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ASSET INTEGRITY

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THE MAGIC

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3
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TCR ADVANCED

FOUNDING VISION:
PRINCIPLES OF PRECISION, TRANSPARENCY AND RELIABILITY

TCR LEGACY

TCR has a growing global presence and is rooted in behaving ethically in all their interactions-with their employees, partners and their customers.

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Historical Milestones

TCR Engineering Services was incorporated in 1973

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 and has many 'firsts' to its credit. It has become a thought leader in the industry because of its pioneering work.

Our journey started as a disruptor for end to end inspection services to a being global leader

.

2018
TCR Qatar is established

2010
TCR establishes an alliance - Malaysia

2007
TCR Engineering enters into a JV in Saudi Arabia to establish TCR Arabia in Dammam

2006
TCR Engineering opens TCR Kuwait, its first international office in Kuwait

1999
TCR Engineering establishes **TCR Advanced** in Vadodara to offer research and consulting solutions for plant management

1980
First to add a chemical analysis spectrometer in India

1975
First to install 100T Tensile Machine in India

1973
TCR Engineering Services Company Founded in Mumbai



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

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TCR CREDIBILITY: Accreditation & Approvals

TCR is among the few leading & independent laboratories that meet the international standards of quality, accredited by reputed global agencies

CERTIFICATIONS

ISO 17025 ACCREDITED LABORATORY

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सत्यं शिवं सुन्दरम्

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Drexel UNIVERSITY

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ASM

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INDUSTRY VERTICALS
FERTILIZER

Since 2012, TCR has provided metallurgical & engineering consulting to QAFCO for effectively assessing failure damages that occur in the reformer section, ammonia converter, ISR (isothermal shift reactor) and RGC (reform gas cooler).

TCR has undertaken several studies across failure in reforming section (reformer tubes) and has expertise in damage specific NDT to discover corrosion, erosion corrosion, cavitation, pitting, creep, IGC related damage mechanisms present in the plant.



MARQUEE CLIENTS
Industry: Fertilizer

GNFC

Oman India Fertiliser Co.

QAFCO
QATAR FERTILISER COMPANY

GUJARAT STATE FERTILIZERS & CHEMICALS LTD.

Zuari Agro Chemicals LTD

IFFCO

MCF
Mangalore Chemicals & Fertilizers Limited

Rashtriya Chemicals and Fertilizers Limited

INDORAMA
ELEME FERTILIZER & CHEMICALS

We sincerely thank TCR team for carrying out failure analysis in a very detail, systematic, methodical and scientific manner. The analysis not only highlights mode and various reasons of failure, but it also throws light on the operational aspects, which might have played an important role in the initiation and which might have been the main cause of the failure. This aspect will help us in taking preventive actions for future.

M Y Joshi, Manager
GUJARAT NARMADA VALLY FERTILIZERS COMPANY

Global Contracts

Client	Year
Long Term 5 Year contract with Saudi Aramco, Qchem	2018- Ongoing
Plant Health Study for SABIC for a 5 year Contract	2013-Ongoing
Preferred vendor for failure analysis at Reliance Industries	2002- Ongoing
5 year contract for Remaining Life Assessment studies at Qatar Fertilizer Company (QAFCO)-renew every five year	2013-2023
Integrity for GE for Power Plant in Kuwait, Boiler Integrity in Doha East Power Station for MEW in Kuwait	2012
Contract for failure investigation, RLA and FFS in Fertilizer Industry :GNFC,CFCL,GSFC,RCF,ZUARI, MATIX ,IFFCO, COROMANDAL,NAGARZUNA, FACT	Numerous industries in India

KEY CLIENTS

KEY PROFILES

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KEY INDIA CLIENTS



KEY GLOBAL CUSTOMERS



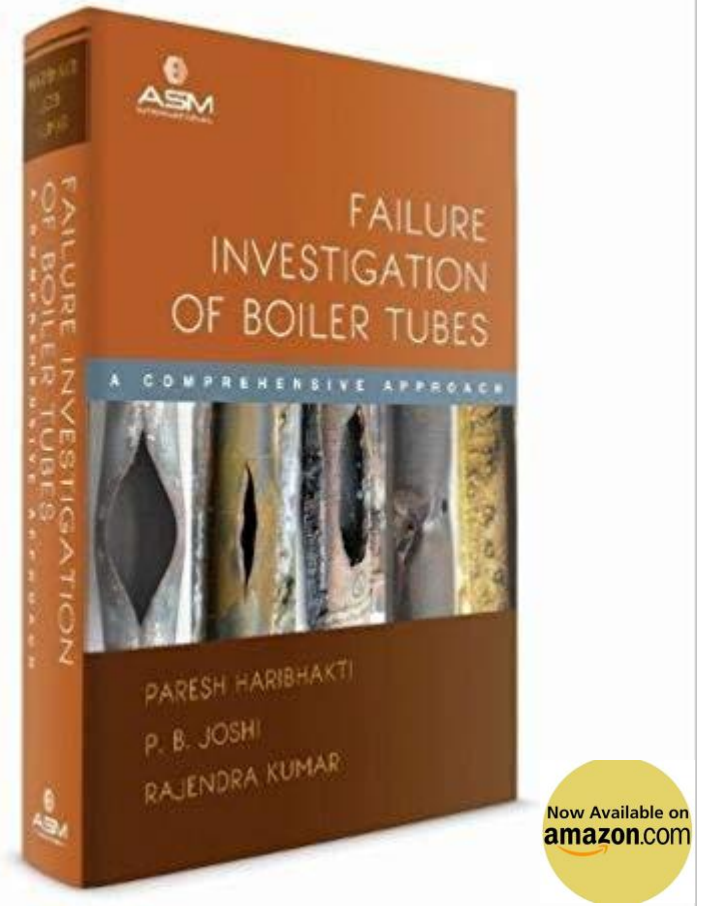
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BOOK ON BOILER TUBE FAILURES

INDUSTRY CONTRIBUTION

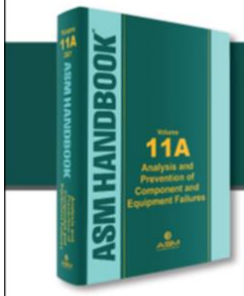
TCR's Managing Director and Chief Metallurgist Paresh Haribhakti has written an award winning book on Boiler Tube Failures and associated damage mechanisms with detailed case studies

Published by ASM International (USA) and available at various university library and engineering companies as reference study material.



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ASM HANDBOOK, VOLUME 11A:
ANALYSIS AND PREVENTION OF COMPONENT AND EQUIPMENT FAILURES
VOLUME EDITORS: BRETT A. MILLER, ROCH J. SHIPLEY, RONALD J. PARRINGTON, AND DANIEL P. DENNIES

The new *ASM Handbook* Volume 11A is a valuable resource for failure analysts, engineers, and technical personnel who are looking to identify the root cause(s) of failures and to prevent future failures.

The editors and hundreds of authors and peer reviewers undertook a wholesale revision and expansion of Volume 11 from its 2002 and 1986 editions and succeeded in producing the go-to reference for those confronted with the failure of a machine or component.

Volume 11A contains divisions devoted to engineering aspects of failure and prevention, structural life assessment methods, metal manufacturing aspects of failure, and failure analysis of metallic components.

The general principles of failure analysis are presented in the companion *ASM Handbook*, Volume 11: *Failure Analysis and Prevention*, which was published in 2021. Its divisions cover the practice of failure analysis, tools and techniques, fatigue and fracture, environmental and corrosion-related failures, wear failures, and distortion.

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ASM Handbook, Volume 11A, *Analysis and Prevention of Component and Equipment Failures*
B.A. Miller, R.J. Shipley, R.J. Parrington, D.P. Dennies, editors
DOI 10.31399/asm.hb.v11A.a0006825

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Failure of Boilers and Related Equipment

Paresh Haribhakti and P.B. Joshi, TCR Advanced Engineering Pvt. Ltd.

FAILURES IN BOILERS and other equipment taking place in power plants that use steam as the working fluid are discussed in this article. The discussion is mainly concerned with failures in Rankine cycle systems that use fossil fuels as the primary heat source. In a Rankine cycle system, the steam is generated in a boiler, followed by its expansion in the prime mover and condensation in the condenser; finally, it is fed into the boiler again. Although, many of the principles that apply to Rankine cycle systems also apply to systems using other steam cycles or to systems using working fluids other than steam.

Boilers/steam generators work on the principle of conversion of the chemical energy in fuel into thermal energy to generate steam or hot water. Power boilers using pulverized coal, fuel oil, or natural gas as the fuel are used in thermal power plants to produce steam for generation of electricity. They are very large in size and are operated at high pressure and temperature in order to produce high-pressure, high-temperature superheated steam for power generation.

The other category of boilers termed as the industrial, commercial, and institutional (ICI) boilers are relatively small in size and are used to cater to captive demand of steam or hot water for the intended application. Boilers installed in chemical industries, petrochemicals and refineries, food processing, paper, textile, and similar other industries belong to this category. Their main function is to provide steam, hot water, or electricity, depending on the nature of the requirement. Institutions and commercial establishments such as hospitals, schools, colleges, hotels, restaurants, and office buildings use boilers for generation of steam and/or hot water.

Likewise, there are boilers termed as heat-recovery steam generators (HRSGs) and kraft-recovery boilers. As the HRSG name indicates, the waste heat released by the exhaust gases or hot air from combustion processes of gas turbines, diesel engines, or other industrial processes is effectively used to produce hot water or steam to improve the process economy. The kraft-recovery boilers (also known as black-liquor-recovery boilers) produce steam that can be used in the kraft process to generate electricity or for heating purposes.

Most boiler/steam generator failures occur in pressurized components, such as the tubing, piping, headers, and pressure vessels that constitute the steam-generating portion of the system. With very few exceptions, failure of pressurized components is confined to relatively small-diameter tubing (such as the water-wall, superheater, reheater, and economizer tubes) making up the heat-transfer surfaces.

This article discusses the main types of failure that occur in steam-power-plant equipment, with major emphasis on the distinctive features of each type that enable the failure analyst to determine the cause of failure.

Power plants, by and large, make use of various nonrenewable sources of energy such as coal, natural gas, oil, and nuclear for electrical power generation, of which coal is the most common source. Approximately 40% of electricity produced worldwide is still from coal-based thermal power plants. With coal as the fuel, there are two distinct technologies used for power generation: subcritical and supercritical. Supercritical is that state of a substance in which there is no clear distinction between the liquid and gaseous phase (i.e., it behaves as a homogeneous fluid). Water reaches this state at a pressure greater than 22.1 MPa (3.2 ksi) and a temperature equal to 374.15 °C (705.50 °F). *Supercritical* is a generic term used in the power plant industry that also includes ultra-supercritical (USC) and advanced ultra-supercritical (A-USC) boiler technologies.

From a design point of view, the conventional or subcritical thermal power plants have a drum-type boiler wherein steam is separated from a nonhomogeneous mixture of water and steam before it is superheated and fed to the turbine. On the other hand, all supercritical boilers are of the once-through type, wherein the water and steam flow through the boiler circuitry only once. Figure 1 explains the basic difference between the functioning of a subcritical and a supercritical boiler.

For a fossil-fuel-based (such as the coal-based) thermal power plant, the operating steam temperature and pressure decide its efficiency. The operating temperature and pressure in cases of subcritical boilers are below 538 °C (1000 °F) and 22.1 MPa (3.2 ksi),

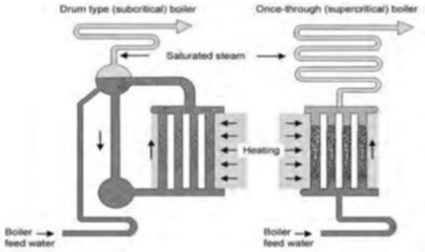
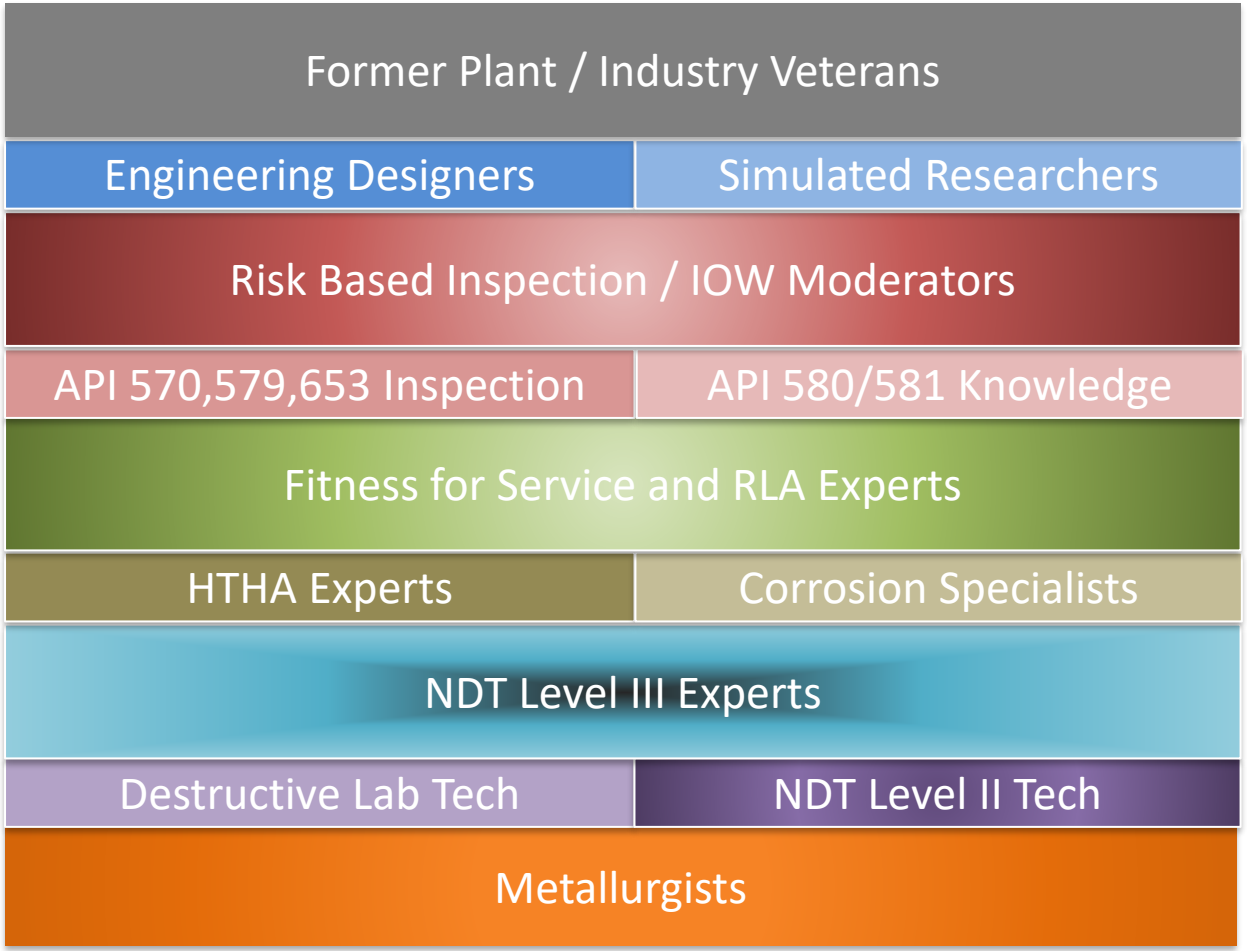


Fig. 1 Schematic showing difference in functioning of subcritical and supercritical boilers

ASSET OPTIMIZATION TEAM

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FITNESS FOR SERVICE AS PER API 579/ASME FFS-1

TCR's in-depth FFS report helps clients take decisions working with plant item in spite of presence a crack, metal loss at localized area, creep damage or mechanical damage like distortion or dents



Brittle Failure / Low Temperature



Decommissioned equipment that may be used in different services



Equipment operating in creep range and cyclic services

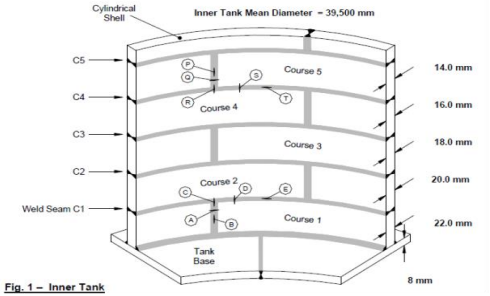


Fig. 1 – Inner Tank

Leak before break assessment of Ammonia Storage Tank



Isomerization reactor certified by TCR with detailed FFS Study post-Fire damage

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Remaining Life Assessment Boiler, Turbine, Pressure Vessels: Ensuring components are used to the fullest extent for operation beyond desired useful life

Components	Dimension Checks	Thickness Measurement	Microscopic Examination Replica	Hardnes Testing	PT/MT	Ultrasonic Testing	Radiographic Testing
- economiser headers	X				X	X	
- waterwalls	X	X				X	
- boilers drums	X			X	X		
- lower waterwalls and headers						X	
- junction headers	X				X	X	
- waterwall risers		X			X	X	
- waterwall headers					X		
- superheater headers (welds)	X	X	X		X	X	
- reheater headers (welds)	X	X	X		X	X	
- desuperheaters :							
liners						X	
nozzles	X				X		
- HT superheater tubing	X	X	X	X	X	X	
- steam piping	X	X	X	X	X	X	X
- feedwater piping		X					X

Conductive Resistance

$$R_{Total} = R_1 + R_2 \qquad R_{Total} = \frac{\ln(r3/r2)}{2\prod lk1} + \frac{\ln(r2/r1)}{2\prod lk2}$$

Temperature Distribution

$$\frac{T1-T3}{R1-R2} = \frac{T2-T3}{R2}$$

Thermal Stress **Thermal Strain** **Lateral Strain**

$$\sigma_t = \mathrm{E}\alpha\Delta t \qquad \varepsilon_t = \sigma_t / E \qquad \varepsilon_x = -\nu\varepsilon_t$$

Thermal Axil Stress

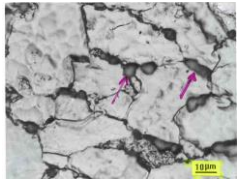
$$\sigma_x = E/(1-v^2)*(\varepsilon_x + v\varepsilon_t)$$

Von Mises Theory

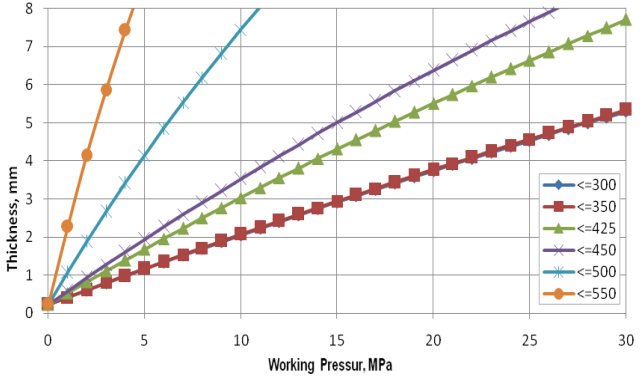
$$(\sigma_1-\sigma_2)^2 + (\sigma_2)^2 + (\sigma_1)^2 = 2\sigma_y^{\ 2}$$

Metallurgy + Engineering + NDT + Lab Destructive

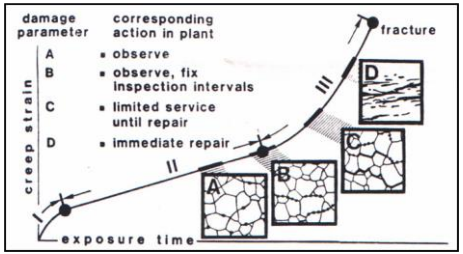
Replica, EMAT, ACRT Creep, PAUT, ABUT, RFET, Videoscopy, Oxide Scale, Mechanical, Chemical

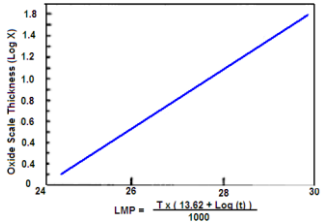


SEM of oriented creep cavitation damage of T11 super tubes – exposed to long term over heating.



Minimum required thickness at different working conditions for materials SA178-C





Oxide Scale Thickness

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Damage Mechanisms

Unravel the mysteries surrounding parts and assembly failures with Fast Turnaround time with in-depth analysis reporting. Strong Recommendations within each report to avoid future failures.



- Corrosion due to carbamate
- Nitriding, HTHA
- Corrosion under insulation, Pitting corrosion
- Stress Corrosion Cracking (Cl, NH3, caustic, CO/CO2, amine, methanol)
- Microbial Induced Corrosion on damaged cold insulation areas
- Bimetallic joint – galvanic corrosion, Crevice corrosion
- Brittle failure due to impacting condition
- Environmental impurities to cause pitting on utility turbine blades
- Erosion & Erosion Corrosion
- High Temperature Creep
- Fatigue (thermal, mechanical, pressure, vibration)
- Metal Dusting,

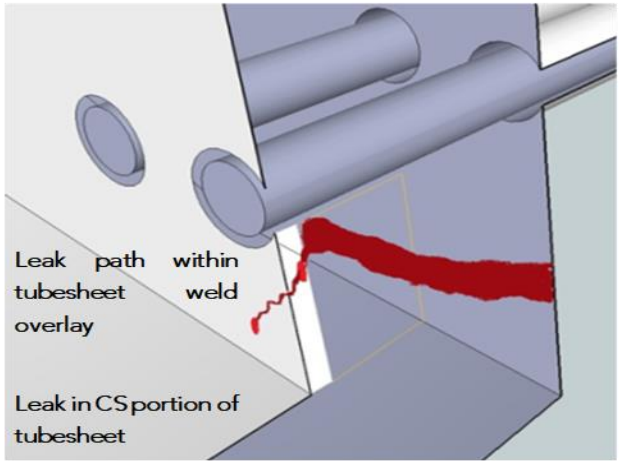
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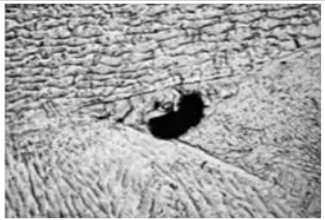
Carbamate Condenser

Case Study	Client	Component details	Material of construction
1	Fertilizers	Carbamate Condenser	Channel Barrel: ASTM A105 Channel Head: ASTM A516 grade 70 Liner material: Originally it was 316L UG Later on it was changed to 2RE 69 when relining Tube-sheet: ASTM A105 (295mm thick), with weld overlay Tubes: 1386 U tubes, 19.05mm OD x 2.1mm, 2RE69







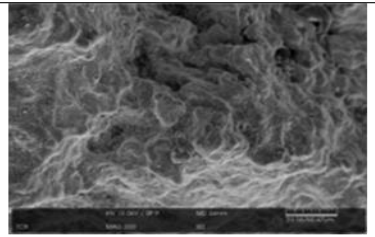


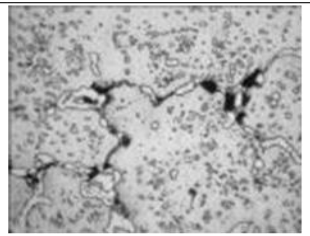
Most probable cause: The leakage of the carbamate condenser occurred, due to micro level corrosion at preferential sites that formed micro path along the carbide precipitated regions in the protective weld overlay. The leakage has observed away from the weld repair region and indicates that carbide precipitations are present in the submicroscopic level from the original weld. Such carbides depletes the chromium from adjacent region and reduced the local corrosion resistance. Once the carbamate touches the carbon steel tube sheet which is not at all resistant to carbamate, it gave away in form of grooving due to high pressure jet.

Reformer

Case Study	Client	Component details	Brief Details
2	Fertilisers	Primary reformer catalyst tube	• Primary reformer catalyst tube of primary reformer failed by way of rupture during operation. • The failure occurred at a distance 3.8 to 4.8 m length from the top and the rupture length was 1 meter. • The failure took place after service life of 1,42,000 hours • The primary function of reformer is to generate hydrogen by cracking of hydrocarbon in presence of catalyst. • The inlet temperature is 475°C and the outlet temperature is 762°C as measured at secondary reformer inlet. • MOC: Manurite







<u>Most probable cause</u>: The failure of reformer tube appears to be on account of localized temperature excursions which resulted in extended creep damage due to flame impingement.

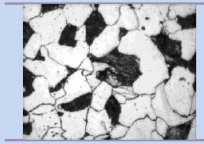
Metallographic Replica:

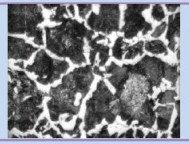
In-depth condition\life assessment of process plant components and detection of Graphitization, Degradation Of Pearlite, Creep, Thermal Fatigue, Oxidation, Grain Growth, Hydrogen Attack, Stress Corrosion Cracking, Sigma Phase

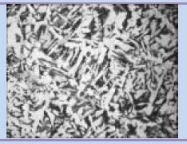
ADVANTAGE

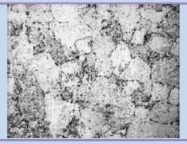
TCR's metallurgists have a database of over 30,000 micro-structure interpretation study of various components and materials.

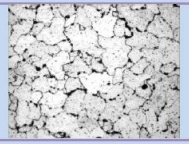
Carbon steels

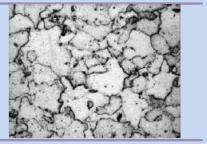

Normalized – 400X


As forged or improperly heat treated–400X

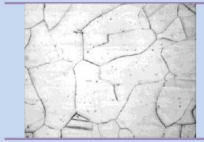

Widmanstatten ferrite and pearlite 100X

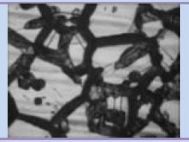

Spherodization of pearlite 400X

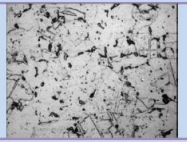

Creep voids at the grain boundaries – 400X

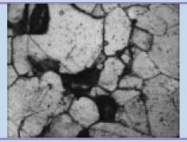

Decarburization- 400X

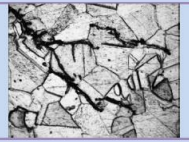
Austenitic stainless steels

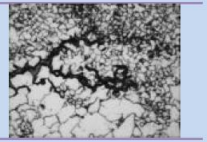

Solution annealed 400X


carbide precipitation– 400X

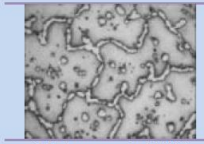

Sigma Phase 400X

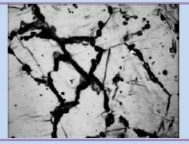

IGC 400X

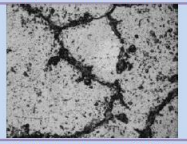

TGSCC 100X

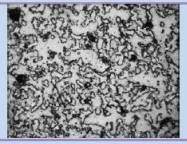

IGSCC 400X

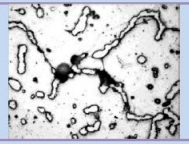
Catalytic convertors / reformer tubes / hot outlet manifolds

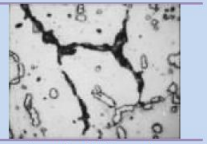

Solution annealed HK40 400X


Inter-granular crack - HK40 400X

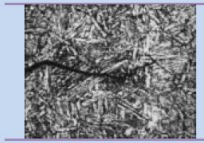

Oxidation-Incoloy 800HT 400X

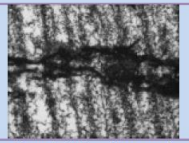

Creep damage In weld HP Mod 400X

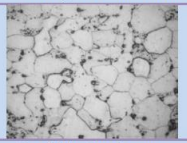

Creep damage in PM 400X

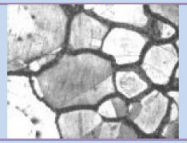

Interdendritic cracks 400X

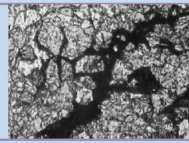
Damage mechanisms identified in the microstructure

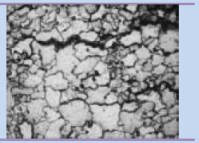

Quench cracks in alloy steel 400X


Caustic SCC carbon steel 400X


Graphitization damage low alloy steel – 400X

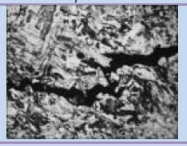

Grain boundary oxidation in CS - 100X

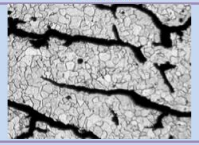

Inter-granular crack in rotor low alloy steel 400X

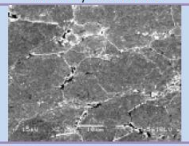

Type IV cracks P22 400X

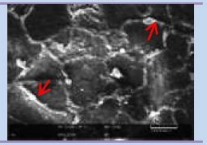

Dissimilar metal weld SS-alloy steel 200X


Thermal fatigue alloy steel 100X


Corrosion fatigue SS 410 400X


High temperature hydrogen damage C-1/2Mo. – 100X


Creep Damage in P91/T91 2000X


High temp. sulphur induced corrosion T11. – 3500X


Scanning Electron Microscopy


Optical Microscopy


Portable Microscope

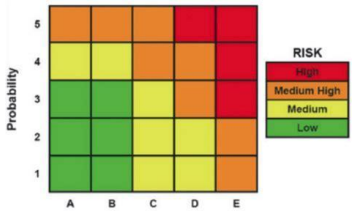

In-situ Metallography by replication method.

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Risk Based Inspection and IOW
Effective Implementation Partner

TCR's experts identify the potential damage mechanisms associated with anticipated operating conditions, and establish inspection methods, alarms, document action plans and testing frequencies on a custom developed software to store and trend lifetime mechanical integrity data.



Step 1: Evaluate corrosion loops of the process unit. Identify all potential damage or corrosion mechanisms. Assess corrosion rates. Define the IOW limits for each damage mechanism.

Step 2: Identify the RBI components and evaluate the risk using API 580 methodology or using APM tool. Analyze recommendations and issue final inspection scope.

Step 3: Evaluation of alarms, indications, and procedures necessary to recognize exceedance of the IOW limit.

Step 4: Define the criticality of the operating limit and define the priority of the IOW limit (critical, standard or informational).

Step 5: Documentation of each IOW. Development of responses to IOW alarms and notifications.

Step 6: Training all personnel involved in the process operation in IOW implementation and timely responses to IOW indicators and alarms.

Step 7: Integrating the IOW program into the rest of the plant operations, maintenance and reliability programs, and plant data-management software.

Step 8: Revalidation of the IOWs - reviewing each IOW for effectiveness and avoidance of spurious alarms and notifications.



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ISO 17025 Accredited LAB

Material Testing Laboratory for Destructive Testing

OFFSHORE ANALYSIS IN INDIA WITH RAPID RESPONSE AND DEDICATED MACHINE SHOP, EXPERT METALLURGISTS AND LAB TECHNICIANS



ARL Quantris
Optical Emissions
Spectrometer



Inductively Coupled Plasma
Spectrometer



Atomic Absorption
Spectrometer



Optical Emission
Spectrometer



Automatic
Carbon – Sulphur
Determination





















Fatigue CTOD
Machine 50/250KN







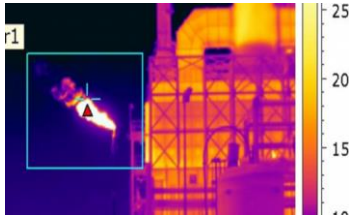




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Key Differentiator

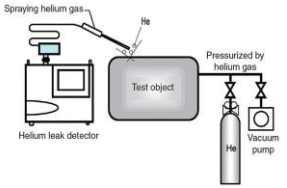
Beyond Material Composition and crack length, TCR provides meaningful insights that drives plant efficiency



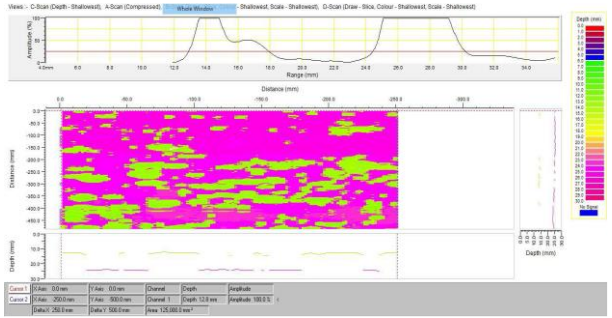
Thermography of Furnace



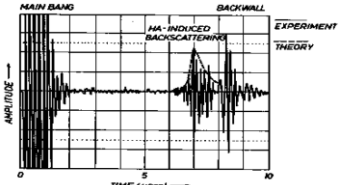
Eddy Current / RFET



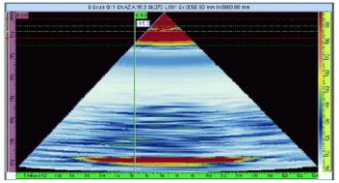
Helium Leak Testing



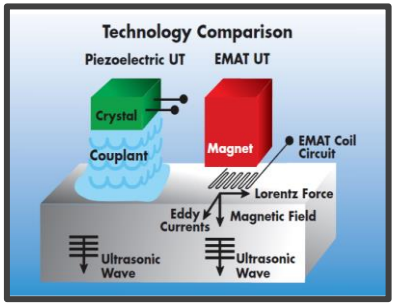
HTHA Inspectio using AUT P-Scan for HIC/SWC/Inclusion/Lamination detection



HTHA using ABUT-L



HTHA confirmation using PAUT



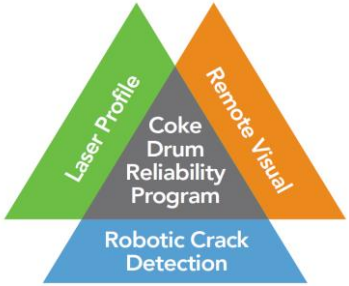
EMAT-Electromagnetic Acoustic Transducer



Automated Reformer Tube Inspection



Videoscopy for remote inspection of headers



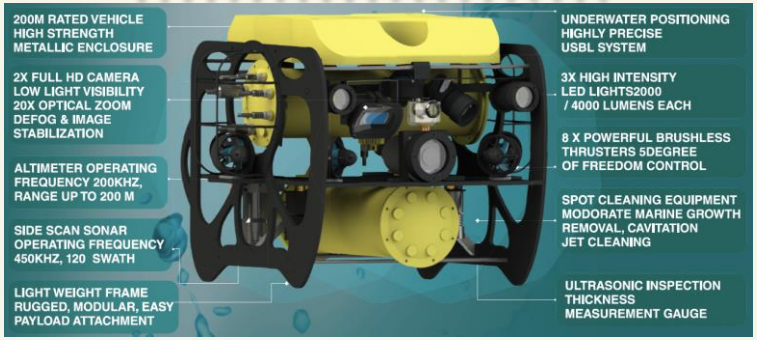
Coke Drum Inspect

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ROBOTIC VISUAL INSPECTION

TCR ADVANCED

UNDERWATER

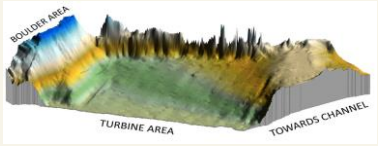




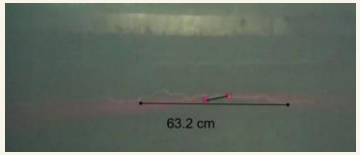
HD live video



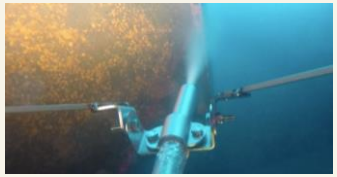
Thickness Measurement



SONAR/Bathymetric Surveys



LASER defect quantification



Spot Cleaning of Marine Growth

UNDERGROUND & ABOVE



Robotic Crawler based pan tilt zoom camera for inspection of pipelines of any diameter upto 200 meter length to ensure the lines are free from defects and foreign particles.









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Reverse Engineering and Design Consultancy

Engineering Design and Analysis Services

Leading Software - CATIA, Pro/ENGINEER, UniGraphics, I-DEAS, Inventor, SolidWorks, DELCAM, Ansys, LS Dyna, HyperMesh, NX Nastran, Moldflow

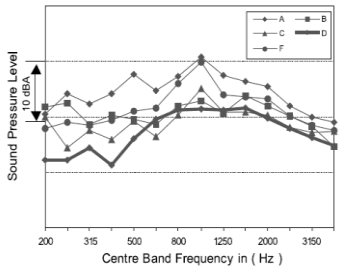
Computer Aided Designing (CAD/CAM) for 2D to 3D Conversions, Solid Modeling, Surfacing as well as Legacy Data Conversion

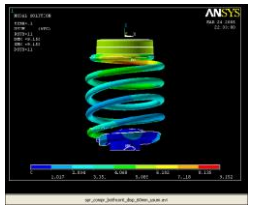
Computer Aided Engineering (CAE) including Finite Element Analysis (FEA) using Ansys

Structural Analysis including Pipe Support Analysis

Noise, Vibration, Harshness (NVH) analysis







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TCR ADVANCED

COMPLETE QUALITY ASSURANCE PARTNER FOR OPTIMUM PLANT HEALTH

Key Highlights

With over 50 years of experience, TCR Engineering Service has built a proprietary model of managing end to – end inspection and advisory services and validate them as per ASTM, BS, GS, JS, IS and other international standards.



For more information, visit us
www.tcradvanced.com

1 SOURCING & PROCUREMENT INSPECTION

TCR Qatar works closely with EPC and Infrastructure companies to provide integrated and end-to-end procurement for their projects. Our solutions encompass the entire procurement value chain, with each offering uniquely configured to each client's specific requirements and objectives.



Third Party Inspection and Quality Assurance Services
Factory Audit, Raw Material Inspection, In-Production Check, Loading Supervision

Product and Material Sourcing
Contract Research And Development

Mechanical Testing
Tensile & Bend, Impact, Hardness, Nick Break and Weldability, Creep, Stress Rupture, Hydrogen Embrittlement ASTM F519/B577

Fatigue and Fracture Toughness Testing
CTOD, K1c, J1c, Fatigue crack growth, High-Cycle/Low-Cycle Fatigue, S-N Curve

Chemical Analysis
Spectrometers (XRF, OES, ICP, AAS), Wet Chemical, Oil Analysis by Ferrography, RoHS Compliance, Lead Inspection, Refractory Testing
Ores and Minerals Testing, Sand Content, Oxygen, Nitrogen and Hydrogen

Corrosion Studies
Sour Gas (HIC/SSC/SOHIC) – NACE TM0284/TM0177/TM0103, Chloride Stress - ASTM G 36, SCC of Aluminum Alloy - ASTM G44/G47, Pitting/Crevice (Critical Temperature) - ASTMG48, Potentiostatic / Potentiodynamic Anodic Polarization - ASTM G5, Chloride Stress - ASTM G 36, Corrosion of Aluminum NAMLT - ASTM G67, Exfoliation of Aluminum - G66/G34, SCC of Aluminum – ASTMG103, Intergranular – ASTM A262/ DIN EN ISO 3651, Immersion Corrosion – ASTM G31 & Ammonia Vapor Test – ASTM B858

For more information, visit us www.tcradvanced.com

2 CONSTRUCTION & COMMISSIONING INSPECTION

TCR designs effective welding solutions coupled with baseline data creation. It provides the right functional expertise for teams to excel in plant maintenance and operations.



Base Line NDT Data Creation
Ultrasonic Flaw Detection, UT Thickness, Dye Penetrant, Magnetic Particle, Ferrite Measurement, Holiday Detection, Surface Roughness, Demagnetization, Paint and Coating Thickness

Phased Array and ToFD in lieu of RT Examination

Welder Certification and Procedure Qualification
Welding Inspectors visits for Qualification of Welder, WPS/PQR Testing per coupon as per ASME Section IX, AWS D 1.1, API 1104, QP-STD-R-006, QP-STD-R-002

Welding Procedure Specification (WPS) development

Weldability Evolution
Microstructure & Micro-Hardness Tests

Welding Consumable Evaluation
Tests as per ASME Section 2 part C

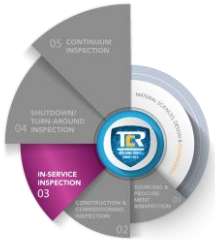
Post Weld Heat Treatment
70kva Electrical Resistance HT Machines with Talented Team, Pre-Heating

Positive Material Identification (PMI)
On site Detection of all chemical elements including C, S,P, Mn and Si

For more information, visit us www.tcradvanced.com

3 IN-SERVICE INSPECTION

TCR undertakes corrosion studies based on Risk-based Inspection API 580 guidelines to map business and operational risks for individual plant items for planning damage specific inspection and effective shutdowns. TCR has in-depth knowledge of high-temperature probes and an understanding of potential corrosion damage mechanisms.



Advanced NDT targeting specific Corrosion Damages: HTHA Inspection, One Micron Detection using UT, Carburization Detection, HIC Detection, High temperature Corrosion Mapping, Mid Wall Fissures Detection, Stepwise Crack Detection (SWC)

Visual Inspection
Thermography, Robotic Underground buried Pipeline Inspection, Underwater Inspection and cleaning by ROV, Boroscopy, Videoscopy

Studies
Risk Based Inspection study program to research corrosion damages

Mapping of Turnaround data based on Business/Operations Risk

For more information, visit us
www.tcradvanced.com

4 SHUTDOWN & TURN-AROUND INSPECTION

TCR has acquired in-depth knowledge, experience, and expertise for over 45 years in managing complex shutdown projects. It ensures planned shutdowns along with rapid deployment of expert consulting teams with solutions for heat exchangers, tanks, pipelines and weld joints to get your facility back online as quickly as possible.



Visual Inspection Services
Boroscopy, Remote Visual ROV, Videoscopy, Thermography,

Pipelines and Weld Inspection
Phased Array, Time of Flight ToFD

Tank Inspection
Robotic Inspection of Coker Drums, In-service Robotic Tank Inspection, Tank Condition by Thermography

Tube / Heat Exchanger Inspection
Eddy Current, RFET, IRIS, MFL, Helium Leak Testing, Acoustic Eye, Saturated Eddy Current, Automated Reformer Tube Inspection (ARTiS), Oxide Scale Measurement

Plant Health Assessment and Metallography Strength
In-Situ Metallography Replica, SEM and EDS analysis, Microstructure Characterization for RLA

Inspection Manpower Consulting
RBI and Asset Integrity Management Experts
Metallurgists and Corrosion Scientists
API Plant Inspectors with 510, 570, 653 as well as 579/580 experience
ASNT Level III Experts and SNT-TC-1A or PCN Level II Techs
QA/QC Inspectors for Static and Rotating Equipment
Welding Inspectors with AWS or CSWIP
Painting/Coating Inspectors with NACE or BGas
Mechanical Destructive Testing and Lab Chemists
Refractory Consultant
Valve Specialists
Heat Treatment PWHT specialists
Engineering Design Consultants on CAD/CAM
Simulated Process and Engineering Researchers

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5 CONTINUUM INSPECTION

TCR optimizes plant performance by analyzing information, examining engineering design and recording key insights from the shutdown for long-term plant reliability. It also undertakes fitness for service, failure analysis, and remaining life assessment studies to give the top management and/or insurance companies a better understanding of the plant's overall health.



Failure Analysis

Pressure Equipment Integrity Incident Investigation per API 585

Remaining Life Assessment

Fitness for Service as per API 579/ ASME FFS-1

Fire Damage Assessment

Engineering Design and Analysis Services for Plant Supports
Computer Aided Designing (CAD), Computer Aided Engineering, Reverse Engineering and Prototyping, 2D to 3D Conversion, Finite Element Modeling, Piping Stress Analysis

Plant Health Study
API 590/581 guideline based Risk-Based Inspection study and implementation

Integrity Operating Window Study as per API 584

Contract Research
Technical Help For Indigenization, Selection of Materials, Solutions Of Critical Weld Problems

Training Programs
Metallurgy and Corrosion Evaluation, NDT and FFS

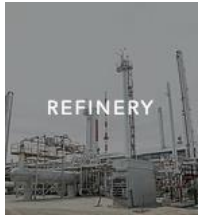
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TCR ADVANCED

INDUSTRY VERTICALS
REFINERY

Many among TCR's professionals are ex-employees of these global majors and have developed the competence to assess failures and fire damages in CDU/VDU, FCCU, hydrogen manufacturing, storage tanks, REAC, reactors, and their internals.

TCR's NDT and in-situ metallographic replica teams have undertaken several studies detecting metallurgical degradation, detachments/ fastener failures, creep, stress corrosion cracking, pitting, erosion, reheat cracking and fatigue-related damage mechanisms.



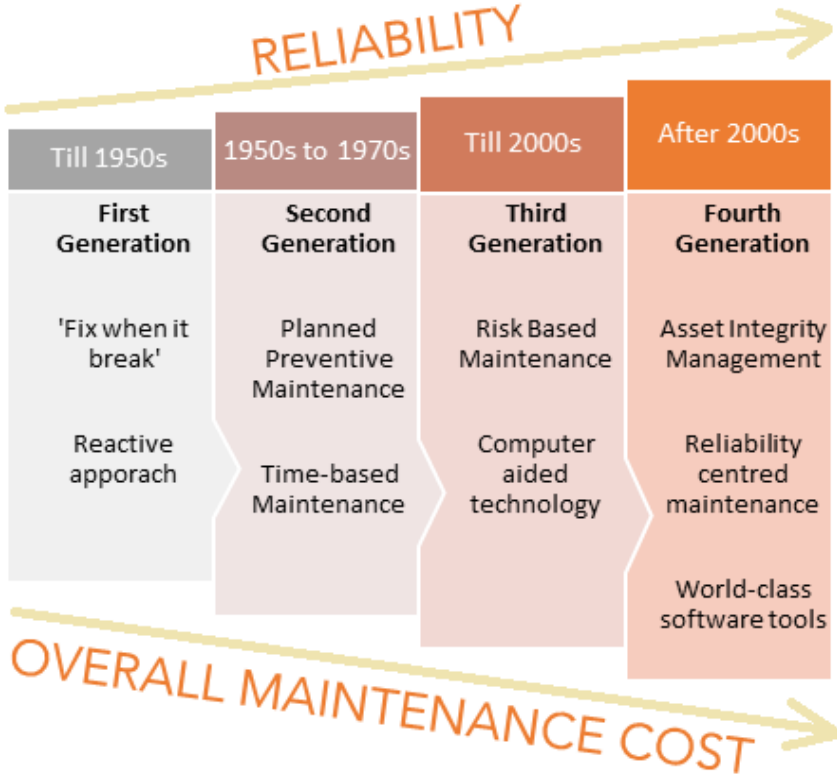
MARQUEE CLIENTS
Industry: Refinery

Reliance Industries Limited
Saudi Aramco
HMEL
IndianOil
Sasol reaching new frontiers
ONGC
PETRONAS
Gulf Petrochem Towards New Horizons
HP
BHARAT OMAN REFINERIES LIMITED
PEMEX
Bharat Petroleum
OPaL
CPCL

> **The knowledge of the crew deployed at site, the quality of the replica's and the zeal and enthusiasm with which the crew completed the work is commendable and highly satisfactory.**

U Anand, Vice President
RELIANCE INDUSTRIES LIMITED

Why TCR For RLA/Integrity Assessment



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Extensive Database of Material Degradations:

At TCR Advanced, we possess a vast and comprehensive database of degradations specific to the fertilizer industry. This valuable resource enables us to make early and informed decisions regarding critical equipment, addressing safety and operational concerns promptly.



- **Material Library**
- **Failure Case studies**
- **Remaining Life assessment**
- **Integrity Operating Windows**
- **Semi-quantitative Risk Analysis**
- **FFS, Quality Assurance**

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Experience with Idle Equipment and to put back in to operation:

We understand that equipment that has been idle for extended periods is more susceptible to damage, especially stainless steel equipment. TCR Advanced has successfully executed similar projects in the past, which involved addressing the challenges associated with idle equipment.



- **Natore Chemical, Nigeria**
- **Baiji Refinery, Iraq**
- **Godrej Industries**
- **Matix Fertilizers**
- **Nagarjuna Fertilizers**
- **Heavy Water Projects**

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Highly Experienced Team of Experts:

TCR Advanced boasts a highly experienced team of experts comprising metallurgists, corrosion specialists, welding experts, design professionals, and NDE experts. Their collective knowledge and diverse backgrounds enable us to tackle various aspects. Our multidisciplinary approach ensures thorough evaluations and effective decision-making.



- **Plant experts and industry veterans**
- **Mechanical Engineers**
- **Design Engineers**
- **Metallurgical Experts**
- **Corrosion Experts**
- **Inspection Experts**
- **Welding Experts**
- **Quality Control experts**

For more information, visit us
www.tcradvanced.com

Digital Platform for Reporting and Evaluation Today and beyond :



TCR Advanced has developed a unique digital platform called AiOM (Advanced Inspection and Operations Management). Our site inspection team will work in coordination with our back home experts, providing day-to-day reporting, evaluation, and support. AiOM also enables real-time progress monitoring and offers future access to all testing records, benefitting your plant's operations beyond the project duration.

For more information, visit us
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TCR is leading the new way of Quality Assurance by defining the future

At TCR, we are continuously working towards improving our offerings to provide a better and a more efficient Quality Assurance for your Optimum Plant Health

Industry-specific Solution

- Plant and industry veterans with understanding of process/operations challenges
- Aware of the business risk versus failure probability
- Keeping abreast on new materials and plant items

Equipment-specific Solution

- Researching new techniques for inspection
- Constantly buying probes and accessories to ensure no downtime at site
- Train-the-trainer approach to spread knowledge

Problem-specific Solution

- Corrosion damage evaluation is a specialty
- Metallurgy is the core of all investigation
- Look at a problem through multiple angles

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TCR ADVANCED

INDUSTRIAL TRAININGS
EVOLVE BY TCR

Highly effective coaching for plant operations, inspections and maintenance personnel with experienced Teachers and practical knowledge.





- ASNT Level II programs in UT,DP,MP,RT,VT, ECT, IR
- Boiler tube failure- mechanisms and mitigation
- RBI of Ammonia Tank in Fertilizer Plant
- REAC Reactors in Refinery
- Selection of NDT for effective end result
- Intensive course on "fracture mechanics, fracture toughness and fatigue testing"
- Introduction to Corrosion and NDT
- Metallography for Non Metallurgists
- Study of different coatings for protection against corrosion under insulation/fire proofing
- Application Methods For Paint Coatings and Inspection Of Painted Panels
- Corrosion in petrochemical process plants
- Corrosion Under Insulation For Pipelines
- Failure of 9% Nickel steel during extended cryogenic service
- Failures and Protection methods for Above Ground Storage Tanks
- Beyond RBI: Striving for zero loss of containment
- API 510, 579, 653 Training programs

For more information, visit us **www.tcradvanced.com**

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Questions?