed under operational vibrations. TCR recommends looking into the possibility of development of high temperature at the time of decoking operation.

CASE STUDY
FAILURE INVESTIGATION & ANALYSIS (CONT.)

III. 8TH STAGE BLADE OF A STEAM TURBINE

After 8-years of useful service life, a steam turbine was reported to have been working with abnormal vibrations. When the turbine was opened five blades of the 8th stage were found in broken condition from the root. Steam turbine operates with the steam temperature of 770°F & working pressure at 568.3 Psi

1. Scanning Electron Microscopy (SEM): Fracture surface kept under SEM show multiple origins of the fracture and clearly shows the progressive mode of failure. Fig. suggest rubbing of the metal surface where the failure had occurred.

2. Microstructure Examination: Microstructure on the cross-section of the blade and showing the defect of deformation. At higher magnification crack shows branching nature progressing in the forwarded direction i.e. perpendicular to the central axis seems to have followed the trans-granular path.

Failure of 8th stage blade has occurred due to corrosion fatigue, initiated at the most stressed area. Only one blade was submitted for investigation. It is difficult to pinpoint which blade failed first.

IV. SAC PLANT PIPING GOING TO V-801

In a Sulphuric acid concentration plant, as a part of the process, condensate is chilled in a heat exchanger. The line, which is connected from heat exchanger (E08-3) to vacuum pump, one elbow was reported to have leaked and needed replacement. Severe corrosion was reported inside the replaced pipeline within 10 days of operation. The extent of corrosion was so severe that the entire replaced pipeline reduced to paper thickness with punctures. The pipeline is operating with 1 to 2% H_2SO_4, 0.5% HNO_2 and 0.6 to 1.0 % HNO_3 at 10 to 20°C temperatures.

1. Low Magnification Examination: Low magnification examination was done by the failure Analysis and Investigation team from TCR Engineering to find out the corrosion characteristics. Internal surface of pipe, weld, and elbow showed severe corrosion on the pipe. The close-up view of the corroded surface inside the pipe show effect of general corrosion and flow pattern. Leakages observed in the form of openings between weld and pipe.

2. Microstructure Examination: Uniform dissolution at ID is observed under microstructure examination at a magnification of 300x at the TCR Engineering laboratory in India.
The fluctuation in Nitric acid concentration did not allow to stabilize passivity on newly fabricated pipeline resulted in severe corrosion

V. INTEGRAL PINION SHAFT OF A CEMENT MILL

Premature failure of integral pinion shaft was reported a cement mill. The shaft failed after a service life of approximately 15,000 hours (625 days) against the intended design life of 30 years. The shaft is made from EN 10083-1 (1991) 30CrNiMo8 with through hardened and tempered to achieve 310-335 BHN. The shaft rotates at 133 to 134 RPM. The failure of the shaft noticed in the form of cracks. Cracks were observed at 45° to the longitudinal axis of the shaft.

1. Low Magnification Examination: Fracture surface at thread region shows relatively flat fracture whereas further fracture shows brittle nature with chevron marks. Fracture surface below the thread region at keyway disclosed multiple ridges with relatively coarse fatigue striations.

2. Scanning Electron Microscopy (SEM): SEM done by TCR Advanced Engineering reveal inter-granular fracture with inter-granular cracks. A fracture is brittle and shows inter-granular mode. Presence of fine cracks is observed.

3. Microstructure Examination: Microstructure examinations at various sections revealed that the general condition of the shaft is in a hardened and tempted condition. Further microstructure revealed presences of inter-granular cracks. The cracks are moving on prior austenitic grain boundaries and are observed filled with oxides. Presence of oxide inside the cracks is the most important evidence in the present case. This was done at a magnification of 560X at the TCR Advanced Engineering laboratory.

TCR Advanced Engineering concluded that the shaft failed due to pre-existing Heat treatment cracks under operational load.

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The TCR team operates globally across different regions and countries. Please reach out to them for any queries or assistance via email or phone

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