

India | Middle-East | USA

# TCR Arabia

Material Testing Lab and NDT Services

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## 1 Executive Summary

GAS Arabian Services (KSA) and TCR Engineering Services (India) have jointly collaborated to form TCR Arabia with an aim to provide outstanding quality assurance services to industries in the Kingdom of Saudi Arabia. TCR Arabia will provide sour gas corrosion testing (HIC and SSC), failure analysis, positive material identification, chemical analysis, physical and mechanical testing, metallurgical studies including micro and macro examination, ultrasonic testing, ToFD, dye penetrant testing, magnetic particle testing, ultrasonic flaw detection, and other advanced NDT services.

The tests will be carried out as per ASTM, NACE, ASME, API and client specified standards with a laboratory emphasis on working as per the ISO 17025 quality standard. TCR Arabia will soon apply to get qualification on some of its services from ARAMCO as well.

TCR's objective is to provide a quality service at a reasonable price. Till date, TCR has worked with more than 2000+ quality driven clients (from all over the world) in Aerospace, Automotive, Oil Refineries, Petrochemical plants, Chemical Processing, Defense, Electronics, Nuclear Power and Capital Goods manufacturing industries to determine material properties, improve product's performance, assist to develop new and better products or materials, evaluate remaining life of an industrial equipment, determine why a component's performance expectations were not met, or to identify why a product may have failed.

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

This corporate profile demonstrates TCR Arabia's keenness to undertake projects in KSA and showcases the company's engineering and metallurgical consulting expertise.

## 2 Advantage TCR Arabia

TCR Arabia (and its associated group companies in USA, Kuwait, KSA and India) presents itself as an excellent resource for providing engineering consulting to expand the current laboratory, ensure equipments are installed in the right manner, meet the Aramco compliance standards and effectively operate the lab at high pace levels. Some of the highlights that TCR brings to KSA include:

- TCR brings its experience gained over the last 34 years in the field of material testing, inspection and quality assurance to this project. We also bring our strong commitment and adherence to the ISO 17025 standards against which we manage and run our own internal network of laboratories. Local support in KSA with TCR-Arabia and remote support from offices in India and USA.
- Experienced by conducting over 500 failure analysis projects. TCR is on the approved list of Schlumberger for Failure Analysis Services. The company has access to Scanning Electron Microscopy with EDAX and Optical Inverted Metallurgical Microscopes.
- Companies from Petronas in Malaysia to Kuwait Oil Company (in-direct supplier), depend on the outstanding positive material identification services (PMI) services provided by TCR. Till date TCR has completed over 600 PMI projects for multiple companies.
- Access to backend laboratory in India for in-depth chemical analysis using GDS, ICP, AAS and a complete wet chemistry laboratory. The back-end lab in India will also perform high temperature tensile testing (upto 850 degree Celsius) and Impact testing. Over time and based on market demands these services will also be started in KSA.

- Use of Advanced NDT techniques including ToFD. Automated UT using ToFD is fast replacing Radiography as a preferred method for faster scanning of weld joints. TCR compliments this service with a range of conventional NDT services.
- Assisting RLA studies by conducting in-situ metallography (Metallographic Replication) by a talented and experienced team that has won praises from Shell, Reliance, KOC and other large Oil Refineries.
- Access to a pool of resource talents, ability to undertake faster mobilization and committed to work under good safety, health and environment principles.
- Customers all over the world use TCR's services to dramatically improve and certify their products, validate material quality, ensure innovation in the marketplace, and to achieve significant competitive advantages. As a result, these companies are bringing the right products to market, at the right time, at the right cost.

### 3. TCR Arabia Commitment and Values

TCR Arabia commitment is to put our customers first by providing excellent service and great quality assurance experiences. This is what we do and this is why we exist.

TCR Arabia will be an active member in the community and will participate in the chapters of the Saudi Arabian Section (SAS) of the American Society for Nondestructive Testing as well as the Bahrain Society of Engineers (BSE). As part of this activity, TCR Arabia is participating in the Fourth Middle East Nondestructive Testing Conference and Exhibition which will be held from December 2-5, 2007 in Bahrain.

By focusing on our customers and being a responsible member of our communities, TCR Arabia will prove to be a trusted QA company, create meaningful work for ourselves and provide something of lasting value for society. As a result, TCR Arabia will be recognized as a great company. In order to keep this commitment, we need to always honor our core values:

#### **INTEGRITY**

Integrity is at the heart of everything we do. We are honest, ethical and upfront because trust is at the foundation of our relationships with our customers, our communities, our stakeholders and each other.

#### **RESPECT**

We know it is critical that we respect everyone at every level of our business. We champion diversity, embrace individuality and listen carefully when others speak.

#### **PERFORMANCE EXCELLENCE**

We hold ourselves to a very high standard of performance. We prize innovative ideas and the teamwork it takes to make them realities. We never stop asking ourselves how we can make the customer experience better, and every day, we find an answer.

#### **ACCOUNTABILITY**

We take responsibility for our actions as individuals, as team members, and as an organization. We work together, support one another and never let the customer — or our coworkers — down. Great companies are judged by what they do, not by what they say. To be the best, we're going to keep pushing ourselves in new and exciting directions. These values will guide our every action.

#### 4. Services in Saudi and Remote Assistance from India

The following is the services distribution:

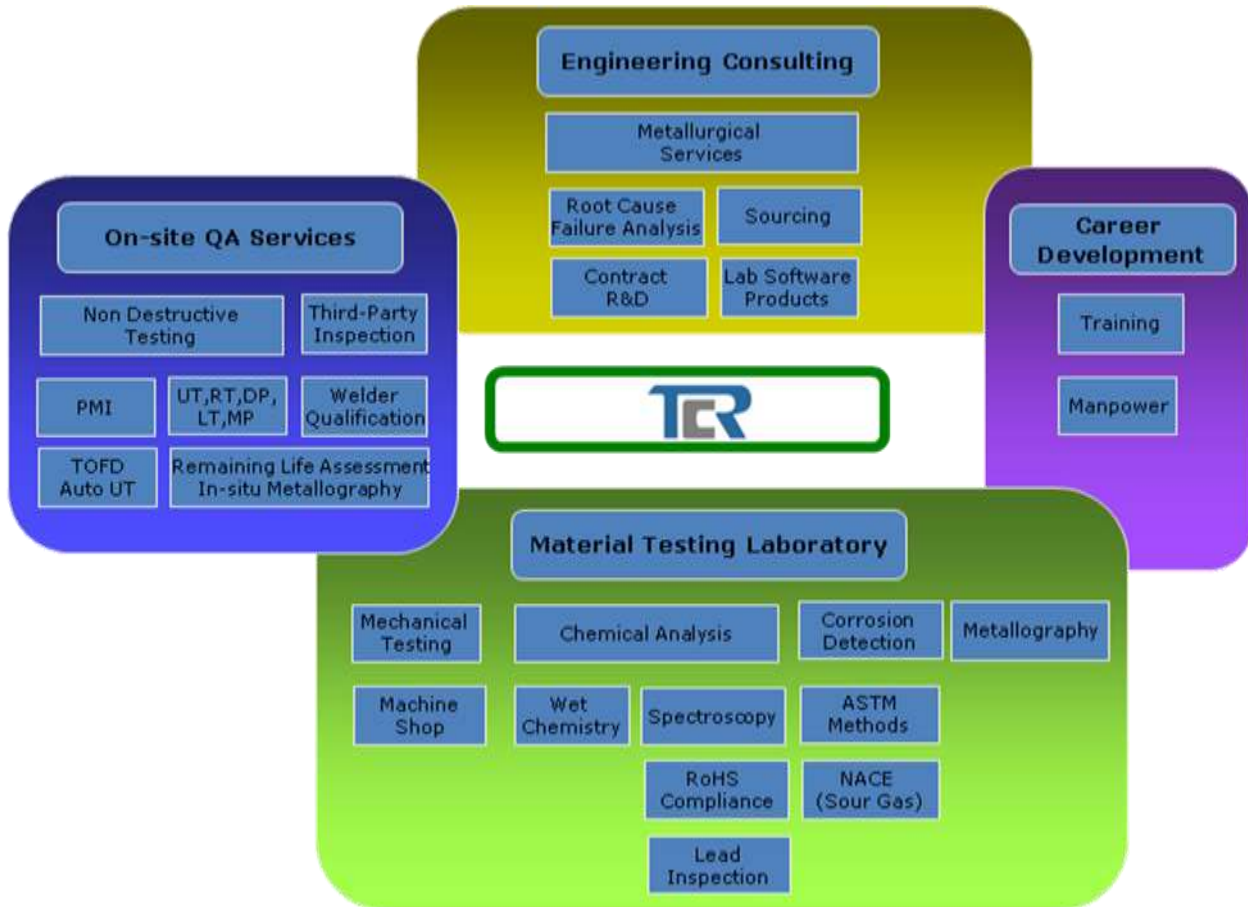
Service Description	Saudi Arabia and Bahrain	Remote Assistance from India and USA
Corrosion Services	All HIC and SSC Tests as per NACE TM0177 and 0284, ASTM A262 (inter-granular attack), pitting corrosion, CSC, salt spray	
Positive Material Identification	Portable XRF and Portable OES Spectrometer	Additional 12 portable alloy analyzers are available on standby in India and can be dispatched if there is a strong project demand
Failure Analysis and Metallurgical Consulting	Complete in-depth investigation of a plant or equipment failure. Chief metallurgist will perform all on-site investigations and data gathering for consulting and failure analysis projects.	SEM, EDAX analysis will be done in India. XRD analysis will be done in USA.
Metallurgical Analysis	An onsite inverted digital microscope will be present to assist in micro and macro examinations. The laboratory in KSA will have an installed copy of the MiC 2.0 software for image analysis.	Any special cases will be sent to the TCR lab in Baroda, India
In-Situ Metallography	Expert Metallographic Replication team will perform the MR work onsite.	MR interpretation using SEM or Optical Microscope will be done in India
NDT Services	All UT, DP, MP will be conducted onsite. Advanced NDT services such as Automated UT using ToFD will be conducted in KSA and Bahrain.  QA/QC inspectors with 5 years of experience and CSWIP inspectors will also be commissioned on site to inspect any fabrication or construction projects.	Access to a pool of resource talent for faster mobilization
Physical and Chemical Testing	Samples will be collected in this regard and sent to India for analysis.	All Physical and Chemical Analysis will be done remotely in India
Third Party Inspection		Vendor and Supplier Inspection in India
Material Sourcing	Local Assistance as needed.	Teams present across India to assist in this area.
Metallurgy and NDT Training	Classes and Seminars held as needed	Trainers and course material development in India.
Manpower Deployment		Contract based expert inspectors may be available for long term projects. Some inspectors may be commissioned from TCR-KIL in Kuwait to work at KSA.

All remote assistance will be provided by TCR group companies.

Please do note that the chain of custody for all samples received at TCR Arabia will be maintained in a professional and quality conscious manner. Tests conducted remotely in India will be done at TCR's ISO 17025 accredited laboratory. All customer billings will be done by TCR Arabia in KSA. The process of sample movement will be transparent to the customer.

## 5. Material Testing Services

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



### A. Mechanical and Physical Testing

TCR provides a comprehensive range of Mechanical Testing services with a dedicated machine shop to assist in sample preparation. Samples for this service will be sent from KSA to the TCR labs in India.

Chain of custody will be maintained by TCR Arabia and results will be delivered in a professional manner.

The Mechanical Testing Facility at TCR conducts tensile tests for understanding the strength characteristics of a material and provides precise determination of Proof Stress by the attachment of various electronic controls and extensometers. Testing temperatures range from 50°C to 850°C and beyond for particularly high temperature applications. The Mechanical Testing department at TCR performs a range of Impact tests, including Izod and Charpy testing from 100°C to -196°C. Highly specialized pressure test facilities are also available.

TCR is well equipped to determine mechanical properties of materials and solve a wide variety of technical problems for industry.

Mechanical Testing Facilities available at TCR in India include:

- Universal Testing Machine of Capacity 100 T with Electronic Extensometer
- Universal Testing Machine of Capacity 40T
- Universal Testing Machine with Extensometer of capacity 0 - 13T
- Charpy Izod Impact Tester
- Charpy Impact Tester (ASTM E 23)
- Brinell / Vickers Hardness Tester
- Rockwell Hardness Tester
- Rockwell Superficial Hardness Tester, Micro Hardness Tester
- Hydraulic Test Pump
- Shadowgraph
- Erichsen Cupping Machine

The following are also available: Welder Qualification, Bend Tests, Compression Tests, Flaring and Flattening Tests, Hardness Testing (Rockwell, Brinell, and Superficial Micro Hardness), Nick Break, Drop Weight, Proof Load, Hydraulic / Pneumatic Test, Component Testing, and more.

Superior technology, responsive versatility, and quality performance ensures reliable and fast turnaround on all test results. A dedicated in-house sample machine shop ensures that all test samples are machined onsite. Experts in the Machine shop are capable of low stress grinding and machining sub-size specimens to very close tolerances. Professionals in the machine shop can custom design fixtures, mount specimens for metallography examinations, and custom fabricate TOFD weld blocks for NDT operators.

Equipment at the machine shop includes CNC wire cut machine, milling and lathe machines, hacksaw, drilling machine, stress-free grinding equipment, saws, surface grinders, and other tools.

## B. Metallography Tests

Qualified metallurgists at TCR are experts in Metallographic preparation & examination to evaluate the characteristics of metals. They can access 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 department has the state-of-the-art Inverted Metallurgical Microscope Olympus GX51 and the Leco 500 Microscope with an Image Analysis System. The team has in-house developed microstructure characterizer software that assists with the analysis of images to determine the micro structural degradation due to creep. The software can also calculate the graphitization, depth or width of decarburization, phase/volume percentage, grain growth, inclusion rating, particle size, volume percentage, particle count, porosity and coating thickness.

## C. Chemical Analysis

An inherent strength of TCR Arabia is the ability to successfully undertake analytical chemistry assignments. Some tests will be outsourced by TCR Arabia to the TCR labs in Mumbai, India.

With an ever-expanding senior staffed team of highly qualified Analytical Chemists experienced in using the full range of analytical instruments which include state-of-the-art Spectrometers and Wet Chemistry lab facilities, TCR can cater to all analytical requirements for Ferrous, Non Ferrous Metals, Ceramics, Glass, Refractory, Minerals and Ferro Alloys.

The chemical department can analyze samples in all forms including drillings or turnings, solid samples and liquids.

State-of-the-art equipment available at TCR in India includes

- Optical Emissions Spectrometer (OES)
- Inductively Coupled Plasma (ICP) Spectrometer
- Glow Discharge spectrometer (GDS)

- Atomic Absorption Spectrometer
- Automatic Carbon Sulphur Determinators

The Classical Wet Chemistry (bench chemistry) department uses Gravimetry and Titrimetry procedures to analyze chemical composition of materials, and assists in the identification of unknown materials and gaining an understanding of their chemical composition, structure and function. Most classical wet chemical methods can accommodate comparatively small amounts of a sample in diverse shapes or forms. Fully compliant to environmental standards of India, the wet chemistry department at TCR is sought by leading companies all over the world for trace chemical analysis to very low detection levels.

#### D. Lead Inspection and Detection

As awareness continues to increase on the ill-effects of Lead (Pb) in day-to-day products in KSA, TCR Arabia undertakes classification of definitive positive/negative results for Pb using the portable XRF instruments. The XRF instrument of TCR Arabia can detect of lead in Paints & Coatings, Oils & Liquids. The tests are done in-situ and it can help in establishing area contamination boundaries and depth profiles including assisting in site investigations, delineation and contamination patterns.

The lead inspection service from TCR will allow manufactures in KSA to create lead-free landfills, hazardous clean-up sites, consumer electronic materials, children's toys and jewelry, cooking or eating materials, packaging, and several other materials.

#### E. Corrosion Detection

TCR Arabia (TCR), undertakes a wide range of corrosion and stress corrosion test per ASTM, NACE or as per an individual client's requirements. Senior staff members are available to provide corrosion consulting, advice on corrosion prevention and corrosion control services including materials selection in laboratory or on-site inspection.

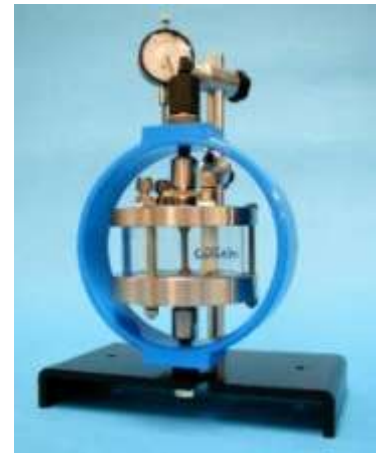
TCR's staff with specific industry expertise covers a variety of corrosion problems that are encountered in industries such as oil and gas production, oil and gas transmission, energy conversion systems, and nuclear power systems. The objective of the corrosion detection department at TCR is to provide quality service at a reasonable price and work with all clients as an extension of their QA team.

A wide variety of corrosion related tests can be undertaken at TCR Arabia to determine weight loss corrosion, inter-granular attack, pitting corrosion, corrosion fatigue, stress corrosion cracking, sulfide stress cracking, and hydrogen-induced cracking.

TCR's Sour Service Corrosion Testing department undertakes Small Scale Tests and Full Ring Testing for SSCC (NACE TM 0177, EFC 16 and 17) and HIC (NACE TM 0284). The range of instruments available to perform these tests is unrivalled in our operating regions. Highly experienced and qualified engineers within the group routinely undertake corrosion studies to include all observations as per NACE MR 0175. We can also carry out the tests listed above under 3rd party inspection of LRS, TUV, DNV, ABS, BV and other inspection agencies.

TCR offers comprehensive material testing of corrosion problems, including:

- Pitting Corrosion test as per ASTM G48 Specification
- Salt Spray Test
- Corrosion test as per ASTM G35 specification
- Inter granular Corrosion Test (IGC) per ASTM A-262 Practice A B C D E & F
- Hydrogen-Induced Cracking Test (HIC) as per NACE TM0284
- Sulfide Stress Corrosion Cracking Test (SSCC) as per NACE TM0177
- Chloride Stress Corrosion Test as per ASTM G36 Specification
- Ammonia Vapor Test
- Corrosion test as per ASTM A761 Specification



- Customized Corrosion Testing
- Inspection as per NACE MR0175

**Inter-granular corrosion**

Inter-granular corrosion attack in stainless steels may result from precipitation of carbides, nitrides or inter-metallic phases. To conduct these tests as per ASTM A262, the corrosion team at TCR carefully chooses a method which is suitable for the steel grade and grain boundary composition to be tested.

**Salt Spray (Neutral / Fog), ASTM B117**

A number of samples can be tested at once at TCR for Salt Spray depending upon their size for salt spray corrosion testing of inorganic and organic coatings, especially where such tests are used for material or product specifications.

**Pitting Corrosion Test**

TCR can undertake Pitting Corrosion as per ASTM G48 Method B, Ferric Chloride Test which involves exposing a specimen to a highly oxidizing acid chloride environment, to determine the extent of pitting. We can also undertake Pitting Corrosion test as per ASTM A923 Method C.

**Hydrogen-Induced Cracking (HIC) Test, NACE TM0284**

HIC Test by TCR evaluates the resistance of pipeline and pressure vessel plate steels to Hydrogen Induced Cracking caused by hydrogen absorption from aqueous sulfide corrosion.

**Sulfide Stress Corrosion Cracking (SSCC), NACE TM0177, EFC 16 and 17**

Sulfide stress corrosion cracking (SSCC) test by TCR is done when a susceptible material is exposed to a corrosive environment containing water and H<sub>2</sub>S at a critical level of applied or residual tensile stress.

## 6. Engineering Consulting

Several senior consultants with many years' experience are available to help and advise on corrosion or materials selection queries. Our team can also advise on your welding engineering and heat treatment problems. From initial product design, through final production, TCR Arabia's in-depth engineering consulting services ensures that clients are producing the best possible product.

Areas of consulting assistance include:

- Determining the right material for a product
- Corrosion engineering, corrosion testing and corrosion investigations
- Metallurgical failure analysis and welding evaluations.
- Investigate the effect of environmental conditions on a product or material
- Prepare material and process specifications for in-house quality control
- Compare vendor or competitive products
- Estimate the remaining service life of a product or machine component
- Develop Non Destructive Testing Plan and TOFD procedures
- Manage Quality Control Projects
- Identify equivalents between Indian and foreign specifications
- Assist to solve product quality problems
- Assist in cost-benefit analysis post failure analysis
- Expert witness and opinion assistance in case of trade conflicts, materials disputes, and litigation issues
- Create a custom Metallurgical Image Analysis Software

The engineering consulting team at TCR routinely banks upon its professional team with strong engineering experience and fully equipped material testing laboratory facility to efficiently uncover the root cause of a failure and help recommend the best solution to prevent recurrence.

### A. Failure and Root Cause Analysis

TCR has completed more than 500 failure investigation assignments, including 80 major projects on manufacturing and metallurgical failures on ASME boiler and pressure vessels, gas turbine engine components, oil and gas transmission pipelines, food processing equipments, heat exchangers, medical supplies, refineries, petrochemical plants, aircraft/aerospace, offshore structures, industrial machinery, weldments and ships. The failure analysis team's strength is in evaluating high temperature and high pressure failures.

The failure analysis team of TCR Arabia team has access to the complete range of testing facilities at our network of laboratories including access of optical microscopes, Scanning Electron Microscopes (SEM) equipped with Energy Dispersive Spectrometry (EDS), microstructure analysis software and photographic instruments.

### Methodology for Failure Investigation

TCR Arabia works with clients to plan the failure analysis before conducting the investigation. A large amount of time and effort is spent carefully considering the background of failure and studying the general features before the actual investigation begins.

In the course of the various steps listed below preliminary conclusions are often formulated. If the probable fundamental cause of the metallurgical failure becomes evident early on in the examination, the rest of the investigation focuses on confirming the probable cause and eliminating other possibilities. The metallurgical failure analyst compiles the results of preliminary conclusions carefully considering all aspects of the failure including visual examination of a fracture surface, the inspection of a single metallographic specimen, and the history of similar failures.

## **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 investigation team produces detailed written reports to ensure that clients fully understand and are able to independently examine the analytical results and conclusions.

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 through 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)

## **B. Contract Research and Development**

TCR Arabia can effectively operate and manage an in-house laboratory for a corporation while retaining the innovative, professional and superior quality service. TCR brings to these engagements, its strong process, our management expertise as well as results reporting method based on integrity and reliability.

## **C. Metallurgical Image Analysis Software**

TCR Arabia is a reseller of the Microstructure Characterizer Software, an image analysis tool which was developed by TCR's metallurgy team in India. Using this software, a Metallurgist or a Material Science engineer can characterize different types of micro structural images for grain size, coating thickness and phases; get images from one or more files; and intensify the image using the filtering and enhancement features.

Microstructure Characterizer Software 2.0 (MiC) characterizes micro structural features using standard methods of material characterization such as ASTM grain size measurements, coating thickness, linear and angular measurements, comparison of super imposed grain size reticules, inclusion rating as per IS and ASTM standards, nodularity measurements, powder particle size distribution and so on. It helps generate custom made formatted reports of live and stored images and offers results as the computer display as well as hard copy multicolor printouts.

The software has been deployed at more than 250 commercial laboratories and universities till date. Custom modifications to this software can be done in conjunction with the engineering consulting team at TCR.

## **D. Product Sourcing**

Leveraging the relationships with customers at the laboratory, TCR started providing sourcing services in 2004. TCR Arabia will provide this service for customers in KSA that wish to import metallurgical products from India.

TCR covers the entire sourcing process from finding the right suppliers to transferring the design specifications. TCR will setup the right supply chain and logistics control, ensuring that the shipment meet all export guidelines. Finally our strength and deep domain expertise in material testing and inspection services helps maintain quality control on all shipments.

TCR continuously harvests her relationships with manufacturers and traders in India by taking the time to meet with these companies including touring their facilities and "first hand" confirming their capabilities. TCR can source, inspect and test

ferrous and non-ferrous metals, casting & forging, sheet metal, bar, pipe, stainless steel, nuts, bolts, engineering goods, non-metallic materials such as polymer, ceramic, glass, machined parts, and machine tool components from India.

### **The Sourcing Process by TCR**

Our 5-step sourcing process is tailored around the following process:

- TCR initially seeks details on product type, drawing, material specifications, required amount and quality with target delivery date from the client.
- TCR goes into the marketplace, contacting Manufacturers, traders and Steel producers, to establish production capability, availability, quality and unit price.
- TCR provides a product price quote in a FOB price format. We directly negotiate with the supplier and provide a competitive bid.
- If price and quality parameters are acceptable by the client, TCR instructs the manufacturer to produce an appropriate sample prototype for approval. The Prototype is shipped to the client.
- Once samples are approved, product order is placed with all manufacturing suppliers. Payment and shipping logistics are verified by TCR.

### **Raw Material Inspection Services**

Material Inspection Services are essential to ensure that all material supplied meets client / project defined specifications. TCR can perform quality analysis (QA) on all engineering goods sourced from India and validate them as per ASTM, BS, GS, JS, IS and other international standards. As part of all product sourcing projects, TCR undertakes Raw Material Inspection Services. We conduct on-site visits to the supplier / manufacturer's plant to determine evaluate fabrication techniques, assembly procedures or quality issues, and ensure that the production is as per client specified requirement. Inspection can range from a simple walkthrough to extensive sample retrieval and onsite analysis. Our sample custody is continuous from on-site photography and logging, through laboratory analysis and secure storage.

## 7. Non Destructive Testing (NDT) Services

At TCR Arabia, a team comprising of expert metallographers and metallurgists perform Time of Flight Diffraction (TOFD), Ultrasonic Flaw detection, Magnetic Particle and Liquid Dye Penetrant testing, Ultrasonic Thickness Gauging survey, Storage/Sphere Tank Inspection. Field service Metallography and structural inspection are also offered. TCR's experienced personnel are respected for their integrity and recognized by all the relevant inspection authorities.

Our NDT services are routinely performed in the following market sectors: nuclear / energy, space and aerospace, petrochemical, automotive, construction, transport, defense and general engineering.

### NDT Facilities

- Time of Flight Diffraction Equipment
- Kraut Krammer USK 7 Ultrasonic Flaw Detector and an Ultrasonic Flaw Detector with printer facility
- Dye Penetrant Test
- Portable Alloy Analyzers
- Ultrasonic thickness gauges
- Magnetic Yoke with AC/DC and Permanent
- Ultraviolet light for MPI
- Post Weld Heat Treatment Equipment with Control Panel and Recorder (conducted by TCR-KIL in Kuwait only)

### NDT Capabilities

- Time of Flight Diffraction (TOFD)
- In-Situ Metallography
- Ultrasonic Inspection
- Dye Penetrant
- Magnetic Particle Testing
- Weldability Study
- Visual Inspection and Field Services
- Portable Hardness
- Non-Destructive Testing: ASNT Level III and Level II

### A. In-Situ Metallography

Performed as an NDT service, In-Situ Metallography from TCR Arabia 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. The Metallurgists have more than 10,000 replica microstructure interpretations that 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. 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.

The TCR Arabia team has In-Situ Metallography equipments that include the Insipol 2000 and advanced electrolytic flow type polisher and etcher, portable rough grinder with self adhesive papers, portable microscope capable up to 400x magnification and replica kits with plastic based slides for replica preservation.

### B. Positive Material Identification (PMI)

TCR Arabia's on-site inspection and testing team has access to over 12 highly sophisticated Portable Alloy Analyzer Spectrometers which can in-situ non-destructively and accurately measure the chemical composition of materials. TCR Arabia's Positive Material Identification service is fast becoming an integral part of process safety management in the petroleum refining, petrochemical and electric power generation industries in KSA.

Using portable alloy analyzer spectrometers, TCR Arabia's engineers can provide elemental identification and quantitative determination without regard to form, size and shape. No samples need to be cut for PMI. Elements that can be identified using PMI include: Ti, V, Cr, Mn, Co, Fe, Cu, Zn, Ni, Se, Nb, Mo. TCR can also deploy the portable optical emission spectrometer that can also detect C, S, P, Mn, Si.



The TCR Engineering Services PMI division has expert engineering and inspection personnel to undertake incoming material inspection and can provide on-site alloy verification for Quality Control and Stock control purposes. TCR can analyze Melt and Weld and can provide a comprehensive maintenance assessment.

Using portable XRF analyzers, TCR provides scrap traders in India with the information necessary to make quick, confident decisions on material purchases, and the speed and throughput necessary to quickly sort volumes of materials and take advantage of sales opportunities.

TCR provides PMI services to a number of Metal producers, Foundries, Metal fabricators, Scrap yards, Scrap traders in the industry, Electric utility companies, Fossil and nuclear power plants, Refining and petrochemical industry, Construction engineering, and the Chemical process industry.



The range of equipments available for undertaking Positive Material Identification (PMI) at TCR is unparalleled in India. The PMI Services Team has Portable X-Ray Florescence (XRF) based instruments including Metorex XMet 3000TX and XMet 3000T, Niton XLt and the Metal Master 2000.



The team also has the ARC MET 8000, a Portable Optical Emission Spectrometer. The portable optical emission spectrometer can detect low carbon levels in 316 L Stainless Steel and provide accurate results reporting.

A wide range of alloys can be analyzed on site using PMI including:

- Carbon and low alloy steels
- Copper Alloys
- Stainless and High Alloy Steels
- Aluminium Alloys
- Nickel Alloys
- Duplex and Super Austenitics
- Titanium Alloys
- Zirconium Alloys

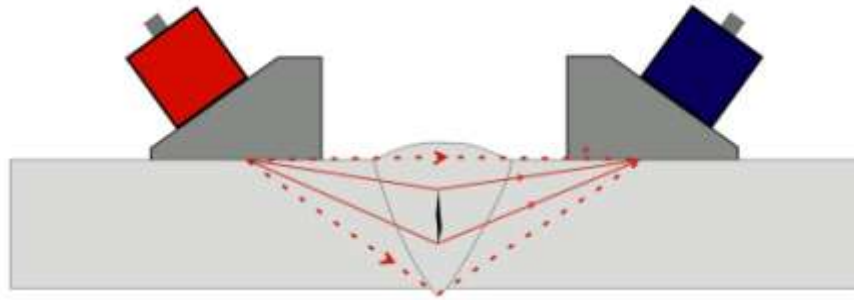
TCR has provided PMI services on over 600 projects including major oil and petrochemical installations in India, Malaysia, and the Middle-East. Some PMI projects were undertaken in conjunction with third party inspection of EIL, Lloyds, KTI, TUV, DNV & BARC.

Inspection services team members of TCR assist the Recycle and Resell Scrap traders in increasing their profit margins by measuring precious metals in electronics - Pt, Ir, Ru, Rh, Pd. This helps traders to quickly sort inventory to sell at optimum prices for each business transaction.

### C. Automated UT using Time of Flight Diffraction

Time-of-flight diffraction (TOFD) technique is an ultrasonic NDT technique which was first described by Silk (1977). This method relies on the diffraction of ultrasonic energies from 'corners' and 'ends' of internal structures (primarily defects) in a component being tested. Currently available at TCR Arabia, Time of Flight Diffraction (TOFD) is an advanced and automated weld examination technique that assists in Fitness For Purpose (FFP) inspections. Using TOFD, the expert NDT team members at TCR Arabia perform amplitude-independent accurate flaw sizing on a wide coverage area.

TOFD is a fast and efficient way to scan a lot of weld area in a very short time period. Dead zones near the front and back surface can be enhanced using combined TOFD and conventional pulse echo techniques.



This technique has many advantages:

- Wide coverage area using a pair of transducers
- Accurate flaw sizing; amplitude-independent
- Sizing technique using time-of-flight information
- One-line volume inspection, provides very fast scanning
- Setup independent of weld configuration
- Very sensitive to all kinds of defects
- No sensitivity to defect orientation
- Amplitude-insensitive, acoustical coupling less critical

#### **Combined TOFD and pulse echo**

While TOFD is a very powerful and efficient technique, it suffers from limited coverage resulting from two dead inspection zones. The first dead zone is near the surface, as a result of the lateral wave; the second is at the backwall, resulting from the width of the backwall reflection.

TCR Arabia's NDT equipment allows inspections simultaneously combining TOFD with conventional pulse echo. Pulse echo complements TOFD and covers the dead zones.

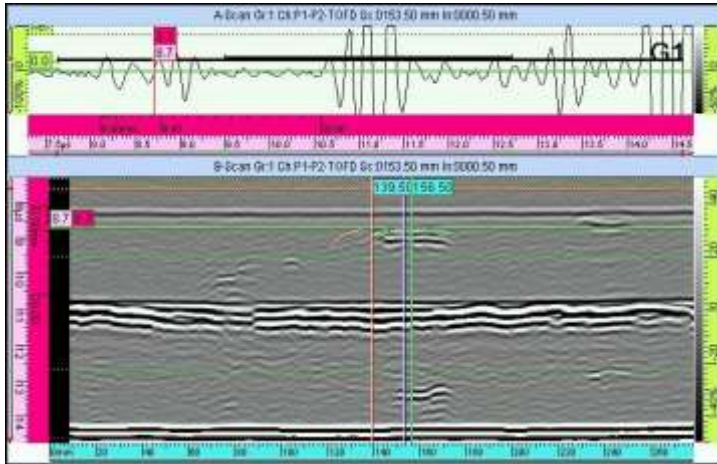
#### **Code Acceptance**

ASME Boiler and Pressure Vessel Standard Section VIII Code Case 2235-9 states that is acceptable to use the TOFD for Ultrasonic examination in accordance with ASME Section V, Article 4. ASME Code Case 2235-9 mentions about replacing RT with UT and has resulted in incorporating TOFD into pressure vessel work for both detection and sizing of flaws. This now allows TOFD to be used on all Section VIII pressure vessels.

API 579 in its current draft form states the Recommended Practice for Fitness-for-Service (The crack depth, length, angle and distance to other surface breaking or embedded cracks is typically determined using UT examination techniques, either TOFD or angle beam).

Draft-API 580 states the Risk Based Inspection Recommended Practice (Base Resource Document recommends automated ultrasonic shear wave testing as a highly effective inspection technique for crack detection and sizing. The capability of the Automated UT technique/type is evaluated using probability of detection (POD) curves from round-robins in the past where TOFD showed the best performance).

British Standards Institute's welding standards policy committee has created the BS 7706 as a guide for the calibration and setting-up of the Ultrasonic Time of Flight diffraction (TOFD) technique for defect detection, location and sizing of flaws. Another well documented guide is the Pr EN 583-6.



The ASME B31.3 code item 344.6.2. gives the ultrasonic examination acceptance criteria for flaw length indications with amplitude exceeding the reference level. The test sensitivity is set using the responses from known dimension reflectors in stipulated calibration pieces to derive a distance-amplitude correction (DAC) curve for each probe utilized.

However Code Case 181 of ASME B31.3 gives alternative ultrasonic acceptance criteria to 344.6.2. Para (i)(1) of the Case states the Data Analysis Criteria and it stipulates the criteria for evaluating reflectors as to their origin, e.g. flaws or geometry and (b) a non-amplitude technique is based on whether or not the indication exceeds a fixed length.

If this is exceeded then the indication has to be further evaluated taking into account its location, length, height and, for materials over 25mm thick, its "aspect ratio", i.e. height-to-length.

ASME B31.3 code case 179 is titled "Use of Alternative Ultrasonic Examination in Lieu of Radiography". This code is for revisions addresses materials ½ inch or less in wall thickness.

TOFD is perfectly acceptable to use as per Code Case 181 and Code Case 179.

ToFD is often done in conjunction with Manual UT. While ToFD brings speed of scanning it is not capable of identifying the exact location of a defect. For proper defect identification a TOFD parallel scan would have to be supplemented by Manual UT with 90 degree scans, multiple angle probes, location interrogation and manipulation (orbital, swivel, rotation, translation) to detect exact identification of the defect.

Experienced analysts from TCR will have clues to the characterization of these types of flaws using TOFD however at times the definitive conclusions may be rare. In the case of Phased Array technology an experienced analyst has a greater chance of determining flaw type based on the percentage of sound transmitted back to the probe.

TOFD is a quick and accurate tool for flaw sizing. Phased Array technology (using a TCG or DAC) and flaw location indicators with experienced analysts is also recommended.

The OmniScan technology has capabilities to indicate to the operator the exact location of a flaw with respect to the weld centerline and bevel face. An experienced analyst may be able to characterize fusion flaws based on location and amplitude response.

## 8. Third Party Inspection and Quality Assurance Services

TCR Engineering Services, from its offices in Mumbai, 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. The pricing structure for the on-site inspection services is set competitively and is based on man-day charges. TCR's inspection services include:

### A. Factory Audit

TCR Engineering Services Factory Audit service verifies the capability of a manufacturer to meet contract conditions for quality, quantity and delivery terms. Such assessments are often tailor-made as per a client's needs and requirements. By availing of this service, we eliminate the need for a client to be present on-site at the manufacturer's plant or factory.

### B. OEM Development

TCR Engineering Services with over 33 years of experience has a team possessing a strong engineering background. This team stands ready to offer consultation based on the latest technological advances, incorporating current national and international norms and standards. TCR can help assist in creating a first production prototype, technical documentation, standards evaluation, establishing production and quality criteria, and technical transfer to the supplier.

### C. Picking of Samples and Testing Coordination

Our inspectors can select a pre-determined number of samples from production at a factory and seal them, label & send them to our material testing laboratory for testing according to customer requirements. At the TCR Engineering Services material testing laboratory, we provide Mechanical Testing, Chemical Analysis, Positive Material Identification (PMI), Non Destructive Testing, Metallography, Corrosion Testing, Failure Analysis, Raw Material Inspection, Metallurgical Product evaluation, Engineering Research and Consulting.

### D. Initial Production Check

The inspection team from TCR Engineering Services can perform a visual inspection of products as available at the beginning of the production cycle against a client's instructions and Purchase Order specifications. The "Initial Production Check" when combined with a "Final Random Inspection" and any other on-line production checks, helps in taking corrective actions at an early stage of production cycle. The inspection team will send out intermediary reports to the client and keep them informed about the production progress relative to the delivery terms.

### E. In-Production Check

The inspection team performs a visual inspection of products as available during production. The inspection team may subject some products for random material testing. The in-production check service helps in reducing the final random inspection failure risk.

### F. Random Inspection

The TCR Engineering Services inspection services team performs a final random inspection comprising of a detailed visual inspection of goods before shipment. It is generally conducted on the premises of the manufacturer, on samples selected according to defined sampling procedures. The inspection criteria covering quality, quantity, marking and packing are based on the client's specifications and reference samples, as provided. Upon completion of the final random inspection a detailed inspection report is sent to the client and the inspection certificate issued to the supplier if all findings are positive.

### G. Loading Supervision

To further manage the product delivery, the TCR Engineering Services inspection team offers Loading Supervision which involves, "as appropriate," the checking of the container condition, identification of the loaded packing units with the previously inspected consignment, tallying of the total number of shipping packing units and sealing of the container. Loading Supervision service is offered in combination with the Final Random Inspection.

## 9. TCR Training Institute for Material Science and NDT

TCR Training Institute for Material Science and NDT in Navi Mumbai, India is committed to train latest technologies in NDT and Material Science to improve the skills of metallurgists, engineers and technicians. The trainers from this school can be commissioned to work on training programs by TCR Arabia in KSA.

The curriculum is formalized to provide custom training programs, best practices and leading knowledge in metallography, Eddy Current Testing, Magnetic Particle Testing, Liquid Penetrant Testing, Radiography Testing, and Ultrasonic Testing. All courses are designed to impart practical knowledge that can be applied immediately to the outside world.

All NDT examinations are held in accordance with ASNT Std. SNT-TC-1A by an ASNT Level III Professional. Metallography students are trained directly in a laboratory environment with challenging real-life projects.

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

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

In some circumstances, immediate job openings are available for qualified students.

### A. Manpower Deployment and On-site Placements

TCR Arabia undertakes NDT manpower assignments for Petrochemical and Power industry and can easily deploy strong engineering and NDT team on contract to the Kingdom of Saudi Arabia.

TCR Arabia's qualified personnel have worked on various projects in India and in the Gulf region in various disciplines of NDT such as Radiography, Ultrasonic, Welding, MPI, In-situ Metallography & Positive Material Identification. The inspection personnel have worked on design, fabrication, construction, inspection and erection of Pressure Vessels, Heat Exchangers, Towers, Stacks, Tanks, Plant Pressure Piping, Offshore oil wells and many advanced projects.

ASNT Level III personnel have a minimum of 7-15 years of experience and Level II personnel have 5-10 years of experience. Senior experience team members are also available; some with over 25 years of experience. Junior NDT inspectors have 2-5 years of experience and can undertake visual inspection, ferrite assessment, PMI operations, etc.

#### Skill Sets of NDT Personnel:

- NDT Level III (with Welding Inspector Qualification)
- NDT Level II in UT with Auto UT, Phased Array and TOFD Experience
- NDT Level II with extensive experience on pressure vessels
- AWS/CSWIP Senior Welding Inspector
- CSWIP Plant Inspector Level I (PL 11, PL 12)
- ASNT LPT Level II
- ASNT VT Level II
- ASNT MPT Level II
- ASNT UT Level II (including nozzle)
- ASNT RT Level II
- ASNT RFI
- Electrical Inspectors
- Positive Material Identification Operators
- Ferrite Assessment
- Ultrasonic Inspection (UT), Magnetic Particle Inspection (MPI), Radiography
- Insitu Metallography

## 10. Customers

TCR Engineering Services believes in establishing long-term, strategic relationships with our customers as opposed to short-term, opportunity-based engagements. TCR greatly values the relationships that it has established with over 2000+ customers and are delighted to meet their technical needs.

TCR has a long standing track record of delivering quality assurance services to some of the best known organizations in the oil and gas, refining, chemicals, electronics, construction, power generation, automotive, defense, aerospace, mining, pharmaceutical, biotechnology, manufacturing, process industry and public sector verticals.

Customers in India - TCR Engineering Services



Customers in India

Global Customers – TCR Engineering



International Customers

International customers include ABJ (Kuwait), Bechtel (USA), Komline-Sanderson (USA), Elliott Company (USA), Fisher, Samsung, Hyundai, Unilever, Johnson Screens (Australia), Xalloy (Thailand), MBH Analytical (UK), Micropak (Pakistan), Al-Multaq and Sons (KSA), NDT-CCS (Saudi Arabia), Ariana Afghan Airways (Afghanistan) and other large corporations. TCR has served customers in Canada, France, UK, USA, UAE, Nigeria, Bangladesh, Indonesia and many other nations.

Armed with the support of numerous faithful customers and a dedicated team of professionals, TCR continues to add to its expertise and capabilities to better address more of the analytical and testing requirements of the community of engineering materials users.

### A. Major Projects

Every one of the below jobs were part of a unique and interesting challenge to our team. The most rewarding part for TCR was when the clients saw a measurable value in the work of TCR, and came back for additional services and projects. Our noteworthy projects include:

#### Major PMI assignments completed at:

- KOC, Kuwait
- Hindustan Petroleum Corp (HPCL) at Mumbai, and Vizag
- Cochin Refineries Ltd., Cochin
- Indian Oil Corporation Ltd., at Baroda, Mathura, Barauni, Guwahati, Haldia, Digboi and Dibrugarh
- Bharat Petroleum Corp. Ltd., Mumbai
- Reliance Industries Limited, Hazira
- Larsen & Toubro Ltd., Mumbai
- Godrej & Boyce Mfg. Co. Ltd., Mumbai
- Oswal Petro Chemicals Ltd.

#### Major Metallography Customers include:

- Constar, USA
- NDT-CCS, Saudi Arabia
- Zamil Group, Saudi Arabia
- Alstom

#### Major Failure Analysis Investigations Completed for

- Schlumberger Oilfield Services
- Wartsila, Finland
- Reliance Industries
- Hindustan Petroleum Corporation
- Unilever, Bangladesh
- Mahindra and Mahindra, India

- Tyco Sanmar Ltd., Tamil Nadu
- Fisher Xomox Ltd.
- Petronas, Malaysia

**Ongoing Third Party Inspection** provided for:

- Komline Sanderson, USA
- Elliott Company, USA
- Bloxwich, U.K.
- Metpost, U.K.
- American Industrial Supply, USA
- Aventech, Canada
- Flowserve, U.K.

**Major RoHS Compliance Testing Customers:**

- Sys Concept, Canada
- Birla Copper

- Indian Oil Corporation

**Major Corrosion Detection Customers include:**

- Caterpillar, USA
- GMMOS, UAE
- Larsen and Toubro (L&T)
- Jutal, China
- NPCC, Oman
- Xaloy, USA and Thailand
- Johnson Screens, Australia
- Walchandnagar Industries

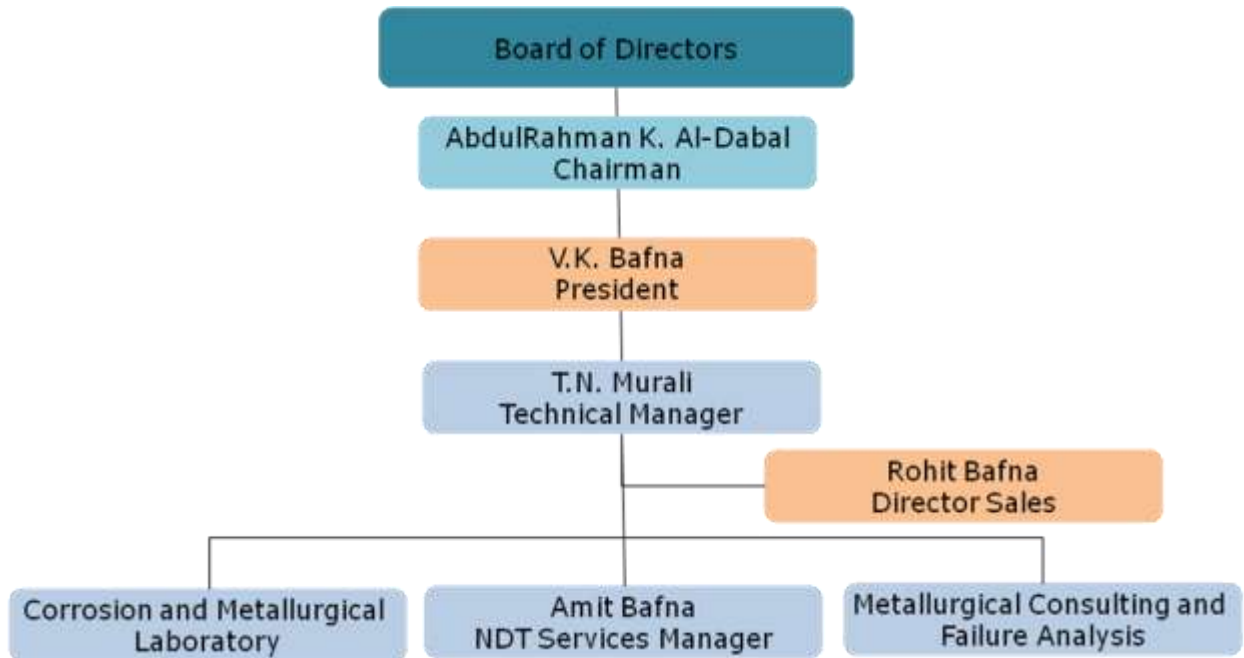
**Major NDT Projects completed at:**

- ONGC, Mumbai
- Unilever, Bangladesh
- KOC, Kuwait
- NPCIL, Kota
- Several Projects under EIL and L&T

## 11 Management

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

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



### A. AbdulRahman K. Al-Dabal, Chairman

President and CEO of Gas Arabian Services and Chairman of TCR Arabia.

### B. V.K. Bafna, Managing Director, TCR Engineering Services

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

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

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

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

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

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

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

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

### **C. Paresh Haribhakti, Chief Failure Analyst**

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

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

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

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

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

Research oriented creativeness of Mr. Haribhakti spearheaded the development of a powerful image analysis software for Metallurgical use - the Microstructure Characterizer Software (MiC). He has also developed a well respected chemical

composition mapping method for identification of dilution in weld zone. He performs color metallography to increase the capabilities of interpretation of microstructure. He has also developed custom electrolytic polishing for carbon and alloy steel material.

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

#### **D. T. N. Murali, Technical Laboratory Manager (KSA)**

Mr. Murali has over 20 years of material testing laboratory experience. He is familiar with the metallurgy of carbon, alloy and stainless steels, superalloys, and with ASTM, ASME, API, IS and NACE material standards and specifications, and with both destructive and nondestructive test methodology. He has strong experience in evaluating properties of materials, materials characterization and behavior, materials specifications, mechanical testing, corrosion detection, machining of materials, and laboratory design and operation.

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

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

#### **E. Amit Bafna, Manager Third party Inspection and NDT Services**

Mr. Amit Bafna has over 5 years of experience in the field of Inspection, Mechanical Testing, Welding and NDT. He assists multiple international customers in maintaining quality deliverables.

He inspects and reviews manufactured components during the manufacturing cycle to insure manufactured items meet all drawing and specification requirements. He determines the proper methods of inspection and works with customer's Quality Planning teams to develop compliance/non-compliance documents, check sheets, and periodic reviews to insure quality deliverables.

He leads a team of inspectors spread across India that undertake plant and factory audits, and Inspect and verify material and products to determine compliance to engineering drawings, procedures, and client provided specifications.

Mr. Amit mentors and develops the skills of junior inspectors in the proper use of all inspection gauging and techniques, reporting formats, coordinate client related meetings, etc and keeps team members abreast of the changing quality environment to implement use of new techniques and the changing customer needs.

Mr. Amit is a trusted communicator who identifies and writes clear, concise reports describing variations and inspection results on products not meeting requirements, processes not being followed, or improper planning that may jeopardize the quality of products. He maintains high levels of safety in all inspection projects and follows established safety and security rules and regulations.

Mr. Amit has a Bachelor of Science degree from Indore University, including a ASNT Level II certification. He is trained in Canada for the use of Automated UT using ToFD.

#### **F. Rohit Bafna, Director Global Sales and Auto UT**

Rohit is currently Director Global Sales based in TCR World in Washington DC, USA. Rohit is responsible for operations of TCR Arabia in the Kingdom of Saudi Arabia and TCR-KIL in Kuwait.



Under his leadership the US office has grown from its incubation stage to one which is now profitable. Prestigious clients that have trusted TCR to carry out material testing and quality assurance services secured by Rohit include Caterpillar, Aventech, Elliot Company, Komline - Sanderson, Constar, Xalloy, Sys-Concept and the US Army.

Mr. Bafna has the cost and technical responsibility for execution of specific contract(s), including devising the planning, directing, and coordinating of project activities to ensure that project objectives are accomplished within the prescribed time and funding parameters. Where subcontracts 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. Mr. Bafna has over 8 years of Sales and Marketing in the Material Testing and Quality Assurance business. Rohit has undergone extensive training on Ultrasonic Testing using Time of Flight Diffraction (TOFD) at Olympus in Quebec, Canada. Mr. Bafna has a Bachelors degree in Computer Sciences from DeVry Institute of Technology, Los Angeles, California.

## 12. Safety, Health and Environment Policy

TCR is very proud to have an exemplary track record in health, safety and environmental compliance, with no major lost time accidents in the thirty four years of our operation. The company intends to imbibe the same principles of its parent in the branch in KSA.

TCR Arabia has a 'Zero Tolerance' Approach with regards to Safety compliance of its employees. TCR is committed to good Health and Safety practices based on sound risk assessments and appropriate training.

TCR is very proud to have an exemplary track record in health, safety and environmental compliance, with no major lost time accidents in the thirty three years we have been in operation.

Throughout TCR Group including TCR Arabia a 'zero tolerance' approach to SHE has been adopted and together with our proactive approach on these issues, we will ensure we remain the safest chain of commercial laboratories in the region.

### A. Safety Training

Each new member of staff is thoroughly briefed on the safety hazards associated with a laboratory environment. The training will, as a minimum, cover the safety aspects of laboratory work including the following:

- Handling of substances hazardous to health.
- Safe operation of cutting, milling, grinding and turning equipment.
- Safe operation of lifting equipment.
- Eye protection.
- Ear protection.
- Respiratory safety.
- Fire Alarm System.

Each member of staff is asked to sign a document to confirm that he has read and understood the safety hazards and precautions. The company supplies safety wear necessary to provide the required protection against laboratory hazards.

### B. Safety Control

Procedures, records and maintenance contracts are in place to control safety. These include:

- Fire Alarm and extinguishers maintenance contract.
- H2S Procedures.
- Training Records.
- Injury Records.
- Control of flammable substances and acids.

### C. On-Site Safety

Each member of the site team working on a particular project will be briefed prior to his or her first visit to site on the safety hazards associated with site work. Should an organized safety-training program be in existence, staff will attend it. A site visit can be organized by the company responsible person to discuss the safety aspects with the site safety officer.

The company responsible person can carry out periodic site visits and regular safety reviews with site staff.

TCR will supply all the required safety wear necessary to provide the required protection on site, if the same is not provided by the client.

### D. TCR Arabia Safety Policy Statement

TCR sets high standards and expects all managers to be actively involved with respect to Health and Safety and the protection of our environment.

This means:

- Each TCR Arabia location will comply with all applicable Safety, Health and Environment Regulations within the territory in which it operates.
- While the Directors and Management accept their responsibilities for Health and Safety at work, they expect all employees to play their part and to fulfill their legal obligations under Health and Safety Legislation by taking reasonable care to avoid accidents to themselves and others and following company procedures. Only by full co-operation can the common objectives TCR be achieved.
- Every employee has the responsibility to maintain a safe working environment in which risks arising from the TCR's working practices are identified and controlled. Any willful violation of safety policy will result in disciplinary action.

The definition of a serious breach of Safety Policy is very difficult to categorize objectively in a prescriptive sense and therefore circumstance will dictate the appropriate disciplinary action. There are of course specific instances where summary dismissal will be applicable, i.e.

1. Recklessness in the use of chemicals and radiation sources or any other hazardous materials.
2. Willfully removing or disabling any safety device.
3. Operating equipment or driving whilst clearly incapacitated through alcohol or drug abuse.
4. Falsification of safety records or incident reports.
5. Disposing illegally of any hazardous substance.
6. Willful negligence to carry out proper maintenance of buildings, equipment, etc.

TCR is committed to conducting its activities in such a way as to protect the safety of clients, the public at large, visitors and contractors on company premises.

## E. Environmental Protection

Environmental matters are of great importance to the Company.

To Avoid Damaging the Environment, all TCR Arabia employees are encouraged to strictly comply the following:

- Do not pour chemicals or other substances down internal drains. Check with your supervisor for the correct disposal procedure.
- Proper waste management system must be used to ensure that all classes of waste are disposed of in accordance with current legal requirements and local rules
- Store all oils and chemicals including solvents and paints in designated bounded areas.
- Refueling site transport, compressors etc. must be carried out in designate areas.
- If you handle substances hazardous to the environment, make sure you are aware of the site emergency procedure for spillage or leakage.
- Make sure that you are authorized and familiar with the local procedures before filling or draining process tanks or bulk storage tanks.
- Report all spillages/leakages and other incidents, the breakdown or malfunction of any plant and equipment controlling discharge into the environment and any poor housekeeping.

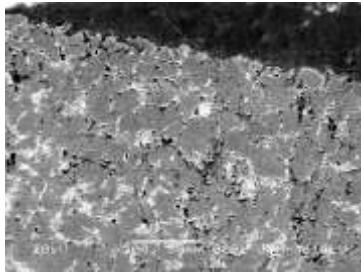
## Appendix A – Case Study of Failure Analysis Projects

### A. Failure Investigation of Primary Super Heater R-4 Zone Tube Of 140 Mw Boiler

**Introduction:**

The MOC of tube is TU 15 CD 205 .The service life of tube is 7 years before failure.. The steam temperature & pressure of tube are and 450°C and 140 kg/cm<sup>2</sup> respectively. The tube has OD 63.5mm and ID 5.5mm. Tubes are located horizontally with flue gas passes vertically.

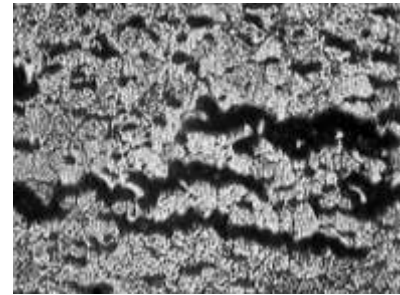
**Scanning Electron Microscopy (SEM):**



SEM examination revealed presence of inter-granular cracks and presence of numerous creep cavities at grain boundary. Presence of micro-cracks are observed more towards outer surface and near by crack region. Severity of cracks and cavity reduces when we move away from the main crack.

**Microstructure Examination:**

Crack displayed inter-granular nature of propagation with many small parallel cracks adjacent to main crack is observed.



Magnification: 300X

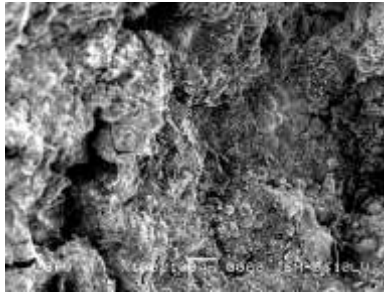
In present case the failure of tube seems to have occurred due to long term over- heating, above allowable design temperature, could be due to higher velocity of flue gas at this region or impingement of flue gases on tube surface facing flue gas or improper steam flow.

**a. Failure Investigation of Radiant Coil of Cracker Furnace H-130 of a Refinery**

**Introduction:**

In a bottom fired furnace tube failure have experienced service of 14 months against the normal life of 6 to 7 yrs. MOC of 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/cm<sup>2</sup> g.

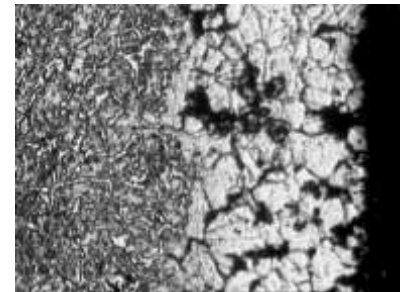
**Scanning Electron Microscopy (SEM):**



SEM analysis revealed progressive nature of fracture especially towards OD side. However, majority evidences on fracture surface were masked under heavy scaling, which is generally expected under such service.

**Microstructure Examination:**

The crack is associated with carburizing more so at outer surface with decreasing the depth of carburizing towards ID. Another important evidence of crack originating from outer diameter and progressing towards ID.



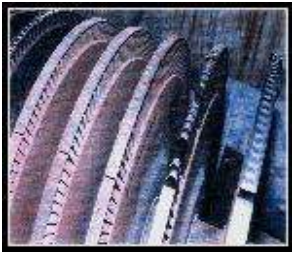
Magnification: 300X

In present case the failure of tube has occurred due to localized overheating, which reduced ductility and failed under operational vibrations.

**Recommendations:**

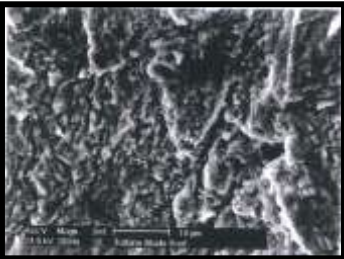
Look in to the possibility of development of high temperature at the time of decoking operation.

**c. Failure Investigation of 8th Stage Blade of a Steam Turbine**



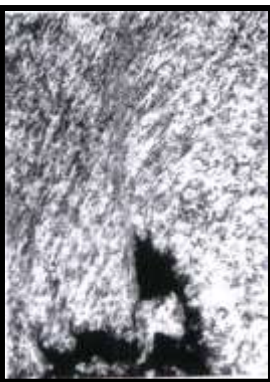
**Introduction:**

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



**Scanning Electron Microscopy (SEM):**

Fracture surface kept under SEM show multiple origins of the fracture and clearly shows progressive mode of failure. Fig. suggest rubbing of the metal surface where the failure had occurred.



**Microstructure Examination:**

Microstructure on cross section of 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 trans-granular path.

Failure of 8th stage blade has occurred due to corrosion fatigue, initiated at most stressed area.

**D. Failure Investigation of SAC Plant Piping Going to V-801**

**Introduction:**

In a Sulphuric acid concentration plant, as a part of 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 entire replaced pipeline reduced to paper thickness with punctures. The pipeline is operating with 1 to 2% H<sub>2</sub>SO<sub>4</sub>, 0.5% HNO<sub>2</sub> and 0.6 to 1.0 % HNO<sub>3</sub> at 10 to 20°C temperature.

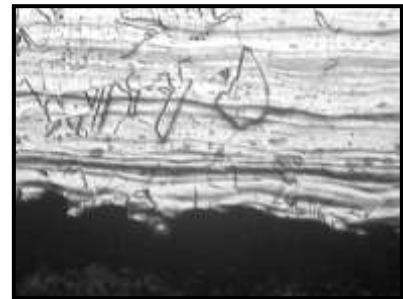
**Low Magnification Examination:**

Low magnification examination was done to find out corrosion characteristics. Internal surface of pipe, weld and elbow showed severe corrosion on pipe. The close-up view of corroded surface inside the pipe show effect of general corrosion and flow pattern. Leakages observed in the form of openings between weld and pipe.



**Microstructure Examination:**

Uniform dissolution at ID is observed under microstructure examination.



Magnification: 300X

The fluctuation in Nitric acid concentration did not allow to stabilize passivity on newly fabricated pipeline resulted into severe corrosion.

**E. Failure Investigation of Integral Pinon Shaft at a Cement Mill**

**Introduction:**

Premature failure of integral pinion shaft was reported at cement mill. The shaft failed after service life of approximately 15,000 hours (625 days) against 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 form of cracks. Cracks are observed at 45° to the longitudinal axis of shaft.

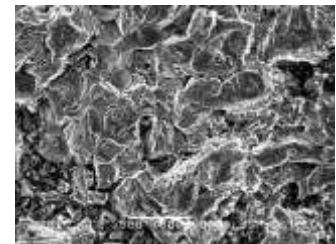


**Low Magnification Examination:**

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

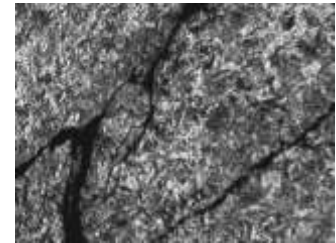
**Scanning Electron Microscopy (SEM):**

SEM reveals inter-granular fracture with inter-granular cracks. A fracture is brittle and shows inter-granular mode. Presence of fine cracks is observed.



**Microstructure Examination:**

Microstructure examinations at various section revealed that, general condition of shaft is in hardened and tempered 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 present case.



Magnification: 560X

The shaft failed due to pre-existed Heat treatment cracks under operational load.



## Document and Project Approval

The individuals or their designee in the positions listed below must acknowledge receipt and review of this document by signing and dating on the appropriate line. Your signature represents that you have read and reviewed this document in detail. Should you have any questions, please contact the concerned persons at the numbers listed below.

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