2011

TCR Advanced Engineering P. Ltd.

Experts in Metallography and Failure investigation

Company Profile

www.tcradvanced.com

| Testing | Inspection | Field Testing | Consultancy

Service Partner Company of TCR Engineering Services P. Ltd.

| India | Kuwait | Saudi Arabia | South Africa |

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1) BRIEF HISTORY OF THE COMPANY:

TCR Advanced Engineering Pvt. Ltd. was established on 12th Feb.1998, and it's operation from 14th March 1999 at Vadodara. It is a service partner of TCR Engineering Services Pvt. Ltd. Mumbai, a company established since 1973.

TCR Advanced Engineering Pvt. Ltd. has been established to cater for advanced metallurgical needs of the Industries at Vadodara a hub of chemical and petrochemical industries. Company has set-up full-fledged advanced Metallography laboratory facilities at Vadodara, Gujarat. TCR ADVANCED offers specializing services in the field of Metallography, The company provides services such as Failure Investigations, In-situ Metallography for process related equipment's in-service degradation, Indigenization of the components, Selection of materials of constructions and Remaining life assessment.

TCR Advanced Engineering has a competent team of metallurgical engineers, technicians and other field staff working for catering the need of Metallography and testing work. Mr. Paresh U. Haribhakti (Managing Director) who is a Metallurgical Engineer and holds Masters degree in 'Materials Technology' heads the company. He is having more than decade experience in the field R & D activities, Failure Investigations, Damage Assessments and RLA studies at India's largest fertilizers and petrochemical complex GSFC Ltd., Vadodara.

TCR Advanced has set up a full fledged TESTING Division to meet the need of routine testing such as raw material testing, Material Identification, Welding Qualification, NDT testing, Microstructure examination for evaluation of material processing, chemical properties & physical properties of metallic materials. The testing division of TCR ADVANCED is a NABL accredited Testing Laboratory in the field of Chemical and Mechanical Testing as per international standard ISO/IEC-17025 – 2005. *(Please refer Annexure B for our scope of NABL Certification)*. The TCR advanced is also approved laboratory for Lloyds Register Asia(LRA) & Indian register for shipping (IRS).

2) RANGE OF SERVICES OFFERED BY TCR ADVANCED

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

Chemical Analysis
- Lab spectrometer
- Wet analysis
- Portable XRF based spectrometer
- Purity Of Metals
- Ash Content

Mechanical Testing
- Tensile Testing
- Bend/ Re-bend Test
- Hardness Testing
- Impact Test
- PQR test
- Peel test
- Flaring/ Flattening Test
- Residual Stress Measurement

Corrosion Testing
- Corrosion rate as per ASTM A-262
- Pitting Corrosion as per ASTM G48
- Crevice corrosion as per ASTM A 923
- Corrosion rate by Potentiostate

Metallurgical Testing
- Microstructure Examination
- Macrostructure Examination
- Linear Measurement on weld
- Grain Size measurement
- Inclusion rating
- Jominy End Quench Test
- Case depth Measurement
- Nitriding/ Coating Layer measurement
- Color Metallography
- Sigma Phase measurement
- Retained Austenite
- Micro Hardness

Specialised Services
- Failure Investigation
- Remaining Life assessment
- Insitu metallography
- Fitness for service
- Third Party Inspection
- Help on indigenization
- Scanning Electron Microscopy
- NDT training
- Metallography training.

Non Destructive Testing
- Ultrasonic Examination
- Dye penetration Test
- Magnetic Particle Inspection
- Thickness measurement
- In-situ Metallography
- Positive Material Identification

3) Material Testing Services

A. CHEMICAL ANALYSIS

TCR ADVANCED is providing chemical analysis facilities for accurate characterization and identification of metals & alloys. TCR ADVANCED by wet chemical analysis and by Optical emission spectrophotometer using advanced Spectra lab machine SPECTROMAXx is capable of accurately analyzing the Iron base, copper base, nickel base and aluminum base alloys.

TCR ADCVANCED is Equipped with Portable XRF based spectrometer for Positive Material Identification. This is a NDT technique for analysis of alloy content of the material. It cannot detect the nonmetallic elements. Typical PMI results are accurate to ±10%. This is very useful technique in material sorting, scrap identification etc. TCR Advanced also provides services chemical analysis at site by portable SPECTRO through its service partner company. With this equipment one can analyze all elements including Carbon, Sulfur, Phosphorous, Silicon apart from alloying elements.

List of chemical Analysis test equipments

SR. NO.	NAME OF EQUIPMENT	MAKE	YEAR OF MFG.
1.	Optical Emission Spectrometer	Spectromax X-German Make	2005
2.	Strohlien's Apparatus for Detecting Carbon and Sulfur	Venus Instruments Mfg. Co.	2001
3.	Kjeldha's Apparatus for N_2 determination	Borosil Glassware with sunbeam heating mantle	2001
4.	Fume Chamber	Fabricated Indigenously	2001
5.	Heater Control System with time totalizer	Indigenously developed	1998
6.	2 KW Furnace with temp. Controller	Fabricated	1998
7.	Distilled water Plant	Lab Hosp	2001
8.	Hot air oven	Jaymet	2001
9.	Electronics Single Pan Balance (0.0001 gm Accuracy)	Ohaus, US make	2001
10.	Full Fledged Lab Glassware for Chemical Analysis	Borosil make	-
11.	Electrolytic Apparatus with Platinum electrodes for Cu and Pb determination	Electrodes are made by Hindustan Platinum ltd.	2001
12	PMI (Portable XRF based spectrometer)	Oxford Instruments, XMET- 3000TX	2009

B. MECHANICAL & PHYSICAL TESTING

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

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

List of Physical & Mechanical test equipments

NAME OF INSTRUMENT	MAKE	YEAR OF MFG.
Rockwell hardness tester with standard accessories Measuring Range –HRA, HRB, HRC & superficial hardness testing scales HR15N, HR30N, HR45N, HR15T, HR30T, HR45T	SMS, Ahmedabad	2005
Vickers Cum Brinell Hardness tester with standard accessories Load range Vickers hardness test 5,10,15,20,30,40,50,60,100 and 120 kgf Brinell – 15, 31.25, 62.5, 187.5 kgf	German make, Sold& serviced by Blue-star	-
Vickers Hardness tester with standard accessories Load range Vickers hardness test 5,10,15,20,30,50,100 and 120 kgf	FIE Make	2010
40 T Computerized Universal testing machine • With mechanical as well as Electronic Digital Display. • Electronic Extensometer for 0.2 % Proof stress • Load range 4, 10, 20, 40 Tons	Akash Industries	2001
Vicker's Micro hardness tester Load range: 10, 25, 50, 100, 200, 300, 500, 1000 gms	Wison Wolpert make	2002
Vicker's Micro hardness tester Load range : 10,25, 50, 100, 200, 300, 500, 1000 gms	Banbros Make	2007
Impact testing machine	FIE make	2008
Jominy End Quench Test setup for hardenability of Steels	In house developed	2008
Lateral Expansion Gauge, Squareness gauge for impact specimen	Anand Testing Machines	2009
3000 Kgf Brinnel hardness tester	FIE make	2010
Profile Projector	Metzer, Megavision	2008

C. METALLURGICAL TESTING

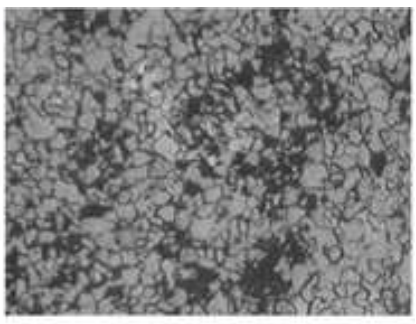
Qualified metallurgists at TCR ADVANCED are experts in Metallographic preparation & examination to evaluate the characteristics of metals. We can assess a material's heat treatment condition, microstructure, and forming process. The team undertakes Macro and Micro examination including Weld Examination,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

TCR Advanced has taken a lead in certifying Heat Treatment Quality aspect from microstructure point of view. A conventional acceptance criterion for heat treatment is through hardness testing. However, hardness testing alone can be misleading, since certain unwanted phases and its distribution is not reflected in hardness reading. Fine distribution of phases and its monitoring through microstructure is the only answer for the acceptance of heat treatment that promises desired or extended life of component. TCR Advanced has taken this challenge and helped many industries for use of microstructure examination as quality control tool for determining heat treatment.

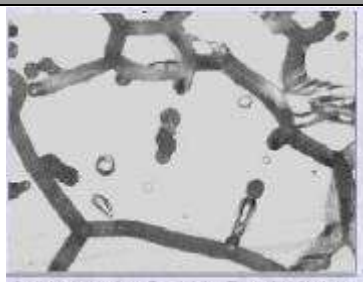
We certify following heat treatments…

Bulk	Surface	Metals / Alloys
Normalising	Nitriding	Steel
Homoginization	Carburizing	Cast Iron
Solution Annealing	Carbonitriding	Super Alloys
Hardening & Tempering	Hard Surfacing	Nickel Alloys
Precipitation Hardening	Induction Hardening	Copper Alloys
		Stainless Steel
		Aluminium Alloys
		Heat Resistant Alloys

As Cast carbon steel

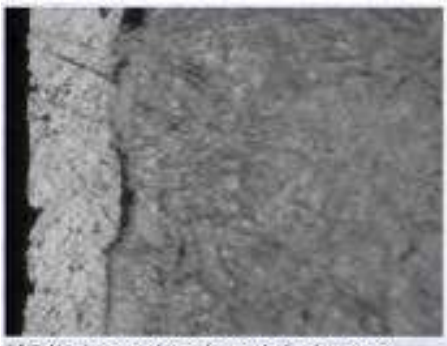


Normalized Carbon Steel



Intergranular Carbide Precipititaion Solution Annealing is not satisfactory.

Isolated Carbide Precipitation Solution Annealing is not satisfactory.



White layer developed during gas nitriding process undesirable structure.

Porosities developed with Sursulf nitriding treatment

TCR advanced has expertise in metallurgical testing. We undertake intermetallic phase identification, volume fraction of various phases in weld, HAZ, and Cast structures. TCR ADVANCED is the only accredited facility for microscopical measurements such as coating thickness, weld penetration measurements, minimum leak path in tube to tube sheet joints etc.

List of Metallurgical test equipments

NAME OF INSTRUMENT	MAKE	YEAR OF MFG.
Inverted Metallurgical Microscope (Model: GX 51-233D) with digital camera	Olympus Corporation, Japan	2005
Optical microscope with CCD camera attachment model EPY TYP – II	Carl Zeiss, Jena	-
Inverted Metallurgical Microscope (Model: GX 51-233D) with digital camera	Olympus Corporation, Japan	2010
Low Magnification observation station with CCD attachment	Machine Vision, MV5100HU	2010
Metallurgical image processing workstation with Microstructure Characterizer(MiC) Software	Developed Indigenously	-
Metallurgical Microscope (Model: BMI-101 A)	Banbros	2005

NAME OF INSTRUMENT	MAKE	YEAR OF MFG.
Inverted Metallurgical Microscope	Radical	2008
Stereo zoom microscope with standard accessories	Carl Zeiss Jena	-
Portable Etching Cum Polishing machine model – Insipol 2000	Instruments Universal	2001
Metal Polishing with D. C. drive	Naresh Industries	2003
Portable Angle grinders & Polishing equipments model – 875	Chicago Pneumatics	2001
Low speed metallographic Cutting/ Sectioning machine Type Vs- 100	HIFIN	2000
Hot moulding machine Type MHP – 310	HIFIN	1999
Automatic Polishing Machine model MoPao 1000	MoPao	2009
Heat treatment Furnace(up to 1100 C)	Shivang furnaces	2009

D. CORROSION TESTING

TCR ADVANCED undertakes a wide range of corrosion tests per ASTM, DIN, or as per an individual client's requirements. Experienced 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. A wide variety of corrosion related tests are undertaken at TCR ADVANCED to determine susceptibility to intergranular corrosion, pitting corrosion, stress corrosion cracking etc. The range of instruments available to perform these tests is unrivalled in our operating regions. Highly experienced and qualified engineers routinely undertake corrosion studies. We also carryout the testing under witness of 3rd party inspection agencies like LRS, TUV, DNV, ABS, BV and other inspection agencies.

List of Corrosion test equipments

NAME OF EQUIPMENT	NO OF SETS
Gamry Make Series G750 Potentiostate/ Galvenostate for Electrochemical Analysis and Corrosion studies.	1
Full fledged set up and Erlen Meyer Apparatus for conducting Various IGC tests as per ASTM A – 262	15

Complete set up for conducting various tests as per ASTM A – 923 for pitting corrosion	12
Complete setup for conducting various tests as per ASTM G-48	6
Constant temperature bath range: 5°C to 80° C	1
Constant Temperature bath Range : RT to 100° C	1

E. NDT TESTING

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

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

List of NDT testing equipments

NAME OF INSTRUMENT	MAKE	YEAR OF MFG.
Portable Hardness Tester	Time Group Inc.	-
Electro Magnetic Crack Detector (Yoke Type) with A. C. & H. W. D. C. Mode,	Magnaflux make	2003
Ultra Violet Black Light with power supply unit	Magnaflux make	2003
Magnetic Field Indicator	Magnaflux make	2003
Magnetic Field Meter (0-10 G.)	In-electronics	2003
Dry and Fluorescent Magnetic Particle Powder	Magnaflux	2003
Dye Penetration Kit	Magnaflux	-
In-situ Metallography Kit	Developed In-house.	1998 –2003

Ultrasonic Flaw Detector (Model: Einstien-II) with Reference Blocks (IIW V1, V2 & Step Wedge)	Modsonic	2004
Ultrasonic Thickness Gauge (Model: ETM-2) High temperature probe.	Parikh Ind. (EEC)	2006
Bench type MPI Machine, (Model -D960)	Magnaflux make	2004
Coil type MPI Machine (Model D500)	Magnaflux make	2008
Internal Oxide thickness Gauge		
Portable Hardness tester Hardness tester UCI method (Model MIC 20) with Diamond Inventor	Kraut Kremer	2010
Rebound type hardness tester	Time Make	2009

4) SPECIALIZED ACTIVITIES:

A. THIRD PARTY INSPECTION AND QUALITY ASSURANCE SERVICES

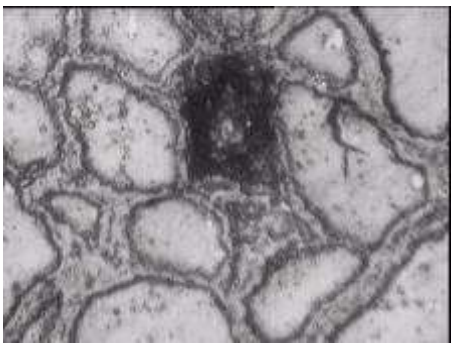
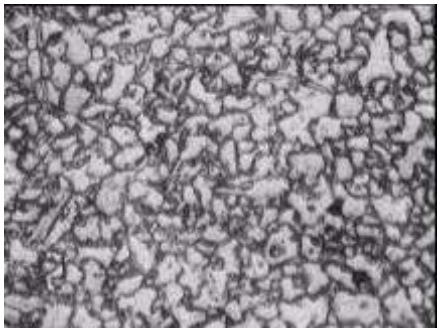
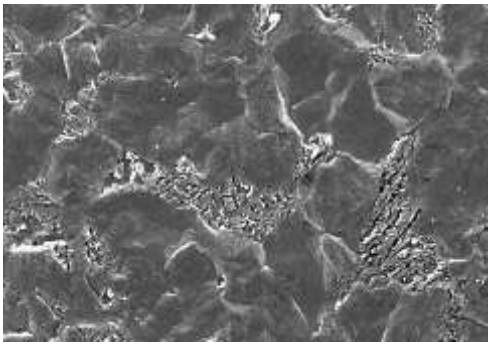
TCR ADVANCED, through its service partner company's offices, provides inspection and quality assurance services to help retailers, trading partners, importers and manufacturers assess product quality and meet the regulatory requirements of their industry vertical. Independent, third-party inspection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

B. IN-SITU METALLOGRAPHY

Performed as an NDT service, In-Situ Metallography from TCR determines in-service degradation of critical components of process plants operating under high temperature, high pressure or corrosive atmosphere. TCR's Metallurgists have strong experience in the interpretation of microstructures. More than 10,000 replica microstructure interpretations have been logged and captured to our databases. These databases contain extensive information from various plants that have been captured over the course of us performing this service. 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 In-Situ metallography is performed for following areas:
- To find out in-service degradation of critical components of the process plants operating under high temperature/high pressure/corrosive atmosphere.
- Damage Assessment of fire affected equipment of the plants.
- Microstructure survey for critical components viz., Boilers, Pipelines, Reactors and Vessels for condition monitoring/health assessment.

- To develop a data bank of critical components of equipment of process plant by periodical monitoring for preventive maintenance and planning for inventory control.
- To provide suggestions on their welding used components of process plants.
- To check the quality of the microstructure of component for intended service before put in to use.

Examples of Replicated structures

C. DAMAGE ASSESSMENT / RLA

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

D. TECHNICAL HELP FOR INDIGENIZATION

To unfold the metallurgical status/properties of imported components by destructive/nondestructive studies, to generate baseline standard for indigenization. Technical help is provided to decide manufacture route and guidance is provided to derive quality checks on indigenously developed components.

Details required from client:

1. Working condition of component.
2. Type of loading & stresses.
3. Design and operation condition.
4. Service history of component.
5. Life of an important component.

E. SELECTION OF MATERIALS

Weight loss experiments. Samples of different metals/alloys are exposed under simulated or actual process plant solution in the laboratory with and without stirring. This technique has limited application. Coupon of different metals/alloys is exposed to actual plant environment. A systematic approach is formulated based on requirement of intended services, literate survey, and relevant standards like NACE, ASTM and API. The laboratory study is performed on exposed sample to categorize their performance and suitable MOC is recommended. Electrochemical experiments to find out relative corrosion resistance perfromed by accelerated testing under laboratory conditions. MOC selection is done with readymade database and experience of others from published literature.

F. QUALITY IMPROVEMENT

TCR Advanced undertakes total quality improvements for stringent requirements against international specifications. Thorough survey is undertaken by auditing existing manufacturing procedure. Stagewise investigations are followed for manufacturing of product including raw material. Effects of processing conditions are derived with respect to different properties of the component. Based on the study recommendations are made for improvements in metallurgical process/raw material. Required optimum quality control checks are suggested to ensure consistency in quality for continuous production. TCR Advanced deputes a team of metallurgical engineers to perform this task. report comprises of fundamentals of metallurgical processing variables on final properties of component is submitted along with recommendations.

G. SOLUTIONS OF CRITICAL WELD PROBLEMS

TCR Advanced Engineering Pvt. Ltd., has vast expertise of solving critical weld repair solution of the aged plant components. Nowadays the material resources are limited and value of new product is increasing day bay day. The repair weld solutions can salvage the critical components of process plant and can made huge saving in terms of production loss. The repair weld technology requires in depth understanding of metallurgical degradations vis-a- vis operating conditions. Clear understanding of physical metallurgy and welding technology. There is a right solution of every problem and the solution can be found out by engineering and technical common sense with strong fundamentals. TCR has been leader in many aspects. The off shoot of knowledge bank at TCR Advanced is the successful stories behind more than 600 failure investigations of the industries. This insight in to the failure mechanisms has strengthen the knowledge of TCR technical team which is directly implemented for repair weld solution. When any plant of critical machinery component is under breakdown the immediate right solution is sought after manier times the repair weldings are done with little or No understanding about the metallurgical fundamentals which in turn proves to be disastrous and management looses the trust in the technical competency. This philosophy promotes hast decisions for replacing the components at premium cost. Instead of this a systematic detailed metallurgical investigation would provide the extent and nature of degradation there by utilizing knowledge of metallurgy a proper welding procedure can be devised. TCR ADVANCED has helped the industries by providing the repair solutions on critical pump casing, shaft, nitrided components reformers, and so on.

The engineering consulting team can be approached with detailed history of problem. Our team can reach to your sight with in 24 hrs and start generating information and data on the components to be repaired. For successful repair a mock up test is necessary from the same material preferably for the aged material of similar grade. Incase it is not available then virgin material of the similar grade is also useful. A mock up test will establish the confidence in welder and welding parameters. After successful welding through NDT testing is recommended to ensure the trouble free welding joint for future service.

H.FERROGRAPHY

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

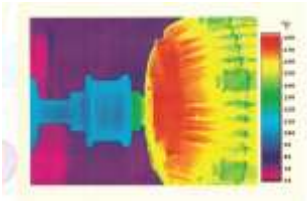
I. EDDY CURRENT TESTING

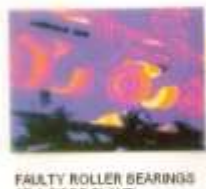
The Eddy current test is not a volumetric technique. This is a surface technique and can readily detect very shallow surface defects (fatigue crack, inter-granular stress corrosion cracks etc), sub surface defects (inclusions, voids etc.) within a depth of say 6 mm. It can also identify pitting, cracking, microbiological induced corrosion damage, support wear, erosion etc. and hence is very widely used as an important

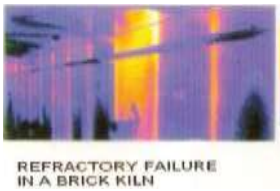
tool of in-service inspection of heat exchangers. This Non destructive testing using a multi frequency Eddy Current system would examine surface and sub-surface areas of materials with suitable electrical conductive and magnetic properties. The instrument used allows Inspection of a large variety of materials and provides documentation of the inspection all in one unit. Our Engineers are well trained in carrying out the test at Site and interpret the results accurately, depicting the actual condition of the tubes based on the test results, particularly very competent in resolving between defects and non-relevant indications. All Eddy current testing jobs were carried out by Level II qualified engineers with a throughput of about 800 tubes per day.

J. THERMOGRAPHY

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



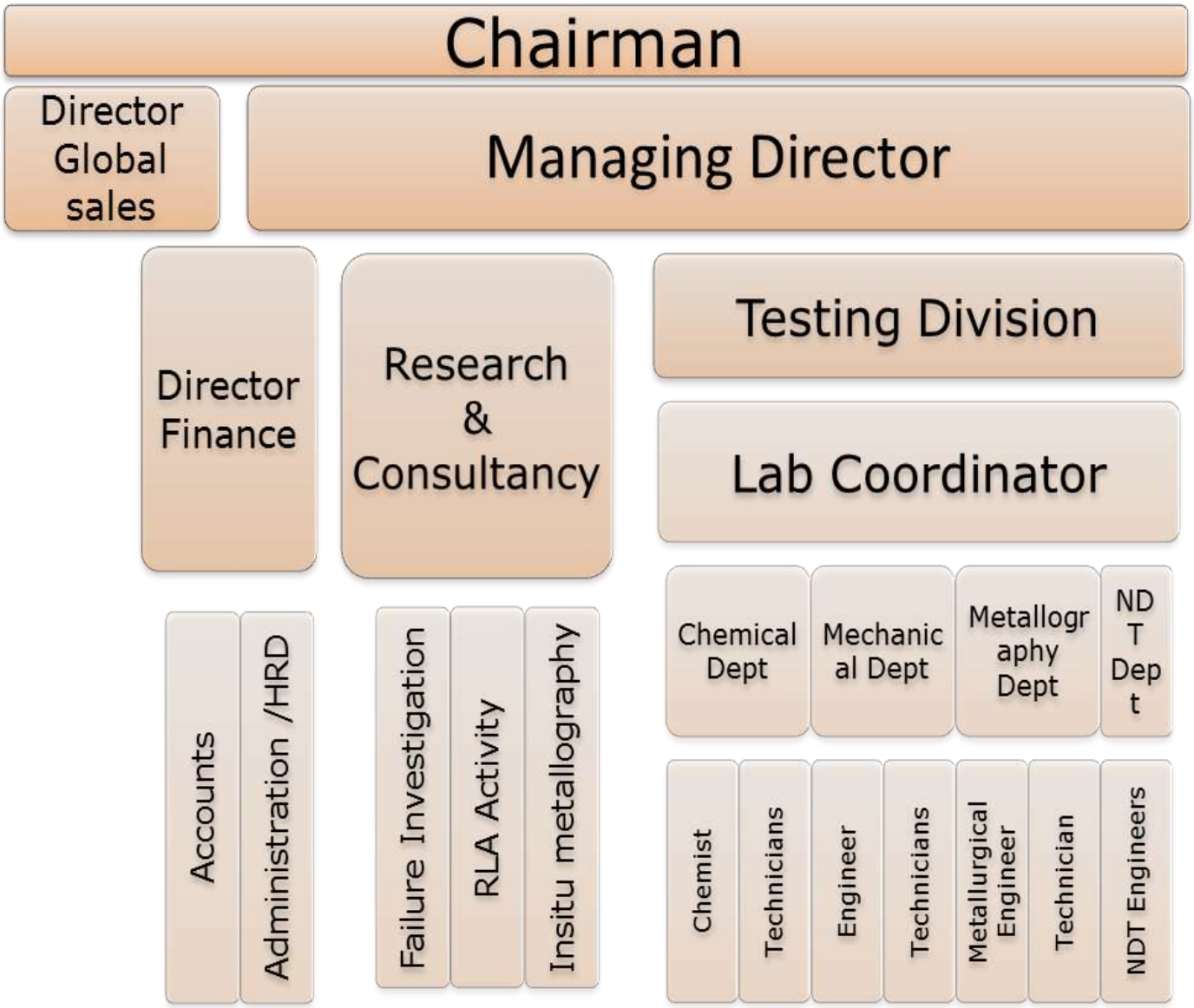




K. ROBOTIC INSPECTION OF TANKS

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

5) OUR MANAGEMENT



6) BRIEF BIO-DATA OF COMPANY DIRECTORS & KEY PERSONNELS

Shri Virendra Bafna, *Chairman*

Mr. V.K. Bafna is Chairman at TCR Advanced, He is also Founder and Managing Director of TCR Engineering Services, Mumbai, and a JV partner of TCR – KIL, Kuwait. A visionary with sound material sciences experience, strong business acumen and relentless sincerity, the TCR ADVANCED is maturing under his able guidance. With clear sense of purpose and urgency, Through hard work, dedication, integrity and love for his field, Mr. Bafna gained 35 years of practical experience in the areas of corrosion detection, chemical analysis, mechanical testing, failure analysis and materials characterization. He 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.

Mr. Bafna, is a gold medalist from the University of Indore and has two masters degrees to his credit. He has done Master of Engineering from the University of Toronto, Canada and Master of Industrial Management from the Clarkson College of Technology, Potsdam, New York. V.K. Bafna is a member of various professional organizations such as American Society for Testing and Materials, Institute of Standard Engineers, ASM International, NACE, Non Destructive Testing Society of India, and Indian Institute of Metals. He is an ex-committee member of ASM India chapter. Mr. Bafna's vast expertise in the field of laboratory testing has brought numerous laurels to TCR notable amongst them is an award of appreciation from the Indian Space Research Organization (ISRO) for the company's contribution to the Project ASLV. He has conducted workshop on "Value Driven Maintenance and Reliability for Process Industries" at International Quality and Productivity Center (IQPC) at Abu Dhabi, UAE in Sept. 2006 as well as conducted a seminar on "World Class Laboratory Management" at the Asia-Pac Conference, Mumbai, India in June 2006.

Mr. Paresh U. Haribhakti, *Managing Director*

Mr. Haribhakti is a B.E. (Metallurgy), M.E. (Materials Technology) From M.S. University, Baroda. He has done basic research in study of hydrogen embrittlement of steels and stainless steels. He has worked as trouble shooting metallurgist for India's largest fertilizers and petrochemicals complex, GSFC Ltd., Vadodara for nearly 10 years. His area of specialty is microstructure degradation of components exposed to high temperature and pressure. He has hands on experience of more than 1000 failure investigation cases of Power Plants, Fertilizers, Chemicals and Petrochemicals Industries. He has provided services of failure investigation and In-situ metallography to major industries in the country and abroad.

Mr. Haribhakti had won first prize for metallography contest held at IISC-Banglore - 1998 under NMD celebration by Indian Institute of Metals (IIM). There are several technical presentations and lectures delivered at National and International seminars to his credit. He is a member of different most of the professional bodies in the field of metallurgy.

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 weldment.

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. Rohit Bafna, *Director Global Sales*

Rohit is currently Director Global Sales based in TCR World in Washington DC, USA. 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. Jaidev Patel, *Chief Executive (Testing Division)*

Mr. J. H. Patel is a B. E. (Metallurgy) from M.S. University Vadodara. He is having hands on experience in Industrial experience in the field of NDT for more than ten years. He is an ASNT Level –III U.T., M.T., and Level -II D.P.T., Eddy Current testing He was actively involved in developing Ultrasonic testing procedure for Railway tracks for Indian Railways as a consultant. He is in-charge of Testing Division of TCR Advanced Engineering Pvt. Ltd. for testing of Chemical, Physical and corrosion testing confirming to the National and International standards. He is also in charge of coordinating NDT site activities. His NDT expertise is also utilized in training and Certifying NDT level II technicians. Under his able guidance more than 20 technicians have qualified for NDT Level II certification. He is actively involved executing NDT testing in life assessment and damage assessment jobs for TCR ADVANCED. His vast experience in NDT field and understanding of various national & international codes is useful in formulating test procedures for various testing activities.

Mr. Gopul Patel, *General Manager*

Is a post graduate from Sardar Patel University. He has an extensive knowledge of vacuum Technology and has worked as Scientific officer at Department of Science and technology sponsored Research centre. He has hands on experience of operation and calibration of various sophisticated analytical instruments such as Transmission Electron Microscope, Scanning Electron Microscope with EDS, X Ray Diffraction, ICP OES, spectrometers, Thermal Analyzers such as DSC, TGA. He has experience of various advanced methods of material characterization and have worked extensively in the field of microscopy.
He has been trained for Operation of Electron microscope at PHILLIPS, The Netherlands. In fact he has handled India's First Environmental Scanning Electron Microscope with EDAX analyser for more than five years.
He is responsible for the establishing & implementing Management system at TCR Advanced and its functionality. He is actively involved in establishing new testing facilities at lab as well as on site. he has played a instrumental role in establishing custom designed web based sample management system.

7) BRIEF BIO-DATA OF COMPANY'S ADVISORY PANNEL-EXPERTS

Dr. Rajendrakumar, *Advisor*

Dr. Rajendrakumar is a renowned metallurgist of our country. He is a doctorate from world famous University of Shefild, UK. Dr. Rajendrakumar was the Director of National Metallurgical Laboratory,

Jamshedpur and a former Director of Regional Research Laboratory, Bhopal. Dr. Rajendrakumar has more than 150 publications in national and international journals of repute. He has been a committee member of IBR for failure investigation. He has written three books on metallurgy.

Dr. P. B. Joshi, *Advisor*

Dr. P B Joshi is a professor in Department of Metallurgical and Materials Engineering, Faculty of Technology and Engineering, Maharaja Sayajirao University, Vadodara. He is a Ph. D. in Material Engineering. Dr Joshi is having more than 25 years of teaching experience in the field of metallurgy. He has more than 50 research publications in International journals & National journals, and authored a book titled "Materials for Electrical and Electronic Contacts".

Dr. K. Baba Pai, *Advisor*

Dr. Baba Pai is the Head of the department of Metallurgical & Materials Engineering Faculty of Technology & Engineering, M. S. University. He is Ph. D from IIT Mumbai. He is having more than 29 years of experience in Educational field. He began his career as lecturer in 1989 and became professor in the Metallurgical and Materials Engineering department since past 18 years. Under his able guidance more than 4 Students were awarded PhD. Presently three students are perusing PhD Under his guidance. He has more than 90 national and international publications in reputed journals. Dr. Pai is actively involved in providing Testing and industrial consultancy assignments for many industries of Gujarat. He is life member of many

Mr. Jagdish Baad, *Consultant*

Mr. Jagdish Baad is Bachelor of Technology in Metallurgical Engineering with First Class honors from IIT, Mumbai. He is having experience of 25 years in forge shop, steel, cast iron, S.G. Iron and Non-ferrous foundries. He has worked reached to Sr. Management position starting from the Engineer level. He has handled Turn key projects related to Foundry Mechanization, Quality Assurance and Product management of critical castings for turbine, material handling and wear resistance applications. Some of them are first of its kind. For last 12 years running an independent consultancy, related to TQM-Product Management of Castings & Forgings and metallurgical related turnkey projects. Well versed in kaizen, Edward Debono /Osborn techniques in creativity management. Energy audits related to metallurgical processes. He is Life member of various institutions such as Institute of Indian Foundrymen , Indian Institute of Metals ,Indian Society of Non-destructive Testing, Indian Institute of Welding Metallography Society of India, Alumni Association of IIT Mumbai.

Mr. Prakash Bhrambhatt, *Consultant*

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

8) LIST OF IMPORTANT EMPLOYEES WITH THEIR QUALIFICATIONS

SR. NO.	NAME OF EMPLOYEE	DESIGNATION	QUALIFICATION
1.	Mr. Jaidev H. Patel	Chief Executive	B. E. (Metallurgy) ASNT Level – III [U.T., M.T.] & Level – II [D.P.T.], ET
2.	Mr. Gopul Patel	General Manager	M. Sc. (Electronics)
3.	Mr. Prashant Shah	Chemist	BSc (Chemistry)
4.	Mr. Dharmendra Joshi	Lab Coordinator	Diploma Mechanical
5.	Mr. Vishal Soni	Engineer Corrosion testing	B. Sc.
6.	Ms. Khushbu Singh	Metallurgical Engineer	B. E (Metallurgy)
7.	Mr. Sohel Vaidya	Lab Manager, Failure investigation	M. Sc.(Applied Physics)
8.	Mr. Kamlesh Solanki	Metallurgical Engineer	Diploma Metallurgy
9.	Mr. Dhaval Patel	Technician	Diploma Metallurgy
10.	Mr. Mitesh Patel	NDT Engineer	M. Sc. (Material Science)
12.	Mr. Vasant Waghela	NDT Engineer	Diploma Mechanical
13.	Mr. Jignesh Bhatia	Engineer Mechanical testing	B. Sc. (Physics)
14.	Mr. Rakesh N. Gandhi	Metallographer	I.T.I
15.	Mr. Darpan H. Parikh	Accountant	B. Com
16.	Mr. Bharat Pandya	Accountant	B. Com
17.	Mr. Pritesh Valand	NDT Engineer	Diploma Mechanical
18.	Mr. Ankit	NDT Engineer	Diploma Mechanical
19.	Mr. Jaimin J. Patel	Metallographer	I.T.I
20.	Mr. Ankur Haribhakti	Mechanical testing	Diploma Mechanical
21.	Mr. Mimanshu Patel	Site technician	H.S.C

9)OUR MAJOR CUSTOMERS

TCR ADVANCED believes in establishing long-term, strategic relationships with our customers as opposed to short-term, opportunity-based engagements. TCR ADVANCED greatly values the relationships that it has established with over 300+ customers and are delighted to provide technical services & Solutions.

10) MAJOR PROJECTS HANDLED

A. INLAND ASSIGNMENTS

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Crevice Corrosion & Electrochemical Study for ITER- India

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

Material selection for Corrosion service at Solvay

M/s Solvay Specialities India Private Limited is manufacturing products such as Veradel and PEEK . There were frequent incidences of finding corrosion of varying degree in reactors & vessels used for the production. This was affecting the Quality of products produced by the plant. In view of seriousness of the matter TCR Advanced was approached to carry out laboratory accelerated corrosion tests on different samples at varying conditions. The purpose of the exposure tests was to find out suitability of SS 304, SS 316L Inconel 600, Hastealloy C276, SS 2205, SMO 254 and Al 6XN materials for defined process conditions in welded and as received conditions in the actual reactors condition and monitor them regularly by destructive as well as weight loss method. This exercise is done to evaluate the different materials of construction in the actual process environment to deicide for suitable material for the given process.

B. OVERSEAS ASSIGNMENTS:

Damage assessment of Hydrocrack Reactors of Refinery Baiji, Iraq

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

Metallurgical input for health assessment to procure second hand equipments from Taiwan for Gujarat Flurochemicals ltd.,

The high grade Inconel 600 Reactor were to be imported from Taiwan by GFL. TCR Advanced was deputed to judge the heath of these Reactors and recovery columns by undertaking various NDT Test. The health of these equipments were judged to provide the final decisions on procurements which helped the company to not only get the writhe equipment by find out the safe useful life.

Remaining life assessment for a package Boiler for Bangladesh lever limited:

RLA was conducted for package boiler at Unilever Bangladesh limited,. And certain tubes were asked to replace.

The Ball mill assessment at Kuwait Cement company, Kuwait.

TCR-KIL approached TCR advanced for metallurgical assessment of cracks observed on the Ball mill a very critical equipment for a cement mill. A detailed report were subjected with the reasons of carking by undertaking NDT approach of assessments.

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

Shell Gas terminal Shrilanka,

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

Nigeria

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

OMAN,

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

SWCC, KSA

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

SABIC,KSA

Metallurgical root cause failure investigation are done from TCR advanced to provide variety of plants having chemical, petrochemical fertilizers and refinery equipment's.

ANNEXURE-A

FAILURE ANALYSIS AND INVESTIGATION SERVICES

TCR Advanced Engineering Pvt. Ltd. and her associate company TCR Engineering Services have completed more than **750 failure investigation assignments**, including 50 major projects on manufacturing or metallurgical failure analysis on ASME boiler and pressure vessels, Gas turbine engine components, Oil and gas transmission pipelines, Food processing equipments, Heat exchangers, Medical supplies, Automotive components, Refineries, Petrochemical plants, Offshore structures, Industrial machinery, Weldment and Ships.

Evaluating high temperature and high-pressure failures are Our strong areas of failure investigation. The Failure Analysis Team at TCR Engineering has experience in the materials, failure analysis, metallurgical, welding, quality assurance, and forensic engineering fields and is conducted by engineers holding advanced degrees in metallurgy, and mechanical, civil, chemical, and electrical engineering.

Our investigation team 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.

We have a methodical approach to determine the mode and root cause of a failure. For experts of TCR, Failure analysis or problem solving is more than just brainstorming a solution to an identified problem. Successful analysis is achieved through a structured technique, which uncovers the facts of the incident and adheres to a defined process for every step of the analysis process.

Failure Analysis Objectives

The first step in managing the actual failure analysis effort is to determine what you expect from the final outcome. During TCR's initial meeting with clients we develop a charter that clearly delineates the terminal objective of the analysis. This is further enhanced through the development of critical success factors that outlines whether the terminal objectives have been obtained. At TCR Advanced Engineering, we adopt a disciplined vertical problem solving methodology used to determine levels of root causes of specific failure events. The following process is necessary to implement a successful failure analysis project.

Prioritize - Determine what is most important to work on.
Analyze - Analyze the failure event to determine root causes.
Recommend - Develop recommendations as solutions to the causes discovered.

The TCR ADVANCED Engineering Approach

Our failure analysis team is always headed by a senior metallurgical engineer who has the following characteristics:

- Ability to remain unbiased and reject conventional wisdom.
- Ability to facilitate a group of people toward a common objective.
- Trained in logic tree approaches to failure analysis.
- Affinity for listening and questioning for understanding.
- Patience and perseverance.

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.

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 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. 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

The Failure Analysis Report

The failure analysis report represents the culmination of the analysis effort and the beginning of failure elimination. The goal of any failure analysis by TCR is targeted towards the elimination of identified causes. The completed failure analysis report includes the following sections:

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

The final failure analysis report provides solutions with expected returns on investments but also identifies how the failure occurred in the first place. To accomplish this event summary, a description of the failure mechanism and list of recommendations are included in the report.

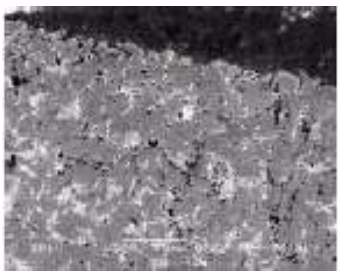
The event summary is a brief description of how the failure was first noticed how long it has been going on and the method(s) used to isolate or mitigate the consequences of the failure.

The failure mechanism can be thought of as a summary of the root cause(s) that led to failure occurrence. TCR will chronologically characterize the things that must occur in order for the failure to manifest itself. The report will outline the Mechanical and metallurgical study of failure including the Metallurgical evaluation of quality. The list of recommendations will explain what, when and who (if TCR consultants are on the project) is going to be responsible for implementation, and also include a recommendations for prevention of similar failures.

BRIEF FAILURE INVESTIGATION & ANALYSIS CASE STUDIES

Primary Super Heater R-4 Zone Tube of a 140 Mw Boiler

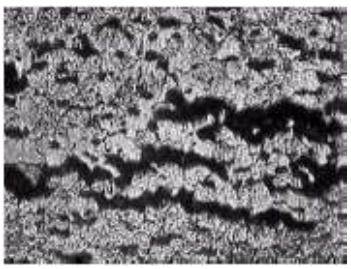
The MOC of tube is TU 15 CD 205 .The service life of tube is 7 years before failure. The steam temperature & pressure of tube are and 450°C and 140 kg/cm^2 respectively. The tube has OD 63.5mm and ID 5.5mm. Tubes are located horizontally with flue gas passes vertically.



Scanning Electron Microscopy (SEM):

Upon SEM examination conducted by engineers at TCR, it 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. This examination was done at the TCR Engineering laboratory using a Leco Image Analyzer at 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.

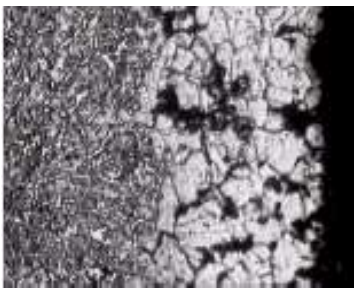
Radiant Coil of a Cracker Furnace H-130 Refinery

In a bottom fired furnace tube failure have experienced service of 14 months against the normal life of 6 to 7 yrs. MOC of tube is 25 Cr/35 Ni. The average tube metal temperature remains between 1000 to 1100 ºC temperatures. As per the manufacturer data, these tubes are designed for 1150ºC. The pressure inside the tube is 1 kg/cm^2 g.

Scanning Electron Microscopy (SEM):

SEM analysis conducted by failure investigation team from TCR Engineering revealed a 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:

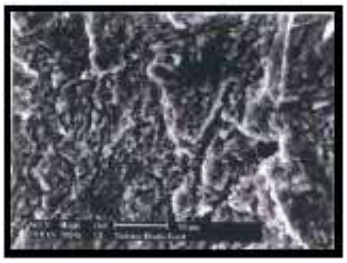


The crack is associated with carburizing more so at outer surface with decreasing the depth of carburizing toward ID. Another important evidence of crack originating outer diameter and progressing towards ID. This magnification was done at the TCR Engineering laboratory using a Leco Image Analyzer at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

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

8th Stage Blade of a Steam Turbine

After 8-years of useful service life, a steam turbine was reported to have been working with abnormal vibrations. When 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. Only one blade was submitted for investigation. It is difficult to pin point which blade failed first.

Sac Plant Piping Going to V-801

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_2SO_4, 0.5% HNO_2 and 0.6 to 1.0 % HNO_3 at 10 to 20°C temperatures.

Low Magnification Examination:

Low magnification examination was done by the failure Analysis and Investigation team from TCR Engineering to find out the corrosion characteristics. Internal surface of pipe, weld and elbow showed severe corrosion on 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 at a magnification of 300x at the TCR Engineering laboratory in India.

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

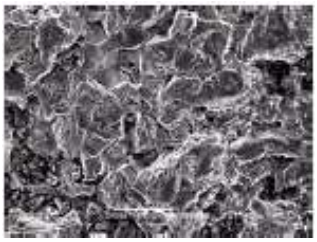
Integral Pinion Shaft of a Cement Mill

Premature failure of integral pinion shaft was reported a 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 were 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 done by TCR Engineering reveal 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 sections reveled that general condition of shaft is in hardened and tempted condition. Further microstructure revealed presences of inter-granular cracks. The cracks are moving on prior austenitic grain boundaries and are observed filled with oxides. Presence of oxide inside the cracks is most important evidence in present case. This was done at a magnification of 560X at the TCR Advanced Engineering laboratory.

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

ANNEXURE- B

NABL

National Accreditation Board for Testing and Calibration Laboratories

Department of Science & Technology, India

CERTIFICATE OF ACCREDITATION

TCR ADVANCED ENGINEERING PRIVATE LIMITED

has been assessed and accredited in accordance with the standard

ISO/IEC 17025:2005

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

for its facilities at

VADODARA

in the field of

CHEMICAL TESTING

Certificate Number T-1330

Issue Date 24/09/2009 Valid Until 23/09/2011

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

Signed for and on behalf of NABL

N. Venkateswaran
Convenor

Dr B. Hari Gopal
Director

Dr T. Ramasami
Chairman

NABL

Department of Science & Technology, India

SCOPE OF ACCREDITATION

Laboratory	TCR Advanced Engineering Private Limited, Vadodara		
Accreditation Standard	ISO/IEC 17025:2005		
Field	Chemical Testing	Issue Date	24.09.2009
Certificate Number	T-1330	Valid Until	23.09.2011
Last Amended on		Page	1 of 4

S.No.	Product / Material of Test	Specific Test Performed	Test Method Specification against which tests are performed	Range of Testing / Limits of Operation / Limits of Detection (%)
1.	**FERROUS ALLOYS** **1) Carbon and low alloy steel** **2) Stainless Steel**	Carbon	ASTM E 415-99 RA 2005 ASTM E 1086-94 RA 2005 IS 9879 (1998) IS 8811 (1998)	0.005-0.010 0.011-0.030 0.031-0.40 0.41-1.00 1.01- 4.30
		Sulfur		0.005-0.020 0.021-0.35
		Phosphorous		0.005-0.020 0.021-0.20
		Manganese		0.05-0.50 0.51-5.00 5.01-10.00
		Silicon		0.05-0.50 0.51-2.50
		Chromium		0.05-0.50 0.51-4.00 4.01-10.00 10.01-27.00
		Nickel		0.05-0.50 0.51-4.00 4.01-8.00 8.01-22.00
		Molybdenum		0.01-0.30 0.31-3.00 3.01 – 6.00
		Copper		0.05 – 0.50 0.51-2.00
		Cobalt		0.05-0.50 0.51-5.00 5.01-11.00
		Titanium		0.05 – 0.50
		Tungsten		0.05-0.50 0.51-6.50 6.50-20.00

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	FERROUS ALLOYS 1) Carbon and low alloy steel 2) Stainless Steel	Vanadium Niobium Nitrogen Carbon Equivalent	ASTM E 415-99 RA 2005 ASTM E 1086-94 RA 2005 IS 9879 (1998) IS 8811 (1998)	0.10-2.00 0.05-0.50 0.51-2.00 0.005-0.5 0.01-1.0
2.	COPPER & ITS ALLOYS	Zinc	TCRADV/ TM-35	0.05- 0.50 0.51-5.00 5.01-10.00 10.01-44.00
		Lead		0.05 - 0.50 0.51-5.00
		Tin		0.05 - 0.50 0.51-5.00 5.01- 10.00
		Phosphorous		0.005-0.05 0.051-0.10 0.11-0.20
		Manganese		0.050-1.00
		Iron		0.050-0.50 0.51- 1.00 1.01 – 6.00
		Nickel		0.050-0.50 0.51 – 5.00
		Silicon		0.050- 0.50 0.51- 7.00
		Aluminum		0.050 - 0.50 0.51 –5.00 5.01 -11.00

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3.	ALUMINIUM & ITS ALLOYS	Silicon	ASTM E 1251 -1999	0.05-0.50 0.51 - 2.00 2.01 - 15.00
		Iron		0.050-0.50 0.51-1.00
		Copper		0.050- 0.50 0.51-1.00 1.01-8.00
		Manganese		0.050-0.50 0.51-2.00
		Magnesium		0.050-0.50 0.51-5.00 5.01-11.00
		Nickel		0.05- 2.00
		Zinc		0.050- 0.50 0.51-5.00 5.01-12.00
		Titanium		0.05-0.50 0.51-2.50
		Tin		0.05-0.50 0.51-5.00
4.	NICKEL & ITS ALLOYS	Carbon	TCRADV/TM-34	0.005-0.20 0.21-1.00
		Sulfur		0.005-0.050
		Phosphorous		0.005-0.10
		Manganese		0.050-0.10 0.11-6.50
		Silicon		0.050-0.10 0.11-4.00
		Chromium		0.050-0.50 0.51-5.00 5.01-25.00
		Molybdenum		0.050-0.50 0.51-5.00 5.01-25.00

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		Aluminum		0.05-0.50 0.51-3.00
		Copper		0.05-0.50 0.51-5.00 5.01-40.50
		Iron		0.050-0.50 0.51-5.00 5.01-25.00
		Niobium		0.050-0.50 0.51-1.00 1.01-5.00
		Titanium		0.05-0.50 0.51-1.00 1.01-5.00
		Cobalt		0.05-0.50 0.51-1.00 1.01-5.00

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Signed for and on behalf of NABL

N. Venkateswaran	Dr B. Hari Gopal	Dr T. Ramasami
Convenor	Director	Chairman

NABL

Department of Science & Technology, India

SCOPE OF ACCREDITATION

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Field	Mechanical Testing	Issue Date	24.09.2009
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S.No.	Product / Material of Test	Specific Test Performed	Test Method Specification against which tests are performed	Range of Testing / Limits of Operation / Limits of Detection
1.	**Metallic Materials**	Tensile Test Ultimate Tensile Strength Proof Stress Yield Strength Reduction in Area Elongation	A:370(2009)a ASTM E:8(2008) IS 1608-2005	0.1 kN to 400 kN
		Bend Test	IS 1599–85 reaffirmed in 1996, IS-1786-2008 ASTM A 370-2009a ASTM E:190-2008 ASTM E:290-2008	0.5 to 28 mm Thickness
2.	**High Strength Deformed bars/Reinforcement**	Rebend Test	IS 1786 2008	26 mm dia
3.	**Metallic Materials Tubes / Pipes**	Flattening Test	ASTM A 370–2009 a ASTM B 111-2009 cl. 11	OD 6 to 250mm
4.	**Nuts**	Proof Load	SA:194(2009) SA:370(2009a) IS:1367-Part 6-1994 (Reaffirmed 1999)	0.1 kN to 400 kN
5.	**Studs / Bolts**	Full size Breaking Load for studs and bolts	SA:370(2009a) SA:193(2009a) IS-1367-Part 3-2002	0.1 kN to 400 kN
6.	**Tube to tube Sheet Mock-ups**	Pull out test/ Push out test	ASME Sec VIII DIV-1 (2007)	0.1 kN to 400 kN

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S.No.	Product / Material of Test	Specific Test Performed	Test Method Specification against which tests are performed	Range of Testing / Limits of Operation / Limits of Detection
7.	Metallic Materials	A) Brinell Hardness Test	ASTM:E10-2008 IS:1500-2005	80-400 HBW 2.5/187.5 30-150 HBW 2.5/62.5
		b)Vickers Hardness Test	IS:1501(2002) ASTM E:92-(2003e2)	HV5, 40 – 1200 HV10, 80-1000 (LD = 0.001 mm)
		c) Rockwell Hardness	IS 1586–2000 ASTM E-18-2008b	HRA 30- 88 HRB 30 – 100 HRC 20 – 70 LD 1 Unit
		d) Micro Hardness Vickers	ASTM E384- 05 IS 1501-2002	Upto 1400 HV 1 Upto 1300 HV0.5 Upto 800 HV 0.2 Upto 800 HV0.1 Upto 400 HV 0.05
8.	Metallic Materials	Micro examination :		
		Micro Structure Examination	ASTM E-3 92007), ASTM E 407 (2007) ASM Handbook Volume 9	NA
		ASTM Grain Size	ASTM E 112(2004e2)	ASTM 1 – 14 Grain Size
9.	Ferrous Materials	Nodularity in SGI iron Cast Iron	IS 7754(2003)	Upto 95%
		Case Depth	IS 6416(2003)	0.001-0.8 mm
10.	Metallic Materials	Thickness of Coating	ASTM B-487(2002) Reaffirmed 2007	0.001-0.8 mm

Director

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11.	Metallic Materials	Macro Examination	ASTM E 381 (2006) ASTM E 340 (2006) ASM Handbook Volume 9	NA
12.	Ferrous Materials	Macro etch Test	ASTM E 340(2000)	0.001-0.8 mm
		Decarburization Depth	ASTM E-1077(2005) IS 6396-2000	0.01-0.8 mm
		Quantitative Metallography	ASTM E-562(2008)	Upto 70%
13.	Wrought Metallic Materials	Inclusion rating	ASTM E-45(2005e2)	Upto value 3
14.	Austenitic Stainless Steel	a) IGC Test 'A'	ASTM A – 262(2002a) RA 2008	NA
		b) IGC Test 'B'	ASTM A – 262(2002a) RA 2008RA 2008	NA
		c) IGC Test 'C'	ASTM A – 262(2002a) RA 2008	NA
		d) IGC Test 'E'	ASTM A – 262(2002a)	NA
15.	Metallic Materials*	Linear Measurement By Microscopic	TCR ADV/TM -37	0.001-10 mm

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